MAY 10 2010

NEW GRADUATE DEGREE OR GRADUATE CERTIFICATE
FORM D

UNIT PREPARES IN QUADRUPLICATE
Route as indicated below under approvals. Return to the Registrar's Office once all signatures have been obtained.

Date: May 6, 2010

***Allow up to one year for the process to be completed for a certificate, and 18 months for a degree.**

Steven W. Graves
(Name of individual initiating Graduate Degree or Graduate Certificate)

Associate Professor, 505-277-6395
(Title, position, telephone number)

graves@unm.edu
(Email address)

Center for Biomedical Engineering
(Department/Division/Program)

Note: Proposals for new graduate degrees or graduate certificates need to follow an approved format. Please call the Office of Graduate Studies and ask for an outline. Revisions of graduate degrees and some new certificates also may need state approval, depending on the extent of changes proposed. Please consult the Office of the Provost for advice prior to initiating this form.

Attach the following required documents:

1. Executive Summary.
2. Program Proposal (in the approved format).
3. Catalog Description (to include program curriculum).
4. Graduate Program Projected Costs (only for new degrees).
5. Library Impact Statement.

Does this new degree affect any existing program? Yes ☐ No ☒ If yes, attach statement.

Proposed date to admit new students: Term Spring Year 2011

Required Signatures:

Department Chair		Date 5/7/2010
College Curricula Committee		Date 10 May 2010
College or School Dean		Date 10 May 2010
Dean of Library Services		Date 7/28/10
Office of the Registrar—Catalog	Elizabeth A. Bacon	Date 07/15/10
FS Graduate Committee		Date 10.21.10
Dean of Graduate Studies		Date 10-20-10
FS Curricula Committee		Date 11-9-10
Office of the Provost		Date 11/18/10
Faculty Senate		Date 11/23/10
Board of Regents		Date 12/14/10

Additional Approvals for Degrees:

Board of Regents	Date
Council of Graduate Deans	Date
Academic Council of Higher Education	Date
Higher Education Department	Date
State Board of Finance	Date

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A Proposal for the Master's of Science Degree Program in Biomedical Engineering at the University of New Mexico

A program to be administered by the School of Engineering Albuquerque, New Mexico

Contact person who can answer specific questions about the program:

Dr. Arup Maji
Interim Dean, School of Engineering
e-mail: amaji@unm.edu
phone 505-277-5521
fax 505-277-1422

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Chapter 1
Executive Summary

Biomedical engineering (BME) is one of the fastest growing engineering fields and a key area of U.S. competitiveness around the globe today. Many established New Mexico businesses are already involved in offering services and products in biomedical engineering, and they need locally-trained graduates. Accordingly, students within the state want to be trained in the field. However, no such programs are offered anywhere in New Mexico. Hence, these students leave the state to pursue degree programs elsewhere, such as those at the state-run flagship universities of Arizona, California, Colorado, Texas, and Utah, all of which have thriving degree programs in BME. BME workers have been identified as a critical missing element of the state of New Mexico's workforce (source: "*Work in New Mexico: New Mexico Career Clusters Guidebook*", State of New Mexico, 2006). To avoid a brain drain of talented New Mexican's to other states, and to stimulate the state economy in a vibrant area by providing a talented local workforce, it is proposed that the University of New Mexico offer advanced degrees in BME.

The propose BME degree program will be synergistic with the BME research program at UNM funded by the State of New Mexico. This synergy will be evident as the research program will provide a training venue for BME students and BME students will provide a source of talented researchers for the research program.

This proposal represents the fruition of funding provided to UNM by the NM Legislature to develop a plan for introducing a new advanced degree program in BME at UNM. The proposal describes the details of those plans and the accomplishments to date in securing all necessary resources for launching the new program. It is proposed that the state approve a new Master's of Science degree program in BME. This proposal is being moved forward in tandem with a new BME concentration in the Ph.D. in Engineering degree, which does not require state approval. Together, the M.S. and Ph.D. programs will form a complete graduate program in BME. The success of these efforts will complement an already successful research program in BME at the University of New Mexico, and thereby strengthen UNM and the State of New Mexico simultaneously.

Chapter 2
Purpose of the Program

2.1 Objective

The purpose of this proposal is to establish a master's of science (M.S.) degree program in Biomedical Engineering (BME) at the University of New Mexico. This graduate degree program will educate and train our best students in the exciting new field of BME. Just as importantly, it will foster the production and application of new knowledge in an area that impacts the health and well-being of all New Mexico citizens. Furthermore, BME is a growing field and, by providing skilled local workers in BME, this program will drive development of the NM economy.

What is biomedical engineering?

This phrase refers to the application of *engineering principles and tools* to problems of medical or biological significance. Though the scope of biomedical engineering is very broad, key subtopics within biomedical engineering are clinical engineering, medical imaging, orthopedic engineering, rehabilitation engineering, systems physiology, bioinstrumentation, biosensors, biomaterials, biomechanics, cellular engineering, tissue engineering, and biomolecular engineering. The output of the practicing biomedical engineer typically takes the form of a tangible product, such as a prosthetic, an engineered skin graft, a biosensor, a surgical tool, or an engineered protein. A remarkable number of key advances in medicine have been invented by engineers or engineering-oriented medical researchers, such as angioplasty, flu test kits, MRI, blood counters, endoscopic surgery, artificial hearts, blood dialysis machines, x-rays, and artificial limbs.

The proposed program will build upon our current collaborative efforts with local and regional industry and academic leaders engaged in state-of-the-art biomedical engineering research. These researchers are employed at TriCore Reference Labs in Albuquerque, Los Alamos National Laboratory (LANL), Sandia National Laboratories (SNL), and elsewhere. The program will be implemented by a productive and well-qualified group of faculty from SOE and selected other individuals. Many new courses have been created to support the proposed master's degree. These courses will also be available to undergraduate students and candidates for the Ph.D. in Engineering with a concentration in Biomedical Engineering.

The proposed degree program follows the pattern of most other programs in the U.S. in which the *master's* degree is granted specifically in the topical area of "biomedical engineering", whereas the *Ph.D.* is granted in Engineering *with a concentration in biomedical engineering*. (In parallel with the present effort to establish a master's degree in BME at UNM, there is an effort to add BME to the list of approved concentrations within UNM's long-standing degree "Ph.D. in Engineering", but this parallel effort does not entail creating a *new degree*, hence does not require state-level approval.)

The proposed BME program is envisioned to eventually address many topics in the area of BME. We anticipate growing the program by developing one focus area at a time and addressing new BME subtopics with additional focus areas as the need arises and resources are secured. Initially, the program will offer only one focus area, namely *Molecular and Cellular Systems*. Future focus areas will be drawn from areas of strength of the UNM School of Engineering. Current candidates for new focus areas include "Biomedical Imaging", "Biomechanics", "Biocomputing", and "Bioelectrocatalysis and Biofuel Cells". There is active teaching and research in all four of these areas, and there are faculty interested in developing them as new focus areas.

2.2 Program is consistent with the role and scope of UNM

An objective of UNM's strategic plan, as approved by the Regents and faculty, is to:

> "*evaluate and restructure UNM's support for graduate education and raise the effectiveness and stature of our programs*."

The proposed BME program is a direct response to this objective. In the past three decades, virtually all universities in the U.S. and abroad have begun to offer specific degree programs in BME. The University of New Mexico is one of only a handful of flagship state universities that does not currently offer an advanced degree program in BME. Notably, the state of NM does not have a graduate program in BME. This prevents the State of NM and UNM from providing specific training in BME to compete for many of the top students and faculty. To compete favorably with other universities for federal funds and for high quality students and faculty, it is imperative that UNM offer a master's of science degree program in BME.

The proposed degree program is consistent with UNM's mission of providing graduate education and training in technical and scientific areas that are critical to the economy of the State of New Mexico, specifically, and to the U.S. economy generally. Our proposed program brings together a superlative combination of BME courses, labs, research programs, and a statewide network of biomedical engineering partners. This program will promote the acquisition and application of new knowledge in BME. It will produce highly trained and skilled graduates well-qualified to move into academic, industrial or federal BME-oriented positions of employment.

An advanced degree program in BME will make it possible for UNM to prepare students for biomedical engineering careers. This training will prepare students for positions in academia and in laboratories across the nation and worldwide, where they will discover and create breakthroughs in medicine, biomedical engineering and basic scientific fields. Such programs will make UNM more competitive for research and training grant funding from NSF, DOE, NIH and other sources, and enhance UNM's research and training partnerships with other institutions, federal and state programs, and private industry. It will also enhance UNM's ability to attract and retain world-class faculty. In summary, the proposed graduate degree program supports UNM's entire vision of growth and service to the citizens of New Mexico.

Dr. Arup Maji, the Interim Dean of the School of Engineering, is fully committed to ensuring that this program will succeed. As the designated Contact Person for this proposal, he can answer questions about the program by e-mail at arup@unm.edu, or by phone at 505-277-5521.

2.3 Proposed program is an institutional priority

The School of Engineering places a high priority on establishing the proposed master's of science program in biomedical engineering. This is demonstrated by the extent to which research and graduate education in BME is already taking place in laboratories and classrooms across campus and at several UNM research centers, most especially the Center for Biomedical Engineering (CBME), which was formed to specifically pursue BME research at UNM and in NM. Furthermore, the Provost has made it one of her priorities to create a new master's degree program in BME.

Finally, one of the 13 "Regents' Goals for the President" in UNM's 2008 Strategic Long-range Plan is a call for economic development. This goal is directly supported by the proposed Biomedical Engineering master's degree program, as it will enlarge the local recruiting pool of talented biomedical engineers, enhance the attractiveness of New Mexico to outside companies considering relocating here, and stimulate a more robust local BME infrastructure. Details of these anticipated positive effects are provided below.

Chapter 3
Justification for the Program

3.1 Need

The need for improved medical treatments provided by biomedical engineering is becoming critically important in the lives of all U.S. citizens. As new medical crises arise and the cost of effective treatment increases, the improved medical treatments and cost efficiencies offered via biomedical engineering are becoming critical for our children, our parents, and ourselves. These demands are only heightened by the needs of the aging U.S. population.

The number of biomedical engineering jobs will increase by 21 percent over the next decade, which is the highest growth rate of any engineering discipline (*source*: U.S. Department of Labor reports that Occupational Outlook Handbook, 2008-2009).

As an economic development engine, biomedical engineering is fast-growing and profitable. It is a major component of the U.S. economy today. In the first 5 months of 2009 alone, the U.S. ran a trade surplus in biotech of more than $3 billion (*source*: U.S. Dept. of Commerce, 2009). Hence, we have an excellent competitive advantage in this area over other countries.

Not surprisingly, more than three-fourths of all U.S. economic development organizations rank biomedical/biotechnology in their top two priorities. More than 40 states have economic development programs targeting the industry (*source:* Brookings Institute, Center on Urban & Metropolitan Policy, 2002).

With regards to the local economy, we in the state of New Mexico have the advantage of having a major research hospital, a major research university, and two national laboratories all within about 100 miles of each other. This density of research drives significant entrepreneurship in many areas and, as all the institutions have strong interests in biomedical engineering, it should be a driver for investment in biomedical engineering in the state of NM.

Federal funding agencies also recognize the importance of biotech. In 2002, the National Institutes of Health (NIH) established a new institute dedicated to fund biomedical engineering research, the "National Institute for Biomedical Imaging and Bioengineering". In it's first year,

the new institute was appropriated $111 million. By 2009, this had nearly tripled to over $311 million (*source*: http://officeofbudget.od.nih.gov/pdfs/FY11/Actual%20Obligations%20by%20IC%201997-2009.pdf). In contrast to the NIH, BME funding levels at the National Science Foundation (NSF) are far harder to quantify. However we know anecdotally that the NSF just launched a new program area in biosensing, and that the budget for NSF's Division of Chemical, Bioengineering, Environmental, and Transport Systems increased from $109 to $159 million dollars from FY08 to FY09 (*source*: "CBET Division Overview" at http://www.nsf.gov/eng/cbet/programs/). Clearly, experts at the NIH and NSF are trying to increase funding allocations for biotech research because they recognize that the heavy and continuous demand for new technology will be satisfied, either in the U.S. or elsewhere, and that it is in our nation's interest to be on the leading edge of this important field.

A BME degree program at UNM can help meet this need.

Across the U.S. there are over 100 biomedical engineering graduate programs. They are found at every leading university in the United States, and most flagship state universities (Table 3.1). In contrast, doctoral or master's program in biomedical engineering are not offered at any

Table 3.1. BME degree programs at flagship state universities in the U.S., as of March 2008

	School	Undergraduate degrees	Graduate degrees	Source
AL	University of Alabama	BS in BME	MS, Ph. D.	http://main.uab.edu/soeng/Templates/Inner.aspx?pid=49344
AZ	University of Arizona	"Undergraduate specialization in BME"	MS, Ph. D.	http://www.bme.arizona.edu/
CA	UCB & UCSF (joint program)	none	Ph. D.	http://bioeng.berkeley.edu/prospectivegrads.php
CA	Univ. California Berkeley	BS in BME	none	http://bioeng.berkeley.edu/
CA	Univ. California Davis	BS in BME	MS, Ph. D.	www.bme.ucdavis.edu/
CA	Univ. California Irvine	BS in BME	MS, Ph. D.	www.bme.uci.edu/
CA	Univ. California Los Angeles	BS in BME	MS, Ph. D.	www.bme.ucla.edu/
CO	University of Colorado Boulder	BS in BME	MS, Ph. D.	http://www.colorado.edu/engineering/BME/
CT	University of Connecticut	BS in BME	MS, Ph. D.	http://www.bme.uconn.edu/
FL	University of Florida	none	MS, Ph. D.	http://www.bme.ufl.edu/academics/degrees/index.php
GA	University of Georgia	BS in Biochemical Engineering	none	http://www.engineering.uga.edu/academics/index.php
HI	University of Hawaii	BS in Bioengineering	MS in Bioengineering	http://www.hawaii.edu/academics/degrees/
IL	University of Illinois UIUC	BS in Bioengineering	MS, Ph. D. in Bioengineering	http://www.bioen.uiuc.edu/about.html
IN	Indiana University	BS in BME	MS, Ph. D.	http://www.engr.iupui.edu/bme/
IA	University of Iowa	BS in BME	MS, Ph. D.	http://www.bme.engineering.uiowa.edu/
KS	University of Kansas	Bioengineering concentrations within BS ChE and ME	MS, Ph. D. in Bioengineering	http://bio.engr.ku.edu/
KY	University of Kentucky	none	MS, Ph. D.	http://www.cbme.uky.edu/faq.htm
ME	University of Maine	minor in BME	none	http://www.catalog.umaine.edu/preview_entity.php?catoid=47&ent_oid=3384&bc=1
MD	University of Maryland	BS in BME	MS, Ph. D.	http://www.bioe.umd.edu/index.php
MA	University of Massachusetts Dartmouth	none	MS, Ph. D.	http://www.umassd.edu/engineering/mtx/bmebt/
MI	University of Michigan	BS in BME	MS, Ph. D.	http://www.bme.umich.edu/
MN	University of Minnesota	BS in BME	MS, Ph. D.	http://www1.umn.edu/bme/
NE	University of Nebraska	BS in Biological Sys Eng	Ph.D.	http://www.engineering.unl.edu/specialty-units/BiomedicalEngineering/index.shtml
NV	University of Nevada Reno	BS in BME	MS, Ph. D.	http://www.unr.edu/bme/
NJ	Rutgers University	BS in BME	MS, Ph. D.	http://biomedical.rutgers.edu/facultyopenings.php
NY	SUNY Stony Brook	BS in BME	MS, Ph. D.	http://bme.sunysb.edu/bme/
NC	University of North Carolina	BS in BME	MS, Ph. D.	http://www.bme.unc.edu/
OH	Ohio University	none	MS in BME	http://www.ohio.edu/engineering/biomedical/research/
OK	University of Oklahoma	BS in Biotech ChE	MS, Ph. D.	http://www.oubc.ou.edu/degrees/g_biomedical_ame.htm
OR	Oregon Health Sci University	none	MS, Ph. D.	http://www.ogi.edu/bme/
PA	University of Pennsylvania	BS	MS, Ph. D.	http://www.seas.upenn.edu/be/grad.html
RI	University of Rhode Island	BS	MS, Ph. D.	http://bme.ele.uri.edu/
SC	University of South Carolina	BS	MS, Ph. D.	http://www.sc.edu/usctimes/articles/2006-03/biomedical_engineering.html
SD	University of South Dakota	none	MS, Ph. D.	http://www.usd.edu/gradsch/degreeProgs/biomedical_engineering.cfm
TN	University of Tennessee	BS in BME	MS, Ph. D.	http://www.utmem.edu/grad/PROGRAMS/Biomed_Eng_Program.htm
TX	University of Texas	BS in BME	MS, Ph. D.	http://www.bme.utexas.edu/
UT	University of Utah	BS in BME	MS, Ph. D. in Bioengineering	http://www.bioen.utah.edu/factsheet.php
VA	University of Virginia	BS in BME	MS, Ph. D.	http://bme.virginia.edu/
WA	University of Washington	BS in BME	MS, Ph. D.	http://depts.washington.edu/bioe/resources/
WI	University of Wisconsin	BS in BME	MS, Ph. D.	http://www.engr.wisc.edu/bme/

school in the State of New Mexico. New Mexico is one of only 13 flagship state universities in the U.S. which do not currently offer a BME program (the others are AR, AK, DE, ID, LA, MS, MO, MT, NH, ND, WV and WY). Although training in the repair of medical equipment is offered at two community colleges in our state (Doña Ana and NMSU-Alamogordo) neither program provides the scope of training of a master's program.

For those students determined to live in New Mexico, *and* to be trained in biomedical engineering, their only choice is to create an *ad hoc* biomedical engineering program, taking whatever relevant courses they can find, and getting whatever on-the-job training they can. For all such students, this is impractical, inefficient and unsatisfactory. As a consequence, most New Mexico students with BME career aspirations tend to exit the state, or abandon their BME career plans. *The BME program proposed here will remedy this problem.*

3.2 Justifications for establishing a graduate program in biomedical engineering

The overarching justification for establishing this new program is that the State of New Mexico and its citizens will benefit from it.

Specifically, the BME program will:

- train students for BME jobs already in New Mexico
- create economic growth
- satisfy students' strong demand for BME training
- fix the "informal BME program"
- retain New Mexico's biomedical engineering talent
- enhance collaborations with local national laboratories
- promote UNM's stature in creating and applying new knowledge
- improve the integration of research and education at UNM

Each of these benefits is discussed in detail below.

A. Train students for BME jobs already in New Mexico

There are a large number of biotech companies in New Mexico that require a trained workforce (Table 3.2), all of whom will benefit from the proposed program. Some of these companies are growing very quickly, and thus have a particularly acute need for trained employees. For instance, in December 2008, the Albuquerque biotech firm TruTouch Technologies, which manufactures and sells blood alcohol testing devices, was cited by *New Mexico Business Weekly* as the single fastest-growing small business in the state, increasing its headcount from 3 to 10 in just two years. Also on the list was biotech firm Lumidigm Inc., which increased its headcount from 12 to 27 in the same time period. Percentage increases such as these are unsustainable without trained graduates.

It is no surprise, therefore, that recruiters from local industry have indicated their strong interest in the establishment of a BME graduate degree program at UNM in order that they might hire graduates from that program (letters of support, Appendix A). That message has been reiterated by both Sandia and Los Alamos national labs (Appendix A). It is clear that as the

Table 3.2
New Mexico companies and research centers that will benefit from the BME program, ranked by number of employees resident in the State of New Mexico

Company	Product	NM employees	Location
TriCore Reference Laboratories	Clinical reference laboratory	>1000	Albuquerque
UNM Health Sciences Center	Research	~750	Albuquerque
Johnson & Johnson Ethicon Endo-Surgery	Surgical tool sterilization and packaging	590	Albuquerque
Lovelace Biomedical & Environmental Research Institute	Research	540	Albuquerque
OSO BioPharmaceuticals Manufacturing, LLC	Sterile injectables manufacturing	350	Albuquerque
Los Alamos National Laboratory (Divisions B, C, D, N, MST-CINT, etc.)	Biothreat research & development	~200	Los Alamos
Sandia National Laboratories	Biothreat research & development	~100	Albuquerque
Mind Research Network	Brain imaging, research	110	Albuquerque
AMO Wavefront Sciences LLC	Eye surgery devices	50	Albuquerque
Voss Scientific	Microwave and laser sources	36	Albuquerque
Lumidigm, Inc.	Biometric devices	28	Albuquerque
UNM Center for Biomedical Engineering	Research & development	20	Albuquerque
VeraLight	Non-invasive diabetes assays	18	Albuquerque
IntelliCyt Corp.	Flow cytometry technology	12	Albuquerque
TruTouch Technologies	Blood alcohol testing devices	11	Albuquerque
Eco Sensors Inc.	Ozone monitors for sterilization	7	Santa Fe
Vista Therapeutics	Nanowire-based biosensors	6	Santa Fe
Maas Biolab LLC	Drug development	7	Albuquerque
Biomoda Inc.	Early cancer diagnostics	5	Albuquerque
Theranostech Inc.	Protein synthesis	5	Albuquerque
Avanca Medical Devices, Inc.	Syringes	5	Albuquerque
Envirco Corporation	HEPA filtration systems	4	Albuquerque
SelraD Inc.	Gene expression software	4	Santa Fe
Interfasys	Lab automation	4	Albuquerque
STAR Cryoelectronics	Magnetic sensors	3	Santa Fe
Mesa Analytics & Computing LLC	Drug discovery software	3	Santa Fe
BioAssist Consulting Services Inc.	FDA consulting	2	Albuquerque
CerroSci LLC	R&D for overexpression & protein isolation	2	Albuquerque
Altaview Technologies Inc.	Human performance sensors	N/A	Albuquerque
Lapsurgical Systems Inc.	Surgical tools	N/A	Roswell
QTL Biosystems	Diagnostic assays	N/A	Santa Fe
InLight Solutions	Non-invasive diagnostics	N/A	Albuquerque
Kestrel Corporation	Hyperspectral imaging	N/A	Rio Rancho
Bioreason Inc.	Drug discovery software	N/A	Santa Fe
Caldera Pharmaceuticals	Drug & biomarker screening	N/A	Los Alamos
	Grand total	**>1822**	

Primary source: "New Mexico Business Weekly 2009 Book of Lists". Also Angel Gonzalez, Albuquerque Plant Manager, Johnson & Johnson; Lucy Eisele, Director of Human Resources, OSO BioPharmaceuticals Manufacturing, LLC; and Spencer Farr, CEO, Vista Therapeutics.

national labs continue to work to fight bioterrorism, develop medical diagnostics and treatments, and research biofuels, they will need engineers trained in BME.

Finally, biomedical engineering is a major growth industry in the United States. It is imperative that we train New Mexico students to participate in this burgeoning field. A new BME degree program at UNM will expand the state's recruiting pool, and in turn make the state more attractive to new companies moving in, and enhance the competitiveness and growth of BME companies already here.

B. Create economic growth

In the early 1980s, Intel Corporation made a decision to locate a semiconductor chip factory in Rio Rancho. The decision to do so was based on the fact that New Mexico ranked at the top of Intel's site selection criteria. Most of the conditions which led to Intel's selection of Rio Rancho still exist today. For instance, Albuquerque was then a short non-stop flight away from Silicon Valley; we are now a short non-stop flight away from 2 of the 3 major U.S. centers of biotechnology, namely San Diego and the San Francisco Bay Area (the third is Boston). We have an excellent climate, a low cost of living, a natural environment that is relatively immune from natural disasters such as earthquakes, wildfires, hurricanes, tornadoes and volcanoes (recall the eruption of Mt. St. Helens in the 1980s which caused Intel's semiconductor chip factories to close temporarily in Portland, Oregon). We have a workforce that tends not to job-hop from

company to company, or state to state. We offer competitive tax and revenue bond incentives. We have an outstanding medical school and hospital at UNM, with a superb faculty engaged in a variety of biomedical research. In short, we have nearly all of the ingredients for being selected by the next biotech "Intel". But Rio Rancho would never have been considered by Intel if the Albuquerque metropolitan area did not have a local university with strong teaching and research programs in electrical engineering, chemistry, chemical engineering and physics. So too New Mexico will never be considered by a major bioengineering company so long as there is no BME degree program at UNM. The proposed degree program is intended to fill a critical gap that can put the state in contention for new site selections by *growing* companies.

The development of the BME program will improve New Mexico's reputation as a key participant in the biomedical engineering field. As the demand for BME professionals increases, and the new BME program meets this demand, then New Mexico will benefit from increased revenue. More specifically, the many biotech companies already in the state will benefit materially from a program in biomedical engineering at UNM in the form of technical assistance from in-state BME faculty, and in a larger biotech infrastructure and network. Many of these companies already employ UNM graduates and former postdoctoral fellows. These companies have indicated their interest in the proposed BME program and in hiring from its pool of graduates. A list of these companies is included in Table 2.

In summary, the proposed educational program will improve New Mexico's attractiveness to numerous companies, new and old, based on improved availability of highly trained graduates, collaborations with faculty, available technology and facilities, and a highly supportive state environment.

C. Satisfy students' strong demand for BME training

There is constant demand for technical developments in biomedical engineering. This demand is fueled by the prosperity of the biotech industry, and by government and citizen interest in improving health care. In turn, there is unrelenting demand for individuals trained in the field of biomedical engineering. According to a May 2009 report by the National Scientific Foundation, biomedical engineering continues to be "one of the fastest-growing engineering fields and has more than doubled in size since 2000." The number of Ph.D. degrees granted in this field increased nearly 250% over the nine-year period ending 2006. An advanced degree in BME prepares students for internships and career opportunities at national labs, hospitals, medical institutions, academia, industry, government regulatory agencies and healthcare institutions. Hence, it is seen by students as a highly attractive field with good job opportunities, good job stability and good wages -- precisely what we want in New Mexico.

UNM students know these facts, and naturally they are eager to be trained in BME.

For more than a dozen years, UNM faculty have taught various courses in biomedical engineering (Table 3.3). The large number of students enrolled in these courses is evidence of students' avid interest in BME, especially when one considers that none of the students had any prospect of receiving a BME degree at UNM or anywhere else in the state.

The student enrollment numbers shown in Table 3.3 are for courses taken *solely* as electives. Even within UNM's existing chemical engineering undergraduate major, many students study for and receive a B.S. in Chemical Engineering *with a concentration in biomedical engineering*.

Table 3.3
Number of students enrolled in BME-relevant courses taught in the UNM School of Engineering, Spring 1999-Spring 2010.

	Biomedical Technology	Medical Radioisotopes	Biochemical Engineering Principles	Bioengineering Seminar	Biosensors: Fundamentals and Applications	Medical Imaging	Introduction to Medical Physics	Biomolecular Engineering	Mathematical methods for medical physics	Applied Biology for Engineers	Mechanics and Thermodynamics of Molecular Components in Cells	Methods of Analysis in Bioengineering	Total
Spring 99	8	1											9
Fall 99			7										7
Spring 00	9												9
Fall 00			8										8
Spring 01	6												6
Fall 01			12	12									24
Spring 02	7		7	10	18	11							53
Fall 02			6	14									20
Spring 03	7			13									20
Fall 03			11	15									26
Spring 04				14	21								35
Fall 04			13	18									31
Spring 05				19									19
Fall 05				15									15
Spring 06				16	17		6						39
Fall 06				18				18	9				45
Spring 07				18									18
Fall 07				12				21					33
Spring 08				9	10								19
Fall 08				10				22					32
Spring 09				4				10					14
Fall 09				7				22		8	3		40
Spring 10				8				5				5	18

Source: UNM Office of the Registrar; Spring 2010 figures provided by the instructors.

A Department of Labor report indicates that a graduate degree is required for many entry level jobs in this field (*source*: U.S. Occupational Outlook Handbook, 2008-2009).

Perhaps even more remarkable is that the student chapter of UNM's Biomedical Engineering Society now has over 40 active members at UNM. This Society is a national professional organization founded in the 1960s to promote BME research and education. (UNM's chapter is notable for high levels of participation by female and minority students.) Of course, none of UNM's members have any immediate prospect of receiving a degree in biomedical engineering. Undaunted, they have organized themselves into a society for the purpose of enhancing their prospective professional careers *in biomedical engineering.*

If launched, the BME master's degree program will enable UNM to compete successfully

in attracting talented graduate students to one of the fastest growing fields in science, engineering and industry. It will enhance student recruitment at UNM with a degree program that is in large demand. And it will lead to a sizeable increase in the number of students enrolled in BME courses.

D. Fix the "informal BME graduate program"

Many UNM engineering graduate students currently pursue BME training *despite* the absence of a BME degree program. The scholastic interest of these students simply does not coincide with any degree program UNM now offers, but nevertheless they remain committed to graduating from UNM with BME training. Fortunately, many BME-relevant courses *are* taught within the School. So these students routinely cobble together as best they can an *informal program* of BME graduate study. In this sense, the School is already "doing BME", but in a scattered and disjointed way. Obviously this is not how we want to serve our student population. Indeed, the current situation forces students to take more than a few irrelevant courses merely to fulfill the requirements of whatever second-best degree program they are in. Even worse, none of the BME-relevant courses they *can* take are offered in the context of a carefully designed BME curriculum.

*Establishing a new BME graduate program immediately remedies these problem*s. With a new graduate degree program, students will be able to pursue a coherent course of study customized for their BME training, with each course offered in the context of a unified curriculum. The relevance and completeness of that curriculum has been established by a group of more than a dozen UNM professors who know the field thoroughly, know the core courses which must be taught, and know which elective courses should be offered. Details of this new curriculum are in the proposed catalog copy shown in Appendix C.

E. Retain New Mexico's Biomedical Engineering Talent

Currently, we lose resident New Mexico students to other states' BME programs. Moreover, our ability to recruit students from other states is handicapped by the absence of a master's degree program to which out-of-state students can be recruited.

Most new BME knowledge and intellectual property in the state is produced as a result of *scientific engineering*, not as a result of deals, mergers, or acquisitions. If we want to grow our state's biotech economy, we need to grow it at home. And the first step in that process is to nurture students who are thoroughly adept at conducting BME-specific *scientific engineering*. These students can be either native-born or recruited beyond our borders. But either way, *students* are at the root of our success.

A group of a dozen or so UNM faculty spent significant time discussing and planning the curriculum for the new degree program proposed here. They have been motivated to do so for various reasons, which include a strong desire to boost the statewide economy and improve citizen health through biotech. They also have a keen interest in their own students' well-being, and in the quality of students they can attract to their labs. Indeed, the availability of a master's degree program in BME is important for both the recruiting *and* training of their own students. In turn, these students are the foundation of each professor's success as a researcher and recipient of federal grants, for it is well-recognized that faculty success depends on student success. If the BME graduate program is approved, then UNM will do a far better job *recruiting* and *retaining*

in- and out-of-state students. We will reduce the pressure that causes most of our BME-focused students to exit the state. As our existing BME faculty become more successful, this will enable recruiting additional quality faculty, drive more industrial interactions, and create more biomedical engineering entrepreneurship opportunities.

F. Enhance collaborations with local national laboratories

Sandia National Labs (SNL) and Los Alamos National Lab (LANL) are heavily involved in biomedical engineering related disciplines to accomplish their national security missions in reducing the threat of bioterrorism and the development of sustainable energy such as biofuels. UNM's proximity to SNL and LANL is a golden opportunity for our students to conduct research at these prestigious labs via internships and summer employment, and for faculty to engage in research collaborations there. Already, some BME researchers at LANL and SNL have appointments at UNM, and some groups of UNM professors and national lab scientists pursue joint research in biomedical engineering. The proposed BME program will stimulate an expansion of such engagements. These kinds of collaborative efforts, with these scientists *in particular*, are important because they expose UNM to the sort of difficult but important BME problems that are *only* being tackled at the national labs. Also, the local national laboratories (LANL and SNL) are enthusiastic about hiring graduates from the proposed program (Appendix A). The absence of a BME program at UNM is an impediment to realizing the above opportunities.

G. Promote UNM's stature in creating and applying new knowledge

The proposed program fits well with New Mexico's long-standing role in conducting cutting-edge science education and research. The proposed program will introduce a coherent curriculum that stimulates the creation of new knowledge and insights for new applications, both on and off campus. It will bolster the faculty's efforts in creating knowledge and developing new applications. In sum, the development of the BME program at UNM will help maintain and grow New Mexico's prominence in biomedical engineering.

If launched, this will be one of a very few BME graduate programs at federally-designated Hispanic Serving Institutions.

Medical sciences ($16.5 billion) and biological sciences ($9.2 billion) accounted for more than one-half of all R&D at universities and colleges in this fiscal year (*source*: NSF, Survey of R&D Expenditures at Universities and Colleges, FY07). These two fields have held the two largest shares of academia's R&D performance total throughout the survey's history. By establishing a new BME graduate program at UNM, we enable UNM to compete more effectively for these research dollars.

H. Improve the integration of research and education at UNM

UNM's lack of a BME degree program is contrary to the persistent requests of the National Science Foundation (NSF) and the National Institutes of Health (NIH), two important national funding agencies, that we integrate our research with education. Once the BME degree program is established, UNM will be in an improved position to do so, and thereby improve our success in securing research grants.

3.3 Duplication

There are no formal BME degree programs in New Mexico. The nearest institutions that offer BME degree programs are, to the north, University of Colorado at Boulder; to the west, Arizona State University; and to the east, University of Texas at Austin. UTEP is in the process of introducing a new advanced degree program in BME.

To maximize the effectiveness of any biomedical engineering degree program, the offering institution should be situated close to a medical school. UNM's main campus is contiguous with the UNM Health Sciences Center, and is the only such campus in the state so situated.

Chapter 4
Clientele, Projected Enrollment, and Recruitment Strategies

4.1 Clientele

"Health and Biosciences" is one of six key "Career Clusters" in the state. It falls under the state-designated career path "Applied Research Engineering" (source: "*Work in New Mexico: New Mexico Career Clusters Guidebook"*, State of New Mexico, 2006). Thus, the proposed program is strategically oriented to serve the needs of current and future industrial and government sectors of New Mexico.

BME students in this program are likely to come from a broad range of disciplines, such as health sciences, biology, biochemistry, chemistry, physics, engineering, or materials science. Also, we expect a significant number of students from existing biotech companies in the state, and from the three New Mexico-based government laboratories, SNL, LANL and the Kirtland Air Force Phillips Laboratory. National lab employees benefit from lab-sponsored mentorship and retraining programs, and these programs are likely to enhance the numbers of lab employees who decide to enroll.

The BME program will be consistent with state goals for equitable representation of various student groups. It is expected that the students in this program will reflect the present ethnic, gender and age make-up of the technical workforce in New Mexico. Biology, chemistry and chemical engineering programs have traditionally attracted a higher percentage of women than physics or other engineering disciplines. Thus, we expect that the proposed program will help recruit talented women to graduate programs at the SOE. Similarly, biology often attracts larger numbers of underrepresented students, and thus serves as a gateway program for introducing these students to scientific and engineering disciplines.

4.2 Projected enrollment and student credit hours

Table 4.1 shows the numbers of students projected to enroll in a master's or Ph.D. level BME program at UNM.

Table 4.1. Projected enrollment

Year	*New students*
1	14
2	15
3	16
4	17
5	18

The number of new students in Year 1 shown in Table 4.1 above are computed as the sum of 5 components, "A", "B", "C", "D" and "E". Details of these components are as follows:

A = number of current UNM graduate students who would have enrolled in a BME graduate degree program if they had had the opportunity when they first applied to UNM

Source: In the Spring Semester of 2010, 2 graduate-level classes were chosen at random within the Department of Chemical and Nuclear Engineering. The students were read the following, then asked for a show of hands:

"*If UNM had had a master's or Ph.D. degree program in biomedical engineering when you first applied to graduate school here, would you have considered enrolling, at that time, in that biomedical engineering graduate program, rather than in the program that you did?*"

Of 5 respondents in one class, 1 replied "yes" (20%); of 10 respondents in the second class, 3 responded "yes" (30%). The lower of these 2 percentages was then multiplied by the average number of graduate students entering the department annually over the past 5 years (~10), viz., 20% x 10 = 2.

B = number of UNM undergraduates in the Department of Chemical Engineering who, projecting forward to the day they receive their bachelors degree, have said they would consider pursuing an advanced degree at UNM in biomedical engineering if such a program was offered at the time of graduation

Source: Two upper-division undergraduate classes were chosen at random from within UNM's Department of Chemical and Nuclear Engineering (ChNE). The students were read the following, then asked for a show of hands:

"Some of you will graduate with a B. S. degree from UNM this May, and others in the next year or 2. Thinking forward to that time when you graduate, if UNM offered a master's or Ph.D. degree program in biomedical engineering, would you consider enrolling in that program?"

Of 19 respondents in one of the 2 ChNE classes, 13 responded "yes" (68%). Of 14 respondents in the second of the 2 ChNE classes, 3 responded "yes" (21%). An average of 15 students have been graduated each year from the Department of ChNE (*source*: Dept. of ChNE). The lower of these 2 percentages, 21%, was then multiplied by the average number of students who have graduated with bachelors degrees from the Department of Chemical and Nuclear Engineering over the past 5 years, viz., 21% x 15 = 3. This number was used as the number of expected enrollees for component "B".

C = number of UNM undergraduates in the Department of Biology who, projecting forward to the day they receive their bachelors degree, have said they would consider pursuing an advanced degree at UNM in biomedical engineering if such a program was offered at the time of graduation

Source: An upper-division undergraduate class in the Department of Biology was chosen

by Biology Professor M. Werner-Washburne. The students of this class were read the following, then asked for a show of hands:

"Some of you will graduate with a B. S. degree from UNM this May, and others in the next year or 2. Thinking forward to that time when you graduate, if UNM offered a master's or Ph.D. degree program in biomedical engineering, would you consider enrolling in that program?"

Of 14 respondents in the class, 2 responded "yes" (14%). The average number of students who have graduated with B.S. degrees from UNM's Department of Biology over the past 5 years is 200 (*source*: UNM Department of Biology). To account for sampling bias, the observed percentage of positive respondents, 14%, was divided by one-sixth, and the resultant number multiplied by 200, to give an estimated number of biology-derived enrollees of 5.

D = number of New Mexicans employed in the biotechnology industry who are projected to enroll annually in a master's or Ph.D. degree in biomedical engineering = 2

Source: UNM estimate

E = number of New Mexicans employees in BME-related research at Sandia National Labs and Los Alamos National Lab who are projected to enroll annually in a master's or Ph.D. degree in biomedical engineering = 2

Source: UNM estimate

A + B + C + D + E = 2 + 3 + 5 + 2 + 2 = 14

The number of new students in Year 2 was computed by assuming that enrollment would increase by 5%, in Years 3 and by 4%, and in Year 5 by 3%.

As shown in Table 4.1, projected enrollment begins with 14 in the first year, and reaches 18 full-time students in the fifth year.

The projected credit hours of these students is given in Table 4.2. Typically students take between 18 and 24 credit hours per hour. Table 4.2 assumes the average number of credit hours to be 21.

Table 4.2. Projected student credit hours

Year	Projected number of students			Projected credit hours per year
	M.S.	Ph.D.	total	
1	4	10	14	294
2	5	10	15	315
3	6	10	16	336
4	7	10	17	357
5	8	10	18	378

4.3 Recruitment strategies

In view of the strong industrial and governmental laboratory support for the program, we expect to attract a continuous pool of applicants from these laboratories and businesses. Robust recruitment strategies will be implemented to attract these and other potential students. Such strategies will include:

- Maintaining a frequently updated web page that tells the story of the opportunities, accomplishments, and excitement of the program.
- Faculty presentations about the program at various technical meetings that are devoted to science and engineering education.
- Faculty visits to other institutions with potential sources of students.
- Mass mailings and e-mailings of flyers and other publicity materials about the program.
- Contact with our alumni and other potential benefactors through e-mail and open houses.

Chapter 5
Institutional Readiness for the Program

5.1 UNM has prepared for this program in 4 critical areas

UNM's has made preparations for the proposed BME program in 4 critical areas:

- all necessary resources have been secured by UNM for the program
- all key stakeholders support the program
- there is a plan for the administrative structure of the program
- there are a set of procedures on how students enroll and meet their degree program requirements

The first three items above are described in the present chapter; the fourth item is discussed in Chapter 10.

5.2 All necessary resources have been secured by UNM for the program

The following necessary resources have already been secured by UNM in preparation for launching the new program:

A. UNM faculty are prepared and committed to teach BME students
B. Courses are already available for the new BME curriculum
C. UNM faculty are prepared and committed to mentor the research of BME students
D. There is adequate space for BME student research
E. There is adequate equipment for BME student research
F. There is adequate money to pay for BME student research
G. School of Engineering is prepared and committed to pay the salary expenses of Program Management
H. There is adequate space for the offices of the Director and staff

The above set of resources is a comprehensive list of expense-related items, which must be in-hand to avoid financial surprise. All the above items have been secured by UNM.

Details of these resources are as follows.

A. UNM faculty are prepared and committed to teach BME students

As a result of a special project funded by the legislature in 2007, 4 new faculty members were hired in 2007-8. These 4 were hired specifically for the BME graduate program proposed here. Along with 23 other professors, they now comprise the 27 faculty who are prepared and committed to bear the teaching load of a state-sanctioned, fully-fledged BME degree program. These 27 are drawn from all 5 departments of UNM's School of Engineering:

- Chemical and Nuclear Engineering
- Computer Science
- Electrical and Computer Engineering
- Mechanical Engineering
- Physics & Astronomy

The 27 faculty are listed in Appendix B. All have expressed a commitment to work in the new program as mentors, advisors, or course instructors. Most have committed to all 3 roles.

There are no headcount shortages at UNM that impede introducing the new degree program. UNM faculty are now in position and fully ready to teach all requisite master's level BME courses. The current budget has sufficient funds to offset instructional costs for faculty required to teach courses from their home departments.

B. Courses are already available for the new curriculum

Planned for the new curriculum are 5 core courses, 3 electives, a graduate seminar, a special topics course, and Master's Thesis. Details of these are provided in Appendix C. For years, UNM professors have been teaching several of the core courses, or very close variants (Table 3.3). Several existing courses have evolved to include instruction in BME, while keeping

in mind plans for the BME graduate degree program. Hence, the amount of faculty effort to introduce these courses is minimal. Curricula vitae of instructors are provided in Appendix E.

Initially, the program will offer only one focus area, namely *Molecular and Cellular Systems*. Future focus areas will be added as need arises and resources are secured, in which case new courses are likely to be added to the program. Candidate new focus areas include *Biocomputing*, *Bioimaging*, *Biomechanics*, and *Bioelectrocatalysis and Biofuel Cells.* These four areas are of importance to UNM's biomedical engineering-oriented faculty, and for each there is faculty expertise within the School of Engineering to begin a new focus area. Future focus areas will be proposed by interested SOE faculty and will utilize existing courses where possible. If and when additional focus areas are initiated, it is anticipated that the initial and new focus areas will each be proposed as a separate *emphasis* within the degree.

To maximize the efficient use of faculty resources, we will cross-list many BME courses where appropriate. Cross-listing is useful when the subject of a particular course is relevant to more than one degree program. Typically a single instructor teaches the cross-listed course to students from outside his or her own department, and thereby achieves an economy of scale. In turn, students benefit from access to a larger number and more frequent offering of courses, which satisfy their department's degree requirements. Upon program approval, the Director will consult with relevant department chairs, and pursue the cross-listing of as many relevant courses as possible.

The administrative structure of the new program includes a Curriculum Planning Subcommittee responsible for fostering the development of new BME courses, and promoting revisions in the syllabi of existing courses as warranted, including more biomedical engineering content or application. In addition, the BME courses will be assigned separate BME codes with cross-listing in relevant departments. Credit for courses and faculty mentoring will be allocated to both the participating department and the BME program.

C. UNM faculty are prepared and committed to mentor the research of BME students

In addition to 4 new professors hired from special funding by the state legislature, UNM hired one new tenure-track BME professor and 4 research-track BME professors. With these recent additions, plus existing faculty already working and teaching in the area of biomedical engineering, the School of Engineering now has vibrant research programs in the following areas:

- Biocomputing
- Bioelectrocatalysis and biofuel cells
- Bioimaging
- Biomaterials for controlled interactions with biomolecules, cells and tissues
- Biomechanical engineering
- Biosensors, diagnostics and high-throughput bioanalytical systems
- Micro- and nano-fluidic systems for biomolecular separations

Moreover, there are now approximately 30 graduate students conducting BME research at UNM, and about 50 undergraduate students, all working in support of the seven research areas in the bulleted list above. UNM has thus attained a critical mass of BME researchers. UNM's 21 BME-affiliated faculty are prepared, committed and of sufficient numbers to mentor the research of students who want to pursue a master's degree in BME.

D. There is adequate space for BME student research

UNM's beautiful new Centennial Engineering Center is an outstanding facility for education and training of master's students. This 147,500 square feet, $42 million building opened Fall semester of 2008. Inside, the Center for Biomedical Engineering operates a contiguous 15,000 square foot state-of-the-art laboratory. Designed in accordance with best practices of industrial and large academic labs, the lab features a common area of lab benches, flanked by enclosed rooms in which large and/or sensitive equipment is located. Within the common lab area are 6 fume hoods, 9 sinks, a large number of cabinets, and 22 lab benches each ~20 feet in length. Currently about 30 students conduct research in this space. It is expected that an additional 30 students can be accommodated easily. In addition to the main lab, there are 2 satellite labs, the 1300 square foot Keck Nanofluidics Laboratory, and the 980 square foot CBME North Labs dedicated to bacteria culture and manipulation. We have plenty of lab space for the research of our anticipated BME master's students.

E. There is adequate equipment for BME student research

UNM has already invested heavily in a BME research program. It has done so with the intention of complementing a yet-to-be-launched BME academic program. Hence, the facilities and equipment in the CBME labs and satellite labs are already adequate for a wide-range of master's level research in biomaterials engineering, surface analysis, cell and tissue engineering, biosensors engineering, biochemical engineering, microfluidics engineering, and bacteria culture and manipulation.

Special facilities and equipment in the CBME labs are as follows:

(i) apparatus and materials for **biomaterials engineering and surface analysis**, including flow cytometry, ellipsometry, tensiometer, contact angle goniometry, circular dichroism spectrophotometry, surface plasmon resonance spectroscopy, UV/Vis spectroscopy, and various commercial and custom-built fluorescence spectrometers; a Zeiss LSM 510 confocal scanning laser microscope; 2 fluorescence microscopes; and electrophoresis equipment, including a Beckman Pace 5000 capillary electrophoresis instrument.

(ii) apparatus and materials for **cell and tissue engineering**, including laminar flow hoods, shakers, incubators, centrifuges, sonicators, cryogenic refrigerator, walk-in cold room, walk-in warm room, a BioSafety Level 2 room, Millipore ultrapure water systems, autoclaves, thermocycler, optical tweezers, hemocytometers, stereomicroscope, and conventional microscopes; researchers using the tissue culture facility are able to perform a wide range of standard mammalian tissue culture procedures;

(iii) apparatus and materials for **biosensors engineering** including metal evaporator, soft lithography processing station (with photoresist spin coater, Pirannha etch, bake oven, UV exposure lamp, wet station and UV mask aligner), high-precision mill, Biodot computer-controlled spotting system, knife plotter, fluorescence microscope and stereo microscope; thin film

engineering and characterization;
(iv) apparatus and materials for **biochemical engineering** including a complete set of organic and bioorganic synthesis equipment and fume hoods, probe sonicator, absorption spectrophotometer, high-pressure liquid chromatograph, and Langmuir trough, a horizontal biomaterials deposition trough, chemostats, instron, and protein adsorption apparatus; and

(v) an **optics laboratory** (~300 sq. ft.) that contains several optics tables, optomechanics, and optics.

In addition to the main 15,000 sq. ft. lab are: (i) the Keck Nanofluidics Laboratory with a full suite of equipment for **microfluidics engineering**; and (ii) the CBME North Labs, offering a full suite of equipment for **bacteria culture and manipulation**.

Finally, over the past twenty years, UNM has invested heavily in establishing other strategic centers of excellence, particularly CHTM (Center for High Technology materials), and CMEM (Center for Micro-Engineered Materials). These unique facilities provide access to an additional array of research equipment which can be tapped to support master's thesis projects. For instance, CHTM is particularly important in providing access to nanofluidics chip fabrication capabilities, whereas CMEM provides back-end semiconductor chip fabrication capabilities. These sophisticated resources are vital for conducting some of the biomedical engineering research being conducted at UNM today, and anticipated in the future.

F. There is adequate money to pay for BME student research

In the past 5 years, School of Engineering faculty have received more than $17,000,000 in competitive grants for biomedical engineering research (Table 5.2). The funding has been obtained from 16 different agencies, including the National Institutes of Health and the National Science Foundation. To date, the number of grant awards is 40.

This level of outside funding is more than adequate for sustaining the master's level research of an estimated 18 students in Year 5. Going forward, it is expected that such funding levels will either remain at the present level, or grow. We feel we are in an excellent to position to attract New Mexico's best and brightest students to this program, and thereby reduce the current brain drain.

The necessary support for graduate students will be in the form of Research Assistantships provided through externally funded research programs of program faculty or will be provided as arranged by the graduate students themselves (e.g., as part of their employment benefits).

G. School of Engineering is prepared and committed to pay the salary expenses of Program Management

The Director will be a tenured faculty member in one of the departments, and will draw 0.5 FTE. The Program Manager will draw 1.0 FTE. These fixed expenses will recur annually. The School of Engineering has secured recurring funds of $208,000 per year from the State Legislature to establish and operate a BME graduate degree program. These funds will be used to pay the salaries of BME faculty members who have been hired specifically to teach the Core

courses in this concentration, and the staff -- Director and Program Manager -- that will enable this program. They will also be used to pay for program and course materials, recruitment, and administration of the program. During the initial phase, no additional funds will be requested from the UNM SOE to support the initial focus area within the BME concentration (Biomolecular and Cellular Systems).

SOE has committed to bear ultimate financial responsibility for the BME graduate program. A letter stating the commitments of the School of Engineering is found in Appendix D.

H. There is adequate space for the offices of Program Management

The program office will be co-located with the main offices of the Center for Biomedical Engineering. Separate offices are currently available for the Director and Program Manager. With the Center for Biomedical Engineering, the program office will share a conference room, kitchen area, mail facilities, photocopier, reception area, and storage area.

I. No new journal subscriptions are required

The field of biomedical engineering dates back more than 40 years, and has been a component of research at UNM's School of Engineering for at least 20 years. Hence, there are no new journal required which are not already within the library's list of current subscriptions, or are not already considered in the library's routine review and selection process.

Table 5.2
Competitive grants received in biomedical engineering by UNM School of Engineering

Source	*FY2004-5*	*FY 2006*	*FY 2007*	*FY 2008*	*FY 2009*
National Science Foundation	$1,995,424				
National Science Foundation	$335,179				
Office of Naval Research	$300,000				
Air Force Office of Strategic Research		$3,499,760			
Office of Naval Research		$300,000			
Defense Threat Reduction Agency		$255,000			
Sandia National Laboratories		$50,000			
Sandia National Laboratories		$11,861			
National Science Foundation			$2,537,500		
Defense Threat Reduction Agency			$1,599,799		
Army Research Office			$450,000		
Sandia National Laboratories			$40,000		
Sandia National Laboratories			$10,000		
Future Technology Fund			$6,000		
Defense Threat Reduction Agency				$720,070	
National Institutes of Health				$683,804	
Defense Threat Reduction Agency				$423,000	
Office of Naval Research & Defense Threat Reduction Agency				$402,065	
National Science Foundation				$159,748	
National Science Foundation				$75,000	
Asemblon Inc.				$60,000	
Sandia National Laboratories				$40,000	
Science & Technology Corporation				$25,000	
American Cancer Society & UNM Health Sciences Center				$20,000	
Office of Naval Research				$15,000	
3M Corporation				$15,000	
American Chemical Society				$20,000	
Future Technology Fund				$10,000	
Oak Ridge Associated Universities				$5,000	
Los Alamos National Laboratory					$748,189
National Institutes of Health					$696,912
National Science Foundation					$476,899
National Institutes of Health					$343,461
National Science Foundation					$337,339
Office of Naval Research					$318,358
Defense Threat Reduction Agency					$200,125
Oak Ridge Associated Universities					$5,000
Office of Naval Research					$5,000
Total	**$2,630,603**	**$4,116,621**	**$4,643,299**	**$2,513,939**	**$3,131,283**
				Grand total	**$17,035,745**

Source: UNM Center for Biomedical Engineering Program Office

5.3 All key stakeholders support the new degree program

Critical to a successful launch of UNM's BME program is the support of all key stakeholders. This support has been obtained from the following five key stakeholders:

A. the students
B. the New Mexico Legislature
C. the faculty of the School of Engineering
D. the School of Engineering Administrative Committee
E. the Center for Biomedical Engineering

A. Students support the new degree program

There is strong student pressure for an education program at UNM that leads to BME degree credentials.

Planning for the new Centennial Engineering Center (CEC) building began over 20 years ago. Funding for the building came from a variety of sources, including severance tax bonds, general obligation bonds, state general fund surpluses, private support, and, quite remarkably, UNM students. A significant portion of the new Center's costs were borne by the students of UNM who voted in 2005 to increase student fees specifically to help fund construction of the new CEC building. It is a testament to the support of students that they helped fund a building whose purpose in part was to provide space for the proposed Biomedical Engineering graduate program.

For more than a dozen years, UNM faculty have taught various courses in biomedical engineering (Table 3.3). The large number of students enrolled in these courses is evidence of students' avid interest in BME, especially when one considers that none of the students had any prospect of receiving a BME degree at UNM or anywhere else in the state.

The relatively large numbers of students whose enrollment is shown in Table 3.3 is for courses taken *solely* as electives. Even within UNM's existing chemical engineering undergraduate major, many students now receive training that bestows upon them, at graduation, the B.S. degree in chemical engineering *with a concentration in biomedical engineering*.

Perhaps even more remarkable is that the student chapter of UNM's Biomedical Engineering Society now has over 40 active members at UNM. This Society is a national professional organization founded in the 1960s to promote BME research and education. (UNM's chapter is notable for high levels of participation by female and minority students.) Of course, none of UNM's members have any immediate prospect of receiving a degree in biomedical engineering. Undaunted, they have organized themselves into a society for the purpose of enhancing their prospective professional careers *in biomedical engineering.*

B. New Mexico Legislature supports the new degree program

In the New Mexico Legislature, there has been over a decade of support for biomedical engineering initiatives at UNM. Most of this support has been requested as part of UNM's long-term strategy to build in advance the capital infrastructure necessary for the new degree program, and to prepare UNM's faculty ranks for the new degree program, particularly with regard to

assuming instructional and research mentorship responsibilities of the new program. Over many years, State House Representative Larry Larrañaga and former State Senator Diane Snyder have been particularly supportive in leadership roles among their fellow legislators. A highlight of this advance planning was the construction of the new Centennial Engineering Center. Planning for that building began over 20 years ago. A main source of funding for the $42 million building was the New Mexico Legislature. Just recently, HB2 of 2008 provided $200,000 for recurring funding to UNM's BME effort, SB611 provided $372,000 in non-recurring funding, and SB827 provided $400,000 in capital funding.

C. Faculty of the School of Engineering support the new degree program

In May 2009 the entire faculty of the School of Engineering reviewed plans for the Biomedical Engineering Graduate Program. By a nearly unanimous vote, the faculty approved moving forward with the plans. Naturally, the faculty wants to participate in one of the most technically, economically and socially important fields of study today, biomedical engineering. Their desire is unlikely to change any time soon, as the incentives to participate are large and growing.

D. School of Engineering Administrative Committee supports the new degree program

The SOE Administrative Committee is comprised of the Dean, Associate Deans and SOE Department Chairs. In August 2009, this Committee reviewed and voted on its top Special Projects priorities. BME was selected as the top priority for the School.

E. Center for Biomedical Engineering supports the new degree program

The UNM Center for Biomedical Engineering (CBME) is an interdisciplinary center that coordinates research activities in biomedical engineering among engineers, biologists and clinicians. The center has been instrumental in fostering research among disciplines and with the high-tech industry, hiring key BME-engaged faculty, and launching a highly successful outreach program for K-12 students. It has also been heavily involved with outreach to university-level females and under-represented minorities.

Establishment of the Center has been one among several strategic steps taken by UNM to achieve its goal of improving New Mexico’s educational, research, and economic environment. The Center was launched in 2005 by the School of Engineering and the Office of the Vice President for Research and Economic Development. It has been supported under the auspices of the Office of the Provost’s Areas of Marked Distinction/Opportunity Strategic Initiative. The Center has been one of several important driving forces behind the effort to introduce new BME educational opportunities at UNM. In particular, CBME has been active in driving the efforts of the School of Engineering to formalize the granting of a "Ph.D. in Engineering With Concentration in Biomedical Engineering". CBME has also been behind the present effort to secure state approval for a new master's degree in biomedical engineering. Naturally, the Center is fully supportive of the effort embodied in the present proposal.

5.4 State and university approval is the only missing element

A. The only missing element

The faculty that are needed are already here, the facilities are in place, the curriculum is designed, the space is allocated, the equipment is purchased, the funding is available, and there are students anxious for the program to begin.

What elements are missing? To launch this program, the single missing element is state and university approval.

B. UNM has been preparing for over 10 years to launch this new program

The present proposal is the result of a concerted effort by UNM leadership for more than 10 years. The absence of missing elements, other than HED approval, is the result of the successful execution of a strategic long-range plan, which included:

(i) raising the number of BME faculty to a critical mass;
(ii) constructing a new building on campus to house both the teaching and research portions of the new degree program;
(iii) gaining the support of the New Mexico Legislature; and
(iv) launching a new organization, the Center for Biomedical Engineering, and chartering it with the task of bringing the proposed program to fruition.

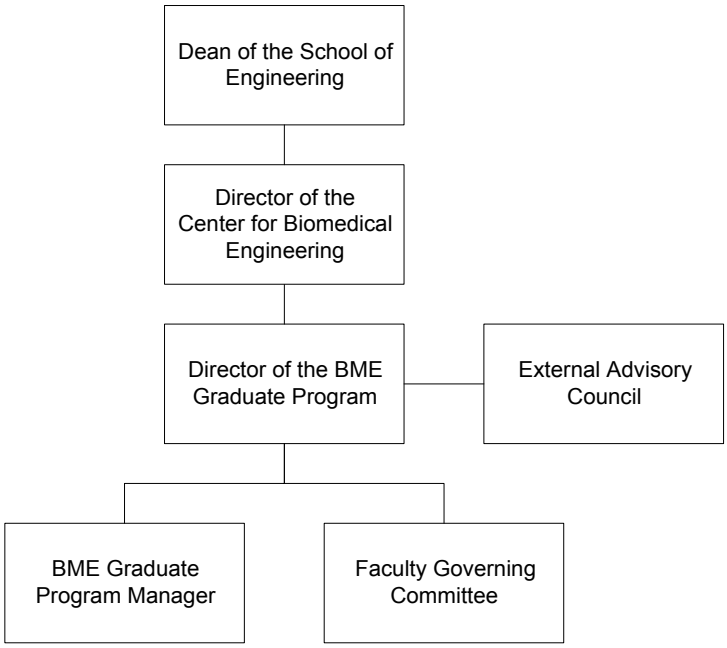
UNM is ready and committed to establish the proposed BME degree program. From the highest levels of the UNM administration, we have received approval and encouragement to develop this program and to commit all necessary resources to implement it. The BME program will build on the biomedical engineering research already in place at UNM. Much of the current research occurs through the Category III research center, Center for Biomedical Engineering. Additional work occurs at CHTM and CMEM, as well as individual and collaborative research projects and grants that cut across the various departments in the School of Engineering, the College of Arts and Sciences, and, especially, the School of Medicine. While we provide excellent research training for students at UNM, we lack a formal curriculum that leads to the credentials desired by many of our students and their prospective employers in private industry, academia, and federal labs.

5.5 Degree program administrative plan

To ensure a smoothly functioning program, we have carefully reflected upon and developed the following administrative plan.

A. Overall administrative structure

The administrative structure of the BME program is depicted as follows:.



B. School of Engineering

The proposed program is to be administered by the School of Engineering.

The primary reason for this program to be administrated by the School of Engineering is the quantitative mathematical approach that is required for an excellent BME program. This program will seek out interaction with the School of Medicine to provide medical relevance and some medical education. However, as BME is an engineering discipline it is appropriate to administer it from the School of Engineering where the appropriate engineering courses in mathematics, design, and engineering are easily taught. Joint administration of the program by both the School of Engineering and School of Medicine is not practical due to the differing class schedules where the School of Medicine uses classes structured in 2 to 3 week modules and the School of Engineering uses classes structured in 16 week lectures. Additionally, the proposed BME program is an engineering program where the emphasis is on training students to function in a research lab, development lab, or design and manufacturing site where mathematical models and deterministic phenomena are the norm. A biomedical engineer needs all the core coursework of the classic engineering curriculum, namely, chemical kinetics, heat and mass transport, thermodynamics, physics, structural mechanics, process control, information processing and statistics. This differs from a traditional medical education where students are trained to function in a clinic or hospital where stochastic phenomena and personal interactions with patients are a central feature of the workplace. Though there would be benefits to expose students to both types of instruction, a true hybrid curriculum of the two will fail to provide adequate training for either the aspiring biomedical engineer, or the aspiring medical practitioner, unless the length of training were to be extended significantly. And to do so would be quite untenable given the already long times needed by engineers and medical students to attain proficiency (4 to 6 years).

Though the program will be administered by the School of Engineering the BME program is working diligently to assure that a close partnership with the School of Medicine is

attained to ensure that few boundaries exist between the biomedical engineering program and classical medical education. Also, to ensure the usefulness of the output of biomedical engineers, a regular dialogue and collaboration between engineers and those trained in medicine and the health sciences will be continuously pursued.

The administration of a BME program through the School of Engineering is similar to other universities around the nation. Of the approximately 80 BME degree-granting institutions in the U.S., most administer their BME programs through an engineering school. We are aware of only one BME program that is administered jointly by an engineering and medical school (A BME program is run jointly by the School of Medicine at the University of California at San Francisco in conjunction with the School of Engineering at the University of California at Berkeley).

In conclusion, we consider it both prudent and standard for the proposed BME program to be administered by UNM's School of Engineering.

C. Dean of the School of Engineering

The Dean of the School of Engineering is responsible for: (i) carrying out a yearly performance evaluation of the BME program, faculty in the program, and the Faculty Governing Committee; (ii) establishing policy and procedures for the BME Graduate Degree Program; (iii) approving revisions of the curriculum and other procedures for awarding degrees; (iv) appointing the Director; (v) appointing the members of the External Advisory Board; and (vi) serving as arbiter of faculty or student complaints.

D. External Advisory Board

The External Advisory Board will assist the Dean of the School of Engineering and the Director by providing broad oversight and recommendations on how the program should be improved. Ideally and probably, this Board will include members from other units at UNM, including the School of Medicine, College of Pharmacy, and the Science and Technology Corporation. It will also have representatives from regional research laboratories, such as Sandia National Laboratories and Los Alamos National Laboratory. Other representatives will be added at the discretion of the Dean. The Board will meet regularly once a year. The Director will nominate members of the Board for approval by the Dean.

E. Director and Staff

Minimum qualifications of the Director are a tenure track appointment in one of the participating departments, and active participation in biomedical engineering research. The Dean of the School of Engineering will appoint the Director of the BME degree program. The Director will report to the Dean of the School of Engineering. The Dean is responsible for carrying out a yearly performance evaluation of the Director. The Director will be allotted 0.5 FTE release time from established teaching responsibilities. Responsibilities of the Director are: (i) ensuring the overall success of the program; (ii) overseeing the activities of the Program Manager; (iii) providing timely and adequate communication to the Dean.

Reporting to the Director will be a full-time Program Manager. Responsibilities of the Program Manager are as follows: (i) maintaining student records from applications to

graduations, and through post-graduation career follow-ups; (ii) monitoring and reporting on students' progress toward degree status; (iii) answering inquiries from prospective and current students, faculty and the public; (iv) coordinating outreach activities; (iv) responding to faculty requests; (v) assisting the Faculty Governing Committee with scheduling meetings and follow-up; and (vi) various other tasks under the direction of the Director, including administrative assistant. In consultation with chairs of participating departments, the Director will nominate for approval of the Dean all members of the Faculty Governing Committee and subcommittees.

F. Faculty Governing Committee

The BME Faculty Governing Committee will be comprised of faculty representing all the departments and centers affiliated with the BME program. Each faculty representative will be an active researcher in BME, or an active instructor of one or more courses listed under the BME course code. Each faculty representative will be selected by their respective department. A term of office will be three years. The Committee will have an official Chair and Vice Chair, to be nominated by the members for approval of the Dean. The Chair and Vice Chair will advise and report to the Director in the performance of several administrative functions, including: (i) developing proposals for changes in policy or practice that are then brought to the Dean; (ii) planning additional curriculum and symposium offerings as needed; (iii) assisting with recruitment; (iv) oversight of the Admissions Subcommittee's processing and dispensation of student applications; (v) assessment of course offerings to ensure curricular goals are met; (vi) planning the semester-by-semester and year-by-year timing of when courses are offered to minimize conflicts and ensure efficient progression of student coursework ; and (vii) assisting the Director with managing and resolving student or student-faculty conflicts and problems. Revisions in the program requirements and relevant courses will be proposed through a subcommittee of the Faculty Governing Committee. These revisions will be reviewed first by the Faculty Governing Committee and Director, then submitted for final review and approval of the Deane. By authority of the Faculty Governing Committee, the following 3 subcommittees will be initiated, each composed of representatives selected by the Committee:

(i) ***Admissions Subcommittee*** of the Faculty Governing Committee will review applications and admit qualified students to the BME master's degree program.

(ii) ***Curriculum Planning Subcommittee*** is responsible for planning course offerings each semester to ensure that students' needs for courses are met and prevent scheduling conflicts, and will encourage development of new courses to be added to the curriculum.

(iii) ***Graduate Subcommittee*** is empowered to make the final decision on pass/fail of the Master's oral examination that is recommended by a student's Committees on Studies. Students will be allowed at most two attempts to pass the Oral Exam. The Graduate Subcommittee will be the first body to review requests and appeals by graduate students who fail to pass examinations, or to resolve other conflicts on academic matters.

In addition to these sub-committees, The Faculty Governing Committee and/or the Director are also authorized to create short-lived, Ad Hoc Task Forces to study and advise on any issue deemed of importance by the Faculty Governing Committee, for example, program administration, curriculum, faculty participation, processes, procedures, etc.

Chapter 6
Projected Costs and Benefits of the Program

6.1 Substantial investments have already been made

Investments have already been made at UNM in 11 critical areas, as described in detail below.

A. Commitments to teach

The BME program will *not* require additional teaching faculty. All required instructors are already UNM faculty members, they have the appropriate skills and knowledge, and are already teaching the proposed core courses, or have committed to do so. A list of participating faculty is to be found in Appendix B.

B. Research mentors

As with all graduate degree programs at UNM, this program requires a substantial number of faculty to mentor the thesis research of enrolled students. *All such faculty are already at UNM.*

C. Office space

Standard UNM offices to house the BME Program Office, comprising the Director and

Program Manager, are already available and committed; no additional space is needed. Students actively engaged in their thesis research will be assigned cubicles in the existing graduate student bullpen adjacent to the main laboratory of the CBME, or to desks within the lab proper.

D. Specialized courses

Initially, the BME curriculum will consist of a carefully selected set of existing and new courses. The full set of courses are described below in Appendix C. In concert with the leadership and guidance of the Curriculum Planning Subcommittee, additional courses will be developed later to provide instruction on important but narrowly-defined topics of biomedical engineering, such as recent breakthroughs. These additional courses will also be offered as electives in the participating departments. The Curriculum Planning Subcommittee will review biomedical engineering courses offered at other New Mexico universities, and arrange with the host institutions to offer these through web-based methods or distance-learning technology.

E. Graduate teaching assistantships

Funding is *not* required for additional graduate teaching assistantships to support the BME program. Sources of funding will be pursued such as the U.S. Department of Education Graduate Assistance in Areas of National Need (GAANN). BME students interested in teaching will be supported through existing state-funded GA monies.

F. Research training facilities

UNM already has excellent BME research facilities and equipment that will be used in the training of BME students. These will be used in the performance of students' BME thesis research. The Center for Biomedical Engineering operates a contiguous 15,000 square foot laboratory suite in UNM's new Centennial Engineering Center (opened September 2008). Designed in accordance with best practices of industrial and large academic labs, the CBME lab features a common area of lab benches, flanked by enclosed rooms in which large and/or sensitive equipment is located. Within the common lab area are 6 fume hoods, 9 sinks, a large number of cabinets, and 22 lab benches each ~20 feet in length. Details of the equipment in this lab and elsewhere is found in section 4.1.E, above.

G. *Salary expenses of director and staff*

The Director will be a tenured faculty member in one of the departments, and will draw 0.50 FTE. The Program Manager will draw 1.0 FTE. These fixed expenses will recur annually. They will be borne by the School of Engineering. SOE has committed to bearing ultimate financial responsibility for the BME graduate program. The present proposal has been developed under the auspices of the School of Engineering, and, once the program is launched, the School will continue to provide direct fiscal and programmatic oversight through the Dean.

H. Library resources

Due to the fact that biomedical engineering is among the most attractive new research areas in the sciences and engineering, there are a large number of journals and other resources that have sprung to life in the last few years. The needs for our program are much more selective. Although it is estimated that the total figure for library resources needed for this

program is about $40,000, a good number of these journals are already available through our science and technology library. However, we are fully cognizant of the current crisis of the University Library System, given planned major budget cuts and current journal price increases for both hard copies and on-line subscriptions. Therefore, the BME program Faculty Governing Committee under the leadership of the Program Director will take the following measures to alleviate the situation as much as possible:

(i) Commit the BME program to find creative ways to obtain research resources or funding for those resources, some of which are identified below.

(ii) Establish a library resources review process to identify journal subscriptions that are relevant, and to prioritize which are most vs. least critical, and whether there are other sources (individual, departmental, center, LANL, SNL) for obtaining access to these media.

(iii) Strongly encourage faculty to post pre- and post-publication prints of publications in a community collection (UNM Dspace at Dspace.unm.edu) archive for use by and distribution to those who need access to these resources.

(iv) Take measures to ensure that all major and large biomedical engineering grants include a budget line to fund research information resources that are needed for the BME program students and faculty, and the University Library System agrees to use those funds to purchase and make those resources accessible to those who need them.

(v) With assistance from the External Advisory Board, investigate and pursue options for sharing information resources that are available to and at LANL and SNL, both through the Fair Use process and through formal collaborative agreements.

I. Laboratory course development, equipment and additional fees

Starting a new BME graduate program will *not* require allocating faculty time to develop laboratory courses. Nor will there be *any* need to procure lab course equipment. This is because the proposed program is at the master's level, a level at which lab courses are essentially non-existent due to the fact that each student conducts his or her own novel research under the one-on-one direction of a thesis advisor. (In the highly unlikely event that any such master's-level lab course were to be offered in the future, a flat fee per credit hour would be charged for high cost lab or computer equipment and materials; and the fee structure would be comparable to fees charged for engineering, physics and chemistry courses.)

J. Student support services

Student Support Services will not need to provide support beyond what is ordinarily provided to graduate students who are part of the UNM community.

K. ITS requirements

Information Technology Services (ITS) will *not* need to provide support beyond what is ordinarily provided to graduate students who are part of the UNM community.

6.2 Expected benefits of establishing the BME degree programs

A. Greater employability of New Mexico graduates

The immediate users and beneficiaries of this proposed program are current and incoming graduate students seeking advanced training in biomedical engineering. Graduates of the program will use their knowledge to discover new knowledge, start new businesses, and/or gain employment in existing biomedical engineering companies and labs. This will enhance the well being of all of NM.

B. UNM established as a leader in creating, disseminating and using new knowledge

If launched, this will be one of a very few BME graduate programs at Hispanic Serving Institutions. We can continue to take pride in our leadership in providing a vigorous and up-to-date education to our students.

C. Improved graduate student recruitment

The proposed BME program capitalizes on the national research reputation of the University in biomedical engineering. It will attract many high quality graduate students who wish to pursue a course of study in BME, especially those who wish to improve their knowledge and skills for positions in the national laboratories and industry. We find that many highly qualified graduate students have elected to go to elsewhere because UNM lacks a formal graduate degree program in biomedical engineering.

D. Attractiveness of a BME master's degree

The BME program will recruit students from various disciplines who want graduate training specifically in BME. These students will have a department home in the BME Graduate Program, not distributed among the various traditional departments. They will receive their BME master's of science degree from the BME Graduate Program. Since all participating faculty are affiliated with a UNM department, it is expected that the graduate students will also participate in seminars (and other academic functions) in their advisor's home department. The BME degree will provide career opportunities that are not as readily available with a traditional physical or engineering science degree program. The degree can also enhance career opportunities for students in traditional fields who take BME courses. Participating departments across the UNM campus can establish an area of concentration in BME and their students can take courses as electives for their traditional degree programs.

E. BME program will enrich undergraduate education

Undergraduate students cannot apply to a graduate level program, of course. However,

establishing the BME program improves their opportunity to take BME graduate-level courses as electives. In turn, high-quality graduate elective courses in BME are likely to be effective in enticing UNM's top undergraduates to pursue an advanced degree in BME at UNM.

F. Attract high-quality faculty

The BME program will attract outstanding biomedical engineering research faculty to UNM. This will strengthen not only UNM departments but also the BME program. New faculty will enhance the excellence of biomedical engineering research at UNM, especially at the departmental level.

G. Greatly enhanced capacity to obtain research funding

Biomedical engineering is an important research arena with increasing opportunities for receiving priority funding from federal agencies. Because of the state-of-the-art research being conducted at the New Mexico national laboratories in biomedical engineering, and the collaborative programs already in place between UNM and national lab researchers, UNM occupies an excellent position to become one of the leading universities conducting biomedical engineering and offering a comprehensive BME-oriented course of study. The BME program provides an opportunity for the integration of research and education, which is an important criterion for research funding as it provides for broader impact.

H. Enhance the New Mexico economy

The establishment and growth of the UNM BME would provide a trained pool of talented BME researchers for currently existing New Mexico high tech businesses and the national labs. It could attract and provide a strong inducement for other high tech companies, new or old, especially those based on biomedical engineering, to locate in New Mexico.

The average annual pay of biotech workers nationally is $51,000. Local wages in biotech are comparable. For example, the average pay of 590 workers employed in Albuquerque at the Johnson & Johnson Ethicon Endo-Surgery facility is more than $67,000 (source: Angel Gonzalez, Albuquerque Plant Manager, Johnson & Johnson, personal communication). These wages bring about $40,000,000 per year directly into the state's economy.

I. Support the goals of the State of New Mexico Higher Education Department

The proposed program supports Strategic Priorities 2, 3 and 4 of the State of New Mexico Higher Education Department (HED) "Strategic Priorities and Goals 2006 - 2010". Within these three Strategic Priorities, the following 9 HED goals (quoted in bold type below) are specifically supported by BME (comments in italics):

HED Goal 2.5: Improve the recruitment and retention of high quality faculty and staff.

To date, the Biomedical Engineering Program has resulted in the recruitment of 5 new tenure-track faculty, and 3 research professors.

HED Goal 3.1: Recognize and fund the role of research in our state's economy.

To date, UNM's BME-affiliated professors have brought in grants totaling more than $17,000,000 (Table 5.1).

HED Goal 3.2: Align programs and services with statewide career clusters.

The career cluster with which the proposed program is aligned is specifically, the "Health and Biosciences" Career Cluster, career path "Applied Research Engineering", as described in the "Work in New Mexico: New Mexico Career Clusters Guidebook", August 29, 2006.

HED Goal 3.4: Improve collaboration between two and four year institutions to create programs that increase the number of educational opportunities for all New Mexicans.

Under the auspices of the Center for Biomedical Engineering, UNM has current, active collaborations with New Mexico Highlands University, San Juan College, New Mexico Tech, CNM, New Mexico State University and the Southwest Polytechnic Institute. In addition, we have research collaborations with Albuquerque Public Schools, TriCore Reference Laboratories, Sandia National Laboratory, Los Alamos National Laboratories, and others.

HED Goal 3.5: Support regional vitality by contributing artistic, cultural, and civic assets that attract employers and other residents seeking a higher quality of life.

Intel's decision to locate in NM was based in part because UNM had good programs in electrical engineering, chemistry, chemical engineering and physics (for a more detailed discussion, see section 3.1.B) . If the state doesn't have a program in BME, we will never make it on the short-list of bioengineering companies who are thinking about locating new facilities here.

HED Goal 3.6: Create funding mechanisms and support for collaborative technology projects that serve the needs of the state.

See notes under "HED Goal 3.4", above.

HED Goal 4.2: Create funding mechanisms that encourage research institutions to be top tier.

Currently there are no institutions in the State of New Mexico which offer a graduate degree in biomedical engineering, even though this a field of major competitiveness for the United States in the global economy, and virtually all other state universities in the U.S. offer such a program. Also, see notes under "HED Goal 3.1", above.

HED Goal 4.4: Develop incentives to keep our best New Mexico students in our state institutions.

No doctoral or master's program in biomedical engineering is offered at any

school in the State of New Mexico. For those students who are determined to live in New Mexico, and want training in biomedical engineering, their only choice is to create an ad hoc biomedical engineering program, taking whatever relevant courses they can find at UNM, and procuring whatever on-the-job training they can find. For virtually all students, this is impractical, inefficient, and burdensome. The central problem is that, as a consequence, New Mexico students tend to exit the state, or abandon their career plans in BME. The BME master's degree program is intended to remedy this precise problem.

HED Goal 4.6: Support institutions' efforts to compete globally and to prepare their student to do so.

BME is a leading discipline that is not formally represented in New Mexico. The BME Program prepares students to compete in this burgeoning field. BME is a growing effort across the state. Also, see notes under "HED Goal 4.2", above.

Chapter 7
Summary of Costs and Benefits

The creation of a master's degree program ordinarily requires a substantial investment of money. However, nearly the entire investment has already been made by UNM over the past twenty years in new faculty hires, curriculum development, student training options, strategic centers of excellence, facilities, buildings, and collaborations with national laboratories and industry partners. ***The only significant remaining expenses are the annual salaries of the Director and the Program Manager.*** Details of the projected expenses are given in Table 7.1.

Table 7.1
Resource Allocation/Reallocation Table

Resources		***What is needed***	***Who pays/ paid for it***	***Recurring***
1.0 Faculty Salaries		$119,368	SOE	yes
2.0 Student Fellowships		Student research fellowship stipends	Competitive research grants	yes
3. Staff	Sr. Program Manager + Academic Advisor	SPM @ 0.15 FTE ($9,584) AA @ 1.0FTE ($35,000) + 5% increase/year	SOE	yes
4.0 Fringe Benefits		$46,169	SOE	yes
5.0 Office Supplies		$3,000/year	Provost, SOE	yes
6.0 Office Equipment		$2100/year	Provost, SOE	yes
7.0 Library Resources		$10,000 Y1, then $7K/year	SOE	yes
8.0 Other	Director	0.5 FTE position ($52,500) + benefits ($15,750)	SOE	yes
	Teaching Laboratory	Not needed	N/A	no
	Office Space	Standard offices for Director and Program Manager	SOE	yes
	Student recruitment materials, mailing, travel	$10,000	SOE	yes
	Web site development and maintenance	$10,000	SOE	yes

A Director of the program has been named. To launch the program, there is nothing left to do but hire the Program Manager, and begin accepting applications from students.

We expect the BME program will benefit from significant continued funding from the

NSF and NIH to BME faculty members, plus support from industry, national labs and other UNM benefactors. We believe continued vibrant research funding will ensure that the degree program will be maintained at a level that is commensurate with other SOE degree programs.

Benefits of the new program are:

- Training of students for BME jobs already in New Mexico
- Creation of economic growth in New Mexico
- Satisfy students' strong demand for BME training
- Retain talented New Mexico resident workforce
- Enhance collaborations with local national laboratories
- Promote UNM's stature in creating and applying new knowledge
- Improve the integration of research and education at UNM
- Enhance UNM student and faculty recruitment

If the program is launched, UNM will join the ranks of 37 out of 50 other flagship state universities who already offer graduate degrees in biomedical engineering.

Given the significance of the BME degree program, it is clear that the academic and research benefits to UNM and the School of Engineering far outweigh the costs. Most of the required funding of the Biomedical Engineering M.S. degree program is *already covered* from existing resources that are available to participating departments from the college offices and other sources. The BME program fits well into the existing framework of science and engineering courses, and within all budget constraints on campus.

Chapter 8
Quality of the BME Graduate Degree Program

Program quality will be comparable or better than the standards of all M.S. programs in the School of Engineering. The Faculty Governing Committee will establish metrics and a process for evaluating quality goals. To maintain the highest quality program possible, the following areas will receive special attention by the Director, program manager, affiliated faculty and Faculty Governing Committee:

Students. Admission standards and requirements for completing the M.S. will meet or exceed the requirements of the departments in the School of Engineering. Details are provided in Chapter 8 on the requirements students must meet to gain acceptance into the program, and to obtain the M.S. degree.

Faculty. The field of biomedical engineering is currently at the forefront of scientific research, and advancing rapidly. It is imperative that BME faculty possess expert knowledge of the current state of BME research and its applications. The faculty will consist mostly of professors from SOE.

Research Facilities and Equipment. Participating faculty and departments will continually seek funding to upgrade the BME facilities and equipment with grant proposals to federal, state and private funding sources.

Course Curriculum. The BME curriculum has been carefully developed to ensure that it is of the highest academic quality. The curriculum is currently comprised of a total of 9 courses, 6 of which are courses that are already taught on campus; and 3 new courses. Initially, the program will offer only one focus area, namely *Molecular and Cellular Systems*. Future focus areas will be added as need arises and resources are secured, in which case new courses, both core and elective, are likely to be added to the program. SOE faculty have identified at least 4 candidate new focus areas: *Biocomputing, Bioimaging, Biomechanics and Bioelectrocatalysis and Biofuel Cells*. The present proposal is explicitly designed to allow the development and introduction of other focus areas, and to accommodate changes in the field in the years to come.

All students must complete the 5 core lecture courses (3 credit hours each for a total of 15 credit hours), and then complete electives from a large cross-listed selection. No courses remain under development, therefore there is no requirement of faculty release time. To ensure continued high quality in course offerings, proposals for new courses in any of the categories will be encouraged to enhance the curriculum in terms of new developments in BME. These proposals will first be reviewed and approved by the BME Curriculum Planning Subcommittee, then the Faculty Governing Committee and

ultimately by the Dean.

Instruction. To ensure high quality instruction, there will be a constant and productive interplay between lectures and graduate thesis research projects.

Student and Faculty Group Identity. A characteristic of all successful graduate programs is a sense of group identity among students and faculty. Typically, newly-launched programs must strive to cultivate this sense of identity. In the present case, however, the work of cultivating an identity is largely *completed* as a result of three events:

(i) the start-up in 2007 of the new Center for Biomedical Engineering, which brought together approximately 20 faculty from 8 departments within SOE, the School of Medicine, and the College of Arts and Sciences;

(ii) the construction and occupation in 2008 of the new Centennial Engineering Center by many of the faculty who have now committed to being part of the BME graduate program, and by their students; and

(iii) the series of meetings and other prior planning activities by the affiliated faculty which resulted in the BME curriculum proposed here.

Together, these 3 events have produced an authentic sense of group identity among students and faculty. It is important that this continue after the program has been launched. To ensure this, various additional activities will be planned and organized by the Director. These will include speakers' events followed by receptions, symposia with research presentations by BME faculty and graduate students, and an Annual BME Symposium. Such events will provide an opportunity for faculty and graduate students to highlight research and academic work on campus to external constituents, particularly the regional federal laboratories and industry liaisons. Students will prepare posters to showcase their research and be given opportunities to visit with guest speakers. Other events will include planned group trips to professional conferences, local and regional cultural and recreational events and activities, and a potluck picnic. Interactions will also be encouraged outside the classroom or laboratory among the BME students with as many participating BME faculty as possible, such as visits to industry locations, particularly start-up companies.

Chapter 9
Assessments of Operations and Impact

The assessment of the BME program will conform to the guidelines that govern all other graduate programs at the University of New Mexico. In consultation with the Dean, the BME Director will establish the goals for the program, and the process for assessing the extent to which goals are achieved. The Director and Faculty Governing Committee will arrange for external reviews by panels of distinguished members in the biomedical engineering academic and industrial research communities. It is anticipated that these reviews will be conducted as part of the graduate reviews that are scheduled periodically. The assessments will be performed by the Program Manager under the supervision of the Director. Results will be submitted in the form of a written report to the Faculty Governing Committee and the Dean.

Assessment criteria will include the following:

(i) Development of new knowledge, and maintaining a leadership role for UNM: Number of research grants awarded to faculty, fellowships awarded to students, publications by faculty, publications by faculty co-authored with students, applications and proposals awarded for patents and trademarks, conferences attended by faculty and students, and presentations given by students and faculty.

(ii) Application and admission records: how many students applied, their qualifications, which students (high/mid/low quality) were accepted, and which of those enrolled.

(iii) Enrollment and grade records: Tracking enrollment and grades of students in the BME program, and their career development activities.

(iv) The number of students that receive BME graduate degrees; and of those, how many go on to secure academic, industrial or federal positions in New Mexico, elsewhere in the nation, and abroad.

(v) Conducting and assessing student evaluations of each course and lecture period as well as each instructor at the end of each semester, with anonymous results provided to each instructor and to the Director.

(vi) Metrics on how well the BME program prepares its graduates for positions in the field. The External Advisory Board may be asked to conduct on-site assessments and report the results to the Dean, with recommendations for improvement.

(vii) Development and implementation of a formal one-on-one exit interview procedure to solicit comments, criticism, and recommendations from each program graduate before they leave campus.

(viii) Creation of and results of a tracking program to monitor the post-graduation careers of the BME program graduates and to conduct periodic surveys to determine the impact that participation in the program has had on their careers, as well as on the careers of faculty participants.

Chapter 10
Admission Criteria and Requirements for the Master's Degree (M.S.)

10.1 Overview

To serve the diversity of backgrounds and interests of students, two plans are offered leading to the M.S. degree in BME. Plan I requires the student to conduct research, to write a research thesis, and to complete coursework. Plan II is generally intended for students working full time in industry or the national labs, and requires only coursework and successful passage of an oral examination. Plan I, but not Plan II, is recognized to be preliminary to advancement to candidacy for the Ph.D. degree in Engineering. If a successful recipient of the master's degree is later admitted to the Ph.D. program, they must pass the standard Ph.D. examination, regardless of whether their M.S. was earned under Plan I or II. The Admissions Subcommittee of the Faculty Governing Committee will decide under which Plan a student is to be admitted.

10.2 Degree Requirements

A. Admission prerequisites

General admission requirements given in the Graduate Program of the UNM Catalog apply to the BME master's degree program. An applicant must hold a bachelor's degree from an accredited institution, and have a scholastic average of B (at least 3.0 on a 4.0 scale). Admission decisions are based on a consideration of the applicant's undergraduate grade point average, letters of recommendation, and Graduate Record Examination scores. Applicants who plan to apply to the BME program must have a bachelor's degree in a natural science or engineering field. A sophisticated level of mathematical ability is expected, at least through differential equations.

Those who meet all requirements except mathematics, but are otherwise well prepared, can meet the mathematics requirement by completing Math 316 during the first semester with a B or better, or by taking and passing with a B or better an equivalency test that certifies sufficient competency in mathematics.

B. Application process

To apply, domestic applicants must complete and submit the on-line application form with a $50 nonrefundable application fee and two unopened official transcripts to the Office of Graduate Studies (OGS) by the annual deadline January 31. OGS will forward these materials to the BME Program Office for the Admissions Subcommittee review and selection. In addition, applicants must submit the following directly to the BME Program Office:

a. letter of intent from the applicant about why this program is of interest

b. three sealed letters of recommendation, sent directly to the BME Program Office

c. GRE entrance examination scores

d. any other materials that are relevant to the application, such as experiential credit

International applicants must submit additional materials as identified in the Catalog to the UNM International Admissions Office, including undergraduate education documents, demonstrated proficiency in English, and evidence of adequate financial resources and health insurance.

C. Admission and advising roles

All applications will be reviewed to determine whether all required materials have been submitted. Applicants will then be contacted immediately to communicate whether the application has been formally accepted or awaits receipt of additional required items. The Admissions Subcommittee of the Faculty Governing Committee will review applications and make admission decisions. Applicants who are selected will be sent a notice of acceptance and program information to guide them in making decisions as they complete their studies and degree programs. This includes whether they qualify for fellowships, how they can apply for fellowships, and details of matriculation, such as obtaining a student identification card, and procedures for enrolling in classes.

(i) Selecting a Faculty Advisor/Mentor. Students will be sent information on how to select a faculty mentor. Once selected, the mentor will guide the student in the process of establishing a Committee on Studies. To facilitate this process, faculty will present their areas of research at the beginning of each fall semester, and indicate how many students they can support within their research groups. Students will indicate their choice of research areas, and based on openings available and student interest, assignment of students to research groups will be made. The Admissions Subcommittee will facilitate this process.

(ii) Committee on Studies. The student and faculty mentor will invite three faculty members to serve on each student's Committee on Studies. This Committee will guide the student in planning a list of courses that meets the student's interests and needs (known as a Program of Studies), which will be counted toward meeting the degree requirements. This plan

must be approved by the student's advisor and the BME Director prior to submission to the OGS. The Committee will also supervise the student's progress, and it will conduct the required thesis exams.

D. General degree completion requirements

The average time to achieve an M.S. degree is expected to be 18-24 months. The maximum time for a student to spend working towards the M.S. degree is 7 years. All students in the program must be enrolled full time for at least three consecutive semesters, unless a written request for a waiver is approved by the Dean. To be a full time student, 9 credit hours must be taken per semester, or 6 credit hours if the student has an assistantship. Students must complete 4 core courses, and 4 courses within BME. Students must maintain a minimum cumulative grade point average of 3.0 in graduate-level courses taken in graduate status, and a grade point average of at least 3.0 for courses listed in the Program of Studies. Students cannot graduate with Incompletes pending, nor while on probation.

Two types of degree programs are offered, a thesis-based program (Plan I), and a course-based degree program (Plan II). Details of these two plans are as follows.

E. Completion requirements of a thesis-based M.S. degree (Plan I)

The minimum requirements for the thesis-based M.S. include 6 hours of thesis credit (BME 599) and 24 hours of course work that must include 18 hours of mandatory courses, as approved by the Committee on Studies, and at least 3 hours from the electives such as those listed below. Plan I automatically meets the requirement of at least 12 hours of course work at the 500 level or higher, exclusive of thesis credit, as stipulated by the UNM Catalog for this plan.

Plan I students must consult with one or more faculty members prior to selecting the topic of their thesis research. Final selection of their topic must be approved by one or more faculty members who agree to mentor the student's research. The student's Thesis Committee must approve the topic before the student begins work.

Copies of a student's completed M.S. thesis must be provided to each Thesis Committee member. Once approved by the Committee, the student must give an oral defense of the thesis in a presentation to the Thesis Committee to which other interested members of the university and general public have been invited.

F. Completion requirements of a course-based M.S. degree (Plan II)

The minimum requirements of the Plan II Course-Based M.S. degree program include 33 hours of course work for credit, with at least 24 hours drawn from the list of BME required and elective courses and 3 hours of research seminar/problems course. At most, 6 hours of *400 level SOE courses are allowed. Also, at least 12 hours of course work should be at a 500 level or higher, as stipulated by the Catalog for this Plan. All students in the Plan II M.S. degree program must pass an Oral Examination. This examination is administered by the student's Committee on Studies. The purpose the Examination is: (i) to determine the extent to which the student has attained knowledge of the subject matter of his or her BME courses; and (ii) to decide whether the student's knowledge meets a level appropriate to a Plan II master's degree in biomedical engineering. Subsequent to the Oral Examination, the student's Committee on Studies decides on

a recommendation that is then forwarded to the BME Graduate Subcommittee. The Subcommittee makes a final pass/fail decision. Students are allowed no more than two attempts to pass the Oral Examination.

10.3 Other Details and Problem Resolutions

A. Notice of Intent to Graduate.

Students who expect to graduate must submit their intent to the BME Program Office and the Office of Graduate Studies early in the semester of graduation: October 1 for Fall Semester, March 1 for Spring Semester, and July 1 for Summer Semester.

B. Catalog Details About Meeting Degree Requirements.

The Catalog provides significant details about requirements that master's candidates must meet to complete their degree, which apply equally for students in the BME Graduate Degree Program. These include what is necessary if a student wishes to defer entry into the program, or have a leave of absence, or to have credits transferred, or issues regarding academic standing or petitions to modify academic requirements.

C. Requests for Changes in Advisor or Committee Member, and Appeals of Decisions.

In the event that issues arise between a student and a committee member (Committee on Studies, Thesis Committee, Dissertation Committee) at any time, students are encouraged to speak with their advisor/mentor to determine whether a change is needed and they will consult with the Director of the BME Program before implementing a change in committee membership. All such communications will be maintained in strict confidentiality. If a student experiences conflict with their faculty mentor/advisor, they are expected to speak with the Director of the BME Program, who will determine whether the Graduation Committee should be asked to intervene and seek a solution. The Dean will be informed about all such requests and incidents.

All decisions regarding approval of the dissertation and passing the defense, can be appealed to the Director and the Graduate Subcommittee, who will follow the *Graduate Student Academic Grievance Procedures* described in the Catalog. The Dean will be advised about the situation and may elect to assist with mediating a dispute.

10.4 Graduate Degree Program Curriculum

The BME curriculum is comprised of 5 core courses, 3 electives, a graduate seminar, a special topics course, and Master's Thesis. In addition, cross-listed electives will also be available. Many of the necessary courses for the BME curriculum are already taught on campus, and some of these have been revised in response to the need to teach biomedical engineering. The proposed Catalog Materials are in Appendix C.

Initially, the program will offer only one focus area, namely *Molecular and Cellular Systems*. Future focus areas will be added as need arises and resources are secured, in which case new courses, both core and elective, are likely to be added to the program. SOE faculty have identified at least 4 candidate new focus areas: *Biocomputing*, *Bioimaging*, *Biomechanics*,

and Bioelectrocatalysis and Biofuel Cells. The present proposal is explicitly designed to allow the development and introduction of other focus areas, and to accommodate changes in the field in the years to come.

A. ***BME Program Core courses***

The BME core courses offer a fundamental introduction to the concepts of biomedical engineering. The suggested prerequisites for the core courses are modern physics, general chemistry and differential equations. The set of courses proposed here will cover students' needs in terms of the core required curriculum.

Biomedical Engineering (BME) Core Courses

BME 517. **Applied Biology for Biomedical Engineers.** (3)
Emphasis on engineering principles and analysis of: (i) the cell as a complete system including cellular subsystems, structures and functions; and (ii) select higher order systems of human physiology. Restriction: Permission of the instructor. {Fall}

BME 544. **Mechanics and Thermodynamics of Molecular Components in Cells.** (3)
Chemical thermodynamics and physics are used to establish a material science perspective of the molecular components – chemical kinetics – and structural properties needed for both understanding cell behavior and advancing biotechnology. Restriction: Permission of the instructor. {Fall}

BME 547. **Biomedical Engineering Research Practices.** (3)
Students will develop research, presentation, and scientific writing skills for theses, proposals, invention disclosures and journal articles. The course includes oral presentations, case studies of research ethics, technology transfer and manuscript preparation. Restriction: Permission of the instructor. {Fall}

BME 556. **Protein and Nucleic Acid Engineering.** (3)
Students will learn the scientific principles and methods for engineering and manufacturing custom proteins, peptides, nucleic acids, and carbohydrates. The course will explicitly discuss methods and tools used in the production of engineered biomacromolecules. Restriction: Permission of the instructor. {Spring}

BME 558. **Methods of Analysis in Bioengineering.** (3)
Presents applied analytical and numerical mathematical methods in the context of biomedical engineering problems. Introduces statistical methods for the design of experiments and analysis of experimental data in research and development activities. Restriction: Permission of the instructor. {Spring}

BME 567. **Biomedical Engineering Seminar.** (1)
Students will gain insight into scientific presentations and current biomedical engineering research by presenting their research and actively participating in an external research seminar which will feature outstanding external and internal researchers as speakers. Restriction: Permission of the instructor. {Fall, Spring}

BME 598. **Special Topics**

BME 599. **Master's Thesis**

B. BME Program Elective Courses

Biomedical Engineering (BME) Electives

BME 570. **Physical Bioanalytical Methods.** (3)
Introduction to the physics and chemistry of classical physical methods of analyzing biological and biologically-related samples. Topics include fluorescence microscopy, chemiluminescence, chromatography, electrophoresis, mass spectrometry, electrochemistry, ultracentrifugation, SPR, SEM, TEM, AFM, XPS, radiochemistry and flow cytometry. Restriction: Permission of the instructor. {Fall}

BME 572. **Biomaterials Engineering.** (3)
Introduction to biomaterials currently in use, including commercial and research applications. Includes an understanding of a material's properties, biological responses to the materials, clinical context of their use, manufacturing processes, and regulatory issues. Restriction: Permission of the instructor. {Fall}

BME 579. **Tissue Engineering.** (3)
A review of the current strategies involved in the design of engineered tissues and organs. The principles underlying the implementation of selected cells, biomaterial scaffolds, soluble regulators, and culture conditions will be addressed. Restriction: Permission of the instructor. {Spring}

C. ***General Electives.***

UNM offers numerous courses of direct relevance to the subject matter of biomedical engineering, including the following:

BIOL ** 351 **General Microbiology**
BIOL 547 **Advanced Techniques in Light Microscopy**
BIOM507/BIOL 581 **Advanced Molecular Biology**
BIOM508/BIOL 582 **Advanced Cell Biology**
BIOM 509 **Principles of Neurobiology**
BIOM 510 **Physiology**
BIOM 514 **Immunobiology**
BIOM 515 **Cancer Biology**
BIOM 516 **Molecular Genetics and Genomics**
CHNE/NSMS 522L. **Fundamentals of Nanofluidics**
CHNE/NSMS 530 **Surface and Interfacial Phenomena**
CHNE/NSMS 538/438. **Biosensors Fundamentals and Applications**
CHNE 504 **Nanomaterials**
CHNE 521 **Advanced Transport Phenomena I**
CS 529 **Introduction to Machine Learning**
CS 530 **Geometric and Probabilistic Methods in CS**
CS 561 **Algorithms and Data Structures**
CS 590 **Topics: Complex Adaptive Systems**

ECE 510 **Medical Imaging**
ECE 500 **Theory of Linear Systems**
ECE 533 **Digital Image Processing**
ECE 537 **Foundations of Computing**
ECE 539 **Digital Signal Processing I**
ME 501 **Advanced Mechanics of Materials**
ME 504 **Computational Mechanics**
ME 512 **Intro to Continuum Mechanics**
ME 530 **Theoretical Fluid Mechanics I**
ME 571 **Advanced Materials Science**

Upon program approval, the Director will consult with relevant department chairs, and pursue the cross-listing of as many relevant courses as possible.

Appendix A
Letters of support

1. New Mexico Biotechnology and Biomedical Association (NM Bio)

    Signed by: Dr. Shannon Sheehan, President

2. Sandia National Laboratories

    Signed by: Dr. J. Stephen Rottler, Chief Technical Officer, Vice President of Science and Technology

3. Los Alamos National Laboratory

    Signed by: Dr. I. Gary Resnick, Division Leader, Bioscience Division

4. University of New Mexico School of Medicine

    Signed by:
    Dr. Deborah Helitzer, Associate Dean, Biomedical Research Education Program
    and
    Dr. Helen Hathaway, Program Director, Biomedical Sciences Graduate Program

NMBIO

January 22, 2010

Arup Maji, Ph.D.
Interim Dean, School of Engineering
University of New Mexico
Albuquerque, New Mexico 87131

Dear Interim Dean Maji,

As President of The New Mexico Biotechnology and Biomedical Association (NMBio) I am pleased to declare my support of the University of New Mexico's proposal for a new graduate program in biomedical engineering.

The mission of NMBio is perfectly in alignment with the main goal and outcome expected of the new degree program, namely, the in-state training of students in the area of biomedical engineering. This will provide a local source of graduates, enhance the economic productivity of biotech companies already located here, and create a more favorable environment for both the start-up of new biotech companies, and the relocation of existing companies to New Mexico.

In specific, let me note our main common goals with UNM's proposal:

(i) to enhance the ability of New Mexico workers to find well-paying jobs in the fields of health care and biomedical engineering;

(ii) to stimulate New Mexico's economic development through new commercial opportunities in biotechnology; and

(iii) to attract and build biotech companies by advancing the quality and availability of bio tech workers in New Mexico.

Naturally, I lend my full support to bringing this new program to fruition.

Sincerely,

Shannon Sheehan, Ph.D., M.B.A.
President
New Mexico Biotechnology and Biomedical Association

www.nmbio.org

Sandia National Laboratories

Operated for the U.S. Department of Energy's
National Nuclear Security Administration
by **Sandia Corporation**

P.O. Box 5800
Albuquerque, NM 87185-0351

P.O. Box 969
Livermore, CA 94551-0969

Dr. J. Stephen Rottler
Chief Technology Officer
Vice President of Science and Technology

Phone: (505) 844-3882
Fax: (505) 844-4394
Internet: jsrottl@sandia.gov

February 15, 2010

Arup Maji, Ph.D.
Interim Dean, School of Engineering
University of New Mexico
Albuquerque, New Mexico 87131

Dear Dr. Maji:

I am writing this letter to endorse the development and implementation of a graduate program in Biomedical Engineering at the University of New Mexico. Though biomedical engineering is a growing element of our state's economy, no university in New Mexico offers graduate degrees in Biomedical Engineering. This forces New Mexico students to leave the state after receiving their Bachelors degree, creating a risk that they will not return to employment upon completion of their academic career.

Sandia National Laboratories employs staff at all degree levels, but we typically seek technical staff that have completed at least one graduate degree in engineering or science. We believe graduate degrees provide the training required and are an excellent indicator of preparedness to work on the challenging problems we are called upon to address. Further, as you know, we seek strategic partnerships with universities to fill gaps in our capabilities, perform joint research and development projects that have national impact, create a pool of future employees, educate on-roll employees, and build a constituency within the state and university. We are pleased to count UNM among the small number of universities with whom we have such relationships, and believe that development of the proposed degree program will be of value to our relationship.

A high quality graduate degree program in Biomedical Engineering at UNM would be of benefit to the State of New Mexico, as well as Sandia National Laboratories and other employers in the state, and I am supportive of your effort to establish such a degree program.

Sincerely,

Exceptional Service in the National Interest

Los Alamos
NATIONAL LABORATORY
EST.1943
Bioscience Division
P.O. Box 1663, MS-M888
Los Alamos, New Mexico 87545
505-667-2690/Fax 505-667-8339

Date: February 9, 2010
Refer To: BDO-10-010

Arup Maji, Ph.D.
Interim Dean, School of Engineering
University of New Mexico
Albuquerque, New Mexico 87131

Dear Interim Dean Maji,

I am delighted to declare both my personal support and the support of the Los Alamos National Laboratory for the Biomedical Engineering Graduate Program at UNM you are proposing for approval by the New Mexico Health and Education Department. This degree program is precisely what we need to find and recruit new employees who strengthen our competency in this nationally-important and burgeoning area of research.

Biomedical engineering is at the core of our large and on-going efforts to fight bioterrorism, and it is one of the growth areas at Los Alamos. For example, we currently host the National Flow Cytometry Resource and have a large program in affinity reagents and biosensors. We avidly seek new graduates, but are keenly aware of the absence of any biomedical engineering degree program in the entire State of New Mexico, which makes it virtually impossible for us to find New Mexico graduates with the right training. Naturally, we are highly motivated to see this critical gap filled. We lend our fullest support to UNM's initiative to launch this new program.

Sincerely,

I. Gary Resnick
Division Leader
Bioscience Division

Cy: file

An Equal Opportunity Employer / Operated by Los Alamos National Security LLC for DOE/NNSA

Appendix B. Affiliated faculty members

Alphabetical listing of affiliated faculty members

Kateryna Artyushkova, Chemical and Nuclear Engineering
Plamen Atanassov, Chemical and Nuclear Engineering
C. Jeffrey Brinker, Chemical and Nuclear Engineering
Vince Calhoun, Electrical and Computer Engineering
Heather Canavan, Chemical and Nuclear Engineering
Thomas Caudell, Electrical and Computer Engineering
Eva Chi, Chemical and Nuclear Engineering
Elizabeth L. Dirk, Chemical and Nuclear Engineering
Jeremy Edwards, Molec. Genetics & Microbiol., Chemical & Nucl. Eng.
Evan Evans, Chemical and Nuclear Engineering
Steven W. Graves, Chemical and Nuclear Engineering
Sang Han, Chemical and Nuclear Engineering
Steven J. Koch, Physics & Astronomy
Ravi Jain, Electrical Engineering
Terran Lane, Computer Science
Zayd C. Leseman, Mechanical Engineering, and Electrical and Computer Engineering
Gabriel P. Lopez, Chemical and Nuclear Engineering
Marek Osinski, Electrical and Computer Engineering
Marios Pattichis, Electrical and Computer Engineering
Dimiter Petsev, Chemical and Nuclear Engineering
Scott S. Sibbett, Chemical and Nuclear Engineering
Darko Stefanovic, Computer Science
David Whitten, Chemical and Nuclear Engineering
John E. Wood, Mechanical Engineering
Steve A. Young, Pathology

Listing of faculty members by department within the School of Engineering

Chemical & Nuclear Engineering

Kateryna Artyushkova
Plamen Atanassov
C. Jeffrey Brinker
Heather Canavan
Eva Chi
Elizabeth L. Dirk
Jeremy Edwards
Evan Evans
Steven W. Graves
Sang Han
Gabriel P. Lopez
Dimiter Petsev
Scott S. Sibbett
David Whitten

Electrical & Computer Engineering

Vince Calhoun
Thomas Caudell
Ravi Jain
Zayd C. Leseman
Marek Osinski
Marios Pattichis

Physics & Astronomy

Steven J. Koch
Kevin K. Malloy

Computer Science

Terran Lane
Darko Stefanovic

Mechanical Engineering

Zayd C. Leseman
John E. Wood

Appendix C. Catalog Copy

CATALOG COPY FOR MS DEGREE IN BIOMEDICAL ENGINEERING

BIOMEDICAL ENGINEERING GRADUATE PROGRAM

Steven W. Graves, Director

Center for Biomedical Engineering

M.S. in Biomedical Engineering

The Biomedical Engineering (BME) Graduate Program prepares individuals for careers in one of the fastest growing disciplines of engineering. The program currently offers one focus area in Molecular and Cellular Systems. Future focus areas will be added as need arises and resources are secured. Instructors from a spectrum of backgrounds in biomedical engineering offer a comprehensive core curriculum comprising 5 courses and a seminar course. Electives are accepted from a number of courses taught in the School of Engineering, College of Arts and Sciences, College of Pharmacy and School of Medicine. Graduates of this program will have the technological background to solve important problems in a number of areas including health care, biomedical research, biotechnology and bioengineering.

M.S. Admission Requirements

The general admission requirements described in the Graduate Program in this Catalog apply to the BMEGP. The following additional requirements hold for the initial focus area in Molecular and Cellular Systems. They may be modified or augmented as other focus areas are added to the program. Successful applicants to the BMEGP must have a bachelor's degree in a natural science or engineering field in which they attained a sophisticated level of ability to study, model or manipulate biological systems at the molecular or cellular level. Because of the multifaceted nature of BME research, the Admissions Committee will make admissions decisions on a case-by-case basis. The following subject areas will be used to judge the suitability of students for admission:

- Introductory Molecular and Cellular Biology
- General Chemistry and Organic Chemistry
- Calculus and Ordinary Differential Equations
- Thermodynamics
- General Physics
- Biochemistry or Biomolecular Engineering

Persons who have not passed courses in one or more of these subject areas may be admitted to the BMEGP, but may be required to take undergraduate courses to eliminate deficiencies in their background. Each case is considered individually.

Application Process

Please see the Graduate Program section of this Catalog for the general process for applying to graduate school. In addition to those requirements, successful applicants to the M.S. program in Biomedical Engineering must submit the following directly to the BMEGP Program Office for review by the Admissions Committee:

- a letter of intent on why the BMEGP is of interest
- three confidential letters of recommendation
- GRE entrance examination scores

M.S. Degree Completion Requirements

The general requirements for this degree are identical to those specified in the Graduate Program section of this catalog. (Please see the Graduate Program section for detailed requirements and procedures common to all UNM graduate programs.) In addition to the general requirement specified in the Graduate Program, graduates must complete the core and elective BME M.S. curriculum specified below. The BMEGP offers both Plan I (thesis) and Plan II (non-thesis) options for completion of an M.S. in Biomedical Engineering. BME 567 (Biomedical Engineering Seminar) should be taken every semester, but a student can only apply a maximum of 4 credit hours of this seminar toward their course degree requirements.

Curriculum for Students in the BME M.S. Degree Program:
Focus area: Molecular and Cellular Systems

The following core courses are required of all Master's students in Biomedical Engineering.

BME 517 Applied Biology for Biomedical Engineers
BME 544 Mechanics and Thermodynamics of Molecular Components in Cells
BME 547 Biomedical Engineering Research Practices
BME 556 Protein and Nucleic Acid Engineering
BME 558 Methods of Analysis in Bioengineering

Equivalent graduate-level courses taken at other institutions may be used to satisfy these requirements. The BMEGP Graduate Advisor or the BMEGP Curriculum Committee must approve such substitutions.

For completion of the BME M.S. degree the student must complete a minimum of 6 credit hours of elective courses from the list below. (Please see the Graduate Program section for detailed requirements and procedures common to all UNM M.S. Plan I and Plan II programs.)

Master's students may substitute electives other than those listed below as approved by the BMEGP Graduate Advisor or the BMEGP Curriculum Committee.

Engineering Electives

CHNE/NSMS 522L. Fundamentals of Nanofluidics
CHNE/NSMS 530 Surface and Interfacial Phenomena
CHNE 536/436. Biomedical Technology
CHNE/NSMS 538/438. Biosensors Fundamentals and Applications.
CHNE 504 Nanomaterials
CHNE 521 Advanced Transport Phenomena I
CS 529 Machine Learning
CS 530 Geometric and Probabilistic Methods in CS
CS 561 Algorithms/Data Structures
CS 590 Topics: Complex Adaptive Systems
ECE 510 Medical Imaging
ECE 500 Theory of Linear Systems
ECE 533 Digital Image Processing
ECE 537 Foundations of Computing
ECE 539 Digital Signal Processing
ECE 547/CS 547 Neural Networks
ECE 561 Engineering Electrodynamics
ECE 581 Colloidal Nanocrystals for Biomedical Applications
ME 501 Advanced Mechanics of Materials
ME 504 Computational Mechanics
ME 512 Intro to Continuum Mechanics
ME 530 Theoretical Fluid Mechanics
ME 571/NSMS 569 Advanced Materials Science

Biology/Biomedical Sciences Electives

BIOM 509 Principles of Neurobiology
BIOM 510 Physiology
BIOM 514 Immunobiology
BIOM 515 Cancer Biology
BIOM 516 Molecular Genetics and Genomics
BIOL **351 Microbiology
BIOC 545L Intensive Introductory Biochemistry
BIOL 547 Advanced Techniques in Light Microscopy

Biomedical Engineering (BME) Courses

BME 517. Applied Biology for Biomedical Engineers. (3)
Emphasis on engineering principles and analysis of: (i) the cell as a complete system including cellular subsystems, structures and functions; and (ii) select higher order systems of human physiology. Restriction: Permission of the instructor. {Fall}

BME 544. Mechanics and Thermodynamics of Molecular Components in Cells. (3)
Chemical thermodynamics and physics are used to establish a material science perspective of the molecular components – chemical kinetics – and structural properties needed for both understanding cell behavior and advancing biotechnology. Restriction: Permission of the instructor. {Fall}

BME 547. Biomedical Engineering Research Practices. (3)
Students will develop research, presentation, and scientific writing skills for theses, proposals, invention disclosures and journal articles. The course includes oral presentations, case studies of research ethics, technology

transfer and manuscript preparation. Restriction: Permission of the instructor. {Fall}

BME 556. Protein and Nucleic Acid Engineering. (3)
Students will learn the scientific principles and methods for engineering and manufacturing custom proteins, peptides, nucleic acids, and carbohydrates. The course will explicitly discuss methods and tools used in the production of engineered biomacromolecules. Restriction: Permission of the instructor. {Spring}

BME 558. Methods of Analysis in Bioengineering. (3)
Presents applied analytical and numerical mathematical methods in the context of biomedical engineering problems. Introduces statistical methods for the design of experiments and analysis of experimental data in research and development activities. Restriction: Permission of the instructor. {Spring}

BME 567. Biomedical Engineering Seminar. (1)
Students will gain insight into scientific presentations and current biomedical engineering research by presenting their research and actively participating in an external research seminar which will feature outstanding external and internal researchers as speakers. Restriction: Permission of the instructor. {Fall, Spring}

BME 570. Physical Bioanalytical Methods. (3)
Introduction to the physics and chemistry of classical physical methods of analyzing biological and biologically-related samples. Topics include fluorescence microscopy, chemiluminescence, chromatography, electrophoresis, mass spectrometry, electrochemistry, ultracentrifugation, SPR, SEM, TEM, AFM, XPS, radiochemistry and flow cytometry. Restriction: Permission of the instructor. {Fall}

BME 572. Biomaterials Engineering. (3)
Introduction to biomaterials currently in use, including commercial and research applications. Includes an understanding of a material's properties, biological responses to the materials, clinical context of their use, manufacturing processes, and regulatory issues. Restriction: Permission of the instructor. {Fall}

BME 579. Tissue Engineering. (3)
A review of the current strategies involved in the design of engineered tissues and organs. The principles underlying the implementation of selected cells, biomaterial scaffolds, soluble regulators, and culture conditions will be addressed. Restriction: Permission of the instructor. {Spring}

BME 598. Special Topics. (1-3, no limit) Δ
{Offered upon demand}

BME 599. Master's Thesis. (1-6, no limit) Δ
See Graduate Programs section for total credit requirements.

Appendix D. Letter of the Dean of the School of Engineering

UNM SCHOOL of ENGINEERING

Office of the Dean

Memorandum

TO: Suzanne Ortega, Provost & EVP

FROM: Arup Maji, Interim Dean

DATE: May 3, 2010

RE: School of Engineering's Support for Biomedical Engineering Graduate Program

---

In consideration of leadership transition in the SOE, I am summarizing the commitments of the School for the proposed Biomedical Engineering Graduate Program. These commitments are a reflection of extensive SOE faculty and SOE committee discussion to date, culminating in two key votes. In May 2009, the entire faculty of the School of Engineering reviewed plans for the Biomedical Engineering Graduate Program. By a near unanimous vote, the faculty approved moving forward with the plans. In August 2009, the SOE Administrative Committee, comprised of the Dean, Associate Deans and SOE Department Chairs, reviewed and voted on its top Special Projects priorities, and selected Biomedical Engineering as the top priority for the School.

Hence, I am delighted to articulate the following commitments of the School of Engineering to the proposed new graduate program:

1. Given the recent commitment of $208,000 of additional I&G funding per year to the School of Engineering to administer the Biomedical Engineering Program, the School is committed to using this money towards the administration, staffing and Associated Faculty as necessary. The school will also seek synergy with other programs and departments to leverage personnel and resources.

2. The School of Engineering will provide space for the offices of the Director and Program Manager.

3. The School of Engineering Dean's office will determine the appropriate programmatic and fiscal oversight of the program.

Given the importance of this new program in advancing the economic interests of the State of New Mexico, and the strategic objectives of the University, I am fully committed to ensuring that this program succeeds.

The University of New Mexico · MSC01 1140 · 1 University of New Mexico · Albuquerque, NM 87131-0001 · Phone 505.277.5521 · Fax 505.277.1422 · www.soe.unm.edu
Centennial Engineering Center, Suite 3071

Appendix E.
Projected program budget in response to possible cost containment efforts*

		% budget cut		
		0%	**3%**	**8%**
Income	I&G	$ 207,000	$ 200,790	$ 190,440
Expenses	Salaries	203,580	197,275	186,878
	Office supplies	1,009	980	1,027
	Equipment rental	1,545	1,500	1,500
	Business food	1,030	1,000	1,000
	Banner tax	36	35	35
	Total expenses	207,201	200,790	190,440
Income minus expenses		-201	0	0

*Budget cuts of 3% or 8% are not expected to compromise the successful launch and long-term vitality of the proposed new program.

Appendix F.
Projected 5-year forecast of revenues, expenses and impact of new program

All necessary resources have already been secured by UNM for the proposed program. No new money is sought or needed. All dollar amounts in the table below refer to money that is already secured and committed. UNM seeks only state approval for the granting of a master's degree in the area of a pre-existing, fully-funded, Ph.D.-granting biomedical engineering graduate program.

Institution: University of New Mexico
Proposed Program: Biomedical Engineering Master's Degree
Date: April 5, 2011

ESTIMATED REVENUES	Year 1 FY 2013		Year 2 FY 2014		Year 3 FY 2015		Year 4 FY 2016		Year 5 FY 2017		Year 6 FY 2018		
	Existing	New	Existing	New	Existing	New	Existing	New	Existing	New	Existing	New	notes
Projected University I&G or Tuition	$203,000	$0	$203,000	$0	$203,000	$0	$203,000	$0	$203,000	$0	$203,000	$0	a, b
External Grants and Contracts	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Other	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
TOTAL REVENUE	$203,000		$203,000		$203,000		$203,000		$203,000		$203,000		

ESTIMATED EXPENSES	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		
	Existing	New	Existing	New	Existing	New	Existing	New	Existing	New	Existing	New	
Salaries and/or benefits (Faculty & Staff)	$199,500	$0	$199,500	$0	$199,500	$0	$199,500	$0	$199,500	$0	$199,500	$0	c
Learning Resources	$2,000	$0	$2,000	$0	$2,000	$0	$2,000	$0	$2,000	$0	$2,000	$0	d
Equipment	$1,500	$0	$1,500	$0	$1,500	$0	$1,500	$0	$1,500	$0	$1,500	$0	d
Facilities & modifications	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Other	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
TOTAL EXPENSES	$203,000		$203,000		$203,000		$203,000		$203,000		$203,000		
DIFFERENCE (Rev.-Exp.)	$0		$0		$0		$0		$0		$0		

ESTIMATED IMPACT OF NEW PROGRAM	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	
FTE Enrollment	4	5	6	7	8	9	e
Projected Annual Credits Generated	84	105	126	147	168	189	f
Tuition Generated	$25,583	$35,176	$46,433	$59,589	$74,912	$84,275	g

Notes
a - There is a pre-exisiting "Ph.D. in Engineering with a Concentration in Biomedical Engineering", approved by UNM Regents December 14, 2010. "Existing" refers to existing, pre-approved secured funds. "New" refers to dollars needed to launch program.
b - "Projected University I&G or Tuition" refers to I&G funds.
c - "Salaries and/or benefits" are computed as the sum of salaries given in Appendix F of Form D BME Master's Degree Program Proposal, plus incremental cost of converting an existing AA position to Program Manager ($10,000), plus the addition of instructor fees for 3 additional course credits ($10,500).
d - As estimated per Appendix F of Form D of BME Master's Degree Program Proposal.
e - "FTE Enrollment" refers to the number of accepted BME master's degree candidates, and is consistent with the estimate of Chapter 4 of the Form D BME Master's Degree Program Proposal concerning the sum of master's and Ph.D. candidates.
f - Assuming 21 credit hours per master's degree candidate per year.
g - Assuming the 2010 I&G rate of $21 per credit hour of instruction; and assuming an annual increase of 10% per year.

Appendix G. Curricula vitae of the course instructors

1. Curriculum vitae of Assistant Professor Heather Canavan

2. Curriculum vitae of Assistant Professor Eva Chi

3. Curriculum vitae of Assistant Professor Elizabeth Dirk

4. Curriculum vitae of Research Professor Evan Evans

5. Curriculum vitae of Research Professor James P. Freyer

6. Curriculum vitae of Associate Professor Stephen W. Graves

7. Curriculum vitae of Assistant Professor Stephen Koch

8. Curriculum vitae of Research Professor Scott S. Sibbett

9. Curriculum vitae of Research Professor David G. Whitten

HEATHER E. CANAVAN, PH.D.

Assistant Professor
Center for Biomedical Engineering (CBME)
Department of Chemical and Nuclear Engineering
University of New Mexico
Centennial Engineering Center, Rm. 2059
Albuquerque, NM 87131-1141

Tel: 505-277-8026
Fax: 505-277-5433
Email: canavan@unm.edu

EDUCATION

The George Washington University
Doctor of Philosophy: Physical Chemistry — May 2002
Advisor: David E. Ramaker

The George Washington University
Master of Philosophy: Physical Chemistry — January 2000

University of California Santa Barbara
Bachelor of Arts: Biology — December 1996

ACADEMIC APPOINTMENTS

University of New Mexico, Albuquerque NM

Assistant Professor, Department of Chemical and Nuclear Engineering — 2005-present

University of Washington, Seattle WA, Laboratory of Dr. David Castner

Senior Postdoctoral Fellow, Departments of Chemical and Bioengineering — 2002-2005
National ESCA and Surface Analysis Center for Biomedical Problems (NESAC/BIO)

PROFESSIONAL EXPERIENCE

Los Alamos National Laboratory, Los Alamos, NM

Chemist, Chemistry Science and Technology Division — 1994-1997

Los Alamos National Laboratory, Los Alamos, NM

Staff Research Assistant, Chemistry Science and Technology Division — 1991-1994

COURSES TAUGHT

Chemical Engineering Thermodynamics (ChNE 302)	Spring 2006-present
Advanced Chemical Engineering Thermodynamics (ChNE 542)	Fall 2005 - 2009
Biomolecular Engineering (ChNE 361)	Fall 2006-2009
Undergraduate Senior Seminar (ChNE 471)	Fall 2005; Fall 2010
Biomaterials Engineering (ChNE 499/515)	Fall 2010

AWARDS

Harrison Faculty Excellence Award	2009
Apple Polisher Award, recognition from Chi Omega sorority members for outstanding contribution to higher education	2008
Untenured Faculty Award, 3M Corporation	2006
Dorothy M. and Earl S. Hoffman Scholarship, AVS	1999
Benjamin D. Van Evera Memorial Teaching Prize, George Washington University	1998

CURRENT RESEARCH

Study of temperature-dependent behavior of poly(*N*-isopropyl acrylamide) (pNIPAM), a "smart polymer" used to detach cells as contiguous sheets, by surface analytical and biological techniques. Characterization of the behavior of the ECM secreted from mammalian cells cultured on pNIPAM-treated surfaces as well as the cell sheets. Development of cell-based sensors and engineered tissues from cell sheets obtained from smart polymer surfaces.

http://www-chne.unm.edu/testche/faculty/canavan/lab%20site/research.htm

SERVICE

Director, Biomaterials Engineering Outreach Program	2006-2007
Volunteer/presenter, Biomaterials Engineering Outreach Program	2006-present
Faculty Advisor, UNM Student Chapter of the Biomedical Engineering Society	2005-present
Member, ChNE Undergraduate Student Curriculum Development Committee	2005-present
Member, ChNE Graduate Student Recruitment Committee	2005-2008
Member, ChNE Graduate Student Qualifications Exam Committee	2008
Member, School of Engineering Dean's Search Committee	2009
Member, ChNE Faculty Search Committee	2006, 2007
Member-at-large, NM Chapter of the American Vacuum Society (AVS)	2006-2008
Member-at-large, AVS BioInterfaces Division	2006-present
Manuscript Reviewer: *Surface and Interface Analysis, Langmuir, Plasma Processes and Polymers, Biomaterials, Advanced Materials, Biomacromolecules, Journal of the American Ceramic Society*	2005-present
Grant Proposal Reviewer: National Science Foundation, Irish Health Research Board	2005-present
Contributor, UNM Higher Learning Commission site visit	2009
Participating Mentor, UNM Initiatives for Minority Student Development (IMSD), UNM Post baccalaureate Research and Education Program (PREP), UNM Cross-disciplinary Optics Research and Education (CORE) IGERT, and REU programs	2005-present

MEMBERSHIPS

American Chemical Society (ACS)
American Institute of Chemical Engineers (AIChE)
American Society for Engineering Education (ASEE)
American Vacuum Society (AVS)
Society for Biomaterials (SFB)
Biomedical Engineering Society (BMES)

SELECTED PUBLICATIONS (of 15 refereed publications, 5 in preparation, 2 submitted/accepted, 1 chapter, 12 non-refereed publications, 15 with undergraduates)

†Indicates undergraduate researcher.

Articles in Preparation

1. Reed, J.A.; Lucero, A.E.; Love, S.; Hughes, C.; CANAVAN, H.E.; "Thermoresponsive film deposition: Comparing Deposition Methods for Mammalian Cell Applications," in preparation for submission to *Langmuir*.
2. Reed, J.A.; Shah, R.; Angelini, T.; Weitz, D.W.; CANAVAN, H.E.; "Uncovering the Extracellular Matrix with Thermoresponsive Microgels," in preparation for submission to *Advanced Materials*.

3. Lucero, A.E.; Reed, J.A.; Cooperstein, M.;† CANAVAN, H.E.; "Fabrication and Characterization of Thermoresponsive Films Deposited by an RF Plasma Reactor," in preparation for submission to *Plasma Processes and Polymers.*

Articles Submitted, Accepted, or In Press

1. Reed, J.A.; Lucero, A.E.; Hu, S.;† Ista, L.K.; Bore, M.; López, G.P.; CANAVAN, H.E.; "A Low-cost, Rapid Deposition Method for 'Smart' Films: Applications in Mammalian Cell Release," *ACS Applied Materials & Interfaces*, in press.

Articles Published

1. Cooperstein, M.;† CANAVAN, H.E.; "Applications and Uses of Biological Cell Detachment from pNIPAM," ," cover art and Feature Article of *Langmuir*, **26** (11), (2010).
2. Chang, M.S.; Stohlman, J.; Molnar, P.; Natarajan, A.; CANAVAN, H.E.; Teliska, M.; Krauthamer, V.; Hickman, J.J.; "Altered Calcium Dynamics in Cardiac Cells Grown on Silane-Modified Surfaces," *Biomaterials*, **31** (4), 602-607 (2010).
3. Mendez, S.; Andrzejewski, B.P.; CANAVAN, H.E.; Keller, D.J.; McCoy, J.D.; López, G.P.; and Curro, J.G.; "Modeling the Force-vs-Distance Profiles of Terminally Anchored Poly(*N*-isopropyl acrylamide) with Self-Consistent Field Theory," *Langmuir*, **25** (18), 10624-10632 (2009).
4. Reed, J.A.; Lucero, A.E.; Cooperstein, M.;† CANAVAN, H.E.; "The Effects of Cell Culture Parameters on Cell Release Kinetics from pNIPAM," *Journal of Applied Biomaterials & Biomechanics*, **6** (2), 81-88 (2008).
5. CANAVAN, H.E.; Stanton, M.; Lopez, K.; Grubin, C.; Graham, D.J., " 'Finger Kits': An Interactive Demonstration of Biomaterials and Engineering for Elementary School Students," *Chemical Engineering Education*, **42** (3), 125-131 (2008).
6. CANAVAN, H.E.; Cheng, X.; Graham, D.J.; Ratner, B.D.; and Castner, D.G., "Comparison of Native Extracellular Matrix with Adsorbed Protein Films using Mass Spectrometry," cover art of *Langmuir*, **23** (1), 50-56 (2007).
7. CANAVAN, H.E.; Cheng, X.; Graham, D.J.; Castner, D.G.; and Ratner, B.D., "A Plasma-deposited Surface for Cell Sheet Engineering: Advantages over Mechanical Dissociation of Cells," *Plasma Processes and Polymers*, **3** (6-7), 516–523, (2006).
8. Cheng, X.; CANAVAN, H.E.; Castner, D.G.; and Ratner, B.D., "Protein Interaction with Plasma Polymerized *N*-Isopropyl Acrylamide," *Biointerphases*, **1** (1), 61-72 (2006).
9. CANAVAN, H.E.; Cheng, X.; Graham, D.J.; Ratner, B.D.; and Castner, D.G., "Cell Sheet Detachment Affects the Extracellular Matrix: A Surface Science Study Comparing Thermal Lift-off, Enzymatic and Mechanical Methods," *Journal of Biomedical Materials Research*, **75A** (1), 1-13 (2005).
10. Cheng, X.; CANAVAN, H.E.; Stein, M.J.; Hull, J.R.; Hull, J.R.; Kweskin, S.J.; Wagner, M.S.; Somorjai, G.A.; Castner, D.G.; and Ratner, B.D., "Surface Chemical and Mechanical Properties of Plasma Polymerized *N*-isopropylacrylamide," *Langmuir*, **21** (17) 7833-7841 (2005).
11. Lee, C.Y.; CANAVAN, H.E.; Gamble, L.J.; and Castner, D.G., "XPS and ToF-SIMS Characterization of Thiolated Single-stranded DNA Oligomers Self-assembled onto Gold Surfaces," *Langmuir*, **21** (11) 5134-5141 (2005).
12. CANAVAN, H.E.; Cheng, X.; Graham, D.J.; Ratner, B.D.; and Castner, D.G., "Surface Characterization of the Extracellular Matrix upon Cell Detachment from a Thermoresponsive Polymer," cover article of *Langmuir*, **21** (5), 1949-1955 (2005).
13. May, C.J.;† CANAVAN, H.E.; and Castner, D.G., "Quantitative XPS and ToF-SIMS Characterization of the Components in DNA Microarrays," *Analytical Chemistry*, **76** (4), 1114-1122 (2004).
14. Barker, S.L.R.; Tarlov, M.J.; CANAVAN, H.; Hickman, J.J.; and Locascio, L.E, "Plastic Microfluidic Devices Modified with Polyelectrolyte Multilayers," *Analytical Chemistry*, **72** (20), 4899-4903 (2000).
15. Goldstein, S.J.; Slemmons, A.K.; and CANAVAN, H.E., "Energy Dispersive X-Ray Fluorescence Methods for Environmental Characterization of Soils," *Environmental Science and Technology*, **30** (7) 2318-2321 (1996).

SELECTED PRESENTATIONS (of 16 invited, 62 contributed, 18 with undergraduates). †Indicates undergraduate researcher.

1. CANAVAN, H.E.; "Assessment of Thermoresponsive Films for Mammalian Cell Release," presented at the NSF UNM/Harvard University PREM Workshop on Cell & Tissue Biomaterial Interactions, June 25, 2009.
2. CANAVAN, H.E. "Use of "Smart" Materials and Cell Sheet Engineering to Characterize Buried Biological Interfaces: Scientific and Engineering Applications," presented at the Harvard University Department of Engineering and Applied Sciences Summer Symposium, August 5, 2008.
3. Canavan, H.E. "'Smart' Polymers and Biological Cells: Current Research on the Buried Biological Interface and its Future Applications, presented at the 3M Corporation Untenured Faculty Award Winners' Meeting, June 19-20, 2007.
4. CANAVAN, H.E. "Characterization of Cells and the Buried Biological Interface using Surface Science Techniques," presented at "Biomaterials from 2D to 3D to Larger than Life" Symposium, Ka'anapali Beach, Maui, December 14-17, 2006.

Contributed Talks

1. Reed, J.A.; Lucero, A.E.; CANAVAN, H.E.; "Effect of Deposition Methods on Cell-releasing Properties of a Thermoresponsive Polymer," presented at the American Institute of Chemical Engineers Annual Meeting, Nashville TN, November 8-13, 2009.
2. Reed, J.A.; Shah, R.; Angelini, T.; Weitz, D.W.; CANAVAN, H.E.; "Uncovering the Extracellular Matrix with Thermoresponsive Microgels," presented at the 55th International Symposium of the American Vacuum Society, San Jose, CA, November 8-13, 2009, 1st place for best student poster.
3. Wilde, K.N.; Corbitt, T.S.; Ding, L.; Whitten, D.G.; CANAVAN, H.E.; "Assessing the Cytotoxicity of Cationic Conjugated Polyelectrolyte Biocides," presented at the NSF UNM/Harvard University PREM Workshop on Cell & Tissue Biomaterial Interactions, June 25, 2009.
4. Pawlikowski, L.; CANAVAN, H.E.; "Development of a Cell-based 'Smart' Microfluidic Sensor," presented at the NSF UNM/Harvard University PREM Workshop on Cell & Tissue Biomaterial Interactions, June 25, 2009.
5. Lucero, A.E.; CANAVAN, H.E.; "Optimizing an RF Plasma Reactor for Biocompatible "Smart" Surfaces," presented at the American Institute of Chemical Engineers Annual Meeting, Philadelphia, PA, November 16-21, 2008.
6. Fulghum, J.E.; Artyushkova, K.; Lucero, A.E.; CANAVAN, H.E. "Use of Multivariate Analysis Techniques to Predict Cellular Response to Plasma Polymerized pNIPAM," presented at the 54th International Symposium of the American Vacuum Society, Boston, MA, October 19-24, 2008.
7. Reed, J.A.; Bore, M.; Ista, L.K.; López, G.P.; CANAVAN, H.E.; "Solution Deposited Poly(*N*-isopropyl acrylamide) Films Optimized for Mammalian Cell Release," presented at the 54th International Symposium of the American Vacuum Society, Boston, MA, October 19-24, 2008, 2nd place for best student poster.
8. CANAVAN, H.E.; Candelaria, S.L.;† Reed, J.A.; Lucero, A.E.; Wilde, K.N.; Liu, X.P.; Gallagher-Gonzales, K.M. "Scientific and Bioengineering Applications of a Plasma Polymerized Thermoresponsive Surface," presented at the 3M Corporation Untenured Faculty Award Winners' Meeting, June 19-20, 2008.
9. CANAVAN, H.E.; Candelaria, S.L.;† Reed, J.A.; Lucero, A.E.; Wilde, K.N.; Joe, R.; Tapia, P.; Werner-Washburne, M.; "Use of a Thermoresponsive Substrate to Separate Cell Populations," presented at the 8th World Biomaterial Congress, Amsterdam, the Netherlands, May 28 – June 1, 2008.
10. Lucero, A.E.; CANAVAN, H.E.; "Optimizing Thermoresponsive pNIPAM Films using an RF Plasma Reactor," presented at the AAAS/SWARM Symposium, Albuquerque, NM, April 11, 2008, honorable mention for best student poster.
11. Mendez, S.; Andrzejewski, B.; Keller, D.H.; CANAVAN, H.E.; Lopez, G.P.; Curro, J.G.; and McCoy, J.D.; "Modeling Force versus Distance Profiles of Terminally Anchored Poly(N-isopropylacrlamide) with Self-Consistent Field Theory," presented at the 53rd International Symposium of the American Vacuum Society, Seattle, WA, October 15-19, 2007.

12. CANAVAN, H.E.; Lucero, A.E.; Wu, X.; Reed, J.A., García, D.F.;† Candelaria, S.L.;† "Construction and Characterization of an rf Reactor to Create Plasma Polymerized Thermoresponsive Coatings," presented at the 3M Corporation Untenured Faculty Award Winners' Meeting, June 19-20, 2007.
13. Lucero, A.E.; Wu, X.; Candelaria, S.L.;† CANAVAN, H.E.; "Construction and Characterization of an rf Reactor to Create Plasma Polymerized Thermoresponsive Coatings," presented at the Regional AVS Meeting, Albuquerque, NM, May 21-25, 2007, 1st place for best student poster.
14. Mendez, S.; CANAVAN, H.E.; Curro, J.G.; and McCoy, J.D.; "Modeling the Force-Distance Profiles of Tethered Poly(N-isopropylacrylamide) with Self-Consistent Field Theory", presented at the 7th Southern School on Computational Chemistry and Materials Science, Jackson, MS, April 2007.
15. García, D.F.;† Reed, J.; Ista, L.K.; López, G.P.; CANAVAN, H.E.; "Switchable Polymers and Microorganisms: The Next-Generation of Enhanced Oil Recovery and Oil Remediation Methods," presented at the UNM Undergraduate Research and Creativity Symposium, Albuquerque, NM, April 3, 2007.
16. Mendez, S.; CANAVAN, H.; Curro, J.G.; McCoy, J.D.; "Modeling the Force-Distance Profiles of Tethered Poly (*N*-isopropyl acrylamide) with Self-Consistent Field Theory," presented at the 7th Southern School on Computational Chemistry & Materials Science, Jackson, MS, April 6-7, 2007.
17. Reed, J.; Romero, E.; Wandinger-Ness, A.; CANAVAN, H.E.; "Thermally Responsive Cell Culture Substrata for Systems Biology and Drug Discovery," presented at the NSF/EPSCoR NM Regional Conference, December 1, 2006, 1st place for best student poster.
18. CANAVAN, H.E.; Cheng, X.; Greenfeld, M.;† Graham, D.J.; Ratner, B.D.; Castner, D.G.; "Surface Characterization of the ECM Proteins and Cell Sheets Released from a Thermoresponsive Polymer," presented at the 20th European Conference on Biomaterials ESB2006, Nantes, France, September 27- October 1, 2006.
19. CANAVAN, H.E.; Greenfeld, M.;† Cheng, X.; Graham, D.J.; Ratner, B.D.; Castner, D.G.; "Use of Cell Sheet Engineering to Characterize Buried Biological Interfaces," presented at the Regenerate World Congress on Tissue Engineering and Regenerative Medicine, Pittsburgh, PA, April 25-27, 2006.
20. CANAVAN, H.E.; Cheng, X.; Graham, D.J.; Ratner, B.D., Castner, D.G.; "Identification of Residual ECM Proteins Retained at pNIPAM Surfaces using Time-of-Flight SIMS," 52nd International Symposium of the American Vacuum Society, Boston, MA, October 30-November 4, 2005.
21. Castner, D.G.; CANAVAN, H.E.; Greenfeld, M.; Cheng, X.; Graham, D.J.; Ratner, B.D., "Development of SIMS as a Novel Investigative Tool for the Analysis of Cell Sheets and Their Extracellular Matrix Proteins," 15th International Conference on Secondary Ion Mass Spectrometry (SIMS XV), Manchester, UK, September 12-16, 2005.
22. CANAVAN, H.E.; Greenfeld, M.; Cheng, X.; Graham, D.J.; Ratner, B.D.; Castner, D.G., "Analysis of Cell Sheets and their Extracellular Matrix Proteins after Non-destructive Removal from ppNIPAM," 30th Annual Meeting of the Society For Biomaterials, Memphis, TN, April 27-30, 2005.
23. Lee, C-Y.; CANAVAN, H.E.; Gamble, L.J.; Castner, D.G.; "Surface Orientation and Hybridization Properties of Thiolated Single-Stranded DNA on Gold," 3rd Annual University of California Symposium on Surface Science and Its Applications, Berkeley, CA March 2005.

Curriculum Vitae

Eva Y. Chi, Ph.D
Assistant Professor
Department of Chemical and Nuclear Engineering
Center for Biomedical Engineering
University of New Mexico
Centennial Engineering Center, 2057
222 University Blvd. NE, MSC 01 1141, Albuquerque, NM 87131
Phone: 505-277-2263
Fax: 505-277-1979
Email: evachi@unm.edu

Education

- Ph.D., Chemical Engineering, University of Colorado, Boulder, CO, 2004
  Thesis Advisor: Theodore W. Randolph
  Thesis: Protein aggregation in aqueous solution – mechanism, thermodynamics, and kinetics
- M.S., Chemical Engineering, University of Colorado, Boulder, CO, 2001
- B.S., Chemistry, B.S., Chemical Engineering, University of California, Berkeley, CA, 1999

Professional Experience

- Assistant Professor, 2008 – present
  Department of Chemical and Nuclear Engineering and Center for Biomedical Engineering
  University of New Mexico, Albuquerque, NM
- Postdoctoral Research Fellow, 2004 – 2008
  Department of Chemistry, Institute for Biophysical Dynamics, and the James Franck Institute, The University of Chicago, Chicago, IL

Awards and Honors

- Alzheimer's Association New Investigator Research Grant Award, 2009
- Oak Ridge Associated Universities Ralph E. Powe Junior Faculty Enhancement Award, 2009
- International Institute for Complex Adaptive Matter Junior Scientist Travel Award, 2007
- Institute for Pure and Applied Mathematics Workshop Travel Award, 2006
- NIH Ruth L. Kirschstein National Research Service Award, 2004 – 2007
- American Institute of Chemists Graduate Award, 2004
- NIH Leadership Training in Pharmaceutical Technology Fellowship, 2003
- NSF Graduate Research Fellowship, 2001-2004
- Department of Education Macromolecular Science and Engineering Fellowship, 2000 – 2004
- Student Annual Research Symposium Award, 2004
- Graduate Interdisciplinary Certificate in Biotechnology, Interdisciplinary Biotechnology Program, 2003
- Professor Serge N. Timasheff Award – Excellence in Graduate Studies in the Field of Protein Stability Research, 2002
- Merck Science & Technology Fellowship, 1998
- U.S. Department of Education Robert C. Byrd Honors Scholarship, 1994 – 1998

Professional Memberships

- American Institute of Chemical Engineers
- American Chemical Society
- American Association of Pharmaceutical Scientists
- Biophysics Society

Original Research or Scholarly Articles in Refereed Journals

1. **EY Chi**, A Winans, SL Frey, KL Lam, J Majewski, G Wu, K Kjaer, KYC Lee. Air/water interface induced folding and self assembly of amyloid-beta peptide seeds fibrillogenesis, (2010) *Biophysical Journal*, in print
2. L Ding, **EY Chi**, KS. Schanze, GP Lopez, DG Whitten, Insight into the mechanism of antimicrobial conjugated polyelectrolytes: lipid head-group charge and membrane fluidity effects, (2009) *Langmuir*, in print
3. L Ding, **EY Chi**, S Chemburu, E Ji, KS. Schanze, GP Lopez, DG Whitten, Insight into the mechanism of antimicrobial poly(phenylene ethynylene) polyelectrolytes: interactions with phosphatidylglycerol lipid membranes, (2009) *Langmuir*, **25** (24): 13742–13751
4. MK Ratajczak, **EY Chi**, SL Frey, KD Cao, LM Luther, K Kjaer, J Majewski, KYC Lee, Ordered nanoclusters in lipid-cholesterol membranes, (2009) *Physical Review Letters*, **103**, 028103
5. PC Stenger, G Wu, CE Miller, **EY Chi**, SL Frey, KYC. Lee, J Majewski, K Kjaer, JA Zasadzinski, X-Ray diffraction and reflectivity study of the competitive adsorption of lung surfactant and albumin, (2009) *Biophysical Journal*, **97**(3):777-86
6. SL Frey, **EY Chi**, Arratia C, KYC Lee. Condensing and fluidizing effects of Ganglioside G_{M1} on phospholipid films, (2008) *Biophysical Journal*, **94**: 3047-3064
7. **EY Chi**, C Ege, A Winans, J Majewski, G Wu, K Kjaer, KYC Lee. Lipid membrane templates the ordering and induces the fibrillogenesis of Alzheimer's disease amyloid-beta peptide, (2008) *Proteins*, **72**: 1-24
8. **EY Chi**, SL Frey, KYC Lee. Ganglioside G_{M1}-mediated amyloid-beta fibrillogenesis and membrane disruption, (2007) *Biochemistry,* **46**: 1913-24
9. **EY Chi**, BS Kendrick, JF Carpenter, TW Randolph. Population balance modeling of aggregation kinetics of recombinant human interleukin-1 receptor antagonist, (2005) *Journal of Pharmaceutical Sciences*, **94**: 2735-2748
10. **EY Chi**, J Weickmann, JF Carpenter, MC Manning, TW Randolph. Heterogeneous nucleation controlled intermittent aggregation of recombinant human platelet-activating factor acetylhydrolase in pharmaceutical formulation, (2005) *Journal of Pharmaceutical Sciences*, **94**: 256-274
11. **EY Chi**, Krishnan, BS Kendrick, BS Chang, JF Carpenter, TW Randolph. Roles of conformational and colloidal stability in the aggregation of recombinant human granulocyte colony stimulating factor, (2003) *Protein Science*, **12**, 903-913
12. S Krishnan, **EY Chi**, SJ Wood, BS Kendrick, C Li, W Garzon-Rodriguez, J Wypych, TW Randolph, L. Narhi, AL Biere, M Citron, JF Carpenter. Oxidative dimer formation is the critical rate-Limiting step for Parkinson's disease a-synuclein fibrillogenesis, (2003) *Biochemistry*, **42**, 829-837
13. S Krishnan, **EY Chi**, JN Webb, BS Chang, D Shan, M Goldenberg, MC Manning, TW Randolph, JF Carpenter. Aggregation of granulocyte colony stimulating factor under

physiological conditions: characterization and thermodynamic inhibition (2002) *Biochemistry*, **41**, 6422-6431

14. YS Kim, SP Cape, **EY Chi**, R Raffen, P Wilkins-Stevens, FJ Stevens, MC Manning, TW Randolph, A Solomon, JF Carpenter. Counteracting effects of renal solutes on amyloid fibril formation by immunoglobulin light chains (2001) *Journal of Biological Chemistry*, **276**, 1626-1633

Invited Review Article

1. **EY Chi**, S Krishnan, TW Randolph, JF Carpenter. Physical stability of proteins in aqueous solution: mechanism and driving forces in non-native protein aggregation, (2003) *Pharmaceutical Research*, **20**, 1325-1336

Invited Lectures and Invited Presentations

1. University of Kansas, Department of Pharmaceutical Chemistry, Lawrence, KS, December 2009
2. Pfizer Inc., St. Louis, MO, July 2008
3. Monoclonal Antibody Workshop of the European Association of Pharma Biotechnology and European Federation of Pharmaceutical Sciences), Heidelberg, Germany, June 2008
4. Cambridge Healthtech Institute PepTalk Workshop, San Diego, CA, January 2008
5. Genetech Inc., South San Francisco, CA, July 2007
6. American Association of Pharmaceutical Scientists National Biotechnology Conference, BIOTEC Open Forum, Flakes and Clumps: Cause, Detection, and Impact of Particulates During Bioprocessing, San Diego, CA, June 2007
7. 8th Los Alamos Neutron Science Center User Group Meeting, Santa Fe, NM, June 2007
8. 42nd Annual Pharmaceutical Technologies Arden Conference - Best Practices for Parenteral Dosage Forms: Formulation and Process Development, Package Selection, and Manufacturing, West Point, NY, January 2007
9. American Association of Pharmaceutical Scientists Roundtable: Impact of Preservatives on Proteins, San Antonio, TX, October 2006
10. American Chemical Society Prospective – Successful Protein Therapeutics: The Interconnection of Formulation, Process Development & Manufacturing, San Diego, CA, July 2006
11. Baxter Healthcare Corp., Round Lake, IL, June 2006
12. Indiana Microscopy Society Meeting, Notre Dame, IN, March 2006
13. Institute for Biophysical Dynamics Research Seminar, Chicago, IL, May 2005
14. 4th Annual Formulation Strategies for Biopharmaceutical Drug Development and Delivery, Washington D.C., March 2005
15. University of Chicago, Chicago, IL, December 2003
16. Colorado Protein Stability Conference, Breckenridge, CO, July 2003

Presentations

1. American Institute of Chemical Engineers Annual Meeting, Nashville, TN, November 2009
2. Biophysical Society Annual Meeting, Boston,MA, February 2009
3. American Institute of Chemical Engineers Annual Meeting, Philadelphia, PA, November 2008
4. Fudan University, Shanghai, China, April 2008

5. American Institute of Chemical Engineers Annual Meeting, Salt Lake, UT, November 2007
6. American Institute of Chemical Engineers Annual Meeting, Salt Lake, UT, November 2007
7. American Chemical Society National Meeting, Chicago, IL, March 2007
8. American Institute of Chemical Engineers Annual Meeting, San Francisco, November 2006
9. American Institute of Chemical Engineers Annual Meeting, San Francisco, November 2006
10. American Chemical Society National Meeting, San Francisco, September 2006
11. 80th American Chemical Society Colloid and Surface Science Symposium, Boulder, CO, June 2006
12. American Institute of Chemical Engineers Annual Meeting, Cincinnati, OH, November 2005
13. American Institute of Chemical Engineers Annual Meeting, Cincinnati, OH, November 2005
14. American Institute of Chemical Engineers Annual Meeting, Austin, TX, November 2004
15. University of Colorado Student Annual Research Symposium, Boulder, CO, February 2004
16. American Institute of Chemical Engineers Annual Meeting, San Francisco, CA, November 2003
17. University of Colorado Student Annual Research Symposium, Boulder, CO, February 2004
18. American Institute of Chemical Engineers Annual Meeting, Minneapolis, IN, November 2002
19. American Chemical Society National Meeting, Boston, MA, August 2002

Posters

1. Biophysical Society Annual Meeting, San Francisco, CA, February, 2010
2. Keystone Symposia, Copper Mountain, CO, January 2010
3. AVS 56th International Symposium and Exhibition, San Jose, CA, November 2009
4. Keystone Symposia, Big Sky, MT, January 2008
5. Biophysical Society Annual Meeting, Baltimore, MD, March 2007
6. Workshop on Protein Aggregation, Breckenridge, CO, September 2006
7. Biophysics Society Annual Meeting, Salt Lake City, February 2006
8. American Institute of Chemical Engineers Annual Meeting, Cincinnati, OH, November 2004
9. American Institute of Chemical Engineers Annual Meeting, Austin, TX, November 2004
10. American Association of Pharmaceutical Scientists Annual Meeting and Exposition, Baltimore, MD, November 2004
11. American Association of Pharmaceutical Scientists Annual Meeting and Exposition, Salt Lake City, UT, November 2004
12. Colorado Protein Stability Conference, Breckenridge, CO, July 2003
13. Butcher Symposium on Genomics and Biotechnology, Denver, CO, November 2002
14. Colorado BioExpo, Denver, CO, December 2002
15. American Association of Pharmaceutical Scientists Annual Meeting and Exposition, Denver, CO, November 2002
16. Colorado Protein Stability Conference, Breckenridge, CO, July 2002
17. American Association of Pharmaceutical Scientists Annual Meeting and Exposition, November 2001
18. Colorado Protein Stability Conference, July 2000
19. The Federation of American Societies for Experimental Biology Summer Research Conference, June 2000

Professional Services

- Chair, Thermodynamics of Protein Folding and Aggregation Session, Food, Pharmaceutical and Bioengineering Division, AIChE Annual Meeting, 2009, 2010
- Reviewer, Biochemistry, Protein Science, European Biophysical Journal, ACS Applied Materials and Interfaces, Macromolecules
- Proposal reviewer, NSF, Alzheimer's Association
- Committee member, Graduate Admissions and Recruitment Committee, Department of Chemical and Nuclear Engineering, UNM, 2008 – present; Website Committee, Department of Chemical and Nuclear Engineering, UNM, 2009 – present; Center for Biomedical Engineering Director Search Committee, UNM 2009-2010
- Invited speaker at professional student organization meetings: AIChE/ANS/BMES Members Meeting, AIChE New Mexico Chapter Members Meeting
- Panelist, Academic Job Search Workshop, UNM Career Service Workshop Series, UNM, 2009

Students Supervised

- Postdoctoral Research Associate
  - Arjun Thapa, Ph.D. Chosun University, South Korea, 2008 –
- Graduate Students
  - Sammeta Swetha, B.S., Jawaharial Nehru Technological University, 2009 –
  - Emmalee Jones, B.S., Brigham Young University, 2009 –
  - Yongming Tian, M.S., Chinese Academy of Sciences, 2008 – 2009
- Undergraduates
  - Briana Givler, UNM, 2009 –
  - Luke Engvall, UNM, 2009 –
  - Golnar Doroudian, UNM, 2008 – 2009
  - Philip Camp, UNM, 2008 – 2009
  - Lena Novikova, University of Hamburg, Germany, 2009
  - Hector Moreno, Princeton University, UNM REU Program, 2009
  - Cristobal Arratia, B.S., University of Chile, University of Chicago-Chile Materials Collaboration, 2006
  - Amy Winans, University of Chicago, Beckman PCBio Scholarship, 2004 – 2007
  - Jen Park, University of Colorado, 2001-2002
  - Renee Esser, Iowa State University, CU REU, 2002
- High school student
  - Stephanie Chang, Illinois Mathematics and Science Academy, 2006

Ongoing Research Support

- Alzheimer's Association New Investigator Research Grant, Chi (PI), Lipid membrane mediated tau aggregation and toxicity, 02/01/2009 - 11/30/2011, Role: PI
- Oak Ridge Associated Universities Ralph E. Powe Junior Faculty Enhancement Award, Chi (PI), "Lipid membrane-templated protein misfolding in Alzheimer's disease", 06/01/2009-05/31/2010, Role: PI
- University of New Mexico Research Allocation Committee, "Interaction of tau protein with lipid membrane in the pathogenesis of Alzheimer's disease", Chi (PI), 01/01/2009-12/31/2009, Role: PI

- Air Force Research Laboratory, PI: Atanasov (PI), "Bio/nano architectures for enzyme catalyzed energy conversion", 09/15/2008- 09/14/2009, Role: Co-PI
- Office of Naval Research, PI: Lopez (PI), "A Comprehensive Facility for Surface Plasmon Resonance Spectroscopy at the University of New Mexico", 10/01/2009-09/30/2010, Role: Co-PI

BIOGRAPHICAL SKETCH: ELIZABETH L. (HEDBERG) DIRK

EDUCATION

University of Colorado, Boulder, Postdoctoral Fellow, 2004-2006
Rice University, Houston, TX, Bioengineering, Ph.D., 2004
University of California, Santa Barbara, B.S., Chemical Engineering (concentration: Biomaterials), High Honors, B.S., 1997

PROFESSIONAL EXPERIENCE

Assistant Professor, Department of Chemical & Nuclear Engineering and Department of Chemistry; University of New Mexico, NM, 2006-present
Special Topics Instructor, Bio-separations, Chemical Engineering Separations and Mass Transfer, University of Colorado, Boulder, 2005
Visiting Researcher, University Medical Center Nijmegen, Department of Biomaterials, Nijmegen, The Netherlands: 2002– 2003
Adjunct Researcher, Chrysalis Biotechnology, Inc., Galveston, TX/ OrthoLogic, Corp., Tempe, AZ: 2000 - 2004
Undergraduate Research Advisor, Rice University, Houston, TX: 2001 - 2004
Graduate Teaching Assistant, Rice University, Houston, TX: 2000 - 2001
Scientist I, Clorox Services Company, Pleasanton, CA: 1997 – 1998

PUBLICATIONS

E.L. Hedberg, H.C. Kroese-Deutman, C.K. Shih, R.S. Crowther, D.H. Carney, A.G. Mikos, J.A. Jansen, "Effect of Varied Release Kinetics of the Osteogenic Thrombin Peptide TP508 from Biodegradable, Polymeric Scaffolds on Bone Formation In Vivo," Journal of Biomedical Materials Research, 72, 343-353, 2005.

E.L. Hedberg, H.C. Kroese-Deutman, J.J. Lemoine, C.K. Shih, M.J. Miller, A.W. Yasko, R.S. Crowther, M.A.K. Liebschner D.H. Carney, A.G. Mikos, J.A. Jansen, "A Comparative Analysis of Radiography, Micro-Computed Tomography, and Histology for Bone Tissue Engineering," Tissue Engineering, 11, 1356-1367, 2005.

P.Q. Ruhe[±], E.L. Hedberg[±], N.T. Padron, P.H.M. Spauwen, J.A. Jansen, A.G. Mikos, "rhBMP-2 Release from Injectable Poly(DL-Lactic-co-Glycolic Acid)/Calcium Phosphate Cement Composites," The Journal of Bone and Joint Surgery 85A, 75-81, 2003. [±] Both authors contributed equally.

E.L. Hedberg, A. Tang, R.S. Crowther, D.H. Carney, A.G. Mikos, "Controlled Release of an Osteoinductive Peptide from Injectable Biodegradable Polymeric Composites," Journal of Controlled Release 84, 137-150, 2002.

Q. Liu, E.L. Hedberg, Z. Liu, R. Bahulekar, R.K. Meszlenyi, A.G. Mikos, "Preparation of macroporous poly(2-hydroxyethyl methacrylate) hydrogels by enhanced phase separation," Biomaterials, 21, 2163-2169, 2000.

P.Q. Ruhe, E.L. Hedberg, P.H.M. Spauwen, J.A. Jansen, A.G. Mikos, "Porous Poly(DL-Lactic-co-Glycolic Acid)/Calcium Phosphate Cement Composites for Bone Tissue Reconstruction," Tissue Engineering, 12, 789-800, 2006.

E.L. Hedberg, H.C. Kroese-Deutman, C.K. Shih, R.S. Crowther, D.H. Carney, A.G. Mikos, J.A. Jansen, "In Vivo Degradation of Porous Poly(Propylene Fumarate)/Poly(DL-Lactic-co-Glycolic Acid) Composite Scaffolds," Biomaterials, 26, 4616-4623, 2005.

P.Q. Ruhe, E.L. Hedberg, N.T. Padron, P.H.M. Spauwen, J.A. Jansen, A.G. Mikos, "Biocompatibility and degradation of Poly(DL-Lactic-co-Glycolic Acid)/Calcium Phosphate Cement Composites," Journal of Biomedical Materials Research, 74A, 533-544, 2005.

E.L. Hedberg,, C.K. Shih, M.D. Timmer, J.J. Lemoine, M.A.K. Liebschner, J.A. Jansen, A.G. Mikos, "In Vitro Degradation of Porous Poly(Propylene Fumarate)/(Poly(DL-Lactic-co-Glycolic Acid) Composite Scaffolds," Biomaterials, 26, 3215-3225, 2005.
E.L. Hedberg, C.K. Shih, L. Solchaga, A.I. Caplan, A.G. Mikos, "Controlled Release of Hyaluronan Acid Oligomers from Biodegradable Polymeric Microparticles," Journal of Controlled Release, 100, 257-266, 2004.

TOTAL PUBLICATIONS IN CAREER (2000 - present)

11 refereed publications, 3 book chapters, 2 patents awarded, 1 patent pending.

SYNERGISTIC ACTIVITIES IN PAST FIVE YEARS

Conference Coordinator, 10th Annual Advances in Tissue Engineering Short Course and Summer 2002 Department of Bioengineering Corporate Affiliates Program, Rice University, Houston TX: 2002
Founder and Chair, Bioengineering Graduate Student Association: 2001-2002
Advances in Tissue Engineering Short Course, Rice University: 1997 - 2002
Reviewer for: Acta Biomaterialia, Biomaterials, Journal of Controlled Release, Journal of Biomedical Materials Research, Journal of the American Society for Artificial Organs, Nature Biotechnology, Pharmaceutical Research, Polymer, Tissue Engineering
Member: American Institute of Chemical Engineers, Society for Biomaterials

RESEARCH COLLABORATORS

David Mooney, K. Kit Parker: Harvard University
Greg Boghart, Kate Boghart: Sandia National Laboratories

RESEARCH MENTORS

Graduate: Dr. Antonios G. Mikos, Rice University, Houston, TX
Postdoctoral: Dr. Kristi S. Anseth, University of Colorado, Boulder

CURRENT STUDENTS

Imran L. Chiragh, undergraduate, Chemical Engineering
Ulises A. Martinez, graduate, Chemical Engineering

TOTAL NUMBER OF STUDENTS ADVISED: 1 undergraduate, 1 graduate
TOTAL NUMBER OF POSTDOCS ADVISED: 0

HONORS AND AWARDS

Student Travel Grant, Biomedical Engineering Society, 2003
Student Award for Excellence in Tissue Engineering, Tissue Engineering Special Interest Group, Society for Biomaterials, 2002,
Student Travel Grant, Materials Research Society, 2001
NIH Biotechnology Training Grant Trainee, 1999-2000; 2001-2002

CURRICULUM VITAE

Evan A. Evans

BORN: Deming, New Mexico, 15 August 1940

EDUCATION:

Rensselaer Polytechnic Institute Troy, New York	BS, MS	1964-66	Engineering Physics
University of California, San Diego La Jolla, California	PhD	1970	Engineering Science

PROFESSIONAL EXPERIENCE:

1997 - present	Professor of Biomedical Engineering, Boston University
2008 – present	Research Professor, Center for High Technology Materials, University of New Mexico
2001 - present	Director, Whitaker Laboratories for Cell and Sub-cellular Bioengineering, Boston University
2006 – present	Professor Emeritus, University of British Columbia
1981 - 2005	Professor of Physics and Pathology, University of British Columbia
2005	RSC Visiting Professor of Physical Chemistry, Imperial College, London
2002	Visiting Professor of Physical Chemistry, Chalmers University, Sweden
1991 - 2000	Associate Fellow and Associate Director, Program in *Science of Soft Surfaces and Interfaces*, Canadian Institute for Advanced Research
1991 - 1992	Visiting Professor of Physics, Technical University of Munich
1973 - 1981	Assistant, Associate, Full Professor of Biomedical Engineering, Duke University
1972 - 1973	Assistant Professor of Engineering Physics, McMaster University

HONORS:

2004 - present	Fellow, Institute of Physics, London
2000 - present	Foreign Member, The Royal Danish Academy of Sciences and Letters
2000 - 2005	Fellow, American Institute for Medical and Biological Engineering
1987, 1991	Senior Scientist Award, Alexander von Humboldt Foundation, Germany
1975 - 1980	Research Career Development Award, National Institutes of Health
1971 - 1972	National Science Foundation, NATO postdoctoral Fellow in Biophysics

RESEARCH INTERESTS:

Research projects in my laboratories are focussed on the physics that underlies the unusual structural properties and complex molecular machinery in biological cells. Combining ultrasensitive micromechanical methods and advanced video optical microscopy, we have developed techniques to *softly touch and probe* organic structures over a scale from molecular dimensions to the size of visible cells. Assembling these techniques into computer controlled instruments, we have established novel methods for *dynamic force – and tension – spectroscopy* providing an intimate view of the molecular-scale kinetics governing strengths of biochemical bonds and cellular materials like membranes. For the first time, measurements of forces to break single bonds or rupture biomembranes can be related to nanoscale interactions, opening up a whole new realm of molecular - to mesoscopic - biophysics. These experiments reveal the key physical functions of biomolecular components and structures important in molecular biology and chemistry. Our objective is to not only establish fundamental understanding of living processes at the molecular level but also to derive insights for condensed matter physics and advanced technologies through study of nature's engineering.

RESEARCH SUPPORT (current and ongoing)

2001 - 2011	Principal Investigator: USPHS NIH Grant HL65333 (at Boston University), "Dynamic Strengths of Single Leukocyte Adhesion Bonds"
1983 - 2011	Principal Investigator: USPHS NIH Grant HL31579 Subcontract (at University of British Columbia), "Rheological and Adherence Properties of Sickle Cells", joint research with Dr. Mohandas Narla, New York Blood Center
2007 - 2011	Principal Investigator: USPHS NIH Grant HL81062 Subcontract (at University of British Columbia), "Force, Conformation, & Affinity in VLA-4 and LFA-1 Adhesion", joint research with Dr. Larry Sklar, Cancer Research Center, University of New Mexico.

COURSES TAUGHT:

2010 - present	Thermodynamics and Statistical Mechanics of Materials (MSE, Boston University)
2003 - present	Physical Chemistry of Cell Structure and Machinery (BME, Boston University)
2008 - 2009	Mechanics and Thermodynamics of Cell Structure (University of New Mexico)
2000 - 2004	Physics of Biocellular Structure (Physics, University of British Columbia)
1999 - 2001	Cell and Biomolecular Mechanics Laboratory (BME, Boston University)
1997 - 2001	Subcellular Biomechanics: Membranes and Interfaces (BME, Boston University)
1996 - 1997	Physics of Solid State Materials (Physics, University of British Columbia)
1993 - 1996	Physics of Soft Organic Interfaces (Physics, University of British Columbia)
1983 - 1993	Continuum Mechanics (Physics, University of British Columbia)
1974 - 1980	Continuum Mechanics; Thermodynamics (Engineering, Duke University)

INVITED LECTURES (last eight years):

- Mechanics of Biomembranes Workshop, Madrid, 2010
- Biotech Forum, Probing the Cell, Dresden, 2009
- International Conference, Energy Dissipation in Nanocontacts & Molecular Bonds, Dresden, 2009
- EMBO Conference on Physics of Cells, Croatia, 2009
- Gordon Conference on Barrier Function of Mammalian Skin, New Hampshire, 2009
- Gordon Conference on Science of Adhesion, New Hampshire, 2009
- International Symposium on Genomic Biomechanics: 21st Century Frontier, La Jolla, 2008
- Neuroscience Summer School, International Institute of Neuroscience, Natal, Brazil 2008
- New Frontiers for Biological Physics, Am. Physical Society March Meeting, New Orleans, 2008.
- Seminar, Laboratory of Physical and Structural Biology, NIH, 2008.
- Summer School, Biological Physics, California Institute of Techology, Pasadena, 2007
- Symposium, The Human Skin Barrier, Wenner-Gren Foundation, Sweden, 2007
- Symposium, Single Molecule Recognition and Unfolding Forces, Biophysical Society, Baltimore, 2007
- European Science Foundation Workshop on Physics of the Cell, Barcelona, Spain 2006
- International Symposium on Molecular Forces of Life, Heidelberg, Germany 2006
- International Workshop on Single Molecule Force Experiments and Simulations, Lyon, France 2006
- Nano-Force Canada Summer School, Montreal, Canada 2006
- International Physics School on Colloids in Biomedicine, Les Houches, France 2006 (*course lecturer*)
- Symposium on Protein Nanomechanics, Madrid, Spain 2005
- Workshop on Polymers, Worms, and Bilayers, Enschede, the Netherlands 2005
- Lipids, Liposomes & Biomembranes Conference, Vancouver, Canada 2005
- Cellular and Molecular Biology of Membranes, FEBS/EMBO course, Corsica, France 2005
- Symposium on Membranes & Vesicles, CAP National Meeting, Vancouver, Canada 2005
- Frontiers in the Interaction between Physics and Biology, Brown University, 2005
- Physics 2005, a century after Einstein, Warwick, England

- Munich Physics Colloquium, Ludwig-Maximilians University, Munich, Germany 2004
- Biomedical Engineering Society Annual Meeting, Philadelphia, 2004
- Symposium on Lipid Signaling, Society of General Physiologists, Woods Hole, 2004 (*keynote speaker*)
- Quantitative Approaches to Biology, SIAM, Los Angeles, 2004
- 24th Annual Conference on Statistical Physics of Macromolecules, Center for Nonlinear Studies, Los Alamos, 2004
- Scanning Probe Microscopy, Royal Microscopical Society, England, 2004 (*keynote speaker*)
- Symposium, Nanoscale Probing of Molecular Interactions, ACS Spring Meeting, Anaheim, 2004
- Symposium, Membrane Mechanics and Mechanosensitive Channels, Biophysical Society, 2004
- Gordon Conference on Colloids, Macromolecules and Polyelectrolytes, Ventura, 2004
- Physics Colloquium, Northeastern University, Boston, 2004
- Symposium on Dynamics in Small Systems, Materials Research Society, Boston, 2003
- International Workshop on Single Molecule Technologies, Ascona, Switzerland, 2003
- International Summer School on Biophysics, Croatia, 2003 (*invited lecturer*)
- 17th Symposium of Protein Society, Boston, 2003 (*keynote speaker*)
- International Symposium on Liposomes: Drug Delivery Vehicles & Models, Ontario, 2003
- Physics School on Complex Fluids, San Luis Potosi, Mexico, 2003 (*invited lecturer*)
- Gordon Conference on Red Cells, Italy, 2003
- Laboratory of Physical and Structural Biology NIH, Bethesda, 2003
- Theoretical and Applied Mechanics Colloquium, University of Illinois, 2003
- Pittsburgh Conference, Analytical Chemistry and Applied Spectroscopy, Orlando, 2003
- Molecular Biophysics, FASEB Conference, Vermont, 2002
- Single Molecule Dynamics, Heraeus Foundation, Germany, 2002
- Micro to Macromechanics of Hierarchical Living Materials, Heraeus Foundation, Germany, 2002
- International Conference, Assembly at Interface between Biology, Chemistry and Physics, Italy, 2001

PUBLICATIONS (119 original papers, 44 book chapters/review articles/proceedings, 1 book; more than 250 abstracts not listed):

Refereed Journals

1. Kinoshita, K., Leung, A., Simon, S.I. and Evans, E. Long-lived high strength states of ICAM-1 bonds to β_2 integrin: II. lifetimes of LFA-1 bonds under force in leukocyte signaling. *Biophys. J.* 98: 1467-1475, 2010.

2. Evans, E., Kinoshita, K., Simon, S.I. and Leung, A. Long-lived high strength states of ICAM-1 bonds to β_2 integrin: I. lifetimes of bonds to recombinant $\alpha_L \beta_2$ under force. *Biophys. J.* 98: 1458-1466, 2010.

3. Rawicz, W., Smith, B.A., McIntosh, T.J., Simon, S.A. and Evans, E. Elasticity, Strength, and Water Permeability of Bilayers that Contain Raft Microdomain-Forming Lipids. Biophys. J. 94: 4725-4736, 2008.

4. Heinrich, V., Wong, W.P., Halvorsen, K. and Evans, E. Imaging Biomolecular Interactions by Fast Three-Dimensional Tracking of Laser-Confined Carrier Particles. Langmuir 24: 1194-1203, 2008.

5. Chen, W., Evans, E.A., McEver, R.P. and Zhu, C. Monitoring Receptor-Ligand Interactions between Surfaces by Thermal Fluctuations. Biophys. J. 94: 694-701, 2008.

6. Evans, E. and Calderwood, D. Forces and Bond Dynamics in Cell Adhesion. Science 316: 1148-1153, 2007.

7. Bayas, M.V., Leung, A., Evans, E. and Leckband, D. Lifetime Measurements Reveal Kinetic Differences between Homophilic Cadherin Bonds. Biophys. J. 90: 1385-1395, 2006.

8. Wong, W.P. and Evans, E. Biological Physics: Rare returns on lost effort. Nature 437: 198-199, 2005.

9. Evans, E., Heinrich, V., Leung, A. and Kinoshita, K. Nano-to-Micro Scale Dynamics of P-selectin Detachment from Leukocyte Interfaces: I. Membrane separation from the cytoskeleton. Biophys. J. 88: 2288-2298, 2005.

10. Heinrich, V., Leung, A. and Evans, E. Nano-to-Micro Scale Dynamics of P-selectin Detachment from Leukocyte Interfaces: II. Tether flow terminated by P-selectin dissociation from PSGL-1. Biophys. J. 88: 2299-2308, 2005.

11. King, M., Heinrich, V., Evans, E. and Hammer, D. Nano-to-Micro Scale Dynamics of P-selectin Detachment from Leukocyte Interfaces: III. Numerical simulation of tethering under flow. Biophys. J. 88: 1676-1683, 2005.

12. Heinrich, V., Leung, A. and Evans, E. Nano-to-Microscale Switches and Fuses Mediate Adhesive Contacts between Leukocytes and the Endothelium. J. Chem. Inf. Model. 45: 1482-1490, 2005.

13. Evans, E., Leung, A., Heinrich, V. and Zhu, C. Mechanical switching and coupling between two dissociation pathways in a P-selectin adhesion bond. Proc. Natl. Acad. Sci. USA 101: 11281-11286, 2004.

14. Perret, E., Leung, A., Feracci, H. and E. Evans. *Trans*-bonded pairs of E-cadherin exhibit a remarkable hierarchy of mechanical strengths. Proc. Natl. Acad. Sci. USA 101: 16472-16477, 2004.

15. Evans, E., Heinrich, V., Ludwig, F. and Rawicz, W. Dynamic tension spectroscopy and strength of biomembranes. Biophys. J. 85: 2342-2350, 2003.

16. Evans, E. and Heinrich, V. Dynamic strength of fluid membranes. Comptes Rendus de L'Academie des Sciences – Physique. vol 4/2, pp 265-274, 2003.

17. Heinrich, V., Ritchie, K., Mohandas, N. and Evans, E. Elastic Thickness Compressibility of the Red Cell Membrane. Biophys. J. 81:1452-1463, 2001.

18. Evans, E., Leung, A., Hammer, D. and Simon, S. Chemically-Distinct Transition States Govern Rapid Detachment of Single Bonds to L-Selectin under Force. Proc. Natl. Acad. Sci. USA 98:3784-3789, 2001.

19. Evans, E. and Ludwig, F. Dynamic Strengths of Molecular Anchoring and Material Cohesion in Fluid Biomembranes. J. Physics Condens. Matter 12: A315-A320, 2000.

20. Rawicz, W., Olbrich, K., McIntosh, T., Needham, D. and Evans, E. Effect of Chain Length and Unsaturation on Lipid Bilayer Elasticity. Biophys. J. 79:328-339, 2000.

21. Olbrich, K., Rawicz, W., Needham, D. and Evans, E. Water Permeability and Mechanical Strength of Polyunsaturated Phosphatidylcholine Bilayers. Biophys. J. 79:321-327, 2000.

22. Evans, E. and Ritchie, K. Strength of a Weak Bond Connecting Flexible Polymer Chains. Biophys. J. 76:2439-2447, 1999.

23. Merkel, R., Nassoy, P., Leung, A., Ritchie, K. and Evans. E. Energy Landscapes of Receptor-Ligand Bonds Explored with Dynamic Force Spectroscopy. Nature 397:50-53, 1999.

24. Evans E. Looking Inside Biomolecular Bonds at Interfaces with Dynamic Force Spectroscopy. Biophys. Chem. 82:83-97, 1999.

25. Evans, E. Energy Landscapes of Biomolecular Adhesion and Receptor Anchoring at Interfaces Explored with Dynamic Force Spectroscopy. Faraday Discuss. Chem. Soc. 111:1-15, 1998.

26. Stone, T.A., Merkel, R., Zukoski, C.F., Evans, E. and Lauffenberger, D.A. Probing Receptor/Ligand Bond Properties with an Ultrasensitive Force Transducer. Annals of Biomed. Eng. 1997.

27. Evans, E. and Ritchie, K., Dynamic Strength of Molecular Adhesion Bonds. Biophys. J. 72: 1541-1555, 1997.

28. Evans, E. and Rawicz, W. Elasticity of *Fuzzy* Biomembranes. Phys. Rev. Lett. 79:2379-2383, 1997.

29. Wortis, M. and Evans, E. Membrane Self Assembly: Mechanical Properties and Vesicle Shapes. Physics in Canada 53:281-288, 1997.

30. Pincet, F., Rawicz, W., Perez, E., Lebeau, L., Mioskowski and Evans, E. Electrostatic Nanotitration of Weak Biochemical Bonds. Phys. Rev. Lett. 79:1949-1952, 1997.

31. Doebereiner, H.-G., Evans, E., Kraus, M., Seifert, U. and Wortis, M. Mapping Vesicle Shapes into the Phase Diagram: a Comparison of Experiment to Theory. Phys. Rev. E 55:4458-4474, 1997.

32. Parsegian, V.A. and Evans, E.A. Long and Short Range Intermolecular and Intercolloidal Forces. Curr. Opin, in Coll. and Surf. Sci. 1: 53-60, 1996.

33. Evans, E., Bowman, H., Leung, A., Needham, D. and Tirrell, D. Biomembrane Templates for Nanoscale Conduits and Networks. Science 273: 933-935, 1996.

34. Evans, E., Klingenberg, D.J. and Szoka, F. Interactions between Polymer Grafted Membranes in Concentrated Solutions of Free Polymer. Langmuir 12: 3031-3037, 1996.

35. Evans, E., Ritchie, K. and Merkel, R. Sensitive Force Technique to Probe Molecular Adhesion and Structural Linkages at Biological Interfaces. Biophys. J. 68:2580-2587, 1995.

36. Yeung, A. and Evans, E. Unexpected Dynamics in Shape Fluctuations of Bilayer Vesicles. J. Phys. II (France) 5:1501-1523, 1995.

37. Döbereiner, H.-G., Evans, E., Seifert, U. and Wortis, M. Spinodal Fluctuations of Budding Vesicles. Phys. Rev. Lett. 75: 3360-3363, 1995.

38. Evans, E. and Yeung, A. Hidden Dynamics in Rapid Changes of Bilayer Shape. Chem. Phys. Lipids 73:39-56, 1994.

39. Knowles, D.W., Chasis, J.A., Narla, M. and Evans, E. Cooperative Action between Band 3 and Glycophorin in Human Erythrocytes. Biophys. J. 66:1726-1736, 1994.

40. Discher, D., Narla, M. and Evans, E. Molecular Maps of Red Cell Deformation: Hidden Elasticity and In Situ Connectivity. Science 266:1032-1035, 1994.

41. Mui, B.L.-S., Cullis, P.R., Evans, E.A. and Madden, T.D. Osmotic Properties of Large Unilamellar Vesicles Prepared by Extrusion. Biophys. J. 64:443-453, 1993.

42. Evans, E. New Physical Concepts for Cell Amoeboid Motion. Biophys. J. 64:1306-1322, 1993.

43. Evans, E. Microscopic Physical Determinants in Biological Cell Adhesion. Blood Cells 19:401-419, 1993.

44. Evans, E., Leung, A. and Zhelev, D. Synchrony of Cell Spreading and Contraction Force as Phagocytes Engulf Large Pathogens. J. Cell Biol. 122:1295-1300, 1993.

45. Evans, E. Entropy-Driven Swelling of Fluid-Multimembrane Assemblies with Underlying Colloidal Interactions. Pure and Appl. Chem. 64:1611-1616,1992.

46. Evans, E. Equilibrium Wetting of Surfaces by Membrane-Covered Droplets. Adv. Colloid Int. Sci. 39:103-128, 1992.

47. Evans, E. Entropy-Driven Tension in Vesicle Membranes and Unbinding of Adherent Vesicles. Langmuir 7:1900-1908, 1991.

48. Evans, E. and Ipsen, J. Entropy-Driven Extension of Electric Double-Layer Repulsion between Highly Flexible Membranes. Electrochim. Acta 36:1735-1741, 1991.

49. Bloom, M., Evans, E. and Mouritsen, O.G. Physical Properties of the Fluid Lipid Bilayer Component of Cell Membranes. Quart Rev. Biophys. 24:293-397, 1991.

50. Evans, E., Berk, D. and Leung, A. Detachment of Agglutinin-Bonded Red Blood Cells: I. Forces to Rupture Molecular-point Attachments. Biophys. J. 59:838-848, 1991.

51. Evans, E., Berk, D., Leung, A. and Mohandas, N. Detachment of Agglutinin-Bonded Cells: II. Mechanical Energies to Separate Large Contact Areas. Biophys. J. 59:849-860, 1991.

52. Berk, D. and Evans, E. Detachment of Agglutinin-Bonded Red Blood Cells: III. Mechanical Analysis for Large Contact Areas. Biophys. J. 59:861-872, 1991.

53. Sugihara, T., Rawicz, W., Evans, E.A. and Hebbel, P. Lipid Hydroperoxides Permit Deformation-Dependent Leak of Monovalent Cation from Erythrocytes. Blood 77: 2757-2763, 1991.

54. Evans, E. and Rawicz, W. Entropy-Driven Tension and Bending Elasticity in Condensed-Fluid Membranes. Phys. Rev. Lett. 64:2094-2097, 1990.

55. Evans, E. Adhesion of Surfactant-Membrane Covered Droplets: Special Features and Curvature Elasticity Effects. Colloids and Surfaces 43:327-347, 1990.

56. Evans, E. Force on Surfaces that Confine a Polymer Solution: Derivation from Self-Consistent Mean-Field Theories. Macromolecules 22:2277-2286, 1989.

57. Merkel, R., Sackmann, E. and Evans, E. Molecular Friction and Epitatic Coupling between Monolayers in Supported Bilayers. J. Phys. (Paris) 50:1-21, 1989.

58. Evans, E. Kinetics of Granulocyte Phagocytosis: Rate Limited by Cytoplasmic Viscosity and Constrained by Cell Size. Cell Motility and the Cytoskeleton 14:544-551, 1989.

59. Evans, E. and Yeung, A. Apparent Viscosity and Cortical Tension of Blood Granulocytes. Biophys. J. 56:151-160, 1989.

60. Yeung, A. and Evans, E. Cortical Shell-Liquid Core Model for Passive Flow of Liquid-Like Spherical Cells into Micropipets. Biophys. J. 56:139-149, 1989.

61. Evans, E. and Sackmann, E. Translational and Rotational Drag Coefficients for a Disc moving in a Liquid Membrane Associated with a Rigid Substrate. J. Fluid Mech. 194:553-561, 1988.

62. Evans, E. and Needham, D. Interactions between Lipid Bilayer Membranes in Concentrated Aqueous Solutions of Non-adsorbing Polymers: Comparison of Mean-Field Theory with Direct Measurements of Adhesion Energy. Macromolecules 21:1822-1831, 1988.

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5. Evans, E. Probing the Relation between Force – Lifetime – and Chemistry in Single Molecular Bonds. Annu. Rev. Biophys. & Biomol. Struct. 30:105-128, 2001.

6. Ludwig, F. and Evans, E. How Strong is Molecular Anchoring in Biomembranes? B.I.F. *Futura* 15:96-103, 2000.

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Conference Proceedings

1. Evans, E., Kinoshita, K. and Leung, A. Strength of integrin-cytoskeletal anchoring in lymphocytic cells. IEEE-EMBS/BMES Proceedings, 2005.

2. Evans, E., Wong, W. P., Heinrich, V. and Halvorsen, K. Glimpse of the Future: control and switching of single molecule reactions at surfaces. IEEE-EMBS/BMES Proceedings, 2004.

3. Wong, W. P., Heinrich, V. and Evans, E. Exploring Reaction Pathways of Single-Molecule Interactions through Manipulation and Tracking of a Potential-Confined Microsphere in Three Dimensions. Mat. Res. Soc. Symp. Proc. Vol. 790, P5.1.1 - P5.1.12, 2004.

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6. Evans, E., Micromechanical Properties of Cells and Destruction in Soft Tissue Injuries. Laser-Tissue Interactions V, S.P.I.E. Proceedings, 1994.

7. Evans, E. Physics of Complex Membranes and Cell Interfaces. MRS Symp. Series Vol. 255, pp. 31-41, 1992.

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9. Evans, E.A. Red Blood Cell Membrane: Two Dimensional Elastomer. Proc., 1973 Biomechanics Symposium, ASME Applied Mechanics Division, Vol. 2:3-4.

Curriculum Vitae **James P. Freyer**

Education

La Salle College, Philadelphia, Pennsylvania	B.A.	1976	Physics
University of Rochester, Rochester, New York	M.S.	1978	Biophysics
University of Rochester, Rochester, New York	Ph.D.	1982	Biophysics

Research and Professional Experience

1976-1981 Graduate Fellow, Radiation Biology and Biophysics, University of Rochester.
1982-1984 Director's Postdoctoral Fellow, Los Alamos National Laboratory.
1984-1987 Staff Member in Toxicology Group of Los Alamos National Laboratory; research on spheroid biology, radiobiology, and flow cytometry.
1987-1999 Staff Member in Cell Biology Group of Los Alamos National Laboratory; research on spheroid biology, radiobiology, flow cytometry, and NMR spectroscopy and imaging.
1985-2005 Member, Institutional Biosafety Committee, Los Alamos National Laboratory.
1988-2003 Chairperson of Institutional Biosafety Committee, Los Alamos National Laboratory.
1989-now Associate Editor, *International Journal of Radiation Oncology, Biology and Physics*.
1998-now Adjunct Professor, Department of Cell Biology and Physiology, University of New Mexico.
1999-now Staff Member in Bioscience Division of Los Alamos National Laboratory; research on tumor models, flow cytometry, optical tumor diagnosis and NMR spectroscopy and imaging.
2000-2001 Acting Deputy Division Director, Bioscience Division, Los Alamos National Laboratory.
2002-2007 Associate Editor, *Radiation Research*.
2003-now Full Member, University of New Mexico Cancer Research and Treatment Center.
2005-2010 Director and PI, National Flow Cytometry Resource.
2007-2008 Group Leader, Advanced Measurement Sciences Group, Los Alamos National Laboratory.
2008-now Biology Councilor, International Society for Analytical Cytology.
2009-now Research Professor, Center for Biomedical Engineering, Department of Chemical and Nuclear Engineering, University of New Mexico.

Teaching and Public Science Activities

1978-1981 Instructor in College of Science, Rochester Institute of Technology, Rochester, New York, teaching a self-designed course in Radiation Biology.
1982-1986 Instructor in Pharmacology Department, University of New Mexico, Albuquerque, New Mexico, teaching a self-designed course in Biosafety in the Laboratory.
1987-now Served as Judge at the New Mexico Regional Science Fair.
1988-1992 Taught a self-designed course entitled "In Vitro Models of Cancer" to High School students under the Los Alamos Student Science Program.
1990-now Numerous presentations through the LANL Educational Outreach Office; the New Mexico Supercomputing Challenge; and the Los Alamos Summer School.
1992-now Average 1-2 presentations per year to Elementary, Middle and High School classes through the New Mexico Academy of Sciences Visiting Scientist Program.
1995-2002 Organize seminars for Technical Staff Members in Life Science/Bioscience Divisions.
1995 Served as mentor for Adventures in Supercomputing team from Pecos High School.
1998-now Mentor for students in Biomedical Sciences Program, University of New Mexico.
2001-2003 Co-Director and mentor, Research Experiences for Undergraduates program, NSF.
2001-now Mentor for graduate and undergraduate students in MentorNet program.
2002 Outstanding REU Program Mentor Award.
2004-2007 Mentor for students, National Science Foundation PUSH Program, with Northern New Mexico Community College.
2007-now Lecturer in LANL qBio Summer School.

Review Service

1986-now Reviewer for: *Cancer Research*; *Radiation Research*; *International Journal of Radiation Biology; International Journal of Cancer; Journal of Cellular Physiology*; *British Journal of Cancer*; *Cytometry; Neoplasia; American Journal of Physiology*; *Magnetic Resonance in Medicine; Radiotherapy and Oncology; Biophysical Journal*, *Journal of Theoretical Biology, Clinical Cancer Research*, *Cancer Letters, Physics Review E, Physical Review Letters, American Institute of Chemical Engineers Journal* and *Analytical Chemistry*.
1990 NIH Site Review Committee, University of Texas at San Antonio.
1992-1999 *Ad Hoc* reviewer: Radiation; Diagnostic Radiology; Biophysical Chemistry; and Pathology B Study Sections, NIH.
1996 NIH Site Review Committee, Core Grant, NMR Facility, Fox Chase Cancer Center.
1996-now *Ad Hoc* Reviewer, National Cancer Institute of Canada.
1996 Member of Fellows Selection Committee, Los Alamos National Laboratory.
1997-2002 Reviewer for the International Society for Magnetic Resonance in Medicine
1998-2001 Member of Postdoctoral Committee, Los Alamos National Laboratory.
1999-2002 Member of Radiation Study Section, Center for Scientific Review, NIH.
2003-now *Ad Hoc* Reviewer, Radiation Study Section, Center for Scientific Review, NIH.
2003-now Member, SBIR Study Section, Center for Scientific Review, NIH.
2005 Member, Medical Countermeasures Against Radiation Terrorism special panel, NIH.
2005 Member, NCRR P41 Reverse Site Visit Review Committee.
2005-now *Ad Hoc* Member, NCRR Special Emphasis Review Panel.
2006-now *Ad Hoc* Member, Innovative Technologies for Molecular Analysis of Cancer Review Team, NIH.
2007 Member, NCRR P41 Site Visit Review Committee, Pacific Northwest National Laboratory.
2007-now *Ad Hoc* Member, SBIR/STTR-Cell Biology Review Committee, NIH.
2007 Member, NCRR P41 Site Visit Review Committee, University of Georgia.
2008-now External Reviewer, Israeli Science Foundation.
2008 Member, NCRR P41 Site Visit Review Committee, Neuroscience Research Institute of North Carolina.
2009 Member, EUREKA Review Team, National Cancer Institute, NIH
2009 Member, Biomedical Technology Research Resource Virtual Review Group, National Center for Research Resources, NIH.
2010 Member, Medical Countermeasures Against Radiation Terrorism special panel, NIH.

Professional Societies

Radiation Research Society
American Association for Cancer Research
International Society for Analytical Cytology

Funding Record (~$35M over 29 years)

1984-1987 Principal Investigator on National Cancer Institute grant R01-CA036535, "Regulation of Proliferation and Viability in Multicellular Spheroids", $200,000 per year for 3 years.
1987-1990 Co-Investigator on National Cancer Institute grant R01-CA022585, "Age Response and OER Using Flow Cytometry", $200,000 per year for 3 years.
1991-1995 Principal Investigator on National Cancer Institute grant R01-CA051150, "NMR Spectroscopy and Imaging of Tumor Models", $300,000 per year for 4 years.
1994-1997 Principal Investigator on Los Alamos National Laboratory Directed Research and Development grant, "Optimization and Monitoring of Hollow-Fiber Bioreactors", $245,000 per year for 3 years.

Funding Record (continued)

1994-1997 Co-Investigator on Los Alamos National Laboratory - University of California Collaborative Research grant, "Cellular Basis for Functional Magnetic Resonance Imaging", $40,000 per year for 2 years.

1994-1997 Co-Investigator on United Sates-Israeli Binational Science Foundation grant #93-00073, "Tumor Angiogenesis: NMR Microscopy of Spheroids", $59,000 per year for 3 years.

1996-1999 Principal Investigator on National Institute of Environmental Health Sciences grant R01-ES007845, "New Method for Isolating Radiation-Sensitive Mutants", $320,000 per year for 3 years.

1996-2000 Co-Investigator on National Cancer Institute grant R01-CA071898, "Light Scattering in Tumor and Normal Tissues", $330,000 per year for 5 years.

1998-2002 Principal Investigator on National Cancer Institute grant R01-CA080316, "Molecular Basis of Microenvironmental Cell Cycle Control", $345,000 per year for 4 years.

2000-2005 Co-Investigator on National Cancer Institute grant R01-CA071898, "Raman Spectroscopy for Cancer Diagnosis and Treatment Monitoring", $600,000 per year for 5 years.

2000-2005 Co-Investigator on National Cancer Institute grant R01-CA071898, "Light Scattering in Tumor and Normal Tissues", $550,000 per year for 5 years.

2001-2003 Co-Principal Investigator on National Science Foundation grant under Research Experiences for Undergraduates Program "Interfaces in Biology", $50,000 per year for 3 years.

2003-2004 Principal Investigator on Department of Energy Office of Science grant, "Role of Fibroblast-Epithelial Cell Interactions in the Response to Low Dose Radiation", $60,000 per year for 1 year.

2004-2006 Principal Investigator on National Cancer Institute grant R21-CA108853, "A New Model of the Tumor Microenvironment", $250,000 per year for 2 years.

2004-2005 Co-Investigator on Department of Energy Office of Science grant, "Development of Radioisotope Labeling Methods for Cancer Diagnosis and Treatment", $400,000 per year for 2 years.

2005-2012 Principal Investigator on National Center for Research Resources grant P41-001315, "The National Flow Cytometry and Sorting Resource", $1,900,000 per year for 7 years.

2006-2009 Co-Investigator on Los Alamos National Laboratory Directed Research and Development grant, "Understanding a Killer: A Predictive Model of Tumor Development", $275,000 per year for 3 years.

2007-2012 Principal Investigator on National Cancer Institute grant R01-CA132629, "Differential Metabolic Network Analysis of Tumor Progression", $450,000 per year for 5 years.

2008-2013 Co-Investigator on National Cancer Institute grant R01-CA071898, "Light Scattering in Tumor and Normal Tissues", $700,000 per year for 5 years.

Peer-Reviewed Publications (~2200 citations as listed below [total: since 2006])

1. Freyer JP, Sutherland RM (1980) Selective dissociation and characterization of cells from different regions of multicell tumor spheroids. *Cancer Res.* **40**: 3956-3965. [146: 8]
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14. Freyer JP, Wilder ME, Raju MR (1987) Rapid assay for cell age response to radiation by electronic volume flow cell sorting. *Int. J. Radiat. Biol.* **52**: 91-106. [12: 1]
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18. Freyer JP, Schor PL, Saponara AG (1988) Partial purification of a protein growth inhibitor from multicellular spheroids. *Biochem. Biophys. Res. Comm.* **152**: 463-368. [17: 2]
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20. Freyer JP, Schor PL (1989) Regrowth kinetics of cells from different regions of multicellular spheroids of four cell lines. *J. Cell. Physiol.* **138**: 384-392. [24: 2]
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30. Freyer JP, Jarrett K, Carpenter S, Raju MR (1991) Oxygen enhancement ratio as a function of dose and cell cycle stage for radiation resistant and sensitive CHO cells. *Radiat. Res.***127**: 297-307. [16: 4]
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68. Freyer JP, LaRue KEA, Kahlil M, Coulter JR (2010) Improved apparatus for obtaining cells from different microenvironments within multicellular spheroids. *Biotechniques*, in preparation.
69. Houston JP, Sanders CS, Trujillo A, Freyer JP (2010) Phase-sensitive flow cytometry measurements of autofluorescence from viable mammalian cells, *J. Biomed. Optics,* in preparation.
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Book Chapters and Reviews

1. Landry J, Freyer JP (1984) Regulatory Mechanisms in Spheroidal Aggregates of Normal and Cancerous Cells. In: *Recent Results in Cancer Research* **95:** *Spheroids in Cancer Research*. Acker H, Carlsson J, Durand R, Sutherland RM, eds. (Springer-Verlag), pp. 50-66. [18: 2]
2. Sillerud LO, Halliday KR, Freyer JP, Griffey RH, Fenoglio-Preiser, C (1991) ^{13}C and ^{31}P NMR Studies of Prostate Tumor Metabolism. In: *Developments in Oncology*, Vol. 61, Evelhoch JL, Negendank W, Valeriote FA, Baker LH, eds. (Springer), pp. 120-134.
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4. Neeman M, Freyer JP, Sillerud LO (1995) Effects of the Imaging Gradients on Diffusion Measurements by MRI. In: *Diffusion and Perfusion Magnetic Resonance Imaging*. LeBihan D, ed. (Raven Press), pp. 73-76.
5. Kunz-Schughart LA, Freyer JP, Hofstaedter F, Ebner R (2004) The use of 3-D cultures for high throughput screening. *J. Biomolec. Screen.* **9**: 273-285. [52: 48]

Proceedings Papers

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2. Mourant JR, Hielscher AH, Freyer JP, Eick AA, Shen D, Johnson,TM (1998) Cancer cell diagnostics with wavelength dependent or polarized light scattering. *Proceed. SPIE* **3250**: 26-32.
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4. Mourant JR, Canpolat M, Brocker C, Esponda-Ramos O, Johnson T, Matanock A, Stetter K, Freyer JP (2000) Light scattering from cells: the contribution of the nucleus and the effects of proliferative status. *Proceed. SPIE* **3917**: 33-42.
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6. Short KW, Carpenter S, Freyer JP, Mourant JR (2002) Raman scattering studies of biochemical changes associated with carcinogenesis using tumorigenic and non-tumorigenic cells. *Proceed. IEEE Engineer. Med. Biol.* **3**; 2263-2264.

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7. Mourant JR, Johnson TM, Aida T, Carpenter S, Freyer JP (2002) Distinguishing morphological changes with polarized light scattering. *Proceed. IEEE Engineer. Med. Biol.* **3**; 2293-2294.
8. Mourant JR, Yamada YR, Carpenter S, Guerra A, Schoonover J, Freyer JP (2002) Vibrational spectroscopy of viable, paired tumorigenic and non-tumorigenic cells. *Proceed. SPIE* **4614**: 109-116.
9. Mourant JR, Dominguez J, Carpenter S, Powers TM, Guerra A, Short KW, Kunapareddy N, Freyer JP (2006) Determining the gross biochemical composition of cells and tissue with Raman spectroscopy. *Proceed. SPIE* **6093**: T1-T9.
10. Kunapareddy N, Carpenter S, Freyer JP, Mourant JR (2006) Biochemical characterization of cell death via Raman spectroscopy. *Proceed. SPIE* **6093**: V1-V11.
11. Houston JP, Naivar M, Martin JC, Goddard G, Carpenter S, Mourant JR, Freyer JP (2008) Endogenous fluorescence lifetime of viable cells by flow cytometry. *Proceed. SPIE* **6859**: T8590.
12. Goddard GR, Houston JP, Martin JC, Graves SW, Freyer JP (2008) Cellular discrimination based on spectral analysis of intrinsic fluorescence *Proceed. SPIE* **6859**: 85908.

Patents

1. Freyer JP, U.S. patent #5,652,0987: "Method for Rapid Isolation of Sensitive Mutants", July 29, 1997.

Invited Seminars and Lectures 2005-2010 (selected from a total of 30)

1. Freyer JP (2005) "Tumor microenvironments and optical cancer diagnosis", University of New Mexico Cancer Cell and Molecular Biology Program Retreat, Albuquerque, NM, March 14.
2. Freyer, JP (2007) "In vitro tumor models: New questions for old systems and new systems for old questions", British Columbia Cancer Research Centre, Vancouver, BC, Canada, April 23.
3. Freyer JP (2007) "The National Flow Cytometry and Sorting Research Resource", British Columbia Cancer Research Centre, Vancouver, BC, Canada, April 24.
4. Freyer JP (2007) "The tumor microenvironment and 3-D tumor models", 1st q-bio Summer School on Cellular Information Processing, Los Alamos, NM, July 26.
5. Freyer, JP (2007) "In vitro tumor models: New questions for old systems and new systems for old questions", Cell and Molecular Biology Graduate Program, Colorado State University, Ft. Collins, CO, September 13.
6. Freyer JP (2007) "The National Flow Cytometry and Sorting Research Resource", Cell and Molecular Biology Graduate Program, Colorado State University, Ft. Collins, CO, September 14.
7. Freyer JP (2008) "The National Flow Cytometry and Sorting Research Resource", Dresden Technical University, Dresden, Germany, May 23.
8. Freyer JP (2008) "The National Flow Cytometry and Sorting Research Resource", University of Mainz, Mainz, Germany, May 27.
9. Freyer JP (2008) "The tumor microenvironment and 3-D tumor models", 2nd q-Bio Summer School on Cellular Information Processing, Los Alamos, NM, July 24.
10. Freyer JP (2008) "The National Flow Cytometry and Sorting Research Resource", Center for Biomedical Engineering, University of New Mexico, Albuquerque, NM, September 2.
11. Freyer JP (2009) "*In vitro* models of the tumor microenvironment", University of New Mexico Cancer Center, Albuquerque, NM, February 9.
12. Freyer JP (2009) "The tumor microenvironment and 3-D tumor models", 3rd q-Bio Summer School on Cellular Information Processing, Los Alamos, NM, July 28.

First-Author Presentations 2005-2010 (selected from a total of ~120 first- or co-author presentations)

1. Freyer JP, Guerra A, Albertini R, LaRue KEA (2005) "Role of cyclin-dependent kinase inhibitors in microenvironmental regulation of tumor cell proliferation", Cell Cycle and Cancer: Pathways and Therapies (AACR Special Conference), December 1-6, Ft. Lauderdale, FL.
2. Freyer JP, Carpenter S, Guerra A, Short K, Kunapareddy N, Mourant JR (2005) "The biochemical basis for cancer diagnosis by optical spectroscopy", 96th Annual Meeting of the American Association for Cancer Research, April, 16-20, Anaheim, CA.
3. Freyer JP, Albertini RA, Guerra A (2005) "A new model of the tumor microenvironment", 52nd Meeting of the Radiation Research Society, October 16-19, Denver, CO.
4. Freyer JP, Sanders C, Field S, Habbersett R (2005) "Flow analysis of individual mitochondria", 15th Cytometry Development Workshop: Technologies for Cell Analysis, October 27-29, Asilomar, CA.
5. Freyer JP, Sanders C, Field S, Habbersett R (2006) "Improved analysis of individual mitochondria by high sensitivity flow cytometry", 23rd International Congress of the Society for Analytical Cytology, May 20-24, Quebec City, Quebec, Canada.
6. Freyer JP, Trujillo A, Guerra A (2006) "Effects of HIF1-a knockout on the growth and morphology of multicellular spheroids", 9th International Workshop on the Tumour Microenvironment, September 15-17, Boston, MA.
7. Freyer JP, Goddard G, Naivar MA, Graves SW, Jett JH, Habbersett R, Martin JC, Nolan JP, Parson J, Wilder ME (2007) "Recent instrument developments at the National Flow Cytometry Resource", P41 Principal Investigator Meeting, National Center for Research Resources, June 18-19, Bethesda, MD.
8. Freyer JP, Habbersett RC, Jett JH (2007) Detection of radiation-induced conformational changes in individual DNA molecules using a high sensitivity flow 'cytometer'", 13th International Congress of Radiation Research, July 8-12, San Francisco, CA.
9. Freyer JP, Naivar MA, Wilder ME, Trujillo JJ, Graves SW (2008) "Recent developments in digital data acquisition systems for flow cytometry", P41 Principal Investigator Meeting, National Center for Research Resources, November 13-14, Bethesda, MD.
10. Freyer JP, Naivar M, Houston JP (2009) Fluorescence lifetime analysis and sorting by digital flow cytometry, P41 Principal Investigator Meeting, National Center for Research Resources, October 13-14, Bethesda MD.

CURRICULUM VITAE

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EDUCATION

Ph. D. Biochemistry, Microbiology and Molecular Biology, 1998
The Pennsylvania State University, University Park, PA
Doctoral Dissertation: "The cloning, purification, and kinetic characterization of the catalytic subunit of the human mitochondrial DNA polymerase."

B.A. Biochemistry and Molecular Biology (Double Major), 1991
University of Colorado, Boulder, CO

PROFESSIONAL EXPERIENCE

2008 – Present **Associate Director**
Center for Biomedical Engineering, University of New Mexico, Albuquerque, NM

2008 – Present **Associate Professor**
Chemical and Nuclear Engineering Department, University of New Mexico, Albuquerque, NM

2007 – 2008 Biosciences Division, Los Alamos National Laboratory, Los Alamos, NM
Team Leader, Optical Spectroscopy and Instrumentation

2003 – Present **Adjunct Assistant Professor**
Biochemistry Department, University of New Mexico, Albuquerque, NM

2002 – 2008 **Technical Staff Member**
Biosciences Division, Los Alamos National Laboratory, Los Alamos, NM

1999 – 2002 **Post-Doctoral Fellow**
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1998 – 1999 **Applications Specialist**
KinTek Corporation, Austin, TX

1992 – 1998 **Graduate Research Assistant**
The Pennsylvania State University, University Park, PA

1991-1992 **Analyst**

Rocky Mountain Analytical Laboratory, Arvada, CO

PUBLICATIONS

1. **Graves S.W.**, Johnson A.A. and Johnson K.A. (1998). Expression, purification, and initial kinetic characterization of the large subunit of the human mitochondrial DNA polymerase. *Biochemistry*, 37(17) 6050-6058

2. Johnson, A.A., Tsai, Y., **Graves S.W.** and Johnson, K.A. (2000) Human mitochondrial DNA polymerase holoenzyme: Reconstitution and characterization. *Biochemistry*, 39(7), 1702-1708

3. Patterton, H.G. and **Graves, S.** (2000) DNAssist, a C++ program for editing and analysis of nucleic acid and protein sequences on PC-compatible computers running Windows 95, 98, NT4.0 or 2000. *Biotechniques*, 28(6) 1192-1197

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5. **Graves, S.W.**, Habbersett, R.C. and Nolan, J.P. (2001) A dynamic inline sample thermoregulation unit for flow cytometry. *Cytometry*, 43(1), 23-30

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7. Sklar, L.A., Edwards, B., **Graves, S.W.**, Nolan J.P,, Prossnitz, E (2002) Flow cytometric analysis of ligand-receptor interactions and molecular assemblies. *Annual Review of Biophysics and Biomolecular Structure* 31:97-119.

8. **Graves, S.W.**, R.C. Habbersett, J.P. Nolan (2002) Dynamic thermoregulation of the sample in flow cytometry. *Current Protocols in Cytometry*, Unit 1.18 (J.P. Robinson, editor), John Wiley and Sons.

9. Kraus, R.H., M.A. Espy, A.N. Matlachov, T.J. Matsson, C. Carr, J.C. Martin, J.P. Nolan, **S. Graves**, A.C. Bergstrom, M.D. Ward, P. Grodzinski (2003) Bioassay with magnetic particles in flow: a method for highly parallel molecular separations of complex biological systems. *EUCAS 2003 Proceedings*.

10. Chigaev A, Zwartz G, **Graves SW**, Dwyer DC, Tsuji H, Foutz TD, Edwards BS, Prossnitz ER, Larson RS, Sklar LA. (2003) Alpha4beta1 integrin affinity changes govern cell adhesion. J Biol Chem. Oct 3;278(40):38174-82.

11. **Graves, S. W.**, Woods, T. A., Kim, H., Nolan, J. P. (2005) Direct fluorescent staining and analysis of proteins on microspheres using ATTO-TAG CBQCA, Cytometry, 65A (1), 50-58

12. **Graves, S.W.** Nolan, J. P. Sklar, L. A., (2005) Molecular Assemblies, Probes, and Proteomics in Flow Cytometry in Flow Cytometry for Biotechnology (L. A. Sklar, editor) Oxford University Press, New York, New York.

13. Woods, T.A., **S.W. Graves,** J.P. Nolan (2005) Protein surface concentration measurements using flow cytometry. Current Protocols in Cytometry 13.2.

14. Goddard G, Martin JC, **Graves SW**, Kaduchak G. (2006) Ultrasonic particle-concentration for sheathless focusing of particles for analysis in a flow cytometer. Cytometry A. Feb;69(2):66-74.

15. Saunders MJ, Kim H, Woods TA, Nolan JP, Sklar LA, Edwards BS, **Graves SW** (2006).Microsphere-based protease assays and screening application for lethal factor and factor Xa. Cytometry A. May;69(5):342-52.

16. Espy, M A; Carr, C; Sandin, J H; Hanson, C J; Daniels, S G; Matlachov, A N; **Graves, S W**; Ward, M D; Jr, R H Kraus; Fritz, S; Leslie-Pelecky (2006) SQUID-Based Bioassay with Magnetic Particles in Flow. Journal of Physics: Conference Series Volume: 43, Issue: 1, June 01, 2006, pp. 1254-1257

17. Deshpande A, Hammon RJ, Sanders CK, **Graves SW**. (2006) Quantitative analysis of the effect of cell type and cellular differentiation on protective antigen binding to human target cells. FEBS Lett. Jul 24;580(17):4172-5.

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20. Habbersett R. C., Naivar M.A., Woods T.A., Goddard G.R., **Graves S.W.**, Evaluation of the use of a green laser pointer for flow cytometry, Cytometry A. 2007 Oct;71(10):809-17.

21. Naivar M.A, Parson J.D., Wilder M.E, Habbersett R.C., Edwards B.S., Sklar L, Nolan J.P., **Graves S.W.**, Martin J.C., Jett J. H., and Freyer, J.P.., Open, Reconfigurable Cytometric Acquisition System: ORCAS, Cytometry Part A. Cytometry; NOV 2007; v.71A, no.11, p.915-924

22. Goddard G.R., Sanders C., Martin J.C., Kaduchak G., **Graves S.W.** Analytical performance of an ultrasonic particle focusing flow cytometer, Anal. Chem., 2007. Nov 15;79(22):8740-6.

23. Watson, D. A., Brown, L. O., Graham, D. A., Naivar, M. A., **Graves, S. W.**, Doorn, S. K., Nolan J. P., *Cytometry Part A. 2008 Feb;73(2):119-28.*

24. Goddard, GR; Houston, JP; Martin, JC; **Graves, SW**; Freyer, JP., Cellular discrimination based on spectral analysis of instrinic fluorescence., *Proc. of the SPIE;* 2008 Feb. 7; vol.6859, p.685908-1-10

25. Marina, O., Goddard, G. R., Sanders, C. K., Graves, S.W., Kaduchak, G. K., Analytical Quantitation of Acoustic Cell Lysis. *Manuscript in preparation for Analytical Chemistry.*

26. Woods, T. A., Goddard. G. R., Naivar, M. A., Martin, J. C., Jett, J. H., **Graves, S. W.**, Scatter Effects on Cytometry Measurements. *Manuscript in preparation for Cytometry Part A.*

27. Naivar, M. A.,Wilder, M. E., Habbersett, R. C., **Graves, S. W.**, Miniature Cytometric Acquisition System: MiCAS, *Manuscript in preparation for Cytometry Part A.*

28. Sanders, C. K., **Graves S. W.**, Gupta, G., Vuyisich, M. ANTHRAX LETHAL TOXIN: IN VITRO ASSEMBLY, RECEPTOR AND CELL BINDING, AND CELL INTOXICATION STUDIES. *Manuscript in preparation for Febs letters.*

INVITED AND CONFERENCE TALKS

Graves, S.W. Low-cost portable flow cytometry. The Fall 2007 Seminar Series in the Chemical Engineering Department, September 7, 2007. Colorado School of Mines.

Graves, S. W. Measurement and analysis of nano scale materials by flow cytometry. 1st Annual Symposium: Integrating Nanotechnology with Cell Biology and Neuroscience, August 15, 2007, The University of New Mexico.

Graves S.W., Kaduchak G., Goddard G. R., Habbersett, R.C. Ward, M.D., Martin J. C., Naivar M. A. Low Cost Hand-Portable Flow Cytometry International Society of Analytical Cytology 23rd Annual Conference, Quebec City, Quebec, Canada, May 20-24th, 2006.

Graves, S. W., A chip based flow cytometer. Flow Cytometry for Exploration Missions – A workshop organized by Wyle Laboratories and NASA/Johnson Space Center. November 5th, 2004

Graves S.W., Molecular Assembly Analysis by Flow Cytometry, La Jolla Bioengineering Institute, La Jolla, CA. September 2004

Graves, S.W. et. al. Design and Quantitative Evaluation microfluidic flow cells. International Society of Analytical Cytology 22nd Annual Conference, Montpellier France, May 21st-27th, 2004. Cytometry; May 2004; v.59A, no.1, p.52

Graves, S.W., Flow cytometry as a platform for analysis and discovery of molecular assemblies for bio-defense and biomedical applications, Biochemistry Department, The University of New Mexico, August 2003

Graves, S.W., Flow cytometry as a platform for analysis and discovery of molecular assemblies, Great Lakes International Imaging and Flow Cytometry Association GLIIFCA, "CellEFTA" 20 years of Immunophenotyping" From OKT-4 Receptors to Cytonomics", Detroit, MI, October 4 - 6, 2002

Graves, S.W., and Nolan J.P., Multiplexed DNA Based Assays for Pathogen Point Detection. Talk presented at the CBNP Quarterly Review Meeting at Livermore National Laboratory. November 2000.

POSTERS AND PRESENTATIONS

Habbersett R.C. Parson J.D. **Graves S.W.**, Low cost light source and miniature detectors yield high performance in a slow-flow system., International Society of Analytical Cytology 23rd Annual Conference, Quebec City, Quebec, Canada, May 20-24th,

2006.

Naivar M, Jett J, Parson J., Habbersett R., **Graves S.**, Martin J. Wilder M., Nolan J. P., Freyer J., Modular, expandable, high-speed digital data acquisition system designed to support mixed mode data from PMTs, photon counting APDs , and high resolution CCD arrays. International Society of Analytical Cytology 23rd Annual Conference, Quebec City, Quebec, Canada, May 20-24th, 2006.

Bae, W; Zhou, JH; Graves, SW, Development of a high throughput and generally applicable screening method for investigating protease/substrate interaction FASEB Journal; MAR 6 2006; v.20, no.4, Part 1, p.A50-A51 Conference: Experimental Biology 2006 Meeting; April 01 -05, 2006 ; San Francisco, CA, USA

Graves, S.W. Woods, T.A. Nolan, J. P. Tools and approaches for protein interaction studies using microsphere arrays, Cytometry; May 2004; v.59A, no.1, p.149 International Society of Analytical Cytology 22nd Annual Conference, Montpellier France, May 21st-27th, 2004.

Martin, J .C., Espy, M. A., Bergstrom, A. C., **Graves, S.W.,** Carr, C., Matsson, T. J. Matlachov, A. N., Kraus, R. H., Nolan, J. P. A magnetic field sensing flow cytometer. Cytometry; May 2004; v.59A, no.1, p.147 International Society of Analytical Cytology 22nd Annual Conference, Montpellier France, May 21st-27th, 2004.

Nolan, J.P., Deshpande, A., Woods, T.A., **Graves, S.W.**, Binding and uptake of bacterial toxins by mammalian cells Cytometry; May 2004; v.59A, no.1, p.132 International Society of Analytical Cytology 22nd Annual Conference, Montpellier France, May 21st-27th, 2004.

Martin, J. C., Yoshida, T. M., **Graves, S. W.**, Spectral analysis flow cytometry, Cytometry; May 2004; v.59A, no.1, p.30 International Society of Analytical Cytology 22nd Annual Conference, Montpellier France, May 21st-27th, 2004

Graves, Steven W.; Nolan, John P.; Jett, James H.; Martin, John C.; Chigaev, Alexandre; Sklar, Larry A. Nozzle design effects on rapid delivery and rapid kinetic measurements in flow cytometry, Cytometry Supplement; 2002; no.11, p.121 Conference: XXI Congress of the International Society for Analytical Cytology; May 04-09, 2002; San Diego, CA, USA

Graves, Steven W.; Habbersett, Robert C.; Nolan, John P. Dynamic thermoregulation of the sample in flow cytometry, Cytometry Supplement; 2002; no.11, p.121 Conference: XXI Congress of the International Society for Analytical Cytology; May 04-09, 2002; San Diego, CA, USA

Jett, James; Albright, Kevin; **Graves, Steven**; Habbersett, Robert; Martin, John; Naivar, Mark; Parson, Jim; Wilder, Mark; Yoshida, Thomas., Spectral analysis flow cytometry, Cytometry Supplement; 2002; no.11, p.142 Conference: XXI Congress of the International Society for Analytical Cytology; May 04-09, 2002; San Diego, CA, USA

Nolan, John; Gallegos, LaVerne; Nolan, Rhiannon; **Graves, Steve**; Cai, Hong; White, P. Scott, Molecular microbiology: Detection and identification of bacterial and viral pathogens , Cytometry Supplement; 2002; no.11, p.27-28 Conference: XXI

Congress of the International Society for Analytical Cytology; May 04-09, 2002; San Diego, CA, USA

Graves S.W., Johnson A.A. and Johnson K.A. (1998). Expression, purification, and initial kinetic characterization of the large subunit of the human mitochondrial DNA polymerase. Poster presented at the 43rd Annual Meeting of the Biophysical Society. Kansas City, MO and the annual meeting of the American Society of Biochemistry and Molecular Biology, New Orleans, LA.

Graves, S.W. and Johnson, K.A. (1994) Kinetic analysis of porcine liver DNA polymerase-gamma. Poster presented at the 38th Annual Meeting of the Biophysical Society. New Orleans, LA

ACTIVE RESEARCH GRANTS (GRANTS WHERE I AM PI HAVE THE TITLE BOLDED)

NIH RR020064 R21/R33 Low cost portable flow cytometry
Role – PI
Dates: R21 Phase 8/15/05-7/31/07 --- R33 Phase 8/01/07- 7/31/10
$250K/yr total costs

This is an R21/R33 grant to develop a low cost portable flow cytometer for use in resource poor settings. We have been approved to start our R33 phase, which will be $400K per year total costs and $250K per year direct costs.

NIH RR01315-25 The National Flow Cytometry Resource
Role Co-I: Specific Research Project – Next Generation Large Particle Sorting
PI: Freyer, Jim
Dates: 7/01/07-6/30/12
~$2.0M/yr total costs (~20% towards my project.)

To provide a national resource in flow cytometry with research, collaborations, service training and dissemination activities. I am one of three research PI's where my project is to develop large particle sorting technology for many purposes but primarily for screening of a variety of combinatorial libraries.

PAST RESEARCH GRANTS (GRANTS WHERE I WAS PI HAVE THE TITLE BOLDED)

LANL LDRD-DR 20070010 Rapid Iterative Detection of Pathogens
Role — PI (I stepped down when I changed positions)
Dates:10/01/06-09/30/09
$1.4M/yr total costs

The aim of this proposal is to develop field based sample preparation and analysis methods combined with the development of multiplexed assays and signatures to develop a platform that can perform truly autonomous pathogen assays.

LANL LDRD-ER SERS Particles for Flow Cytometry
Role – Co-PI
PI – Stephen Doorn
Dates: 10/01/05-9/30/08
$270K/yr total costs

The major goal of this project is to use SERS particles for flow cytometry. My part is to develop custom flow cytometry instrumentation to analyze the SERS particles.

NIH 1R01EB003824-01 Raman Flow Cytometry for Diagnostics and Drug Discovery
Role LANL PI and Co-I on the Development of Protease Lead Substrates via Flow Cytometry (I

stepped down when I changed positions)
PI: Nolan, John P.
~$180K total costs into LANL
Dates: 9/01/04-8/31/09

The goal of this project is to develop a Raman Flow Cytometer and associated assays. My group will be developing optimal protease assays and data systems.

UNM Joint Science and Technology Laboratory – High Throughput Flow Cytometry and Protease Screening
Role – LANL PI
UNM PI – Bruce Edwards
01/05 -01/07
~$50K per year total costs

This project represents a collaborative effort where UNM's high throughput proprietary flow cytometry platform will be integrated with Los Alamos' fluorescent bead-based bioassay system and novel flow cytometry system to establish a new paradigm for high throughput screening and analysis of proteases and a range of other biologically important proteins.

LANL LDRD-ER High Throughput Selection of Optimal Protease Substrates
Role – PI
Dates 10/01/03-9/30/06
$300,000/yr total costs

The major goal of this project was to use cellular display systems combined with flow cytometry to select optimal protease substrates and develop microsphere based screening of proteases.

NIH RR01315 The National Flow Cytometry Resource
Role Co-I: Specific Research Project – Low Affinity Molecular Assemblies
PI: Freyer, Jim
Dates: 7/01/02-6/30/07
$1.5M/yr total costs (~20% towards my project.)

To provide a national resource in flow cytometry with research, collaborations, service training and dissemination activities. I was one of four research PI's where my project was to develop assays and instrumentation to analyze low affinity molecular assemblies by flow cytometry.

LANL LDRD-ER Development of a Program for the Study of Bacterial Metalloproteases
Role – PI
Dates – 4/01/02-10/01/03
$150,000 total

This project was essentially my start-up package to develop external funding projects around the idea of microsphere based assays for mechanism studies, diagnostics and screening. The target proteins were bacterial metalloproteases relevant to the bio-threat reduction mission of the Laboratory, such as Lethal Factor of Anthrax and the light chain of Botulinum toxin.

INDUSTRIAL PARTNERSHIPS

CRADA – Company name withheld
Role – PI
Development of custom instrumentation for flow cytometry
2005-present

FUNDS IN – LIKE KIND SUPPORT

CRADA – Company name withheld
Role – PI
Develop custom instrumentation for flow cytometry
07/01/2004 – 6/30/2005
FUNDS IN ~$95K

CRADA – Company name withheld due to non-disclosure agreement.
Role – PI
Develop protease assays for commercial use.
10/01/2003 – 03/01/2005
FUNDS IN – LIKE KIND SUPPORT

PATENTS

Ultasonic analyte concentration and application in flow cytometry, Gregory Goddard, Gregory Kaduchak, John C. Martin, **Steven W. Graves**, Gary C. Salzman, Dipen Sinha. Patent number: 7340957

Acoustic Method for High-Throughput Particle Sorting and Analysis. Gregory R. Goddard, James H. Jett, Steven W. Graves and Gregory Kaduchak. Provisional patent filed in 2007 by Los Alamos National Laboratory – Status Patent Pending

Low-Cost DPSS Laser Pointer Module Based Flow Cytometer Using Extended Analysis Time, **Steven W. Graves** and Robert C. Habbersett. Provisional patent number S-109,054. Filed in 2006 by Los Alamos National Laboratory – Status Patent Pending

Dynamic thermoregulation for flow cytometry. **Steven W. Graves,** John P. Nolan and Robert C. Habbersett. Provisional patent application number S-94,735, filed December 8th, 2000 by Los Alamos National Laboratory. Status- Patent Pending.

PROFESSIONAL ACTIVITIES

2008	Member, International Society for Advancement of Cytometry (ISAC) 2008 Congress Program Committee
2007	Lecturer, 30th Annual Flow Cytometry Course, June 2007, Los Alamos, NM
2007 – Present	Member, Los Alamos National Laboratory LDRD-DR strategy team tasked with reviewing about $25M worth of internal proposals per year.
2006 – Present	Member, LANL Bioscience Division Post-Doctoral Conversion Committee
2006	Session Lead: Future of Biodetection Systems Workshop, October 2006, Santa Fe, N.M.
2006	Member, ISAC Data Standards Committee
2005	Laboratory presenter, 28th Annual Flow Cytometry Course, June 2005, Los Alamos, NM
2004 – Present	Member, NIH peer review GGG-J study section

2003	Laboratory presenter, 26th Annual Flow Cytometry Course, June 2003, Los Alamos, NM
2002 – Present	Member, International Society for Analytical Cytology
1999-2003	Member, Association for Laboratory Automation
1999-Present	Member, American Association for the Advancement of Science
1993-1995	Graduate Representative for the Biochemistry, Microbiology and Molecular Biology department at the Pennsylvania State University

AWARDS AND HONORS

2008	Northern New Mexico Regional Economic Impact Award, Technology Transfer Division, Los Alamos National Laboratory
2007	R&D 100 Award for the development of the Portable Acoustic Cytometer
2004	Certificate of Appreciation Received from CTO of the Intelligence Community
2004	Bioscience Division Employee Award for Outstanding Achievement
2001	Bioscience Division Employee Award for Outstanding Achievement with the National Flow Cytometry Resource Team
1992-1995	NIH Pre-Doctoral Research Fellowship

TEACHING AND MENTORING EXPERIENCE

I have advised and trained ten undergraduate students (Keith Corbino, Zev Binder, Siyoung Lee, Travis Woods, DeeAnn Martinez, Heungbok Kim, Naveen Sinha, Rebecca McIntosh, Laura Marler, and Chris Thompson), one Ph. D. student (Matthew Saunders – still in progress at UNM), and five post-doctoral research associates (Robert Applegate, Alina Deshpande, Gregory Goddard, Weon Bae, and Antonietta Lillo). This has given me insight into most phases of a young researcher's career. Additionally, it has kept me fresh on teaching critical concepts (both lab skills and fundamental scientific concepts) to an undergraduate and graduate level audience. I have also begun to add course tutorials to my efforts in developing specific laboratory sessions for the National Flow Cytometry Resource Annual Course in Flow Cytometry (see below).

Specific Courses:

University of New Mexico ChNE 406/506 Biomedical Engineering Seminar, Fall 2008

University of New Mexico ChNE 499/599 Special Topics "Biological Macromolecular Engineering," Spring 2009

Steven J. Koch Physics and Astronomy December 13, 2009

Educational History:

Ph.D.	2003 May	Cornell University, Ithaca, NY	Physics (Biophysics Minor)
M.S.	2000	Cornell University, Ithaca, NY	Physics (Biophysics Minor)
B.S.	1996	U. Michigan, Ann Arbor, MI	Physics (Honors)

Ph.D. Dissertation: Probing protein-DNA interactions by unzipping single DNA molecules with a laser trapping microscope, Dr. Michelle D. Wang advisor (Cornell Physics)

Employment History – principal positions since the Bachelor's degree

Assistant Professor	2006 Aug.-pres.	University of New Mexico, Albuquerque
Postdoctoral Fellow	2004-2006	Center for Integrated Nanotechnology (CINT) / Sandia National Labs, Albuquerque
Postdoctoral Appointee	2003-2004	Sandia National Labs, Albuquerque
Research Assistant	1997-2003	Cornell University, Ithaca, NY
Teaching Assistant	1996-1997	Cornell University, Ithaca, NY

Professional Recognition, Honors, etc. (Teaching, research, service)

CINT Postdoctoral Fellowship	2004-2006	Sandia National Labs
Molecular Biophysics Training Grant	200-2003	NIH / Cornell
GAANN TA/RA Award	1996-2000	US Dept. Ed. / Cornell
Honorable Mention NSF Grad.Research Fellowship	1996	NSF
Sigma Pi Sigma, Physics Honor Society	1996	U. Michigan
Phi Beta Kappa	1995	U. Michigan
James B. Angell Scholar, 2 Consec. 4.0 Semesters	1995	U. Michigan
Sharon Naughton-Briggs Memorial Scholarship	1993-1996	U. Michigan

Articles in Refereed Journals:

Liu Haiqing, Spoerke Erik D., Bachand M, Koch Steven J, Bunker Bruce C., Bachand George D. (2009) "Biomolecular Motor-Powered Self-Assembly of Dissipative Nanocomposite Rings" Advanced Materials, **20**: 4476-4481.

Xia Deying, Gamble Thomas C., Mendoza Edgar A., Koch Steven J., He Xiang, Lopez Gabriel P., and Brueck S. R. J. "DNA Transport in Hierarchically-Structured Colloidal-Nanoparticle Porous-Wall Nanochannels." Nano Lett., **8** (6) 1610 - 1618, 2008, http://pubs.acs.org/cgi-bin/abstract.cgi/nalefd/2008/8/i06/abs/nl080190s.html

Rivera SB, Koch SJ, Bauer JM, Edwards JM, Bachand GD. 2007. "Temperature dependent properties of a kinesin-3 motor protein from Thermomyces lanuginosus." Fungal Genetics and Biology **44**:1170-1179. Pub Med 17398126

Koch SJ, Thayer GE, Corwin AD, de Boer MP. 2006. "Micromachined piconewton force sensor for biophysics investigations." Applied Physics Letters **89**, 173901 http://link.aip.org/link/?APPLAB/89/173901/1

Koch SJ, and Wang MD (2003). "Dynamic force spectroscopy of protein-DNA interactions by unzipping DNA." Phys Rev Lett **91**(2): 028103.

Koch SJ, Shundrovsky A, Jantzen BC, and Wang MD (2002). "Probing protein-DNA interactions by unzipping a single DNA double helix." Biophys J **83**(2): 1098-105.

Lawes G, Zassenhaus GM, Koch SJ, Smith EN, Reppy JD, Parpia JM. 1998. "Reduction of vibrational noise from continuously filled 1 K pots." Review of Scientific Instruments **69**:4176-4178.

Works in Progress: (divide into subsections by type, as for published work)

Herskowitz, Lawrence, Salvagno, Anthony, Maloney, R. Andy, Le, Linh, and Koch, Steven. "Proof of principle for shotgun DNA mapping by unzipping." Available from Nature Precedings http://hdl.handle.net/10101/npre.2009.2808.1 (2009).

Invited or Refereed Abstracts and/or Presentations at Professional Meetings:

"Probing site-specific protein-DNA interactions by mechanically unzipping single DNA molecules." Koch SJ. Nanoelectronics and Dynamics of DNA International Workshop, Honolulu, HI, August 28-31, 2005. Sponsored by Osaka Univ. / LANL. Invited for 30 minute presentation.

"Probing protein-DNA interactions by unzipping single DNA molecules." Koch SJ. Graduate Student Symposium, Cleveland Clinic Foundation / Learner Research Institute, Cleveland,OH, October 15-17, 2002. Invited for 30 minute oral presentation

Contributed (unrefereed) Abstracts and/or Oral Presentations at Professional Meetings:

Presenting author is in bold

"Proof of principle for shotgun DNA mapping by unzipping." **Herskowitz LJ**, Salvagno AL, Le LN, Koch SJ. Abstract for poster at 2009 Biophysical Society Annual Meeting, Boston, MA.

"Mapping Nucleosome-DNA Interactions on Single Molecules of Chromatin Isolated from Living Cells." **Diego F. Ramallo Pardo**, Kelly M. Trujillo, Cory Hillyer, Mary Ann Osley, Steven J. Koch. Abstract for poster at 2008 Biophysical Society Annual Meeting, Long Beach, CA.

"Dynamic self-assembly of nanocomposite ring structures through the interaction of thermodynamic and energy-dissipating processes." **Haiqing Liu**, Erik Spoerke, Marlene Bachand, Steven Koch, Bruce Bunker, George Bachand. Abstract for oral presentation at 2008 American Physical Society March Meeting, New Orleans, LA.

"Calibration of Micromachined Force Sensors by Gravitational Force on Precision Microspheres." **Koch SJ**, Thayer GE, Corwin AD, de Boer MP. Abstract for oral presentation at 2007 American Physical Society March Meeting, Denver, CO.

"Micromachined piconewton force sensor for biophysics investigations." **Koch SJ**, Thayer GE, Corwin AD, de Boer MP. Abstract for oral presentation at 2006 American Physical Society March Meeting, Baltimore, MD.

"Biomolecular Transport Systems: Building a Foundation for Adaptive Nanomaterial and Device Assembly." **Amanda Trent**, Steve Koch, Gayle Thayer, George Bachand. Abstract for poster at 2006 Biophysical Society Annual Meeting, Salt Lake City, UT.

"Site Specific Protein-DNA Binding Kinetics Probed by Unzipping DNA with an Electromagnetic Force Instrument." **Steven J. Koch**, Gayle E. Thayer, James E. Martin, Bruce C. Bunker, James H. Werner, Peter M. Goodwin, Richard A. Keller, George D. Bachand. Abstract for poster at 2005 Biophysical Society Annual Meeting, Long Beach, CA.

"Active and Dynamic Nanomaterials Based on Active Biomolecules." **Koch, Steven J.**; Rivera, Susan B.; Boal, Andrew K.; Edwards, J. Matthew; Bauer, Joseph M.; Manginell, Ronald P.; Liu, Jun; Bunker, Bruce C.; Bachand, George D. Abstract for poster at 2004 American Physical Society March Meeting, Montreal, Quebec, Canada.

"Kinesin from Thermomyces lanuginosus Displays Novel Kinetic Properties and Fast Velocities at High Temperature." **Susan B. Rivera**, Joseph M. Bauer, Steven J. Koch, J. Matthew Edwards, George D. Bachand. Abstract for oral presentation at 2004 Biophysical Society Annual Meeting, Baltimore, MD.

"Unzipping force analysis of protein association (UFAPA): a novel technique to probe protein-DNA interactions." **Wang, Michelle D.**; Koch, Steven J.; Shundrovsky, Alla; Jantzen, Benjamin C. Paper presented at Fluctuations and Noise in Biological, Biophysical, and Biomedical Systems, SPIE meeting Santa Fe, NM 2003.

"Unzipping Force Analysis of Protein Association (UFAPA)." **Michelle D. Wang**, Steve J. Koch, Alla Shundrovsky, Ben C. Jantzen. Abstract for oral presentation at 2003 Biophysical Society Annual Meeting, San Antonio, TX

Research Funding:

1. Coupled Atomistic Modeling and Experimental Studies of Energy Transduction and Catalysis in the Molecular Motor Protein Kinesin
   Susan Atlas (Lead PI); Steven J. Koch (co-PI); Steven Valone (co-PI)
   Defense Threat Reduction Agency (DTRA)
   July 2009-June 2012 (3 years), $708,000 for Koch component. ($1,452,000 direct for entire proposal.)

2. Renewal: Single-Molecule Analysis of DSB Repair Events in Vivo
   Steven J. Koch PI; Janet Oliver is the PI of the overall ACS IRG grant #IRG-92-024
   American Cancer Society
   April 2009 – June 2010, $20,000

3. Single-Molecule Analysis of DSB Repair Events in Vivo
   Steven J. Koch PI; Janet Oliver is the PI of the overall ACS IRG grant #IRG-92-024
   American Cancer Society
   May 2007 – May 2008, $22,500

Pending Research Funding:

1. Optical Tweezer Analysis of Initial Events in NHEJ DNA Repair – Activities to Promote Research Collaboration (NCI).
Steven J. Koch co-PI
National Institutes of Health
July 2010-June 2012 (2 years), $90,000
Currently under review

Teaching

Doctoral Advisement:

No Ph.D.s awarded yet

Lawrence J. Herskowitz. Candidacy Exam Fall 2009. Advisor since Spring 2007.

Anthony L. Salvagno. Candidacy Exam Fall 2009. Advisor since Spring 2007.

Roger A. Maloney. Candidacy exam passed with Prof. James Thomas (P&A). Advisor since Fall 2008.

Service as minor committee member:

Thomas Gamble: M.S. in Chemical Engineering, Fall 2008. Served on examination committee.

Douglas Read; Chemical Engineering Ph.D. in progress. Served on comprehensive exam committee, April 2008

Amarin Ratanavis; Optical Sciences & Engineering Ph.D. in progress. Served on comprehensive exam committee, August 2007.

Bachelor's Honors Advisement:

Linh N. Le; Honors thesis expected May 2009; Physics; "Optical Tweezers Construction and Single-Molecule DNA Unzipping."

Undergraduate Student Mentoring:

Brian P. Josey; August 2009-present; Physics B.S. student. Working on various kinesin projects.

Patrick L. Jurney; May-August 2008; Mech. E. undergraduate candidate at Portland University; National Nanotechnology Infrastructure Network (NNIN) Research Experience for Undergraduates (REU) intern for summer 2008, "Nano- and Micro-fluidics for biophysics applications."

Diego Ramallo-Pardo; May 2007-August 2008; Earned B.S. degree from James Madison University prior to time at UNM as PREP Fellow (Post-baccalaureate research via NIH fellowship--David Keller, Chemistry, PI).

Caleb D. Morse; December 2006-present; UNM ECE undergraduate candidate; Computer networking projects in our lab; research for credit and summer pay.

Athanasios K. Manole; May 2007-present; UNM Biochemistry undergraduate candidate; Various lab set-up projects, recent main project YAG laser repair; research for credit and summer pay.

Classroom Teaching:

2009 Fall	Junior Lab	307L	11 Students
2009 Spring	Intro Physics	102	155 Students
2008 Fall	Junior Lab	307L	15 Students
2008 Spring	Intro Physics	102	134 Students
2007 Fall	Junior Lab	307L	16 Students
2006 Fall	Intro Physics	102	97 Students

Service (UNM years only):

Referee and Review Service

AY09-10 Academic Editor for PLoS ONE
AY08-09 Referee for European Biophysical Journal
AY07-08 Referee for European Biophysical Journal and American Society of Mechanical Engineers
AY06-07 Referee for Physical Review Letters and Nucleic Acids Research
Reviewer for Foundation for Fundamental Research on Matter (FOM, Netherlands), and DOE SBIR program

National Service

Biophysical Society – National Membership Committee, Starting summer 2010
OpenWetWare – PI Leadership team, 2009-

UNM Committee and Administrative Service

Physics & Astronomy Graduate Committee – Fall 2009 to present, S. Seidel chair
Physics & Astronomy Regener Hall Committee – Spring 2008 to present, D. Fields chair
Chair, Physics & Astronomy ad hoc Website/IT Committee – Fall 2009 to present.
Physics & Astronomy colloquium advisement committee – 2007-2009, J. McGraw chair
NSMS IGERT and degree program management committee – Spring 2007 to present, A. Datye (ChNE) and D. Huffaker (ECE) chairs
CHTM / ECE faculty search committee – AY 2007-2008, L. Lester (ECE, CHTM) chair
Young research faculty ad hoc committee to advise Pres. Schmidly – Spring 2008 to present, J. Geremia (P&A) chair, meeting with Schmidly April 2008
Ad hoc "nano" committee to advise Pres. Schmidly – Spring 2007 to Fall 2007, S. Brueck (CHTM) informal chair
Committee for Biomedical Science and Engineering certificate program with nanoscience concentration – Spring 2009, M. Osinksi (ECE, CHTM) chair
Biomedical Engineering (BME) degree program committee – Fall 2008 to present, G. Lopez (ChNE) chair (currently in proposal stage)
Represented UNM biophysics on special visit by UNM delegation to DOE in Germantown, MD, Fall 2007

Community Outreach

Central NM Science and Engineering Research Challenge – Judge, 2007-2009
Junior Lab Winter Fest – 2008
Cleveland Middle School Science Fair – Judge 2008
NNIN Summer Nano Camp – Guest speaker Summer 2008
Menaul Middle School – Hosted visit for Alex Cimon-Hurt's science students, Fall 2007
NM MESA – Judge at North Central Fall Design 2006

BIOGRAPHICAL SKETCH

Provide the following information for the key personnel and other significant contributors in the order listed on Form Page 2.
Follow this format for each person. **DO NOT EXCEED FOUR PAGES.**

NAME Sibbett, Scott S. eRA COMMONS USER NAME	POSITION TITLE Research Professor, Chemical Engineering and Chemistry Co- Director, Center for Biomedical Engineering

EDUCATION/TRAINING (Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)

INSTITUTION AND LOCATION	DEGREE	YEAR(s)	FIELD OF STUDY
University of California at Berkeley	B.S.	1979	Soils and Plant Nutrition
Oregon Health Sciences University (OGI School of Eng)	Ph.D.	1985	Chemistry
Stanford University	Postdoc	1985-1987	Chemistry

A. POSITIONS AND HONORS:

1979-1980	Research Assistant	Research & Educational Planning Ctr, Univ of Nevada, Reno
1980-1984	Graduate Assistant	Dept. of Biological and Chemical Sciences, Oregon Health Sciences University
1985-1987	Postodoctoral Research Scientist	Department of Chemistry, Stanford University
1987-1991	Lab Manager	Intel Corporation
1991-1993	Engineering Manager	Intel Corporation
1993-1995	Co-Director, Research Center	Sandia National Labs (assignee from Intel Corporation)
1995	Visiting Associate Professor	Dept. of Chemical & Nuclear Engr UNM
1996-1997	Fab Conceptual Design Manager	Intel Corporation
1997-2002	External Programs Manager	Intel Corporation
2002	Visiting Professor	Dept. of Chemical & Nuclear Engr UNM
2002-2005	Research Scientist	Intel Corporation
2002 - present	Research Professor	Dept. of Chemical & Nuclear Engr UNM
2005 - present	Co-Director	Center for Biomedical Engineering, UNM

HONORS

2002	Sandia National Laboratories plaque of recognition
1998	Intel Group Recognition Award, Intel Process Equip. Dev. Group
1995	SEMATECH Outstanding Contribution Award
1995	Sandia National Laboratories plaque of recognition
1991	Intel Achievement Award (highest technical award within Intel)
1991	Intel GSO Division Award
1991	Intel Divisional Recognition Award
1990	Intel Exceptional Contributor Award
1988	Intel Exceptional Contributor Award

B. SELECTED PEER-REVIEWED PUBLICATIONS (IN CHRONOLOGICAL ORDER):

S.S. **Sibbett**, J.K. Hurst, "Structural analysis of myeloperoxidase by resonance Raman spectroscopy". Biochemistry 23:3007-13 (1984).

S.S. **Sibbett**, S.J. Klebanoff, J.K. Hurst, "Resonance Raman characterization of the heme prosthetic group in eosinophil peroxidase." FEBS Lett. 189:271-5 (1985).

S.S. **Sibbett**, and J.K. Hurst, "Micellar Hemin-Copper(I) Binuclear Ions: Potential Models for Reduced and Mixed-Valent Oxygen Reductase Sites in Cytochrome Oxidase". In: "Biological and Inorganic Copper Chemistry", Vol. II; (Karlin, K.D.; Zubieta, J., Eds.); Adenine Press, Guilderland, New York, 1986; pp 123-141.
S.S. **Sibbett**, T.M. Loehr, J.K. Hurst, "Resonance Raman Spectroscopic Evidence for Perturbation of Vinyl Modes in Copper(I)-Protoheme π-complexes", Inorganic Chemistry 25:307-313 (1986).

S. N. Kempka, J.R. Torczynski, A.S. Geller, J.R. Rosato, R.N. Walters, S.S. **Sibbett**, "Evaluation of Overflow Wet Rinsing Efficiency", Proceedings of Microcontamination 94, 1994, pp 225-234.

A.S. Geller, D.J. Rader, S. **Sibbett**, "Particle Reduction in LPCVD Chambers", Proceedings of Microcontamination 94, 1994, pp29-38.

M. J. O'Brien, P. Bissong, L. K. Ista, E. M. Rabinovich, A. L. Garcia, S. S. **Sibbett**, G. P. Lopez, S. R. J. Brueck, "Fabrication of an integrated nanofluidic chip using intererometric lithography". J. Vac. Sci. Technol. B 21:2941 (2003).

Linnea K. Ista, Gabriel P. Lopez, Cornelius F. Ivory, Moises J. Ortiz, Thomas A. Schifani, Christopher D. Schwappach and Scott S. **Sibbett**, "Microchip countercurrent electroseparation". Lab on a Chip 3:273 - 279 (2003).

D. N. Petsev, G. P. Lopez, C. F. Ivory and Scott **Sibbett**, "Microchannel protein separation by field gradient focusing", Lab on Chip, 5:587-597 (2005).

C. RESEARCH SUPPORT.

Intel Corporation grants, 2002-2005.

Ongoing Research Support

None.

BIOGRAPHICAL SKETCH

Provide the following information for the key personnel and other significant contributors in the order listed on Form Page 2.
Follow this format for each person. **DO NOT EXCEED FOUR PAGES.**

NAME	POSITION TITLE
David G. Whitten	Professor, Department of Chemical and Nuclear Engineering, University of New Mexico
eRA COMMONS USER NAME Whitten	

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	YEAR(s)	FIELD OF STUDY
The Johns Hopkins University	A.B.	1959	Chemistry
The Johns Hopkins University	M.A.	1961	Organic Chemistry
The Johns Hopkins University	Ph.D.	1963	Organic Chemistry
California Institute of Technology	Postdoctoral	1965-1966	Physical Organic Chem.

A. Positions and Honors. List in chronological order previous positions, concluding with your present position. List any honors. Include present membership on any Federal Government public advisory committee.

1963-1965 Research Fellow, U.S. Army at California Institute of Technology Jet Propulsion Laboratory.
1965-1966 Research Fellow, California Institute of Technology, Professor George S. Hammond, advisor.
1966-1970 Assistant Professor of Chemistry, University of North Carolina.
1970-1973 Associate Professor of Chemistry, University of North Carolina.
1973-1980 Professor of Chemistry, University of North Carolina.
1975-1976 Vice Chairman, Department of Chemistry, University of North Carolina.
1980 Invited Visiting Professor, Ecole Polytechnique Federale de Lausanne, Switzerland.
1980-1983 M. A. Smith Professor, University of North Carolina.
1983-1997 C. E. Kenneth Mees Professor, University of Rochester.
1988-1991 Chair, Department of Chemistry, University of Rochester.
1989-1995 Director, NSF Center for Photoinduced Charge Transfer, University of Rochester.
1995-1997 Chair, Department of Chemistry, University of Rochester
Technical Staff Member, Los Alamos National Laboratory
1997-present Editor-in-Chief, Langmuir
2000-2005 Cofounder and Chief Technical Officer, QTL Biosystems, LLC
2000-2004 Professor of Chemistry and Biochemistry, Arizona State University
2005-present Professor, Department of Chemical and Nuclear Engineering, University of New Mexico
2005-present Co-Director, Center for Biomedical Engineering, UNM

Awards

1970 Alfred P. Sloan Foundation Fellowship.
1973 John van Geuns Fellowship, University of Amsterdam, The Netherlands.
1975 Special U.S. Scientist Award, Alexander von Humboldt Foundation, Göttingen, Germany.
1978 Distinguished Visiting Lecturer, University of Texas.
1980 Invited Visiting Professor, Ecole Polytechnique Federale de Lausanne, Switzerland.
1982 Japan Society for the Promotion of Science Fellowship.
1982 National Science Foundation Research Award for Special Creativity.
1983 Distinguished Lecturer, Peter Leermakers Symposium, Wesleyan University.
1983 Elected President, Inter-American Photochemical Society.
1983 Chevron Lecturer, University of Nevada.
1984 Humboldt Award, Alexander von Humboldt Foundation, Göttingen.
1990 National Science Foundation Research Award for Special Creativity.

1992	ACS Award in Colloid or Surface Chemistry
1993	Elected Chair, 1997 Gordon Research Conference on Organic Photochemistry
1994	University of North Carolina at Chapel Hill, Bicentennial Symposium Lecturer
1997	Elected Editor-in-Chief, *Langmuir*
1998	Received 1998 Award of the Inter-American Photochemical Society
2001	National Science Foundation Science and Technology Pioneer Award

B. Selected peer-reviewed publications (in chronological order). Do not include publications submitted or in preparation.

Publications: Over 300 publications and reviews. Examples from the past 5 years:

L. Chen, S. Xu, D. McBranch and D. Whitten, "Tuning the Properties of Conjugated Polyelectrolytes Through Surfactant Complexation," J. Am. Chem. Soc. 2000, 122, 9302-9303.

Whitten, D.; Chen, L.; Jones, R.; Bergstedt, T.; Heeger, P.; McBranch, D. "From Superquenching to Biodetection; Bulding Sensors Based on Fluorescent Polyelectrolytes" in "Molecular and Supramolecular Photochemistry, Volume 7: Optical Sensors and Switches", Marcel Dekker, New York, 2001, Eds. V. Ramamurthy and K. S. Schanze, Chapter 4, pp 189-208..

Jones, R. M., Bergstedt, T. S., Buscher, C. T., McBranch, D., Whitten, D., "Superquenching and its applications in J-aggregated cyanine polymers," Langmuir, **2001**, 17, 2568-2571.

Bergstedt, T, Jones, R., Helgeson, R., McBranch, D., Whitten, D., "Superquenching of fluorescent polyelectrolytes and applications for chemical and biological sensing," Organic Photonic Materials/devices III. pp 94-100.

Jones, R. M.; Bergstedt, T. S.; McBranch, D. W.; Whitten, D. G., "Tuning of Superquenching in layered and mixed fluorescent polyelectrolytes," J. Am. Chem. Soc., **2001,** 123, 6726-7.

Wang, H.-L.; McBranch, D. W.; Donohoe, R. J.; Xu, S.; Kraabel, B.; Chen, L.; Whitten, D.; Helgeson, R.; Wudl, F. "Highly efficient energy and charge transfer in thin self-assembled multilayered polymer films" Synthetic Metals **2001**, 121, 1367-1368.

Lu, L.; Helgeson, R.; Jones, R. M.; McBranch, D.; Whitten, D., "Superquenching in cyanine pendant poly-L-lysine dyes: dependence on molecular weight, solvent and aggregation", J. Am. Chem. Soc., **2002**, 124, 483-488.

Jones, R. M.; Lu, L.; Helgeson, R.; Bergstedt, T. S.; McBranch, D. W.; Whitten. D., "Building highly sensitive dye assemblies for biosensing from molecular building blocks," Proceedings Natl. Acad. Sci. US, **2001**, 98, 14769-14772.

Lu, L.; Jones, R. M.; Helgeson, R.; McBranch, D.; Whitten, D. "Cyanine pendant polymers on nanoparticles and in solution; superquenching and sensing applications", Polymeric Materials Science and Engineering, 2002, 86, 17-18.

Lu, L.; Jones, R. M.; McBranch, D.; Whitten, D. "Surface enhanced superquenching of cyanine dyes as J-aggregates on Laponite clay nanoparticles" Langmuir, 2002, 18, 7706-7713.

Lucia, L. A.; Yui, T.; Sasai, R.; Takagi, S.; Takagi, K.; Yoshida, H.; Whitten, D. G.; Inoue, H. "Enhanced aggregation behavior of antimony (V) porphyrins in polyfluorinated surfactant/clay hybrid microenvironment" J. Phys. Chem. B 2003, 107, 3789-3797.

Kushon, S. A.; Ley, K. D.; Bradford, K.; Jones, R. M.; McBranch, D.; Whitten, D. "Detection of DNA Hybridization via Fluorescent Polymer Superquenching" Langmuir (2002), 18(20), 7245-7249.

Kushon, Stuart A.; Bradford, Kirsten; Marin, Violeta; Suhrada, Chris; Armitage, Bruce A.; McBranch, Duncan Whitten, David. "Detection of Single Nucleotide Mismatches via Fluorescent Polymer Superquenching." Langmuir (2003), 19(16), 6456-6464.

Kumaraswamy, S.; Bergstedt, T.; Shi, X.; Rininsland, F.;Kushon, S.; Xia, W.; Ley, K.; Achyuthan, K.; McBranch, D.; Whitten, D. "Fluorescent Conjugated Polymer Superquenching Facilitates Highly Sensitive Detection of Proteases" Proceedings Natl. Acad. Sci. US, 2004, 101 (20), 7511-7515.

Rininsland, F.; Xia, W.; Wittenberg, S.; Shi, X.; Stankewicz, C.; Achyuthan, K.; McBranch, D.; Whitten, D. "Metal Ion Mediated Polymer Superquenching for Highly Sensitive Detection of Kinase and Phosphatase Activities" Proceedings Natl. Acad. Sci. US, 2004, 101 (43), 15295-15300.

Kim, O.-K.; Je, J.; Jernigan, G.; Buckley, L.; Whitten, D. "**Super-Helix Formation Induced by Cyanine J-Aggregates onto Random-Coil Carboxymethyl Amylose as Template"** *J. Am. Chem. Soc.;* **2006**; *128*(2); 510-516.

Zeineldin, R.; Piyasena, M. E.; Bergstedt, T. S.; Sklar, L. A.; Whitten, D.; Lopez, G. P. "**Superquenching as a Detector for Microsphere-Based Flow Cytometric Assays"** *Cytometry, Part A,* **2006,** *69A,* 335-341.

Whitten, D. G.; Kim, O.-K.; Lopez, G. P.; Achyuthan, K. E. "**Cooperative Self-Assembly of Cyanines on Carboxymethylamylose and other Anionic Scaffolds"** *Pure Appl. Chem.* **2006,** *78*, 2313-2323.

Achyuthan, K. A.; Lu, L.; Lopez, G. P.; Whitten, D. G. "**Supramolecular Photochemical Self-Assemblies for Fluorescence "turn on" and "turn off" Assays for Chem-Bio Helices"** *Photochem. Photobiol. Sci.* **2006**, 5, 859-868.

C. Research Support. List selected ongoing or completed (during the last three years) research projects (federal and non-federal support). Begin with the projects that are most relevant to the research proposed in this application. Briefly indicate the overall goals of the projects and your role (e.g. PI, Co-Investigator, Consultant) in the research project. Do not list award amounts or percent effort in projects.

PI:	D. Whitten (PI); F. Gilfeather, G. Lopez (Co-PI's)
Title:	"Workshop and Developmental Roadmap on Advanced Biotechnology"
Agency:	Defense Threat Reduction Agency
Term:	Sept. 2005 – Sept. 2006