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
Missing Course Description - please contact the teaching department.

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.

03-101 Biological Sciences First Year Seminars
Fall and Spring: 3 units
Various seminars are offered that introduce first-year students to current topics of modern biology. These are mini courses that meet for half a semester. Topics have included: Proteins in Disease, Genes and Diseases, Pills and Poisons, Curing Cancer, Organ Transplantation and amp; Blood Substitutes, and Prions - Mad Cows and Englishman. Courses restricted to first year students in the Mellon College of Science.

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

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.

03-120 Biology for Life Special Topics Mini
Fall and Spring
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. Spring 2021 Section A4: Applied Research in Brewing: Research-based lab class that works in collaboration with local breweries to investigate the complex microbiome responsible for the maturation of barrel-aged beers. This course is designed to be a research opportunity for students with a novice’s background in Biology or Chemistry. No previous bench experience is required, only a cursory knowledge of Biology and an interest in the scientific method! Recommended pre-req of one of the following: 03-117, 03-118, 03-121, 03-124, 03-151, 09-207, 09-221. Section B4: Mini Lab Bio in Your Basement: Introductory biology laboratory experience, focusing on experiments using materials and reagents commonly found in homes and grocery stores. You will apply the scientific principles learned in introductory biology classes to guide experiments conducted in your home. No previous laboratory experience required. Recommended pre-req/co-req of 03-121 or 03-151.

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.
03-126 Cellular Response to the Environment
Spring: 4 units
This laboratory course provides a multifaceted view of the cell, with the opportunity for new discovery, through microscopic imaging of a cell's response to environmental changes. We will identify yeast gene products that undergo changes in expression or subcellular localization after simple environmental perturbations or drug treatments. Students will be trained in basic molecular biological methods, including recombinant DNA manipulation, and basics of functional genomic resources. Enrollment is limited to first-year students in MCS. Special permission required.

03-127 How Biological Experiments Work - A Project Course
Spring: 9 units
The goal of this course is to provide an understanding of the nuts and bolts of biological experimentation. We will discuss the molecular principles behind the wide variety of experiments that were used to discover how cells work. The first half of the class will be a lecture based discussion of key experimental methods used in biological research. The second half of the class will be dedicated to group projects that create "story boards" to explain in molecular terms how these experiments work. The story boards will be used by modelers at the Pittsburgh Supercomputing Center to generate high-end animations of these experimental processes. This will prepare students for working in research labs and biology courses beyond "Modern Biology": This course is limited to first, second, and third year students.
Prerequisites: 03-121 or 03-151

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. Fall 2019 Section A: Environmental Science 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 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. Spring 2020 Section A: Environmental Science 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 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.
Course Website: https://www.cm.edu/bio/undergrad/courses/index.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.

03-131 Genes Drugs & Diseases
Fall: 9 units
The central goals of this course are to explore the genetic basis of diseases and to explain the molecular basis of action for various drugs used to treat diseases. The first part of the course provides the student with sufficient background to understand the biological basis of drug action with emphasis on retroviral inhibitors. The usefulness of genetic engineering in the production of proteins for drug discovery is then explored. This is followed by an overview of DNA replication, transcription, and protein synthesis, with an emphasis on the inhibitory action of antibiotics on prokaryotic processes. The fundamental properties of carbohydrates, lipids, and membranes are discussed at a level to develop an understanding of penicillin and the treatment of elevated cholesterol levels. Signaling processes in eukaryotic cells is discussed with reference to cancer treatment and pain management. The treatment of disease using antibody, and the treatment of inappropriate immune responses (allergy) is also discussed. The course ends with a discussion of inheritance and genetic deficiencies that give rise to disease.
Course Website: http://www.andrew.cmu.edu/user/rule/03_131/

03-132 Basic Science to Modern Medicine
Fall and Summer: 9 units
This course will provide 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 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 fall 2021 will include COVID-19, genome editing, and cancer. We will explore these topics from both a basic science and a modern medicine perspective. Student 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
Course Website: http://www.cmu.edu/bio/undergrad/courses/index.html

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 and gain proficiency in these evaluation techniques. We will discuss neurological 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

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. Because no prerequisite knowledge is required, 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.cm.edu/bio/undergrad/courses/index.html (http://www.cm.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, please contact Dr. Conrad Zapanta and Dr. Maggie Braun (in the same email) for permission 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: (03-121 or 03-151) 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.

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: 03-151 or 03-121

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 (15-259 Min. grade C or 36-225 Min. grade C or 21-124 Min. grade C or 36-217 Min. grade C or 36-200 Min. grade C or 15-359 Min. grade C or 36-218 Min. grade C or 36-201 Min. grade C or 36-247 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: (03-121 or 03-151) 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: 03-121 or 03-151
**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: 09-106 or 06-221

**03-250 Introduction to Computational Biology**
Spring: 12 units
This class provides a general introduction to computational tools for biology. The course is divided into two modules, which may be taken individually as courses 03-251/02-251 and 03-252/02-252. Module 1 covers computational molecular biology/genomics. It examines important sources of biological data, how they are archived and made available to researchers, and what computational tools are available to use them effectively in research. In the process, it covers basic concepts in statistics, mathematics, and computer science needed to effectively use these resources and understand their results. Specific topics covered include sequence data, searching and alignment, structural data, genome sequencing, genome analysis, genetic variation, gene and protein expression, and biological networks and pathways. Module 2 covers computational cell biology, including biological modeling and image analysis. It includes homeworks requiring use or modification of Matlab scripts. The modeling component includes computer models of population dynamics, biochemical kinetics, cell pathways, neuron behavior, and stochastic simulations. The imaging component includes basics of machine vision, morphological image analysis, image classification and image-derived models. Lectures and examinations are joint with 02-250 but recitations are separate. Recitations for this course are intended primarily for biological sciences or biomedical engineering majors at the undergraduate or graduate level who have had little or no prior experience with computer science or programming. Students may not take both 03-250/02-250 and either 03-251/02-251 or 03-252/02-252 for credit. Prerequisites: (03-121 or 03-120 or 03-151) and (03-233 or 03-232 or 03-231)

**03-251 Introduction to Computational Molecular Biology**
Spring: 6 units
This class provides a general introduction to computational tools for biology with specific emphasis on molecular biology and genomics. Along with 03-252, it makes up one half of the full Introduction to Computational Biology, 03-250, although either half can be taken individually. Major topics covered are computer models of population dynamics, biochemical kinetics, cell pathways, neuron behavior, and stochastic simulations. The imaging component includes basics of machine vision, morphological image analysis, image classification and image-derived models. It includes homeworks requiring use or modification of Matlab scripts. Lectures and examinations are joint with 02-252 but recitations are separate. Recitations for this course are intended primarily for biological sciences or biomedical engineering majors at the undergraduate or graduate level who have had little or no prior experience with computer science or programming. Students may not take both 03-252/02-252 and 03-250/02-250 for credit. Prerequisites: (03-120 or 03-121 or 03-151) and (03-233 or 03-232 or 03-231)

**03-252 Introduction to Computational Cell Biology**
Spring: 6 units
This course presents an overview of important modeling and image analysis applications of computers to solve problems in cell biology. Along with 03-251, it makes up one half of the full Introduction to Computational Biology, 03-250, although either half can be taken individually. Major topics covered are computer models of population dynamics, biochemical kinetics, cell pathways, neuron behavior, and stochastic simulations. The imaging component includes basics of machine vision, morphological image analysis, image classification and image-derived models. It includes homeworks requiring use or modification of Matlab scripts. Lectures and examinations are joint with 02-252 but recitations are separate. Recitations for this course are intended primarily for biological sciences or biomedical engineering majors at the undergraduate or graduate level who have had little or no prior experience with computer science or programming. Students may not take both 03-252/02-252 and 03-250/02-250 for credit. Prerequisites: 03-121 or permission of the instructor. Prerequisites: 03-151 or 03-121

**03-302 Undergraduate Colloquium for Juniors**
Spring
Missing Course Description - please contact the teaching department.

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

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

**03-326 Evolution of Regulatory Genomics**
Fall: 5 units
This course will introduce central concepts of evolutionary theory, e.g. drift, selection, phylogenetics and an introduction into how genomes are sequenced, assembled and annotated. This will require a basic understanding of genetics. Course topics will then unify these two areas of biology to examine processes by which genomes evolve and how this in turn has led to the diversity of animal phenotypes. This will include discussion of how genomes control embryonic development, how gene regulation has evolved (focusing on cis regulatory evolution and non-coding RNA regulatory evolution) and the concept of gene regulatory network evolution. Concepts and specific examples will come through lectures, selected readings from advanced texts and primary literature. Prerequisites: 03-231 or 03-232

**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 throughput 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/
03-330 Genetics
Intermittent: 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: 03-151 or 03-121

03-342 Introduction to Biological Laboratory Practices
Fall: 1 unit
This course is designed for students in the BS in Computational Biology degree program. It is a required co-requisite for 03-343, Experimental Genomics. 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 (09-223 or 09-222 or 09-208)
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, enzymes, 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 course is designed to teach experimental methods and concepts 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 (03-231 or 03-232) and (03-240 or 03-320)

03-346 Experimental Neuroscience
Intermittent: 12 units
This laboratory course 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 genetics, 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: 03-320 or 03-240

03-355 Stem Cell Engineering
Spring: 9 units
This course is offered only at CMU’s campus in Qatar. This course covers the progress of stem cell research and its application to tissue engineering and regenerative therapy. The students will learn about the different types of stem cells, the biochemical stimuli that are responsible for regulating stem cell differentiation and techniques involved in the culture of stem cells. This subject will also highlight the development of various biomaterials that are used as biological substitutes in regenerative therapy. Current and emergent stem cell technologies in selected applications of tissue engineering in bone, skin and vascular tissues will be emphasized. The course will be delivered through problem-based learning where students are expected to participate in discussions, perform literature search, present their findings through presentations and written reports on selected topics. The class is designed for undergraduates with a strong interest in stem cell biology and tissue engineering, and the desire to actively contribute to discussions in the class. Prerequisite: 03-240

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 epigenetic 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: 03-220 or 03-330

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

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 85-219 or 03-161 or 42-202 or 03-230 or 03-240
03-364 Developmental Neuroscience
Fall: 9 units
This course examines the principles that govern the developmental assembly of a complex nervous system. Topics range from the earliest steps of induction of neural tissue and birth of neurons to the plasticity within developing circuits and the development of behavior. By the end of this course students should be able to describe the major steps in neural development and to interpret key experiments using vertebrate and invertebrate models that have helped to elucidate these steps. This course is taught on the University of Pittsburgh campus by faculty from Carnegie Mellon and Pitt.
Prerequisites: 03-362 or 03-363 or 03-240

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: 85-219 or 03-240 or 03-161 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, students 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/)

03-370 Principles of Biotechnology
Spring: 9 units
This course is intended to provide an introduction to a set of core areas important for understanding and managing biotechnology business. Essentially, the focus of the course will be the basics of the biotechnology entrepreneurial process and a deep background on biotechnology enabled products. The objective is to provide the background for management-level personnel to make decisions based on knowledge of contemporary biotechnologies and the legal and regulatory environment. Because it is impossible to be comprehensive with regard to all applications, the goal is to provide students with sufficient familiarity with current biotechnology and with a framework for assessing bio-related business questions that they may encounter in the future through a combination of independent research, assessment of opportunities and pitfalls, and historical comparisons. NOTE: This course CANNOT be counted towards the advanced biology electives for any major or minor in Biological Sciences.
Prerequisites: (03-231 or 03-232) and (03-240 or 03-320)

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

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: 03-231 or 03-232

03-392 Microbiology Laboratory
Intermittent: 6 units
This is an upper level biology course for students who have taken or are currently taking the Microbiology course and are interested in laboratory experience in microbiology. It is designed with the recommendations of the American Society for Microbiology for a student laboratory course in mind in order to introduce the student to a broad spectrum of techniques in microbiology. You will learn the skills needed to perform experiments that help to differentiate various types of microbes, examine antimicrobial and antibiotic sensitivity and resistance, and begin to explore microbial diversity. Finally, you will develop an understanding of the theory behind the techniques you use and will be given the opportunity to further develop your skills in the process of experimental design. THIS COURSE WILL BE OFFERED EVERY OTHER SPRING, BEGINNING IN THE SPRING 2017 (NOT offered spring 2016).

03-402 Undergraduate Colloquium for Seniors
Spring
Missing Course Description - please contact the teaching department.

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 TECH Technical Skills at the Bench
Fall and Spring
This course is designed to complement the Lecture Course Experimental Techniques in Molecular Biology ACT (Analytical Critical Thinking). 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. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.
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.
03-428 Genome Editing
Intermittent: 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.
Prerequisites: 03-121 or 03-709 or 03-151

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

03-439 Introduction to Biophysics
Fall: 10 units
This intermediate level course is primarily offered to Physics and Biology undergrads (junior/senior) and provides a modern view of molecular and cellular biology as seen from the perspective of physics, and quantified through the analytical tools of physics. This course will not review experimental biophysical techniques (which are covered, e.g., in 03-871). Rather, physicists will learn what sets "bio" apart from the remainder of the physics world and how the apparent dilemma that the existence of life represents to classical thermodynamics is reconciled. They also will learn the nomenclature used in molecular biology. In turn, biologists will obtain (a glimpse of) what quantitative tools can achieve beyond the mere collecting and archiving of facts in a universe of observations: By devising models, non-obvious quantitative predictions are derived which can be experimentally tested and may lead to threads that connect vastly different, apparently unrelated phenomena. One major goal is then to merge the two areas, physics and biology, in a unified perspective.
Prerequisites: (03-121 or 03-151) and (33-142 or 33-112 or 33-132 or 33-122 or 33-107 or 33-121)
Course Website: http://www.cmuf.edu/smsl/teaching/IntroBioPhys.html

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 03-330 Min. grade B or 03-220 Min. grade B
Course Website: http://www.cmuf.edu/bio/undergrad/courses/index.html (http://www.cmuf.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.

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

03-490 Advanced topics in Immunology
Intermittent: 6 units
Course topics include antibody engineering, cytokine therapeutics, T-cell based therapies, vaccine development

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/

03-512 Computational Methods for Biological Modeling and Simulation
Fall: 9 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problems sets with significant programming components and independent or group final projects.
Prerequisites: (03-121 or 03-151) and 15-122

03-534 Biological Imaging and Fluorescence Spectroscopy
Fall: 9 units
Fluorescence detection is a powerful technology that is the basis of most biomedical imaging, high speed flow cytometry, cell sorting, DNA sequencing, gene expression arrays, diagnostics and drug discovery. It is not surprising, then, that it is the basis of many commercial technology organizations with billions of dollars in sales. It is almost impossible to turn the page of a biomedical journal without seeing multicolor images acquired with powerful microscopes and fluorescent probes of cell structure and function. The sensitivity of fluorescence detection is so high that single biological molecules can be monitored as they function in living cells. This course covers principles and applications of optical methods in the study of structure and function in biological systems. Topics to be covered include: absorption and fluorescence spectroscopy; interaction of light with biological molecules, cells, and systems; design of fluorescent probes and optical biosensor molecules; genetically expressible optical probes; photochemistry; optics and image formation; transmitted-light and fluorescence microscope systems; laser-based systems; scanning microscopes; electronic detectors and cameras: image processing; multi-mode imaging systems; microscopy of living cells; and the optical detection of membrane potential, molecular assembly, transcription, enzyme activity, and the action of molecular motors. This course is particularly aimed at students in science and engineering interested in gaining in-depth knowledge of modern light microscopy.
Prerequisites: 09-106 and (03-240 or 03-320) and (21-122 or 21-124) and (33-121 or 33-141 or 33-111) and (03-231 or 03-232)

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.
Prerequisite: 03-445

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.
03-603 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.

03-620 Techniques in Electron Microscopy
Fall: 9 units
This course is designed to teach basic methods in transmission electron microscopy to graduate and undergraduate students. Sophomores with an interest in electron microscopy are encouraged to enroll, and will have the option and opportunity to utilize their skills in various laboratories during their junior or senior year. The course will be offered once each year, during the spring semester. Course enrollment will be limited to 4-6 students. Preferential enrollment will be given to graduate students and undergraduate students who have demonstrated a need for this technique in their research. The class will include one hour of lecture and 4 hours of laboratory each week (some additional laboratory time outside of the scheduled laboratory time is required). Students will learn basic methods in specimen preparation for both transmission and scanning electron microscopy (fixation, embedding, and ultramicrotomy, drying and metal coating) and will be trained in the operation of both the Hitachi 7100 and 2460N electron microscopes. Lectures and laboratories during the last few weeks of the semester will introduce the students to special techniques (e.g. immunoelectron microscopy, cryoultramicrotomy, freeze substitution, variable pressure SEM, etc.) and will allow them to work with samples from their own research. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

03-622 Metabolism, Cell Biology, and Molecular Biology
Fall: 12 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.

03-635 Advanced Cancer Biology
Fall: 9 units
TBA

03-700 MS 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.

03-709 Applied Cell and Molecular Biology
Fall: 12 units
This course is designed to teach 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: (03-151 or 03-121) and 15-122
Course Website: http://www.cs.cmu.edu/~durand/Phylogenetics/

03-712 Computational Methods for Biological Modeling and Simulation
Spring: 12 units
This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problems sets with significant programming components and independent or group final projects. Prerequisites: 02-201 or 02-613 or 15-112 or 15-110

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.

03-726 Evolution of Regulatory Genomics
Fall: 6 units
This course will examine the processes by which genomes evolve and how this genetic variation leads to phenotypic diversity. An introduction to gene regulation, how the genome controls development, comparisons of development and the phenotypic diversity in animals will be provided. Then we will consider ways in which genomes evolve, followed by in depth coverage of how gene regulation has evolved (focusing on cis regulatory evolution and non-coding RNA regulatory evolution). Finally the concept of gene regulatory network control of development and understanding evolution as change in these networks will be examined. Concepts and specific examples will come through reading of primary literature and selected readings from advanced texts. Grading will be based on written assignments from readings of literature, participation in class discussion, and two in class exams. The graduate level course (03-726) will in addition require a term paper based on thorough and critical reading of primary literature focused on one of the general topics presented in the course.

03-727 Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method
Intermittent: 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 2011, phylogenetics is emerging as an essential technique in metagenomes, cancer, and infectious disease, driven by technological advances such as high throughput 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.
03-730 Advanced Genetics
Spring: 12 units
This course considers selected current topics in genetics at an advanced level. Emphasis is on classroom discussion of research papers. Topics change yearly. Recent topics have included nucleocytoplasmic trafficking of RNA in yeast, genome imprinting in mammals, genetics of learning and memory in Drosophila, and viral genomics. Prerequisites: (03-320 Min. grade B or 03-221 Min. grade B or 03-220 Min. grade B) and (03-442 or 03-742)

03-740 Advanced Biochemistry
Spring: 12 units
This is a special topics course in which selected topics in biochemistry will be analyzed in depth with emphasis on class discussion of papers from the recent research literature. Topics change yearly. Recent topics have included single molecule analysis of catalysis and conformational changes; intrinsically disordered proteins; cooperative interactions of aspartate transcarbamoylase; and the mechanism of ribosomal protein synthesis. Prerequisites: (03-240 or 03-320) and (03-232 or 03-231)

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. Prerequisites: 03-320 or 03-240

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

03-745 Core Course in Biochemistry
Fall: 6 units
This course is designed to provide first year doctoral students in the Department of Biological Sciences with a broad foundation in biochemistry and biophysical techniques. Topics include protein structure, enzymology, and methods to characterize protein structure and function. Students will be evaluated throughout the course, and with a final exam.

03-746 Core Course in Cell Biology
Fall: 6 units
This course is designed to provide first year doctoral students in the Department of Biological Sciences with a broad foundation in cell biology. Topics include, but are not limited to, intracellular trafficking, signal transduction, the cytoskeleton, the cell cycle, and cell-cell interactions. This is a lecture-based course and will include some discussion of the primary literature. Students will be evaluated weekly, and with a final exam. Enrollment requires instructor permission.

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.

03-748 Scientific Speaking and Peer Review
Fall: 3 units
Effective public presentation of scientific data is an important skill for every scientist. This interactive course will provide students with specific guidelines on organizing, preparing, and delivering an effective and engaging scientific talk. The topics covered include data organization, choice of content based on audience, PowerPoint and graphic design, charts and graphs representation, use of animation, fonts and color schemes, body language, overcoming stage-fear, and compensation for accents. The course is designed for third year graduate students. Students will present their upcoming Journal Club talk a week or two before in class, and receive formal review from a panel comprising of other students in the class, departmental multimedia designer, and the instructor. Further, each talk will be video recorded, and students will use the recording for self-critique and further input from the instructor. Each students Journal Club talk will then be recorded to provide a benchmark for the final talk incorporating the critiques provided. Students are required to participate in review of each others work throughout the duration of the course, and will therefore actively learn the elements of an effective presentation.

03-750 Graduate Seminar
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. Prerequisites: (03-320 or 03-240) and (03-330 or 03-220)

03-755 Graduate Research Club
Fall and Spring: 3 units
Each semester, all Department 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.

03-757 Special Topics
Intermittent: 12 units
Special topics course for graduate students.
03-758 Special Topics
Fall: 6 units
Carnegie Mellon University is defined by innovation and driving forward the future of science through academic and research pursuits. This independent study is a collaboration with the CMU Mellon College of Science and the Tepper School of Business to help achieve that aim by bringing Emerald Cloud Lab's automated cloud-based lab experimentation capabilities within an academic setting at CMU. This involves developing a compelling business case for the university to adopt this new automated model for conducting research. The components of this business case include identifying key stakeholders and amp; decision making criteria, conducting a fit-gap analysis of the university's core capabilities, analyzing financial information, developing viable revenue model, and identifying a go-forward strategy with buy-in from key university stakeholders.

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

03-765 Advanced Neural Correlates of Learning and Memory
Spring: 12 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.

03-770 Principles of Biotechnology
Spring: 12 units
This course is intended to provide an introduction to a set of core areas important for understanding and managing biotechnology business. Essentially, the focus of the course will be the basics of the biotechnology entrepreneurial process and a deep background on biotechnology enabled products. The objective is to provide the background for management-level personnel to make decisions based on knowledge of contemporary biotechnologies and the legal and regulatory environment. Because it is impossible to be comprehensive with regard to all applications, the goal is to provide students with sufficient familiarity with current biotechnology and with a framework for assessing bio-related business questions that they may encounter in the future through a combination of independent research, assessment of opportunities and pitfalls, and historical comparisons. NOTE: This course CANNOT count towards the advanced electives required for majors or minors in Biological Sciences.