New Centers and Training Programs at the interface of nanotechnology and biology

Rashid Bashir

Electrical and Computer Engineering & Bioengineering
Director, Micro and Nanotechnology Laboratory
University of Illinois at Urbana-Champaign, IL. USA
Micro and Nanotechnology Laboratory (MNTL)

- Built in 1989; expanded in 2008; 56,615 square feet of assignable research space
- 8,000 sq.ft. of class 100 and class 1000 clean-room labs
- 3,000 sq.ft. lab complex designed for bionanotechnology
- ~160 residents, ~300 users of the facilities, over 90 faculty involved

- Legendary contributions in electronics and photonics
  - III-V Materials and Devices
  - LED, Lasers, Quantum Optoelectronics
  - High Speed Electronics

- Visible LED Invention
- World Fastest Transistor ➔ Transistor Laser

- Strong emphasis on integration of nanotechnology and biology/medicine
  - NIH : Cancer Nanotechnology Training Center
  - NSF IGERT : Cellular Mechanics and Nanotechnology
  - NSF STC : Cellular and Biological Machines (with MIT and GT)
MNTL Research Themes

Optoelectronics & Nanophotonics

Micro & Nano-electronics

Nanomedicine & BioNanotechnology

MEMS & Integrated Systems
On Size and Scale!

Top-Down Fab

System on A board

System on a chip

Microelectronic and MEMS

Nanoelectronics and Nanoscale Sensors

Bottoms-Up Biological

Bottoms-Up Chemical

Feature Size

100mm
10mm
1mm
100µm
10µm
1µm
100nm
10nm
1nm
0.1nm

Organs
Tissue
Ants
Plant and Animal Cells
Most Bacteria
Virus
Proteins
Helical Turn of DNA
C-C Bond Atoms

CNT, QD, NS, NWs, AAO

35nm Feat. of MOS-T (in 2008)
Nanopores
Gate Insulator

Nano-structures
Evolution of Technologies

1900-1950:
- Vacuum Tube Technology
- Radio
- Television
- Radar

1950-2000+:
- Semiconductor Technology
- Transistor Radios
- Cell Phones
- Computers
- The Internet

2000-2050+:
- Nanotechnology
- Modern Biology
- Biotechnology
- Medicine
- Personalized Diagnostics and Therapeutics (Cancer, Infectious Disease, etc.)
- Synthetic and Systems Biology
- Hybrid Biodevices & Tissue Engineering
M-CNTC: Mid-West Cancer Nanotechnology Training Center

- Produce the next generation of intellectual leaders who will define the new frontiers and applications of nanotechnology in cancer research.
- More than 1.5 million people were diagnosed with cancer and half a million died of cancer in US alone during 2007 (Cancer Statistics 2007, ACS).
- Limited success in reducing per capita deaths from cancer since 1950.
- New technologies and approaches are needed to address this urgent challenge.
- Response to NCI Alliance for Nanotechnology

![Diagram showing cancer cells, DNA shedding, blood vessel, and diagnostic processes involving nanotechnology.]

1. In-vivo Imaging
2. Therapeutic Nanotechnology
3. Ex-vivo Diagnostics
4. Mechano-biology & Nanotechnology

More than a 1.5 million people were diagnosed with cancer and half a million died of cancer in US alone during 2007 (Cancer Statistics 2007, ACS).

Cancer deaths/100,000: 193.9 in 1950, 185.8 in 2004.
Preface

- Significant depth and breadth in cancer nanotechnology research on our campus (diagnostic, Imaging, therapeutics, mechanisms of cancer)

- We were partners in Siteman CCNE (Center of Cancer Nanotechnology Excellence) at WashU from 2005 – 2010

- Increasingly strong partnerships with UIC and Mayo Clinic

- Cross-campus activities and collaborations exist

- Strong training programs/modules
M-CNTC: Mid-West Cancer Nanotechnology Training Center

Co-PIs: R. Bashir, A. Nardulli
Program Manager: L. Miller
Management Support: Irfan Ahmad

Central Hub, UIUC

Clinical Partner Training Sites
(UIC, Mayo Clinic, IU School of Medicine, Washington Univ. at St. Louis)

External Advisory Board Members
(Stanford University, University of Houston, Georgia Tech, Harvard Medical School)
List of Participants

External Advisory Committee

1. Bao, Gang Professor/Director Georgia Institute of Technology/Emory
2. Ferrari, Mauro Professor University of Houston
3. Gambhir, Sanjiv S. Professor/Director Stanford University School of Medicine
4. Toner, Mehmet Professor/Director Harvard University/MGH

Internal Advisory Committee
Dean COE, Dean LAS, Dean, CVM, Dean of Graduate School

M-CNTC Curriculum Committee (Chair: J. Hsia)
M-CNTC Rec. & Retention Committee (Chair: I. Ahmad)
M-CNTC Assess. & Eval. Committee (Chair: L. DeStafano)

Co-PI/Co-PDs
R. Bashir, A. Nardulli
PM: I. Ahmad

Clinical Collaborators

NCI Alliance for Nanotechnology in Cancer

Collaborating Institutions: US-wide (See Letters of Support)

<table>
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<tr>
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Leadership Council

Trainees/Fellows Leadership Council

Clinical Collaborators

External Advisory Committee
Bao, Ferrari, Gambhir, Toner
Nanotechnology In Cancer at UIUC

Label Free IR Cancer Imaging

Nano-discs for Membrane Bound Proteins

Targeted Nanoparticle Delivery And Thermal Ablation

Ex-vivo Diagnostic Nanotechnology

In-Vivo Imaging Nanotechnology

NCI M-CNTC

Therapeutic Nanotechnology

Mechano-biology & Nanotechnology

Nanopores for DNA Methylation

Au Nanorods for Imaging and Therapeutics

PLGA-PEG nanoparticles Nanoparticles for Targeted Delivery

Silicon BioChips for Detection of Cancer Proteins

Nano-discs for Membrane Bound Proteins

Movement along a chemo-attractant gradient
Some Labs involved in Cancer Nanotechnology

Ryan Bailey lab:
• Optical characterization of nanoring resonators
• Functionalization of nano-resonators for detection of proteins
Rashid Bashir lab:
• Nanomanufacturing of silicon nanowire sensors for detection of cancer proteins
• Functionalization of nanowires for detection of proteins
Steve Boppart lab:
• Optical coherence tomography theory and methods
• Application of OCT for imaging tissues and identifying malignant tumors
J. J. Cheng lab:
• Synthesis techniques for various polypeptides
• Development of nanoparticles for targeted cancer therapy
Brian Cunningham lab:
• Nanostructured photonic crystals for detection of cancer proteins
• Evaluation of plant extracts for cancer apoptosis
Tim Fan lab:
• Synthesis of Tc99m labeled radioactive nanoparticles
• Application of nanoparticles in animal models for visualizing the accumulation of particles at the bone tumor site.
William Helferich Lab:
• Examine the effects of nano-particles and bioluminescent imaging of metastatic progression in vivo.
• Use of engineered metastatic cancer cells that express Luciferase and used to follow these cancer cells in the whole animal in "real time"
Yi Lu lab:
• Synthesis of liposomal drug delivery technology
• Selection of aptamer targeting ligands
Gang ‘Logan’ Liu Lab:
• Fabrication of nanoparticles for SERS imaging and diagnostics
• Endocytosis of nanoparticles in cells and thermal ablation
Catherine Murphy lab:
• Influence of nanoparticles on cell-ECM interaction
• Imaging of cellular strain fields with nanoparticles
Ann Nardulli lab:
• Imaging and characterizing normal mammary and breast cancer tissue
• Identification of novel tumor markers
Taher Saif lab:
• Preparation of cell culture substrates with variable stiffness with nanoscale force sensors
• Culture of cancer cells with different metastatic potentials on these substrates
Steve Sligar lab:
• Preparation of Nano-discs with varying diameters
• Imaging and Characterization
Clinical Collaborators

• UIC Cancer Center
  – Seed grant program ($400K per year)

• Mayo Clinic
  – MOU signed on individualized medicine
  – Seed grants program (expect 2-3 rounds)

• Wash U
  – Partnership and co-advising

• IUSOM Simon Cancer Center
  – Partnership and co-advising
Assessment/Evaluation

• The evaluation is designed to answer four questions:
  – Implementation: Is the CNTC program being implemented on schedule and as planned?
  – Effectiveness: Are key components of the CNTC model (e.g. student recruitment, faculty involvement, introductory course, co-advising, laboratory modules, new courses, seminars, internships, Student Leadership Council, etc.) operating effectively? How might they be improved?
  – Impact: What outcomes are associated with participation in the CNTC program? How do these compare with a comparable group of students in traditional programs? What is the value-added of participation in the CNTC program?
  – Institutionalization: How and to what extent are elements of the CNTC becoming institutionalized at Illinois and other participating institutions? What opportunities and barriers exist?

• Internal evaluator, Lizanne Destefano and associates from the College of Education
Midwest - Cancer Nanotechnology Training Center
Two-Track Course Curriculum

**Introduction to Nanotechnology in Cancer Research**

- **Lab Modules**
  - **Cell & Molecular Biology**
    - Basic and Advanced Cell Culture
    - Advanced Cell Subs.
    - DNA and Proteins
  - **Nanofabrication**
    - Nanofabrication Methods
    - Nanofabrication of Cell Sensors
    - Micro-fluidics
  - **Imaging**
    - Advanced Microscopy
    - Single Molecule Visual.
    - Cell Visualization
    - Cell Force Probes
  - **Computation**
    - Computational Molecular Biology
    - Biology Student Workbench

- **Career Module**
  - Communication skills
    - Leadership skills
    - SAT Policy
  - Patent and IP
    - Industry-environment
    - Entrepreneurship

- **Advanced Courses**
  - **Molecular and Cellular Bioengineering**, BIOE 461v
  - **Mechanobiology for Engineers**, ME 598
  - **Physical Biology: From Single Molecule to Sys. Biol.**, PHYS 5981
  - **Physics of Nanomachines**, PHYS 598NM
  - **Semiconductor Nanotechnology Lab**, ECE 583

- **Biomedical Applications of Nanotechnology (videolink)** BioE 598WU
- **Design and Use of Biomaterials**, MSE 470
- **Comparative Oncology Pathobiology**, 555
- **Special Topics in Cell Biology**, MCB 592

- **Capstone Course in Cancer Nanotechnology**
- **Summer Workshop with Lectures and Hands on Modules**
- **Graduate certificate in Cancer Nanotechnology**
Summer Schools

2009 GEM$^4$ Summer School Lab Modules

**Cell Biology Lab**
- Cell culture basics
- Transfection
- Fixing and staining
- Microscopy

**Molecular Biology Lab**
- Lab safety/protocols
- Purification of DNA
- Gel electrophoresis
- Quanti./real time PCR

**Micro-Nano Fab Lab**
- Lithography basics
- Thin film deposition
- Dry etching
- SEM inspection

**Enabling Technology Lab**
- PDMS device fab
- Neutrophil chemotaxis
- Cell capture in biochip
- Dielectrophoresis

NSF-GEM$^4$ summer school on cellular and molecular mechanics @ UIUC, 2009.

http://gem4-2009.mechse.illinois.edu/index.php
http://bsbasi-2010.mechse.illinois.edu/

*Similar Summer schools also held in 2007 and 2010*
Outreach Activities/Dissemination Plan:

• **Cancer Nanotechnology Outreach from UIUC M-CNCTC to Broader Community:**
  – WILL radio, Chicago Museum, Spurlock Museum, and Urbana Farmers’ Market

• **CNST* Nanotechnology Workshop and Seminars:**

• **Cancer Nanotechnology Outreach at Indiana University School of Medicine:**
  – Catherine Peachy Fund and Amelia Project Meetings

• **Network for Computational Nanotechnology/nanoHub and Cyber Enablement of the M-CNCTC:**

*University of Illinois Center for Nanoscale Science and Technology*
Fellowship Details

- **NIH:** 10 ($22K salary and benefits). Tuition remission not included

- **Matching:** 7
  - 1 from Vet Med
  - 1 from LAS
  - 1 from College of Education
  - 2 from College of Engineering SURGE – SURGE/M-CNTC Fellow
  - 1 from VCR
  - 1 from Provost

- **Balance between new students and existing students that are eligible**

- **Initially focus on existing students to get the program started**
REQUEST FOR PROPOSAL FOR CNTC FELLOWSHIP:
CNTC-01-FALL 2010

SUBMISSION DEADLINE: October 29th, 2010 by 5pm CST

Date for announcement of awards (anticipated): November 12th, 2010

FELLOWSHIP DURATION: 2 years (upon satisfactory participation and performance)

Anticipated YEARLY AWARDS: up to 8 total every year

Proposal Requirements

1. Proposals should be maximum of two pages in length, with single line spacing, and Arial font size 12.
2. 2 or more PIs from the list of NCI M-CNTC participant faculty are needed per proposal; co-PIs from participating institutions are encouraged
3. Each participant faculty can be part of 1 proposal.
4. The proposal should provide the following details:
   i. Project Title
   ii. PI and co-PIs and Affiliations.
   iii. Fellow Name (in case of current student, or potential student if known; provide: Student Name, Dept., Current Academic Status, GPA, GRE Scores, Any Awards)
   iv. Relevance to the M-CNTC mission (see premise below and also indicate which one of the 4 themes the proposal plans to address)
   v. Intellectual Merit and Approach
   vi. Broad Impact, & Research and Training Aspects of the Proposed Project
   vii. 1-2 figures
   viii. Contact Information
   ix. Research References (if needed, up to 3)
SUBMISSION PROCEDURE

Proposals submitted after the deadline will not be considered. Email proposals to: nanotechnology@illinois.edu

File Naming Convention (follow carefully):
Example: *LASTNAME_First Initial_Short Title_NCI_CNTC_UIUC_01_Fall_2010.pdf
DOE_J_Cellular_Mechanics_in_Cancer_NCI_CNTC_UIUC_01_Fall_2010.pdf
*Lead PI.

NOTE: Submission of proposal implies that the lead PI agrees to:

As per our NCI M-CNTC proposal, below are the minimum requirements for the M-CNTC fellows:

(i) enrolling in the capstone course,
(ii) performing the 3 lab rotations in the first semester (for new students)
(iii) taking the lab modules in the first or second summer
(iv) collaborator lab experience
(v) participation and presentation in the seminar series and at the annual symposium
(vi) There would be additional requirements such as help in teaching/executing the summer schools, participation in assessment, and participation in the student leadership council

The PIs would agree to the following:

(i) be willing to co-advise each fellow with another faculty
(ii) each advisor would be available to serve on committee of students
(iii) advisor would give a seminar per year in the series and participate in the annual symposium, and other meetings as requested
(iv) Open and involve their labs for rotations for new students
(v) Provide info and report in a timely manner as and when requested
NSF IGERT: ‘Cellular and Molecular Mechanics and Bionanotechnology’ (CMMB)

R. Bashir, M. Gillette, K. J. Hsia, T. Saif, Univ. of Illinois at Urbana-Champaign
M. Sheetz (Columbia Univ./Singapore)
(+27 faculty from UIUC+UC Merced)

• Produce the next generation of intellectual leaders who will define the new frontiers of Cellular & Molecular Mechanics and BioNanotechnology

• Mechano-chemical transduction processes linking inter-cellular, cellular, and extra cellular scales

• Utilize nanotechnology, imaging, and molecular scale computational

• Applications in regenerative engineering, mechano-biology, sensing and actuation, synthetic biology, etc.
Acknowledgments

Leadership Team:

Co-PIs: R. Bashir, M. Gillette, K. J. Hsia, T. Saif - UIUC
M. Sheetz, Columbia Univ./Singapore
Also: L. Destefano, I. Ahmad - UIUC
And: V. Leppert - UC Merced

Participants:

Faculty colleagues from UIUC, UC Merced, NCCU

University Support:

Strong support from Engineering, Education, LAS, graduate School, VCR, Provost Office
Partners and Collaborators

NSF IGERT: Molecular and Cellular Mechanics and Bionanotechnology (CMMB)

- Institutions with Co-PIs (UIUC, Columbia)
- Minority Serving Collaborators (UC Merced – Satellite IGERT Site; NCCU)
- US Collaborators (Argonne; GIT; Harvard; MIT; UCSD)
- International Collab., iWORLD (Cambridge; Max Plank; NUS; Tsinghua)
C. Project Description

C.1. List of Participants (Co-PIs and Affiliated Faculty)

<table>
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<td>Assistant Professor</td>
<td>Cell &amp; Dev Biology/MCB</td>
<td>Participant</td>
</tr>
<tr>
<td>31</td>
<td>Wang, Ning*</td>
<td>Professor</td>
<td>MechSE</td>
<td>Participant</td>
</tr>
<tr>
<td>32</td>
<td>Wang, Peter</td>
<td>Assistant Professor</td>
<td>BioE/Physiology/Beckman</td>
<td>Participant</td>
</tr>
<tr>
<td>33</td>
<td>Waggoner, Amy</td>
<td>Assistant Professor</td>
<td>MechSE</td>
<td>Participant</td>
</tr>
</tbody>
</table>

Collaborating Institutions: US-wide

| 1  | Bao, Gang        | Professor/Institute    | BioE, Georgia Tech.    | Affiliate / Saif   |
| 2  | Chien, Shu       | Professor/University   | BioE, UCSD             | Affiliate / P. Wang |
| 3  | Kamm, Roger      | Professor/Institute    | ME, MIT / GEM*         | Affiliate / Hsia   |
| 4  | Leppert, Valerie* | Associate Professor    | Engr. UC Merced        | Merced Lead**/Hsia |
| 5  | McCloskey, Kara* | Assistant Professor    | Engr. UC Merced        | Affiliate / Gillette |
| 6  | Mooney, David    | Professor/University   | SEAS, Harvard University | Affiliate / Kong   |
| 7  | Orlando, Aciello | Research Leader        | Argonne National Lab   | Affiliate / Bashir |
| 8  | Sheetz, Michael* | Professor/Director     | Biological Sc, Columbia University | Co-PI / Saif |
| 9  | Toner, Mehmet    | Professor/Director     | Harvard Medical School | Affiliate / Bashir |
| 10 | Yeh, Li-an       | Professor/Director     | BRITE, NCCU            | NCCU Lead**/Bashir |

Collaborating Institutions: International

| 1  | Lim, C. T.       | Professor/Institute    | Natl. U. Singapore     | Affiliate / Hsia  |
| 2  | Oyen, Michelle*  | Professor/University   | Cambridge University, UK | Affiliate / Hsia  |
| 3  | Spatz, Joachim*  | Professor/Institute    | Max-Planck-Inst. Germany | Affiliate / Saif |
| 4  | Zheng, Q*        | Professor/Institute    | Tsinghua University, China | Affiliate / Hsia |

*Asterisk* indicates CV included in the proposal package; **indicate lead external collaborators at Minority-Serving Institution partners; All US and International Collaborators have committed to be part of our IGERT network and participate in student exchanges in their Centers/Labs; Names in italics are external collaborators; Industry list in the proposal (C.4.5(vi)).
iGERT Scientific Structure and Organization

**Integrative Research Themes (IRT)**

1. **Molecular Mechanics**
2. **Cellular Mechanics**
3. **Cells and ECM**

**Participants**

Bao, G.; Briher, W.; Ha, T. J.; Leppert, V.; Liu, L.; Selvin, P.; Jakobsson, E.; Ravaioi, U.; Schulten, K.; Takhirshid, E.; Yeh, L.


*Italicized are external US collaborators*

**Core Technologies (CT)**

1. **Molecular and Cellular Computation**
2. **Micro and Nanotechnology**
3. **Molecular and Cellular Imaging**

**Application Domains**

(i) tissue and regenerative engineering, (ii) cellular and molecular medicine, (iii) mechano-biology, (iv) biological energy harvesting, (v) bio-mimetic sensing and actuation, (vi) cellular factories, (vii) synthetic biology
iGERT Student Experience

Year 1: Grad Prog Curriculum
Mol.&Cell Biology Core Courses - F/S
PhysSci/Engineering Dept. Cores - F/S
Research Lab Rotations - Fall 1 inside/2 outside home dept
Select PhD lab & co -mentors - Spring

Summer 1: 4 week lab modules
Cell culture, substrates
NanoFab/Microfluidics
Microscopy, analyze image
Mol. manipulation, computation

Summer 2: 2 week
Team building, Ethics
Presentation skills, Entrepreneurship

Year 2: CMMB Core Curriculum
CMMB Core Courses - F/S
Home Engr. Dept. Cores F/S
Scientific Ethics Course - F
Qualifying Exam - Spring
Thesis research

Summer 3: Thesis Research/External Experience

Year 3: CMMB Curr., Research
CMMB Seminar Course - F/S
Advanced cross-disciplinary courses
Prelim. Thesis Exam - Spring
Thesis Research

Summer 4: Thesis Research/External Experience

Year 4: CMMB Curr., Research
CMMB Seminar Course - F/S
Preliminary Thesis Exam - Spring
Thesis Research
Publish thesis research

Summer 5: Thesis Research/External Experience

Year 5: CMMB Curr., Research
CMMB Core Courses - F/S
Entrepreneurship course
Publish thesis papers
Write & defend thesis

Pipeline/Recruiting Sources:
Mol&Cell Bio, MechSE, BioE, ECE, Biophysics, Medical Scholars,
REU, SROP, SPI (see Equity Programs)
NSF-funded NanoCEMMS, WaterCAMPWS, at UIUC

Leaders in Cross-Disciplinary Science/Eng
(Academia, Industry, Govt. Labs)

• External experiences in summers includes international experience, or US Collaborators, or industry internships
• The IGERT fellows would follow the two track curriculum in Figure 12
Concept of a 2-Track Educational Program

Introduction to Cellular and Molecular Mechanics and Bionanotechnology, New

Lab Modules

- Cell Culture
  - Basics of Cell Culture
  - Advanced Cell Culture
  - Advanced Cell Substrates

- Imaging
  - Advanced Microscopy
  - Single Molecule Visual.
  - Cell Visualization

- Computation
  - Computational Molecular Biology
  - Biology Student Workbench

- Nanofabrication
  - Nanofabrication Methods
  - Nanofabrication of Cell Sensors
  - Microfluidics

- Mechanics of Biological Solids, MCB 498
- Computational Chemical Biology, BIOP 470
- Mechanics of Biological Solids, ME 498
- Cellular Biomechanics, TAM 461
- Musculoskeletal Biomechanics, ME 481
- Mechanical Modeling of Biomaterials, ME 498-IJ
- Biomolecular Physics, BIOP 550
- Non-equilibrium Stat. Mechanics, PHYS 598BSN
- Physics of Nanomachines, PHYS 598NM

Life/Career Module

- Communication skills
- Leadership skills
- S&T Policy
- Ethics training
- Patent and IP
- Industry environment
- Entrepreneurship
- Advanced course in Bionanotech, new
- Hands-on Course in Comput. Biology, PHYS 590C
- Analytical Methods in Bioengineering, BIOE
- Advanced Bioinstrumentation, BIOE 507
- Special Topics in Cell Biol, MCB 592
- Mechanical Modeling of Biomaterials, ME 498-IJ
- Computational Mechanics Seminar, new
- Engineering Applications of Biological systems, ABE 498
- Introduction to Nanotechnology, ECE 498 JL
- Semiconductor Nanotech, ECE 598
- Cellular and Molecular Mechanics Seminar, new
- Physical Biology: From Single Molecule to Sys. Biol., PHYS 5981
- Mechanobiology for Engineers, ME 598
- Molecular and Cellular Bioengineering, BIOE 461v

Advanced Courses
UC Merced Diversity and Interdisciplinarity

Fast Facts

School of Engineering Demographics

- 60% Urban
- 27.5% Non-URM
- 6.0% African-American
- 0.4% Native-American
- 15.4% Female

Students from
- Central Valley (1/3)
- Northern CA (1/3)
- Southern CA (1/3)

Three Schools
- Social Sciences, Humanities, Arts
- Natural Sciences
- Engineering

Enrollment ~4200 (Fall 2010)

Nine Graduate Groups

Three Institutes
- Health Sciences
- Energy
- Sierra Nevada
IGERT Partnership

“Sharing Research, Education, and Outreach Opportunities”

- Two IGERT Fellows @ UCM + Match
- UCM Faculty/Student Participation in
  - IGERT Symposium
  - Summer Workshop
  - International Experience
  - Web-based Course Development and Delivery
  - REU Experience (possible pipeline of URM students to UIUC)
  - IGERT Executive Committee (SOE Assoc. Prof. Valerie Leppert)
  - External Advisory Board (NS Dean Maria Pallavicini)
- UIUC Faculty Involvement with UCM (helping a new campus)
  - Participation on Select Qualifying and/or PhD Exam Committees
  - Guest Seminars and Joint Symposia
  - Advice on establishing UCM’s new Micro/Nano Core Facility
Fellow and PI Requirements

As per our IGERT proposal, below are the minimum requirements for the IGERT fellows:

- enrolling in the capstone course,
- performing the 3 lab rotations in the first semester (for new students),
- taking the lab modules in the first or second summer,
- choosing between either international experience (strongly preferred), US collaborator lab experience, or industry experience for one summer,
- participation and presentation in the seminar series and at the annual symposium.
- There would be additional requirements such as help in teaching/executing the summer schools, participation in assessment, participation in the student leadership council.

The PIs would agree to the following:

- be willing to co-advise each fellow with another faculty,
- each advisor would be available to serve on committee of students from Merced as needed,
- advisor would give a seminar per year in the series and participate in the annual symposium,
- Open and involve their labs for rotations for new students.
Engineering of Biological Systems

Use biological building blocks to ‘design’ and ‘forward engineer’ biological systems and machines.

Dissect larger components to smaller components to understand their structure and function.

DNA
mRNA
Proteins
Protein Interactions, Metabolites
Cells
Cell-Cell /ECM
Tissue
Organs
Body

Polymers and hydrogels, Ink-jet Printing, 3-D Stereo-lithography,
Micro-fluidics, Soft-Lithography,
Nano-pores, Cantilevers, NWs, NTs, Quantum Dots, Nano-particles,
**Basic Science**: To gain a deeper understanding of how cooperative cell behavior leads to the formation of large organized cellular structures.

**Applications**: To create biological "machines" in which multiple cell types coordinate to perform a specified function.
EBICS Organization: Overall Projects

New Enabling Technologies
- Model neuronal activation/secretion
- Fluorescent protein tagged minibodies
- Model endothelial activation/secretion
- Develop microfluidic system
- Study matrix physical properties and network formation
- Measure toxin sensing
- Measure minibody release
- Measure neurotransmitter release

Grand Challenge Machines
- On-demand factories
- Autonomous bio-bots

Modules and Simple Machines
- Neuron-muscular clusters
- Neuronal toggle switch
- Endothelial synthesis from neuronal signal
- Grow partitioned microvascular network
- Neuron-effector clusters

Building blocks / ‘Parts’
- Neurotoxin sensors
- Specific neuronal I/O
- Contractile muscle
- ES→Endothelial
- ES→Neurons
- ES→Myocytes
- Soluble signal sensors