Indiana University Life Sciences Strategic Plan

Life sciences – the science of humanity; the future of Indiana's economy

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Indiana University

Life Sciences Strategic Plan

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Foreword

Dear Colleagues –

The life sciences are in a very real sense the sciences of today – and the sciences of tomorrow. They build on the foundation of past discoveries, and with techniques made possible by new methods, technologies, and instrumentation, achieve insights and understanding of an entirely new order. Scientific discovery in the life sciences has advanced at ever accelerating rates since the discovery in 1953 of the structure of DNA by IU graduate James Watson and his colleague Francis Crick. The momentum increased significantly with the development in the 1990s of high-throughput approaches (combining new concepts, robotic DNA sequencing systems, and advanced information technology) that could determine the DNA sequences of entire genomes. The determination of the sequence of the three billion nucleotides in the human genome in 2001 accelerated the transformation in biology, medicine, and the life sciences. These discoveries suggest that advances in life science can now go beyond the descriptive and become predictive. Arriving at such a place will have significant implications in improved health care – in treatment, diagnosis, and cure.

The State of Indiana is vigorously engaged in the life sciences, now with considerable momentum. The leaders of Indiana business, academic, and government sectors galvanized broad support in 2002 for an effort to develop the State as a world-class center for the life sciences industry. This brought into coordinated action many existing loci of activity. Indiana has one of the nation's most firmly grounded life science economies. With pharmaceutical giants like Eli Lilly and Company and Cook Incorporated, Indiana is a national leader in the research and development of pharmaceuticals and in the design and manufacture of medical devices. Combining Methodist Hospital, Indiana University Hospital, and Riley Hospital for Children, Clarian Health Partners is one of the largest health organizations in the Midwest.

With the State's only medical school and other schools in the health sciences such as Nursing and Dentistry, and with world-renown life sciences research on both its main campuses, Indiana University is a major contributor to the continuing development of the life sciences in Indiana.

In order to then raise these contributions to even higher levels, President Herbert requested the preparation of an *Indiana University Life Sciences Strategic Plan* that would seek to leverage in a coordinated way the combined life sciences research resources of both campuses while defining a bold vision for their future development. IU is a partner in helping to transform the Hoosier economy, and a key result of the *Indiana University Life Sciences Strategic Plan* will be new innovations and transferable research that together will help create the basis for economic transformation and growth in Indiana.

This Strategic Plan is similar in form and in the scope of its aspirations to the *Indiana University Information Technology Strategic Plan*, finalized in 1998. This Plan builds on many of the University's strengths, and can lead Indiana University to a new level of preeminence in the life sciences, much as the *Information Technology Strategic Plan* led IU to new heights in IT.

While this document is structurally similar to the IT Strategic Plan, the process of creating it differed in many regards. At the time of the creation of the IT Strategic Plan, begun in 1997, the state of information technology at IU was such that it was necessary to engage in a broad "bottom up" process as little strategic thought had been given to the development of information technology.

The situation with the life sciences is very different. Many subunits of the University already have strong and clearly stated objectives in the life sciences. The task of preparing the *Indiana University Life Sciences Strategic Plan*, then, was much more a process of attempting to consolidate, harmonize, and prioritize plans that already exist at School and College levels. INGEN, METACyt, and the Bloomington Commitment to Excellence proposals have also helped shape these plans and priorities. This plan does not attempt to identify strategies and activities for the interaction between the human population and the global environment. Such activities, core concerns of the School of Public and Environmental Affairs, are tightly linked to such matters as geography, geology, and atmospheric science. A comprehensive agenda for all of these important disciplines is beyond the scope of this plan.

The *Indiana University Life Sciences Strategic Plan* recognizes that the University and the State are poised for a new level of collaboration and engagement in the life sciences. Momentum has been building. The Plan has been prepared with the intention of setting new directions and focusing activities on a broad range of Goals and Actions that will move Indiana University and the State boldly ahead in the life sciences. The Plan builds on and focuses the strengths of the world-class life sciences enterprises at the IUPUI campus in Indianapolis (especially the IU School of Medicine) and the Bloomington campus (especially the College of Arts and Sciences). Collaborations across all eight Indiana University campuses and cooperation with business and industry are fundamental expectations of this Plan. This document looks far into a promising future for our University and the State.

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A. Executive summary

Since ancient times, people have theorized about the workings of the human body. High-throughput genome sequencing systems developed in the 1990s created fundamental new opportunities and insights into the genetic information at the core of our being. The sequencing of the human genome in 2001 was one of the great scientific accomplishments of all time. But it has proved more a beginning than an end. To understand what our genome sequence means, we must understand what genes exist within that genome, understand how those genes are expressed, and understand how genes interact with our environments. These are complex and daunting challenges. Nearly half a decade after the sequencing of the human genome, scientists are not yet near consensus on critical matters such as the number of genes in the human genome, or where they are. Still, the sequencing of the human genome and the genomes of many other organisms has created the basis for a phenomenal growth in our understanding of living systems.

The life sciences stand at an unparalleled confluence of scientific opportunities. It is now becoming possible to develop detailed knowledge of the functioning of living systems. In the coming years, it will be possible to develop predictive models of the functioning of humans that will lead to breakthroughs in disease prevention and treatment.

Indiana University is well positioned to become a national and international leader in the life sciences. Four Nobel laureates have been associated with Indiana University – all in the life sciences. The IU School of Medicine and Clarian Health Partners have made seminal discoveries in the genetic bases of human disease and in treatments for cancer and other serious diseases. IU Bloomington's biology department is an international leader in a range of areas, from genomics and developmental biology to microbiology and plant biology. IU Bloomington's chemistry department is among the best in the world at developing new analytical chemistry instruments that enable us to understand the expression of genetic information. IU Bloomington's psychology department is at the forefront of advances in neuroscience. Other schools within IU are leaders in their respective disciplines: Dentistry, Nursing, and Optometry. The IU School of Informatics is pursuing research at the forefront of efforts to manage, understand, and make use of the massive stream of life sciences data now being produced around the globe and around the clock.

Indiana University and the State of Indiana have established a solid direction in the life sciences through such initiatives as:

- The Indiana Genomics Initiative, funded by two grants totaling $155,000,000 from the Lilly Endowment, Inc. primarily to the IU School of Medicine.
- The Indiana METACyt Initiative, funded by a $53,000,000 grant from the Lilly Endowment, Inc.
- The collaboration of Indiana University Hospital, Methodist Hospital, and Riley Hospital to create Clarian Health Partners, the largest health care provider in Indiana and one of the largest in the Midwest.

- Funding of $10,000,000 for the neurosciences at Indiana University through the Lilly Endowment, Inc. Initiative to Recruit and Retain Intellectual Capital for Indiana Higher Education Institutions.
- The Human Biology Program, funded via the IU Commitment to Excellence Initiative
- The Center for Glycomics and the national *Drosophila* Genomics Resource Center, both located in Bloomington and both established with National Center for Research Resources (NCRR) grants from the National Institutes of Health (NIH).
- The development of bioinformatics and cheminformatics as major areas of strength in the IU School of Informatics.
- Indiana University's excellence in information technology, particularly in advanced supercomputer and grid applications for the life sciences.
- The generous support of private donors, including gifts from Linda and Jack Gill, Philip and Ruth Holton, Samuel Regenstrief, the Simon family, Paul and Carole Stark; and gifts from private corporations and trusts, including the Beatrice P. Delany Charitable Trust, Eli Lilly and Company, the Eli Lilly and Company Foundation, the Richard M. Fairbanks Foundation Inc., and the Krannert Charitable Trust.

The challenge now is for IU to build upon existing areas of excellence and establish international preeminence in the life sciences.

The *Indiana University Life Sciences Strategic Plan* will channel the University's core strengths in the life sciences toward a common purpose, and challenges the University to forge new areas of excellence. The combined strengths of the life sciences enterprises at IU's two major campuses, in Indianapolis (IUPUI) and Bloomington (IUB), together with important contributions from IU's regional campuses, create possibilities and opportunities at Indiana University that allow us to compete effectively with the best research universities in the country. Indiana University's excellence in information technology serves as a foundation for life sciences research and as an enabler of collaboration among Indiana University's scientists. Together, these many assets will enable IU scientists to understand genetic information and how that genetic information is processed and expressed to make us what we are. Such understanding will create new opportunities for genomic researchers and cancer clinicians, behavioral scientists and neurobiologists, analytical chemists, and model systems biologists. IU scientists, working together in new ways, will create new opportunities to apprehend solutions to medical problems that were formerly beyond our grasp.

Indiana University has set forth the following mission for its activities in the life sciences:

> *Indiana University will become an international leader in basic and translational research in the life sciences and in research, development, and delivery of advanced clinical care. In the process Indiana University will help lead the creation of a robust life sciences economy in the State of Indiana. Indiana University will accomplish this by expanding and building upon the traditional basic life science strengths at IU Bloomington and the traditional basic and clinical research and advanced clinical care strengths at the IU School of Medicine; by growing the basic research strength of the School of Medicine; by expanding the roles of many units within the University in the life sciences; and through the important education and service roles of each of the eight campuses of Indiana University and the nine campuses for medical school education and research.*

The *Indiana University Life Sciences Strategic Plan* specifies a set of Goals and Actions in several areas of the life sciences in which Indiana University has, is developing, or must acquire particular strength, as follows:

- **Analytical chemistry and analytical technology.** The study of living systems requires knowledge of the chemicals and compounds that compose those systems and of the reactions that take place within them. Indiana University has long been home to one of the nation's leading groups in analytical chemistry; it has received significant recent grant support for analytical chemistry, including support via the Indiana METACyt Initiative and NIH funding for a national resource center for analysis of glycoproteins. Basic research in instrument technology and analytical chemistry and collaborations with other research groups at Indiana University are essential to IU's leadership in the life sciences.

  Goal 1. Indiana University should maintain and enhance its top-tier research program in analytical chemistry.

- **Organic chemistry and biochemistry.** Organic chemistry and biochemistry, including bioorganic chemistry and structural biology, are the keys to initiatives ranging from the discovery of new drugs to the development of consumer products. Along with analytical chemistry, these form major bridges from academic research to industry. Organic chemistry and biochemistry are also vitally important areas of basic research in the life sciences.

  Goal 2. Indiana University should build research strength in organic chemistry and biochemistry to nationally competitive levels to complement and strengthen the top-ranked life sciences programs in Bloomington and research programs at the IU School of Medicine, and to help support the State's biotechnology industry.

- **Cancer biology.** Cancer biology is an area of import and opportunity for Indiana University. Indiana University and its partners in the Clarian Health Partnership have

exceptional records in development and delivery of advanced clinical treatments for cancer. IU's Gamma Knife and the IU Midwest Proton Radiotherapy Institute offer some of the world's most advanced treatment options. In addition, IU's strengths in genomics, proteomics, metabolomics, and cytomics will serve in the study of the root causes of cancer. Cancer biology, perhaps more than any other area within the life sciences, is an area where today's state of scientific and clinical knowledge, IU's existing leadership, and possibilities enabled by new investment offer an opportunity for Indiana University to become one of the very best comprehensive centers for basic research, translational research, and advanced clinical treatment of cancer.

Goal 3: Indiana University should become an international leader in basic and translational research about cancer, and in advanced clinical care for cancer.

- **Diabetes and metabolic disorders.** Diabetes is one of the leading health problems of our time. It is a major cause of blindness and kidney disease, is linked to heart attacks and stroke, and causes circulatory problems that result in amputation and permanent disability in many of its victims. Diabetes is the eighth leading cause of death for Indiana citizens. IU has several assets that form a foundation for excellence in diabetes research and treatment, including advanced treatment programs, new translational research, and studies of the genetic and nutritional bases of diabetes. METACyt offers new possibilities for basic research in cell metabolism that will help researchers better understand diabetes. IU will tackle diabetes prevention and treatment with a concerted, interdisciplinary, and collaborative approach that combines basic research, translational research, and advanced clinical care.

Goal 4. Indiana University should become a nationally recognized leader in research and clinical care related to diabetes and metabolic disorders.

- **Neurosciences.** The neurosciences have benefited immensely from the molecular genetics revolution and are central to understanding many important human diseases. This area also offers a superb opportunity for programs in Indianapolis and Bloomington to collaborate in ways that will bring distinction to the University as a whole. With such focused collaborative effort, IU will establish programs of international significance, and leveraging strengths in related areas, overtake existing national and international leaders in this area.

Goal 5. Indiana University should build its research programs in neurosciences (basic research, translational research, and advanced clinical care) so that they are ranked in the top tier nationally.

- **Model systems in biological research.** Going back to Nobel Laureate Hermann Muller, IUB has possessed a world-renowned group of researchers working on the fruit fly *Drosophila*, the premier invertebrate model system for the study of fundamental genetic and development processes and most human diseases. Biologists at IUB also garner major funding from the NIH to study a wide range of other such model systems, including other animal models, diverse microorganisms, and even plant model systems.

The excellence of this model systems research is limited, however, by the small number of biologists at IUB compared to other leading institutions and the concomitant absence of much activity on important vertebrate model systems, such as mice and zebrafish.

Goal 6. Indiana University should expand and elevate its already outstanding research programs on model biological systems to rank among the top 10 in the country.

- **Personal wellness and health**. Nationally, the top dozen diseases in terms of annual economic cost include injury, alcohol abuse, heart disease, disability, mental illness, smoking, drug abuse, Alzheimer's, obesity, diabetes, cancer, and chronic pain. Together the annual economic costs of these diseases run into the trillions of dollars; the cost in human loss and suffering is incalculable. Many of these diseases are exacerbated by personal lifestyle choices. The consequences of these lifestyle choices affect individuals, families, and the economic future of the entire State and nation. Simply put, good health is good for individuals, good for business, and good for the State.

Goal 7. Indiana University should engage in research and education (particularly State- and federally-funded education efforts) that will help residents of the State of Indiana to lead healthier, better, and longer lives.

Achieving excellence in these areas relies on solid infrastructure and support. The *Indiana University Life Sciences Strategic Plan* includes several goals related to infrastructure and efforts that support excellence in the life sciences, as follows:

- **Buildings for life sciences research.** Indiana University does not have enough laboratory space to support the Goals and Actions identified in this Plan. Because the life sciences are so dependent upon laboratory space, new buildings are critical if the University is to achieve its life sciences goals.

Goal 8. Indiana University should enhance its physical research infrastructure with buildings that permit and support the expansion of IU's life science research activities.

- **Life sciences and informatics.** With the explosion of genomic information from living organisms, it is now possible to envision the development of predictive theories about living systems, including gene expression, biochemical pathways, and processes that take place at the level of whole populations. Testing these theories will be a daunting challenge. New theory and simulation methods in the fields of computational biology, bioinformatics, biocomplexity, and computer science will be required in order to develop predictive and detailed models of biological systems.

Goal 9. Indiana University should lead in the development and utilization of new theory and technique in bioinformatics, computational biology, cheminformatics, medical informatics, health informatics, and biocomplexity.

- **Cyberinfrastructure for the life sciences.** Advanced cyberinfrastructure — high performance computers, massive data storage systems, visualization environments, data resources, advanced instruments, and people all linked together by high-speed networks and advanced software, enabling research breakthroughs and increases in research productivity not otherwise possible — is essential to leadership in the life sciences. Life sciences data are essentially irreproducible; a data set, if lost, is lost forever. Careful preservation of the University's data assets is thus a key concern. Similarly, the most advanced high performance computers and visualization environments are required to simulate and understand the functioning of living systems.

  Goal 10. Indiana University should develop and deploy a cyberinfrastructure that provides capabilities for new scientific insights, new breakthroughs in technology development, and enhanced competitiveness for grant funding.

- **Interdisciplinary Research and Service Centers**. The revolution in the life sciences has created opportunities for and interdependencies between life science researchers. The dependence of breakthrough science on multiple cutting-edge techniques characterizes the life sciences and distinguishes them from many other fields. Interdisciplinary Research and Service Centers are vital parts of the University's life sciences ecosystem. A concentration of excellent centers that provide advanced services to life science researchers will provide an important competitive advantage for Indiana University.

  Goal 11. Indiana University should provide strong support for Interdisciplinary Research and Service Centers (IRSCs) on both campuses. These centers function as developers of new research technology and as service providers in support of IU's mission in the life sciences so that important new research techniques are created and made available to enable new discoveries and facilitate IU's research competitiveness.

Public service is an important part of the University's mission in the State. Translational research extrapolates the results of basic science into improved medical care. The development and commercialization of new technologies promises opportunities for economic growth for the State. IU's efforts to create an educated, 21st-century workforce in the State will help retain Indiana's life science industries and attract new ones.

There are three reasons that many states and universities have life science initiatives: the inherent interest, the opportunity to improve human health through better medicine, and the opportunity to improve the quality of life for its constituents through economic growth. Indiana University, located in a state harshly treated by global changes in industry, will give particular attention to helping to develop a vibrant life sciences economy in Indiana:

- **Advanced clinical care and translational research.** Scientific breakthroughs have their greatest impact when they become integrated into the fabric of everyday lives. New medical procedures and treatments are a prime example. New medical and health care advances occur as a result of breakthrough basic science, applied and tested in clinical research. Clinical trials of new procedures and treatments are also the means by which advanced care is delivered to Indiana residents before such procedures and treatments are

generally available. Social and behavioral aspects of health and disease are equally important.

Goal 12. Indiana University should continue to strengthen and expand its translational research enterprise, doubling the clinical research dollars awarded to the University by 2013, and expanding the cutting-edge medical services and health care delivered to the public.

- **Technology transfer and economic development.** New discoveries ultimately acquire their significance when they are implemented and adopted in ways that improve medical and health care outcomes. The development of stannous fluoride at Indiana University and its subsequent deployment as the critical new ingredient in Crest® toothpaste in 1955 resulted in worldwide improvements in dental health. Universities are increasingly seeing local and regional economic development as a critical part of their service missions. A new generation of entrepreneur-faculty in the sciences sees the commercialization of their research not as a distraction but as a key component of their interest in advancing knowledge. Leveraging the expertise of the Indiana University Research Technology Corporation (IURTC) will result in effective technology transfer, better financial terms, and effective use of innovations to advance the Indiana economy.

  Goal 13. Indiana University should increase transfer of technology from the University to the private sector, managing licenses in a way that enhances the Indiana economy whenever possible.

- **Educating the next generations of life scientists, technologists, and clinicians.** As better medical treatment creates a population living longer and better lives, and as life science industries seek skilled workers, IU needs to generate a steady stream of scientists, technologists, and skilled care givers to create a 21st-century workforce for our State. The availability of a skilled workforce will help draw new life science businesses into the State of Indiana. Important to this goal will be coordination of educational efforts and collaboration among all eight IU campuses to afford 21st-century opportunities to Hoosiers of all backgrounds.

  Goal 14. Indiana University should educate the next generations of life scientists and help the State develop, recruit, and retain a 21st-century workforce that will facilitate the growth of a life science economy in Indiana.

Last, and most definitely not least, the *Indiana University Life Sciences Strategic Plan* calls for unity in purpose and collaboration across the University in order to achieve its goals.

- **Collaboration.** Scientific changes, and changes in technology that enable real-time collaboration largely independent of physical location, enable new collaborations in the life sciences across schools and campuses. Indiana University's competitive position and overall scientific and technological accomplishment will be greatly enhanced by increased collaboration between and among its eight campuses.

Goal 15. Indiana University should enable important new discoveries and achieve greater competitiveness for grant funding through collaboration across geographic and organizational boundaries within, and where appropriate, outside Indiana University.

Indiana University stands at the threshold of greatness in the life sciences. The *Indiana University Life Sciences Strategic Plan* forms a roadmap by which greatness may be achieved. In the process IU will be engaged in creating fundamental new, basic discoveries about living organisms; developing new medical diagnoses, treatments, and technologies; and contributing to the creation of a robust new life sciences economy in Indiana.

B. Preface

"It is evident that there must be something or other really existing, corresponding to what we call by the name of Nature. For a given germ does not give rise to any random living being, nor spring from any chance one, but each germ springs from a definite parent and gives rise to a predictable progeny. And thus it is the germ that is the ruling influence and fabricator of the offspring."
— Aristotle

Since the earliest times, people have asked the great questions that concern us to this day: Why is there something, rather than nothing? What is the nature of matter? What are we made of, how do we work, and how do we fit into our natural environment? By the end of Aristotle's life in 322 BCE, people had formed a significant body of theory and accumulated some data toward answers to these questions. Aristotle was also the creator of logic, the foundation of modern day computer science and informatics. These have become significant partners in decoding the human genome and understanding the information system of proteins that it expresses.

For thousands of years, the life sciences have been of compelling intellectual interest and great practical value. But over the past three hundred years, the life sciences have seemed descriptive and lacking in basic theoretical insights when compared with sciences such as chemistry and physics. Chemistry and physics have had comparatively longstanding and thorough theoretical underpinnings. Critical turning points in the history of chemistry include Dalton's theory of atoms in 1803 and Mendeleyev's organization of elements into the periodic chart in 1870. Mendeleyev's accomplishment was particularly important in providing a framework for understanding the elements and leading to his later prediction of additional elements. In physics, Newton had formulated his three basic laws by 1666. Einstein wrote on the special theory of relativity in 1905. The depth of our understanding of physics at the subatomic level was demonstrated at the first atomic blast – Trinity – on 16 July 1945 in New Mexico. Our understanding of physics and chemistry makes possible important and accurate predictions about chemical and physical systems of enormous practical significance using only theory, numerical methods, and computers.

This predictive power is not yet present in the life sciences. From Aristotle through da Vinci and on to Robert Hooke (who coined the term "cell" in 1665), advances in biology more often took the form of new descriptions of structures and processes rather than lasting theoretical insights. Important turning points in the life sciences include the theory of the cell as the basic unit of life (1824); Darwin's theory of evolution through natural selection, which serves as the central organizing principle of biology to this day (1859); and Mendel's basic theories of genetic inheritance (published in 1865 but neglected until 1900). These theories, however, lacked underlying mechanistic explanations, and for all their insight in postscriptive understanding, never permitted real predictions.

A critical breakthrough in life sciences came in 1953 when James Watson (who received his Ph.D. at Indiana University three years earlier) and Francis Crick determined the structure of DNA, the store of genetic information in living organisms. The germ that, as Aristotle put it,

constituted the "ruling influence," was genetic information stored in sequences of the four basic components of DNA (adenine, cytosine, thymine, and guanine) within a double helix structure. This insight transformed biology and the life sciences. The life sciences were again transformed in the late 1990s by the development of equipment capable of rapidly and for the most part robotically determining DNA sequences.

One of humankind's great technological achievements was determining the entire genetic makeup of humans, published in 2001 — the result of years of intensive work. This discovery was, however, widely misrepresented in the popular press. Commentary and hyperbole were widespread; even serious thinkers said such things as "When your blood type is determined at birth, your genetic defects will be identified and your heart bypass surgery at 53 will be scheduled before you are a week old." But the authors of one of the two papers that simultaneously announced the sequence of the human genome were more circumspect. In their article in *Nature*, they wrote: "In principle, the string of genetic bits [of the human genome] holds long-sought secrets of human development, physiology, and medicine. In practice, our ability to transform such information into knowledge remains woefully inadequate." [6]

The sequencing of the human genome has proven more analogous to Mendeleyev's discovery of the periodic chart than to Einstein's theories of relativity – a profound beginning rather than an overarching explanatory framework. Indeed, the process of elucidating the sequence of the human genome has led to considerable research predicting the existence and location of genes unknown when the sequence was first published, much as Mendeleyev predicted elements not known when he created the first periodic chart.

We stand on the cusp of a new era in the life sciences: an era in which theory, data, and computational capabilities will make possible predictive theories of biology. By combining the principles of physics and chemistry, new capabilities in information technology, and tremendous advances in biology, we may arrive at a new synthesis of understanding in the life sciences that is thorough, deep, *and* predictive. Quoting again from *Nature:*

"[T]he string of genetic bits [of the human genome] holds long-sought secrets of human development, physiology, and medicine." [6]

The *Indiana University Life Sciences Strategic Plan* is predicated on the belief that Indiana University is particularly and especially qualified to pursue the quest for understanding of human development, physiology, and medicine, based on our knowledge of the human genome, our ability to determine how genetic information is expressed, and our ability to understand and influence how the expression of this genetic information impacts our health. In so doing, IU will help improve the quality of life through better medical treatments and through contributing to the development of a more vibrant, dynamic, and larger life sciences economy in Indiana.

The *Indiana University Life Sciences Strategic Plan* echoes the *Indiana University Information Technology Strategic Plan* [13]. Information technology is essential to progress in the life sciences. IU's top-ranked information technology infrastructure provides a foundation upon which future preeminence in the life sciences will rest. IU's leadership in information technology is based on the consolidation of effort and common purpose, University-wide, as established by

the 1998 *Indiana University Information Technology Strategic Plan*. The *Indiana University Life Sciences Strategic Plan* echoes the structure of the 1998 IT Plan, and will be successful if it leads to a similar commonality of purpose and collaborative effort across the University.

C. Background

"When you build, build for a long time. Build for a thousand years — do not build structures that will be cast away by tomorrow's fashion. Tradition has a role to play in our institutions . . ."
— Herman B Wells

President Wells' advice regarding building was directed at the physical buildings of the University, but is apt as regards Indiana University efforts in the life sciences, built upon a solid foundation developed into a distinguished history over the course of many years. IU leadership in basic biological research goes back more than a century, to the famous biologists Carl Eigenmann and David Starr Jordan (the latter becoming IU's seventh president and Stanford University's founding president). Four researchers associated with Indiana University have received the Nobel Prize. The first was Hermann Muller, recognized in 1946 for his discovery that X-rays could be used to create mutations in fruit flies and that these mutations could be used to better understand genetics. Three other IU-affiliated researchers received Nobel Prizes: James Watson, 1962; Salvador Luria, 1969; and Renato Dulbecco, 1975. These three seminal figures in modern molecular biology all worked together at Indiana University Bloomington during the 1940s and the beginning of the1950s. Luria was Watson's dissertation advisor. Watson was heavily influenced by Muller as well. His dissertation was a study of the effect of X-rays on bacteriophage viruses. The collaboration at IU between Luria and Dulbecco started both on the way to their prize-winning work in genetics. IU excellence in life sciences has continued uninterrupted since, in areas as diverse as developmental biology (Robert Briggs), microbial genetics and physiology (Tracy Sonneborn, John Preer, Howard Gest), and plant genetics and evolution (Ralph Cleland, Marcus Rhodes, and Charles Heiser). The current generation of biology leaders at Bloomington includes Thomas Kaufman and Rudolph Raff, who were largely responsible for the creation of the booming area known as evolutionary/developmental biology; and Michael Lynch, Jeff Palmer, and Loren Rieseberg, all pioneers in comparative genomics.

Indiana University is likewise a longstanding leader in biomedical research. Dr. P. Michael Conneally spent a decade searching for the genes that cause Huntington's disease, and in the process helped identify 20% of the human genome. Conneally and collaborator James Gusella of Harvard University identified the location of the Huntington's gene on human Chromosome 4 in 1983 – a discovery that was hailed as one of the most important advances in human genetics. The IU School of Medicine is now widely regarded as a leader in the study of genetic origins of alcoholism through the pioneering work of T.K. Li – work now being continued by David Crabb. Renowned researchers from the IU School of Medicine have also made critical discoveries in physiology (Douglas Zipes and Harvey Feigenbaum), pediatrics (Morris Green), and in understanding Alzheimer's disease (Hugh Hendrie). IU's School of Medicine is the home of the renowned Regenstrief Institute and its electronic medical record system – a critical development by Dr. Clem McDonald, who is widely acclaimed for this innovation. These foundations of excellence are being extended in areas such as genetic origins of diseases (Tatiana Foroud and Linda Malkas), cancer (Kathy Miller and George Sledge), hematology (Hal Broxmeyer), pharmacogenomics (David Flockhart), and bioethics (Eric Meslin).

Research excellence and excellence in clinical services are often linked, as they are at Indiana University. The IU School of Medicine has operated highly regarded hospitals for decades, most notably the Riley Hospital for Children, recognized as one of the best children's hospitals in the world. IU oncologist Lawrence Einhorn developed a novel form of chemotherapy that changed testicular cancer from being almost universally and rapidly fatal to having a cure rate of better than 90%. This regimen, coupled with IU neurosurgeon Scott Shapiro's use of novel surgical techniques, successfully treated the cancer that struck bicycle champion Lance Armstrong. The IU Midwest Proton Radiotherapy Institute is one of only three currently operating proton therapy centers in the US [17], offering new hope for patients suffering from particular forms of cancer that are otherwise not treatable.

These islands of excellence exist within a state that suffers from poor rankings in other areas of health, as shown in these rankings for 2004 (where high ranks are undesirable) [22]:

- 47th in cancer deaths
- 44th in prevalence of smoking
- 32nd in obesity
- 32nd in diabetes
- 39th in cardiovascular-related deaths
- 32nd overall in health

Only six states in the nation have higher rates of smoking. Only three have more deaths from cancer per year, per capita. That these statistics are related is irrefutable. Likewise clearly linked are Indiana's high rate of obesity (only 18 states rank more poorly) and its high levels of diabetes and cardiovascular-related deaths. Overall, the residents of 31 states enjoy better health than the residents of Indiana. In only 18 states is the overall health worse.

Indiana ranks poorly in economic status as well. Data from the US Census Bureau ranks Indiana 35th in the nation in personal income, with a 2003 statewide average of $27,328 [23] as compared to a national average of $30,033. The State of Indiana has at various times in this century been ranked one of the highest in the nation in loss of jobs, personal bankruptcies, and home foreclosures [5, 16]. The percentage of the nation's overall earnings by Indiana residents has fallen since the Korean War, and the global changes that have brought the decline in Indiana's heavy industry will not change in the foreseeable future. On the other hand the life sciences sector of Indiana's economy has been expanding [2]. This performance has been fueled considerably by success at IU, reflected in part by an increase of 156% in annual funding over the past five years for life science research. These data say two things. First, the strong life sciences foundation in Indiana provides opportunity for substantial growth. Second, Indiana University is a critical factor in any future success in this arena.

Just as personal health and income are linked at every level from the individual to the nation, Indiana's health status and economic status are linked. A better economy results in better attention to medical conditions. A healthier workforce can enhance economic growth. Better health (with attendant lower costs for health care and insurance) is a factor when businesses select locations for large facilities. Both health and economic standing can benefit from life

sciences research through its contributions to improving health, reducing the economic cost of illness, and creating new jobs based on a growing life sciences economy.

Beyond the personal and emotional costs of ill health, the economic costs of ill health can be staggering. One example is the cost of cardiovascular disease and the associated costs of medical care and lost productivity. The annual national cost related to death from cardiovascular disease decreased by an estimated $1.5 trillion between 1970 and 1990. As posited in multiple reports [20] if only one third of this decrease were attributed to advances that resulted from medical research, that would result in a $500 billion national benefit per year, during a time when the annual total national investment in biomedical research was approximately one twentieth of this figure [7].

The State of Indiana is doing increasingly well in developing its life sciences economy. Since the sequencing of the human genome, at least 40 states have announced a life science initiative [1]. In such an environment, it is significant that IU is ranked "legitimately in the second tier of state life science initiatives." [10] Thanks in large part to such companies as Eli Lilly and Company, Inc., and the Cook Group, Indiana ranks seventh in the nation in drug and pharmaceutical employment and in medical devices manufacturing. Five percent of the nation's pharmaceutical industry [1] workforce resides in Indiana. Indiana University's efforts in the life sciences — specifically in genomics, bioinformatics, cytomics, metabolomics, and neurosciences — have benefited from more than $228 million in support from the Lilly Endowment, Inc. During the 2004/2005 fiscal year Indiana University received a record-setting $477 million in grant funding for research, nearly half of which was for life sciences research.

Indiana University and the State of Indiana have already benefited from major life sciences initiatives at Indiana University, including the following:

- The Indiana Genomics Initiative, funded by two grants totaling $155,000,000 from the Lilly Endowment, Inc. primarily to the IU School of Medicine.
- The Indiana METACyt Initiative, funded by a $53,000,000 grant from the Lilly Endowment, Inc.
- The collaboration of Indiana University Hospital, Methodist Hospital, and Riley Hospital to create Clarian Health Partners, the largest health care provider in Indiana and one of the largest in the Midwest.
- Funding of $10,000,000 for the neurosciences at Indiana University through the Lilly Endowment, Inc. Initiative to Recruit and Retain Intellectual Capital for Indiana Higher Education Institutions.
- The Human Biology Program, funded via the IU Commitment to Excellence Initiative
- The Center for Glycomics and the national *Drosophila* Genomics Resource Center, both located in Bloomington and both established with National Center for Research Resources (NCRR) grants from the National Institutes of Health (NIH).
- The development of bioinformatics and cheminformatics as major areas of strength in the IU School of Informatics.
- Indiana University's excellence in information technology, particularly in advanced supercomputer and grid applications for the life sciences.

- The generous support of private donors, including gifts from Linda and Jack Gill, Philip and Ruth Holton, Samuel Regenstrief, the Simon families, and Paul and Carole Stark; and gifts from private corporations and trusts, including the Beatrice P. Delany Charitable Trust, Eli Lilly and Company, Inc., Eli Lilly and Company Foundation, the Richard M. Fairbanks Foundation Inc., and the Krannert Charitable Trust.

These major activities have built and are continuing to build areas of excellence within the life sciences at Indiana University. The possibility of international preeminence in the life sciences for Indiana University is based, in part, on the progress these grants enable. The achievement of international preeminence will be possible only if these initiatives, and other Indiana University activities in the life sciences, can be coordinated so that the University is focused on the most challenging and promising areas within the life sciences.

The news about the State of Indiana's investment in research is, however, not uniformly good. The 2004 Milken Institute Analysis of State Technology and Science [4] put Indiana in the third quartile of almost all important indices of scientific development, ranking it 33rd in research and development, behind all other Midwestern states but Iowa. Investment in the infrastructure needed for science and technology development must be greatly expanded if Indiana University is to help lead the State in developing a new life sciences economy. IU must provide unwavering and astute leadership in advancing Indiana in life sciences research, development, and delivery, and in building a life sciences economy. The role of a research-oriented university in a successful life sciences economy is clear: all robust US life sciences economies are associated with the nation's top NIH-funded medical schools in concert with a very strong basic science program.

The *Indiana University Life Sciences Strategic Plan* will chart the course for Indiana University's life science initiatives until at least the end of the decade (FY 2010/2011), and should provide the sort of cohesive University planning that has enabled Indiana University to become a leader in information technology. The scope of this Plan is life sciences, from the molecule to the individual and population of individuals. That is, how do individual chemicals affect our health? How does the body of a particular person work? How do human populations interact with each other, with other organisms, and with disease-causing agents, to affect human health? This plan draws significantly from existing plans in the IU School of Medicine and the College of Arts and Sciences. This plan does not attempt to identify strategies and activities for the interaction between the human population and the global environment. Such activities, core concerns of the School of Public and Environmental Affairs, are tightly linked to such areas as geography, geology, and atmospheric science, and a comprehensive agenda for all of these important disciplines is beyond the scope of this plan.

The IU School of Medicine has created three critical plans: the *Indiana University School of Medicine Research Business Plan,* the *Clinical Research Plan*, and the *Life Sciences Strategic Plan.* All are based on elevating the IU School of Medicine into the upper tier of medical schools that serve as the foundations for robust life sciences economies in their states.

- The *Indiana University School of Medicine Research Business Plan* details the School's goals for growing its research infrastructure and faculty in order to achieve a national

ranking of 10th among state-supported schools of medicine and 20th among all schools of medicine in grant awards from the National Institutes of Health. To accomplish this, the Plan calls for the School, by fiscal year 2013, to do the following:

  - Add 1 million gross square feet of research laboratory space.
  - Increase the number of research-focused faculty by 400.
  - Double all contract and grant awards to $393 million.

- The *Indiana University School of Medicine Clinical Research Plan* sets out the following goals for clinical and translational research:

  - Provide financial incentives for departments/divisions to increase the amount of clinical research they are conducting.
  - Increase space and promote a research-friendly environment with Clarian and other partner hospitals.
  - Increase the recognition of the importance of clinical research in providing incentives for faculty, namely, the ability to be promoted based on clinical research.
  - Improve the infrastructure for conducting clinical research.

- The *Indiana University School of Medicine Life Sciences Strategic Plan* sets out eight major goals for the School:

  - Continue to strengthen its focus on research and clinical programs in cancer to become a national and international leader in cancer research and treatment. Achieve recognition as one of the nation's top five cancer programs.
  - Become nationally recognized for its neurosciences research and clinical care.
  - Become nationally recognized for its research and clinical care in diabetes and metabolic disorders.
  - Sustain and enhance its research cores (e.g., proteomics, imaging, etc.) as a component of the infrastructure necessary to attain its goals.
  - Continue to strengthen and expand its clinical research enterprise.
  - Become nationally recognized for its graduate medical education programs.
  - Continue to implement its research initiative business plan.
  - Increase entrepreneurial activity among faculty.

The College of Arts and Sciences, which includes the majority of the faculty who focus on life sciences research on the Indiana University Bloomington campus, developed a working life sciences strategic plan during 2005. This plan takes account of the College's existing strengths, its goals and aspirations for national leadership stature, and the recent investments from the Lilly Endowment's METACyt grant as well as the Commitment to Excellence proposals funded by the Campus. Goals identified by the College of Arts and Sciences include:

- Add 500,000 gross square feet of general research space by 2013, including a significant amount of space for life science research.
- Significantly increase the number of life sciences faculty.
- Double all grant and contract awards by 2013.
- Reorganize the College's life sciences units, possibly into a new School of Life Sciences, housed within the College of Arts and Sciences and with the IUB Medical Sciences Program of the School of Medicine fully integrated within the School with respect to graduate training.
- Achieve national premier status in the basic life sciences, including ranking among the top 10 among all basic life science units (public and private).
- Maintain or achieve top-five ranking in selected research areas, including analytical chemistry, evolutionary and developmental biology, microbiology, neuroscience, and plant biology.
- Build research strength in organic chemistry, biochemistry, and cancer biology to nationally competitive levels to complement and strengthen both the above top-rank programs and also research at the IU School of Medicine, and to help support the State's biotechnology industry.
- Contribute significantly to the development of bioinformatics, computational biology, and biocomplexity at IU.
- Strengthen and enhance research facilities (e.g., in biochemistry, genomics, imaging, proteomics, and the like).
- Increase transfer of technology from and entrepreneurial activity among life science researchers.
- Offer, in some cases in partnership with other campus Schools, internationally competitive undergraduate and graduate programs in biology, chemistry, and microbiology; and in interdisciplinary areas such as neuroscience, biochemistry, biotechnology, and bioinformatics.

The *Indiana University Life Sciences Strategic Plan* draws most heavily on the strategic plans of the School of Medicine and the College of Arts and Science. It also builds upon the activities and goals of other Schools that have a stake and significant profile in the life sciences: the School of Informatics; School of Nursing; School of Optometry; School of Dentistry; School of Health, Physical Education, and Recreation; and the Purdue School of Science and Purdue School of Engineering and Technology at IUPUI.

The *Indiana University Life Sciences Strategic Plan* sets forth Goals and Actions that will place Indiana University in the very top tier – nationally and internationally – in life sciences research, development, deployment, clinical service delivery, and economic development. In executing the elements of this Plan, Indiana University will contribute to a robust 21st-century economy for the State of Indiana and help it attain a position of leadership within the US in life science industries, while contributing to a foundation of improved personal health and economic well being.

D. Indiana University's mission in the life sciences

"'There is a tide in the affairs of men,
Which taken at the flood leads on to fortune.
On such a sea we are now afloat,
And we must take the current where it serves.'

And so we will, with bold plans, extraordinary talent . . . and great hope
for even higher levels of future accomplishment."
—Adam Herbert, quoting William Shakespeare, at the announcement of the
Indiana METACyt Initiative

In his 2005 State of the University Address, "Creating a future of shared purpose," President Adam W. Herbert stated: "a . . . major institutional priority that will receive significant University focus throughout the balance of this decade is an expansion of the University's capacity to become an international-class life sciences research community. This priority is consistent with the State's economic growth and development agenda." [8] The life sciences are of such great importance for Indiana University that they appear repeatedly as part of the Indiana University Strategic Goals and Presidential Priorities. Within six broad Strategic Goals and 30 specific Presidential Priorities, the life sciences appear explicitly or implicitly five times, as follows:

Strategic Goal	Presidential Priorities
Advance University distinction and distinctiveness.	• Develop and begin implementation of a strategic plan and organizational structure for Life Sciences distinction. • Continue development of IU into a national center of excellence in cancer research, diagnosis, and treatment.
Enhance academic program quality.	• Continue enhancing the quality and advancing the academic research reputation of IU's top nationally ranked academic programs and services.[1]
Expand the scope and impact of research and creative activities.	• Continue to increase growth of externally funded research, particularly in such university priority areas as life sciences and information technology.
Advancing Indiana.	• Develop and implement a program to expand technology transfer activities.[1]

[1] Note: Many of the programs and activities referenced here are in the life sciences

In response to the mandate set by IU's leadership, Indiana University establishes the following mission for Indiana University in the life sciences:

> *Indiana University will become an international leader in basic and translational research in the life sciences and in research, development, and delivery of advanced clinical care. In the process Indiana University will help lead the creation of a robust life sciences economy in the State of Indiana. Indiana University will accomplish this by expanding and building upon the traditional basic life science strengths at IU Bloomington and the traditional basic and clinical research and advanced clinical care strengths at the IU School of Medicine; by growing the basic research strength of the School of Medicine; by expanding the roles of many units within the University in the life sciences; and through the important education and service roles of each of the eight campuses of Indiana University and the nine campuses for medical school education and research.*

This goal, then, becomes the basis of bold plans and expectation for even higher levels of future accomplishment – new discoveries, new insights, and new accomplishments, all made meaningful through their application to benefit the quality of life of citizens of the State and beyond.

Indiana University's strategic directions in the life sciences may be viewed in a matrix fashion across two dimensions: organized by topical focus areas on one dimension, and organized along the lines of the University's traditional roles in research, service, and education on a second dimension.

Subdivided by areas of concentration, IU will focus on the following areas of basic research, translational research, and/or advanced clinical care:

- Analytical chemistry and analytical technology
- Organic chemistry and biochemistry
- Cancer biology
- Diabetes and metabolic disorders
- Neurosciences
- Model systems in biological research
- Personal wellness and health

IU is also involved in several crosscutting activities that support basic research, clinical research, and advanced clinical care in all of these areas. Some of these activities focus on enabling technologies and infrastructure in support of life sciences research:

- Buildings for life sciences research
- Life sciences and informatics
- Cyberinfrastructure for the life sciences
- Interdisciplinary Research and Service Centers

And, as a public university, Indiana University is also deeply engaged in activities related to public service and economic development:

- Advanced clinical care and translational research
- Technology transfer and economic development
- Educating the next generations of life scientists, technologists, and clinicians
- Collaboration

BioCrossroads, a privately-funded organization dedicated to . . . "leveraging Indiana's existing world-class life science assets in order to create new jobs and spur new business opportunities in Indiana" [2] has identified eight focus areas that offer special potential statewide for expanding the Indiana economy:

- Agbiotech
- Biosensors
- Cancer
- Cardiovascular medicine
- Evidence-based medicine
- Neuroscience
- Protein analysis
- Sports-centered life sciences

While there are slight differences in the terminology, the focus areas identified by Indiana University map with the areas of potential and opportunity identified by BioCrossroads. Both lists identify cancer and neurosciences as focal areas. Protein analysis is a subset of IU's "analytical chemistry and analytical technology" area. Much that BioCrossroads includes in the "biosensors" category the IU life sciences plan references in the "analytical chemistry and analytical technology" category, and in the activities of the Interdisciplinary Research and Service Centers (IRSCs). IU's "personal wellness and health category" relates to BioCrossroads' areas of cardiovascular medicine and sports-centered life sciences. The IU category "model systems in biological research" has much to do with Agbiotech. Life sciences and Informatics will create many of the tools for use in the biosensors category and evidence-based medicine.

The life sciences are characterized by their diversity: diversity in topics of study, diversity in important methodologies, and diversity in potential areas of distinction. This *Indiana University Life Sciences Strategic Plan* will identify those areas in which the University aims to distinguish itself nationally and internationally. The achievement of excellence in these areas will require substantial collaboration within the University. Thus, one section of this proposal is devoted specifically to collaboration between and within the various subunits of IU.

This plan echoes the foundation of the *Indiana University Information Technology Strategic Plan*, which in 1998 set the ambitious goal for Indiana University to "rise to a position of absolute leadership among institutions of public higher education in the creative use and application of information technology" [13]. Indiana University has achieved this goal.

Indiana University can similarly dramatically advance its accomplishments and standing in the life sciences through such a University-wide strategic planning process, followed by single-minded execution of this Plan by the University as a whole. Indiana University's investment in information technology should now pay handsome additional dividends as it enables bold efforts in the life sciences. Information technology and the life sciences continue to be areas of University-wide focus and IU distinction.

Towards the realization of Indiana University's mission in the life sciences, this Plan sets forth a number of Goals and Actions to be executed over the course of the remainder of this decade (that is, between FY 2005/2006 and FY 2010/2011). The Plan includes a strategy of collaboration and cooperation essential to achieving these goals (Section F). The Goals and Actions are subdivided by the topics identified above. Section I contains a summary of the Goals and Actions.

E. Basic and translational research

"Nature uses only the longest threads to weave her patterns, so that each small piece of her fabric reveals the organization of the entire tapestry."
—Richard P. Feynman

Basic research in the life sciences has been an area of strength for more than a century at Indiana University. The life sciences have already transformed interdisciplinary research and created collaborations within the research community in ways not expected. IU researchers in several disciplines have found that the answers to fundamental research questions are revealed only through collaboration with researchers in other disciplines. Our goal of international leadership in the life sciences requires that IU make excellence in basic life sciences research a core of its strategic and operational efforts.

Translational research creates the means by which basic research findings are translated into benefits to human health and to the economic vitality of the State. Translational research includes the transfer of technology such as new analytical chemistry tools to research and industrial purposes, and the clinical research required to develop, test, and refine new medicines, medical devices, and clinical procedures.

As an example, consider the discovery of a protein that plays a role in cancer, and the use of organic chemistry to develop a molecule that inhibits the function of that protein. Translating those findings into procedures that benefit human health requires studies on animal models, studies that themselves require additional biochemistry, imaging, and other types of analyses. Before the clinical research on introducing the new molecule into the human can begin, this translational research must take place. It may well be that, as Richard Feynman put it, each small thread of the fabric of nature reveals the organization of the entire tapestry. But pursuing each thread of discovery requires collaboration across teams of researchers within and across multiple disciplines and areas of specialty.

Indiana University has carefully selected a set of focus areas for basic and translational research in the life sciences:

- Analytical chemistry and analytical technology
- Organic chemistry and biochemistry
- Cancer biology
- Diabetes and metabolic disorders
- Neurosciences
- Model systems in biological research
- Personal wellness and health

These are focus areas of particular strength and opportunity for Indiana University.

In the remainder of this section specific strategies and actions for the seven focus areas of basic and translational research efforts for Indiana University are set out in detail.

E.1. Analytical chemistry and analytical technology

Indiana University has long been home to one of the nation's leading research groups in analytical chemistry. This leadership provides a unique advantage for IU in life sciences research. Studying living systems requires knowledge of the chemicals and compounds that compose those systems. The NIH Roadmap [21] places great importance on the need to understand biological pathways and networks, and states: "To better understand the proteome, innovative tools must be developed that will enable researchers to determine in real time the amounts, locations and interactions of large numbers of individual proteins within a single cell."

IU's leadership in analytical chemistry provides capabilities for understanding the composition of living systems that do not exist elsewhere, particularly in the area of proteomic analysis. MALDI-TOF spectrometers (Matrix Assisted Laser Desorption Ionization - Time of Flight Spectrometers) are a widely used and essential tool for understanding the components of a cell. Essentially every MALDI-TOF spectrometer manufactured and sold today includes technology developed and licensed under patent from Indiana University. Indiana University must continue to capitalize on this advantage and expand the leadership of IU's analytical chemistry group.

IU has received significant recent grant support for analytical chemistry, including support via the Indiana METACyt Initiative and NIH funding for a national resource center for analysis of glycoproteins. METACyt has as one of its key goals answering questions such as: What proteins and small molecules are present in a cell? How do these chemical species vary in time or in response to a specific perturbation? What are the interactions among these components? IU's analytical chemists will leverage the loci of technology development on the campuses – including unique Cyclotron-based resources – to develop next-generation technology. Advances planned by IU researchers include collaboration with the Biological Microscopy group of the School of Medicine to custom design compounds that can be used to trace the movement of proteins and organelles within the cell and among cells. Basic research in instrument technology, analytical chemistry, and collaborations with other research groups at Indiana University are essential to IU's leadership in the life sciences.

Goal 1. Indiana University should maintain and enhance its top-tier research program in analytical chemistry.

Action 1.1. The University should maintain and take steps to strengthen its world-class analytical chemistry faculty and program, including senior-level faculty and those with a primary interest in advancing bioanalytical technologies.

Action 1.2. The University should strengthen the Center for Proteomics Research and Development through hiring appropriate engineering and computational staff, and creating a renewable equipment upgrade fund.

Action 1.3. The University should obtain ongoing funding from federal sources to operate national centers of excellence and national resource centers in analytical chemistry.

E.2. Organic chemistry and biochemistry

Organic chemistry, including bioorganic and peptide synthesis in particular, is the key to applications ranging from the discovery of new drugs to the development of consumer products. Along with analytical chemistry, organic chemistry is the bridge from academic research to industry. It is also important as a tool in basic research. For scientists to better understand living systems, they must have ways to perturb those systems — increasing and/or decreasing the activity of particular components to observe the effect of so doing. Pairing biological scientists with synthetic chemists allows custom design of probes that aid the accomplishment of this task. The result is two-fold: first, IU scientists will be able to stay ahead of the competition by having unique tools, ensuring better outcomes in the competition for grant funding; and second, some of these probes will have intellectual property potential as reagents desired by other scientists and industry, and perhaps as pharmaceutical agents. The chemistry department at IU Bloomington is recognized in industry and academia for the quality of its analytical and organic chemistry groups. IU must rebuild and enhance its organic chemistry cluster by hiring more faculty and expanding the graduate student population.

Tightly related to organic chemistry is biochemistry — the chemistry of living systems. A leading research program in the life sciences must have outstanding expertise in biochemistry. The Department of Biochemistry in the IU School of Medicine is growing in size, accomplishment, esteem, and national profile, as is the Biochemistry Program at IU Bloomington. This Plan calls for Indiana University's campuses to act as one University to the fullest extent possible. Accomplishing this means IU's two research campuses must house excellent, complementary, and highly collaborative programs in biochemistry.

Goal 2. Indiana University should build research strength in organic chemistry and biochemistry to nationally competitive levels to complement and strengthen the top-ranked life sciences programs in Bloomington and research programs at the IU School of Medicine, and to help support the State's biotechnology industry.

Action 2.1. The University should rebuild a nationally competitive program in organic chemistry on the Bloomington campus. This effort must include in the near term the recruitment of outstanding senior and junior faculty in synthetic organic chemistry, increasing the number of faculty in the group.

Action 2.2. The University should establish a Center for Research in Chemical Synthesis in Bloomington to encourage an interdisciplinary approach to novel synthetic pathways.

Action 2.3. The University should provide a world-class instrumentation infrastructure for organic chemistry and biochemistry.

Action 2.4. The University should create a critical mass in biochemistry at IU Bloomington through implementation of the Interdepartmental Biochemistry Graduate Program (IBGP). The IBGP would be created through establishing new faculty lines and formal ties to the IBGP for existing faculty (including those in the Departments of Biology, Chemistry, and the Medical Sciences Program at IU Bloomington).

E.3. Cancer biology

Cancer biology is an area of both import and opportunity for Indiana University, where a unique constellation of research strengths promises continued advances in uncovering the root causes of cancer, and in developing improved treatments.

Cancer is, fundamentally, the result of abnormal gene expression and perturbed relationships between cells. IU's vigorous programs in genomics, proteomics, metabolomics, and cytomics, along with the cancer research done by the IU School of Medicine and Clarian Health Partners at the IUB Medical Science Program, position IU for progress in understanding the root causes of cancer. These strengths also place IU on the path to discovering the specific genes or gene pathways that give rise to cancers with particularly poor prognoses. Such discoveries hold the keys to improved treatment.

In treating cancers, IU has a distinguished record of achievement. Riley Hospital is one of the world's best hospitals for the treatment of childhood cancers. The Indiana University Cancer Center received renewed NIH funding for 2005 through 2008 and was re-designated as a National Cancer Institute Clinical Cancer Center. IU's Gamma Knife and Midwest Proton Radiation Therapy Center offer some of the most advanced treatment options. Through the collaboration of researchers and clinicians involved in METACyt, INGEN, and Clarian Health Partners, IU is uniquely poised to advance the kinds of combined personalized analysis and advanced clinical treatment required in treating advanced cancer.

Recognizing the importance of cancer research and IU's excellence in the many areas involved in the field, President Herbert has made it a goal for IU to achieve a ranking among the nation's top five centers in cancer research, diagnosis, and treatment. Greater focus on cancer biology within the Medical Sciences Program, Department of Chemistry, and the Interdepartmental Biochemistry Graduate Program (IBGP) will enable closer integration of cancer research in Bloomington and better complementary and collaborative relationships between IU Bloomington and the IU School of Medicine in Indianapolis.

Cancer biology stands out as an area of the life sciences where today's state of scientific and clinical knowledge, IU's leadership, and the possibilities enabled by new investment offer IU the chance to become one of the best comprehensive centers for basic research, translational research, and advanced clinical treatment of cancer.

Goal 3. Indiana University should become an international leader in basic and translational research about cancer, and in advanced clinical care for, cancer.

Action 3.1. The University should ensure that the IU School of Medicine and the IU Cancer Center in Indianapolis advance to Comprehensive designation status within the certifications awarded by the National Cancer Institute, by:

- *Implementing the necessary basic science, clinical, prevention, control, behavioral, and population-based research activities.*
- *Implementing the necessary interactive and collaborative activities among researchers in those areas.*
- *Implementing early phase, innovative clinical trials and participating in the NCI's cooperative clinical trial group system.*
- *In collaboration with the School of Nursing, performing the necessary activities related to outreach, education, and cancer information in the community.*
- *Adding significant numbers of new cancer researchers to meet the goals in this Action.*

Action 3.2. The University should, through the IU School of Medicine and the IU Cancer Center, create and support new programs in health services research/epidemiology, molecular carcinogenesis, and gastrointestinal and ovarian cancers.

Action 3.3. The University should establish a Program for Cancer Biology in Bloomington, bringing together faculty from Medical Sciences, Biology, Chemistry, and Biochemistry with an interest in aspects of cancer biology, including basic research in cell signaling, differentiation, epigenetics, DNA repair, and other relevant areas. Seed funding should be provided to increase collaborative cancer research with the School of Medicine.

Action 3.4. The Bloomington campus should recruit, in collaboration with the School of Medicine, additional faculty with expertise in basic research relevant to cancer biology, with shared appointments between the IU Bloomington Medical Sciences Program and the Biochemistry Interdepartmental Graduate Program.

E.4. Diabetes and metabolic disorders

Diabetes is one of the leading health problems of our time. Diabetes includes type 1 diabetes as well as the "metabolic syndrome" that encompasses obesity, insulin resistance, type 2 diabetes, and cardiovascular disease, including hypertension, atherosclerosis, and vascular biology. Diabetes is a major cause of blindness and kidney disease, and can lead to amputation and permanent disability. Some 7.4 percent of Hoosiers (338,000 people) have diabetes (significantly higher than the national average). Nationally, 18.2 million Americans have diabetes. Diabetes is the sixth leading cause of death for Indiana citizens [11].

Indiana University has several key assets that form a foundation for excellence in diabetes research and treatment. Advanced treatment programs, translational and clinical research, and studies of genetic bases of diabetes are strengths of the IU School of Medicine, represented in

such programs as the Center for Diabetes Research, the Division of Endocrinology and Metabolism in the Department of Medicine, and the Pediatric Section of Endocrinology and Diabetes. Programs such as the Human Biology Program at IUB funded by the Commitment to Excellence also enhance IU's activities related to diabetes and diabetes prevention.

Diabetes can be viewed as a metabolic disorder in which cellular controls do not work effectively. The Indiana METACyt Initiative offers new possibilities for basic research in cell metabolism that will help researchers better understand diabetes. Biochemical analyses and cell imaging resources made possible at IU thanks to the Indiana Genomics Initiative and METACyt also offer new opportunities for improved understanding. Indiana University is poised to undertake the challenge of treating and preventing diabetes with a concerted, interdisciplinary, and collaborative approach that combines basic research, translational research, and advanced clinical care.

Goal 4. Indiana University should become a nationally recognized leader in research and clinical care related to diabetes and metabolic disorders.

Action 4.1. The University should establish within the IU School of Medicine the Indiana Center of Excellence in Diabetes, to be directed by an internationally recognized leader in this area. The University should recruit additional well-established investigators that do both basic and translational research from the departments of Medicine, Pediatrics, Surgery, Biochemistry, and Physiology.

Action 4.2. Following recruitment of the Center Director, the University should recruit nationally additional accomplished investigators to join the already well-established investigators that conduct both basic and translational research from the departments of Medicine, Pediatrics, Surgery, Biochemistry, and Physiology, as well as the peptide synthesis group in Bloomington.

E.5. Neurosciences

The neurosciences have benefited immensely from the molecular genetics revolution and are central to understanding many important human diseases. This area also offers a superb opportunity for programs in Indianapolis and Bloomington to collaborate in ways that will bring distinction to the University as a whole.

The centerpiece of neurosciences research in Indianapolis is the IU School of Medicine Stark Neurosciences Research Institute (SNRI). The Stark Neurosciences Research Institute was created by a $15-million gift from Paul and Carole Stark, to which an additional $10 million was added from other sources. Dr. Gerry Oxford was recently recruited to be its director. The center is now building on existing strengths in neurosciences, neurophysiology, radiology, psychiatry, addiction sciences, and Alzheimer's disease.

The Linda and Jack Gill Center of Biomolecular Science at IU Bloomington is dedicated to biomolecular research in the neurosciences and serves as a centerpiece and point of coordination

and collaboration for neuroscience activities. More than 30 IUB faculty have research interests in, or related to, neuroscience. Neuroscience funding at IUB includes more than $8 million in support via the METACyt Initiative, funding for vacant Gill Chairs, the establishment of an fMRI (brain imaging) facility at IUB, funding for the Human Biology Program from the Commitment to Excellence, and the reframing of the Department of Psychology as the Department of Psychological and Brain Sciences.

The use of specially bred mice with particular genetic features is particularly important in neuroscience research. The recently completed Biotechnology Research and Training Center in Indianapolis contains an advanced mouse facility. The METACyt Initiative is funding a complementary mouse facility in Bloomington.

Neuroscience is one of the areas identified by BioCrossroads as an excellent area of opportunity for development of the life sciences economy in the State of Indiana [2]. IU is rapidly developing new strengths in the neurosciences on both main campuses. Focused collaborative effort will enable Indiana University to establish programs of international significance and, leveraging strengths in related areas, overtake existing national and international leaders in this area.

Goal 5. Indiana University should build its research programs in neurosciences (basic research, translational research, and advanced clinical care) so that they are ranked in the top tier nationally.

Action 5.1. The University should create the leadership structures and coordination facilities for the Gill Center for Biomolecular Research and the Stark Neurosciences Research Institute (SNRI) to become leaders in their respective areas of focus, and to enable them to collaborate and coordinate their activities so as to most effectively advance basic research, translational research, and advanced clinical service delivery.

Action 5.2. The University should recruit additional Gill Chairs, Presidential Life Science Professorships (funded by the Lilly Endowment, Inc.), and other faculty with a general focus in molecular neuroscience.

Action 5.3. The University should, through partnership between the SNRI and the Department of Neurological Surgery, recruit an outstanding senior researcher with a nationally/internationally recognized research program in the areas of neuronal plasticity and/or recovery from spinal cord injury to fill The Mari Hulman George Chair in Neuroscience Research.

Action 5.4. The University should, through the SNRI, complete recruitment for additional outstanding individuals for tenure-track faculty positions at the assistant or associate professor level who will conduct research in the following areas: pain and sensory systems, developmental neurobiology and regeneration, mechanisms of substance abuse and addiction, and neurodegenerative disorders.

Action 5.5. The University should recruit a Director of Neuroimaging at the IU School of Medicine. The University should recruit additional outstanding individuals for tenure-track faculty positions with specializations in pain and sensory systems, developmental neurobiology

and regeneration, mechanisms of substance abuse and addiction, and neurodegenerative disorders.

E.6. Model systems in biological research

Basic discoveries in genetics, molecular biology, development, and evolution have been and continue to be the source of new advances in biomedical research and medical treatment, and in turn the source of new industries and economic development. Basic discoveries lead, years later, to important practical benefits not originally foreseen. The migration of new discovery to medical treatment may take years or decades, and persistent and consistent investment in basic life sciences is essential.

Accordingly, the National Institutes of Health directs billions of dollars each year to basic, fundamental research in the life sciences. Much of this research involves so-called "model systems," i.e., non-human organisms possessing attributes (small size, short generation time, experimental manipulability, and the like) that enable studies that would be impractical or even unethical in humans.

The fundamental concept underlying the model systems approach is the shared evolutionary history of all life on Earth. Lessons learned from one organism apply to many others. The majority of human genetic diseases can be studied in model systems, and most genes known in humans have an analog that may be studied in fruit flies and other model organisms. The principal model systems used in NIH-funded research include other vertebrates (such as mice, the African clawed frog, and zebrafish), invertebrates (e.g., the fruit fly *Drosophila* and the nematode worm *Caenorhabditis*), fungi (such as yeast), bacteria, and even plants (especially the model plant *Arabidopsis*). Indeed, one of the most remarkable and unexpected facts to emerge during the last few decades is that the fundamental molecular processes of living organisms are extraordinarily well conserved through the course of evolution. This discovery, based in part on pioneering studies performed at Indiana University, means that what we learn about the genetics of model organisms leads to better understanding of the human condition. In addition, research on diverse model organisms often has indirect and unpredictable applications and pay-offs.

IUB excels in research using many of the most important model organisms. For example, since the time of Nobel Laureate Hermann Muller, IUB has been known as an outstanding center for study of the fruit fly, which remains the most important of all model organisms for genetic research. In addition to (and because of) its outstanding community of *Drosophila* researchers, IU Bloomington is home to key centers that support the *Drosophila* research community worldwide: the Flybase web-based information resource, the *Drosophila* Stock Center, and the *Drosophila* Genomics Resource Center. All are supported by major NIH and NSF grants and are internationally recognized as critical resources for genetic and genomic research. Further, 80% of IUB senior faculty studying genetics in plants receive major NIH funding, and one plant research project has been recognized for its potential insights into mechanisms of and treatments for human aging. IUPUI and IUB both make use of mice as model systems, and activities with mice have received significant support from the INGEN and METACyt grants. IUPUI is also a leader in use of other vertebrate model organisms. In addition to mice, IU School of Medicine researchers use rats, African clawed frogs (*Xenopus*), and zebrafish (*Danio*) as model organisms

in biomedical research. At IUPUI, the Center for Regenerative Biology & Medicine (affiliated with the Department of Biology of the Purdue School of Science) uses amphibians to study the process of regeneration. Model organisms used by the Center include axolotls (*Ambystoma mexicanum*) – an unusual aquatic salamander that retains the lifelong ability to regenerate lost limbs. The IU School of Medicine receives considerable NIH funding for use of model organisms as well as research with viruses (technically not organisms). The School is the home of the coordinating center for the NIH-funded National Gene Vector Library, led by Dr. Ken Cornetta of the IU School of Medicine, which is a national resource facility for research that involves several types of nonpathogenic viruses.

A fundamental insight from the study of model organisms is the large degree to which the basic molecular processes of life are conserved through the course of evolution. Another insight is that genetic differences between organisms create a significant array of model organisms that are particularly well suited for specific research problems. For example, IU researchers studying plants have overturned some fundamental concepts about the sources of genetic variation in populations. IUPUI researchers have developed two strains of rats – one prone to excessive consumption of alcohol, and another that dislikes alcohol. These strains of rats are of inestimable value in understanding the genetic bases of alcoholism. Ten years ago few people would have predicted that water fleas – *Daphnia* – would become an important model system for understanding genetics and the relationships between environmental influences and genetic systems. Today IU Bloomington is a leader in the use of *Daphnia* as a model organism in genetic research. IU researchers are pursuing the use of such esoteric animals as sea urchins and dung beetles as model systems for studying development. The identification of model organisms as excellent tools for important research projects is a key enabler of new, significant discoveries. Indeed, Muller's Nobel Prize was given in part to recognize his development of techniques that added to the importance of fruit flies as model systems.

Most of the model systems and related biological research on the Bloomington campus takes place within the Department of Biology, while most in Indianapolis takes place within the IU School of Medicine. These research groups – working with interdisciplinary centers such as the Center for Genomics and Bioinformatics, the Institute for Biocomplexity, the Center for Proteomics Research and Development, and the Center for Computational Biology and Bioinformatics – are developing particularly effective synergistic relationships with other departments and computational biologists, bioinformaticists, mathematicians, computer scientists, and information technologists. With Indiana's excellence in informatics and information technology, these relationships represent a powerful edge in the competition for leadership in model systems biology.

The excellence of IUB's groups of model systems biologists is imperiled by their relatively small sizes. The top universities in the country have much larger groups working on key model organisms. Attaining critical mass with respect to group size is essential in order to attract and retain the very best faculty, postdoctoral fellows, and graduate students. Therefore, significant growth is called for so that IUB can build upon its current excellence to reach the elite status of the nation's top 10 across all public and private institutions. As one part of this growth, IUB should build, largely from scratch, strong groups working on key vertebrate models, such as mice and zebrafish. Development of programs on these vertebrate models will not only

strengthen IUB's life sciences group but also increase its collaborative partnership with the IU School of Medicine.

This plan calls for substantial growth in the life sciences in Bloomington. In particular, the Department of Biology, a large unit of almost 60 tenure-track faculty already set for substantial growth, would reach a size commensurate with that at other major top public universities (e.g., Michigan, Illinois, Texas, and the Universities of California at Berkeley, Los Angeles, San Diego, and Davis). This level of growth would render the department large and unwieldy, unable to respond nimbly to opportunities and changing directions. Restructuring is called for, possibly following the model at many of these and other top public universities, where several departments or sections of manageable size are organized into a School of Life Sciences (or Biological Sciences). The School would be integrated within the College of Arts and Sciences. Such an arrangement would also enable the IUB Medical Sciences Program, which would still report to the School of Medicine from the standpoint of its budget and medical training program, to benefit from full integration within the new School with respect to graduate training.

Goal 6. Indiana University should expand and elevate its already outstanding research programs on model biological systems to rank among the top 10 in the country.

Action 6.1. The College of Arts and Sciences should significantly increase the number of life sciences faculty.

Action 6.2. The University should add significant faculty strength in model systems and related areas of biology, enhancing current excellence in molecular, cell, and developmental biology; microbiology and plant biology; and ecology, evolution, and animal behavior.

Action 6.3. The University should build high-quality research groups at IU Bloomington working on important vertebrate model systems, such as mice and zebrafish.

Action 6.4. Indiana University should create a Center for Synthesis in Evolutionary Studies to integrate the knowledge gained at all scales to better understand evolution and to better use the comparative approach to apply knowledge gained from model systems to the human condition.

Action 6.5. The University should consider reorganizing many of the College's life sciences units, possibly into a new School of Life Sciences, housed within the College of Arts and Sciences, and with the IU Bloomington Medical Sciences Program of the School of Medicine fully integrated within the School with respect to graduate training.

E.7 Personal wellness and health

Nationally, the top dozen diseases in terms of annual economic cost are (according to the most recently available figures from 2001) [18, 19]:

1. Injury $338 billion
2. Alcohol abuse $185 billion
3. Heart disease $183 billion

4. Disability $169 billion
5. Mental illness $161 billion
6. Smoking $138 billion
7. Drug abuse $110 billion
8. Alzheimer $100 billion
9. Obesity $ 99 billion
10. Diabetes $ 98 billion
11. Cancer $ 96 billion
12. Chronic pain $ 79 billion

These costs include the cost of care, as well as the cost of economic losses created by absence of workers from their jobs due to illness, and loss of skilled workers due to disability or death. Of the twelve most economically important diseases in the U.S., at least eight are directly linked to such personal lifestyle choices as smoking, exercise, and use of drugs (alcohol and controlled substances). Hoosiers, overall, are not choosing well, as indicated earlier in the poor rankings for the State of Indiana for obesity, prevalence of smoking, and incidence of diabetes, cardiovascular disease, and cancer.

The occurrence of obesity in teenage Hoosiers has risen by roughly a third in just the last two years (2003 to 2005). Some 15% of teenagers in grades 9 to 12 are now overweight [12]. The dangers and costs of obesity run the gamut from the decreased quality and duration of life to the skyrocketing cost of medical care and a workforce facing functional limitations. Obesity is a critical risk factor for development of diabetes; researching cures for diabetes must include focusing on educational efforts to help prevent it.

Other personal choices have important health consequences. Sexually transmitted diseases pose a significant health risk. There have been more than 7,500 reported cases of Acquired Immune Deficiency Syndrome in Indiana (Indiana ranks in the middle of the nation in prevalence of HIV/AIDS) [12]. While the tragedy of AIDS is recognized, other, more common sexually transmitted diseases carry significant health risks. Human Papillomavirus affects at least 50 percent of sexually active teenagers and young adults, and is for women a key risk factor in the development of cervical cancer. [3]

The personal health choices of Indiana citizens have consequences for the State's economic future. While Indiana's educational systems strive to create a well-educated workforce for the 21st century, a more robust and vibrant economy will not be realized if it depends for its construction on a workforce facing chronic health problems that spring from poor decisions about health. Companies that consider locating in Indiana will take into account the cost of medical insurance and the health of the workforce. Even small differences in overall healthcare and insurance costs can have dramatic impact on a company's bottom line. Simply put, good health is good for individuals, good for business, and good for the State.

Goal 7. Indiana University should engage in research and education (particularly State- and federally-funded education efforts) that will help residents of the State of Indiana to lead healthier, better, and longer lives.

Action 7.1. The University should continue and expand efforts to inform residents of the State of Indiana about the importance of exercise and proper nutrition.
Action 7.2. The University should continue and expand efforts within the State of Indiana to reduce prevalence of smoking, excessive use of alcohol and controlled substances, and risky sexual activities.

F. Enabling activities: infrastructure and related disciplines

" . . . . .. I believe the development of specialized facilities, which represent the adornment of a great university and which all great universities have, should be a high priority."
--Herman B Wells

Life sciences research makes unusually heavy demands on laboratory space, laboratory services, and information technology resources. Any university that hopes to lead in the life sciences must lead first in adequate laboratory space and teaching facilities, quality and quantity of wet lab space, and appropriate environments for advanced instruments.

It is impossible for any one person or research group to maintain expertise in the many techniques and technologies that are fundamental in life sciences research. For the University to lead in the life sciences, it must provide a broad array of infrastructure support and advance the state of the art in technology and in experimental techniques. While we must implement known proteomics methods as a service to researchers, we must at the same time pursue research into proteomics methodology to ensure new approaches are discovered and to advantage IU researchers by putting them on the cutting edge of the implementation of these new technologies.

The escalation in the ability to generate data in the life sciences has led to an explosion in demand for information technology facilities and informatics research and development. One of IU's strengths is its excellent information technology support for the life sciences. In addition, the IU School of Informatics includes programs in bioinformatics, cheminformatics, health informatics (including health information administration), and computer science that are vital to IU's leadership in the life sciences.

The following sections detail Goals and Actions related to buildings, technology service, and information technology required for IU to achieve its mission in the life sciences. The development of specialized facilities must, as President Wells stated, be a high priority if Indiana University is to achieve its goals in the life sciences.

F.1. Buildings for life sciences research

Indiana University does not have enough building or lab space to support the Goals and Actions identified in this Plan. To quote from the recent joint task force on research space at Indiana University:

> " . . . school deans believe that the key limiting factor on advancing their school's research missions is space. Many have restricted or altered the course of their school's progress to fit their current, inadequate space; others have neglected to hire new faculty due not to a lack of salary or research funds, but to lack of space; in some cases, faculty we have sought to recruit have declined to come to Indiana because of space limitations; and still other disciplines have encountered acute

> shortages of space even after acquiring a new building, their needs having outgrown these buildings during the planning stage."

And:

> "We believe that this represents a very grave situation and represents possibly the biggest single impediment to IU reaching its full potential as a research university. We are very strongly of the opinion that the President and Trustees at Indiana University must take urgent action to begin to put a plan in place to address this problem over the next 10 to 20 years. Without such a plan, IU will begin to slip behind other comparable research universities as it simply will not have the space to sustain increases in research activities." [14]

Because the life sciences are so dependent upon laboratory space, new buildings are critical if the University is to achieve its life sciences goals.

Goal 8. Indiana University should enhance its physical research infrastructure with buildings that permit and support the expansion of IU's life science research activities.

Action 8.1. Following the Indiana Department of Health departure from the Van Nuys Medical Science building, the University should expand and renovate research space in the building and make it available for diabetes research, significantly increasing space dedicated to diabetes research on the IUPUI campus and to expanded research programs in the Departments of Biochemistry and Surgery.

Action 8.2. The University should, on the IUPUI campus, complete construction of facilities included in Phase 1 of the building activities proposed in the Indiana University School of Medicine Research Business Plan:

- *Medical Information Sciences Building, currently under construction, to be completed in early 2007.*
- *Research III construction to begin in 2006, with completion in 2009.*
- *Renovation of Van Nuys Medical Science building facilities vacated by the Indiana Department of Health, to be completed in 2008.*
- *Fort Wayne Regional Center for Medical Education research facility, to be completed in 2008.*
- *The Ernestine Raclin and O.C. Carmichael Jr. Hall at the IU School of Medicine - South Bend, completed in 2005 and dedicated in October 2005.*

Action 8.3. The University should, on the IU Bloomington campus, complete current and planned enhancements to building infrastructure in the life sciences and those areas that directly benefit the life sciences, including:

- *Complete the renovation of Jordan Hall.*
- *Complete building and occupy Simon Hall and MSB-II without delay.*
- *Obtain funding for and build the proposed Cyberinfrastructure Building to support information technology infrastructure, which has direct benefit for the life sciences at IU.*

Action 8.4. The University should work to obtain appropriations from the Indiana General Assembly for construction of the following facilities:

- *For the IU School of Medicine, as called for in Phase II of the building activities proposed in the Indiana University School of Medicine Research Business Plan: Van Nuys Medical Science Renovation Phase III; several facilities at regional centers for medical education.*
- *For IU Bloomington, obtain funding for the planned MSB III building, and build and plan new laboratory buildings to accommodate further growth in life sciences research, as well as centralized research support infrastructure and new research centers.*

Action 8.5. The University should obtain the necessary authorization and appropriations from the Indiana General Assembly for construction of the following facilities called for in Phase III of the building activities proposed in the Indiana University School of Medicine Research Business Plan:

- *Research IV – to be supported in part by private funds raised by the IU School of Medicine.*
- *Facilities at regional centers for medical education.*

Action 8.6. The University should create and implement a long-term plan for the expansion and modernization of animal quarters at Indiana University Bloomington.

Action 8.7. The University should engage in ongoing long-range planning for buildings in the life sciences so that the University is always excellently equipped with a physical infrastructure that will enable and support its life science research objective.

F.2. Life sciences and informatics

With the explosion of genomic information from living organisms, it is now possible to envision the development of predictive theories about living systems, including gene expression, biochemical pathways, and processes that take place at the level of whole populations. Testing these theories will be a daunting challenge. New developments in bioinformatics will be required to manage and make use of the life sciences data now being produced at an ever-accelerating rate.

New theory and simulation methods in the fields of computational biology, bioinformatics, biocomplexity, and computer science will be required in order to develop predictive and detailed models of biological systems. And collaboration between informatics experts and life science researchers will be essential to the development of theory and understanding in the life sciences. Leadership in the life sciences will depend upon new developments in bioinformatics, cheminformatics, medical informatics, health informatics, and computer science applicable to the life sciences. The IU School of Informatics has led Indiana University in developing faculty research programs in these areas. From the fields of computational biology, bioinformatics,

cheminformatics, and biocomplexity come techniques that will make possible predictive and detailed models of biological systems. Indiana University must continue its leadership in the development of new theories and new techniques in life sciences informatics. This involves both new research by the IU School of Informatics and the IU School of Medicine Regenstrief Institute.

Goal 9. Indiana University should lead in the development and utilization of new theory and technique in bioinformatics, computational biology, cheminformatics, medical informatics, health informatics, and biocomplexity.

Action 9.1. The University should develop and strengthen several programs related to bioinformatics, computational biology, and biocomplexity (the computational partners of the life sciences), and coordinate these activities so that the combined strengths of IU's many and diverse efforts in these areas are brought together, coordinated, and leveraged to become an area of competitive strength for Indiana University.

Action 9.2. The University should develop the IU School of Informatics program in cheminformatics into the nation's leading program in this area, and develop bioinformatics into one of the nation's leading programs.

Action 9.3. The University should seek to expand the application of the Regenstrief Medical Record System within the State of Indiana. This will enhance medical care and create an invaluable repository of clinical data — namely, phenotypic information that can be mined to address biologic and genetic questions.

F.3. Cyberinfrastructure for the life sciences

Advanced cyberinfrastructure – high performance computers, massive data storage systems, visualization environments, data resources, advanced instruments, and people all linked together by high-speed networks and advanced software – is essential to leadership in the life sciences.

Indiana University's excellence in advanced information technology is a factor that will aid and accelerate the University's accomplishments in the life sciences. Indiana University in 2001 announced that it had acquired a supercomputer capable of 1 trillion mathematical operations per second – the first supercomputer owned by a US university to break the 1-TeraFLOPS barrier. Indiana University continues to be a leader in the implementation and use of some of the largest supercomputers in the world.

Life science data are essentially irreproducible; a data set, if lost, is lost forever. Careful preservation of the University's data assets is thus a key concern. Similarly, the most advanced high performance computers and visualization environments are required to simulate and understand the functioning of living systems. Indiana University provides a particularly robust data storage infrastructure, with the ability to keep copies of important data in Bloomington and Indianapolis, assuring that data will remain properly preserved if a disaster were to strike one of these two cities.

Life science data are often so complex that only through advanced visualization can data sets, or the results of simulations, be understood. Indiana University is a leader in the implementation and use of advanced visualization, including immersive 3-D visualization environments. Such facilities enable research discoveries that are not otherwise possible.

Goal 10. Indiana University should develop and deploy a cyberinfrastructure that provides capabilities for new scientific insights, new breakthroughs in technology development, and enhanced competitiveness for grant funding.

Action 10.1. The University should lead in nationally funded cyberinfrastructure research and development activities, emphasizing development and delivery of new tools for life scientists that will enable advanced new calculations to be performed and then understood through visualization.

Action 10.2. The University should develop new tools and techniques for long-term management and curation of life sciences data, and leverage these tools and techniques so that research data produced by Indiana University is used to the fullest extent possible. The University should establish and expand externally funded data repositories serving state, national, and worldwide life science communities.

F.4. Interdisciplinary Research and Service Centers (IRSCs)

The critical importance of gene sequencing, advanced spectroscopy, and other new technologies has created interdependencies and opportunities in life sciences research that would have been hard to anticipate a decade ago. A researcher studying animal behavior might need to obtain the DNA sequence for a particular gene, have the gene's product(s) identified, and then have the gene products measured in a number of different organs or animals. A cancer researcher might need gene sequences analyzed, gene products assayed, the presence of particular compounds in particular cells imaged, and the presence of cancerous tissue in an entire patient body assayed. The interdependence of breakthrough science on multiple cutting-edge techniques characterizes the life sciences in a way that differs from many other intellectual pursuits. It is impossible for any particular research group to maintain on its own the expertise and equipment required for scientific breakthroughs.

Interdisciplinary Research and Service Centers (IRSCs) are vital parts of the University's life sciences ecosystem and are present in Indianapolis and in Bloomington. In the IU School of Medicine they are known as Cores; within the METACyt Initiative they are called Integrative Science and Technology Centers (ISTCs). These centers, and the individuals who lead them, are typically leaders in advancing new technologies, concepts, and theories. Quality and economy of scale call for core and technology service facilities that provide many, varied measurement services, including chemical assays, gene sequencing, advanced imaging, and maintenance of laboratory animal colonies. The collection of many excellent centers that provide advanced services to life science researchers can thus be an important competitive advantage for Indiana University.

With the support of resources from the Indiana Genomics Initiative, the IU School of Medicine has developed a set of research cores recognized for their excellence. Cores in imaging, microscopy, proteomics, genomics and genotyping, animal models and others provide IU scientists with resources for modern biomedical research. Such resources have helped in recruiting and retaining faculty, competing for extramural grants and awards, and developing collaborations with other scientists at IU and other public and private institutions, including industry.

The IUSM Core Oversight Committee has established criteria for recognizing a research, development, and service organization as an IU School of Medicine Core. As of September 2005, 17 cores have received such a designation [15]. The Core Oversight Committee has also begun overseeing the process of awarding grants to support upgrades and/or establish new Cores. In addition, a core pilot funding program supports research proposals that utilize the IUSM research cores.

IUSM Cores have led to innovations and prompted economic development in Indiana. An example is the creation of the Indiana Center for Applied Protein Sciences (INCAPS) to support the Proteomics Core [9]. INCAPS is a fee-for-service contract research organization created by the School, IU Bloomington, Purdue University, Eli Lilly and Company, Inproteo, and BioCrossroads. The IUSM Proteomics core facility was transformed into the academic component of INCAPS in May 2004. The structure enables the Core to provide academic researchers access to proteomics services using the most advanced technology at reasonable prices, while ensuring the Core financial stability as part of INCAPS. In like manner, an element of one of IU's analytical chemistry laboratories has grown into the Bloomington high-tech startup Predictive Physiology and Medicine.

The concept of technology research and service centers has been in practice informally at IU Bloomington for many years. Over the past several years, the Center for Genomics and Bioinformatics has demonstrated the importance of the joint roles of interdisciplinary collaboration, research, development, and service. The Center has helped forge alliances between biologists, chemists, physicists, mathematicians, computer scientists, and information technologists. It serves as a research center, has developed important new technologies, and provides ongoing services in sequencing and gene expression analysis for researchers across IU.

The concept of Interdisciplinary Research and Service Centers has been formalized within the Indiana METACyt Initiative through the creation of four centers – referred to as Integrating Science and Technology Centers within the METACyt Initiative.

The goals outlined in the *Indiana University Life Sciences Strategic Plan* may be more effectively realized if there are more Interdisciplinary Research and Service Centers that are widely accessible and widely used. These centers will develop new scientific techniques and insure that the greatest possible array of experimental techniques is available at IU. IU must develop economic models that ensure the sustainability of these centers. IU's research competitiveness will be enhanced greatly if such centers can deliver services at internal costs that are lower than those charged within other universities.

Goal 11. Indiana University should provide strong support for Interdisciplinary Research and Service Centers (IRSCs) on both campuses. These centers function as developers of new research technology and as service providers in support of IU's mission in the life sciences so that important new research techniques are created and made available to enable new discoveries and facilitate IU's research competitiveness.

Action 11.1. The University should create formal mechanisms for certifying Interdisciplinary Research and Service Centers (similar to those in place within the IU School of Medicine) throughout the University generally.

Action 11.2. The University should create financial models and endowments for Interdisciplinary Research and Service Centers that will support use of these centers in pilot research, enhance grant competitiveness through internal costs lower than those at other universities, and enable development of new scientific and technological innovations – all leading to enhanced grant competitiveness and new innovations.

Action 11.3. The University should implement mechanisms to ensure that new Interdisciplinary Research and Service Centers are created as state-of-the-art technologies develop, and review existing Centers regularly so that University efforts are directed to the best possible effect.

Action 11.4. The University should ensure that Interdisciplinary Research and Service Centers have ample space and provide state-of-the-art facilities.

Action 11.5. The University should encourage usage of IU's Interdisciplinary Research and Service Centers by researchers at other universities and private enterprise. The University should secure funding to transform such Centers into national service centers funded by federal agencies and used by the private sector on a fee-for-service basis.

G. Public service and economic development

"The biosciences are a range of industry sectors relying on insights into the way living organisms function."
—Battelle Technology Partnership Practice Report, 2004

The role of the public university in public service has long been recognized. University hospitals have been a longstanding example of such service. In the past several years, there has been increasing understanding that economic development of the State of Indiana is an important aspect of Indiana University's service role.

Indiana University has benefited from increased investments in the life sciences by the State and by philanthropic organizations. The State's BioCrossroads initiative, in which IU is a partner, works with corporate, government, economic, and academic leaders to strengthen Indiana as a center for the life sciences. Its work in facilitating the provision of capital for start-ups and formation of the Indiana Seed Fund supplies financial encouragement for young businesses in the life sciences. With this increased investment comes the opportunity and obligation to return economic benefits to the public, whose taxes and other forms of support sustain University operations. A high priority and natural responsibility recognized by Indiana University is to improve the health and prosperity of the residents of the State of Indiana. This is done through translational research, advanced clinical care, and technology transfer into the private sector.

G.1. Advanced clinical care and translational research

Advanced clinical care, delivered in partnership with Clarian Health Partners and others, combined with translational research, is important to the success of the research enterprise at the IU School of Medicine. These efforts simultaneously give hope to patients suffering from medical conditions for which established treatments are inadequate, while allowing the University to extrapolate the results of basic science into better medical care. Reengineering the translational research enterprise has been identified as a fundamental challenge by the National Institutes of Health in its "Roadmap" initiative. According to the Clinical Research Strategic Planning Committee appointed in September 2003, IUSM investigators held more than $70 million in clinical research awards in 2003, about 34% of the total grants and contracts awarded to IUSM investigators in that fiscal year. The IU School of Medicine has created a new centralized clinical research office and the position of Associate Dean for Clinical Research to oversee this important activity.

Advanced clinical care and translational research and service are not unique to the IUPUI campus and the IU School of Medicine. The Midwest Proton Radiotherapy Institute (MPRI) offers proton therapy treatment, a precise method for delivering radiation to a disease site, while minimizing the dose to healthy tissues. MPRI treats children and adults with certain brain tumors and tumors adjacent to vital organs incapable of being treated by traditional methods. MPRI is one of only three facilities in the nation that offer proton radiation therapy. Previously available only on the coasts, MPRI brings proton radiation therapy to the Midwest.

Goal 12. Indiana University should continue to strengthen and expand its translational research enterprise, doubling the clinical research dollars awarded to the University by 2013, and expanding the cutting-edge medical services and health care delivered to the public.

Action 12.1. The University should enhance translational research infrastructure, enabling centralized and uniform data management, improved business management, improved recruitment of clinical trial volunteers, improved services to investigators, and enhanced education and training for investigators and study personnel.

Action 12.2. The University should promote a culture of support for clinical research activities including mechanisms for promotion for faculty focused in this area.

Action 12.3. The University should streamline and make more consistent its Internal Review Board processes and oversight of clinical research in order to facilitate this research while enacting the highest standards of ethics.

Action 12.4. The University should compete aggressively and successfully for new grants to develop clinical and translational science, increase the efficiency and speed of clinical research, and train the next generations of clinical and translational scientists.

G.2. Economic development

New discoveries ultimately acquire their significance when they are implemented and adopted in ways that improve medical care outcomes. The development of stannous fluoride at Indiana University and its subsequent deployment as the critical new ingredient in Crest® toothpaste in 1955 resulted in worldwide improvements in dental health. The enhancements in quality of life for millions of people worldwide, and economic benefits for Indiana University and the residents of Indiana, depend upon translating basic and clinical research into medical practice and commonly used products.

Universities are increasingly seeing local and regional economic development as a critical part of their service missions. A new generation of entrepreneurial faculty in the sciences sees the commercialization of their research not as a distraction but as a key component of their interest in advancing knowledge. At IU Bloomington, analytical chemists have a long tradition of commercializing their discoveries via patents and licenses. One of the most advanced types of instruments in use today to identify the chemical components of any sort of sample is the MALDI-TOF spectrometer (Matrix Assisted Laser Desorption Ionization - Time of Flight). MALDI-TOF spectrometers are widely used in industrial and scientific settings. Almost all such spectrometers sold today include technology developed, patented, and licensed by IU Bloomington analytical chemists. Research disclosures by IUSM scientists and the resulting licensing revenues have risen dramatically in recent years, from 20 and $909,000 respectively in FY 1999 to 60 and $3.9 million in FY 2005. The number of research disclosures and resulting licensing revenues for the College of Arts and Sciences has risen from 13 and $277,350 in FY 1999 to 23 and $405,347 in FY2005.

University administration can continue and enhance this acceleration of technology transfer by creating a streamlined process for commercialization, and a reward and recognition structure that values such activity. Leveraging the expertise of the Indiana University Research Technology Corporation (IURTC) will result in effective technology transfer, better financial terms, and effective use of innovations to advance the Indiana economy.

Goal 13. Indiana University should increase transfer of technology from the University to the private sector, managing licenses in a way that enhances the Indiana economy whenever possible.

Action 13.1. The University should increase entrepreneurial behavior among faculty and create a culture wherein technology transfer activity is valued and rewarded and considered a critical part of individual faculty, department, and center evaluations, including faculty evaluation for promotion and tenure.

Action 13.2. The University should enhance the relationship and collaborative efforts between scientists and the Indiana University Research Technology Corporation. The University should work proactively with the IURTC to disclose inventions and leverage IURTC expertise to commercialize technologies to the benefit of the Indiana economy whenever possible.

Action 13.3. The University should revise the Indiana University Intellectual Property Policy in order to facilitate technology transfer from IU faculty and staff into the private sector.

Action 13.4. The University should establish collaborative relationships between IU life scientists and the Kelley School of Business in order to improve the effectiveness and accelerate the rate of technology transfer from Indiana University into the private sector.

Action 13.5. The University should increase the number of invention disclosures, the dollars returned from technology transfer activities, and the number of start-up companies created.

G.3 Educating the next generations of life scientists, technologists, and clinicians

As life science industries seek increasing numbers of skilled workers, IU needs to generate a steady stream of life scientists and create a 21st-century workforce that will draw new life science businesses into the State of Indiana. At the same time, widely accessible educational opportunities will make a high-paying career in the life sciences a goal that many Hoosiers may aspire to and attain.

The Health Professions Programs within the IU School of Medicine offer a range of opportunities for careers in the life science in Indiana for those without a four-year degree. At the graduate level, the School's Biotechnology Training Program offers a Graduate Certificate and an M.S. in Biotechnology. IUB's recently created B.S. Program in Biotechnology is a joint degree program between the biology and chemistry departments that also partners with the School of Business and School of Law. The graduates of these programs comprise a skilled

workforce of value to Indiana life science companies, and a serve as a magnet attracting new business to the State. The program in human biology, funded by the Commitment to Excellence, provides an opportunity for four-year students to obtain education in the functioning of the human body. IUPUI and IUB will soon provide a Masters of Science in Biotechnology. For younger children, IUB and IUPUI conduct outreach programs. IUB science faculty were instrumental in the creation and growth of Bloomington's nationally recognized Wonderlab Museum of Science, Health, and Technology. Faculty in the IU School of Medicine and on the IUPUI campus have been responsible for displays at the Indianapolis Children's Museum. Bloomington and Indianapolis life sciences faculty have collaborated to create displays in the Indiana State Museum.

Indiana University has many programs that attract first-rate incoming undergraduate and graduate students. However, Indiana University must respond to fierce competition for student talent in the life sciences, especially at the graduate level, if it is to accomplish its overarching mission of leadership in the life sciences. Efforts such as the Wells Scholarship program at IUB address this issue at the undergraduate level. IUB has summer programs that introduce talented undergraduates to research in the life sciences and that serve to steer these students into graduate programs, including the nationally recognized Holland Summer Enrichment Program for Indiana high school students from traditionally underserved minority groups. The IU School of Medicine has created a new position of Associate Dean for Graduate Student Education to address the issue of recruitment at the graduate student level.

Goal 14. Indiana University should educate the next generations of life scientists and help the State develop, recruit, and retain a 21st-century workforce that will facilitate the growth of a life science economy in Indiana.

Action 14.1. The University should reach out to school children, particularly early in their educational careers, in ways that increase interest and accomplishment in preparation for careers in the life sciences.

Action 14.2. The University should enhance recruitment and admissions management processes to make Indiana University a more appealing destination for students at all levels, ensuring that Indiana University attracts the best students at the undergraduate and graduate levels. Indiana University should work to develop and retain a well educated workforce for the life sciences in Indiana.

Action 14.3. The University should increase graduate fellowship funding for the life sciences in order to compete successfully for the best graduate students.

Action 14.4. The University should intensify efforts to attract students from diverse racial, social, and cultural backgrounds to educational programs in the life sciences, preparing them for rewarding careers in the field.

H. Collaboration

"Great discoveries and improvements invariably involve the cooperation of many minds."
—Alexander Graham Bell

For much of IU's history, the cores of excellence in the life sciences on the Bloomington campus and at the IU School of Medicine have acted largely independently. For some time it was difficult for what were historically distant subspecialties in the life sciences to collaborate. Recent developments in instrumentation, analytical chemistry, imaging, and gene sequencing have since encouraged collaborative relationships that span formerly disparate subdisciplines. These changes, along with advances in technology that enable real-time collaboration largely independent of physical location, encourage collaborations in the life sciences across schools and campuses.

Increased collaboration between and among IU's eight campuses will advance the University's competitive position and encourage scientific and technological accomplishment. The geographic distribution of the University's presence in the State offers opportunities to work with diverse populations and impact people from many walks of life, across the State. The size, strength, and diversity of IU's expertise in many areas of science and technology related to the life sciences provide a tremendous advantage in life sciences research. Access to collaborators in different disciplines provides life sciences researchers with expertise, techniques, and instrumentation that help speed discovery. Collaborations between researchers in chemistry and biology have led to the development of new technology of benefit to both. Another extrapolation of research findings to improvements in health care occurs through the Biomedical Engineering program of the Purdue School of Engineering and Technology at IUPUI. Collaborations between researchers at the IU School of Medicine, Purdue schools on the IUPUI campus, and IU Bloomington will create an abundance of new possibilities. The breadth of the University's expertise must be well utilized in order to facilitate achievement of the Goals set forth in this plan.

Goal 15. Indiana University should enable important new discoveries and achieve greater competitiveness for grant funding through collaboration across geographic and organizational boundaries within, and where appropriate, outside Indiana University.

Action 15.1. The University should continue to enhance the collaborative relationships among Analytical Chemistry, the Biological Microscopy Core, and the Whole Animal Imaging Core of the School of Medicine.

Action 15.2. The University should enhance collaborations between IUB and IUPUI programs in organic chemistry, biochemistry, and cheminformatics with the IUPUI-based Center for Chemical Imaging and the Chemical Genomics Core at the School of Medicine in the development of novel molecules that can be used as probes of biological systems.

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Action 15.4. The University should establish a Program for Cancer Biology at IUB, bringing together faculty from Medical Sciences, Biology, Chemistry, and Biochemistry, and create vibrant new collaborations between this center and the IU Cancer Center's established cancer research programs of the IU School of Medicine in Indianapolis.

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Action 15.7. As part of its reorganization of much of its life science activities at IUB (see Action 6.3.), the University should recognize and stimulate the growing partnership between the Medical Sciences Program and the basic life sciences at IUB by creating a fully integrated graduate training program for these units.

Action 15.8. The University should establish a joint committee on the life sciences that incorporates leaders from those colleges and schools with major stakes in the life sciences to ensure effective collaboration and sharing of knowledge and expertise.

I. Summary of Goals and Actions

Goal 1. Indiana University should maintain and enhance its top-tier research program in analytical chemistry.

Action 1.1. The University should maintain and take steps to strengthen its world-class analytical chemistry faculty and program, including senior-level faculty and those with a primary interest in advancing bioanalytical technologies.

Action 1.2. The University should strengthen the Center for Proteomics Research and Development through hiring appropriate engineering and computational staff, and creating a renewable equipment upgrade fund.

Action 1.3. The University should obtain ongoing funding from federal sources to operate national centers of excellence and national resource centers in analytical chemistry.

Goal 2. Indiana University should build research strength in organic chemistry and biochemistry to nationally competitive levels to complement and strengthen the top-ranked life sciences programs in Bloomington and research programs at the IU School of Medicine, and to help support the State's biotechnology industry.

Action 2.1. The University should rebuild a nationally competitive program in organic chemistry on the Bloomington campus. This effort must include in the near term the recruitment of outstanding senior and junior faculty in synthetic organic chemistry, increasing the number of faculty in the group.

Action 2.2. The University should establish a Center for Research in Chemical Synthesis in Bloomington to encourage an interdisciplinary approach to novel synthetic pathways.

Action 2.3. The University should provide a world-class instrumentation infrastructure for organic chemistry and biochemistry.

Action 2.4. The University should create a critical mass in biochemistry at IU Bloomington through implementation of the Interdepartmental Biochemistry Graduate Program (IBGP). The IBGP would be created through establishing new faculty lines and formal ties to the IBGP for existing faculty (including those in the Departments of Biology, Chemistry, and the Medical Sciences Program at IU Bloomington).

Goal 3: Indiana University should become an international leader in basic and translational research about cancer, and in advanced clinical care for cancer.

Action 3.1. The University should ensure that the IU School of Medicine and the IU Cancer Center in Indianapolis advance to Comprehensive designation status within the certifications awarded by the National Cancer Institute, by

- *Implementing the necessary basic science, clinical, prevention, control, behavioral, and population-based research activities.*
- *Implementing the necessary interactive and collaborative activities among researchers in those areas.*
- *Implementing early phase, innovative clinical trials and participating in the NCI's cooperative clinical trial group system.*
- *In collaboration with the School of Nursing, performing the necessary activities related to outreach, education, and cancer information in the community.*
- *Adding significant numbers of new cancer researchers to meet the goals in this Action.*

Action 3.2. The University should, through the IU School of Medicine and the IU Cancer Center, create and support new programs in health services research/epidemiology, molecular carcinogenesis, and gastrointestinal and ovarian cancers.

Action 3.3. The University should establish a Program for Cancer Biology in Bloomington, bringing together faculty from Medical Sciences, Biology, Chemistry, and Biochemistry with an interest in aspects of cancer biology, including basic research in cell signaling, differentiation, epigenetics, DNA repair, and other relevant areas. Seed funding should be provided to increase collaborative cancer research with the School of Medicine.

Action 3.4. The Bloomington campus should recruit, in collaboration with the School of Medicine, additional faculty with expertise in basic research relevant to cancer biology, with shared appointments between the IU Bloomington Medical Sciences Program and the Biochemistry Interdepartmental Graduate Program.

Goal 4. Indiana University should become a nationally recognized leader in research and clinical care related to diabetes and metabolic disorders.

Action 4.1. The University should establish within the IU School of Medicine the Indiana Center of Excellence in Diabetes, to be directed by an internationally recognized leader in this area. The University should recruit additional well-established investigators that do both basic and translational research from the departments of Medicine, Pediatrics, Surgery, Biochemistry, and Physiology.

Action 4.2. Following recruitment of the Center Director, the University should recruit nationally additional accomplished investigators to join the already well-established investigators that conduct both basic and translational research from the departments of Medicine, Pediatrics, Surgery, Biochemistry, and Physiology, as well as the peptide synthesis group in Bloomington.

Goal 5. Indiana University should build its research programs in neurosciences (basic research, translational research, and advanced clinical care) so that they are ranked in the top tier nationally.

Action 5.1. The University should create the leadership structures and coordination facilities for the Gill Center for Biomolecular Research and the Stark Neurosciences Research Institute (SNRI) to become leaders in their respective areas of focus, and to enable them to collaborate

and coordinate their activities so as to most effectively advance basic research, translational research, and advanced clinical service delivery.

Action 5.2. The University should recruit additional Gill Chairs, Presidential Life Science Professorships (funded by the Lilly Endowment, Inc.) , and other faculty with a general focus in molecular neuroscience.

Action 5.3. The University should, through partnership between the SNRI and the Department of Neurological Surgery, recruit an outstanding senior researcher with a nationally/internationally recognized research program in the areas of neuronal plasticity and/or recovery from spinal cord injury to fill The Mari Hulman George Chair in Neuroscience Research.

Action 5.4. The University should, through the SNRI, complete recruitment for additional outstanding individuals for tenure-track faculty positions at the assistant or associate professor level who will conduct research in the following areas: pain and sensory systems, developmental neurobiology and regeneration, mechanisms of substance abuse and addiction, and neurodegenerative disorders.

Action 5.5. The University should recruit a Director of Neuroimaging at the IU School of Medicine. The University should recruit additional outstanding individuals for tenure-track faculty positions with specializations in pain and sensory systems, developmental neurobiology and regeneration, mechanisms of substance abuse and addiction, and neurodegenerative disorders.

Goal 6. Indiana University should expand and elevate its already outstanding research programs on model biological systems to rank among the top 10 in the country.

Action 6.1. The College of Arts and Sciences should significantly increase the number of life sciences faculty.

Action 6.2. The University should add significant faculty strength in model systems and related areas of biology, enhancing current excellence in molecular, cell, and developmental biology; microbiology and plant biology; and ecology, evolution, and animal behavior.

Action 6.3. The University should build high-quality research groups at IU Bloomington working on important vertebrate model systems, such as mice and zebrafish,

Action 6.4. Indiana University should create a Center for Synthesis in Evolutionary Studies to integrate the knowledge gained at all scales to better understand evolution and to better use the comparative approach to apply knowledge gained from model systems to the human condition.

Action 6.5. The University should consider reorganizing many of the College's life sciences units, possibly into a new School of Life Sciences, housed within the College of Arts and Sciences, and with the IUB Medical Sciences Program of the School of Medicine fully integrated within the School with respect to graduate training.

Goal 7. Indiana University should engage in research and education (particularly State- and federally-funded education efforts) that will help residents of the State of Indiana to lead healthier, better, and longer lives.

Action 7.1. The University should continue and expand efforts to inform residents of the State of Indiana about the importance of exercise and proper nutrition.

Action 7.2. The University should continue and expand efforts within the State of Indiana to reduce prevalence of smoking, excessive use of alcohol and controlled substances, and risky sexual activities.

Goal 8. Indiana University should enhance its physical research infrastructure with buildings that permit and support the expansion of IU's life science research activities.

Action 8.1. Following the Indiana Department of Health departure from the Van Nuys Medical Science building, the University should expand and renovate research space in the building and make it available for diabetes research, significantly increasing space dedicated to diabetes research on the IUPUI campus and to expanded research programs in the Departments of Biochemistry and Surgery.

Action 8.2. The University should, on the IUPUI campus, complete construction of facilities included in Phase 1 of the building activities proposed in the Indiana University School of Medicine Research Business Plan:

- *Medical Information Sciences Building, currently under construction, to be completed in early 2007.*
- *Research III, construction to begin in 2006, with completion in 2009.*
- *Renovation of Van Nuys Medical Science building facilities vacated by the Indiana Department of Health, to be completed in 2008.*
- *Fort Wayne Regional Center for Medical Education research facility, to be completed in 2008.*
- *The Ernestine Raclin and O.C. Carmichael Jr. Hall at IU School of Medicine - South Bend, completed in 2005 and dedicated in October 2005.*

Action 8.3. The University should, on the IU Bloomington campus, complete current and planned enhancements to building infrastructure in the life sciences and those areas that directly benefit the life sciences, including:

- *Complete the renovation of Jordan Hall*
- *Complete building and occupy Simon Hall and MSB-II without delay*
- *Obtain funding for and build the proposed Cyberinfrastructure Building to support information technology infrastructure, which has direct benefit for the life sciences at IU.*

Action 8.4. The University should work to obtain appropriations from the Indiana General Assembly for construction of the following facilities:

- *For the IU School of Medicine, as called for in Phase II of the building activities proposed in the Indiana University School of Medicine Research Business Plan: Van*

Nuys Medical Science Renovation Phase III; several facilities at regional centers for medical education.

- *For IU Bloomington, obtain funding for the planned MSB III building, and build and plan new laboratory buildings to accommodate further growth in life sciences research, as well as centralized research support infrastructure and new research centers.*

Action 8.5. The University should obtain the necessary authorization and appropriations from the Indiana General Assembly for construction of the following facilities called for in Phase III of the building activities proposed in the Indiana University School of Medicine Research Business Plan:

- *Research IV – to be supported in part by private funds raised by the IU School of Medicine*
- *Facilities at regional centers for medical education.*

Action 8.6. The University should create and implement a long-term plan for the expansion and modernization of animal quarters at Indiana University Bloomington.

Action 8.7. The University should engage in ongoing long-range planning for buildings in the life sciences so that the University is always excellently equipped with a physical infrastructure that will enable and support its life science research objective.

Goal 9. Indiana University should lead in the development and utilization of new theory and technique in bioinformatics, computational biology, cheminformatics, medical informatics, health informatics, and biocomplexity.

Action 9.1. The University should develop and strengthen several programs related to bioinformatics, computational biology, and biocomplexity (the computational partners of the life sciences), and coordinate these activities so that the combined strengths of IU's many and diverse efforts in these areas are brought together, coordinated, and leveraged to become an area of competitive strength for Indiana University.

Action 9.2. The University should develop the IU School of Informatics program in cheminformatics into the nation's leading program in this area, and develop bioinformatics into one of the nation's leading programs.

Action 9.3. Expand the application of the Regenstrief Medical Record System within the State of Indiana. This will enhance medical care and create an invaluable repository of clinical data — namely, phenotypic information that can be mined to address biologic and genetic questions.

Goal 10. Indiana University should develop and deploy a cyberinfrastructure that provides capabilities for new scientific insights, new breakthroughs in technology development, and enhanced competitiveness for grant funding.

Action 10.1. The University should lead in nationally funded cyberinfrastructure research and development activities, emphasizing development and delivery of new tools for life scientists that

will enable advanced new calculations to be performed and then understood through visualization.

Action 10.2. The University should develop new tools and techniques for long-term management and curation of life sciences data, and leverage these tools and techniques so that research data produced by Indiana University is used to the fullest extent possible. The University should establish and expand externally funded data repositories serving state, national, and worldwide life science communities.

Goal 11. Indiana University should provide strong support for Interdisciplinary Research and Service Centers (IRSCs) on both campuses. These centers function as developers of new research technology and as service providers in support of IU's mission in the life sciences so that important new research techniques are created and made available to enable new discoveries and facilitate IU's research competitiveness.

Action 11.1. The University should create formal mechanisms for certifying Interdisciplinary Research and Service Centers (similar to those in place within the IU School of Medicine) throughout the University generally.

Action 11.2. The University should create financial models and endowments for Interdisciplinary Research and Service Centers that will support use of these centers in pilot research, enhance grant competitiveness through internal costs lower than those at other universities, and enable development of new scientific and technological innovations – all leading to enhanced grant competitiveness and new innovations.

Action 11.3. The University should implement mechanisms to ensure that new Interdisciplinary Research and Service Centers are created as state-of-the-art technologies develop, and review existing Centers regularly so that University efforts are directed to the best possible effect.

Action 11.4. The University should ensure that Interdisciplinary Research and Service Centers have ample space and provide state-of-the-art facilities.

Action 11.5. The University should encourage usage of IU's Interdisciplinary Research and Service Centers by researchers at other universities and private enterprise. The University should secure funding to transform such Centers into national service centers funded by federal agencies and used by the private sector on a fee-for-service basis.

Goal 12. Indiana University should continue to strengthen and expand its translational research enterprise, doubling the clinical research dollars awarded to the University by 2013, and expanding the cutting-edge medical services and health care delivered to the public.

Action 12.1. The University should enhance translational research infrastructure, enabling centralized and uniform data management, improved business management, improved recruitment of clinical trial volunteers, improved services to investigators, and enhanced education and training for investigators and study personnel.

Action 12.2. The University should promote a culture of support for clinical research activities including mechanisms for promotion for faculty focused in this area.

Action 12.3. The University should streamline and make more consistent its Internal Review Board processes and oversight of clinical research in order to facilitate this research while enacting the highest standards of ethics.

Action 12.4. The University should compete aggressively and successfully for new grants to develop clinical and translational science, increase the efficiency and speed of clinical research, and train the next generation of clinical and translational scientists.

Goal 13. Indiana University should increase transfer of technology from the University to the private sector, managing licenses in a way that enhances the Indiana economy whenever possible.

Action 13.1. The University should increase entrepreneurial behavior among faculty and create a culture wherein technology transfer activity is valued and rewarded and considered a critical part of individual faculty, department, and center evaluations, including faculty evaluation for promotion and tenure.

Action 13.2. The University should enhance the relationship and collaborative efforts between scientists and the Indiana University Research Technology Corporation. The University should work proactively with the IURTC to disclose inventions and leverage IURTC expertise to commercialize technologies to the benefit of the Indiana economy whenever possible.

Action 13.3. The University should revise the Indiana University Intellectual Property Policy in order to facilitate technology transfer from IU faculty and staff into the private sector.

Action 13.4. The University should establish collaborative relationships between IU life scientists and the Kelley School of Business in order to improve the effectiveness and accelerate the rate of technology transfer from Indiana University into the private sector.

Action 13.5. The University should increase the number of invention disclosures, the dollars returned from technology transfer activities, and the number of start-up companies created.

Goal 14. Indiana University should educate the next generations of life scientists and help the State develop, recruit, and retain a 21st-century workforce that will facilitate the growth of a life science economy in Indiana.

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This document was created by a drafting committee consisting of the following (listed in alphabetical order):

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