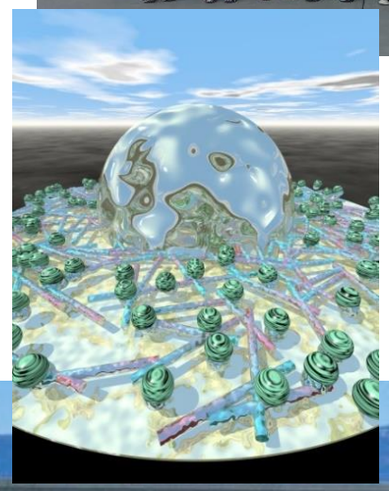
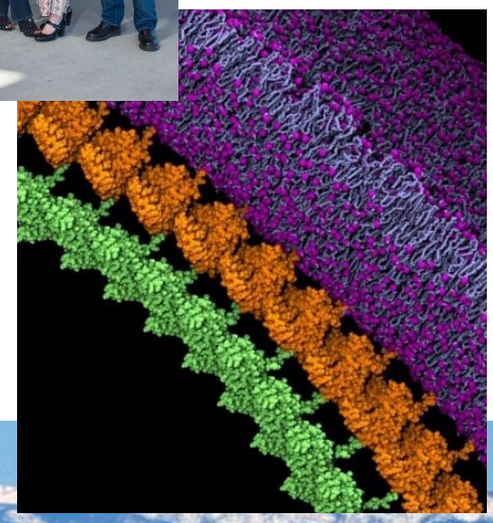
NSF-CREST Center for Cellular and Biomolecular Machines (CCBM)



All-Hands Meeting
March 20, 2017



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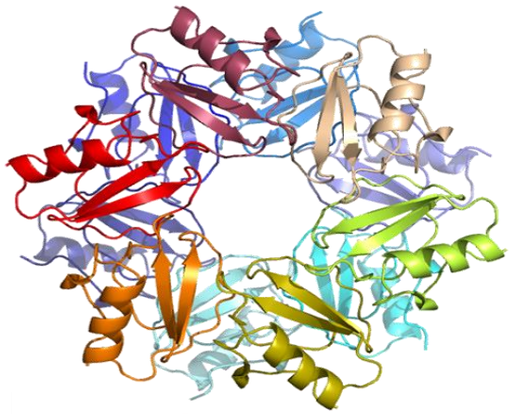
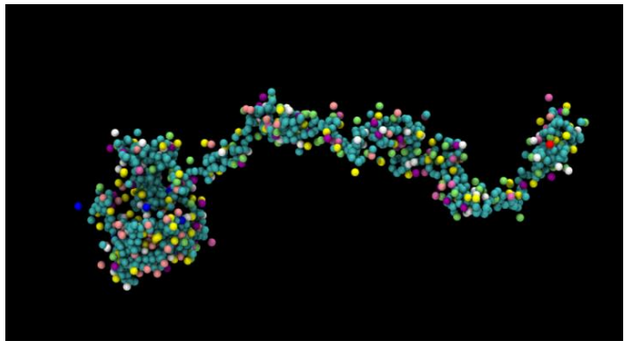
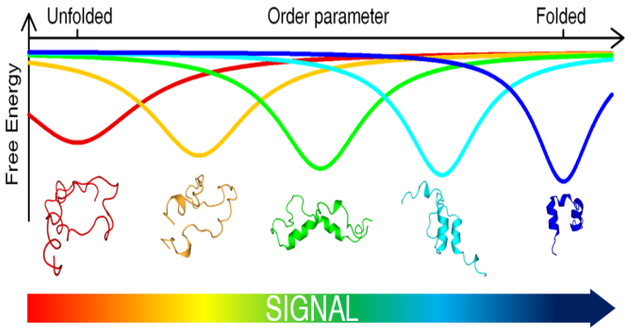
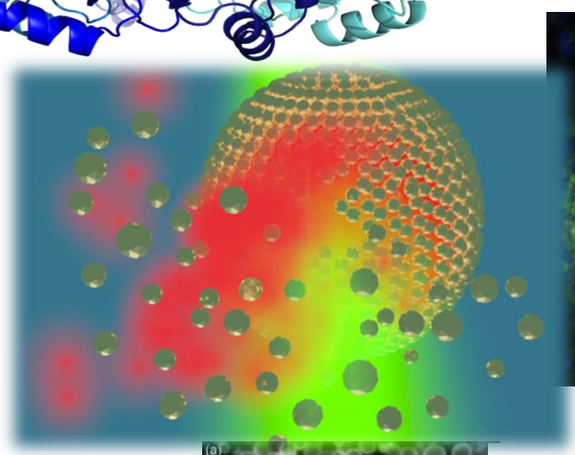
Project Goals and Significance

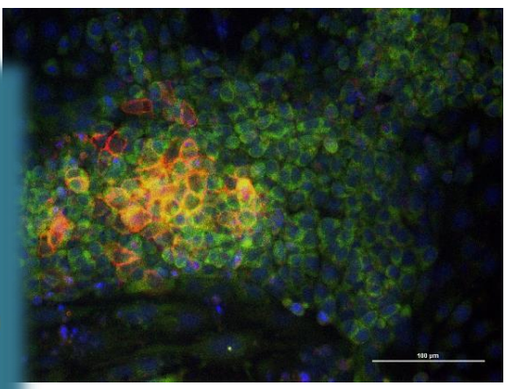
- **Multidisciplinary**:
  Chemistry, physics, biology, and engineering fields—to study **how biological matter assembles to perform specific tasks**, in hopes of eventually being able to **engineer and develop innovations** (from designer cells and tissue to novel diagnostic and therapeutic devices)
- **Research Thrusts**:
  Biomolecular Instruments
  Macromolecular Assemblies and Hybrid Devices
  Cellular and Multicellular Systems
- **Significance:**
  Nobel Prize, 2016—molecular machines
  Multi-scale biomolecular and cellular assemblies
  Control over Biological Systems and Designs
- **Education and outreach:**
  A pipeline for highly qualified STEM workforce
  Produce high caliber, diverse trainees at all levels
  Spur growth in Central Valley

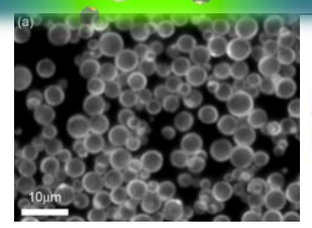


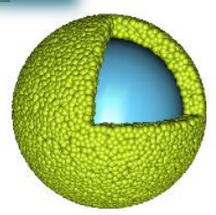


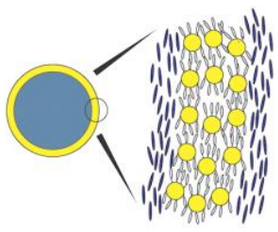












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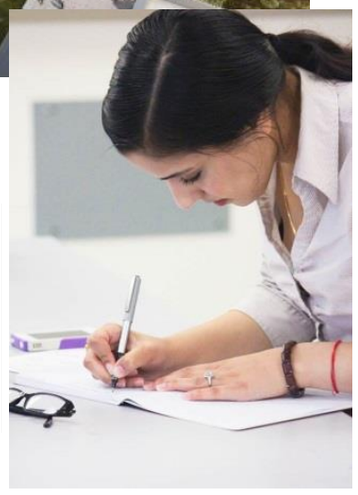
Novel Approaches and Challenges

Novel Approaches:

A. Interdisciplinary research and training across physics, chemistry and biology, hands on training modules

B. Entrepreneur/scholar program

C. Team-based student-led research



Challenges and opportunities for a center on young campus with local UR demographics

- Newest UC campus (2005)/first American research university of 21st century
- Extends URM student access to UC system
- Major base of advanced research, model of sustainable design-construction and stimulus to economic growth and diversification
- Horizon 2020 Project—$1.3 billion to duplicate campus size and number of faculty
- Aligned with Strategic Academic Focusing Initiative

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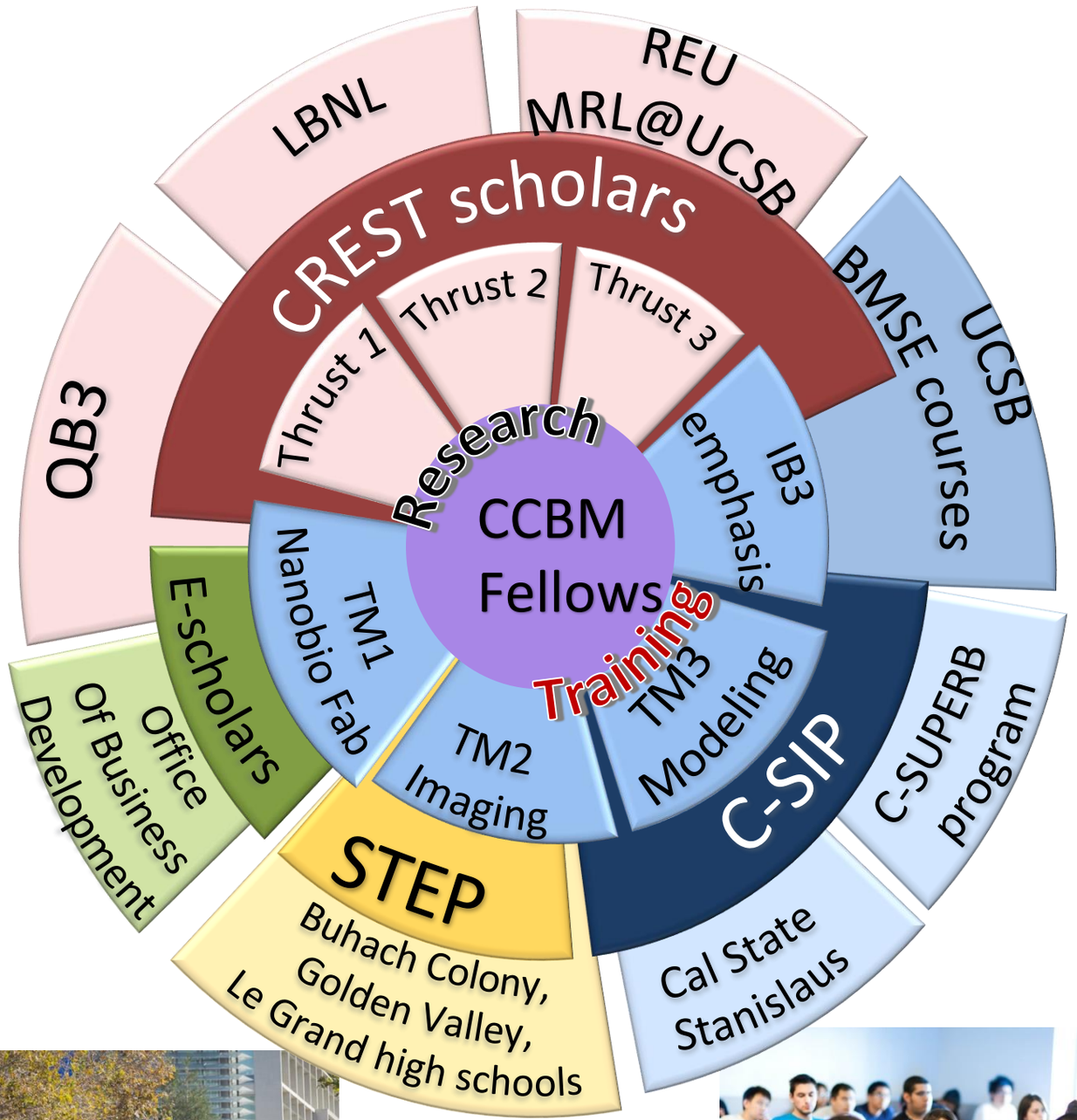
Collaborations and Future Plans/Next Steps



- Strong internal and external partnerships/collaborations to enhance programming and efforts
- Recruitment of URM students from the Central Valley
- First NSF center on campus
- Maintaining NSF center presence on campus
- Grow into a Full Fledged Research Institute
- Influencing direction of university in growth stage
- Nucleate expertise, research facilities and funding opportunities in biophysics and bioengineering

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Research Focus

Quantitative (Physical) Biology:
Integration of experiment, theory and computation into general descriptions that rationalize experiments, distill mechanisms, and make new testable predictions of molecular and cellular biological phenomena

Synthetic Molecular-Cellular Biology (Biological Engineering):
Transformation of quantitative knowledge into engineering strategies for designing and building synthetic biological components with novel functionalities and/or behaviors

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Challenges and Goals

Bringing together physical and engineering approaches to understand biological machines and design and develop new functional machines

Research Challenge: Understand

We are interested in investigating hierarchical assemblies of molecular, cellular and multicellular structures seeking to:
1- understand how they perform remarkably robust functions in their highly noisy natural environments
2- exhibit emergent properties unanticipated from just the sum of the components (e.g. filament-motor assemblies involved in mitosis to slime molds and biofilm formation to morphogenesis)

Technological Goals: Exploit

1-Better fundamental understanding of multi-scale biological assemblies
2-Attain control of their functional dynamics potentially leading to therapeutic improvements in human health
3-Implement design principles for building bio-inspired materials and machines

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Why do we need a center to work in this area?

Transformative advances in this area require contributions from many different fields:

Biochemistry to understand biomolecular recognition and signaling mechanisms

Soft matter physics and materials science and engineering to understand and characterize material properties

Optical physics for cutting edge imaging and manipulation

Bioengineering approaches for molecular, mechanical and manipulation

Biology and chemical biology to probe functional properties in vivo

Theory and computation to rationalize and test what is observed experimentally

No single department, unit or group can accomplish such an innately interdisciplinary task

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Why at UC Merced?

It Makes Strategic Sense

UCM has the right mixture of expertise to achieve significant progress and national prominence in this area with faculty that shares a common vision for research and education

CCBM leverages the uniquely interdisciplinary structure at UCM with few departmental boundaries, to join faculty from physics, bioengineering, materials science, quantitative biology, applied mathematics, chemistry and chemical biology forming a diverse, interdisciplinary research community

UCM has a significantly large fraction of its faculty working at the interface of the physical and biological sciences and engineering (*CCBM participants alone make up more than 12% of the total faculty at UCM)*

At UCM, interdisciplinary collaborations can thrive in an academic structure without academic boundaries that fosters collaboration by proximity and sharing of space

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Why at UC Merced?

It is Key for the Future Development of UCM

UCM is still in its early developmental stages, the establishment of CCBM can have truly transformative impact

UCM has world-class faculty but the research infrastructure is still very much in its growth phase

NSF-CREST center will allow us to marshal resources and acquire critical infrastructure and technical support staff to

(i) actively recruit and retain diverse, stellar faculty in this broad area

(ii) attain critical mass, expertise and facilities to subsequently compete for STC, ERC or MRSEC type grants as a lead institution

CCBM dovetails with the UCM strategic academic focusing (SAF) pillars of excellence by perfectly aligning with the Adaptive and Functional Matter Pillar

Establishment of CCBM's innovative, interdisciplinary training program and aggressive recruitment of STEM graduates will have a key impact on culminating the 2020 Project

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Research Thrusts

Biomolecular Machines

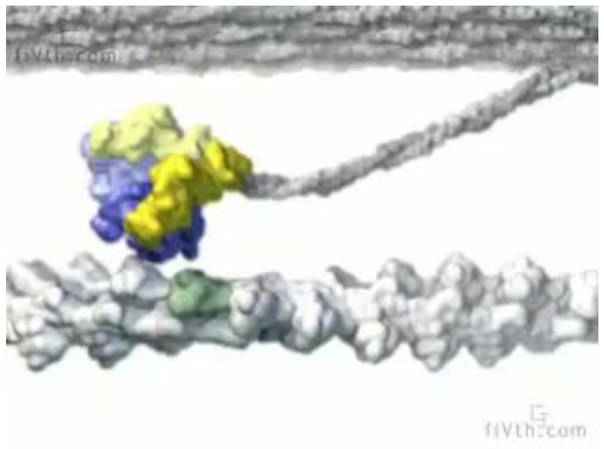
Circadian Molecular Clocks
Rheostatic Protein Biosensors
(Munoz (co-director), Escobar, Colvin, LiWang)

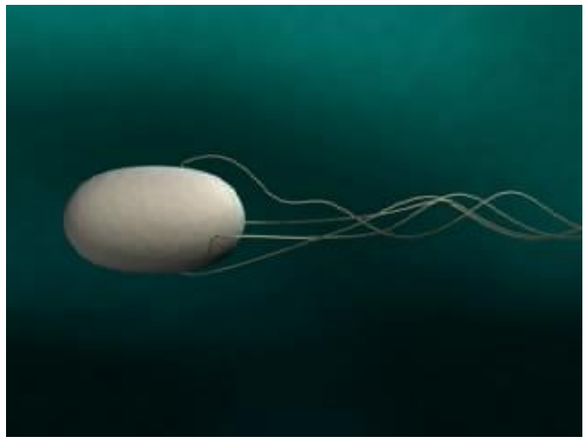
Macromolecular Assemblies and Hybrid Devices

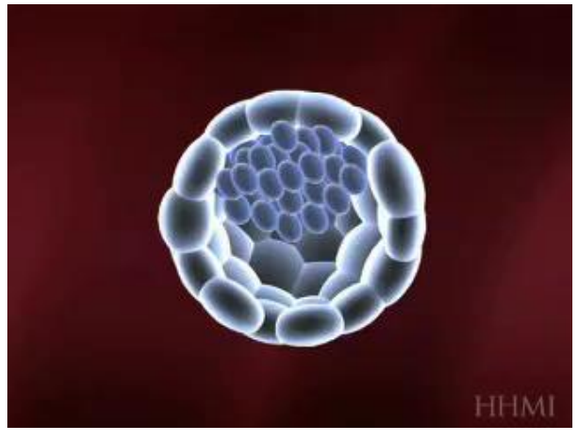
Designer Vesicles for Transport
DNA Origami-Nanocomposites
Graphene-based Biosensors
(Gopinathan (co-director), Hirst, Xu, Ghosh, Ye, Tian, Tung, Chin, Gadre)

Cellular and Multicellular Systems

Differentiating Tissue
Bacterial Community Motility
(McCloskey, Gopinathan, Lu, Liu, BalaSubramanian, Gopinath)







Supplementary Movie 1:
Simulating movement of transfer RNA into the ribosome during decoding

Sanbonmatsu*, K.Y., Joseph, S. and C.S. Tung
Los Alamos National Laboratory

Explicit Solvent Targeted Molecular Dynamics

$N_{atoms} = 2.64 \times 10^6$

ASCI Q Machine (LANL)

*corresponding author: kys@lanl.gov

www.t10.lanl.gov/kys

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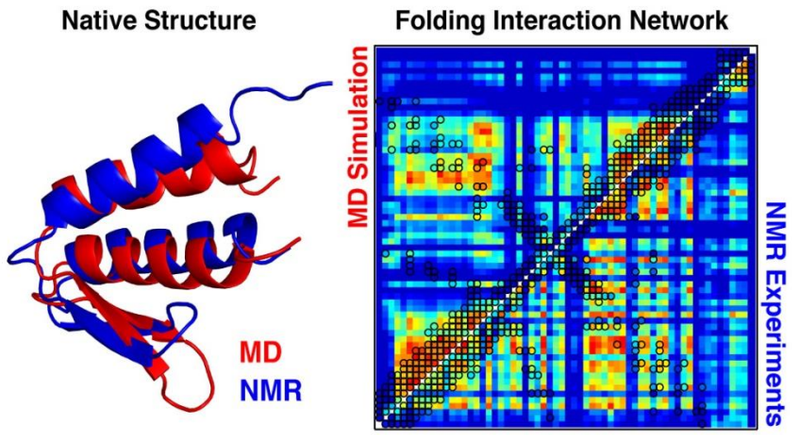
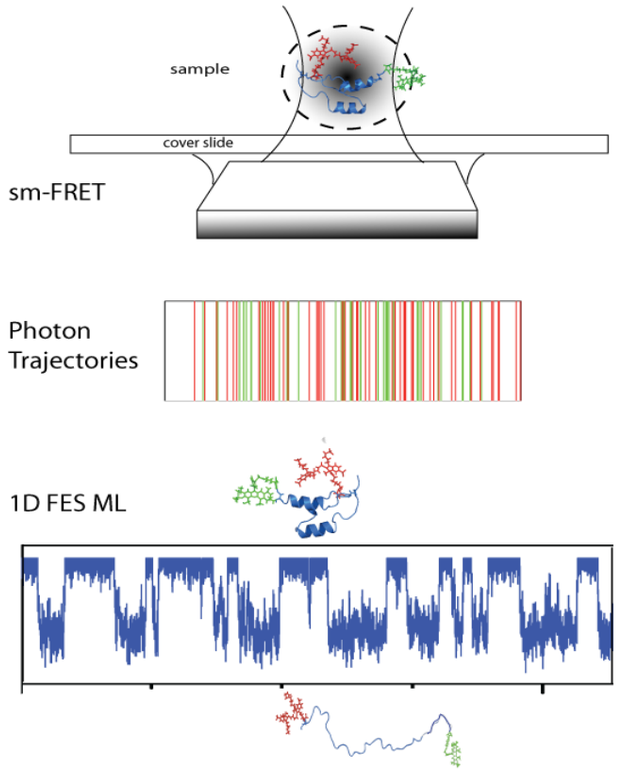
Thrust 1: Biomolecular Machines

V. Munoz, A. Li Wang

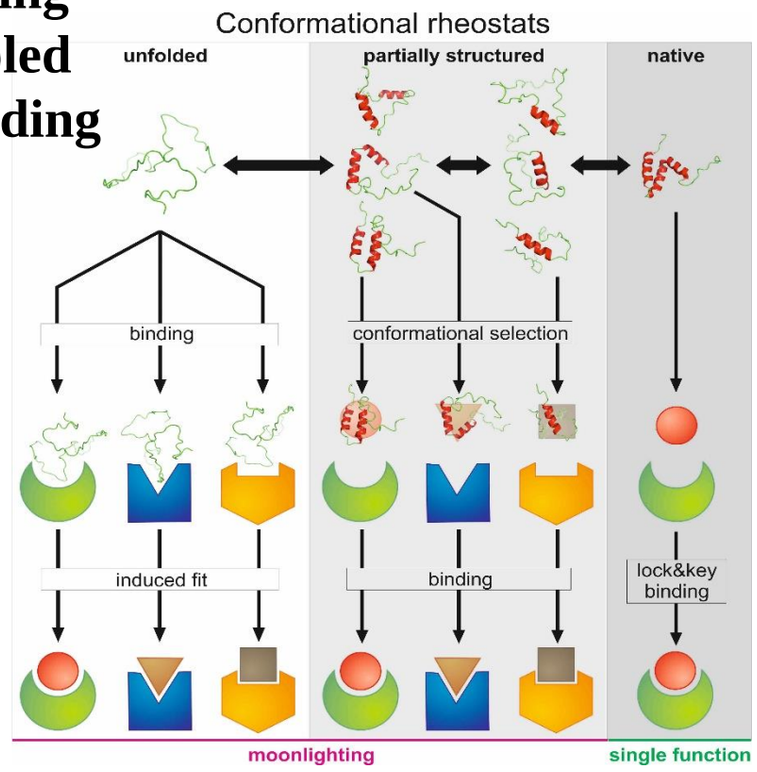
Protein Folding at Atomic Resolution



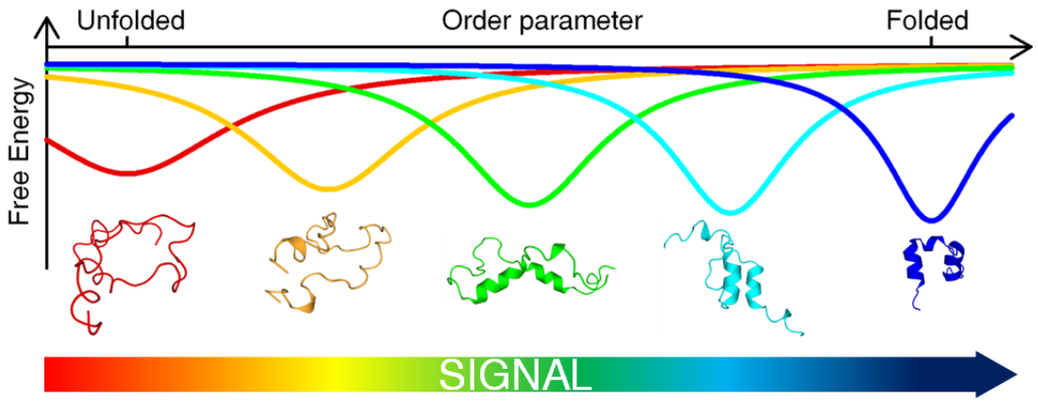


Protein Folding in Single Molecules

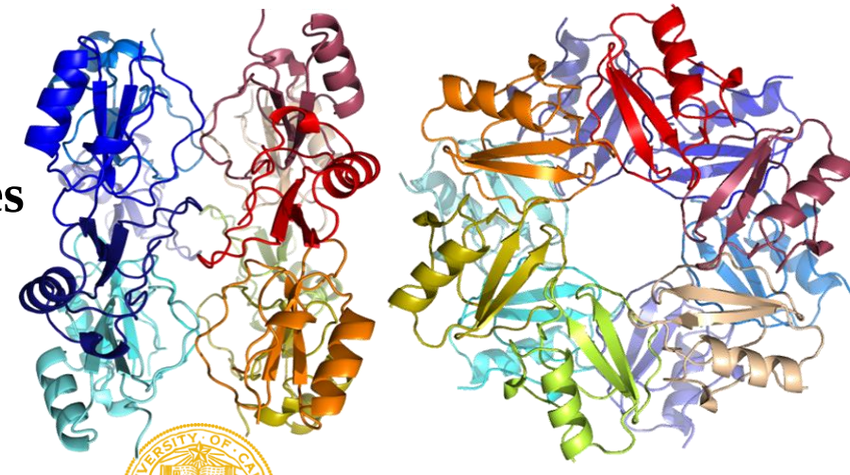
Folding Coupled to Binding



Engineering Protein Analogical Nanosensors



Engineering Controllable Macromolecular Assemblies



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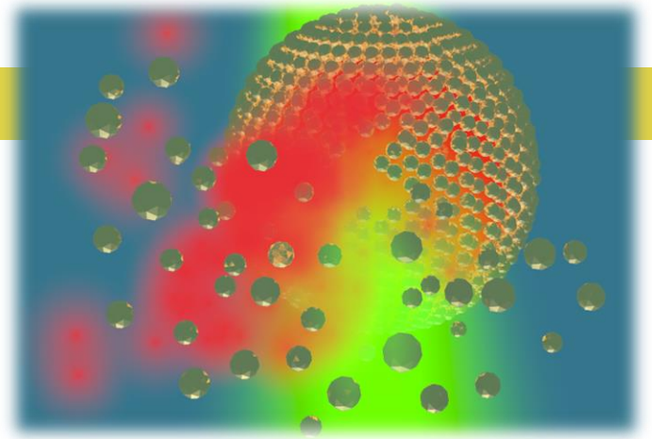
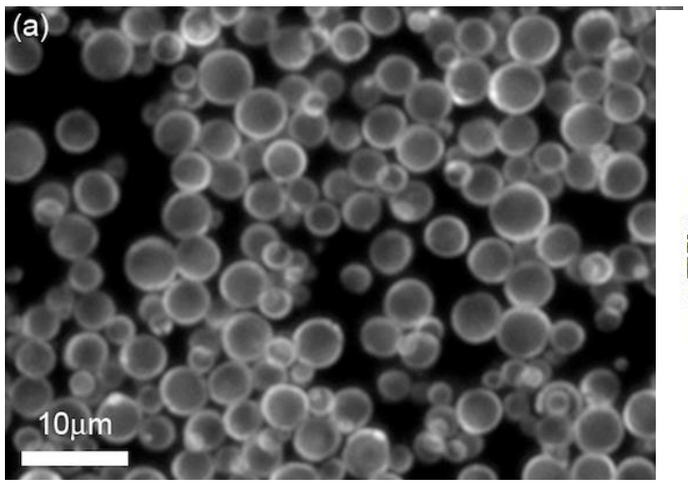
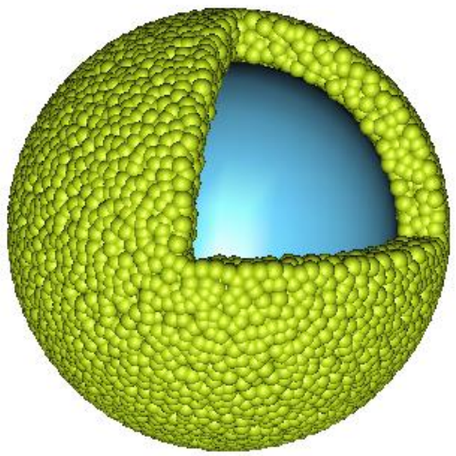
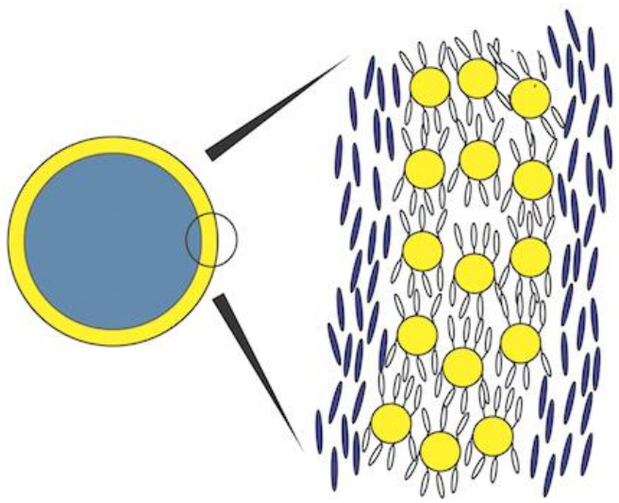
Thrust 2: Macromolecular Assemblies



Plasmon actuated cargo delivery

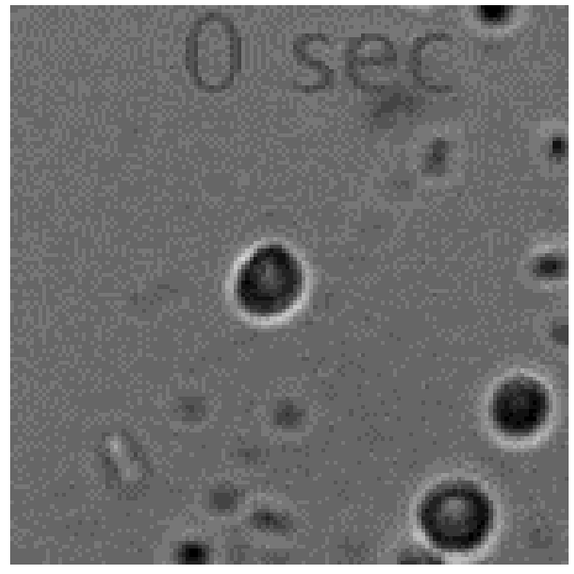




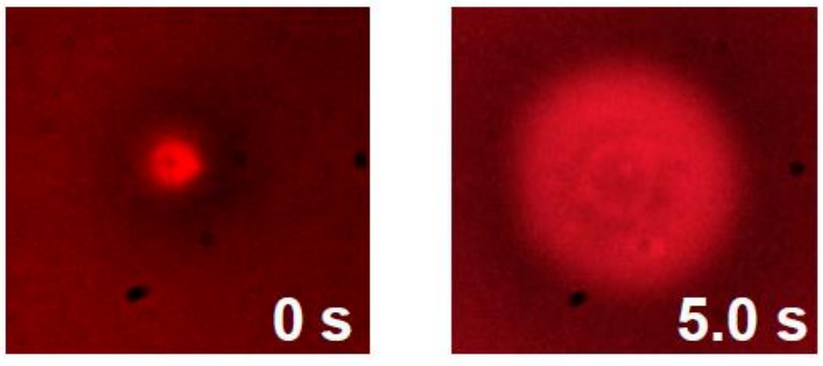


S. Ghosh, L.S. Hirst

Gold quantum dot shells self-assembled by liquid crystal ordering



Plasmon heating releases cargo



Versatility in encapsulation
Low power, fast, tunable release

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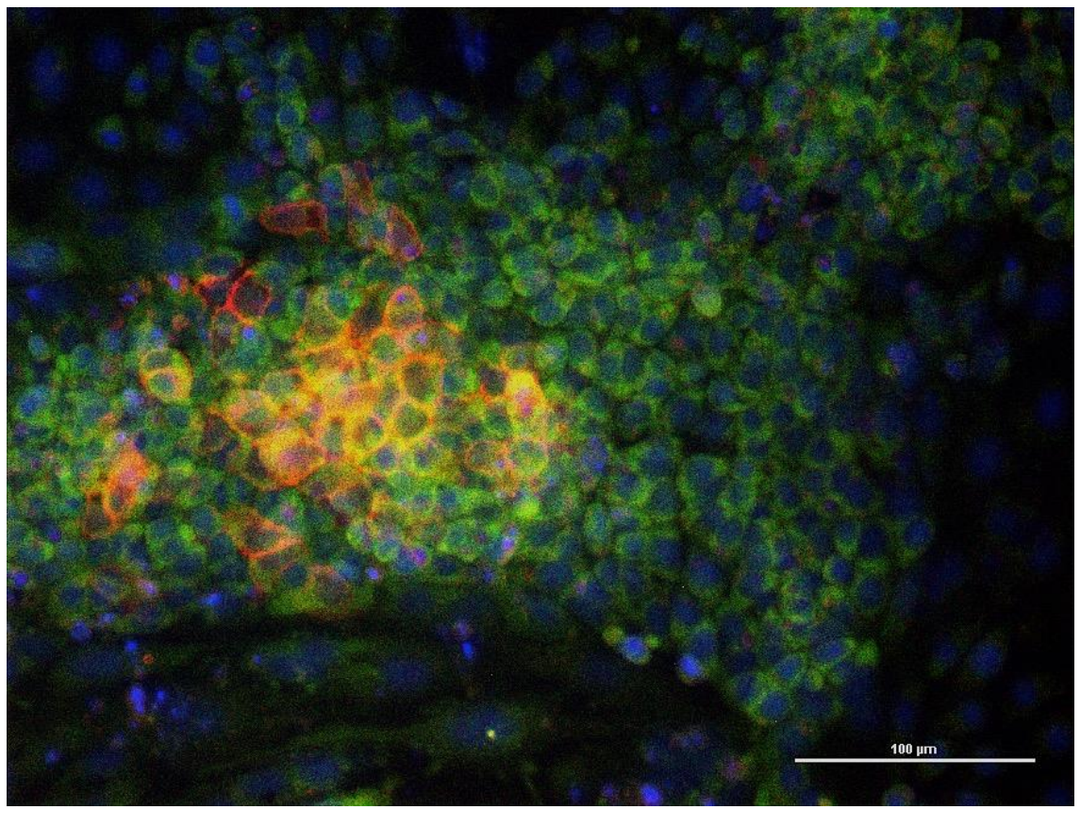
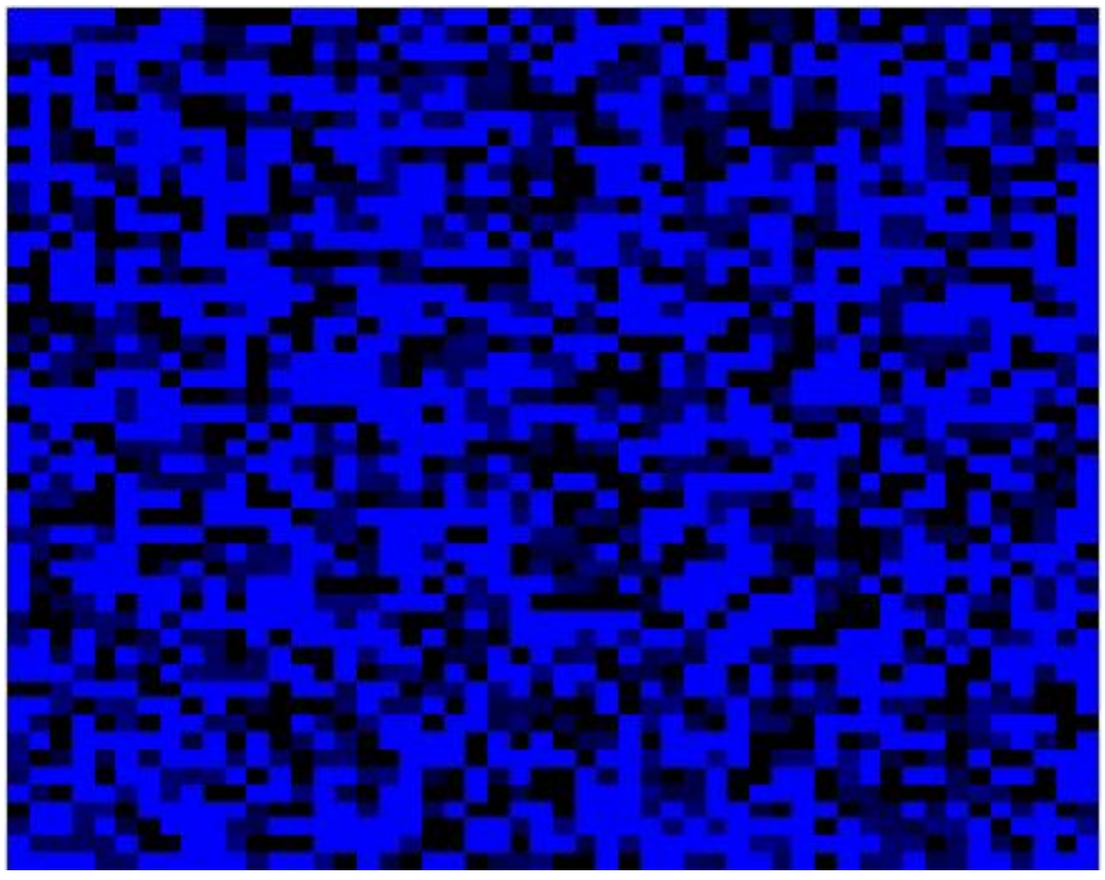
Thrust 3:
Cellular and Multicellular Assemblies

K. McCloskey, A. Gopinathan



Development of spatially patterned cardiac tissue from stem cells



Mathematical model

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Affiliated Faculty and Leadership

Kara McCloskey
biological engineering
stem cell and tissue engineering for regenerative medicine applications

Victor Muñoz, co-director
biological engineering
protein folding, structure prediction and design, protein aggregation

Andy LiWang
chemistry and chemical biology
structural biology of circadian clock proteins and nucleic acids, NMR spectroscopy

Anand Bala Subramaniam
biological engineering
experimental biophysics, cellular reconstitution, experimental synthetic biology

Lin Tian
physics
theoretical quantum optics, quantum information processing and quantum simulation in condensed matter systems

Vincent Tung
materials science and engineering
nanotechnology for sensing and renewable energy

Jing Xu
physics
experimental biophysics, quantitative biology
single-molecule analysis of molecular motors

Tao Ye
chemistry and chemical biology
biomolecular science and engineering, nanotechnology

Wei-Chun Chin
biological engineering
polymer physics and engineering of cellular and environmental systems

Mike Colvin
chemistry and chemical biology
models of biological processes and molecular dynamics of disordered proteins

Ariel Escobar
biological engineering calcium in cardiac cellular signaling and techniques to study cardiac cells in vivo

Anand Gadre
stem cell instrumentation foundry
nanotechnology, medical device development, sensor development, drug delivery

Sayantani Ghosh
physics
experimental condensed matter physics, magnetism, metamaterials, nanoscience and quantum systems

Ajay Gopinathan, co-director
physics
theoretical biophysics, biopolymers, transport and collective behavior

Arvind Gopinath
mechanical engineering
fluid dynamics, polymers and active soft matter – theory and simulations

Linda Hirst
physics
experimental soft matter physics and biophysics

Bin Liu
physics
bacterial motility in complex media and single-cell behavior in biological processes

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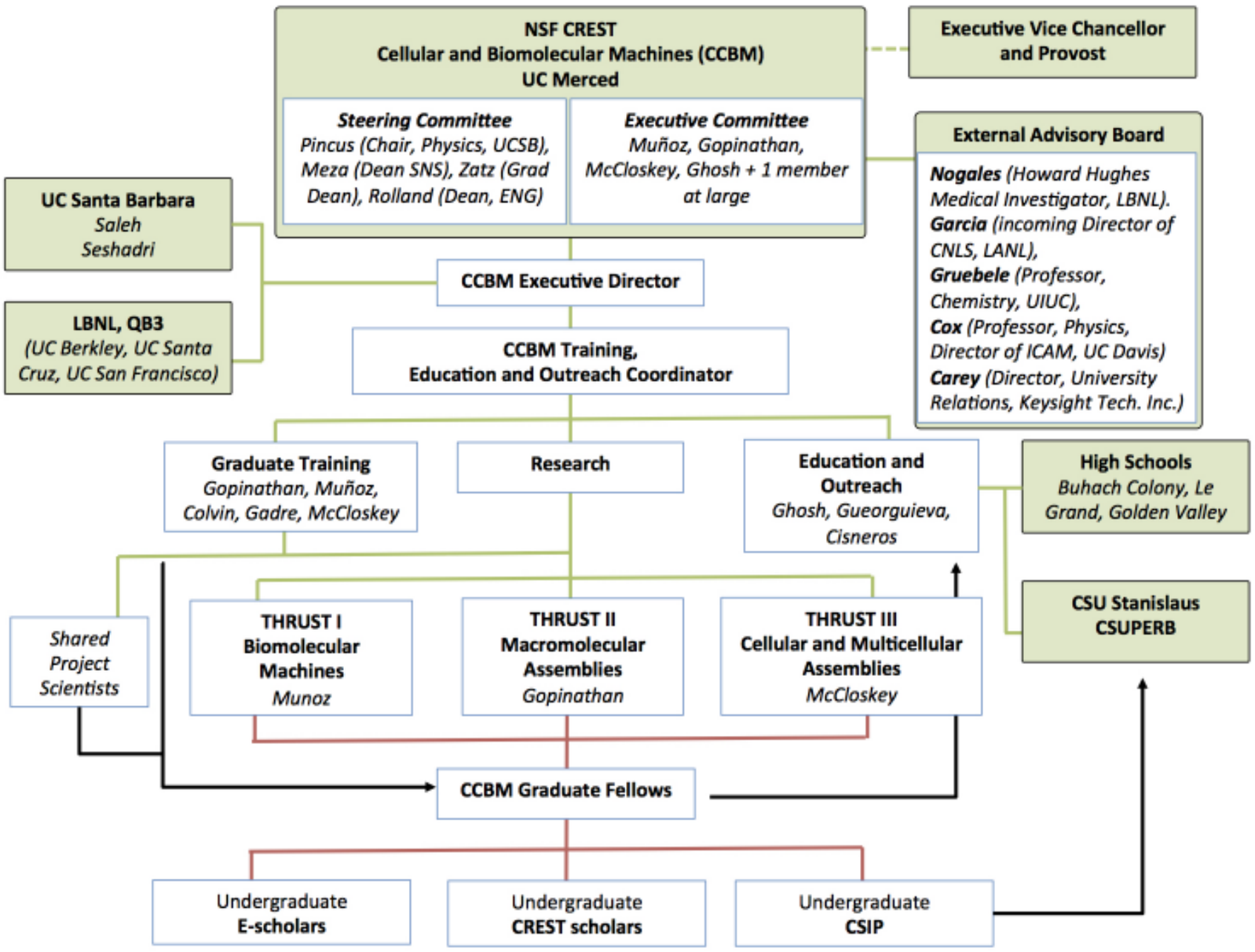
Center Organization



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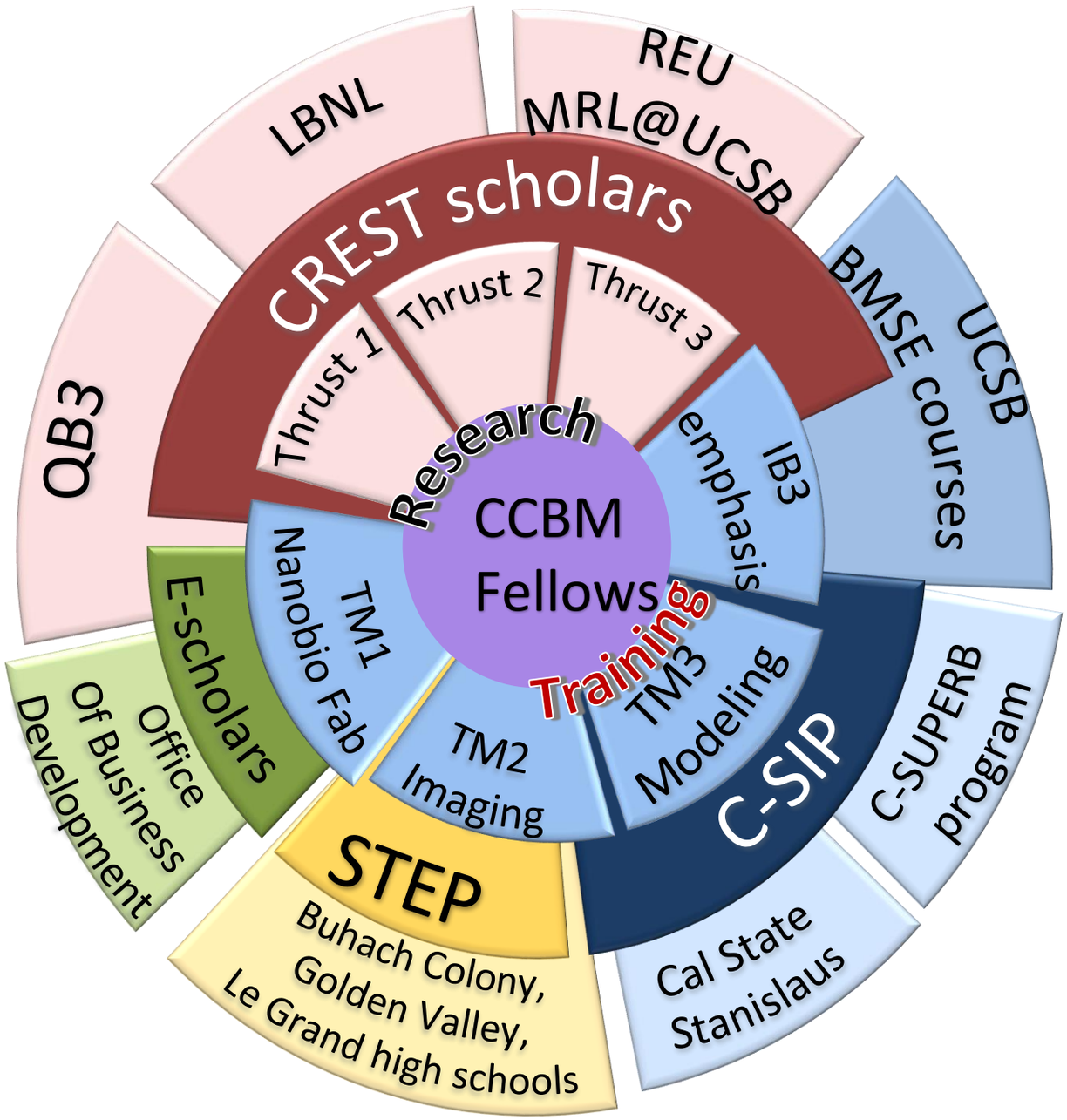
Research, Education, & Outreach



Mission

1- Perform cutting edge interdisciplinary research on multi-scale biomolecular and cellular assemblies

2- Become a model for integrated research, education and outreach that develops a pipeline for a highly qualified STEM workforce and produces high caliber, diverse trainees at all levels

1. IB3 graduate training emphasis
2. 2 project scientists
3. Team based research Grad+UG
4. Training Modules
5. Entrepreneurship
6. High school outreach
7. CCBM fellowships
8. Summer research program/UG
9. Travel fellowships, supplies $$

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Graduate Education & Training

Benefits of being a CCBM scholar

a. You will be **eligible to become a CCBM fellow** (a renewable semester by semester GSR equivalent fellowship). There will be 4 such fellowships in spring and this will increase in subsequent years. CCBM fellows will be selected from the pool of CCBM scholars based on their applications.

b. All CCBM scholars will be awarded up to **$500 in supplies** which can be used toward research related equipment/supplies/recharge in consultation with your PI.

c. You will benefit from our **new IB3 (Interdisciplinary Biophysical sciences, Biomaterials, Biotechnology) graduate emphasis program**. You can take our new specialized electives (from the UCSB BMSE program via videoconference) which are cross-listed as BEST, Physics and Chemistry grad courses (BEST/PHY/CCB 299).

d. You can take advantage of our **2-week hands-on training modules** in Imaging/Spectroscopy, Nano-micro fabrication and/or Computational methods during the summer (starting in summer 2017).

e. You will be able to take part in all center activities that include **career skills workshops, networking, outreach, etc**. Details of activities will be available on our website - ccbm.ucmerced.edu

f. You will be able to host and meet with **special CCBM seminar speakers**

g. You will be eligible for **CCBM travel fellowships**

One of the conditions of being awarded a CCBM fellowship is that you take at least two of our specialized IB3 electives (these can count toward your own grad group elective requirements) and the summer training modules once during your graduate studies.

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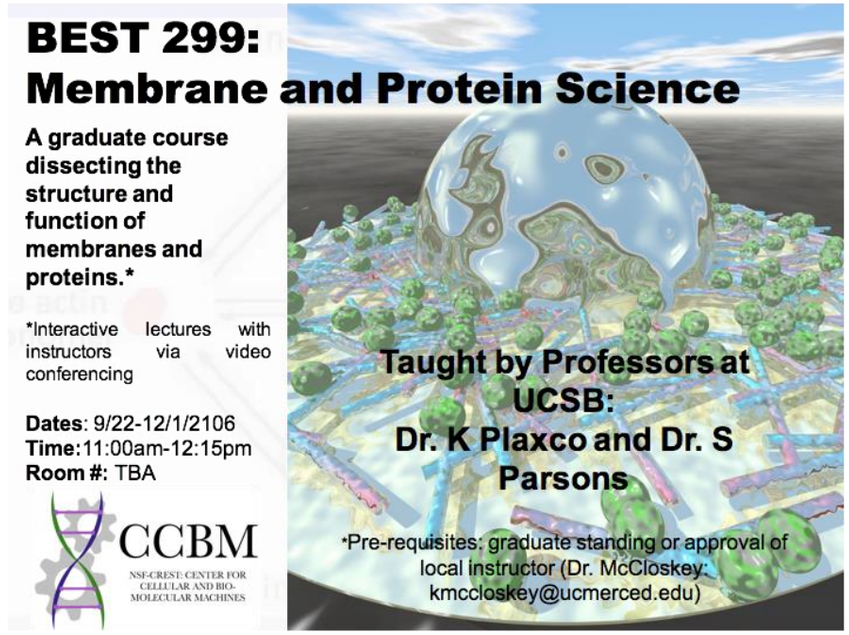
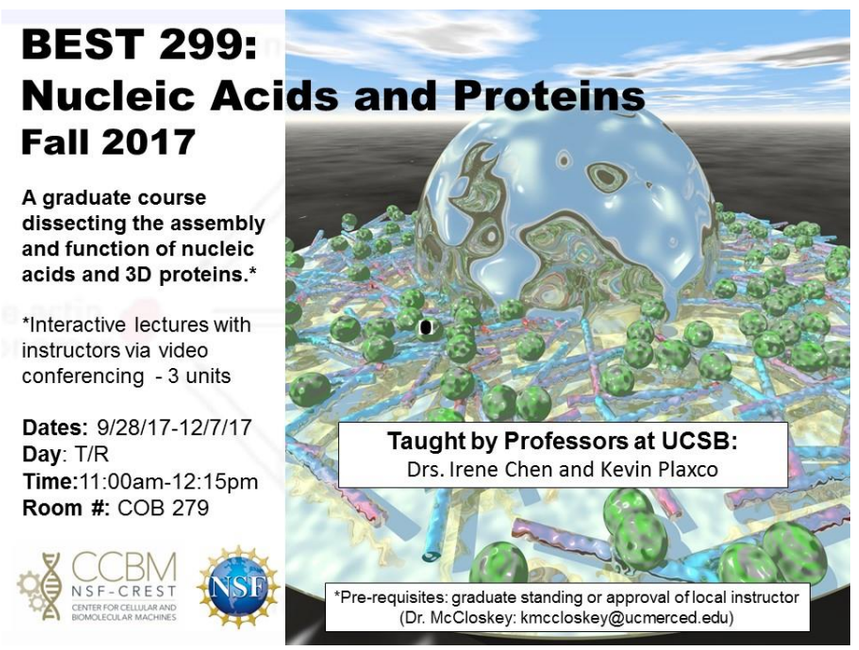
Graduate Education & Training

The IB3 graduate training emphasis
-Coursework

CCBM courses:
Fall 2016: Membrane and Protein Science
Fall 2017: Nucleic Acids and Proteins

Graduate Group	BioEngineering and Material Science and Engineering	Chemistry and Chemical Biology	Physics
Required Courses	▪ **BEST 240**: Bimolecular Engineering ▪ **BEST 214**: Tissue Engineering and Design ▪ **PHYS 204**: Biophysics ▪ **CHEM 216**: Interfacial & Surface Chemistry	▪ **CHEM 212**: Quantum Chemistry ▪ **CHEM/PHYS 212**: Statistical Mechanics ▪ **CHEM 216**: Interfacial & Surface Chemistry ▪ **PHYS 204:** Biophysics	▪ **PHYS 237:** Quantum Mech. I ▪ **PHYS 210:** Electrodynamics ▪ **PHYS 212:** Statistical Mechanics ▪ **PHYS 204:** Biophysics
Elective Courses (Any 3 from list)	▪ **BMSE 201B:** Chemistry & Structure of Nucleic Acids ▪ **BMSE 201C:** Biomembranes Structure & Function ▪ **BMSE 276A:** Biomolecular Materials I: Structure and Function ▪ **BMSE 276B:** Biomolecular Materials II	▪ **BMSE 201A:** Protein Structure and Function ▪ **BMSE 201B:** Chemistry & Structure of Nucleic Acids ▪ **BMSE 215:** Biophysical Thermodynnamics ▪ **BMSE 293:** Computational Methods Biochemistry & Molecular Biology	▪ **BMSE 215**:Biophysical Thermodynnamics ▪ **BMSE 217:** Electrostatics of Biopolymers ▪ **BMSE 250:** Bionanotechnology ▪ **BMSE 271:** Mechanical Force and Biomolecules





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Graduate Education & Training

1. A team based approach
2. Management, entrepreneurship, outreach

Team Research Approach

- CCBM graduate fellow + CREST undergrad scholar(s) + >2 PIs
- weekly team meetings
- monthly thrust meetings

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Graduate Education & Training

The IB3 graduate training emphasis
-Hands-on Training Modules

3 modules
2 week duration each during summer

Computation and Modeling, Colvin, June 5-16, 2017
Imaging/Spectroscopy, Muñoz, June 19-30, 2017
Nano/Bio Fabrication, Gadre, July 31-Aug. 11, 2017

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Spectroscopy and Imaging Workshop

- The workshop will cover training in basic spectroscopic-spectrometric methods to investigate biomolecules and optics based imaging methods (microscopy) to visualize macromolecular assemblies and living cells
- 2 weeks (5 hours/day)
- Problem oriented labs using standard molecular systems
- Access to UCM Instrumentation
- Data acquisition and analysis software
- Hands on training:
    - 1 hour lecture
    - 2 hours on instrument
    - 2 hours data analysis

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Spectroscopy and Imaging Workshop

Biomolecular Spectroscopy:

Protein Expression

Protein Purification by HPLC

Circular Dichroism

Fluorescence (quantum yield, lifetime, anisotropy, FRET)

Nuclear Magnetic Resonance (NMR)

Mass Spectrometry

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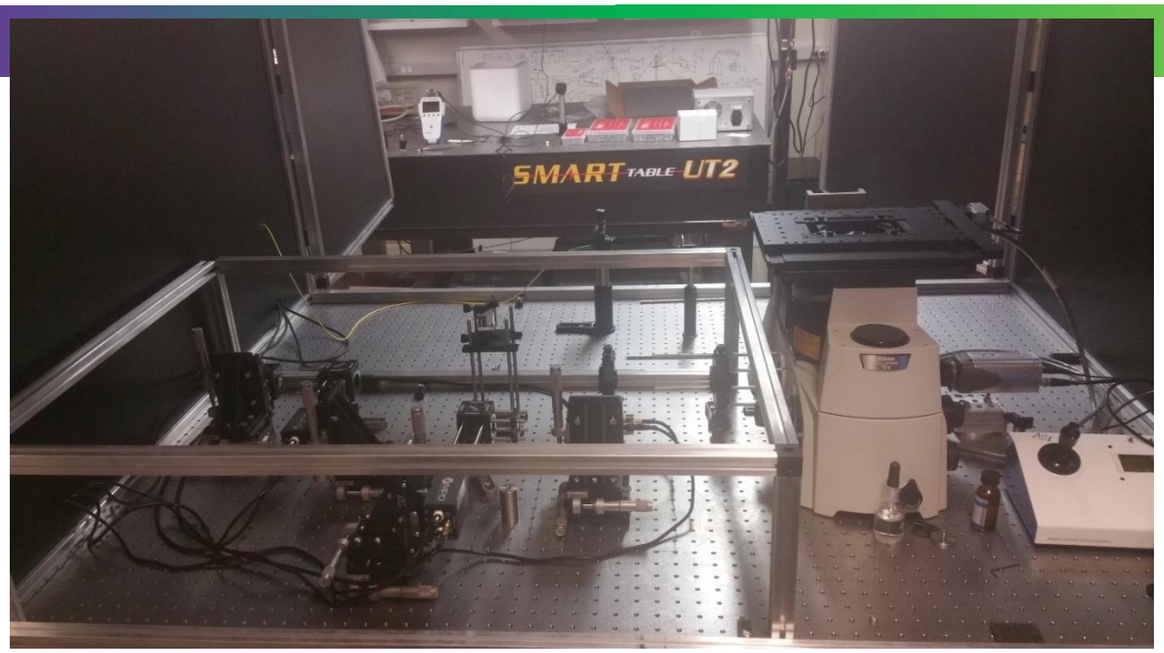
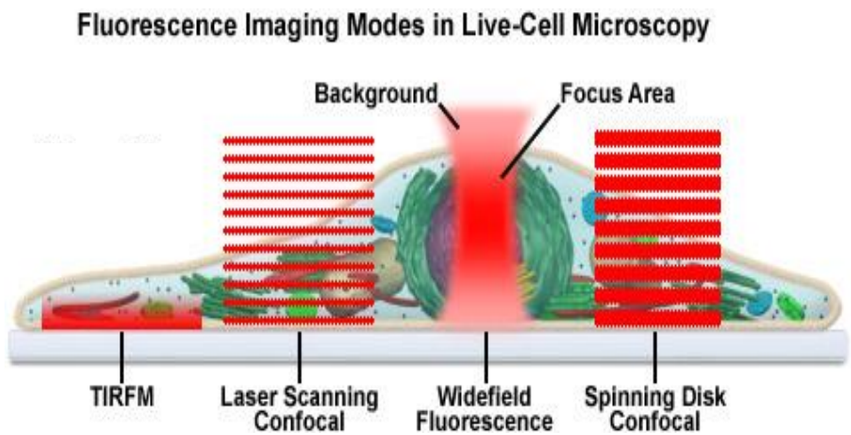
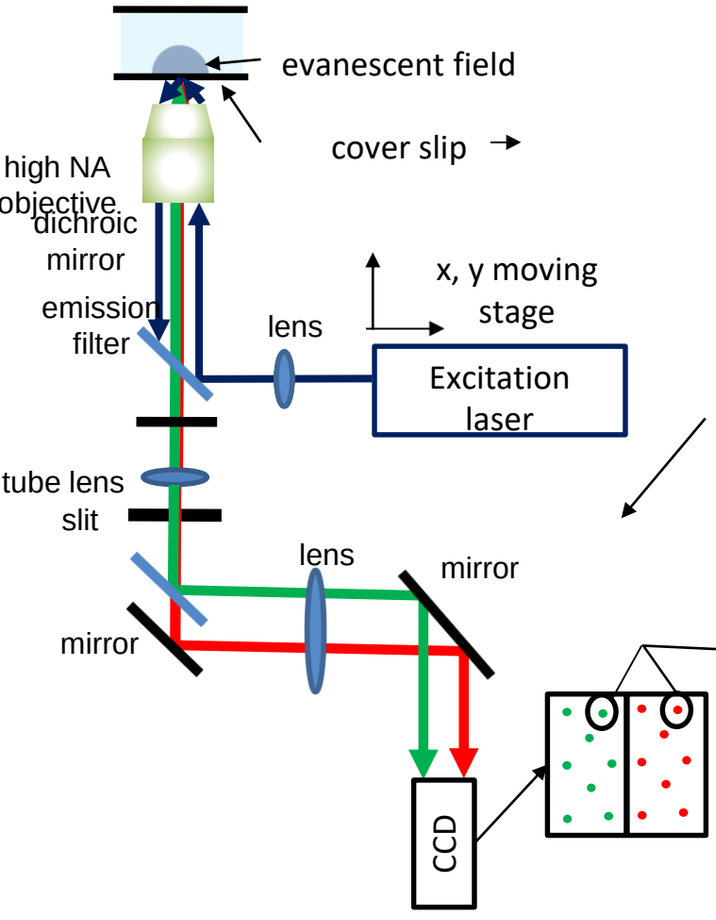
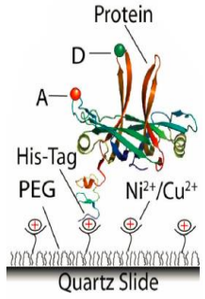
Spectroscopy and Imaging Workshop

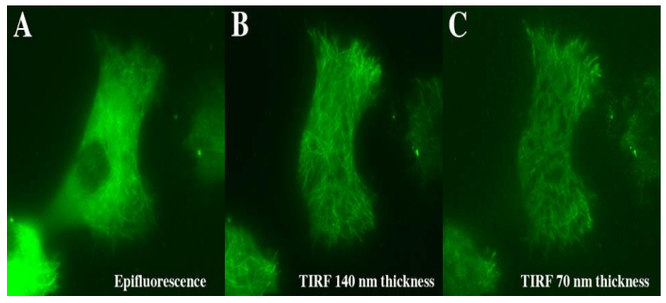


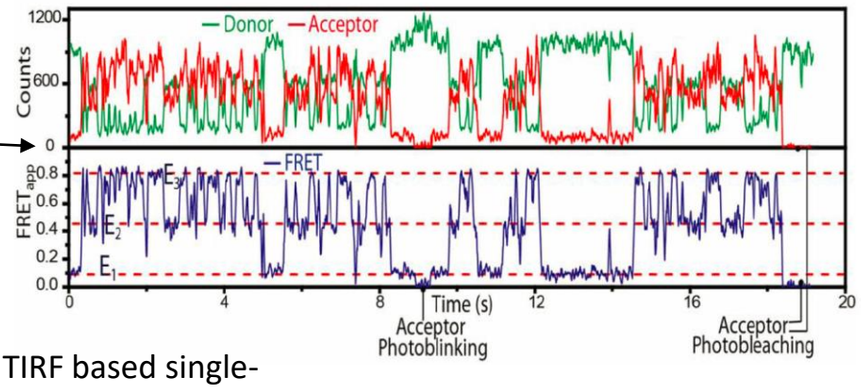
Microscopy and Imaging:











TIRF based single-molecule FRET

Single-Molecule Confocal Fluorescence Microscopy

Total Internal Reflection Fluorescence Microscopy

Fluorescence Lifetime Imaging Microscopy

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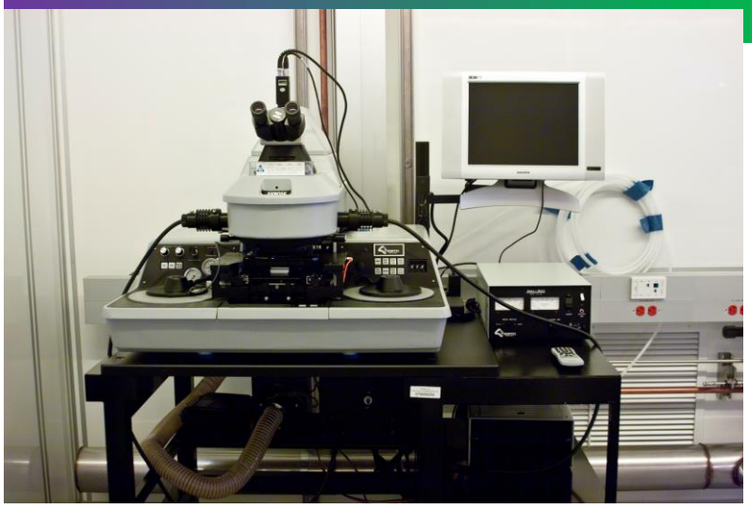
NanoBio Fabrication Workshop



- This workshop will be housed in the Stem Cell Instrumentation Foundry (SCIF).
- 2 weeks (4 hrs/day),
- Hands on training in Class 1000 and Class 100 Cleanrooms for graduate students
  - Micro/nanofabrication processing
  - Bacterial/cell/tissue culture techniques.
  - Instrumentation - related to photolithography, microfluidics, electrospinning, and cell culture experiments.
  - Equipment specific training
  - Virtual demonstrations to introduce the concepts of nanotechnology and cell/tissue culture work.

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Computation and Modeling Workshop

Goal: Basic proficiency with a range of scientific computing tools through exposure to hands-on examples

Format: Two weeks@6 hr per day in Linux computer lab

Part 1: Scientific computing "toolkit"

- Linux/BASH: Job control and data management
- R: Data analysis and statistical modeling
- Python: OO scientific simulations & data manipulation
- C: High speed simulations

scientific computing and classical molecular dynamics

Part 2: Molecular simulations

- Basic principles of classical MD
- Transport properties and EOS for Argon
- Mixtures: NaCl, PE in H_2O or C_6H_{12}, Micelles
- DNA and proteins: Effects of structural mutations

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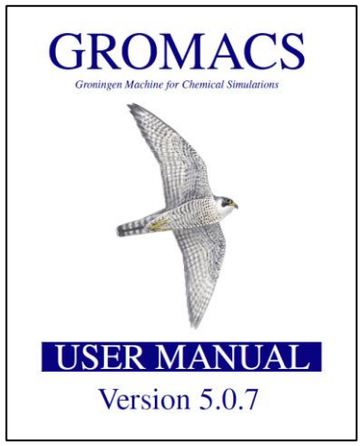
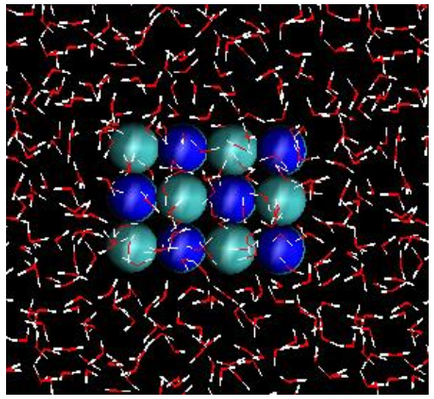
Computation and Modeling Workshop

Molecular dynamics demonstrating increasing more complex simulations

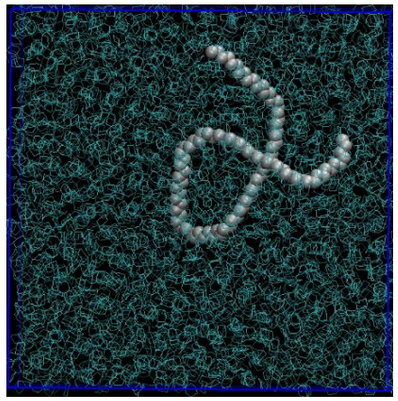
Labs taught using Gromacs & associated tools



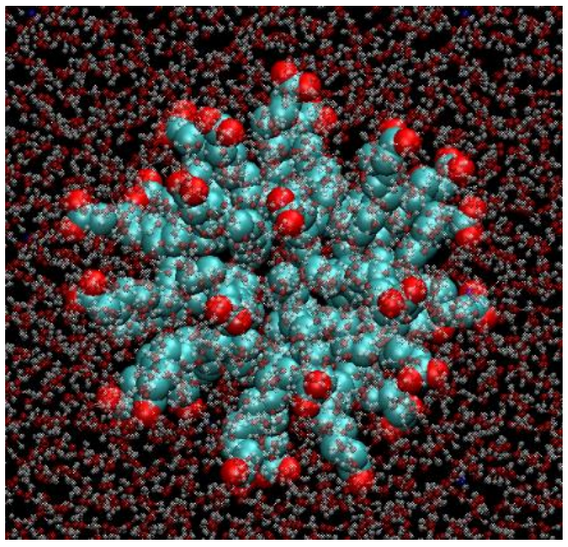
T dependence of salt dissolution



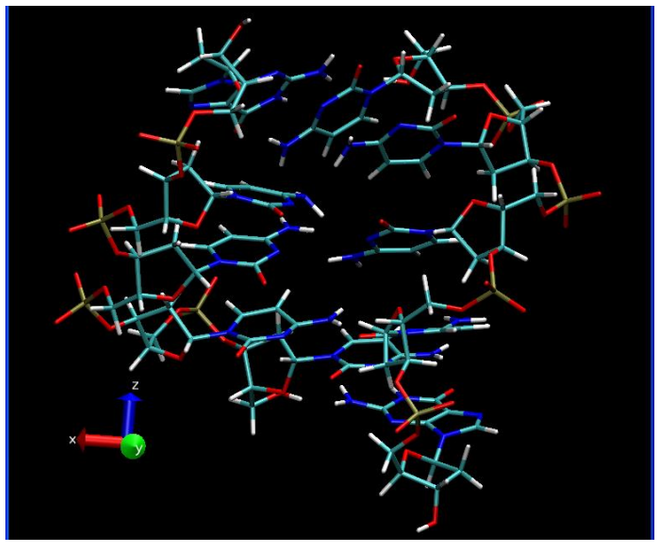
Polymers in good and bad solvents



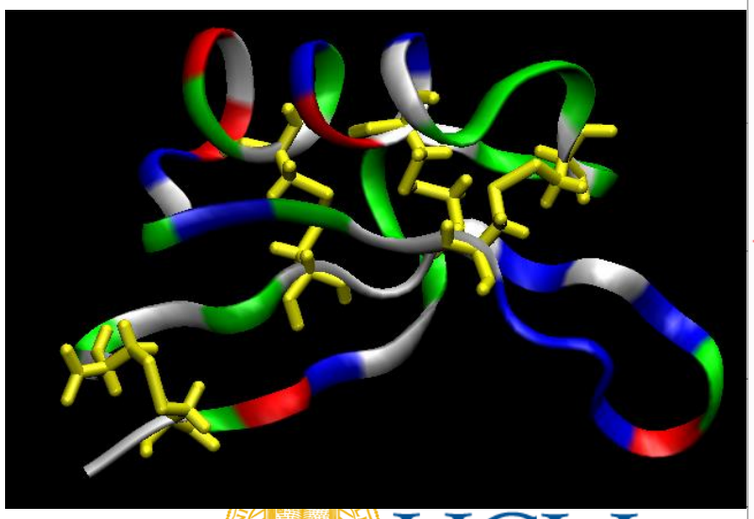
Simple micelle thermo-stability

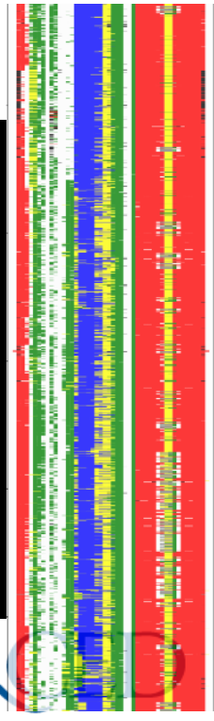


DNA Structural effects of single mismatches



Thermo-destabilizing mutations in proteins





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Undergraduate Education and Outreach

THE CALIFORNIA STATE UNIVERSITY
Vox Veritas Vita
1857

NSF

qb3
ucb·ucsc·ucsf

UCSB

BERKELEY LAB
Lawrence Berkeley National Laboratory

UC MERCED

http://ccbm.ucmerced.edu/

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CREST Scholars

- **Research with CREST faculty**
- **Introduction to graduate school and GRE preparation:** CREST mentor led workshop to be held once per semester
- **Enhanced student learning and community building:** Academic help on understanding specific math and science concepts through STEM resource center
- **Summer Internships:**

A. *NSF MRSEC REU @UCSB:* biophysical sciences, biomaterials and biotechnology
B. *California Institute for Quantitative Biosciences (QB3):* wide-range of entrepreneurial activities
C. *Molecular Foundry (Lawrence Berkeley National Lab, LBNL):* Science Undergraduate Laboratory Internship program

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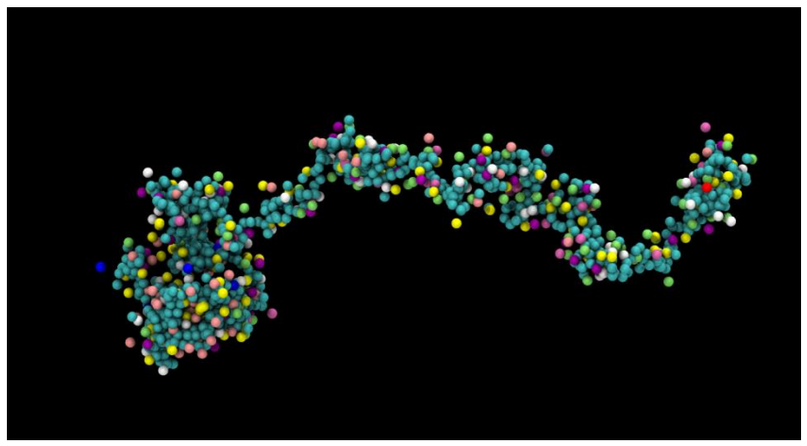
Undergraduate Research Fellowship Overview/C-SIP

- 9 week undergraduate research fellowship at the University of California, Merced
- June 4-August 5, 2017
- Research experience in biophysics, biochemistry & bioengineering
- Experimental learning & hands-on training on cutting edge research instrumentation
- Research & academic guidance and mentoring from CCBM faculty & graduate students

Create a STEM pipeline for our graduate programs and beyond



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Undergraduate Research Fellowship Overview/C-SIP

- $3000 stipend
- Free room and board provided on UC Merced campus
- $500 in expenses for off-campus participants
- Training expenses covered
- Rich professional development
- Faculty, graduate student, and peer networking
- Social activities
- Collaborations with the other university units, including UROC and STEM Resource Center

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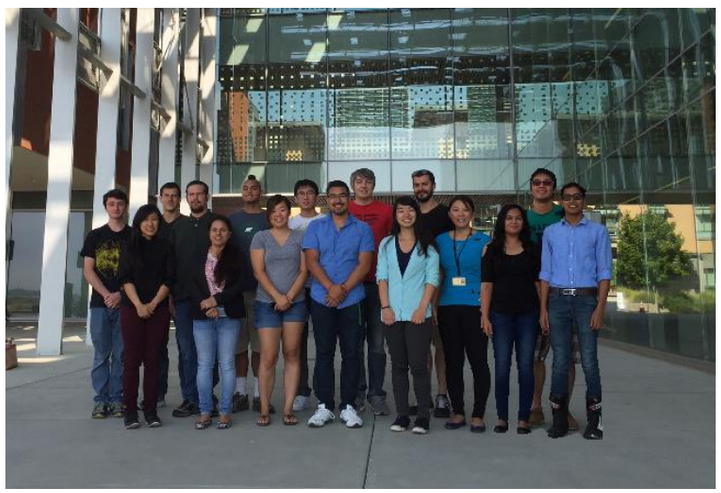
Undergraduate Research Fellowship Overview/C-SIP

NSF

- Special CCBM sessions, lectures, and meetings
- Undergraduate Research Opportunities Center (UROC) cohort
- Orientation, social events, Summer Research Symposium (presentation and poster)
- Trainings, including safety training
- Bootcamps (Matlab, Wetlab, more)
- Workshops



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Undergraduate Research Fellowship Overview/C-SIP

Workshop Topics:

1. Getting the Most Out of Your Research Experience
2. Graduate School Panel
3. CV Review
4. Graduate School Admissions
5. Abstract Review
6. Predoctoral Fellowships
7. Communicating and Presenting Your Research
8. Career Planning

Other Sessions:

- GRE preparation panel discussions
- Lab group meetings
- Training for oral presentation
- Poster presentation at a Summer Research Symposium

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Undergraduate Research Fellowship Overview/C-SIP

Application Deadline: February 28, 2017

--Applications may be considered after this date if space permits

--It is best to apply early, as we will begin to review applications before the application deadline (semi-rolling applications).

Prepare application materials:

1. Resume/CV
2. Unofficial transcript(s)
3. 300 word statement of research interests including thrust area preference (http://ccbm.ucmerced.edu/research.html)
4. Contact information of one reference

Eligibility:

- Full time undergraduate students with at least two semesters of college experience (GPA 3.0 or above)
- U.S. citizen, U.S. national, or permanent residency required to participate (due to NSF funding)

Please note:

- CSU and Merced College students strongly encouraged to apply
- Students from underrepresented minority groups, women, and students with disabilities strongly encouraged to apply

Email application as a combined PDF:
Carrie Kouadio, CCBM Executive Director ckouadio@ucmerced.edu

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Recruitment

Undergraduate recruitment

Strong culture of undergrad research, 2000+ S&E majors

- Faculty participation in SWE, ACS, APS… student chapters
- Freshman seminar series
- Tables at UC Merced Preview Day, CCBM open day

Graduate Recruitment

- CREST scholars
- CSU participants in CSIP program
- Other REU programs on campus
- participation in CSUPERB annual symposium
- publicizing at SACNAS, ABRCMS…

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E-scholars

- **Management undergraduate majors**
- Training to secure investment for STEM-centered start-up businesses
- UCM Office of Business Development (OBD) will provide mentoring
- Graduate students will:

a) serve as STEM mentors for the Management undergraduates, assisting and guiding them in selecting research projects for further development and helping them learn and understand the scientific principles behind them, and

b) will learn the basics of business development and market research via their interactions with the E-scholars

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STEP

- Enhance science curriculum in local high schools - develop educational modules
- Summer training workshop for HS teachers and 1-2 HS students
- Semester long module presentation in schools by CCBM fellows and faculty
- Research opportunities for high school students
- College application prep for high school students

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Timeline

Spring 16 -
CREST Fellowship and Scholarship nomination calls;
Coordination for delivery of Fall courses for IB3 emphasis with UCSB BMSE.
Research begins on all thrusts.
Searches for the two project scientists begin.

Summer 16 –
First visit of external advisory board. Selected CREST Fellows and Scholar teams enroll in thrusts.
Project scientists are interviewed and hired.

Fall 16 –
IB3 coursework begins.
Annual recruitment drives (SACNAS, ABRCMS, CSUPERB (Jan), CSUs).
Purchase and set-up of core facility instrumentation (LCMS and Bioreactor).

Spring 17 -
Hiring of Executive Director, Program Manager;
Prep for Annual Summer programs - STEP, E-Scholars, and C-SIP.
Coordination with MRL-UCSB, LBNL and QB3.
Prep for summer training modules

Summer 17 -
Summer training modules (6 week bootcamp).
STEP, E-scholar prep, C-SIP kickoff.

Fall 17 -
First annual symposium/open day.
Annual visits of External Advisory Board and evaluator to overlap with symposium.
CCBM Grad fellows continue with E-scholar teams/STEP program.
CCBM co-sponsored seminars begin.
Purchase and set-up of first set of HPC nodes (next set in F19).

Spring 18 - *At this point all elements of the center and activities have been implemented and will proceed as per plan.*

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Assessment/Evaluation

Internal and External Evaluation

Internal - SATAL

- pre-post course evaluations, administer surveys

External Evaluation

- *develop evaluation instruments; design surveys*
- review findings from surveys, interviews, website analytics, program records…
- monthly phone meetings, annual site visit, annual report

Activity	Sample Evaluation Questions	Possible Indicators (Outputs and Outcomes)	Data, Evaluation Methods
Graduate and Undergraduate Education and Training	Are students receiving high quality quantitative research training across disciplines that emphasize working in multi-disciplinary environments? Is the program building a pipeline to the graduate program, especially for underrepresented students? Are the E-Scholars and STEP programs enhancing students' educational experiences? Are PhD graduates securing employment in academia or industry?	Short-term: # of URM students participating Long-term: # of project-related collaborations, # of project-related publications, # of students placed in industry and academia, # of undergraduate students applying to graduate school in STEM E-scholars report they have knowledge to secure investment for STEM-centered start-ups and engage in start-ups; STEP participants report enhanced engagement with educational outreach Students report the program activities: • increased their interest in STEM fields and STEM careers including graduate school in a STEM field (including at UC Merced)	Pre-post course assessments (SATAL) Mentor assessment of participant progress (CREST Program) Annual surveys of faculty and students , Interviews/Focus groups (External Evaluator) Program records (Student Demographics, # of Collaborations, # of Publications, Course Grades, etc.)

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Center Requirements

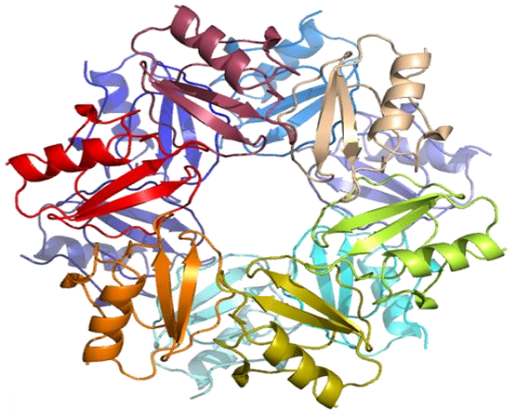
Reporting:

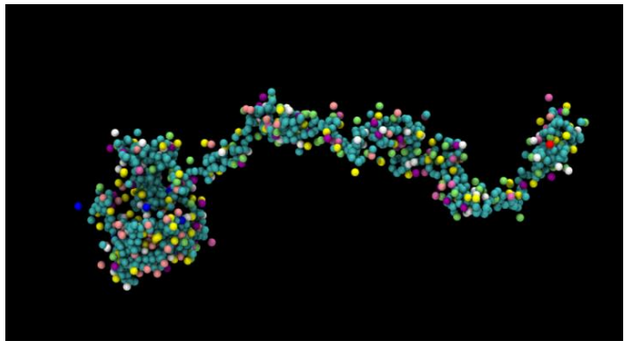
NSF Annual Report due March 31 each year

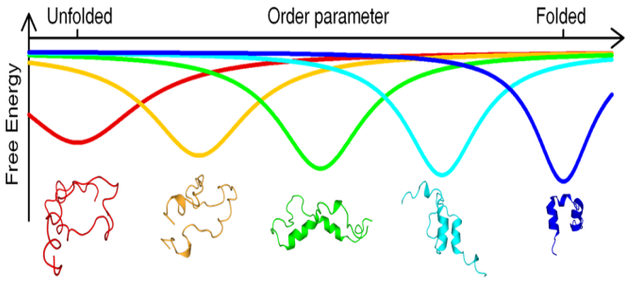
Visits to Washington, D.C./NSF:

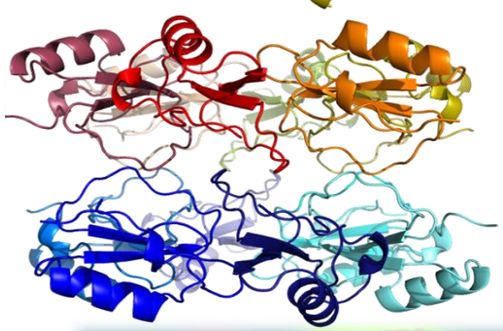
Reverse Site Visits

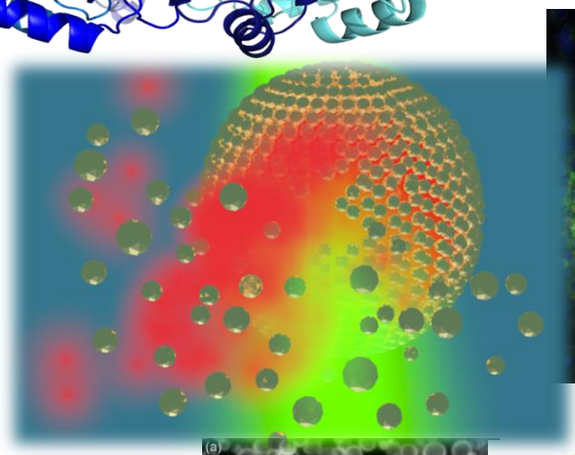
Annual CREST Meetings (March)

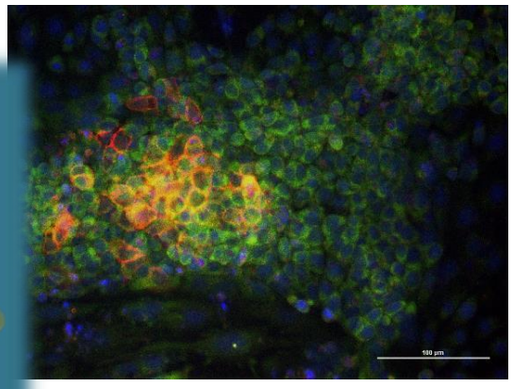


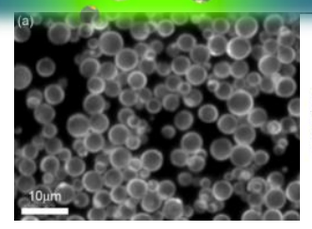


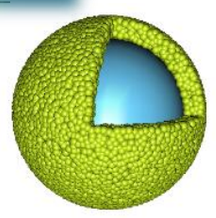


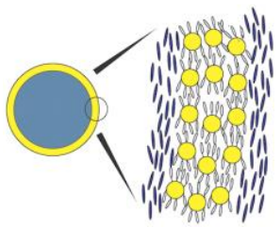












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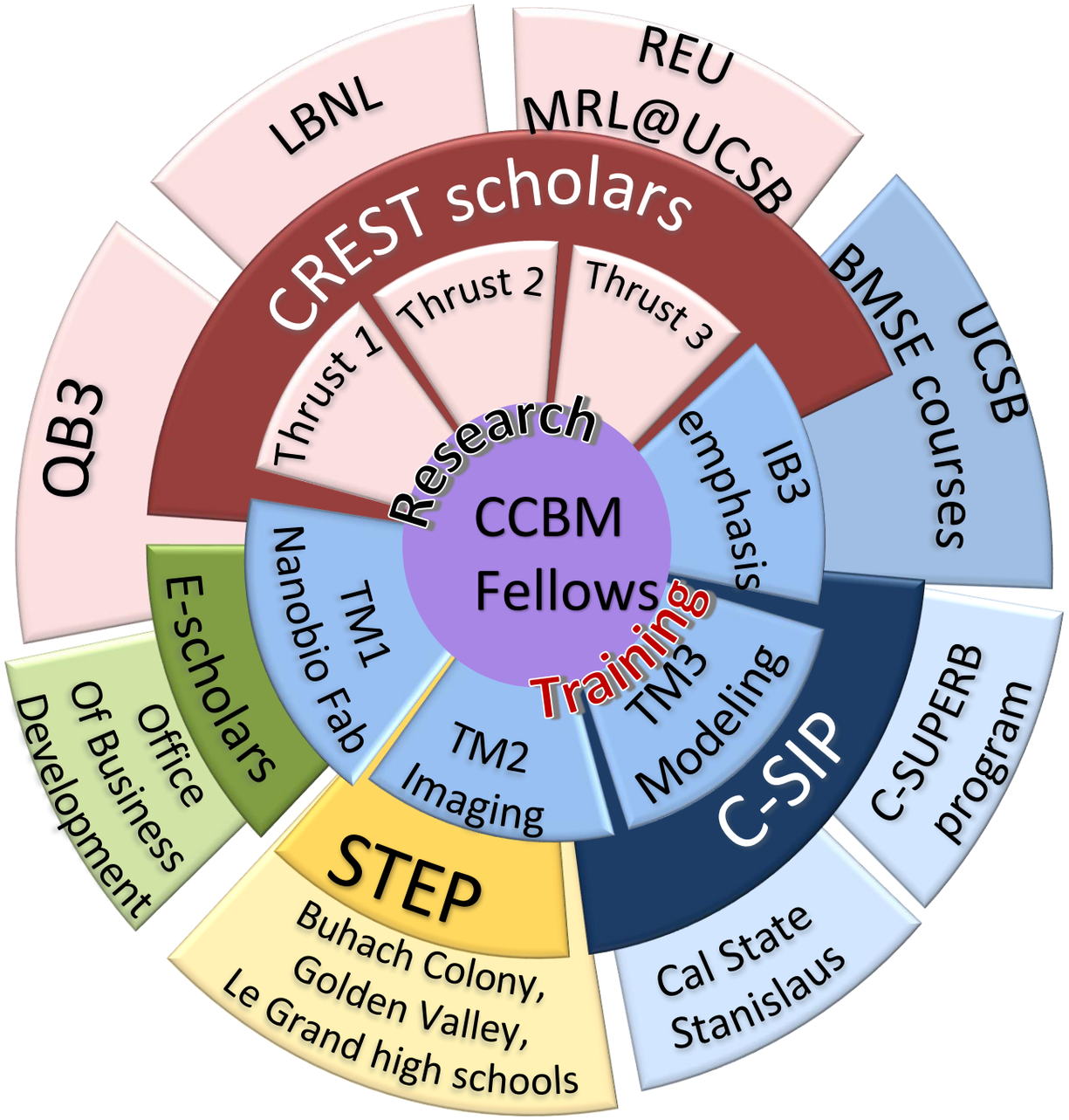
Other Opportunities



- Outreach events (April 11)
- External Advisory Board Meeting (August 21)
- Open House (September)
- Thrust Meetings
- News for website and announcements

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Questions?

Center Website

http://ccbm.ucmerced.edu

General Inquiries:

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ckouadio@ucmerced.edu

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