BIOL 114. Principles of Biology. 3 Units.
A one-semester course in biology designed for the non-major. A primary objective of this course is to demonstrate how biological principles impact an individual's daily life. BIOL 114 introduces students to the molecules of life, cell structure and function, respiration and photosynthesis, molecular genetics, heredity and human genetics, evolution, diversity of life, and ecology. Minimal background is required; however, some exposure to biology and chemistry at the high school level is helpful. This course is not open to students with credit for BIOL 214 or BIOL 250. This course does not count toward any Biology degree.

BIOL 116. Introduction to Human Anatomy and Physiology I. 3 Units.
This is the first course in a two-semester sequence that covers human anatomy and physiology for the non-major. BIOL 116 covers homeostasis, cell structure and function, membrane transport, tissue types and the integumentary, skeletal, muscular and nervous systems. This course is not open to students with credit for BIOL 216, BIOL 340, or BIOL 346. This course does not count toward any Biology degree. Prereq or Coreq: (Undergraduate Student and BIOL 114) or Requisites Not Met Permission.

BIOL 117. Introduction to Human Anatomy and Physiology II. 3 Units.
This is the second course in a two-semester sequence that covers human anatomy and physiology for the non-major. BIOL 117 covers the endocrine, circulatory, respiratory, digestive, lymphatic, urinary systems including acid-base regulation, and reproductive systems. This course is not open to students with credit for BIOL 216, BIOL 340, or BIOL 346. This course does not count toward any Biology degree. Prereq: (Undergraduate Student and BIOL 114 and BIOL 116) or Requisites Not Met Permission.

BIOL 214. Genes, Evolution and Ecology. 3 Units.
First in a series of three courses required of the Biology major. Topics include: biological molecules (focus on DNA and RNA); mitotic and meiotic cell cycles, gene expression, genetics, population genetics, evolution, biological diversity and ecology. Prereq or Coreq: (Undergraduate Student and CHEM 105 or CHEM 111) or Requisites Not Met permission.

BIOL 214L. Genes, Evolution and Ecology Lab. 1 Unit.
First in a series of three laboratory courses required of the Biology major. Topics include: biological molecules (with a focus on DNA and RNA); basics of cell structure (with a focus on malaria research); molecular genetics, biotechnology; population genetics and evolution, ecology. Assignments will be in the form of a scientific journal submission. Prereq or Coreq: (Undergraduate Student and BIOL 214) or Requisites Not Met permission.

BIOL 215. Cells and Proteins. 3 Units.
Second in a series of three courses required of the Biology major. Topics include: biological molecules (focus on proteins, carbohydrates, and lipids); cell structure (focus on membranes, energy conversion organelles and cytoskeleton); protein structure-function; enzyme kinetics, cellular energetics, and cell communication and motility strategies. Requirements to enroll: 1) Undergraduate degree seeking student; AND 2) Previous enrollment in BIOL 214 and (CHEM 105 or CHEM 111); AND Previous or concurrent enrollment in CHEM 106 or ENGR 145; OR Requisites Not Met permission.

BIOL 215L. Cells and Proteins Laboratory. 1 Unit.
Second in a series of three laboratory courses required of the Biology major. Topics to include: protein structure-function, enzymes kinetics; cell structure; cellular energetics, respiration and photosynthesis. In addition, membrane structure and transport will be covered. Laboratory and discussion sessions offered in alternate weeks. Prereq: (Undergraduate Student and BIOL 214L and Prereq or Coreq: BIOL 215) or Requisites Not Met permission.

BIOL 216. Development and Physiology. 3 Units.
This is the final class in the series of three courses required of the Biology major. As with the two previous courses, BIOL 214 and 215, this course is designed to provide an overview of fundamental biological processes. It will examine the complexity of interactions controlling reproduction, development and physiological function in animals. The Developmental Biology section will review topics such as gametogenesis, fertilization, cleavage, gastrulation, the genetic control of development, stem cells and cloning. Main topics included in the Physiology portion consist of: homeostasis, the function of neurons and nervous systems; the major organ systems and processes involved in circulation, excretion, osmoregulation, gas exchange, feeding, digestion, temperature regulation, endocrine function and the immunologic response. There are two instructional modes for this course: lecture mode and hybrid mode. In the lecture mode students attend class for their instruction. In the hybrid mode students watch online lectures from the course instructor and attend one discussion section with the course instructor each week. The online content prepares students for the discussion. Which mode is offered varies depending on the term. Students are made aware of what mode is offered at the time of registration. The total student effort and course content is identical for both instructional modes. Either instructional mode fulfills the BIOL 216 requirement for the BA and BS in Biology. Prereq: (Undergraduate Student and BIOL 214) or Requisites Not Met permission.

BIOL 216L. Development and Physiology Lab. 1 Unit.
Third in a series of three laboratory courses required of the Biology major. Students will conduct laboratory experiments designed to provide hands-on, empirical laboratory experience in order to better understand the complex interactions governing the basic physiology and development of organisms. Laboratories and discussion sessions offered in alternate weeks. Prereq: (Undergraduate Student and BIOL 214L and Prereq or Coreq: BIOL 216) or Requisites Not Met permission.

BIOL 223. Vertebrate Biology. 3 Units.
A survey of vertebrates from jawless fishes to mammals. Functional morphology, physiology, behavior and ecology as they relate to the groups’ relationships with their environment. Evolution of organ systems. Two lectures and one laboratory per week. The laboratory will involve a study of the detailed anatomy of the shark and cat used as representative vertebrates. Students are expected to spend at least three hours of unscheduled laboratory each week. This course fulfills a laboratory requirement for the biology major. Prereq: Undergraduate Student or Requisites Not Met permission.
BIOL 225. Evolution. 3 Units.
Multidisciplinary study of the course and processes of organic evolution provides a broad understanding of the evolution of structural and functional diversity, the relationships among organisms and their environments, and the phylogenetic relationships among major groups of organisms. Topics include the genetic basis of micro- and macro-evolutionary change, the concept of adaptation, natural selection, population dynamics, theories of species formation, principles of phylogenetic inference, biogeography, evolutionary rates, evolutionary convergence, homology, Darwinian medicine, and conceptual and philosophic issues in evolutionary theory. Offered as ANTH 225, BIOL 225, EEPS 225, HSTY 225, and PHIL 225.

BIOL 240. Personalized Medicine. 3 Units.
The emphasis of clinical practice is slowly shifting from one-disease and one-treatment-fits-all to more personalized care based on molecular markers of disease risk, disease subtype, drug effectiveness, and adverse drug reactions. This course, designed for non-biology majors, will introduce how the developments in gene sequencing, genetic markers, and stem cells can be applied for predictive testing and personalized therapies. Core concepts to be covered include the principles of genetics including the inheritance of traits determined by single genes and by multiple genes, the assignment of risk to particular genetic constitutions, and the nature and use of stem cells. The emergence of private companies as resources for the performance of the tests, and how the general public will be able to interpret their own data (with or without the access to genetic counselors), will also be covered. The course will include hands-on laboratory experiences of DNA manipulation and detection using the polymerase chain reaction and gel electrophoresis. The ethical, legal, and social issues associated with personal genetic testing will also be covered. This course does not count towards any Biology degree, nor towards the Biology minor. Prereq: Undergraduate Student or Requisites Not Met permission.

BIOL 300. Dynamics of Biological Systems: A Quantitative Introduction to Biology. 3 Units.
This course will introduce students to dynamic biological phenomena, from the molecular to the population level, and models of these dynamical phenomena. It will describe a biological system, discuss how to model its dynamics, and experimentally evaluate the resulting models. Topics will include molecular dynamics of biological molecules, kinetics of cell metabolism and the cell cycle, biophysics of excitability, scaling laws for biological systems, biomechanics, and population dynamics. Mathematical tools for the analysis of dynamic biological processes will also be presented. Students will manipulate and analyze simulations of biological processes, and learn to formulate and analyze their own models. This course satisfies a laboratory requirement for the biology major. Offered as BIOL 300 and EBME 300.

BIOL 301. Biotechnology Laboratory: Genes and Genetic Engineering. 3 Units.
Laboratory training in recombinant DNA techniques. Basic microbiology, growth, and manipulation of bacteriophage, bacteria and yeast. Students isolate and characterize DNA, construct recombinant DNA molecules, and reintroduce them into eukaryotic cells (yeast, plant, animal) to assess their viability and function. Two laboratories per week. This course satisfies a laboratory requirement of the B.A. in Biology. This course satisfies an additional laboratory requirement of the B.S. in Biology. Offered as BIOL 301 and BIOL 401. Prereq: Undergraduate Student and BIOL 215 or Requisites Not Met permission.

BIOL 302. Human Learning and the Brain. 3 Units.
This course focuses on the question, “How does the human brain learn?” Through assigned readings, extensive class discussions, and a major paper, each student will explore personal perspectives on learning. Specific topics include, but are not limited to: the brain’s cycle of learning; neocortex structure and function; emotion and limbic brain; synapse dynamics and changes in learning; images in cognition; symbolic brain (language, mathematics, music); memory formation; and creative thought and brain mechanisms. The major paper will be added to each student’s SAGES writing portfolio. In addition, near the end of the semester, each student will make an oral presentation on a chosen topic. Offered as BIOL 302 and COGS 322. Counts as SAGES Departmental Seminar. Prereq: Undergraduate Student or Requisites Not Met Permission.

BIOL 303. From Blackbox to Toolbox: How Molecular Biology Moves Forward. 3 Units.
The pioneers of modern biology knew very little about the internal workings of the cell, and they had access to only a very limited set of very low-resolution tools. Yet clean experimental design and careful analysis let them ask and answer fundamental biological questions and enabled the development of better tools to use the next time around. In just seven decades, biologists have built a toolbox that offers astonishing precision and power, but the logic of biological experimentation hasn’t changed. In this course, we will study that underlying logic, and what it lets us do. We will read key papers spanning the development of modern biology, from the most basic working-out of the Central Dogma to recent advances. We will pay particular attention to how well the authors used the tools available, and how successfully they accounted for their shortcomings—if indeed they did. The emphasis of the course will be on classroom discussion. In lieu of exams, students will (1) write brief responses to weekly in-class prompts for understanding, (2) write in-depth proposals for a molecular biology research project, and (3) present their proposals orally to the class. These assignments are designed to check that students are keeping up with weekly discussions and synthesizing what they have learned into a deeper understanding of how we develop questions and construct arguments in biological research. This course is offered as a SAGES departmental seminar and fulfills the Cell and Molecular breadth requirement of the B.A. and B.S. in Biology. Counts as SAGES Departmental Seminar. Prereq: Undergraduate Student and BIOL 215 or Requisites Not Met permission.

BIOL 304. Fitting Models to Data: Maximum Likelihood Methods and Model Selection. 3 Units.
This course will introduce students to maximum likelihood methods for fitting models to data and to ways of deciding which model is best supported by the data (model selection). Along the way, students will learn some basic tenets of probability and develop competency in R, a commonly used statistical package. Examples will be drawn from ecology, epidemiology, and potentially other areas of biology. The second half of the course is devoted to in-class projects, and students are encouraged to bring their own data. Offered as BIOL 304 and BIOL 404. Prereq: Undergraduate Student and MATH 121 and MATH 122 or (Undergraduate Student and MATH 125 and MATH 126) or Requisites Not Met permission.
BIOL 305. Herpetology. 4 Units.
Amphibians and reptiles exhibit tremendous diversity in development, physiology, anatomy, behavior and ecology. As a result, amphibians and reptiles have served as model organisms for research in many different fields of biology. This course will cover many aspects of amphibian and reptile biology, including anatomy, evolution, geographical distribution, physiological adaptations to their environment, reproductive strategies, moisture-, temperature-, and food-relations, sensory mechanisms, predator-prey relationships, communication (vocal, chemical, behavioral), population biology, and the effects of venomous snake bite. Laboratory sessions will be devoted to learning species identification and evolutionary relationships, discussion of the ecology of Ohio’s amphibians and reptiles, survey techniques for determining population size and structure, and observations of the behavior of live reptiles and amphibians. Laboratory sessions may include trips to Squire Valley Farm, Cleveland Museum of Natural History, and Cleveland Metroparks Zoo. This course satisfies a laboratory requirement of the B.A. in Biology. This course satisfies an additional laboratory requirement of the B.S. in Biology. Prereq: Undergraduate Student and BIOL 214 or Requisites Not Met Permission.

BIOL 306. Mathematical Analysis of Biological Models. 3 Units.
This course focuses on the mathematical methods used to analyze biological models, with examples drawn largely from ecology but also from epidemiology, developmental biology, and other areas. Mathematical topics include equilibrium and stability in discrete and continuous time, some aspects of transient dynamics, and reaction-diffusion equations (steady state, diffusive instabilities, and traveling waves). Biological topics include several “classic” models, such as the Lotka-Volterra model, the Ricker model, and Michaelis-Menten/type II/saturating responses. The emphasis is on approximations that lead to analytic solutions, not numerical analysis. An important aspect of this course is translating between verbal and mathematical descriptions: the goal is not just to solve mathematical problems but to extract biological meaning from the answers we find. Offered as BIOL 306 and MATH 376. Prereq: Undergraduate Student and (BIOL 300 or MATH 224 or MATH 228) or Requisites Not Met Permission.

BIOL 307. Evolutionary Biology of the Invertebrates. 3 Units.
Important events in the evolution of invertebrate life, as well as structure, function, and phylogeny of major invertebrate groups.

BIOL 308. Molecular Biology. 4 Units.
An examination of the flow of genetic information from DNA to RNA to protein. Topics include: nucleic acid structure; mechanisms and control of DNA, RNA, and protein biosynthesis; recombinant DNA; and mRNA processing and modification. Where possible, eukaryotic and prokaryotic systems are compared. Special topics include yeast as a model organism, molecular biology of cancer, and molecular biology of the cell cycle. Current literature is discussed briefly as an introduction to techniques of genetic engineering. Recommended preparation: BIOL 307. Offered as BIOC 308, BIOL 308, BIOC 408, and BIOL 408. Prereq: BIOL 215 or BIOC 307.

BIOL 309. Biology Field Studies. 3 Units.
Intensive investigation of living organisms in a natural environment. Location of the field site may vary with each course offering, and may be either domestic or international. Topics covered include logistics, biodiversity, and current ecological, environmental, and social issues surrounding the specific ecosystem being studied. Time at the field site will be spent listening to resident lecturers, receiving guided tours, observing and identifying wild organisms in their natural habitat, and conducting a research project. The undergraduate version requires students to plan and conduct a group research project and present results independently. The graduate version requires students to plan, conduct, and present an independent research project. Instructor consent required to register. This course will fulfill a laboratory requirement of the B.A. in Biology. This course will fulfill an additional laboratory requirement of the B.S. in Biology. Course may be repeated for credit up to two times if traveling to a new destination. Offered as BIOL 309 and BIOL 409. Prereq: BIOL 216.

BIOL 310. Field Studies in Evolutionary Ecology. 3 Units.
The field of Evolutionary Ecology examines how the interactions between organisms and their environments evolve. In this field-based course, students will conduct a variety of experimental and observational field studies aimed at addressing key concepts in Evolutionary Ecology. Students will gain experience in study design and data collection in natural populations, data analysis, and the writing and presentation of scientific results. This course satisfies a laboratory requirement of a B.A. in Biology. This course satisfies an additional laboratory requirement of a B.S. in Biology. Prereq: BIOL 214.

BIOL 311A. Survey of Bioinformatics: Technologies in Bioinformatics. 1 Unit.
SYBB 311A/411A is a 5-week course that introduces students to the high-throughput technologies used to collect data for bioinformatics research in the fields of genomics, proteomics, and metabolomics. In particular, we will focus on mass spectrometer-based proteomics, DNA and RNA sequencing, genotyping, protein microarrays, and mass spectrometry-based metabolomics. This is a lecture-based course that relies heavily on out-of-class readings. Graduate students will be expected to write a report and give an oral presentation at the end of the course.

SYBB 311A/411A is part of the SYBB survey series which is composed of the following course sequence: (1) Technologies in Bioinformatics, (2) Data Integration in Bioinformatics, (3) Translational Bioinformatics, and (4) Programming for Bioinformatics. Each standalone section of this course series introduces students to an aspect of a bioinformatics project - from data collection (SYBB 311A/411A), to data integration (SYBB 311B/411B), to research applications (SYBB 311C/411C), with a fourth module (SYBB 311D/411D) introducing basic programming skills. Graduate students have the option of enrolling in all four courses or choosing the individual modules most relevant to their background and goals with the exception of SYBB 411D, which must be taken with SYBB 411A. Offered as SYBB 311A, BIOL 311A and SYBB 411A. Prereq: (BIOL 214 and BIOL 215) or BIOL 250. Coreq: BIOL 311B, BIOL 311C, and BIOL 311D.
BIOL 311B. Survey of Bioinformatics: Data Integration in Bioinformatics. 1 Unit.
SYBB 311B/411B is a five-week course that surveys the conceptual models and tools used to analyze and interpret data collected by high-throughput technologies, providing an entry point for students new to the field of bioinformatics. The knowledge structures that we will cover include: biomedical ontologies, signaling pathways, and interaction networks. We will also cover tools for genome exploration and analysis. The SYBB survey series is composed of the following course sequence: (1) Technologies in Bioinformatics, (2) Data Integration in Bioinformatics, (3) Translational Bioinformatics, and (4) Programming for Bioinformatics. Each standalone section of this course series introduces students to an aspect of a bioinformatics project - from data collection (SYBB 311A/411A), to data integration (SYBB 311B/411B), to research applications (SYBB 311C/411C), with a fourth module (SYBB 311D/411D) introducing basic programming. Graduate students have the option of enrolling in all four courses or choosing the individual modules most relevant to their background and goals with the exception of SYBB 411D, which must be taken with SYBB 411A. Offered as SYBB 311B, BIOL 311B, and SYBB 411B. Prereq: (BIOL 214 and BIOL 215) or BIOL 250. Coreq: BIOL 311A, BIOL 311C, and BIOL 311D.

BIOL 311C. Survey of Bioinformatics: Translational Bioinformatics. 1 Unit.
SYBB 311C/411C is a longitudinal course that introduces students to the latest applications of bioinformatics, with a focus on translational research. Topics include: omic drug discovery, pharmacogenomics, microbiome analysis, and genomic medicine. The focus of this course is on illustrating how bioinformatic technologies can be paired with data integration tools for various applications in medicine. The course is organized as a weekly journal club, with instructors leading the discussion of recent literature in the field of bioinformatics. Students will be expected to complete readings beforehand; students will also work in teams to write weekly reports reviewing journal articles in the field. The SYBB survey series is composed of the following course sequence: (1) Technologies in Bioinformatics, (2) Data Integration in Bioinformatics, (3) Translational Bioinformatics, and (4) Programming for Bioinformatics. Each standalone section of this course series introduces students to an aspect of a bioinformatics project - from data collection (SYBB 311A/411A), to data integration (SYBB 311B/411B), to research applications (SYBB 311C/411C), with a fourth module (SYBB 311D/411D) introducing basic programming. Graduate students have the option of enrolling in all four courses or choosing the individual modules most relevant to their background and goals with the exception of SYBB 411D, which must be taken with SYBB 411A. Offered as SYBB 311B, BIOL 311B, and SYBB 411B. Prereq: (BIOL 214 and BIOL 215) or BIOL 250. Coreq: BIOL 311A, BIOL 311C, and BIOL 311D.

BIOL 312. Introductory Plant Biology. 3 Units.
This course will provide an overview of plant biology. Topics covered will include: (1) Plant structure, function and development from the cellular level to the whole plant (2) plant diversity, evolution of the bacteria, fungi, algae, bryophytes and vascular plants; (3) adaptations to their environment, plant-plant interactions, and human uses of plants. Prereq: (Undergraduate student and BIOL 215) or Requisites Not Met permission.

BIOL 314. Taming the Tree of Life: Phylogenetic Comparative Methods-from Concept to Practical Application. 3 Units.
"Nothing in biology makes sense except in the light of evolution" – Dobzhansky Biologists have long been fascinated by the diversity of life. Why are there so many species? Why are some of them similar and others divergent? How has evolution shaped ecological interactions, such as disease-host dynamics? The "tree of life" describes phylogenetic hypotheses for evolutionary history among species, and modern phylogenetic comparative methods allow us to incorporate the tree of life into statistical analyses. This course will introduce phylogenetic comparative methods, why they are needed to answer many biological questions, how they are conducted, and how they can be used to evaluate hypotheses. These methods can be used for any group of organisms, from humans and their diseases, to plants, animals, or fungi. These methods also can be used to address a broad suite of questions in biology, including biomedical, ecological, evolutionary, developmental, and neuromechanical questions. For example, issues of public health can be more deeply addressed using these tools. Students may bring their own data sets, or may use existing data sets, and will develop an independent research project using these tools. Undergraduates will present a poster at a public poster fair, as part of the requirements for the SAGES capstone. No prior experience with the R statistics language is necessary for this course. BIOL314 fulfills the requirements for an undergraduate capstone in biology. Offered as BIOL 314 and BIOL 414. Counts as SAGES Senior Capstone. Prereq: (Undergraduate student with at least Junior standing and BIOL 214) or Requisite Not Met permission.

BIOL 315. Quantitative Biology Laboratory. 3 Units.
This course will apply a range of quantitative techniques to explore structure-function relations in biological systems. Using a case study approach, students will explore causes of impairments of normal function, will assemble diverse sets of information into a database format for the analysis of causes of impairment, will analyze the data with appropriate statistical and other quantitative tools, and be able to communicate their results to both technical and non-technical audiences. The course has one lecture and one lab per week. Students will be required to maintain a journal of course activities and demonstrate mastery of quantitative tools and statistical techniques. Graduate students will have a final project that applies these techniques to a problem of their choice. Offered as BIOL 315 and BIOL 415. Prereq: (Undergraduate Student and BIOL 214) or Requisites Not Met permission.

BIOL 316. Fundamental Immunology. 4 Units.
Introductory immunology providing an overview of the immune system, including activation, effector mechanisms, and regulation. Topics include antigen-antibody reactions, immunologically important cell surface receptors, cell-cell interactions, cell-mediated immune, innate versus adaptive immunity, cytokines, and basic molecular biology and signal transduction in B and T lymphocytes, and immunopathology. Three weekly lectures emphasize experimental findings leading to the concepts of modern immunology. An additional recitation hour is required to integrate the core material with experimental data and known immune mediated diseases. Five mandatory 90 minute group problem sets per semester will be administered outside of lecture and recitation meeting times. Graduate students will be graded separately from undergraduates, and 22 percent of the grade will be based on a critical analysis of a recently published, landmark scientific article. Offered as BIOL 316, BIOL 416, CLBY 416, PATH 316 and PATH 416. Prereq: BIOL 215 and 215L.
BIOL 318. Introductory Entomology. 4 Units.
The goal of this course is to discover that, for the most part, insects are not aliens from another planet. Class meetings will alternate; with some structured as lectures, while others are laboratory exercises. Sometimes we will meet at the Cleveland Museum of Natural History, or in the field to collect and observe insects. The 50 minute discussion meeting once a week will serve to address questions from both lectures and lab exercises. The students will be required to make a small but comprehensive insect collection. Early in the semester we will focus on collecting the insects, and later, when insects are gone for the winter, we will work to identify the specimens collected earlier. Students will be graded based on exams, class participation and their insect collections. This course satisfies either the Organismal breadth requirement of the B.A. and B.S. in Biology, or the laboratory requirement of the B.A. in Biology, or an additional laboratory requirement of the B.S. in Biology. Offered as BIOL 318 and BIOL 418. Prereq: (Undergraduate Student and BIOL 214 and BIOL 215 and BIOL 216) or Requisites Not Met permission.

BIOL 319. Applied Probability and Stochastic Processes for Biology. 3 Units.
Applications of probability and stochastic processes to biological systems. Mathematical topics will include: introduction to discrete and continuous probability spaces (including numerical generation of pseudo random samples from specified probability distributions), Markov processes in discrete and continuous time with discrete and continuous sample spaces, point processes including homogeneous and inhomogeneous Poisson processes and Markov chains on graphs, and diffusion processes including Brownian motion and the Ornstein-Uhlenbeck process. Biological topics will be determined by the interests of the students and the instructor. Likely topics include: stochastic ion channels, molecular motors and stochastic ratchets, actin and tubulin polymerization, random walk models for neural spike trains, bacterial chemotaxis, signaling and genetic regulatory networks, and stochastic predator-prey dynamics. The emphasis will be on practical simulation and analysis of stochastic phenomena in biological systems. Numerical methods will be developed using a combination of MATLAB, the R statistical package, MCell, and/or URDME, at the discretion of the instructor. Student projects will comprise a major part of the course. Offered as BIOL 319, EECS 319, MATH 319, SYBB 319, BIOL 419, EMBE 419, MATH 419, PHOL 419, and SYBB 419. Prereq: MATH 224 or MATH 223 and BIOL 300 or BIOL 306 and MATH 201 or MATH 307 or consent of instructor.

BIOL 321. Design and Analysis of Biological Experiments. 3 Units.
In this laboratory course, students will learn how to use a computer programming language (MATLAB) to design, execute, and analyze biological experiments. The course will begin with basic programming and continue to data output and acquisition, image analysis, and statistics. Students who are interested in carrying out research projects in any lab setting are encouraged to take this course and use the skills acquired to better organize and analyze their experiments. No prior programming knowledge is assumed. This course satisfies a laboratory requirement of the B.A. in biology. This course satisfies a laboratory or quantitative laboratory requirement of the B.S. in biology. Students will complete a final project on a topic of their choice; graduate students will be required to give an oral presentation of this project. Offered as BIOL 321 and BIOL 421. Counts for CAS Quantitative Reasoning Requirement. Prereq: Undergraduate Student and BIOL 216 or Requisites Not Met permission.

BIOL 322. Sensory Biology. 3 Units.
The task of a sensory system is to collect, process, store, and transmit information about the environment. How do sensory systems convert information from the environment into neural information in an animal’s brain? This course will explore the ecology, physiology, and behavior of the senses across the animal kingdom. We will cover introductory neurobiology and principles of sensory system organization before delving more deeply into vision, olfaction, audition, mechanosensation, and multi-modal sensory integration. For each sensory modality, we will consider how the sensory system operates and how its operation affects the animal’s behavior and ecology. We will also explore the evolution of sensory systems and their specialization for specific behavioral tasks. Students will finish the course with a research project on a topic of their choice; graduate students will present this project to the class. Offered as BIOL 322 and BIOL 422. Prereq: (Undergraduate Student and BIOL 216) or Requisites Not Met permission.

BIOL 324. Introduction to Stem Cell Biology. 3 Units.
This discussion-based course will introduce students to the exciting field of stem cell research. Students will first analyze basic concepts of stem cell biology, including stem cell niche, cell quiescence, asymmetric cell division, cell proliferation and differentiation, and signaling pathways involved in these processes. This first part of the course will focus on invertebrate genetic models for the study of stem cells. In the second part of the course, students will search for primary research papers on vertebrate and human stem cells, and application of stem cell research in regenerative medicine and cancer. Finally, students will have the opportunity to discuss about ethical controversies in the field. Students will rotate in weekly presentations, and will write two papers during the semester. Students will improve skills on searching and reading primary research papers, gain presentation skills, and further their knowledge in related subjects in the fields of cell biology, genetics and developmental biology. This course may be used as a cell/molecular subject area elective for the B.A. and B.S. Biology degrees. Offered as BIOL 324 and BIOL 424. Prereq: Undergraduate Student and (BIOL 325 or BIOL 326 or BIOL 362) or Requisites Not Met permission.

BIOL 325. Cell Biology. 3 Units.
This course will emphasize an understanding of the structure and function of eukaryotic cells from a molecular viewpoint. We will explore cell activities by answering the questions: What are the critical components of specific cellular processes and how are they regulated? An important part of this course will be appreciation of the experimental evidence that supports our current understanding of cell function. To achieve this aim, we will highlight a variety of experimental techniques currently used in research, and students will read papers from the primary literature to supplement the text. Topics will include cell structure, protein structure and function, internal organization of the eukaryotic cell, membrane structure and function, protein sorting, organelle biogenesis, and cytoskeleton structure and function. The course will also cover the life cycles of cells, their interactions with each other and their environment, intracellular signaling and cell death mechanisms. After establishing a detailed understanding of cell biology, we will explore how normal cellular processes go awry, leading to diseases such as cancer. This course fulfills the Cell and Molecular breadth requirement of the B.A. and B.S. in Biology. Prereq: (Undergraduate Student and BIOL 215) or Requisites Not Met permission.
BIOL 326. Genetics. 3 Units.
Transmission genetics, nature of mutation, microbial genetics, somatic cell genetics, recombinant DNA techniques and their application to genetics, human genome mapping, plant breeding, transgenic plants and animals, uniparental inheritance, evolution, and quantitative genetics. Offered as BIOL 326 and BIOL 426. Prereq: (Undergraduate student and BIOL 214) or Requisites Not Met permission

BIOL 327. Functional Genomics. 3 Units.
In this course, students will learn how to access and use genomics data to address questions in cell biology, development and evolution. The genome of Drosophila melanogaster will serve as a basis for exploring genome structure and learning how to use a variety of available software to identify similar genes in different species, predict protein sequence and functional domains, design primers for PCR, analyze cis-regulatory sequences, access microarray and RNAseq databases, among others. Classes will be in the format of short lectures, short oral presentations made by students and hands-on experimentation using computers. Discussions will be centered in primary research papers that used these tools to address specific biological questions. A final project will consist of a research project formulated by a group of 2-3 students to test a hypothesis formulated by the students using the bioinformatics tools learned in the course. Graduate students will be required to make additional presentations of research papers. They also will have additional questions in exams and a distinct page requirement on written assignments. This course satisfies a laboratory requirement of the B.A. in Biology. This course satisfies a laboratory or quantitative laboratory requirement of the B.S. in Biology. Offered as BIOL 327 and BIOL 427. Prereq: Undergraduate Student and (BIOL 214L and BIOL 326) or Requisites Not Met permission.

BIOL 328. Plant Genomics and Proteomics. 3 Units.
The development of molecular tools has impacted agriculture as much as human health. The application of new techniques to improve food crops, including the development of genetically modified crops, has also become controversial. This course covers the nature of the plant genome and the role of sequenced-based methods in the identification of the genes. The application of the whole suite of modern molecular tools to understand plant growth and development, with specific examples related agronomically important responses to biotic and abiotic stresses, is included. The impact of the enormous amounts of data generated by these methods and their storage and analysis (bioinformatics) is also considered. Finally, the impact on both the developed and developing world of the generation and release of genetically modified food crops will be covered. Recommended preparation: BIOL 326. Offered as BIOL 328 and BIOL 428. Prereq: Undergraduate Student or Requisites Not Met permission.

BIOL 330. Human Microbiome. 3 Units.
This departmental seminar is designed to reveal how the abundant community of human-associated microorganisms influence human development, physiology, immunity and nutrition. Using a survey of current literature, this discussion-based course will emphasize an understanding of the complexity and dynamics of human/microbiome interactions and the influence of environment, genetics and individual life histories on the microbiome and human health. Grades will be based on participation, written assignments, exams, an oral presentation and a final paper. This class is offered as a SAGES Departmental Seminar and fulfills an Organismal breadth requirement of the BA and BS in Biology. Counts as SAGES Departmental Seminar. Prereq: (Undergraduate Student and BIOL 214 and BIOL 216) or Requisites Not Met Permission.

BIOL 334. Structural Biology. 3 Units.
Introduces basic chemical properties of proteins and discusses the physical forces that determine protein structure. Topics include: the elucidation of protein structure by NMR and by X-ray crystallographic methods; the acquisition of protein structures from data bases; and simple modeling experiments based on protein structures. Offered as BIOL 334, BIOL 334, BIOC 434, and BIOL 434.

BIOL 336. Aquatic Biology. 3 Units.
Physical, chemical, and biological dynamics of lake ecosystems. Factors governing the distribution, abundance, and diversity of freshwater organisms. This course satisfies the Population Biology/Ecology breadth requirement of the B.A. and B.S. in Biology. Offered as BIOL 336 and BIOL 436. Prereq: Undergraduate Student and BIOL 214 or Requisites Not Met permission.

BIOL 338. Ichthyology. 4 Units.
Biology of fishes. Students will develop fundamental understanding of the evolutionary history and systematics of fishes to provide a context within which they can address aspects of biology including anatomy, physiology (e.g., in species that change sex; osmoregulation in freshwater vs. saltwater), and behavior (e.g., visual, auditory, chemical, electric communication; social structures), ecology, and evolution (e.g., speciation). We will explore the biodiversity of fishes around the world, with emphasis on Ohio species, by examining preserved specimens, observing captive living specimens, and observing, capturing, and identifying wild fishes in their natural habitats. Practical applications will be emphasized, such as aquaculture, fisheries management, and biomedical research. Course will conclude with an analysis of the current global fisheries crisis that has resulted from human activities. There will be many field trips and networking with the Cleveland Metroparks Zoo, the Cleveland Museum of Natural History, and local, state, and federal government agencies. Some classes meet at the Cleveland Museum of Natural History. This course satisfies a laboratory requirement of the B.A. and B.S. in Biology. The graduate version of the course requires a research project and term paper. Offered as BIOL 338 and BIOL 438. Prereq: (Undergraduate Student and BIOL 216) or Requisites Not Met permission.

BIOL 339. Aquatic Biology Laboratory. 2 Units.
The physical, chemical, and biological limnology of freshwater ecosystems will be investigated. Emphasis will be on identification of the organisms inhabiting these systems and their ecological interactions with each other. This course will combine both field and laboratory analysis to characterize and compare the major components of these ponds. Students will have the opportunity to design and conduct individual projects. This course satisfies a laboratory requirement of the B.A. in Biology. This course satisfies an additional laboratory requirement of the B.S. in Biology. Prereq or Coreq: Undergraduate Student and BIOL 336 or Requisites Not Met permission.

BIOL 340. Human Physiology. 3 Units.
This course will provide functional correlates to the students’ previous knowledge of human anatomy. Building upon the basic principles covered in BIOL 216 and BIOL 346, the physiology of organs and organ systems of humans, including the musculoskeletal, nervous, cardiovascular, lymphatic, immune, respiratory, digestive, excretory, reproductive, and endocrine systems, will be studied at an advanced level. The contribution of each system to homeostasis will be emphasized. Prereq: (Undergraduate Student and BIOL 346 and BIOL 215 and BIOL 216) or Requisites Not Met permission.
Biol 342. Parasitology. 3 Units.
This course will introduce students to classical and current parasitology. Students will discuss basic principles of parasitology, parasite life cycles, host–parasite interaction, therapeutic and control programs, epidemiology, and ecological and societal considerations. The course will explore diverse classes of parasitic organisms with emphasis on protozoan and helminthic diseases and the parasites' molecular biology. Group discussion and selected reading will facilitate further integrative learning and appreciation for parasite biology. This course counts as an elective in the cell/molecular biology subject area for the Biology B.A. and B.S. degrees. Offered as BIOL 342 and BIOL 442. Prereq: (Undergraduate Student and BIOL 214, BIOL 215, BIOL 216 and BIOL 326) or Requisites Not Met permission.

Biol 343. Microbiology. 3 Units.
The subject will be approached both as a basic biological science that studies the molecular and biochemical processes of cells and viruses, and as an applied science that examines the involvement of microorganisms in human disease as well as in workings of ecosystems, plant symbioses, and industrial processes. The course is divided into four major areas: bacteria, viruses, medical microbiology, and environmental and applied microbiology. Offered as BIOL 343 and BIOL 443. Prereq: (Undergraduate Student and BIOL 215) or Requisites Not Met permission.

Biol 344. Laboratory for Microbiology. 3 Units.
Practical microbiology, with an emphasis on bacteria as encountered in a variety of situations. Sterile techniques, principles of identification, staining and microscopy, growth and nutritional characteristics, genetics, enumeration methods, epidemiology, immunological techniques (including ELISA and T cell identification), antibiotics and antibiotic resistance, chemical diagnostic tests, sampling the human environment, and commercial applications. One three hour lab plus one lecture per week. Prereq or Coreq: (Undergraduate Student and BIOL 343) or Requisites Not Met permission.

Biol 345. Mammal Diversity and Evolution. 4 Units.
This course focuses on the anatomical and taxonomic diversity of mammals in an evolutionary context. The emphasis is on living (extant) mammals, but extinct mammals are also discussed. By the end of the course, students will be able to: (1) describe the key anatomical and physiological features of mammals; (2) name all orders and most families of living mammals; (3) identify a mammal skull to order and family; (4) understand how to create and interpret a phylogenetic tree; (5) appreciate major historical patterns in mammal diversity and biogeography as revealed by the fossil record; (6) read and critique a scientific article dealing with mammal evolution. One weekend field trip to Cleveland Metroparks Zoo; additional individual and group visits to the Cleveland Museum of Natural History. This course satisfies a laboratory requirement for the biology major. Offered as ANAT 445 and BIOL 345. Prereq: BIOL 214.

Biol 346. Human Anatomy. 3 Units.
Gross anatomy of the human body. Two lectures and one laboratory demonstration per week. Prereq: (Undergraduate Student and BIOL 216) or Requisites Not Met permission.

Biol 351. Principles of Ecology. 3 Units.
This lecture course explores spatial and temporal relationships involving organisms and the environment at individual, population, and community levels. An underlying theme of the course will be neo-Darwinian evolution through natural selection with an emphasis on organismal adaptations to abiotic and biotic environments. Studies and models will illustrate ecological principles, and there will be some emphasis on the applicability of these principles to ecosystem conservation. This course satisfies the Population Biology/Ecology breadth requirement of the B.A. and B.S. in Biology. Students taking the graduate level course will prepare a grant proposal in which hypotheses will be based on some aspect of ecological theory. Offered as BIOL 351 and BIOL 451. Prereq: Undergraduate Student and BIOL 214 or Requisites Not Met permission.

Biol 351L. Principles of Ecology Laboratory. 2 Units.
Students in this laboratory course will conduct a variety of ecological investigations that are designed to examine relationships involving organisms and the environment at individual, population, and community levels. Descriptive and hypothesis-driven investigations will take place at Case Western Reserve University's Squire Valleeve Farm, in both field and greenhouse settings. The course is designed to explore as well as test a variety of ecological paradigms. Students taking the graduate level course will prepare a grant proposal in which hypotheses will be based on a select number of lab investigations. This course satisfies a laboratory requirement for biology majors. Recommended preparation for BIOL 451L: prior or concurrent enrollment in BIOL 451. Offered as BIOL 351L and BIOL 451L. Prereq or Coreq: Undergraduate Student and BIOL 351 or Requisites Not Met permission.

Biol 352. Ecology and Evolution of Infectious Diseases. 3 Units.
This course explores the effects of infectious diseases on populations of hosts, including humans and other animals. We will use computer models to study how infectious diseases enter and spread through populations, and how factors like physiological and behavioral differences among host individuals, host and pathogen evolution, and the environment affect this spread. Our emphasis will be on understanding and applying quantitative models for studying disease spread and informing policy in public health and conservation. To that end, computer labs are the central component of the course. This course satisfies a laboratory requirement of the B.A. in biology. This course satisfies a laboratory or quantitative laboratory requirement of the B.S. in biology. Offered as BIOL 352 and BIOL 452. Prereq: (Undergraduate Student and BIOL 214 and (MATH 121 or MATH 125) and (MATH 122 or MATH 126)) or Requisites Not Met permission.
BIOL 353. Ecophysiology of Global Change. 3 Units.
Global change is an emerging threat to human health and economic stability. Rapid changes in climate, land use, and prevalence of non-native species generate novel conditions outside the range of typical conditions under which organisms evolved. Already we are witnessing the global redistribution of plants and animals, changes in the timing of critical life cycle events, and in some cases local extinction of populations. This course explores the impacts of global change on biological systems at levels from individuals to ecosystems; among animals, plants and microbes; across ecological to evolutionary timescales; and from local to global spatial scales. Throughout, physiology is emphasized as a core driver of biological responses to global change. Traditional lectures will be accompanied by discussions of primary literature articles. The laboratory component will involve the development of an independent project at the University Farm, and dissemination of results through traditional (e.g. written paper) and new (e.g. podcast) media. This class will fulfill a laboratory requirement of the B.A. in Biology. This class will fulfill an additional laboratory requirement of the B.S. in Biology. Offered as BIOL 353 and BIOL 453. Prereq: (Undergraduate Student and BIOL 214. Prereq or Coreq: BIOL 216) or Requisites Not Met Permission.

BIOL 357. Backyard Behavior Capstone. 3 Units.
Interesting animal behavior is all around us. We need not go into a laboratory to observe it, but laboratory tools can help to understand the behaviors that we encounter every day. We interact with animals in our homes, in forests and wilderness areas and even in our own backyards. As pet dogs or cats interact with wild squirrels and birds, they provide insights regarding predation, neuromechanics, and mating behaviors, just to list a few concepts. This course takes advantage of the rich behavior that exists around us to provide a capstone experience for students who have an interest in animal behavior. The course will be open to 10 senior Biology majors who have emphasized the animal behavior and neurobiology courses offered by the Biology department. Each student will have taken at least one advanced course in Animal Behavior, Neurobiology, or Neuroethology. Entry into the course will be by permit, and permits will be issued only after an interview in which each student demonstrates to the instructor a deep interest in animal behavior and underlying neural control systems. Through classroom discussion, viewing of behaviorally-based video shows, and field trips, each student will choose one behavior to investigate in detail over the course of the semester. In order to move beyond casual observation to in-depth analysis, video cameras will be available to the students, as well as computer based motion analysis systems. The class will meet as a group twice weekly. During this formal classroom period, students will discuss behaviors in general and, as the course progresses, the specific topics that each student is investigating. They will present journal articles that are relevant to their topics, a prospectus on their intended study, and ultimately describe their projects outside of class time and will present a poster at a public poster fair. Counts as SAGES Senior Capstone. Prereq: BIOL 305 or BIOL 318 or BIOL 358 or BIOL 373 or BIOL 374.

BIOL 358. Animal Behavior. 4 Units.
Ultimately the success or failure (i.e., life or death) of any individual animal is determined by its behavior. The ability to locate and capture food, avoid being food, acquiring and defending territory, and successfully passing your genes to the next generation, are all dependent on complex interactions between an animal’s design, environment and behavior. This course will be an integrative approach emphasizing experimental studies of animal behavior. You will be introduced to state-of-the-art approaches to the study of animal behavior, including neural and hormonal mechanisms, genetic and developmental mechanisms and ecological and evolutionary approaches. We will learn to critique examples of current scientific papers, and learn how to conduct observations and experiments with real animals. We will feature guest appearances by the Curator of Research from the Cleveland MetroParks Zoo and visits to working animal behavior research labs here at CWRU. Group discussions and writing will be emphasized. This course satisfies a laboratory requirement for biology majors. Offered as BIOL 358 and BIOL 458. Prereq: (Undergraduate Student and BIOL 214, BIOL 215 and BIOL 216) or Requisites Not Met permission.

BIOL 362. Principles of Developmental Biology. 3 Units.
The descriptive and experimental aspects of animal development. Gametogenesis, fertilization, cleavage, morphogenesis, induction, differentiation, organogenesis, growth, and regeneration. Students taking the graduate-level course will prepare an NIH-format research proposal as the required term paper. Offered as BIOL 362, BIOL 462 and ANAT 462. Prereq: Undergraduate Student and (BIOL 216 or (EBME 201 and EBME 202)) or Requisites Not Met Permission.

BIOL 363. Experimental Developmental Biology. 3 Units.
This laboratory course will teach concepts and techniques in developmental biology. Emphasis will be on the mechanisms that pattern the embryo during development and how these mechanisms are explored using molecular, cellular, and genetic approaches. A term research paper is required. Students taking the graduate-level course will prepare a grant proposal. One laboratory and one lecture per week. Offered as BIOL 363 and BIOL 463. Prereq: Undergraduate Student and BIOL 362 or Requisites Not Met permission.

BIOL 364. Research Methods in Evolutionary Biology. 3 Units.
The process of evolution explains not only how the present diversity of life on earth has formed, but also provides insights into current pressing issues today, including the spread of antibiotic resistance, the causes of geographic variation in genetic diseases, and explanations for modern patterns of extinction risk. Students in Research Methods in Evolutionary Biology will be introduced to several of the major research approaches of evolutionary biology, including methods of measuring natural selection on the phenotypic and genotypic levels, quantifying the rate of evolution, reconstructing evolutionary relationships, and assessing the factors that affect rates of speciation and extinction. The course will consist of a combination of interactive lectures, in-class problem solving and data analysis, and the discussion of peer-reviewed scientific papers. Grades are based on participation in class, discussions and written summaries of published papers, in-class presentations, and two writing assignments. Offered as BIOL 364 and BIOL 464. Counts as SAGES Departmental Seminar. Prereq: (Undergraduate Student and BIOL 214) or Requisites Not Met Permission.
**BIOL 365. Evo-Devo: Evolution of Body Plans and Pathologies. 3 Units.**

This discussion-based course offers a detailed introduction to Evolutionary Developmental Biology. The field seeks to explain evolutionary events through the mechanisms of Developmental Biology and Medical Genetics. The course is structured into different modules. First we will look at the developmental genetic mechanisms that can cause variation and medical pathologies. Then we focus on how alterations of these mechanisms can generate novel structural changes. We will then examine a few areas of active debate, where Evo-Devo is attempting to solve major problems in evolutionary biology and congenital birth defects. We will conclude with two writing assignments. Students will be required to present, read, and discuss primary literature in each module. This course is offered as a SAGES Departmental Seminar and fulfills a Cell and Molecular breadth requirement of the BA and BS in Biology. Offered as BIOL 365 and BIOL 465. Counts as SAGES Departmental Seminar. Prereq: Undergraduate Student and (BIOL 225 or BIOL 326 or BIOL 362) or Requisites Not Met permission.

**BIOL 368. Topics in Evolutionary Biology. 3 Units.**

The focus for this course on a special topic of interest in evolutionary biology will vary from one offering to the next. Examples of possible topics include theories of speciation, the evolution of language, the evolution of sex, evolution and biodiversity, molecular evolution. ANAT/ANTH/EEPS/PHIL/PHOL 467/BIOL 468 will require a longer, more sophisticated term paper, and additional class presentation. Offered as ANTH 367, BIOL 368, EEPS 367, PHIL 367, ANAT 467, ANTH 467, BIOL 468, EEPS 467, PHIL 467 and PHOL 467. Prereq: BIOL 225 or equivalent.

**BIOL 369. Evolutionary Biology Capstone. 3 Units.**

This course focuses on a special topic of interest in evolutionary biology that will vary from one offering to the next. Examples of possible topics include theories of speciation, the evolution of language, the evolution of sex, evolution and biodiversity, molecular evolution. Students will participate in discussions and lead class seminars on evolutionary topics and in collaboration with an advisor or advisors, select a topic for a research paper or project. Each student will write a major research report or complete a major project and will make a public presentation of her/his findings. Offered as ANTH 368, BIOL 369, and PHIL 368. Counts as SAGES Senior Capstone.

**BIOL 373. Introduction to Neurobiology. 3 Units.**

How nervous systems control behavior. Biophysical, biochemical and molecular biological properties of nerve cells, their organization into circuitry, and their function within networks. Emphasis on quantitative methods for modeling neurons and networks, and on critical analysis of the contemporary technical literature in the neurosciences. Term paper required for graduate students. This course satisfies a lab requirement for the B.A. in Biology, and a Quantitative Laboratory requirements for the B.S. in Biology. Offered as BIOL 373, BIOL 473, and NEUR 473.

**BIOL 374. Neurobiology of Behavior. 3 Units.**

In this course, students will examine how neurobiologists interested in animal behavior study the linkage between neural circuitry and complex behavior. Various vertebrate and invertebrate systems will be considered. Several exercises will be used in this endeavor. Although some lectures will provide background and context on specific neural systems, the emphasis of the course will be on classroom discussion of specific journal articles. In addition, students will each complete a project in which they will observe some animal behavior and generate both behavioral and neurobiological hypotheses related to it. In lieu of examinations, students will complete three written assignments, including a theoretical grant proposal, a one-page Specific Aims paper related to the project, and a final project paper. These assignments are designed to give each student experience in writing biologically-relevant documents. Classroom discussions will help students understand the content and format of each type document. They will also present their projects orally to the entire class. Offered as BIOL 374, BIOL 474 and NEUR 474. Counts as SAGES Departmental Seminar.

**BIOL 377. Biorobotics Team Research. 3 Units.**

Many exciting research opportunities cross disciplinary lines. To participate in such projects, researchers must operate in multi-disciplinary teams. The Biorobotics Team Research course offers a unique capstone opportunity for undergraduate students to utilize skills they developed during their undergraduate experience while acquiring new teaming skills. A group of eight students form a research team under the direction of two faculty leaders. Team members are chosen from appropriate majors through interviews with the faculty. They will research a biological mechanism or principle and develop a robotic device that captures the actions of that mechanism. Although each student will cooperate on the team, they each have a specific role, and must develop a final paper that describes the research generated on their aspect of the project. Students meet for one class period per week and two 2-hour lab periods. Initially students brainstorm ideas and identify the project to be pursued. They then acquire biological data and generate robotic designs. Both are further developed during team meetings and reports. Final oral reports and a demonstration of the robotic device occur in week 15. Offered as BIOL 377, EMAE 377, BIOL 467, and EMAE 477. Counts as SAGES Senior Capstone.

**BIOL 378. Computational Neuroscience. 3 Units.**

Computer simulations and mathematical analysis of neurons and neural circuits, and the computational properties of nervous systems. Students are taught a range of models for neurons and neural circuits, and are asked to implement and explore the computational and dynamic properties of these models. The course introduces students to dynamical systems theory for the analysis of neurons and neural learning, models of brain systems, and their relationship to artificial and neural networks. Term project required. Students enrolled in MATH 478 will make arrangements with the instructor to attend additional lectures and complete additional assignments addressing mathematical topics related to the course. Recommended preparation: MATH 223 and MATH 224 or BIOL 300 and BIOL 306. Offered as BIOL 378, COGS 378, MATH 378, BIOL 478, EBME 478, EECS 478, MATH 478 and NEUR 478.
BIOL 379. Transformative Animal Models in Modern Biology. 3 Units.
Animal models are extremely important in the study of biology and in modern medicine. They allow us to determine fundamental biological mechanisms and cellular and molecular causes of disease. There is logic to how each animal model has found its place in the menagerie of accepted animal models. Certain animal models allow us to test particular hypotheses that may not be possible to address in other animals. Moreover, some animal models are more relevant than others to studying a particular human disease. This seminar-based course will focus on animal models that either are effective at modeling human disease, approach relevant neurobiological questions, or play a role in translational medicine. The course will focus on mammalian and non-mammalian animal models that are important to biomedical research, including the primate, mouse, zebrafish, and roundworm. Comparisons between popular animal models will be made. This course satisfies the Organismal breadth requirement of the B.A. and B.S. in Biology. Offered as BIOL 379 and BIOL 479. Counts as SAGES Departmental Seminar. Prereq: Undergraduate student and (BIOL 326 or BIOL 373) or Requisites Not Met permission.

BIOL 384. Reading and Writing Like an Ecologist. 3 Units.
Students usually learn from textbooks, but scientists communicate with each other through journal articles. The purpose of this class is to help you learn to read and write like an ecologist. We will spend our time reading and discussing journal articles about three or four issues in ecology, including papers from both empirical and theoretical perspectives. In addition to the science, we'll talk about strategies for how to keep reading when you encounter something you don't understand and what makes a paper well or poorly written. At the end of each section, you will synthesize your ideas into a review article. Your initial paper will be submitted to me as hypothetical journal editor. I will send your paper out for review to two fellow classmates, and I'll send their comments back to you along with brief comments of my own. As all scientists know, it is virtually unheard of for a journal to accept a paper for publication without revisions. After this peer review, you will revise your papers and resubmit them to me. Your grade will be based on your participation in class discussions, your papers (both drafts) and your work as a reviewer for other students. This course satisfies the Population Biology/Ecology breadth requirement of the B.A. and B.S. in Biology. Counts as SAGES Departmental Seminar. Prereq: Undergraduate Student and BIOL 214 or Requisites Not Met permission.

BIOL 385. Seminar on Biological Processes in Learning and Cognition. 3 Units.
Students will read and discuss research papers on a range of topics relevant to the biological processes that lead to cognition and learning in humans. Sample topics are: cellular and molecular mechanisms of memory; visual sensory detection of images, movement, and color; role of slow neurotransmitters in synaptic plasticity; cortical distribution of cognitive functions such as working memory, decision making, and image analysis; functions of emotion-structures and their role in cognition; brain structures and mechanisms involved in language creation; others. Some papers will be assigned and others will be selected by students. Discussions will focus on the methods used, the experimental results, and the interpretations of significance. Students will work in groups on a semester project to be presented near the end of the semester. Counts as SAGES Senior Capstone. Prereq: Undergraduate Student and BIOL 302 or Requisites Not Met permission.

BIOL 388. Undergraduate Research. 1 - 3 Units.
Guided laboratory research under the sponsorship of a biology faculty member. May be carried out within the biology department or in associated departments. Appropriate forms must be secured in the biology department office. A written report must be approved by the biology sponsor and submitted to the chairman of the biology department before credit is granted. Only 3 credit-hours may count towards the biology majors or minor. Offered as BIOL 388 and SYBB 388.

BIOL 388S. Undergraduate Research - SAGES Capstone. 3 Units.
Guided laboratory research under the sponsorship of a biology faculty member. May be carried out within the biology department or in associated departments. May be taken only one semester during the student's academic career. Appropriate forms must be secured in the biology department office. A written report must be approved by the biology sponsor and submitted to the chairman of the biology department before credit is granted. A public presentation is required. Offered as BIOL 388S and SYBB 388S. Counts as SAGES Senior Capstone.

BIOL 389. Selected Topics. 1 - 3 Units.
Individual library research projects completed under the guidance of a biology sponsor. May be carried out within the biology department or in associated departments. Appropriate forms must be secured in the biology department office. A written report must be approved by the biology sponsor and submitted to the chairman of the biology department before credit is granted. Only 3 credit-hours may count towards the biology majors or minor.

BIOL 389S. Selected Topics in Biology--SAGES Capstone. 3 Units.
Individual library research projects under the guidance of a biology sponsor. A major paper must be submitted and approved before credit is awarded. A public presentation is required. Counts as SAGES Senior Capstone.

BIOL 390. Advanced Undergraduate Research. 1 - 3 Units.
Offered on a credit only basis. Students may carry out research in biology or related departments, but a biology sponsor is required. Does not count toward the 30 hours required for a major in biology, but may be counted toward the total number of hours required for graduation. A written report must be submitted to the chairman’s office and approved before credit is granted. Prereq: BIOL 388 or BIOL 388S.

BIOL 396. Undergraduate Research in Evolutionary Biology. 3 Units.
Students propose and conduct guided research on an aspect of evolutionary biology. The research will be sponsored and supervised by a member of the CASE faculty or other qualified professional. A written report must be submitted to the Evolutionary Biology Steering Committee before credit is granted. Offered as ANTH 396, BIOL 396, EEPS 396, and PHIL 396.
BIOL 397. Molecular Phylogenetics. 4 Units.
This course is designed to teach the theory and practice of molecular based phylogenetics with attention to evolutionary analysis through lecture, readings, discussion, and a quantitative laboratory section. A comprehensive overview of the history of systematics and morphology based phylogenetics will help familiarize students with the theory, methods, and character analysis frameworks used in current genetic based approaches. A laboratory section of the course will provide working knowledge in designing and carrying out an original phylogenetics project beginning with data procurement to writing a research manuscript. Through readings and discussions of research articles as well as presented content, the relevant course material will be utilized in practice by students analyzing their project data sets. The semester-long research project will take students through the process of building a data set, aligning sequences, reconstructing phylogenies, conducting evolutionary analyses, and interpreting and writing results as a scientific manuscript. In addition, students will orally present their research proposal as well as the final research project. Undergraduate students will work in teams of two on the research project component of the course and independently throughout the other course components (discussions). Graduate students will work independently and have an extra assignment. This course satisfies a laboratory requirement of the B.A. in Biology. This course satisfies a laboratory requirement of the B.S. in Biology. Offered as: BIOL 397 and BIOL 497. Prereq: Undergraduate Student and BIOL 214 and (BIOL 225 or BIOL 364) or Requisites Not Met permission.

BIOL 398. Modern Human Biological Variation. 3 Units.
The objectives of this course are to provide students with an introduction to human biological variation and to understand the variation within an evolutionary framework through lecture, readings, discussion, and labs. We will examine the patterns of morphological and genetic variation in modern human populations and discuss the evolutionary explanations for the observed patterns. In order to do this, we will first build a solid foundation in the scientific method, population genetics, and evolutionary theory before exploring the adaptive significance of the observed variation. A major component of the class will be the discussion of the social and health implications of these patterns of biological variation, particularly in the construction and application of the concept of race and its use in medicine. There are three units to the course. Unit 1 focuses on the fundamentals to understanding biological variation, we will cover basic population genetics, evolution, and the human fossil record. Unit 2 concentrates on surveying modern human biological variation, examining both morphological and genetic traits, and why these variations exist. Unit 3 examines how race is constructed using population-based biological differences, its validity, and the implications for health and medicine. This course fulfills the Population and Ecology breadth requirement of the B.A and B.S. in Biology. Offered as BIOL 398 and BIOL 498. Prereq: Undergraduate Student and BIOL 214 or Requisites Not Met permission.

BIOL 401. Biotechnology Laboratory: Genes and Genetic Engineering. 3 Units.
Laboratory training in recombinant DNA techniques. Basic microbiology, growth, and manipulation of bacteriophage, bacteria and yeast. Students isolate and characterize DNA, construct recombinant DNA molecules, and reintroduce them into eukaryotic cells (yeast, plant, animal) to assess their viability and function. Two laboratories per week. This course satisfies a laboratory requirement of the B.A. in Biology. This course satisfies an additional laboratory requirement of the B.S. in Biology. Offered as BIOL 301 and BIOL 401.

BIOL 402. Principles of Neural Science. 3 Units.
Lecture/discussion course covering concepts in cell and molecular neuroscience, principles of systems neuroscience as demonstrated in the somatosensory system, and fundamentals of the development of the nervous system. This course will prepare students for upper level Neuroscience courses and is also suitable for students in other programs who desire an understanding of neurosciences. Recommended preparation: CBIO 453. Offered as BIOL 402 and NEUR 402.

BIOL 404. Fitting Models to Data: Maximum Likelihood Methods and Model Selection. 3 Units.
This course will introduce students to maximum likelihood methods for fitting models to data and to ways of deciding which model is best supported by the data (model selection). Along the way, students will learn some basic tenets of probability and develop competency in R, a commonly used statistical package. Examples will be drawn from ecology, epidemiology, and potentially other areas of biology. The second half of the course is devoted to in-class projects, and students are encouraged to bring their own data. Offered as BIOL 304 and BIOL 404. Prereq: MATH 121 and MATH 122 OR MATH 125 and MATH 126 or consent of instructor.

BIOL 407. Introduction to Biochemistry: From Molecules To Medical Science. 4 Units.
Overview of the macromolecules and small molecules key to all living systems. Topics include: protein structure and function; enzyme mechanisms, kinetics and regulation; membrane structure and function; bioenergetics; hormone action; intermediary metabolism, including pathways and regulation of carbohydrate, lipid, amino acid, and nucleotide biosynthesis and breakdown. The material is presented to build links to human biology and human disease. One semester of biology is recommended. Offered as BIOL 307, BIOL 407, and BIOL 407. Prereq: CHEM 223 and CHEM 224.

BIOL 408. Molecular Biology. 4 Units.
An examination of the flow of genetic information from DNA to RNA to protein. Topics include: nucleic acid structure; mechanisms and control of DNA, RNA, and protein biosynthesis; recombinant DNA; and mRNA processing and modification. Where possible, eukaryotic and prokaryotic systems are compared. Special topics include yeast as a model organism, molecular biology of cancer, and molecular biology of the cell cycle. Current literature is discussed briefly as an introduction to techniques of genetic engineering. Recommended preparation: BIOC 307. Offered as BIOC 308, BIOC 407, BIOC 408, and BIOC 408. Prereq: BIOL 215 or BIOC 307.

BIOL 409. Biology Field Studies. 3 Units.
Intensive investigation of living organisms in a natural environment. Location of the field site may vary with each course offering, and may be either domestic or international. Topics covered include logistics, biodiversity, and current ecological, environmental, and social issues surrounding the specific ecosystem being studied. Time at the field site will be spent listening to resident lecturers, receiving guided tours, observing and identifying wild organisms in their natural habitat, and conducting a research project. The undergraduate version requires students to plan and conduct a group research project and present results independently. The graduate version requires students to plan, conduct, and present an independent research project. Instructor consent required to register. This course will fulfill a laboratory requirement of the B.A. in Biology. This course will fulfill an additional laboratory requirement of the B.S. in Biology. Course may be repeated for credit up to two times if traveling to a new destination. Offered as BIOL 309 and BIOL 409. Prereq: Graduate Standing.
BIOL 414. Taming the Tree of Life: Phylogenetic Comparative Methods- from Concept to Practical Application. 3 Units.

“Nothing in biology makes sense except in the light of evolution” – Dobzhansky Biologists have long been fascinated by the diversity of life. Why are there so many species? Why are some of them similar and others divergent? How has evolution shaped ecological interactions, such as disease-host dynamics? The "tree of life" describes phylogenetic hypotheses for evolutionary history among species, and modern phylogenetic comparative methods allow us to incorporate the tree of life into statistical analyses. This course will introduce phylogenetic comparative methods, why they are needed to answer many biological questions, how they are conducted, and how they can be used to evaluate hypotheses. These methods can be used for any group of organisms, from humans and their diseases, to plants, animals, or fungi. These methods also can be used to address a broad suite of questions in biology, including biomedical, ecological, evolutionary, developmental, and neuromechanical questions. For example, issues of public health can be more deeply addressed using these tools. Students may bring their own data sets, or may use existing data sets, and will develop an independent research project using these tools. Undergraduates will present a poster at a public poster fair, as part of the requirements for the SAGES capstone. No prior experience with the R statistics language is necessary for this course. BIOL314 fulfills the requirements for an undergraduate capstone in biology. Offered as BIOL 314 and BIOL 414. Counts as SAGES Senior Capstone.

BIOL 415. Quantitative Biology Laboratory. 3 Units.

This course will apply a range of quantitative techniques to explore structure-function relations in biological systems. Using a case study approach, students will explore causes of impairments of normal function, will assemble diverse sets of information into a database format for the analysis of causes of impairment, will analyze the data with appropriate statistical and other quantitative tools, and be able to communicate their results to both technical and non-technical audiences. The course has one lecture and one lab per week. Students will be required to maintain a journal of course activities and demonstrate mastery of quantitative tools and statistical techniques. Graduate students will have a final project that applies these techniques to a problem of their choice. Offered as BIOL 315 and BIOL 415.

BIOL 416. Fundamental Immunology. 4 Units.

Introductory immunology providing an overview of the immune system, including activation, effector mechanisms, and regulation. Topics include antigen-antibody reactions, immunologically important cell surface receptors, cell-cell interactions, cell-mediated immunity, innate versus adaptive immunity, cytokines, and basic molecular biology and signal transduction in B and T lymphocytes, and immunopathology. Three weekly lectures emphasize experimental findings leading to the concepts of modern immunology. An additional recitation hour is required to integrate the core material with experimental data and known immune mediated diseases. Five mandatory 90 minute group problem sets per semester will be administered outside of lecture and recitation meeting times. Graduate students will be graded separately from undergraduates, and 22 percent of the grade will be based on a critical analysis of a recently published, landmark scientific article. Offered as BIOL 316, BIOL 416, CLBY 416, PATH 316 and PATH 416. Prereq: Graduate standing.

BIOL 417. Cytokines: Function, Structure, and Signaling. 3 Units.

Regulation of immune responses and differentiation of leukocytes is modulated by proteins (cytokines) secreted and/or expressed by both immune and non-immune cells. Course examines the function, expression, gene organization, structure, receptors, and intracellular signaling of cytokines. Topic include regulatory and inflammatory cytokines, colony stimulating factors, chemokines, cytokine and cytokine receptor gene families, intracellular signaling through STAT proteins and tyrosine phosphorylation, clinical potential, and genetic defects. Lecture format using texts, scientific reviews and research articles. Recommended preparation: PATH 416 or equivalent. Offered as BIOL 417, CLBY 417, and PATH 417.

BIOL 418. Introductory Entomology. 4 Units.

The goal of this course is to discover that, for the most part, insects are not aliens from another planet. Class meetings will alternate; with some structured as lectures, while others are laboratory exercises. Sometimes we will meet at the Cleveland Museum of Natural History, or in the field to collect and observe insects. The 50 minute discussion meeting once a week will serve to address questions from both lectures and lab exercises. The students will be required to make a small but comprehensive insect collection. Early in the semester we will focus on collecting the insects, and later, when insects are gone for the winter, we will work to identify the specimens collected earlier. Students will be graded based on exams, class participation and their insect collections. This course satisfies either the Organismal breadth requirement of the B.A. and B.S. in Biology, or the laboratory requirement of the B.A. in Biology, or an additional laboratory requirement of the B.S. in Biology. Offered as BIOL 318 and BIOL 418. Prereq: BIOL 214, and BIOL 215, and BIOL 216.

BIOL 419. Applied Probability and Stochastic Processes for Biology. 3 Units.

Applications of probability and stochastic processes to biological systems. Mathematical topics will include: introduction to discrete and continuous probability spaces (including numerical generation of pseudo random samples from specified probability distributions), Markov processes in discrete and continuous time with discrete and continuous sample spaces, point processes including homogeneous and inhomogeneous Poisson processes and Markov chains on graphs, and diffusion processes including Brownian motion and the Ornstein-Uhlenbeck process. Biological topics will be determined by the interests of the students and the instructor. Likely topics include: stochastic ion channels, molecular motors and stochastic ratchets, actin and tubulin polymerization, random walk models for neural spike trains, bacterial chemotaxis, signaling and genetic regulatory networks, and stochastic predator-prey dynamics. The emphasis will be on practical simulation and analysis of stochastic phenomena in biological systems. Numerical methods will be developed using a combination of MATLAB, the R statistical package, MCell, and/or URDME, at the discretion of the instructor. Student projects will comprise a major part of the course. Offered as BIOL 319, EECs 319, MATH 319, SYBB 319, BIOL 419, EBME 419, MATH 419, PHOL 419, and SYBB 419.
**BIOL 421. Design and Analysis of Biological Experiments. 3 Units.**
In this laboratory course, students will learn how to use a computer programming language (MATLAB) to design, execute, and analyze biological experiments. The course will begin with basic programming and continue to data output and acquisition, image analysis, and statistics. Students who are interested in carrying out research projects in any lab setting are encouraged to take this course and use the skills acquired to better organize and analyze their experiments. No prior programming knowledge is assumed. This course satisfies a laboratory requirement of the B.A. in biology. This course satisfies a laboratory or quantitative laboratory requirement of the B.S. in biology. Students will complete a final project on a topic of their choice; graduate students will be required to give an oral presentation of this project. Offered as BIOL 321 and BIOL 421. Counts for CAS Quantitative Reasoning Requirement. Prereq: Graduate standing.

**BIOL 422. Sensory Biology. 3 Units.**
The task of a sensory system is to collect, process, store, and transmit information about the environment. How do sensory systems convert information from the environment into neural information in an animal’s brain? This course will explore the ecology, physiology, and behavior of the senses across the animal kingdom. We will cover introductory neurobiology and principles of sensory system organization before delving more deeply into vision, olfaction, audition, mechanosensation, and multi-modal sensory integration. For each sensory modality, we will consider how the sensory system operates and how its operation affects the animal’s behavior and ecology. We will also explore the evolution of sensory systems and their specialization for specific behavioral tasks. Students will finish the course with a research project on a topic of their choice; graduate students will present this project to the class. Offered as BIOL 322 and BIOL 422. Prereq: Graduate standing.

**BIOL 424. Introduction to Stem Cell Biology. 3 Units.**
This discussion-based course will introduce students to the exciting field of stem cell research. Students will first analyze basic concepts of stem cell biology, including stem cell niche, cell quiescence, asymmetric cell division, cell proliferation and differentiation, and signaling pathways involved in these processes. This first part of the course will focus on invertebrate genetic models for the study of stem cells. In the second part of the course, students will search for primary research papers on vertebrate and human stem cells, and application of stem cell research in regenerative medicine and cancer. Finally, students will have the opportunity to discuss about ethical controversies in the field. Students will rotate in weekly presentations, and will write two papers during the semester. Students will improve skills on searching and reading primary research papers, gain presentation skills, and further their knowledge in related subjects in the fields of cell biology, genetics and developmental biology. This course may be used as a cell/molecular subject area elective for the B.A. and B.S. Biology degrees. Offered as BIOL 324 and BIOL 424. Prereq: Graduate standing.

**BIOL 426. Genetics. 3 Units.**
Transmission genetics, nature of mutation, microbial genetics, somatic cell genetics, recombinant DNA techniques and their application to genetics, human genome mapping, plant breeding, transgenic plants and animals, uniparental inheritance, evolution, and quantitative genetics. Offered as BIOL 326 and BIOL 426.

**BIOL 427. Functional Genomics. 3 Units.**
In this course, students will learn how to access and use genomics data to address questions in cell biology, development and evolution. The genome of Drosophila melanogaster will serve as a basis for exploring genome structure and learning how to use a variety of available software to identify similar genes in different species, predict protein sequence and functional domains, design primers for PCR, analyze cis-regulatory sequences, access microarray and RNAseq databases, among others. Classes will be in the format of short lectures, short oral presentations made by students and hands-on experimentation using computers. Discussions will be centered in primary research papers that used these tools to address specific biological questions. A final project will consist of a research project formulated by a group of 2-3 students to test a hypothesis formulated by the students using the bioinformatics tools learned in the course. Graduate students will be required to make additional presentations of research papers. They also will have additional questions in exams and a distinct page requirement on written assignments. This course satisfies a laboratory requirement of the B.A. in Biology. This course satisfies a laboratory or quantitative laboratory requirement of the B.S. in Biology. Offered as BIOL 327 and BIOL 427. Prereq: Graduate standing.

**BIOL 428. Plant Genomics and Proteomics. 3 Units.**
The development of molecular tools has impacted agriculture as much as human health. The application of new techniques to improve food crops, including the development of genetically modified crops, has also become controversial. This course covers the nature of the plant genome and the role of sequenced-based methods in the identification of the genes. The application of the whole suite of modern molecular tools to understand plant growth and development, with specific examples related agronomically important responses to biotic and abiotic stresses, is included. The impact of the enormous amounts of data generated by these methods and their storage and analysis (bioinformatics) is also considered. Finally, the impact on both the developed and developing world of the generation and release of genetically modified food crops will be covered. Recommended preparation: BIOL 326. Offered as BIOL 328 and BIOL 428.

**BIOL 431. Statistical Methods I. 3 Units.**
Application of statistical techniques with particular emphasis on problems in the biomedical sciences. Basic probability theory, random variables, and distribution functions. Point and interval estimation, regression, and correlation. Problems whose solution involves using packaged statistical programs. First part of year-long sequence. Offered as ANAT 431, BIOL 431, CRSP 431, PQHS 431 and MPHP 431.

**BIOL 432. Statistical Methods II. 3 Units.**
Methods of analysis of variance, regression and analysis of quantitative data. Emphasis on computer solution of problems drawn from the biomedical sciences. Design of experiments, power of tests, and adequacy of models. Offered as BIOL 432, PQHS 432, CRSP 432 and MPHP 432. Prereq: PQHS/EPBI 431 or equivalent.

**BIOL 434. Structural Biology. 3 Units.**
Introduces basic chemical properties of proteins and discusses the physical forces that determine protein structure. Topics include: the elucidation of protein structure by NMR and by X-ray crystallographic methods; the acquisition of protein structures from data bases; and simple modeling experiments based on protein structures. Offered as BIOL 334, BIOL 334, BIOL 434, and BIOL 434.
BIOL 436. Aquatic Biology. 3 Units.
Physical, chemical, and biological dynamics of lake ecosystems. Factors governing the distribution, abundance, and diversity of freshwater organisms. This course satisfies the Population Biology/Ecology breadth requirement of the B.A. and B.S. in Biology. Offered as BIOL 336 and BIOL 436.

BIOL 438. Ichthyology. 4 Units.
Biology of fishes. Students will develop fundamental understanding of the evolutionary history and systematics of fishes to provide a context within which they can address aspects of biology including anatomy, physiology (e.g., in species that change sex; osmoregulation in freshwater vs. saltwater), and behavior (e.g., visual, auditory, chemical, electric communication; social structures), ecology, and evolution (e.g., speciation). We will explore the biodiversity of fishes around the world, with emphasis on Ohio species, by examining preserved specimens, observing captive living specimens, and observing, capturing, and identifying wild fishes in their natural habitats. Practical applications will be emphasized, such as aquaculture, fisheries management, and biomedical research. Course will conclude with an analysis of the current global fisheries crisis that has resulted from human activities. There will be many field trips and networking with the Cleveland Metroparks Zoo, the Cleveland Museum of Natural History, and local, state, and federal government agencies. Some classes meet at the Cleveland Museum of Natural History. This course satisfies a laboratory requirement of the B.A. and B.S. in biology. The graduate version of the course requires a research project and term paper. Offered as BIOL 338 and BIOL 438. Prereq: Graduate Standing.

BIOL 442. Parasitology. 3 Units.
This course will introduce students to classical and current parasitology. Students will discuss basic principles of parasitology, parasite life cycles, host-parasite interaction, therapeutic and control programs, epidemiology, and ecological and societal considerations. The course will explore diverse classes of parasitic organisms with emphasis on protozoan and helminthic diseases and the parasites’ molecular biology. Group discussion and selected reading will facilitate further integrative learning and appreciation for parasite biology. This course counts as an elective in the cell/molecular biology subject area for the Biology B.A. and B.S. degrees. Offered as BIOL 342 and BIOL 442. Prereq: Graduate standing and consent of instructor.

BIOL 443. Microbiology. 3 Units.
The physiology, genetics, biochemistry, and diversity of microorganisms. The subject will be approached both as a basic biological science that studies the molecular and biochemical processes of cells and viruses, and as an applied science that examines the involvement of microorganisms in human disease as well as in workings of ecosystems, plant symbioses, and industrial processes. The course is divided into four major areas: bacteria, viruses, medical microbiology, and environmental and applied microbiology. Offered as BIOL 343 and BIOL 443.

BIOL 451. Principles of Ecology. 3 Units.
This lecture course explores spatial and temporal relationships involving organisms and the environment at individual, population, and community levels. An underlying theme of the course will be neo-Darwinian evolution through natural selection with an emphasis on organismal adaptations to abiotic and biotic environments. Studies and models will illustrate ecological principles, and there will be some emphasis on the applicability of these principles to ecosystem conservation. This course satisfies the Population Biology/Ecology breadth requirement of the B.A. and B.S. in Biology. Students taking the graduate level course will prepare a grant proposal in which hypotheses will be based on some aspect of ecological theory. Offered as BIOL 351 and BIOL 451.

BIOL 451L. Principles of Ecology Laboratory. 2 Units.
Students in this laboratory course will conduct a variety of ecological investigations that are designed to examine relationships involving organisms and the environment at individual, population, and community levels. Descriptive and hypothesis-driven investigations will take place at Case Western Reserve University’s Squire Valleeve Farm, in both field and greenhouse settings. The course is designed to explore as well as test a variety of ecological paradigms. Students taking the graduate level course will prepare a grant proposal in which hypotheses will be based on a select number of lab investigations. This course satisfies a laboratory requirement for biology majors. Recommended preparation for BIOL 451L: prior or concurrent enrollment in BIOL 451. Offered as BIOL 351L and BIOL 451L.

BIOL 452. Ecology and Evolution of Infectious Diseases. 3 Units.
This course covers the effects of infectious diseases on populations of hosts, including humans and other animals. We will use computer models to study how infectious diseases enter and spread through populations, and how factors like physiological and behavioral differences among host individuals, host and pathogen evolution, and the environment affect this spread. Our emphasis will be on understanding and applying quantitative models for studying disease spread and informing policy in public health and conservation. To that end, computer labs are the central component of the course. This course satisfies a laboratory requirement of the B.A. in biology. This course satisfies a laboratory or quantitative laboratory requirement of the B.S. in biology. Offered as BIOL 352 and BIOL 452. Prereq: Graduate standing.

BIOL 453. Ecophysiology of Global Change. 3 Units.
Global change is an emerging threat to human health and economic stability. Rapid changes in climate, land use, and prevalence of non-native species generate novel conditions outside the range of typical conditions under which organisms evolved. Already we are witnessing the global redistribution of plants and animals, changes in the timing of critical life cycle events, and in some cases local extinction of populations. This course explores the impacts of global change on biological systems at levels from individuals to ecosystems; among animals, plants and microbes; across ecological to evolutionary timescales; and from local to global spatial scales. Throughout, physiology is emphasized as a core driver of biological responses to global change. Traditional lectures will be accompanied by discussions of primary literature articles. The laboratory component will involve the development of an independent project at the University Farm, and dissemination of results through traditional (e.g. written paper) and new (e.g. podcast) media. This class will fulfill a laboratory requirement of the B.A. in Biology. This class will fulfill an additional laboratory requirement of the B.S. in Biology. Offered as BIOL 353 and BIOL 453. Prereq: Graduate Standing.

BIOL 457. Conversations on Protein Structure and Function. 2 Units.
The goal of this course is to supplement the short and basic presentation of Proteins in C3MB by lectures and discussions for students with backgrounds in physical-chemical sciences or students who already have a good basic background in protein science. The course presents an overview of Protein structure/function. Following an introduction to the principles of protein structure, the physical basis of protein folding and stability, and a brief overview of structural and bioinformatics approaches to protein analysis is presented. Typically two lecture/discussion style presentations are followed by a student lead journal club on recent high profile papers. The way the Journal club is done is that one student presents a paper (background and figures in powerpoint slides) while presentation of the main figures is shared between the class. Papers and Figures will be assigned by instructor. Typically two papers will be presented per session. Offered as PHOL 456 and BIOL 457.
Biol 458. Animal Behavior. 4 Units.
Ultimately the success or failure (i.e., life or death) of any individual animal is determined by its behavior. The ability to locate and capture food, avoid being food, acquiring and defending territory, and successfully passing your genes to the next generation, are all dependent on complex interactions between an animal's design, environment and behavior. This course will be an integrative approach emphasizing experimental studies of animal behavior. You will be introduced to state-of-the-art approaches to the study of animal behavior, including neural and hormonal mechanisms, genetic and developmental mechanisms and ecological and evolutionary approaches. We will learn to critique examples of current scientific papers, and learn how to conduct observations and experiments with real animals. We will feature guest appearances by the Curator of Research from the Cleveland MetroParks Zoo and visits to working animal behavior research labs here at CWRU. Group discussions and writing will be emphasized. This course satisfies a laboratory requirement for biology majors. Offered as Biol 358 and Biol 458.

Biol 462. Principles of Developmental Biology. 3 Units.
The descriptive and experimental aspects of animal development. Gametogenesis, fertilization, cleavage, morphogenesis, induction, differentiation, organogenesis, growth, and regeneration. Students taking the graduate-level course will prepare an NIH-format research proposal as the required term paper. Offered as Biol 362, Biol 462 and Anat 462.

Biol 463. Experimental Developmental Biology. 3 Units.
This laboratory course will teach concepts and techniques in developmental biology. Emphasis will be on the mechanisms that pattern the embryo during development and how these mechanisms are explored using molecular, cellular, and genetic approaches. A term research paper is required. Students taking the graduate level course will prepare a grant proposal. One laboratory and one lecture per week. Offered as Biol 363 and Biol 463.

Biol 464. Research Methods in Evolutionary Biology. 3 Units.
The process of evolution explains not only how the present diversity of life on earth has formed, but also provides insights into current pressing issues today, including the spread of antibiotic resistance, the causes of geographic variation in genetic diseases, and explanations for modern patterns of extinction risk. Students in Research Methods in Evolutionary Biology will be introduced to several of the major research approaches of evolutionary biology, including methods of measuring natural selection on the phenotypic and genotypic levels, quantifying the rate of evolution, and ecological and evolutionary approaches. We will learn to critique examples of current scientific papers, and learn how to conduct observations and experiments with real animals. We will feature guest appearances by the Curator of Research from the Cleveland MetroParks Zoo and visits to working animal behavior research labs here at CWRU. Group discussions and writing will be emphasized. This course satisfies a laboratory requirement for biology majors. Offered as Biol 358 and Biol 458.

Biol 465. Evo-Devo: Evolution of Body Plans and Pathologies. 3 Units.
This discussion-based course offers a detailed introduction to Evolutionary Developmental Biology. The field seeks to explain evolutionary events through the mechanisms of Developmental Biology and Medical Genetics. The course is structured into different modules. First we will look at the developmental genetic mechanisms that can cause variation and medical pathologies. Then we focus on how alterations of these mechanisms can generate novel structural changes. We will then examine a few areas of active debate, where Evo-Devo is attempting to solve major problems in evolutionary biology and congenital birth defects. We will conclude with two writing assignments. Students will be required to present, read, and discuss primary literature in each module. This course is offered as a SAGES Departmental Seminar and fulfills a Cell and Molecular breadth requirement of the BA and BS in Biology. Offered as Biol 365 and Biol 465. Counts as SAGES Departmental Seminar.

Biol 467. Biorobotics Team Research. 3 Units.
Many exciting research opportunities cross disciplinary lines. To participate in such projects, researchers must operate in multi-disciplinary teams. The Biorobotics Team Research course offers a unique capstone opportunity for undergraduate students to utilize skills they developed during their undergraduate experience while acquiring new teaming skills. A group of eight students form a research team under the direction of two faculty leaders. Team members are chosen from appropriate majors through interviews with the faculty. They will research a biological mechanism or principle and develop a robotic device that captures the actions of that mechanism. Although each student will cooperate on the team, they each have a specific role, and must develop a final paper that describes the research generated on their aspect of the project. Students meet for one class period per week and two 2-hour lab periods. Initially students brainstorm ideas and identify the project to be pursued. They then acquire biological data and generate robotic designs. Both are further developed during team meetings and reports. Final oral reports and a demonstration of the robotic device occur in week 15. Offered as Biol 377, Emae 377, Biol 467, and Emae 477. Counts as SAGES Senior Capstone.

Biol 468. Topics in Evolutionary Biology. 3 Units.
The focus for this course on a special topic of interest in evolutionary biology will vary from one offering to the next. Examples of possible topics include theories of speciation, the evolution of language, the evolution of sex, evolution and biodiversity, molecular evolution. ANAT/ANTH/EEPS/PHIL/PHOL 467/Biol 468 will require a longer, more sophisticated term paper, and additional class presentation. Offered as Anth 367, Biol 368, Eeps 367, Phil 367, Anat 467, Anth 467, Biol 468, Eeps 467, Phil 467, and Phol 467.

Biol 471. Foundations of Advanced Ecology. 3 Units.
Advanced ecology, including discussion of the classic literature, in-depth study of key terms and concepts, applications of these foundational ideas to the modern literature, and current and future directions in the field. Intended for graduate students who have already taken undergraduate ecology (Biol 351/451 or equivalent). Prereq: Graduate standing.

Biol 472. Foundations of Advanced Evolution. 3 Units.
Advanced evolutionary biology, including discussion of the classic literature, in-depth study of key terms and concepts, applications of these foundational ideas to the modern literature, and current and future directions in the field. Intended for graduate students who have already taken undergraduate evolution. Prereq: Graduate standing.
BIOL 473. Introduction to Neurobiology. 3 Units.
How nervous systems control behavior. Biophysical, biochemical and molecular biological properties of nerve cells, their organization into circuitry, and their function within networks. Emphasis on quantitative methods for modeling neurons and networks, and on critical analysis of the contemporary technical literature in the neurosciences. Term paper required for graduate students. This course satisfies a lab requirement for the B.A. in Biology, and a Quantitative Laboratory requirements for the B.S. in Biology. Offered as BIOL 373, BIOL 473, and NEUR 473.

BIOL 474. Neurobiology of Behavior. 3 Units.
In this course, students will examine how neurobiologists interested in animal behavior study the linkage between neural circuitry and complex behavior. Various vertebrate and invertebrate systems will be considered. Several exercises will be used in this endeavor. Although some lectures will provide background and context on specific neuronal systems, the emphasis of the course will be on classroom discussion of specific journal articles. In addition, students will each complete a project in which they will observe some animal behavior and generate both behavioral and neurobiological hypotheses related to it. In lieu of examinations, students will complete three written assignments, including a theoretical grant proposal, a one-page Specific Aims paper related to the project, and a final project paper. These assignments are designed to give each student experience in writing biologically-relevant documents. Classroom discussions will help students understand the content and format of each type document. They will also present their projects orally to the entire class. Offered as BIOL 374, BIOL 474 and NEUR 474. Counts as SAGES Departmental Seminar.

BIOL 478. Computational Neuroscience. 3 Units.
Computer simulations and mathematical analysis of neurons and neural circuits, and the computational properties of nervous systems. Students are taught a range of models for neurons and neural circuits, and are asked to implement and explore the computational and dynamic properties of these models. The course introduces students to dynamical systems theory for the analysis of neurons and neural learning, models of brain systems, and their relationship to artificial and neural networks. Term project required. Students enrolled in MATH 478 will make arrangements with the instructor to attend additional lectures and complete additional assignments addressing mathematical topics related to the course. Recommended preparation: MATH 223 and MATH 224 or BIOL 300 and BIOL 306. Offered as BIOL 378, COGS 378, MATH 378, BIOL 478, EBME 478, EECS 478, MATH 478 and NEUR 478.

BIOL 479. Transformative Animal Models in Modern Biology. 3 Units.
Animal models are extremely important in the study of biology and in modern medicine. They allow us to determine fundamental biological mechanisms and cellular and molecular causes of disease. There is logic to how each animal model has found its place in the menagerie of accepted animal models. Certain animal models allow us to test particular hypotheses that may not be possible to address in other animals. Moreover, some animal models are more relevant than others to studying a particular human disease. This seminar-based course will focus on animal models that either are effective at modeling human disease, approach relevant neurobiological questions, or play a role in translational medicine. The course will focus on mammalian and non-mammalian animal models that are important to biomedical research, including the primate, mouse, zebrafish, and roundworm. Comparisons between popular animal models will be made. This course satisfies the Organismal breadth requirement of the B.A. and B.S. in Biology. Offered as BIOL 379 and BIOL 479. Counts as SAGES Departmental Seminar. Prereq: Graduate Standing.

BIOL 480. Physiology of Organ Systems. 4 Units.
Our intent is to expand the course from the current 3 hours per week (1.5 hour on Monday and Wednesday) to 4 hours per week (1.5 hours on Monday and Wednesday plus 1 hour on Friday). Muscle structure and Function, Myasthenia gravis and Sarcoptes; Central Nervous System, (Synaptic Transmission, Sensory System, Autonomic Nervous System, CNS circuits, Motor System, Neurodegenerative Diseases, Paraplegia and Nerve Compression); Cardiovascular Physiology (Regulation of Pressure and flow; Circulation, Cardiac Cycle, Electrophysiology, Cardiac Function, Control of Cardiovascular function, Hypertension); Hemorrhage, Cardiac Hypertrophy and Fibrillation; Respiration Physiology (Gas Transport and Exchange, Control of Breathing. Acid/base regulation, Cor Pulmonaris and Cystic Fibrosis, Sleeping apnea and Emphysema); Renal Physiology (Glomerular Filtration, Tubular Function/transport, Glomerulonephritis, Tubulopaties); Gastro-Intestinal Physiology (Gastric motility, gastric function, pancreas and bile function, digestion and absorption, Liver Physiology; Pancreatitis, Liver Disease and cirrhosis); Endocrine Physiology (Thyroid, Adrenal glands, endocrine pancreas, Parathyroid, calcium sensing receptor, Cushing and diabetes, Reproductive hormones, eclampsia); Integrative Physiology (Response to exercise, fasting and feeding, aging). For all the classes, the students will receive a series of learning objectives by the instructor to help the students address and focus their attention to the key aspects of the organ physiology (and physiopathology). The evaluation of the students will continue to be based upon the students’ participation in class (60% of the grade) complemented by a mid-term and a final exam (each one accounting for 20% of the final grade). Offered as BIOL 480 and PHOL 480.

BIOL 491. Contemporary Biology and Biotechnology for Innovation I. 3 Units.
The first half of a two-semester sequence providing an understanding of biology as a basis for successfully launching new high-tech ventures. The course will examine physical limitations to present technologies and the use of biology to identify potential opportunities for new venture creation. The course will provide experience in using biology in both identification of incremental improvements and as the basis for alternative technologies. Case studies will be used to illustrate recent commercially successful (and unsuccessful) biotechnology-based venture creation and will illustrate characteristics for success.

BIOL 492. Contemporary Biology and Biotechnology for Innovation II. 3 Units.
Continuation of BIOL 491 with an emphasis on current and prospective opportunities for Biotechnology Entrepreneurship. Longer term opportunities for Biotechnology Entrepreneurship in emerging areas including (but not limited to) applications of DNA sequence information in medicine and agriculture; energy and the environment; biologically-inspired robots. Recommended preparation: BIOL 491 or consent of department.

BIOL 493. Feasibility and Technology Analysis. 3 Units.
This course provides the tools scientists need to determine whether a technology is ready for commercialization. These tools include (but are not limited to): financial analysis, market analysis, industry analysis, technology analysis, intellectual property protection, the entrepreneurial process and culture, an introduction to entrepreneurial strategy and new venture financing. Deliverables will include a technology feasibility analysis on a possible application in the student’s scientific area. Offered as BIOL 493, CHEM 493, and PHYS 493.
**BIOL 495. Introduction to Graduate School in the Biological Sciences. 1 Unit.**
This course will help incoming Biology MS and Ph.D. students navigate their way through graduate school and participate in the scientific process. Students in the Biology graduate program will be strongly encouraged to take this course in their first year. This will be a skill-based course that will become part of their academic toolbox. In addition, there will be sessions to offer general tips for life in graduate school. Prereq: Graduate Standing.

**BIOL 497. Molecular Phylogenetics. 4 Units.**
This course is designed to teach the theory and practice of molecular based phylogenetics with attention to evolutionary analysis through lecture, readings, discussion, and a quantitative laboratory section. A comprehensive overview of the history of systematics and morphology based phylogenetics will help familiarize students with the theory, methods, and character analysis frameworks used in current genetic based approaches. A laboratory section of the course will provide working knowledge in designing and carrying out an original phylogenetics project beginning with data procurement to writing a research manuscript. Through readings and discussions of research articles as well as presented content, the relevant course material will be utilized in practice by students analyzing their project data sets. The semester-long research project will take students through the process of building a data set, aligning sequences, reconstructing phylogenies, conducting evolutionary analyses, and interpreting and writing results as a scientific manuscript. In addition, students will orally present their research proposal as well as the final research project. Undergraduate students will work in teams of two on the research project component of the course and independently throughout the other course components (discussions). Graduate students will work independently and have an extra assignment. This course satisfies a laboratory requirement of the B.A. in Biology. This course satisfies a laboratory or quantitative laboratory requirement of the B.S. in Biology. Offered as BIOL 397 and BIOL 497. Prereq: Graduate Standing.

**BIOL 498. Modern Human Biological Variation. 3 Units.**
The objectives of this course are to provide students with an introduction to human biological variation and to understand the variation within an evolutionary framework through lecture, readings, discussion, and labs. We will examine the patterns of morphological and genetic variation in modern human populations and discuss the evolutionary explanations for the observed patterns. In order to do this, we will first build a solid foundation in the scientific method, population genetics, and evolutionary theory before exploring the adaptive significance of the observed variation. A major component of the class will be the discussion of the social and health implications of these patterns of biological variation, particularly in the construction and application of the concept of race and its use in medicine. There are three units to the course. Unit 1 focuses on the fundamentals to understanding biological variation, we will cover basic population genetics, evolution, and the human fossil record. Unit 2 concentrates on surveying modern human biological variation, examining both morphological and genetic traits, and why these variations exist. Unit 3 examines how race is constructed using population-based biological differences, its validity, and the implications for health and medicine. This course fulfills the Population and Ecology breadth requirement of the B.A. and B.S. in Biology. Offered as BIOL 398 and BIOL 498. Prereq: Graduate Standing.

**BIOL 549. Mathematical Life Sciences Seminar. 1 - 3 Units.**
Continuing seminar on areas of current interest in the applications of mathematics to the life sciences. Allows graduate and advanced undergraduate students to become involved in research. Topics will reflect interests and expertise of the faculty and may include topics in mathematical biology, computational neuroscience, mathematical modeling of biological systems, models of infectious diseases, computational cell biology, mathematical ecology and mathematical biomedicine broadly construed. May be taken more than once for credit.

**BIOL 599. Advanced Independent Study for Graduate Students. 1 - 3 Units.**
Independent study of advanced topics in biology under the supervision of a biology faculty member. Registration requires submission of a proposal for a project or study and approval of the department.

**BIOL 601. Research. 1 - 9 Units.**

**BIOL 651. Thesis M.S.. 1 - 9 Units.**

**BIOL 701. Dissertation Ph.D.. 1 - 9 Units.**
Prereq: Predoctoral research consent or advanced to Ph.D. candidacy milestone.