

# BIOLOGY

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## Department Website:

<https://www.haverford.edu/biology>

Modern biology has seen tremendous growth in our ability to understand and compare the structure and function of living organisms at the cellular, molecular and genetic levels, and what were traditionally regarded as many different areas of biology have become integrated, particularly in the research laboratory. Our approach to teaching biology therefore emphasizes unifying principles and research method while offering students the flexibility to customize an integrative program of study tailored to their specific interests. We involve students in the process of discovery in a research-focused curriculum that stresses the experimental method as a teaching tool. Students at all levels of the curriculum frame their own experimental questions and use current research techniques to search for answers. In the junior year students participate in research-focused laboratories (BIOL H300/BIOL H301 “Superlab”) and as seniors they conduct their own laboratory-based, year-long research projects. This research may result in presentations at local and national meetings, and occasionally publications in peer-reviewed journals. Our curricular approach allows students to develop the conceptual tools to both follow and contribute to the rapid advance of knowledge and understanding.

Located in the Marian E. Koshland Integrated Natural Sciences Center (KINSC), the Biology Department maintains close interdisciplinary ties with the Chemistry, Physics, Math, Computer Science and Psychology Departments.

## Learning Goals

Students completing a major in biology at Haverford will be able to:

- work both independently and collaboratively;
- understand fundamental concepts in modern biology;
- integrate knowledge and experimental approaches from multiple scientific disciplines such as chemistry, physics, mathematics, and geology;
- read, understand, and critique the primary scientific literature;
- interpret and analyze scientific data;
- design and conduct hypothesis-driven research;
- troubleshoot experimental approaches;
- integrate new knowledge into a framework that advances understanding;

- communicate scientific ideas and concepts, both orally and in writing;
- understand and practice ethical conduct in scientific inquiry.

Haverford’s Institutional Learning Goals are available on the President’s website, at <http://hav.to/learninggoals>.

## Curriculum

### Perspectives in Biology

Perspectives in Biology courses without prerequisites are offered at the 100 level for exploration by students interested in learning about biology but not intending to major in the subject. These are appropriate for students from all backgrounds and disciplines and are separate from the major track.

### Major

Students who wish to major in biology enter the department in their second year, building on a first-year natural science experience. Students take BIOL H200 and BIOL H201, the year-long sophomore introductory course, followed by their choice of four half-semester lecture courses in the junior year that explore fundamental areas of biology. Juniors also engage in a unique, year-long laboratory course (BIOL H300 and BIOL H301 “Superlab”), in which they employ contemporary techniques to answer open-ended biological questions.

The Senior Research Program is the capstone of the Haverford major in biology. The Biology Department provides every major with the opportunity to work directly with our faculty on original research projects. Four to six students work with each professor in that professor’s area of expertise, be it cell biology, genetics, immunology, microbiology, neurobiology, developmental biology, protein biochemistry or the coevolution of plants and the environment. Senior research can account for as much as half of a student’s senior courses. All seniors present a public talk and poster on their research in their senior year and they write both a research proposal and a final thesis. Students are sometimes co-authors on faculty publications and often travel with them to local and national meetings to present their work. A tradition in the Biology Department, this close research partnership between students and faculty is a distinctive feature of a Haverford education.

## Major Requirements

- Both semesters of BIOL H200 and BIOL H201. Successful completion of a one-credit natural science course (which includes a laboratory experience) at Haverford, Bryn Mawr or Swarthmore College is a prerequisite for enrolling in BIOL H200.

- A minimum of a one-credit chemistry course (with associated lab).
- At least one semester of advanced coursework (200 level or higher) in a natural sciences course outside the biology department. Courses crosslisted in biology may not be counted toward this requirement.
- Two semesters of the junior laboratory, BIOL H300 and BIOL H301.
- Four half-semester 300-level advanced topics courses (selected from BIOL H311-H329). Occasionally, an upper-level course from Bryn Mawr or Swarthmore may substitute for one or two of the half-semester lecture courses, but only with the specific permission of the student's major advisor. Students are encouraged to take additional topics classes beyond the minimum of four to enhance their biology experience.
- One half-semester 450-level seminar course in the Haverford Biology Department (chosen from BIOL H450-H463-; no substitutions permitted). Students may take additional seminar courses to enrich their knowledge of the discipline.
- A minimum of two 400-level Senior Research Tutorial credits, generally taken over both semesters of the senior year, including active participation in weekly lab meetings and submission of a notebook and a thesis describing the progress and results of the project. The tutorial may be taken for single or double credit each semester.
- Senior Department Studies, BIOL H499.

In addition to the required courses, the Biology Department strongly recommends a year of physics, a course in probability and statistics, and advanced coursework in another natural science department.

Department policy is to limit study abroad biology major credit to a maximum of two 31X/32X courses and one Superlab quarter (with rare exceptions of a full semester Superlab credit).

## Senior Project

The senior thesis is a major component of a year-long research experience that is the capstone of the Biology major at Haverford. The process begins in the junior year, when students and faculty work together to distribute students evenly across all the available Senior Research Tutorials for the following year (each faculty member normally supervises four to six students in all).

During the senior year students enroll in a Senior Research Tutorial (numbered BIOL H401-H411, depending on the faculty mentor) which is taken for a minimum of one credit in each semester of the senior year. The Senior Research Tutorial

involves 10 hours of laboratory work per week per credit, and is completed under the guidance of a faculty mentor. Students may elect to increase their commitment to their research project by enrolling in 1.5 or 2 credits of Senior Research per semester, for up to four credits in the senior year. In addition, all seniors must take Senior Departmental Studies (BIOL H499), which is a pass/fail, half-credit course taken for a full year in parallel with their Senior Research. This senior seminar course provides an opportunity for all majors to be trained in lab safety, hear invited seminar speakers, and to present thesis proposals as well as the results of senior research work.

## Thesis Content

### Fall Semester

In the fall, all senior majors complete at least one credit of Senior Research Tutorial during which they begin an original research project that will be continued throughout the year. In the Senior Research Tutorial, students participate in weekly laboratory meetings, keep a laboratory notebook as a record of their work, and interpret and analyze their data. In the fall semester students write a formal project proposal and also present their proposal as a short talk to the department during Senior Departmental Studies.

### Spring Semester

In the spring, all majors complete a second semester of Senior Research Tutorial and participate in Senior Departmental Studies. Students continue the research projects started in the fall under the guidance of their faculty mentor. Senior majors write a final thesis and present a scientific poster describing the results of their research project. They submit their lab notebook as a permanent record of the work they have completed in the lab.

## Thesis Preparation (prior to senior year)

Preparation for thesis research begins with the introductory course for biology majors, BIOL H200/BIOL H201, and builds in each course thereafter, so that all of the departmental learning goals are consistently reinforced. For example, all students in laboratory courses (such as BIOL H200/H201 and BIOL H300/H301 ) work with a lab partner or in small groups so that they learn to work collaboratively. At the same time, students are also called upon to present their work individually and to maintain their own research lab notebooks, so that they learn to work independently and are responsible for all parts of the project. The students participate in directed journal clubs in BIOL H200/H201 and majors in upper-level courses read and critique research papers from the original scientific literature, presenting their analyses to the class.

The BIOL H31x/H32X courses, typically taken during the junior year, are based on current research in biology, with an emphasis on integrating this information into a broader understanding of biological topics. The primary focus in these courses is not simply the information itself but rather on how it was determined experimentally. This emphasis provides the students with the skills needed to understand how research is done.

BIOL H300/BIOL H301, the junior-level laboratory course, is intentionally modeled on the work that students are expected to conduct for their senior research thesis, and can be described as a class-based research experience. The emphasis in this yearlong course, which is required for all Biology majors, includes the acquisition of new research techniques but places greater emphasis on hypothesis—testing, data analysis, experimental troubleshooting, record keeping, and oral and written presentations. The projects in BIOL H300/H301 are designed to be intellectually open-ended; students share results and insights, and work to understand the current literature and to connect their findings to what is already known.

### Senior Project Learning Goals

The learning goals for the senior thesis include:

- increasing intellectual independence and initiative.
- developing creativity and rigor in experimental design, execution, and interpretation.
- ensuring reproducibility of experimental results, accurate record keeping, and productivity.
- understanding and participating in collaborative and ethical conduct of research
- learning to present research orally, visually, and in writing.

These are criteria by which the department can assess the students' maturation as scholars.

### Senior Project Assessment

The department has developed criteria for evaluating the research proposal and thesis, as well as a grading rubric that is distributed to students at the start of their senior year (available on the departmental website). Each faculty member plays a role in the assessment of senior work, which consists of:

- faculty supervision of weekly laboratory work that includes maintenance of laboratory notebook and participation in lab meetings.
- formal project proposal, including written proposal, and oral presentation to the department in the fall.

- poster presentation summarizing research results in the spring semester.
- evaluation of written thesis based on set criteria and grading rubric provided to students at start of senior year.

See the Biology Department website for detailed grading guidelines and standards used in evaluating the senior project (PDF download).

## Requirements for Honors

The department awards honors in biology based on superior work in major courses.

## Interdisciplinary Programs

Many Haverford biology majors participate in academic work that crosses departmental boundaries. The Biology Department contributes to many interdisciplinary programs and has particularly close ties with the following ones:

### Environmental Studies Minor

The Environmental Studies minor aims to cultivate in students the capacity to identify and confront key environmental issues through a blend of multiple disciplines, encompassing historical, cultural, economic, political, scientific and ethical modes of inquiry.

### Health Studies Minor

The goal of the Health Studies minor is to give greater context to the issues facing health professionals on local, national, and global scales. The structure of this program is intentionally multidisciplinary, bringing scientists together with social science and humanities professors to guide students through the political, cultural and ethical questions that relate to health issues worldwide.

### Neuroscience Minor

The Minor in Neuroscience is designed to allow students with any major to pursue interests in behavior and the nervous system across disciplines. Students should consult with any member of the advisory committee in order to declare the minor.

### Biochemistry & Biophysics Concentration

The Concentration in Biochemistry and Biophysics recognizes current and undoubtedly enduring trends in interdisciplinary science by establishing in the curriculum a formal program of classroom and laboratory training at the interface between the physical and biological science.

### Scientific Computing Concentration

The Concentration in Scientific Computing gives students an opportunity to develop a basic facility with the tools and concepts involved in applying

computation to a scientific problem, and to explore the specific computational aspects of their own major disciplines.

## Affiliated Programs

### 4+1 Bioengineering Program with the University of Pennsylvania

Study for four years at Haverford, then one year at Penn, and receive a Bachelor of Science from Haverford and a Master's in Engineering from Penn. Haverford is the first liberal arts college in the world to enter into such an agreement with an Ivy League engineering program.

### 4+1 Bioethics Program with the University of Pennsylvania

Study for four years at Haverford, then one year at Penn, and receive a Bachelor of Arts or Bachelor of Science from Haverford and a Master's in Bioethics (M.BE.) from Penn's Bioethics Program in the Perelman School of Medicine.

## Research Opportunities

The Koshland Integrated Natural Sciences Center is the nucleus of a vital summer research program, where faculty members from across the sciences engage students on supervised but independent research projects. Full-time work in the lab permits students to make significant contributions to these studies. Alternatively, many students pursue summer research off campus and bring their experiences and insights back to Haverford, further enriching a diverse curriculum. We encourage all students to present their summer research work at an annual interdisciplinary poster session in the fall.

## Pre-Health

Students from Haverford who enter medical schools have graduated with a great variety of majors—philosophy, Spanish, English and several others of which the most common are, as might be expected, biology and chemistry.

## Study Abroad

Many biology majors take the opportunity to participate in study abroad programs during their junior year. It is possible for students to devote a semester abroad to studies outside of biology or to include some study of biology (depending on the program). Equivalencies for certain major requirements may be granted by the department to biology majors participating in study away programs during the junior year, depending upon the specific program and coursework undertaken.

## Prizes

The department awards three prizes annually:

**The Irving Finger Prize in Biology:** Established in 2003 by family, friends, and alumni in memory of Irving Finger, professor of biology from 1957 to 1994. It is awarded to a graduating senior (or seniors) in biology for outstanding growth and accomplishment in the major.

**The Marian E. Koshland Prize in Biology:** Established in 1997 by biology faculty, College administrators, and Board members. The prize is awarded to a graduating senior (or seniors) who, in the judgment of the department, demonstrated outstanding performance in senior research.

**The Ariel G. Loewy Prize for Senior Research in Biology:** Established in 2001 in memory of Ariel G. Loewy, professor of biology from 1953 to 2000. This prize is given to a graduating senior (or seniors) in biology whose efforts and accomplishments incorporate the rigor and diligence of experimental science.

## Facilities

See the departmental web page for a description of laboratories, equipment and other special facilities for this program.

## Faculty

### Amy Cooke

Assistant Professor of Biology

### Danielle De Leo

Visiting Assistant Professor of Biology

### Robert Fairman

Professor of Biology

### Rachel Hoang

Associate Professor of Biology

### Roshan Jain

Associate Professor of Biology

### Karl Johnson

Professor and Chair of Biology

### Shirley Lang

Laboratory Instructor

### Courtney Marshall

Visiting Assistant Professor of Biology

### Eric Miller

Assistant Professor of Biology

### Judith Owen

Professor Emeritus of Biology; Visiting Professor of Biology

**Foen Peng**

Assistant Professor of Biology

**Kristen Whalen**

Assistant Professor of Biology

## Affiliated Faculty

**Laura Been**

Associate Professor of Psychology

**Lou Charkoudian**

Associate Professor of Chemistry

**Casey Londergan**

Professor of Chemistry

**Megan Massa**

Visiting Assistant Professor of Psychology

**Sara Mathieson**

Assistant Professor of Computer Science

**Patrese Robinson-Drummer**

The Prockop Assistant Professor of Neuroscience

**Kristina Streu**

Post Doctorate Scholar

**Jonathan Wilson**

Associate Professor and Chair of Environmental Studies

## Courses

**BIOL H115 EXPLORING BIOLOGY - BIOLOGY SEMINAR WITH LAB (1.0 Credit)**

*Robert Fairman*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

An introduction to the study of biological science and its relationship to allied fields. Intentionally designed for first-year students that either intend to major in biology or seek to enhance their literacy with biology, this course uses a modular approach to explore core biological concepts and their connections to society. By successfully completing this seminar, students should feel literate within the biological sciences, and if applicable, prepared, confident, and empowered to pursue a Biology major. Does not count towards the Biology major. The required laboratory meets on average every other week during the semester. Two lab sections will be offered, Monday or Tuesday evenings starting at 7:30 pm, and each is limited to 18 students. The labs will typically be about 1.5 hours long. Prerequisite(s): none. Not open to students who have completed 200-level BIOL courses. Concurrent

enrollment in 200-level will require instructor permission.

**BIOL H200 EVOLUTION, GENETICS & GENOMICS (1.0 Credit)**

*Danielle De Leo, Eric Miller, Foen Peng, Rachel Hoang, Shirley Lang*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

Three hours of lecture and one laboratory period per week. A one-year course in cellular and molecular biology, Biology 200 considers the cell as a unit of biological activity. Biology 200A discusses the gene as a storehouse of biological information, the flow and transmission of genetic information, and genomics in the context of evolution, as well as the cellular context in which these processes occur. The laboratory introduces the student to cell and molecular biology, genetics and biochemistry. Enrollment per lab section is limited to 28. Preference for a specific lab section will be given to students preregistering for that lab section; students who do not preregister will be assigned on a space available basis. When two sections of the lecture component are offered one lecture section will be limited to 50. Four sections, limited to 35. Prerequisite(s): The prerequisite for Biology 200A is successful completion, with a grade of 2.0 or higher, of a one credit Natural Science course (which includes a laboratory experience) at Haverford, Bryn Mawr or Swarthmore, or instructor consent

**BIOL H201 MOLECULES, CELLS, & ORGANISMS (1.0 Credit)**

*Amy Cooke, Robert Fairman, Shirley Lang, Staff*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

Three hours of lecture and one laboratory period per week. A one-year course in cellular and molecular biology, Biology 200B is an introduction to the major macromolecules of the cell, which includes a discussion of their synthesis and breakdown and leads into a discussion of cellular structures. The laboratory introduces the student to cell and molecular biology and biochemistry. Enrollment per lab section is limited to 28. Preference for a specific lab section will be given to students preregistering for that lab section; students who do not preregister will be assigned on a space available basis. When two sections of the lecture component are offered one lecture section will be limited to 50. Four sections, limited to 28. Prerequisite(s): BIOL H200 with a grade of 2.0 or higher, or instructor consent

**BIOL H203 UNLOCKING KEY CONCEPTS IN BIOLOGY (0.5 Credit)**

*Staff*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

A course for BIOLH200 students designed to teach the principles and methods of biological investigation. Students are taught how biological hypotheses are identified, developed and tested and how biological data are articulated, analyzed and interpreted. The class meets once a week during the semester and draws material from current literature, groundbreaking classical experiments and concurrent topics in BIOLH200. Enrollment by invitation from the Department. Course is taken Pass/Fail only. Prerequisite(s): Concurrent enrollment in BIOL H200B and instructor consent

**BIOL H217 BEHAVIORAL NEUROSCIENCE (1.0 Credit)**

*Laura Been*

**Division:** Natural Science

**Domain(s):** B: Analysis of the Social World; C: Physical and Natural Processes

Interrelations between brain, behavior, and subjective experience. The course introduces students to physiological psychology through consideration of current knowledge about the mechanisms of mind and behavior. Crosslisted: Psychology, Biology Prerequisite(s): Any one of the following or instructor consent: PSYC 100, PSYC B105, BIOL H123, BIOL H124, BIOL H128, BIOL H129, NEUR H100, Psychology AP Score 4

**BIOL H300 ADVANCED LAB IN BIOLOGY SEM 1 (1.0 Credit)**

*Amy Cooke, Karl Johnson, Kristen Whalen, Staff*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

One lecture and two laboratory periods per week. An introduction to the application of modern experimental approaches in the study of interesting biological questions. Techniques employed are drawn from: cloning and nucleic acids (DNA and RNA) manipulation, including polymerase chain reaction (PCR) and site-directed mutagenesis; protein expression, purification and characterization, with emphasis on circular dichroism and fluorescence spectroscopy; immunofluorescence, confocal and electron microscopy; and fluorescence-activated cell sorting (FACS) analysis. Preference for a specific lab section will be given to students preregistering for that lab section; students who do not preregister will be assigned on a space available basis. Each lab section enrollment is limited to 16. Prerequisite(s): BIOL H200 and BIOL H201 with a grade of 2.0 or above, or instructor consent

**BIOL H301 ADVANCED LAB IN BIOLOGY SEM 2 (1.0 Credit)**

*Danielle De Leo, Eric Miller, Foen Peng, Karl Johnson, Roshan Jain, Staff*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

One lecture and two laboratory periods per week. An introduction to the application of modern experimental approaches in the study of interesting biological questions. Techniques employed are drawn from: cloning and nucleic acids (DNA and RNA) manipulation, including polymerase chain reaction (PCR) and site-directed mutagenesis; protein expression, purification and characterization, with emphasis on circular dichroism and fluorescence spectroscopy; immunofluorescence, confocal and electron microscopy; and fluorescence-activated cell sorting (FACS) analysis. Preference for a specific lab section will be given to students preregistering for that lab section; students who do not preregister will be assigned on a space available basis. Prerequisite(s): BIOL H200 and BIOL H201 with a grade of 2.0 or above, or instructor consent

**BIOL H303 LABORATORY IN BIOCHEMICAL RESEARCH (1.0 Credit)**

*Kristina Streu, Lou Charkoudian*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

An introduction to the laboratory concepts and techniques at the chemistry-biology interface including: molecular cloning, protein purification, biophysical spectroscopy, molecular modeling, and biochemical assays. Crosslisted: Chemistry, Biology Prerequisite(s): CHEM H225

**BIOL H311 ADVANCED GENETIC ANALYSIS (0.5 Credit)**

*Danielle De Leo*

**Division:** Natural Science

The molecular mechanisms governing the transmission, mutation and expression of genes. Particular emphasis is placed on the use of experimental genetic methods to analyze other areas of biology. Crosslisted: Biology, Health Studies Prerequisite(s): BIOL H200 and BIOL H201 with a grade of 2.0 or above, or instructor consent

**BIOL H312 DEVELOPMENT & EVOLUTION (0.5 Credit)**

*Rachel Hoang*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

This course introduces important links between developmental and evolutionary biology. Genetic changes that produce variations between organisms are an important aspect of evolutionary change. Since development can be viewed as a process

that links genetic information to final form of an organism, the fields of development and evolution clearly impact one another. We will look at model developmental systems where mechanisms have been elucidated in remarkable detail. We will then look beyond model systems to comparative studies in a range of organisms, considering how these provide insight into evolutionary mechanisms, and how underlying differences in development may account for the differences we see between organisms. Prerequisite(s): BIOL H200A and B with a grade of 2.0 or above, or instructor consent

### **BIOL H314 BIOCHEMISTRY: METABOLIC BASIS OF DISEASE (0.5 Credit)**

*Robert Fairman*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

This course will introduce students to advanced biosynthetic processes associated with carbohydrate, nucleic acid, protein and lipid metabolism. A coverage of the pathways and the experiments which defined them will be accompanied by discussions of their direct relevance to disease, abnormality and evolutionary adaptation. Prerequisite(s): BIOL H200A and B or instructor consent

### **BIOL H319 MOLECULAR NEUROBIOLOGY (0.5 Credit)**

*Roshan Jain*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

This course will give students the tools to start answering "how/why did I do that?" by exploring the major molecular players and regulators controlling the development, form, function, and flexibility of the nervous system. We will approach neurobiology from an experimental stance, focusing on how the field has come to understand the way genes and molecules can control simple and complex behaviors in model organisms and humans. We will also explore how disrupting these genes, molecules, and processes can lead to neuropsychiatric and neurodegenerative diseases. Prerequisite(s): BIOL H200 and BIOL H201 with a grade of 2.0 or above, or instructor consent

### **BIOL H320 MOLECULAR MICROBIOLOGY (0.5 Credit)**

*Eric Miller*

**Division:** Natural Science

A study of prokaryotic biology with emphasis on cell structure, gene organization and expression, which will incorporate selected readings from the primary literature. Topics include the bacterial and viral cell structure, the genetics of bacteria and bacteriophage, gene regulation, horizontal gene

transfer and microbial genomics. The course will be taught via lecture, class presentation and discussion, and workshops. Prerequisite(s): BIOL H200A and H201B with a grade of 2.0 or above, or instructor consent

### **BIOL H322 CELL ARCHITECTURE (0.5 Credit)**

*Karl Johnson*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

An examination of cellular structure and function. Topics include the eukaryotic cytoskeleton and endomembrane systems, with particular emphasis upon the dynamic qualities of living cells. Prerequisite(s): BIOL H200 and H201 with a grade of 2.0 or above, or instructor consent

### **BIOL H325 MOLECULAR VIROLOGY (0.5 Credit)**

*Eric Miller*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

This course will focus on the study of virus structure, genome organization, replication, and interactions with the host. Many different families of viruses will be highlighted, with an emphasis on those that infect humans, and specific viruses, especially those of clinical importance, will be incorporated as models within each family. Prerequisite(s): BIOL H200 and BIOL H201 with a grade of 2.0 or above, or instructor consent

### **BIOL H326 BIOCHEMICAL ADAPTATIONS (0.5 Credit)**

*Kristen Whalen*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

This course will cover the diversity of physiological mechanisms and biochemical strategies that help organisms, from microbes to mammals, adapt to various environmental conditions. Emphasis put on biochemical evolution in response to changing environmental conditions. Crosslisted: Biology, Environmental Studies Prerequisite(s): BIOL H200A and B with a grade of 2.0 or above, or instructor consent

### **BIOL H328 IMMUNOLOGY (0.5 Credit)**

*Judith Owen*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

This course will provide an introduction to the rapidly expanding discipline of immunology. Students will learn about the molecular and cellular basis of the immune response through the study of the genetics and biochemistry of antigen receptors, the biochemistry of immune cell activation, the cell physiology of the immune system, immune memory, immune tolerance induction and immune-mediated

cell death. Prerequisite(s): BIOL H200 and BIOL H201 with a grade of 2.0 or above, or instructor consent.

### **BIOL H329 COMPARATIVE CELL BIOLOGY OF INVERTEBRATES (0.5 Credit)**

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

Invertebrates comprise over 90% of all animal life, and are found in every ecosystem on Earth. To this extent, invertebrates exhibit a diverse array of adaptations to enable functioning in various habitats. In this upper-level biology course, we will explore the cellular basis of these adaptations using a systems-level approach, with topics including immunity, endocrinology, excretion, reproduction, cellular respiration, integument, and others. Prerequisite(s): BIOL H200 and BIOL H201, grade 2.0 or above

### **BIOL H333 MARINE ECOLOGY (0.5 Credit)**

*Danielle De Leo*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

An introduction to ecological themes in the marine environment. The course will give an overview of ecological concepts, including species interactions, food webs, and human impacts, from the level of individual to populations, communities, and ecosystems in the marine realm. Prerequisite(s): BIOL H200 and BIOL H201 with a grade of 2.0 or above, or instructor consent

### **BIOL H334 BIOCHEMISTRY OF GENE EXPRESSION (0.5 Credit)**

*Amy Cooke*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

The main goal of this course is to develop a fundamental understanding of the biochemical properties that impact gene expression, and how these properties influence the regulation that allows for proper gene expression. The class will use case studies from primary scientific literature to understand how disease can result from mis-regulation. Students will read and critique scientific articles and gain skills of communication of scientific ideas and concepts via oral presentations and writing assignments. Pre-requisite(s): BIOL H200 and BIOL H201 with a grade of 2.0 or above, or instructor consent

### **BIOL H380 INDEPENDENT STUDY FOR JUNIORS (1.0 Credit)**

*Staff*

**Division:** Natural Science

Students may receive credit for approved study and/or work in the laboratory under the supervision of a professor. This work may take the form of a guided series of readings with associated written work, or a

supervised laboratory research project with a final write-up and presentation. Prerequisite(s): Instructor consent

### **BIOL H400 SENIOR RESEARCH TUTORIAL AT OFF-CAMPUS RESEARCH LABS (1.0 Credit)**

*Karl Johnson*

**Division:** Natural Science

Research in an area of cell, or molecular biology is conducted under the supervision of a member of a nearby research laboratory who has volunteered time and space for a Haverford student. All students enrolled in Biology 400 must have designated on-campus and off-campus supervisors. Prerequisite(s): BIOL H300 and BIOL H301 with a grade of 2.0 or above and instructor consent.

### **BIOL H403 SENIOR RESEARCH TUTORIAL IN PROTEIN FOLDING AND DESIGN (1.0 Credit)**

*Robert Fairman*

**Division:** Natural Science

The laboratory focuses on protein folding and design, with a particular emphasis on the use of proteins in nanoscience. Students will have the opportunity to apply chemical and genetic approaches to the synthesis of proteins for folding and design studies. Such proteins are characterized in the laboratory using biophysical methods (such as circular dichroism spectroscopy, analytical ultracentrifugation, and atomic force microscopy). Functional and structural approaches can also be applied as necessary to answer specific questions relating to protein science. Exploration of the primary literature and various opportunities to hone scientific communication skills will supplement lab work. Prerequisite(s): Instructor consent

### **BIOL H404 SENIOR RESEARCH TUTORIAL IN MOLECULAR MICROBIOLOGY (1.0 Credit)**

*Eric Miller*

**Division:** Natural Science

Microbes live and grow in environments that include other microbes; how do these microbe-microbe interactions change microbial genomes (through evolution) and change the composition of communities (through ecological dynamics)? Laboratory work will focus on pathogen and commensal *Streptococcus* species to investigate how cells communicate with each other, how they exchange genes, and how they produce toxins that modify their surrounding community. Bioinformatic approaches will examine evolution within and between bacteria species, while computational approaches will investigate fundamental questions in evolutionary biology. Exploration of the primary literature and various opportunities to hone scientific



communication skills will supplement lab work.  
Prerequisite(s): Instructor consent

**BIOL H405 SENIOR RESEARCH TUTORIAL  
IN MARINE NATURAL PRODUCT DRUG  
DISCOVERY (1.0 Credit)**

*Kristen Whalen*

**Division:** Natural Science

Marine organisms are important producers of substances useful for treatment of human diseases. Students will integrate ecological and evolutionary theories, cellular physiology, and natural-product chemistry to guide discovery of new compounds with beneficial properties. Exploration of the primary literature and various opportunities to hone scientific communication skills will supplement lab work.  
Prerequisite(s): Instructor consent

**BIOL H406 SENIOR RESEARCH TUTORIAL  
IN DEVELOPMENTAL BIOLOGY AND  
EVOLUTION (1.0 Credit)**

*Rachel Hoang*

**Division:** Natural Science

In this course students explore processes of embryonic development and their evolutionary underpinnings. Using primarily insect model systems students design research projects drawing on a variety of techniques including cell and molecular biology, embryology, genetics, genomics and cell imaging. Exploration of the primary literature and various opportunities to hone scientific communication skills will supplement lab work.  
Prerequisite(s): Instructor consent

**BIOL H407 SENIOR RESEARCH TUTORIAL IN  
BIOARCHITECTURE (1.0 Credit)**

*Karl Johnson*

**Division:** Natural Science

Studies of structure in living systems and applications in nanotechnology. Approaches employed include genetic analysis, biochemistry, biophysics, molecular biology, microscopy and imaging, bioengineering and synthetic biology. Exploration of the primary literature and various opportunities to hone scientific communication skills will supplement lab work. Prerequisite(s): Instructor consent

**BIOL H408 SENIOR RESEARCH TUTORIAL IN  
PLANT BIOLOGY AND EVOLUTION (1.0 Credit)**

*Jonathan Wilson*

**Division:** Natural Science

Plants are an important interface between biology and the environment, and the study of plants' evolutionary history illuminates this interaction. This course will focus on the physiology and evolution of living and extinct plants. Techniques employed include anatomical studies of living and fossil plant

tissues; imaging and quantitative investigation of plant structure; and the collection and analysis of fossil plant material. Exploration of the primary literature and various opportunities to hone scientific communication skills will supplement lab work.  
Prerequisite(s): Instructor consent

**BIOL H409 SENIOR RESEARCH TUTORIAL IN  
MOLECULAR NEUROBIOLOGY (1.0 Credit)**

*Roshan Jain*

**Division:** Natural Science

In this course we will use the zebrafish model system to ask "how do genes control behavior?" at multiple complementary levels of analysis: molecular genetics, imaging of neural circuit development and function, and high-throughput behavioral approaches. Students will use established genetic tools and behavioral assays, as well as develop new methods to probe the underlying control of decision-making, learning & memory, motor control, anxiety, and more. Exploration of the primary literature and various opportunities to hone scientific communication skills will supplement lab work.  
Prerequisite(s): Instructor consent

**BIOL H417 SENIOR RESEARCH TUTORIAL IN  
MOLECULAR GENOMICS/BIOCHEMISTRY (1.0  
Credit)**

*Amy Cooke*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

This course will focus on how RNA regulation mediated by RNA-binding proteins dictates and responds to cellular physiology at the molecular level. Students will approach this problem using a range of techniques including biochemistry, molecular genetics, systems biology, bioinformatics and mammalian tissue culture. Students will use an established functional genomic dataset to develop new tools and cell-lines in order to uncover the molecular mechanisms of RNA regulation and connect this regulation to physiological events such as amino acid transport in skeletal muscle cells. As a supplement to lab work, students will explore the scientific literature and have opportunities to present their scientific findings in both written and oral format to hone their scientific communication skills. Prerequisite(s): Instructor Consent

**BIOL H418 SENIOR RESEARCH TUTORIAL IN  
EVOLUTIONARY GENETICS (1.0 Credit)**

*Foen Peng*

**Division:** Natural Science

**Domain(s):** C: Physical and Natural Processes

In this course we will use wild *Mimulus* flower species to explore how plants adapt to pollinators through evolution. Approaches include genetic mapping, plant transformation, gene expression analysis,

population genetics simulation, pollinator behavior assays, mathematical modeling and 3D printing. Students will have opportunities to learn many generalizable skills, like experiment design, data analysis, and basic molecular lab skills. Exploration of the primary literature and various opportunities to hone scientific communication skills will supplement lab work. Pre-requisite(s): Instructor consent Lottery Preference: None (this is a senior capstone course for Biology Majors)

**BIOL H450 ADVANCED TOPICS IN BIOLOGY (0.5 Credit)**

*Danielle De Leo*

**Division:** Natural Science

A seminar course exploring the primary literature in a specialized area of cell and molecular biology. Students will read current and historically important original papers as well as pertinent review articles. Oral presentations and written work provide the opportunity for students to demonstrate their ability to critically evaluate current literature in a sub-field of their major discipline. Prerequisite(s): BIOL H300 and BIOL H301 with a grade of 2.0 or above, or instructor consent

**BIOL H453 ADVANCED TOPICS IN NEUROBIOLOGY (0.5 Credit)**

*Courtney Marshall*

**Division:** Natural Science

A seminar course exploring the primary literature in a specialized area of neurobiology. Students will read current and historically important original papers as well as pertinent review articles. Oral presentations and written work provide the opportunity for students to demonstrate their ability to critically evaluate current literature in a sub-field of their major discipline. Prerequisite(s): BIOL H300 and BIOL H301 with a grade of 2.0 or above, or instructor consent

**BIOL H456 ADVANCED TOPICS IN BIOLOGY OF MARINE LIFE (0.5 Credit)**

*Kristen Whalen*

**Division:** Natural Science

Exploration of marine metazoan evolution through the lens of behavioral, morphological, biochemical, and physiological adaptations to various ocean regimes. Readings from primary literature will cover physio-chemical properties of seawater, abiotic/biotic organismal interactions, symbiosis, energy production, human impacts, and phylogenetic relationships. Crosslisted: Biology, Environmental Studies Prerequisite(s): BIOL H300 and BIOL H301 with a grade of 2.0 or above, or instructor consent

**BIOL H480 INDEPENDENT STUDY FOR SENIORS (1.0 Credit)**

*Kristen Whalen*

**Division:** Natural Science

Students may receive credit for approved study and/or work in the laboratory under the supervision of a professor. This work may take the form of a guided series of readings with associated written work, or a supervised laboratory research project with a final write-up and presentation. Prerequisite(s): Instructor consent

**BIOL H499 SENIOR DEPARTMENT STUDIES (0.5 Credit)**

*Roshan Jain*

**Division:** Natural Science

Participation in the department's seminar series; attendance at seminars by visiting speakers; senior seminar meetings, consisting of presentation and discussion of research plans and research results by students; and class activities related to the senior year in biology. Prerequisite(s): Department consent