BIOLOGY

haverford.edu/biology

Modern biology has seen tremendous growth in our ability to understand the structure and function of living organisms at the cellular and molecular 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 the common molecular basis of a variety of biological disciplines. We also 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 300 "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.

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 200, the year-long sophomore introductory course, followed by four half-semester lecture courses in the junior year that explore fundamental areas in cell and molecular biology. Juniors also engage in a unique, year-long laboratory course (BIOL 300A and BIOL 300B "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 200A and 200B. 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 200A.
- 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 department other than biology. Courses crosslisted in biology may not be counted toward this requirement.
- Two semesters of the junior laboratory, BIOL 300A and 300B.
- Four half-semester 300-level advanced topics courses (selected from BIOL 301-315 and 331-332). 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 350-level seminar course in the Haverford Biology Department (chosen from BIOL 350-375; 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 499.

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.

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 H402, 403, 404, 407, 408, 409, 410, 411, 413 or 415, 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 half their academic 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 first course for biology majors, BIOL 200, 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 200 and BIOL 300) 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 200 and majors in upper-level courses read and critique research papers from the original scientific literature, presenting their analyses to the class.

The BIOL 30x courses (301, 302, 303, etc.), 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 300, 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 a class-based research experience. The emphasis in this year-long 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 300 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 we 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 Interdisciplinary Minor
The Environmental Studies Interdisciplinary 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 Multidisciplinary Minor
The goal of the Health Studies Multidisciplinary

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 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.

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.

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.

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.

FACILITIES

See the departmental web page for a description of laboratories, equipment and other special

facilities for this program.

FACULTY

Matthew Carrigan
Visiting Associate Professor

Robert Fairman
Professor and Department Chair

Katherine Heston
Instructor
Rachel Hoang *(on leave Fall 2017)*
Associate Professor

Roshan Jain
Assistant Professor

Karl Johnson
Professor

Jay Lunden
Visiting Assistant Professor

Philip Meneely
Professor

Judith Owen
Elizabeth Ufford Green Professor of Natural Sciences

Kristen Whalen
Assistant Professor

Jonathan Wilson
Assistant Professor

COURSES

BIOL H118 PLANTS AND PEOPLE

Jonathan Wilson
Natural Science (NA)
A multidisciplinary approach to the co-evolution and co-domestication of plants and humans. Topics will include the biology, physiology, evolution, and cultivation of key plants, embedded within their social history and environmental effects. Intended for non-majors and meets in parallel with BIOL 318. Crosslisted: Biology, Environmental Studies (Offered Spring 2018)

BIOL H123 PERSPECTIVES IN BIOLOGY: SCIENTIFIC LITERACY

Karl Johnson
Natural Science (NA)
An introduction to current topics through reading and discussion of articles from the primary and popular literatures. Our texts will include Science, Nature and The Science Times. We will follow new breakthroughs and discoveries as they are reported and consider both evolution and revolution in scientific thought in real time from the viewpoint of the larger scientific community. Does not count towards the Biology major. (Offered occasionally)

BIOL H127 PERSPECTIVES IN BIOLOGY: HUMAN GENETIC DIVERSITY

Philip Meneely
Natural Science (NA)
A major scientific milestone marking the start of the 21st century was the publication of the human genome sequence. With the subsequent reading of many human genomes, comparisons reveal clues to the natural history of the human species. Starting with basic concepts of human genetics and topics such as natural selection, founder effects and genetic drift, the course will examine issues of human origins and migrations, diversity and the relationship between different populations and ethnic groups. Does not count towards the Biology major. (Offered occasionally)

BIOL H129 PERSPECTIVES IN BIOLOGY

Jay Lunden
Natural Science (NA)
An exploration of a current topic in Biology. Foundational concepts will be covered and then built upon through reading and discussion of articles from the primary and popular literatures. Evaluation and critique of what constitutes reliable scientific data for the topic under discussion will also be reviewed. Does not count towards the Biology major. (Offered Fall 2017)

BIOL H200A CELL STRUCTURE AND FUNCTION

Roshan Jain, Philip Meneely, Matthew Carrigan, Jay Lunden, Katherine Heston
Natural Science (NA)
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. 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. (Offered Fall 2017)

BIOL H200B CELL STRUCTURE AND FUNCTION
Robert Fairman, Kristen Whalen, Judith Owen, Jay Lunden, Katherine Heston
Natural Science (NA)
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 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. Prerequisite(s): The prerequisite for Biology 200B is successful completion of Biology 200A with a grade of 2.0 or higher, or instructor consent. (Offered Spring 2018)

BIOL H217 BEHAVIORAL NEUROSCIENCE
Mary Ellen Kelly
Natural Science (NA)
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 H100, PSYC B105, BIOL H123, BIOL H124, BIOL H128, BIOL H129, Psychology AP Score 4 (Offered Fall 2017)

BIOL H220 UNLOCKING KEY CONCEPTS IN BIOLOGY
Roshan Jain
Natural Science (NA)
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 BIOLH200A and instructor consent (Not offered 2017-18)

BIOL H300A LABORATORY IN BIOCHEMISTRY AND MOLECULAR BIOLOGY
Karl Johnson, Robert Fairman, Judith Owen, Matthew Carrigan
Natural Science (NA)
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. Crosslisted: Biology, Chemistry; Prerequisite(s): BIOL H200A and B with a grade of 2.0 or above, or instructor consent. (Offered Fall 2017)

BIOL H300B LABORATORY IN BIOCHEMISTRY AND MOLECULAR BIOLOGY
Kristen Whalen, Bashkim Kokona, Roshan Jain, Philip Meneely
Natural Science (NA)
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. Crosslisted: Biology, Chemistry Prerequisite(s): BIOL H200A and B with a grade of 2.0 or above, or instructor consent. (Offered Spring 2018)

BIOL H301 ADVANCED GENETIC ANALYSIS
Philip Meneely
Natural Science (NA)
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 H200A and B with a grade of 2.0 or above, or instructor consent. (Offered Fall 2017)

BIOL H302 CELL ARCHITECTURE
Karl Johnson
Natural Science (NA)
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 H200A and B with a grade of 2.0 or above, or instructor consent. (Offered Spring 2018)

BIOL H303 STRUCTURE AND FUNCTION OF MACROMOLECULES
Robert Fairman
Natural Science (NA)
A study of the structure and function of proteins, including enzymes, assembly systems and proteins involved in interactions with nucleic acids and membranes. Prerequisite(s): BIOL H200A and B with a grade of 2.0 or above, CHEM H221 or equivalent to be taken previously or concurrently, or instructor consent. (Offered Fall 2017)

BIOL H308 IMMUNOLOGY
Judith Owen
Natural Science (NA)
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 H200A and B with a grade of 2.0 or above, or instructor consent. (Offered Fall 2017)

BIOL H309 MOLECULAR NEUROBIOLOGY
Roshan Jain
Natural Science (NA)
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 H200A and B with a grade of 2.0 or above, or instructor consent. (Offered Spring 2018)

BIOL H310 MOLECULAR MICROBIOLOGY
Jay Lunden
Natural Science (NA)
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 B with a grade of 2.0 or above, or instructor consent. (Offered Spring 2018)

BIOL H312 DEVELOPMENT & EVOLUTION
Rachel Hoang

Natural Science (NA)
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. (Offered Spring 2018)

BIOL H316 BIOCHEMICAL ADAPTATIONS
Kristen Whalen
Natural Science (NA)
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. (Offered Fall 2017)

BIOL H318 ECONOMIC BOTANY
Jonathan Wilson
Natural Science (NA)
A multidisciplinary approach to the coevolution and co-domestication of plants and humans. Topics will include the biology, physiology, evolution, and cultivation of key plants, embedded within their social history and environmental effects, and explored at an advanced level. Meets in parallel with BIOL 118. Crosslisted: Biology, Environmental Studies; Prerequisite(s): 200-level course in anthropology, biology, chemistry, or geology or ENVS 101 and instructor consent. (Offered Spring 2018)

BIOL H351 MOLECULAR MOTORS AND BIOLOGICAL NANO-MACHINES
Karl Johnson
Natural Science (NA)
The world of the cell contains a rich array of molecular machinery that carries out life's dynamic processes. Interdisciplinary studies of these mechanisms employing a variety of biological, chemical and physical approaches are revealing a wealth of detail spanning from visible phenomenon to the scale of atoms and molecules. Extensive reading of the primary literature will be used as a basis for student-led discussions. Topics will be selected from a list including viral assembly, cellular clocks, mechanoenzyme engines, biosynthetic machinery and the assembly and regulation of cytoskeletal arrays. These systems provide novel insights into how work is accomplished (and regulated) in a nano-scale environment and serve as models for the development of nanotechnologies for science and medicine. Prerequisite(s): BIOL H300A and B with a grade of 2.0 or above, or instructor consent. (Offered Fall 2017)

BIOL H352 CELLULAR IMMUNOLOGY
Judith Owen
Natural Science (NA)
Topics include description and classification of the cells and tissues of the immune system; cell collaboration in the immune response; transplantation antigens and their role in graft rejection and recognition of virally-infected cells; immune tolerance; lymphokines. There will be student presentations of articles in the original immunological literature, followed by critical discussion. Prerequisite(s): BIOL H300A and B with a grade of 2.0 or above, or instructor consent. (Not offered 2017-18)

BIOL H356 ADVANCED TOPICS IN BIOLOGY OF MARINE LIFE
Kristen Whalen
Natural Science (NA)
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 H300A and B with a grade of 2.0 or above, or instructor consent. (Offered Fall 2017)

BIOL H375 ADVANCED TOPICS IN BIOLOGY
Matthew Carrigan

Natural Science (NA)
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 H300A and B with a grade of 2.0 or above, or instructor consent. (Offered Fall 2017)

BIOL H390 LABORATORY IN BIOCHEMICAL RESEARCH
Louise Charkoudian, Karl Johnson
Natural Science (NA)
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): BIOL 300A and CHEM 301, or instructor consent. (Offered Spring 2018)

BIOL H403 SENIOR RESEARCH TUTORIAL IN PROTEIN FOLDING AND DESIGN
Robert Fairman
Natural Science (NA)
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. (Offered Fall 2017 and Spring 2018)

BIOL H404 SENIOR RESEARCH TUTORIAL IN MOLECULAR MICROBIOLOGY
Staff
Natural Science (NA)
Studies in bacterial genetics and pathogenesis. Molecular methods will be used to identify and characterize features of diarrhea-causing Escherichia coli that are absent in commensal strains. Laboratory work is supplemented by readings from current literature. Exploration of the primary literature and various opportunities to hone scientific communication skills will supplement lab work. Prerequisite(s): Instructor consent. (Not offered 2017-18)

BIOL H407 SENIOR RESEARCH TUTORIAL IN BIOARCHITECTURE
Karl Johnson
Natural Science (NA)
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. (Offered Fall 2017 and Spring 2018)

BIOL H409 SENIOR RESEARCH TUTORIAL IN MOLECULAR NEUROBIOLOGY
Roshan Jain
Natural Science (NA)
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. (Offered Fall 2017 and Spring 2018)

BIOL H410 SENIOR RESEARCH TUTORIAL AT OFF-CAMPUS RESEARCH LABS
Robert Fairman
Natural Science (NA)
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 BIOL 410 must have

designated on-campus and off-campus supervisors. Prerequisite(s): BIOL H300A and B with a grade of 2.0 or above and instructor consent. (Offered Fall 2017 and Spring 2018)

BIOL H411 SENIOR RESEARCH TUTORIAL IN DEVELOPMENTAL BIOLOGY AND EVOLUTION
Rachel Hoang
Natural Science (NA)
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. (Offered Fall 2017 and Spring 2018)

BIOL H413 SENIOR RESEARCH TUTORIAL IN PLANT BIOLOGY AND EVOLUTION
Jonathan Wilson
Natural Science (NA)
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. (Offered Fall 2017 and Spring 2018)

BIOL H415 SENIOR RESEARCH TUTORIAL IN MARINE NATURAL PRODUCT DRUG DISCOVERY
Kristen Whalen
Natural Science (NA)
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. (Offered Fall 2017 and Spring 2018)

BIOL H480 INDEPENDENT STUDY
Staff
Natural Science (NA)
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. (Offered every year)

BIOL H499 SENIOR DEPARTMENT STUDIES
Robert Fairman
Natural Science (NA)
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. (Offered Fall 2017 and Spring 2018)