AC 2010-1682: AN INTERDISCIPLINARY MASTER'S OF SCIENCE SPECIALIZATION IN STEM CELL RESEARCH

Lily Laiho, California Polytechnic State University

Nikki Adams, California Polytechnic State University

Matthew Burd, California Polytechnic State University

Kristen Cardinal, Cal Poly, San Luis Obispo

Daniel Walsh, California Polytechnic State University

Trevor Cardinal, California Polytechnic State University

An Interdisciplinary Master's of Science Specialization in Stem Cell Research

Abstract

With funding from the California Institute of Regenerative Medicine Bridges to Stem Cell Research Award[1], we have developed a unique interdisciplinary MS degree specialization in Stem Cell Research. This paper describes the structure of this new program. The interdisciplinary nature of our program stems from the involvement of faculty and students from three departments that span three academic units at our university - Biomedical Engineering, Biological Sciences, and Animal Science. The goals of our program are to prepare students for careers in stem cell research by providing them with 1) broad technical skills, 2) critical thinking and problem solving skills, 3) familiarity with current research, 4) familiarity with the ethics and theory of stem cell investigation, and 5) presentation and communication skills.

To accomplish these goals, students from the three departments progress through three components - one year of coursework, a nine-month research internship, and a Master's project. For their coursework, students complete five common-core courses - Principles of Tissue Engineering, Cell Transplantation and Biotherapeutics, Introduction to Biomedical Imaging, Stem Cell Research Seminar, and Principles of Stem Cell Biology. Through the laboratory coursework, students gain experience with cell culture, scaffold development, cell sodding, histochemical staining, animal surgery, therapeutic delivery, animal experimentation, fluorescent and laser microscopy, and cell staining. In addition to the core courses, students also complete classes specific to their discipline, i.e. Biomedical Engineering, Biological Sciences, or Animal Science.

After completing their coursework, students complete a nine-month internship in a stem cell research lab at one of our partner institutions. The nine-month internship, which addresses all of our programmatic learning goals, allows students to further develop their laboratory and critical thinking skills in a research-intensive environment with a rigorous and independent project.

Upon completion of their research internships, students return for one final quarter of coursework. During the quarter, students complete a Master's Project Course that allows them to apply the skills gained during the research internship to existing research efforts at our university. This Master's Project provides students with the opportunity to demonstrate transfer of knowledge and skills gained during the completion of their degree and therefore represents the culmination of their training MS degree training in stem cell research.

Introduction

In order to prepare our students for an increasing number of careers in stem cell research[2], we established three Master's of Science degree specializations in Stem Cell Technology at California Polytechnic State University, San Luis Obispo. The specializations are available to students from three departments at our university- Biomedical Engineering in the College of Engineering, Animal Science in the College of Agriculture, and Biological Sciences in the

College of Science and Mathematics. Students in the Stem Cell Technology specializations complete a set of common-core courses in stem cell related technology as well as courses specific to their fields. The common-core coursework is laboratory-intensive and provides vital preparation for our trainees' research experiences: an off-site internship and on-site Master's project. In addition to the coursework and research experiences, trainees gain professional skills through a seminar course and yearly conference held at Cal Poly. Upon completion of these activities, trainees from our program will be well prepared to matriculate into doctoral programs or to begin employment as research specialists at either for-profit or non-profit institutions. This paper details the structure of the program.

Program Structure

For their coursework, students are required to complete five core courses - Tissue Engineering, Principles of Stem Cell Biology, Cell Transplantation and Biotherapeutics, Biomedical Imaging, and Stem Cell Research Seminars. The flow of courses can be seen in Figure 1. In addition to the core courses, students will take a one-week stem cell techniques course[3] and complete a nine-month internship at one of our partner institutions – Stanford University, University of California San Diego, Salk Institute for Biological Studies, the Scripps Research Institute, and Novocell. They must also complete coursework required for Master's degrees specific to their discipline, i.e. Biomedical Engineering, Biological Sciences, or Animal Science. The purpose of the core coursework is to provide students with skills that are essential for stem cell research. Descriptions of each of the required courses are detailed below.

Required CIRM Courses:

Year 1

Fall	Tissue Engineering Stem Cell Research Seminar Principles of Stem Cell Biology
Winter	Cell Transplantation and Biotherapeutics Stem Cell Research Seminar
Spring	Intro to Biomedical Imaging Stem Cell Research Seminar
Summer	Stem Cell Techniques Course Stem Cell Research Internship

Year 2

Fall	Stem Cell Research Internship
Winter	Stem Cell Research Internship
Spring	Appliations in Stem Cell Research

Additional Department Requirements:

Biomedical Engineering
Engineering Physiology
Biomedical Engineering Horizons
Engineering, Science, or Math Electives (6 units)

Biological Sciences
Molecular and Cellular Biology
Biology of Organisms
Biology Electives 400 or 500 level (8 units)
Comprehensive exam

Animal Science
Statistical methods
Applied Experimental Design and Regression Models
Agriculture Electives (6 units)

Figure 1. Courses required for the Master's of Science Specialization in Stem Cell Technology program. Required courses, as well as department specific courses, are included.

Tissue Engineering

This course focused on fundamental principles and current applications of tissue engineering. Lectures, discussions, and laboratories are used to explore areas including cell source and isolation, scaffold selection and modification, tissue cultivation and bioreactor design, and patient implantation. Current applications of tissue engineering for the reconstruction of skin, cartilage, bladder, blood vessels, and other tissues are discussed, with an emphasis on examples from the primary literature.

The laboratory component of this course is a major focus, with students learning hands-on skills and techniques necessary in the tissue engineering field[4], as well as the field of stem cell research. Students begin by learning aseptic technique and skills for working in a laminar flow hood, followed by practice thawing and passaging mammalian cells. Students then learn techniques for viability and en face fluorescent staining, followed by histological techniques for sectioning and staining paraffin embedded tissue engineered constructs. Students have an opportunity to assemble and work with perfusion bioreactors and are exposed to methods for acquiring pressure and flow data. During the last three weeks of the quarter, students combine skills to prepare for, set up, and analyze a tissue engineered blood vessel.

Principles of Stem Cell Biology

This course focuses on principles of stem cell biology including characteristics, types, and roles in development, therapeutic uses, historical perspectives, and ethical issues. Topics covered include principles of cells, developmental biology, mammalian fetal development, primordial germ cells, embryonic stem cells and therapeutic cloning, adult stem cells and lineage specific stem cells, aging and regeneration, induced pluripotent embryonic stem cells[5], guidelines for human embryonic stem cell research, and ethics and policies. By the end of the course, students are able to explain the main characteristics of adult and embryonic stem cells as well the history of stem cell research, understand ways stem cells are isolated and cultured, identify and understand therapeutic uses for stem cells, and understand the ethical issues surrounding stem cell research.

Cell Transplantation and Biotherapeutics

The primary objective of this course is to train students in the use of rodents for assessing the effectiveness of cell transplantation. During the laboratory portion of the course, students learn animal handling and restraint, anesthesia, survival surgery, and experimentation. Additionally, students apply their skills in cell culture and histology - gained in the Tissue Engineering course. Specifically, students perform the femoral artery ligation surgery to induce peripheral ischemia. At the time of surgery, students implant a construct composed of fibroblasts and collagen to assisting with healing the ischemic injury. Students assess the therapeutic effectiveness of their cell construct by measuring muscle force product and performing histo-morphological analysis of muscle damage in the distal limb.

Biomedical Imaging

This course provides an introduction to the fundamental principles and applications of biomedical imaging modalities in medicine. In addition to understanding the fundamental principles and applications of each modality, students ware able to compare the diagnostic utility of images from different modalities, critically evaluate scientific and medical literature, and analyze complex issues in diagnostic imaging. Topics covered include fluorescence microscopy, confocal and multiphoton microscopy, brightfield microscopy, differential interference contrast, phase contrast, scanning electron microscopy, X-ray radiography, computed tomography, magnetic resonance imaging, ultrasound, and nuclear medicine. Students obtain hands-on experience synthesizing quantum dots, using brightfield, widefield fluorescence, laser scanning confocal, multiphoton, and scanning electron microscopes, and analyzing images using ImageJ software[6] to study specimens such as pediastrum, mouse intestine, normal and melanoma engineered skin tissues, and quantum dots.

Stem Cell Research Seminars

Students enroll in this course each term during their first year in the program. The first quarter allows students to identify stem cell research performed at laboratories associated with CIRM Bridges to Stem Cells host institutions. Through critical review and presentation of literature, students identified specific host laboratories performing research congruent with student research goals. During the second and third terms, students will continue to review and present primary literature relevant to their interests in stem cell research. Additionally, invited speakers will discuss approaches to current problems in stem cell research.

Stem Cell Techniques Course

After completing all of their coursework and before the beginning of the research internship, students complete a weeklong stem cell techniques course at the Scripps Research Institute. During this experience, students apply their experience in cell culture to culturing hES cells, developing embryoid bodies, and directing cellular differentiation[7].

Research Internship at Partner Institutions

After completion of the stem cell techniques course, students begin their nine-month research internship in a stem cell research lab at one of our partner institutions: Stanford University, University of California San Diego, Salk Institute for Biological Studies, the Scripps Research Institute, and Novocell. The nine-month internship, which addresses all of our programmatic learning goals, allows students to further develop their laboratory and critical thinking skills in a research-intensive environment with a rigorous and independent project. Students receive a $2,500 per month stipend while away at the internship as well as funding to support their research.

The goal of our internship placement procedures is to ensure that students are optimally prepared and properly matched to their internship site to enable maximum productivity during this research experience. Trainees will have a diverse option of internship sites, which is appropriate

for the diverse nature of our student population. These options include medical therapeutics, commercial products, and fundamental research.

To match trainees with their internship-host institutions, trainees are given literature related to the projects available at all of our partner institutions. From this literature, trainees select their top-six internship sites. Once these selections have been made, we provide trainee information to the partner institutions that the trainee lists in the top-six internship sites. Trainees conduct phone interviews with the host-institutions, and if successful, are invited to the host-institutions for an in-person interview. Following the interviews, the representatives from the internship-host institutions provide confidential feedback to the key personnel in the program who then match trainees with one of their top selected internship sites.

Applications in Stem Cell Research

Upon completion of their research internships, students return to our institution for one final quarter of coursework. During the quarter, students complete a Master's project course that allows them to apply the skills gained during the research internship to existing research efforts at our institution. This MS Project provides students with the opportunity to transfer the knowledge and skills gained with their degree and, therefore, represents the culmination of their MS degree training in stem cell research.

Conclusions

This program has an Advisory Committee, which provides feedback on our program. The committee is comprised of mentors from our partner institutions, as well as all five faculty from our university that are involved in the program. During the first meeting of this committee the Advisory Committee reviewed our coursework and program logistics to ensure the efficiency and efficacy of our program in preparing trainees for careers in stem cell research. The Advisory Committee was extremely satisfied with the content of all courses and felt that our program provides excellent training for students pursuing doctoral programs or beginning employment as research specialists at either for-profit or non-profit institutions.

Our first cohort of students has been paired with their internship hosts. After a series of phone interviews followed by in-person interviews, all of the students were matched with their number one choice. The internship sponsors uniformly found the students had excellent course and laboratory preparation for work in their laboratories. Additional assessment will be conducted upon completion of the internships. The effectiveness of their preparation is to be assessed by surveying the mentors at the techniques course and internship sites, as well as the trainees themselves on trainee preparation. Our program's effectiveness as a whole is to be assessed by tracking trainee placement and the trainees' sense of preparation through surveys following graduation.

This program is already underway at our institution and has been well received by the students, faculty, and administration. The goal of the program is to prepare trainees for careers in stem cell research. In order to achieve this goal, trainees in our program progress through three main components, including coursework, a research internship, and a Master's project. The

laboratory-intensive coursework and stem cell techniques course provides trainees with a broad foundation of laboratory skills that should allow them to maximize their productivity during the research internship. The research internship provides the trainees with an opportunity to refine their laboratory, critical thinking, and problem solving skills through their immersion in a rigorous, research-intensive environment. Additionally, the research internship provides valuable professional contacts for future careers in stem cell research. After completing their research internship, trainees complete a Master's project that is aimed towards building from their coursework and internship activities. Completion of these components provides trainees with an excellent foundation to begin pursuing careers in stem cell research by continuing their education in doctoral programs or beginning employment as research specialists in stem cell laboratories at both for-profit and non-profit institutions. The careful planning of this program supports the success of the program and the effective preparation of our trainees for careers in stem cell research.

[1] http://www.cirm.ca.govs
[2] Baker, L., & Deal, B. CIRM - Interim economic impact review. Menlo Park: Analysis Group. (2008)
[3] http://stemcells.nih.gov/research/training/defaultpage.asp
[4] Saterbak, A. "Laboratory courses focused on tissue engineering applications," Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition, 2002.
[5] Phillips BW, Crook JM. "Pluripotent human stem cells: a novel tool in drug discovery," BioDrugs, 24(2): 99-108, April 1, 2010.
[6] http://rsbweb.nih.gov/ij/
[7] http://www.nhnscr.org/stem-cell-culture-course/