THE UNIVERSITY OF UTAH

Memorandum

To: Dean David Pershing

From: Joseph D. Andrade, Chairman

Date: October 24, 1988

Subject: The Plan for Bioengineering 1989-94....and Beyond

Enclosed are five copies of the Department of Bioengineering Five Year Plan, which is also a request for Presidential Discretionary support.

Even in hard times the University of Utah administration can focus limited resources on key programs. This has been done in Computer Science, Genetics and Biochemistry. Bioengineering is a world class, very small, highly productive program which is vital to the state's economic development thrusts and efforts. A relatively small growth commitment to Bioengineering can be expected to "pay" a very large rate of return in terms of student productivity, research support, and community support - and would significantly enhance the University of Utah's and the college's - local, national, and international reputation and visibility.

I had the opportunity to briefly mention this plan to President Peterson recently - and he expressed considerable interest. A growth commitment for 1988-89 has already been made via the Jindrich Kopecek appointment. This could be considered a college match for the plan.

I hope you can give this request your enthusiastic endorsement and submit it to the University of Utah administration for consideration.

Thank you.

Department of Bioengineering
2480 Merrill Engineering Building
581-8528

The Plan for

Bioengineering

1989 - 1994

and

Beyond

An Investment in the Growing Strength and Excellence in Bioengineering - an Internationally Recognized Program Vital to the University, the State, and the Region.

A Request for

Presidential Discretionary Support

BACKGROUND

Bioengineering is generally regarded as one of the University of Utah's truly outstanding, world class programs. Maintaining a world class activity is rewarding but difficult. A number of major universities are attempting to develop Bioengineering programs and institutes modeled in large part after the program here in Utah[1]. Although a number of our key faculty are being recruited to lead and participate in such programs, the strength of the program at Utah has thwarted such recruitment efforts so far.

Bioengineering in Utah is so successful because it is a highly inter-disciplinary program (Figure 1). In addition to the strong Utah interactions, the Department participates in many national (Figure 2) and international (Figure 3) collaborations.

The Department and its faculty are among the most active in the University in corporate relations and state economic development activities (Figure 4). The Department has strong interactions with five of the States' Centers of Excellence (Appendix 4) and has close interactions with several local companies, many of them university spinoffs.

NEEDS: So...what's the problem? There are four major needs and opportunities - all of which must be at least partially met in order for Bioengineering at Utah to continue to be a world class activity:

1. Student Support: The rigorous first year academic program required of all Bioengineering students precludes extensive research activity and Graduate Research Assistant support. A program for first year graduate student support is essential if we are to continue to attract outstanding students - the heart and core of any quality academic program.

2. Space: Space continues to be a chronic problem. The Department is in desperate need of faculty, staff, student and research space for its growing programs. Space for teaching laboratories is also needed. The new Medical Polymers Building may help, but such space will not be ready for roughly five years - and relatively little space in the building has been assigned to Bioengineering.

3. Faculty and Staff: Although the Department has grown modestly in the last several years, it is still very small (4.66 FTE) and must continue to grow to a more stable size. This will require some additional university support and significant private support. The Department needs help from the University and Alumni in soliciting endowment funds, chairs, and foundation support, and will require some state and university matching commitment. The Department needs additional office staff and technical/laboratory staff.

4. Student Support: First year student stipends should average $15,000 in order to attract quality students in todays highly competitive graduate student market. The University of Utah's policy of requiring students to pay full tuition (including out of state tuition) makes it very difficult for Utah graduate programs to compete. Most competitive schools offer $12,000-$15,000 stipends plus full tuition waivers, with no required TA duties. Clearly we cannot expect the University to come up with 15 such fellowships each year ($225,000/yr), but it is reasonable to expect the University to provide some stipend and tuition support.

The rationale is as follows: Bioengineering is one of the largest per capita (per FTE) indirect cost producers on the campus. Graduate students do much of the work on the grants which generate the indirect costs. It is certainly reasonable that some fraction of indirect costs be used to help guarantee an excellent graduate student pool.

REQUEST:

We recommend and request the following for student fellowship support:

Source	1989-90	1990-91	1991-92	1992-93	1993-94
University of Utah	25,000	50,000	75,000	75,000	75,000
Corporate Fellowship Funds	25,000	50,000	75,000	75,000	75,000
Department Faculty Research Assistance Funds	25,000	50,000	75,000	75,000	75,000
Total Number of $15K Stipends	5	10	15	15	15

The three way match provides an incentive for all partners to work hard to solve the graduate funding problem. We will, of course, work closely with University Development in raising the corporate match.

We feel this is a reasonable and modest request which will help guarantee that Bioengineering in Utah remains strong and viable. There certainly is a precedent on campus of using Presidential Discretionary Funds for investing in excellent, world class programs.

Faculty: Although the Department certainly wishes to continue its strong interdisciplinary tradition and interaction with other Departments and

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1. The University of Pittsburg has established a Center for Bioengineering using state, university and private gift money for a new building and endowed chair. The University of Minnesota has raised over $5 million in corporate gifts for an endowed chair for a Bioengineering Institute Director. The University of Toronto is also expanding its Institute of Biomedical Engineering. The Singapore Polytechnic Institute has initiated discussion with Utah's bioengineering faculty for assistance in the establishment of a program in biomaterials.

programs, it must also grow at a reasonable rate if it is to continue to maintain world class status and serve the growing biomedical engineering economic and academic community. We are probably the smallest (in state FTE) quality bioengineering program in the country. The University has recognized the need to provide for modest growth for its other "star" programs. For example, the University Administration, some five years ago, made a 10%/year growth commitment to Computer Science. We request a 10% faculty increase commitment to Bioengineering, which would amount to a 0.5 FTE position per year for 1989-90, rising to a 0.6 FTE in the 5th year of the plan. This is both reasonable and modest in light of the quality and importance of Bioengineering to the university, state and region. A 0.5 FTE per year commitment could be easily leveraged via development/endowment funds and joint appointments with other departments.

FTE growth, endowments, and foundation support will be focused in one or more of the following areas - areas with special opportunities and potential in the near future.

Neuroengineering - our rapidly-strengthening program in neuroprostheses would expand into neural simulation, parallel processing, neurochemistry and drug delivery, in cooperation with colleagues in computer science and pharmaceutics.

Hybrid Devices - the synergism between inanimate materials and cultured cells and tissues would lead to a new generation of hybrid bioartificial organs. An individual with cell tissue engineering area would orchestrate our existing strengths in all biology and artificial organs.

Protein Machines - Nature's molecular machines, proteins, perform a wide range of functions (motion, recognition, light detection, light emission, catalysis, information storage and processing, etc.) which could be used for general industrial and consumer, as well as biomedical purposes. At least one local company has already been formed (Protein Solution, Inc.) to pursue such opportunities. This area could rapidly develop by encouraging collaboration and joint appointments of existing faculty.

Mathematical Matching and Simulation - the growing interest and need to minimize animal and human experimentation is creating a major opportunity for detailed modeling and simulation of physiologic systems and organisms. One should do all screening experiments on the computer and save animal experiments for testing specific, well-refined hypotheses. The University's existing strengths in biomathermatics and computer science would be augmented with bioengineering and quantitative physiology to develop a strong program in animal modeling.

Polymer Composite Surgical Implants - Recent biomaterials conferences have predicted a growing need for more sophisticated composite materials to replace a substantial portion of conventional polymer and metal surgical implants. Composites allow fabrication of implants with mechanical properties more like bone and other tissues. Also biodegradable composites will allow devices designed to stabilize tissues during healing to be absorbed by the body after healing is established. This effort would build on the composite materials expertise in the Departments of Mechanical Engineering and Material Science and Engineering.

We know how to make maximum use of small FTE resources. Even a modest 10% FTE growth per year would be leveraged and enhanced to permit at least several of the above programs to be developed.

Staff: In order to support and service the growing graduate academic and research programs, increased office staff and some technical laboratory support is vital. A relatively modest commitment of 15% increase per year (based on the 1988-89 state budget) would be of significant help in solving this chronic problem. We are already charging much of the office activities and subsidizing teaching activities via direct research grant charges. We will work hard to begin to develop a Department endowment to help alleviate the problem in the future.

SPACE: The new federally funded Medical Polymers Building provides an opportunity and avenue for a significant increase in space for the Department and its allied programs. Although space in the building is already largely allocated, a case can be made for doubling the size of the building using private and foundation funds. A private donor may be willing to provide much of the additional cost (of the order of $10 - 15 million) in exchange for his/her name on the building. We feel an effort should be made to raise the funds and to provide a place for Bioengineering and allied programs. We would like to work closely with the Development Office and with the President's Office in this regard.

THE COMMUNITY: Biomedical industries are a major component of the Utah economy and a key target/thrust area in both the Bangeter and Wilson economic development plans. A growing and strengthening bioengineering program is important - even vital - to the economic well being of the city, state, and region.

We are now establishing a Department Advisory Board of local biomedical industry President's and CEO's. We are initiating publication of the Utah Bioengineering News to serve as a communication medium.

We would like to address the manpower and technical needs of the local community. Although Bioengineering's graduate program cannot supply all these needs, we are beginning to formulate an undergraduate option or minor in Bioengineering which would be available to selected undergraduates in the sciences or engineering. Such a minor would greatly improve the job prospects for science majors and help fill the manpower gap in bioengineering and technology.

We have already been active in industrial interactions and spin-off company formations (Figure 4). We are all eager and willing to further increase and enhance these and related activities in support of the University of Utah and its community.

SUMMARY: We request the following:

1. $25,000 in graduate student support funds for 1989-90, rising to $75,000/year in the 1991-1994 period.

2. Continued and augmented efforts of the University to provide space and remodeling funds needed to maintain and develop our research and teaching programs, including possible doubling the size of the Medical Polymers Building to provide an appropriate home for Bioengineering.

3. A 10%/year faculty FTE growth commitment.

4. A 15%/year staff (office and technical) growth commitment.

These relatively modest commitments ($25,000 + $20,000 + $10,000 or $55,000 the first year) will help guarantee that Utah Bioengineering will continue to enhance its world class reputation and its strong service benefiting the university, the state and the region. The University commitment will also greatly aid us in our continued efforts to obtain funding from non-university sources.

Please contact J. D. Andrade, Chairman, Department of Bioengineering, X8528 (home 277-1259) for clarification or for other information.

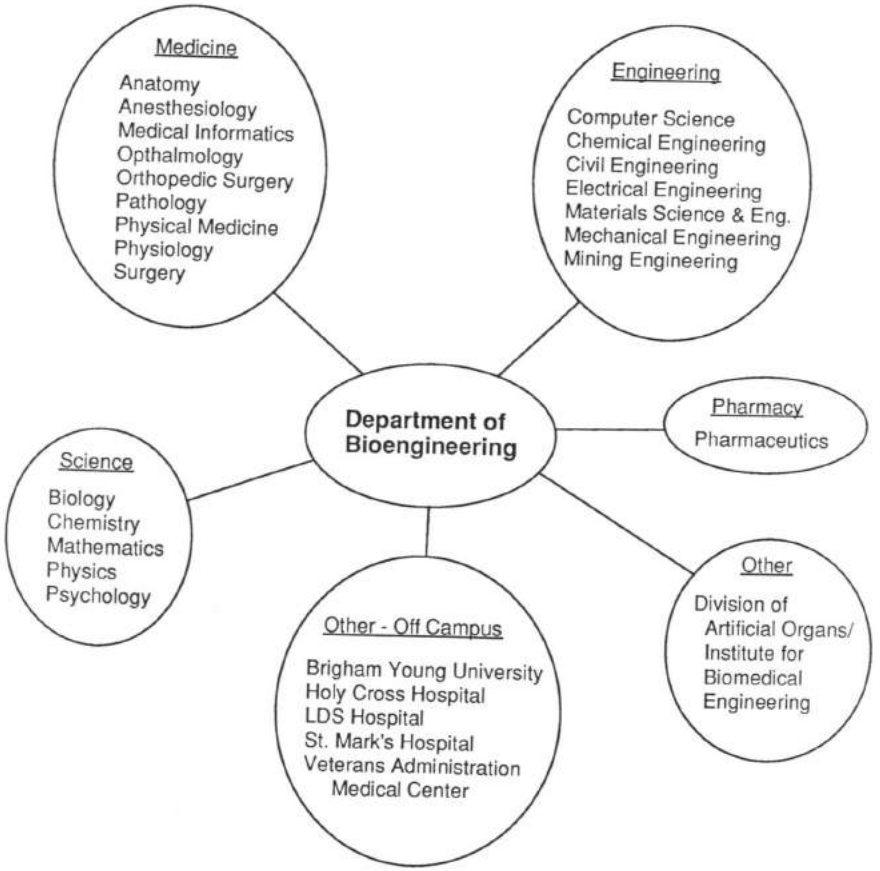

Figure 1: Interdisciplinary and cooperative research activities between Bioengineering and other components of the University and the local community (see Appendix 1 for details).

International Collaboration Activity
Europe

Figure 2a: Department of Bioengineering ongoing collaborations in Europe (see Appendix 2 for details).

International Collaboration Activity
Asia

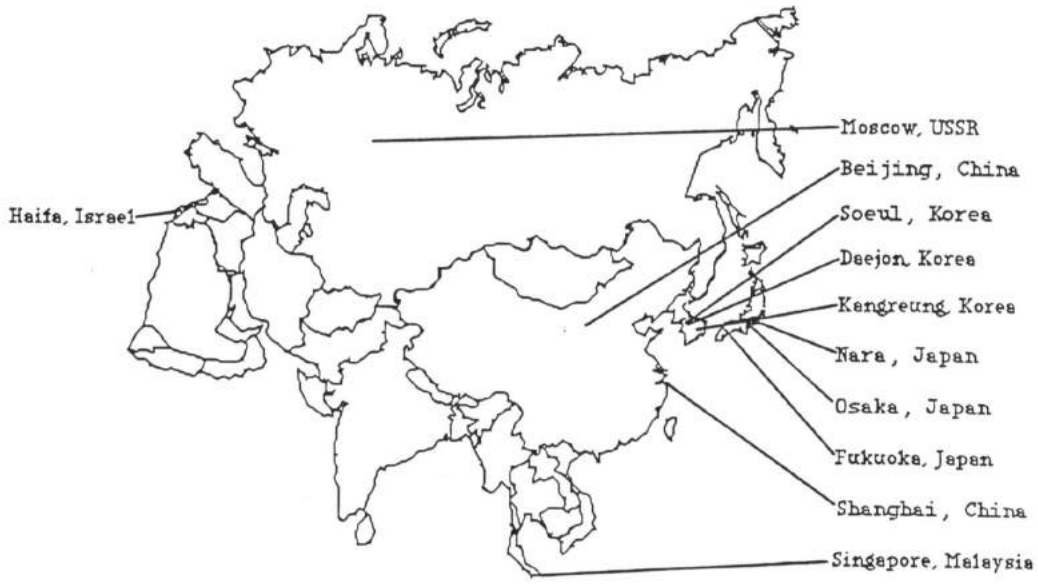

Figure 2b: Department of Bioengineering ongoing collaborations in Asia (see Appendix 2 for details).

National Collaboration Activity

Figure 3: National collaborations with Department of Bioengineering faculty (see Appendices 3 and 4 for details).

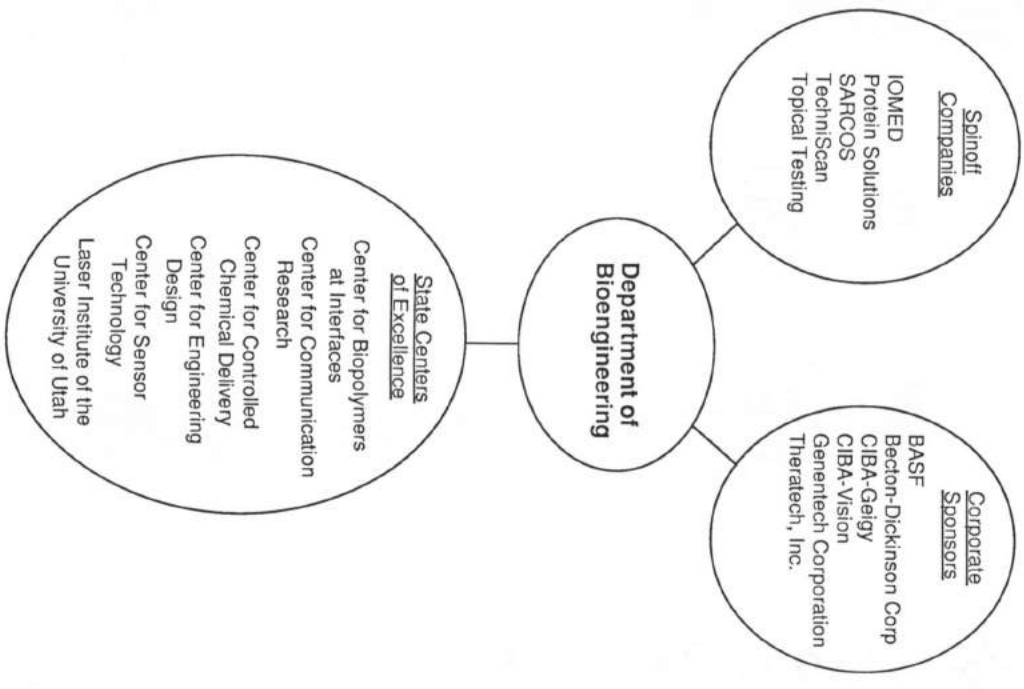

Figure 4: Department of Bioengineering corporate interactions and activities in support of state economic development (see appendix 4 for details).

Appendix 1

Bioengineering on campus and local interdisciplinary activities.
The names are bioengineering faculty members with collaborative activities in the Department or other organization listed.

Medicine
- Anatomy
  - Caldwell
- Anesthesiology
  - Westenskow
  - East
- Medical Informatics
  - East
- Opthalmology
  - Normann
- Orthopedic Surgery
  - Daniels
  - Newman
- Pathology
  - Caldwell
  - Horch
  - Normann
- Physical Medicine
  - Schoenberg
- Physiology
  - Horch
  - Normann
  - Johnson
  - Kruger
- Surgery
  - Kolff
  - Peters
  - Lyman

Science
- Chemistry
  - Caldwell
  - Harris
  - Janata
  - Lyman
- Biology
  - Herron
  - Ely
- Mathematics
  - Berggren
  - Johnson
- Physics
  - Durney
  - Johnson
- Psychology
  - Horch
  - Normann

Engineering
- Computer Science
  - Normann
  - Wood
- Chemical Engineering
  - Andrade
  - Caldwell
- MS&E
  - Andrade
  - Janata
  - Kopecek
  - Lyman
  - Daniels
- Electrical Engineering
  - Berggren
  - Christensen
  - Cotter
  - Durney
  - Johnson
  - Normann
- Mechanical Engineering
  - Wood
  - Jacobsen
  - Meek
- Mining Engineering
  - Johnson

Pharmacy
- Pharmaceutics
  - Andrade
  - Herron
  - Kim
  - Knutson
  - Kopecek

Other
- Division of Artificial Organs
  - Kolff
  - Olsen
  - Pantalos
  - Burns

Continued next page

St. Mark's Hospital
- Anesthesia
  - Peters

Brigham Young University
- Chemical Engineering
  - Pitt
  - Solen

LDS Hospital
- Orthopedics
  - France

Veterans Adminstration Hospital
- Orthopedics
  - Bloebaum

Appendix 2

Bioengineering International Collaborative Activities.

Country, City	Institution	Professor
Australia, Sydney	University of New South Wales Optometry	Normann
China, Beijing	Tsinghua University Modern Applied Physics Department	*Wang
China, Beijing	Beijing University (under discussion) Department of Chemistry	Bioen. Dept
China, Beijing	Tsinghua University (under discussion) Department of Applied Biology and Biotechnology	Bioen. Dept
China, Shanghai	Shanghai Institute of Physiology	*Chen
Czechoslovakia, Prague	Institute for Macromolecular Chemistry	Andrade Kopecek Kopeckova
England, London	Queen Mary College Department of Materials (Doyle)	Daniels
France, Bordeaux	University of Bordeaux	Andrade
France, Grenoble	Universite Scientifique and Medicale, Technologique	Horch
France, Paris	College de France	Andrade
Germany, Ludwigshafen	BASF Ludwigshafen	Caldwell
Germany, Mainz	Gutenberg University Institute of Organic Chemistry	Reichert Andrade
Germany, Munich	Unversitat der Bundeswehr Munchen Institute for Physik	Janata
Germany, Munich	Unversitat der Bundeswehr Munchen Institute for Physiology	Normann
Hungary, Budapest	Labor MIM Instruments Works	Janata *Pungor

* International visitors in Bioengineering laboratories.

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Appendix 2 (continued)

Bioengineering International Collaborative Activities.

Country, City	Institution	Professor
Hungary, Budapest	Technical University of Budapest Department of General and Analytical Chemistry (*Gratzel)	Janata
Italy, Turin	Sorin Biomedica	Andrade
Israel, Haifa	Technion Department of Physiology (*Perlman)	Normann
Korea, Daejan	Korea Research Institute of Chemical Technology (KRICT)	Andrade
Korea, Seoul	Korean Advance Institute of Science and Technology (KAIST) (*Jeon)) Johnson	Andrade
Korea, Kangreung	Kangreung University Department of Chemistry (*Jeon)	Andrade
Japan, Fukuoka	University of Kyushu Department of Surgery II	Lyman
Japan, Naha	University of Ryukyu Department of Surgery II	Lyman
Japan, Osaka	National Cardiovascular Research Center, (*Matsuda)	Andrade
Malaysia, Singapore	Singapore Polytechoric Institute (Phua)	Daniels
Sweden, Stockholm	Royal Institute of Technology (*Golander)	Caldwell
Sweden, Linkoping	Linkoping Institute of Technology	Andrade
Sweden, Uppsala	Pharmacia	Caldwell
Yugoslavia, Zagreb	Institute Ruder Boskovic (*Hlady)	Andrade Caldwell

* International visitors in bioengineering laboratories.

Appendix 3

Bioengineering National Collaborative Activities.

Country, City	Institution	Professor
CA, Irvine	Baxter Health Care Technology and Ventures Division	Daniels
CA, Menlo Park	SRI International Polymer Sciences (Heller)	Daniels
CA, Palo Alto	Stanford University Department of Applied Physics (Ratner)	Andrade Caldwell Hu
CA, San Francisco	Smith Kettlewell Institute Psychology (Tyler)	Normann
FL, Tampa	Shriners Hospital System	Daniels
MA, Cambridge	Massachusetts Institute Of Technology AI-Lab (Hollerbach, Winston)	Jacobsen Wood
KY, Louisville	Bellarmine College Department of Biology (Bennett)	Pantalos
NB, Omaha	University of Nebraska Medical School Departments of Physiology and Biophysics (Clark)	Horch
NY, Rochester	University of Rochester Physiology (Doty)	Horch Normann
OH, Columbus	Battelle Institute National Biomedical Spectroscopy Lab (Dluhy)	Andrade
OH, Columbus	Ohio State University, Physiology (Lipetz) Veterinary School (Hamlin) Circulation Technology (Beckley)	 Normann Pantalos Pantalos
VT, Burlington	University of Vermont Department of Biochemistry (Church, Mann)	Andrade
WA, Seattle	University of Washington National ESCA Laboratory (Ratner)	Andrade
WV, Morgantown	University fo West Virginia, School of Medicine (Brown)	Horch

Appendix 4

Bioengineering Activities in Corporate Relations
and Regional Economic Development

SPINOFF COMPANIES

Utah

Protein Solutions	Andrade
TechniScan	Johnson
SARCOS	Jacobsen/Wood
IOMED	Jacobsen/Wood
Topical Testing	Horch

State of Utah Centers of Excellence

Center for Biopolymers at Interfaces (CBI)	K. Caldwell
Center for Sensor Technology	J. Janata
Center for Controlled Chemical Delivery	S. Kim
Center for Communication Research	C. Rushforth S. Johnson
Center for Engineering Design	S. Jacobsen J. Wood

In State Sponsors

Becton-Dickinson	Normann/Christensen
Hoggan Health Industries	Daniels
Morton Thiokol	Johnson
Protein Solutions	Andrade
Thera Tech, Inc	Kopecek

Out of State

CBI Members
Allegan Optical
Bausch & Lomb
Baxter Health Care Corp.
Becton Dickinson & Co.
Biosym Technologies, Inc.
CIBA-GEIGY Corp.
E. I. DuPont de Nemours & Co.
Eastman Kodak
Eli Lilly and Co.
Kimberly Clark (pending)
Johnson & Johnson
Silicon Graphics, Inc.
Sola Ophthalmic

CST Members
Boehringer Mannheim Biochemicals
CIBA-Corning Diagnostic Corp.
IC Sensors
Sorin Biomedica S.p.A.

Corporate Sponsors
BASF
CIBA-Geigy
CIBA-Vision
Genetech Corporation
Thera Tech, Inc.

STRATEGIC PLAN About 1991

Department of Bioengineering
College of Engineering
University of Utah

EXECUTIVE SUMMARY:

The Department of Bioengineering is a graduate program within the College of Engineering at the University of Utah. Most of its faculty have joint appointments in other engineering departments, in the College of Science, the College of Pharmacy, or the School of Medicine. It is one of the most inter-disciplinary and clinically integrated bioengineering programs in the nation.

The Department serves as the academic and administrative focus for bioengineering activities throughout the University of Utah, and indeed throughout the region. It has adjunct and research faculty located in most of the major hospitals and throughout the School of Medicine. Some two thirds of its seventy graduate students conduct their research activities in the School of Medicine or in the local hospitals.

The Department continually ranks among the highest in the College of Engineering in external research dollars per State FTE. It is the smallest department in the College of Engineering and one of the smallest in the University, with less than 5 State FTEs.

Its entering graduate student class last Fall was nearly double that of the previous year. It selects its graduate students from an excellent pool. The Program is nationally and internationally recognized as one of the premier bioengineering programs in the nation.

The Department's highest priority and immediate goal is to add a faculty member in the general area of tissue engineering, the engineering of scaffolds and matrices on which cells can be made to grow and organize into tissues. This expertise would relate to nearly all of the Department's current ongoing programs. It is also an area that is beginning to become recognized nationally as one of importance and high priority.

The acquisition and development of expertise in this area would held insure the Department's continued prominence as one of the nation's leading bioengineering programs.

A second, and also very important priority, is to enhance interactions and activities with clinical medicine departments in the School of Medicine, including an expansion of its activities in the area of decreasing the costs of health care, and particularly in the area of rehabilitation engineering.

Priority three is to attract a leading individual in the general area of molecular automation to help hybridize and synthesize the Department's existing strengths in sensors, microsystems, and

instrumentation, as well as to relate closely to the Genome Initiative in the Department of Human Genetics.

These three priorities are proposed to be implemented one per year over the next three years; State FTE and private support will be required.

Priority One, tissue engineering, will require a 0.67 FTE at the assistant to associate professor level. The Department has now a 0.33 FTE slot, presently unfilled, which would be allocated to this position.

Priority Two would require a 1.0 FTE to be distributed among existing faculty involved in various clinical medicine departments and to be used for the support of existing individuals involved with rehabilitation engineering and related activities.

Priority Three would require 1.0 FTE, although it is possible that the position could be shared with the Department of Human Genetics, the Department of Biology, or others interested in the general initiative.

Thus, 2.67 FTEs over the next three years would enable the strategic plan to be implemented. This would amount to about a 50% growth in the State FTE over a four year period, or of the order of 15% per year.

The Department has a national reputation for quality and productivity with a very limited state and university commitment. It has managed to maintain its leadership position nationally, but that position is now being threatened by developments at a large number of schools. Most major universities who have historically not had bioengineering programs, or who have had weak programs, are now giving increased attention and resources to these activities.

The Department is facing severely increased competition and cannot be expected to maintain its national leadership without some recognition of its resource needs.

The Strategic Plan presents several avenues with which the Department can maintain leadership in the field of bioengineering and continue to dramatically contribute to the health and well being of the University and its local community.

Contents:

BACKGROUND:

The Department of Bioengineering is a graduate program within the College of Engineering at the University of Utah. Most of its faculty have joint appointments other Engineering Departments, the College of Science, the College of Pharmacy, and/or the School of Medicine. It is one of the most interdisciplinary and clinically integrated bioengineering programs in the nation.

In a recent survey of 1,000 bioengineers in industry the Department was ranked number 1 in the nation. Other schools ranking in the top five included Johns Hopkins, the University of Washington, Case Western Reserve and Duke University[1].

Bioengineering is the smallest department in the College of Engineering. It has less than 5 FTEs. As a number of its key faculty hold joint appointments with other departments, these FTEs translate into 9 faculty with major and strong affiliations with the Department. These faculty are largely responsible for most course instruction and for a significant part of graduate student supervision.

In addition there are a number of research faculty who have their major affiliation with the department and other research faculty who supervise, direct, and support graduate students and teach elective courses. In addition there are a large number of very active adjunct faculty, all of whom supervise, direct, and support graduate students and occasionally teach elective and special topics courses.

Bioengineering has approximately 70 graduate students; its Fall 1990 entering class was some 25 students. The Graduate Council recently completed a review of the department and was quite complementary and positive but cautioned that low faculty salaries and low graduate students stipends are problems which need to be addressed.

UNDERGRADUATE EDUCATION:

Although Bioengineering is a graduate department, it has a number of strong undergraduate activities. Its courses are open to advanced undergraduates. Its bioinstrumentation course sequence has been very popular with electrical engineering undergraduates. Its biomaterials courses are frequently taken by students in Materials Science and Pharmaceutics. Its courses in medical imaging are also taken by students in Electrical Engineering and Physics. Biomechanics courses are very popular with Mechanical Engineering undergraduates.

Medical Engineering: The Department has already begun negotiations to develop an undergraduate minor in medical engineering, designed primarily for undergraduate students who intend to go on to graduate school in biomedical engineering or as a supplement to a pre-med program for those students deciding to go to medical school. It would also be useful for engineers in more classical disciplines who intend to go to work immediately for one of the health care products industries. Many undergraduates in traditional departments take a number of bioengineering courses -- a "formal" minor would recognize this activity and provide evidence as to their strong bioengineering backgrounds.

Biological Engineering: The Department is now working to develop a formal minor in Biological Engineering for students in engineering and the sciences. There is a small but rapidly growing group of engineering educators which is arguing that engineering needs to look to biology for ideas and inspiration for the future. This has been argued in a recent paper by George Bugliarello, President of the Polytechnic Institute of New York[2] and by J. Andrade[3] in a paper titled, Bioengineering: A Model For Engineering Education?

The Department is considering working with the Department of Biology to offer an advanced undergraduate course, primarily for engineering and physical science students. The course would be a broad, comprehensive survey of biology, perhaps as much as one year in length, and would basically ask the question of what engineers can learn from biology to help them better solve tomorrow's societal problems.

Given the rapidly increasing funding available for undergraduate science and engineering education and the national interest in these topics, it is expected that such an effort could acquire significant external support. Drs. Andrade and Horch are coordinating this effort.

GRADUATE EDUCATION & RESEARCH (see Figure):

Mechanics, materials, instrumentation, and physiology represent the four key core course fields which the Department requires of all its students. The surrounding ellipse of topics represent the practical research areas of the various faculty.

Tissue Engineering[4] is an activity which is not now well represented in the Department and one which is our highest and number one priority for strengthening and developing. It has relationships to biotechnology, to biosensors, and to artificial organs and limbs, as well as to microsystems. Basically it refers to the growth and development of cells in a controlled manner so as to form functional biological tissues. These tissues can then be used to augment or replace damaged tissue. Examples include the development of cell layers for artificial blood vessels, the successful implantation of living cells and tissues for the production of insulin, and related topics. The National Science Foundation recently instituted a program in tissue engineering. A number of workshops have recently been held[4]. We consider it to be the most immediate major growth area in bio- and biomedical engineering. It is also the future of the field of artificial organs. Hybrid organs, that is the engineering of scaffolds and

matrices on which cells can grow and organize into tissues, is considered to be the future of organ replacement. It is highly likely that the University's activities in artificial organs, and particularly in the artificial heart, will greatly diminish when the current NIH contract expires and when Dr. Don Olson retires -- both of which are expected to happen within the next three or four years. The State's, the University's and the Department's future in this area will not be artificial devices, but rather in hybrid devices, devices which utilize integrated cell and tissue components. The Department expects to hire an outstanding junior faculty member to build a major activity in this area. Our only existing activity is in the lab of Dr. C Rappaport, a research member of the faculty. Her space and laboratory could function as a nucleus from which to launch this growing program.

Clinical Medicine. The Department has close affiliations and interactions with the majority of the clinical medical departments in the School of Medicine. Dr. A.U. Daniels has a joint appointment with the Division of Orthopedics and the Department of Surgery and has a 0.33 FTE position in Bioengineering. Dr. Duane Westenscow has a small component in the salary line in Bioengineering and is a tenured Professor in the Department of Anesthesiology. Dr. Grant Gullberg heads the Biophysics Laboratory in the Department of Radiology and is responsible for the medical diagnostic imaging courses in the Department of Bioengineering. We now have a small salary line for him in our budget. Dr. Richard Normann has a joint appointment in Ophthalmology. The establishment of the Duran Eye Institute and the new Eye Institute Building should lead to increased interactions with Ophthalmology. Dr. Karin Caldwell has a contract in the Center for Biopolymers at Interfaces dealing with contact lenses. Several other industrial members deal with contact lenses and one member of CBI deals with intra-ocular lenses. All of this leads us to expect that there will be considerably increased activity in the area of Ophthalmology in the near future.

We have adjunct faculty from the Departments of Nephrology, Pathology, and the Nora Eccles Cardiovascular Research and Training Institute.

There are a variety of areas in clinical medicine in which bioengineering has not had a strong presence, including pediatrics and obstetrics and gynecology. As the State's health care products industry continues to grow and diversify and as the Department of Bioengineering itself continues to develop as the nucleus, center, and catalyst for bioengineering activities in the state, it is likely that we will be asked and expected to extend our interests and activities into these other clinical arenas. This will of course require additional resources and support.

Clinical Medicine and the related areas of Rehabilitation Engineering and Health Care Costs are the Department's Number 2 Priority.

Molecular Automation is a new area for the Department. It is discussed below under Strategic Plans and Needs.

Neuroprosthesis is an active and dynamic program led by Drs. Richard Normann and Ken Horch. This program has received considerable federal and private support and visibility. It is strong, active, dynamic, and a thrust which is expected to continue for at least a ten year period.

Biosensors is another major activity. It relates to electrochemical and optical sensors, both indwelling and ex-vivo, which measure body properties such as electrolyte levels, hormone levels, immunological products, etc. Drs. Janata, Christensen, Herron, Hlady, and Andrade all participate in this area. This program is well funded by both federal and private sources. A number of fundamental problems remain in the area of biosensors and a considerable number of engineering, integration, and systems opportunities are developing as sensors progress from the research stage to design and manufacturing. There is enormous industrial interest in this area, particularly in Japan, Britain, The Netherlands, and Sweden. Increasing private support can be expected.

Microsystems. This topic refers to the work of the Center for Engineering Design. The associate director of that center, Dr. John Wood, has his full time appointment in Bioengineering. The director, Dr. Stephen Jacobsen, holds a research appointment in Bioengineering. The Center for Engineering Design began as the Center for Biomedical Design, focused almost exclusively on medical devices and equipment. They are now focused on microelectromechanical systems and other approaches to miniaturize instrumentation, robotics, sensors, and machines and devices in general. We certainly expect this area to continue to be active in the near and far future.

Drug Delivery is a strong activity represented by Dr. J. Kopecek, whom we share with the Department of Pharmaceutics. Dr. Kopecek co-directs, together with Professor Sung Wan Kim, the Center for Controlled Chemical Delivery. Dr. Kim also has a research appointment in Bioengineering. Drug delivery is a very strong activity on campus, primarily in the Department of Pharmaceutics but with strong input and collaboration from Bioengineering.

Artificial Organs and Limbs is the area represented by Dr. W.J. Kolff and Dr. Don Olson. We have already discussed this briefly above in the section dealing with tissue engineering. Dr. Kolff is now largely retired but still remains an active engineer and developer. His office has been moved from the DUMKE Building to MEB so that our students and faculty have the opportunity to interact with him. We are hopeful that we can encourage him to put many of his thoughts and experiences on paper for future generations of scientists and engineers. We hope to work closely with him in this regard. We also expect to revitalize an earlier project to develop a chair in Dr. Kolff's name for either a permanent or visiting professor of Bioengineering. We hope to work closely with Dr. Kolff in identifying possible donors for such a chair.

The artificial organ activities are primarily located in the Northgate Industrial Park in space owned by a local private

foundation and leased by the University of Utah . The faculty feel that the lifetime of conventional artificial organs is really quite limited. Within the next decade most of that activity will disappear and will be replaced by hybrid organs and by complete replacement organs produced by cell and tissue culture. Hence our interest in emphasizing and developing the area of tissue engineering.

Diagnostic Imaging. This area was already referred to above under Clinical Medicine and is very strong. It involves research faculty Steve Johnson and Mike Bergren as well as our research and adjunct faculty in the Department of Radiology, Grant Gullberg, Jeremy Hebden, and Dennis Parker. We anticipate that this area will continue to be a strong and growing one, funded primarily through the Department of Radiology.

Biotechnology. This area is under rapid development under the auspices of the Center for Biopolymers at Interfaces, one of the State's Centers of Excellence. Dr. Karin Caldwell, Director of the Center and Associate Professor of Bioengineering and Dr. Timothy Oolman, Associate Professor of Chemical Engineering and Adjunct Associate Professor of Bioengineering, have recently submitted an NIH training grant in this area and has put together a coordinated research and graduate program in this area. We expect this to be a growing activity and a major focus of both the Departments of Bioengineering and Chemical Engineering.

Rehabilitation. One could call this the field of bioengineering for the acute or chronically handicapped. Our major contributor here is Dr. Andy Scheonberg, who also has an appointment in Physical Medicine and Rehabilitation. There is a growing federal interest in this area. This interest, coupled with the concern with health care costs and the rapid increase in aging of our population, means that rehabilitation engineering will be a very rapidly growing field in the near future. Andy is a research professor with absolutely no state support. Given the importance of this area to the state of Utah, to its health care industries, and indeed to its population, some University commitment would be appropriate. This is part of our Priority 2 (see below).

Health Care Costs. We recently offered a course and seminar series in this area jointly with Dr. Robert Huefner and his program for health policy and administration. We are presently seeking private support to continue and to augment this activity. Although this area is one of enormous opportunity, rather than being a specific emphasis, it will be incorporated and integrated throughout all of the Department's activities. We anticipate offering a course every other year on this topic. We anticipate taking a leadership role in the bioengineering academic community in this area. Indeed we are already conducting a symposium at the Fall Biomedical Engineering Society (BMES) Meeting, October 1991 on this topic. The Department will host the Fall 1992 BMES meeting in Salt Lake City and there will certainly be symposia on all of the thrust areas in the Department, including that of health care costs. The local health care providers, particularly the FHP Group and Intermountain Health Care, have been

particularly supportive and interested in this activity. This area is also part of Priority 2.

THE COMPETITION

Although Utah's Department of Bioengineering is ranked among the top five nationally, and often considered to be number one in the nation[1], it is becoming increasingly difficult to maintain its world class position. The main reason is that other schools and states have recognized that a strong bioengineering effort is important to their institutions, and to the economic health and well being of their local communities.

Schools which have provided significantly increased resources for their bioengineering activities in recent years include Johns Hopkins, Clempson University, Arizona State University, University of Pittsburg, University of Wyoming, University of Minnesota, Case Western Reserve University, Duke University, the University of California at San Diego, and the University of Washington.

As just one example, Arizona State has increased its effort from about 2 FTE faculty to over 10 FTE faculty in about 5 years. Arizona State is recruiting among our faculty, not only to try to entice some of our graduating students to accept assistant professor positions, but they have instituted a set of presidential chairs to attempt to seduce away full professors of international standing.

Most universities are beginning to realize that they can no longer be all things to all people, and that they must focus their resources and activities in areas where they can make unique and special contributions, and which can significantly maintain and enhance the stature and reputation of the university and the health and well-being of its local community.

The State has targeted the bio-medical industries as one of the industrial development areas which can significantly improve the state's economy in the years ahead[5]. It is imperative that the University match the State's interest in focusing with a University focus. The health and well-being of this institution and of the State will be enhanced by the focusing of its resources and activities in areas of unique strength, expertise, and importance -- and not in directing resources to perhaps more traditional departments and programs which have no particular possibility or even probability of world class standing, particularly if such programs are already represented in other institutions in the region.

INDUSTRIAL INTERACTION:

The Department is actively involved with the biomedical industries -- locally, nationally and internationally. The Department's Industrial Advisory Board (Appendix) meets regularly and has worked closely with the State to increase awareness of the role of bioengineering in the local economy. The Advisory Board was well represented on the Governor's Task Force on Biomedical Industry Development, whose report was issued in September, 1990 (Appendix).

As a result of input from the Advisory Board the Department will offer a seminar course during Spring, 1991 titled Entrepreneurial Studies in Bioengineering. In Fall, 1991 we will offer the Course Manufacturing for Bioengineers. Both courses will have major involvement of Advisory Board members and local industry.

The Department's Center for Biopolymers at Interfaces (CBI), directed by Dr. Karin Caldwell, Associate Professor of Bioengineering, is perhaps the State's most successful Center of Excellence. This Center has developed over the past 5 years and is recognized internationally as the leading group on the subject of biopolymers at interfaces, which incorporates biocompatibility, and a variety of other interfacial processes vital to medical devices, biotechnology, and biochemical engineering.

The Center now has 25 member companies -- most of them major multi-national firms. In addition, it has a strong representation of local Utah companies. The 25 member companies support Center activities, not only through their membership dues, but also through graduate student fellowships and research contracts..

The Department is also involved with other Centers of Excellence dealing with diagnostic imaging, laser applications in medicine, controlled chemical and drug delivery, signal processing, and the Center for Engineering Design, which was noted earlier.

Industrial financial support is beginning to develop. The Becton Dickinson Foundation supports two outstanding bioengineering students each year ($15,000 stipend each). The Department has also received foundation support for other projects and needs. Alumni support is also increasing.Bioengineering Spotlight, an annual newsletter, has a distribution of over 1,000 and has been very well received.

The Department is generally perceived locally as being involved with industry and responsive to local needs.

STRATEGIC PLANS AND NEEDS:

The Department's Strategic Plan is simply to maintain its stature, reputation, and world-class standing as one of the premier bioengineering programs.

The Department plans to increase the number of state supported FTEs and the number of auxiliary and research faculty with positions in other departments on campus. In addition, it expects to involve increasing numbers of industrial participants directly, as well as through its affiliated Centers of Excellence. It expects to continue to play its leading and catalytic role in the region in the coordination and enhancement of bioengineering activities among the University, departments, and programs, and also among regional hospitals, industries, and other institutions.

Its strategic priorities outlined below reflect an earlier discussion that it expects to exert leadership and a major presence in the areas of tissue engineering, clinical medicine, including rehabilitation engineering and the future area of molecular automation.

The Department's number one priority is to develop expertise and strength in tissue engineering. We have a 0.33 position in our budget as a result of the retirement of Dr. Donald J. Lyman. A 0.67 position, the appropriate laboratory space, and start-up costs will be required. We are hopeful that the position can be developed as a result of the Engineering Initiative. A request to initiate this search has already been submitted to the Dean's Office.

Priority two is to continue to enhance our interactions with clinical medicine departments, including increasing our activities into the areas of pediatrics and obstetrics. This will require and additional 0.5 FTE.

We also plan to significantly expand the Department's activities in the area of rehabilitation engineering and bioengineering for decreasing the costs of health care. Rather than seeing these as individual thrust areas, we see these as areas integrated and incorporated throughout all of the curriculum and all of the research programs. Nevertheless, this will require individuals on our faculty who have this as a primary area of interest in order to see to it that it is indeed integrated across the Department. Rather than full time people, this activity could be accommodated, we think, by part time positions, possibly two 0.25 FTE positions, which could be joint with the appropriate departments in the Medical School or even in other parts of campus such as the Health Policy Administration Program in the Department of Political Science.

Our number three priority is molecular automation. This basically involves bringing in a leading individual who can hybridize and synthesize our existing strengths in biosensors, microsystems, and medical instrumentation and build on the strengths of the Center for Biopolymers at Interfaces, the Center for Engineering Design, and the Department of Human Genetics, particularly its human genome sequencing initiative. We feel there is an enormous future for ultraminiature multichannel sensing and detection systems which incorporate chemical, mechanical, electrical, and optical functions and components into fully integrated systems for the analysis, measurement, and even production of appropriate biochemicals. This area would completely revolutionize clinical chemistries and clinical diagnostics, it would completely revolutionize process control in biotechnology and biochemical engineering. It would completely change the way biological and medical experiments are conducted. It would probably permit the chronic, long term, continuous monitoring of patients, animals, and other organisms. It would contribute in a major way to the economic competitiveness of the chemical, biotechnological, and medical industries in Utah and in the country. We are hopeful that the new University Administration and the College of Engineering will see this as a unique area of opportunity which builds upon and significantly augments and enhances existing strong activities at the University of Utah.

We will continue to increase our graduate student population with the increased FTE positions and by close collaboration with those members of the Medical School faculty who have research programs and interests related to bioengineering. Significant growth, however, can only come from increased permanent faculty.

The Department's activities relating to the Center for Biopolymers at Interfaces are expected to be accommodated in the new Biopolymers

Research Building, recently funded by the federal government. This is both an opportunity and a problem. The opportunity is clear. The problem, however, stems from the fact that part of the Department faculty will be located deep in the middle of upper campus which will of course inhibit and impact upon the interactions with those faculty located physically in the College of Engineering.

It is hoped and expected that the plans for a major new engineering building will continue and will eventually come to fruition. At that time we are hopeful that the Department would have a home in College of Engineering space on lower campus, with only its more clinically related activities and programs housed on upper campus, possibly continuing in the Biopolymers Building.

In Summary,

Priority 1: Immediately (1991-2); 0.67 FTE with the appropriate space and start of funds to recruit an outstanding junior professor in the area of tissue engineering.

Priority 2: Clinical Bioengineering growth and development, including the area of rehabilitation engineering and health care costs, 1.0 FTE (1992-93).

Priority 3: 1.0 FTE with appropriate space and recruitment funds to become available 1993-94 to recruit an outstanding individual in the area of molecular automation.

Space: Occupancy by the Center for Biopolymers at Interfaces of space in the new Biopolymers Research Building, with the expectation that a significant amount of the space now occupied by those faculty would be remodeled and available for the continued growth of the Department, in particular for its new activities in tissue engineering and molecular automation. A combined area of 10,000 square feet.

REFERENCES:

1. R. Normann, V. DeCaprio, and J. Wood, manuscript in preparation.
2. G. Bugliarello, "Merging the Artifact and its Maker," *Mech. Eng.*, Sept., 1989, pp.46-48.
3. J. Andrade, "Bioengineering -- A Model for Engineering Education," *Biomed. Engineering Soc. Newsletter* (1991) in press.
4. R. Skalak and C. Fred Fox, eds. *Tissue Engineering*, A.R. Liss, Inc., 1988.
5. *Biomedical Industry Development Task Force -- Report and Recommendations*, Sept. 24,1990 (Appended).

APPENDICES:

State Biomedical Industry Development Task Force Report.

Department Industrial Advisory Board.

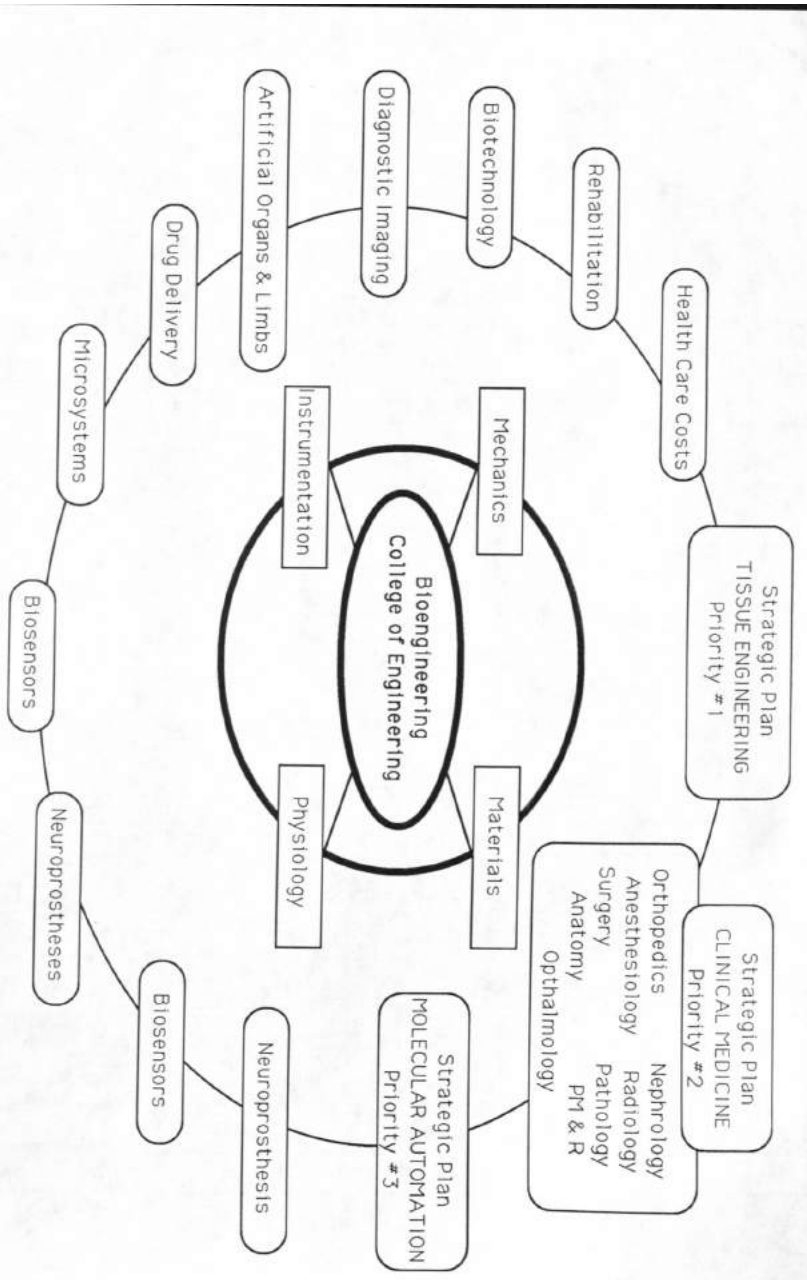

Figure 1: Research Areas and Priorities.