A University of the First Class

The legislature shall as soon as practicable establish, organize and provide for the maintenance, support and direction of a University of the first class, to be located by a vote of the people of this State, and styled, "The University of Texas," for the promotion of literature, and the arts and sciences, including an Agricultural, and Mechanical department.

TEXAS CONSTITUTION, ARTICLE 7, SECTION 10

What characterizes a university of the first class? Graduate and undergraduate education of the highest quality directed and delivered by internationally respected faculty who are experts in their disciplines, and a culture of innovation and discovery that supports graduate training, research programs, and students pursuing new knowledge at the cutting edge of science, technology and scholarship.

EXECUTIVE SUMMARY

- Research defines what it means to be a first class university
- Research and education work together to produce graduates that become innovators and community leaders
    - The Freshman Research Initiative is a prime example of how faculty research can directly impact and educate students
- Basic research leads to economic development and growth
    - The university contributes $5.8 billion to the state economy
- Academic research brings federal and private funding into a university
    - College of Natural Sciences faculty received more than $134.1 million in research support from federal grants and contracts and other external sources in 2009–2010.
- Basic research changes our lives and improves society

Research is Characteristic of a First Class University and Valuable to Students and to Texas

The commonly held belief that research and teaching are at odds in a major research university is simply not true. Graduate student education requires immersion in research activities and no university could be considered first class without strong graduate programs. But on a more basic level there is a strong correlation between research productivity and classroom teaching success among both faculty and graduate students.

The excitement, creativity, and dedication that result in great research carries over to the classroom directly and indirectly in the quality of students and faculty that we can recruit. Even more important is the opportunity a strong research faculty provides for undergraduates as well as graduate students to participate in discovery of new knowledge. A research experience empowers and motivates students, teaches self-reliance, prepares them to succeed, and creates a bond with science and the university that lasts a lifetime. Students can learn basic principles of science in large classes or on line, but to learn research skills and experience the transforming effect of self-motivated discovery they need hands-on work in a laboratory or in the field. If students are to become innovators that propel our economy and society towards an improved future, it is essential that their college education include interaction with and mentoring by professors actively involved in the thrill (and frustration) of research and discovery. A major research university can provide these experiences better than any other kind of educational institution.

The Freshman Research Initiative (FRI)

An innovative, ground breaking, faculty initiated program

- Connects undergraduates with authentic, advanced research projects from the beginning of their first semester on campus as part of their regular course of study
- Is scalable, both in numbers and disciplines, and allows UT Austin to offer unique, authentic research experience to a large portion of the freshman class.
  - Over 5 years > 1600 freshman have participated
  - Again in 2010, > 500 students enrolled in FRI, 25% of the incoming Natural Sciences class
- Merges the twin missions of a major research university: Research and Education
- Retains and helps our students succeed in a science, technology or mathematics degree plan
- Recruits students to scientific careers
- Is attractive to students not traditionally well-represented in science practice

3 FRI THE UNIVERSITY OF TEXAS AT AUSTIN

One of The University of Texas at Austin's key undergraduate programs is built upon this philosophy. The Freshman Research Initiative (FRI) is unique in that science and math students entering the university start working right away on authentic faculty-led research projects in small cohorts. FRI merges the twin missions of a research university: Research and Education; FRI undergraduates learn through doing research for three semesters, working on projects such as programming artificially intelligent cars, creating and studying dark matter, using "molecular evolution" in the lab to create potential drugs, studying viral evolution, or investigating new materials for energy production and storage or catalysis.

The five-year-old program is now serving 25 percent of the entering freshman class in the College of Natural Sciences[1]. It connects around 500 freshmen each year with authentic, advanced research projects from their first semester on campus, as part of their regular course of study; we are hoping to considerably expand the FRI enrollment in the years ahead.

1 25% of the incoming Natural Sciences class. FRI has served 1680 students in the past 5 years. Of students entering FRI in 2009, 25% were first generation college students and 25% were Hispanic.

EFFECT OF FRI ON RETENTION OF STUDENTS IN SCIENCE

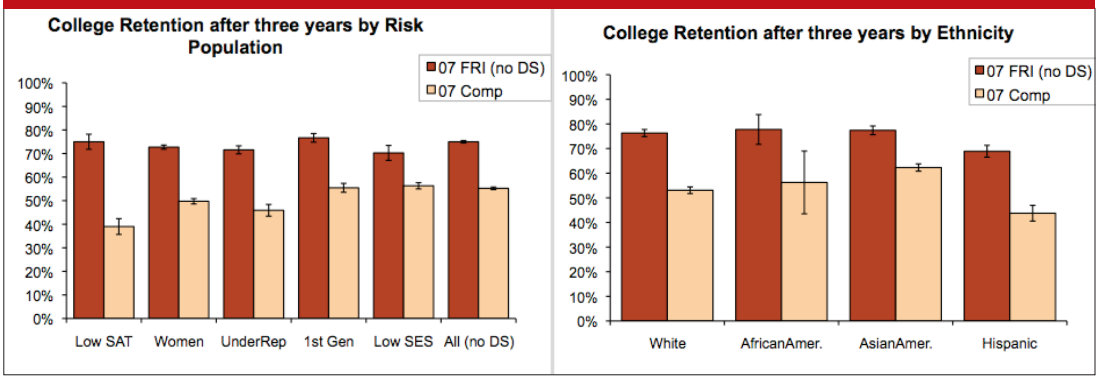

Figure 1. *College of Natural Science (CNS) retention data broken down for the various risk populations. Left The FRI group (N=320) shows better CNS retention than the comparison group (N=400) for all risk populations after three years at UT with statistical significance. Right The FRI group (N=320) shows better CNS retention than the comparison group (N=400) for White, Asian American and Hispanic ethnicities with statistical significance after three years. (no DS = Dean's Scholars honors students, all of whom take FRI, are excluded from this comparison as they would skew the results in favor of FRI)*

Already in the early cohorts we see that FRI significantly increases retention in science. In the 2007 cohort retention has been improved by 35 percent overall, but even more in at-risk student groups that traditionally do not seek a research experience or envision themselves in any kind of science-related career except medicine. Preliminary results from our larger and more recent cohorts indicate even more dramatic results. FRI is scalable, both in numbers and disciplines, and it is unique to The University of Texas at Austin.

EFFECT OF FRI ON RETENTION OF STUDENTS IN SCIENCE

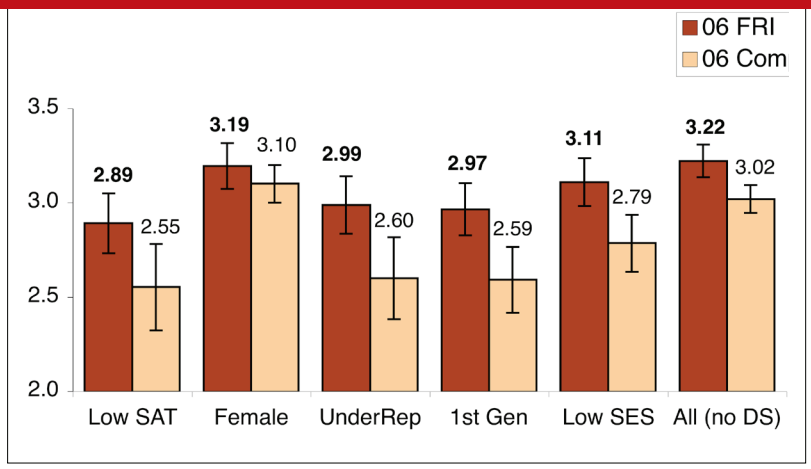

Figure 2. *Third year upper division major GPA for all 2006 FRI students retained in CNS. Performance in upper division classes in the major is better among FRI students (again Dean's Scholars are excluded from the data). Comparison groups start off with statistically indistinguishable predicted GPAs. All differences between the FRI06 cohort and its comparison group are statistically significant, other than for the risk group of women.*

FRI is inspiring students to continue in science and technology after graduation. Thirty-two percent of students who entered FRI in 2006 entered graduate school in Fall 2010 compared with only nine percent of the students in the comparison control group[2]. This is almost a quadrupling of students headed for a professional science career. Without innovative faculty working on basic science projects and designing/leading the research streams, FRI could not work. This is an example of the power of research experience in science as a teaching/learning paradigm and a life-changing opportunity that cannot be duplicated by an on-line learning experience or even a traditional lab or lecture course.

STUDENT OUTCOME DATA FOR FRI PARTICIPANTS VS COMPARISON GROUPS

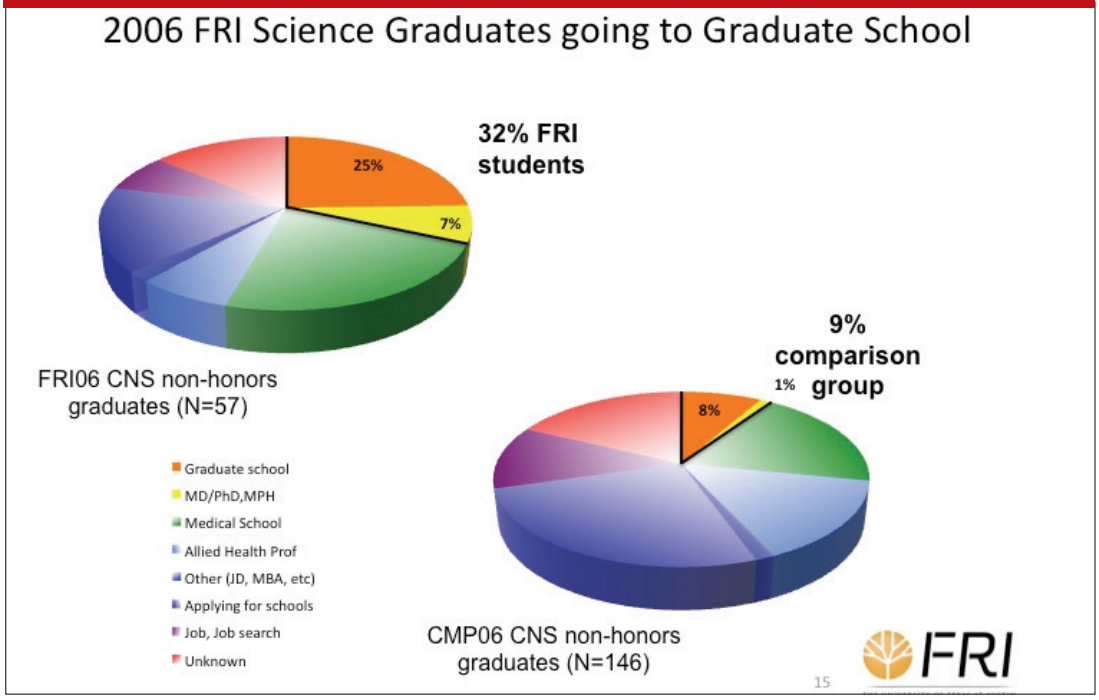

Figure 3. *32% of the students who participated in FRI went on to do graduate work in science compared to only 9% of the comparison group from the 2006 cohort.*

2 Comparison control groups are formed for each year from CNS freshman not in FRI, who meet the same requirements expected for entry into our program: We remove honors students from the FRI data base, and we remove students from the comparison data base from majors that do not currently have an opportunity to participate in FRI. We also remove "non-math ready" students who are not eligible for FRI and those for whom we have no survey results or demographic information. Thus the resulting comparison group, when compared to the year's FRI cohort is demographically similar with comparable numbers of risk students and statistically indistinguishable in terms of predicted first semester GPA.

Basic research at Research Universities Generates Significant Economic Activity

For Texas to thrive, it must be capable of fostering talent and innovation, not simply importing it…Many companies cite the presence of The University of Texas at Austin and its human capital as their reason for locating in Austin.[3]

Dr. Jay Davis, president of the Hertz Foundation said: "Scientists and engineers are only 4 percent of the U.S. workforce, but they account for up to 85 percent of the gross domestic product. We believe their creativity and risk-taking bring forth innovation for the most pressing problems faced today."

The Bureau of Business Research, whose mission is to provide Texas business people and policy-makers with applied economic research and data to strengthen the state's business environment, provides these figures on the economic contributions of the university:

- A total of $5.8 billion in statewide economic impact is attributable to the economic activity of The University of Texas at Austin campus.
- The university generated more than $18 in total spending for the state economy for every state tax dollar invested in 2009–2010. The 2009-2010 State appropriation for the university was $318 million. ($5.8 billion/$318 million).
- Researchers at the university have attracted an average of $440 million/year in research funding over the past three years.
    - College of Natural Sciences faculty received more than $134.1 million in research support from federal grants and contracts and other external sources in fiscal year 2009/2010.
- Research faculty leverage every dollar of state appropriations into $6 of economic activity through out-of-state research funding attracted to, and spent by, the university. And that doesn't even consider the almost incalculable benefits of the teaching function in return for the state's $318 million appropriation!
- For every dollar of out-of-state research funding attracted to and spent by the university, $3.57 in economic activity was generated across the state of Texas in 2009-2010. The ratio has been higher in times when the economy was stronger (in 2004-2005 it was 5.5:1). These are research funds that would not come to Texas but for research activities of the faculty of the university.

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3 *The Economist* , March 24, 2011

Investments in faculty and research programs generate funds and jobs from contracts and grants for many years. For example faculty members in neurobiology average about $550,000/year in grant funds. That means that although start-up costs for new faculty in this area are high (~$750,000), the likelihood that start-up costs will be returned many times over in grant funds over the professional life of a faculty member is also high. Indeed, start-up costs will be recouped within the first 3-5 years in overhead alone. Research-active faculty members also support large numbers of graduate students studying in their labs with research assistantships. A formal classroom teaching load that does not allow such a faculty member time for research and graduate student mentoring will have serious negative consequences in research and graduate student productivity, research funding, retention of research-active faculty and quality of the graduate program.

The average cost of losing or not hiring a faculty member in Natural Sciences is ~$355,000/year in grant funds, not counting the funds required to hire temporary staff to teach courses that should be taught by permanent faculty.[4] It is false economy to cut or lose research faculty numbers in the College of Natural Sciences (CNS) or to create a situation in which they cannot be competitive for grant funds with faculty at medical schools and peer institutions. Table 1 shows the cost in grant funding that would be incurred by losing and/or not hiring 3 research-active faculty/year in CNS for the next 5 years.

TABLE 1. COST OF NOT HIRING RESEARCH-ACTIVE FACULTY IN CNS

Year	Number of Faculty	Grant funding	Overhead Return	Cost of reducing faculty
2009–10	360	$128,235,024	$32,058,756	$1,500,024
2010–11	357	$126,735,000	$31,683,750	$2,565,024
2011–12	354	$125,670,000	$31,417,500	$3,630,024
2012–13	351	$124,605,000	$31,151,250	$4,695,024
2013–14	348	$123,540,000	$30,885,000	$5,760,024
2014–15	345	$122,475,000	$30,618,750	$6,825,024
2015–16	342	$121,410,000	$30,352,500	$7,890,024
Total Loss	**18**			**$32,165,868**

4 This is likely an underestimate because it is based on an average that includes non-research active faculty.

Basic research experience educates innovators and entrepreneurs who found companies, invent new technologies and serve in leadership positions

Both graduate and undergraduate students in the sciences and mathematics move on after graduation to work in the science, medical and technology sectors of our economy. Many studies have shown that science and math alumni are both creative and entrepreneurial, and contribute to our economy through the development of new technologies and by entrepreneurial activities. The world would not be the same without Microsoft, IBM, Texas Instruments, and Exxon/Mobil, all companies founded by and filled with employees who are trained researchers.

Many high-tech companies cite the availability of a skilled science, technology and math workforce as the primary reason for determining where they locate their offices, and research universities are the biggest generators of that workforce. Graduates of research universities are armed with the ability to solve and think creatively about new problems in important ways. For example, Ray Perryman of the Perryman Group, a respected economics consulting firm, estimates that two-thirds of our Department of Computer Science graduates stay in Texas, and each graduate has an annual economic impact of $1.3 million, creating 5.7 permanent jobs. Furthermore, he estimates that the department's overall contribution (in terms of expenditures) to the growth of the Texas high-tech economy is $8.7 billion annually.

Former MIT president Charles M. Vest said about a report on the economic impact of MIT: "The report demonstrates clearly part of the return to society on the investment that the federal government makes in our students and faculty through the sponsorship of research at universities."

Pharmaceutical development, for example, has been a major economic and social force in the U.S. and has contributed to improvement of health worldwide. This progress has been possible because of basic science discoveries in university laboratories that have been commercialized by pharmaceutical and biotechnology companies. Without basic science these companies would not have new drugs to develop. For example, in the 1970s, the laboratory of Herbert Boyer at University of California San Francisco was working on very esoteric experiments with bacterial DNA. Many people thought it a waste to put so much effort into something that had no practical application. Boyer started a company in 1976 to develop gene technology, but this was seen as unlikely to succeed since there was no established product and it was a small company with little chance of success in medical research. This company was Genentech, which was one of the first and the most successful biotechnology companies in the world. In 2009, Roche paid $46.8 billion for the publicly held portion of Genentech.

The Value of Basic Research: Changing Lives, Improving Society

The development of new knowledge through scientific research can have profound benefits to mankind. Many examples exist of world-changing discoveries that have emerged from work by professors and their graduate and undergraduate students on questions in basic science. It is usually not a quick trip from the university lab to a marketable product, but basic research is critical for the initial innovation.

THERE IS NO MORE STRIKING EXAMPLE OF THE IMPACT *and value of basic research in recent history than the story of the discovery of green fluorescent protein (GFP). This begins with basic curiosity about why a jellyfish is bioluminescent and culminates in the award of a Nobel Prize in Chemistry in 2008 following the transformation of basic biological research at many levels. In 1961 marine biologists working at the University of Washington's Friday Harbor Marine Lab were curious about why the jellyfish Aequorea victoria emits bioluminescent light of a particular color. In the course of their work they discovered a molecule they named green fluorescent protein or GFP, which had the ability to absorb blue and emit green light. Other scientists genetically engineered cells in which the DNA for this protein was inserted into host cell DNA, making it possible to follow the developmental fate of individual cells and parts of cells within living organisms using fluorescence microscopy. This resulted in profound discoveries about the function of cells in the brain. But because the DNA sequence for GFP can be fused to the DNA coding sequence for many different proteins in an experimental animal, making it a "reporter" of gene activity, almost any protein of interest can be tagged with fluorescence and its action visualized. Scientists learned to shift wavelengths, creating a palette of man-made (and natural) variants of GFP, including red, yellow, blue and photoswitchable fluorescent proteins. Creation of transgenic animals in which different kinds of cells or proteins are marked with different colors allowed scientists to image cell function. Today these techniques are used in cell, molecular, developmental, and neurobiology, and for crucial medical researcht of virtually all diseases. By the time the Nobel Prize was awarded for GFP in 2008, there were more than 30,000 papers published using this technique. —All of this because a scientist was curious about how a jellyfish could produce fluorescent light.*

When University of Texas at Austin's Dr. Peter Thomas began studying the reproduction of Atlantic Croaker—a common fish in the Gulf of Mexico—he wasn't looking for a treatment for human breast cancer. But that's what he found. He wanted to understand the hormonal control of fish reproduction, but his research led to the discovery of a new mechanism of steroid hormone action that relates directly to human health and fertility.

This outcome—*basic* research leading to *unexpected discovery*, insight and applications far different and more consequential than the original goal—is common when research faculty and their students pursue fundamental knowledge. It is far less likely in a product-oriented corporate research environment. Furthermore the university research environment involves student training and mentoring, creating a legacy of transformation and discovery that is the envy of the world and that generates long-term economic and societal benefit.

If our research programs deteriorate, the graduate student population will decline in size and quality as will research productivity. In a rapid downward spiral top faculty will leave if they cannot attract the best students, and we will quickly lose the national respect and economic advantage for Texas that we have built at The University of Texas at Austin

> ***"Basic research makes it possible to discover entirely new materials and new ways of doing things that could not otherwise have been imagined or discovered. These type of discoveries are almost always made in universities, and increasingly less in companies."***
>
> DR. ALAN LAMBOWITZ, DIRECTOR OF THE INSTITUTE FOR CELL AND MOLECULAR BIOLOGY, PROFESSOR, CHAIRHOLDER, AND MEMBER OF THE NATIONAL ACADEMY OF SCIENCE.

over the last three decades. The quality of graduate students greatly affects the undergraduate experience as well since Teaching Assistants and Assistant Instructors play a major role in lab and discussion class instruction. Thus undergraduate instruction will suffer in multiple ways if the research environment deteriorates.

Here at The University of Texas at Austin, we have many, many additional examples of basic, curiosity-driven research leading to major breakthroughs in technology.

- Through basic research on the evolution of genomes, Alan Lambowitz and his students discovered an entirely new mechanism for modifying DNA. The mechanism has led to a spin-off biotechnology company and is now sold commercially and widely used for genetic engineering of bacteria, where it has led to understanding of mechanisms of disease, is being applied for cancer therapies, and holds promise for the engineering of bacteria for biofuels production.

- The University of Texas at Austin Culture Collection of Algae is a living collection of algae – one of the largest of it's kind in the world. The collection builds on years of basic scientists studying these small, photosynthetic protists. And thanks to faculty members' years of dedication to this seemingly esoteric area of research, the university now holds the keys to the development of algal biofuels. People from around the world now rely on the collection for research into the development of these new fuels.

- Without University of Texas at Austin computer science professor Simon Lam's basic research, our Internet transactions would not be secure and protected e-commerce could have been a thing of science fiction. Lam and his students invented secure sockets and prototyped the first secure sockets layer (SSL). Today, SSL forms the basis of the security for almost all web e-commerce transactions.

- Invasive fire ants are a scourge across the Southern U.S., causing great economic and ecological damage, primarily through disruptions of agriculture. Basic research on the ecological interactions among species by Professor Larry Gilbert led to the discovery of a number of important parasites of the ants that are currently being deployed as biological controls, causing measurable decreases in fire ants in the treated locations.

- Basic theoretical research by physicists in The University of Texas at Austin Institute for Fusion Studies has led to the development of new technology that could enable the production of large numbers of high-energy neutrons for destruction of nuclear waste or for breeding nuclear fuel.

- Physics professor Manfred Fink is developing a means of diagnosing lung cancer via a breath analysis using a novel Raman instrument that he developed and patented at the university to investigate the mass of neutrinos. The instrument is very efficient and inexpensive, uses a tunable diode laser with modest power as an excitation source, and interference filters rather than a spectrometer. Resting patients with cancer are expected to show an unusually rapid rise and decay of the $^{13}CO_2$ signature in their breath after ingesting ^{13}C labeled glucose when compared to subjects without cancer. The diagnostic procedure will be convenient and give results within a minute or less.

- Texas physics professor and chairholder Mark Raizen has discovered a mechanism of separating the isotopes of any atom while studying basic atomic physics. This technology has great potential for providing inexpensive pure isotopes for medical research and treatment as well as pure isotopes of weapons grade uranium.

In Summary

Beyond the obvious and profound value of research to mankind and society as the source of new knowledge and the engine of innovation, basic research is valuable because it leads to economic development and growth directly through federal and private funding to the university generating economic return locally, and indirectly through students that are trained in research and go on to found companies, invent new technologies and serve in leadership positions. Graduate students trained in a research environment are the primary agents of innovation and discovery in this country, and their economic and societal impact cannot be over estimated. Research and teaching are closely linked at a research university. The best, most productive researchers are typically the best classroom teachers, and there is no more effective means of empowering, exciting or retaining students in science than to provide a research experience as a major part of a student's undergraduate experience. It is truly the means of "transforming lives for the benefit of society."

Mary Ann Rankin
Dean, College of Natural Sciences
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April 19, 2011