BIOLOGY (BIOL)

BIOL 112. Biology's Survival Guide to College. 3 Units.
Stress can test the limit of an individual's ability to maintain balance, thrive and survive. This course explores how cells, organs and organ systems work together to maintain homeostasis. Equipped with knowledge of how the body functions, students will explore how common stressors experienced by college students (sleep deprivation, lack of relaxation, poor diet, and others) can test the limits of maintaining homeostasis. Understanding the body's stress response and how stress impacts well-being will enable students to make informed decisions about how to promote balance and self-care in their own life. This course does not count toward any Biology major or minor. Counts as a Full-Semester Wellness/Non-movement course.

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 205. Climate Change Science and Society. 3 Units.
This course provides a synoptic, multi-disciplinary understanding of the past, present, and future of anthropogenic climate change by integrating three distinct fields: the earth and environmental sciences, biology and ecology, and history. What is changing in the global climate? Why? How do we know? What should we expect in the future? What can be done? No single discipline can answer these questions fully, and by organizing the course around these big questions, we will demonstrate how different disciplines each contribute essential answers. Course covers diverse sources of evidence for climate change in the past and present, the core mechanisms of climate change at different timescales and their consequences, the impact of climate change on human history and history of the discovery of climate change, climate models and ecological forecasts, the modern politics and diplomacy of climate, climate communication, and multiple paths forward for the earth's physical, ecological, and social systems. Offered as BIOL 205, EEPS 205, and HSTY 205.

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 or BIOL 222L) and Prereq or Coreq: BIOL 216 or Requisites Not Met permission.

BIOL 222L. Introductory Research Lab in Biology. 2 Units.
This is a Course-based Undergraduate Research Experience (CURE) in which students will learn modern laboratory skills, conduct authentic research, and effectively communicate research findings orally and in writing. Students will develop ownership of their projects, gain confidence in their ability to conduct research, and will grow to see themselves as true members of the broader scientific community. Prereq or Coreq: BIOL 214 or BIOL 215.

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 224L. Bacteriophage Genome Annotation and Analysis Lab. 2 Units.
This course is an open-ended research laboratory course in which students will annotate the genome of at least one bacteriophage isolated by students from a previous BIOL 222L: Bacteriophage isolation and purification class. As such, students will learn techniques used in bioinformatics, and develop deeper understanding of gene structure, expression and function. Students will also learn basic phylogenetic analysis and address questions relating to evolution of phage genomes. In the second half of the semester, student groups will design and execute research projects of their own design. Students will also develop oral and written communication skills through informal lab meetings, formal presentations (including poster presentations) and written reports. This course fulfills the Cell and Molecular breadth requirement of the BA and BS in Biology. Prereq: BIOL 222L.

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 248. Human Anatomy and Physiology Laboratory. 2 Units.
Laboratory course that provides in-depth instruction on the organization, structures, and functions of the human body. Students will learn the anatomy and physiology of each body system and how they interrelate to maintain homeostasis. Prereq: (BIOL 116 and BIOL 117) or (BIOL 346 and BIOL 340) or (BIOL 346 and coreq: BIOL 340).

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 my brain learn and how can its learning best be facilitated?" Each student is required to develop a comprehensive theory about personal learning. These theories will take the form of a major paper which will be expanded and modified throughout the semester. Readings and class discussions will focus on the following topics: learning and education systems, major structures of the brain and their role in learning, neuronal wiring of the brain and how learning changes it, the emotional brain and its essential role in learning, language and the brain, the role of images in learning, memory and learning (and related pathologies, such as PTSD). Students are expected to incorporate information on these topics into their personal theory of learning. In so doing, students are expected to articulate meaningful questions, skillfully employ research and apply their own knowledge to address such questions, produce clear, precise academic prose to explicate their ideas, and provide relevant and constructive criticism during class discussions. Offered as BIOL 302 and COGS 322. Counts as a SAGES Departmental Seminar course. Prereq: Undergraduate Student or Requisites Not Met Permission.

BIOL 303. From Black Box 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 develop better tools to use the next time around. Though biology's toolbox now offers astonishing precision and power, 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. There are no exams. Instead, you will (1) write brief responses to weekly prompts for understanding, (2) write an in-depth proposal for a molecular biology research project, and (3) present your proposal orally to the class. These assignments are designed to check that you are keeping up with weekly discussions and synthesizing what you have learned into a deeper understanding of how we develop questions and construct arguments in biological research. Counts as a Disciplinary Communication course. Counts as a SAGES Departmental Seminar course. 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. 3 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. The graduate version of the course requires a research project and term paper. This course satisfies the Organismal breadth requirement of the B.A. and B.S. in Biology. Offered as BIOL 305 and BIOL 405. Prereq: Undergraduate Student and BIOL 214 or Requisites Not Met permission.

BIOL 305L. Herpetology Lab. 2 Units.
This course will combine field and laboratory sessions to investigate the diversity and biology of reptiles and amphibians. Topics covered will include identification and classification, field research techniques, experimental design and statistical analysis, safe handling of live individuals and working with museum specimens. Laboratory sessions will include trips to the Squire Valleevue Farm, and may also include trips at the Cleveland Museum of Natural History and the 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 or Coreq: BIOL 305.

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 308. From Cloning to CRISPR: Advancements and Prospects in Genetic Engineering. 3 Units.
The foundations of genetic engineering and genome editing began with the discovery of DNA and the ability to synthesize DNA in the 1950s. Advances in gene editing technologies over the past sixty years have brought us to an unprecedented time in science in medicine, where the possibility of generating personalized treatments with molecular biology tools seems attainable. In this course, we will explore the major advances in genetic engineering and consider the implications for the future of medicine and biotechnology. We will read and discuss several peer-reviewed scientific articles to guide our survey of the history of genetic engineering. Along the way, we will develop our own research question that uses genetic engineering and biotechnology to provide an answer. This will take the form of a research grant proposal. We will also reflect upon and discuss some of the ethical considerations of the future of genetic engineering. The format of the course is discussion and workshop based. Discussions will be focused on peer-reviewed literature and workshops will give us time to work in small groups or individually on specific components of the research grant proposal and other scientific writing. Counts as a Disciplinary Communication course. Prereq: BIOL 215.

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 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. Coreq: BIOL 311B and BIOL 311C.

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 points 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. Coreq: BIOL 311A and BIOL 311C.

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 311C, BIOL 311C and SYBB 411C. Prereq: BIOL 214 and BIOL 215. Coreq: BIOL 311A and BIOL 311B.

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-animal 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 a SAGES Senior Capstone course. 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 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: BIOL 215 and BIOL 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, ECSE 319, MATH 319, SYBB 319, BIOL 419, EBME 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 as a CAS Quantitative Reasoning course. 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 organisms. 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 organism's behavior and ecology. We will also explore the evolution of sensory systems and their specialization for specific behavioral tasks. Offered as BIOL 322 and BIOL 422. Counts as a SAGES Departmental Seminar course. 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 326 and BIOL 214L or BIOL 222L) 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 329. Genome Dynamics. 3 Units.
We will examine how the physical architecture of the genome facilitates a dynamic genome ecosystem. Topics will be selected from current research in the field, including: how the three dimensional architecture of chromosomes within the nucleus impacts information storage and retrieval, how biochemical phase separation impacts nucleic acid storage (including RNA), how structural features of chromosomes are critical for function, genome engineering approaches, and the clinical implications of mutations in the 3D nuclear architecture. Course materials will come from the primary research literature, supplemented with appropriate background material. This course fulfills the cell and molecular biology breadth requirement of the BA and BS in Biology. Counts as a SAGES Departmental Seminar. Offered as BIOL 329 and BIOL 429. Counts as a SAGES Departmental Seminar course. Prereq: Undergraduate Student and BIOL 326 or Requisites Not Met permission.

BIOL 333. The 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 a SAGES Departmental Seminar course. Prereq: (Undergraduate Student and BIOL 214 and BIOL 216) or Requisites Not Met Permission.

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 341. Basic Biology of Blood and Blood Diseases. 3 Units.
This course incorporates biology, physiology, biochemistry, and pathology to understand how one of the most important tissues in the human body functions: blood. The course will investigate the normal flow of traffic in the body, as well as some of the biological diseases that hinder this flow. It will focus on understanding the basic and fundamental principles as it relates to biological and disease processes of blood. The course will apply scientific reasoning and critical thinking in investigating these processes. Additionally, it will explore the basic understanding of how scientific research in the area of hematology and oncology is conducted and how we apply laboratory discoveries towards treating blood-related disorders. Our focus will center upon examining the molecular mechanisms associated with bone marrow and several blood disorders. Specifically, we will study cancer (leukemia and lymphoma), anemia (sickle cell disease), blood coagulation (hemophilia and thrombosis), and atherosclerosis. Upon completion of this course, students will have gained the knowledge to apply basic biological concepts to larger, complex pathological diseases. This course fulfills the Cell & Molecular Breadth Requirement of the BA and BS in Biology. Prereq: Undergraduate Student and BIOL 214 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 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. 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. Recommended preparation: BIOL 223, BIOL 225, or BIOL 346. Offered as ANAT 345, 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 Valleevue 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. 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 354. Evolutionary Game Theory. 3 Units.
This course will introduce students to evolutionary game theory and its offshoots and related mathematical frameworks. Evolutionary game theory is mathematical framework that views evolution as a series of reciprocal interactions between individuals. It incorporates both ecology and evolution simultaneously, which makes it useful for understanding eco-evolutionary dynamics. Evolutionary game theory is broad enough to be applied to topics like biodiversity and conservation, epidemiology and pathogen evolution, and human-nature interactions. Students will understand both the mathematics of evolutionary game theory and also ecological and evolutionary principles that can be derived from it. Prior programming experience and a mathematical background is helpful but are not required as these topics will be reviewed and discussed throughout the course. The graduate student offering requires an independent project and paper. This course will satisfy a laboratory requirement for the B.A. and B.S. in Biology and the quantitative laboratory requirement for the B.S. in Biology. Offered as BIOL 354 and BIOL 454. Prereq: (Undergraduate Student and BIOL 214) 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 a SAGES Senior Capstone course. Prereq: BIOL 305 or BIOL 318 or BIOL 358 or BIOL 373 or BIOL 374.

BIOL 358. Animal Behavior. 3 Units.
Ultimately the success or failure (i.e., life or death) of any individual animal is determined by its 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 finally ecological and evolutionary approaches. We will read and discuss examples of current scientific papers, and learn how animal behaviorists conduct observations and experiments. We will feature guest appearances by research scientists studying subjects relevant to animal behavior. Group discussions will be emphasized. This course may be used as a population/ecology subject area elective for the B.A. and B.S. Biology degrees, and one of the elective core courses required for the Neuroscience B.S. degree. Offered as BIOL 358 and BIOL 458. Prereq: (Undergraduate Student and BIOL 214, BIOL 215 and BIOL 216) or Requisites Not Met permission.

BIOL 358L. Animal Behavior Lab. 2 Units.
This course will be both a foundations course in animal behavior and an introduction to animal behavior research in settings that may include the Cleveland Metroparks Zoo, campus laboratories, and field settings. Students will gain a basic understanding of the evolutionary basis of behavior that will be complemented by examples of current scientific investigations of behavior. Because this is a laboratory course, the bulk of students' time and effort will be spent conducting laboratory exercises focused on animal behavior and an independent research project of animal behavior. Students will have the option to choose their study species and research question(s) based on a list of options provided by the instructor. Project options will vary each year. This course may be used as a Population biology/ecology area elective and qualifies as a laboratory course for the B.A. and B.S. Biology degrees. Offered as BIOL 358L and BIOL 458L. Prereq: (BIOL 214, BIOL 215 and BIOL 216) or Requisites Not Met permission. Coreq: BIOL 358.

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 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 a SAGES Departmental Seminar course. 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 a SAGES Departmental Seminar course. Prereq: Undergraduate Student and (BIOL 225 or BIOL 326 or BIOL 362) or Requisites Not Met permission.

BIOL 366. Genes, Embryos and Fossils. 3 Units.
This multidisciplinary seminar course is designed to help students understand fundamental concepts of development and evolution of biological systems. Because scientists communicate their ideas through journal articles, seminars, and in grant proposals, the course will focus upon reading and synthesizing primary literature. In this discussion-based course, students will also learn to effectively present and write on three topics that are at the exciting intersection of genetics, developmental biology, and evolution. Finally, students will be provided with the technical and intellectual skills which are needed to write a grant proposal and a literature review. Counts as a SAGES Departmental Seminar course. Prereq: BIOL 225, BIOL 326, BIOL 251, BIOL 362 or BIOL 365.

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. The graduate level offerings of this course 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 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 a SAGES Departmental Seminar course.

BIOL 375. Brain Evolution and Function. 3 Units.
Over 500 million years ago, animals were already walking around, burrowing, and displaying signs of learning and memory. How have brains evolved since then to control the diverse behaviors displayed by animals when escaping predators, courting mates, and interacting socially? In this course we will discuss the origins of brains and how they have adapted to various selective pressures. Through comparisons of animals in different ecological niches, we will also explore how brains function during natural behaviors. Classes will alternate between illustrative lectures and student-led discussions of scientific publications. Students will also report on current studies in the field of evolutionary neuroethology through written exercises. This course satisfies a breadth requirement in population biology and ecology for the BA and BS in Biology or an elective requirement for the Neuroscience BS. Prereq: Undergraduate student and BIOL 216.

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, CSDS 478, EBME 478, ECSE 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 a SAGES Departmental Seminar course. Prereq: Undergraduate student and (BIOL 326 or BIOL 373) or Requisites Not Met permission.

BIOL 381. Nervous System Development. 3 Units.
This course will introduce the principles guiding the development of the nervous system. Students will learn molecular mechanisms governing the formation of vertebrate and invertebrate nervous systems and become versed on pioneering research studies leading to major discoveries in the field. This course fulfills the neurobiology core requirement for the B.S. in Neuroscience and the organismal breadth requirement of the B.A. and B.S. in Biology. Offered as BIOL 381 and BIOL 481. Prereq or Coreq: Undergraduate Student and NEUR 201 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 a SAGES Senior Capstone course. 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.

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. Counts as a SAGES Senior Capstone course.

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 a SAGES Senior Capstone course.

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 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. Prereq: Graduate student standing.

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: Graduate student standing.

BIOL 405. Herpetology. 3 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. The graduate version of the course requires a research project and term paper. This course satisfies the Organismal breadth requirement of the B.A. and B.S. in Biology. Offered as BIOL 305 and BIOL 405. Prereq: Graduate student standing.

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 410. Interdisciplinary Team Science. 3 Units.
Modern science is increasingly a team endeavor, and teams often cross traditional disciplinary boundaries. While interdisciplinary research can illuminate complex and pressing questions, crossing these boundaries can introduce culture shocks that undermine collaborations. In this course, students will learn practical skills for building productive collaborations as they design and conduct analyses of an unpublished dataset, with the goal of producing a publishable manuscript. The emphasis of the course will be on hands-on data analysis, interpretation, data visualization, and writing, in the context of interdisciplinary teams. Students will build skills in R; previous programming experience is helpful but not required. There are no exams. 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 a SAGES Senior Capstone course. Prereq: Graduate student standing.

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. Prereq: Graduate student standing.

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 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: Graduate student standing.

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, ECSE 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 as a CAS Quantitative Reasoning course. 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 organisms. 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 organism's behavior and ecology. We will also explore the evolution of sensory systems and their specialization for specific behavioral tasks. Offered as BIOL 322 and BIOL 422. Counts as a SAGES Departmental Seminar course. 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. Prereq: Graduate student standing.

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 student 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. Prereq: Graduate student standing.

BIOL 429. Genome Dynamics. 3 Units.
We will examine how the physical architecture of the genome facilitates a dynamic genome ecosystem. Topics will be selected from current research in the field, including: how the three dimensional architecture of chromosomes within the nucleus impacts information storage and retrieval, how biochemical phase separation impacts nucleic acid storage (including RNA), how structural features of chromosomes are critical for function, genome engineering approaches, and the clinical implications of mutations in the 3D nuclear architecture. Course materials will come from the primary research literature, supplemented with appropriate background material. This course fulfills the cell and molecular biology breadth requirement of the BA and BS in Biology. Counts as a SAGES Departmental Seminar. Offered as BIOL 329 and BIOL 429. Counts as a SAGES Departmental Seminar course. Prereq: Graduate student standing.

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. Prereq: Graduate student standing.

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. Prereq: Graduate student standing.

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. Prereq: Graduate student standing.

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 Valleevue 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. Offered as BIOL 351L and BIOL 451L. Prereq: Graduate student standing.

BIOL 452. 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: 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 454. Evolutionary Game Theory. 3 Units.
This course will introduce students to evolutionary game theory and its offshoots and related mathematical frameworks. Evolutionary game theory is mathematical framework that views evolution as a series of reciprocal interactions between individuals. It incorporates both ecology and evolution simultaneously, which makes it useful for understanding eco-evolutionary dynamics. Evolutionary game theory is broad enough to be applied to topics like biodiversity and conservation, epidemiology and pathogen evolution, and human-nature interactions. Students will understand both the mathematics of evolutionary game theory and also ecological and evolutionary principles that can be derived from it. Prior programming experience and a mathematical background is helpful but are not required as these topics will be reviewed and discussed throughout the course. The graduate student offering requires an independent project and paper. This course will satisfy a laboratory requirement for the B.A. and B.S. in Biology and the quantitative laboratory requirement for the B.S. in Biology. Offered as BIOL 354 and BIOL 454. Prereq: Graduate student standing.

BIOL 458. Animal Behavior. 3 Units.
Ultimately the success or failure (i.e., life or death) of any individual animal is determined by its 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 finally ecological and evolutionary approaches. We will read and discuss examples of current scientific papers, and learn how animal behaviorists conduct observations and experiments. We will feature guest appearances by research scientists studying subjects relevant to animal behavior. Group discussions will be emphasized. This course may be used as a population/ecology subject area elective for the B.A. and B.S. Biology degrees, and one of the elective core courses required for the Neuroscience B.S. degree. Offered as BIOL 358 and BIOL 458. Prereq: Graduate student standing.

BIOL 458L. Animal Behavior Lab. 2 Units.
This course will be both a foundations course in animal behavior and an introduction to animal behavior research in settings that may include the Cleveland Metroparks Zoo, campus laboratories, and field settings. Students will gain a basic understanding of the evolutionary basis of behavior that will be complemented by examples of current scientific investigations of behavior. Because this is a laboratory course, the bulk of students' time and effort will be spent conducting laboratory exercises focused on animal behavior and an independent research project of animal behavior. Students will have the option to choose their study species and research question(s) based on a list of options provided by the instructor. Project options will vary each year. This course may be used as a Population biology/ecology area elective and qualifies as a laboratory course for the B.A. and B.S. Biology degrees. Offered as BIOL 358L and BIOL 458L. Coreq: BIOL 458 and Graduate student standing.

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 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, 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 a SAGES Departmental Seminar course. Prereq: Graduate student standing.

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 a SAGES Departmental Seminar course. Prereq: Graduate student standing.

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. The graduate level offerings of this course 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 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 a SAGES Departmental Seminar course.

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, CSDS 478, EBME 478, ECSE 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 a SAGES Departmental Seminar course. Prereq: Graduate Standing.

BIOL 481. Nervous System Development. 3 Units.
This course will introduce the principles guiding the development of the nervous system. Students will learn molecular mechanisms governing the formation of vertebrate and invertebrate nervous systems and become versed on pioneering research studies leading to major discoveries in the field. This course fulfills the neurobiology core requirement for the B.S. in Neuroscience and the organismal breadth requirement of the B.A. and B.S. in Biology. Offered as BIOL 381 and BIOL 481. Prereq: Graduate student standing.

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 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.
(Credit as arranged.)

BIOL 701. Dissertation Ph.D.. 1 - 9 Units.
(Credit as arranged.) Prereq: Predoctoral research consent or advanced to Ph.D. candidacy milestone.