

Undergraduate Research: Models for Student Success

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1. Department of Biomedical Sciences

2. Council for Undergraduate Research, Health
Sciences Councilor



What is Undergraduate Research?

- An inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline
 - National Science Foundation, 2003

Boyer Commission - 1998

- Ernest L. Boyer, President of the Carnegie Foundation for the Advancement of Teaching
- “Many students graduate having accumulated whatever number of courses is required, but still lacking a coherent body of knowledge or any inkling as to how one sort of information might relate to others.”

Boyer Commission - 1998

- The Boyer Commission concluded that research-based learning must become “. . . the standard for undergraduate education, noting that the ideal undergraduate education would turn the prevailing undergraduate culture of receivers into a culture of inquirers”

The Boyer Commission on Educating Undergraduates in the Research University, 1998. <http://naples.cc.sunysb.edu/pres/boyer.nsf/>

What is Undergraduate Research?

- A complimentary activity in CMB
 - Embedded and/or extra-curricular
- Intended to
 - Advance scientific understanding
 - Increase scientific skills and literacy
 - Deepen appreciation for scientific processes
 - Broaden awareness of career opportunities

Outcomes of UR

- **Scientific** (Wei & Woodin. *CBE Life Sci Educ.* 2011)
 - enhanced understanding of the scientific process
 - increased interest in science
 - Increased confidence in various scientific skills
- **Diversity**
 - Introducing more underrepresented minorities to scientific research in the classroom

7 Benefits of UR

CATEGORY	OBSERVATIONS
Personal/professional	Increased confidence in ability to do research and other tasks; feeling like a scientist; working relationships
Thinking and working like a scientist	Application of knowledge and skills; increased knowledge and understanding of science and research work
Skills	Improved communication, lab/field techniques, work organization, computer, reading, working collaboratively, information retrieval

Seymour, et al. (2004). Science Education, 88, 493-534.

7 Benefits of UR

CATEGORY	OBSERVATIONS
Clarification, confirmation and refinement of career/education	Validation of disciplinary interests; graduate school intentions; increased interest for the field
Enhanced career/graduate school preparation	Authentic research experience; opportunities for collaboration/networking ; résumé enhanced
Changes in attitudes toward learning	Undertaking greater responsibility for project; increased independence ; intrinsic interest in learning
Other benefits	A good summer job; access to good lab equipment

Seymour, et al. (2004). Science Education, 88, 493-534.

3 Models of UR

- Classroom-based
 - Josh Smith, BMS 110H
- Classroom/Research Lab Hybrid
 - Rob Delong, BMS 321/Nano-Biotechnology Laboratory
- Traditional Apprenticeship
 - Scott Zimmerman, Alzheimer's Disease Research Laboratory

UR in the Classroom

BMS 110H and BMS 558

Dr. Josh Smith

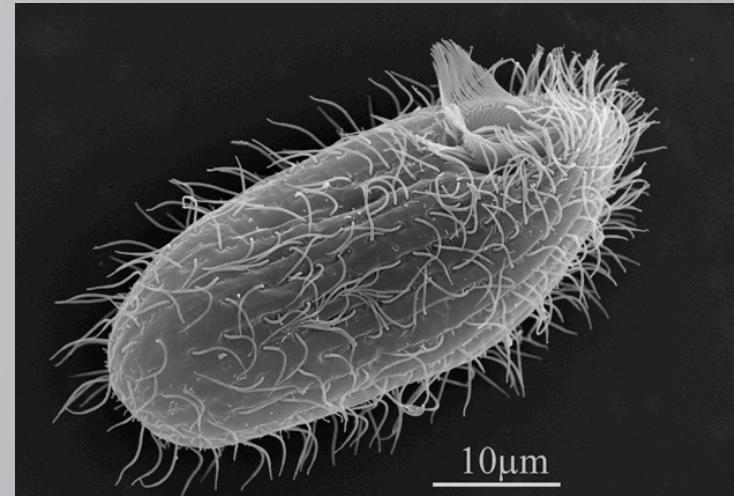
follow your
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Integration of Research into the Classroom

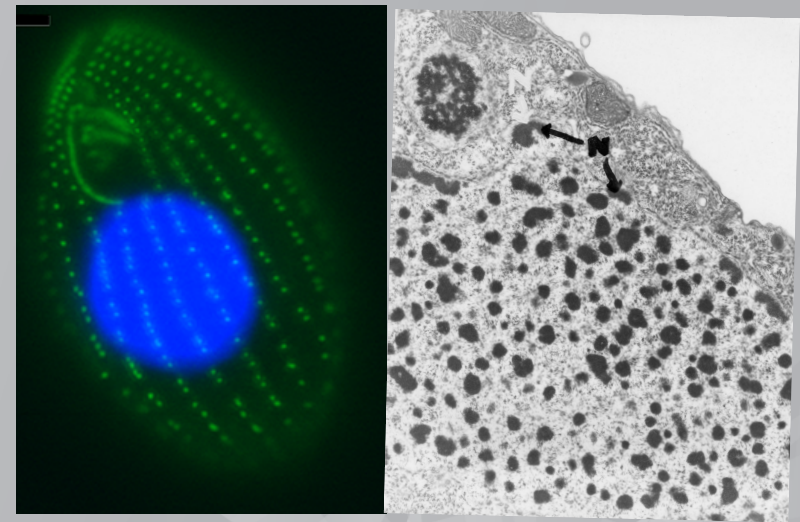
- **Goals:**
 - Engage students in a research experience
 - Freshman Honors students (BMS110: Introduction to Biomedical Sciences)
 - Cell and Molecular Biology Seniors/Graduate students (BMS558/658: DNA Recombinant Techniques)
 - “Fishing” experiments - high risk/high reward experiments
 - Increased numbers = increased chance of success
 - Characterize genes in *Tetrahymena*
 - Confirm annotation of genome database

Tetrahymena thermophila

- **Unicellular Eukaryote**
 - Protozoan
 - Genome Sequenced 2006
 - 104 Mb
 - 27,000 **PREDICTED** coding genes
 - 2 Nuclei
 - Macronucleus (Somatic)
 - 225 chromosomes
 - 45N
 - Micronucleus (Germline)
 - 5 Chromosomes
 - 2N



Aswati Subramanian, Miami University, Dec. 2009



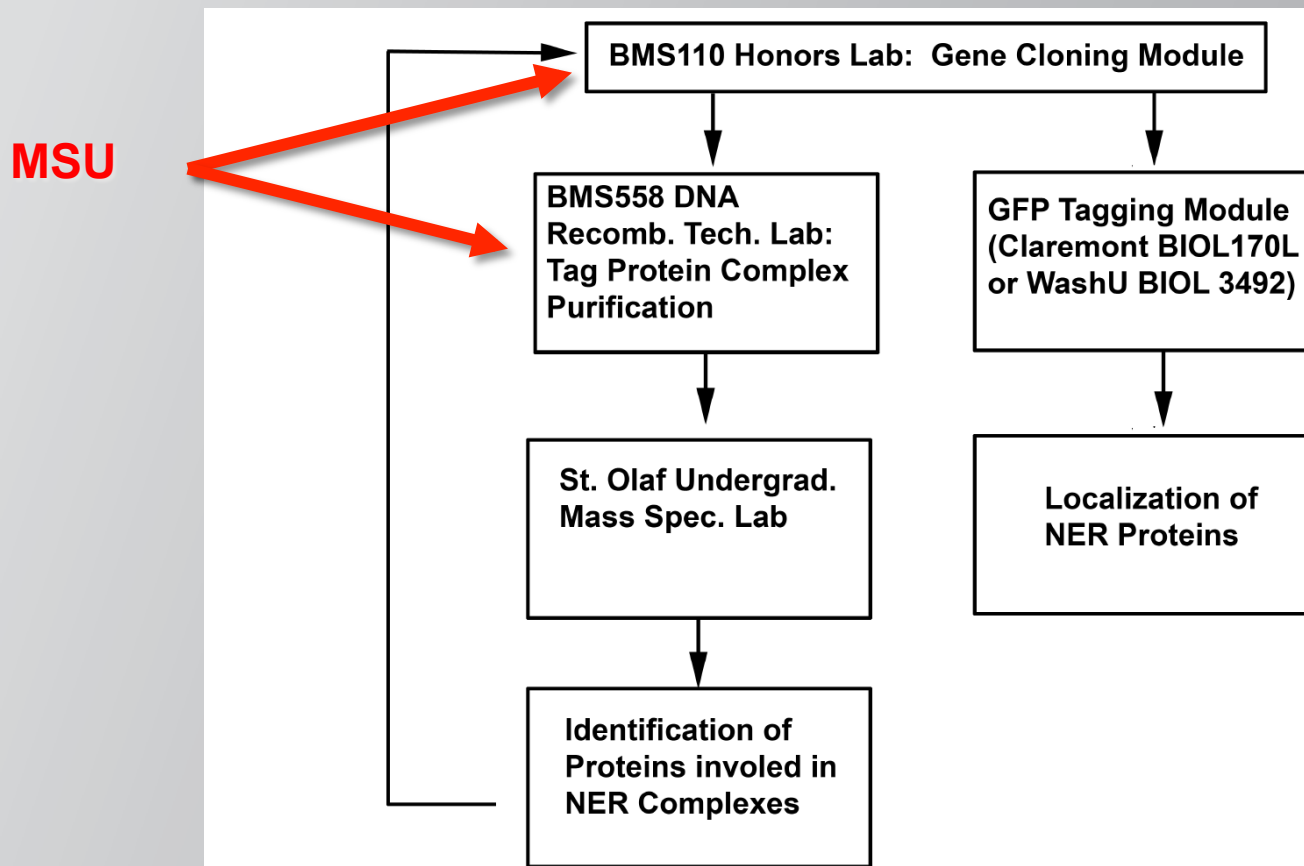
Milestone Discoveries Using *Tetrahymena*

1. First cell whose division was synchronized , lead to the 1st insights into **cell cycle** control mechanisms.
2. Identification and purification of the 1st **cytoskeletal motor** protein (Dynein).
3. Participation in the discovery of **Lysosomes** and **Peroxisomes**.
4. One of earliest molecular descriptions of somatic **genome rearrangement**.
5. Nobel-prize winning discoveries
 - **Telomers** and Telomerase (Blackburn and Grieder 2009, in Physiology or Medicine).
 - Catalytic RNA-**Ribozyme** (Cech 1989, in Chemistry).
6. Discovery of the function of **histone acetylation**.
7. Discovery of the roles of RNA Interference-like pathway in the heterochromatin formation (**RNAi**).
8. The physiological roles of the **posttranslational modifications** (acetylation, methylation, glycylation, & glutamylation) on histones and tubulin.

Advantages of Research-based Classroom Lab

- **Increased Retention Rate**
 - Increase in student interest in science/program
 - Increase in critical thinking skills
 - Higher success rate in higher level science classes
 - Increase in laboratory techniques/skills for science
- **Stretches Departmental Resources for Research**
 - Reagents and Supplies used in classroom and research
 - Data generated can be published and presented at scientific meetings

Multi-Institution Learning Community Model



BMS110 Lab (Honors Lab)

- **Clone genes from Tetrahymena (9 weeks)**
 - Bioinformatics and Literature Search (2 weeks)
 - *Tetrahymena* Genomic DNA Isolation Lab (1 week)
 - Polymerase Chain Reaction Lab (1 week)
 - TOPO Cloning & E. Coli Transformation Lab (2 weeks)
 - Construction of Plasmid Map (Gene Construction Kit) & Restriction Enzyme Digestion Design Lab (1 week)
 - Plasmid Purification & Restriction Enzyme Digest Lab (2 weeks)
- **Saccharomyces Genetics Module (Making UV Resistant Mutants) - Genetic mutation, Dominance, phenotype/genotype (3 weeks)**
- **Mouse Dissection/Establish Primary Cell Culture (2-3 weeks)**

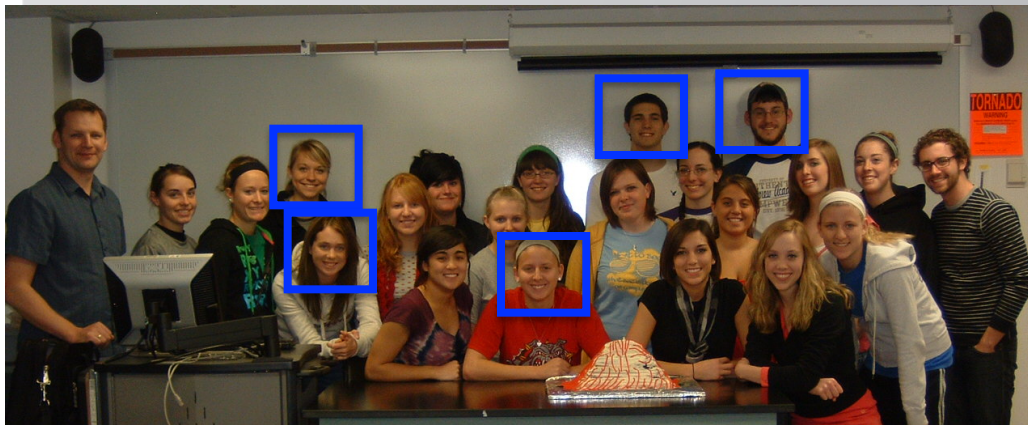
Class demographics

- ~24 Honors College Students/Semester (Fall)
 - 69 total students (2008-2010)
 - **Major:** 26 Cell & Molecular (38%), 31 Other Sciences (45%); 12 Non-science (17%)
 - **Year:** 55 Freshman (80%), 10 Sophomore (13%), 3 Juniors (4%), 2 Seniors (3%)
 - **Grades:** 45 A's, 16 B's, 3 C's, 1 D, and 4 Withdrawals (**93% Success Rate!**)

BMS110 Honors Students

Fall 2008

Fall 2009



Fall 2010



Tetrahymena Gene Cloning

- Histone Deacetylases (Sirtuins)
 - THD8, THD9, THD11, THD12, THD13, THD15, THD16
- Histone Acetyl Transferase
 - GCN5
- Ubiquitin, SUMO, & URM Pathway
 - UBA22, UBI4, URM1, UBC13, MMS2, HTR1, AOS2, UBA4
- DNA Repair Pathways
 - DMC1, RAD23, DDI1, RAD6, PHR1, PHR2, RAD4
- 20/23 Genes cloned (**87% Success Rate!**)

Annotate Genes on TGD Wiki

Gene Details

http://ciliate.org/index.php/feature/details/TTHERM_00013290

Most Visited Getting Started Latest Headlines Your Wiley Instructo... ScienceCareers.org Higher Education Jobs Chronicle Careers: J... Higher Education Jo... Tcoffee First Baptist Church ... sakai

Gene Details (Untitled)

Tetrahymena
GENOME DATABASE WIKI

Home BLAST GBrowse Resources Links

Quick Search

Login

USERNAME

PASSWORD

Login

[Click Here to Register](#)

Identifiers and Description

Gene Model Identifier
TTHERM_00013290

Standard Name
None

Aliases
PreTt11835 | 1.m00883

Description
UBA/TS-N domain containing protein

Gene Activity

TTHERM_00666429
Added By NSRP

TTHERM_0238473
Added By UWW

Recent Papers

Akematsu T, Pearlman RE,
Endoh H (2010) Gigantic
macroautophagy in
programmed nuclear death
of Tetrahymena thermophila.
Autophagy 6(7):
[PUBMED:20798592](#)

Genome Browser

CH445775
1397k 1398k

Protein Gene Predictions
TTHERM_00013290
UBA/TS-N domain

RNA Gene Predictions

Tetrahymena GenBank with a Unique Hit (BLAT)

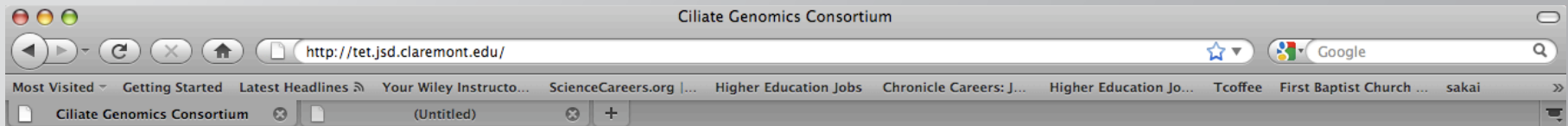
Tetrahymena GenBank seqs with Multiple Hits (BLAT)

Tetrahymena ESTs with a Unique Hit (BLAT)
BM399358-CH445775-15886
BM399361-CH445775-8464

Tetrahymena ESTs with Multiple Hits (BLAT)

CX576340-CH445775-39668

Students Publish Research-CGC Website



Ciliate Genomics Consortium

Overview

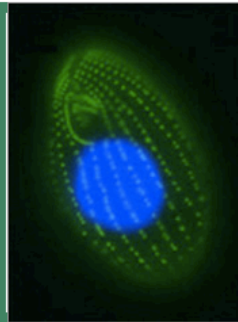
Tetrahymena Facts

Gene Database

Research Modules

Research Community

Getting Involved



Welcome to the Ciliate Genomics Consortium, a collaborative research initiative for undergraduate students to investigate gene function in the ciliated protozoan *Tetrahymena thermophila*. The initiative is based at the [Joint Science Department of the Claremont Colleges](#) in Claremont, CA. On this website you can access results from student research on determining coding sequence, localization, and expression patterns for various *Tetrahymena* genes by searching the [Gene Database](#). Progress on gene knockout constructions are also available.

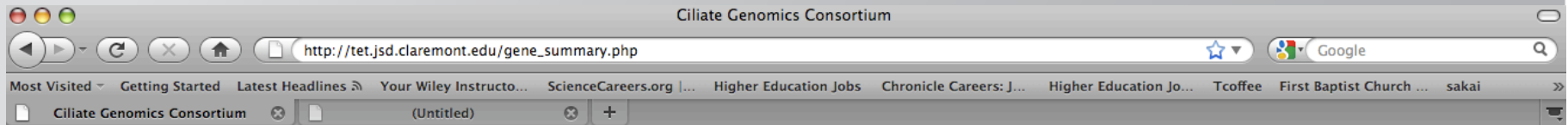
If you would like to get involved with the consortium, please visit [Getting Involved](#), a place where you can also download protocols.

This site is supported by the [National Science Foundation](#)

Joint Science Department

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Students Publish Research-CGC Website



Ciliate Genomics Consortium

Select Organism

Overview

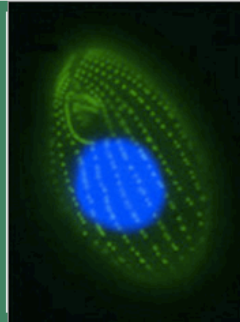
Tetrahymena Facts

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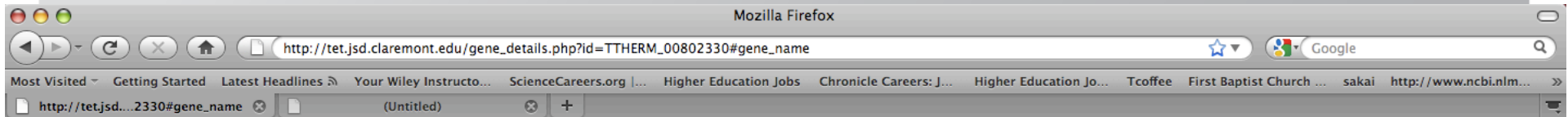
W. M. Keck Science Center

[Upload Data](#)

Gene Database Summary

Gene Name	Gene ID	Localization				Expression		
		Mic	Mac	Cyt	Veg	St	Conj	Knockout
TST1	TTHERM_00526990			X	X	X	X	
SIR2	TTHERM_00112480							
FGFR3	TTHERM_01502010						X	
THD2	TTHERM_00621610	X			X	X	X	
CYC11	TTHERM_00526250				X	X	X	
RAS	TTHERM_00267910				X	X	X	
SIR2	TTHERM_00194150					X	X	
WEG1	TTHERM_01044780				X		X	
DNC1	TTHERM_00031680				X	X	X	
RPD 3	TTHERM_0050610							
THD3	TTHERM_00663840				X	X	X	
JAL1	TTHERM_00683350						X	

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Gene Id TTherm_00802330

Name: UBI4

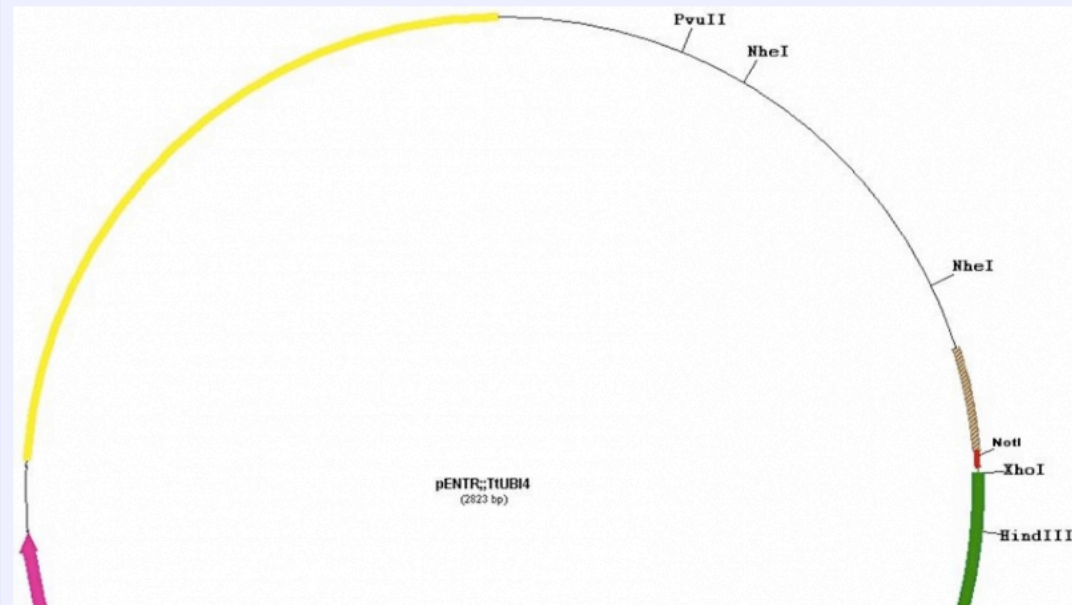
Contributer: Ann Granich of Biomedical Science in Missouri State University

Date Submitted: 2009-12-26 16:57:20

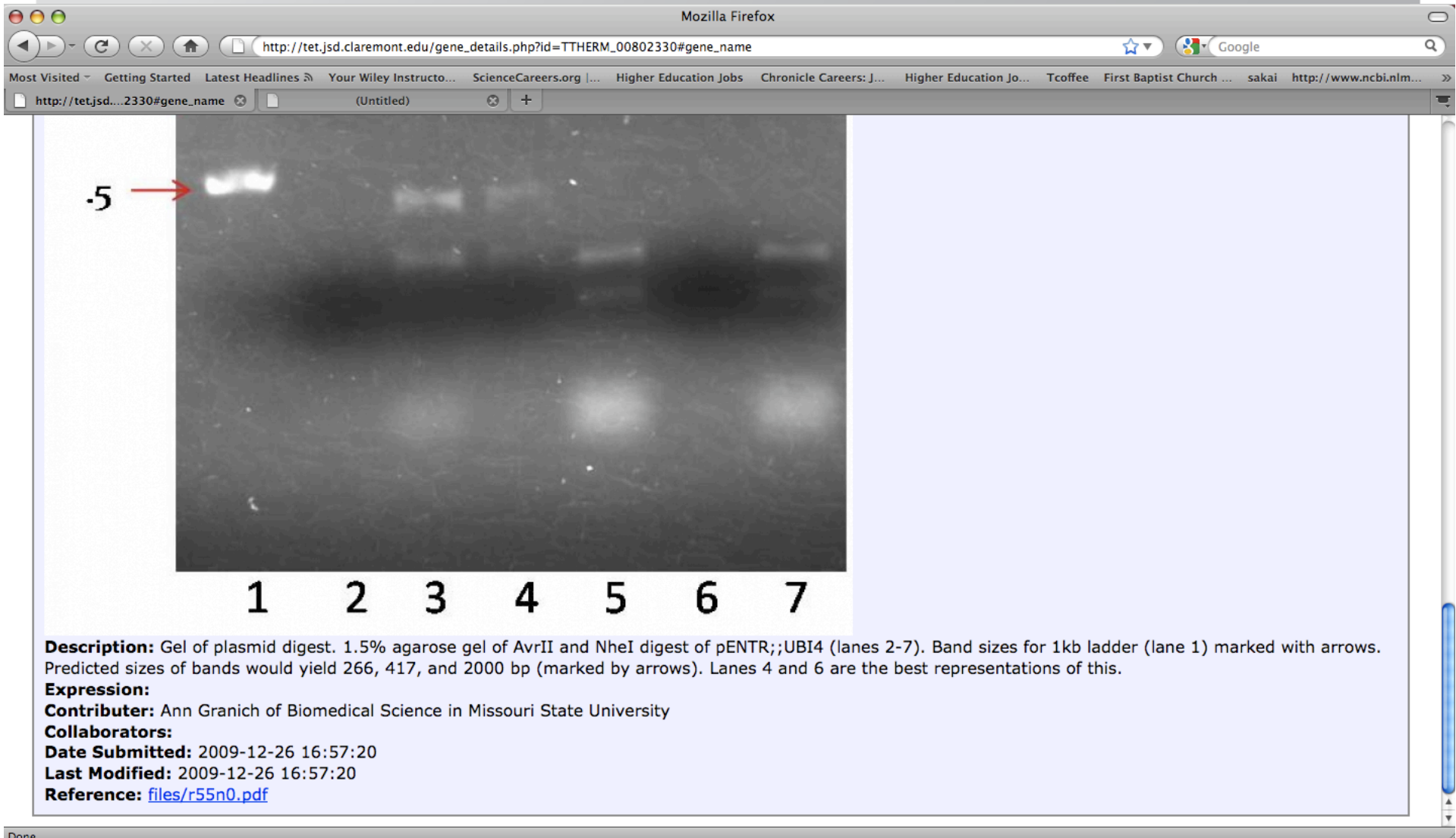
Last Modified: 2009-12-26 16:57:20

Reference: [files/r55n0.pdf](#)

Expression

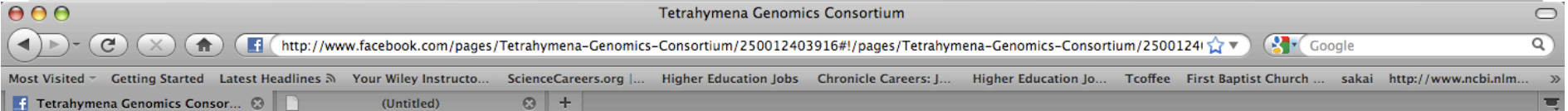


Students Publish Research-CGC Website



Students Join TGC Facebook

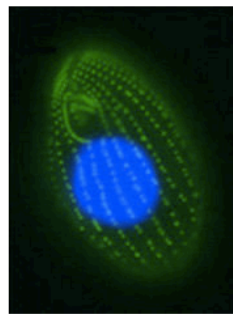
Tetrahymena Genomics Consortium



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The Tetrahymena Genome Consortium is an NSF funded collaborative research i...

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33

people like this

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Missouri State
University
Biomedical

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Tetrahymena Genomics Consortium

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[Edit Page](#)



Wall

Tetrahymena Genomics Cons... · Most Recent

Share: [Status](#) [Question](#) [Photo](#) [Link](#) [Video](#)

What's on your mind?



Tetrahymena Genomics Consortium

New Pictures are posted from Missouri State University BMS110 and BMS558 classes from 2010

4 minutes ago · Like · Comment



Tetrahymena Genomics Consortium added 52 new photos to the album BMS110 Honors Fall 2010.



BMS110 Honors Fall 2010

22 minutes ago · Like · Comment · Share

RECENT ACTIVITY

Admins (2) [?]

[See All](#)



[Use Facebook as Joshua](#)

[Promote with an Ad](#)

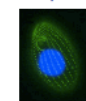
[View Insights](#)

Quick Tips

Get more people to like your Page with Facebook Ads today!

[Get More Connections](#)

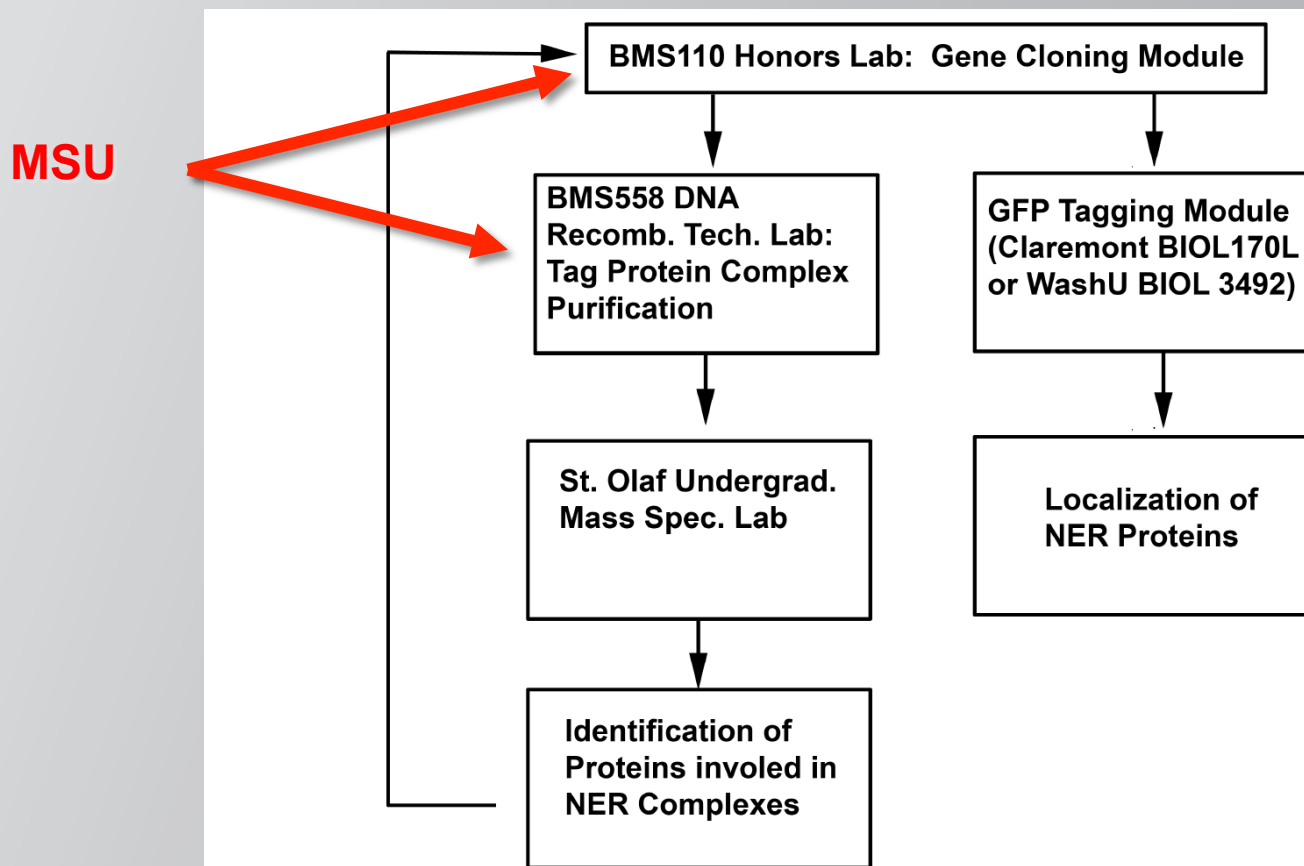
Sample Ad: Tetrahymena Genomics...



The text of your ad will go here.

[Like](#) · Joshua J. Smith likes this.

Multi-Institution Learning Community Model

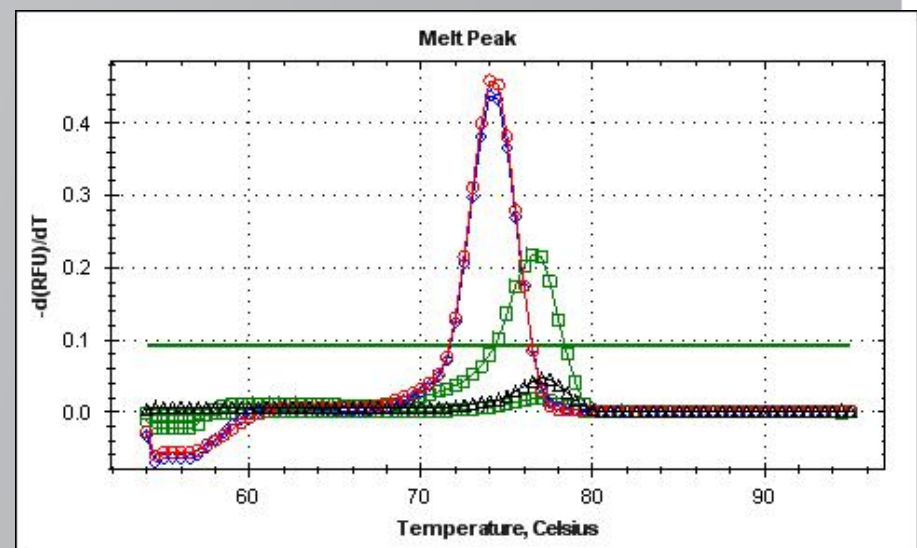
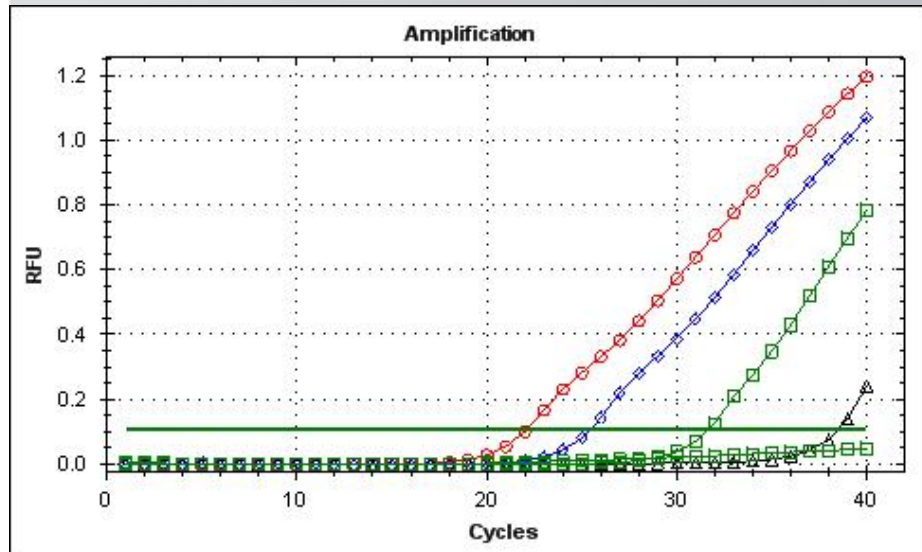


BMS558: DNA Recombinant Techniques Lab

Gene Tagging & Isolation of Protein Complexes

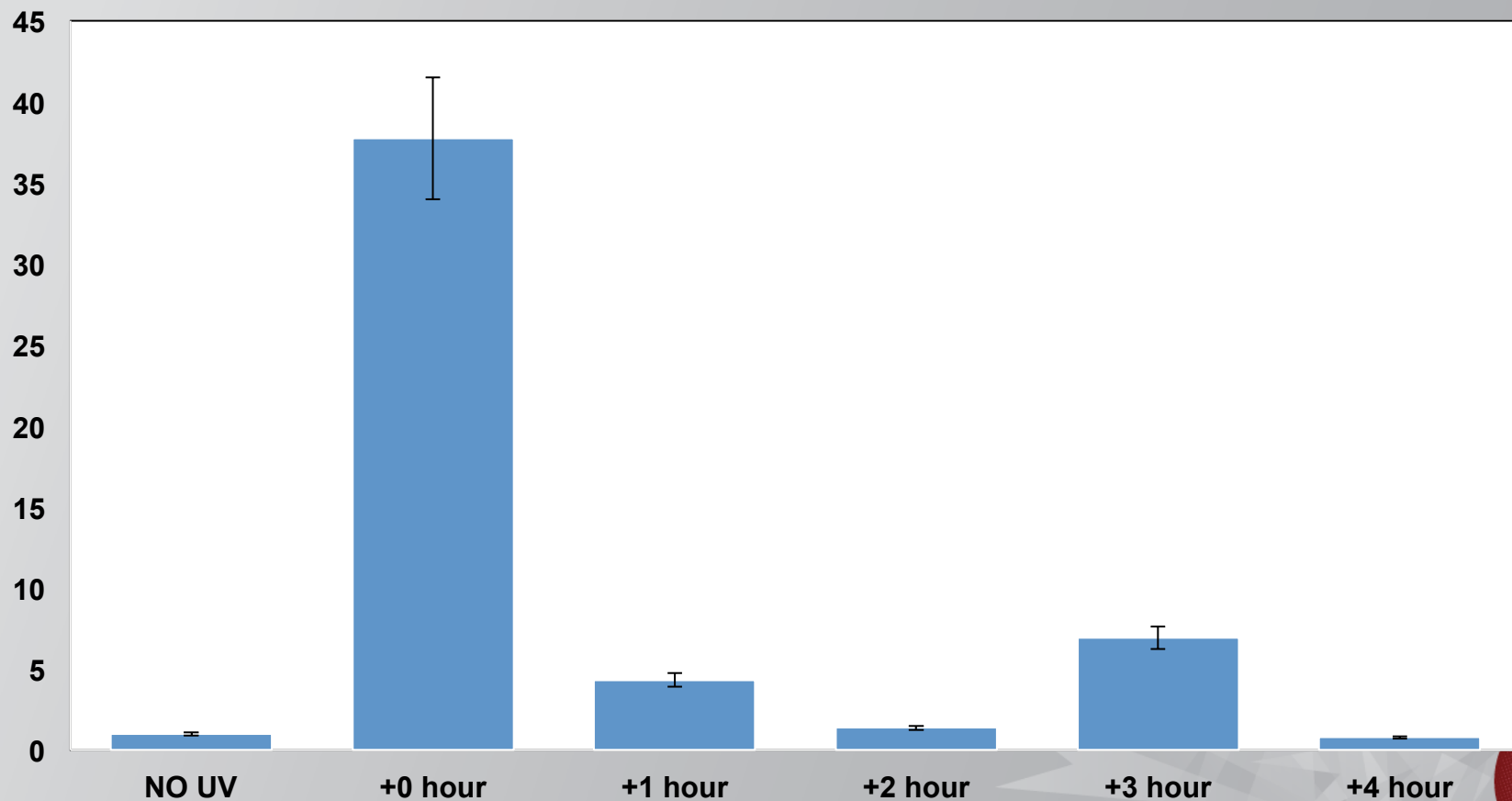
- 9 major techniques
- Arrangement as would occur in actual research setting
- Goal:
 - Classification of gene (Bioinformatics)
 - Expression pattern of gene (qRT-PCR)
 - Isolate interacting proteins (Blots & Gels)
 - Allows for new tags to be identified (Mass Spec.)
 - Location of the Tagged gene (GFP)

Expression of Genes using qRT-PCR



Expression after DNA Damage

THD 11 after UV Treatment

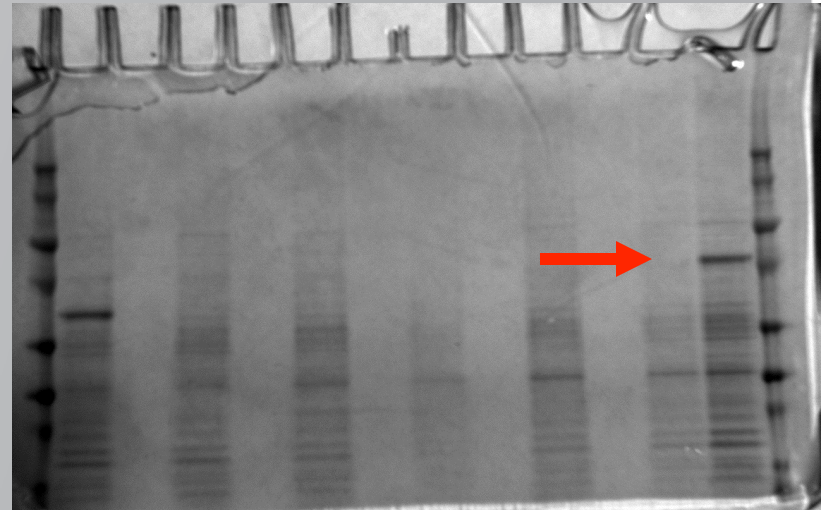


Proteome Analysis

Western Blot

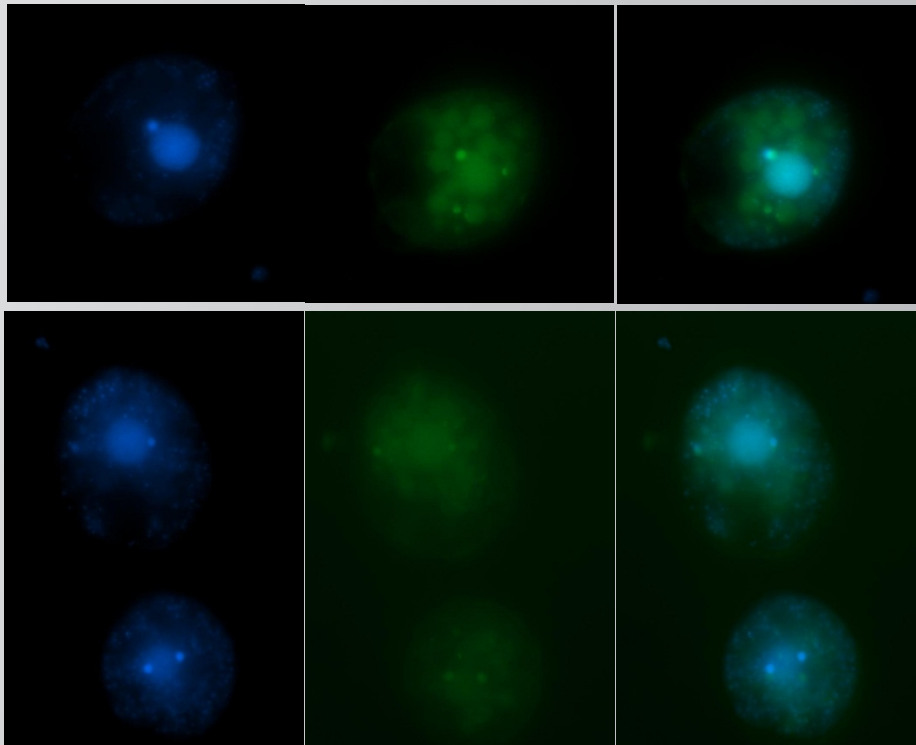


Coomassie Prep Gel

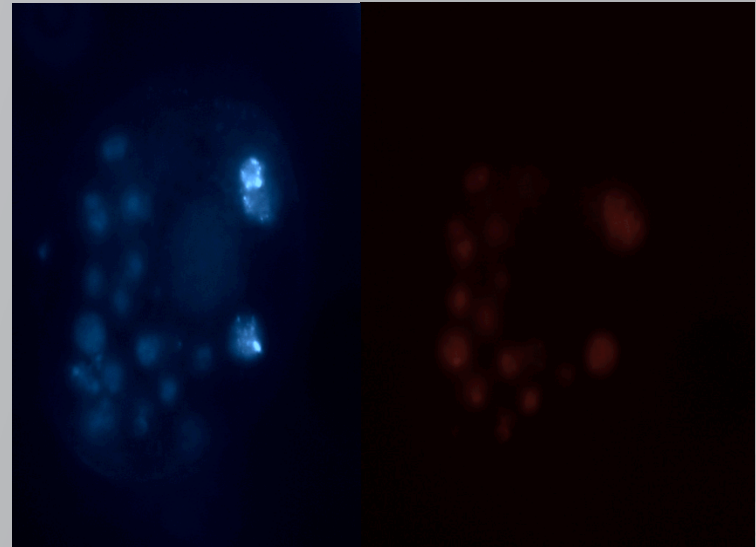


Localization of GFP/RFP Tag

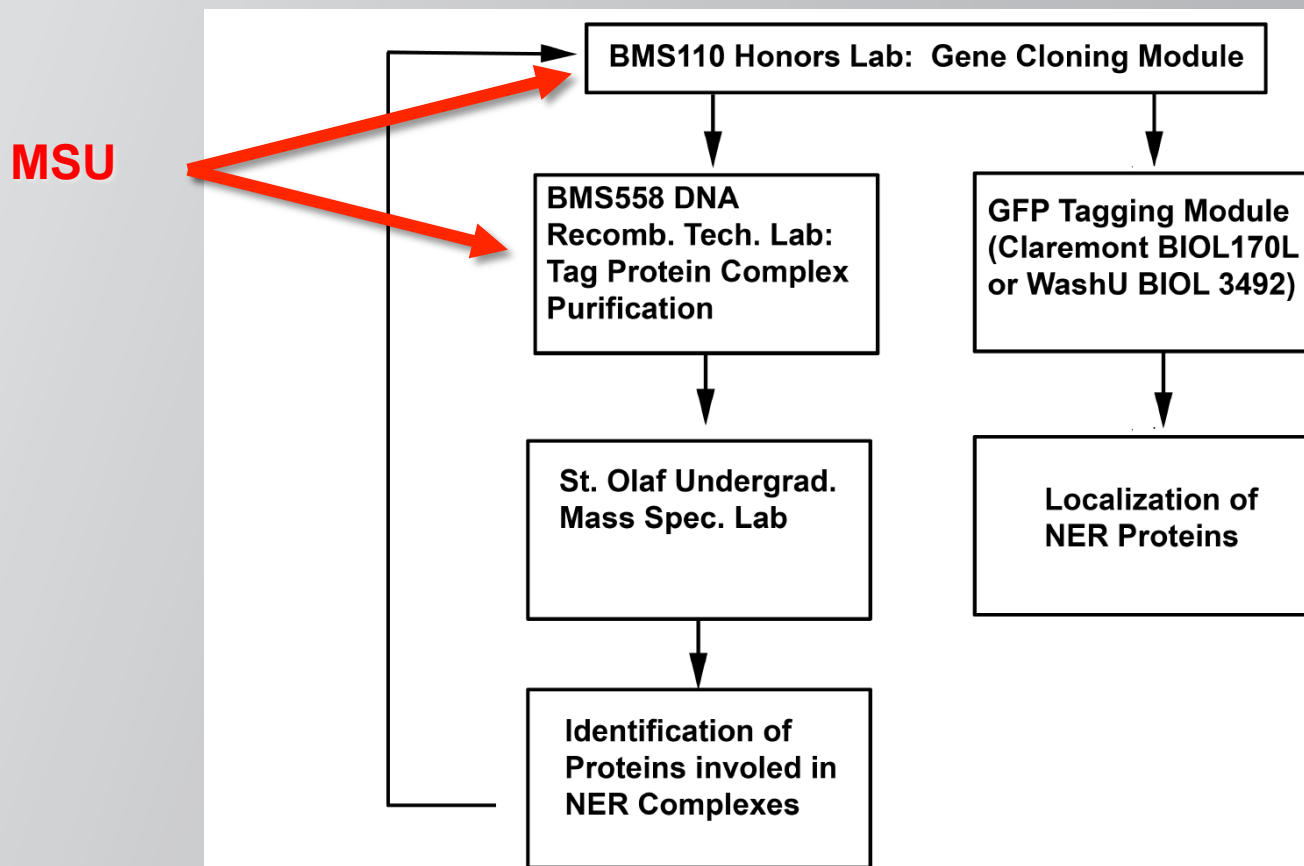
GFP-GCN5



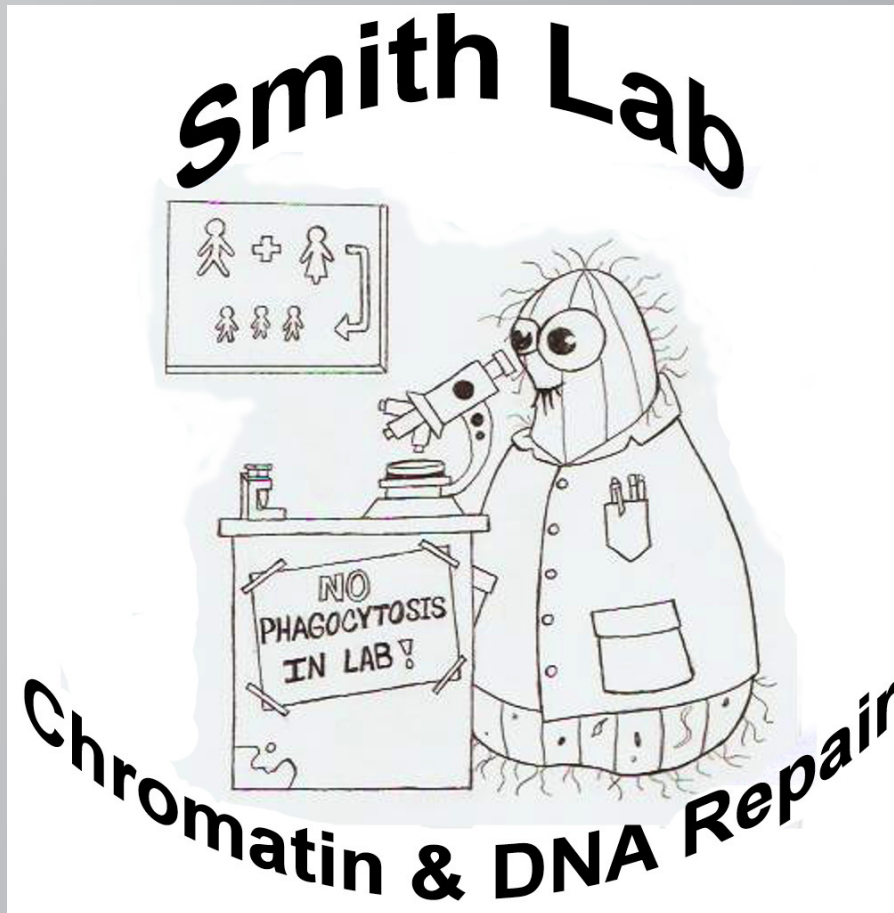
RFP-THD11



Multi-Institution Learning Community Model



Transition into Independent Research



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Hybrid UR Model

BMS 321/Traditional Research Lab

Dr. Rob DeLong

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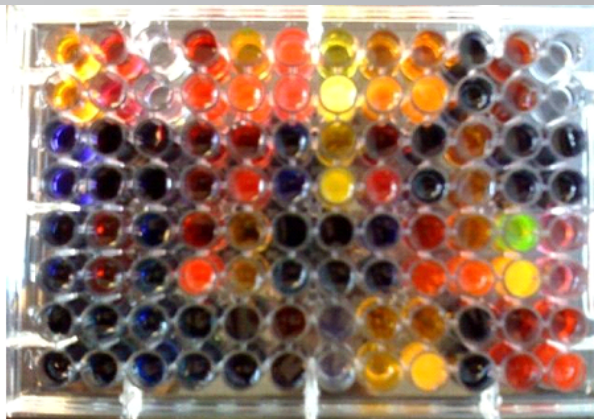
BMS 321/Research Lab

BMS 321 Biomolecular Interactions

Prerequisite: "C" grade or better in BMS 231. Recommended Prerequisite: concurrent enrollment in CHM 342. Concentration is on the major classes of biomolecules (proteins, nucleic acids, carbohydrates, and lipids) important in cell and molecular biology that signal, control, and regulate cellular function and the coordination of these interactions. Other topics include: biosynthesis and catabolism of biological macromolecules and related topics in biotechnology, biological nanotechnology and molecular medicine. ***Laboratory emphasizes hands-on experience with current techniques in biomolecular science.***

Research focuses on the binding, stabilization and delivery of DNA vaccines, siRNA and splice-site switching oligomers via nanomaterials. The group currently has two main grants or projects; 1) "Anti-Cancer RNA Nanoconjugates" funded by the National Cancer Institute R15/ARRA and 2) "Gene Vaccine Nanoparticles Against Tuberculosis" which is an R01 pending to NIBIB/NIH. We're also interested in novel liposome biomaterials as model cell membrane structures and are investigating these for their interactions with nanoparticles and nanorods.

BMS321 Lab



Introductory Experiments on Biomolecules and Their Interactions

Laboratory Manual

for

BMS 321

By Robert K. DeLong, Ph.D. (5th edition) copyright 2008, 2009, 2010, 2011

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Lab topics

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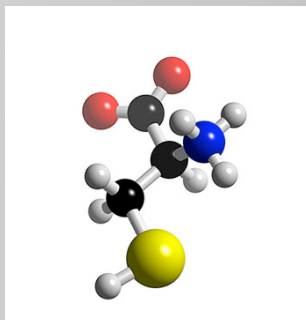
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Learning environment

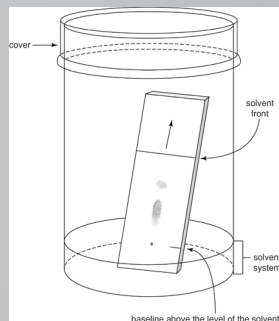
- Inquiry-based
- Deliberately somewhat open-ended
- Risk of failure
- High expectations
- Highly motivated and engaged
- Accountable to each other (e.g. - solutions prep)

Allowing room to push the envelope (e.g. TLC of amino acids)

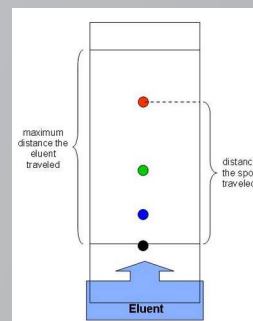
Amino acid (Cys)



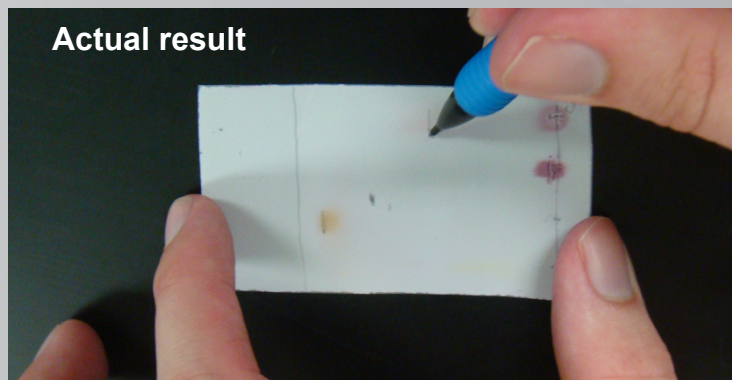
Apparatus



Expected result



Actual result



Some qualities we look for in selecting our research students

- Performance in BMS321: exhibit experimental design and critical thinking capability
- High quality written communication: well-organized, legible research notebook
- Good questions: demonstrate understanding and a step beyond
- Team player: Good fit within the group
- Leadership: in other aspects of their life and have other interests in which they excel
- Personality: competitive, yet genuine with a high degree of integrity

Our approach to training and developing student researchers

- 1) Usually, but not always, during the first semester (or ideally, summer), they “volunteer” to assist others in the lab.
- 2) They attend group meetings and begin attending grant/project or other team meetings to develop an understanding of the broader concepts.
- 3) We try to involve them in the peer review of a manuscript under consideration for journal publication.
- 4) Depending on their time and commitment, they can progress to having their own sub-project within a research team.
- 5) Alternatively, they get tasked with executing a critical technique, performing it routinely as “research service” to the group or our external and internal collaborators.

A Traditional Approach to UR

The Alzheimer's Disease Research
Laboratory

Dr. Scott Zimmerman

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The Alzheimer's Disease Research Laboratory

- Apprentice model of UR
- No direct connection to any course
 - Topics related to several courses
 - Physiology of Exercise Metabolism, BMS 567
 - Pathophysiology, BMS 561
 - Recombinant DNA Techniques, BMS 558

Apprentice Model of UR

- Students work with experienced researchers to learn how to produce data.
 - Progressive independence
 - Initially, close supervision
 - Later, regular interaction and guidance
 - Ultimately, independence

The Alzheimer's Disease Research Laboratory

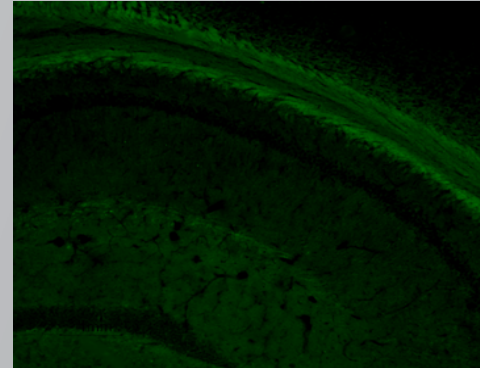
- Explore the impact of exercise on the AD process
 - Amyloidogenesis and plaque development
 - Intensity and timing of exercise
 - Forced versus volitional exercise



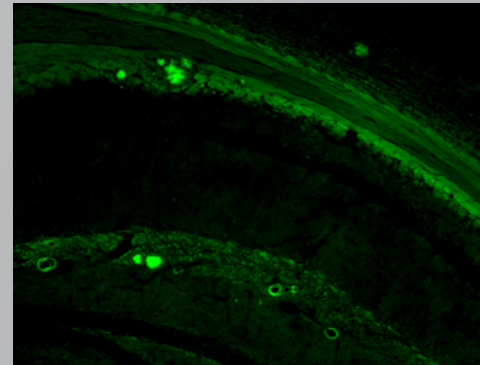
AD Lab - Student Demographics

- Since 2009
 - 3 Graduate Students
 - One male, two female
 - 17 Undergraduate Students
 - 13 BMS 498/499
 - 4 Volunteers
 - 11 Females, 6 Males
 - 3 High School Students
 - All female

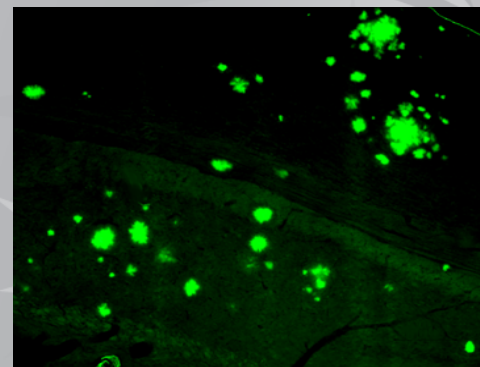
Plaque Development in APP Transgenic Mice



6 mos.
old



9 mos.
old



12 mos.
old

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AD Lab - UR Student Characteristics

- Dependability primary differential
- Animal care is first responsibility
 - Mundane, unpleasant
 - Critical



AD Lab - UR Student Characteristics

- Data collection secondary
- Ability to work in the group
 - Enjoyable
 - Interested
- Build on skills from previous experiences

Brainstorm

- Challenges
- Rewards

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Challenges of UR

What Do We Overcome to Do This?

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Challenges/Sustainability

- **Time Commitment**

- Longer time to setup lab reagents
- More grading responsibility
- Sustainability Solution:
 - BMS490-Peer Instructors in the Biomedical Sciences
 - Realization that teaching and research activities combined

- **Support Commitment**

- Increased cost of inquiry-based labs
 - BMS110 - \$42.72/Honors student vs. \$11.27/regular student (FY11)
 - BMS498: Undergraduate Research – lack of funding
- Increased space requirement for research with undergraduates

Challenges/Sustainability

- **Support Commitment**
 - Sustainability Solution:
 - Obtain Funding for research with undergraduates
 - Travel, supplies, equipment, etc.
 - Students fees for labs for High impact learning experience
- **Student preparation**
 - Increased time outside of class for student success
 - Increased effort for learning
 - Sustainability Solution:
 - Communicate high expectations
 - Positive Rewards – publications, conference presentation

Rewards of UR

What Do We (and our students) Get From This?

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Currently funded projects:

- 1) Anti-Cancer Nanoconjugates (NIH/NCI R15 AREA)
- 2) MRI-RUI: Acquisition of a Micro-Raman-Photoluminescence Instrument for Materials-Related Research and Education (NSF)
- 3) Application of aptamer nanoconjugates as novel cancer diagnostic tools (patent and partnership with St. Johns/Inveno/Mercy Health)

Other projects where funding is pending:

- 1) Anti-TB DNA Vaccine Nanoparticles (NIBIB, R01 pending)
- 2) Nanoconjugate interactions on model liposome membranes (NSF/RUI)

Undergraduate research in the DeLong lab

Research groups:

2010 – 2011 Research Group

National Cancer Institute / "Anti-cancer RNA Nanoconjugates":

Students working on this project: Kristin Flores, Ashley Schaeffer, Chris Reynolds, Brooke Jones, Yaneika Malcolm, Mohammed Abdelhakeim, John Black, Jiang Li, Lisa Cillessen and Stephanie Barber

National Science Foundation Project/"Biomaterials"

Students working on this project: Masaaki Kanomata, Juan Reyes-Reveles, Azure Risor, Jiang Li, Brooke Jones, John Dean, Joseph McGreevy, Kelsey Chown

National Institute of Bioimaging and Bioengineering/"DNA vaccine nanoparticles"

Students working on this project: Alyssa Irlmeier and Kristin Flores

2009 – 2010 Research Group

National Cancer Institute / "Anti-cancer RNA Nanoconjugates":

Students working on this project: Hannah Gann, Matt Warner, Laramie Pence, Stephanie Barber, Chris Reynolds, Jenna McNew, Lisa Cillessen

National Science Foundation Project/"Biomaterials"

Students working on this project: Masaaki Kanomata, and Jacob Thompson.

National Institute of Bioimaging and Bioengineering/"DNA vaccine nanoparticles"

Students working on this project: Amanda Scholz-Laymon and Lisa Cillessen

2008 – 2009 Research Group

National Cancer Institute / "Anti-cancer RNA Nanoconjugates":

Students working on this project: Daniel Davis and Scott Kelsey

National Science Foundation Project/"Biomaterials"

Students working on this project: Kindra Grozinger

National Institute of Bioimaging and Bioengineering/"DNA vaccine nanoparticles"

Students working on this project: Ryan Gillihan and Curtis Bonham

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Publication examples with undergraduates:

1.

[Interaction of MnO and ZnO nanomaterials with biomedically important proteins and cells.](#) **Gann H**, Glaspell G, Garrad R, Wanekaya A, Ghosh K, **Cillessen L**, **Scholz A**, **Parker B**, **Warner M**, DeLong RK. J Biomed Nanotechnol. 2010 Feb;6(1):37-42. PMID: 20499830 [PubMed - indexed for MEDLINE]

2. [Challenges and potential for RNA nanoparticles \(RNPs\).](#)

Davis D, Akhtar U, Keaster B, Grozinger K, Washington L, Kelsey S, Sarkar A, DeLong RK. J Biomed Nanotechnol. 2009 Feb;5(1):36-44. Review. PMID: 20055104 [PubMed - indexed for MEDLINE]

3.

[Characterization and performance of nucleic acid nanoparticles combined with protamine and gold.](#) **DeLong RK**, Akhtar U, Sallee M, Parker B, Barber S, Zhang J, Craig M, Garrad R, Hickey AJ, Engstrom E. **Biomaterials**. 2009 Nov;30(32):6451-9. Epub 2009 Sep 1. PMID: 19726081 [PubMed - indexed for MEDLINE]

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Functionalized gold nanoparticles for the binding, stabilization, and delivery of therapeutic DNA, RNA, and other biological macromolecules

(2135) Article views [Review](#)

Authors: Robert K DeLong, Christopher M Reynolds, Yaneika Malcolm, et al
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Abstract: Nanotechnology has virtually exploded in the last few years with seemingly limitless opportunity across all segments of our society. If gene and RNA therapy are to ever realize their full potential, there is a great need for nanomaterials that can bind, stabilize, and deliver these macromolecular nucleic acids into human cells and tissues. Many researchers have turned to gold nanomaterials, as gold is thought to be relatively well tolerated in humans and provides an inert material upon which nucleic acids can attach. Here, we review the various strategies for associating macromolecular nucleic acids to the surface of gold nanoparticles (GNPs), the characterization chemistries involved, and the potential advantages of GNPs in terms of stabilization and delivery.

Keywords: gold, nanoparticles, nanomaterials, RNA, nucleic acid

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Collaborators:

- BMS (C. Witkowski, R. Garrad, and M. Craig)
- MSU (A. Wanekaya, B. Datta, K. Ghosh, and R. Herati)
- University of North Carolina (A. Hickey and R. Juliano)
- Virginia Commonwealth (G. Glaspell)
- University of Kansas (C. Russ Middaugh)
- Catholic University (A. Sarkar)

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Conclusions

Why Do We Do This?

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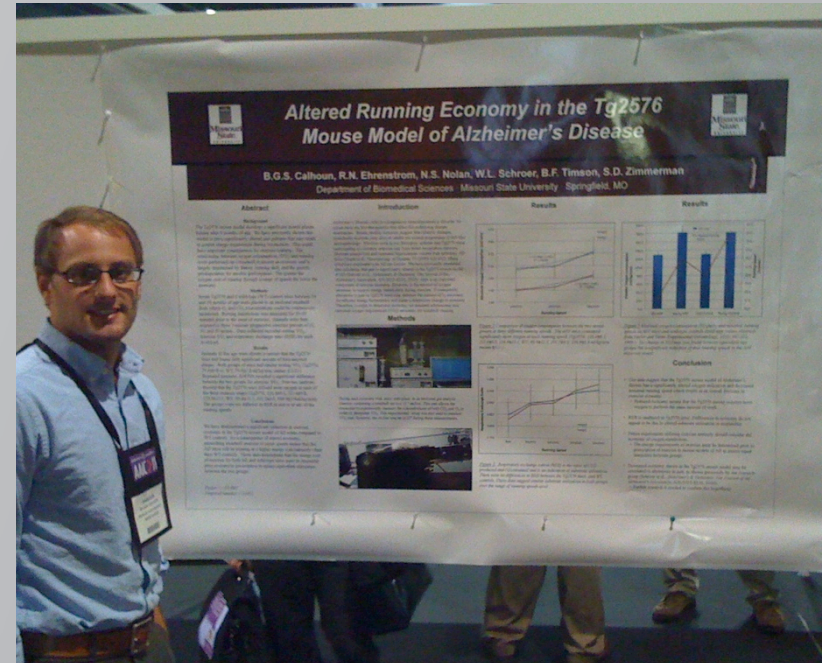
Conclusions

- Three models for UR
- Multiple entry points into research
- Research as part of the culture
- Eventually an expectation of the students

Conclusions

- UR offers students unique opportunities
 - Gain a deeper understanding
 - Apply knowledge
 - Link information
 - Think critically and deeply
 - Work collaboratively
 - Contribute to a body of knowledge

Osborn & Karukstis. 2009. The Benefits Of Undergraduate Research, Scholarship, And Creative Activity. In: Boyd & Wesemann (Eds.). *Broadening Participation in Undergraduate Research: Fostering Excellence and Enhancing the Impact*. Council on Undergraduate Research



Brandon Calhoun
Alzheimer's Association International
Conference
Paris, France
July 2011

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Conclusions

- UR benefits the students
 - Higher GPA
 - Increased retention
 - Greater persistence
 - Higher graduation rates

Osborn & Karukstis. 2009. The Benefits Of Undergraduate Research, Scholarship, And Creative Activity. *In*: Boyd & Wesemann (Eds.). *Broadening Participation in Undergraduate Research: Fostering Excellence and Enhancing the Impact*. Council on Undergraduate Research

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Conclusions

- UR offers faculty an opportunity to
 - Contribute to the intellectual growth of students
 - Work collaboratively with students
 - Gain assistance with current research projects
 - Generate student excitement and interest in a discipline
 - Aid students in contributing new knowledge to a field
 - Improve the quality of future applicants to the program
- UR is energizing

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