Connecticut Strategic Platform: Translational Medicine

WHAT IS IT?

Translational medicine involves advancing basic research to generate discoveries with implications for treating diseases and then advancing those discoveries through pre-clinical developments and clinical research in humans. The ultimate result of translational medicine is improved clinical care often involving new therapeutics, devices or diagnostics.

But translational medicine is more than just a one way road from basic sciences through clinical research, often referred to as connecting bench to bedside. It is just as important for clinical issues to inform the approaches and research questions for basic research to focus upon and so go from bedside to bench. So translational medicine should be regarded as a two-way road from bench to bedside and bedside to bench.

Translational medicine covers a broad range of scientific, regulatory and clinical disciplines not typically found in any one organization. Advancing translational medicine depends upon bringing together research centers, hospitals and medical centers, and bioscience industry across contract research organizations, pharmaceutical companies, biotechnology companies and medical device companies.

The opportunities for translational research are significant. A 2002 article in the Journal of the American Medical Association suggests why:

"Breakthroughs in the molecular and genetic bases of disease have opened up vast therapeutic opportunities underscoring the importance of research that can translate fundamental biological insights into clinical progress. Such research into the basic mechanisms of disease delineates pathways and targets for clinical intervention. Understanding the electrophysiology of the heart, for example, has critically shaped the design of pacemakers and defibrillators…"1

But the challenges for advancing translational medicine are significant. A study of reports published between 1979–1983 in 6 top basic science journals (Science, Nature, Cell, Journal of Biological Chemistry, Journal of Experimental Medicine, and Journal of Clinical Investigation) found 101 articles that clearly made a promise for a major clinical application of their findings. Two decades later, only 5 of these promises were in licensed clinical use and only one of them had a major impact on current medical practice. Three quarters of the basic science promises had not yet been tested in a randomized trial.[2]

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[1] Dr. Annetine C. Gelijns and Dr. Samuel O. Thier, on "Medical Innovation and Institutional Interdependence," Journal of the American Medical Association, 2002.

[2] John PA Ioannidis, Department of Medicine, Tufts University School of Medicine, "Materializing research promises: opportunities, priorities and conflicts in translational medicine," *Journal of Translational Medicine, Jan* 2004

CONNECTION WITH CONNECTICUT CORE TECHNOLOGY COMPETENCIES

Connecticut's strengths in translational medicine are extensive given the strong presence of bioscience industry and university research in Connecticut.

- Patent activity in biosciences: There are two key clusters of patent activity involved in the biosciences:
    - Drug Development Clusters: Represents 13% of patents invented in Connecticut from 2000 to 2004. Key patent activities include advancing novel drug compounds to inhibit disease processes, target identification technology and drug delivery approaches. There is a broad range of disease targets including anti-psychiotics, nicotine addiction, HIV, anti-infectious agents and anti-cancer agents.
    - Genomics & Proteomics Clusters: Represents 3% of patents invented in Connecticut from 2000 to 2004. Key patent activities involve molecular biology and microbiology applications such as gene sequencing, expression and regulation, protein expression, SNP analysis and protein-protein interactions.
- NIH activity in biosciences: Given the base of over 2,000 awards to Connecticut researchers from the National Institutes of Health, there is an extensive range of cluster activities found in Connecticut:
    - Genomics & Proteomics: Represents 37% of NIH awards to Connecticut researchers from 2000 to 2004. Similar to patent activities, these involve a range of gene sequencing, expression and regulation studies, protein expression and protein-protein interaction studies and other genomic-related research studies such as SNP analysis.
    - Public Health: Represents 17% of NIH awards to Connecticut researchers from 2000 to 2004. Examples of activities include epidemiology-based studies of disease risk, as well as prevention and behavioral interventions including for HIV/AIDS prevention, mental health and drug and alcohol abuse.
    - Neurosciences: Represents 14% of NIH awards to Connecticut researchers from 2000 to 2004. Among the research activities founded are those involved with basic mechanisms of hearing, learning, cognition, memory and vision, as well as neuroimaging, analysis of synaptic transmission and neuro-informatics.
    - Cell and Vascular Biology: Represents 10% of NIH awards to Connecticut researchers from 2000 to 2004. Considerable research activities found in ion cell channels and endothetial cell mechanisms.
    - Immunology: Represents 9% of NIH awards to Connecticut researchers from 2000 to 2004. Among research activities are those involved in immune mechanisms involved with transplantation, asthma, diabetes, HIV, Lyme Disease, and bacterial pathogens.
    - Drug Development: Represents 4% of NIH awards to Connecticut researchers from 2000 to 2004. Includes research into pharmacological activities of drugs on disease processes as well as novel drug delivery and compounds.
    - Musculoskeletal: Represents 3% of NIH awards to Connecticut researchers from 2000 to 2004. Focus of research activities includes bone biology, osteoporosis, bone loss, bone cancers, bone resorption and dental implants.

COMPETITIVE POSITION OF CONNECTICUT IN TECHNOLOGY INDUSTRY PRESENCE, R&D ACTIVITY AND TALENT GENERATION

Technology Industry Position:

- **Connecticut is Highly Specialized in Pharmaceuticals and Drug Industry Employment and Still Emerging in the Commercial Biosciences Research & Testing Industry Employment**: Recent study by the national Biotechnology Industry Organization, State Bioscience Initiatives 2004, found that Connecticut is the third leading state in the concentration of pharmaceutical and drug industry employment compared to overall state employment, behind only New Jersey and Delaware. Connecticut is 175% more concentrated in the pharmaceutical and drug industry than the nation as a whole, employing 10,573 workers across 31 establishments.

  In the biosciences commercial research and testing sector, which includes many of the cutting-edge biosciences companies commercializing new technologies, Connecticut has 85 establishments with 1,164 workers, but is 24% less concentrated in this sector than the nation as a whole.

- **The Corptech database of technology-focused companies with company-wide or divisional headquarters in the state suggests similar results.** Connecticut well exceeds the national average of pharmaceutical firms per million workers – 15 versus 8 firms per million workers – and overall ranks 12th in pharmaceutical technology firm presence. For biotechnology sector – which is largely found in the commercial biosciences research & testing sector – Connecticut equals the national average in firms per million workers and ranks 17th among all states in biotechnology firm presence.

R&D Position:

- **Connecticut ranks highly given the size of the state in both university life sciences research and NIH research funding – generally considered the "gold standard" of biomedical research funding.** Connecticut ranked 16th in the nation in life sciences university research funding for FY 2002 and 13th in the nation in NIH funded research, which takes place largely in university research settings.

- **But in both university life sciences research and NIH funding, Connecticut is falling behind the growth found across the nation**. From FY 1996 to FY 2002, Connecticut grew in university life sciences research by 56%, but well off the national pace of 80%. Similarly in NIH research funding, Connecticut grew by 59% from FY 1997 to FY 2002, while the growth for the nation stood considerably higher at 82%

- Publications analysis reveals that Connecticut is well positioned in the life sciences with both high volume of publications and high quality as measured by citations per publication for fields related to core competency areas identified:

Publications Analysis of Connecticut University Performance in Engineering and Physical Science Fields, 1999 to 2003			
Field of Publications	Number of Connecticut Publications	% of U.S. (Overall Connecticut Average Across All Fields is 1.8%)	Level of Citations Per Publication (Above or Below US Average for Field)
Genomics & Proteomics			
Biotechnology & Applied Microbiology	63	1.4%	31%
Molecular Biology & Genetics	611	2.3%	6%
Biochemistry & Biophysics	1205	1.1%	2%
Drug Development			
Pharmacology & Toxicology	291	25851	10%
Neurosciences			
Neurosciences	2168	3.4%	13%
Psychology	1057	2.4%	39%
Psychiatry	727	6.6%	11%
Public Health & Behavioral Research			
Public Health & Health Care Sciences	654	2.6%	20%
Environmental Medicine & Public Health	218	2.2%	16%
Immune Responses, Mechanisms and Control			
Immunology	750	2.6%	27%
Clinical Immunology & Infectious Diseases	227	1.6%	17%
Cell & Vascular Biology			
Cell & Development Biology	742	3.0%	5%
Musculoskeletal Research			
Orthopedics	166	1.4%	13%
Rheumatology	54	1.5%	11%
Source: Institute of Scientific Information, Thomson Publications			

Talent Position:

- **Recent occupational trends in Connecticut for medical scientists and chemists – two key drivers of translational medicine – have been positive, though not uniformly ahead of the nation.**
    - For medical scientists, Connecticut posted a gain in jobs of 300 workers or 38.3% from 2000 to 2003, though this was below the national gain of 85.6%.
    - For chemists – who are key in the pharmaceutical and drug industry, though employed by other industry sectors – Connecticut posted a gain of 250 workers or 15.6%, compared to a decline nationally of 0.7%.
- **Connecticut's share of total national graduates in the biological sciences is close to its share of national biological scientists employed, but Connecticut is well below for chemists in its share of national graduates compared to how many it employs**. Connecticut employs 1.5% of the biological scientists in the nation, and generates a nearly equivalent 1.2% of biological science graduates. In chemistry, however, Connecticut employs 2.2% of chemists in the nation, but generates only 1.2%, suggesting that significant numbers of chemists must be recruited from outside of the state.
- **Connecticut is generally following the patterns of the nation in declining levels of life sciences graduates in the nation with differences in sub-fields.** Nationally, graduates in the life sciences fell 13.6% from 1996 to 2002, including declines of 5.5% in medical sciences, 4.7% in biological sciences and 9.2% in chemistry. For Connecticut, the declines were in line with the national patterns with 15.5% overall decline in life science-related graduates, though a significantly greater decline in biological scientists at 20.3% and a lower declines in chemistry graduates at 4.5% and in medical scientists at 4.1%.

POSSIBLE NICHE AREAS FOR CONNECTICUT

From interviews and further analysis of company and university activity, there appears to be several areas in biomedical engineering where Connecticut is positioned to have a significant presence including:

- **Systems Biology** is a newly emerging area of biosciences, which brings an inter-disciplinary approach to devising computational models of complex biological systems. Many view it as a key to unlocking the complexity of disease processes and enabling better targeting of therapeutic interventions. Research and Markets reports that commercial applications of systems biology are starting to emerge at an accelerating pace as pharmaceutical and biotechnology research organizations start to combine various forms of genomic and proteomic data into more comprehensive computer models, and bioinformatics companies increase their attention toward offering systems biology solutions to drug developers and diagnostics companies. Market projections for systems biology products and services are expected to grow at an annual compound rate of 66% to $785 million by 2008. In Connecticut, Yale is recognized as one of the world leaders in bioinformatics and the emerging field of systems biology with more than two dozen faculty engaged in research in this area. UConn through its Center on Cell Analysis and Modeling brings a unique capacity to understand the spatial organization of molecules in cells and how their behavior is impacted by different chemicals. Wesleyan's Molecular Biology and Biochemistry Department

emphasizes molecular and physical basis of biological processes and has a prestigious NIH training grant in molecular biophysics focused on DNA complexs, modeling and application of statistical techniques.

- **Personalized Medicine** presents the opportunity to more precisely develop and prescribe medications based on an individual's genetic make-up rather than on educated guesses and trial and error on what will work best. This field is technically referred to as "pharmacogenomics" and considers how genetic variations affect the ways in which people respond to drugs for treatment of diseases. In the near term, Frost and Sullivan, a leading market research firm, sees pharmacogenomics as having the potential to revolutionize gene-based diagnostics, helping to grow that market to $3.5 billion by 2005. Dorland Healthcare Information projects pharmacogenomics-related drug discovery revenues will reach $1.7 billion by 2008, a growth rate of nearly 20% a year from 2002 to 2008. Developing an expertise in pharmacogenetics can also enhance the value of clinical trials activities. Analysts at McKinsey recently estimated that pharmacogenetics could eliminate $60 to $85 million in costs for each approved drug out of an average $240 million spent on clinical trials. The savings would be due to reduced number of compounds tested in clinical trials based on expected toxicity effects, reduced number of patients needed in clinical trials through pre-selection and reducing the length of trials and increasing the revenue potential for drugs. Yale University offers a strong program in pharmacology and molecular medicine that examines a wide range of disease processes, such as the consequences of genetic changes underlying cancer, hematopoietic, and cardiovascular disorders. In addition, Yale's leading genomics and computational biology efforts offer opportunities for developing genomic-based diagnostics. In Connecticut, companies such as Genaissance and newly started, Genomas, are actively advancing pharmacogenomic approaches to both new drug discovery and to disease treatment.

- **Stem Cell Research & Applications**, while largely still at the basic research stage of development, is expected to have tremendous potential for treating or even curing heart diseases, liver disease, diabetes, spinal cord injuries, Alzheimer's Disease, Parkinson's Disease and other degenerative diseases. Stems cells are the most basic cell found in human life. It can grow into any human cell from tissues to bone to organs. Its versatility and ability to divide and differentiate into various cell types provide the potential to reverse many catastrophic diseases and injuries. Through advances in stem cell research a new era of regenerative medicine is at hand. Connecticut is clearly a player in stem cell research. A high level search of stem cell research activity in NIH award database reveals that Connecticut with 41 active grants involving some aspect of "stem cell" research the description of its award with over 30 faculty involved. This places Connecticut competitively with states such as Maryland, North Carolina, Michigan, and Wisconsin – though below the national leaders of Massachusetts and California. Areas of research focus in stem cells in Connecticut today include diabetes research, bone formation, organ failure and neurodegenerative diseases.
- **Targeted Drug Development** is utilizing tools of genomics, combinatorial chemistry and high-throughput screening technologies to discover and develop new drugs in a more rapid and cost effective manner. Connecticut has a long tradition in drug development with the presence of many leading pharmaceutical companies from Pfizer, Bayer and

Boehringer Ingelheim. More recently, an emerging set of companies building upon recent discoveries from genomic research are now advancing targeted drug development in Connecticut, including Curagen, Neurogen and Rib-X. UConn School of Pharmacy has an active research program in pharmaceutical sciences involved in novel delivery systems, toxicology of inhalation drugs and traditional medicinal chemistry that is moving to structural biology and gene-based therapies. A significant share of these firms have university relationships and are also making use of the SBIR progam, particularly with the National Institutes of Health.

- **Clinical Research** activities involve many of the key steps involved in clinical trials management from study protocol design to recruitment of sites and investigators to patient enrollment and study monitoring and data collection. NIH has targeted clinical research as an area requiring major re-engineering in the face of growing complexity of regulations and technology. Clinical research is also a significant business activity. Just the outsourced clinical development market was estimated to be nearly $8 billion in 2001 and is expected to grow a healthy 12% a year through 2006, according to Dorland Healthcare Information. Connecticut offers an active setting for clinical research. Leading hospital centers in the state, such as Hartford Hospital and St. Francis Hospital, are actively involved in clinical research with their large patient populations. Moreover, major pharmaceutical companies in Connecticut bring strong expertise in clinical research and are making significant investments, as demonstrated by Pfizer's opening a new clinical research center in New Haven.

DEVELOPMENT CHALLENGES

From interviews and further analysis, a set of specific development challenges facing translational medicine have been identified across talent generation, R&D enhancements and technology commercialization:

Talent Generation:

- Universities need more physician researchers able to translate discoveries into human diseases and advance clinical research.
- Key gaps in drug development skill sets from medicinal chemists through to those with regulatory experience in advancing drugs through clinical trials to market.
- Smaller companies interviewed noted that they are having some difficult in finding core lab support staff. These companies differ in specific skill sets required – not strong connections with colleges and universities.

R&D Enhancements:

- Connecticut's biomedical research base is substantial, but not keeping up with national growth. Lots of competing states seeking to build up their bioscience research capacities. Connecticut needs to ensure it can remain competitive by investing in continuing to maintain its relative position in biomedical research.

- One area of particular concern is stem cell research where a number of states – including California, Wisconsin and New Jersey – are targeting significant investments being used to recruit researchers in this growing field.

Technology Commercialization:

- The ability of Connecticut to translate research discoveries made in research laboratories found in the state needs to be enhanced. This is an issue of national concern, but one which requires local solutions tailored to local circumstances. In particular:
    - Advancing clinical research is a major need across both industry and universities.
    - Universities face key gaps in drug discovery and development to advance basic discoveries of new biological targets into specific drugs and biologics that can intervene in the disease process.
- Advancing new start-up firms based on university technologies and creating an environment in which they can grow are key drivers of future bioscience growth in Connecticut.

HIGHLIGHTS OF LEADING POST-SECONDARY RESEARCH ACTIVITIES

Yale University is one of the top biomedical research universities in the nation. US News & World Report ranks Yale University as the 11th top research medical school in the nation, and 9th leading biology program in the nation. In NIH funding, Yale University ranked 11th in the nation in FY 2003. Given Yale University's high national rankings, it is not surprising that its strengths are extensive. Interviews with top officials at Yale summarized these extensive strengths where Yale University has deep levels of excellence and critical mass as spanning across basic research, technology, organs and diseases as follows:

- Basic research: Neurobiology, pharmacology, cell biology, genomics & proteomics
- Technology: Imaging/radiology, high throughput genomics and proteomics, transgenic models
- Organs – Brain, immunology, microbiology (microbial pathogenesis)
- Diseases – Psychiatric, drug abuse, infectious diseases, asthma, autoimmune diseases (MS)

More specifically, interviews with Yale biomedical research leadership noted the following areas of outstanding strength in both quality and critical mass:

- ***Neurosciences***: Yale University is ranked 8th in the nation in neurosciences by US News and World Report. Strengths found in cognitive mechanisms, brain development, brain disorders, neuropharmacology, neurophysiology (ion channels, mechanisms and functions of neural cells). Psychiatry is very large and is able to integrate well with other departments which focus on neuro aspects (neurobiology, neurology, neuroimaging, neuropharmacology, etc.). Child Study Psychology is a separate department and together with pediatrics brings strong focus on childhood neuroprocesses and diseases like Sudden Infant Death Syndrome.

- ***Immunology***: One of the nation's top programs with a particularly outstanding specialty in basic immune mechanisms, where Yale is the world leader in research into immune system via transgenic models, having identified whole new mechanisms of immune system
- ***Microbial pathogenesis*** has been another key area of focus – host-pathogen analysis. Disease connections include: Infectious diseases, asthma, MS, end stage kidney disease, dermatology
- ***Genomics/Proteomics***: A cross-cutting strength at Yale that is positioned to advance all disease areas which is strongly linked with Yale's growing focus on ***systems biology***, which is integrating Yale's excellence in genomics with its strengths in cell biology and immunology to focus on organ systems using high through-put, real time analysis. Yale, through its world class genomics and proteomics core housed in the Keck Foundation Biotechnology Resource Laboratory, is a national resource serving Yale's researchers and researchers across hundreds of other institutions. It is especially well-known for its expertise in protein profiling. Yale's genomics and proteomic strengths also are closely linked with the university's strengths in bioinformatics, biostatistics and scientific computing found in computer science, with a new supercomputing capacity tied directly to Yale's proteomics core.
- ***Cell Biology***: Highly broad and integrated effort is found at Yale to use cell biology (ranked third in the nation by US News and World Report), in combination with genetics, biochemistry and development biology to study diverse areas such as the cellular basis of developmental processes as well as the study of basic cellular processes of diseases. In the future, Yale is committed to advancing its ***stem cell research efforts***, which naturally build upon Yale's depth in cell biology.
- ***Behavioral sciences*** is a considerable strength at Yale, with its nationally recognized School of Health, with significant strengths at the interface of psychology and psychiatry. Includes a number of outstanding research centers in aging, HIV/AIDS, child studies and substance abuse.
- ***Cardiology***: Not an across the board strength but very good in focused areas, including vascular biology and epidemiology of cardiac diseases.

While Yale's Medical School is highly rated for its number of investigator-led clinical research activities and its continued involvement as only one of four centers in the Robert Wood Johnson Clinical Research Scholars program, Yale is making significant investments in upgrading its focus on translational research that link its strengths in basic research with more of a focus on human diseases. These investments will span cancer diseases, neurodegenerative diseases (such as Alzheimer's Disease and Parkinson's Disease) and autoimmune diseases (such as arthritis and diabetes). Yale is a strategic planning phase where it will be identifying centers of excellence in which it will broadly be upgrading clinical research activities to take basic research to the bedside through combination of clinical research and latest treatments being advanced.

Another key area of investment for translational research, which Yale is considering, is in medicinal chemistry. Given the long-standing focus of NIH on basic research, Yale's competencies in taking discoveries on biological targets relating to disease processes into drug discovery of lead compounds has atrophied. As part of Yale's strategic planning process, the development of medicinal chemistry in coordination with Yale's pharmacology and chemistry strengths is expected.

University of Connecticut has a relatively young medical school with an active biomedical research program generating over $70 million in NIH funding. While not as large a research program as found at Yale University, UConn does have several areas of biomedical research strength, including:

- ***Bone and connective tissue biology*** is one of the most significantly funded areas at UConn with several NIH grants including two core center grants and several program grants. Key focus is on the genetics of bone disease, leading to osteoporosis and genetic predisposition to bone injuries. There is also a focus on the genetics of bone cancer. UConn researchers have developed unique transgenic models that can identify cellular processes at the time of bone failure and are making extensive use of micro-array technologies to map genetic pathways of bone diseases. This strength in bone and connective tissue biology is now being integrated into a larger program effort at UConn through the establishment of a center of excellence and signature research facility in musculoskeletal research, which is expected to focus on osteoporosis, rheumatoid arthritis, spinal surgery, and inflammation of joints. time of bone failure.
- ***Immunology*** is a broad strength at UConn involving roughly 25 labs with 150 faculty, staff and clinical care physicians. UConn is recognized for three key themes in immunology: Immunological responses of heat shock proteins focusing on experimental therapeutics initially for cancer, but broader applications being investigated for biodefense and autoimmune diseases such as MS and diabetes; Immune systems of the gut and how they give us immune responses from what we eat, where UConn has one of the world's leading researchers; and Tic borne diseases, such as Lyme disease.
- ***Vascular biology*** is a long-standing strength at UConn over the years. In UConn's early years, it was well known for its vascular biology efforts related to cardiovascular diseases. Today, UConn's vascular biology research efforts is more closely linked with cancer diseases examining how tumor cells in cancer develop when exposed to various stresses, such as low oxygen. UConn is well known for its work in lipids in regulating new vessel growth.
- ***Neurosciences*** continues to evolve at UConn. The traditional strength found at UConn focusing on more systems neurosciences related to auditory systems with a strong focus on clinical problems, such as deafness, hearing testing in infants and damage to hearing from loud noises. This focus involves a broad research effort spanning anatomy, behavior/perception, neuro chemistry, signal processing aspects of audition/acoustics as well as neural synopsis formation. UConn is also building up its research program in neurobiology focusing on glial cell biology with several PIs active in this area. Among its research focus is on stroke and how to limit damage and on MS. UConn was recently awarded an NIH funded training grant for neurosciences.
- ***Pharmaceutical Sciences*** is an active area of research at the Storrs Campus lead by the School of Pharmacy which today has 40 faculty and $5 million in research funding. The primary areas of research today focus on process and delivery systems for therapeutics and on toxicology involving inhalation therapies. There is a growing emphasis on medical chemistry, moving into structural biology and gene based therapies.

- ***Behavioral interventions*** related more to public health is a major research focus at UConn including a well-funded alcohol research center. UConn at the Storrs campus is also involved in behavioral research related to HIV/AIDS treatment and prevention.

Looking to the future, UConn is placing a strong emphasis on specific centers of excellence in biomedical research to build strong translational research platforms linking its basic research strengths to clinical research and new treatments. The Musculoskeletal Research Center has already been mentioned. Another center of excellence is in the area of cancer, building on a diverse, but growing body of research including immunology of cancer, bone cancer, colon cancer, and cellular processes of cancer growth and development. UConn recently launched a new cancer center with the donation of a major gift. A third center of excellence is in cardiology, which builds upon a growing clinical practice at UConn and seeks to build connections with established research strengths in vascular biology.

Wesleyan University has active research efforts in molecular biology, biochemistry and neurosciences. In molecular biology, there are nearly two dozen faculty involved in research activities which include a well-established molecular biophysics program focusing in DNA complexes, modeling, application of statistical techniques, and use of graphical interfaces based on simulations. This biophysics program has received an NIH training grant award. In addition, molecular biology research at Wesleyan focuses on the molecular and physical basis of biological processes such as DNA replication, gene expression and development using recombinant DNA technologies. There is also a strong emphasis on genetics research focusing on cell and developmental biology, evolutionary biology and neurobiology. In more traditional chemistry efforts, several researchers are active in enzyme analysis including penicillin resistance, RNA protein complexes, and use of NMR to study proteins. Finally, in neurosciences and behavior, comprising cognitive psychologists and molecular biologists, research activities include processing of sensory information, development neurobiology of vocal learning by song birds, and neuronal cell death.

The University of Bridgeport, meanwhile, brings a unique focus on biomedical research with its emphasis on alternative medicine as well as environmental and marine sciences. There is an active research program underway in toxicology related to cancer at the University of Bridgeport, especially examining the impact of chromium and nickel in damaging DNA. There is also active research program on evaluating natural therapies, applying the university's analytical chemistry strengths with strong ties to food science. And, there is a growing emphasis on linking research efforts with the University of Bridgeport's professional schools in Chiropratic Health and Naturopathy.

Other schools, such as University of New Haven, Trinity, University of Hartford, Sacred Heart, Connecticut College as well as the State Universities, particularly Central and Southern, also have individual faculty members involved in research activities, often in collaboration with laboratories at UConn or Yale. For instance, both the University of Hartford and Sacred Heart has faculty engaged in research efforts in the neurosciences, with University of Hartford active in brain energy metabolism research with implications for epilepsy and diabetes, while neuroscience research at Sacred Heart focuses on hormonal stress reactions and drugs of abuse. At Central Connecticut there has been NIH supported work among both chemistry and biology departments investigating soil based micro-organisms.

MAJOR TALENT GENERATION PROGRAMS AMONG POST-SECONDARY INSTITUTIONS

As expected, both Yale and UConn have active biomedical research PhD programs. At Yale University, they recently reorganized their approach to graduate education and formed the interdepartmental Combined Program in the Biological and Biomedical Sciences (BBS) linking 13 departments together across the Medical School and Arts & Sciences. Rather than pigeon-holing students into narrow departments, Yale's BBS program offers eight broad tracks that can vary over time and provides all students with access to courses across tracks that they elect. This unique approach provides a more inter-disciplinary approach to biomedical research training and allows Yale to more actively pool their faculty expertise and facilities for education and training.

UConn's Medical School similarly offers one biomedical research PhD program which students are able to gain a broader exposure to different specialty areas. Given the distance between its campuses, however, the Storrs campus offers a more traditional academic program in the biological sciences of specific PhD programs by department.

Wesleyan University is also active in doctoral and master's education in the biological sciences and chemistry. It offers students a PhD and masters program in molecular biology and biochemistry, with an opportunity to concentrate in molecular biophysics. In addition, the biology department offers a PhD and master's program with concentrations in evolution and ecology, cell and developmental and neurobiology. Chemistry at Wesleyan, in addition to traditional PhD and master's program, offers a unique Industry-Based Doctoral Program for those currently with master's degrees working in industry. Under this program, an industry-based project can serve as the dissertation research.

There are also other graduate education programs in the biological and biomedical-related areas. For instance, the University of New Haven offers a master's program in biotechnology – with approximately 60 students involved – providing hands-on training in biotechnology techniques. University of Hartford, meanwhile, offers a master's degree in neurosciences through its biology department. Sacred Heart offers a new Doctoral program in physical therapy, with a focus on motion analysis and motor control. Quinnipiac University's medical lab sciences and veterinary technology programs are well established. Western Connecticut State's med tech program has continued to fill chronic shortages for imaging and other technician positions at area health care institutions and laboratories. Going forward, the State University System, with strong economic and geographic linkages back through the Community College System will be an increasingly important generator of graduate talent. In particular, Central Connecticut has been mounting more focused efforts to develop graduate programs in biotechnology with the creation of its Biotechnology Institute.

What stands out across the colleges and universities in Connecticut is the growing emphasis on undergraduate research. Both Wesleyan University and Trinity College are one of 17 recipients nationally of Howard Hughes Medical Institute awards for undergraduate education which provide resources for summer research projects, as well as upgrading labs and professional development of faculty. But the emphasis on undergraduate research goes well beyond focused foundation supported efforts. At Trinity College more than 60 students are involved in summer research projects and there is a new interdisciplinary science offering specialized curriculum that links scientific disciplines with outside world. At Sacred Heart there is now a requirement for a senior capstone project and strong interest in having undergraduates undertake research mentored by faculty. At the University of Hartford, the chemistry department provides funding for summer research positions. Connecticut College in New London has had a long established tradition of

supporting summer research internships, a number of which have afforded chemistry, biology and other science majors opportunities at Pfizer and other health care companies and laboratories.