Proposal for a Ph.D. Program in Biotechnology
New Mexico Institute of Mining and Technology

Executive Summary. New Mexico Institute of Mining and Technology (New Mexico Tech, NMT) proposes a multidisciplinary Ph.D. program in Biotechnology to begin in August 2016. The aim of this novel program is to prepare students at the highest level for careers in research, development, and practical applications of the tools of biotechnology, e.g., biomolecular, biochemical, biomedical and bioengineering approaches, as well as in teaching the principles and techniques of biotechnology. Biotechnology has huge potential for solving societal problems and for creating useful products and processes, thereby also creating economic development. It is fully anticipated that this program will not only expand the biotechnological workforce in New Mexico but will also stimulate bioentrepreneurship. New Mexico Tech has placed this bio-related doctoral degree among its highest priorities in its Strategic Plan for 2015-2020. The new program will fill significant needs in the state of New Mexico and also within New Mexico Tech’s research community. The new program will involve the Departments of Biology, Chemistry, Psychology, Computer Science, Mathematics, Earth and Environmental Sciences, Chemical Engineering, Mechanical Engineering, Materials Engineering, Environmental Engineering and Management, with potential for expansion to include other departments/disciplines, e.g., Physics, Electrical Engineering. Faculty members in participating departments have solid records in research grantsmanship and in publishing the results of their research. Being a STEM institution and as such both specialized and applied, the academic and research program at New Mexico Tech has very little overlap with New Mexico’s other research universities. While some fundamental overlap is inevitable, New Mexico Tech’s Biotechnology Program aims to complement the research and the coursework offered at the related Ph.D.-granting departments at the University of New Mexico and New Mexico State University. The new program will be a rigorous one, requiring a range of coursework from various disciplines, including four core courses in Biotechnology, along with completion of a significant body of research leading to a dissertation and first authorship on at least one accepted, peer-reviewed publication. Students will be recruited from within New Mexico and also nationally and internationally. We plan to ramp the program up gradually so as to begin graduating about two students per year in five years. Biotechnology Ph.D. students will be supported by existing and new teaching assistantships as well as by externally funded research assistantships. The physical facilities and library resources at New Mexico Tech are sufficient for at least the first five years of the program. New upper-level courses will be created, requiring additional faculty members. New Mexico Tech’s administration has committed to one new tenure-track biotechnology-relevant faculty recruitment during year one, with further hires being projected as the program grows. Additionally, Biology is currently recruiting two new faculty members and is giving priority to applicants engaged in applied interdisciplinary research. A Biotechnology Advisory Panel consisting of one representative of each of the above-named departments will provide leadership for the program. The Biotechnology Graduate Faculty, consisting of faculty members eligible to advise Biotechnology Ph.D. students, will make decisions regarding acceptance of new students, changes in degree requirements, appeals of decisions, etc. The program will be assessed regularly for quality, both internally and with the aid of external reviewers.
Core courses

- BIOT 5XX Molecular Biotechnology, 3 cr, 3 cl hrs. A lecture-supported, laboratory-based course on molecular biotechnology of microbial and mammalian systems. Techniques used in prokaryotic and mammalian molecular biotechnology. Recombinant DNA methodologies (DNA/RNA isolation and manipulation, restriction mapping, cloning, PCR, site-directed mutagenesis, DNA sequencing, CRISPR/CAS editing) combined with classical biochemical protein (SDS-PAGE protein gels, ELISA, Western blotting, enzyme assay) techniques. Textbook: Molecular Biotechnology by Glick & Pasternak. This will be a new course but based on existing BIOL 333 & BIOL 333L.

- BIOT 5XX Biochemical Technology, 3 cr, 3 cl hrs. After an introduction to basic biochemistry and cell biology this course covers biotechnology routes to foods, drugs, polymers and fuels. Fermentation reactions with immobilized enzymes, bacteria, fungi, plants and animal cells are covered; also separation and purification. Offered mostly online with occasional in person classes. Existing Materials course, Bioprocess Engineering (MATE 489) offered during Fall 2015 by Calvert.

- BIOT 5XX Biophysical Technology, 3 cr, 3 cl hrs. Covers biomedical materials and devices including properties of hard and soft tissue, orthopedic implants, cardiovascular devices, skin. cartilage and tendon, eye and ear implants, neural prosthetics, cyto- and biocompatibility. Offered as an online course with occasional meetings. Existing Materials Course (MATE 599) course, last offered spring 2015 by Calvert.

- BIOT 5XX Biomechanical Technology, 3 cr, 3 cl hrs. The mechanical functionality of the human body. Covers mechanics of cells, fluid mechanics of blood, respiration and lymph, muscle bone and joints, gait analysis, exercise, injury and orthopedic fixtures, eyes and ears. Existing Materials Biomechanics (MATE 599) course, last offered spring 2014 by Calvert.

Electives

- BIOT 5XX Applied Microbiology, 3 cr, 3 cl hrs. Principles of applied and industrial microbiology and microbial technology. Application of microbes in various products and processes, biofermentors and scale-up of microbial culturing, molecular engineering of microbes, bioenergy. Prerequisite: BIOL 341 or BIOL 343 or equivalent, graduate standing or consent of instructor. New Course.

- BIOT 5XX Experimental Cell Biology with Lab, 3 cr, 3 cl hrs +1 cr, 3 cl hr lab. This advanced course explores in detail the methodological tools of experimental cell biology. These include prokaryotic and eukaryotic cell culture, cloning and gene transfections, biochemical studies of signaling pathways, membrane behavior and
analysis of changes in gene expression; (SEM, TEM, fluorescence, confocal) microscopy, electrophoresis, fractionation, microbiological assays (MIC/MBC), transgenic animals, preclinical studies for drug development as well as finding and interpreting methodologies available in the literature and other resources. Preq. BIOL 331 (cell Biology) and BIOL 333 and BIOL 333L (Molecular Biology with lab) Previously offered as BIOL 489 by Rogelj.

• BIOT 5XX Drug Delivery, 3 cr, 3 cl hrs. Focus is on current developments in drug delivery techniques, with only a brief discussion of common clinical techniques. The first portion of the class focuses on various delivery mechanisms and the tools needed to validate successful targeted drug delivery (both in vitro, in vivo and diagnostic tools). The second part of the course focuses on current developments in drug delivery based on published research articles. Students will read, digest, and critically analyze scientific work from leading research laboratories. Students will also gain valuable communication tools, as each student will present an article of interest to the class. Finally, the third part of the course focuses on important materials characterization methods such as biological sample prep, SEM, TEM, DSC, flow cytometry, fluorescence microscopy, ELISA assays. Shares lecture with MATE 576 but is graded separately. Extra Work for Grad-level credit. Tartis existing course CHE 476 Drug Delivery Techniques.

• BIOT 5XX Principles of Drug Design, 3 cr, 3 cl hrs. Principles in Drug Design course provides an overview of the multilayered and multidisciplinary processes involved in starting from a potentially drug-responsive problem and ending with a novel clinically-used drug. This includes molecular or phenotypic target identification, compound design (including computational, combinatorial chemistry and structure-based drug design methods), drug synthesis, development of model assays, discovery of a lead, optimization of the lead, identification of mode of action, kinetics of molecular targeting, prodrug design and drug development from this in vitro analysis via preclinical studies to clinical studies and introduction of new drugs into clinical practice. Regulations pertaining to each of these steps will be discussed. New course, co-taught between Chemistry (Frolova, Tello-aburto) and Biology (Rogelj).

• BIOT 5XX Behavioral Neuroscience, 3 cr, 3 cl hrs +1 cr, 3 cl hr lab. Study of the neural bases of behavior, including functional neuroanatomy of sensory and motor system, and clinical correlates of neurological abnormalities. Behavioral neuroscience (Elliott) plus directed review and discussion of current research in application of biotechnology in the neurosciences (Thompson). New Psychology Course.

• BIOT 5XX Cell and Molecular Neuroscience 3 cr, 3 cl hrs. A study of the molecular and cellular basis of the nervous system, covering fundamentals of cell biology, principles of neuronal signaling and neuronal courses, and cell and molecular
approaches to the investigation, diagnosis and treatment of the diseases of the nervous system. Applications of emerging technologies. *Existing course PSY 409.*

- **BIOT 5XX Entrepreneurial Biotechnology**, 3 cr, 3 cl hrs. Rules and regulations governing product development and post-approval marketing from medical devices and pharmaceuticals. From cGMP compliance to federal regulations. Introduction of students to the creation of a company; from pitching a concept and securing funding as a venture capital investment. Current research and industrial trends in the evolution of a biotechnological idea to a biotech venture. Strategic and tactical approaches for marketing of biotechnological products and services. *New Course, offered by Management Department (Anselmo and Reinaw)*

- **BIOT 5XX Bioinformatics**, 3 cr, 3 cl hrs. Computer analysis of biological sequence data used to perform in silico experiments. Students will design and perform experiments using public domain software and databases. Prerequisite: BIOL 311 or consent of instructor. *Existing course: BIOL 535, Bioinformatics.*

- **BIOT 5XX Bio-inspired Design**, 3 cr, 3 cl hrs. Tartis will provide description ASAP. *Dr. Tartis’ previously offered, highly successful Chemical Engineering course.*

- **BIOT 5XX Biomaterials** (3 credit hours): Description to be provided ASAP. *Dr. Calvert and Dr. Tartis are currently preparing this course to be taught in the Spring 2016.*

- Biotechnology 595 Dissertation, cr to be arranged.

**Learning Outcomes:**

*Students in the Biotechnology Ph.D. Program will develop the following skills and competencies:*

- critical thinking
- problem solving
- communication (written and oral)
- breadth of knowledge, ability to function well in an interdisciplinary, multi-disciplinary enterprise
- depth of knowledge in one or more areas of research
- knowledge and hands-on skills in a broad range of laboratory techniques and use of a wide range of scientific instruments
- conceptual ability to design and technical ability to implement a complex science- and engineering-spanning research project
- understanding the entrepreneurial mindset, including intellectual property laws, biotechnology commercialization and marketing approaches
- appreciation of ethical issues and potential consequences associated with biotechnology

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Doctor of Philosophy in Biotechnology

Students of exceptional ability, as demonstrated in previous courses or in a master’s degree program, may pursue a program leading to the doctoral degree. The prospective doctoral candidate in Biotechnology should develop a good background in biology, chemistry, and mathematics plus at least one of the following: computer science, mechanical engineering, chemical engineering, or materials engineering. Additionally, students should achieve a high level of competence in the field of specialization defined by their dissertation research. Additional information is found in the Graduate Catalog.

Research fields appropriate for the biotechnology candidate include bioengineering, molecular biology, microbiology, tissue engineering, pathogen detection, drug discovery, drug delivery, medical instrument development, neuroscience, and biochemistry. Interdisciplinary projects are strongly encouraged.

Degree Requirements

- Up to 30 credit hours from an appropriate master’s degree, excluding thesis and S/U courses, may be included.
- Students are normally expected to take BIOT. 501 each semester that they are in residence on the New Mexico Tech campus.
- 48 hours of coursework approved by the student’s advisory committee, to include:
  - Core Biotechnology courses:
    - BIOT 5XX Molecular Biotechnology
    - BIOT 5XX Biochemical Technology
    - BIOT 5XX Biophysical Technology
    - BIOT 5XX Biomechanical Technology
  - 12 hours of upper-division or graduate-level coursework outside the Biology Department.
- Dissertation (24 credit hours): BIOT 595
- Preliminary exams in microbiology, molecular biology, cell biology, and biochemistry are usually taken in the third semester, or in the second semester for students who already have a master’s degree. Students may, if necessary, repeat one or more exams the following semester. Students who do not receive satisfactory scores after two attempts will be dropped from the Ph.D. program.

Admission Requirements

Completion of a bachelor’s degree in a relevant field (e.g., biology, biotechnology, chemistry, biochemistry, bioengineering, biophysics, computer science with a biology minor, etc.) or the expectation of completing such a degree before the beginning of the first semester of graduate study. Students are expected to have competencies in math, chemistry, and physics equivalent to those required for completion of a B.S. degree at New Mexico Tech. Students who are deficient in one or more of these areas will be required by their advisory committee to complete undergraduate coursework in the area(s) of deficiency. Students should have an academic record that indicates a good potential for
success in a doctoral program. An undergraduate GPA of 3.0 or higher is used as a general guideline in New Mexico Tech’s graduate program.