The Department of Biology offers a broad program of undergraduate, graduate, and postgraduate study in the biological sciences. Included among the areas in which instruction and research opportunities are available are biochemistry and biophysics, cell biology, molecular biology, microbiology, developmental biology, genetics, neuroscience, and immunology.

The Biology Department offers two degree options for undergraduate students, a Bachelor of Arts degree for biology majors and a Bachelor of Science degree for molecular and cellular biology majors.

**Requirements for the B.A. Degree**

(Also see Requirements for a Bachelor’s Degree. [http://catalog.jhu.edu/undergrad-students/academic-policies/requirements-for-a-bachelors-degree](http://catalog.jhu.edu/undergrad-students/academic-policies/requirements-for-a-bachelors-degree))

The B.A. degree in biology is designed to provide students with a thorough grounding in modern biology, with special emphasis on the molecular aspects of the discipline.

All courses required for the biology major must be taken for a letter grade (not S/U) and be passed with a grade of C- or better with one exception. The department will accept one passing grade below C- in the senior year (not S/U) and be passed with a grade of C- or better with one exception.

All courses required for the Biology major must be taken for a letter grade (not S/U). No more than two courses may be taken on an S/U basis. The laboratory in a course must be completed for a letter grade.

http://bio.jhu.edu/undergraduate/ba-requirements/

**Sample Program of Study**

### Freshman

<table>
<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.030.101 Introductory Chemistry I</td>
<td>3</td>
<td>AS.030.102 Introductory Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>or AS.030.105 Introductory Organic Chemistry</td>
<td>4</td>
<td>or AS.0315 Biochemistry Laboratory</td>
<td>2-3</td>
</tr>
<tr>
<td>or AS.0316 Genetics Laboratory</td>
<td>2</td>
<td>or AS.250.253 Protein Engineering and Biochemistry Lab</td>
<td>4</td>
</tr>
<tr>
<td>or AS.202.340 Cell Biology Lab</td>
<td>2</td>
<td>or AS.020.373 Develop Biology Lab</td>
<td>3</td>
</tr>
<tr>
<td>or AS.020.363 Developmental Biology</td>
<td>3</td>
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<td>Total Credits</td>
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### Sophomore

<table>
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<th>Spring</th>
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</thead>
<tbody>
<tr>
<td>AS.020.303 Genetics</td>
<td>4</td>
<td>AS.020.306 Cell Biology</td>
<td>4</td>
</tr>
<tr>
<td>AS.020.340 Genetics Laboratory</td>
<td>2</td>
<td>AS.020.316 Cell Biology Lab</td>
<td>2</td>
</tr>
<tr>
<td>or AS.020.305 Organic Chemistry I</td>
<td>4</td>
<td>or AS.202.340 Cell Biology Laboratory</td>
<td>2</td>
</tr>
<tr>
<td>or AS.202.315 Biochemistry Laboratory</td>
<td>4</td>
<td>or AS.020.325 Introductory Organic Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>or AS.202.327 Applied Chemical Equilibrium and Reactivity w/lab</td>
<td>4</td>
<td>or 227 Introductory Organic Chemistry Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>AS.030.205 Introductory Organic Chemistry I</td>
<td>4</td>
<td>(if not taken previously)</td>
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</tr>
<tr>
<td>or AS.030.206 Organic Chemistry II</td>
<td>4</td>
<td></td>
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<tr>
<td>or AS.030.212 Honors Organic Chemistry II with Applications in Biological and Materials Chemistry</td>
<td>3</td>
<td></td>
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<tr>
<td>AS.030.225 Introductory Organic Chemistry Laboratory</td>
<td>3</td>
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</tr>
</tbody>
</table>

Total Credits 12 13
B.S. Degree in Molecular and Cellular Biology

The Biology Department offers a B.S. degree in molecular and cellular biology. The B.S. program is designed to provide a rigorous preparation for advanced study in the biomedical sciences. The program is tailored not only to students planning to enter Ph.D. programs or obtain employment in the biotechnology industry but also for premedical students.

All courses required for the molecular and cellular biology major must be taken for a letter grade (not S/U) and be passed with a grade of C- or better with one exception. The department will accept one passing grade below C- in senior year provided that the average for all formal lecture and laboratory courses is at least 2.0. http://bio.jhu.edu/undergraduate/bs-requirements/

Requirements

Same as BA except:

- 6 credits of research required
- 2 additional electives (2 total electives must be AS.020.xxx courses)
- General Biology is not required

The B.S. degree in molecular and cellular biology requires, in addition to the requirements for the B.A. degree in biology, at least two additional upper level elective courses totaling five additional credits or more (for a total of at least 13 credits) from the elective list, and two of those electives must be at least 3 credit hours and have an 020 number. The B.S. degree also requires six credits of research supervised or sponsored by a faculty member in Biology. The supervised research will include participation in group meetings and writing a summary of accomplished work at the end of the year. General Biology I and II are not required for the B.S. degree.
Honors in Biology

Students completing either a biology major or molecular and cellular biology major are eligible to receive their degree with honors. http://www.advising.jhu.edu/honors.php

The B.A. in biology with honors requires, in addition to the regular requirements for the B.A. in biology, a 3.5 GPA for natural sciences and quantitative studies courses, two semesters of research, a presentation of a poster describing the independent research, and a recommendation from the research sponsor.

The research requirement must be completed under the direction of a faculty member in a department associated with the Johns Hopkins University or the Johns Hopkins Medical Institutions. If the student’s research director for independent research is not a member of the Department of Biology, a Biology faculty member must serve as a sponsor and approve the recommendation from the research director.

B.A./M.S. Degree in Molecular and Cellular Biology

The Biology Department offers a B.A./M.S. (or B.S./M.S.) degree if the student has completed the requirements for the B.S. degree in molecular and cellular biology. The B.A./M.S. (or B.S./M.S.) degree provides Hopkins biology majors with advanced training in preparation for careers in science and medicine. Please see the Graduate Tab for details.

Requirements for the M.S. Degree in Molecular and Cellular Biology

The Biology Department offers a B.A./M.S. (or B.S./M.S.) if the student has completed the requirements for the B.S. degree in molecular and cellular biology. The B.A./M.S. (or B.S./M.S.) degree provides Hopkins biology majors with advanced training in preparation for careers in science and medicine. Please see the Graduate Tab for details.

Students in the program must complete all requirements for the B.A. (or B.S.) degree. In addition, students enrolled in the combined bachelor’s/master’s program must complete the following requirements.

Four additional advanced or specialized courses, at least two of which are at the 600-level or above.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.020.401</td>
<td>Advanced Seminar: Molecular and Cellular Biology</td>
<td>3</td>
</tr>
<tr>
<td>AS.020.402</td>
<td>Seminar: Molecular &amp; Cellular Biology</td>
<td>3</td>
</tr>
<tr>
<td>AS.020.551</td>
<td>Mentored Research</td>
<td>9</td>
</tr>
<tr>
<td>AS.020.553</td>
<td>Mentored Research</td>
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</tr>
<tr>
<td>or AS.020.554</td>
<td>Mentored Research Program in Cellular and Molecular Biology</td>
<td>9</td>
</tr>
</tbody>
</table>

Final report and presentation **

Teaching ***

* Eligible courses are listed on the Biology Department website.
** The Mentored Research Program culminates in the preparation of a written report of the research project in the form of a thesis. The written report and an oral presentation of the work are evaluated by a Thesis Committee. Passing performance, as judged by the committee, is required for the M.S. degree.
*** Teaching is an integral component of the master’s degree. The teaching requirement is fulfilled as a teaching assistant for the General Biology and General Biology Laboratory courses (or other Biology lecture and lab courses) for two semesters.

Requirements for the Ph.D. Degree in Cellular, Molecular, Developmental Biology and Biophysics (CMDB Program)

A program of study leading to the Ph.D. degree is open to students who are candidates for, or who already have, the bachelor’s or master’s degree in the biological or physical sciences. To be admitted, the applicant should have had either a thorough training in the fundamentals of biology and both organic chemistry and general physics, or a broad training in the physical sciences and mathematics. Special attention is given to the applicant’s quality of scholarship and his or her promise as an investigator.

In addition to the general university requirements for an advanced degree (see Academic Information for Graduate Students (http://e-catalog.jhu.edu/grad-students/academic-policies/#graduationanddegreecompletiontext)), doctoral candidates must meet the following departmental requirements:

- Four core courses and four 600- and 700-level electives.
- At least one year of laboratory teaching during the period of graduate residence.
- A high level of achievement in a comprehensive written proposal and oral examination covering proficiency in the field of the student’s research interest and various areas of biology and related fields.
- A dissertation based on a program of independent research, a public seminar followed by an oral examination by the thesis committee.

All graduate students are required to complete the four core courses during the first year. In addition, students are required to complete four elective courses before graduation chosen from the list below of 600-
level electives and 700-level seminars offered each semester. At least two out of the four courses must be 600-level.

Core Courses, Fall Semester

- AS.020.601 Current Research in Bioscience
- AS.020.607 Quantitative Biology Bootcamp
- AS.020.686 Advanced Cell Biology
- AS.020.668 Advanced Genetics and Molecular Biology
- AS.020.699 CMDB Responsible Conduct in Research

Core Courses, Spring Semester

- AS.020.674 Graduate Biophysical Chemistry
- AS.020.637 Genomes & Development
- AS.020.617 Quantitative Biology Lab 1
- AS.020.618 Quantitative Biology Lab II

Teaching Opportunities

Since most biology Ph.D.’s will teach at some time during their careers, experience in teaching is considered an essential part of the Ph.D. program. The minimum teaching requirement is three contact hours a week for one year in the laboratory sections of undergraduate courses. Further teaching experience is gained through the preparation and presentation of reports in seminars and journal clubs. The department stresses organization of material and clarity of presentation.

Facilities

The lecture rooms, teaching laboratories, and research facilities of the Biology Research Complex (consisting of Seeley G. Mudd Hall and Undergraduate Teaching Laboratories) offer a thoroughly modern research facility for molecular biology.

Financial Aid

The department has fellowship funds for the support of graduate students. Awards are granted for tuition and living expenses. Laboratory fees and research expenses are paid by the department.

Carnegie Institution for Science, Department of Embryology

The Carnegie Institution’s Department of Embryology is located on the Homewood campus, close to the Biology research complex. Members of this group hold part-time appointments in the Department of Biology and participate in the training of graduate students. With the approval of both the department and the Carnegie staff, a number of graduate students in biology conduct thesis research in the Carnegie laboratory. The interests of the Carnegie staff include developmental and molecular biology.

For current faculty and contact information go to http://www.bio.jhu.edu/Directory/TenuredPlusTenureTrack.aspx

Faculty

Chair

Vincent J. Hilser
Professor: thermodynamics, protein structure and dynamics, molecular recognition, protein folding.

Professors

Karen Beemon

retroviral RNA processing and transport; avian leukosis virus tumorigenesis.

Kyle W. Cunningham
calcium transport and signaling mechanisms in yeast.

Ernesto Freire

Edward M. Hedgecock
developmental genetics of the nervous system of Caenorhabditis elegans.

M. Andrew Hoyt
genetics of chromosome segregation and signal transduction in yeast.

Evangelos N. Moudrianakis
assembly and dynamics of nucleoproteins and chromosomes, bacterial, and chloroplast bioenergetics.

Joel F. Schildbach
Vice Dean for Undergraduate Studies: structural biology of bacterial conjugation.

Robert Schleif
protein-DNA interactions and regulation of gene activity.

Trina Schroer
microtubule-based motors, organelle transport.

Mark Van Doren
gonad development and the formation of sexual dimorphism in the soma and germline.

Beverly R. Wendland
James B. Knapp Dean, Arts and Sciences: molecular mechanisms of endocytosis in yeast

Haiqing Zhao
cellular and molecular mechanisms underlying the development and function of olfactory sensory neurons.

Associate Professors

Xin Chen
understanding how genes are expressed in an ordered way to regulate germ cell differentiation; epigenetic mechanisms that participate in regulation.

John Kim
Co-Director of Graduate Studies; deciphering the epigenetic mechanisms of small RNA-mediated gene regulation and their collaboration with RNA binding proteins.

Rejji Kuruvilla
Co-Director of Graduate Studies: local retrograde signaling by target-derived neurotrophins in neuronal development.

James Taylor
genomics of gene regulation, chromatin structure and organization, computational genomics and bioinformatics

Assistant Professors

Andrew Gordus
Understanding how novel and innate behaviors are encoded at the cellular and genetic level.

Robert Johnston
stochastic and long-range gene regulatory mechanisms that diversify neuronal subtypes.

Christian Kaiser
single-molecule biochemistry studies of the machines and processes in protein translation, translocation, and folding.

Yumi Kim
molecular mechanisms of chromosome segregation during meiosis.

Young-Sam Lee
regulation by small metabolites: phosphate signaling pathways.

**Professors Emeriti**

Maurice J. Bessman
biochemistry and enzymology, synthesis of nucleic acid derivatives, biochemical basis of spontaneous mutations.

Ludwig Brand
fluorescence studies of protein and membrane dynamics.

Michael Edidin
immunology, membrane organization and dynamics, immunology.

Douglas Fambrough
membrane proteins, targeting, structure, function, and regulation, Na, K-ATPase, Ca-ATPase.

Richard E. McCarty

Allen Shearn
developmental genetics, imaginal disk development in Drosophila studied in lethal and temperature-sensitive mutants.

**Research Professor**

Ru Chih Huang
William D. McElroy Research Professor: gene regulation and chromosomal structure and function, principles of cancer biology and control of cancer and viral growth.

Yuan Chuan Lee
glycoproteins, glycolipids, carbohydrate receptors, and cell-surface substances.

J. Michael McCaffery
Integrated Imaging Center Director

Peter Privalov
physics of protein structure.

**Academy Professor**

Ludwig Brand
fluorescence studies of protein and membrane dynamics.

Yuan Chuan Lee
glycoproteins, glycolipids, carbohydrate receptors, and cell-surface substances.

**Lecturers**

Anna Coppola
Christov Roberson
Richard Shingles

**Associate Research Professor**

Jocelyn DiRuggiero
genomic diversity, DNA repair mechanisms and environmental stress responses in extremophiles.

**Senior Lecturer**

Robert Horner
Carolyn Norris
Kathryn Tifft Oshinnaiye
Rebecca Pearlman

**Bloomberg Distinguished Professors**

Rachel Green
Professor (Biochemistry)

Carol Greider
Professor (Cell Biology)

Taekjip Ha
Professor (Biophysics)

Ulrich Mueller
Professor (Neuroscience)

Michael Schatz
Associate Professor (Computer Science)

Carl Wu
Professor (Biology)

**Adjunct**

Alex Bortvin
Assistant Professor: genetic and epigenetic controls of germ cell development and function in vertebrates.

Donald D. Brown
Professor Emeritus: gene expression in development.

Orna Cohen-Fix
Adjunct Professor (NIH); nuclear structure and its effect on nuclear function.

Victor G. Corces
Professor (Emory): control of gene expression, molecular mechanisms of mutagenesis by transposable elements.

Chen-Ming Fan
Professor: molecular and cellular interactions that contribute to vertebrate embryogenesis.

Steven Farber
Associate Professor: real-time imaging of lipid metabolism in live zebrafish; identification of genes which regulate cholesterol absorption using biochemical and genetic strategies.

Joseph G. Gall
Professor: chromosome structure and functions, nucleic acids in development.

Marnie Halpern
Professor: zebra fish development.

Audrey Huang
Lecturer.

Michael Lichten
Adjunct Professor (NIH): genetic recombination and chromosome structural changes that occur during meiosis and DNA damage repair, using budding yeast as a model system.

George Scangos
Professor.

Allan Spradling
Professor: molecular genetics of Drosophila.

Yixian Zheng
Professor and Interim Director of Carnegie Institution for Science: cell division, cell morphogenesis, and cell fate specification.

**Associate Teaching Professor**
Emily Fisher
Director of Undergraduate Studies

For current course information and registration go to https://sis.jhu.edu/classes/

**Courses**

**AS.020.104. Freshman Seminar: From Genes to DNA and Back. 1.5 Credits.**
A course consisting of introductory lectures followed by student presentations in the form of seminars. The issues we usually analyze are: How did we arrive at the concept of the "gene"? What are the early observations that gave substance to this concept? How did we arrive at the "one gene, one enzyme" dogma? What is the chemical nature of the gene? Is DNA enough for regulated gene expression? Is it "all in our genes"? What is genetic plasticity and epigenetics? What about genomics and proteomics? In the course of our analyses we bring together observations, and experimental results and ideas not only from biological sciences (Genetics, Cell and Developmental Biology and Genetics) but also from Physics, Sociology, Politics and Philosophy. We do all this in order to clarify how observations turn to ideas, then dogmas and even biases that distort the true meaning of objective Sciences. Freshmen Only.
Instructor(s): E. Moudrianakis
Area: Natural Sciences.

**AS.020.106. Freshman Seminar: Tuberculosis. 1.0 Credit.**
Mycobacterium tuberculosis is an extremely successful intracellular bacterial pathogen able to manipulate phagocytic cells and its own metabolism to survive within a host. The molecular mechanisms of this survival and resistance to antibiotics will be studied. Freshmen only.
Instructor(s): R. Horner
Area: Natural Sciences.

**AS.020.111. Freshman Seminar: The 'Nobels' in Medicine and Chemistry. 2.0 Credits.**
Key events in our understanding of the life sciences will be traced with the aid of Nobel awards.
Instructor(s): L. Brand
Area: Natural Sciences.

**AS.020.115. Bioenergetics. 2.0 Credits.**
This course is a combination of lectures, student presentations and group discussions that address fundamental principles and also contemporary issues examining the way all forms of Life on Earth are ultimately dependent on sunlight to satisfy their food and energy requirements. We examine the steps from the capture of Physical energy (photons), to the development of electrochemical potentials and finally, to their utilization by cellular organelles towards the synthesis of the chemical "currency" that fuels all biological processes (biosynthesis, cell communication, movements, etc.). Special emphasis will be on current developments in biotechnologies that utilize microbial populations to supply us with fuels and also to clean up environmental hazards. The course will also consider ways to extract lessons from Nature's successful designs and harmonious adaptations so that we, in the long run, can utilize them towards a minimization of our negative impact on the environment. Note: Freshmen and Sophomores only, with good foundations in any two of the following: Physics, Chemistry, Biology, Biophysics.
Instructor(s): E. Moudrianakis
Area: Natural Sciences.

**AS.020.120. Introduction to Laboratory Research. 1.0 Credit.**
This course will introduce students to a variety of biochemical and molecular biological laboratory techniques. These will include DNA analysis by restriction enzyme mapping, amplification of DNA segments by PCR, lipid analysis by chromatography. Additionally, students will visit a variety of biological laboratories to observe actual research projects. * Prerequisites: High school biology and chemistry.
Instructor(s): Staff
Area: Natural Sciences.

**AS.020.126. Techniques in Molecular Biology. 1.0 Credit.**
This course is designed to supplement the scientific classroom experience of students by providing hands on experience with the essential core molecular biology techniques of bacterial DNA cloning, DNA analysis, and protein analysis. Students will be able to understand and explain how these methodologies work scientifically and will develop the basic laboratory skills necessary for the successful completion of the assays.
Instructor(s): J. Gordy.

**AS.020.127. Concepts in Cancer Research I: Pre-Diagnosis. 1.0 Credit.**
This course will introduce current topics in cancer research with a focus on the current state of knowledge regarding pre-diagnosis concepts in cancer research. We will first provide students with the context in which to interpret the latest findings in cancer research by giving a brief overview of cancer biology and descriptive epidemiology of the most common cancers in the United States. We will then discuss the current state of knowledge regarding cancer etiology and primary prevention strategies, providing specific examples from research currently being conducted at the National Cancer Institute along with other emerging research in the field of cancer prevention. Finally, we will introduce students to concepts and research in cancer screening. We will employ multiple formats to promote student learning and to introduce different tools for research. These may include lectures, case studies, in-class discussions, online discussions, and select film and Internet resources.
Instructor(s): M. Patel; S. Nash.
AS.020.128. Concepts Cancer Research II: Diagnosis through Recovery. 1.0 Credit.
This course will introduce current topics in cancer research with a focus on "life after cancer," including research questions about medical and psychosocial issues at diagnosis, during treatment and throughout recovery for patients that have been diagnosed with cancer. Health recommendations for cancer survivors will be discussed. Throughout the course, we will hear from researchers at the National Cancer Institute (and other research entities) who represent a variety of disciplines, applied in many settings (e.g., laboratory, clinics and communities). We will also use multi-media to promote active learning and to introduce tools for research. These may include lectures, case studies, in-class discussion, online discussion, and select film (including clips from the recent PBS documentary "Cancer: The Emperor of All Maladies") and internet resources. Active participation and peer learning will enhance the value of this course for students.
Instructor(s): D. Georgess; N. Neumann.

AS.020.129. Discover Hopkins: Introduction to Biology & Medicine. 1.0 Credit.
Introduction to Biology & Medicine: from Textbook to Application. Biology is the study of life dynamics, and medicine is the application of biology to enhance human health. With a particular emphasis on imaging approaches from the scale of the cell to that of the whole body, this course explores how biology research is designed to improve our knowledge and health. The goal is to show students the possible ways of using information learned in textbooks as a starting point to explore new application frontiers and careers in academic research, industrial/biotech development, and medicine. Course is highly interactive and includes lectures, readings, field trips, and guest lectures by professors involved in the scientific advancements. Grades determined by class participation, attendance, quizzes, and oral presentation.
Instructor(s): D. Georgess; N. Neumann.

AS.020.130. Bacterial Evolution Project Lab. 2.0 Credits.
In this project-based laboratory course, students will conduct research into mechanisms of bacterial adaptation to conjugative plasmids. In the wet-lab portion of the course, students will learn standard laboratory techniques for bacterial culture and DNA extraction and will carry out experiments to assess phenotypic differences between different laboratory-evolved bacterial populations. In the computational portion of the course, students will learn how to analyze whole-genome sequencing data and will identify mutations present in laboratory-evolved bacteria. This project-based course is part of a larger research project investigating co-evolution of conjugative plasmids and their bacterial hosts. Students will be exposed to fundamental questions concerning the mechanisms of evolution and will learn about current research in the rapidly expanding field of Experimental Evolution. No previous experience with bacterial culture, genomics, or computer programming is required.
Instructor(s): K. Cox
Area: Natural Sciences.

AS.020.131. Techniques of Phage Isolation and Characterization. 1.0 Credit.
In this small-section introductory research lab course, students are introduced to basic microbiological techniques as they isolate and characterize a bacteriophage, a virus that infects bacteria, from an environmental sample. One meeting per week. No textbook required. Modeled after the Phage Hunting project lab course, but with a focus on benchwork. Students cannot receive credit for both AS.020.130 and AS.020.131.
Instructor(s): J. Schildbach
Area: Natural Sciences.

AS.020.132. Biology, Policy, and the Media. 3.0 Credits.
We live in the age of information. Through various forms of media we are constantly being inundated by data—whether or not we are aware of it. This information includes science as the media presents it to us. We will examine different topics in biology that are discussed in different forms of media. We will also look at how scientific research, and the way that it is reported to the layperson, is used to inform policy decisions. Some of the biological topics that we will discuss include human diseases and their treatment, stem cells and cloning, and genetically modified organisms. All of these topics have a significant effect on how we live our lives. The choices that we make based on the science we see affects our decisions when it comes to medical care, what we choose to eat, the manner in which we interact with our environment, and how we vote to enact science policy.
Instructor(s): J. Winger; R. Gupta
Area: Natural Sciences.

AS.020.135. Phage Hunting. 2.0 Credits.
This is an introductory course open to all freshman regardless of intended major. No science background is required. This is the first semester of a year-long research-based project lab course in which students will participate in a nation-wide program in collaboration with undergraduates at other colleges. Students will isolate and characterize novel bacteriophages (viruses that infect bacteria) from the environment using modern molecular biological techniques. The course includes two lab meetings per week. Continues in the spring. Each semester provides 2 credit hours of Natural Sciences (N) distribution credits and/or counts 2 hours toward the research requirement for the Molecular and Cellular Biology degree. No textbook is required. Freshmen only.
Instructor(s): E. Fisher; J. Schildbach
Area: Natural Sciences.

AS.020.136. Phage Hunting II. 2.0 Credits.
This is an introductory course open to all freshman regardless of intended major. No science background is required. This is the second semester of a year-long research-based project lab course in which students will participate in a nation-wide program in collaboration with undergraduates at other colleges. In the spring semester, students will annotate the genome of a bacteriophage isolated and characterized by a student in AS.020.135, in preparation for submission to a database and eventual publication. The course includes two lab meetings per week. Provides 2 credit hours of Natural Sciences (N) distribution credits and/or counts 2 hours toward the research requirement for the Molecular and Cellular Biology degree. No textbook is required. Freshmen only. Enrollment by permission of the instructor only.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): E. Fisher; M. Mefford
Area: Natural Sciences.

AS.020.137. Techniques of Phage Isolation and Characterization. 1.0 Credit.
In this small-section introductory research lab course, students are introduced to basic microbiological techniques as they isolate and characterize a bacteriophage, a virus that infects bacteria, from an environmental sample. One meeting per week. No textbook required. Modeled after the Phage Hunting project lab course, but with a focus on benchwork. Students cannot receive credit for both AS.020.135 and AS.020.137.
Instructor(s): J. Schildbach
Area: Natural Sciences.
AS.020.140. Emerging Infectious Diseases. 3.0 Credits.
This class will investigate the infectious agents and evolutionary drivers of disease emergence and its consequences on public health. Additionally, the class will address epidemiological characteristics in settings of demographics, as well as surveillance mechanisms used to control disease emergence. We will focus on the underlying infectious diseases, factors governing microbial emergence, resistance, and endemics. Instruction format will include a combination of lectures, open discussions and student presentations to encourage broad participation. 
Instructor(s): M. Malhotra; S. Winans
Area: Natural Sciences.

AS.020.151. General Biology I. 3.0 Credits.
This course is an introduction to biology from an evolutionary, molecular and cellular perspective. Specific topics and themes include evolutionary theory, the structure and function of biological molecules, mechanisms of harvesting energy, cell division, classical genetics and gene expression. This section will involve in-class problem solving and the use of assigned pre-class videos and questions.
Instructor(s): C. Roberson; R. Pearlman; R. Shingles
Area: Natural Sciences.

AS.020.152. General Biology II. 3.0 Credits.
This course builds on the concepts presented and discussed in General Biology I. The primary focis of this course will be on the diversity of life and on the anatomy, physiology, and evolution of plants and animals. There will be a special emphasis on human biology.
Prerequisites: Prereq: AS.020.151
Instructor(s): C. Roberson; R. Pearlman; R. Shingles
Area: Natural Sciences.

AS.020.153. General Biology Laboratory I. 1.0 Credit.
This course reinforces the topics covered in AS.020.151. Students participate in a semester-long project, identifying bacteria from Homewood campus soils using molecular biology techniques. Other laboratory exercises cover aspects of evolution, genomics and biochemistry. Cross-listed with Behavioral Biology. Student must have enrolled in AS.020.151 either this term or in past terms. Students who have credit for AP Biology but take General Biology Lab I will lose four credits of AP Biology credit. Cross-listed with Behavioral Biology.
Prerequisites: AS.020.151
Instructor(s): R. Pearlman
Area: Natural Sciences.

AS.020.154. General Biology Lab II. 1.0 Credit.
This course reinforces the topics covered in AS.020.152. Laboratory exercises explore subjects ranging from evolution to anatomy and physiology. Students participate in a project using molecular biology techniques to determine whether specific foods are made from genetically engineered plants. Cross-listed with Behavioral Biology. Students who have credit for AP Biology but take General Biology Lab II will lose all four credits of their overall credit for AP Biology.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): R. Pearlman
Area: Natural Sciences.

AS.020.161. Current Events in Biology I. 1.0 Credit.
In this lively and collaborative course, students discuss current events and controversies in biology ranging from bioterrorism to the health of the Chesapeake Bay.
Instructor(s): R. Pearlman
Area: Natural Sciences.

AS.020.162. Current Events in Biology II. 1.0 Credit.
Students will discuss current events and controversies in biology, ranging from genetic engineering to nanotechnology in medicine.
Instructor(s): R. Pearlman
Area: Natural Sciences.

AS.020.205. Introduction to Biological Molecules. 3.0 Credits.
This course presents an overview to biochemistry and molecular biology, especially focusing on biotechnology and medicine. Students will have classroom and laboratory experience and group presentations. Prerequisite: High school level Chemistry and Biology (both with a grade of A)
Instructor(s): R. Shingles
Area: Natural Sciences.

AS.020.214. Self Organizing Patterns in Nature. 1.5 Credits.
The manifestations of all biological structures and related functions are the end effect of the formation and maintenance of complex molecular and cellular patterns. These patterns (macromolecules, cellular organelles, cells, and tissues) are assembled from their constituent parts under fundamental rules not too dissimilar to those that govern the formation of snowflakes or the dewdrops on a spider web. This course (lectures and student presentations) attempts to describe these common rules and to explain the formation and function of significant biological assemblies.
Instructor(s): E. Moudrianakis
Area: Natural Sciences.

AS.020.227. Human Physiology. 3.0 Credits.
This is an introduction to Human Physiology. It will cover an overview of the subject that is appropriate for undergraduates and will be of interest to those planning to pursue medical or health related careers. While there is no formal prerequisite, a basic understanding of chemistry and biology at the undergraduate level will be helpful.
Instructor(s): T. Woof
Area: Natural Sciences.

AS.020.229. Introduction to Immunology. 2.0 Credits.
This course is designed to introduce students to the cells, major receptors and signals critical for understanding more advanced concepts in immunology. They should leave with a basic understanding of the players and events leading to an effective immune defense against pathogens. They should also begin to recognize disease consequences of certain immune malfunctions. Recommended Course Background: Biology
Instructor(s): A. Geis
Area: Natural Sciences.

AS.020.244. The Biology of Cancer. 2.0 Credits.
This course runs from June 30 - July 11. This course provides an overview of cancer and its diagnosis and treatment. Lectures, demonstrations, and discussions will explore the roles that genetic errors, growth factors, oncogenes, tumor suppressors, genetic caretakers, cell survival and death, angiogenesis, and metastasis play in cancer development. Covered topics also include cancer diagnosis, cancer prevention, genetic testing, treatment and patient self-advocacy. Course will include several guest experts to discuss topics of interest.
Instructor(s): M. Safford.
AS.020.303. Genetics. 3.0 Credits.
Presentation of the principles of heredity and variation, and their application to evolution and development; physico-chemical nature of the gene; problems of recombination; gene action.
Prerequisites: AS.020.330: Students may receive credit for AS.020.330 or AS.020.303, but not both.
Instructor(s): E. Fisher; K. Cunningham; M. Hoyt
Area: Natural Sciences.

AS.020.305. Biochemistry. 4.0 Credits.
The molecules responsible for the life processes of animals, plants, and microbes will be examined. The structures, biosynthesis, degradation, and interconversion of the major cellular constituents including carbohydrates, lipids, proteins, and nucleic acids will illustrate the similarity of the biomolecules and metabolic processes involved in diverse forms of life. Sophomores, Juniors, and Seniors Only.
Prerequisites: Prereq or Co-req: AS.030.206 OR AS.030.212 OR EN.540.202.
Instructor(s): A. Coppola; C. Kaiser; J. Schildbach; K. Tifft Oshinnaiye; V. Hilser
Area: Natural Sciences.

AS.020.306. Cell Biology. 4.0 Credits.
How the molecules of living systems are organized into organelles, cells, tissues, and organisms will be explored, as well as how the activities of all of these are orchestrated and regulated to produce "life"—a phenomenon greater than the sum of its parts. Considerable emphasis is placed on experimental approaches to answering these questions. Topics covered include biological membranes, cytoskeletal elements, cell locomotion, membrane and protein traffic, the nucleus, second messengers, signal transduction, cell growth, the cell cycle, the extracellular matrix, cell contacts and adhesion, intercellular communication, epithelial structure and function, and the cell biology of early development and organ function. Sophomores, juniors, and seniors only. Recommended Course Background: (AS.020.151 or AS.020.305) or equivalent knowledge of biomolecules or AS.020.303.
Prerequisites: Cell Biology restriction: students who have completed EN.540.307 may not enroll.
Instructor(s): E. Fisher; K. Tifft Oshinnaiye; T. Schroer
Area: Natural Sciences.

AS.020.307. Enzymes, Metabolism and Metabolic Disorders. 3.0 Credits.
This course will cover basic and advanced concepts in enzymology and metabolic processes while focusing on how these processes contribute to human health and diseases. This course is composed of lectures, discussion sessions, and student presentations.
Instructor(s): Y. Lee
Area: Natural Sciences.

AS.020.311. Introduction to the Human Brain. 3.0 Credits.
This course explores the outstanding problem of biology: how knowledge is represented in the brain. Relating insights from cognitive psychology and systems neuroscience with formal theories of learning and memory, topics include (1) anatomical and functional relations of cerebral cortex, basal ganglia, limbic system, thalamus, cerebellum, and spinal cord; (2) cortical anatomy and physiology including laminar/columnar organization, intrinsic cortical circuit, hierarchies of cortical areas; (3) activity-dependent synaptic mechanisms; (4) functional brain imaging; (5) logicist and connectivist theories of cognition; and (6) relation of mental representations and natural language.
Instructor(s): E. Hedgecock
Area: Natural Sciences.

AS.020.312. Introduction to the Human Brain. 3.0 Credits.
This course explores the outstanding problem of biology: how knowledge is represented in the brain. Relating insights from cognitive psychology and systems neuroscience with formal theories of learning and memory, topics include (1) anatomical and functional relations of cerebral cortex, basal ganglia, limbic system, thalamus, cerebellum, and spinal cord; (2) cortical anatomy and physiology including laminar/columnar organization, intrinsic cortical circuit, hierarchies of cortical areas; (3) activity-dependent synaptic mechanisms; (4) functional brain imaging; (5) logicist and connectivist theories of cognition; and (6) relation of mental representations and natural language.
Instructor(s): E. Fisher; J. Diruggiero
Area: Natural Sciences.

AS.020.315. Biochemistry Laboratory. 2.0 Credits.
This course will reinforce the topics presented in Biochemistry AS.020.305 or AS.250.307 through laboratory exercises which use quantitative measurement to study cellular components and processes. Topics include pH, proteins, carbohydrates, lipids, nucleic acids, and enzymes Sections 5-8 are for BIOLOGY AND MOLECULAR & CELLULAR BIOLOGY MAJORS ONLY.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.;Pre/Corequisite AS.020.305 OR AS.250.307 OR AS.250.315
Instructor(s): J. Schildbach; R. Horner
Area: Natural Sciences.

AS.020.316. Cell Biology Lab. 2.0 Credits.
This course will reinforce the topics presented in AS.020.306 Cell Biology through laboratory exercises which use visible and fluorescence microscopy to study chromosomes, cell organelles, cell surface receptors, contractile proteins, and microfilaments.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.;Prerequisite or Corequisite: AS.020.306. OR (EN.540.307 AND EN.540.202).
Corequisites: EN.540.202 cannot be taken concurrently with AS.020.316.
Instructor(s): R. Horner
Area: Natural Sciences.

AS.020.317. Signaling in Development and Disease. 3.0 Credits.
An advanced undergraduate level seminar on current topics on signal transduction mechanisms underlying neuronal morphology, development and function. The proper functioning of the nervous system relies on the establishment of precise neuronal circuits through a developmental program including proliferation, neuronal migration, axonal growth, and neuronal survival. This course pertains to the extracellular cues and downstream neuronal signaling pathways that coordinate these key events during neuronal development. The course will also cover the role of aberrant signaling mechanisms in neuronal degeneration and disease. Recommended Course Background: AS.020.305, AS.020.306, and AS.080.306
Instructor(s): R. Kuruvilla
Area: Natural Sciences.

AS.020.328. Genomics: Theory and Practice. 2.0 Credits.
This course is designed to introduce the students to all facets of genomics and provide a hands-on approach to genomics research. The core of the course will be to introduce a biological problem that requires a genomics solution, design experiments, conduct them, obtain sequencing data and analyze them. In addition to this, lectures will also cover the current topics in and future of genomics. This course is conceived as an interactive one and student participation is required.
Prerequisites: AS.020.305 OR AS.020.303
Instructor(s): V. Balagopal
Area: Natural Sciences.

AS.020.329. Microbiology. 3.0 Credits.
This course explores the physiology and genetics of microorganisms within an evolutionary and ecological framework. Concepts in microbiology will be supported by molecular studies of microbial evolution and microbial communities including that of the human microbiome. Recommended Course Background: AS.020.305
Instructor(s): E. Fisher; J. Diruggiero
Area: Natural Sciences.
AS.020.331. Human Genetics. 2.0 Credits.
Will examine the growing impact of human genetics on the biological sciences, on law and medicine, and on our understanding of human origins. Topics include structure and evolution of human genome, genetic and physical mapping of human chromosomes, molecular genetics of inherited diseases and forensic genetics.
Prerequisites: Pre-reqs: AS.020.303 OR AS.020.330
Instructor(s): E. Moudrianakis
Area: Natural Sciences, Social and Behavioral Sciences.

AS.020.332. Photosynthesis by Land and Aquatic Organisms. 2.0 Credits.
This course analyzes the fundamental process of photosynthesis, the process on which all life on Earth depends for its existence. We begin from the level of the structural organization of the photosynthetic machinery and progress to the essentials of the photophysics of light capture by the primary pigments. Next we follow the conversion of photon flow to electron flow through the electron transport chain, and finally we study the formation of chemical gradients that serve as temporary "energy stores" utilized in the synthesis of the essential chemicals that are consumed to drive carbon dioxide and nitrogen fixation and yield biomass. Finally, we compare the specializations of land and aquatic photosynthetic systems that serve the two different ecosystems. Recommended Course Background: AS.020.305 or AS.020.306 or special permission by the instructor.
Instructor(s): E. Moudrianakis; R. Horner
Area: Natural Sciences.

AS.020.335. Bioenergetics. 2.0 Credits.
This course is a combination of lectures, student presentations and group discussions that address fundamental principles and also contemporary issues examining the way all forms of Life on Earth are ultimately dependent on sunlight to satisfy their food and energy requirements. We examine the steps from the capture of Physical energy (photons), to the development of electrochemical potentials and finally, to their utilization by cellular organelles towards the synthesis of the chemical "currency" that fuels all biological processes (biosynthesis, cell communication, movements, etc.). Special emphasis will be on current developments in biotechnologies that utilize microbial populations to supply us with fuels and also to clean up environmental hazards. The course will also consider ways to extract lessons from Nature's successful designs and harmonious adaptations so that we, in the long run, can utilize them towards a minimization of our negative impact on the environment. Note for Juniors and Seniors: in addition to attending the lectures they are expected to analyze assigned relevant research articles and submit reports of their analyses and conclusions. Admission, by approval of instructor.
Instructor(s): E. Moudrianakis
Area: Natural Sciences.

AS.020.337. Stem Cells & the Biology of Aging & Disease. 2.0 Credits.
This will be a team-taught lecture course that focuses on the properties of stem cells, their possible role in cancer (breast and prostate), stem cell aging, and the potential utilization of stem cells for therapy. Topics will include: mechanisms of stem cell renewal, stem cell potency, the impact of the stem cell niche, stem cells and the hematopoietic system, stem cells and the neural system, stem cells in the male and female gonads, induced pluripotent stem cells and cellular reprogramming, stem cell changes with aging, and ethical and policy issues in stem cell research and use. Most lectures will be research-oriented. Students will be expected to read and critically analyze current literature, with an emphasis on the experimental bases from which our current understandings derive.
Prerequisites: AS.020.305 (Biochemistry) or AS.020.306 (Cell Biology) or EN.580.221 (Molecules and Cells) or EN.540.307 (Cell Biology for Engineers) or permission of instructor.
Instructor(s): B. Zarkin
Area: Natural Sciences.

AS.020.340. Genetics Laboratory. 2.0 Credits.
This laboratory explores the genetics of living organisms, and students in each section will therefore be required to return to lab on succeeding days to observe and record the results of their experiments. Recommended Course Background: AS.020.316
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): C. Norris
Area: Natural Sciences.

AS.020.344. Virology. 3.0 Credits.
This course will cover basic principles of viral replication and pathogenesis, as well as the host response to viral infection. It will then focus on several viruses of interest, including HIV-1, Influenza, Human Papilloma Virus, Hepatitis C, Ebola Virus, and Zika Virus.
Prerequisites: AS.020.305 OR AS.250.315
Instructor(s): K. Beemon
Area: Natural Sciences.

AS.020.346. Immunobiology. 3.0 Credits.
A course for upper level undergraduates that introduces the molecules, cells, systems and biology of the immune system.
Prerequisites: AS.020.305 OR AS.030.316 OR AS.250.316
Instructor(s): J. Schildbach
Area: Natural Sciences.

AS.020.347. AIDS. 3.0 Credits.
AIDS is the world's deadliest infectious disease. This course will cover the biology of human immunodeficiency virus (HIV, the infectious agent that causes AIDS), the effects of HIV on the immune system, the pharmacology of the anti-viral agents that are used to suppress HIV infection, and the ongoing quest for an HIV vaccine. Because HIV drugs cannot cure HIV-infected individuals and no HIV vaccine yet exists, we will also study the long-term consequences of HIV infection including opportunistic infections, comorbid conditions, and the HIV-related cancers Kaposi's Sarcoma and AIDS-Related lymphoma. Recommended Course Background: AS.020.306
Instructor(s): T. Schroer
Area: Natural Sciences.

AS.020.350. Introduction to Clinical Medicine. 2.0 Credits.
Perm. Req’d. Post-Bac Students Only
Instructor(s): E. Ruiz; M. Brady; W. Merritt; W. Ziai
Area: Natural Sciences.
AS.020.351. Cancer Biology. 3.0 Credits.
While the “war on cancer” has produced modest victories with respect to clinical outcomes, our knowledge of the cellular mechanisms of cancer is now vast and represents one of the most significant scientific achievements of the past 40 years. Key aspects of cancer biology will be covered with a combination of textbook and original literature readings. Topics will include cancer cell characteristics, oncogenes, tumor suppressor genes, apoptosis, metastasis and immuno-surveillance of cancer cells. Application of our knowledge to the rational treatment of cancer will also be discussed.
Prerequisites: Cell Biology 020.306 or permission of instructor
Instructor(s): M. Hoyt
Area: Natural Sciences.

AS.020.355. Fundamentals of Genome Informatics. 3.0 Credits.
This course will cover fundamental methods used in the analysis of genomic sequencing data, with a particular focus on recent developments in comparative and functional genomic assays. In particular, we will cover approaches for 1) genomic sequencing and assembly, including resequencing and personal genomes, 2) comparing genomes and modeling genome evolution, 3) identifying functional elements using both functional genomics and computational models. While the course will focus on particular problems in genomics, we will emphasize core algorithmic concepts that generalize to the analysis of other types of biological data.
Prerequisites: General Biology 020.151-152 and (Calculus I 110.106 or Calculus I 110.108)
Instructor(s): J. Taylor
Area: Natural Sciences.

AS.020.360. Gene Regulation During Development and Disease. 3.0 Credits.
This course examines how regulation of gene expression impacts development and disease. The course will focus on the mechanisms controlling transcriptional, post-transcriptional, translational, and post-translational regulation. For each topic, one class will be a lecture/discussion of key concepts and experimental approaches followed by a class with student-led presentations of related publications.
Recommended Course Background: AS.020.303 and AS.020.305.
Instructor(s): R. Johnston
Area: Natural Sciences.

AS.020.363. Developmental Biology. 3.0 Credits.
This class will explore the development of animals from a single fertilized egg into a fully formed organism. We will emphasize experimental methods to understand the molecular mechanisms controlling development.
Prerequisites: AS.020.306 AND (AS.020.330 OR AS.020.303)
Instructor(s): C. Norris; C. Roberson; M. Van Doren
Area: Natural Sciences.

AS.020.365. Intro To Human Skeleton. 3.0 Credits.
This course will provide a basic understanding of human skeletal biology, including bone composition and bone growth, recognition of skeletal elements, functional anatomy of different skeletal systems, comparative anatomy, and forensic anthropology (sexing and aging, body size reconstruction, bone pathology). Lectures will be combined with hands-on experience with bone models and real bone specimens.
Instructor(s): C. Ruff
Area: Natural Sciences.

AS.020.367. Primate Adaptation and Evolution. 3.0 Credits.
A close look at our closest relatives, the primates. Topics include: evolutionary theory, primate evolution, primate behavior and ecology, human evolution, and modern human variation.
Instructor(s): J. Perry
Area: Natural Sciences.

AS.020.373. Develop Biology Lab. 2.0 Credits.
This laboratory is designed to give students exposure to the different techniques and organisms used in Developmental Biology research. Our primary goal in this course is to help you learn to think like a scientist and gain a better understanding of how scientists study development. With that goal in mind, students design and execute an independent project during the second half of the semester. The independent projects will culminate with a poster session in which the project and its outcome will be shared with the other students. Please be aware that because we are working with live developing embryos, you will sometimes be required to return to lab between scheduled class times.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Instructor(s): C. Norris.

AS.020.374. Comparative Animal Physiology. 3.0 Credits.
This class examines animal physiology from an evolutionary and comparative viewpoint. The goal is to examine the commonalities, as well as unique differences, in how various animal organisms address the necessary life functions. Topics will include metabolism, neural systems, respiration, muscle systems, water and salt homeostasis, thermal regulation, and reproduction
Prerequisites: AS.020.305
Instructor(s): A. Coppola
Area: Natural Sciences.

AS.020.379. Evolution. 3.0 Credits.
This course takes a broad look at the impact of natural selection and other evolutionary forces on evolution. Emphasis is placed on what we can learn from genome sequences about the history of life, as well as current evolutionary pressures. Recommended Course Background: AS.020.306, AS.020.330, or permission required
Instructor(s): C. Norris
Area: Natural Sciences.
**AS.020.380. Eukaryotic Molecular Biology. 3.0 Credits.**
The course will present analysis of the structural basis of the genome organization in a eukaryotic nucleus and the utilization of its genomic content. We start with the analysis of the fluctuations of the structure of the double helix in response to its cellular microenvironment that yield DNA structural and functional polymorphism. Next we will deal with the mechanics of its compaction into chromatin and the differentiation of the chromatin structure at the level of the nucleosome via histone variants and posttranslational modifications and chromatin-based epigenetics. We will next move to chromosomal territories, chromosomal imprinting and chromosome inactivation. Finally, the lectures will address mechanisms of DNA replication and the nature of telomeres; the role of transcription factors in the regulated expression of the genome. It will conclude with analysis of the events of RNA processing and export to the cytoplasm. Paradigms of the role of chromatin differentiation to certain human diseases will be presented.

**Prerequisites:** AS.020.305 OR AS.020.306; AS.020.303 with approval of the instructor only.

**Instructor(s):** K. Tifft Oshinnaiye

**Area:** Natural Sciences.

**AS.020.385. Epigenetics. 3.0 Credits.**
Course description: This course emphasizes epigenetic regulatory mechanisms including DNA methylation, histone modifications, histone variants, non-coding RNA regulation, and chromatin remodeling, etc. We will discuss the broad impact of epigenetic regulation in various biological events, ranging from stem cell activity, small RNAs’ and long non-coding RNAs’ function, to transgenerational epigenetic inheritance and human diseases. We will mainly use recent literatures to discuss various topics. There are both students’ presentation and writing components for this course. Students will be assigned a series of papers for their presentation and faculty will meet with student presenters ahead of the time to go through the presentation content.

**Prerequisites:** AS.020.303 OR AS.020.330

**Instructor(s):** J. Kim; X. Chen

**Area:** Natural Sciences.

**AS.020.401. Advanced Seminar: Molecular and Cellular Biology. 3.0 Credits.**
This is a weekly seminar designed for graduate students enrolled in the B.A./M.S. and Ph.D. programs. The seminar involves student presentations of research and discussion of topics of current interest in the field. BA/MS candidates only.

**Instructor(s):** K. Tifft Oshinnaiye

**Area:** Natural Sciences.

**AS.020.402. Seminar: Molecular & Cellular Biology. 3.0 Credits.**
This is a weekly seminar designed for students enrolled in the BA/MS program. The seminar involves student presentations of research and discussion of topics of current interest in the field. BA/MS students only.

**Instructor(s):** K. Tifft Oshinnaiye

**Area:** Natural Sciences.

**AS.020.415. Advanced Biomedical Research. 3.0 Credits.**
This course for advanced undergraduates includes classroom instruction in interdisciplinary research approaches and lab work on an independent research project in the lab of a Bloomberg Distinguished Professor. Lectures will focus on cross-cutting techniques such as data visualization, statistical inference, and scientific computing. In addition to two 50-minute classes per week, students will commit to working approximately 3 hours per week in the lab of one of the professors. The student and professor will work together to schedule the research project. Students will present their work at a symposium at the end of the semester. This course can be used as 1 credit of independent research for the MCB major requirement.

**Instructor(s):** M. Schatz

**Area:** Natural Sciences.

**AS.020.420. Build-a-Genome. 4.0 Credits.**
In this combination lecture/laboratory "Synthetic Biology" course students will learn how to make DNA building blocks used in an international project to build the world's first synthetic eukaryotic genome, Saccharomyces cerevisiae v. 2.0. Please study the wiki www.syntheticyeast.org for more details about the project. Following a biotechnology boot-camp, students will have 24/7 access to computational and wet-lab resources and will be expected to spend 15-20 hours per week on this course. Advanced students will be expected to contribute to the computational and biotech infrastructure. Co-listed with EN.580.420, AS.020.451 and EN.540.420. Successful completion of this course provides 3 credit hours toward the supervised research requirement for Molecular and Cellular Biology majors, or 2 credit hours toward the upper level elective requirement for Biology or Molecular and Cellular Biology majors. Must understand fundamentals of DNA structure, DNA electrophoresis, and analysis, Polymerase Chain Reaction (PCR), and must be either a) Experienced with molecular biology lab work or b) Adept at programming with a biological twist.

**Instructor(s):** J. Bader; K. Zeller

**Area:** Natural Sciences.

**AS.020.431. JHU Oxford: Advanced Biochemistry & Molecular Biology. 4.0 Credits.**
Open to JHU Oxford participants only.

**Instructor(s):** J. Schildbach

**Area:** Natural Sciences.

**AS.020.441. Mentoring in General Biology. 1.0 Credit.**
This course provides students who have taken General Biology I & II the opportunity to mentor new students in General Biology I & II. Mentors collaborate with faculty on how to lead effective sessions, help student teams complete team assignments, and generally help students understand difficult concepts and principles in biology. Mentors must have a firm command of the topics covered in biology and must meet with both faculty and students through the course of the semester. To become a mentor, students must have successfully completed AS.020.151/152, must apply using the form on the Biology Dept. Website, and must be accepted by the instructors. The deadline to apply is April 1st. S/U only. Perm. Req’d

**Instructor(s):** C. Roberson; R. Pearlman; R. Shingles

**Area:** Natural Sciences.
AS.020.442. Mentoring in General Biology. 1.0 Credit.
This course provides students who have taken General Biology I & II the opportunity to mentor new students in General Biology I & II. Mentors collaborate with faculty on how to lead effective sessions, help student teams complete team assignments, and generally help students understand difficult concepts and principles in biology. Mentors must have a firm command of the topics covered in biology and must meet with both faculty and students through the course of the semester. To become a mentor, students must have successfully completed AS.020.151/AS.020.152, must apply using the form on the Biology Department website, and must be accepted by the instructors. The deadline to apply is April 8th. Recommended Course Background: AS.020.151/AS.020.152
Instructor(s): R. Pearlman; R. Shingles
Area: Natural Sciences.

AS.020.451. Build-a-Genome Mentor. 4.0 Credits.
In this combination lecture/laboratory, "Synthetic Biology" course students will learn how to make DNA building blocks used in an international project to build the world's first synthetic eukaryotic genome, Saccharomyces cerevisiae v. 2.0. Please study the wiki www.syntheticyeast.org for more details about the project. Following a biotechnology boot-camp, students will have 24/7 access to computational and wet-lab resources and will be expected to spend 15-20 hours per week on this course. Advanced students will be expected to contribute to the computational and biotech infrastructure. Must understand fundamentals of DNA structure, DNA electrophoresis, and analysis, Polymerase Chain Reaction (PCR) and must be either a) Experienced with molecular biology lab work or b) Adept at programming with a biological twist.
Instructor(s): J. Bader; K. Zeller
Area: Natural Sciences.

AS.020.501. Introduction Independent Study. 3.0 Credits.
An independent course of study may be pursued under the direction of an adviser on those topics not specifically listed in the form of regular courses. Freshmen and Sophomores only. Perm. Req'd.
Instructor(s): Staff.

AS.020.502. Introduction Independent Study. 0.0 - 3.0 Credits.
Instructor(s): B. Kondo; K. Cunningham; R. Horner.

AS.020.503. Introduction To Research. 3.0 Credits.
Perm. Req'd. Freshmen and Sophomores only
Instructor(s): Staff.

AS.020.504. Introduction to Research. 0.0 - 3.0 Credits.
Perm. Req'd. Freshmen or Sophomores only
Instructor(s): Staff.

AS.020.505. Internship - Biology. 0.0 - 3.0 Credits.
An independent course of study may be pursued under the direction of an adviser on those topics not specifically listed in the form of regular courses. Consent of adviser required.
Instructor(s): C. Roberson; H. Zhao.

AS.020.506. Internship - Biology. 1.0 Credit.
Instructor(s): Staff.

AS.020.511. Independent Study. 3.0 Credits.
An independent course of study may be pursued under the direction of an adviser on those topics not specifically listed in the form of regular courses. Perm. Req'd.
Instructor(s): Staff.

AS.020.512. Independent Study. 0.0 - 3.0 Credits.
Instructor(s): Staff.

AS.020.513. Research Problems. 3.0 Credits.
Planning and conducting original laboratory investigations on biological problems, collection and analysis of data, reporting of results. Juniors and Seniors Only. Recommended Course Background: Permission of full-time faculty member in Biology dept.
Instructor(s): Staff.

AS.020.514. Research Problems. 0.0 - 3.0 Credits.
Perm. Req'd. Juniors and Seniors only
Instructor(s): Staff.

AS.020.551. Mentored Research. 9.0 Credits.
This courses provide BA/MS students with intensive research experience for a full academic year. Students in the program work under the direction of a research mentor on an original research project, produce a written report in the form of a thesis, and make a presentation of the work to the Biology Department. BA/MS or BS/MS candidates only.
Instructor(s): R. Horner.

AS.020.553. Mentored Research. 9.0 Credits.
BA/MS candidates only.
Instructor(s): H. Zhao; K. Beemon; M. Bessman; R. Horner.

AS.020.554. Mentored Research Program in Cellular and Molecular Biology. 3.0 Credits.
BA/MS Candidates Only
Instructor(s): R. Horner.

AS.020.591. Summer Research Experience. 0.0 - 3.0 Credits.
Instructor(s): J. Schildbach.

AS.020.594. Internship - Summer. 1.0 Credit.
Instructor(s): Staff.

AS.020.597. Research. 3.0 Credits.
Instructor(s): Staff.

AS.020.599. Independent Study. 3.0 Credits.
Instructor(s): C. Norris; M. Bessman; R. Horner; T. Schroer.

This course involves 30 minute sessions with each member of the training faculty. It is designed to acquaint incoming graduate students with the research topics and research philosophy of each laboratory. This should help students choose future rotations. More generally the course provides a range of perspectives on the future of specific fields and strategies for success in science. First year Biology Graduate students only
Instructor(s): Staff.

AS.020.607. Quantitative Biology Bootcamp.
Quantitative and computational methods have become essential to modern biological research. The goal of this course is to provide an introduction to basic skills that will enable students to employ these methods. Students will learn how to work in a command line shell and use software to perform analyses of large biological datasets. Students will learn basic programming using the Python language. Throughout the course students will apply the skills learned to practical analysis problems emphasizing parsing and working with biological data formats, exploratory data analysis and visualization, and numerical and statistical methods. This course is only open to first-year students in the CMBD program and will be held from September 2nd through September 5th, 2014.
Instructor(s): F. Tan; J. Taylor.
AS.020.612. Introduction to the Human Brain.
This course explores the outstanding problem of biology; how knowledge is represented in the brain. Relating insights from cognitive psychology and systems neuroscience with formal theories of learning and memory, topics include (1) anatomical and functional relations of cerebral cortex, basal ganglia, limbic system, thalamus, cerebellum, and spinal cord; (2) cortical anatomy and physiology including laminar/columnar organization, intrinsic cortical circuit, hierarchies of cortical areas; (3) activity-dependent synaptic mechanism; (4) functional brain imaging; (5) connectivist theories of cognition; and (6) relation of mental representations and natural language. Co-listed with AS.020.312.
Instructor(s): E. Hedgecock.

AS.020.613. Biology Science Writing.
Students will learn how to write abstracts and grant proposals, organize scientific manuscripts and thesis dissertations by writing and rewriting about their own research and editing other students' work. Focus will be on structure, substance, accessibility, and clarity of writing. Biology Graduate students only. Permission Req'd.
Instructor(s): A. Huang.

AS.020.614. Signaling in Development and Disease.
A seminar on current topics on signal transduction mechanisms underlying neuronal morphology, development and function. The proper functioning of the nervous system relies on the establishment of precise neuronal circuits through a developmental program including proliferation, neuronal migration, axonal growth, and neuronal survival. This course pertains to the extracellular cues and downstream neuronal signaling pathways that coordinate these key events during neuronal development. The course will also cover the role of aberrant signaling mechanisms in neuronal degeneration and disease.
Instructor(s): R. Kuruvilla
Area: Natural Sciences.

AS.020.615. Genetics & Development.
A graduate seminar course that will explore RNA from its beginning in the primordial RNA world to its present-day roles in gene regulation in bacteria, mammals, and viruses. Topics will include: The early RNA world, Riboswitches, Ribozymes, evolution of protein synthesis, splicing, telomerase, RNA interference, microRNAs, long non-coding RNAs, viral non-coding RNAs, and RNA therapeutics. Biology PHD students only.
Instructor(s): K. Beemon
Area: Natural Sciences.

AS.020.616. Planets, Life and the Universe.
This multidisciplinary course explores the origins of life, planets’ formation, Earth’s evolution, extrasolar planets, habitable zones, life in extreme environments, the search for life in the Universe, space missions and planetary protection. Grad Students Only. Co-listed with AS.020.334, AS.171.333 and AS.270.335
Instructor(s): J. Diruggiero; N. Levin
Area: Natural Sciences.

AS.020.617. Quantitative Biology Lab I.
This computer lab is designed for first year CMDB graduate students to enhance their quantitative skills for fall core courses. This course will cover quantitative and computational analysis of biological datasets, emphasizing molecular biology. In a hands on lab setting, students will carry learn to perform essential analyses including assembly of genomes, detection of DNA methylation, analysis of transcription factor binding and motifs, detecting genome variation, measuring expression of genes, and understanding genome evolution.
Instructor(s): J. Taylor.

AS.020.618. Quantitative Biology Lab II.
This computer lab is a continuation of the fall quantitative biology lab for CMDB graduate students. This semester will cover quantitative and computational modeling of selected topics from biophysics, cellular biology, and developmental biology
Instructor(s): E. Roberts.

AS.020.619. Microbiology.
This course explores the physiology and genetics of microorganisms within an evolutionary and ecological framework. Concepts will be supported by primary literature exploring microbial evolution and microbial communities including that of the human microbiome.
Instructor(s): J. Diruggiero.

AS.020.620. Stem Cells.
A student seminar will be based on selected literatures by the faculty. A summary mini-review paper is required for a chosen topic at the end of the semester.
Instructor(s): X. Chen.

AS.020.621. Human Genetics.
Will examine the growing impact of human genetics on the biological sciences, on law and medicine, and on our understanding of human origins. Topics include structure and evolution of human genome, genetic and physical mapping of human chromosomes, molecular genetics of inherited diseases and forensic genetics.
Instructor(s): E. Hedgecock
Area: Natural Sciences, Social and Behavioral Sciences.

AS.020.630. Genomes & Development.
This course covers gametogenesis, embryogenesis, post-embryonic development, genetic analysis, developmental genetics, model developmental systems, and cell determination. Biology graduate students only except with written permission from the instructor.
Instructor(s): Staff.

Instructor permission required for undergraduate students
Instructor(s): K. Beemon
Area: Natural Sciences.

AS.020.644. RNA.
A graduate seminar course that will explore RNA from its beginning in the primordial RNA world to its present-day roles in gene regulation in bacteria, mammals, and viruses. Topics will include: The early RNA world, Riboswitches, Ribozymes, evolution of protein synthesis, splicing, telomerase, RNA interference, microRNAs, long non-coding RNAs, viral non-coding RNAs, and RNA therapeutics. Biology PHD students only. MCB MS students with instructor’s permission during ADD/DROP Period.
Instructor(s): K. Beemon
Area: Natural Sciences.
AS.020.650. Eukaryotic Molecular Biology.
The course will present analysis of the structural basis of the genome organization in a eukaryotic nucleus and the utilization of its genomic content. We start with the analysis of the fluctuations of the structure of the double helix in response to its cellular microenvironment that yield DNA structural and functional polymorphism. Next we will deal with the mechanics of its compaction into chromatin and the differentiation of the chromatin structure at the level of the nucleosome via histone variants and posttranslational modifications and chromatin-based epigenetics. We will next move to chromosomal territories, chromosomal imprinting and chromosome inactivation. Finally, the lectures will address mechanisms of DNA replication and the nature of telomeres; the role of transcription factors in the regulated expression of the genome. It will conclude with analysis of the events of RNA processing and export to the cytoplasm. Paradigms of the role of chromatin differentiation to certain human diseases will be presented.
Instructor(s): E. Moudrianakis
Area: Natural Sciences.

AS.020.664. Advanced Graduate Biophysical Chemistry.
This is a computer-assisted course that requires each student to bring a laptop to class AND lab each day they meet. The class will be taught in the Mathematica programming language and/or UNIX, but familiarity with the programs are NOT a requirement. The course is divided into two parts. In the Class portion (Tuesdays and Thursdays) students will be given instruction in the concepts of physical and quantitative biology. Students will learn to simulate biological processes, identify the relationship between data and models, and will learn to fit biological data. In the Lab portion (Mondays) students will learn to operate in the UNIX environment using standard UNIX commands and shell scripting. Database searches applicable to research questions of interest will be performed. The data will be processed and analyzed with UNIX and Mathematica. Must be taken in the same semester as 020.607. Biology graduate students only.
Instructor(s): K. Fleming; V. Hilser

AS.020.668. Advanced Genetics and Molecular Biology.
This course examines modern concepts in genetics and molecular biology. The course focuses on the mechanisms controlling replication, recombination, transcriptional, translational, and posttranslational regulation. Lectures will have three parts: a student-led paper presentation, a discussion about the concepts surrounding a topic, and a discussion of modern techniques to experimentally probe the topic. Biology PHD students only.
Instructor(s): J. Kim; R. Johnston.

AS.020.679. Advanced Biological Microscopy.
This course is intended to build upon the basic skills students acquired in the previous course. Students will be required to work on actual ongoing research projects. The course will emphasize the integration and use of various light and electron microscopic techniques and their application to various research related questions. The course will have primarily a practical "hands-on" component; but will also include theoretical considerations as students will read, analyze, and discuss current journal articles.
Instructor(s): J. McCaffery
Area: Natural Sciences.

The creation and implementation of new approaches to the drug discovery and development process is a very active area of research. Currently, only one compound out of 5,000 that enter preclinical studies becomes a drug. Moreover, the development process is time consuming, lasting more than ten years on average. The rate of failure is extremely high. It has become evident that this field is in urgent need of revolutionary changes. This course will cover drug discovery issues ranging from the identification of hits to their optimization as drug candidates. Current as well as novel and proposed approaches aimed at accelerating discovery, potency optimization, selectivity, pharmacokinetics and other drug properties will be discussed. Grad students only.
Instructor(s): E. Freire
Area: Natural Sciences.

All aspects of cell biology are reviewed and updated in this intensive course through critical evaluation and discussion of the current scientific literature. Topics include protein trafficking, membrane dynamics, cytoskeleton, signal transduction, cell cycle control, cell physiology, and the integration of these processes in neurons. Recommended Course Background: AS.020.306
Instructor(s): S. Farber.

AS.020.687. Foundations & Applications of Molecular Biology.
An advanced course for graduate students in the biological sciences, although undergraduates are welcome, that stresses fundamental principles and analysis. It is generally focused on gene and protein structure and function.
Instructor(s): R. Schleif
Area: Natural Sciences.

AS.020.699. CMDB Responsible Conduct in Research.
This course involves discussions of ethical conduct and the responsible practice of scientific research. Department signature only; restricted to graduate students in Biology PhD students only.
Instructor(s): Staff.
AS.020.731. Critical Thinking in Biology.
In this course, students will critically analyze modern and seminal primary research papers in molecular, cellular and developmental biology. This analysis will emphasize the logic and experimental design of a selected set of outstanding research publications from diverse fields. Graduate students enrolled will develop the skills needed to efficiently understand and critique the rapidly expanding literature and growing diversity of biological research methods. In preparation for each class, all course participants will be expected to read and thoroughly critique the assigned paper(s). All students will submit a short, critical analysis of each paper in advance of the class session in which the paper(s) will be covered. A student will lead each discussion (once per semester, dependent upon enrollment). Recommended Course Background: AS.020.637, AS.020.668, AS.020.674, and AS.020.686
Instructor(s): D. Zappulla; R. Johnston.

AS.020.735. Seminar: Membrane Trafficking.
The Membrane Trafficking seminar course consists of several weeks of lectures and discussions led by the professors discussing key background concepts in the field of membrane trafficking. Class meetings during the final weeks of the course are seminars on current topics in membrane trafficking, led by the students. Over the course of the semester, students will learn about the methods and logic of experiment design, model building and hypothesis testing, gain exposure to and skills in reading and summarizing scientific literature, and get experience with preparing and delivering an effective oral presentation. Fall/odd years.
Instructor(s): B. Wendland; J. McCaffery
Area: Natural Sciences.

AS.020.739. Topics in Biochemistry.
The course is open to graduate students and advanced undergraduates. Undergraduates with instructor’s permission - "Topics in Biochemistry" deals with minireviews taken from the Journal of Biological Chemistry. Students select a topic of their choice from the "Compendium of Minireviews" for the current year, and present it before the class for discussion.
Instructor(s): M. Bessman.

AS.020.753. Logic and Methods in Modern Biology.
The purpose of this course is to gain experience in critical thinking about the logic and methods used in modern biological research. The main approach will be the critical reading, presentation, and discussion of primary research papers, and the preparation and presentation of a research proposal. It is held once a week on the NIH Bethesda campus. Grad students only.
Prerequisites: AS.020.637 AND AS.020.668 AND AS.020.674
Instructor(s): M. Lichten; O. Cohen-Fix
Area: Natural Sciences.

AS.020.801. Research – Biological Problems.
Independent research for the Ph.D. dissertation. Biology Ph.D. students only
Instructor(s): V. Hilser.

AS.020.802. Research-Biological Problems.
Biology Graduate students only.
Instructor(s): Staff.

AS.020.823. Introduction to Biology Research.
First year Biology Graduate Students only
Instructor(s): Staff.

AS.020.824. Introduction to Biology Research.
First year Biology Graduate Students only
Instructor(s): Staff.

AS.020.825. Introduction to Research.
Open to first year Biology graduate students only.
Instructor(s): Staff.

AS.020.826. Introduction to Biology Research.
Open to first year Biology graduate students only.
Instructor(s): Staff.

Cross Listed Courses

Neuroscience
AS.080.305. Neuroscience: Cellular and Systems I. 3.0 Credits.
(Formerly Nervous Systems I) Neuroscience: Cellular and Systems I is a fully integrated, two-semester course that surveys the cellular and molecular biology of neurons as well as the structure and function of the nervous system. Students must register for Neuroscience: Cellular and Systems II offered in the second term. Course open to JHU undergraduates only.
Prerequisites: AS.080.203 OR AS.050.203 OR AS.200.141 or 080.105 or permission
Instructor(s): H. Zhao; S. Hendry
Area: Natural Sciences.

Biophysics
AS.250.351. Reproductive Physiology. 2.0 Credits.
Focuses on reproductive physiology and biochemical and molecular regulation of the female and male reproductive tracts. Topics include the hypothalamus and pituitary, peptide and steroid hormone action, epididymis and male accessory sex organs, female reproductive tract, menstrual cycle, ovulation and gamete transport, fertilization and fertility enhancement, sexually transmitted diseases, and male and female contraceptive methods. Introductory lectures on each topic followed by research-oriented lectures and readings from current literature.
Instructor(s): B. Zirkin
Area: Natural Sciences.

Computer Science
EN.601.448. Computational Genomics: Data Analysis. 3.0 Credits.
Genomic data has the potential to reveal causes of disease, novel drug targets, and relationships among genes and pathways in our cells. However, identifying meaningful patterns from high-dimensional genomic data has required development of new computational tools. This course will cover current approaches in computational analysis of genomic data with a focus on statistical methods and machine learning. Topics will include disease association, prediction tasks, clustering and dimensionality reduction, data integration, and network reconstruction. There will be some programming and a project component. [Applications] Recommended Course Background: EN.601.226 or other programming experience, probability and statistics, linear algebra or calculus. Students may receive credit for EN.601.448 or EN.601.748, but not both.
Prerequisites: Students may receive credit for EN.601.448 or EN.601.748, but not both.
Instructor(s): A. Battle
Area: Engineering.

EN.601.748. Computational Genomics: Data Analysis. 3.0 Credits.
Graduate level version of EN.601.448. [Applications] Recommended Course Background: EN.601.226 or other programming experience, probability and statistics, linear algebra or calculus. Students may receive credit for EN.601.448 or EN.601.748 but not both.
Prerequisites: Students may receive credit for EN.601.448 or EN.601.748, but not both.
Instructor(s): A. Battle
Area: Engineering.
3.0 Credits.
The goal of this course is to study the leading computational and quantitative approaches for comparing and analyzing genomes starting from raw sequencing data. The course will focus on human genomics and human medical applications, but the techniques will be broadly applicable across the tree of life. The topics will include genome assembly & comparative genomics, variant identification & analysis, gene expression & regulation, personal genome analysis, and cancer genomics. The grading will be based on assignments, a midterm & final exam, class presentations, and a significant class project. [Applications]
Expected course background: familiarity with UNIX scripting and/or programming.
Instructor(s): M. Schatz.