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THE WHITAKER FOUNDATION

BIOMEDICAL ENGINEERING SPECIAL OPPORTUNITY AWARDS

Name of Institution: University of Utah

Project Title: Enhancing Bioengineering Education: Projects for the Utah Science Center

Requested Amounts: **Proposed Starting Date:** 8/1/93

Year 1: $250,000

Year 2: $250,000

Year 3: $249,378

Total: $749,378

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III. Summary

Bioengineering is inter- and multi-disciplinary, utilizing the basic sciences, the medical sciences, clinical medicine, and all of the disciplines and sub-areas in engineering. Biomedical engineers enjoy dealing with complex problems and with a variety of subjects and techniques.

The state of Utah is now planning The Science Place!, Utah's unique science center, a hands-on, discovery-based, science and technology center scheduled to partially open in 1996, the state's Centennial year. Joe Andrade is Chairman of the Program Committee for this Utah Science Center. Because of his interests in bioengineering and medicine, and because of the importance of bioengineering and medical research in the state, "Experiments on 'You' the Visitor" will be a very major theme in the Utah Science Center.

Bioengineering students want to be involved in using their technology, their skills, and their talents for the enhancement of public understanding and appreciation of bioengineering, in particular, and of medicine and engineering in general.

We propose to involve Utah's bioengineering graduate students, as well as undergraduate and high school students, in the design, development, and construction of projects and exhibits for a major interactive science center. We expect the following outcomes from this project:

- Utah's Bioengineering students obtain an integrated, hands-on experience in the understanding of scientific, engineering, and medical phenomena, in direct interfacing with the public, and in the design and development of robust, inexpensive, highly reliable and effective equipment and apparatus with which to make physiologic and related measurements.
- The involvement of undergraduate and high school students in these projects, working side by side with bioengineering and other graduate students, provides an incredible stimulation and motivation for these students to consider biomedical engineering as a career.
- The publicity and community exposure resulting from these activities will provide an enhanced level of awareness in the public education community and among the general public of bioengineering as a discipline and a field.
- This set of activities will have national and international significance. It will serve as a model for other bioengineering programs and communities to develop comparable activities and experiences in their own areas. We expect that the exhibits, activities, and projects developed will be disseminated nationally and internationally.

Our general objective is to design, develop, and integrate physiologic, chemical, and biochemical measurements, made in a safe, non-invasive, non-threatening manner, quickly, effortlessly, and inexpensively, directly on the visitor. Such projects will provide an absolutely unique and effective educational experience for bioengineering and other students, while making significant contributions to the development of technologies which can enhance personal medicine and diagnostics, thereby decreasing the costs of health care, while enhancing the science and technological education and appreciation of the general public.

Abbreviations

ARUP: Associated Regional University Pathologists (Salt Lake City)

ASTC: Association of Science-Technology Centers

BBE: Bio-Based Engineering

BME: Biomedical Engineering

BMES: Biomedical Engineering Society

CBI: Center for Biopolymers at Interfaces, University of Utah

CID: Charge Injection Device (a 2-D photon detector)

CISE: Center for Integrated Science Education, University of Utah

ESCA: Electron Spectroscopy for Chemical Analysis (same as XPS)

GI: Gastrointestinal

HPLC: High Performance Liquid Chromatography

ICP: Inductively Coupled Plasma

MS: Mass Spectrometry

NHLBI: National Heart, Lung, and Blood Institute

NSF: National Science Foundation

NSTA: National Science Teachers Association

OES: Optical Emission Spectrometry

SIMS: Secondary Ion Mass Spectrometry

PPB: Parts per Billion

PPM: Parts per Million

SAL: Surface Analysis Laboratory

TCMU: The Children's Museum of Utah

UMNH: Utah Museum of Natural History

UUSC: Utah's Unique Science Center

XPS: X-ray Photoelectron Spectroscopy (same as ESCA)

IV. Background

A. History of Department of Bioengineering

Bioengineering is a graduate program in the College of Engineering at the University of Utah. The department originated in 1974 under the leadership of the late Dr. Curtis C. Johnson. Dr. Willem J. Kolff, a "charter" professor in the department, also played a key role in the recruitment and building of its faculty.

Bioengineering at Utah is among the most interdisciplinary and clinically related bioengineering programs in the country. The Department maintains strong ties with the University of Utah School of Medicine, the largest medical school in the Intermountain West: nearly all members of our faculty have joint appointments in the School of Medicine.

Bioengineering has been directed over the years by Curtis C. Johnson, Joseph D. Andrade, Peter Barber, Jiri Janata, Douglas A. Christensen, and Richard A. Normann, the Department's current chairman. The program in "Enhancing Bioengineering Education" will be administered and directed by Joseph D. Andrade.

B. Faculty and Staff

The Bioengineering Department has a total of 61 Full, Research, and Adjunct Professors. Of these, 14 faculty members make up the department's "Core" faculty. They include all Bioengineering tenure-tract faculty, as well as five members of the Research faculty whose primary appointments are in Bioengineering or who are heavily committed to Departmental teaching and research. Research and adjunct faculty participate in a significant way in the direction of student research as chairs of supervisory committees or as committee members, support graduate students via research grants, and contribute through the teaching of special seminars and courses.

C. Educational Programs

1. General

Most students admitted into our department enter the Master's program. Students already having a Master's degree from a recognized bioengineering program, or a Medical Doctorate degree from a recognized program, may be directly admitted into the Ph.D. program. A student does not need to complete a Master's degree in order to be admitted into the Ph.D. program. Master's degrees typically take two years to complete; Ph.D. degrees take an additional two or three years.

All entering Master's degree candidates currently take one year (a total of 35 "credit-hours") of "core" courses consisting of Bioinstrumentation, Biomaterials, Biomechanics, and Medical Physiology. Courses in Effective Scientific Communication and a sequence of three integrated laboratory courses complete this core. Each student continuing onto the Ph.D. degree then takes a set of advanced courses (an additional 30 to 35 "credit-hours") in one of nine "tracks" that reflect the student's interests and the research expertise of our faculty:

- Artificial Organs
- Bio-Based Engineering
- Biomaterials and Biocompatibility
- Biotechnology and Molecular Engineering
- Diagnostic Imaging
- Instrumentation, Sensors, and Microsystems
- Neuroprosthetics and Electrophysiology
- Orthopedic Bioengineering and Robotics
- Tissue Engineering

The "Tissue Engineering" tract is being developed by Assistant Professor Dr. Pactrick Tresco.

Courses in these tracks are made up of advanced classes in Bioengineering and in other departments in the College of Engineering, Medicine, Pharmacy, and Science.

A major component of our Bioengineering program is the conduct and teaching of research. Each student joins a research project soon after entering the program, and each is expected to aggressively pursue his/her research throughout their tenure in the Department. Individual faculty members have traditionally supported a number of postdoctoral fellows via their research grants and contracts. They are currently nine Postdoctoral Fellows in the Department.

2. Center for Integrated Science Education (CISE)

CISE was founded by J. Andrade nearly 2 years ago as a joint effort of the Colleges of Engineering and Science and the Graduate School of Education. The Center's major objective is to enhance science literacy and experience with the scientific process among Utah's students, teachers, and general population.

A major activity of CISE is The Science Place!, Utah's Unique Science Center (UUSC). UUSC is scheduled to open, in part, in 1996 -- the state's centennial year.

CISE now has limited support from the Dreyfus Foundation, American Chemical Society, Michael Foundation, US West, and the Department of Education for its programs to enhance the science content and process skills of elementary teachers.

3. Whitaker "Bio-Based Engineering" Department Development Award

The Department of Bioengineering recently received a Whitaker Foundation Department Development award. This major grant is permitting the Department to develop a major emphasis in Bio-Based Engineering (BBE)(1). Three additional faculty will be hired over the next two years in this new and exciting area.

Although the funding requested in this Special Opportunity Award proposal does not overlap with the Bio-Based Engineering Department Development Award, the faculty and students recruited via the Department Development Award are expected to become involved and otherwise aid this Special Opportunity Project on Enhancing Bioengineering Education.

4. Science Projects

The Utah Science Center initiative began about four years ago. At that time J. Andrade was asked to serve on a Higher Education subcommittee. At about the same time Joe decided to devote a major part of his time and activities to science and technology education of the general public. Through CISE he began to develop courses and other mechanisms by which University students, faculty, and staff could become involved in science literacy projects.

Bioengineering 596 -- Using Bioengineering for Science Education -- was offered Summer, 1992 and led to several of the projects which will be described later in Section V.C. Student interest in science science projects and interactive science education culminated in the "Dueling Bicycles" exhibit at the October, 1992 BMES meeting in Salt Lake City. This exhibit, developed and constructed by bioengineering students Scott McClellan, Karl Wenger, and their student colleagues, is now being modified for the Children's Museum of Utah (TCMU). Joe is now completing a course with 15 students, Bioengineering 595 -- Science Projects for the Utah Science Center, which includes undergraduate students as well as bioengineering graduate students. It is clear that practical projects significantly enhance the education of engineering students (2). If those same projects can also significantly enhance the science literacy of the general population, then we really have useful, cost-effective, educational activities (3, 4)!

D. Students

There are 70 graduate students in the Bioengineering Department with over half in the Ph.D. program (of the M.S. students, over half plan to continue on to the Ph.D. program).

The department receives about 800 inquiries each year regarding its graduate program. Our response to these inquiries describes the highly competitive nature of our admission process and the high credentials and accomplishments expected by the admissions committee. Thus, only high-quality applicants are urged to complete their application and be eligible for consideration by the admissions committee. A completed application consists of a full university transcript, GRE scores, TOEFL scores for foreign applicants, three letters of recommendation, and a personal letter of intent from the applicant.

Over the past five years, we have awarded 20 Ph.D. and 36 M.S. degrees. Nine Ph.D. graduates are pursuing academic careers; the remaining have gone into either industrial or hospital research and development groups.

E. Existing Research Programs

The Bioengineering Department's research programs generally fall into the areas that constitute our academic tracks, with some faculty members conducting or participating in research in more than one area. With the additional of Drs. P. Tresco and V. Hlady to the full-time, tenure-track faculty in Autumn 1992, new research programs and teaching activities are being developed in the areas of tissue engineering and nano-micro fabrication. Activities in Bio-Based Engineering are now underway and will be significantly expanded with the recruitment of the new faculty. The major current research areas are:

- Artificial Organs;
- Biomaterials and Biocompatibility;
- Biotechnology and Molecular Engineering;
- Diagnostic Imaging;
- Instrumentation, Sensors, and Microsystems;
- Neuroprosthetics and Electrophysiology;
- Orthopedic Bioengineering; and
- Tissue Engineering.

F. Funding

One of the Department's main goals is to educate students to become independent researchers in their chosen research speciality. Thus, the cornerstone of its academic program has been the strong research activities of its faculty. These research activities are supported by grants and contracts from federal and state government agencies, private foundations and industry.

Funding of the 3 key faculty participants in this program is as follows:

Andrade:

- Center for Biopolymers at Interfaces, University of Utah: $25,000
  Small, student support grants
  Trehalose for protein stabilization
  Analysis of multi-domain proteins
- National Science Foundation (NSF) $20,700
  Support for AIMBE 3/93 meeting
  Conference and book support
- NHLBI, Co-Investigator on Direct Observation of Interfacial Processes
  Scanning Force Microscopy (V. Hlady, P.I.)
- Department of Education: $15,000
  Teacher Courses on Integrated Science Concepts and Themes
- Dreyfus Foundation: $25,000
  Elem-Net: A resource for elementary teachers
- NSF (Submitted 5/17/93)
  Non-Invasive Monitoring of the Elements
  3 years, $420,000 total costs
  J.D. Andrade, P.I.

G. Pantalos:

- NIH PHS: HL41777-03: $509,924
  Energetic Comparison of Ventricular Assist Techniques, 12/1/88-11/30/93
- NASA Grant Subcontract U. of Utah Acct 5-22020, P.I. D. Westenskow
  Rocky Mountain Space Grant: $1,980,000, 10/1/91-9/30/93 (three Utah Universities.)

K. Horch:

- A Silicon-based Three Dimensional Microsystem for Stimulation of the Visual Cortex
  National Science Foundation, 8/1/91-1/31/95, $336,000

- Information Extraction from Peripheral Nerves
  Federal Health and Human Services, 4/1/91-3/31/93, $78,665

- Recruitment Properties of Intraneural Electrodes for Long-term Motor Nerve Stimulation to Restore Movement in Paralyzed
  Federal - Department of Education, 7/1/91-12/31/92, $85,779

G. Space and Facilities

This project will utilize space assigned to CISE, CBI, SAL, and the Anesthesia Instrumentation Lab. The major home and focus of the project will be the CISE office and Labs, Rooms 3581 and 3475, in Merrill Engineering Building. 1200 sq. ft. are now assigned to CISE, under J. Andrade's direction. In addition the Department of Bioengineering's extensive research space, including the 5th floor of the new Biopolymers Building, assigned to the Whitaker BBE program, is also available as needed.

Refer to Section VI. C., Budget Justification for equipment needs and discussion.

V. Proposed Enhancements

A. Rationale:

We all know from personal experience that among our very highest personal priorities and motivations is our own individual health and well-being, together with that of our immediate family and friends. When there is a significant health problem, every other priority sinks into the background.

There is growing realization that the general population and the individual citizen must begin to take more responsibility for their personal health, their lifestyle, and even decisions related to medical treatments and therapies. The recent work by Wennberg on empowering patient decision making is a good example (7). Unfortunately, the general public often has very weak science, technology, and medical backgrounds, making it very difficult for them to understand medical and health related issues, or to be involved in decisions in their own therapy or treatment.

Newborn children begin their learning process by using their senses to explore and eventually understand their environment and the people and organisms around them. We believe that the single most important exhibit and set of activities in a major science center should be the visitor herself. She/he will serve as the specimen and sample for a wide range of experiments and activities. These activities would be of much less interest if they were performed on animals or on other humans. When performed <u>on the visitor himself</u>, they suddenly become orders of magnitude more interesting and motivating.

We propose to involve Utah's bioengineering graduate students, as well as undergraduate and high school students, in the design, development, and construction of projects and exhibits for a major interactive science center.

In the words of Scott McClellan, one of the Bioengineering graduate students in the Bioengineering 596 course (see Section IV. C.): "In the past year approximately 1/3 of the bioengineering graduate students at the University of Utah have, in some way, helped on the design and construction of two functioning science museum exhibits. One was the *Dueling Bike* exhibit and the other was a *Friction and Joint Degeneration* exhibit." "The engineering experience gained from participating in these two projects is immeasurable. While there are numerous exercises that bioengineering students encounter during their core curriculum, advantages gained by addressing *real* bioengineering design and implementation problems firsthand, is pivotal. Researching the problem and linking the bioengineering/bio-based concepts is significant, but it lacks the practical knowledge gained from design implementation. The mechanical interfacing, ergonomic user-interaction, and instrumentation challenges are all real issues. These issues are not typically addressed, or have been given limited exposure, in bioengineering education. We have many obligations aimed at honing our physiological and engineering skills, but most programs have neither the time nor the financial resources to offer a *"complete"* educational engineering

package. Bioengineering science museum exhibits offer invaluable exposure to practical problem situations. This exposure is *"completing"* our education."

Scott will be one of the participants and student supervisors in this project. So will Steve Kern, another student in the Bioengineering 596 course. (Steve is the Post doc budgeted in Years 1-3):

> "One advantage of the course on developing science museum exhibits based on bioengineering principles was the relative parallels of the task of designing a museum exhibit to solving "real world" bioengineering problems. Of the experiences that I have faced in my return to graduate school from industry, that museum project closely resembled the process that occurs when one takes a bioengineering concept and tries to develop it into a workable, manufacturable design. The student is challenged trying to demonstrate the bioengineering concept in terms that an exhibit visitor can relate to, touch, experiment, and understand. In this sense, it is much like designing a medical device which must accommodate a broad range of users and help translate whatever information is being derived from the bioengineering system (that is, the patient) into a useful source of information from which a clinician can make clinical judgement. I was forced to consider the broad range of potential users, the challenge of accommodating their varying needs for information to understand the exhibit principle, and to do so in a simple, durable, user friendly manner. Typical didactic courses cannot offer this hands on, interactive experience that characterizes the types of tasks bioengineers must do in real world jobs."

The evolving Utah Science Center provides a special and unique opportunity for Utah's bioengineering students, together with other graduate students, undergraduate students, faculty, and staff, to enhance their education by developing novel and unique bioengineering-based interactive science and technology exhibits.

B. Specific Aims

Our general objective is to design, develop, and integrate physiologic, chemical, and biochemical measurements, made in a safe, non-invasive, non-threatening manner, quickly, effortlessly, and inexpensively, <u>directly on the visitor</u>. Such projects will provide an absolutely unique and effective educational experience for bioengineering and other students, while making significant contributions to the development of technologies which can enhance personal medicine and diagnostics, thereby decreasing the costs of health care, while enhancing the science and technological education and appreciation of the general public.

Figure 1 shows the 5 initial bioengineering-based projects for the Utah Science Center's <u>Experiments on You</u> activities. These 5 project concepts were all initiated by students and faculty in the Department of Bioengineering and have already been discussed with science museum and educational professionals. They serve as specific examples of what we propose to accomplish -- others may be added -- one or more of the existing five may be dropped or changed.

Our specific aims and objectives are:

- Thoroughly formulate the activity and its educational objectives, develop connections to other activities and exhibits in UUSC, assure a safe and non-threatening experience, and formulate the educational benefits and objectives for the bioengineering students involved (3,4,6,7,9-13);

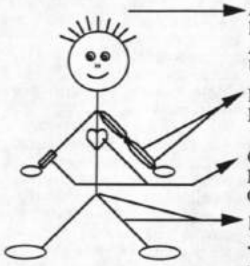
- Develop a working prototype; and test the prototype using "knowledgeable" volunteers -- bioengineering students and faculty; discuss and further test the prototype with our consultants, UUSC staff, and with other science center advisors and colleagues;

- Revise and enhance the prototype for field testing at UMNH, TCMU, the Hansen Planetarium (16), and via selected junior high and high school populations;

- Evaluate and assess the effectiveness of the projects in enhancing science literacy of the public <u>and</u> in enhancing the education of bioengineering students (9-13);

- Secure funding for ongoing efforts in science project development and improvement by Utah Bioengineering students.

The approximate time plan is given in Table 1 (next page).



A Personal Periodic Table: Non-Invasive Elemental Analysis via Hair and Urine	J. Andrade, P. Dryden (O. Ash)
Nerve Conduction and Muscle Contraction	S. Kern, K. Horch, (R. Normann)
Cardiovascular Work, Heart Rhythms, Chaos, Oximetry	G. Pantalos, S. McClellan J. Biggs, (C. Johnson)
Musculo-Skeletal: Joints/Friction (Hip, Knee)	S. McClellan, (D. Bloswick) (D. Hoeppner)
Drugs and Chemicals	J. Andrade, S. Kern (V. Hlady), (J. Herron)

Figure 1: Experiments on YOU -- the Visitor (names in parentheses denote on campus, faculty advisors).

Tasks/ Objectives	Year 1	Year 2	Year 3
a. Personal Periodic Table			
b. Nerve Stimulation and Muscle contraction			
c. Heart Rhythms and Chaos			
d. Musculo Skeletal: Joints and Friction			
e. Drugs and Chemicals			
f. New Projects/Additional funding			

Table 1: Time Line for the Various Projects

Table 2 briefly lists basic science concepts which will be readily obtained from these exhibits/activites.

a. Periodic Table:	Atoms/Chemistry/Fission/Fusion/Reactions/Radioactivity/Analysis
b. Nerve/Muscle:	Electricity/Conduction/Cells/Membranes/Proteins/Physiology
c. Heart/Chaos:	Electrocity/Conduction/Order/Disorder/Pumps/Fluids/Pressure
d. Joints/Friction:	Physiology/Pathology/Friction/Physics/Prosthesis
e. Drugs/Chemicals:	Molecules/Biochemistry/Physiology/Molecular Graphics/ Computers and Graphics/Personal Health

Table 2: Basic Science Topics and Concepts derived from Experiments on You!

C. Methods and Plans

1. Personal Periodic Table

The general population is quite aware of elements and the role of at least some elements in environmental and occupational health. They are more comfortable or at least receptive to discussion of specific elements than

they are to organic compounds or biochemicals. This is probably because almost everyone in our population has had at least some exposure to the concept of the atom and elements in their junior high and high school education.

Although they have heard about atoms and elements, the typical visitor has little appreciation or understanding as to what they are, what they do, or what they "look" like. The Periodic Table is an abstract, intimidating, and poorly understood concept. We want to make atoms, ions, elements, and the Periodic Table a set of personal concepts and experiences.

The visitor's hair contains a broad and wide repertoire of chemical and biochemical components and information (25, 27, 31, 34, 35, 36, 42). The structure and mechanical properties of the hair, the fact that the length of the hair is essentially a core sample backward in chemical time, the fact that hair is becoming used in forensics as a means of identification -- this makes a simple chemical analysis on your own hair a highly effective means of learning chemistry and related topics. Urine is also informative. The Japanese are developing an "intelligent" toilet, which will perform a full urinalysis in real time (17, 37).

There has been much interest over the years in using hair as a non-invasive source for chemical information (42). There are commercial laboratories which specialize in elemental and biochemical analysis of hair. It is widely used in the forensic community, mainly to provide identification information, and it is now being used for determining toxic trace metal burdens and metabolites of drugs of abuse. Hair stores information somewhat chronologically over an extended period. Over 40 elements have been detected in hair in concentrations ranging from parts per billion on up. Such measurements are now made with little difficultly, although the interpretation of such data is subject to considerable question. The concentrations of most elements in hair are at least 10 and often 100 times greater than they are in blood or urine. There has even been some speculation that hair might be considered a secretory organ for toxic trace materials. Hair is an important indicator of elemental concentration and status. Hair is now widely used for assessing exposure to mercury, lead, thalium, and cadmium (25).

4 Elements make up 99% of all atoms in Humans:	H, O, C, N
7 Elements make up another 0.9%:	Na, K, Ca, Mg, P, S, Cl
10 more elements are required and essential:	Mn, Fe, Co, Ni, Cu, Zn, Mo, B, Si, Se, especially Iron and Zinc.
7 more elements are probably essential:	V, Cr, F, I, As, Br, Sn
7 or more elements are generally viewed as highly toxic:	Be, Cd, Hg, Pb, Tl, As
9 or more additional elements are being studied and used for therapeutic purposes -- as drugs or components of drugs:	Li, F. Pt, Au, Bi, Sb, Ba, Se, Sn

Table 3: Chemical Elements in Biology and Medicine (26)

Nearly half of the elements in the Periodic Table have medical/nutritional/ environmental significance (Table 3). Nearly 80 elements can be detected in hair and other tissues in the 0.1 ppb range and up -- almost the entire periodic table. Such analyses are now relatively straight forward to perform with modern elemental analysis instruments (Figure 2). We have focused on two major techniques, both utilizing an inductively coupled plasma (ICP) as the means to break the sample down into its atomic and ionic constituents (27, 28, 38, 39). The only real problem with an ICP approach is that it generally requires a liquid sample with a relatively low solids content. Methods utilizing direct solid samples are also available (15). There are 2 basic methods of detection of the elemental constituents of the sample: optical emission spectroscopy (OES) and mass spectroscopy (MS). There are perhaps 50,000 lines in this range representing some 80% or more of the periodic table. Although there are interferences and problems with OES and MS, used together the two methods detect most of the elements of interest in the ppm to ppb range. Dual detection systems have recently become available and provide a very cost-effective solution to the problem of analyzing 40 to 80 elements at very high sensitivity and throughput with minimal sample volumes on a regular basis, 24 hours a day, 7 days a week. We have budgeted such a system in this proposal. Details are given in the Budget Justification section.

Although one could argue that spending the $240,000 on a much more sensitive mass spectrometry system would be a better use of the funds, such a system would not have the mass resolution to distinguish the multiply charged ion and other interferences. Although such a system would provide sub parts per trillion sensitivity, our studies indicate that such sensitivity is not really required. Virtually all of the elements we wish to detect are already present under normal conditions in the sub parts per billion range. We anticipate little or no problem with sample preparation techniques. Our lab is used to working with highly purified chemicals, solvents, and solutions, and we anticipate little or no problem in dealing with sample preparation methods which require sub-part per billion levels of trace contaminants.

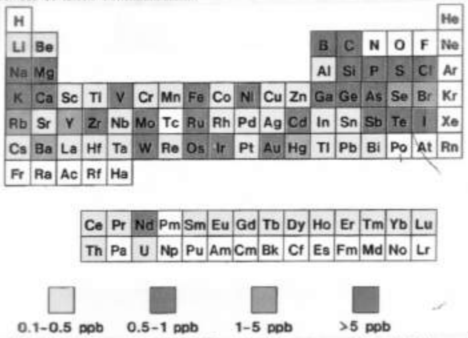


Figure 2: Detection limits for a common ICP-MS analysis system, which includes a full 7 orders of magnitude linear dynamic range, handled by the instrument without operator intervention. (Courtesy of Fisions Inst.) Of course, the personal periodic table will be much more colorful, graphical, informative, interactive, and interesting.

In this proposal we are not after medical or nutritional significance of elemental analysis, although we certainly expect the visitor to ask questions on such topics (29-34). Here we want him/her to obtain an appreciation and understanding of elements, the Periodic Table, concentrations, range and variation (why are my two samples so different?), statistics, scale (what is a ppb?), personal health choices (Why is the cadmium level so much higher among smokers?), occupational health, etc.

In addition to analyzing their hair and urine, analyses for many other samples will be available (air particulates, tap water, sea water, beer, wine, soft drinks, etc.). We will experiment with means to rapidly solubilize hair samples and with direct analysis of hair (35, 40, 42). The visitor needs to be able to submit their sample and receive the results very quickly, within 5 minutes. Other topics and exhibits may include hair microscopy -- mechanism and rates of growth, hair chemistry and structure, use of hair follicles and shafts for drug delivery, etc. Each of the elements detected will be further developed with respect to source, structure, chemistry (32), nutritional benefits, toxicity, medical aspects, etc. There will be graphical computer simulations of electron orbits, nuclear structure, chemical bonding and reactivity, etc. We may even get into exhibits related to metal binding to proteins (40), (a key part of the NSF proposal (14)), enzymes and their inactivation, chelate therapies, etc.

They will leave the Personal Chemistry exhibit with a printout of their own Personal Periodic Table (Figure 2). These are their elements -- in their bodies -- it's now an internalized, self-discovered concept, not an abstract, academic, dull set of facts -- and that makes all the difference (3,7, 18).

2. Nerve Conduction and Muscle Contraction (S. Kern, K. Horch)

This exhibit will use a nerve stimulator to generate currents capable of stimulating the ulnar nerve from surface electrodes. The stimulation will result in adduction of the thumb as a "witnessable" event for students to see. Stimulation of other nerve sites are also possible such as the posterior tibial nerve which make the toes flex and the orbicularis oculi nerve that make the eyebrow twitch. From this witnessable event, several natural questions arise:

1. How did the muscle movement occur?
2. How does the current get from the stimulation site to the site of muscular contraction?
3. How does current get from the stimulator to the site of stimulation?
4. What happens if I turn up the current? If I turn down the current?

These questions can be used to develop an understanding into the basis of muscle contraction from nerve stimulation. Understanding is gained by coupling the "witnessable" event with a computer simulation of what is actually taking place within the body. The simulation provides in essence, an animated microscope for viewing

the physiologic events that are taking place to cause the witnessable event. In this way, the "black box" feeling of how the arm allows nerve stimulation to travel and then cause the thumb to twitch is removed. At a macroscopic level, graphics will show the local stimulation occurring, the impulse travelling along the ulnar nerve, then crossing to the muscle and finally causing the muscle to contract. The increasing levels of understanding in this display result from the computer simulation. As desired, the participant can look closer to what is actually happening in the nerve and muscle by touching the computer screen and "zooming" in on a particular physiologic structure. As the witnessable event is repeated, the microscopic view of such structures as the nerve axon, a muscle fiber, the neuromuscular junction, etc. can be observed for their contribution towards the witnessable event. The simulation will have multiple levels of observation from the macroscopic view of the whole arm to the microscopic view of the neuromuscular junction.

To formulate and develop this concept, consideration for communicating the technical content of the display in an interesting and uninhibiting way to the target population is a significant challenge. Development of how the display will actually be built, what its main components will be, how much it will cost, how much physical effort it will take to realize, are all extremely pertinent issues for designing a "real world" system to be used by a variety of individuals.

This project will be conducted by S. Kern and K. Horch. S. Kern has already produced a prototype using a commercial nerve stimulator.

3. Cardiovascular work, Heart Rhythms, Chaos, and Oximetry (G. Pantalos, S. McClellan, J. Biggs)

Understanding cardiovascular work can be a formidable task for a health science graduate student -- it is even more formidable for a typical visitor. The subtleties of heart-rate, metabolic rate, and gas exchange are not trivial concepts. However, with the aid of a user interactive exhibit, the visitor can leave with a conceptual understanding of the heart rate -- activity relationship, hemoglobin O2 carrying capacity, and decreased efficiency of hemoglobin O2 saturation with increased heart rate. Quite an impressive return for a 5 minute investment.

The exhibit consists of two small bicycles driving a hydraulic (positive displacement) pump. The pumps will pump green fluorescent fluid into clear, 4 inch, tubes which are illuminated by black lights. Once the bicycle is straddled, the visitor will place their finger into a LED finger probe connected to a pulse oximeter (8) which will display pulse rate and the partial pressure of arterial oxygen, dynamically. This will drive a graphic display, dynamically representing the circulation system and in sync with the visitors pulse rate.

Their heart rate will increase with increased and prolonged activity as they attempt to beat their competitor. Additionally, their PaO2 will decrease as their heart rate goes to maximum and pumping efficiency starts to decrease. Typical resting PaO2 levels are around 95%. In the absence of any major pulmonary deficits, a maximum physical output PaO2 will only decrease to about 90%. While this is a relatively small change, the representation can be made much more dramatic and our point will be made.

A video display will accompany the bikes offering an interactive, detailed description of the physiological compensatory mechanisms at work. The exhibit will facilitate an easily relatable, take-home message of decreasing hemoglobin saturation with increased activity and heart-rate. While other visitor are waiting to test their cycling prowess, the video display will be appropriately positioned, offering user controlled detail of explaining the physiological compensatory mechanisms at work to maintain homeostasis, as well as other basic concepts of biochemistry and physiology.

This exhibit was partially implemented in fall, 1992 and used during the 1992 BMES meeting. This project will be an expanded and enhanced implementation.

A chaotic system is presently defined as any non-linear, deterministic system which has a fractal dimension and produces a strange attractor curve when graphed. It is a system where both randomness and order can be found at one point or another. Such systems can be found throughout science, from the micro to the macro level, and could be incorporated into many different exhibits that could become part of the Utah Science Center.

The idea for this exhibit was drawn from a paper by R. Johnson, "Techniques for Quantifying Chaos and Heart Rhythms (19)," where chaos theory is applied to experimental ECG data to study "complex phenomena to approach and model heretofore seemingly intractable" systems. The first part of the exhibit would be a pendulum demonstrating various paths around a base and plots of each path's phase space. The visitor would then be prompted by a sign to ask which graph most represented the functioning of the various systems in his or her body.

The next part of the proposed exhibit generates a personal "strange attraction" using pulse oximetry data produced by the visitor. The visitor's strange attractor curve can be compared to those of other visitors, providing an interesting view of uniqueness or similarity with the rest of the population. Chaotic systems, thus demonstrated on a personal level, should be meaningful to the visitor when he/she is shown other chaotic systems, such as the weather, the flow of water over rapids and the growth of crystals. This will also show how common chaotic systems are in nature.

Because the concept of chaotic systems is relatively new, few other museums have exhibits which introduce it to the public. The Museum of Scientific Discovery (Harrisburg, PA) has a new math exhibit titled "Chaos to Symmetry." The New Curiosity Shop, which sells exhibits to museums, has produced a "Chaotic Pendulum with Tracer," which uses colored pens to trace the path of a magnetic pendulum over four fixed magnets in the base. Ilan Chabay of the New Curiosity Shop is a consultant to this project (see Section VII. E.).

4. Musculo-Skeletal: Joints and Friction (S. McClellan, J. Andrade)

With a potential for approximately 500,000 partial or total knee and hip replacement surgeries annually (21, 22), joint replacement surgery is rapidly becoming one of the more common procedures. It is done to mitigate the painful condition of joint degeneration.

The proposed exhibit is a hands-on, scientific display incorporating several advanced concepts in engineering, math, and physiology. The concepts of friction (engineering), order of magnitude (math), and joint longevity (physiology) are brought together in concert to illustrate the loss of joint mobility and need for possible replacement due to inadequate joint lubrication and accelerated wear. However, the project is not limited in scope to its obvious focus. The elements of the display are presented in such a way as to also impress the significance of each scientific concept, friction, order of magnitude, and joint mechanics.

The exhibit will have three primary elements, (1) two mechanical legs, (2) an anatomically correct leg with a prosthetic knee and hip free for visitor inspection, and (3) a poster-board and user interactive video display. The friction and roughness of the mechanical legs portion of the exhibit will provide a "hands-on" example of one leg being an order of magnitude easier to move than the other. The visitor will experience a rough, gritty, and difficult operation of the "diseased knee" distinguishing it from the smooth, easy operation of the "healthy knee." The visitor is encouraged to fully examine and touch the structure and learn the basic construction of the anatomically intact and prosthetic knee joint.

The final element of the display consists of a three-part poster-board/video display explaining the exhibit. One portion of the poster-board will contain general information about friction, joint degeneration, and replacement. The video portion of the display will be user interactive and explore the concepts of friction as it relates, micro and macroscopically, to the various joint tissues. The user interactive video will have the capability to "zoom in" to an ever increasing degree of detail and sophistication. The visitor will control the resolution and depth of the explanation concerning physiology, physics, and mathematics.

5. Drugs and Chemicals (J. Andrade)

Although we argued earlier that visitors know little organic chemistry, we have found that they are very interested if the topic is directly and immediately relevant. A good example is the current film Lorenzo's Oil, which included a lot of biochemistry in the film (18).

Imagine Grandpa is on nitroglycerin, junior on nicotine, or mom on insulin. Again we depend on highly personal involvement and relevance. The structure of the drug selected is now on a large, color screen, in pseudo 3-D, in all of its covalent bond glory! They can move and rotate the structure (mom's insulin, for example), but they can also interact with the image. How does this drug work? How is it made, where does it come from? Why is it so expensive? Why does she need it? What is Diabetes? Etc.

Drugs and Chemicals is a proposed, unique interactive exhibit which focuses on drugs, including prescribed drugs, over the counter drugs, nutrition supplements, quackery or fad drugs or supplements, "social" drugs (alcohol, caffeine, and nicotine), and drugs of abuse. The main intent of the interactive exhibit is for the individual to appreciate and understand the action and behavior of drugs and chemicals. They will then be able to make the best decisions for themselves regarding their diet, therapeutic drugs, and drugs of abuse.

Using modern interactive computer graphics, the visitor queries the system regarding particular drugs or chemicals. The response will include the distribution of that particular drug in the individual, where and how the

drug acts, what the side effects of that particular drug might be, and interactions with other drugs or nutrients. The visitor is expected to discover the potential harmful and beneficial effects on their own body and to others.

By working with physicians, pharmacists, and drug treatment professionals, a listing and inventory of the initial repertoire of drugs and chemicals will be produced. By working with major pharmaceutical firms and major institutions involved in medicinal and biochemistry, together with standard reference sources and databases, we will obtain the information and the relationships needed for the interactive exhibit. We will categorize and organize the drugs into generic classes; teams of Chemistry, Pharmacy, and bioengineering students, together with science education professionals, will develop the best means of providing information about each drug class. Each drug will be connected to a visitor-based model which can accurately show in dramatic graphics the distribution and action of the drug throughout the individual as a function of method of entry (delivery), dosage, and other characteristics. The effect of such drugs on the mental state and performance of the individual, including his/her physical state, performance, and well-being, will be dramatically simulated.

This project will focus on 15 common drugs: 5 drugs of abuse, 5 over the counter drugs, nicotine, caffeine, alcohol, and 2 prescription drugs. This set of 15 common drugs will be used to develop a prototype interactive exhibit which can be implemented on relatively simple and inexpensive computer graphics equipment (see Budget Justification).

This project will involve Dr. Art Broom, Chairman of the Department of Medicinal Chemistry and Dr. Doug Rollins, Director of the Poison Control Center, as on campus advisors. Molecular Graphics advisors are Dr. Vladimir Hlady and Dr. James Herron, both Associate Professors of Bioengineering with extensive molecular graphics experience. We will use the Biosym Technologies software packages on an existing Silicon Graphics Indigo R4000 work station with an X-24 Graphics Processor (This is Dr. Hlady's machine --a work station is budgeted in year 2 -- please see Section VI. C.)

6. Other Projects

The 5 projects briefly described and illustrated in Figure 1 are the concepts that have received preliminary analysis and activity. As we get more students and faculty involved, we expect to develop additional project concepts which may prove more useful and more interesting. About 3 months into the project we will conduct a critical review with our advisors, consultants, and local museum/educational professionals (including local junior high and high school teachers) to determine if one or more of the 5 projects should be replaced, or if resources need to be solicited for the inclusion of additional projects.

D. Significance

There has been some criticism of interactive science centers in that they are fun and games with no bottom line learning (41). We need to guard against the "Disneyland mentality (4)." Entertainment and fun can be highly effective learning modes, if handled appropriately (3-7). Our goal is education.

By involving Utah's bioengineering graduate students, as well as undergraduate and high school students, in the design, development, and construction of projects and exhibits for a major interactive science center, we accomplish the following:

Utah's Bioengineering students obtain an integrated, hands-on experience in the understanding of scientific, engineering, and medical phenomena, in direct interfacing with the public, and in the design and development of robust, inexpensive, highly reliable and effective equipment and apparatus with which to make physiologic and related measurements.

The involvement of undergraduate and high school students in these projects working side by side with bioengineering and other graduate students, provides an incredible stimulation and motivation for these students to consider biomedical engineering as a career.

The publicity and community exposure resulting from these activities will provide an enhanced level of awareness in the public education community of bioengineering as a discipline and a field.

Incorporation of bioengineering-based projects and exhibits in a major national science center will, in addition to contributing to the science, technology, and medical education of the general public, further contribute to the understanding and appreciation of bioengineering as an important discipline and activity.

This set of activities will have national and international significance. It will serve as a model for other bioengineering programs, other universities, and other communities to develop comparable activities and experiences in their own areas. We expect that the exhibits, activities, and projects developed will be disseminated nationally and internationally.

In addition to the enormous benefit to our own students and faculty (9-13), enhancement of the science and technology education of the general public will promote:

- greater questioning by and higher expectations of patients -- forcing health care providers, including the medical device industry (5), to be more aware of and effective in their communications and interaction with the general public;
- patient empowerment, by providing the science and technology background -- and confidence -- which can permit patients to choose healthier lifestyles and choose among various treatment modalities (24).

Results of our activities will be disseminated to BMES student chapters nationally and via annual meetings of BMES, ASTC, and NSTA. We expect our project to launch a major national collaboration between BME programs and science museum/science center communities.

E. Evaluation and Continuity

General grant activities and each specific project will be assessed and evaluated every 6 months by our on-campus technical advisors, a critical evaluation committee, and by our two consultants (see Section VII). The project leaders involved will visit other science centers, participate in the annual ASTC conference or the NSTA meeting, and be full participants in the UUSC Program Committee (chaired by J. Andrade). Critical "visitors" and evaluators will include Utah's Bioengineering students, the University's undergraduate student population, junior high and high school teachers and their classes, and local upper elementary (4th-6th grade) teachers and their students.

As the projects reach the full public implementation stage, additional funds will be needed for full project construction, testing, and on-going maintainance and operation. Some of these funds may be obtained from capital sources for UUSC. UUSC has an extensive fundraising effort underway (chaired by former U.S. Senator and astronaut, Jake Garn), for on-going operations as well as for construction. We expect exhibit-specific funds to be generated from local and national foundations and interest groups. Local medical and health associations and providers are expected to provide ongoing support. More advanced exhibit projects will also seek funds from the Informal Science Education Program of the NSF and the Hughes Medical Institute.

C. Justification

Personnel:

J.D. Andrade, P.I., is budgeted at 2 months per year for the 3 year duration of the grant. Joe will spend far more than this amount of time on this research. He began redirecting his research program 2 years ago towards activities which could enhance the science and technical education of the general public and of patients. He spends over half of his time on research in these areas.

Dr. Ken Horch, Professor of Bioengineering and Physiology, is budgeted at 1 month. Ken is a neurophysiologist/bioengineer and also teaches the Integrated Laboratory course in the Department of Bioengineering. He is an excellent teacher and researcher.

Dr. George Pantalos, Associate Research Professor of Bioengineering, is a cardiovascular bioengineer/fluid mechanician. George has worked with the Ohio Museum of Science and Industry (OMSI) in Columbus; he is experienced in science center exhibit development.

S. Kern is completing his graduate work in Bioengineering working in the area of anesthesia bioinstrumentation. He has worked extensively in industry, has worked on science museum exhibits, and is an effective and eager UUSC participant.

Paul Dryden, Manager of the Surface Analysis Laboratory, a facility directed by J. Andrade, will spend 15% time on the project. Paul will set up and run the Inductively Coupled Plasma (ICP) Optical Emission System and, in the second year of the program, the Mass Spectrometry system. These two instruments permit the analysis of about 80% of the elements in the periodic table, most of them in the parts per billion range (Fig. 2). Paul is very experienced at elemental analysis, as he has operated an X-ray photoelectron spectroscopy (ESCA) facility for the past 10 years. He will be responsible for virtually all of the elemental analysis work on this project; he will be assisted in part by the graduate and undergraduate students which are budgeted.

Andras Pungor is a highly experienced electro/optical/mechanical technician. He will work with all aspects of the grant in developing instrumentation, prototypes, etc.

Several graduate students are budgeted. The students will work closely with Drs. Andrade, Horch, and Pantalos. Undergraduate student assistants and one part-time secretary are also budgeted.

Equipment:

An inductively coupled plasma optical emission/mass spectrometer system is budgeted. This system will be shared with another anticipated grant (14). The total acquisition cost of this system is $240,000. This will permit parts per billion analysis of about 4/5 of the elements in the periodic table. Although an ICP Mass Spectrometry system exists at the ARUP laboratory, it is used for clinical samples and operates with a very strict protocol utilizing a small number of elements.

We propose a 2 stage acquisition process: the Inductively Coupled Plasma sample introduction system and the optical emission detection system in year one, with the mass spectrometry detection system in year 2. Half of the cost of each component is apportioned to this grant. The other half of the acquisition costs we anticipate will come from a grant now being considered by the NSF/Whitaker Cost-Effective Medical Technologies Program (14). We plan to use the instrument for these two programs literally around the clock, 7 days a week, for the wide range of analyses required to fully establish the importance, variation, relevance, and educational aspects of the personal periodic table. We are confident that we will be successful in generating the funds which, together with those requested in this proposal, would permit the acquisition of this unique and powerful instrument.

Travel:

Three trips are budgeted to attend ASTC and NSTA national meetings.

Consultant Services:

Dr. Ilan Chabay has designed and produced hands-on science exhibits for museums throughout the world. After serving as a senior research scientist at the National Bureau of Standards for 8 years, he joined the

Exploratorium in San Francisco (6) in 1982 as Associate Director. He now runs the New Curiosity Shop, Inc. in Menlo Park, California.

Taizo Miake is the former exhibits developer for the Ontario Science Center near Toronto. He also was very instrumental in the design and development of one of the newest interactive science centers, Science North, in Sudbury, Ontario. Mr. Miake's ideas and vision have had a great influence on J. Andrade and others on the UUSC Task Force and Program Committee.

The two consultants will visit 1-2 times per year and critique all aspects of the project two times per year.

Other Costs:

Instrument time charges are budgeted for other analytical services, including scanning electron and optical microscopy, X-ray photo electron spectroscopy (ESCA) and imaging Secondary Ion Mass Spectrometry (SIMS).

Limited publication costs are requested as well as normal materials and supplies costs. Much of the materials and supplies costs is for sample preparation for the Argon gas and other consumables required for the ICP instrument operation, and for exhibit development and construction.

Years 2-3:

The budget is basically the same for year 2, no salary increase is budgeted for year 3.

In year 2 the Mass Spectrometer unit for the ICP is budgeted. It is anticipated this unit will cost $100,000, of which half, or $50,000 is allocated to this project.

We have also budgeted in Year 2 a Silicon Graphics computer work station at $20,000 (Indigo R4000, X-24) with extra storage capacity for full time use with projects a and e in Section C. This unit is needed because of the extensive interactive molecular graphics and data base needs in these 2 projects -- especially the one on Drugs and Chemicals. The unit will also be used for the interactive and simulation parts of the other three exhibits as well.

The Year 3 budget includes an increase in faculty and student/post doc support as well as in Other Costs. As the projects develop to the prototype and implementation stage in year 3, there will be large personnel and construction needs to see them to completion, installation, and on-going maintainance and evaluation.

Equipment Management, Operation, and Maintenance:

The elemental analysis equipment would be installed in the Surface Analysis Laboratory under J.D. Andrade's direction. The laboratory is managed and the equipment maintained and operated by Mr. Paul Dryden. Mr. Dryden is very experienced in the operation and maintenance of sophisticated analytical equipment utilizing modern electronics, computers, and high vacuum hardware. We anticipate negotiating a 3-year service agreement as part of the overall purchase price of the instrument. Therefore a service contract is not budgeted.

The equipment will be set up as a cost center, and, after the conclusion of this 3-year project, will continue to be utilized for these and related studies utilizing instrument time charges, to pay for Mr. Dryden's services and for a partial service contract. We have considerable experience with this mode of operation, particularly with the Hewlett-Packard X-Ray Photo Electron Spectrometer, the key instrument in our Surface Analysis Laboratory.

We fully expect that in year 3 and beyond additional funding will be available to expand and to apply these analytical methods to additional cost-effective bioengineering projects.

VII Biosketches/Personnel

A. General

Brief Biosketches for faculty, staff, and consultants were given in the previous section (Budget Justification). Brief vitas for Andrade, Horch, Pantalos, Chabay, and Miake follow.

23 May 1993

Dr. J.D. Andrade
Department of Bioengineering, 2480 MEB
University of Utah
Salt Lake City, UT 84112

Dear Joe,

I was pleased to learn of your very innovative and most exciting proposal to the Whitaker Foundation titled "Enhancing Bioengineering Education by Developing Projects for the Utah Science Center."

I have been very interested in the Utah Science Center initiative, and was privileged to participate in the feasibility study and in the formative discussions of your Program Committee.

In the event that it is funded, I would consider it a unique challenge and privilege to serve as a consultant to the development of your proposal. Your proposal as the prototype, core and inspiration for the development of the Science Place has the greatest hope and promise for effective public understanding of science since the simultaneous and independent public openings in 1969 of Dr. Frank Oppenheimer's EXPLORATORIUM in SanFrancisco and the ONTARIO SCIENCE CENTRE in Toronto with which I was involved from 1965 to 1975.

Very sincerely,

Taizo Miake
Museum Consult·ant
1304 Lakewood Drive
S.S. 1, Site 12, Box 1
Sudbury, Ontario P3E 4S8
CANADA

Phone: 705 675-2933
FAX: 705 675-1223

Scott McClellan is included under graduate students in the budget. Scott was the prime mover behind the 1992 BMES exhibit, Dueling Bikes, and will be responsible for project d, Musculo-Skeletal: Joints and Friction. Other students will also be involved, generally selected from the entering class in Bioengineering each year.

On Campus Advisors include:

Dr. Owen Ash, Professor of Pathology, Chief Executive Officer of ARUP (Associated Regional University Pathologists), a major clinical chemistry laboratory adjacent to the University of Utah. Dr. Ash has had a personal interest and extensive experience in trace element analysis for the past 20+ years. He will meet with the project staff on a regular basis to give them the benefit of his experience and advice regarding the design and conduct of the study and the correlations and the conclusions generated. Through Dr. Ash we will have access to major parts of the ARUP database, access to their technical staff, particularly their ICP mass spectrometry facility, to help develop the methodologies and sample preparation techniques for the hair and urine analysis studies. ARUP is the major clinical chemistry laboratory in the Intermountain United States, with branch offices in Chicago and Cleveland. It conducts over 1000 different tests and assays.

Dr. Douglas E. Rollins is Professor of Pharmacology and Toxicology and Director of the Center for Human Toxicology at the University of Utah. Dr. Rollins' particular expertise is toxicology and poisoning. His facility has experience in certain aspects of this project and his input and advice will be very valuable. He currently has a large project on detection and measurement of drugs of abuse in hair.

Dr. James McClowsky, Professor of Medicinal Chemistry, is an expert in the area of biological mass spectrometry. Dr. McClowsky recently edited, with A.L. Burlingam, the volume Biological Mass Spectrometry, published by Elsevier, 1990. He is expert in all areas of mass spectrometry as applied to biological samples and systems.

Dr. Arthur Broom is Professor and Chairman of Medicinal Chemistry. Dr. Broom is a strong advocate of the use of molecular graphics to help teach pharmacology to pharmacists and medical students and chairs a subcommittee of the UUSC Program Committee working on the Drugs and Chemicals project.

Dr. Don Bloswick, Associate Professor of Mechanical Engineering and Bioengineering, is an expert on ergonomics, man-machine studies, and musculo-skeletal disorders.

Dr. David Hoeppner, Professor and former Chair of Mechanical Engineering, is an expert on friction, wear, and lubrication with a particular interest in human and artificial joints.

Dr. Chris Johnson, Associate Professor of Computer Science, is an expert on myoelectric phenomena and on the application of mathematics, including chaos theory, to heart rhythms.

Dr. Robert Johnson, Professor and former Chair of Computer Science, is an expert on computer graphics and education. He serves on the UUSC task force.

Other on campus advisors include Drs. Trish Stoddart and Julie Gess-Newsome, Department of Educational Studies. They are experts on learning and elementary education and work with J. Andrade in CISE.

U T A H   S C I E N C E   C E N T E R

May 24, 1993

J.D. Andrade, Ph.D.
Professor
Department of Bioengineering, 2480 MEB
University of Utah
Salt Lake City, UT 84112

Dear Joe:

It is my pleasure to confirm and affirm your important role in the development of the Utah Science Center and your service to date on the Science Center Task Force and Hansen Planetarium Board.

The Program Committee, under your Co-Chairmanship has made rapid progress in defining the themes and the emphasis of the Utah Science Center.

We are particularly excited by the general theme of "Experiments on You, the Visitor" which is the basis of your proposal to the Whitaker Foundation, "Enhancing Bioengineering Education by Developing Projects for the Utah Science Center."

The Science Center Board join me in affirming our enthusiastic support for this project. We will do everything we can to assist you and the students in the Department of Bioengineering in the development of these unique, interactive science and technology experiences for our Utah Science Center visitors.

I am also delighted that you have chosen Ilan Chabay and Taiso Maike as consultants to advise and assist your group in these projects. Their vision, experience, and creativity, together with those of you and your colleagues on the project, ensure that the interactive exhibits and activities which you produce will set a completely new standard for public education and appreciation in bioengineering, physiology, and medicine.

You have my enthusiastic support.

Sincerely,

Von Del Chamberlain
Director, Hansen Planetarium
Member, Utah Science Center Board

VDC/lh

Hansen Planetarium
15 South State Street
Salt Lake City, Utah 84111-1590

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