ANNUAL REPORT

BIOMEDICAL ENGINEERING DEPARTMENT

Boston University

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by

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TABLE OF CONTENTS

Table of Contents i
List of Appendices ii
Executive Summary 1

1. Overview 2
   1.1 AY 97/98 Achievements 2
   1.2 AY 98/99 Goals 4

2. Personnel 5
   2.1 Faculty Recruiting 5
   2.2 Academic Faculty 5
   2.3 Administrative Staff 6
   2.4 Technical Staff 6

3. Research and Publications 6

4. Academic Programs 8
   4.1 Graduate Program 8
   4.2 Undergraduate Program 17
   4.3 Teaching Activities 21

5. Facilities and Equipment 22
   5.1 Teaching and Computer Laboratories 22
   5.2 Department Research Equipment 22
   5.3 Space 22
   5.4 Computer Upgrades 22

6. Future Plans 23
   6.1 Faculty Recruiting 23
   6.2 Program Development 23
      6.2.1 Graduate Program 23
      6.2.2 Undergraduate Program 24
   6.3 Equipment 24
   6.4 Physical Plant Issues 24

Appendices
List of Appendices

A Faculty
B Faculty Research Interests
C Faculty and Student Publications
D Faculty Awards and Patents
E Grant and Contract Funding and Proposals
    Funded
    Submitted

F Seminar Series
    Bioinformatics Workshop
    Biomechanics Seminar Series
    Biomedical Engineering BE 790 Seminar Series
    Biomedical Engineering Industrial Seminar Series
    Brain and Vision Research Seminar Series
    FA Bourke Distinguished Lecture Series in Biotechnology
    Center for Biodynamics Seminar Series
    Hearing Research Seminar Series
    Molecular Biology and Biomolecular Engineering Seminar Series
    Neuromuscular Research Center Seminar Series
    What’s Cool in BME

G Program Statistics
H Application Evaluators
I GRE/GPA Averages
J Background Comparison of Admitted Applicants 1998 vs. 1997
K Graduate Student Funding
L Graduate Student Awards
M Student Travel Awards
N Ph. D. Dissertation and Prospectus Defenses
O M. S. Thesis Defenses and Proposals
P Current Ph. D. and M.S. Students
Q Ph. D. Degrees Awarded
R Qualifier Timetable
S BME Qualifier Exam Information
T Advisor’s Progress Report
U BME Graduate Student Winter Symposium
V Undergraduate Program Statistics
W Undergraduate Program Planning Sheets
X Undergraduate Alumni Survey
Y Proceedings of the BME Senior Project Conference
Z BME Teaching Summary Statistics
EXECUTIVE SUMMARY

The department of Biomedical Engineering continues to progress toward its goal of becoming the best Biomedical Engineering department in the country. The past year has been highlighted by our success in building our bioinformatics program and most visibly by the completion of the Center for Biodynamics and construction of the Cellular and Subcellular Biomechanics Laboratory.

The department was a major participant in the Boston University effort that won a NSF IGERT award to help develop our growing bioinformatics program. This will enable us to establish a post graduate program in bioinformatics. We are currently recruiting new faculty in this area and have already developed several courses and sponsored an industry workshop, which we will expand to include teachers this year.

Dr. Joyce Wong has joined the BME faculty and will complement our already robust cell mechanics group including Professor Evan Evans and Micah Dembo. The Cellular and Subcellular Biomechanics Laboratory will complete renovations in the fall and these faculty will then establish the laboratory needed to continue to grow their own research programs and also create new state of the art teaching facilities in cellular mechanics.

The Departmental Advisory Committee met for the second time. They were impressed by the department and made the suggestion that we compete for a Whitaker Foundation leadership award. This would not only bring prestige to BME but also $10-$20M into the department. All of the faculty will be brainstorming to put together the best proposal possible in the coming year.

The Biomedical Engineering faculty continues to be among the most productive on campus in terms of attracting external research funding. External grant funding for our research programs for 7/1/97 - 6/30/98 totaled $8,496,450. For the past four years our total grant funds have been above the $6M mark, and they are continually moving upward.

Our graduate and undergraduate programs remain strong. The Accreditation Board for Engineering and Technology (ABET) completed the departmental evaluation and from preliminary comments recertification of our undergraduate program for the next five years is almost a certainty. Our graduate program continues to be progressive and energetic, and with our Department’s increasing stature in the national and international community we find ourselves competing for the very best graduate students. To continue to improve and be attractive to these students we must have the help of the College and University to find innovative ways to provide better financial aid packages so that we are not competing at a disadvantage with other top schools.

Our successful academic and research programs have benefited from and continue to need College and University support for faculty recruitment. With our departmental goal of hiring one new faculty member each year we will need further support to renovate space to accommodate them. We are currently working to devise an alternative to the current “buyout” policy to alleviate the problem of faculty feeling pressured to cover academic salary with research funding, thus depleting available resources for student and postdoctoral research.
1. OVERVIEW

The Department of Biomedical Engineering (BME) was formed in 1966 and functioned predominantly as an undergraduate teaching department until the early 1980s. In 1978, the department had only two full-time faculty. Since then, BME, through its own efforts and with the cooperation of the BU administration, has increased its faculty by a factor of ten, increased its annual grant expenditures to $8.4M from next to nothing, and led the College along the path to becoming a research-oriented engineering school with a strong interdisciplinary flavor in all four of its departments. The number of undergraduate BME majors is among the largest in the country. BME research is carried out in departmental laboratories like the Brain and Vision Research Laboratory, Cell and Tissue Mechanics Laboratory, Fields and Tissues Laboratory, Molecular Engineering Laboratory, Neuronal Dynamics Laboratory, Respiratory Research Laboratory (RRL), Respiratory Systems Analysis Laboratory, Subcellular Biomechanics Laboratory, and Visual and Circulatory Biophysics Laboratory as well as in five affiliated research centers, the Neuromuscular Research Center (NMRC) the Center for Advanced Biotechnology (CAB), the Biomolecular Engineering Research Center (BMERC), the Hearing Research Center (HRC), and the newly formed Center for Biodynamics (CBD).

Since 1990, the BME Department has continued to increase in size and strength not only by recruiting additional biomedical engineers but also by augmenting its engineers with selected faculty from the physical and biological sciences. BME currently enjoys flourishing and vibrant undergraduate (BS) and graduate (M.S. and Ph.D.) programs and participates in BS/MD and MD/Ph.D. programs with the Boston University Medical Center (BUMC). BME collaborates with many medical institutions in addition to our own Boston University School of Medicine (BUSM) and Boston Medical Center. The department presents a unique, state-of-the-art approach encompassing a wide spectrum of length scales spanning from the molecular and cellular levels through the whole-organism functional level.

The past year has been a time of great activity in the Department. Our new biomechanics faculty, Evan Evans and Joyce Wong, are now resident and overseeing the renovation of 5000 sq. ft. of space in 44 Cummington into our new Cellular and Subcellular Biomechanics Laboratory to be operational by fall of next year. We are continuing our growth by starting recruitment for a new faculty member in the field of Bioinformatics and another faculty member in the area of Biomechanics. We achieved a tremendous boost in out goal of becoming a world leader in the Bioinformatics field with the awarding of an IGERT Grant from the National Science Foundation to fund a graduate program in Bioinformatics. Two of the faculty, Temple Smith and Zhiping Weng, have taught newly developed Bioinformatics courses: Bioinformatics, Biological Database Analysis, and DNA and Protein Sequence Analysis. The department sponsored a workshop in Bioinformatics for industry in the summer of 1997, and will run a similar workshop for teachers this summer.

1.1 Academic Year 1997/1998 Achievements

Held second meeting of the department’s External Advisory Committee.

Completed Accreditation Board for Engineering and Technology review of the BME undergraduate program.
Received approval to expand Professor Vaina’s and Dean DeLisi’s Whitaker Special Opportunities preliminary grant proposals to full proposals.

Received an IGERT award from the National Science Foundation to help us develop our Graduate program in bioinformatics.

BME Chair started meeting periodically with the Chairs of the Chemistry and Biology departments to try to more closely coordinate interdisciplinary programs in academics and research, to better take advantage of training awards, and to try to compete better for this type of funding.

There are currently 67 students in the BME graduate program (43 Ph.D. students, 22 MS students, 2 MD/Ph. D. students). The Ph.D. program has 28 US students and 17 international students. The MS program has 22 students, 17 US students and 5 international. There are 12 female Ph.D. students and 11 female MS students.

Three of nine applicants accepted offers during fall recruitment.

14 new Ph. D. students matriculated in the fall 1997 with an average total GRE score of 2082, with a 3.5 GPA and 11 new Ph. D. students are anticipated this fall who have an average total GRE score of 2046 and 3.7 GPA.

15 new M. S. students matriculated in September 1997 with an average GPA of 3.4 and GRE total of 1998. 11 new M. S. students are expected September 1998 with an average GPA of 3.3 and average GRE total of 1903.

Restructured the Ph. D. qualifying exam and schedule with the goal to establish clear guidelines for the design of individualized Ph.D. programs, to provide each student with choices that optimize his/her experience in BME within the department’s current areas of research specialization, and to ensure adequate preparation for thesis research.

In AY 97-98 three new graduate courses were approved and included to the curriculum: BE 537: Subcellular Biomechanics I: Membranes and Interfacial Structures; BE561: DNA and Protein Sequence Analysis; BE563 Cellular and molecular Systems Analysis.

Awarded 3 Ph.D. and 6 M. S. degrees.

Created graduate student mentoring program to assist new BME graduate students in their adjustment to life at Boston University and the City of Boston. Mentors offer assistance in housing searches, course selections, and in other sources of immediate acclimation.

Organized a very successful Winter Symposium where graduate students displayed their work to the BU community and invited guests. This forum serves to allow an exchange of ideas and research methods among graduate students from different laboratories and to disseminate general information about ongoing student research in the BME department.

Started the Biomedical Engineering Industrial Seminar Series to expose the students to other important areas of biomedical engineering beyond their affiliated research in BME
laboratories with emphasis on issues of particular importance to commercial biomedical research and development.

BME Graduate students organized another series of seminars dubbed “What’s Cool in BME”. The seminars address specific “hot topics” in BME not already covered by the department’s extensive network of available lectures and seminars. BME’s enrollment this past year was 365, 30% of the College of Engineering. We awarded 76 Bachelor of Science degrees, 26% of the bachelor’s degrees awarded by the College of Engineering.

The Undergraduate Committee revised the undergraduate mechanics curriculum. The Solid Biomechanics course (BE 420) was revised and approved as a requirement for the BS in BME. The course is designed to precede fluid mechanics (BE 436). The restricted elective in the second semester of the junior year was deleted, providing a two course sequence in solids and fluids tailored to the needs of biomedical engineering.

The student chapters of the Biomedical Engineering Society (BMES) and Alpha Eta Mu Beta (AEMB), the national biomedical engineering honor society, sponsored the 2nd BME day. The purposes of the program were: to promote Boston University’s Biomedical Engineering Program; to give students a better definition of biomedical engineering; and to inform students of the opportunities that lie ahead of them as biomedical engineers.

The Undergraduate Committee with the College of Engineering conducted a survey of BU BME Alumni last year, and the department composed a summary of the biomedical engineering respondents. Such data will be very valuable in supporting our undergraduate recruiting efforts. Outcomes that are perceived as being good (e.g., good jobs, good graduate programs, good medical schools) will help our program convert greater numbers of high quality students.

There were 14 applications to the ENGMEDIC program this year. Of these, 7 students were interviewed, and 3 this year were accepted. Both of the seniors in the program have been promoted to the Medical School.

The 13th annual Senior Project Conference was held, attended by students, faculty, and representatives from hospitals and industry.

Working closely with the Biology Department we continue to improve the educational experience of our undergraduates during their two-course biology sequence, BI 109 and BI 312. This year we included separate laboratory sections for BME students in BI 109, and thanks to efforts by Laurel Carney and her informal collaboration with the instructor of BI 312 BME students’ experience in BI 312 this past fall were markedly improved.

1.2 Academic Year 1998/1999 Goals

Recruit one more Cell-Mechanics faculty (with current Whitaker Special Opportunity Grant in Cellular Mechanics funds).

Recruit additional faculty in Bioinformatics, with potential support from Whitaker funding and the existing funding from IGERT.

Recruit additional faculty in Imaging with potential support from Whitaker funds.
Submit a proposal to the Whitaker Special Opportunity grant program for support for bioinformatics and neuroimaging programs.

Formulate a departmental plan to submit a proposal for a Whitaker Foundation Leadership Award.

Plan and prepare departmental expansion into areas in 44 Cummington St.

Formalize a Masters and Ph. D. program in Bioinformatics.

Restructure the Masters Program to make it consistent with the new Ph.D. curriculum.

Fully implement the new BME curriculum requirements in AY 98/99. We anticipate full changeover by AY 99/00.

We will continue to explore alternatives to improve our undergraduate advising while maintaining quality advising.

We will continue are efforts in gathering quantitative data on where our students go after leaving the undergraduate program.

Stabilize BME staff.

2. PERSONNEL

2.1 Faculty Recruiting

We have started the effort to recruit a new faculty in Bioinformatics. The search committee has been formed and the position advertised. We expect to have a large pool of candidates by August from which to select.

We have also started a search for the third cellular mechanics faculty to be funded by our Whitaker Foundation Special Opportunity grant in Cellular Mechanics.

We will continue efforts to attract outstanding junior faculty to this department in Academic Year 98/99. We also hope to recruit one faculty per year in other targeted growth areas.

2.2 Academic Faculty

Faculty names, titles, dates of appointments, and mandatory tenure review years may be found in Appendix A. The department currently has 21 regular, full-time faculty, 4 full-time faculty with primary appointments in ECE, and 2 full-time faculty with primary appointments in CNS. The professional ranks of full-time faculty are currently distributed as follows: 12 professors, 7 associate professors, and 2 assistant professors. 10 of our current faculty are tenured. Dr. Merletti was on a leave of absence for the 97/98 academic year. Appendix B lists the research interests of our faculty.
2.3 Administrative Staff

During this year, we experienced a large influx of new personnel. The Department director was replaced in January, the Financial Administrator was replaced in November and again the position will be vacated in July. The Program coordinator position was left vacant by the untimely passing of Barbara Mate. We are actively recruiting for this position, and temporary employees now fill the position. The Administrative Assistant position was vacated in January and permanently filled in February. The use of temporary support personnel and increased student employment has helped to keep department operations functioning. This high level of turnover has created a great deal of stress in the remaining staff who have handled the burden well, but the administration of the department has suffered as a result. Additionally the department has been required to assume the responsibility of maintaining Ph. D. records, a previous function of the College graduate office, increasing the workload of the departmental staff without a commensurate increase in numbers. Although the department is taking on additional work the workload will reach at point where additional personnel will be required.

2.4 Technical Staff

The Department Engineer position was filled and a noted improvement in the teaching lab operation is evident. With the stability now in this position we are able to better plan for laboratory improvements.

3. RESEARCH AND PUBLICATIONS

Research in the department is conducted in a number of laboratories: the Fields and Tissues Laboratory, the Brain and Vision Research Laboratory, the Cell Mechanics Laboratory, the Molecular Engineering Laboratory, the Neuronal Dynamics Laboratory, the Respiratory Research Laboratories, the Visual and Circulatory Biophysics Laboratory, and five affiliated research centers: the BioMolecular Engineering Research Center, the Center for Advanced Biotechnology, the Hearing Research Center, the Center for BioDynamics and the NeuroMuscular Research Center.

Research in the department is characterized by a combination of

- empirical and theoretical work with an attention to explicit mathematical models for the phenomena under study,
- intensive computer use for experimental and theoretical work,
- a basic scientific flavor to the fundamental questions being asked,
- an attention to the applications of the work to the improvement of health care, and
- a thorough understanding of the underlying physiological processes.

The variety of evidence of the continued growth of the research activity of the department is contained in the following Appendices: Faculty and student publications, Appendix C, recent patent activity, Appendix D, and funding from external grants and
contracts, Appendix E. The department, affiliated centers, laboratory and interdisciplinary groups held a broad variety of seminars. The series, speakers and titles are contained in Appendix F.

External grant funding for our research programs for 7/1/97 - 6/30/98 totaled $8,496,450 (including indirect costs), which is 37% higher than the $6,202,479 reported for the same period last year. Annual fluctuations of this amount are partially attributable to the timing of funding awards and year-end cutoffs. These statistics do not include funds brought into the University from the affiliated NeuroMuscular Research Center. Figure 1 shows the department annual total grant income from FY 83 through FY 98.

![BME Department Annual Total Grant Income](image)

Figure 1 - BME Department Total Grant Income

The department, with its sustained grant income levels, must be viewed as having a substantial financial impact on the University. The sponsored research activities are enabling us to recruit excellent faculty and students, and enhance the reputation of Boston University throughout the scientific and engineering profession. Several programs have been initiated at the College and Department level to support research initiatives with University funds. The College provides: research initiation awards; College Post-Doc awards; graduate student fellowships; bridge funding; and funds to support undergraduate research on cost-shared basis. The department continues its policy to cost-share purchases of office computers for faculty. This initiative is intended to continually upgrade the computer capabilities of our faculty to keep pace with technology and ensure maximum productivity.
Although we have been successful in obtaining funding, retaining research awards is becoming increasingly difficult. We are concerned about the present climate wherein the levels of government research funding are highly uncertain. Faculty have been encouraged to seek private sector research funds however, private companies sometimes balk at the high overhead rate incurred when subcontracting research effort to an educational institution. We will continue to negotiate with the private sector and the University to resolve these difficulties. The department continues a conservative fiscal management policy for department funds.

With some of our faculty salaries exceeding the existing NIH salary cap we must charge the salary in excess to the operating budget, thus negatively impacting our traditionally strong faculty buyout levels. For many reasons, the current system of buyout of teaching responsibilities by funding faculty academic salary with research funding is not optimal. This is detrimental to the sustained economic welfare of the department in the long term. Alternative systems are being investigated.

4. ACADEMIC PROGRAMS

4.1 Graduate Program

The department's graduate programs have been evolving steadily since 1982. In 1985 permission was granted to offer a M.S. degree in Biomedical Engineering (with thesis) and in 1990 permission was granted to offer a Ph.D. in Biomedical Engineering. Beginning in 1993, students with a Bachelor of Science could be admitted directly into the Ph.D. program. In 1994, the Ph.D. and M.S. programs were restructured to formalize areas of concentration and make the initial years of the M.S. and Ph.D. curriculum more similar. In addition to the Ph.D. and M.S. program, the Department and the Boston University School of Medicine offer a M.D./Ph.D. program. Several department faculty are involved with the Molecular Biology, Cell Biology & Biochemistry graduate program.

The Graduate Committee, chaired by Professor Lucia Vaina administers the graduate programs.

Committee Members and Charges AY 97-98

During the 97/98 academic year, members of the Department of Biomedical Engineering were: Professors Lucia M. Vaina (chairperson), H. Steven Colburn, Herbert F. Voigt, Sandor Vajda, and Dimitrije Stamenovic. The major functions of the Graduate Committee are:

- Act as a Graduate Admissions and Financial Aid Committee for the review, admission, and recruitment of the very best candidates to our graduate programs and for identifying financial aid candidates from among new and continuing students.
• Act as a Graduate Policy Committee with responsibility for maintaining, reviewing, and modifying the graduate programs in BME, including program organization and requirements.

• Act as a Graduate Oversight Committee for consideration of individual student cases regarding qualification, disqualification, and time-line constraints.

Changes in the Management of the BME Graduate Program

In the fall semester the College of Engineering informed the departments that the maintenance of Ph. D. candidate records was now a departmental responsibility rather than the college's. Although meetings were held and training offered and conducted the additional work required of the already overburdened BME staff is significant.

Effective November 6, 1997 and following the decision of the College Graduate Committee: Ph.D. advisors are responsible for constituting the Thesis Committee and appointing a Chairman for the Thesis Defense. The Department Administrative Coordinator continues to manage the scheduling, and other paperwork for the thesis proposal and defense. The Associate Dean for the Graduate program continues to review and approve thesis abstracts.

State of the Graduate Biomedical Engineering Program

The Continuing Students

Summarizing from the Program Statistics (Appendix G) there are currently 67 students in the graduate program (43 Ph.D. students, 22 MS students, 2 MD/Ph. D. students). The Ph.D. program has 28 US students and 17 international students. The MS program has 22 students, 17 US students and 5 international. There are 12 female Ph.D. students and 11 female MS students.

Admissions

The Department is committed to continue admitting only the best of the very strong applicants who are likely to complete a Ph.D. or a MS degree. The admission process explicitly recognizes distribution of faculty research interests, diversity of students’ background and the availability of research funding. Faculty are now more directly and deliberately involved in the admission/recruitment process than in previous years.

The review of applications was handled by multiple subcommittees formed of faculty drawn from several areas represented in the BME Department. We do not advocate admission by specific, individual areas because migration of students across areas is common, nor do we feel that a single admissions committee (consisting of the members of the graduate committee) is viable. This year, we had several broadly defined admissions subcommittees, each with at least one representative from the graduate committee (Appendix H).
Applicant Backgrounds

The already excellent caliber of applicants to our graduate program is increasing (Appendix I). For AY 98-99, a total of 129 applications have so far been reviewed for Fall ’98 entrance (83 Ph.D. and 46 MS). The average total GRE score of Ph. D. applicants was 2012 (average Q+A = 1444) with an average GPA of US applicants of 3.5. Similarly high, the average GRE of MS applicants was 1856 (average Q+A= 1355) and GPA 3.2.

The proportion of domestic applicants remains roughly the same comparing AY 97-98 with figures from AY 98-99. (For 1998, 37% Ph. D. applicants were from US, 71% MS applicants; in AY97-98, 45% of Ph.D. applications were from US, 65% MS respectively.)

The educational backgrounds of the majority of our applicants are BME majors (Appendix J).

Results from an informal comparison of three areas of declared research interest for the AY 97-98 and AY 98-99 applicants indicate an increase in the percentage of Ph.D. applicants interested in molecular engineering (from 12% in 1997 to 27% in 1998), High and constant interests that increased slightly and remain high were in imaging & signal processing (32% in 1997 and 35% in 1998) and in neuroscience (16% in 1997 and 17% in 1998).

Of the nine applicants who visited us in March 1998, three will join our graduate program in the Fall 1998 semester. Overall, we made financial aid offers to eight of them, and two accepted. Those who declined have chosen to attend graduate school at Carnegie Mellon, Johns Hopkins, MIT, Northwestern, North Carolina, and UC Berkeley, where they were offered full scholarships.

First year BME students and expected September 1998 matriculates

The 14 students matriculated in the Ph.D. Program in September 1997 had an average total GRE score of 2082, with a 3.5 GPA. We anticipate 11 new Ph.D. students in September 1998, who have an average total GRE score of 2046 and 3.7 GPA.

In the MS program, 15 students matriculated in September 1997, and for the Fall 1998 we expect 11 new students. The GPA of the September 1997 MS matriculations was 3.4 and of the expected September 1998 matriculations it is 3.3. Average GRE totals were is also similar; in September 1997 it was 1998 and in September 1998 is 1903.

In the past year there was a significant increase in the proportion of international students in our program, due to increases within the Ph.D. ranks. For the Ph.D. program, the amount of international students rose from 30% in AY 96-97, to 83% in AY 1997-1998. In the MS program the proportion of international students remained roughly the same.

All first year students in the Ph.D. and MS programs have found research homes by the Summer 1998, and are making excellent progress. In addition, after familiarizing herself with the graduate program, one newly admitted MS student opted to transfer to the Ph.D. program.
Funding Mechanisms

Research assistantships continue to provide primary support for the Ph.D. students in our program; 60%, while 32% of our MS students are full-time Research Assistants, Appendix K.

The academic credentials of applicants to our program are excellent. However, to be competitive with other institutions in recruiting students we must be able to offer better financial support to the students who we wish to recruit into our program. For AY 98-99 the basic funding mechanisms available at the moment to recruit new students are PUGF (5 awarded), Dean Fellowships (6 awarded) and GTF (requested 12.5).

Other mechanisms: BME Fellows (stipend from the Department and tuition from College): 2 in 1997; in 1998 offers are pending approval of tuition matching from the college. Partial tuition scholarships were available to three full time MS students in 1997, and three more were allocated in 1998.

Research Assistantships: As a result of faculty involvement in the review and admission process, RAs were offered to five incoming Ph.D. students and to one MS student.

Training Grants: In 1997 we awarded the department's final three GAANN fellowships to full time Ph.D. students. In place of a broad departmental training grant, we now benefit from two interdepartmental training grants:

(1) 1997-2002: Joint Program in Biomedical Pharmacology, involving BME, Pharmacology and Medical Biophysics. The grant covers a total of four students per year for 2 years of pre-doctoral training.

2) 1998 start: IGERT; Bioinformatics Interdepartmental/ Interdisciplinary Grant

Graduate Policy

Restructuring of the BME Doctoral Program

Revision of the BME Ph.D. qualifying examinations

Since 1995, the BME Ph.D. qualifying examination consisted of a common General Section (Engineering Physiology/ Biomedical Signal and Measurement Theory) and two of an additional four sections: Bioelectrical Engineering, Biosignals and Systems, Biomolecular Engineering, and Biomechanics. During this past academic year, the Graduate Committee responded to faculty and student comments about the current graduate program. The BME Graduate Committee has reviewed the graduate curriculum and the department qualifier examination. Goals of the review were to establish clear guidelines for the design of individualized Ph.D. programs, to provide each student with choices that optimize his/her experience in BME within the department’s current areas of research specialization, and to ensure adequate preparation for thesis research.

Written and oral components were included in the department’s revised qualifier structure. The goal of having both written and oral portions in the exam is to provide a uniform mechanism for testing mastery of appropriate academic material, including
some graduate-level material. The second goal is to increase the predictability of success of students in the doctoral program, and to provide a smooth alternative to a MS degree for those who fail.

Written Qualifying Exam (WQE)

The WQE must be taken by the end of the second semester after admission into the Ph.D. program. This examination will last no more than three hours, and will be administered in written format only once. When a student fails miserably s/he will be advised to fulfill the requirements for an MS degree in BME (for postgraduate students), or leave the program (for post-MS students). Students with a decent failure, will be given an additional chance, via oral examination, to be combined with the Oral Qualifying Examination (OQE). The WQE tests knowledge at the undergraduate level in Signal and Systems (the general section) and two of the following three areas: Mechanics, Thermodynamics, Circuits & Fields.

Oral Qualification Exam (OQE)

The OQE must be taken at the end of the fourth semester after matriculation in the Ph.D. program. The purpose of this portion of the exam is to probe the student's ability to present research work, and to explain the fundamental ideas behind a particular research problem. The oral examination is two hours in duration. This portion of the examination is organized by topics, with each topic defined in terms of a coherent group of three, 500 level courses from a depth-sequence with no other graduate courses as prerequisites.

The oral component is tailored to the individual student. It enables the committee to evaluate the "whole student," in academic categories and in research ability. Oral examination tests student's ability to integrate material across graduate level courses and examines research and/or fundamental topics that sensibly fall within the domain of that research. It includes relevant background material within the scope of OQE, and ensures that students do not approach their research too narrowly. However, it is essential that the scope be sufficiently limited so that students can reasonably prepare. OQE focuses on issues related to the student’s research.

Other Changes to the Ph.D. Curriculum

- Related to the new BME qualifying examination, the Department approved the graduate committee’s proposal that all Ph.D. students in BME be required to complete their Physiology/Biology requirement by taking a Cell & Molecular course (GMS 753: Cell Biology) and a systems level course (PH542 or PH543). As part of the preparation for the oral qualifying examination, Ph.D. students are required to take at least three beginning graduate level BME courses from a depth-sequence.

- In AY 97-98 three new graduate courses were approved and included to the curriculum: BE 537: Subcellular Biomechanics I: Membranes and Interfacial Structures; BE561: DNA and Protein Sequence Analysis; BE563 Cellular and molecular Systems Analysis.
• Recognizing the need for a laboratory associated with the BME courses, nine beginning graduate courses have associated laboratory work.

• Recognizing the importance of signal processing in all areas of current biomedical engineering, and at the request of the Graduate Committee, Professor Carney has agreed to develop a beginning graduate course in Signal Processing. This course commences in September 1998.

• In response to student demands for a medical imaging course, arrangements have been made with BUSM to have a member of their imaging faculty teach BE515: Introduction to Medical Imaging. This course now has a laboratory component.

Graduate Student Accomplishments

Within the last year, students have not only received awards and fellowships (Appendix L), but have also had many items published (Appendix C).

This was also an extremely active year for the graduate students in presenting posters and abstracts at national scientific conferences and workshops (Appendix M). Last year, BME policy was to limit travel awards to one per student per year (September-August). In addition, the budget for this activity was reduced significantly. Unfortunately, due to the limited funds, the department was forced to reduce the number of students subsidized, as well as the amount of cost sharing with each student. In some cases, this may have prevented some students from being able to attend desirable conferences related to their research areas. The department will augment the graduate student travel budget next year, and has already committed significant funding for a large contingent of students to attend the annual BME Society meeting and a student organized retreat immediately thereafter.

During AY 97-98, there were 3 Ph.D., and 6 M.S. degrees awarded in Biomedical Engineering. Names of students who successfully defended a Ph.D. Dissertation or MS thesis are found respectively in Appendices N and O. These appendices also list names and thesis titles of Ph.D. Prospectuses Presentations, as well as those M.S. students who have completed MS Thesis Proposals and are anticipated to finish thesis in upcoming year. We expect to graduate an additional 3 MS students by September 1998, and 1 Ph.D. in January 1999.

Our current Ph.D. students are listed in Appendix P. In addition, our program’s 25 Ph.D. graduates are listed in Appendix Q.

During the summer of 1997, graduate students instituted the Graduate Student Mentoring Program to benefit incoming students, led by third year Ph.D. student Peter Meyer. It was created to assist new BME graduate students in their adjustment to life at Boston University and the City of Boston. A total of 22 new Biomedical Engineering graduate students, M.S. and Ph.D., and two post-doctoral fellows were paired with 16 BME graduate student volunteer mentors. Assigned mentors contacted the new students before their Boston arrival in order to offer assistance in housing searches, course selections, and in other sources of immediate acclimation.
During the AY 97-98, mentors continued to provide advice and assistance. A social event, funded by the Department of Biomedical Engineering, was held in the Fall of 1997 to obtain candid feedback from the new students and their mentors regarding the mentoring program and the BME department in general. A report based upon this meeting was submitted to the Graduate Committee via the Graduate Committee Student Liaison for further discussion. The students involved considered the program a great success and requested its subsequent continuation. Second year Ph.D. student, Alan Dorval, has volunteered to preside over the mentor program in the upcoming year.

The Graduate students have organized a Graduate Student Council to help foster communications between the student and the faculty. The council is in the preliminary stages of formation and when fully instituted we hope it will become a useful vehicle to voice and solve concerns between students and faculty.

Graduate Committee Accomplishments

- **Restructuring the BME Doctoral Program:** The BME graduate program is very strong, and of high quality. The program receives periodic re-examination and updating to ensure it remains vital. During AY 97-98 the Graduate Committee examined the Ph.D. program, generated a new set of requirements for the Ph.D. degree, and defined a new time-line (Appendix R) for completion. The requirements and timeline were voted on and approved by BME faculty at the meeting of May 4, 1998, at which time they became the department’s Ph.D. requirements. Central to this change are the new qualifying examination, aimed at evaluating both the student’s mastery of technical material fundamental to Biomedical Engineering, and also his/her ability to conduct and analyze research. (Appendix S).

- **Evaluation of students’ progress:** The Graduate Committee generated a form to be used by academic and research advisors for evaluating educational progress and prospects of all assigned students. It will enable advisors to counsel effectively both the student and the Graduate Committee. On the basis of accumulated information from examinations, individual academic record, and the rate of research progress, the Advisors will make recommendations to the Graduate Committee regarding each student’s future status in the graduate program. Final decisions for actions are the responsibility of the Graduate Committee. A sample evaluation form is included as Appendix T.

- **Graduate Students’ Winter Symposium:** The Graduate Committee, in collaboration with senior graduate students, has organized a very successful Symposium (Appendix U). The primary intent of this symposium is to serve as a forum to exchange ideas and research methods among graduate students from different laboratories, and to disseminate general information about ongoing student research in the BME department. This also provides positive examples of research approaches and quality of work to junior graduate students.

- **Describing and advertising the BME Graduate Programs:** The graduate coordinator together with the graduate committee, have designed and finalized the new departmental brochure. This up-to-date material will assist next year’s
student recruitment. The department’s Website (http://eng.bu.edu/BME) has also been updated to reflect the content in the brochure.

• **Graduate Students Handbook**: Important information about graduate requirements and administration of the graduate program is available in the *BME Graduate Student Handbook*. The handbook is useful to both students and faculty academic advisors. The graduate coordinator, together with the associate chair, produced an updated edition in August 1997 for the incoming graduate students. During the year, as the academic program evolved, modifications to the handbook were distributed to all graduate students and faculty.

• **Graduate Student Liaison to the Graduate Committee**: To strengthen communication between the Graduate Committee and its graduate students, and to better understand the students’ needs and goals, the Graduate Committee has nominated a graduate student Liaison to the Committee. The student Liaison is instrumental in creating a feedback loop in the BME department. This Liaison reports the BME graduate student platform to the Graduate Committee, and provides feedback to the graduate student body. The Liaison does not serve as a replacement for one-to-one student-faculty interaction. During AY 97-98, John Kaufhold was selected as Liaison. He energetically conducted several surveys, collected student opinions on specific graduate courses, qualifying examinations, the basis for choosing BU for graduate school, and other matters. These survey results were communicated to the Graduate Committee, and were taken into consideration in its revisions of the program.

• **Graduate students and Graduate Committee initiatives**: To expose the students to other important areas of biomedical engineering beyond their affiliated research in BME laboratories, and in addition to on campus seminars, two initiatives were undertaken this academic year, The Biomedical Engineering Industrial Seminar Series, and “What’s Cool in BME”.

The Biomedical Engineering Industrial Seminar Series (BME ISS) was designed to increase faculty and student exposure to issues of particular importance to commercial biomedical research and development. A committee of graduate students was formed to organize, direct, and implement this seminar series with guidance from Professor James Collins. The Department of Biomedical Engineering provided funding for this project. Through this series, BME hosted seminars dealing with specific research areas, such as nonlinear biodynamics, hearing, biomechanics, and biomolecular research (Appendix F). Selected speakers came from academia rather than the industrial research community. After graduation, however, many undergraduate and graduate biomedical engineering students will obtain employment in the private sector rather than academia. The BME ISS Committee sought to increase both faculty and student awareness of commercial biomedical research and encourage interaction between the academic and private sectors. The Industrial Seminar Series was well attended, establishing this program as an unqualified success. Arrangements for the academic year 1998-1999 seminar schedule will be made during the Summer of 1998.
The second initiative, also formed during the summer of 1997, was called “What’s Cool in BME”. This student organization was dedicated to address specific “hot topics” in BME not already covered by the department’s extensive network of available lectures and seminars. A committee of graduate students was formed to organize, direct, and implement this series of presentations under the guidance of Professor Lucia M. Vaina. The Department of Biomedical Engineering provided funding for this project. Students hosted informal presentations where researchers from areas of biomedical engineering were invited to present their work, and the paths taken for reaching this work. (Appendix F)

Charges for the Future

- **Recruitment**: The department will need to be significantly more aggressive in recruiting graduate students for the following year. Consistent with the College Graduate Committee Report of November 6, 1997, competition for US applicants is extremely high. Because BU BME is one of the best Departments in the country, we are competing among the very best schools for students. We must persuade the central administration that to be successful in graduate student recruitment, we must be able to offer outstanding applicants a significantly improved financial aid package from what is currently available. We have an inclusive, updated brochure, and an updated Website that will be regularly maintained. Augmented with other methods, and combined with increased faculty participation, these two recruitment mechanisms should positively influence years ahead. The Graduate Committee will plan the recruitment strategy early in the fall semester.

- **Implementation of the new Ph.D. Qualifier Examination**: The new qualifying examination will be implemented in the Fall 1998 semester. The committee must establish clear procedures and guidelines for administration of the exams, and for assuring uniformity in the qualification process. Administration of these exams will require substantial faculty participation to ensure meaningful implementation.

- **Counseling of academic advisors**: To be effective in advising both the student and the Graduate Committee, the academic advisors should be responsible for maintaining and updating first-hand evaluation of their advisees. They should also ensure the students understand their options and educational goals, as well as the requirements of the graduate curriculum in the BME programs. The Graduate Committee will generate a policy guide for the academic advisors highlighting their responsibilities.

- **Lab rotations**: The lab rotation required of all Ph.D. students is an excellent method of introduction to the Department research laboratories. It helps students locate a suitable research home. In conjunction with the BME Faculty, the Graduate Committee will review the outcome and modus operandi of last year’s rotation experience and generate a clear policy for the graduate students.

- **Graduate Curriculum Development and Organization**: The Graduate Committee, in conjunction with the BME faculty, will continue to monitor the graduate
curriculum, and to identify the need for new courses (e.g. the new graduate Signals & Systems course) and to advise on modifications of existing courses.

- **MS program**: During the past year, the Graduate Committee focused on restructuring the requirements of the Ph.D. program. This year the Committee will address the MS program, with two goals in mind. First is to make the program consistent with the new Ph.D. curriculum. Second is to generate a substantial BME curriculum that responds to the demands of the growing biomedical engineering industry.

### 4.2 Undergraduate Program

The department’s undergraduate program has been ABET-accredited since 1983. Our enrollment of 365 this past year represented 30% of the College of Engineering. This past year, we awarded 76 Bachelor of Science degrees, 26% of the bachelor’s degrees awarded by the College of Engineering. Program statistics are provided in Appendix V. The Undergraduate Committee, chaired by Associate Professor Sol Eisenberg administers the undergraduate program.

**Committee Membership**:

During the 97/98 academic year, members of the Department of Biomedical Engineering Undergraduate Committee were Professors Solomon Eisenberg (Chair), Cassandra Smith, Temple Smith, John White, Kenneth Lutchen and J.J. Collins.

The central mission of the Undergraduate Committee is to oversee the undergraduate curriculum in biomedical engineering. As such, the committee serves as the focal point for continued review and further development of the undergraduate program.

**State of the Undergraduate Biomedical Engineering Program**:

The undergraduate program in Biomedical Engineering continues to be strong. Last year, the Undergraduate Committee participated in the ABET self-study process, in preparation for our upcoming accreditation visit which took place in the Fall of 1997. The visit went quite well, with the only major criticism from the reviewer dealing with the design content of the Senior Project Program. The reviewer was concerned that we did not have a sufficiently robust method of assuring that each project contained sufficient engineering design. We have subsequently put such a monitoring method in place by requiring that the student explicitly address the engineering design content of the project in both the proposal and final report documents.

This change appears to have satisfied the reviewer in that no departmental program deficiencies were noted in the draft of the accreditation final report. We fully expect a positive accreditation outcome when ABET’s actions are communicated later this summer (expected August 1998).

After a year of stability in the undergraduate curriculum in preparation for the ABET accreditation visit, the undergraduate committee took up some revisions in the undergraduate mechanics curriculum. The Solid Biomechanics course (BE 420) was revised and approved by the College Faculty as a requirement for the BS in BME. BE
420 is intended for second semester juniors and is an introduction to the mechanics of solid elastic continua. In addition to classical Hookean elasticity, finite deformation theory will be presented to describe mechanical behavior of soft biological tissues and cells. The course is designed to precede fluid mechanics (BE 436), which has been moved into the first semester of the senior year.

To accommodate this new requirement, the restricted elective (SC 412 / EK 305) in the second semester of the junior year was deleted, providing a two course sequence in solids and fluids tailored to the needs of biomedical engineering. Also, EK 424 was moved from first semester senior year to second semester junior year. BE 420 will be offered for the first time during Spring 1999. AY 98/99 will be a transition year in which the juniors will follow the new requirements while continuing to offer necessary courses in the old sequence for seniors. We anticipate full changeover by AY 99/00. Undergraduate Program Planning Sheets incorporating theses revisions are included as Appendix W.

The student chapters of the Biomedical Engineering Society (BMES) and Alpha Eta Mu Beta (AEMB), the national biomedical engineering honor society, sponsored the 2nd BME day on Friday, February 27, 1998. The purposes of the program were: to promote Boston University's Biomedical Engineering Program; to give students a better definition of biomedical engineering; and to inform students of the opportunities that lie ahead of them as biomedical engineers. The day consisted of laboratory tours, hosted primarily by BME seniors, an interview workshop, an alumni career panel, a guest speaker, the AHMB induction ceremony, and a banquet. Distinguished CCNY Professor Sheldon Weinbaum spent the day with the students and gave a lecture entitled, "Models to Solve Mysteries in Biomechanics at the Cellular Level." The students raised about $3000 to fund the event.

**Undergraduate Enrollments in Biomedical Engineering:**

While neither the Department nor the Undergraduate Committee control undergraduate admissions, it is important that we remain informed and aware of enrollment trends and their impact on the biomedical engineering undergraduate program. Incoming biomedical engineering freshman have remained stable at approximately 105 for the past three years, and overall biomedical engineering enrollment has stabilized in the range of 350-380 students. (Figure 2) This still establishes us as one of the largest biomedical engineering programs in the nation.
Undergraduate Advising:

A few years ago, the department implemented a rotation system to handle freshmen advising and orientation (EK 100), with roughly half the faculty advising freshmen through participation in EK 100 every year on an alternate year basis. Faculty will continue advising the same students throughout their undergraduate years, although students are free to change advisors if they so desire. This rotation system was intended to help the department achieve a more equitable distribution of the advising load among the faculty. In AY 95/96 and Fall 1996, we also experimented with group (class by class) advising sessions to ensure that all students received important curricular information. Due to low attendance, these class sessions have been dropped.

These initiatives to improve our advising system have not been entirely successful, and we continue to explore alternatives. Student migration from some advisors to others has frustrated our efforts at equalizing advisor loads. Also, the faculty is not quite large enough to accommodate the alternate year rotation system due to the large freshman enrollment. Hence, some faculty are assigned EK100 sections in consecutive years.

Tracking Alumni:

It is becoming increasingly clear that we need to do far better in gathering quantitative data on where our students go after leaving the undergraduate program. Such data would be very valuable in supporting our undergraduate recruiting efforts. Outcomes that are perceived as being good (e.g., good jobs, good graduate programs, good medical schools) will help our program convert greater numbers of high quality students. Success in this area will clearly provide positive feedback for our undergraduate program. We need to be able to document in a convincing way that an undergraduate
biomedical engineering degree from Boston University provides a competitive advantage in the marketplace (or at the very least does not put someone at a competitive disadvantage). The College of Engineering conducted a survey last year, and the department proposed a summary of the biomedical engineering respondents (Appendix X). Expanded outcome based evaluation and assessment will be mandatory under the ABET 2000 accreditation criteria.

ENGMEDIC:

The ENGMEDIC program is an early selection program designed to train biomedical engineers who have the MD as their ultimate degree objective. ENGMEDIC admits to the School of Medicine a small number of highly qualified students who have completed two years of the pre-medical option of the undergraduate biomedical engineering curriculum. The program integrates elements of pre-clinical medical training with the upper division requirements for the BS degree in Biomedical Engineering, enabling admitted students to fulfill portions of the curriculum at the School of Medicine during the latter two years of study in the College of Engineering. The program is not designed to accelerate the engineering or medical training, but rather to effect a better transition from undergraduate engineering study to graduate medical training. The BS in Biomedical Engineering is normally earned after four years of undergraduate study, and the MD after an additional four years of study at the School of Medicine.

This program accepted its first students in 1990, and 1996 marked the medical school graduation of the first students admitted (2).

The number of completed applications to the program this year was the same as last year (14). Of these, 7 students were interviewed, and 3 this year were accepted. Both of the seniors in the program have been promoted to the Medical School.

The ENGMEDIC program continues to generate considerable interest and inquiries during recruitment activities. The existence of the program affords unique opportunities to students interested in both biomedical engineering and medicine, and helps to further differentiate biomedical engineering at Boston University from other competitive programs.

Senior Project:

A strong point of our curriculum continues to be the required Senior Project. Each student is required to develop a project proposal with an individual faculty member. The project is then carried out with the assistance of his/her faculty supervisor, possibly in collaboration with one or two other students. This project brings together multiple elements of engineering science and engineering design. In addition to technical work, this course includes experience in planning, establishing priorities, and oral and written presentations of work. The project extends over a full academic year and culminates in a Senior Project Conference that is attended by students, faculty, and representatives from hospitals and industry. A copy of the Proceedings of the Senior Project Conference of 1998 is included as Appendix Y.

Biology Courses:
For the past few years, we have been working closely with the Biology Department to improve the educational experience of our undergraduates during their two-course biology sequence. This past year, the BI 109 course followed the design that was introduced in AY 95/96. This past Spring, our students had separate laboratory sections, which included several computer demonstrations in the BME computer teaching lab. These sections greatly improved students’ experience in BI 109. Additionally, BME students’ experience in BI 312 this past fall were markedly improved thanks to past efforts by Laurel Carney and her informal collaboration with the instructor of BI 312, Mary Erskine. We look forward to continued progress with the biology sequence.

4.3 Teaching Activities

The BME Department was responsible for 24 course offerings during AY 97/98. These courses and their enrollments are listed in Appendix Z. The student credit hours for these courses total 3819 student credit hours, down slightly from 4,060 student-credit hours last year. The trend in credit hours taught over the past several years is illustrated in Figure 3.

![Biomedical Engineering Teaching History](image)

* Due to an error in past reports, access labeling has been shifted up one year.

5. FACILITIES AND EQUIPMENT
5.1 BME Teaching and Computer Laboratories

The department’s teaching and computer laboratories opened in a new facility designed to our specifications in Fall 1997. An ad hoc committee of faculty teaching the key laboratory courses reviewed and recommended necessary equipment upgrades during Spring 1998, resulting in instrument and computer purchases in excess of $100,000 over the summer of 1997. All 486 computers in the teaching lab were retired and new Pentium machines were installed. In addition, old electronic instrumentation and test equipment was retired and state of the art equipment was purchased for each laboratory station. The number of stations was also expanded from 10 to 12 to accommodate larger classes without increasing the number of lab sections required. This considerable investment in the teaching laboratory had an immediate impact on the quality of the students’ lab experiences. We plan on continuing to invest in these facilities as necessary to keep student labs current. At minimum, this will require an annual assessment of lab computer hardware with planned replacement every three years.

A new Windows NT server will be purchased and installed over the summer to replace the old server that was part of the AT&T gift four years ago. The new server will support the new computers purchased last summer. 12 additional ethernet ports will also be installed to facilitate print service and allow for some expansion. We also plan on adding memory to all of the computers to bring them up to 64 Mbytes, which will provide improved performance and accommodate new and upgraded software requirements. We will also need to replace the D/A boards in the next year or two (these were not replaced last year).

5.2 Department Research Equipment

The vast majority of the research equipment available to department faculty has been purchased by individual principal investigators for specific sponsored research efforts.

5.3 Space

The Department has established plans for the 19,000 sq. ft. of space in 44 Cummington St. vacated by the move of the Electrical and Computer Engineering Department to the Photonics Engineering Building, including projected faculty hires over the next two to three years. The planned relocation of the Neuromuscular Research Center and the subsequent renovation of this space to satisfy the interim needs of the Biology department will provide future expansion space for the department when the Biology department moves out of 44 Cummington. We anticipate this happening after the planned construction of a new Biology Building in at least five years into the future, so in the interim BME expansion may be space limited.

5.4 Computer Upgrades

We continue our policy to upgrade the office computing equipment for faculty by cost-shared upgrades for research-active faculty.

6. FUTURE PLANS
6.1 Faculty Recruiting

In order to achieve our goal of becoming the best Biomedical Engineering department in the country, we must carefully select areas for development that will add expertise and visibility and also enhance the activities of existing faculty by fostering interactions. Seven key recruitment targets have been. We will actively recruit in the targeted areas, depending on the availability of suitable candidates. Our hope is to attract one new faculty per year over the next two years. We continue to pursue a two-pronged approach to recruiting: seizing opportunities to bring in the best biomedical engineers and scientists; and targeting searches in specific disciplines.

High priority is being given to junior faculty and to engineers who can contribute immediately to our undergraduate and core graduate courses. The long-term strength of the department demands a balanced mix of senior and junior faculty to provide the benefits of experience and field recognition, and to bring in the newest educational backgrounds and enthusiasm of those just starting their academic careers.

6.2 Program Development

As the department grows in size and scope, it is becoming increasingly obvious that we need to ensure adequate coverage of subspecialty areas within the broad area of biomedical engineering. The Graduate Committee will be considering how to group courses within the curriculum.

With the University’s IGERT award from NSF we will be continuing to develop our Bioinformatics Program. The Whitaker Foundation approved a preliminary Special Opportunity award proposal in Bioinformatics for expansion into a full proposal.

The Whitaker Foundation has also asked us to expand our preliminary Special Opportunity award proposal for a Neuroimaging Program into a full proposal.

6.2.1 Graduate Program

The future plans of the Graduate program include more competitive recruitment, continually improving the curriculum, and improving and updating program requirements. The department will need to be significantly more aggressive in recruiting graduate students. Because BU BME is one of the best Departments in the country, we are competing among the very best schools for students, and competition for US applicants is extremely high. To be competitive we must develop with the College and University an improved financial aid package from what is currently available. The Graduate Committee will plan the recruitment strategy early in the fall semester.

In conjunction with the BME faculty, the Graduate Committee will continue to monitor the graduate curriculum, and to identify the need for new courses (e.g. the new graduate Signals & Systems course) and to advise on modifications of existing courses. Also, they will review the outcome and modus operandi of last year’s lab rotation experience and generate a clear policy for the graduate students. To improve advising, both the student
and the Graduate Committee, the Graduate Committee will generate a policy guide for the academic advisors highlighting their responsibilities.

During the past year, the Graduate Committee focused on restructuring the requirements of the Ph.D. program. This year the Committee will address the MS program, with two goals in mind. First is to make the program consistent with the new Ph.D. curriculum. Second is to generate a substantial BME curriculum that responds to the demands of the growing biomedical engineering industry.

6.2.2 Undergraduate Program

AY 98/99 will be a transition year in which the juniors will follow new curriculum requirements while continuing to offer necessary courses in the old sequence for seniors. We anticipate full changeover by AY 99/00.

We will continue to explore alternatives to improve our advising. We will continue to provide quality advising while equalizing advisor loads.

It is becoming increasingly clear that we need to do far better in gathering quantitative data on where our students go after leaving the undergraduate program. We will continue our efforts in this area to support our undergraduate recruiting efforts, provide positive feedback for our undergraduate program, and to show that an undergraduate biomedical engineering degree from Boston University provides a competitive advantage in the marketplace.

6.3 Equipment

Now that we have stabilized the Teaching Laboratory Technician position we will undertake a continual review of our computer laboratory to determine whether any software or hardware upgrades are needed to maximize productivity.

The administrative computing network needs to be upgraded to increase productivity and to maintain adequate network security. We are currently formulating plans in conjunction with Information Technology to replace and enhance existing networking equipment to satisfactorily meet our need for productivity, efficiency, and security. The BME phone system is an older design and may require an upgrade to meet our needs in the future.

6.4 Physical Plant Issues

Our highest priority in the next few years is to successfully allocate our new expansion space. In order to accommodate the Cellular Mechanics group in contiguous space, we need to relocate one faculty member’s laboratory. Since his research efforts have grown and his laboratory space is not adequate, we need to consider a renovation project. We have temporarily solved our problem with adjunct faculty, visiting collaborators, post doctoral and graduate student office space requirements with this expansion space but as our faculty require this space for expansion the need will arise again. We will also use some of this space for our storage needs. We have collocated all of the BME staff into the same general area on the fourth floor but optimally we need a contiguous office cubical complex to house the two staff who now are not in the BME staff area.
Several faculty have asked for small renovations in their labs and offices which we will have to handle in the most cost-effective manner, but may require additional funding to support.