Transforming the University

Final Recommendations of the College Design: Science/Engineering Task Force

Submitted on behalf of the Task Force by:

Claudia Neuhauser
Frank Bates
David Bernlohr
Co-Chairs of the Task Force
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Executive Summary

Mission: Advances in the biological sciences will transform the physical sciences, engineering, biomedical research, agriculture, and the environmental sciences. Critical to this transformation are strong connections between biology and the physical sciences, mathematics, and engineering. The University of Minnesota seeks to be a leader in promoting these new connections among the sciences, engineering, and related disciplines.

Deliverables

1) Recommendations regarding the optimal design, structure, and organization of the physical sciences, engineering, mathematics, biology and such related disciplines as biomedical research, agriculture, and the environmental sciences.
2) Recommendations regarding how to identify and take maximum academic advantage of important future directions at the interface of the core disciplines.
3) Recommendations regarding how to configure the sciences and engineering to best integrate and promote academic synergies, teaching, and research between academic units and across the Academic Health Center.
4) Recommendations for a plan to optimally position the University of Minnesota to achieve prominence in the sciences, engineering, and health-related disciplines, consistent with the University's goal to become one of the top three public research universities in the world.
5) Recommendations regarding how to promote strengths in the core disciplines of the Biological Sciences (CBS) and the Institute of Technology (IT) and basic science within the Medical School (MS).
6) Recommendations regarding how science and engineering on campus also can be a model for the promotion of public engagement.

Summary of Findings and Recommendations:

This task force concluded that the sciences and engineering at the University of Minnesota have a unique structure that is progressive and ideally suited for greater collaboration across department boundaries. Therefore, we find no reason to recommend change to the current organizational structure of IT or CBS. The following is a summary of the recommendations:

- The University of Minnesota, in partnership with the State of Minnesota and the private sector, should seek funding for a Science and Technology Interdisciplinary Research (STIR) Institute based on research excellence, faculty competitiveness, and focused investments.
- Research collaborations among the sciences and engineering must be strengthened, in particular those between IT, CBS, and the AHC. The task force recommends focused investments in three intercollegiate areas: materials, energy, and environmental genomics. Faculty must take the lead in identifying research thrusts, organizing competitive teams, and orchestrating major proposals that draw on multi-disciplinary and, increasingly, multi-

institutional expertise. Disciplinary research must remain a priority with strategic initiatives providing continued support.

- The task force recommends maintaining strength in traditional departments, while encouraging greater interdisciplinary activities, especially among the physical and biological sciences, engineering and the medical sciences, through graduate education and the formation of research teams.
- The University of Minnesota must continue to establish and support centralized multi-user facilities based on competitive proposals that enhance the research infrastructure in the sciences and engineering.
- The University of Minnesota must take steps to increase research capacity through facilitating collaborative research and securing training grants, especially at the interface of engineering and biology. The University must develop more effective ways to establish institutionally sustainable, multi-disciplinary graduate training opportunities across the sciences and engineering.
- A key step towards integrating biology with the physical sciences and engineering is the creation of an undergraduate minor in biological engineering, jointly organized and administered by IT and CBS.
- The Office of the Vice President for Research should play a major role in articulating and implementing a vision for interdisciplinary research and facilitate associated funding initiatives. The Vice President for Research should actively participate in the development of research capabilities as part of the Office's responsibility for creating university-wide research strategies.

Task Force Members:
Frank Bates, *Co-chair,* Distinguished McKnight University Professor and Head, Department of Chemical Engineering & Materials Science, IT
David Bernlohr, *Co-chair,* Distinguished McKnight University Professor and Head, Department of Biochemistry, Molecular Biology & Biophysics, CBS/Medical School
Claudia Neuhauser, *Co-chair,* Professor and Head, Department of Ecology, Evolution & Behavior, CBS
Katie Fleming, Graduate Student, Department of Mechanical Engineering, IT
Cathy French, Professor, Department of Civil Engineering, IT
Wayne Gladfelter, Professor, Department of Chemistry, IT
Harry Orr, Professor, Department of Lab Medicine & Pathology, Medical School
Michael Sadowsky, Distinguished McKnight University Professor, Department of Soil, Water, and Climate, and Biotechnology Institute COAFES
Marc von Keitz, Associate Director, Biotechnology Institute, CBS/IT
Staff: Jon Binks, Office of the Senior Vice President for Academic Affairs and Provost

Industry Consultant: Douglas Cameron, Ph.D., Chief Scientist, BioTDC, Cargill, Incorporated, Minneapolis, MN

Introduction

Our task force was charged to propose recommendations that will enable scientists and engineers at the University of Minnesota to propel our institution into the top tier of public research universities[1] and to strengthen the connections between biological and the physical sciences, mathematics, and engineering. The timing of this strategic positioning exercise is uniquely favorable as we have arrived at a critical juncture for the future of sciences and engineering. Biology is becoming a quantifiable science, with profound implications for the physical and engineering sciences[2]. We can expect to see much stronger collaborations among basic scientists in the physical and biological sciences, working together with engineers and medical researchers. Making the very most of these collaborations and scientific developments will be essential in addressing some of our most challenging problems in energy, health, and the environment.

This report will both convey this remarkable promise and point to critical shortcomings that, this task force concludes, have impaired the ability of the University of Minnesota to fulfill its potential as a top tier research university. Commitment to excellence in integrating research, teaching, and public engagement, combined with the highest aspirations and highest expectations must become the cultural norm at the University of Minnesota. The University of Minnesota can be one of the world's leading public research institutions only if we aggressively and strategically pursue research directions at the frontiers of our disciplines. The University must create a more collaborative culture with a commitment from University leadership to enable and facilitate research across departments and colleges, and must become a national model for attracting, retaining, and preparing the next generation of scientists and engineers. In addition, faculty must embrace the concept of collaboration across traditional boundaries and culturally adapt to an environment where interdisciplinary research is the norm rather than the exception.

Strong core disciplines in the sciences and engineering are a *sine qua non* for the University to emerge as a leader in disciplinary and interdisciplinary research. While our charge was to deal primarily with three colleges, the committee believes that the conclusions drawn from this study are applicable to all of sciences and engineering. Excellence in graduate education and postdoctoral training must become a top priority to attract the best and the brightest to our science and engineering faculty. Departments and graduate programs must strive to create intellectual communities for students and postdocs both within and across disciplines.

Several high-profile reports[3] underscore the need to better educate students in the physical and biological sciences and engineering, and Minnesota faces significant demographic changes that

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[1] See Appendix A for the charge letter to this committee.

[2] See Appendix J: Computational Biology.

[3] Roadmap For National Security; Imperative For Change. G. Hart and W.B. Rudman. 2001. (http://www.fas.org/man/docs/nwc/phaseiii.pdf). Rising Above the Gathering Storm. 2006. (http://www.nap.edu/catalog/11463.html). American Competitiveness Initiative, February 2006, Domestic Policy Council, Office of Science and Technology Policy (http://www.whitehouse.gov/stateoftheunion/2006/aci/aci06-booklet.pdf). Science and Engineering Indicators 2006 (http://www.nsf.gov/statistics/seind06/). America's Pressing Challenge: Building a Stronger Foundation. (http://www.nsf.gov/statistics/nsb0602/nsb0602.pdf).

might challenge its economic position[4]. A partnership among the State of Minnesota, its private sector, and all educational institutions is necessary to maintain the high standard of living and the high educational level of citizens in Minnesota, and the University of Minnesota as the state's public research university must take the lead. The task force has outlined a series of ideas to facilitate **public engagement** throughout the activities of faculty, staff, and students in the sciences and engineering[5].

The first charge of this task force was to make "recommendations regarding the optimal design, structure, and organization" of the sciences and engineering[6]. Evaluation of the administrative structure of a large number of research universities in the U.S. reveals that no two universities are alike and that organizational structure is not a predictor of excellence (see Appendix B for full rationales and additional data). The Institute of Technology (IT) and the College of Biological Sciences (CBS) in their current forms were established in the mid 1960s, well before biology received such prominence. This structural organization has proven to be visionary and forward-looking. Other universities (such as UC Davis and UCLA) much later recognized the importance of providing a separate home to the biological sciences. No university has a college structured like IT, which has served to eliminate the artificial separation of the physical sciences, engineering, and mathematics. The recommendations in this report, therefore, are predicated on the following:

This task force concluded that the sciences and engineering at the University of Minnesota have a unique structure that is progressive and ideally suited for greater collaboration across department boundaries. Therefore, we find no reason to recommend change to the current organizational structure of IT or CBS.

The Case for Change

While we concluded that the structural organization of the physical and biological sciences and engineering at the University of Minnesota is forward-looking and well-suited to meet our aspirations of becoming a top-tier university, the following analysis of the current state of research and education in the sciences and engineering at the University of Minnesota convinced us of the urgent need for change. Although we made progress during the last decade, key peer universities have greatly outpaced us.

Academia has become intensely competitive, from attracting the best faculty and students to securing research funds. Great universities must constantly strive to be at the leading edge. This requires faculty leadership in research, education, and administration. Without a culture of excellence and competition, in addition to aggressive strategic investments in highly promising areas and intensive pursuit of research funding, the University will fail to move forward and

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[4] Mind the Gap. Brookings Institution Metropolitan Policy Program. 2005.

[5] Action items are provided in Appendix L.

[6] The sciences and engineering include the physical sciences, engineering, mathematics, biology and such related disciplines as biomedical research, agriculture, and the environmental sciences.

reach its goal to be among the top tier public research universities in the world within a decade. Faculty must step forward and shape and focus the intellectual landscape to a much greater extent than in the past. Far too often, the University community has responded to challenges years after our competitors have already determined the research and education agenda[7]. This task force spent considerable time developing metrics pertinent to sciences and engineering in order to define and measure success in achieving our goal of becoming a top tier university[8] and used these to compare the University of Minnesota to a group of benchmark research universities[9].

During 1996-2003, total R&D expenditure at the University of Minnesota[10] increased by 49%. Our peer universities research expenditures, however, grew at a more rapid pace: UCLA 139%, Ohio State 89%, University of Wisconsin-Madison 75%, and the University of Michigan 66%. The gap has grown over time[11]. All of our peer public universities outperformed the University in total R&D expenditure during this time period[12]. As a result, the University of Minnesota dropped from 10th place in 1996 to 13th place in 2003 in total R&D funding. An analysis of R&D growth rates predicts that without nimble and strategic efforts to pursue research funding, the University of Minnesota will fall further in this ranking in the future: we anticipate dropping to 25th place in 2011 and to 34th rank in 2016, and the gap in funding relative to top tier universities will widen dramatically[13]. This predicted decline, the task force argues, can be effectively met by focused investments in core and interdisciplinary research and increasing the competitiveness of our faculty for large, collaborative research and center grants. We do not endorse a pure growth strategy that simply increases the number of faculty (and hence the total funding for research). Instead, a focus on excellence, driven by faculty, must be the guiding strategy.

We find similar cautionary signs when we examine the quality of graduate education[14]. In the most recent ranking of graduate programs by the National Research Council[15], 13% (48%) of the University of Minnesota's graduate programs in the sciences and engineering (including statistics) are ranked in the top 10 (top 20). Yet these figures are often more than double at universities in our top tier comparison group[16]. Recognition of the importance of graduate

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[7] This is reflected in our relatively low success rate in federal grants (see Appendices D and F).

[8] See Appendix C.

[9] Details of this comparative analysis are given in Appendices D, E, and F.

[10] The NSF annually publishes data on academic institutions, including total spending of institutions on research and development in the sciences and engineering (total R&D expenditures). It is a key metric for assessing a university's success in obtaining funds.

[11] The gap in total R&D expenditure in 2003 to other universities was significant and increased from 1996 to 2003 (see Appendix D). See also Appendix I for the crucial factors that led to such growth at UCLA and OSU.

[12] See Appendix D.

[13] See Appendix D. These predictions are based on the assumption that R&D funding growth rates between 1996 and 2003 are representative of future growth rates.

[14] See Appendix F for details.

[15] The National Research Council (NRC) publishes rankings on a limited number of graduate programs about every ten years. The most recent ranking was published in 1995.

[16] UC Berkeley 78% (83%), University of Wisconsin 39% (74%), University of Washington 35% (70%), UCLA 9% (70%), and the University of Michigan 30% (65%).

education and top-quality graduate programs for our research enterprise and for the need for focused investments in science and engineering graduate programs are the crucial first steps.

This brief assessment of our current state clearly underscores the urgency to develop a strategic plan to achieve academic excellence that will move us into the group of top tier research universities. This task force report proposes such an action plan. Our recommendations further each of the five broad action strategies and address the deliverables in our charge[17].

Promoting Interdisciplinary Research and Strengthening the Core

Recommendation #1: The University of Minnesota, in partnership with the State of Minnesota and the private sector, should seek funding for a Science and Technology Interdisciplinary Research (STIR) Institute, based on research excellence, faculty competitiveness, and focused investments.

Funding agencies will continue to award a significant portion of their funding to interdisciplinary research teams to address questions that defy answers within a single discipline[18]. This requires the coordination and collaboration of multidisciplinary teams, often involving multiple departments and colleges, and institutions, both within the U.S. and abroad[19]. We identified the lack of optimally organized, interdisciplinary research space that includes laboratory space and research infrastructure as a barrier to gather and house such teams and to successfully compete for large grants.

We are not simply proposing a new building. That alone would be inadequate to achieve our goals. We are proposing a faculty-led, competition-driven, focused, interdisciplinary research environment unlike any currently existing at the University. The organizational structure is very important: An advisory board comprised of internal and external researchers would establish three or four research themes and faculty at the University would compete for resources and participation through a stringent external peer-review process. The programs in this Institute and all participating faculty members would undergo regular and rigorous external reviews that determine whether research themes and membership of individual faculty in this Institute should be continued. Stringent external peer review will ensure that the programs are central to the mission of the University and represent a competitive advantage and key strengths. Faculty would continue to teach in their home departments with an identical teaching load, and maintain their independent research laboratories supported by investigator initiated grants, but as members, they would be provided with cutting-edge space, support to hire research staff independent of their primary laboratories, and research infrastructure in this facility for the duration of the research activity. Interdisciplinary research teams should ideally combine faculty whose interests straddle biological, chemical, physical, and computational sciences. There would be no

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[17] See Appendix G.

[18] The FY 2007 NSF budget request to Congress includes a number of cross-cutting priority areas. These include Climate Change Science, Cyberinfrastructure, National Nanotechnology Initiative, Networking and Information Technology, and Sensor Research

[19] See Appendix H for examples at other universities.

permanent membership in the STIR Institute. Resources in this Institute must include administrative and technical staff support; upgrading of existing instrumentation and purchase of new, state-of-the-art instrumentation; and graduate student and postdoctoral fellow support. To develop and leverage resources and to catalyze collaborations during the planning stages of STIR and after its establishment, faculty must meet the cost of the building and its subsequent operation with matches in research funding[20]. Leveraging of resources through external grants must be a central means of operation and support of this Institute. The STIR Institute would be a primary mechanism for increasing interdisciplinary research competitiveness at the University.

Recommendation #2: Beyond Recommendation #1, research collaborations among the sciences and engineering must be strengthened, in particular those between IT, CBS, and the AHC. The task force recommends focused investments in three intercollegiate areas: materials, energy, and environmental genomics[21]. Faculty must take the lead in identifying research thrusts, organizing competitive teams, and orchestrating major proposals that draw on multi-disciplinary and, increasingly, multi-institutional expertise. Disciplinary research must remain a priority with strategic initiatives providing continued support.

We recognize the importance of University initiatives to fund promising new research areas. With limited funds, however, the University must not continue to provide broad (and often shallow) support equally to all units. Resources should be focused on fewer yet more competitive projects. Mobilizing existing resources, in addition to new resources and deploying them strategically to fewer but highly promising areas, is required to move the University of Minnesota into the group of top-tier universities. The University of Minnesota has established seven criteria[22] for program review and establishment of priorities: these must be stringently applied to all centers, institutes, and programs in the sciences and engineering. To ensure excellence, a new policy of rigorous peer evaluation that includes external reviewers should be adopted.

Initial research directions should draw on current strengths and leadership in IT, CBS, and the Medical School and should expand in areas where particular weaknesses could compromise major promising areas of science and engineering research[23].

Materials: Innovative materials constitute one of the principal enabling engines of modern technological development, with applications in electronic devices, biomedical equipment, biocompatible composites, alternative energy, transportation, environmental engineering, and

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[20] A similar approach energized faculty at UCLA and, in part, contributed to their remarkable growth (Appendix I).
[21] Details and justification for the choice of these directions are provided in Appendix J.
[22] These seven criteria from *The University of Minnesota: Advancing the Public Good*, a report of the Strategic Positioning Work Group, February 2005. pp. 19-22, address (1) centrality of mission, (2) quality, productivity, and impact, (3) uniqueness and comparative advantage, (4) enhancement of academic synergies, (5) demand and resources, (6) efficiency and effectiveness, and (7) development and leveraging of resource.
[23] Computational biology is an area where the University lacks strength that is critical to advances in all scientific areas that intersect with biology, and ultimately to our success in competing for funding in these areas. See Appendix J for detail.

many other areas of commerce. Biomolecules and nanostructures have extended the engineering of materials to the level of the atom. Nanotubes and nanowires functionalized with chemical or biological molecules are now used as probes or sensors. Nanoscale materials and devices are being developed for drug delivery and, in addition, for other applications outside of the medical sciences[24]. The University of Minnesota can strongly compete and lead in this arena[25]. IT, CBS, and the Medical School have significant academic strengths to conduct cutting-edge collaborative research in material research initiatives. The potential results for our state, and beyond, are enormous.

Energy: Perhaps no other technical challenge, other than human health, carries the significance for our planet of identifying renewable sources of energy. Direct conversion of visible light to electricity can be realized with photovoltaic devices. Microbial and plant engineering provides a promising venue for producing biofuels, such as hydrogen or ethanol. These and other possibilities all require research and development across numerous academic disciplines. The Initiative for Renewable Energy and the Environment (IREE) with funding from the State of Minnesota and President Bruininks' initiative on the environment and renewable energy (PIERE) have provided leadership to coordinate and facilitate research at the University of Minnesota in this area. With its breadth of research strengths and a plan to establish a National Center for Biofuels Research, the University of Minnesota is poised to be one of the national leaders in this massive, and significant, undertaking[26].

Environmental Genomics[27]: Studies of gene-environment interactions aim to describe how environmental factors contribute to the control of normal gene expression and affect the risk of developing common and complex human diseases and how organisms interact with the environment. Whereas environmental factors that affect genetic and epigenetic processes have been appreciated for years, the availability of molecular tools for genomic, proteomic and metabolomic analysis and the potential engineerability of such regulatory circuits provides opportunities to expand interdisciplinary research in areas that Minnesota has strength (biomedical genomics, microbial and plant genomics, proteomics, structural and molecular biology, ecology, evolution, microbiology, environmental sciences, and public health), and that would play a key role in several areas critical to the future directions of the Medical School, CBS,

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[24] See the Special Section of the November 18, 2005 issue of *Science*.

[25] One measure of the competitiveness of IT in this area is the success of the Materials Research Science and Engineering Center (MRSEC). Chosen as one of approximately 120 competing institutions in 1998, the MRSEC was renewed in 2002 for an additional six years at a funding level of nearly $3 million annually. This center draws faculty from six IT departments with a focus on polymers, magnetic materials, and organic semiconductors.

[26] Other states are not standing still and have taken major steps in this direction. Governor Jennifer Granholm of Michigan announced in January 2006 a $2 billion initiative to develop new sectors of the economy, including life sciences and alternative energy. In her words, Michigan "will be the alternative energy epicenter of America." A recent $2.5 million DOE grant to Wayne State University (Detroit, Michigan) has already made a National Biofuels Energy Lab (the first-of-its kind biofuel technology development lab) a reality for Michigan.

[27] The recently announced NIH sponsored initiative on environment-gene interactions points towards an increasing awareness of how external stimuli affect genetic and epigenetic processes related to all facets of biology from behavior to cancer.

IT, and CFANS, e.g. behavioral genetics, metabolic disorders, biomedical engineering, environmental engineering, cancer biology, infectious disease, and neurological disorders.

In addition to the three areas mentioned above, we recommend that the University continue to focus on the environmental sciences and engineering and biotechnology where it already has considerable strengths that extend to other colleges as well.

Fostering Research and Education

Recommendation #3: The task force recommends maintaining strength in traditional departments, while encouraging greater interdisciplinary activities, especially among the physical and biological sciences, engineering and the medical sciences, through graduate education and the formation of research teams[28].

The importance of strong core disciplines cannot be understated, for both disciplinary and interdisciplinary research[29]. Excellent core departments are important to attract and retain first-rate faculty and to deliver excellent education. Aggressive hiring has to be followed by rigorous mentoring and strict adherence to quality at the time of the tenure decision and at post-tenure review. To attract the best faculty, competitive salaries and start-up packages must be offered. A solid financial basis of colleges is needed to stay competitive. The new (and any future) budget model should be critically examined for its impact on financial stability and competitiveness. At the undergraduate level, the emphasis must remain on providing a solid foundation in core disciplines with minors in emerging areas[30]. Top tier graduate programs are required for the success of our research enterprise and must be funded at competitive levels. *Underperforming academic departments that train few students at either the undergraduate or graduate level should be disbanded, thereby providing an opportunity to invest aggressively in strategic areas through resource reallocation and redistribution of faculty lines across colleges.*

The University of Minnesota is well positioned to benefit from the recently announced proposal to double the federal funding in the physical sciences[31]. The importance of strong governmental support for the physical sciences and engineering also aligns with traditionally strong

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[28] The recently proposed biomedical sciences initiative with five new research facilities and 500 new faculty over the next ten years, which was approved at the March 2006 meeting of the Board of Regents, should be seriously explored as a venue for interdisciplinary research space and joint hires between IT, CBS, and the Medical School to advance biomedical sciences at the University at the intersection of engineering and the medical sciences. (http://www1.umn.edu/umnnews/Feature_Stories/Regents_approve_biomedical_initiative_to_move_the_U_among_the_top_3_public_research_universities.html)

[29] This point was also emphasized in President Bruininks' 2006 State of the University address: "The big questions that confront society in the 21st century require interdisciplinary teams of researchers who are strong in their disciplines but able to cross boundaries."

[30] Examples include biological engineering and bioinformatics.

[31] President George W. Bush in his 2006 State of the Union address proposed "to double the federal commitment to the most critical basic research programs in the physical sciences over the next 10 years. This funding will support the work of the most creative minds as they explore promising areas such as nanotechnology, supercomputing, and alternative energy sources." This increase would amount to an additional $50 billion in R&D.

departments in the physical sciences, mathematics, and engineering. The key will be to take optimal advantage of these strengths and not, as in the recent past, allow our peer universities to outmaneuver us. While the NIH will continue to provide major funding for biology[32], the biological sciences will also benefit from funding increases in the physical sciences and engineering through collaborative research projects, as the following two examples illustrate: The quest for alternative energy sources will require collaborations among physical and biological scientists and engineers because microbial and plant systems surely must be part of the solution to this problem[33]. Biology has become dependent on information science that requires biologists to collaborate increasingly with computer scientists, mathematicians, and statisticians to manage and analyze the complex mass of new data and to develop predictive models.

While interest in interdisciplinary research is high among faculty and students[34], much of the research is accomplished within core disciplines. Funding for core research through grants by single investigators or small groups of investigators from the same or closely related disciplines remains an important venue for much of the research in the sciences and engineering. Faculty who engage in high-quality and cutting edge core research must continue to receive recognition and resources within the University community. Strategic initiatives can play a significant role in advancing core research, in particular in times of rapid change. The Molecular and Cell Biology Initiative was the first focused and sustained investment in biology since the formation of the College of Biological Sciences four decades ago and it significantly strengthened genomics at the University of Minnesota. Strategic investments must continue and close attention should be paid to rapidly advancing fields of biology, such as genomics[35], computational biology[36], and systems biology[36], as is underway at our key peer institutions.

Recommendation #4: The University of Minnesota must continue to establish and support centralized multi-user facilities based on competitive proposals that enhance the research infrastructure in the sciences and engineering.

Instrumentation facilities are essential to academic research. Sophisticated and expensive instrumentation is increasingly shared among multiple users. This requires continuous investments in research infrastructure and allocation of funds for staffing and maintenance. Examples of such facilities at the University are the Characterization Facility, the Center for Mass Spectrometry and Proteomics, and an interdisciplinary Nanofabrication Center that should

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[32] The NIH budget doubled between 1996 and 2004 yet the University of Minnesota failed to fully capitalize on this opportunity. Total NIH funding to the U of M increased by 76% between 1996 and 2003. This figure is 108% for the University of Washington, Seattle; 122% for UCLA; 102% for the University of Michigan; 103% for the University of Wisconsin, Madison; 109% for the University of Iowa; and 137% for The Ohio State University. The U.S. Senate voted on March 16, 2006 to increase the NIH budget by 7%, which reversed recent trends of a flat NIH budget.

[33] The DOE Roadmap clearly lays out the importance of basic biological research for solving the problems of energy, carbon sequestration, and bioremediation, and made a strong push for systems biology. See also Review of the Department of Energy's Genomics GTL Program, National Research Council, February 2006.

[34] See Appendix K.

[35] Genomics is defined in the broad sense, including other '-omics', such as proteomics and metabolomics.

[36] See Appendix J.

serve as models for future intercollegiate initiatives. There is need to upgrade and invest in additional multi-user facilities, for example in the areas of high-performance computing[36], high-through-put biological analysis, and microscopy. This requires strategic investments from the University that should be leveraged, if possible, through extramural grants.

Recommendation #5: The University of Minnesota must take steps to increase research capacity through facilitating collaborative research and securing training grants, especially at the interface of engineering and biology. The University must develop more effective ways to establish institutionally sustainable, multi-disciplinary graduate training opportunities across the sciences and engineering.

To succeed in a competitive research environment, faculty must seek more opportunities to collaborate with faculty across departmental boundaries; international collaborations should be fostered[37]. The sabbatical supplemental funding program should be expanded and used to encourage science and engineering faculty to spend time away from their home departments to develop such collaborations.

Training grants play an important role in developing interdisciplinary research and faculty collaborations: chemical biology started as an NIH training grant that catalyzed the formation of the Chemical Biology Initiative, which in turn was a significant factor in the renewal of their NIH training grant. The IGERT in Nanoscience catalyzed a number of collaborations in the NSF NIRT program[38] and is now establishing increased interactions between IT and the Medical School. The task force identified a lack of training grants. To increase the number of training grants, the University needs to take active steps. Proposed NIH training grants often require ‘proof of concept’ to be successful, whereas NSF training grants do not. This difference must be recognized, and to increase the number of NIH training grants, a seed funding program should be established jointly by the Graduate School and the Office of the Vice President for Research[39].

A critical institutional weakness is the disciplinary isolation of faculty within IT and the basic sciences in CBS and the Medical School. While CBS and the Medical School graduate programs draw faculty from many departments across different colleges within the life sciences, IT graduate programs draw faculty almost exclusively from the affiliated departments. Disciplinary diversity of graduate programs, in particular across CBS, IT, and the Medical School, would facilitate collaborations and interdisciplinary training. The Graduate School and the Office of the Vice President for Research should play a more central role in facilitating research across departmental lines and should be an advocate for the development of training opportunities and

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[37] International collaborations are now commonplace: In 2003, about 20% of the world’s scientific and technical articles had authors from two or more countries compared with 8% in 1988; one quarter of articles with U.S. authors had international co-authors. (Source: Science and Engineering Indicators 2006)

[38] The University of Minnesota was highly successful in competing for grants through the NSF Nanoscale Interdisciplinary Research Teams (NIRT) program: The UMN currently has 8 such grants. In comparison, University of Illinois has 6; UCLA, UCB, UW Madison, and UT Austin each have 5; and OSU has 2 such grants.

[39] Submission of training grant proposals should be a condition for obtaining seed funding.

their institutional sustainability. Incentives should be provided for graduate programs to align with strategic research areas through disciplinary diversity.

A New Future for Biological Engineering

Recommendation #6: A key step towards integrating biology with the physical sciences and engineering is the creation of an undergraduate minor in biological engineering, jointly organized and administered by IT and CBS.

The dramatic advances in biology over the past two decades hold great promise for solving some of the most vexing problems, human health, climate change, renewable energy, clean water, and sustainable food supply. Each of these problems will require engineering solutions that will grow out of the basic physical and biological sciences and the agricultural, environmental, and biomedical sciences.

Educating scientists and engineers across this expansive set of disciplines will require thoughtful changes. Given the breadth and depth of biology and engineering, any educational program intended to unify these fields must offer a flexible set of courses without detracting from the rigorous technical training required by the workplace.

A minor would build on existing strengths in well-established units, and encompass many disciplines across multiple colleges. Funds should be provided to develop this new program and resources should be made available for the development of new courses with laboratory components. Partnerships with the private sector should be sought to provide students with internship opportunities.

The Office of the Vice President for Research

Recommendation #7: The Office of the Vice President for Research should play a major role in articulating and implementing a vision for interdisciplinary research and facilitate associated funding initiatives. The Vice President for Research should actively participate in the development of research capabilities as part of the Office's responsibility for creating university-wide research strategies.

For the University to move forward through increased research and scholarship in all of the sciences and engineering, a strong advocate must be present at the top levels of University decision making. The VP for Research can best serve this role. The Office of Research should coordinate and facilitate University-wide research initiatives including providing coordination among Deans, Institute Directors, and the Academic Health Center. Oversight of STIR (Recommendation #1) represents a logical responsibility. Of particular importance is the facilitation of interdisciplinary relationships between the Academic Health Center and other research units. In order to bring faculty creativity to the process of initiative development, a faculty advisory board should be established to help achieve this goal.

Appendices

Acronyms

AHC Academic Health Center
CBCB Consortium of Bioinformatics and Computational Biology
CBS College of Biological Sciences
CFANS College of Agricultural, Food and Environmental Sciences
CNR College of Natural Resources
COAFES College of Agricultural, Food, and Environmental Sciences
DOE Department of Energy
HHMI Howard Hughes Medical Institute
IT Institute of Technology
NASA National Aeronautics and Space Administration
NAS National Academy of Sciences
NIH National Institutes of Health
NRC National Research Council
NSF National Science Foundation
SJTU Shanghai Jiao Tong University

Appendix A

Attachment C of the Charge Letter to the Task Force on College Design: Science/Engineering and Mission and Deliverables

ATTACHMENT C

College Design: Science/Engineering
Report due: May 1, 2006

Mission:

Advances in the biological sciences will transform the physical sciences, engineering, biomedical research, agriculture, and the environmental sciences. Critical to this transformation are strong connections between biology and the physical sciences, mathematics, and engineering. The University of Minnesota seeks to be a leader in promoting these new connections among the sciences, engineering, and related disciplines.

Deliverables:

- Recommendations regarding the optimal design, structure, and organization of the physical sciences, engineering, mathematics, biology and such related disciplines as biomedical research, agriculture, and the environmental sciences.
- Recommendations regarding how to identify and take maximum academic advantage of important future directions at the interface of the core disciplines.
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- Recommendations for a plan to optimally position the University of Minnesota to achieve prominence in the sciences, engineering, and health-related disciplines, consistent with the University's goal to become one of the top three public research universities in the world.
- Recommendations regarding how to promote strengths in the core disciplines of the Biological Sciences (CBS) and the Institute of Technology (IT) and basic science within the Medical School (MS).
- Recommendations regarding how science and engineering on campus also can be a model for the promotion of public engagement.

Appendix B

Organization of Universities

To understand the organizational structure of peer schools, private universities, and non-peer schools, we used the following classification scheme.

Sciences, Mathematics, Engineering, and the Humanities can be arranged into four categories:

A. Engineering
B. Mathematical and Physical Sciences
C. Biological Sciences
D. Liberal Arts/Humanities

Just using the first three categories, there are five "pure" models:

I.	A	B	C
II.	AB	C	
III.	A	BC	
IV.	AC	B	
V.	ABC		

In the first model, A, B, and C are in their separate colleges. In model II, Engineering and the Physical Sciences/Mathematics are in one college, and the Biological Sciences are in a separate college; this is the U of M model. In model III, Engineering is in its own college, the Mathematical and Physical Sciences and the Biological Sciences are together. We did not find models IV and V at research universities.

Using the first three models, we then added D, the Liberal Arts and Humanities. We refer to the lower case letters as the different submodels in Table 1 that is included at the end of this appendix.

MODEL I					**MODEL II**					**MODEL III**		
	A	**B**	**C**			**AB**	**C**			**A**	**BC**	
a	D				**a**	D			**a**	D		
b		D			**b**		D		**b**		D	
c			D		**c**			D	**c**			D
d				D								

Analysis and Comparisons

The physical and biological sciences and engineering at the University of Minnesota are organized in the two colleges Institute of Technology (IT) and the College of Biological Sciences (CBS). These two colleges were established in the early 1960s when the physical sciences and engineering were combined and a separate College of Biological Sciences was founded. This was a visionary reorganization of departments. The engineering sciences are based on physical sciences and the merger of physical sciences and engineering departments removed the artificial separation among these fields. A separate College of Biological Sciences gives biology a prominent place at the University of Minnesota, without preventing research on biological systems outside of CBS in IT, the Medical School, the College of Natural Resources (CNR) and the College of Agricultural, Food and Environmental Sciences (COAFES).

A comparison of the organizational structure of the sciences and engineering, and in particular of IT and CBS, revealed that (1) there is no university that has a college like IT where the physical and engineering sciences are combined in one college, and (2) increasingly, universities are creating separate colleges of biological sciences.

While eliminating smaller colleges by merging them with larger ones might reduce some administrative costs and may result in streamlining some processes, including admission and undergraduate education, this must be done with great care in order not to destroy important research and educational directions. This task force studied three options: (1) merge CBS and IT, (2) break up CBS and distribute departments among other colleges, and (3) leave CBS and IT in their current form. Each of these options has their own strengths and weaknesses. In the end, however, this task force strongly favored Option 3.

It should be noted that the question of eliminating or reorganizing CBS has arisen in the past, and each time, the value of a College of Biological Sciences was affirmed. In 1985, Professor Charles Speaks led the Biological/Life Sciences Review Committee that produced a report that became known as the Speaks Report. The Committee spoke out against splitting CBS or merging it with either the Medical School or the Institute of Agriculture, Forestry and Home Economics (IAFHE). It also spoke out against merging CBS and IT because Biology "would probably then be the 'low person on the totem pole.'" The Speaks Report recommended the formation of a College of Science. However, there was a strong minority opposition since IT was not consulted and this would have resulted in the break-up of IT. The Speaks Report also pointed out that the formation of CBS was beneficial, and mentioned the "great improvements in the undergraduate curriculum in biology."

In 1996, Professor Ron Phillips chaired the Biological Sciences Enhancement Committee that was charged "to define the core of biology at the University of Minnesota" and "to make the case for any recommended changes in the conduct of biological sciences at the University." This report recommended to "[c]reate a single unit of Basic Biological Sciences responsible for teaching and research of basic biology." While the recommendations of that committee went much further than was ultimately implemented, it resulted in a reorganization of basic biology and the current structure of CBS with joint departments and a teaching mission of teaching basic biology to undergraduate students across a wide variety of undergraduate and graduate majors who are not only in CBS, but also in COAFES, CNR, IT, the Academic Health Center (AHC), the College of Liberal Arts (CLA), and other units.

Merging CBS and IT

It is often said that the 21st century will be the century of biology. New technologies allow scientists to probe the biological world at all scales of biological organizations, from the molecular to the global scale, and to generate data at unprecedented rates. For instance, in 1989, sequencing of the 12.5-million base-pair genome of S*accharomyces cerevisiae*, a common laboratory yeast, took the effort of 74 laboratories and seven years to complete. Today, this can be done by a single sequencing facility within a week. With the enormous increase in sequencing speed, the price also fell tremendously. Sequencing of entire genomes, a dream in the 1990 when sequencing of the human genome would have cost $30 billion, is now done routinely at a cost that is four orders of magnitude less expensive ($0.001 per base pair in 2005 versus $10 per base pair in 1990). These advances have resulted in a deluge of data at the molecular level. New technologies will continue to be developed and will result in a similar increase in data in all fields in biology. The availability of vast amounts of data is changing the ways of biological research, and will require strong collaborations among physical, mathematical[1], and biological scientists and engineers. Experiments and models will increasingly be informing each other, and biology will become a quantifiable science that will enable engineering based on biological systems.

The success of IT and the need for biologists to collaborate with physical scientists, mathematicians, and engineers may suggest combining the biological and physical sciences and engineering in one college. This, however, is a one-dimensional view of biology and neglects the diversity of research in biology and the multitude of interactions that biologists at the University of Minnesota have developed with colleagues across the University.

While collaborations between CBS and IT must be strong, scholarship in biology will continue to be significantly different from the physical sciences. Understanding the complexities of life cannot be reduced solely to physical and chemical laws. Because biological systems evolve, biology is distinct from the physical and chemical sciences. While physical laws allow us to predict the path of a comet, there are no analogous laws in biology that would allow us to predict the evolutionary path of an organism because the course of evolution is context-dependent and largely unpredictable.

A merger of CBS and IT might accelerate the development of quantitative approaches to biology, in particular in areas that rely on molecular data where large data sets are already available that are amenable to quantitative approaches. However, it would likely de-emphasize and hence delay

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[1] The mathematical sciences are defined broadly to include not only mathematics but also statistics, computational science, and applied mathematics.

developments of biology in other areas, including those that are organismal based. Some areas of biology rely heavily on field-based research in managed or natural systems. For instance, CBS is home to two field stations (Cedar Creek and Itasca) that are important to the research and educational mission of CBS. Cedar Creek is an NSF funded Long-term Ecological Research site that is internationally renowned. Summer field courses are taught at Itasca and provide valuable educational experiences to biology undergraduate students in organismal fields. Itasca also provides research opportunities and serves as a training facility for graduate students across diverse fields of biology. The physical sciences and engineering have little experience with running and maintaining field stations and field courses.

While biology will be much more quantitative and interdisciplinary research teams in biology will draw from IT faculty, there are a number of areas within biology that would not feel at home in a college whose primary focus is the physical sciences and engineering. For instance, plant and microbial biology interacts naturally with the agricultural science in COAFES; genetics and development have their primary interactions with the Medical School; behavioral research in CBS has connections to psychology and the Medical School; ecology has close connections to environmental sciences and applied economics in both CNR and COAFES, in addition to close collaborations with IT. Many more areas of biology could be mentioned to illustrate the diverse interactions of biologists.

Breaking up CBS

CBS has an organizational structure that is very different from any other college at the University of Minnesota. Three of the four departments are jointly administered with other colleges: Biochemistry, Molecular Biology and Biophysics (BMBB) and Genetics, Cell Biology and Development (GCD) are jointly administered departments with the Medical School, and Plant Biology is jointly administered with COAFES; Ecology, Evolution and Behavior (EEB) is the only department in CBS that is not jointly administered (it has a number of joint appointments). This structure reflects the breadth of biology and demonstrates that there is not a single natural partnership college. It is important for biology to flourish at the University of Minnesota that these partnerships receive attention.

Integrating across levels of biological organization will be a major theme in the decades to come. By distributing biology departments among other colleges, we would lose the synergy that comes from having them in one college and would likely reduce biology to support units within their new home colleges. Because of the highly collaborative nature of biology, there are not always natural homes for each of the departments, which would likely lead to a break-up of departments, in particular of EEB, which is the highest ranked department in CBS and is typically a single department at other universities. EEB faculty interact quite broadly with faculty in other colleges: Ecologists have developed a number of interactions with IT, CNR, COAFES, and Medical School faculty, behavior faculty collaborate with faculty in Psychology (CLA), Neuroscience (Medical School), and Computer Science (IT); faculty in evolution interact with faculty in COAFES. It should be noted that collaborations change over time, new collaborations are formed, existing ones are disbanded. There is no organizational chart that can reflect the dynamic nature of the networks of collaborations. A single college of biological sciences is best suited to maintain, foster, and expand these interactions with multiple colleges.

Leaving CBS and IT as Separate Colleges

The above analysis convinced us that changing the organizational structure of IT and CBS would not help the University of Minnesota to become a top tier university. The increased efficiency and lower cost that comes from larger colleges and the potential for synergies in quantitative aspects of biology is not enough to overcome the problems that would result from a merger or break-up. Since graduate programs report to the Graduate School and not to colleges, it is unclear how structural changes would affect graduate programs. Therefore, graduate training is not addressed here. There are a number of other aspects, however, that convinced us that the current structure is optimal.

CBS is one of the most selective colleges at the University of Minnesota and it provides unique educational experiences, especially at the freshman level. The Nature of Life[2] program has transformed the first-year experience of CBS majors. Maintaining this program would be difficult if CBS and IT were merged since it cannot be easily scaled up to the much larger undergraduate population of a combined college and would also not be appropriate for physical science and engineering majors with its emphasis on biology-oriented laboratory and field experiences.

The largest major in CBS is Biology, which is not departmentally based. A college-based major would be difficult to maintain in a college were the vast majority of majors are departmentally based. Because of the integrative nature of biology, there is no natural departmental home for this major in any of the existing biology departments. Currently, all CBS departments contribute to the education of undergraduates in this major through teaching and undergraduate research experiences.

It is often mentioned that CBS majors take a large fraction of their courses already in IT (a total of about 36 credits of IT courses are required). While this is correct, it should be pointed out that all of these courses are freshman or sophomore courses. It is undeniable that physics, chemistry, and mathematics provide an essential foundation to the education of a biologist. The core training, however, is in biology, and goes far beyond the introductory courses in physics, chemistry, and mathematics. There is a need for increased quantitative and computational training of biology students but this cannot simply be achieved by requiring biology students to take additional quantitative courses that are designed for IT students. Instead, quantitative training must be integrated into biology courses[3].

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[2] http://www.cbs.umn.edu/studentservices/nol/index.html

[3] See recommendations made by the Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century, National Research Council, published in BIO 2010: Transforming Undergraduate Education for Future Research Biologists. National Academy of Sciences. 2003. (http://fermat.nap.edu/catalog/10497.html)

Research in the physical sciences and in physical sciences based engineering has not come to an end. IT must remain a strong college with college leadership that is knowledgeable in the physical sciences and engineering to ensure that the physical sciences and engineering continue to move forward. The National Science Foundation (NSF) contributes 46% of the federal support of basic research in engineering at academic institutions and 45% of the federal support of basic research in mathematics and physical sciences at academic institutions[4]. The mission of the Mathematical and Physical Sciences directorate (MPS) is "to make discoveries about the Universe and the laws that govern it" and "to create new knowledge, materials, and instruments which promote progress across science and engineering." The list below gives an indication of the breadth of research in the mathematical and physical sciences, most of it is unrelated to biology (http://nsf.gov/mps/about.jsp):

- Charting the evolution of the Universe from the Big Bang to habitable planets and beyond
- Understanding the fundamental nature of space, time, matter, and energy
- Creating the molecules and materials that will transform the 21st century
- Developing tools for discovery and innovation throughout science and engineering
- Understanding how microscopic processes enable and shape the complex behavior of the living world
- Discovering mathematical structures and promoting new connections between mathematics and the sciences
- Conducting basic research that provides the foundation for our national health, prosperity, and security

The Engineering Directorate at the NSF (ENG) has major research thrusts in nanotechnology, information technology, cyberinfrastructure, human and social dynamics, sensors and sensor networks, and earthquake simulations. In their 2005 Strategic Planning Report, the Engineering Directorate identified five new priority areas that have intersections with the physical sciences and biology (see: http://www.nsf.gov/attachments/104206/public/Strategic.doc)

- ***Biology in Engineering**:* Research is needed to develop engineering principles that are based in biology in the same manner that mechanical and electrical engineering have been based in mechanics and electronic/physics principles, and chemical engineering on principles of chemistry.
- ***New Frontiers in Nanotechnology:*** Challenges and opportunities for engineering reside in creating new tools, nanoelectronics, nanosystem design, and nanomanufacturing
- ***Critical Infrastructure Systems:*** Engineering research is needed to develop, sustain, and protect the nation's infrastructure, which include human assets and physical, energy and cyber systems that work together in processes and networks.
- ***Complexity in Engineered and Natural Systems:*** Fundamental understanding of complex systems – such as ecosystems, the worldwide web, metabolic pathways, and

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[4] NSF FY 2007 Budget Request to Congress (http://www.nsf.gov/about/budget/fy2007/pdf/fy2007.pdf)

the power grid – has the potential to predict a specific system's behavior, engineer its design, and build-in response to arrive at a highly robust system.

- ***Manufacturing Frontiers:*** Engineering research and education opportunities that ENG can lead include: new materials and zero waste use; nano and nano-bio manufacturing; convergence of bio-engineered discoveries, and manufacturing innovations.

Research in IT will not be restricted to purely physical systems and will include biological systems, as it has in the past, for instance, the Chemical Biology Initiative and Biological Physics. In a combined college, there is the danger though that the biological sciences would receive too little attention, as was pointed out in the Speaks Report already.

There is little faculty support to merge CBS and IT or to break up CBS. Faculty from neither college feel that collaborations would be facilitated if the two colleges were merged. During a CBS town hall meeting, one faculty member brought up the issue of merging CBS and IT but this received little support. In fact, the reorganization of CBS that took place in the mid 90s is considered successful by most CBS faculty, and there is no desire to reorganize the college at this point again.

Table 1

	MODEL	SUBMODEL	Medical School	Agriculture	Natural Resources	Comments
UC Davis[1]	I	b	0	1	1	College of Biological Sciences
Ohio State	I	d	1	1	1	most similar to U of M, except that engineering is separate
Maryland	I	d	0	1	1	College of Health; College of Life Sciences and Chemistry
UCLA	I*	d	1	0	0	College of Letters and Arts but divisions have deans
UCSD	I	d	1	0	0	Division of Biological Sciences
Minnesota	II	c	1	1	1	
Nebraska	III	b	0	1	1	
Kentucky	III	b	1	1	0	
Tennessee	III	b	1	1	1	Nursing
Kansas State	III	b	0	1	0	
Florida State	III	b	1	0	0	
Arizona State	III	b	0	0	0	separate School of Life Sciences within BC
Iowa State	III	b	0	1	0	
Berkeley	III	b	0	0	1	Division of Biological Sciences
Florida	III	b	1	1	1*	Natural Resources and Ag together, some bio in Ag, Biology and Zoology in Liberal Arts and Sciences
Virginia	III	b	1	0	0	
Michigan	III	b	1	1	1	
Iowa	III	b	1	0	0	
Cornell	III	b	1	1	0	
U. Pennsylvania	III	b	1	0	0	Associated deans for subdivisions in BCD
Northwestern	III	b	1	0	0	
Wash U	III	b	1	0	0	
Johns Hopkins	III	b	1	0	0	
Harvard	III	b	1	0	0	
U Penn	III	b	1	0	0	
Duke	III	b	1	0	1	School of the Environment
Georgia Tech	III	c	0	0	0	
Texas at Austin	III	c	1	0	0	Nursing/Pharmacy
Oregon State	III	c	1	1	1	
Michigan State	III	c	1	1	1	
Penn State	III	c	0	1	0	
Purdue	III	c	1	1	0	
MIT	III	c	1*	0	0	Medical School with Harvard
Stanford	III	c	1	0	0	
Chapel Hill	III*	b	1	0	0	biomedical and environmental engineering
U. Washington	III*	b	1	0	1	Divisional deans for BC and D
Wisconsin	III*	b	1	0	1	associate deans with subcolleges for BCD
Illinois	III*	b	0	1	0	associate deans with subcolleges for BCD
Indiana	III*	b	1	0	0	no engineering

[1] Orange indicates structure similar to U of M.

Appendix C

Metrics

There is no universally accepted set of metrics that would allow us to rank universities without encountering criticism. Yet, comparative data is the only way to assess the quality of a university. Commonly used rankings are the Florida Study (http://thecenter.ufl.edu/) and the SJTU ranking (http://ed.sjtu.edu.cn/ranking.html). The Florida Study measures total research and development (R&D) expenditures, federal R&D expenditures, endowment assets, annual giving, the number of members of the National Academy, number of major faculty awards, doctorates granted, and the number of postdoctoral appointees[5]. The SJTU ranking forms a composite index based on measuring the quality of education (by the number of alumni that won Nobel Prizes and Fields Medals), the quality of faculty (number of faculty that won Nobel Prizes and Fields Medals and number of highly cited researchers in 21 broad categories), research output (number of articles published in *Nature* and *Science* and number of articles indexed in Science Citation Index and Social Science Citation Index), and the size of the institution (academic performance with respect to the size of the institution). Details on these ranking systems are given below.

To assess the quality of an institution, we focused solely on quantitative indicators that measure quality and impact of research, quality of faculty, and quality of graduate programs, and that can be used in a comparative way. There is clearly more to a university than is measured by quantitative indicators. Scholarship cannot simply be reduced to a few numbers. Quantitative indicators, however, are well suited for comparative analysis and allowed this Task Force to gain a better understanding of the comparative strengths and weaknesses of the University of Minnesota. The development of a set of metrics that is comprehensive goes far beyond the charge of this Task Force and was therefore not attempted. For instance, our indicators do not include diversity metrics or metrics that would allow us to assess how we are perceived by the public. It is also important to note that not all indicators below are equally suitable to all fields in the sciences and engineering. For instance, *Nature* and *Science* consistently rank at the top of high impact journals[6] in the biological sciences, yet they are of no importance in engineering. We selected indicators from existing rankings and added some of our own indicators. The metrics we chose were selected to assess the quality of science and engineering in particular and allow for comparisons across universities. We included metrics that measure trends and go beyond providing a static snapshot. Below, we will also demonstrate that many of the indicators are positively correlated, potentially implying a positive feedback that could be used to develop strategies to move the University of Minnesota into the top tier of public universities.

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[5] The University of Minnesota and other universities pay much attention to the Florida Study. In the March 2006 Board of Regents meeting, President Bruininks pointed out that the U of M improved its standing from the 2004 report in five of nine indicators and is now tied for six among public research universities in the U.S.

[6] High Impact Journals in selected fields were published in the May-June 2003 issue of Science Watch (http://www.sciencewatch.com/)

Quality and impact of research: (1) Total and federal R&D expenditure[7], (2) Annual rate of increase in total R&D expenditure[7], (3) Total R&D expenditure in the sciences and engineering[7] (about 75% of total funding is in the sciences and engineering), (4) Total NSF funding, (5) Total NIH funding, (6) Patents and licenses, (7) Spin-off companies, (8) Number of extramurally funded centers.

Quality of faculty: (1) Number of members of the National Academy[8], (2) Number of faculty awards[9] including fellows of major scientific societies, (3) SJTU score on awards, number of highly cited researchers, publications in *Nature* and *Science*, number of citations[9], (4) Number of HHMI investigators, (5) Participation on panels that shape the national research agenda, for instance, NRC panels, NIH study sections, advisory boards of major funding agencies.

Quality of graduate and postgraduate education: (1) Number of top 10 and top 20 graduate programs[10], (2) Ratio of graduate students to postdocs[7] in the life sciences, (3) NIH and NSF training grants, (4) NSF and NIH fellowships for graduate students.

To reach our goal of being a top tier public research university in the world, we must compare ourselves against peer research universities. These comparisons should, at a minimum, identify the best and the worst in each group, the average, and the position of the University of Minnesota. In addition, data in each category should be collected that spans several years to assess trends.

We used subsets of the following research universities as benchmark universities:

Big Ten Universities

Indiana University
Michigan State University
Northwestern University
The Ohio State University
Pennsylvania State University
Purdue University
University of Illinois, Urbana Champaign
University of Iowa
University of Michigan
University of Minnesota
University of Wisconsin

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[7] National Science Foundation, Division of Science Resources Statistics, *Academic Research and Development Expenditures: Fiscal Year 2003*, NSF 05-320, Program Director, John E. Jankowski (Arlington, VA 2005). (http://www.nsf.gov/statistics/nsf05320/)

[8] Florida Study

[9] SJTU Study

[10] 1995 NRC ranking of graduate programs and U.S. News and World Report

National Group

The Ohio State University
University of California, Berkeley
University of California, Los Angeles
University of California, San Diego
University of Florida
University of Illinois, Urbana-Champaign
University of Iowa
University of Michigan
University of North Carolina
University of Texas-Austin
University of Virginia
University of Wisconsin, Madison
University of Washington, Seattle

Correlations between different metrics

We are cognizant of the fact that many of the indicators we propose are highly correlated, indicating potential feedback among them. Thus no action should focus on a single indicator of excellence but rather multi-pronged approaches are needed to improve a university.

To illustrate these correlations, we compared the Federal Research Control Rank 2003 (Florida Study), the percentage of top 20 science and engineering graduate programs (1995 NRC ranking) and the number of National Academy Members in 2005 (NAS) (Table 1). The Federal Research Control Rank in the Florida Study is the rank when public and private universities are ranked separately.

In Table 2, we list the correlations between these three measures. We see strong correlations, suggesting that universities that attract more federal funding have a more distinguished faculty, who in turn might attract better graduate students and postdocs, making the faculty more competitive for federal funding, thus becoming more research productive, and ultimately more distinguished.

Table 1	**Federal Research Control Rank 2003**	**% Top 20 NRC 1995 Sci&Eng Graduate Program Ranking**	**Number of National Academy Members 2005**
University of Washington - Seattle	1	70%	86
University of Michigan - Ann Arbor	2	65%	74
University of California - Los Angeles	3	70%	72
University of Wisconsin - Madison	5	74%	71
University of Minnesota - Twin Cities	8	48%	36
Ohio State University - Columbus	19	4%	22

Table 2

Correlation	**% Top 20 NRC 1995 Sci&Eng Graduate Program Ranking**	**Number of National Academy Members 2005**
Federal Research Control Rank 2003	0.9218	0.8527
% Top 20 NRC 1995 Graduate Program Ranking		0.8145

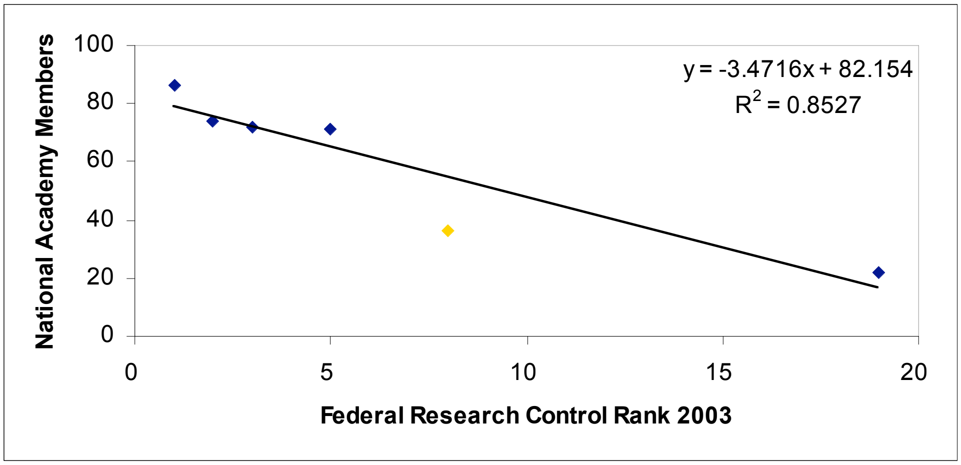

Figure 1: Correlation between federal research control rank and number of National Academy of Sciences members

Trends

Data that is collected every year allows for identifying trends and can provide ways to assess progress of the strategic positioning process. Here are two examples that illustrate this kind of analysis:

The first example looks at total R&D funding (NSF 2003). Figure 2 shows the total R&D expenditures in 2003 of public universities, which puts the University of Minnesota in a group of universities that include Pennsylvania State University, University of California, Berkeley, Ohio State, and the University of Illinois, Urbana-Champaign. Note that the rankings in Figure 2 are based on Table 26 of the *Academic Research and Development Expenditures: Fiscal Year 2003* publication[7]. The rankings differ somewhat from that given in the Florida Study since Table 26 lists data sometimes for all campuses of a university. This results, for instance, in Pennsylvania State University being ranked ahead of the University of Minnesota in total R&D expenditures, since total R&D expenditures of all campuses of these two universities are listed, instead of only the main campuses (as is done in the Florida Study).

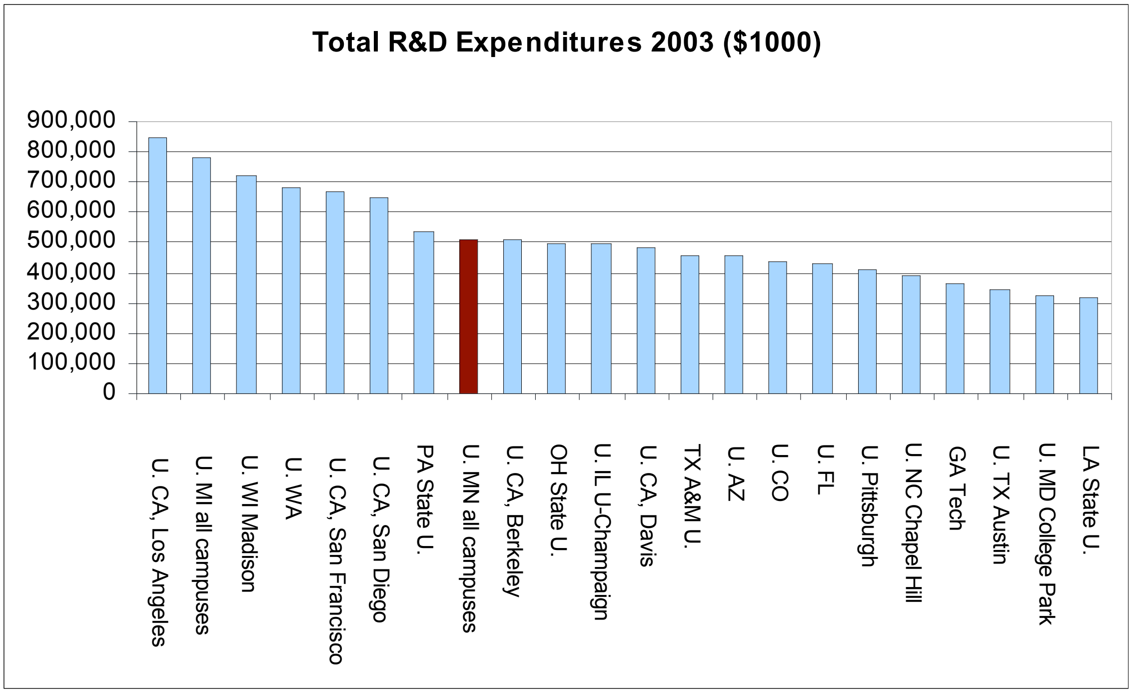

Figure 2: Total R&D expenditures of a select group of public universities.

Figure 3 compares growth rates during the time window from 1996-2003, which gives an indication of our current momentum. The data is also based on Table 26[7].

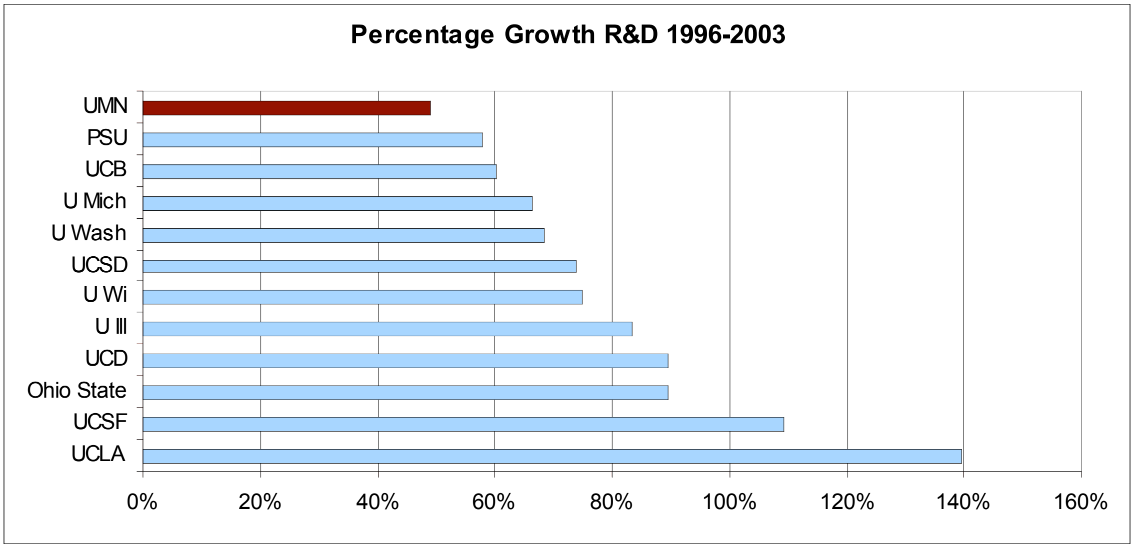

Figure 3: Percentage growth

The second example looks at the number of current members of the National Academy of Sciences and the number of members each institution added during the past five years. While the total number of NAS members gives a static picture that includes achievements that are more than twenty years in the past, the number of National Academy of Sciences (NAS) and National Academy of Engineering (NAE) members who were added over the past five years, gives an indication of how we currently compare to other institutions. The data compiled in Table 3 comes from the online directory of the National Academies[11].

Table 3:

	Total Number of NAS Members	New NAS Members since 2000	Total Number of NAE Members	New NAE Members since 2000
UCB	131	28	70	14
Wisconsin	43	8	19	5
U Wash	41	8	13	5
UCLA	32	9	17	4
Illinois	27	5	24	8
Michigan	22	7	20	10
UMN	12	1	18	5
Ohio State	9	4	10	2

Data[12] Driven Decision Making

Decision making at any university must be data driven and data must objectively inform a university about its strengths and weaknesses. The same scientific rigor we demand of a scientist who collects data to understand a complex system must be demanded of any university administration. Data must be used in an objective way that promotes strategies that will ultimately bring transformative change. Quick fixes are to be avoided. For instance, we would do little to transform the University of Minnesota if we simply hired a large number of new faculty who would increase federal and total R&D expenditures simply because of the increased size of the faculty. Similarly, hiring faculty who are already members of the National Academy might not have a transformative effect, though would quickly help us improve our ranking in that specific category.

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[11] http://www.nationalacademies.org/

[12] Data here is meant in the broad sense and includes both quantitative and qualitative data.

Appendix D

Total R&D Expenditures of Public Research Universities

The following analysis is based on TABLE 26: R&D expenditures at universities and colleges, ranked by FY 2003 R&D expenditures: FY 1996–2003. National Science Foundation/Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, FY 2003. This table provides data on total R&D expenditures at public and private universities in the U.S. in 2003.

Figure 1 shows the 2003 total R&D expenditures (dollars in thousands). The University of Minnesota ranked 13th among all universities and 8th among public universities in 2003[13].

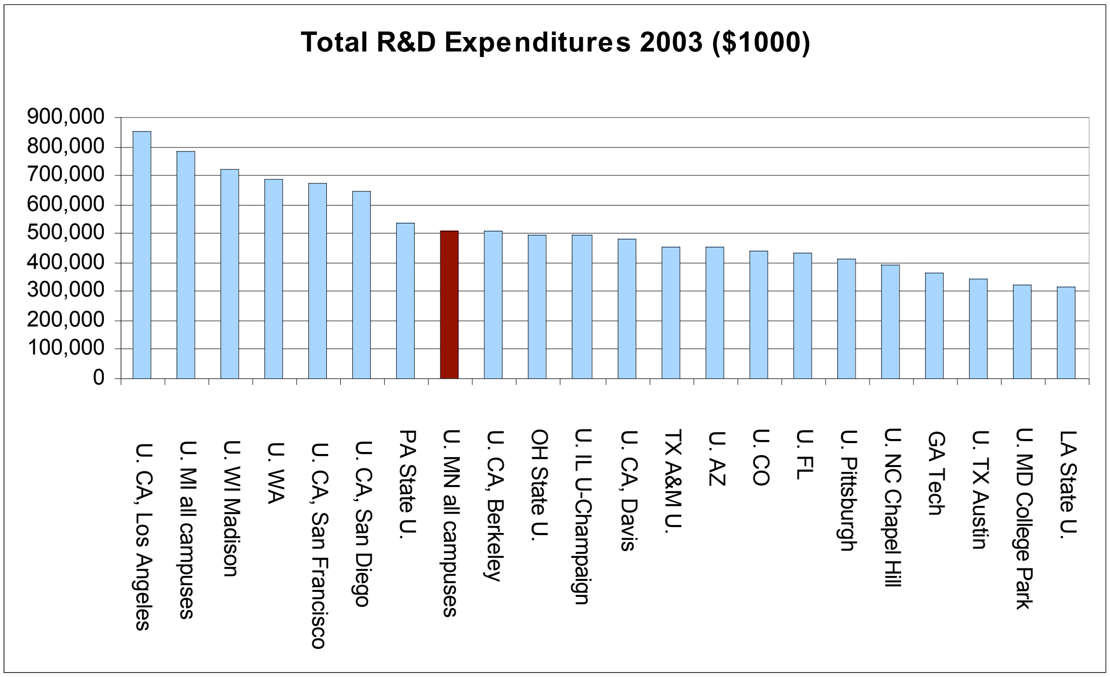

Figure 1: Total R&D expenditure in 2003.

The gap in total R&D expenditure in 2003 (gap in 1996 in parentheses) to other universities was significant and increased from 1996 to 2003: UCLA 67% (4%), University of Michigan 53% (37%), and University of Wisconsin 42% (21%). The Ohio State University lagged by 23% in

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[13] The rankings differ somewhat from that given in the Florida Study since Table 26 lists data sometimes for all campuses of a university. This results, for instance, in Pennsylvania State University being ranked ahead of the University of Minnesota in total R&D expenditures, since total R&D expenditures of all campuses of these two universities are listed, instead of only the main campuses (as is done in the Florida Study). In the Florida Study, the University of Minnesota ranked 11th among all universities and 7th among public universities in Total Research in 2003.

1996, but merely by 2% in 2003. Figure 2 shows the gap between our research funding and that of our competitors for 2003. The U of M falls into the group of second tier universities (Pennsylvania State University, The Ohio State University, University of Illinois, and University of California Davis). (Note that UC Berkeley has no Medical School, which significantly reduces the funding opportunities. UCB's funding without a Medical School is comparable to the University of Minnesota, which has a Medical School.) The top group of universities (UCLA, U. Michigan, U. Wisconsin, U. Washington, UCSF, and UCSD) is significantly ahead of the group of second tier universities. To get into the top group of universities in terms of total R&D funding, the U of M would need to increase their research expenditures by 30-40%. This will require a significant effort.

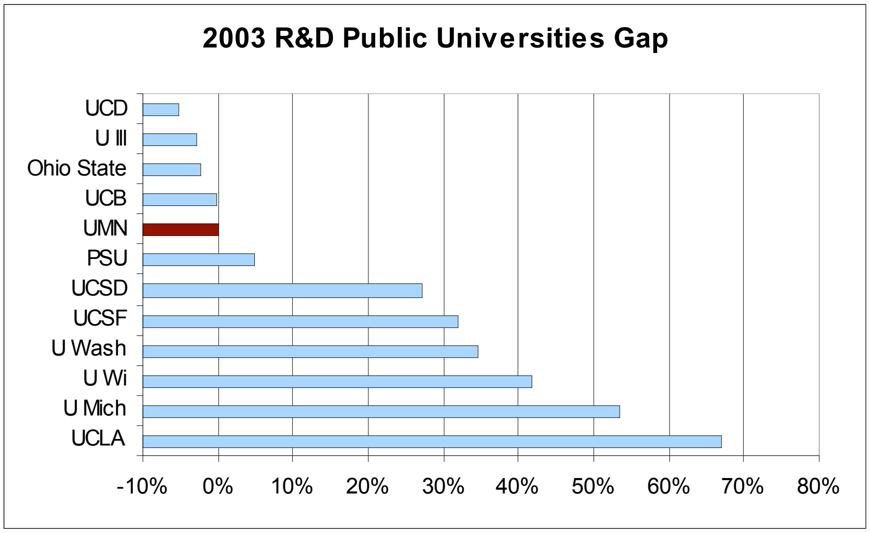

Figure 2: R&D Funding Gap

The potential of a university can be measured when looking at the percentage growth over a certain period. Table 26 lists R&D expenditures for each of the years 1996 to 2003. The percentage growth of all public universities among the top 20 universities during 1996-2003 is displayed in Figure 3.

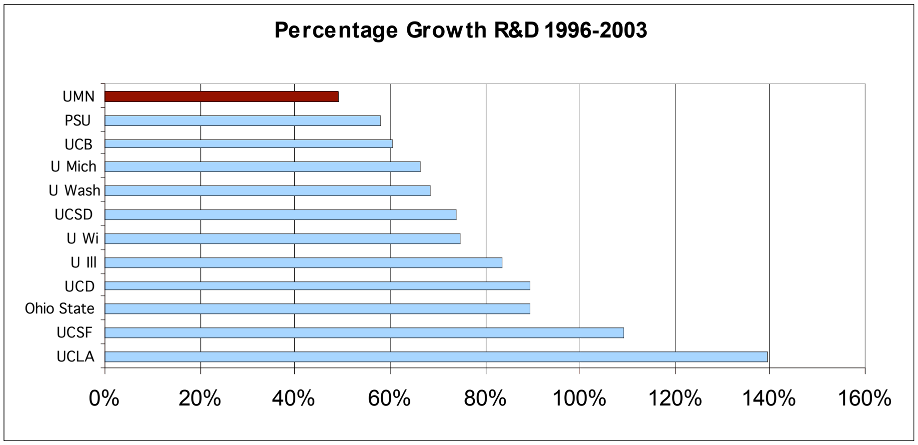

Figure 3: Percentage growth

Predictions of Future Ranking in R&D Expenditure

The University of Minnesota grew by a mere 49% during that period[14], while other universities grew much faster: UCLA 139%, University of Michigan 66%, University of Wisconsin 75%, and Ohio State 89%. Table 1 lists the annual percentage growth for each of the years 1997 to 2003 for UCLA, University of Michigan, University of Washington, and University of Wisconsin. For instance, UCLA's total R&D expenditures grew by 12.5% between 1996 and 1997. The last column is the average annual percentage growth during the period 1996-2003.

Table 1	1997	1998	1999	2000	2001	2002	2003	**AVG**
U. CA, Los Angeles	12.5%	12.2%	6.8%	11.1%	30.7%	13.5%	7.8%	13.3%
U. MI all campuses	3.1%	2.7%	2.4%	8.4%	8.9%	12.2%	15.8%	7.5%
U. WI Madison	1.8%	5.7%	12.6%	10.9%	9.0%	9.6%	8.9%	8.3%
U. WA	0.9%	6.9%	10.1%	9.7%	11.4%	6.4%	9.2%	7.7%
U. MN all campuses	6.4%	-0.8%	3.1%	10.8%	12.3%	7.0%	2.9%	5.9%

We will use the average annual percentage growth during 1996 and 2003 to predict future rankings by assuming that each university will continue to grow at its current rate in the future. For instance, the University of Minnesota grew an average of 5.9% annually during 1996 and 2003. We assume that it will continue to grow at 5.9% annually in the future. Since 2003 is the last year when R&D expenditure data is available, our predictions start in 2004. Using each of the average annual percentage growth, we predict future total R&D expenditures and then rank universities according to expenditures.

We are well aware of the shortcomings of such predictions but it serves to illustrate that if the University of Minnesota continues its research enterprise as in the past, we will not reach the group of the top tier universities; instead the University of Minnesota will fall significantly in ranking. Table 2 shows the rankings for 1996 and 2003 and the predictions for 2011 and 2016. The columns called "All" are the ranks when ranking all universities; the columns called "Public" are the ranks when ranking only public universities. If all universities stay on their current course, the University of Minnesota will rank 25th in 2011 and 34th in 2016 among all research universities in the U.S.

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[14] The consumer price index during this period rose by 17.2%. The NIH budget, a major source of R&D funding, doubled between 1996 and 2004.

Table 2:

Public Institution	1996		2003		2011		2016	
	All	Public	All	Public	All	Public	All	Public
U. MI all campuses	2	1	3	2	4	3	7	4
U. WI Madison	3	2	4	3	5	4	6	3
U. WA	4	3	5	4	8	5	12	7
U. CA, San Diego	6	4	7	6	9	6	11	6
TX A&M U.	7	5	21	13	42	25	50	30
U. CA, Los Angeles	8	6	2	1	1	1	1	1
U. MN all campuses	10	7	13	8	25	17	34	22
PA State U.	12	8	11	7	19	12	27	16
U. CA, San Francisco	13	9	6	5	3	2	3	2
U. CA, Berkeley	14	10	14	9	21	13	29	18
U. AZ	17	11	22	14	27	19	31	20
U. IL U-Champaign	18	12	16	11	15	9	18	12
OH State U.	19	13	15	10	13	7	15	9
U. FL	20	14	25	16	30	20	30	19
U. CA, Davis	21	15	18	12	14	8	16	10
U. CO	22	16	24	15	23	15	28	17
U. TX Austin	25	17	32	20	46	28	54	34
GA Tech	28	18	31	19	37	23	40	25
U. MD College Park	30	19	35	22	50	32	53	33
U. NC Chapel Hill	32	21	29	18	26	18	26	15
LA State U.	34	23	39	25	45	27	45	27
U. Pittsburgh	36	25	27	17	16	10	13	8

We can use this simple model to predict which universities will pass us up in the next several years. According to our predictions, we find that among the public research universities, The Ohio State University and University of California-Berkeley should have passed us up in 2004, UC Davis and University of Illinois at Urbana-Champaign in 2005; University of Pittsburgh will pass us up in 2008 and the University of Colorado in 2010.

This model also allows us to determine whether the private or the public universities will be the big winners: The following table counts the number of private universities in the top10, 20, 30, and 40 for the four years 1996, 2003, 2011, and 2016. There is very little change.

Table 3: Number of Private Universities

Table 3	1996	2003	2011	2016
Top 10	3	4	4	5
Top 20	6	8	8	7
Top 30	11	12	10	11
Top 40	14	14	16	15

Current and Future Gaps

It is illustrative to determine the gap in funding between the University of Minnesota and other universities. The gaps we compute are the gaps in 2003 and 2011, respectively. The gap in 2003 is based on actual total R&D expenditures (Table 26). The gap in 2011 comes from the predictions that are based on the growth rates between 1996 and 2003.

The gap in 2003 to the top tier public universities was large: UCLA 67%, University of Michigan 53%, University of Wisconsin 42%. In 2003, the University of Minnesota was still ahead of The Ohio State University by 2%. If the growth rates for each university remains the same as during the 1996-2003 period, the gap will increase by 2011: UCLA 187%, University of Michigan 74%, University of Wisconsin 70%. In 2011, the University of Minnesota will be behind The Ohio State University by 28%. The data for a larger set of public universities is displayed in Table 4.

Table 4: Gap

Public Institution	2003	2011
U. CA, Los Angeles	67%	187%
U. MI all campuses	53%	74%
U. WI Madison	42%	70%
U. WA	35%	55%
U. CA, San Francisco	32%	95%
U. CA, San Diego	27%	52%
PA State U.	5%	12%
U. MN all campuses	0%	0%
U. CA, Berkeley	0%	8%
OH State U.	-2%	28%
U. IL U-Champaign	-3%	23%
U. CA, Davis	-5%	25%
TX A&M U.	-10%	-27%
U. AZ	-11%	-1%
U. CO	-14%	2%
U. FL	-15%	-3%
U. Pittsburgh	-19%	23%
U. NC Chapel Hill	-23%	0%

Because of the uncertainty in funding increases in future years, we also performed a more conservative analysis. We asked "What percentage annual growth will the University of Minnesota need to achieve to catch up with UCLA, U. Michigan, U. Washington, and U. Wisconsin in 2011 and 2016, respectively if the growth at these other universities is fixed." Table 5 provides the annual percentage growth rates the University of Minnesota of Minnesota needs to sustain to reach this goal for 0%, 3%, 5%, and 8% annual growth rates at these other universities.

	0.0%		3.0%		5.0%		8.0%	
Table 5	**2011**	**2016**	**2011**	**2016**	**2011**	**2016**	**2011**	**2016**
U. CA, Los Angeles	6.6%	4.0%	9.8%	7.1%	11.0%	9.2%	15.1%	12.3%
U. MI all campuses	5.4%	3.3%	8.7%	6.4%	10.8%	8.5%	13.9%	11.6%
U. WI Madison	4.5%	2.7%	7.6%	5.8%	9.7%	7.9%	12.9%	10.9%
U. WA	3.8%	2.3%	6.9%	5.4%	9.0%	7.4%	12.1%	10.5%

For instance, if UCLA's total R&D expenditures grew by 5% annually between 2003 and 2011, the University of Minnesota's R&D expenditures would need to grow by 11.0% annually during the same period to reach the same total R&D expenditures as UCLA in 2011.

Looking back at Table 1, UCLA, U. Michigan, U. Wisconsin, and U. Washington were able to sustain growth rates that typically exceeded 5% and often 8%. If we wish to achieve the goal of becoming one of the top tier public research universities, we need to be prepared to sustain high growth rates not just for one year, but for each of the next ten years.

Appendix E

Faculty Quality

Faculty quality is the key to a successful research university. In Appendix C, we suggested the following metrics:

Quality of faculty: (1) Number of members of the National Academy[15], (2) Number of faculty awards including fellows of major scientific societies, (3) Number of HHMI investigators, (4) SJTU score on awards, number of highly cited researchers, publications in *Nature* and *Science*, number of citations[16], (5) Participation on panels that shape the national research agenda, for instance, NRC panels, NIH study sections, advisory boards of major funding agencies.

While we do not attempt a complete analysis of all measures, we wish to present some of the data that convinced us of the urgency of the strategic positioning process.

National Academy

The following table includes the number of faculty who are currently members of the National Academy of Sciences (NAS), the Institute of Medicine of the National Academy (Medicine), and the National Academy of Engineering (Engineering)

Table 1	**NAS**[1]	**Medicine**[1,2]	**Engineering**[1]
UCB	131	8	70
UW Madison	43	9	19
UW Seattle	41	32	13
UCLA	32	23	17
U Illinois	27	5	24
U Michigan	22	32	20
UMN	12	6	18
Ohio State	9	3	10

[1] Includes only active and retired members

[2] Includes Medical Schools

It is also instructive to look at how the University of Minnesota did in comparison to benchmark universities over the past five years: During 2000-2005, only one faculty member of the University of Minnesota was inducted into the National Academy of Sciences, whereas the numbers are 28 for UC Berkeley, 9 for UCLA, 8 each for the University of Washington and University of Wisconsin, 7 for the University of Michigan, 5 for the University of Illinois, Urbana-Champaign, and 4 for The Ohio State University. Between 2000 and 2005, the number

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[15] The Center: *The Top American Research Universities* (http://thecenter.ufl.edu/)

[16] SJTU Study (http://ed.sjtu.edu.cn/en/index.htm)

of fellows inducted into the National Academy of Engineering (NAE) is: UCB 14, University of Michigan 10, University of Illinois, Urbana-Champaign 8, University of Wisconsin and University of Washington 5 each, UCLA 4, University of Minnesota 5, and The Ohio State University 2.

Other Faculty Awards

Every year, the American Association for the Advancement of Science (AAAS) elects scientists as fellows. Here are the figures for the number of 2005 American Association for the Advancement of Science (AAAS) Fellows. Whereas only two faculty members of the University of Minnesota were elected as AAAS Fellows in 2005, the figures were 19 for The Ohio State University, 10 for the University of Washington, 7 for UC Berkeley, 6 each for the University of Michigan and the University of Wisconsin, and 4 for UCLA.

Another measure of quality of faculty are Howard Hughes Investigators. According to the Howard Hughes Medical Institute web page (http://www.hhmi.org/research/investigators/) "[t]here are more than 300 Howard Hughes Medical Institute investigators, who continue to push the bounds of knowledge in many of the hottest areas in biomedical research. Widely recognized for their creativity and productivity, the current group of HHMI investigators includes several Nobel Prize winners and more than 100 members of the National Academy of Sciences." The table below shows the current number of HHMI investigators at the University of Minnesota and benchmark universities. Table 2 also lists the NIH rank according to NIH awards to Medical Schools in 2003[17].

Table 2:

Institution	**Number of HHMI Investigators**	**NIH Rank**
UCSF	16	4
UCLA	9	7
UCSD	9	15
Michigan	5	11
Wisconsin	4	29
Washington	13	6
Iowa	4	28
Minnesota	1	31
Ohio State	0	53
Illinois	1	47

If we graph the number of HHMI investigators as a function of the NIH rank, we find that the correlation of this non-linear regression is strong. The number of HHM investigators is recognized as a measure of quality. While it might be tempting to increase the pool of faculty who are NIH funded through new hires to improve the NIH ranking, we warn against the fallacy

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[17] http://grants.nih.gov/grants/award/rank/medttl03.htm

of correlation implying causation. Universities that have excellent Medical Schools, like UCSF or the University of Washington, tend to attract more federal funding and have a higher number of HHMI investigators because of the quality of their research.

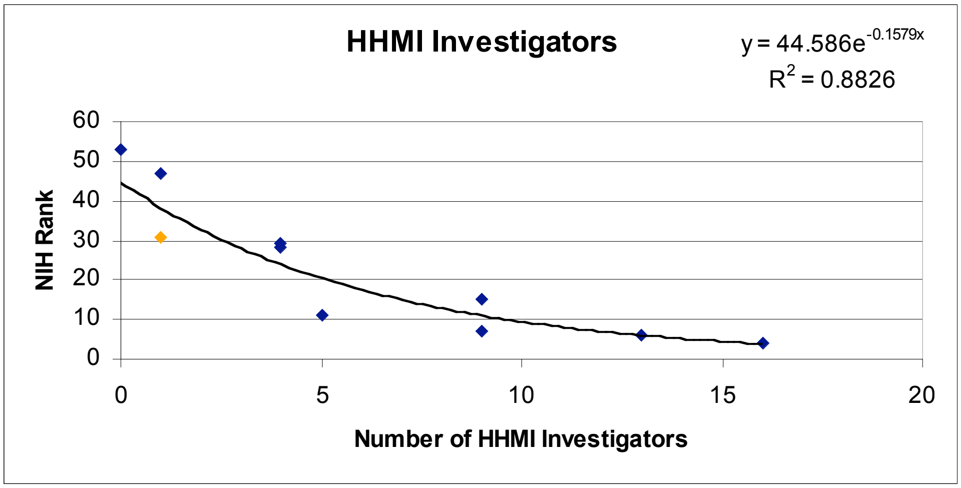

Figure 1: Correlating number of HHMI investigators and NIH rank

The SJTU Ranking[18]

The Institute of Education in Shanghai at Jiao Tong University (SJTU) provides a ranking system that allows for comparisons of universities in the world. The table below shows the criteria for the 2004 ranking:

Table 3:

Criteria	Indicator	Code	Weight
Quality of Education	Alumni of an institution winning Nobel Prizes and Fields Meds	*Alumni*	10%
Quality of Faculty	Staff of an institution winnin Nobel Prizes and Fields Medals	*Award*	20%
	Highly cited researchers in 21 broad subject categories	*HiCi*	20%
Research Output	Articles published in Nature and Science	*N&S*	20%
	Articles indexed in Science Citation Index-Expanded and Social Science Citation Index	*SCI*	20%
Size of Institution	Academic performance with respect to size of an institution	*Size*	10%
Total			100%

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[18] http://ed.sjtu.edu.cn/ranking.htm

The indicators are solely research based and take the size of the institution into account (the Florida Study[15] rewards size that results, for instance, in the California Institute of Technology being ranked below The Ohio State University). Taking four of the SJTU indicators, Highly Cited Researchers, Articles published in *Nature* or *Science*, Articles indexed in the Science Citation Index, and Size, we can compare the ranks in each category of a small group of U.S. benchmark universities when compared against all ranked institutions (Table 4) or only against U.S. institutions (Table 5).

Table 4:

International	**Rank on HiCi**	**Rank on N&S**	**Rank on SCI**	**Rank on Size**	**Average Rank**
UCB	3	2	9	8	5.5
UCSD	9	9	22	11	12.75
UCLA	11	14	5	31	15.25
UCSF	13	6	35	13	16.75
Michigan	5	23	4	42	18.5
Wisconsin	17	19	13	57	26.5
Washington	15	17	6	70	27
Minnesota	19	37	15	111	45.5
Illinois	25	41	36	85	46.75
Ohio State	33	101	28	177	84.75
Iowa	56	90	69	155	92.5

Table 5:

U.S.	**Rank on HiCi**	**Rank on N&S**	**Rank on SCI**	**Rank on Size**	**Average Rank**
UCB	3	2	7	6	4.5
UCSD	9	8	15	8	10.0
UCLA	11	11	4	22	12.0
UCSF	13	6	26	10	13.8
Michigan	5	20	3	29	14.3
Washington	15	14	5	41	18.8
Wisconsin	16	16	10	35	19.3
Minnesota	18	29	11	62	30.0
Illinois	23	32	27	46	32.0
Ohio State	30	68	21	90	52.3
Iowa	46	65	42	75	57.0

Appendix F

Graduate and Postdoctoral Education

Graduate and postdoctoral education and training are at the heart of a first-class research university. To attract the best and the brightest graduate students and postdoctoral researchers requires first-class faculty and first-class graduate programs that provide a wealth of cutting edge research opportunities in a well-supported environment. Financial support for graduate students and postdoctoral researchers includes research grants through faculty, training grants (both at the graduate and postdoctoral level), fellowship opportunities at the national and the university level, and research and teaching assistantships—issues that were addressed in the Task Force for Graduate Student Support. Research support goes beyond financial support. It includes infrastructure, both in terms of buildings and equipment, and logistic support to enable a rich intellectual environment.

The Task Force concludes that the structure of the Graduate School facilitates interdisciplinary research. Graduate programs are overseen by the Graduate School and not by departments. According to Article III.2 of the Graduate School Constitution, faculty are appointed to the Graduate Faculty of a program and can be members of multiple graduate faculties. There are many faculty members at the University who hold multiple appointments, even if they are not members of the department that is the primary home of the graduate program. The voting faculty of a graduate program and its DGS have the authority to administer and govern the program (Article I.5 of the Graduate School Constitution). This is an important organizational structure of graduate programs and the Graduate School and allows faculty to organize graduate programs not solely based on departmental homes. In fact, there are a number of graduate programs, such as Water Resources and Conservation Biology, that do not even have departmental homes.

To achieve our goal of becoming a top tier public research university, we need an assessment of where we stand today and what it takes to achieve this goal. Comparisons with top research universities are essential to this. In the following, we provide comparison data to assess the quality of our graduate programs and the research environment for graduate students and postdoctoral researchers.

In Appendix C, we suggested a number of metrics to measure the quality of graduate and postgraduate education:

<u>Quality of graduate and postgraduate education:</u> (1) Number of top 10 and top 20 graduate programs[19], (2) Ratio of graduate students to postdocs in the life sciences, (3) NIH and NSF training grants, (4) NSF and NIH fellowships for graduate students.

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[19] 1995 NRC ranking of graduate programs and U.S. News and World Report

To be considered among the top tier public research universities in the U.S., which includes UC Berkeley, UCLA, University of Wisconsin, University of Washington, and the University of Michigan, our graduate programs must strive for quality of graduate programs that are on par with those in the top tier. We present data that allows for comparison with top public universities to define our future goals in measurable ways.

NRC Ranking

The National Research Council regularly conducts surveys of graduate programs at U.S. institutions. Based on these surveys, graduate programs are being ranked. Although no ranking scheme is free of criticism, the NRC ranking is acknowledged as one of the most reliable rankings and is the one graduate programs around this country pay the most attention to. The last such ranking was done in 1995 when a total of 41 graduate programs were ranked across a large number of schools. The following analysis of 40 of these graduate programs (Religion was excluded from this study) shows how the University of Minnesota compares to its competitors.

Figure 1 shows the percentage of graduate programs that ranked in the top 10 and the top 20. 90% of the 40 graduate programs at UC Berkeley are ranked in the top 20, even though UCB has no medical school and thus does not have representation in all programs that were ranked. The University of Minnesota has only 38% of its graduate programs ranked in the top 20.

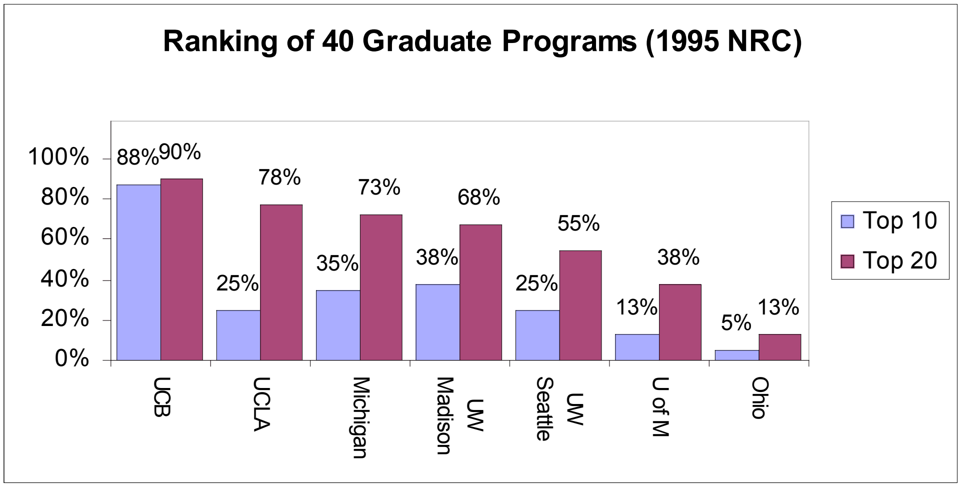

Figure 1: The percentage of programs among the 40 ranked programs that rank in the top 10 and the top 20, respectively.

If we only include the sciences and engineering (including statistics), we can compare 22 graduate programs. The results are displayed in Figure 2.

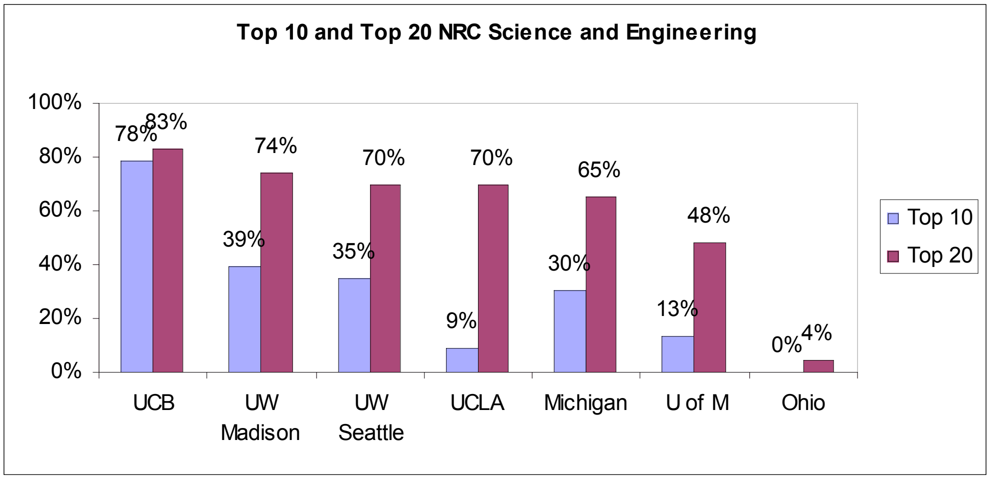

Figure 2: The percentage of programs in the sciences and engineering among the 22 ranked programs that rank in the top 10 and the top 20, respectively.

Fellowships

The following figure shows the number of NIH training grants and fellowships. While our numbers compare favorably with the University of Wisconsin, Madison, we are clearly behind UCLA, UW Seattle, and Michigan.

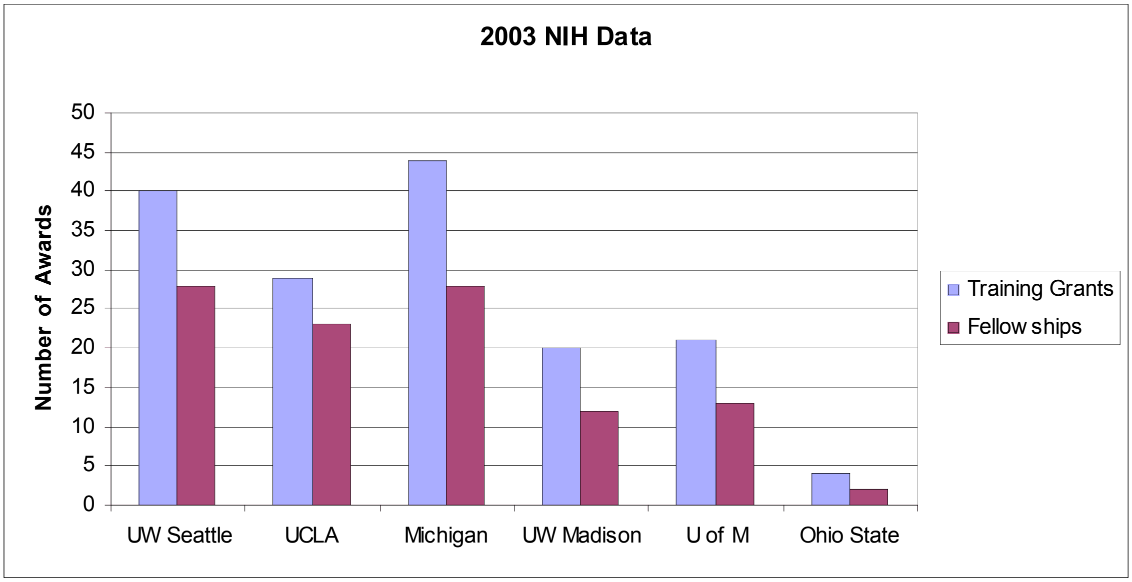

Figure 3: NIH fellowships and training grants

This has consequences for how we fund graduate education in the life sciences. Many of our graduate students in the Medical Sciences (Anesthesiology; Cardiology; Oncology/Cancer Research; Endocrinology; Gastroenterology; Hematology; Neurology; Obstetrics and

Gynecology; Ophtalmology; Otorhinolaryngology; Preventive Medicine and Community Health; Psychatry; Pulmonary Disease; Radiology; Surgery; Clinical Medicine, n.e.c.; Dental Sciences; Pharmaceutical Sciences; Veterinary Sciences) are funded on research assistantships and relatively few on fellowships (Figure 4).

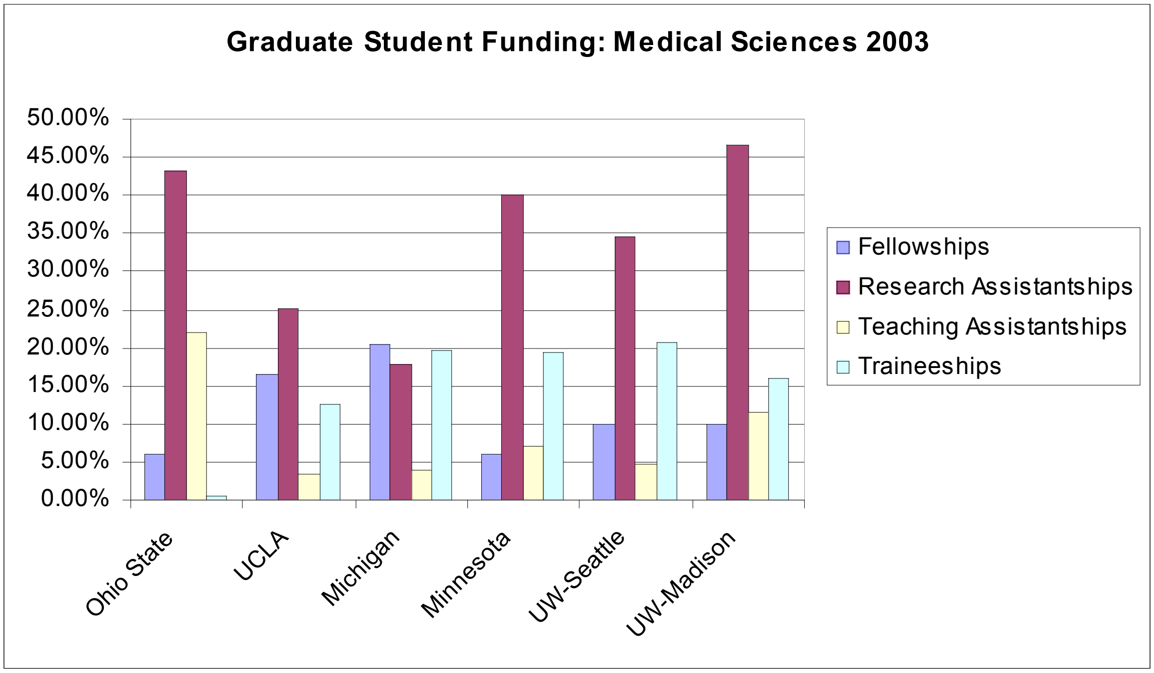

Figure 4: Graduate student funding in the medical sciences

We see a similar picture when we look at graduate student funding in the Biological Sciences (Anatomy; Biochemistry; Biology; Biometry and Epidemiology; Biophysics; Botany; Cell and Molecular Biology; Ecology; Entomology and Parasitology; Genetics; Microbiology; Immunology, and Virology; Nutrition; Pathology; Pharmacology; Physiology; Zoology; Biosciences, n.e.c.) (Figure 5).

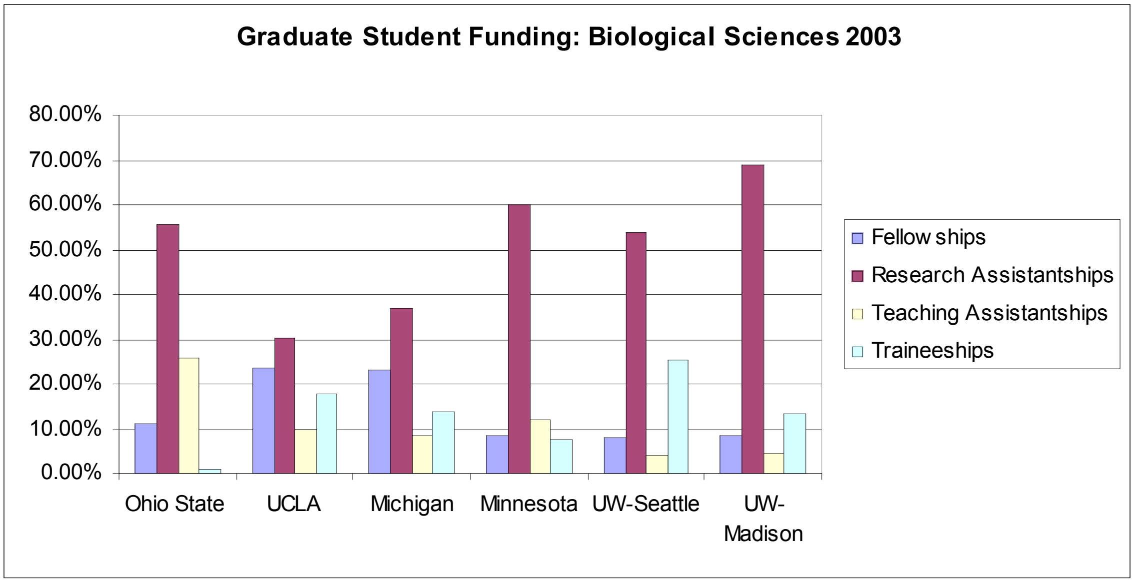

Figure 5: Graduate student funding in the biological sciences

This task force identified a lack of training grants at the University of Minnesota. There are components that are common to all training grants. In the case of NSF grants, broader impact and assessment could be centralized so that faculty could tap into a pool of resources. Centralization would increase our competitiveness for such grants and ultimately result in more collaborations and better positioning for federally funded center grants.

Postdoctoral Training

Postdoctoral researchers play an important part in the research endeavor of a university, in particular in the life sciences and the physical sciences (Figure 6).

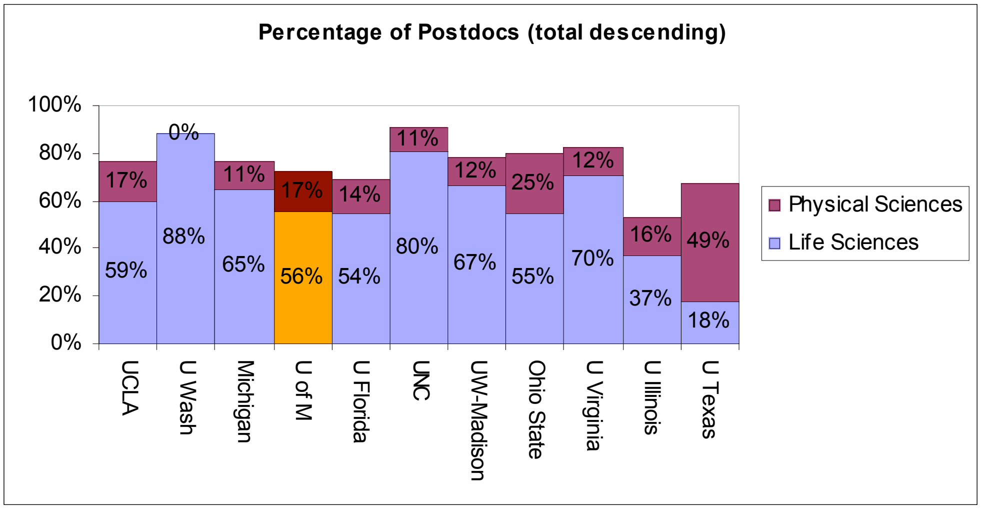

Figure 6: The percentage of postdocs that are in the life sciences and physical sciences, respectively.

The number of graduate students in the medical and biological sciences is comparable to other universities. [We have a disproportionate number of graduate students in the category “Other Life Sciences” (Nursing, Health-related, n.e.c., and Communication Disorder Sciences).] (Figure 7)

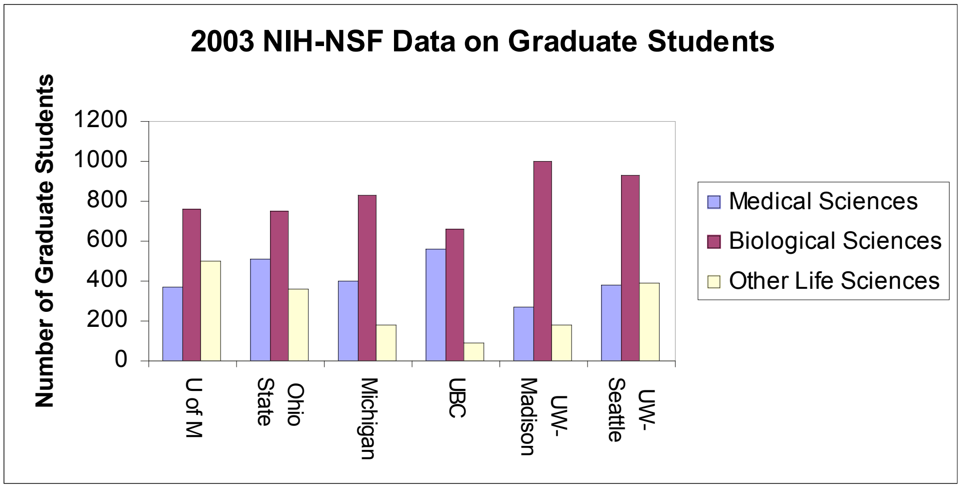

Figure 7: Number of graduate students in the Life Sciences

In the life sciences, the University of Minnesota trains more graduate students relative to postdocs in the biological and medical sciences compared to UCLA, Michigan, and University of Washington (Figure 8).

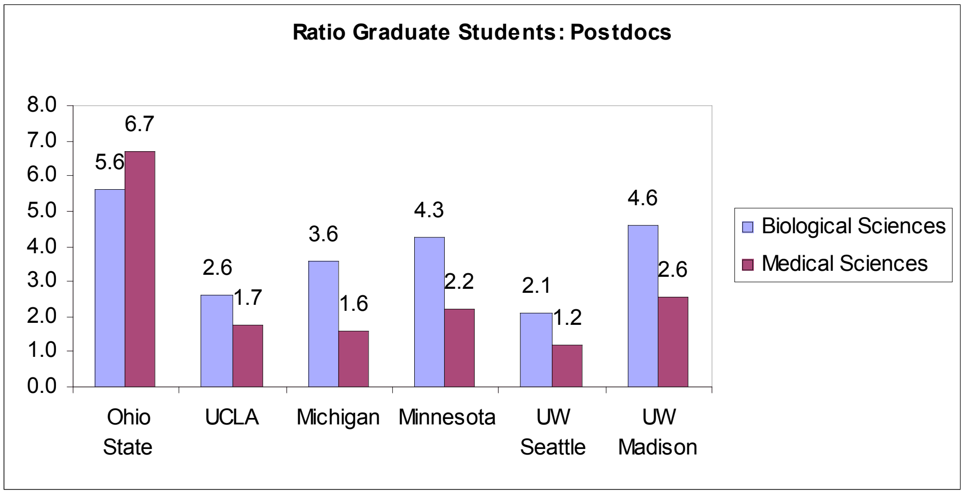

Figure 8: Ratio of graduate students to postdocs in the biological sciences and the medical sciences.

In the physical sciences, the University of Minnesota is comparable to Ohio State and trains more graduate students relative to postdocs compared to UCLA (Figure 9).

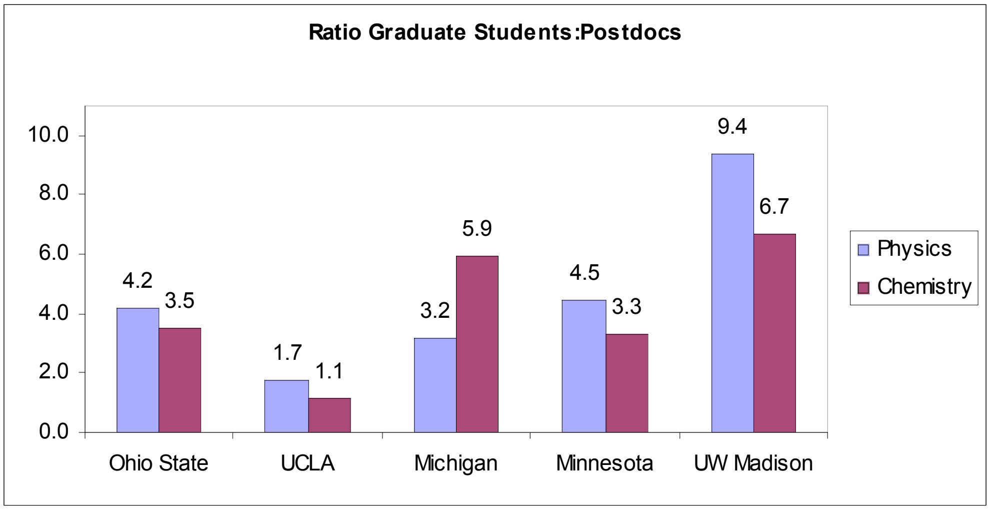

Figure 9: Ratio of graduate students to postdocs in the physical sciences.

Appendix G

Action Areas and Deliverables

Action Areas

i. Recruit, educate, challenge, and graduate outstanding students
ii. Recruit, monitor, reward, and retain outstanding faculty and staff
iii. Enhance and effectively utilize our resources and infrastructure
iv. Communicate clearly and credibly with all our constituencies and practice public engagement responsive to the public good
v. Promote an effective organizational culture that is committed to excellence and responsive to change

Deliverables

1) Recommendations regarding the optimal design, structure, and organization of the physical sciences, engineering, mathematics, biology and such related disciplines as biomedical research, agriculture, and the environmental sciences.
2) Recommendations regarding how to identify and take maximum academic advantage of important future directions at the interface of the core disciplines.
3) Recommendations regarding how to configure the sciences and engineering to best integrate and promote academic synergies, teaching, and research between academic units and across the Academic Health Center.
4) Recommendations for a plan to optimally position the University of Minnesota to achieve prominence in the sciences, engineering, and health-related disciplines, consistent with the University's goal to become one of the top three public research universities in the world.
5) Recommendations regarding how to promote strengths in the core disciplines of the Biological Sciences (CBS) and the Institute of Technology (IT) and basic science within the Medical School (MS).
6) Recommendations regarding how science and engineering on campus also can be a model for the promotion of public engagement.

		Recommendations								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**[1]	**9**[2]
Action Area	**(i)**	✓	✓	✓		✓				
	(ii)	✓	✓	✓						✓
	(iii)	✓	✓	✓	✓		✓			
	(iv)								✓	
	(v)	✓				✓			✓	✓
Deliverables	**1)**				✓			✓		✓
	2)	✓	✓	✓		✓	✓			
	3)	✓						✓		✓
	4)	✓	✓			✓	✓			
	5)	✓	✓	✓				✓		✓
	6)								✓	

[1] Recommendation #8: Appendix L

[2] Recommendation #9: Boldface text on page 2 of the report

Appendix H

Interdisciplinary Research Infrastructure

"At the universities, interdepartmental institutes can provide the "productive collisions" between scientists of different disciplines, but they work best if they are centered or anchored by a free-standing building, such as the Beckman Institute (University of Illinois, Urbana-Champaign), the Broad Institute (Harvard University, Whitehead Institute, and Massachusetts Institute of Technology, in Cambridge, Mass), or Stanford University's Bio-X program (Stanford, Calif)." (Source: T.R. Cech, President of the Howard Hughes Medical Institute. Fostering Innovation and Discovery in Biomedical Research. JAMA 294: 1390-1393. 2005.)

The University of Minnesota

With the exception of the Cargill Building, a 64,000 square-foot facility for about 22 faculty and 175 supporting researchers, which is dedicated to microbial and plant genomics, the University of Minnesota lacks opportunities to house faculty from different disciplines together. In 2003, the Minnesota legislature directed funds towards the newly formed Initiative for Renewable Energy and the Environment (IREE), which has provided leadership to coordinate and facilitate research at the University of Minnesota in the area of energy and products from renewable resources. To date, nearly $17 million have been allocated to research projects, which have supported over 225 faculty, research scientists, and students. A proposal for a National Center for Biofuels Research (NCBR) was made in 2000 and this center is listed in the 6-year Capital Plan under "Federal Funding. This plan has also been endorsed by Governor Pawlenty. Federal support for energy research is strong with nearly $10 billion already having been invested by the federal government in initiatives such as the Biofuels Initiative and the President's Hydrogen Initiative.

The Cargill Building and the proposed NCBR together will provide about 130,000 square feet of interdisciplinary research space. Other universities are ahead of us and have already made significant investments into interdisciplinary research space with investments that are largely driven by state funding[20]: The University of Illinois at Urbana-Champaign has had an interdisciplinary research facility, the Beckman Institute, since 1989. This 313,000 square-foot premier research facility has brought international renown to the University of Illinois. The University of Michigan started in 1999 to build a 230,000 square-foot wet lab facility, which just opened. The University of Wisconsin is building a 450,000 square-foot facility for interdisciplinary research. UCLA and UCSB started construction for interdisciplinary research space in 2000 after having won a competition for $100 million from the state of California that the faculty was asked to match with $200 million in research funding. This challenge-grant catalyzed research collaborations at UCLA and UCSB[21].

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[20] The institutional share for new construction of laboratory space nationally is 63% and the state/local share is 32%. Federal funding fell from 16% in 1991 to 5% in 2003. (Source: Science and Engineering Indicators: 2006 report)

[21] See Appendix I for more detail

University of Illinois, Urbana-Champaign: The Beckman Institute
(http://www.beckman.uiuc.edu/)

The Task Force contacted Dr. Wiltzius, Director of the Beckman Institute at the University of Illinois, Urbana-Champaign, which is a well established interdisciplinary institute that has been in existence since 1989. It occupies a 313,000 square foot building with 200 offices, meeting areas, specialized, state-of-the-art laboratories and other facilities. A significant portion of the daily operating expenses of the Institute are funded by the state and its research programs are mainly supported by external funding from the federal government, corporations, and foundations. The Institute is a pure research entity without an educational mission and reports directly to the provost. Faculty who reside in the institute have home departments and are "visitors" of the Institute. The Institute does not provide salaries to faculty and all faculty are expected to fulfill their teaching and service obligations within their home departments. Approximately 159 faculty have appointments at the Beckman Institute. They fall into four categories, full time (48 faculty), part-time (59 faculty), affiliated faculty (48 faculty), and emeritus faculty (4 faculty). Only full-time faculty have all their research activities in the institute. Part-time faculty have lab space in the Beckman Institute and in their home departments. Affiliated faculty have no space in the Institute; this level serves as a stepping stone for a deeper involvement. About 21% of the full-time and part-time faculty have been there since inception; the turnover is about 15% every 3-4 years. The average duration of faculty participation is less then six years. New faculty are being recruited through collaborations with current faculty. Key benefits of the Institute for its members are co-location with collaborators from other disciplines, high-quality office and lab space, the centralized research facilities, and the research and business support staff.

In the first five years, there was little coherence in research activities. In the mid 90s, there was a shift towards strategic planning and identifying research themes that build on the strength of the institution. Research themes are now selected through a rigorous planning process. There are currently three themes: Biological Intelligence, Human-Computer Intelligent Interactions, and Molecular & Electronic Nanostructures. Every 3-4 years, research initiatives are being reviewed by external reviewers. Continued participation of faculty is based on scholarship, measured, for instance, by numbers of joint papers, joint proposals, participation in activities, and the degree to which faculty contribute to the mission of the Institute, including fostering interdisciplinary research.

The Beckman Institute plays an important part in attracting new faculty to the University of Illinois, including help with start-up cost and space. However, it does not conduct searches. The Beckman Institute is not involved in tenure or promotion decisions. Junior faculty are generally not full members, and graduate students receive their degrees from their home departments.

Dr. Wiltzius pointed out advantages of a brick and mortar institute versus a virtual institute, namely the tremendous value of people from different disciplines working together on problems that require teams of researchers from different disciplines. This is the model industry has used for a long time. The research facilities in the Beckman Institute are of very high quality, which is an added attraction to faculty. In addition, the Beckman Institute has funding through donations from the Beckman family to seed new research (with the expectation that extramural funding will be sought), provide fellowships for graduate students and postdocs, and supplement sabbatical visits.

Most of the funding for the Institute comes from extramural research grants that support the approximately 500 graduate students, postdocs and visitors. The largest fraction of funding comes from the NIH, followed by NSF, with some funding from the DOD, DOE, and NASA, and industrial support. The 60-70 staff members are mostly supported on the state budget, which is about 5% of the operating cost.

Other Universities (in no particular order)

Universities around the country have invested in interdisciplinary facilities to bring together scientists and engineers. Some of these are well-established, others are under development. We list a few examples of forward-looking, exciting initiatives.

Cornell University (http://lifesciences.cornell.edu/about/initiative.php)

Cornell University has committed $600 million over several years for life sciences research, education and discovery. This initiative includes 120 new faculty "who are skilled in working across academic boundaries," a new Life Sciences Technology Building (240,000 square-foot facility), renovation of existing buildings, the Physical Sciences Project "to offer space, tools and resources to enable vital collaborations among physical scientists, engineers, computer scientists, and biologists," and the creation of the Cornell Institute of Molecular and Cell Biology.

University of Wisconsin (http://www.news.wisc.edu/10446.html and http://www.uwec.edu/newsbureau/bulletin/2004-05/03-14-05/discovery.pdf)

The state of Wisconsin will invest up to $750 million, including more than $500 million in new facilities and research support for researchers at the University of Wisconsin-Madison. This includes the Wisconsin Institute for Discovery, an interdisciplinary research facility of about 450,000 square feet of space that includes space for technology transfer and incubator space and educational space.

Stanford University (http://biox.stanford.edu/)

"The Stanford University Bio-X program supports, organizes, and facilitates interdisciplinary research connected to biology and medicine. Ideas and methods embodied in engineering, computer science, physics, chemistry, and other fields are being brought to bear upon important challenges in bioscience. In turn, bioscience creates new opportunities in other fields. Significant discoveries and creative inventions are accelerated through formation of new collaborative teams." (Source: http://biox.stanford.edu/about/index.html) This effort was facilitated by a new building, the James H. Clark Center, that was completed in 2003 and houses interdisciplinary research space.

University of California-Berkeley (http://ls.berkeley.edu/new/03/stanley/)

UCB is completing a new facility with about 40 laboratories as part of the California Institute of Quantitative Biomedical Research, a collaborative effort among UCB, UCSF, and UCSC. "The mission of the institute is to better understand important biological and medical problems using quantitative methods such as physics, mathematics, chemistry, and engineering."

University of Michigan (http://www.lifesciences.umich.edu/lsinstitute/index.html)

The University of Michigan created the Life Sciences Institute that brings together faculty from the basic biological sciences and the Medical School to gain "profound insights into the complexity of life that lies between the genome and the organism." The institute's themes are focused on three areas: (1) Genetics, Genomics, and Proteomics, (2) Structural, Chemical, and Computational Biology, and (3) Molecular and Cellular Biology. In 1999, began building a $100 million, 230,000 square-foot wet lab facility for this institute to house about 30 faculty and their students, postdocs, etc.

UCLA and UCSB (http://www.cnsi.ucla.edu/ and http://www.cnsi.ucsb.edu/)

UCLA and UCSB's California Nanosystems Institute is a joint venture that was a result of the $100 million challenge grant from the State of California. Faculty who participate in this institute are drawn from the life and physical sciences, engineering, and medicine from both campuses. About half of the 188,000 square-foot building on the UCLA campus will be devoted to lab space. On the UCSB campus, a 110,000 square-foot building will provide about 62,000 square feet of interdisciplinary modular research laboratories. Both buildings will be completed in mid 2006. CNSI-UCSB was recently awarded a $5 million, 5-year NSF grant to support the Center for Nanotechnology in Society.

Columbia University (http://www.columbia.edu/cu/news/06/03/science_center.html)

Columbia University announced on March 20, 2006 a plan to establish The Jerome L. Greene Science Center. According to a letter by Columbia University President Lee C. Bollinger to the Columbia community, "the Center will be among the world's most advanced facilities specializing in the study of the brain and will house the new Columbia Mind, Brain, and Behavior Initiative. The creation of the Center is made possible by a donation of more than $200 million from Dawn M. Greene and the Jerome L. Greene Foundation in honor of her late husband Jerry Greene (CC '26, Law '28)." Furthermore, "[t]he Center will include laboratories in which Columbia scientists will explore the causal relationship between gene function, brain wiring and behavior. […] The Center will establish an educational outreach facility and clinical programs with a focus on childhood developmental disorders and diseases of the aging brain. Through exploration of the brain's organization and function, the Center will aim to clarify the workings of the mind – the mental processes that permit us to perceive, act, learn and remember, and that govern the individuality of human action.”

Biopolis, Singapore (http://www.one-north.com/pages/lifeXchange/bio_intro.asp)

Biopolis is a center for biomedical sciences, located near the National University of Singapore, National University Hospital, and the Singapore Science Parks. Biopolis Phase 1 was completed in 2004 and is a 185 sqm biomedical complex of seven buildings, including the Bioinformatics Institute, the Bioprocessing Technology Institute, the Genome Institute of Singapore, the Institute of Bioengineering and Nanotechnology, and the Institute of Molecular and Cell Biology.

Appendix I

Case Studies: University of California, Los Angeles and The Ohio State University

University of California, Los Angeles (UCLA)

The growth in R&D expenditures of UCLA far exceeded that of the University of Minnesota in the past few years (Figure 1). We asked the Vice Chancellor for Research at UCLA, Roberto Peccei, what crucial factors led to such growth at UCLA.

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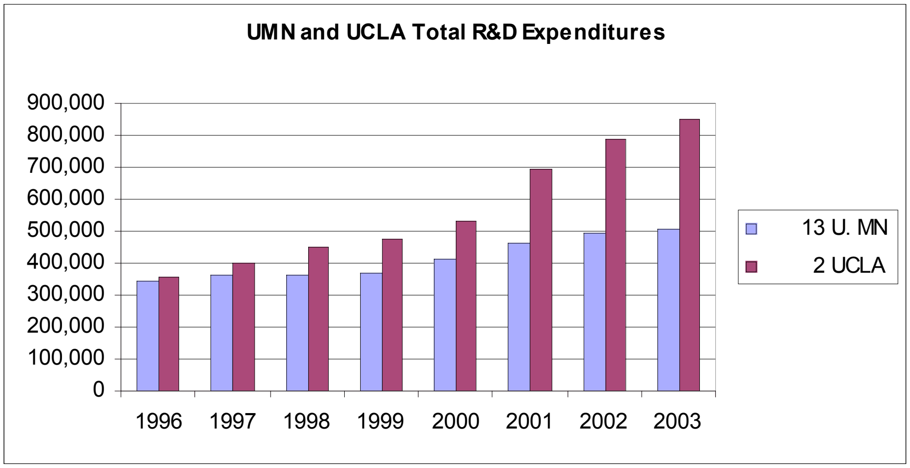


Figure 1: University of Minnesota and UCLA R&D Expenditures between 1996 and 2003.

A change in the academic leadership positioned UCLA to respond effectively to a major challenge by the State of California in 2000, namely to create a California Institute of Science and Innovation. The University of California was asked to propose an institute to match $100M in state funding that came from a state budget surplus with $200M from other sources. This large challenge galvanized the research community of UCLA. Jointly with UC Santa Barbara, UCLA developed a proposal for the California NanoSystems Institute (http://www.cnsi.ucla.edu/) that ultimately won this competition. To raise the $200M in matching funds, the university needed to change its culture to one where collaborations among units prevail. No single unit by itself would have been able to meet this challenge. A theme was sought that allowed the mobilization of a large group of faculty to meet the match through securing new extramurally funded center grants and collaborations with industry.

Engineering in particular played an important role in this change in culture. Moving from a largely insular to a collaborative culture, facilitated by seed money from the Office of Research and college leadership that was receptive to multidisciplinary research, groups of faculty across engineering, the physical, and the biological sciences began to collaborate and compete successfully for National Centers in Engineering. Here are a few examples of centers that sprung up from these new collaborations (more centers can be found at http://www.engineer.ucla.edu/research/centers.html). The Center for Embedded Network Sensing, one of six National Science Foundation Science and Technology Centers established in 2002, is interdisciplinary and multi-institutional and is projected to receive $40 million in core funding from the NSF over the next ten years. The Center on Functional Engineered Nano Architectonics is funded by industry and the federal government and is a multi-institutional and interdisciplinary center. The Institute for Cell Mimetic Space Exploration at UCLA was awarded a $2 million grant from NASA in 2003 to develop an automated, chip-based metabolic analysis tool. The Biomedical Informatics Center plans to develop new approaches to collecting and managing medical data. It is a joint venture between the Henry Samueli School of Engineering and Applied Sciences and the David Geffen School of Medicine.

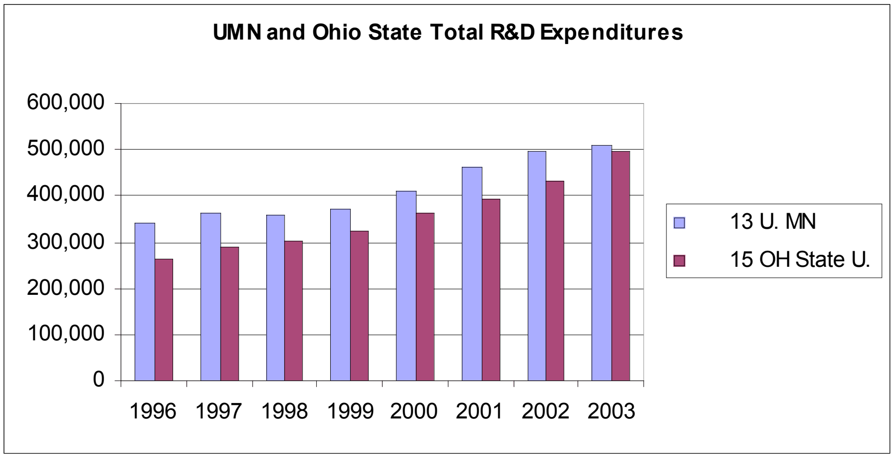
Another important factor, independent of the $100M challenge of the state, was the ability of UCLA’s life science faculty to take advantage of the doubling of the NIH budget: total research expenditures during 1998-2005 increased by 90%. Increases in some of the parts of the Medical Sciences were even more impressive: the basic science departments in the School of Medicine increased their awards by over 200%.The Neuropsychiatric Institute increased its awards by 130% between 1998 and 2005; this steep increase was partially facilitated by fostering more collaborations.

The Vice Chancellor of Research acts horizontally at UCLA to balance the vertical silo structures of departments and schools. This office has become the agent of change in the research landscape while maintaining its regulatory functions.

Funding at all levels is now much tighter than it was during the first few years of the 21st century. But UCLA continues to look at new opportunities for interdisciplinary research. An example is the social inequities initiative where administrators and faculty convene workshops and seminars to build a research community.

It was not restructuring or hiring of star faculty that propelled UCLA into the top tier research universities. It took commitment from administrative leadership to facilitate collaborations. It took initiative from faculty to respond to new opportunities by putting together competitive proposals for large centers. It took initiative from administrators and faculty to respond to federal funding trends. But above all, it was the institutional change in people to collaborate that caused this transformation.

The Ohio State University



The Ohio State University has made significant progress over the past ten years and almost closed the gap in research funding to the University of Minnesota. We asked Dean Thomas Rosol what crucial factors led to such growth at The Ohio State University (OSU). Dean Rosol was Interim Vice President of Research between 2003 and 2004 and served as Senior Associate Vice President for Research in 2002-03 and 2004-05. He is now Dean of the College of Veterinary Medicine at OSU.

OSU only supports excellence now according to Dean Rosol. This change is affecting every part of the university and has been critical to the success of OSU in recent years.

Admission of undergraduate students at OSU changed from an open admission process to selective admission. This increased ACT scores from the high teens to the mid twenties and resulted in a much higher quality undergraduate population. OSU pays a lot of attention to the quality of life of their freshmen, for instance, by offering small seminars, making OSU feel like a much smaller and friendlier place to incoming students. A special program, the First Year Experience[22], offers a large number of events designed to help students to make the transition to college.

OSU became much more research oriented. OSU used to focus primarily on the clinical sciences and teaching. This increased emphasis on research was accompanied by focus on excellence. Instead of broadly funding all activities, only the best programs receive funding. This requires leadership and the ability to make hard decisions by high-level administrators. There is a shift towards providing support to programs instead of simply departments, which encourages interactions among departments and provides ways to fund specific research areas. The academic climate at OSU has also become much more competitive. For instance, a seed fund program by

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[22] http://fye.osu.edu/

the Office of Research had to be matched by research grants within a certain period and if the faculty failed to generate the match through grants, the college had to pay back the seed grant.

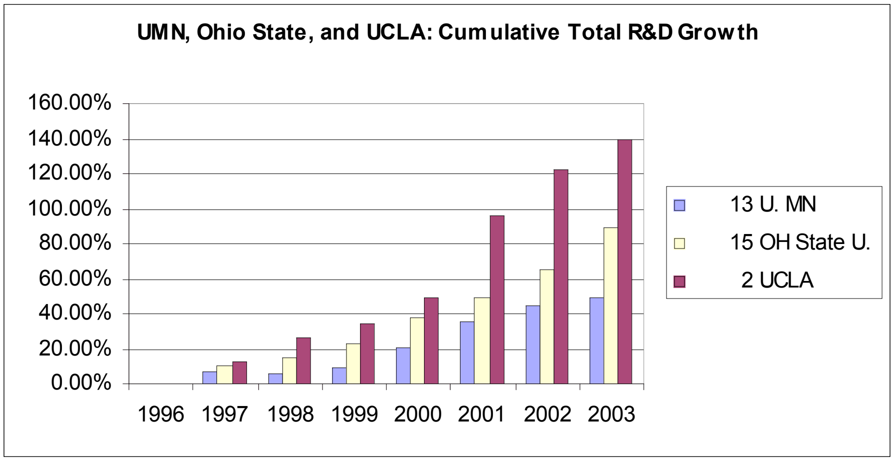
There were structural changes as well. For instance, a large fraction of the indirect cost is now returned to colleges, providing incentives for colleges to engage in extramurally funded research. There are now more joint appointments. Graduate education has not undergone significant changes, but this might change and focus on excellence might become the guiding principle as well. Changes might extend to funding of graduate students as well. Currently, all colleges compete for a fixed pool of resources to fund graduate education. The share a college gets depends on the number of graduate students. Since the number of graduate students a college can admit is unrestricted, there is an incentive to admit more graduate students. But since the resource pool is fixed, this leads to funding short comings.

Administrative leadership plays an important role in achieving excellence. Deans of the different colleges work well together and promote collaborations among colleges. The provost promotes excellence by funding successful programs. But ultimately, it is the faculty that makes a university a great university. The traditionally interactive culture at OSU has facilitated interactions that now result in more success in funding.

Faculty and the administration at OSU follow research trends closely. OSU took advantage of the doubling of the NIH budget. With the promise of increased funding for the physical sciences and engineering over the next ten years, OSU will promote interactions between the physical sciences and engineering and the medical sciences.

A Comparison

The following graph shows the cumulative percentage growth of total R&D funding at UMN, Ohio State, and UCLA since 1996. Both UCLA and Ohio State have clearly outpaced us during this period.



OSU's shift towards excellence and the challenge grant to UCLA catalyzed the faculty at either institution. Research funding is just one measure. In other appendices, we provide additional comparisons that also illustrate the success of these two universities.

Appendix J

Research

Intercollegiate Research Areas for Recommendation #2

1) Materials

Innovative materials constitute one of the principal enabling engines of modern technological development, with applications in electronic devices, biomedical equipment, biocompatible composites, alternative energy, transportation, environmental engineering, and many other areas of commerce.

The University of Minnesota can strongly compete in this arena. IT, CBS, and the Medical School are poised to collaborate in the coordination of joint material research initiatives, reinforced by close physical proximity, a biomedical engineering department and institute, and an extensive set of biomedical device companies in the Twin Cities. Other competitive industries in the State of Minnesota that rely heavily on materials science and engineering include 3M, with a broad spectrum of consumer and business products, IBM and Seagate who rely on innovations in microelectronics, and Cargill, a company that has expanded into renewable plastics such as poly(lactic acid). Numerous smaller companies and emerging technologies are reliant on materials innovations as well.

Nationally and internationally materials play a crucial role in the economy. This field is amongst the youngest in science and engineering, emerging as a new discipline in the 1960's leading to directorates in major funding agencies such as the National Science Foundation and the Department of Energy in the following decades. Advances in synthesis, characterization and processing techniques have driven materials design down to the nanometer (one-billionth of a meter) length scale resulting in an explosion of innovation often referred to as nanotechnology. Continued progress in this exciting area requires the integration of many core disciplines. For example, evolution of high-capacity magnetic memory (presently standard equipment on personal computers) was catalyzed by fundamental discoveries in several disciplines. Growth of thin films of complex magnetic alloys (materials science) required characterization by new magnetic microscopes (physics). Data transfer was limited by the ability to float a reading head just 10 nanometers above a magnetic disk that spins at many thousands of revolutions per minute. New lubricating materials (chemistry) and coating techniques (chemical engineering) were required to make feasible such staggering engineering feats. Integrating these pieces of hardware requires complex circuitry (electrical engineering) and maximum data transfer rates a governed by software development (computer science). This level of interdisciplinary cooperation is typical of modern materials science and engineering.

Another challenging research area critically dependent on materials is photovoltaic devices (see section on Energy, below). Converting sunlight directly to electricity represents the ultimate solution to the global energy crisis. The underlying phenomena associated with this technology are well understood: a photon is absorbed by a semiconductor generating a free electron and a hole, which can be separated and recombined after delivering work through an electrical circuit. However, due to various inefficiencies such as electron-hole recombination, commercial photovoltaic devices operate at just 10% efficiency, too low to offset capital investment and productions costs. Many innovative ideas have been proposed to overcome this limitation. All involve the manipulation of inorganic and organic materials at microscopic length scales. New light absorbing dyes (e.g., complex organic molecules or quantum dots) must be designed and synthesized by chemists, then coupled to electron and hole conductors typically created by materials scientists or physicists. In order to deliver adequate current at desired efficiencies these electrodes must be configured to have high surface areas, fabricated using nanotechnology generally available at centralized facilities. The basic photovoltaic device must be contained in an environmentally compatible package, likely constructed from plastics, and made compatible with a power system prepared by electrical engineers. Finally, solar cells only operate when the sun shines. Therefore, a fully engineered unit must be capable of storing the power generated in batteries or in the form of chemical energy such as hydrogen. These storage systems also represent fertile topics for advanced research.

IT maintains competitive programs in chemistry and physics with accomplished faculty in the synthesis and characterization of organic and inorganic materials. All the engineering programs are active in some form of materials research and both undergraduate and graduate degrees in Materials Science and Engineering are offered. One measure of the competitiveness of IT in this area is the success of the Materials Research Science and Engineering Center (MRSEC)[23] in addition to multi-user facilities: the IT characterization facility and an interdisciplinary microfabrication center should serve as models for future intercollegiate initiatives. An NSF IGERT graduate training grant for Nanoparticle Science and Engineering provides graduate student funding that has enabled a number of faculty collaborations[24].

Significant materials opportunities can be identified beyond IT. Medical sciences have traditionally relied heavily on advanced materials, ranging from prosthetic devices to artificial scaffolding for tissue engineering, implantable and biodegradable plastics, devices such as pacemakers, and balloon catheters and drug eluting stents. In recent years, biomolecules and nanostructures have extended the engineering of medical devices to the nanoscale. Nanotubes and nanowires functionalized with chemical or biological molecules are now used as probes or sensors. Nanoscale materials and devices are being developed, for instance, for drug delivery, for removal of toxins from the blood stream, and for tissue engineering. Biomimetic nanotechnology seeks to mimic nature's way of fabricating new materials that goes beyond applications in the

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[23] Chosen as one of approximately 120 competing institutions in 1998, the MRSEC was renewed in 2002 for an additional six years at a funding level of nearly $3M annually. This center draws faculty from six IT departments with a focus on polymers, magnetic materials, and organic semiconductors.

[24] The University of Minnesota has been quite successful in competing for grants through the NSF Nanoscale Interdisciplinary Research Teams (NIRT) competition with eight active grants. For comparison, the University of Illinois is listed with 6, Texas, Wisconsin, UCB, and UCLA each with 5, Michigan with 3, Ohio State with 2, and Iowa with 1.

medical sciences[25]. Advances in these fields require close collaborations among biologists and engineers. Researchers at other institutions collaborate, for instance, on the development of heat sensitive materials that expand in response to heat similar to materials in heat-sensing organs of the beetle *Melanophila acuminate* that can detect forest fires some 80km away.

Perhaps the greatest opportunities will be found through intercollegiate collaborations: engineers working with surgeons or genetic biologists creating new bacteria that produce polymers with specific surface and structural properties. Materials are ubiquitous; they literally form the fabric of our economy. The University of Minnesota is poised to become a national leader across many aspects of this intrinsically interdisciplinary endeavor.

2) Energy

Perhaps no other technical challenge, other than human health, carries the significance of identifying renewable sources of energy. The U.S. energy demands are projected to increase by 35% between 2003 and 2025, which far exceeds the projected increase in domestic production[26], thus increasing the dependence on foreign sources for our energy even further unless we identify alternative sources of energy. With global energy demands continuing to rise rapidly and the primary energy source coming from fossil fuels, the emission of carbon dioxide, a greenhouse gas, will continue to increase and contribute to global climate change. U.S. energy policy seeks to both increase domestic energy supply and to broaden the range of energy sources to decrease the dependence on foreign sources of energy and to abate the emission of carbon dioxide.

Although the ultimate solution – the sun - is indisputable, finding economically viable means of converting photons into electricity, heat, or chemicals, is a daunting task. Many attractive possibilities have been identified and all require research and development across numerous academic enterprises.

Direct conversion of visible light to electricity can be realized with photovoltaic devices. While the physics of producing and separating charges in conventional semiconductors such as silicon are well understood, the manufacturing costs of such photovoltaic cells are prohibitively high. A plethora of innovative alternative designs have been proposed in recent years, most involving nanoscale patterning and hybrid combinations of inorganic and organic materials. Semiconducting plastics offer the possibility of low cost and the feasibility of large-scale manufacturing. Any successful technology will require extensive materials integration that draws from physical science and engineering across numerous disciplines.

Bioenergy is a promising source of renewable energy and a recent report by the Natural Resources Defense Council[27] concluded that by 2050, an amount equal to half of the oil that is

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[25] See the Special Section of the November 18, 2005 issue of *Science*.
[26] Annual Energy Outlook 2005 with Projections to 2025, DOE/EIA-0383. 2005. Energy Information Administration, U.S. Department of Energy (www.eia.doe.gov/oiaf/aeo).
[27] NRDC (National Resources Defense Council). 2004. Growing Energy. How Biofuels Could Help End America's Dependence on Oil. The Natural Resources Defense Council, Washington, DC.

currently used for transportation could be replaced by biofuels. While it is too early to say which biofuels will ultimately replace fossil fuels, there are a number of promising candidates, for instance, ethanol, biodiesel, and hydrogen. Their cost-effective production will likely require genetic engineering of plants and microbes. To increase yield of plant biomass that can be converted into ethanol, plants might be genetically engineered for increased yield. Similarly, microbes might be genetically engineered to produce hydrogen or hydrocarbons cost-effectively. A current route to ethanol is the conversion of food starch to ethanol. The energy yield for ethanol from cornstarch, however, is low (14%). The energy yield from cellulose[28] is expected to be much higher (>37%) but requires improved enzymatic conversion of cellulose into sugar and subsequent fermentation of sugar to ethanol by microbes. The Department of Energy (DOE) has begun screening microbes and fungi for enzymes to improve the conversion of cellulose into sugars.

Many other new approaches that contribute to solving the world's energy needs can be identified: Fuel cells to burn hydrogen generated from ethanol acquired from biomass; energy storage devices for use with wind turbines; superconducting materials for loss free transmission of electricity, and much more.

These and other possibilities all require research and development across numerous academic disciplines. In 2003, the Minnesota legislature directed funds towards the newly formed Initiative for Renewable Energy and the Environment (IREE), which has provided leadership to coordinate and facilitate research at the University of Minnesota in the area of energy and products from renewable resources. To date, nearly $17 million have been allocated to research projects, which have supported over 225 faculty, research scientists, and students. President Bruininks elevated research on renewable energy to a top priority through his initiative on the environment and renewable energy (PIERE). A proposal for a National Center for Biofuels Research (NCBR) at the University of Minnesota was made in 2000 and this center is listed in the 6-year Capital Plan under "Federal Funding." This plan has also been endorsed by Governor Pawlenty. Federal support for energy research is strong with nearly $10 billion already having been invested by the federal government in initiatives such as the Biofuels Initiative[29] and the President's Hydrogen Initiative[30]. Other states are not standing still and have taken major steps in this direction[31]. With continued support for energy research and a plan to establish a National Center for Biofuels Research, the University of Minnesota is poised to participate in this massive undertaking.

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[28] Cellulose is a structural component of plant cell walls.

[29] http://www.whitehouse.gov/infocus/budget/2007/states/ia.html

[30] http://www.whitehouse.gov/news/releases/2003/01/20030128-19.html

[31] Governor Jennifer Granholm of Michigan announced in January 2006 a $2 billion initiative to develop new sectors of the economy, including life sciences and alternative energy. In her words, Michigan "will be the alternative energy epicenter of America." A recent $2.5 million DOE grant to Wayne State University (Detroit, Michigan) has already made a National Biofuels Energy Lab (the first-of-its kind biofuel technology development lab) a reality for Michigan.

3) Environmental Genomics[32]

The study of gene-environment relationships extends from the single gene locus level in a single organism to complex genetic networks within communities of organisms. This broad theme combines the traditional disciplines of chemistry, toxicology, neuroscience, microbiology, ecology, biochemistry, cancer biology, engineering, genetics and epidemiology to the evaluation and assessment of how the natural and engineered environment affect genetic and epigenetic processes. Recent research initiatives sponsored by the National Institutes of Health[33], the National Science Foundation[34] and the Department of Energy[35] all emphasize a systems biology approach to the analysis of complex genetic and epigenetic phenomena linking the environment to humans, plants and microbes. As such, environmental genomics (and the requisite technologies and computational infrastructure needed to evaluate and assess the data) link broad aspects of biological and engineering sciences.

Systems biology emphasizes the need for multidimensional bioanalytical methods to profile complex biological processes. Because of the extraordinarily large data sets (thousands of genes, tens of thousands of proteins and small molecules), high performance computational technologies and corresponding queryable databases are absolutely necessary for evaluation of experimental design and results. Independent of biological context, studies of environmental genomics coordinately measure the functions of cells, tissues, and organisms using genomic, proteomic and metabolomics approaches in response to environmental factors in single organisms or within complex populations. Existing University investments in biomedical, microbial, and plant genomics as well as mass spectrometry and proteomics will need to be paralleled with the development of high-throughput bioanalytical technologies for small molecule analysis to provide systems capabilities to University researchers.

With regard to environmental genomics and human health the three key research components are gene discovery, gene function and diseases susceptibility and risk. The University of Minnesota has research strength and technological capabilities to become world leaders in this area. The AHC supported Biomedical Genomics Center coupled with the University wide Center for Mass Spectrometry and Proteomics affords investigators an opportunity to assess genome-wide association studies for environmentally induced diseases and the impact of environmental exposures on disease progression. Besides acknowledged effects of environmental factors on metabolic disease, future work will extend to neurological and behavioral processes. In this regard, it is critical to utilize large-scale longitudinal cohort studies for environmental exposure analysis and to focus on outcomes and prognostic factors. The research capabilities of School of Public Health will play a key role in this area and a multidisciplinary evaluation of molecular, cellular and systems results will involve large teams of investigators. Development of teams of investigators will provide training opportunities for students and postdoctoral scholars and new avenues to obtain dynamic and integrative training grants.

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[32] Genomics is understood in the broad sense, including proteomics and metabolomics.
[33] National Institute of Environmental Health Sciences (NIEHS) workshop on June 28-29, 2005
[34] www.nsf.gov/about/budget/fy2007/pdf/4-ResearchandRelatedActivities/1-BiologicalSciences/20-FY2007.pdf
[35] DOE Genomics:GTL, Systems Biology for Energy and the Environment

Environmental genomics will play an ever-increasing role in plant biological systems. The impact of the environment on cultivatable plants for human and animal consumption will become commonplace and the demand for federal and regulatory oversight in how environmental factors affect food production is ever increasing. Additionally, while environmental genomics has been considered within the context of xenobiotics, pesticides, and herbicides, microbe-plant interactions can now be addressed at the molecular, cellular and organismal levels. As genetically modified crops and microbes become more commonplace in the environment, a systems approach to gene network interactions will expand. The University should position itself to become leaders in this field that broadly encompasses agriculture, ecology and natural resources. As with medically related contexts, plant systems biology as a training site for students allows for broadly-based education and integration with computational biologists.

To optimally use microbial capabilities for the development of bioenergy and biomaterial applications, scientists must first learn how microbes operate. Moreover, our understanding of the environment effects on microbial growth, dynamics, genetic processes and community function at the systems level must also be expanded. This understanding, however, has been limited by our inability to grow the vast majority of these organisms outside of the restricted laboratory environment. Organisms that live in complex soil and water environments of low pH, low temperature or high pressures provide roadmaps on how to engineer of microbes in various environments. As such, the tools of genomics, proteomics and metabolomics will need to be applied to entire microbial communities in their natural environments. Moreover, computational efforts will need to be energized to analyze such populations at all levels. For example, genomics studies that isolate and analyze genome dynamics directly from the environment--be it a gram of soil, or a liter of water from the open sea, or a scraping from a biofilm at the bottom of a highly contaminated mine all represent opportunities to explore biological diversity at the molecular and cellular level[35,36,37]. Such systems analyses have revealed a broad spectrum of genomes, genes, and thus previously undiscovered functions present in these regions. Eventually, these studies will result in a multitude of new insights into the dynamics between these critical ecosystem players and their environments.

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[36] *Nature* **428**, 37-43 (March 4, 2004,).

[37] *Sciencexpress* (March 4, 2004)

Computational Biology

The synergy between the physical sciences and mathematics has resulted in a deep understanding of physical processes that made the physical sciences into a predictive science. Predictability of physical processes is a prerequisite for physical science-based engineering disciplines. A similar synergy between the biological sciences and the computational sciences is needed to understand fundamental biological processes and biological complexity, and to transform biology into a quantitative science, a prerequisite for applying engineering approaches to biology.

Computation in biology will likely play a different role than mathematics has played in physics. Whereas fundamental equations, such as Maxwell's equations in electrodynamics or Schrödinger's equation in quantum physics, are the mainstay of physics, we cannot expect to summarize biology in similarly fundamental equations due to the intrinsic complexity of biology. The need for a robust interface between computation and biology was recently emphasized[38]: "The exponentially increasing amounts of biological data at all scales of biological organization, along with comparable advances in computing power, create the potential for scientists to construct quantitative, predictive models of biological systems. Broad success would transform basic biology, medicine, agriculture, and environmental science. The main push in biology during the coming decades will be toward an increasingly quantitative understanding of biological function; the rate at which progress occurs will depend on a deeper, effective implementation of quantitative methods and a quantitative perspective within the biological sciences."

The following diagram explains the role computation plays in biological research[39]. This diagram was originally developed to explain the iterative process of discovery in systems biology[40], but is applicable to all of modern biology. It emphasizes that the development of a theoretical framework relies on the iterative approach of integrating data and observations into models that in turn inform experiments.

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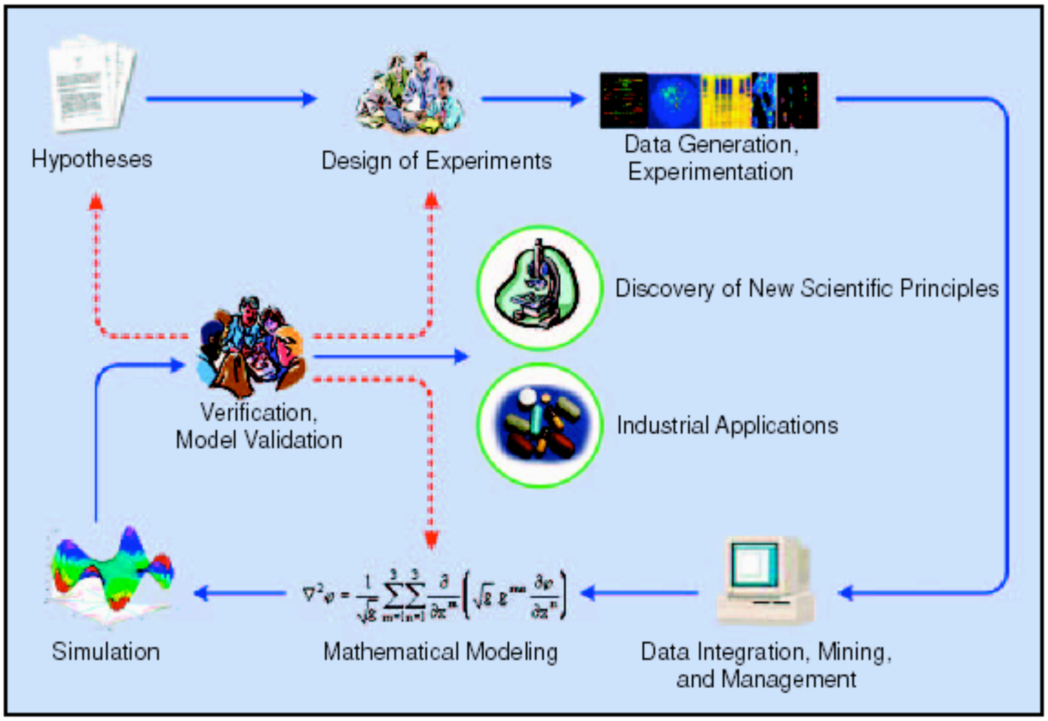
[38] For a comprehensive view of the role of mathematics in biology, see *Mathematics and 21st Century Biology*. National Academy of Sciences. 2005. (http://www.nap.edu/catalog/11315.html)

[39] Wolkenhauer, O., B.K. Gosh, and K.-H. Cho. 2004. Control and Coordination in biochemical networks. IEEE Control Systems Magazine, 30-34.

[40] Systems biology is a way to study "biological systems by systematically perturbing them (biologically, genetically, or chemically); monitoring the gene, protein, and informational pathway responses; integrating these data; and ultimately formulating mathematical models that describe the structure of the system, and its responses to individual perturbations." (Ideker, T., T. Galistiki, and L. Hood. 2001. A new approach to decoding life: Systems biology. *Annual Review in Genomics and Human Genetics* 2:343-372.)



Synergy between biology and computation will strongly depend on our ability to integrate data into theoretical frameworks and to develop this iterative process between models and experiments. This will require close collaboration between theoretical and empirical scientists in IT, CBS, the AHC, and other colleges at the University.

Major advances in biology in the past 10-15 years were enabled by the availability of large data sets, from genomic data to global ecology data. This was made possible through the development of new tools and instrumentation, in particular at the two extremes of spatial scales, the molecular level and the global scale. Examples include automation of DNA sequencing, the development of microarrays, new imaging tools at the subcellular level, and high-resolution satellites. New technologies to probe biological processes will continue to be developed and increase the rate at which data can be gathered. Infrastructure for high-throughput biology will be as essential as infrastructure for high-performance computing. To utilize the information contained in these data sets, algorithms to mine the data, statistical tools to interpret the data, and quantitative models to test and refine our understanding of biological processes will need to be developed. High performance computing to process the information will become a standard tool.

Here are some examples where integration of large data sets and models will give new insights into biological processes:

- Systems biology[41]: integration of genomics, proteomics, and metabolomics to gain a system-level understanding of biological processes
- Mechanisms of evolution: integration of molecular data to understand the evolution of biological function across species
- Microbial diversity: integration of molecular data to assess microbial diversity, including evolutionary relationships, their metabolic capacity, and their role in ecosystem processes
- Global Change: integration of data of physical and biological processes from the local to the global scale to help understand the ecological consequences of petroleum versus biobased energy sources
- Biological Diversity: integration of molecular and morphological data to understand species relationships, in particular at the microbial level

The University of Minnesota is lagging behind in the area of computational biology. While other universities aggressively pursue this area, we have only managed to create a minor in bioinformatics and a Consortium of Bioinformatics and Computational Biology (CBCB) that was announced more than a year ago. The initial planning document by the former dean of IT, Ted Davis, and Associate Vice President and CIO (Information Technology) Steve Cowley states the rationale for CBCB[42]:

“Optimal progress in life sciences research will not be possible without computational biology/informatics expertise. Therefore, the university’s substantial investments in molecular and cellular biology and in genomics and proteomics will not be fully realized without comparable enhancement of our computational biology/bioinformatics abilities. Although units of the university have invested in hardware and software to support this research, we have not yet adequately developed the academic expertise in computational biology/bioinformatics appropriate for our institution. Indeed, on two occasions in the past two years the University of Minnesota has been unable to even assemble a competitive application to become one of several national centers for bioinformatics funded by the NIH because of insufficient expertise and leadership recognition in bioinformatics. We have several faculty members who are renowned for their individual work, but no visionary computational biologists who can lead a University-wide program. In no other area related to life sciences research are we so obviously deficient.

”There are activities in bioinformatics and computational biology already going on in many colleges of the University. However, they are not fully effective, because there is duplication of effort, lack of coordinating leadership, lack of well-planned service facilities, and some weaknesses in strategic areas (in particular, theoretical biology). We propose that the CBCB become the focus of the University’s data handling and computational services for bioinformatics and computational biology, as well as provide leadership in theoretical biology and the computational science of biology.”

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[41] Aggarwal, K. and K.H. Lee. 2003. Functional genomics and proteomics as a foundation for systems biology. Briefings in Functional Genomics and Proteomics, 2: 175-184.

[42] http://www.cbcb.umn.edu/planning.html

After more than a year, CBCB is still in its planning stages, while other universities already have centers and institutes dedicated to this important topic.

Initiatives at Other Universities

University of Michigan (http://www.bioinformatics.med.umich.edu/)
A Bioinformatics Program was established in 1998 and the graduate program began admitting students in 2001. The graduate program currently has 36 students and 73 faculty. This is a highly interdisciplinary program that draws faculty from Electrical Engineering and Computer Science, Biomedical Engineering and Chemical Engineering, School of Public Health, School of Information, Center for Study of Complex Systems, Department of Mathematics, Department of Human Genetics, Microbiology and Immunology, Medicine, Pathology, Biological Chemistry, and Psychiatry. In September 2005, the University of Michigan competed successfully for a $18.7 million NIH grant to create a National Center for Integrative Biomedical Informatics.

University of California QB3 (http://www.qb3.org/index.html)
The California Institute for Quantitative Biomedical Research (QB3) is a cooperative among UCB, UCSF, and UCSC to “harnesses the quantitative sciences to integrate our understanding of biological systems at all levels of complexity - from atoms and protein molecules to cells, tissues, organs and the entire organism.” More than 140 scientists across biology, engineering, and the physical and medical sciences participate.

Massachusetts Institute of Technology (MIT) (http://csbi.mit.edu/)
A campus-wide Computational and Systems Biology Initiative (CSBi) links about 80 faculty from over ten different units across the School of Science and Engineering, the Sloan School of Management, and the Whitehead Institute for Biomedical Research. The MIT Center of Excellence in Cell Decision Processes (CDP) is part of CSBi. This is an NIH funded center that was awarded in 2003 and provides $16 million for five years.

University of Wisconsin, Madison (http://www.bacter.wisc.edu/)
The Bringing Advanced Computational Techniques to Environmental Research (BACTER) Institute is funded by a 3-year, $3.67 million grant from the Department of Energy’s Genomics:GTL program. It is one of three DOE Institutes for the Advancement of Computational Biology Research and Education.

Appendix K

Faculty and Student Survey

The Task Force conducted an e-mail survey of faculty and students in CBS, CNR, COAFES, IT, and the Medical School. A total of 237 faculty (CBS 11%; CNR 5.5%; COAFES 16%; IT 34%; Medical School 39%; Other 1.7%) and 635 graduate students (CBS 8.6%; CNR 5%; COAFES 10%; IT 51%; Medical School 20%; Other 6.3%) responded. The purpose of this survey was to assess the role of interdisciplinary research, teaching, and training in the sciences and engineering, and to identify factors that impede collaborative research. An open-ended question to identify the most important factor that would allow the University of Minnesota to achieve excellence in research in the sciences, engineering, and health-related disciplines concluded the survey.

Faculty Survey

The following table shows the percentage of faculty who advised 0, 1, 2, 3, or more than 3 Ph.D. and M.S. graduate students:

	M.S. Students	Ph.D. Students
0	55%	31%
1	20%	18%
2	9.8%	11%
3	4.3%	14%
>3	11%	26%

When asked about their interest level in interdisciplinary activities, 44% responded Very High, 38% High, 16% Average, and 1.3% Low.

When asked to rank the importance of issues that impede collaborative research, 31.5% identified availability of funding as the most important factor and 21.8% as the second most important factor. Availability of institutional support was identified as the most important issue by 13.8% and as the second most important issue by 21.8%. Lack of time to develop new collaborations was identified as the most important issue by 25.7% and as the second most important issue by 21.6%. In the table below, we summarize the results. Note that the questionnaire did not allow ties. The most important issue was assigned the value 1, the least important the value 10. Availability of funding was clearly identified as the most important issues, followed by lack of time and tuition allocation (values are mean score and, in parentheses, standard deviation):

Availability of funding: 2.84 (2.04)
Lack of time to develop new collaborations: 3.20 (2.10)

Availability of institutional support to develop multi-investigator grants: 3.59 (1.98)
Indirect cost recovery allocation: 5.39 (2.40)
How much the department/college values interdisciplinary research: 5.78 (2.40)
Tuition allocation 6.20 (2.49)
Geographic distance between Minneapolis and St. Paul campuses: 6.28 (2.57)
Availability of high-quality colleagues: 6.32 (2.87)
Stage in tenure: 7.10 (2.71)
Family issues: 8.00 (2.37)

The two highest ranked issues were consistently identified as the two highest ranked issues in each of the surveyed colleges, except in CBS where lack of time to develop new collaborations and availability of institutional support to develop multi-investigator grants were the two highest ranked issues. Geographic distance between Minneapolis and St. Paul campuses was not regarded an important issue, even for CBS faculty (avg score 5.7) with shared departments on both campuses.

An open ended question asked respondents to identify the most important factor that would allow the University of Minnesota to achieve excellence in research in the sciences, engineering, and health-related disciplines. Across all colleges, the lack of availability of internal funding for research, in particular seed grants, and high cost of graduate students were identified most often. Both IT and Medical School faculty also identified the lack of means to meet researchers in other disciplines to initiate collaborations as a problem. Lack of competitive salaries was identified in IT as a problem. IT faculty frequently cited hiring and tenuring only highest-quality faculty as the most important factor to achieve excellence.

Student Survey

Among the 635 respondents, 30% were M.S. and 58% Ph.D. students. 8.6% of their advisors were in CBS, 4.9% in CNR, 10% in COAFES, 51% in IT, 20% in the Medical School, and 6.3% Other. 19% of the students are co-advised and 41% of the students are advised by faculty who also have graduate students in other programs. During Fall 05, most of the students were supported on research assistantships (36%); 17% of the students were supported on teaching assistantships, and 13% on fellowships.

When asked about their interest level in interdisciplinary activities, 29% responded Very High, 35% High, 27% Average, and 6% Low.

About 65% of the respondents are planning on a research career. For 45% of the respondents, the availability of interdisciplinary research support was an important factor to their coming to the University of Minnesota. 72% of the respondents indicated that the level of interdisciplinary activity at the University of Minnesota met their expectations.

Students were asked the same open-ended question as faculty. Better financial support for graduate students, recruitment and support of excellent faculty, more funding to attract the best researchers, recruit the best graduate students, support for infrastructure (facilities and equipment), and fostering interdisciplinary research were the most frequently mentioned. Better financial support for graduate students was by far the most frequently cited factor. Funding of graduate students has two aspects, competitive stipends and duration of support. Many students complained about insufficient funding for both stipends and research. Encouraging collaborations and fostering interdisciplinary research has many components. It includes interdisciplinary courses, avoidance of duplication in research, simply knowing what kind of research is pursued at the University of Minnesota, and opportunities for students and faculty to interact across disciplines. Specifically mentioned was bioinformatics/systems biology and collaborations between engineering and the AHC. Improving the reputation of the University through better PR, improving connections to industry, and better mentoring of students were mentioned as well.

Appendix L

Public Engagement

Public engagement in the sciences and engineering is of particular importance at a time when insufficient numbers of K-12 students are interested in careers in the sciences and engineering[43] and when citizens must be well-informed to participate effectively in public discussions on scientific issues of great national and international importance.

The University of Minnesota has had a long tradition of public engagement through, for example, the Extension Service, the Bell Museum, and K-12 partnerships. Numerous faculty initiatives and graduate and undergraduate involvement add to this. For effective public engagement, the University of Minnesota must continue to provide infrastructure and resources for faculty, students, and scientific staff to participate in these activities. The recent creation of an Office for Public Engagement must play the role of a One Stop for the University community to facilitate involvement in public engagement activities and for the public to tap into the vast sources of knowledge at the University.

Public engagement is defined[44] as "the partnership of university knowledge and resources with those of the public and private sectors to: 1) enrich scholarship, research, and creative activity; 2) enhance curriculum, teaching and learning; 3) prepare educated, engaged citizens; 4) strengthen democratic values and civic responsibility; 5) address critical societal issues; and 6) contribute to the public good."

Granting agencies, foremost the National Science Foundation, emphasize the importance of broader impact.

The Task Force met with Associate Vice President Vic Bloomfield (Office for Public Engagement). The following ideas on how to foster public engagement, in particular for the science and engineering disciplines, resulted from this discussion.

- Engagement of K-12: There is a need to reach, teach, and engage an increasingly diverse preK-12 population, in particular as the interest of U.S. students in science and engineering careers is low. Engagement should include both activities on campus and in local schools, including mentoring and research opportunities for grades 9-12.
- Engagement of the public: The need for informed citizens is greater than ever as citizens are increasingly asked to determine whether the benefits of new technologies, such as the use of genetically modified organisms, stem cell research, or nanotechnologies, outweigh their risks.

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[43] Science and Engineering Indicators 2006

[44] See http://www.academic2.umn.edu/about.html

- Engagement of the University community: Public engagement is by no means restricted to communities outside of the University. Science and engineering issues affect all citizens and the University needs to continue to engage faculty, staff, and students across the University.
- Means of engagement: With the increased use of the Internet[45], a university has the opportunity to reach out to the public and offer short tutorials and research highlights on a One Stop web page. As part of Broader Impact, faculty could contribute to this centrally administered web page and this web page could become the One Stop for information on scientific topics for citizens in Minnesota and could become a valuable resource for K-12 by providing up-to-date and accurate information on scientific issues. Multidisciplinary teaching with faculty outside of the sciences and engineering (for instance, law or political sciences) can bring scientific or engineering issues to a broader student population. Public lectures, talking with students in K-12 and on campus, writing for public audiences, talking with legislators and public officials, being accessible to local companies, or partnerships with the Science Museum are ways to engage the community at large in discussions of scientific issues.
- Engagement as public service: Departments should review their 7.12 statements to evaluate faculty participation in public engagement and to ensure that faculty are appropriately recognized for it in P&T and salary considerations.

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[45] 52% of respondent in a 2004 NSF survey named the Internet as the most important role when information is sought on specific scientific issues (Science and Engineering Indicators 2006)

Appendix M

Consultation Plan

Consultants within the University

- Deans of IT, CBS, Medical School, and COAFES
    - **October 21**: Dean Muscoplat (COAFES)
      October 21: Dean Crouch (IT)
    - **December 2**: Dean Elde (CBS)
      December 2: Dean Powell (Medical School)
- **January 18:** Dean Dubrow (Graduate School)
- **January 20**, Vice President for Research Mulcahy (Office of Research)
- **January 27:** Associate Vice President Bloomfield (Office for Public Engagement)
- **December 13:** CBS All College Meeting
- **December 13:** IT All College Meeting
- **January 6:** Medical School Advisory Committee
- **February 24:** Professors Karin Musier-Forsyth and Paul Iaizzo
- **February 28:** Professors Steve Ekker and Tim Ebner
- **April 4:**Minneapolis Town Hall Meeting
- **April 18:** Medical Basic Science Heads Meeting
- **April 21:** St. Paul Town Hall Meeting
- Faculty in IT, CBS, COAFES, CNR, Medical School (electronic surveys)
- Graduate Students in the sciences and engineering (electronic surveys)

Consultants from Institutes or Centers outside of the University of Minnesota

- **January 27:** Director of the Beckman Institute at the University of Illinois: Dr. Pierre Wiltzius (phone conference)
- **April 21:** Minnesota High Tech Association

Consultants from Other Universities

- **January 26:** Vice Chancellor for Research, Roberto Peccei, UCLA (phone)
- **March 17:** Dean of the College of Veterinary Medicine and former Interim Vice President of Research, Thomas Rosol, OSU (at OSU)

Consultants from Industry

- **March 2:** Douglas Cameron, Ph.D., Chief Scientist, BioTDC, Cargill, Incorporated, Minneapolis, MN (phone)