Bio-Nanotechnology: Challenges for trainees in a multidisciplinary research program

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University of California, Davis
NASA Ames Research Center
Where I came from

• Received a BS in chemistry from Santa Clara University
  – Traditional chemistry education
• Worked 3 years for the NASA Ames Center for Nanotechnology
  – Introduction to interdisciplinary research

Team: chemists, physicists, engineers, molecular biologists
Nanomaterials size lends them to biological investigations

Cell impalement and cell surgery

Site specific drug delivery

Carbon Nanofiber (CNF) Array Platform

Carbon Nanotube (CNT) AFM tip

AFM = atomic force microscope

Cell imaging

High resolution of membrane morphology

Silicon AFM Probe

Carbon Nanotube (CNT) AFM Probe
Skills acquired growth, characterization and functionalization of CNTs and CNFs

Koehne, J.; Chen, H.; Li, J.; Cassell, A.; Ye, Q.; Ng, H. T.; Han, J.; Meyyappan, M. Nanotechnology, 2003, 14, 1239-1245.
PC12 cells grown on CNF array

NASA Ames
Substrate preparation
CNT functionalization

UC Davis
3-D fluorescence characterization

Use AFM for:
1) High-resolution imaging
2) Three-dimensional imaging
3) Hydrated cell imaging

3 distinct bone marrow derived mast cells with varied membrane structure

Collaboration with CoVsystems
CNT AFM probes

High aspect ratio CNT probes with control over geometry, angle and length

CNT AFM probes for cellular imaging

<table>
<thead>
<tr>
<th>NASA</th>
<th>UC Davis</th>
<th>CoVsystems</th>
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<tbody>
<tr>
<td>Growth, characterization and functionalization of CNT/CNFs</td>
<td>High-resolution imaging of hydrated cells</td>
<td>Fabrication of CNT AFM imaging probes</td>
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Thesis became interdisciplinary out of necessity

Images represent the top surface of the same rat basophilic leukemia cell

Koehne, J. E.; Stevens, R.; Zink, T.; Liu, G. Y.
Interdisciplinary Programs at UC Davis

Definition: A group that gives students intellectual freedom to transcend disciplines and areas of research.

- **Interdisciplinary Departments**
  - UCD has 47
- **Programs, Centers and Institutes**
  - UCD has 57

Nanomaterials in the Environment, Agriculture and Technology (NEAT)

Northern California Nanotechnology Center (NCNC)
# How to participate in interdisciplinary research

<table>
<thead>
<tr>
<th>Interdisciplinary department</th>
<th>Standard core department</th>
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<tr>
<td><strong>Advantages</strong></td>
<td><strong>Advantages</strong></td>
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<tr>
<td>– Program is designed to</td>
<td>– Strong sense of</td>
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<tr>
<td>promote interdisciplinary</td>
<td>community</td>
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<tr>
<td>exposure and training</td>
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<tr>
<td>– University advisors are</td>
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<td>participating in</td>
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<tr>
<td>interdisciplinary</td>
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<td>research</td>
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<tr>
<td><strong>Disadvantages</strong></td>
<td><strong>Disadvantages</strong></td>
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<tr>
<td>– No centralized</td>
<td>– Student has to find</td>
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<tr>
<td>department</td>
<td>advisor who is</td>
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<tr>
<td>– Students can feel lack</td>
<td>participating in</td>
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<tr>
<td>of camaraderie with</td>
<td>interdisciplinary</td>
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<tr>
<td>fellow graduate</td>
<td>research</td>
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<tr>
<td>students</td>
<td>– Curriculum can be</td>
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<td>limiting</td>
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</table>
Outcomes of an interdisciplinary thesis

Challenges

• Large number of courses
• Longer thesis completion time
• Pulled between collaborators
• Lack depth of knowledge

Benefits

• Wide range skill set
• Well equipped for the 21st century
• Very employable
Recommendations to current educators

Embrace paradigm shift from multidisciplinary research as the minority to the majority

- Universities
  - Develop interdisciplinary departments and programs
  - Encourage faculty participation
  - Provide university wide interdisciplinary conferences

- Departments
  - Encourage cross department collaborations
  - Encourage participation in interdisciplinary departments and programs
  - Allowance for more cross discipline curriculum
Conclusions

• Interdisciplinary thesis is formed out of necessity to answer complex problems

• Interdisciplinary research is fostered by interdisciplinary departments and groups, centers and institutes

• Graduate students may face additional obstacles, but will be prepared for research of the 21st century

• Universities and departments can utilize interdisciplinary departments and groups, centers and institutes to foster graduate education
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