The Art and Craft of Team Science

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Presentation Overview

- Experience in Team Science (TS)
- What TS is and what it is not?
- What's driving TS?
- The gentle yet firm touch of nuanced TS leadership — managing, motivating and inspiring individuals toward a common goal.
- Is TS appropriate for graduate students, postdoctoral fellows and assistant professors
- How we identified collaborators and built TS networks
- How we identified and foster effective lines of communication (in the context of different interdisciplinary languages)

Past Team Science Experience

- **R Rodriguez** Team Science Experience
  - DARPA — Human Butyrylcholinesterase in Plants
  - Global HeathShare Initiative
  - Center of Excellence in Nutritional Genomics
  - Ventria Bioscience Inc.
  - International Rice Genome Organization
  - Co-instructor for MCB263, Instructor for Molecular Biology and Biotechnology Design Methodology
- **K McDonald** Team Science Experience
  - DARPA — Human Butyrylcholinesterase in Plants
  - CREATE IGERT Graduate Training Grant in Plant Biotechnology
  - NSF I-Corps Program
  - NSF Large Interdisciplinary Award, Chevron Grant, and NSF with focus on Plant Production of Cellulase Enzymes
  - Co-instructor for MCB263, Instructor for Biochemical Engineering Capstone Design Course

What TS is and what it is not?

- Team Science is not just a multi-investigator agreement to research the same problem or question (i.e., typical collaboration)
- It is not just interdisciplinary research
- It is not distributed effort on different workpackages to solve the same problem (i.e., distributed computing)
- Team Science is a "***transdisciplinary***" approach to solving complex problems that integrates and aligns expertise and technologies around a shared vision with common expectations.

Factors Driving Team Science

- Complexity (complex, not complicated problems)
- Translational research
- Tenuous funding environment
- Open access to Internet and cloud-based datasets
- Connectedness
- Globalization
- Need for synergistic and highly non-linear results

Case Study in Team Science

Expression of Recombinant Human Butyrylcholinesterase in *Nicotiana benthamiana* and its Postproduction *in-vitro* Glycan Redecoration

University of California at Davis Colleges of:

Biological Sciences

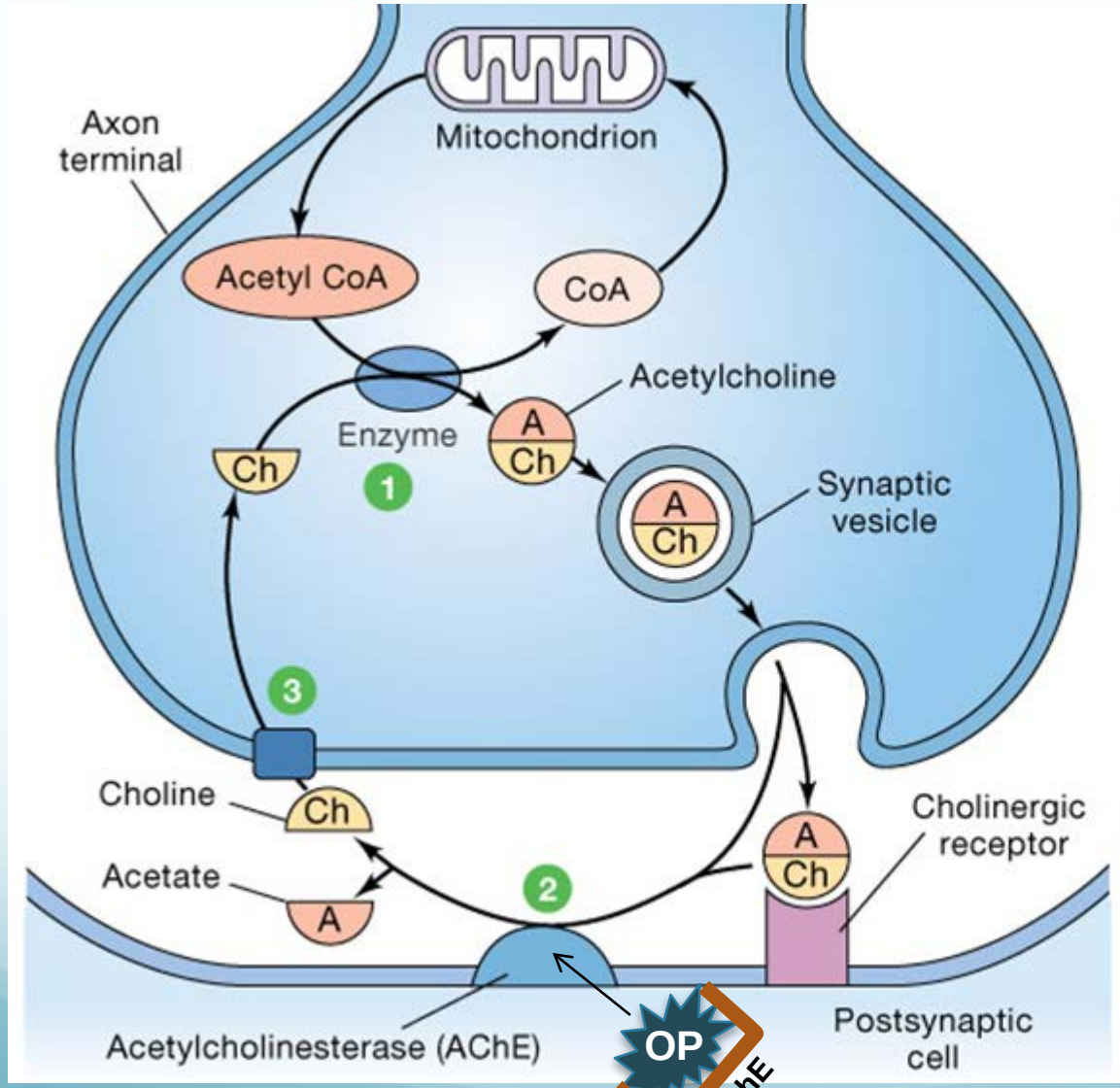
Engineering

Letters and Science

Agriculture and Environmental Sciences

Syria, August 21, 2013

BuChE as Bioscavanger



1. **Acetylcholine** (ACh) is made from choline and acetyl CoA.
2. In the synaptic cleft ACh is rapidly broken down by the enzyme **acetylcholinesterase.**
3. Choline is transported back into the axon terminal and is used to make more ACh.

DARPA Butyrylcholinesterase Project

- Goal: To make recombinant BuChE in plants, purify it and use *in vitro* enzymatic methods to modify the glycosylation to generate sialylated glycoforms
- Challenges:
  - Time: 12 month project, milestone oriented
  - Reporting: Monthly telecons with sponsor, quarterly reports, final report
  - Resources: budget reduction – cut one team member and reduced budgets of others, logistics for spending funds
  - Project coordination and communication: 7 faculty from 4 colleges, 2 graduate students, 3 postdocs,3 research staff members, and 1 undergraduate

Investigator Team and Workflow by Task

1

rBuChE gene design and synthesis

2a

rBuChE gene constructs

2b

rBuChE (KDEL) gene constructs

3

Cloning into agrobacterium expression vectors

4

Transient production of rBuChE in N. benthamiana

5

rBuChE purification and characterization

6

rBuChE glycoform analysis

Clone/Express glyco-modifying enzymes

7

8

In vitro glycan modification

Post-production glycoform and product characterization

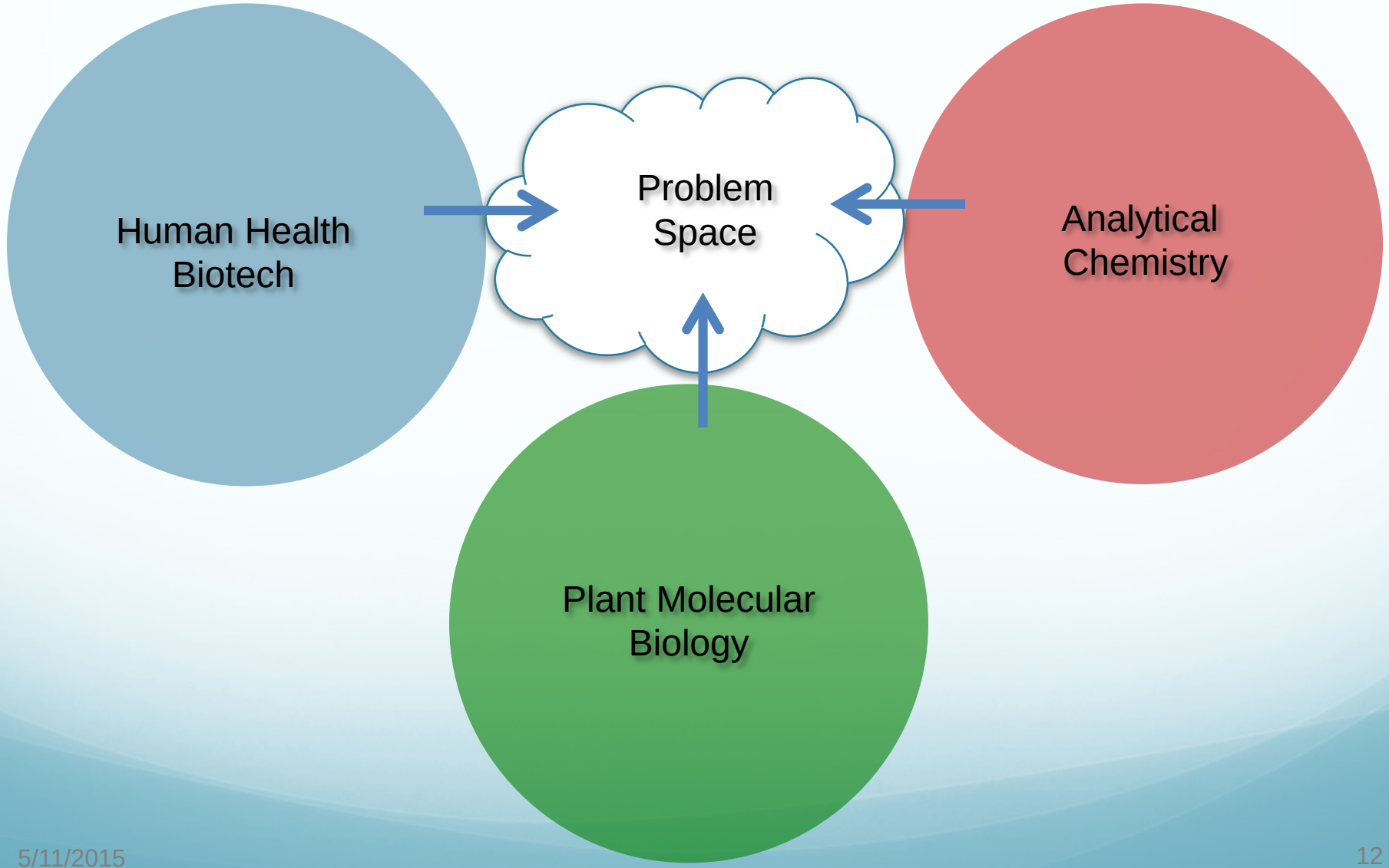
9

Sialylated rBuChE

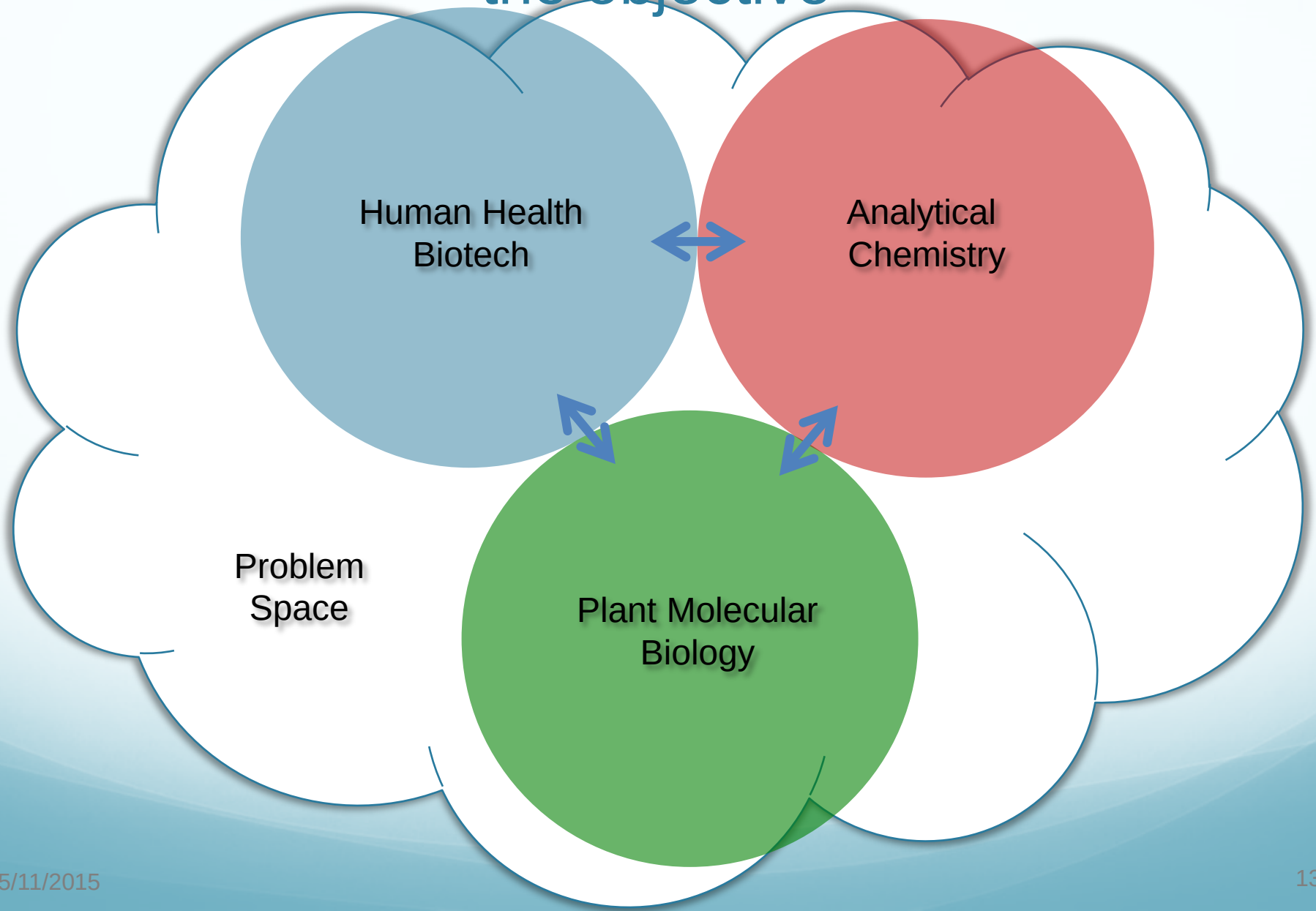
Three Steps from Multidisciplinary to Transdisciplinary (Team)Science

knowing, planning, sharing

Step 1: Knowing and understanding the problem and opportunities



Step 2: Planning innovative ways to accomplish the objective



Step 3: Aligning technology and expertise around a shared vision and expectations

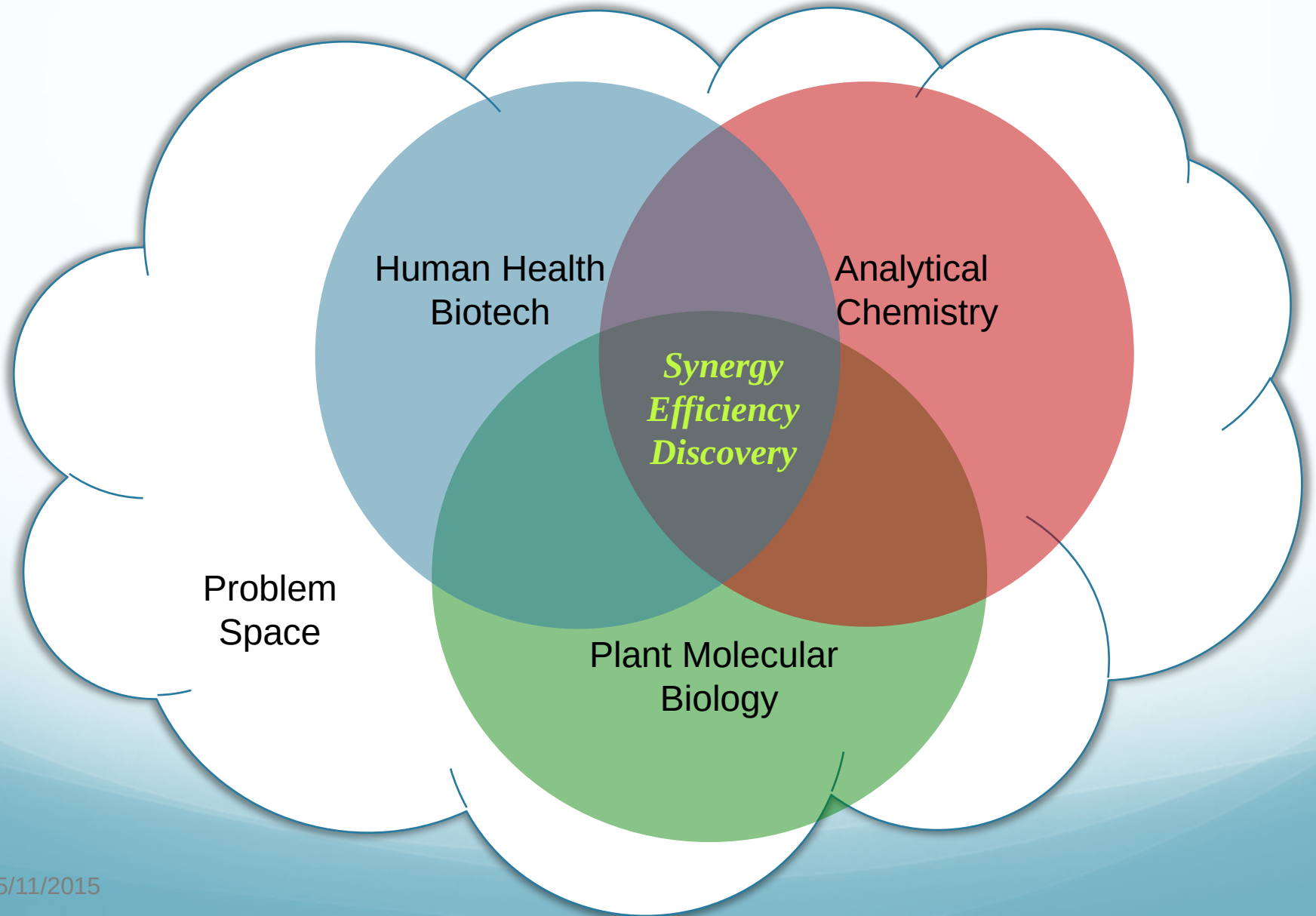
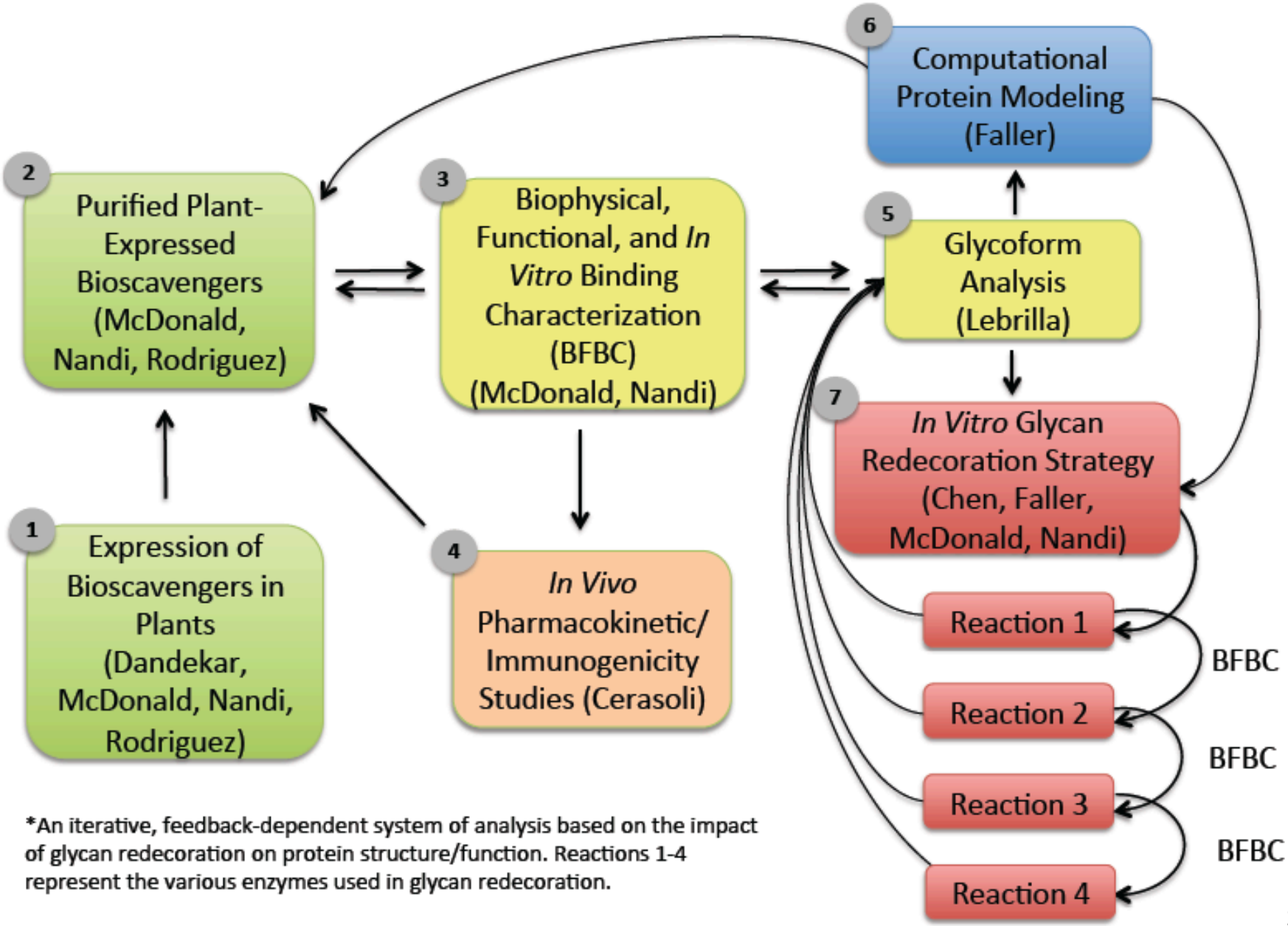


Figure A. Schematic of Bioscavanger Structure/Function Analysis*



*An iterative, feedback-dependent system of analysis based on the impact of glycan redecoration on protein structure/function. Reactions 1-4 represent the various enzymes used in glycan redecoration.

Team Science does not happen spontaneously or come easily!

Fact and Fiction of Team Science Leadership

- Fiction: Collaboration = Consensus
  - “In order for us to effectively collaborate we must always be in full agreement with each other to take action.”
  - My needs are opinions are equal to everyone else on the team.
  - “When we collaborate with each other, there has to be an abdication of leadership and decision-making authority is handed over to the group.”
- Fact: Collaboration ≠ Consensus
  - Effective TS does not require 100% agreement
  - Effective TS does requires visionary leadership that is flexible, fair and competent
  - Effective TS has goals that transcend individual needs, ambitions and affiliations

Three Common Styles of Team Leadership

- Command and Control:
  - Emphasis on speed and strict adherence to standard operating procedures (SOPs)
- Consensus:
  - All members have equal authority. Emphasis is on buy-in (getting members to share relevant knowledge for the greater good) not on speed or quality
- Collaborative:
  - Found in dispersed cross-functional networks where designated team or project leaders have decision making authority. Emphasis on information sharing, discovery and quality over speed.

Nuanced TS Leadership is a Mixture of Leadership Styles

- Command and Control:
  - Ability to make difficult resource decision and mid-course adjustments to the project
  - Ability to meet milestones and deadlines
- Consensus Leadership
  - Ability to achieve buy-in from members who already have productive and well-funded research programs
  - Encourages feedback and self-evaluation
- Collaborative Leadership
  - Ability to bring the best minds and highly specialized technologies to bear on difficult, complex problems

Assigning Responsibilities

Subtask #	Task	Team Members	Time line										
			Aug 2012	Sept 2012	Oct 2012	Nov 2012	Dec 2012	Jan 2013	Feb 2013	Mar 2013	Apr 2013	May 2013	Jun 2013	Jul 2013
0	Start growing *N. benth*	BF	X	X	X	X	X	X	X	X	X	X	X	
1	Produce and purify plant-made AAT for practice	KM, SN, SA	X	X										
2	Gene and vector design	KM, SN, MP, AD, BF, MH	X	X										
3	Gene and Vector synthesis (outside)	AD		X	X									
4	Expression vector construction and confirmation	AD, BF, MH, MP			X	X								
5	Generation of recombinant agrobacteria	AD, BF, MH, MP				X								
6	rBuChE expression and activity verified in crude extracts	KM, SN, SA, MH, AT				X	X	X	X	X	X	X	X	
7	Production and purification (including purification process development) of functional rBuChE at µg level for initial characterization and *in vitro* modification, ultimately produce and purify 1 - 2 mg	KM, SN, CL, RLR, AG, SA, AT				X	X	X	X	X	X	X	X	
8	Basic biochemical analysis (PAGE, Western, MW, amino acid sequencing, CD, MS, HPLC profile) (outside)	CL, SN, AT						X	X	X	X	X	X	
9	Basic glycan characterizations of rBuChE before in vitro modification and hBuChE for comparison*	CL, AG			X	X	X	X	X	X	X	X	X	
10	Synthesize and clone genes for recombinant enzyme	XC, YL	X	X	X	X	X	X						
11	Demonstration of ability to replace and add galactose and sialic acid residues to rBuChE glycans at mg scale	XC, YL, CL, AG				X	X	X	X	X	X	X	X	X
12	Demonstration of homogeneous sialylated glycoforms	XC, YL, CL, AG								X	X	X	X	X

BF: Bryce Falk; AD: Abhaya Dandekar; CL: Carlito Lebrilla; XC: Xi Chen; RLR: Ray Rodriguez; KM: Karen McDonald; SN: Somen Nandi; SA: Salem Al-Kanaimsh; MY: My Phu; AG: Andres Guerrero; AT: Aye Tu; YL: Yanhong Li; MH: MinSook Hwang

Is TS Appropriate for Graduate Students, Postdoctorals and Junior Faculty?

TS and Career Development

- Independence:
  - TS participation can make it difficult to develop one's reputation as a independent investigator.
  - Multi-author publications, even in high-impact journals, can obscure ones contribute to the project.
  - Establishing one's creativity, originality and independence is essential for career advancement. This should be a concern for the TS leader.
- Authorship:
  - Assigning authorship can be challenging because the regular criteria for this process is complicated by TS dynamics
- Benefits of TS:
  - Participation in a TS project can be a rewarding and life changing experience, if managed properly. Excellent opportunity to network and interact with science leaders on problems of great importance.

Building a Team and Team Communication

Professor Karen McDonald

Identifying Collaborators and Building a Team

- TRANSDISCIPLINARY RESEARCH TEAMS

Desirable Attributes

- Essential and complementary expertise
- Passion (and time) for the project
- Good person – someone you want to be around and enjoy bouncing ideas off of
- Good teacher – someone who will spend time explaining things to you
- Good listener - provides constructive criticisms/critiques
- Contributor
- Upbeat/optimistic
- Sense of humor
- Moderate ego – team player

Methods

- Network, network, network
- Sit in on classes outside of your area
- Seminars/seminar visitors
- Funding opportunities – grant proposal writing

DARPA Butyrylcholinesterase Project

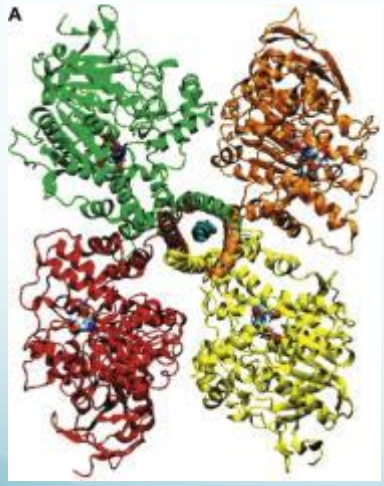
- Organophosphorus nerve agents (OPs) are considered to be likely weapons for use both in military and terrorist attacks
- OPs are relatively easy to produce in quantity, and can effectively be used to inflict harm

Selected "Performers"

UC DAVIS
UNIVERSITY OF CALIFORNIA

Plant Form

KBP
KENTUCKY BIOPROCESSING



- Human butyrylcholinesterase is an effective prophylactic bioscavenger **but**
  - Stoichometric binding 1:1 requires **large doses** (400mg)
  - **High cost** from donated plasma ($10,000/dose)
  - **Complex protein** – 340kDa tetramer, highly glycosylated
  - Recombinant versions to date lack human-like glycosylation and have **reduced circulatory half life**

DARPA Butyrylcholinesterase Project

- Positive outcomes:
  - Tremendous learning experience
  - Contribution to science and an important problem - demonstrated in vitro enzymatic sialylation of plant made BuChE
  - New proposals and follow on projects with other sponsors
  - Expansion of team to include computational expertise
  - Joint posters and publications
  - Incorporation into undergraduate teaching

NSF Integrative Graduate Education and Research Traineeship (IGERT)

"The IGERT program has been developed to meet the challenges of educating U.S. Ph.D. scientists and engineers who will pursue careers in research and education, with the interdisciplinary backgrounds, deep knowledge in chosen disciplines, and technical, professional, and personal skills to become, in their own careers, leaders and creative agents for change.

The program is intended to catalyze a cultural change in graduate education, for students, faculty, and institutions, by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries. It is also intended to facilitate diversity in student participation and preparation, and to contribute to a world-class, broadly inclusive, and globally engaged science and engineering workforce."

NSF Program Synopsis

Identifying Collaborators and Building a Team

- TRANSDISCIPLINARY GRADUATE TRAINING TEAMS

Additional Desirable Attributes

- Good mentors
- Good funding record
- Champion of diversity, inclusiveness
- Selflessness
- Responsiveness/persistence
- Strategic partners off campus

Methods

- Start with a small group (PI/Co-PIs) to develop vision, define theme and develop ideas for training components
- Share vision with broader group of faculty to gauge interest, refine ideas, recruit trainers
- Utilize expertise of Research Development staff!!
- Talk to graduate students, post-docs and other faculty
- Identify faculty who give their time to graduate program activities
- Develop networks off campus with other academics and industry

February 2004
Initiated Proposal Development

April 2004
Preliminary Proposal #1 Submitted

July 2004
Invited!!

August 2004
Seven UCD preproposals invited – only 3 allowed

Sept 2004
Selected to go forward

October 2004
Full Proposal #1 Submitted

February 2005
Preliminary Proposal #2 Submitted

March 2005
Full Proposal #1 Reviews

May 2005
Invited!!

June 2005
Four UCD preproposals invited

June 2005
Selected to go forward

August 2005
Full Proposal #2 Submitted

June 2006
Invited!!

March 2006
Preliminary Proposal #3 Submitted

February 2006
Limited Submission Preproposals Due

February 2006
Full Proposal #2 Reviews

February 2006
Selected to go forward

Sept 2006
Full Proposal #3 Submitted

August 2007
Awarded!!!

The importance of persistence!!!!

CREATE

IGERT

COLLABORATIVE RESEARCH & EDUCATION IN AGRICULTURAL TECHNOLOGIES & ENGINEERING

A multi-institutional IGERT with an international component:

Tuskegee University

University of California at Davis

National University of Ireland, Maynooth

Teagasc Oak Park Research Center, Carlow

University College Dublin

National University of Ireland, Galway

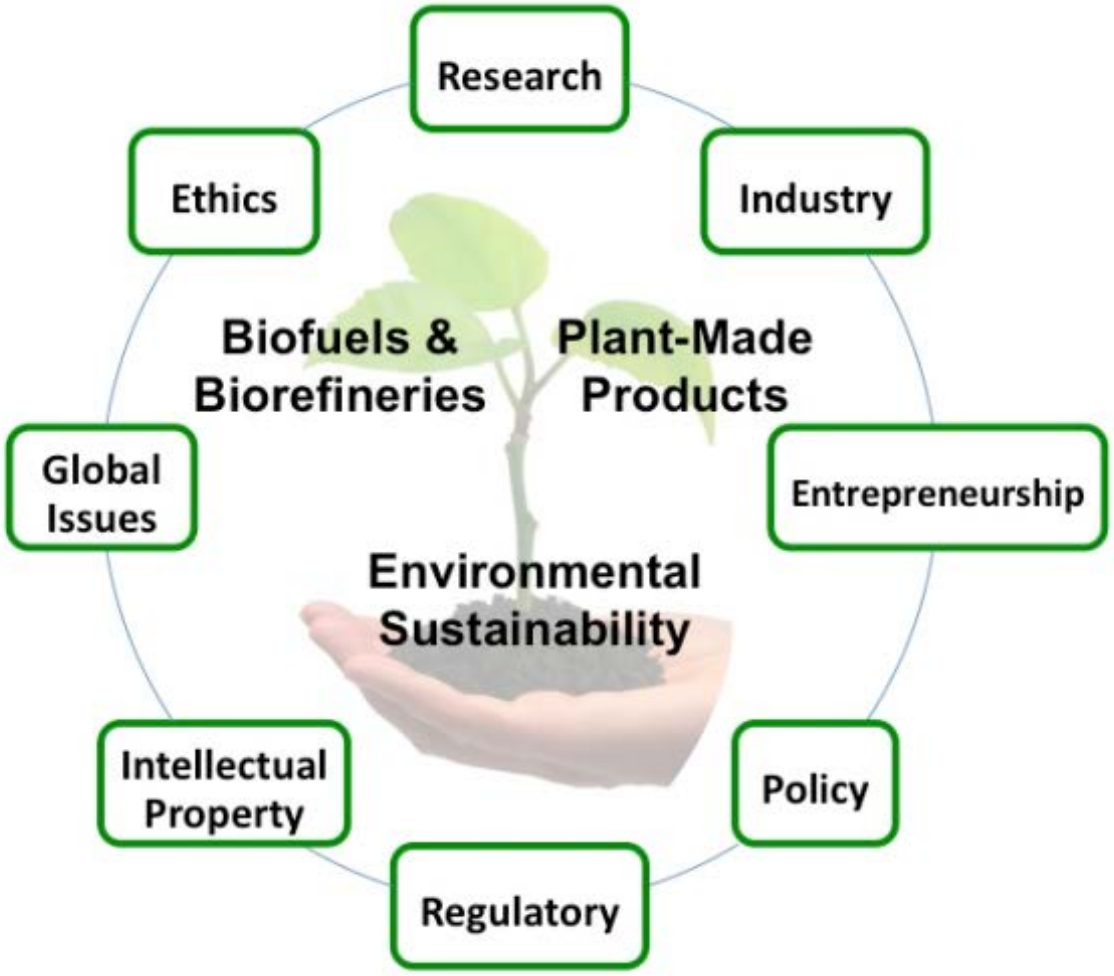
CREATE

IGERT

COLLABORATIVE RESEARCH & EDUCATION IN AGRICULTURAL TECHNOLOGIES & ENGINEERING

The CREATE-IGERT graduate training program integrates:

- Plant sciences
- Cellular and molecular biology
- Engineering



Funded 27 students at UCD and TU over the past 6 years!

CREATE-IGERT Faculty Trainers

34 faculty trainers from 7 colleges/schools

Biological and Agricultural Engineering (Engineering)
- Julia Fan
- Tina Jeoh
- Bryan Jenkins
- Jean VanderGheynst

Biomedical Engineering (Engineering)
- Michael Savageau

Chemistry (MPS)
- Carlito Lebrilla

Chemical Engineering and Materials Science (Engineering)
- Karen McDonald

Food Science and Technology (CAES)
- Bruce German
- Nitin Nitin
- Sharon Shoemaker

Integrative Biosciences (TU)
- Clayton Yates
- C. S. Prakash
- Jesse Jaynes
- Marcia Martinez
- Marceline Egnin
- Ramble Ankumah

Medical Microbiology and Immunology (Med)
- Satya Dandekar

Microbiology (CBS)
- Rebecca Parales

Molecular and Cellular Biology (CBS)
- Ray Rodriguez

Pathology, Microbiology and Immunology (Vet Med)
- Tilahun Yilma

Plant Biology (CBS)
- Katie Dehesh
- John Labavitch
- Clark Lagarias
- Bo Liu
- Steve Theg

Plant Pathology (CAES)
- Gitta Coaker
- Bryce Falk
- Martina Newell-McGloughlin
- Pam Ronald

Plant Sciences (CAES)
- Dianne Beckles
- Eduardo Blumwald
- Abhaya Dandekar
- Daniel Kliebenstein
- Richard Michelmore
- David Neale
- John Yoder

CREATE

IGERT

COLLABORATIVE RESEARCH & EDUCATION IN AGRICULTURAL TECHNOLOGIES & ENGINEERING

CREATE-IGERT aims to train PhD students in these **integrative skill sets**:

1) Desire and ability to work in **interdisciplinary research teams.**
2) Frequent and **effective communication** between research team members.
3) Establishment of a **common ground** (a common set of scientific principles and laboratory skills to build upon).
4) **Deep knowledge** in one's own field coupled with **broad exposure** in related areas.
5) A commitment to **teach others** outside one's field as well as a desire to **learn from others** outside of their field.
6) **Creativity** and "out of the box" thinking.
7) **Ethical and responsible conduct** in research, development and business.
8) An understanding of the **global impact**, as well as different needs and/or perspectives on the technology in different parts of the world.

Contributors

- Guest Lectures
- Seminars/Workshops
- Equipment Donations
- Plant Tours
- Internships
- Grant Applications
- External Advisory Board
- Research Funding

NOMAD

CREATE IGERT Project

- **Goals:**

1) Develop a framework for interdisciplinary graduate training at the interface of plant science, biotechnology, and engineering

2) leading to new scientific knowledge to move the fields of biofuels/biorefineries, plant-made products and environmental sustainability,

3) attract, recruit, retain and graduate a diverse cohort of doctoral students,

4) cultivate the integrative skill set in graduate students as well as faculty trainers.

- Challenges:
  - Project coordination particularly with international and university partners
  - Unrealistic expectations for international internships
  - Varying levels of faculty participation in training activities

CREATE IGERT Project

Highlights:

- New joint research projects among trainers, co-supervised students
- Interdisciplinary training helped students achieve diverse career goals (faculty positions, AAAS fellowship in plant biotechnology regulatory policy, industry positions, entrepreneur)
- Many new extramural projects have been funded (NSF, DARPA, NSF REU, NSF GK-12) and subteams continue to write joint proposals (STC, ERC, PFI, REU, DOE, USDA, NSF)
- Industrial internships continue (required by DEB at UCD and IBS at TU) as well as joint proposals with industry colleagues, TU and international partners

Team Communication: DARPA Project

- TRANSDISCIPLINARY RESEARCH TEAMS

Project management related: within the team

- Smartsite: Web based data repository, documents, mailtool, calendar
- Monthly meetings prior to telecon and then after telecon, weekly subgroup meetings
- Gantt chart updates
- Email

Project management related: outside of the team

- Single point of communication with sponsor
- Group presentations
- Coordinated requests

Team Communication: IGERT

- TRANSDISCIPLINARY GRADUATE TRAINING TEAMS

Project management related: within the team

- Smartsite: Web based data repository, documents, mailtool, calendar
- Website
- Listserves/Email
- New trainee orientation, meeting prior to annual reporting
- Annual retreat and Distinguished Lecture
- Mid-project “Self Study Report”

Major challenge – keeping all participants, stakeholders, international partners up to date

Toolbox Session with IGERT Team

Michigan State University, University of Idaho,

Boise State University,
University of Alaska, Anchorage & the National Science Foundation

http://www.cals.uidaho.edu/toolbox/index.asp

- **A workshop and survey tool to help researchers in a team comprised of members from different disciplines to understand differences in the way they approach science, what they value, what they think is important, etc.**

Toolbox Experience

- Interdisciplinary team comprised of 2 PhD students (Immunology and Chemical Engineering), Postdoc (Bio and Ag. Engr) and Faculty Member (Engineering)
- Goal: Increase self awareness and mutual understanding about participant's assumptions, expectations and values related to scientific research
- Methodology: Pre-questionnaire, facilitated discussion of responses, post-questionnaire
- Deliverables: Toolbox Profile, a collection of documents that serves as a record of the workshop experience including pre and post-questionnaire responses, transcript of discussion, facilitator observations and personalized list of references

Toolbox Findings

- Identified fundamental differences between the way research is conducted in different fields - value and importance of
  - Clearly stated hypotheses
  - Quantitative vs qualitative studies
  - Basic versus fundamental versus applied research
- “We had not really discussed these issues in the past but just forged ahead on our project”
- “For collaboration to work well, everyone must get something out of it and it helps to know what they think is important, worthwhile, and of value to their career.”

Summary

- Team science is an emerging trend for solving complex, multivariate problems that require diverse skillsets, knowledge and technologies.
- Successful TS project are characterized by:
  - Clearly defined objectives, goals and milestones
  - Goals that transcend individual needs, ambitions and affiliation
  - A project manager with broad technical knowledge and managerial skills (a skilled accounts manager is also good).
  - Nuanced leadership that provides vision, promotes buy-in from all stakeholders, encourages feedback and is capable of making hard decisions.
  - Leaders with integrity, communication and motivational skills and the use of consensus leadership to engage all stakeholders