**Title**: A Yeast and CRISPR Course-Based Undergraduate Research Experience (CURE)

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Traditional undergraduate research experiences within the laboratory of a faculty member have been linked with student success. However, these opportunities are limited by the capacity of faculty members to mentor students. Course-based undergraduate research experiences (CUREs) have a goal of using traditional teaching laboratories to deliver many of the benefits of an authentic research experience at a larger scale. Yeast is an ideal model organism to deploy in CUREs due to the low-cost, rapid growth, and relative ease of experimental use. We have developed a yeast and CRISPR/CAS9 based CURE for an undergraduate biochemistry teaching laboratory. This approach involves the students generating their own hypothesis and deciding on a specific mutation(s) to make to the yeast genome using CRISPR/Cas9. The students are provided with a database of human cancer associated mutations, where they can find missense mutations in conserved residues of alkaline phosphatase to develop their hypothesis. The CRISPR strategy relies on commercially synthesized oligonucleotides, allowing for cost-effective control over the desired CRISPR target site and the oligo-based DNA repair template used to introduce the genetic modification. The resulting student generated novel yeast strain is then used in a simple colorimetric biochemical enzyme assay to test the student hypothesis. The current CURE is cost effective, robustly developed, and is focused on a biochemistry teaching laboratory. However, the underlying CURE approach of using student generated hypotheses, CRISPR/CAS9 genetic engineering in yeast, and assaying a cost-effective and easy to assess phenotype is a widely applicable and modular approach that could be deployed in a variety of biological teaching labs.

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**Multi-week, student-driven project to study effect of diet on *Drosophila* fertility and development in an upper-level Developmental Biology course**

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This Spring 2021 in a 300-level Developmental Biology lab, 3rd and 4th year undergraduates carried out an independent 6-week project to study the impact of dietary changes on female fertility and developmental timing of *Drosophila melanogaster*. Students first conducted a review of the literature to choose the dietary modification they would test and wrote a short proposal. They then grew wild-type fly cultures, collected virgin females to pre-treat on the experimental and control diet, and set up mating experiments with both young and aged females to measure fertility (eggs laid) and time to eclosion of progeny. The experiment was designed to give the students a sense of ownership and creativity to pursue a research question of interest, while still reducing logistical complexity for the instructor. The techniques employed of fly husbandry, egg lay plates, and fly media preparation, are relatively simple and easy for novice students to acquire. The reduced technical complexity allows for a fuller discussion of principles of experimental design, controls, multiple independent and dependent variables, and appropriate statistical analyses. There were some challenges faced in this first run of this new lab project that I would like to address and improve in future iterations. First, as with many lab projects reliant on *Drosophila*, this required students at certain times to come in to do lab tasks in between lab sessions. Second, the experimental design (two independent variables: diet and age, and two dependent variables: fertility and developmental timing) is complex, and more time needs to be taken to help students understand how to analyze and appropriately interpret the results. Third, providing students with complete freedom to choose the dietary condition to test can sometimes lead to additional logistical issues, and students choosing hypotheses that are not novel. Overall, this project could be expanded and deployed at relatively low cost at many other institutions, and could be easily adapted to lower-level courses and upper-level courses in other topics, such as Genetics.

**Title: Research replication in undergraduate lab courses**

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**Abstract**: Course-based Undergraduate Research Experiences (CUREs) are known to democratize access to research opportunities for students that otherwise might not engage in faculty-mentored research projects. CUREs are also useful mechanisms for faculty with sizable teaching loads to perform research while teaching. Over the past three years, I have redesigned a required upper-division undergraduate laboratory course in cell biology and genetics for biology majors. This lab course now involves student-directed research projects using the nematode *Caenorhabditis briggsae* (a model organism and close relative of *C. elegans*). This course serves over 100 students per semester.

One of the obstacles faculty often identify when planning and leading a CURE is that it can be difficult to sustain the required number of unique projects that students develop, perform, interpret, and share. I advocate for a principle that I have developed as part of my involvement in this course. I leverage CUREs to serve the students and also the scientific community by replicating published research. This approach involves each group of students first identifying a published study, and then the instructor verifying that it can be replicated given any constraints (equipment and other resources). Next, the students read that study and other relevant background literature. Each group then has the rest of the semester to iteratively pilot the published research design and ultimately perform a rigorous replication. In my course, student groups collaboratively write lab reports in the format of a short-format journal article that contribute to the students score in class, and then at the end of the semester any projects that failed to replicate published literature are further considered for submission to the journal *Micropublication Biology* for peer review and possible publication.

Student surveys have indicated strong positive support for this approach, including requests that such research courses be offered earlier in the curriculum and responses that the possibility of lab efforts being published helps sustain interest and motiviation in pursuing lab-based research. Critically, although this approach doesn't meet the most widely-held definition of a CURE, because students don't design their own hypothesis and experiments themselves, it does adhere to the other tenets of CUREs. Most importantly, this approach provides a valuable service that overcomes a major obstacle in science: that no funding agency provides support for research replication. By leveraging opportunities for training undergraduate students in research with the existing laboratory infrastructure of university courses (often including funding for materials and supplies by the university and/or from student lab fees), this style of CURE stands to play an important role in the scientific process.

**SPEED TALKS**

**Arabidopsis for research and teaching: An overview of resources from the ABRC**

Presenters: Emma Knee (Associate Director) and Courtney Price (Education & Outreach Specialist)

Abstract: The Arabidopsis Biological Resource Center (ABRC) is one of two global stock centers dedicated to maintaining Arabidopsis resources. Established in 1991, the ABRC’s mission is to collect, propagate, maintain, and distribute seed, DNA and other resources for *Arabidopsis thaliana* and other related species. Today, the ABRC maintains approximately one million unique samples in its seed and plasmid collection. These resources are made available to researchers and educators around the world. In addition to its mission to support researchers, the ABRC has a robust education program that aims to increase plant sciences in K-12 and undergraduate curriculum. The center maintains a suite of ready-to-teach laboratory modules and other teaching resources that can be used in combination with seeds (and DNA) from the collection to demonstrate a variety of science concepts from the elementary classroom to the undergraduate lab. This session will showcase the variety of resources available through the ABRC, highlight opportunities to collaborate and/or donate teaching modules, and demonstrate our new website and database.

**Courtney Price**

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**Using the nematode C. elegans in an undergraduate neuropsychopharmacology course**

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Drugs and the Brain is 300-level elective course for neuroscience majors at St. Lawrence University, a small liberal arts college located in northern NY. It is lecture course with a 3-hour weekly laboratory component that enrolls up to 12 students a semester. The aim of the Drugs and the Brain laboratory component is to give students hands-on experience applying the scientific method as it relates to neuropharmacology. Specifically, through their laboratory work, students: develop their scientific reasoning abilities; develop practical laboratory skills such as pipetting, worm picking, concentration calculations, data analysis; practice maintaining an up-to-date laboratory record; increase their understanding of the nature of scientific research; practice their oral and written scientific communication skills. In this laboratory, students use the nematode C. elegans to explore drug action. During the first part of the semester in the lab, students learn how to pick and maintain worms, familiarize themselves with worm resources (e.g., wormbook.org, wormbase.org, wormatlas.org) and perform behavioral assays in an effort to replicate some experiments from various published studies that used C. elegans as a model system to study neuropharmacology. This then sets the foundation for students to design and implement an independent research project to test their own hypothesis of interest related to drug action. Throughout the years, students have proposed and carried out experiments to address a wide variety of interesting and relevant neuropharmacology questions such as the transgenerational effects of alcohol, effects of alcohol pre-treatment on nicotine preference, to name just a few. Students in a recent iteration of the course indicated that they developed a deeper appreciation of the scientific process while working on their independent projects. They also appreciated the freely available C. elegans resources that facilitated their work.

**Undergraduate research project to understand post-translational modification using large-scale data**

Yee Mon Thu, Assistant Professor Biology, Allegheny College

In response to the pandemic associated situations, I initiated a remote research project with a group of undergraduate students during the academic year 2020-2021. Our lab is interested in a post-translational modification namely sumoylation. Sumoylation is a process in which a small peptide SUMO (small ubiquitin like modifier) is covalently linked to target proteins. Sumoylation plays a central role in DNA damage response and repair. Many mass spectrometry studies have been performed to identify sumoylated proteins under conditions of genome instability. First, we used some of these data sets to understand if proteins that are in complex with sumoylated proteins are more likely to harbor consensus sequences associated with sumoylation. For this analysis, we used [www.yeastgenome.org](http://www.yeastgenome.org/) to acquire the primary sequences of proteins and [www.sumosp.biocuckoo.org](http://www.sumosp.biocuckoo.org/) to identify associated SUMO consensus sequences. Second, we performed gene ontology analyses to get some insights into whether the E3 SUMO ligases (enzymes that are responsible for conjugating the SUMO peptide to target proteins) experience subcellular re-localization. To this end, we used gene ontology tools on [www.yeastgenome.org](http://www.yeastgenome.org/). Third, we asked if SUMO interacting motifs (a stretch of hydrophobic amino acids that are responsible for interacting with SUMO) are likely to be found in unstructured regions of a protein. To complete this analysis, we utilized<https://iupred2a.elte.hu/> in conjunctions with<https://www.uniprot.org/>.

We performed these analyses over two semesters. The general structure of the research program was set up in such a way that I met with students every week for approximately 30mins-1hr and students worked independently or as a group outside of the meeting time. Each of them spent approximately 3 hours per week. There are three main activities of the program: reading relevant literature (both primary and review articles), collecting data and data analysis followed by discussion. We alternated those three main activities throughout the semesters. These activities helped us to achieve the following learning outcomes: to understand and analyze literature, to maintain and handle large data sets, to understand how to analyze large-scale data and to be able to interpret large-scale analyses. Students prepared a poster on this study to present it at the National Council for Undergraduate Research in April 2021. The title of the poster is “Bioinformatics approach to understand the dynamics of Mms21 SUMO ligase and sumoylated protein complexes.” Three students participated in this project and one of them will apply what we learned from this project in a wet lab experiment next year. Another student is able to secure an off-campus undergraduate research opportunity for this summer. The structure of this project can be generalized for other undergraduate research groups who might be interested in post-translational modifications and protein-protein interactions.

**Using *C. elegans* in Genome-Wide Association Studies as a model for doing novel healthcare related research in an undergraduate genetics lab class**

**Lisa Petrella**

Teaching authentic research in undergraduate laboratory classes can be a challenge as it requires time to acquire technical skills to perform methods and it can be difficult to find a topic that is engaging to all students. To this end I have developed a six to seven week module where students perform a genome-wide associate study (GWAS) using *C. elegans.* This module provides 24-28 students with a real research experience and produces novel data for potential future research publications. GWAS is a method for associating loci in the genome with changes in a particular phenotype that shows differences across a population, e.g., finding loci associated with a disease state or muscule strength. Although this is one of the most common and successful tools used in human genetics, it is not taught extensively in genetics classes and very few students are exposed to the workings of this type of research as undergraduates. This module provides students with the time to gain technical expertise in a particular technique, have a shared research goal across the entire cohort of the class, and is set up to provide novel data on genetic loci that are unknown thus allowing the students to contribute to the field as a whole. Due to publicly available pipelines for running the GWAS and the ability of *C. elegans* strains to be frozen, after an initial investment in ~150 *C. elegans* strains this module can be run for many years with no further investment. Instructors can modify the module to any type of phenotype that can be scored by undergraduates in as little as a one hour timeframe. Over the course of three years I can run this module with ~75 students to gain sufficient information for a research publication; however, clear loci are found even in the first year of data acquisition. This module is adaptable to many teaching settings for giving students an authentic research experience for any number of phenotypes related to the interest of both the students and the instructor.

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**The Genomics Education Partnership (GEP) — a Classroom Undergraduate Research Experience with collaborative instructor training and support**

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Ann K. Corsi, Department of Biology, The Catholic University of America, Washington, DC