

Department of Biological Sciences Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

03-050 Study Abroad

Fall

This course number is a placeholder for biological sciences majors who are studying abroad.

03-051 Study Abroad

Spring

This course number is a placeholder for biological sciences majors who are studying abroad.

03-052 Summer Internship

Summer: 3 units

Course Description: The Department of Biological Sciences considers experiential learning opportunities important educational options for its undergraduate students. One such option is an internship, normally completed during the summer. Students do not need to officially register for an internship unless they want it listed on their official transcripts. The Director of Undergraduate Programs (or designee) will add the course to the student's schedule, and the student will be assessed tuition for 3 units. Upon completion of the internship, students must submit a 1-2 page report of their work experience to the Director of Undergraduate Programs (or other designated faculty member). After the reports have been reviewed and approved, a "P" grade will be assigned.

03-116 Phage Genomics Research

Spring: 6 units

Spring Semester: The DNA sequences will be analyzed with bioinformatic tools and compared with those of phages isolated at other locations to identify genes, their organization, the differences that may characterize different phage groups, and how these have arisen during evolution.

Prerequisite: 03-115

03-117 Frontiers, Analysis, and Discovery in Biological Sciences

Fall and Spring: 6 units

In this hands-on laboratory class, students will investigate a current biology problem. Students will read literature articles, design hypotheses, plan and carry out experiments, analyze and interpret data, and design future questions as part of a collaborative research team. In addition, teams will work with faculty and fellow students to understand and explore the relevance of their projects in the field of biology and other disciplines. Finally, teams will communicate results in an oral presentation to peers and faculty. Students will gain research skills, analytical skills, communication skills (both written and oral), and project design skills.

Prerequisites: 03-110 or 03-151 or 03-121

03-118 Beer: A Yeast's Perspective

Fall and Spring: 6 units

This is a combined lecture and laboratory course in which students will investigate the biochemistry of fermentation using strains of yeast commonly used in brewing science. Lectures and readings will cover all necessary information to succeed in the course, including topics like yeast metabolism, fermentation at the micro and industrial levels, and a history of fermentation's influence on society. Lab experiments will investigate yeast growth and fermentation processes in various strains used in brewing, and quantitative assessments of beer at the molecular level. The course puts a focus on microbiology lab techniques and yeast biochemistry; however, no previous lab experience or biology coursework is required, and anyone with an interest in the science behind brewing yeast can succeed in the class.

03-119 Biology for Life Special Topics Micro

Intermittent: 3 units

Special Topics in Biological Sciences Micro Courses. Topics will vary depending on the semester and instructor. Courses offered under this course number will not require prior knowledge of or exposure to biological sciences and are open to students from any major and class year. Please read individual section descriptions for more information. Spring 2023: Sections W3 and amp; A4: Stayin' Alive: Human Immunity: This course will provide the tools for the layperson to understand how their immune system works to prevent disease and cancer. The course also explains the basis of modern immunotherapies such as vaccines and cancer treatment. Biology at the high-school level is the only requirement. This requirement can be waived after completing a short series of simple on-line modules.

03-120 Biology for Life Special Topics Mini

Fall and Spring: 6 units

Special Topics in Biological Sciences Mini Courses. Topics will vary depending on the semester and instructor. Courses offered under this course number will not require prior knowledge of or exposure to biological sciences and are open to students from any major and class year. Please read individual section descriptions for more information. Fall 2023 Section A2: Bench Skills with Fluorescent Proteins: In this combined lecture and lab course we will develop our toolkit of molecular biology bench skills in order to identify unknown fluorescent proteins. You will complete experimental work to isolate plasmids, characterize DNA, express fluorescent proteins in bacteria, purify those proteins, and finally identify the unknowns. This course will be a colorful opportunity to practice lab skills before taking required lab classes or starting research. Recommended corequisite of 03-121 Modern Biology.

Course Website: https://www.cmu.edu/bio/undergrad/academics/intro_courses.html

03-121 Modern Biology

All Semesters: 9 units

This is an introductory course that provides the basis for further studies in biochemistry, cell biology, genetics and molecular biology. This course emphasizes the chemical principles underlying biological processes and cell structures as well as the analysis of genetics and heredity from a molecular perspective. This is the introductory biology course for all science and non-science majors.

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html> (<http://www.cmu.edu/bio/undergrad/courses/>)

03-124 Modern Biology Laboratory

Fall and Spring: 9 units

This laboratory is designed to introduce students to modern concepts in the biological sciences. The experiments illustrate many of the principles covered in 03-121 and 03-230. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

03-125 Evolution

Fall: 9 units

Evolutionary theory is the unifying principle of biology. A good comprehension of the concepts that underlie this theory is therefore important to properly appreciate and understand any biological process. This course is designed for students intending to continue studies in biology so that they may gain an understanding of the evolutionary framework in their more advanced courses, and also non-biology majors who want to extend their knowledge of biology at an introductory level. The lectures will include (i) an examination of the history and development of evolutionary theory, (ii) consideration of some of the facts that have established the theory, (iii) an introduction to the concepts of phylogenetics, (iv) discussion of the patterns and mechanism that lead to the diversity and origins of the groups of life, (v) an introduction to genetics and population genetic theory, and (vi) discussion of and how this applies to natural selection and speciation. The course will also include some more specialist topics, including evolution of development, sexual selection, evolutionary applications to medicine and conservation biology, and genome evolution. Assessment will be based on several in-class exams and quizzes, homework assignments, a written term paper, and a final exam.

03-128 Biology for Life Special Topics

Fall and Spring: 9 units

Special Topics in Biological Sciences. Topics will vary depending on the semester and instructor. Courses offered under this course number will not require prior knowledge of or exposure to biological sciences and are open to students from any major and class year. Please read individual section descriptions for more information. Summer 1/All 2023: Tropical Ecology at Monteverde Institute. This is a course offered through a study abroad program to Costa Rica. Students will be addressing general questions about tropical ecosystems such as: What are tropical forests? What makes them different than other forests? Where are they and why do global climate patterns result in their geographic distribution? What are the different kinds of tropical forests? What controls the diversity, phenology and successional processes of tropical forests? What are tropical marine ecosystems? This course will also cover specific ecological interactions between organisms such as: seed dispersal, pollination, herbivory, mutualisms, prey-predator interactions in the tropics. Students will also learn about humans in the tropics, both those groups that have evolved and adapted to these environments and the current threats imposed by local/global economic systems. As a part of this course, students will participate in field work and use nature as a laboratory to study the diversity of life forms and interactions between plants, animals, and microorganisms and with the physical environment.

Course Website: https://www.cmu.edu/bio/undergrad/academics/intro_courses.html

03-129 Human Health and Disease

Intermittent: 9 units

The main objective of the course is not only to teach the students how the body works but also to construct a global view of all 9 organ systems and how these organ systems coordinate with each other when homeostasis is challenged. An additional emphasis of this course is the pathophysiological changes that can be associated with each organ malfunction.

03-132 Basic Science to Modern Medicine

Fall and Summer: 9 units

The goal of this course is to give students an understanding of the biology that impacts their everyday lives. Disease can be a tragic part of human life, a fact that is even more apparent in during a global pandemic. To understand how specific diseases like COVID-19 or cancer affect the human body, and how modern medicine can tackle them, this course includes a fundamental study of the basic molecular biology, genetics, and cell biology that underlies disease. This is a topics-based course, with topics chosen to cover aspects of biology and health that students are likely to encounter in their daily lives. The topics for summer 2023 will include COVID-19, genome editing, and cancer. We will explore these topics from both a basic science and a modern medicine perspective. Student's will gain the expertise to critically evaluate media reports about biology and health, and to ask the questions that will help them to make educated decisions in their lives. Key topics: The course will cover at least COVID-19, cancer, and genome editing, in addition to the essential aspects of molecular biology, cell biology, and genetics needed to understand those topics.

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html> (<http://www.cmu.edu/bio/undergrad/courses/>)

03-133 Neurobiology of Disease

Spring: 9 units

This course will explore the biological basis of several neurological and neuropsychiatric diseases, with an emphasis on medical diagnostic tools and techniques. It will include discussions of the anatomical basis of neurological diseases as well as recent research into understanding the mechanisms of disease. This course is intended to broaden students' understanding of how diseases are diagnosed and studied. Students will also learn how basic neurological and psychiatric evaluations are conducted. We will discuss neurobiological research to serve as a basis for understanding brain structures and functional alterations in a variety of developmental, degenerative, neurological, and psychiatric disorders.

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html> (<http://www.cmu.edu/bio/undergrad/courses/>)

03-135 Structure and Function of the Human Body

Fall: 9 units

Structure and Function of the Human Body is a non-majors course designed to explore fundamental relationships between form and function of the human body. The anatomy and physiology of major organ systems will be studied in the context of normal and disease states. Students will learn about critical biological processes such as the central dogma, membrane diffusion and transport, cell signaling, gas exchange, blood flow, nutrient absorption, blood pH balance, and action potential generation and propagation. Students will then apply this knowledge to understand how organs respond to various inputs in maintaining homeostasis. Hands-on demonstrations will be incorporated to provide a practical framework for the information presented in lectures. At the culmination of the semester, students will gain a broad understanding of how the body systems function at the cellular, tissue and organ levels and be able to relate simple physiological processes to better understand highly prevalent diseases in society.

03-140 Ecology and Environmental Science

Fall: 9 units

Environmental science is a highly interdisciplinary field that integrates knowledge and modes of inquiry from across the sciences to understand some of the most important challenges of the 21st century. This course provides a foundational background in scientific method, critical thinking and problem solving strategies used to study and evaluate the environment. Modules include: principles of ecology and eco-systems, biological diversity, biogeochemical cycles, endangered species management, human population growth, atmosphere, climate and global warming. Assessment will include class attendance, quizzes, individual and small group projects, in class exams. Projects may involve visits to local sites.

03-151 Honors Modern Biology

Fall: 10 units

Honors Modern Biology (03-151) is an honors introductory course. This course has been designed for freshman students with an interest in a major in the biological sciences who have had solid preparation in this field as indicated by the following examinations: SAT II Molecular Biology, AP, or IB Biology. This course will present the concepts and principles necessary for a general understanding of the processes occurring in living cells and is the basis for further study in cell biology, biochemistry, genetics, molecular and developmental biology. While similar core topics will be covered in all sections of Modern Biology, this section will be offered at an accelerated pace, requiring more independent learning. The extra class time this pacing provides will allow the exploration of the molecular basis of life to help students integrate and apply the core principles of biology covered in the course. THIS SECTION IS RESERVED FOR INCOMING FIRST-YEAR MCS STUDENTS.

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html> (<http://www.cmu.edu/bio/undergrad/courses/>)

03-161 Molecules to Mind

Spring: 9 units

This course provides a depth-first approach to understanding neuroscience.

We will begin with a clinical focus on neuroanatomy, introducing students to some basic neurological diagnostic techniques. We will then explore the biological basis of neuronal function and link the function of individual neurons to a broader context of neural systems. This will be done in the context of primary literature. Students who complete this course will therefore have an understanding of research methods and be prepared to evaluate scientific literature. The course will have a strong focus on the biological and cellular basis of neuronal excitability and also give students significant, in depth exposure to the function of synapses and their plasticity. Finally, the course will give students an in depth look at sensory and/or motor systems by focusing on one system in particular.

03-201 Undergraduate Colloquium for Sophomores

Fall

The purpose of this seminar series is to update biology undergraduates about university and departmental functions, seminars, etc. that are pertinent or useful. In addition, research talks by faculty and undergraduates will be used to introduce students to the research being conducted in faculty laboratories. Additional topics may include graduate and medical school applications, career options, topics in the press, and important scientific discoveries.

03-202 Undergraduate Colloquium for Sophomores

Spring

Missing Course Description - please contact the teaching department.

03-206 Biomedical Engineering Laboratory

Fall and Spring: 9 units

This laboratory course is designed to provide students with the ability to make measurements on and interpret data from living systems. The experimental modules reinforce concepts from 42-101 Introduction to Biomedical Engineering and expose students to four areas of biomedical engineering: biomedical signal and image processing, biomaterials, biomechanics, and cellular and molecular biotechnology. Several cross-cutting modules are included as well. The course includes weekly lectures to complement the experimental component. Priority for enrollment will be given to students who have declared the Additional Major in Biomedical Engineering. Notes: This course number is reserved for students who are CIT majors and registered with the HPP program. If you require a biology lab for pre-health admissions requirements, register for 42-203 and Dr. Sang Chalacheva will work with students once the semester begins to register for 03-206 instead of 42-203. Priority for enrollment will be given to students who have declared the Additional Major in Biomedical Engineering. Prerequisites: (03-151 or 03-121) and 42-101

03-210 Independent Study

Fall and Spring

Students will read papers from the original literature under the direction of a faculty member. Students will be required to demonstrate mastery of the readings by discussions with the sponsoring faculty member, oral presentations, or writing of one or more papers summarizing and extending the information in the readings. If appropriate, students may write a program(s) to satisfy this last requirement. A student may take this course only once. This is a mini format course. Special permission required. **Students MUST contact bio-unggrad@andrew.cmu.edu and complete the application form in order to participate and register.**

03-220 Genetics

Fall: 9 units

The mechanisms of transmission of inherited traits in viruses, bacteria, fungi, plants and animals are discussed. Molecular mechanisms of gene expression and gene regulation are analyzed. Recombinant DNA and its applications in genetic analysis, biotechnology, forensics, agriculture, medicine, and the pharmaceutical industry are presented. Special topics in human genetics are considered, such as the genetics of cancer. Principles and methods for the study of developmental genetics, population genetics and complex traits are also introduced.

Prerequisites: 03-121 or 03-151

03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis

Spring: 9 units

Scientific and technical advances in genetics have accelerated dramatically since the draft human genome sequence was published in 2001. The development of massively parallel DNA sequencing and associated technologies has transformed the way we approach genetic questions. Contemporary genetics is increasingly concerned with generating, processing and analyzing vast amounts of data to extract information about genetic variation, expression, interactions and associations. At the same time, comparative genomics, bioinformatic and reverse genetic methods are transforming the way in which gene functions are investigated, while the development of powerful methods for precise modification of genomes is opening the way to cell- and gene-based therapies for disease. In parallel, the promise of precision or personalized medicine is predicated on advances in understanding of complex traits, genetic interactions and networks. These and other topics will be covered following a review of basic principles of gene structure and expression, the fundamental principles of Mendelian genetics, and their underpinnings in cellular mechanisms for the replication, recombination and transmission of genetic material. Although the topics overlap extensively with 03220 (Genetics), they will be presented at a more advanced level, with a greater emphasis on current methods of quantitative and statistical analysis. This course is recommended for students with a particular interest in emerging technologies for analysis of human genetics, genomics, gene therapy and precision medicine.

Prerequisites: (03-121 Min. grade B or 03-151 Min. grade B) and (36-225 Min. grade C or 21-124 Min. grade C or 36-200 Min. grade C or 15-359 Min. grade C or 15-259 Min. grade C or 36-218 Min. grade C or 36-201 Min. grade C or 36-247 Min. grade C or 36-217 Min. grade C)

03-230 Intro to Mammalian Physiology

Spring: 9 units

This course has been designed to explore human physiology at an introductory level. Emphasis will be placed on the physiological processes in an organ system framework and focus on a wide range of pertinent clinical topics. Our aim is to instill in you a deeper appreciation for the complexity and beauty of the human body, and most importantly, to motivate you to carry away physiological principles that you may need later in your profession or simply may be relevant to a real-world situation.

Prerequisites: (03-151 or 03-121) and (03-231 or 03-232)

03-231 Honors Biochemistry

Spring: 9 units

This course provides an introduction to molecules and processes found in living systems. Amino acids, sugars, lipids and nucleotides and their corresponding higher structures, proteins, polysaccharides, membranes and nucleic acids are studied. Kinetics and mechanisms of enzymes as well as elementary metabolic cycles and the energetics of biological systems are studied with a quantitative approach.

Prerequisites: 03-151 or 03-121

03-232 Biochemistry I

Spring: 9 units

This course provides an introduction to the application of biochemistry to biotechnology. The functional properties of amino acids, nucleotides, lipids, and sugars are presented. This is followed by a discussion of the structural and thermodynamic aspects of the organization of these molecules into higher-order structures, such as proteins, nucleic acids, and membranes. The kinetics and thermodynamics of protein-ligand interactions are discussed for non-cooperative, cooperative, and allosteric binding events. The use of mechanistic and kinetic information in enzyme characterization and drug discovery are discussed. Topics pertinent to biotechnology include: antibody production and use, energy production in biochemical systems, expression of recombinant proteins, and methods of protein purification and characterization. The course is an alternate to 03-231.

Prerequisites: 06-223 or 09-107 or 06-221 or 09-105

03-320 Cell Biology

Fall: 9 units

This course provides descriptive information and mechanistic detail concerning key cellular processes in six areas: membrane function, protein targeting, signaling, cytoskeleton, cell division, and cell interaction. An attempt is made to introduce the methodology that was used to obtain this information and to discuss how our understanding of these processes relates to the treatment of human disease.

Prerequisites: (03-151 or 03-121 or 03-120) and (03-231 or 03-233 or 03-232)

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html>
(<http://www.cmu.edu/bio/undergrad/courses/>)

03-327 Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method

Intermittent: 9 units

An advanced introduction to the evolutionary concepts and bioinformatic skills that are central to molecular, cell, developmental, and microbiology. Proteins that share common ancestry also share functional properties. This is the guiding principle of model organism research and sequence-based bioinformatics. Evolutionary trees (phylogenies) and multiple sequence alignments provide evidence for predicting structural and functional constraints, sites of molecular interaction, and residues that confer functional specificity. In 2021, phylogenetics is emerging as an essential technique in metagenomics, cancer, and infectious disease, driven by technological advances such as high through-put sequencing and single-cell phenotyping. This course covers both the conceptual foundation and the practical skills of evolutionary bioinformatics. Students will acquire the "tree thinking" skills required for critical interpretation of phylogenetic analyses and figures in the literature and a rigorous understanding of phylogenetic inference methods. Theoretical knowledge will be complemented by hands-on experience with sequence data repositories, bioinformatic tools for database retrieval, sequence analysis, and tree building. Students will walk out of the course with the knowledge required to apply those tools correctly to messy, genuine data sets, and the ability to evaluate alternate hypotheses in light of these bioinformatic analyses. Students with a range of computational backgrounds are welcome.

Prerequisites: 03-151 or 03-121

Course Website: <http://www.cs.cmu.edu/~durand/Phylogenetics/>**03-342 Introduction to Biological Laboratory Practices**

Fall: 1 unit

This course is designed for students in the BSA degree program. It is designed to be an introduction to basic laboratory practices. The course will introduce biological and chemical safety training and basic laboratory practices. Techniques of solution preparation and titration, pipetting, UV/VIS spectroscopy, and quantitation of biological compounds will be covered.

03-343 Experimental Techniques in Molecular Biology

Fall: 12 units

This laboratory course is designed to teach experimental methods of modern biology. Experiments in microbial genetics, molecular biology and eukaryotic genetics are performed. Emphasis is placed on understanding and applying the biological principles of each experiment. This course is designed to be taken during the junior year and is intended to prepare students for undergraduate research. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

Prerequisites: (03-231 or 03-232) and (qc211 or 09-223 or 09-208 or 09-222)

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html>
(<http://www.cmu.edu/bio/undergrad/courses/>)

03-344 Experimental Biochemistry

Spring: 12 units

This course is designed to be taken as a sequel to 03-343. Experiments cover a variety of methods for investigating the structure and function of biological molecules. Experimental methods with proteins, enzyme kinetics, lipids, spectroscopy, and isolation and quantization of biological molecules are covered. During several experiments, students design their own projects. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

Prerequisites: 03-343 and (03-231 or 03-232)

03-345 Experimental Cell and Developmental Biology

Spring: 12 units

This laboratory is designed to teach concepts and experimental methods in cell and developmental biology. Students work with a variety of organisms to examine how cells traverse development from rapidly dividing, undifferentiated cells, through cell commitment and the establishment of spatial and temporal patterns of gene expression, to the specific characteristics and responses of terminally differentiated cells. The course makes extensive use of video microscopy with phase contrast, DIC and fluorescence microscopes. Biochemical, immunological and molecular biological techniques are used to probe the molecules and processes of cells undergoing development. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

Prerequisites: 03-343 and (03-232 or 03-231) and (03-240 or 03-320)

03-346 Experimental Neuroscience

Intermittent: 12 units

This laboratory is designed to teach concepts and experimental methods in neurobiology. Students work with a variety of organisms to study the anatomy, function, and development of the nervous system. Immunological, molecular, biochemical, and ballistic labeling techniques are used to examine the gene expression and structure in the mature and developing nervous system. Students study the function of neurons through neurophysiological techniques in invertebrates and computer simulation. This course makes extensive use of video microscopy and phase contrast, DIC, and fluorescence microscopes.

Prerequisites: (03-240 or 03-320) and 03-362 and 03-343

03-350 Developmental Biology

Spring: 9 units

How does a complex, multicellular organism arise from a single cell? How do cells with identical genomes acquire distinctive properties? What are the medical consequences of abnormal embryonic development? How does regeneration occur? How has evolution modified developmental programs to produce different body plans? These are some of the central questions in the field of developmental biology. This course serves as an introduction to current concepts and experimental approaches in this rapidly advancing field. Topics in the course include genomics, differential gene expression, cell signaling, cell movements, tissue morphogenesis, stem cells, human development, and regeneration. The course examines the genes and signaling pathways that control development and the role that mis-regulation of these pathways plays in human disease.

Prerequisites: 03-240 or 03-320

03-351 Computation and Biology Integrated Research Lab

Fall: 9 units

Modern biological research is heavily interdisciplinary in nature requiring the use of a diverse set of experimental techniques and computational analysis. This course provides students with a modern research experience while training them to communicate and collaborate in an interdisciplinary setting to better prepare them to join the workforce as members of interdisciplinary teams. This will be accomplished by focusing efforts on a real research problem requiring sophisticated experimentation and computation for success. Class time will include both laboratory research time (wet lab and computational) and activities designed to teach and practice communication methods for interdisciplinary teams. Students are expected to have a strong background in biology or computation and an interest in both.

Prerequisites: 03-343 or 03-124 or 03-117 or 15-112

03-360 Genomics and Epigenetics of the Brain

Fall: 9 units

This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in genomic technology are in the process of revolutionizing how we conduct molecular biology research. These new techniques have given us an appreciation for the role that epigenetics modifications of the genome play in gene regulation, development, and inheritance. In this course, we will cover the biological basis of genomics and epigenetics, the basic computational tools to analyze genomic data, and the application of those tools to neuroscience. Through programming assignments and reading primary literature, the material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.

Prerequisites: 03-330 or 03-220

03-362 Cellular Neuroscience

Fall: 9 units

Modern neuroscience is an interdisciplinary field that seeks to understand the function of the brain and nervous system. This course provides a comprehensive survey of cellular and molecular neuroscience ranging from molecules to simple neural circuits. Topics covered will include the properties of biological membranes, the electrical properties of neurons, neural communication and synaptic transmission, mechanisms of brain plasticity and the analysis of simple neural circuits. In addition to providing information the lectures will describe how discoveries were made and will develop students' abilities to design experiments and interpret data.

Prerequisites: 03-161 or 85-219 or 42-202 or 03-230 or 03-320

03-363 Systems Neuroscience

Spring: 9 units

Modern neuroscience is an interdisciplinary field that seeks to understand the function of the brain and nervous system. This course provides a comprehensive survey of systems neuroscience, a rapidly growing scientific field that seeks to link the structure and function of brain circuitry to perception and behavior. This course will explore brain systems through a combination of classical, Nobel prize-winning data and cutting edge primary literature. Topics will include sensory systems, motor function, animal behavior and human behavior in health and disease. Lectures will provide fundamental information as well as a detailed understanding of experimental designs that enabled discoveries. Finally, students will learn to interpret and critique the diverse and multimodal data that drives systems neuroscience.

Prerequisites: 03-320 or 03-230 or 42-202 or 03-240 or 85-219 or 03-161

03-365 Neural Correlates of Learning and Memory

Spring: 9 units

This course will examine the biological substrates of learning, memory, and behavioral adaptation. The focus will be on addressing how neural circuits change during new skill acquisition and adapt to variations in the environment. An introduction to experience-dependent changes in neural structure and function, in addition to behavioral learning paradigms, will be provided. Then we will consider the ways in which specific changes in biological substrates give rise to the emergent properties that drive behavioral adaptation, followed by in depth coverage of deciphering which biological substrates constitute a lasting memory trace. Finally, the concept of age-dependent learning will be examined. Concepts and specific examples will come through reading of primary literature and selected readings from advanced texts.

Prerequisites: 03-161 or 85-219 or 03-240 or 03-320

03-366 Neuropharmacology: Drugs, Brain and Behavior

Fall: 9 units

This course is designed to give students a comprehensive understanding of the major neurotransmitter systems in the brain. Students will explore approaches to understanding how various neurotransmitters function in sensory and motor systems as well as how they are modulated by endogenous and exogenous agents. The exploration will include basic principles of neural communication, signal transduction and second messenger systems, main classes of neurotransmitters, and the effects of medications and drugs of abuse. In terms of sensory and motor systems, student will learn how different neurotransmitters affect different aspects of systems neuroscience and how a single neurotransmitter can have multiple roles in different systems. Students will learn how these processes affect the endocrine system, neuroinflammatory responses, addictive behaviors, and neurotoxic or degenerative conditions.

Prerequisites: 03-133 or 03-362 or 03-231 or 03-232

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html>
<http://www.cmu.edu/bio/undergrad/courses/>

03-380 Virology

Fall: 9 units

The concepts and methods of virology are covered, with emphasis on animal viruses, within the framework of cell biology, genetics, molecular biology, immunology, pathology, and epidemiology. The strategies that a wide variety of different DNA and RNA viruses, including some new and emerging ones, use to replicate and express their genomes during infection of host cells will be examined in some detail. The effects that viruses inflict on these cells will also be examined, as will some of the host cell responses generated by such virus-cell interactions, including interferon induction, the antiviral response generated by interferon, and oncogenic transformation. In addition, an overview of procedures used for prevention and treatment of viral diseases via vaccines and antiviral drugs, respectively, will be presented, as will a brief discussion of viroids and prions, and the characteristics of these agents which distinguish them from viruses.

Prerequisites: 03-240 or 03-320

03-390 Molecular and Cellular Immunology

Spring: 9 units

This is a course that covers the fundamentals of cellular and molecular immunology in a comprehensive manner. The objective of this course is to introduce the students to the immune system, the cells that constitute it, their ontogeny, their structure, activities and responses to stimuli and the systems/signals that integrate these cells into a coherent functional entity. Additionally, the course will demonstrate where, when, and how, the immune system responds in pathologic states, how its cells can themselves become the causes of pathologies, and how medical science targets and uses the immune system to prevent and treat a wide range of diseases.

Prerequisites: 03-231 or 03-232 and (03-320 or 03-240)

03-391 Microbiology

Spring: 9 units

The course provides introductory level microbial science and molecular biology that is aimed for students from all disciplines of natural science. It covers microbiology, genetics, genomics, as well as bacterial, fungal, and protozoan pathogenesis. Topics include: the human microbiome, genome sequencing, gene transfer across species, virulence, and drug resistance.

Prerequisites: 03-232 or 03-231

03-409 Applied Cell Biology

Intermittent: 3 units

The course provides a hands-on experience in biology lab to conduct experiments, collect and analyze scientific data with the purpose of using the data to infer biological principals. Students will learn the details of western blot technique, commonly used in biology labs. In addition, they will apply the technique to study how insulin triggers specific signaling in target cells. This lab module will reinforce the students' understanding of material seen in Cell Biology lecture course (co-requisite 03-240) and will prepare them for future lab courses.

03-410 Special Topics in Biological Sciences

Fall and Spring: 9 units

Special Topics in Biological Sciences. Topics will vary depending on the semester and instructor. Please read the individual section descriptions for more information.

Prerequisites: 03-231 or 03-232

03-411 Topics in Research

Fall

During the year students attend weekly seminars given by outside speakers or members of the Biology Department on current research topics in modern biology; some seminars outside of the department may be substituted.

03-412 Topics in Research

Spring

Students attend weekly seminars by scientists from other universities who have been invited by the Department of Biological Sciences to present their research to our faculty, postdoctoral scientists, graduate students, and staff. A written response to questions about the seminar is prepared by each student during the seminar and turned in to the instructor at the end of the seminar.

03-435 Cancer Biology

Fall: 9 units

Cancer affects roughly 1 in 3 people worldwide, and originates from both hereditary as well as environmental causes. Its prevalence makes it practically inescapable. Its of great relevance from both scientific and sociocultural perspectives. This course aims to examine various hallmarks of the biology of cancer while exploring novel concepts that challenge our understanding of cell biology. From the perspective of a cancer cell, we will learn about basic concepts of cell division, DNA replication, cell signaling, cell cycle control, cell metabolism, the regulation of gene expression in human cells, oncogenes, tumor suppressor genes, mutations, the process of metastasis, cancer diagnosis, cancer treatments and ethical questions surrounding treating patients, the epidemiology of cancer including prevalence and historical trends in diagnosis, as well as social impacts of a cancer diagnosis. Students will also explore the primary literature and scientific review articles to better understand research and methods of investigation into the cellular and molecular processes of tumorigenesis. This course will include interactive lectures, guest speakers, and in class discussion exercises aimed at building class participation and association, as well as confidence in public speaking about the sciences. Given the well-documented link between stress and cancer, there will also be a small component aimed at making students aware of health and wellness, such as reducing stress and anxiety.

Prerequisites: 03-330 or 03-220 or 03-221

03-439 Introduction to Biophysics

Fall: 10 units

Biological physics, or the physics of living systems, is an exciting interdisciplinary frontier of physics that aims to understand the phenomenon of life using concepts and tools from Physics. This intermediate level course will introduce the general concepts and principles underpinning the physical behavior of living systems, from the dynamics of proteins and molecules to collective behavior of living cells and organisms. The course will develop key physics concepts that are most vital to biological processes, including energy conversion, information transfer, mechanics of movement, statistical phenomena, and fluid flow. We will apply these physics concepts to demonstrate how biological systems function, build simplified mathematical models to predict behavior, and use experimental data to inform and test models. The integration of biological phenomena, physical concepts, mathematical modeling, and analysis of experimental data represents an entirely new mode of learning, based on strategies adopted in research. These strategies will break traditional disciplinary barriers between physics and biology. The students will be expected to gain an intuitive grasp of ways to: frame the physical problem, identify appropriate theoretical frameworks, analyze experimental data, and ways to generalize and to understand the dependence of biophysical phenomenon on time and length scales. No prior knowledge of biology is expected. This class is offered in Fall of even years (e.g. Fall '22, 24, etc.)

Prerequisites: (03-151 or 03-121) and (33-122 or 33-112 or 33-142 or 33-107 or 33-152 or 33-132)

03-442 Molecular Biology

Fall: 9 units

The structure and expression of eukaryotic genes are discussed, focusing on model systems from a variety of organisms including yeast, flies, worms, mice, humans, and plants. Topics discussed include (1) genomics, proteomics, and functional proteomics and (2) control of gene expression at the level of transcription of mRNA from DNA, splicing of pre-mRNA, export of spliced mRNA from the nucleus to the cytoplasm, and translation of mRNA.

Prerequisites: 03-221 Min. grade B or 03-220 Min. grade B or 03-330 Min. grade B

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html>
<http://www.cmu.edu/bio/undergrad/courses/>

03-445 Undergraduate Research

Fall and Spring

Students may investigate research problems under the supervision of members of the faculty. Permission of a faculty advisor required. **Students MUST contact bio-ungrad@andrew.cmu.edu and complete the application form in order to participate and register. ** BIO MAJORS: The Biology Undergraduate Office will send out the paperwork to you on the first day of classes each semester. Paperwork and research mentor approval will be due the Friday before the add deadline. NON BIO MAJORS: Please contact the office (bio-ungrad@andrew.cmu.edu) to request the updated form.

03-451 Advanced Developmental Biology and Human Health

Fall: 9 units

This course will examine current research in developmental biology, focusing on areas that have important biomedical implications. The course will examine stem cell biology, cellular reprogramming, cell signaling pathways, tissue morphogenesis, and genetic/developmental mechanisms of birth defects and human diseases. Emphasis will be placed on the critical reading of recent, original research papers and classroom discussion, with supporting lectures by faculty. Instructor permission is required to register. Please contact Dr. Ettensohn and lt;ettensohn@cmu.edu and gt;. Prerequisites: (03-240 Min. grade B or 03-320 Min. grade B) and (03-220 Min. grade B or 03-330 Min. grade B)

03-511 Computational Molecular Biology and Genomics

Fall: 9 units

An advanced introduction to computational molecular biology, using an applied algorithms approach. This course provides an in-depth treatment of the algorithmic foundations of computational molecular biology. Prerequisites: (03-121 or 03-151) and 15-122

Course Website: <http://www.cs.cmu.edu/~durand/03-711/>**03-545 Honors Research**

Spring: 9 units

This semester of research consists primarily of research and preparation of an acceptable written thesis. Oral presentation and defense of the thesis research will be required. This course ordinarily will be taken in the second semester of the senior year. Permission of the research advisor required. **Students MUST contact bio-ungrad@andrew.cmu.edu and complete the application form in order to participate and register. ** Prerequisite: 03-445

03-600 Biotechnology or Biopharmaceutical Engineering Internship

All Semesters

This course allows a student to gain biotechnology experience in a "real-world" setting. Internships vary widely in scope, but common to all is the chance to practice biotechnology skills acquired in the classroom. Typically, students seek and secure their own internships. Students are required to write written reflections summarizing their internship work and submit those to the course instructor.

03-601 Computational Biology Internship

All Semesters

This course allows a student to gain computational biology experience in a "real-world" setting. Internships vary widely in scope, but common to all is the chance to practice computational biology skills acquired in the classroom. Typically, students seek and secure their own internships.

03-602 Quantitative Biology Internship

All Semesters

This course allows a student to gain quantitative biology experience in a "real-world" setting. Internships vary widely in scope, but common to all is the chance to practice quantitative biology skills acquired in the classroom. Typically, students seek and secure their own internships. Students are required to write written reflections summarizing their internship work and submit those to the course instructor.

03-603 Applied Professional Skills for Computational Biologists

Fall and Spring: 3 units

This course gives Masters in Computational Biology students the opportunity to refine the professional skills necessary for a successful career in industry. This course, required for students completing the "Applied Study" option in the MS in Computational Biology program, provides opportunities to connect with computational biology professionals as part of industry outreach. The course will also include additional, customized review of application materials.

03-604 Professional Skills for Biotechnology, Quantitative & Computational Biology

Fall: 3 units

This course gives Masters students in Biological Sciences and related fields the opportunity to develop the professional skills necessary for a successful career in either academia or industry. The first set of topics will include assistance with elevator pitches, interview preparation, resume and cover letter writing, and presentation skills. The course will also guest speakers to connect with students professionally and to provide students with perspectives from within industry on regulatory compliance issues. The course is pass/fail only.

03-622 Modern Biology

Fall: 9 units

This is an introductory course that provides the basis for further studies in biochemistry, cell biology, genetics and molecular biology. This course emphasizes the chemical principles underlying biological processes and cell structures as well as the analysis of genetics and heredity from a molecular perspective. This is the introductory biology course for all science and non-science majors.

03-699 MS Research

All Semesters

A student enrolled in this course conducts an independent investigation on a project in a faculty advisor's lab. The project is selected from a major area of research study with the advice and approval of the faculty advisor. Students who are writing an honors thesis should enroll in 03-700 instead.

03-700 MS Honors Thesis Research

All Semesters

A student enrolled in this course conducts an independent investigation on a project in a faculty advisor's lab. The project is selected from a major area of research study with the advice and approval of the faculty advisor. This course is required of students who are enrolled in the Master of Science program and wish to write and defend a thesis. This course is only for students who are writing an honors thesis.

03-709 Applied Cell and Molecular Biology

Fall: 12 units

The purpose of this course is to review key cellular and molecular phenomenon in biological pathways with strong emphasis on latest experimental techniques used in applications including but not limited to disease diagnosis, therapeutics, large-scale genomic and proteomic analysis. Knowledge gained from this course will be both conceptual and analytical. Students will periodically write extensive research reports on select topics and give oral presentations on a select few, while critically analyzing primary literature.

03-711 Computational Molecular Biology and Genomics

Fall: 12 units

An advanced introduction to computational molecular biology, using an applied algorithms approach. This course provides an in-depth treatment of the algorithmic foundations of computational molecular biology. Prerequisites: (03-121 or 03-151) and 15-122

Course Website: <http://www.cs.cmu.edu/~durand/03-711/>**03-713 Bioinformatics Data Integration Practicum**

Spring: 6 units

This course provides a hands-on, self-directed experience dealing with biological data and integrating it to produce software and analyses that are of use to biologists. Data are taken from a variety of sources, including academic research labs, large scale public genomics projects and data from private industry partners. Students will be given a project and asked to design a solution using a combination of existing tools and their own developed software.

03-727 Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method

Fall: 12 units

An advanced introduction to the evolutionary concepts and bioinformatic skills that are central to molecular, cell, developmental, and microbiology. Proteins that share common ancestry also share functional properties. This is the guiding principle of model organism research and sequence-based bioinformatics. Evolutionary trees (phylogenies) and multiple sequence alignments provide evidence for predicting structural and functional constraints, sites of molecular interaction, and residues that confer functional specificity. In 2021, phylogenetics is emerging as an essential technique in metagenomics, cancer, and infectious disease, driven by technological advances such as high through-put sequencing and single-cell phenotyping. This course covers both the conceptual foundation and the practical skills of evolutionary bioinformatics. Students will acquire the "tree thinking" skills required for critical interpretation of phylogenetic analyses and figures in the literature and a rigorous understanding of phylogenetic inference methods. Theoretical knowledge will be complemented by hands-on experience with sequence data repositories, bioinformatic tools for database retrieval, sequence analysis, and tree building. Students will walk out of the course with the knowledge required to apply those tools correctly to messy, genuine data sets, and the ability to evaluate alternate hypotheses in light of these bioinformatic analyses. Students with a range of computational backgrounds are welcome.

Course Website: <http://www.cs.cmu.edu/~durand/Phylogenetics/>**03-728 Genome Editing Biotechnology**

Fall: 6 units

How can we create genetically engineered cells, animals, plants, and even humans? This course will focus on the technologies that enable genome modification, with an emphasis on the recently developed CRISPR-Cas9 system. Specific topics will include an introduction to CRISPR technology and its history; DNA double strand break repair; Off target effects; Gene regulator CRISPRs; Alternate technologies; Ethics of modifying our genomes; Applications - cell screening; Applications - organism engineering; Applications - anti-HIV and immunotherapy; Overview of Gene therapy. Student in-class presentations will cover late-breaking topics and specific areas of student interest.

Prerequisites: 03-709 or 03-621 or 03-221 or 03-220

03-729 Entrepreneurship and protein-based drug development

Spring: 6 units

This is a course for students with background in biochemistry who want to learn about business opportunities and advances in protein-based treatments. As protein-based biologic drugs become more and more prevalent understanding the role of protein-protein interactions is vital for both design and production of biologic drugs. We will focus on the fundamentals of protein-interactions, giving examples of protein-protein interactions in important cellular pathways. We will also focus on how protein-protein interactions are used in the processing of biologic drugs, where antibody-Protein A interactions are key for the purification of antibody-based biologics. We will study case-studies of how the pharmaceutical industry develops biologics from conception, through FDA approval, to mass production.

Prerequisites: 03-709 or 03-231

03-730 Advanced Genetics

Spring: 12 units

This course considers selected current topics in molecular genetics at an advanced level. Emphasis is on classroom discussion of research papers. Topics are subject to change yearly. Examples of past topics include: nucleocytoplasmic trafficking of RNA in yeast, genome imprinting in mammals, molecular genetics of learning and memory in *Drosophila*, viral genomics, using yeast as a model system to study the molecular basis of human neurodegenerative diseases, and CRISPR/Cas9 genome editing.

Prerequisites: (03-221 Min. grade B or 03-220 Min. grade B or 03-330 Min. grade B) and (03-742 or 03-442)

03-738 Synthetic Biology

Fall: 6 units

This course discusses the design of artificial biological parts or systems for research, engineering and medical applications. The course is divided into two parts: top-down and bottom-up synthetic biology. In top-down synthetic biology, engineering of cells with new functions or new products with metabolic and genetic engineering techniques such as circuit building, directed evolution, CRISPR-Cas9 will be covered. In bottom-up synthetic biology, the assembly of molecules to obtain a specific biological output such as in vitro reconstitution of cellular machinery, cell free protein expression system and construction of artificial cells will be discussed.

Prerequisites: 03-231 or 03-232

03-741 Advanced Cell Biology

Spring: 12 units

This course covers fourteen topics in which significant recent advances or controversies have been reported. For each topic there is a background lecture by the instructor, student presentations of the relevant primary research articles and a general class discussion. Example topics are: extracellular matrix control of normal and cancer cell cycles, force generating mechanisms in trans-membrane protein translocation, signal transduction control of cell motility, and a molecular mechanism for membrane fusion.

Prerequisites: (03-240 or 03-320) and (03-231 or 03-232)

03-742 Advanced Molecular Biology

Fall: 12 units

The structure and expression of eukaryotic genes are discussed, focusing on model systems from a variety of organisms including yeast, flies, worms, mice, humans, and plants. Topics discussed include (1) genomics, proteomics, and functional proteomics and (2) control of gene expression at the level of transcription of mRNA from DNA, splicing of pre-mRNA, export of spliced mRNA from the nucleus to the cytoplasm, and translation of mRNA.

03-744 Membrane Trafficking

Spring: 9 units

While the focus of this course is to analyze membrane/protein traffic along both the biosynthetic and endocytic pathways, our general goal is to teach students how to read and interpret the literature. In particular, we emphasize the conclusions and discuss their validity. The course is updated each year to include topics in which new and interesting developments have occurred. Emphasis is placed on how membrane traffic is regulated and where applicable how it is disrupted or subverted during disease processes. The course is of general interest to students, fellows, and faculty interested in cell biology, immunology, neurobiology, pharmacology and virology.

Prerequisites: 03-320 or 03-240

03-747 Proposal Preparation and Peer Review

Fall: 4 units

The concise and clear presentation of an experimental research plan is an essential skill for research scientists. This mini course is designed to introduce 2nd year students to the structure and preparation of a structured research proposal as well as formalize instruction in professional standards in research ethics, CV preparation, and scientific writing and data presentation. Course material is taken from actual grant proposals and previous years' qualifying exam proposals, as well as primary research publications and faculty grant proposals. The course is highly interactive, and students are required to participate in review of each others' work throughout the duration of the course. Coursework is expected to form the basis of the Ph.D. qualifying exam proposal in the winter of the second year.

03-750 Graduate Seminar

Fall and Spring: 1 unit

Each semester, all Department of Biological Sciences graduate students are required to register for and attend the weekly departmental Research Seminar (03-750; 1 unit). Graduate students are strongly urged to meet the speakers to broaden their knowledge of cutting-edge biological science, to discuss career paths and strategies and to make useful contacts; the faculty host can arrange group meetings for interested students.

03-751 Advanced Developmental Biology and Human Health

Fall: 12 units

This course will examine current research in developmental biology, focusing on areas that have important biomedical implications. The course will examine stem cell biology, cellular reprogramming, cell signaling pathways, tissue morphogenesis, and genetic/developmental mechanisms of birth defects and human diseases. Emphasis will be placed on the critical reading of recent, original research papers and classroom discussion, with supporting lectures by faculty. Instructor permission is required to register. Please contact Dr. Ettensohn and ltettensohn@cmu.edu and gt;

Prerequisites: (03-320 or 03-240) and (03-220 or 03-330)

03-755 Graduate Research Seminar

Fall and Spring: 3 units

Each semester, all Departmental of Biological Sciences graduate students are required to register for and attend the weekly departmental Journal Club (Graduate Research Seminar 03-755; 3 units) during which students and faculty members give 25-minute presentations. Second-year students present a research paper or topic from the literature, and more senior students present their research results; typically, graduate students give four Journal Club presentations during their time in the department. Each succeeding year those students who speak at the Departmental Retreat or who are graduating by May of their fifth year are not required to present at Journal Club that year.

03-756 Graduate Independent Study

Fall and Spring

N/A

03-762 Advanced Cellular Neuroscience

Fall: 12 units

This course is an introductory graduate course in cellular neuroscience. As such it will assume little or no background but will rapidly progress to discussions of papers from the primary literature. The structure of the course will be about half lectures and half discussions of new and classic papers from the primary literature. These discussions will be substantially led by students in the course. Topics covered will include ion channels and excitability, synaptic transmission and plasticity, molecular understanding of brain disease and cell biology of neurons. Assessment will be based on class participation, including performance on in-class presentations and a writing assignment.

03-763 Advanced Systems Neuroscience

Spring: 12 units

This course is a graduate version of 03-363. Students will attend the same lectures as the students in 03-363, plus an additional once weekly meeting. In this meeting, topics covered in the lectures will be addressed in greater depth, often through discussions of papers from the primary literature. Students will read and be expected to have an in depth understanding of several classic papers from the literature as well as current papers that illustrate cutting edge approaches to systems neuroscience or important new concepts. Use of animals as research model systems will also be discussed. Performance in this portion of the class will be assessed by supplemental exam questions as well as by additional homework assignments.

Prerequisites: 03-762 or 03-151 or 03-121 or 03-362

03-776 Molecular Techniques for Bioprocessing

Spring: 6 units

This course is the first in a sequence of two lab minis (03-776 and amp; 06-777) required for an MS degree in Biotechnology and Pharmaceutical Engineering. It is designed to teach you techniques used in molecular biology research, specifically those involved with upstream bioprocessing. In addition, you will further develop your skills in experimental design, quantitative reasoning, and critical analysis. While specific experiments may change from semester to semester, core topics include cloning techniques (plasmid isolation and characterization, PCR, restriction enzyme digests, gel electrophoresis) and cell culture (bacteria and mammalian). Experiments are designed to generate a eukaryotic cell line expressing a protein of interest. The follow-up lab, 06-777 for downstream bioprocessing, will build on the techniques and share some reagents.

Prerequisite: 03-709

03-791 Advanced Microbiology

Spring: 12 units

This course will use both lectures and current research literature in the area of Microbiology and Infectious Diseases to introduce such topics as prokaryotic cytoskeletal functions, the human microbiome and its impact, metabolic engineering, transposon mutagenesis for gene function elucidation, synthetic genome construction and applications, pathogenicity islands, functional and expression-based identification of pathogenicity determinants, horizontal gene transfer, regulatory RNAs, biofilm formation quorum sensing, and antimicrobial drug development.

03-871 Structural Biophysics

Fall: 12 units

This course (MB-1) is the first-semester core course for the joint CMU-Pitt graduate program in Molecular Biophysics and Structural Biology (MBSB). The physical properties of biological macromolecules and the methods used to analyze their structure and function are discussed in in-depth lectures. Topics covered include: protein architecture and folding; nucleic acid structures and energetics; structure determination by X-ray crystallography and NMR; optical spectroscopy with emphasis on absorption and fluorescence, NMR spectroscopic methods; other methods to characterize proteins and protein-ligand interactions, such as mass spectrometry, calorimetry, single-molecule manipulation and measurements, and surface plasmon resonance. Sufficient detail is given to allow the student to critically evaluate the current literature.

Prerequisites: (03-231 or 03-232) and (09-214 or 09-344) and (21-120 or 21-122)

03-900 Doctoral Thesis Research

All Semesters

Doctoral Thesis Research consists of an independent investigation on a project selected from a major area of research study with the advice and approval of the faculty advisor.