GRADUATE SCHOOL SELF-ANALYSIS

THE DEPARTMENT OF BIOENGINEERING

UNIVERSITY OF WASHINGTON
YONGMIN KIM, CHAIR

MANDATED INFORMATION

DEGREE PROGRAM TITLE

Bioengineering

YEAR OF LAST REVIEW

1991

DOCUMENTATION OF CONTINUING NEED

Changes in Our Field Over the Past Decade

The field of Bioengineering has grown significantly during the past ten years. This growth has been fueled by increased recognition of the value and need of Bioengineering, expanding Bioengineering frontiers and opportunities, and rapidly-developing industry. For example, the Washington Biotechnology and Biomedical Association (WBBA) counts 250 Bioengineering and Biotechnology firms in the State of Washington. In addition, the Whitaker Foundation has dedicated its generous support to the development of Bioengineering (Biomedical Engineering) as an established engineering discipline.

The Health Industry Manufacturers Association and Merrill Lynch estimated the worldwide medical device industry at $146 billion, and the U.S. at a level of $62.3 billion in 1999. The biotech industry is burgeoning as well: the NASDAQ Biotech Index rose 102% in 1999. Bioengineering educational programs have grown from less than 60 to over 100 in the past ten years. Student populations in Bioengineering have grown by 70% while many other engineering disciplines (except computer engineering) maintain flat or declining student populations.

Our local experience also tells us that Bioengineering is a growth field. In addition to a markedly increased interest in Bioengineering by prospective students nationwide, the opportunities are great for our students when they graduate. Students throughout the U.S. find excellent jobs or can choose from rich career options. Appendices E and F show the placement of our students over the past three years in detail. Furthermore, research funding by our faculty and entrepreneurial activities have increased substantially in the past decade.

STUDENT LEARNING OUTCOMES AND PROGRAM EFFECTIVENESS

To develop our program and assess its effectiveness, we have established goals and objectives for our new undergraduate program (to get started in 2001) and for our master's and doctoral programs. The goals and objectives are listed below. They form the basis of our strategic plan for the foreseeable future. They form the measures against which student progress and program effectiveness are assessed.

Undergraduate Program

Goal

To send our graduates to doctoral programs in bioengineering, medicine or MD/Ph.D. programs, and industry.

Objectives

1. To provide students with a solid foundation in mathematics, physics, chemistry, computer programming, engineering, and biology.
2. To train students to address and solve biological problems quantitatively.
3. To train students to apply engineering synthesis and analysis to solve biological problems.

4. To train students to glean design principles from nature to solve medical problems and innovate biomedical devices and materials.
5. To train students to communicate problems and their solutions effectively to physicians, biologists and other engineers.

Assessment

Our undergraduate degree program is currently under development. Assessment of the undergraduate program in Bioengineering will take place at key points in the program. Learning will be assessed at the time of admission, throughout student's progress through the core curriculum, at the time of the capstone research/design project, and after their graduation.

Master's and Doctoral Program

Goal

To prepare master's and doctoral bioengineers for careers in industry and the academy.

Objectives

1. To provide students with an in-depth understanding of mathematics, engineering principles, physics, chemistry, physiology and modern biology.
2. To train students to apply basic sciences to medical and biological problems using engineering principles.
3. To train students to recognize and provide engineering solutions to clinical problems.
4. To train students to do Bioengineering research.
5. To train students to teach Bioengineering at the undergraduate and graduate level.
6. To train students to apply Bioengineering research to commercially viable problems.

Not all students need to be trained in all of the above areas.

Assessment

The Department follows the progress of students in the graduate program through the students' initial advisors, their supervisory committees and the Student Affairs Committee. Each student and his/her initial advisor prepare a preliminary plan of study as the student enters the program. By the end of the third quarter in the program, the student should be in the laboratory of a particular Bioengineering faculty member. The student and the faculty member develop a long-term plan of study. Master's students seek faculty to serve as members of a supervisory committee that follows and monitors the particular student until he or she completes the program. The final check takes place at the time of the student's final examination. The supervisory committee determines whether the master's thesis is satisfactory. The oral portion of the final examination allows the faculty to question the candidate broadly and to determine what has and has not been learned.

Assessment of the learning of our doctoral students is similar to that of the master's students, although there is a Qualifying Examination and General Examination, which make the evaluation more thorough. In Bioengineering, the Qualifying and General Examinations include a written proposal, an oral defense and a question and answer period. The student is expected to request a Qualifying Examination during the second year of graduate study, which consists of a written portion and an oral presentation of the student's response to a question assigned five weeks before the examination.

A student who has passed the Qualifying Examination moves forward to form a doctoral supervisory committee, complete and submit a student study plan, and prepare for the General Examination. The General Examination is the major examination in the career of a student. The exam has both written and oral components and topics are determined by the student's research plan. The purpose of this exam is to assure the student's potential to become an independent researcher.

The final check of progress takes place at the time of the student's final examination. The supervisory committee carefully evaluates and determines whether the candidate has made significant contributions, the doctoral dissertation is of high quality, and he/she can perform competently as an independent investigator.

PLANS TO IMPROVE THE QUALITY AND PRODUCTIVITY OF THE PROGRAM

The eight objectives that will guide us to improve the quality and productivity of the programs in Bioengineering are listed below:

- To create a baccalaureate degree program in Bioengineering and expand our undergraduate population from 16 students (Autumn 1999) to 100 by 2003 and 140 by 2006.
- To expand and improve our graduate curriculum in order to give our students a well-balanced education in Bioengineering and enlarge our graduate population from 116 students (Autumn 1999) to 130 by 2003 and 140 by 2005.
- To develop and nurture a new program on distributed diagnosis and home healthcare;
- To capitalize on our existing world-class program in engineered biomaterials by adding a new program in cardiovascular tissue engineering.
- To further enhance our unique program in molecular bioengineering and nanotechnology with new programs on drug delivery and molecular biomechanics.
- To establish a leading program in medical imaging and image-guided therapy, in which education and research are closely integrated.
- To expand our program in computational bioengineering, to prepare for its more central role in future Bioengineering education and research.
- To establish a unique training program in technology transfer and entrepreneurship for graduate students in Bioengineering.

As we enter the new millennium, we have developed a plan that we believe will propel us to a higher level of excellence. The plan is grounded in our strength in education and research. This strength has led to our high reputation with Bioengineering academic and industrial communities. We will broaden our mission to include full undergraduate and graduate educational programs that are well integrated with our research. Implementation of the plan will allow us to become a model, full-service Bioengineering department, excelling in research, education, services, clinical applications, and technology transfer.

DEGREES GRANTED IN THE LAST 3 ACADEMIC YEARS (AUTUMN '97-SUMMER '00)

Thirty-nine Ph.D. degrees in Bioengineering have been awarded since Autumn '97. 17 MS degrees have been awarded. Eleven students received their BS degrees in Engineering, focusing on Bioengineering.

FTE FACULTY AND GRADUATE ASSISTANTS WHO TEACH IN THE DEPARTMENT

The Department of Bioengineering has a total of 14.7 FTE faculty positions, 7.1 FTE from the School of Medicine and 7.6 FTEs from the College of Engineering. Currently, there are 14 tenure-track faculty members and one opening created by the resignation of Professor Terry Lybrand in July 2000. All tenure-track faculty members teach. We have 12 research faculty members and they teach occasionally. The Department currently has state support of 1.6 FTE Teaching Assistants. We have had sixteen graduate students serving as teaching assistants in various courses while working on their graduate degrees in the last five years.

CONTEXT

NAME OF UNIT AUTHORIZED TO OFFER DEGREES

Department of Bioengineering

SCHOOL AND COLLEGE

School of Medicine and College of Engineering

EXACT TITLES OF DEGREES OFFERED

- BS in Engineering (Interengineering Programs in the College of Engineering)
- MS & MSE (Master of Science in Engineering)
- BS/MSE
- Ph.D.

HISTORY OF THE DEPARTMENT

Bioengineering began at the University of Washington with the development of extensive research and training programs that were integral to the Department of Physiology and Biophysics and funded by the NIH. Quantitatively monitoring cardiovascular function in healthy active dogs began in the early 1950s. It was logical that such studies would lead to data more representative of normal cardiovascular activity than would studies of excised or exposed hearts in anesthetized animals. The development of advanced instrumentation and quantitative biology demanded a program of training in modern cardiovascular research techniques. Dr. Robert Rushmer initiated the program, which focused on training in comprehensive cardiovascular research, microcirculation, operation of the human peripheral vascular system, fluid dynamics, and the quantitative analysis of heart sounds. The students were trained to select, define and design research projects rationally. They created instruments that were appropriate to their specific experimental designs.

Bioengineering had attained national recognition for its extensive research and educational programs linking engineering and the life sciences. The program could not be accommodated comfortably within a single basic science department. A proposal was submitted to the Deans of Engineering and Medicine to establish a program administered jointly by both organizations, which resulted in the creation of the Center for Bioengineering in 1967.

In 1975, Dr. Rushmer resigned and Dr. James Bassingthwaighte was recruited to replace him. Dr. Bassingthwaighte brought national recognition and notable additions to the Center, including the National Simulation Resource Facility on Mass Transport. In 1979, Dr. Bassingthwaighte stepped down as Director in order to devote more time to his research activities.

An extensive national search selected Dr. Lee Huntsman as the new Director of the Center. He moved the Center to a status like that of a department. In the 1980s, the Center became a degree-granting academic unit with a faculty of 20, eleven of whom were in tenure-track positions. Authority to grant doctoral degrees was given provisionally in 1984 and made permanent in 1991, after a review by the Graduate School. In 1985, the Center began an undergraduate program, offered through the Interengineering Programs of the College of Engineering. This program has been small and elite, training highly motivated students mainly for MD, Ph.D. and MD/Ph.D. programs.

Huntsman led the Center to expand into emerging areas at the boundary between engineering and biomedicine. He selected a key group of faculty to respond to a request for proposals from the Whitaker Foundation in 1988. The UW proposal was ranked highest among many proposals and was funded in 1989. The initiative brought more than $4 million to the Center for Bioengineering, and enabled us to recruit three faculty members, Drs. Lybrand, Stayton and Vogel. The program has moved Bioengineering from the application of engineering principles to biomedical problems to bringing knowledge and technology from biology to solve engineering problems. The latter was demonstrated materially in 1995 when Dr. Buddy Ratner, working with the new Molecular Bioengineering faculty, successfully proposed the University of Washington Engineered Biomaterials (UWEB) Engineering Research Center to the National Science Foundation (NSF). UWEB began its operation in 1996.

During 1997 Dr. Viola Vogel, one of the Whitaker Molecular faculty members, was granted one of the first awards from the University Initiatives Fund to begin the Center for Nanotechnology. This Center follows the successful formula of entrepreneurial innovation and promotion of collaborative research by bioengineers. In 2000, Dr. Vogel and her team received an NSF Integrative Graduate Education and Research Traineeship (IGERT) grant on Nanotechnology.

In June 1996, Dr. Huntsman left his position as Director of the Center for Bioengineering to become Provost of the University of Washington. A national search was undertaken and attracted Dr. Yongmin Kim to become the Chair of the Department of Bioengineering in March 1999.

In 1993, Bioengineering at the University of Washington was ranked third in the nation by the National Research Council. In the last several years, the U.S. News & World Report's annual survey of graduate and professional schools placed Bioengineering 5th in the nation. In 2000, we admitted 24 graduate students who had an average GPA of 3.62 and an average total GRE score of 2072. This will bring our graduate enrollment to a total of 122 as of Autumn 2000. External research funding continues to increase. Research expenditures from external sources between July 1999 and June 2000 were $10.2 million including those of the UWEB, while new extramural research awards (including those to the UWEB) totaled $14.4 million during the same time period—an all-time high.

UNIT ROLES AND RESPONSIBILITIES

PRINCIPAL ROLES AND RESPONSIBILITIES IN SCHOOL, COLLEGE AND UNIVERSITY

The Department of Bioengineering of the University of Washington belongs to both the School of Medicine and College of Engineering. The Department has been responsible to perform excellent research, engage in first-rate scholarly activities and concentrate its education on graduate programs at the master's and doctoral levels. The Department has offered a baccalaureate degree to 35 students in the last 10 years through the Interengineering Programs of the College of Engineering. The number of students in the program is small (16 in the 1999-2000 academic year). In contrast, our graduate program is the largest of its kind in the U.S. with a population of 116 in Autumn 1999. This number does not include 27 (Autumn 1999) students in the Masters of Medical Engineering (MME) program, a part-time evening degree program.

The Department plans to expand both undergraduate and graduate programs. The expansion will increase the undergraduate population to 140, and the on-campus graduate population from 116 in Autumn 1999 to 140 by 2006.

The mission statement of the Department is:

To become a model, full-service Bioengineering department, excelling in research, education, services, clinical applications, and technology transfer.

The mission statement leads us to four specific aims:

1. To develop outstanding undergraduate and graduate educational programs to prepare our students for careers in industry, academe and government.

2. To enhance our place as one of the best Bioengineering departments in the world.

3. To develop integrated research and education programs in five Bioengineering thrust areas: Distributed Diagnosis and Home Healthcare (D_2H_2), Engineered Biomaterials, Molecular Bioengineering and Nanotechnology, Medical Imaging and Image-Guided Therapy, and Computational Bioengineering.

4. To construct a building in which the expanded role of Bioengineering can flourish.

OPPORTUNITIES FROM THESE ROLES

The roles summarized in the specific aims present the opportunities that are listed below.

- To create a baccalaureate degree program in Bioengineering and expand our undergraduate population from 16 students (Autumn 1999) to 100 by 2003 and 140 by 2006.

- To expand and improve our graduate curriculum in order to give our students a well-balanced education in Bioengineering and enlarge our graduate population from 116 students (Autumn 1999) to 130 by 2003 and 140 by 2005.

- To develop and nurture a new program on distributed diagnosis and home healthcare;

- To capitalize on our existing world-class program in engineered biomaterials by adding a new program in cardiovascular tissue engineering.

- To further enhance our unique program in molecular bioengineering and nanotechnology with new programs on drug delivery and molecular biomechanics.

- To establish a leading program in medical imaging and image-guided therapy, in which education and research are closely integrated.

- To expand our program in computational bioengineering to prepare for its more central role in future Bioengineering education and research.

- To establish a unique training program in technology transfer and entrepreneurship for graduate students in Bioengineering.

As we enter the new millennium, we have developed a plan that we believe will propel us to a higher level of excellence. The plan is grounded in our strength in education and research. This strength has led to our high reputation with Bioengineering academic and industrial communities. We will broaden our mission to include full undergraduate and graduate educational programs that are well integrated with our research. Implementation of the plan will allow us to become a model, full-service Bioengineering department, excelling in research, education, services, clinical applications, and technology transfer. Our graduate and undergraduate curricula and their interrelationship as well as descriptions of our five education and research thrust areas are included in Appendix G.

Despite the exciting opportunities listed above, there have been missed chances for development and leadership. They are presented here. Our Department still has room to grow and become better. Our students, particularly at graduation, have commented that some courses taught by our own faculty are survey-oriented and could concentrate more on in-depth analysis and practical skills. This has led to some of the changes we have planned that will be described in this document.

We believe that our historical approach to education has had great merit in broadening the definition of Bioengineering into vital new areas—Bioengineering is the dynamic and respected field that it is today in part because we have pushed back the boundaries of classical biomedical engineering. However, we also plan to upgrade our engineering training. We addressed this in 1999 through a restructuring of the course requirements of the curriculum and confronting the issue of core Bioengineering competence. We believe that we have now instituted a program that will train our students well for both their MS/Ph.D. research and future careers. Furthermore, in our admission process, we have begun to consider whether an applicant with a non-engineering degree can succeed in our new curriculum and be trained as a bioengineer. A trend toward more classroom and laboratory teaching contact hours by the faculty will continue.

Some students have also commented during their exit interviews that our department has historically done better at preparing its students for academic life than for work in the corporate world. However, in reality, this has varied from laboratory to laboratory, with some laboratories, particularly in the medical imaging and biomaterials areas, being highly focused on industry and producing well-trained researchers and engineers who will become future leaders in industry. Today, the trend is toward greater industrial involvement in daily operation of University laboratories, and Bioengineering is no exception. There are very few UW Bioengineering laboratories that do not have direct corporate connection and/or support. This industrial connection/support promotes technology transfer and direct contact between our students and industry. The recent rapid growth of the Biotechnology and Biomedical Device industries in the Seattle area has further strengthened a local Bioengineering industrial base. This growth promises even greater opportunities for collaborative research and students to be involved with industry during and after graduation. In addition, we are initiating a very innovative entrepreneurship program called Technology Entrepreneurship Certificate (TEC) program.

A continuing barrier to the full development of our department has been a lower level of state support for the Department of Bioengineering, e.g., faculty salary, staff support, TAs, and other operational support since the Department has been viewed more as a research unit. With the new undergraduate program in Bioengineering and expanded graduate educational program, however, the University of Washington has committed increased resources to the Department of Bioengineering. These increases are essential for success with this major educational initiative, while minimizing the possibility of lowering the quality and productivity of our leading research.

Another challenge is the graying of our distinguished faculty. However, this challenge is also a wonderful opportunity for our department to reshape itself. Of 14 state-funded faculty, six are 45 or younger and six are over 56 years of age: a clear bimodal distribution. In the next six years, four more senior faculty are likely to retire. It is critical for the Department to recruit a healthy mix of junior and senior faculty, support them well, nurture, mentor, and enable them to sustain the academic leadership position that our senior faculty have developed, or even enhance it.

The most serious weakness in the Department, one on which we all agree, is the dispersion of Bioengineering across the UW campus. This dispersion is a legacy of our growth as an entity of both Engineering and Medicine. While both schools find Bioengineering to be a credit to their programs, neither has, historically, felt obligated to make a single contiguous space for us. We have continuously and energetically pressured the University to provide as much contiguous space as possible over the last decade, particularly since the origin of the Whitaker Development Award in 1989. While admirable steps have been made along these lines (e.g., in Bagley Hall 4th floor, we currently have 11,600 asf of contiguous space, which will increase to approximately 17,000 asf in the next 15 months), the problem remains largely unsolved. Today, we are faced with the embarrassing situation of being spread across nine buildings, and 17 locations within those buildings.

While we feel we have performed admirably as a department *despite* this handicap, the dispersion has created a series of problems for us. Among the worst of these are:

- a lack of coherence within the student body due to the lack of common spaces in which to interact on a daily basis
- historical difficulty in attracting our students and faculty to departmental seminars and meetings
- difficulties for faculty and students to manage individual research groups spread over multiple sites in multiple buildings
- reduced mentoring of students by faculty due to multiple locations
- requirements for redundant research equipment (that might otherwise be in shared spaces), with resulting great expense
- requirements for redundant administrative staffing and equipment to keep multiple sites functioning
- difficulties in communicating with staff and administrators across campus
- difficulties in managing staff over multiple sites
- difficulties in creating and maintaining collaborative research interactions within the department
- difficulties in recruiting the best faculty and students into a suboptimal physical arrangement

While our modern electronic society has given us ways to communicate despite this dispersion, it is generally acknowledged that there is no substitute for direct human contact. Indeed, without it, there is no reason to attend undergraduate or graduate school at UW or anywhere else. Our students could just as well stay home and get their degrees over the Internet. This lack of human contact has been a problem for all Bioengineering faculty, students and staff at the University of Washington. We sincerely hope that the proposed Life Sciences II (LS II) building can address most of the problems listed above.

Our View of Bioengineering vs. College or University Expectations

Historically, the Department of Bioengineering has concentrated on developing and maintaining an excellent graduate program and a superb research effort. We developed and maintained a small undergraduate program (16 students in 1999-2000). We admit between three and six undergraduate students per year. We have graduated 35 students over the last 10 years, the majority of whom have entered into MD and MD/Ph.D. programs.

Until recently, we believed that the opportunities for baccalaureate graduates were limited. Our view has changed as Bioengineering industry and research have changed. We will increase the number of undergraduate students in our program from a total of 16 (Autumn 1999) to 25 per year in 2001, 45 per year in 2003, and 60 per year in 2006. We will apply for ABET accreditation in 2007, the next available date (most likely) that the University of Washington College of Engineering will be reviewed after we produce our first BS degree in Bioengineering in 2003.

The demand for Bioengineering undergraduate training will be high within the University of Washington. Thus, our role in undergraduate education will change from training elite students primarily for medical school to a full-service program for more UW undergraduate students. We have enthusiastic support from our current and former students, industry, the Bioengineering community, and the UW Administration. This changed role will place us in a position to contribute more directly and significantly to the educational mission of the College of Engineering, School of Medicine and University of Washington.

Changes in Our Field Over The Past Decade: Documentation of Need

The field of Bioengineering has grown dramatically over the past ten years. This growth has been fueled by increased recognition of the value and need of Bioengineering, expanding Bioengineering fields, and rapidly-developing industry. For example, the Washington Biotechnology and Biomedical Association (WBBA) counts 250 Bioengineering and Biotechnology firms in the State of Washington. In addition to the recognized value of bioengineers, the Whitaker Foundation (Rosslyn, VA) has dedicated its assets to the development of Bioengineering (biomedical engineering) as an established engineering discipline.

In the U.S., the Health Industry Manufacturers Association and Merrill Lynch estimated the worldwide medical device industry at $146 billion, and the U.S. at a level of $62.3 billion in 1999. The biotech industry is burgeoning as well: the NASDAQ Biotech Index rose 102% in 1999. Bioengineering educational programs have grown from less than 60 to over 100 in the past ten years. Student populations in Bioengineering have grown by 70% while other engineering disciplines (except computer engineering) maintain flat or declining populations.

Standards for Success

Research Funding

Bioengineering faculty have been extraordinarily productive in competing for and obtaining external research funding as shown in Table 1. For example, from July 1, 1998 to June 30, 1999, the faculty attracted $11.4 million, and from July 1, 1999 to June 30, 2000, external research grant and contract awards totaled $14.4 million. Indeed, in the federal fiscal year 1998, the University of Washington led the U.S. in NIH awards to engineering, while in 1999 the UW was second to MIT. NIH awards to Bioengineering were $5.98 million in 1998-99 and $8.26 million in 1999-00. Research funding supports tenure-track and research faculty, staff and the vast majority of our students. 27 out of 116 graduate students have external fellowships from the DOE, DOD, NSF, Whitaker Foundation, government of Canada, and others.

Table 1: External Research Grants and Contract Awards

Year	NIH	NSF	Other Federal	Industry	Foundations	Other	TOTAL
94/95	$5,667,152	$584,804	$1,227,491	$414,700	$603,000	$335,880	$8,833,027
95/96	$6,176,715	$309,338	$424,858	$485,748	$253,437	$472,115	$8,122,211
96/97	$5,419,006	$2,182,734	$1,236,765	$1,053,878	$383,443	$313,340	$10,589,166
97/98	$4,901,705	$2,213,826	$727,416	$979,951	$513,570	$354,082	$9,690,550
98/99	$5,982,365	$2,960,107	$452,278	$664,073	$747,449	$558,405	$11,364,677
99/00	$8,264,553	$2,826,461	$675,160	$1,509,019	$880,039	$257,865	$14,413,097

Graduates and Their Positions

In Appendix E and F, we list the placement of graduates with BS (Interengingeering), MS or Ph.D. degrees in the last 3 years. Eleven students completed their undergraduate training during the past three years. Of those, 2 entered industry, 2 are in or entering graduate school, 6 are in or entering medical school (one in an M.D./Ph.D. program), and one is in dental school. Nine of our 17 master's students entered industry, 6 engaged in further study, and 1 became a research engineer at UW. Of our 39 doctoral students, 18 moved into industry, 11 took post-doctoral positions, 5 took research positions, 3 took teaching positions and 2 graduates continued on to medical school. One additional graduate was the first to complete our Master's of Medical Engineering program. She earned this degree in February 2000 while fully employed by industry.

Patents and Start-ups

The Department of Bioengineering is fortunate to have imaginative and productive faculty and students. Over the past thirty years, the Department claims 347 invention disclosures, 112 issued patents, 83 patents pending, 74 license agreements, and 183 cases of copyrighted software. 23 start-up companies have significantly benefited from the intellectual properties generated by the Department of Bioengineering. The Department continues to produce substantial, useful ideas, processes, inventions, patents, and devices that spur industrial growth.

Publications

The faculty and students of Bioengineering actively publish books, papers in first-rate journals, and significant conference papers. They are widely referred to in the scientific and engineering communities. Selected publications for each faculty can be found in the Department's brochures and web pages.

LEADERSHIP

We have a very diverse but cohesive faculty (14 tenure-track, 12 research, 29 adjunct and 23 affiliate). A search for more tenure-track faculty is under way. We expect to have two to three new tenure-track faculty members in the next six months. In fact, we will be in a constant faculty recruiting mode over the next six years since we expect to hire 12 new tenure-track faculty (some will be senior) by 2006 due to new positions, retirements and resignation (Professor Terry Lybrand resigned in July 2000).

Evidence of leadership by departmental faculty abounds. Taking advantage of the faculty hired when the Whitaker Foundation established the Molecular Bioengineering Program here, Dr. Buddy Ratner conceived and organized the University of Washington Engineered Biomaterials (UWEB) Engineering Research Center. Under his leadership, UWEB was enthusiastically supported by the National Science Foundation and has attracted 27 industrial partners. Early this year, Dr. Ratner was awarded a large Bioengineering Research Partnership (BRP) grant from the NIH to develop a tissue-enigneered myocardial patch.

Dr. Viola Vogel inspired 35 faculty across the UW campus to plan a program of education and research in phenomena that occur at nanometer dimensions. Her leadership of a proposal for a Center for Nanotechnology produced one of the first interdisciplinary programs to be funded under the first University Initiatives Fund of UW in 1997. Recently, Dr. Vogel received a $2.7 million grant from the NSF on the Integrative Graduate Education Research Training (IGERT) program on nanotechnology.

For more than 13 years, the Department of Bioengineering has had three Research Resources supported by the NIH/NCRR. Dr. James Bassingthwaighte established the National Simulation Resource (NSR) for Circulatory Mass Transport and Exchange. The resource boasts national and international research subcontracts and collaborations, the result of its pioneering work and recognized leadership in simulation analysis of tracer transport in intact organs, of PET and MR image sequences for regional tissue metabolism, blood flows and receptor function. Dr. David Foster established the Resource Facility for Kinetic Analysis (RFKA), which has evolved into the Resource Facility for Population Kinetics (RFPK). Both facilities have been devoted to the compartmental analysis of metabolism. The RFKA has grown into a local software company, the SAAM Institute.

The RFPK seeks to optimize the data that can be acquired from small populations of test subjects, focusing on the pharmaceutical industry. The RFPK, like its predecessor, is an international center for the development and execution of cutting-edge metabolic studies. Drs. Buddy Ratner and Dave Castner established the National ESCA and Surface Analysis Center for Biomedical Problems (NESAC/Bio) and contributed numerous surface analysis techniques to the biomedical community.

Dr. Paul Yager joined with Dr. Bruce Darling of Electrical Engineering to found the Center for Applied Microtechnology (CAM) under the College of Engineering. CAM provides leadership in microtechnology and microelectromechanical systems on the UW campus. This Center followed Dr. Yager's success in attracting two DARPA awards for microfluidic chemical analytical devices–awards that led to the development of a new company, Micronics, in Redmond, WA.

Drs. Ben Clopton (former research faculty) and Francis Spelman joined with a small company, BioElectric Corporation (formerly PI Medical, Inc.) to perform research on an advanced electrode array for cochlear implants. This work was the focus of the first STTR award on the UW campus. The development of the array sparked an interest in cochlear processors, which, in turn, became the foundation of Advanced Cochlear Systems, a company started in 1995. Dr. Clopton is now a full-time employee of Advanced Cochlear Systems.

Dr. Yongmin Kim had been a faculty member of UW Electrical Engineering since 1982 and became Chair of Bioengineering in March 1999. In 1984, he was given an adjunct appointment in Bioengineering. Being trained as an electrical and computer engineer with a strong interest in medical applications, he started collaborating on biomedical imaging with the Departments of Radiology and Pathology upon his arrival in Seattle. He and his group have developed a unique combination of expertise, including computer architecture, image processing, instrumentation, human body computer modeling and clinical applications. He has worked with more than 60 companies in the last 18 years. Multiple times, he has been deeply involved in the process of starting out with an untested idea, going through the stages of research, development, testing and evaluation, and pre-clinical studies, receiving an FDA clearance, and finally seeing it commercialized. From this experience, he understands well what it takes to convert an exciting idea to routine clinical use. Also, he has helped several companies get started and advised numerous other companies in their research and development strategies.

He has been and will be a good role model for the current and new Bioengineering faculty in demonstrating that a faculty member can succeed simultaneously in more than one area of our academic mission, e.g., research, teaching, service, and technology transfer. His excellent record in traditional engineering areas and experience in education (he is an ABET program evaluator for biomedical engineering and computer engineering and was a key faculty member in creating and implementing a new BS degree program in Computer Engineering in 1987) and clinical applications coupled with our outstanding faculty, their brilliant research record and enthusiastic support will enable the Department of Bioengineering to go through a series of changes (sometimes painful) to become an outstanding full-service department, excelling in research, education, services, clinical applications and technology transfer.

During its existence, Bioengineering has always advanced the commercial development of its research activities and is considered the campus hotbed of inventiveness by the Office of Research and Office of Technology Transfer at the University of Washington. As mentioned earlier, the Department can boast of numerous invention disclosures, awarded patents, patents in process, and viable companies that are outgrowths of its intellectual property. In addition, 74 technology transfers have been made via license agreements to commercial organizations that exploit the developments from Bioengineering. In 1999, the UW licensing and royalty income generated by these commercial licenses originating from the Department of Bioengineering exceeded $1 million.

The strength of our Department comes largely from its outstanding faculty and their leading research. We are very fortunate and proud to have many distinguished faculty members in the Department. Dr. James Bassingthwaighte was elected to the National Academy of Engineering, received the Alza Award and Distinguished Service Award from the Biomedical Engineering Society, the Landis Award from the Microcirculatory Society, the Burlington Award for Outstanding Research, and many other awards and honors. Another senior faculty member, Dr. Allan Hoffman, received the Founders Award for the Society of Biomaterials and received the Japanese Biomaterials Science Prize. Dr. Buddy Ratner received the Clemson Award for Contributions to the Biomaterials Literature, the Burlington Award for Outstanding Research, the Perkin-Elmer Physical Electronics Award for Excellence in Surface Science, and the C.M.A. Stine Award in Material Science. Dr. Francis Spelman received the IEEE Third Millennium Medal, Dr. Larry Crum received the 2000 Acoustical Society of America Helmholtz-Rayleigh Interdisciplinary Silver Medal for his contributions in physical acoustics and biomedical ultrasound/bioresponse to vibration, while Dr. Patrick Stayton received the Faculty Honorary Award from the Minority Science Engineering Program, an Award for Excellence in Guiding Graduate Student Research for the Controlled Release Society, and was recently nominated for the 2000 Presidential Awards for Excellence in Science, Mathematics, and Engineering Mentoring. In 1996, Dr. Joan Sanders received the Whitaker Foundation's George W. Thorn Award and the IEEE/EMBS Early Career Achievement Award. In 1998, she was awarded the University Faculty Mentor Award for outstanding mentoring of undergraduates in research. Dr. John Medina was the winner of the 2000 College of Engineering Teaching Award.

Most senior faculty members are at the highest grade level of their professional societies, for example, AIMBE, Society for Biomaterials, IEEE, Biomedical Engineering Society, and American Physiological Society. Our faculty members have made an enormous impact on the advancement of science, technology and healthcare in many areas ranging from cardiovascular systems, diagnostic and therapeutic ultrasound, biomaterials, surface analysis, computational modeling, medical imaging, and computing.

As mentioned, the UW Department of Bioengineering has the largest graduate program in the U.S. with 116 resident students as of Autumn 1999 in both our master's and doctoral programs. The majority of the student's (97) are enrolled in the doctoral program. Students continue to eagerly apply to our program. This year, 24 out of 264 students who applied will enter the program in September 2000. The average GPA of the 24 students is 3.62 and the average GRE is 600V, 758Q and 720A. From 1989 to 2000, the 267 entering students had an average GPA of 3.58 with GREs of 590V, 745Q and 697A.

Aside from excellence in academics, many students within the Department of Bioengineering also receive awards while working on their graduate degrees as shown in Table 2.

Table 2: Graduate Student Awards

NAME	AWARD	SOCIETY
Vikram Chalana	Best Student Paper Award	SPIE Medical Imaging Symposium
Danial Graham	Graduate Research Award	American Vacuum Society
Hongbo Lu	Travel Award (based on highest ranking abstract)	2000 International Controlled Release Society
Sayan Pathak	2nd Prize for student paper	SPIE Medical Imaging Symposium
Galen Shi	1st Prize for student paper	Society for Biomaterials
Galen Shi	1st Prize for Ph.D. student paper	American Vacuum Society
Susie Steitz	Young Investigator Poster Award	American Vascular Biology Organization

Leadership by the Department of Bioengineering is supported by the following data that are offered in summary:

- UW has the largest population of Bioengineering graduate students in the U.S. The strong research programs of our faculty support this population. Approximately 15 Ph.D. and 6 MS degrees are awarded per year.
- The College of Engineering at UW garnered the largest NIH research support in the U.S. in 1998, and was second to MIT in 1999. Bioengineering is responsible for 80% of the awards to Engineering. Indeed, Bioengineering external funding from all sources has increased from $3.98 million in 1989-1990 to $14.4 million in 1999-2000, a 262% increase.
- Bioengineering is one of the most productive departments at UW in terms of numbers of patents and start-ups companies.
- The novel idea to bring Molecular Bioengineering to UW was the first such effort in the nation. This idea spawned UWEB, the Center for Nanotechnology and the Cardiovascular Tissue Engineering Program.
- The Center for Nanotechnology was among the first centers supported by the University Initiatives Fund (UIF); Bioengineering collaborates on the Biomedical and Health Informatics UIF.
- Bioengineering has been a leader in the development of the Computational Biology program on the UW Campus.

COLLABORATION WITH UNITS AT OTHER INSTITUTIONS

The various collaborations of the three departmental NIH-sponsored Research Resources (NESAC/Bio, NSR, and RFPK) are listed below:

NESAC/Bio

- Brown University
- Colorado State University
- Duke University
- Howard University
- Lawrence Livermore Laboratory
- Louisiana State University Eye Center
- Massachusetts Institute of Technology
- Montana State University
- Naval Research Lab, Washington DC
- Northwester University
- Rice University
- Rutgers University
- University of Connecticut
- University of Delaware
- University of Maryland at Baltimore
- University of Michigan
- University of New Mexico
- University of Pittsburgh
- University of Texas
- Physical Electronics GmbH, Germany
- Technische Universitat, Germany
- Tokyo Institute of Technology, Japan
- University of Sheffield, England

National Simulation Resource (NSR)

- Amsterdam Medical College
- Case Western University
- Dresden University
- Free University of Amsterdam
- Marquette University
- MathSoft, Inc.
- Mayo Clinic
- McGill University
- Medical College of Wisconsin
- Michigan State University
- Oak Ridge National Laboratory
- Technion University, Haifa
- University of California, Berkeley
- University of California, San Diego
- University of Auckland
- University of Dusseldorf
- University of Iowa
- University of Maastricht
- University of Minnesota
- University of Padova in Italy
- University of Utah
- VA Medical Center, Seattle

- Prince of Songkla University, Thailand
- Semmelweis University, Budapest
- Vanderbilt University

Resource Facility for Population Kinetics (RFPK)

- University of Oklahoma HSC
- University of Padova in Italy
- University of Southern California
- University of Western Australia

UWEB, an NSF-sponsored Engineering Research Center has extended its collaborations to 27 industrial firms in addition to various educational institutions. The new UWEB Cardiovascular Tissue Engineering grant under the NIH BRP has collaborators from the University of Toronto, Georgia Tech, MIT and Advanced Tissue Sciences.

University of Washington Engineered Biomaterials (UWEB)

- California Institute of Technology
- Clemson University
- Duke University
- Georgia Institute of Technology
- Institut für Biomedizinische Technik und Departement Werkstoffe, Zurich
- Massachusetts Institute of Technology
- Mississippi State University
- Montana State University
- University of Hawaii
- University of California, Berkeley
- University of Southern California
- University of Florida
- University of Toronto
- University of Wisconsin
- Vanderbilt University
- Virginia Polytechnic Institute

University of Washington Engineered Biomaterials (UWEB) Industry Consortium Members

- 3M Life Sciences
- Abbott Laboratories
- Advanced Tissue Science
- Affymetrix, Inc.
- Alcon
- Batelle Pacific Northwest Labs
- Bausch & Lomb
- Baxter Healthcare Corp
- Becton Dickinson
- Bend Research
- Boston Scientific
- C. R. Bard
- Dow Corning Corp.
- Edwards LifeScience
- Genetics Institute Inc.
- Genzyme Corp.
- Guidant Corp.
- Kendall Health Care
- Integra LifeSciences
- Industrial Technology Res. Inst.
- National Applied Science
- Medtronic Corp.
- Prolinx, Inc.
- Roche Diagnostics
- St. Jude Medical
- Sulzer Medica
- W.L. Gore & Associates

Various individual faculty members collaborate with colleagues at other institutions. These collaborations are outlined below. It should be noted that Dr. Stayton collaborates with faculty from Prairie View A&M and North Carolina A&T in developing ways to attract graduate students of diverse backgrounds to Bioengineering as well as in research projects.

Allan S. Hoffman

- University of Kobe, Japan

Thomas A. Horbett

- McMaster University, Ontario

Yongmin Kim

- Georgetown University
- Korea Advanced Institute of Science and Technology
- University of Nijmegen, The Netherlands

Gerald H. Pollack

- Ural State University, Ekaterinburg, Russia

Francis A. Spelman

- Georgia Institute of Technology
- Johns Hopkins University
- Prairie View A&M
- University of New South Wales, Australia
- University of Melbourne, Australia

Patrick Stayton

- Max Planck at Mainz, Germany
- North Carolina A&T
- Prairie View A&M
- University of British Columbia
- University of Kobe, Japan
- University of Toronto

Pedro Verdugo

- University of Cambridge, UK
- University of Manchester, UK
- Ben Gurion University of the Negev, Israel
- Universidad Miguel Hernandez, Spain
- Catholic University of Chile, Chile

Paul Yager

- Naval Research Laboratory, Washington DC

On the educational front, UW faculty joined with Johns Hopkins, Georgia Tech, and Prairie View A&M to write a proposal for an NSF ERC on Bioengineering Educational Technology. While the proposal was not successful, collaboration extended over a year's time.

Collaboration Across Campus

The faculty members of the Department of Bioengineering have a large variety of collaborations across campus. Indeed, seven core faculty members in the Department hold joint appointments in other departments. Eight of the core faculty members hold adjunct appointments in at least one other department, and some are adjunct in two or more departments. A few of those collaborations are exemplified below:

Technology Entrepreneurship Certificate (with the School of Business)

The Technology Entrepreneurship Certificate (TEC) is a collaboration between the School of Business Administration and its Program in Entrepreneurship and Innovation (PEI), the College of Engineering and the School of Medicine. Bioengineering is the focal department and initiated the idea. A key design element of the TEC Program will be the inclusion of both MBA and engineering/science students in the classroom and project-oriented settings. This ensures interaction of people with diverse perspectives and gives the students valuable experience to communicate at the interface of development in technology-based business.

The Center for Nanotechnology

Professor Viola Vogel of Bioengineering and Professor Charles Campbell of Chemistry organized and proposed the Center for Nanotechnology. The Center concentrates 35 faculty from nine departments and three schools and colleges. It exemplifies the collaborative spirit that emanates from Bioengineering and is made possible by the low barriers to interdisciplinary work that exists at the University of Washington.

Bioengineering began as an interdisciplinary center in 1967 and the spirit of entrepreneurship still thrives in the Department.

Joint Course Offerings

Bioengineering has collaborated actively in its research, seeking partners inside and outside of the University of Washington. The Department is collaborative in its teaching as well. Twelve courses are offered jointly with other departments, spanning the School of Medicine and the Colleges of Arts and Sciences and Engineering. Joint courses are offered with The Departments of Radiology, Molecular Biotechnology, Chemistry, Chemical Engineering, Electrical Engineering and Materials Science and Engineering.

Biology in Engineering

The College of Engineering, the Center for Engineering Learning and Teaching (CELT) and Bioengineering have jointly proposed a program to introduce biology to engineering students. This NSF-funded program, which begins in October 2000, will be part of the Action Agenda of the National Science Foundation.

DEGREE PROGRAMS

We are currently in the process of expanding both our undergraduate and graduate programs. The plans for this are described below and full descriptions of the curriculum and the five thrust areas are found in Appendix G.

BACHELOR'S DEGREES

The demand for Bioengineering undergraduate training is high within the University of Washington. As mentioned, we will increase the number of undergraduate students in our program from 16 (Autumn 1999) to 40 in 2001, 100 in 2003, and 125 in 2005 as shown in Table 3. We will apply for ABET accreditation in 2007, the next available date (most likely) that the University of Washington College of Engineering will be reviewed (assuming that all of the engineering degree programs in 2001 receive NGR) after we produce our first BS degree in Bioengineering (BS BIOE) in 2003.

Table 3: Planned growth of the Department of Bioengineering

Academic Year	Undergraduate Students	Graduate Students	Tenure-track Faculty	Research Faculty	Staff	PostDocs
2000	20	120	17	12	54	18
2001	40	125	19	11	58	20
2002	70	130	20	11	58	21
2003	100	130	20	10	60	21
2004	110	135	20	10	60	22
2005	125	140	22	10	61	22
2006	140	140	22	10	62	23

Goal and Objectives

Goal

To send our graduates to doctoral programs in Bioengineering, medicine or MD/Ph.D. programs, and industry.

Objectives

1. To provide students with a solid foundation in mathematics, physics, chemistry, computer programming, engineering, and biology.
2. To train students to address and solve biological problems quantitatively.
3. To train students to apply engineering synthesis and analysis to solve biological problems.
4. To train students to glean design principles from nature to solve medical problems and innovate biomedical devices and materials.
5. To train students to communicate problems and their solutions effectively to physicians, biologists and other engineers.

Standards for Success.

Admission

We will admit our first BS BIOE students in 2001. In the beginning, the number of students will be relatively small (25 per year) and we will increase the enrollment as we receive more qualified applicants. We plan to actively market the newly developed BS BIOE degree program to UW freshman/sophomore groups and high school students.

Evaluation of Progress

Thirteen new courses will be developed for the BS BIOE degree program. Each of the courses stresses the application of engineering principles to biology and the use of biological principles in engineering. Students will be assessed as they complete each of their courses. At the same time, the courses will be evaluated to determine whether they fit the objectives enumerated above. If they do, the courses will continue with minimal changes. If not, the courses will be carefully evaluated and modified so that the objectives are achieved.

Evaluation in BIOEN 480W

One unique characteristic of our undergraduate degree program is that every student will be involved in research as an undergraduate student via 12-credit BIOEN 480W. This capstone research and design course (see Appendix G) will be used to evaluate learning on the part of the students. Each student will work closely with a faculty mentor. The students will undertake projects that solve either a Bioengineering problem or one of Bioengineering design. The students and faculty will develop milestones to assess progress. We expect weekly reports from each student. The reports will be evaluated to determine whether the students understand the basic concepts that support the project, whether they can apply Bioengineering principles to solve a problem, whether they can articulate the problem and their solution clearly and whether they are able to produce innovative solutions. The objectives articulated earlier will be the standards used to assess student and programmatic success.

Placement of Our Graduates

We will monitor where our students go after graduation with a BS BIOE degree and objectively assess whether we are achieving a balance among graduate school, medical school and industry, or if it is skewed too much toward one or two target areas.

Impeding Factors

Impediments to the undergraduate program are similar to those outlined in the section on the graduate school curriculum. One factor that may impede the successful development of an undergraduate program of high quality is the lack of adequate resources (faculty, TAs, staff, space and laboratories) made available to the Department of Bioengineering and a delay in completing the proposed Life Sciences II building.

Undergraduates in Research

(See *Increase in Undergraduate Research* under **RESPONSES TO CHANGE**)

State-mandated Accountability Measures

We have a small elite undergraduate program that has been focused on ensuring that students are able to attend medical school. In the new program, we have reduced the curriculum from 192 to 180 credits to help students get through more quickly (students going to medical school will complete 186 credits), and this program will be continually monitored and refined to reach the goals of the State.

MASTER'S DEGREES

The Department of Bioengineering offers four master's degrees: the MS (Master of Science), originally designed for students who stress the biological aspects of Bioengineering; the MSE (Master of Science in Engineering), originally designed for students who stress the engineering aspects of Bioengineering; the MME (Master of Medical Engineering), which is an evening program designed for practicing engineers in the medical device industry; and the BS/MSE, a simultaneous bachelor's and master's degree offered to students in our undergraduate program who spend an additional year to complete the master's degree. We plan to award a Master of Science in Bioengineering (MS BIOE), the MME, and the BS/MS BIOE. The plan recognizes that bioengineers must stress both engineering and biology. We believe that there should be no division between the two facets of Bioengineering. This unified MS degree in Bioengineering will eliminate the division and the confusion that can arise for both students and potential employers of graduates when different master's degrees are offered.

Goal and Objectives

Goal

To prepare students for careers in industry and Ph.D. programs in Bioengineering.

Objectives

1. To provide students with an in-depth understanding of mathematics, engineering principles, physics, chemistry, physiology and modern biology.
2. To train students to apply basic sciences to medical and biological problems, using engineering principles.
3. To train students to recognize and provide engineering solutions to clinical problems.
4. To train students to do Bioengineering research.
5. To train students to teach Bioengineering at the graduate and undergraduate level (mainly for doctoral students).
6. To train students to apply Bioengineering research to commercially viable problems (mainly for doctoral students).

Not all students need to be trained in all the above areas.

Standards for Success

Assessment

The Department follows the progress of students in the graduate program through the students' initial advisors, their supervisory committees and the Student Affairs Committee. Each student and his/her initial advisor prepare a preliminary plan of study as the student enters the program. By the end of the third quarter in the program, the student should be in the laboratory of a particular faculty member. The student and faculty member develop a long-term plan of study. Master's students seek faculty to serve as members of a supervisory committee that follows the particular student until he/she completes the program.

The student's plan is sent formally to the Student Affairs Committee, which is responsible to review and approve the plan, ensuring that it meets the requirements of our program and that the student is making satisfactory progress. Upon the approval of the Student Affairs Committee, responsibility to monitor progress is passed to the student's supervisory committee. As the student takes courses, the instructors monitor satisfactory progress and assess the performance of the students within the courses.

The final check takes place at the time of the student's final examination. The supervisory committee determines whether the master's research and corresponding thesis are satisfactory. The oral portion of the final examination allows the faculty to question the candidate broadly and to determine what has and has not been learned. Some students pursue the doctoral degree after completing their MS degrees, while others join industry or go to different institutions. Tracking them throughout their careers would give us one measure to assess whether our training has been effective.

While we follow the outline described above, we are continually reviewing the process and trying to better assess the training that we give our students. Some of the assessment techniques we are investigating are employer questionnaires and postgraduate questionnaires to the students.

Impeding Factors

The Department of Bioengineering reports to the School of Medicine and the College of Engineering. The collective wisdom of both organizations provides great benefit to the Department, but the complexity of dealing with both is a minor impediment to efficient operation. The cultures of the two differ in their approaches to the design of curricula and the way that student's progress through their programs. Despite the disadvantage of facing more complexity of administration of student programs, the advantages of a direct connection to colleagues and the Deans in both organizations outweigh the disadvantages by far.

A much more serious impediment to the progress of students and the efficiency of their programs is Bioengineering's spread over a large part of the campus. We are located in nine buildings and occupy 17 different locations in those buildings. Students must travel across large distances to visit individual faculty members and take advantage of their advice. Classes are spread in different locations. Student laboratories are in several different locations. When the development and construction of Life Sciences II is completed, this impediment will be eliminated.

The interdisciplinary nature of Bioengineering is a blessing. Students and faculty have depth of understanding of broadly differing aspects of the field that benefits the students as they progress through their graduate programs. The disadvantage of breadth is that entering students come from widely different fields. The majority of students come from undergraduate programs in engineering; others come from biology, chemistry or physics. The introductory courses in Bioengineering have been designed to accept students with disparate backgrounds, and faculty instructors typically spend several weeks at the beginning of each course reviewing fundamental principles.

We have redesigned the selection process to account for the disparity of student backgrounds. Students will be expected to enter our program with undergraduate courses in ordinary differential equations, linear algebra, instrumentation, signal processing, engineering systems analysis, thermodynamics, and biology. If they lack parts of this background, they will be expected to make up the deficiencies. We have designed appropriate prerequisites for our graduate courses. This will enable all students to take graduate-level courses with common understanding. Both teaching and learning should be enhanced as we admit better-trained students and ensure that they begin each course with common backgrounds.

DOCTORAL PROGRAMS

The Department of Bioengineering offers the doctoral degree to qualified graduate students. Indeed, the majority of graduate students (97/116) in our program seek the doctoral degree. The goal and objectives for the doctorate are listed above under **MASTER'S DEGREES**. The objectives remain the same; it is the depth and number of objectives achieved that distinguish doctoral graduates from those who earn the master's degree.

Goal and Objectives

(see above under **MASTER'S DEGREES**)

Standards for Success

Assessment

Assessment of the learning of our doctoral students is similar to that of the master's students, although more milestones in the process make the evaluation more thorough. Students are tracked from the time of their arrival in the program, through their course work and their dissertation research. Informal assessment follows the procedures described for the master's degree. Additional milestones include the Qualifying Examination and the General Examination.

In Bioengineering, the Qualifying and General Examinations include a written proposal, an oral defense and a question and answer period. The student is expected to request a Qualifying Examination during the second year of graduate study. The student declares his/her intention to take the Qualifying Examination and asks six faculty members to serve as an examination committee. The Student Affairs Committee chooses an examination committee of three, a chair and two members. The student's advisor sits on the examination committee as well, although as a non-voting member. The examination committee meets with the student, and then in closed session determines a set of questions for the student. The student is given the questions five weeks before the examination. The student chooses one question and writes an NIH-style proposal describing the way in which the scientific question can be answered. The student returns the proposal to the examination committee one week before the oral examination. At the oral examination, the student presents the proposal formally and then is questioned at length by the committee. The questions can cover any topic of Bioengineering.

The examination committee has the following options:

- The student passes unequivocally.
- The student passes and is required to complete an additional requirement before taking the General Examination.
- The student fails and is required to take additional courses before retaking the Qualifying Examination.
- The student fails.

A student who has passed the Qualifying Examination then moves forward to form a doctoral supervisory committee, complete and submit a student plan, and prepare for the General Examination.

The General Examination is the major examination in the career of a student. The exam has both written and oral components and topics are determined by the student's research plan. The Supervisory Committee of each student administers the General Examination. This supervisory committee is recommended by the Department and appointed by the Graduate School and consists of at least two core Bioengineering faculty, the student's advisor, and a Graduate School Representative. The purpose of this exam is to assure the student's potential to become an independent investigator. The suggested format for both the written and oral examination is as follows:

1. Brief summary of thesis plan
2. Review of pertinent literature
3. Summary of current work performed by the student
4. Evaluation of key issues to be addressed in future work
5. Detailed plan of work

The examination committee has the following options:

- The student passes the examination.
- The student passes the examination under the condition that some additional action be taken within a specified time.
- The student fails the examination and the Committee can advise the student to retake the examination only after completing some additional action.
- The student fails.

The Department follows the progress of students in the graduate program through the student's initial advisors, their supervisory committees and the Student Affairs Committee. Each student and his/her initial advisor prepare a plan of study as the student enters the program. By the end of the third quarter in the program, the student should be in the laboratory of a particular faculty member. The student and faculty member develop a long-term plan of Ph.D. study.

The student's plan is sent formally to the Student Affairs Committee, which is responsible to approve the plan, ensuring that it meets the requirements of our program and that the student is making satisfactory progress. Upon the approval of the Student Affairs Committee, responsibility to monitor progress is passed to the student's supervisory committee.

The final check of progress takes place at the time of the student's final examination. The supervisory committee determines whether the doctoral research and corresponding dissertation are satisfactory. The oral portion of the final examination allows the faculty to question the candidate broadly and deeply.

Whether our students become successful after graduation as educators, scientists, engineers, and entrepreneurs is an ultimate measure of the quality of our Ph.D. program. In addition to the one-on-one exit interviews with all the graduates by the Chair, we are reviewing the process and trying to better assess the training we give our students. Some of the assessment techniques we are investigating are employer and postgraduate questionnaires to the students.

Impeding Factors

The impediments to the success of the doctoral program are similar to those of the master's program. Briefly, the dispersion of the department severely limits the students' perception that students belong to Bioengineering. Indeed, they identify themselves more with particular laboratories. Unless their work requires collaboration across laboratories, they lose contact with other students and faculty in the Department. To increase the number of graduate students will require additional research and desk spaces for them as well as additional research funding to support the students and their Ph.D. research. When Life Sciences II is complete, we believe that most of these impediment will be eliminated.

As was stated in the discussion of the master's program, an impediment to the success of the doctoral program is the heterogeneity of our incoming graduate students. We have attempted to redesign the doctoral program to account for that heterogeneity and to establish expected background criteria and prerequisites for acceptable applicants. Both of these approaches should limit the level of the impediment to the future training of doctoral students.

RESPONSES TO CHANGE

TEACHING AND LEARNING CHANGES IN THE LAST TEN YEARS

Increase in Undergraduate Research

We strongly believe in the importance of undergraduate students being exposed to and involved in research. To take advantage of the main strength of the University of Washington, the quality and quantity of faculty research, and give our students the complete education and training, the undergraduate program in Bioengineering has included research opportunities for students since its inception. Students are required to do clinical and/or research lab rotations. We have expanded the concept, and the new undergraduate program includes a 12-credit capstone research/design course for our students. Dr. Joan Sanders, Associate Professor of Bioengineering, has mentored more than 30 undergraduate students including students from other departments since she joined our faculty.

UWEB has two programs to encourage undergraduate research. The first is the Undergraduate Scholars in Research Program (USIRP). The goal of this program is to provide a cross-disciplinary research experience to qualified and deserving undergraduate students for four quarters. The expectation is that each student will participate in ongoing research in a laboratory and then write a research paper that will be published in *The UWEB Journal of Undergraduate Research in Engineering.* They will attend selected lectures and workshops on ethics, and written, oral, and presentation skills. They also have the opportunity to be mentored by faculty, graduate students, and industry researchers.

The second research opportunity is the Summer Research Experience for Undergraduates. This is a program mandated by the NSF to encourage participation of students of color. This ten-week program brings seven students from other institutions from across the country and six or seven students from the University of Washington together to participate in ongoing research. It is important for students to develop a mentoring relationship with graduate students and faculty. Students also participate in a written and oral communication class and a biweekly Journal Club. They visit a UWEB industrial partner. They organize and participate in a poster session at the end of summer, and write a research paper that is published in *The UWEB Journal of Undergraduate Research and Engineering.*

Lab Rotations

During the past decade, the Bioengineering faculty began a system of laboratory rotations for entering graduate students. Students can spend one quarter within a laboratory. During that time, they work with the faculty, staff and students in the laboratory and often complete a project. The process helps students learn the process of research and clearly understand the work that is taking place in various laboratories before they decide to settle on a single lab. They finish rotations by the end of the third quarter of the first year of study, focusing on a specific lab.

Change From Pathways To Thrusts

Two years ago, Bioengineering faculty began a thorough review of the undergraduate and graduate programs in the Department. At that time, we pursued seven research pathways that we had followed since the mid-1980s. We decided to follow the developments of biomedicine and engineering and to define five thrusts in which the Department should lead the research and education over the next several decades. They are Distributed Diagnosis and Home Healthcare (D_2H_2), Engineered Biomaterials, Molecular Bioengineering and Nanotechnology, Medical Imaging and Image-Guided Therapy, and Computational Bioengineering. We will focus our research and graduate educational programs in areas where we have existing strengths and can build on them with new faculty to create unique graduate research and training programs of high quality for the benefit of Bioengineering as a discipline. Our undergraduate students will be able to participate in this program via their senior research.

More Cohesive Program Planned

Our past undergraduate and graduate programs have focused on the fundamentals of engineering, biology and medicine and on the research done in laboratories by our students. We have developed new undergraduate and graduate programs that concentrate more on Bioengineering while retaining the fundamentals of science and engineering.

The undergraduate program has a core of 36 credits of Bioengineering courses. The core exposes students to systems engineering and biology. The courses are defined from a systems viewpoint, so the students learn to analyze biological systems as engineering systems. They are given the tools of analysis and synthesis, and then shown how those tools can be applied to biology. Previously, fundamental courses in engineering and biology were given to students, but the connection between them was not made explicit. Courses were often drawn from other departments at the University rather than Bioengineering.

The graduate program was designed for students who came from a broad range of backgrounds. Accepting students with diverse backgrounds required that the introductory courses for graduate students start from a rather basic level. We have made entry requirements more specific, requiring both engineering and biological experience. Courses are being redesigned to begin at more advanced levels. Students can be expected to understand more about biology and to dissect biological information analytically.

Many Bioengineering undergraduate and graduate courses will be taught and there will be clearer paths through course sequences with well-defined prerequisites for each course. Research will continue apace in both the undergraduate and graduate programs. Students will leave both the undergraduate and graduate programs with a greater understanding of the synergy between engineering and biology. They will be shown that engineering can be applied to biology at the cellular, organ and systems levels. Finally, we will show students how basic biology and engineering lead to medical benefit.

New Developments

In June 1996, Dr. Lee Huntsman, who had been the Center Director since 1981, left Bioengineering to become the Provost of the University of Washington. Dr. Francis Spelman was appointed as Acting Director of the Center while a search was undertaken for a new Director.

In the spring of 1997, Bioengineering was changed from a Center to a Department. While the Center had been allowed to run academic programs, departmental status prepared it for a future, expanded academic role.

In March 1999, Dr. Yongmin Kim was appointed Chair of the Department of Bioengineering. He began an enthusiastic program to bring Bioengineering to the next level of excellence. Before he assumed his new role, the faculty of the Department of Bioengineering met to discuss a research and teaching plan for the future. The discussion led to the development of a cohesive plan for the future of Bioengineering (described above). The strategic plan has been described in detail in a proposal that we prepared and submitted to the Whitaker Foundation in April 2000 to seek a Leadership Award.

Fundamentals of the new developments were the design of a new undergraduate program and an expanded graduate program (see Appendix G). These new designs have the enthusiastic support of the College of Engineering, School of Medicine and Office of the Provost of the University. The support from the University of Washington includes, among other things, six new faculty positions (2 in 2000, 2 in 2001, and 2 in 2002) and returning the faculty positions from retirements and resignations to the Department at the same salary level.

Interdisciplinary Programs

From its beginning in 1967, Bioengineering has been a hotbed of interdisciplinary activity in a University whose hallmark is collaboration and enthusiastic interdisciplinary work. In the past decade, three developments increased the diverse capabilities of Bioengineering in a dramatic way.

1) **Bioengineering was awarded a Development Grant by the Whitaker Foundation** to begin the first program in Molecular Bioengineering (see **HISTORY OF THE DEPARTMENT**).

2) **UWEB was created** (see **HISTORY OF THE DEPARTMENT**). UWEB seeks to revolutionize ~~biomaterials~~ research and the application of biomaterials to human problems. UWEB has already changed the face of biomaterials research, built liaisons with industry and begun ambitious outreach programs to the lower schools. The graduate student population is burgeoning in biomaterials; several of our students have won national prizes for their work. UWEB is clearly an interdisciplinary center that helps advance the education and research programs of Bioengineering.

3) **Center for Nanotechnology was established** (see **HISTORY OF THE DEPARTMENT**). This interdisciplinary center has supported several of our students and contributes solidly to the research and teaching missions of the Department. Dr. Vogel was placed on the Presidential Committee of Advisors in Science and Technology to serve on the panel on Nanotechnology in 1999.

Distance Learning

Bioengineering has taken advantage of the technology for distance learning. Its weekly seminar course, BIOEN 599J, is broadcast live via the Internet and cable television. Lectures have also been available for review as video-on-demand via the Internet and can be viewed anywhere in the world. The College of Engineering has a program called EDGE (Engineering at a Distance for Growth and Excellence) that provides the technical expertise to enable this broad dissemination of engineering courses. We will take advantage of available on-campus resources and experience and apply them to other Bioengineering courses.

MME Evening Program

In Autumn 1996, in conjunction with UW Educational Outreach, Bioengineering began an evening educational program in Medical Engineering. The Master's of Medical Engineering Degree program was approved by the Graduate School in Spring 1999. The students come from local biomedical device industries and take classes in the evening. Course work for the master's degree takes four years; completing the thesis requires an additional year. The program has been offered through the University's Educational Outreach. The majority of students are funded by their employers while they participate in the program. As mentioned, one student in early 2000 completed all of her MME degree requirements.

Experiential Learning

We have long recognized the value of laboratory experience in the training of our students. Most of the new undergraduate and graduate courses have laboratory components while some will require final student projects in addition.

International Study

Although a large number of faculty members have international research collaborators, international study is not common for Bioengineering students. Several students have visited research laboratories outside the U.S. for a short period of time, e.g., one week.

Educational Technology

Several faculty members in Bioengineering use the Internet for delivering their courses and improving their effectiveness, e.g., broadcasting courses or implementing web-based courses. In addition, one of our faculty members, John Medina, developed classes in molecular biology for engineers that employ animation extensively. In 2000, Professor Medina received a teaching award from the College of Engineering for his work. We plan to take advantage of those developments, although we recognize that they are not panaceas (see impediments below). The promise of these developments is balanced by the time and efforts that it takes individual faculty members to make them work in their courses.

Plans to Maximize Effectiveness; Impediments and Their Reduction

Other developments on the "courseware" side include courses that are designed to teach teamwork among students and project-based courses. As was outlined above, quite a few new Bioengineering courses will be project-oriented. Students will work in teams to complete research, design, and development. Project-oriented courses facilitate students' learning of the subjects and obtaining valuable hands-on experience. We believe that it will increase our effectiveness in helping the students learn Bioengineering and Bioengineering research even though it will require additional effort from faculty and staff.

We also believe that technology can improve teaching effectiveness. An impediment to the effective use of technology is the amount of time and learning required of faculty to become fluent with new advances and put them to good use. The University of Washington has tried to overcome this impediment through its development of organizations, support people, and tools that assist and train faculty who want to move their course materials to the web.

In the case of technologies such as course animations, the time commitment by faculty can be immense. We have proposed to employ an Educational Technology Specialist to help faculty take advantage of the new technology. The specialist will be responsible to implement course materials in web-based presentations, interactive exercises and examples. The help of the specialist will allow faculty to concentrate on course content rather than on the mechanisms and protocols required to implement courses technologically. Currently, the specialist will be funded if the Whitaker Leadership Proposal is successful.

New Developments That Influence Research, Scholarly or Creative Activity

Revolutionary Advances

Earlier we described the revolution that began in Bioengineering as a result of its commitment and dedication to Molecular Bioengineering. This revolution nurtured the development of UWEB and the Center for Nanotechnology. A fundamentally new development that has just begun is a tissue engineering program under the sponsorship of the NIH. Dr. Ratner, a professor in Bioengineering and the Director of UWEB, is leading a Bioengineering Research Partnership program to develop autologous tissue for the heart. The tissue will substitute for infarcted tissue or, potentially, provide a permanent, compatible left ventricular assist device. The program is a collaboration between the UW Department of Bioengineering, the University of Toronto, Advanced Tissue Sciences and the National Institutes of Health.

Technology Entrepreneurship Certificate (TEC)

The Pacific Northwest is one of the nation's leading entrepreneurial communities. The Seattle region is the center of activity for technology-based start-ups as well as established organizations like Microsoft, Immunex, ATL, Medtronic Physio-Control, HP Heartstream, and Spacelabs Medical. The University of Washington was ranked first in 1997 in creation of start-up companies. The University of Washington's research germinates about a dozen companies each year, and the Department of Bioengineering is a leader of the University in the numbers of patents awarded and commercial licenses in the past.

The 1995 report, "Reshaping the Graduate Education of Scientists and Engineers," written by a joint committee from the National Academy of Sciences, the National Academy of Engineering and the Institute of Medicine, clearly stated the national need for science and engineering graduate programs to develop curricula for professional development. The report specifically recommended the development of training models to strengthen and broaden graduate students' career opportunities in business settings.

There are few models to train engineering graduate students in business principles and entrepreneurial practice. Most of the existing models represent management degree programs, such as master's degree programs, that are designed for students with technical backgrounds. The TEC Program is designed to be integrated into science and engineering training for our graduate students. Unique to the TEC Program is its emphasis on innovation and entrepreneurship instead of project management. Georgia Tech has the closest program to the TEC Program, offering a graduate minor in "Management for Bioengineers," but it does not integrate MBA students with engineering students, nor does it include a capstone business plan as a final project.

These factors, and strong student demand, led us to design the TEC Program. A key design element of the TEC Program is the inclusion of both MBA and technology students in the classroom and project-oriented settings. This ensures interactions between people with diverse perspectives and gives the students valuable experience to actively participate in and communicate at the interface of development in technology-based business.

Clinical Rotations

Medicine is a complex discipline with an increasing dependence on technology for diagnosis, e.g., MRI assessment of tumors, and treatment, e.g., brachytherapy and laser keratotomy. To help students to understand the ultimate goal of Bioengineering, the improvement of human healthcare, and ensure that our students gain an appreciation of the end products of their work, we are planning to initiate a clinical rotation related to their research interests. The clinical rotation will last one quarter: three four-week rotations or one three-month focused rotation in clinical departments. For example, a student who is working in Computational Bioengineering might choose a rotation in radiology, cardiology or endocrinology. Radiology would provide a clinical framework via Magnetic Resonance Imaging and Spectroscopy for the student's interest in the transport of metabolites in muscle. Cardiology could provide a foundation for the student's interest in the distribution of blood flow in the heart. Endocrinology could give the student an understanding of targeted drug delivery and its pharmacokinetics for the treatment of metabolic disorders. A student in medical imaging and image-guided therapy could spend the full quarter in Radiology, Neurological Surgery, Urology, or OB/GYN. The proximity of the School of Medicine makes this program practical since joint mentoring between bioengineers and physicians is not hampered by distance.

We have already begun a clinical rotation for one undergraduate student in the critical care areas of Children's Hospital. The collaboration is with Dr. Kenneth Schenkman, MD/Ph.D., a faculty member in Pediatrics, a graduate of UW Bioengineering and an adjunct faculty member of Bioengineering. We will expand this to include graduate students in the future.

Through this clinical rotation program, students will develop an awareness of complex healthcare systems and issues and an understanding of clinical needs by dealing with existing techniques and studying, analyzing and discussing potential future diagnoses and treatments. The rotation program will foster cross-fertilization between bioengineers and physicians. It is likely that collaborative research projects will blossom from the rotations and benefit both groups substantially. The rotation program will involve many clinical departments, e.g., Radiology, Cardiology, Surgery, Pediatrics, OB/GYN, Neurological Surgery, Orthopedics, Internal Medicine, and Laboratory Medicine. The clinical department chairs are enthusiastic about this initiative and collaboration opportunity.

Changing Paradigms

Bioengineering faces a dramatically changing world in both biology and medicine. The biological revolution has illuminated a nano-world of sub-cellular particles, molecular messengers and unraveled genomes. The healthcare revolution has on one side, exciting developments in diagnosis and therapy, and on the other side, shrinking budgets. Bioengineers are likely leaders to bring quantitation, computation and modeling to the biological world. Similarly, they will develop sensors and devices to improve diagnosis and therapy at reduced cost. Recognition of these changing patterns and the potential role of future bioengineers in their logical development led us to the five thrust areas that we have chosen for our future research and education foci.

Indeed, these thrust areas represent the most dramatic paradigm shift of the most recent years and a development for the near and far future. Distributed Diagnosis and Home Healthcare will focus research and training on the development of systems that can improve healthcare at lower cost and with greater convenience. Engineered Biomaterials will take the results of modern biology and apply them to the design and development of new implants and tissues. Molecular Bioengineering and Nanotechnology will provide the basic knowledge that enables engineers to develop new devices, sensors and materials. Medical Imaging and Image-Guided Therapy will seek to improve non-invasive diagnosis and therapy, reducing the costs of both the detection and treatment of disease. Computational Bioengineering will provide the tools that systematize biology and apply newly understood biological principles to the treatment of disease.

Changing Funding Patterns

The Whitaker Foundation has been the greatest player in the growth of Bioengineering funding during the past decade. The Foundation has led the establishment and growth of several dozen Bioengineering programs. The largesse is soon to end. The founders of the Foundation mandated that it end in 2006. Thus, many bioengineers must seek other funding in the future.

The University of Washington was an early beneficiary, receiving the Molecular Bioengineering Development Award in 1989 ($4.5 million). The Award was extended in 1997. We hope to receive a Leadership Award of approximately $20 million to start the design and construction of Life Sciences II in late 2000.

Bioengineers organized the American Institute for Medical and Biological Engineering (AIMBE) in 1992. Several of our faculty members are Founding Fellows. AIMBE is a policy-making organization that seeks to improve Bioengineering nationally. In 1999, after extended work by AIMBE, the NIH formed an Office of Bioengineering, Bioimaging, and Bioinformatics. Another development after the work of AIMBE was the establishment of the major Bioengineering Research Partnership (BRP) grants in the NIH. We are fortunate to have garnered one of the first BRP awards in cardiovascular tissue engineering. Our NIH funding increased from $5.67 million in 1994-1995 to $8.26 million in 1999-2000.

The National Science Foundation has long supported individual bioengineers in their investigations. In the latter half of the last decade, several Engineering Research Centers were funded with a focus on Bioengineering. UWEB is one of those centers. As a result, our funding from NSF increased from $585K in 1994-1995 to $2.83 million in 1999-2000.

Industrial funding within the Department has increased significantly from $415K in 1994-1995 to $1.51 million in 1999-2000. Notable is funding from small firms, e.g., Micronics and Biomolecular Switches, for Drs. Yager and Stayton's laboratories, and large firms, e.g., Siemens, Canon, and Hitachi, with Dr. Kim, and Applied Tissue Sciences with Dr. Ratner. Some of this industrial funding is the result of the federal government's funding of industry-University projects through the mechanisms of STTR and BRP.

In summary, the funding prospects for Bioengineering as a discipline are excellent. Despite the finite life of the Whitaker Foundation, other organizations recognize the productivity and innovation of bioengineers and support Bioengineering research eagerly.

New Technologies

New technologies that have influenced Bioengineering and will continue to influence activities are changes in teaching, research and technology transfer. We described some of the changes in teaching above. They include electronic, computing and communications technologies and increased understanding of the processes of teaching and learning. The technologies provide challenges. Bioengineering can face the challenge. First, the faculty and students are enthusiastic and energetic. Second, the University of Washington provides several centers whose foci are on teaching and learning and the development of teaching technologies.

As mentioned, the biological and healthcare revolutions provide opportunities for new technologies: sensors, systems approaches to biology, computational techniques, telemedicine and electronic medical records, imaging at cellular and molecular levels, materials, surface understanding and analysis. The faculty and students in Bioengineering are actively engaged in the leading edges of these research areas.

Technology transfer of intellectual property is an increasing enterprise within all universities and certainly within the University of Washington. The infrastructure at the University of Washington is currently inadequate to support this endeavor, resulting in slow progress, lost opportunities and increased level of frustration. The Department of Bioengineering is and intends to remain one of the UW leaders in technology transfer.

Measures of Performance

Research funding, publications, patents, honors, awards and professional leadership are our measures of performance, and Bioengineering has been at a high level of performance in each of these areas in the past decade. We expect that the Department's success will continue.

SERVICE

University of Washington

Seven of the core faculty members in the Department have served on 11 University-wide committees in the past three years.

Discipline or Profession

Fourteen members of the Core Faculty have served on editorial boards, the boards of professional societies, review panels and conference committees during the past decade. The service has spanned 72 different boards, panels, editorial boards and review boards.

This service, along with the excellent research that has been done by our faculty, has led to their election to the highest grades in their professional societies and to their receipt of many awards. Some of the awards and honors have been described previously.

The Broader Community

Bioengineering has engaged in outreach to the local and more distant communities. Dr. Stayton encouraged our graduate students to prepare presentations for local K-12 schools, a program that culminated in two GAANN awards from the U.S. Department of Education to formally support the activity. Students prepared materials and provided classes for local schools.

In 1994 and 1999, the Department of Bioengineering provided the Chair and a large number of laboratory leaders and guides for the Biotech Day of the Institute for the Academic Advancement of Youth. The Institute is part of Johns Hopkins University, and the UW School of Medicine has been selected as a focal location for the program. The day brings students and their families to the UW for introductory and closing lectures and morning and afternoon laboratories. The junior high students are exposed to science, engineering and the opportunities available to them.

UWEB has an active outreach program and many faculty members from Bioengineering have been participants. In particular, faculty invited teachers into their laboratories to prepare teaching modules for junior high students. Modules on angiogenesis and cochlear implants were prepared last summer and tested over the past year.

The Department's faculty are both permanent and ad hoc members of NIH study sections, NSF panels and review boards of the Whitaker Foundation, as well as centers and departments at other universities, e.g., Stanford, Michigan, UCSD, UCLA, Johns Hopkins, Wisconsin, and the Cleveland Clinic.

Bioengineering participates actively in the open houses of the College of Engineering and the School of Medicine. Similarly, Bioengineering faculty members participate in the Health Sciences Tour Program, a program that brings high school students into laboratories in the UW Health Sciences.

Editorial Boards

Bioengineering faculty members are active reviewers and members of the editorial boards of professional journals. Faculty members review manuscripts; six faculty have been or are members of editorial boards or serve as journal editors.

Measures of Success in the Above Areas

Measures of success in the areas described above include the numbers of requests for service and the times that requests are made repeatedly. We have not tracked these numbers precisely. However, there is no question that the Department has been successful considering that the majority of senior faculty have achieved the highest ranks of their professional societies; six serve or served on editorial boards; virtually all have participated in the UW open houses that serve about 2,500 people whenever they are held; the GAANN award was renewed, an unusual occurrence for a grant from the Department of Education.

ANTICIPATED CHANGES IN THE NEXT TEN YEARS

Faculty Retirements

As mentioned, we face a graying of our distinguished faculty. With fourteen state-funded faculty members at present (the number of tenure-track faculty positions will increase to 22), we face the potential retirement of four faculty members within the next six years. The UW Administration recognizes the potential problem this presents and has granted Bioengineering the permission to retain the faculty positions with full salaries rather than returning them to the Provost's Office.

Bioengineering has factored the potential retirement of older faculty and the recruitment of new faculty into its strategic plan. New hires will nourish the five Thrust Areas that we have planned for the future of the Department. Two or three new tenure-track faculty members are likely to join the Department by March 2001.

Increasing Numbers of Undergraduates (new program)

We expect that the demand for undergraduate training in Bioengineering will increase. To face the demand, we have planned our new undergraduate program, a program that will grow to a level of 60 students per year and a total of 140 students in 2006.

Increasing Demand for Graduate Programs for Professionals

The development of the Master's of Medical Engineering (MME) meets an expected demand by local practicing engineers for enrichment and further training to improve their understanding of Bioengineering, medicine and biology. With the growth of the medical device and biotech industries, engineers with more traditional training are likely to need training and research in Bioengineering. MME is designed to address this need.

Doctoral Training for All Four-Year Institutions (Future Faculty Training)

Many doctoral graduates would like to pursue academic careers in research universities. This trend is likely to continue, perhaps to increase, over the next decade. With a limited undergraduate program, there have been minimal opportunities for our graduate students to teach. We recognize this and have organized a program of Future Faculty Training (FFT). The program will give our graduate students pedagogical training, opportunities to teach and develop new course offerings. It will prepare them for careers in both research institutions and teaching-oriented institutions. With the development of our BS BIOE degree program, our graduate students will be provided with expanded opportunities to participate in course development and teaching.

Doctoral Training for Industry

A substantial fraction of our doctoral graduates take industrial positions in their first post-graduate appointments. More move into industry several years after their graduation. With increasing opportunities in the medical device and biotech industries, the trend is likely to continue during the next decade. The Technology Entrepreneurship Certificate (TEC) will train our students to lead start-up companies and to manage/develop research and development growth projects in larger organizations.

Technologies for Research and Teaching

Bioengineering research faces increasing opportunities in biology and medicine. The new century is often defined as "The Century of Biology." Bioengineering research veers toward biology in UWEB and in the new thrusts that have been defined for the Department. The new thrusts ask two types of questions: (1) Can a deeper understanding of biology lead to a better diagnostic device? (2) Can a deeper understanding of biology lead to better treatment?

Synergistic with biological growth is a realization that computational power can shed light on biological understanding, diagnosis and treatment. "Smart" instruments can sense biological variables that are incomprehensible to human observers. Engineering systems analysis can dissect biological data and make them powerfully predictive.

Bioengineers have the skill and training to develop analytical and computational techniques that, paired with new biological understanding, can produce better medical treatment at lower cost. It is our responsibility to ensure that our graduates learn how to understand biological systems and analyze them quantitatively and precisely. The new curricula at the undergraduate and graduate levels are designed to provide that learning to our students.

The developments in research concentrations in Bioengineering will be accompanied by additional developments in our curriculum as well. Web-based technology has been and is used by faculty in Bioengineering to facilitate learning within their courses. Both Bioengineering and the University of Washington are making the integration of course-based technology easier. A new Engineering Research Center of the NSF, centered at Vanderbilt University, focuses directly on learning in Bioengineering. Professor Thomas Harris, the Director of that Center, is a long-time collaborator with Dr. Bassingthwaighte, who is the next Chair of Bioengineering's Curriculum Committee. We will stay abreast of the developments in the new educational center to incorporate their findings in our program.

Pressure on Space

Growth of faculty and students requires contiguous space of greater area. The strategic plan proposes to move Bioengineering into new space by 2004. With the completion of LS II, we will move substantially toward solving our space problems.

Pressure on Budgets

Pressure on the budget of the UW is likely to increase during the next decade. The imaginative idea of the UIFs has already required UW departments to reduce their budgets. The trade has provided UW with several exciting opportunities. Still, reduced budgets or even level budgets force reductions in staff and services. The pressure may be relieved by the development of intellectual properties that would return more income (than the current UW distribution policy allows) to the departments where the intellectual properties were generated. Bioengineering is in a good position to take advantage of this approach. Furthermore, the Department will be organizing a development program to bring new funding from private sources.

Demand for Accountability

The next decade will likely increase the demand for accountability. The benefit of a focus on results is that better graduates, greater research funding, more intellectual property and increased satisfaction for personnel will accompany it. The difficulty is the increased workload tracking and reporting produced. Generally, the benefits exceed the difficulty. The Strategic Plan of Bioengineering develops strategy for the continuous improvement of the Department that will benefit students, faculty and staff.

College/UW Assistance

The School of Medicine, College of Engineering and UW Administration can help most by bringing all of Bioengineering into one location. This strategy would provide several key improvements, among them better mentoring of our students, more synergistic research, increased collaboration, more efficient administration, and improved communication between students, faculty and staff.

Another way the University of Washington could help greatly is to increase the level of state support for faculty salaries. As mentioned, The Department of Bioengineering consistently ranks in the top 5 programs in the nation and most senior faculty members are at the highest grade level of their professional societies (NAE, AIMBE, BMES, IEEE, AVS, others). However, faculty salaries in the Department of Bioengineering are lower than their colleagues at other Universities whose programs have inferior rankings.

Lastly, strong support from the University for our new educational initiatives is critical. With the new undergraduate program in Bioengineering and expanded graduate educational program, in the next five years, the Department will experience much growth and change, which will be very difficult. However, if the University is committed to provide the Department with sufficient resources, while minimizing the possibility of lowering the quality and productivity of our leading research, we are confident that we will be able to achieve success.

DEMOGRAPHIC CHANGES

The number of underrepresented minorities who would like to enter the professional work force will increase during the next decade. As of Autumn 2000, we have 9% full-time minority students in our graduate program and are hoping to increase this percentage. We have followed a plan to attract underrepresented minorities to our program. Some limits on this activity have been imposed by the passage of I-200, an initiative that reduced the options of the University to focus on diversity.

Inclusive

Faculty and black students have traditionally visited black schools. We have sent representatives to Prairie View College in Texas and to North Carolina A&T. We continue to recruit at these schools and expand our recruiting to Florida A&M and Howard University. These schools graduate the largest numbers of black engineers in the U.S.

Meet with Engineering Groups of Underrepresented Minorities

The Chair and Vice Chair have spoken before the minority students' engineering societies. We will continue to do so, and with greater vigor as the new undergraduate program grows.

Name-exchange Lists and Recruitment Fairs

We employ the Name-exchange Lists and names obtained in various recruitment fairs sent to us by the Graduate Opportunities and Minority Achievement Division of the Graduate School. We send recruitment materials inviting students to apply to our graduate programs in Bioengineering. We will continue this practice.

Additional

Our outreach activities extend to the K-12 schools throughout the Puget Sound region. We are preparing advertising materials for our new undergraduate program to distribute to students and advisors in these schools. We will recruit actively for early acceptance into our undergraduate program, considering up to 25% of each entering class as eligible for direct admission as they leave high school and enter the University of Washington.

Minority Students in the Department

All students are included in the Department's life. Minority students participate actively in laboratory rotations and the research in Bioengineering laboratories. Counseling for students is provided when they request it. Minority students sit on the Student Advisory Committee.

PRODUCTIVITY OF FACULTY

Encourage Faculty Productivity

The Strategic Plan of the Department of Bioengineering includes additional support from the UW. The plan improves the quality and increases the size of the undergraduate and graduate programs. Teaching productivity must increase since teaching responsibilities will increase; research productivity must increase or at least remain the same.

The University of Washington recognizes the needs of the Department and has committed faculty, TA and staff support. The support is tangible evidence of the University's approval of Bioengineering and its Strategic Plan.

The faculty will grow from 14 to 22 between 2000 and 2006 (two are currently open positions and six are new faculty positions). Three teaching assistantships as well as a 50% technical staff person will be provided to Bioengineering in Autumn 2000. Three additional TAs will be provided in 2001. A new Undergraduate Academic Counselor and two secretaries will be added in 2001. A technician will be hired in 2003.

The increase in faculty will improve productivity by at least 37.5%, by virtue of sheer numbers. Collaborative efforts and team teaching will likely help productivity grow beyond that number. Additional TA and staff support will support the new teaching programs of the Department. This will allow faculty to develop new teaching materials, methods and laboratories, and train graduate students to teach. The planned technical assistance will release faculty from some of the mechanics of maintaining laboratory courses, freeing them for course development and teaching enhancement.

The faculty and staff support that the UW has committed will encourage the faculty greatly and likely increase their teaching and research productivity.

Mentor Junior Faculty: Assign Mentors

We assign mentors to junior faculty in the tenure-track and research ranks. The mentors meet regularly with junior faculty to discuss strategies to improve teaching and increase research productivity. Mentors offer advice and review grant proposals at the request of the junior faculty.

Impediments To Faculty Productivity

The dispersion of the Department is a serious impediment to faculty productivity. Many of our faculty members have offices in one building and laboratories in another. Some faculty members have multiple laboratories in different buildings. The constant travel is inefficient, time consuming and demoralizing. Contiguous space would solve the problem.

The level of bureaucracy within the University of Washington has increased over the past decade. Faculty members are held accountable for minutiae of research budgets, safety, travel, personnel issues and interminable reporting. The requirements take time, sap energy, and reduce morale and productivity. Streamlining such functions or providing each department with staff to manage these problems would increase productivity.

Intellectual property issues are a morass. Faculty members must be attorneys, accountants, managers and researchers as they enter the minefield of technology transfer. The UW process is very inefficient; fundamental restructuring with streamlining and additional staffing are absolutely needed in addition to proper faculty training.

Faculty members are trained to be excellent researchers and teachers. When they embark on their academic careers, they find themselves immersed in personnel issues. Management and leadership training for faculty would benefit them as they progress through their careers.

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Overcoming Impediments

(See comments with each point above)

PRODUCTIVITY OF STAFF

Encourage and Preserve Productivity: Training Classes and Awards

The Department of Bioengineering has encouraged its staff to take classes through the University's Staff Training Program. Seven staff members have taken classes that include workshops on leadership, administration, contract language, grants management and understanding the use of database software.

Recognition

The Bioengineering staff was recognized as a whole by the College of Engineering when they were nominated for and won the College Staff Award (1997). Individual staff members have been nominated for a variety of various awards, ranging from the departmental level to the University level. Individual faculty and the departmental administration have tried to recognize and reward the work of the staff.

Programs for Professional Development

The Department of Bioengineering does not have internal programs for professional development. However, the Department encourages staff to attend professional classes for staff, and has supported staff who take University classes through the staff education program within the UW.

GOALS

GOAL SETTING PROCESS

In 1998 and 1999, the faculty, staff, and students had numerous meetings and discussions to map the future of the Department of Bioengineering. Through this process, we established goals, on which the Whitaker Leadership Proposal was developed. Also, they became the foundation of the departmental strategic plan. The strategic plan discusses the restructuring of the Department and the new educational programs and research thrusts.

Reviews

Bioengineering reviews its plans continually. We are implementing the proposed educational plan in the Whitaker Proposal by Spring 2003. Careful review and necessary modifications will continue as we evaluate the early benefits and detriments of the plan.

Changes in the Next Ten Years

The faculty and staff discuss the state of the Department annually at the Faculty Retreat, held prior to the start of Autumn Quarter. In the retreat, we discuss critical issues and the changing landscape of the field of Bioengineering. We consider the implications of the change of the field and discuss how the Department can be improved further, e.g., how our teaching and research programs should be focused on those changes that are significant.

GOALS FOR THE NEXT 5-7 YEARS

The long-range goal for the Department of Bioengineering at the University of Washington is to become a model, full-service bioengineering department, striving for the highest levels of excellence in research, education, services, clinical applications, and technology transfer.

This goal leads to four specific aims for our Department in the new millennium:

- **To develop outstanding undergraduate and graduate educational programs to prepare our students for careers in industry, academe and government.** We will launch, for the first time, a modern full-service undergraduate Bioengineering program. To accommodate the increased teaching requirements of the Department, we will hire new faculty and staff, and our teaching load will increase modestly. In addition, our graduate students will have a chance to be active in teaching via teaching assistantships.

- **To enhance our place as one of the best Bioengineering research departments in the world.** This requires that we build on our internationally recognized strength in research. To this end, we will renew and expand our faculty with engineers and scientists who are uniformly top-notch researchers. We plan to add 12 new faculty in the next 6 years through a combination of new positions and replacements of retiring faculty.

- **To develop integrated research and education programs in five Bioengineering thrust areas: D_2H_2, Engineered Biomaterials, Molecular Bioengineering and Nanotechnology, Medical Imaging and Image-Guided Therapy, and Computational Bioengineering.** We will focus our research and graduate educational programs in areas where we have existing strengths and can build on them with new faculty to lead the fields and create unique graduate training programs for the benefit of bioengineering as a discipline. Our undergraduate students will be able to participate in this program via their senior research.

- **To construct a building in which the expanded role of Bioengineering can flourish.** A new building, the first space dedicated to the Department of Bioengineering, will provide a common meeting place, enhance the efficiency of teaching in the Department, particularly for the new undergraduate program, provide instructional and research laboratories, offices for faculty, students and staff, academic advising, and administration.

The four specific aims will be carried out by implementing the tasks outlined below.

- To create a baccalaureate degree program in Bioengineering and expand our undergraduate population from 16 students (Autumn 1999) to 100 by 2003 and 140 by 2006.
- To expand and improve our graduate curriculum in order to give our students a well-balanced education in Bioengineering and enlarge our graduate population from 116 students (Autumn 1999) to 130 by 2003 and 140 by 2005.
- To develop and nurture a new program on distributed diagnosis and home healthcare.
- To capitalize on our existing world-class program in engineered biomaterials by adding a new program in cardiovascular tissue engineering.
- To further enhance our unique program in molecular bioengineering and nanotechnology with new programs on drug delivery and molecular biomechanics.
- To establish a leading program in medical imaging and image-guided therapy, in which education and research are closely integrated.
- To expand our program in computational bioengineering, to prepare for its more central role in future Bioengineering education and research.
- To establish a unique training program in technology transfer and entrepreneurship for graduate students in Bioengineering.

Additionally, we will work closely with the School of Medicine, the College of Engineering, and the UW Administration including the Office of Development to facilitate the design and completion of Life Sciences II.

College/UW Assistance

The University of Washington can help the Department of Bioengineering by providing additional faculty positions, developing contiguous space for departmental use (and interim space for new faculty until Life Sciences II is completed), increasing staff support, providing start-up funds for new faculty, proactive development efforts to raise more resources for the Department in addition to the support for Life Sciences II, and reducing the bureaucratic burdens that are imposed on faculty as they do research, teaching and perform service.

More Faculty

Earlier in this self-study we discussed the development of expanded curricula and research programs in Bioengineering. The present tenure track faculty will not be able to teach all of the proposed classes while maintaining our excellence and productivity in research. However, the University of Washington has recognized this need and will support the recruitment of 12 new faculty over the next six years. Six new faculty positions will expand the faculty in the Department; four will replace older faculty who plan to retire in the next six years; one is currently an unfilled position; one faculty resigned on July 3, 2000. The University is realistically recognizing the need and has made definite plans and commitments to satisfy it.

Space

The most pressing limit to the growth and development of Bioengineering is space. The space available is adequate to the present faculty, staff and students, but will not support the growth in population and excellence that we plan during the next decade. The University of Washington recognizes the problem and is working assiduously to solve it. In 1998-99, the University sponsored a pre-design of Life Sciences II-III. Bioengineering will occupy Life Sciences II. The University has been developing a means to finance the building. This financial plan will be tremendously aided by the success of the Whitaker Leadership Award.

The site visit is scheduled on November 13 and 14, 2000. UW support is enthusiastic and solid. Our space problems are being faced and should be solved, we hope, within the next four years.

Staff

Bioengineering needs staff support to make its new curricula work and to support the expansion of its education and research programs. The University of Washington recognizes the need and has committed clerical, technical and TA support for our new curricula in the next three years.

Start-up Funds

The University will provide start-up funds of $3 million for the new faculty hires. If the Whitaker proposal is successful, we hope to receive an additional $1.4 million from the Whitaker Foundation. Although it is not sufficient, this level of support is absolutely needed to be able to recruit excellent faculty candidates, at both junior and senior levels.

Challenge for UW: Space, Start-up, Staff, Reduce Burdens on Faculty, Reduce Bureaucracy

The University of Washington provides valuable tangible support to the Department of Bioengineering. It is in the area of intangibles that both UW and Bioengineering are challenged. As a state institution, UW is burdened with innumerable regulations and restrictions that limit what faculty and students can do. The onus is placed on the faculty and Department to meet the needs for requesting and reporting in response to regulations and their interpretations. This burden diverts us from more appropriate tasks such as teaching, advising or research. We hope that the University will actively seek ways to reduce the bureaucratic limits placed on the faculty and Department.

The Department of Bioengineering faces opportunities and challenges and has planned to take advantage of opportunities and overcome the challenges with exciting new plans. The University of Washington recognizes the need and the benefits that will accrue to the State of Washington and to the University if Bioengineering succeeds. Support is enthusiastic, strong and timely. We strongly believe that Bioengineering will continue to thrive and increase its excellent quality in the near and long term.