# BIOLOGY

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*Consulting Professors:* Cathy Laurie, Catherine Squires, Marc Tessier-Lavigne
*Librarian:* Michael Newman

* Recalled to research.

** Recalled to active duty.

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Courses offered by the Department of Biology have the subject code BIO, and are listed in the "Biology (BIO) Courses" section of this bulletin.

The department provides: (1) a major program leading to the B.S. degree; (2) a minor program; (3) a coterminal program leading to the M.S. degree; (4) a doctoral program leading to the Ph.D. degree; and (5) courses designed for the non-major. An undergraduate major in Biology serves as preparation for professional careers, including medicine, dentistry, veterinary sciences, teaching, consulting, research, and field studies. For undergraduate students, the department offers courses and research opportunities that can satisfy either a general or specific interest in the various fields of biology. For graduate-level students, the department offers resources and experience learning from and working with world-renowned faculty involved in research on ecology, neurobiology, population biology, plant and animal physiology, biochemistry, immunology, cell and developmental biology, genetics, and molecular biology.

The facilities and personnel of the Department of Biology are housed in the Gilbert Biological Sciences Building, Herrin Laboratories, Herrin Hall, the Jasper Ridge Biological Preserve, the James H. Clark Center, the Lorry I. Lokey Laboratory Building and the Carnegie Institution of Washington on the main campus, and at the Hopkins Marine Station in Pacific Grove on Monterey Bay.

Jasper Ridge Biological Preserve (JRBP) is located near Stanford University's campus in the eastern foothills of the Santa Cruz Mountains. The preserve encompasses geologic, topographic, and biotic diversity within its 1,189 acres and provides a natural laboratory for researchers from around the world, educational experiences for students and docent-led visitors, and refuge for native plants and animals. See http://jrbp.stanford.edu.

The Hopkins Marine Station, located 90 miles from the main University campus in Pacific Grove, was founded in 1892 as the first marine laboratory on the west coast of North America. For more information, including courses taught at Hopkins Marine Station with the subject code BIOHOPK, see the "Biology, Hopkins Marine Station" section of this bulletin, immediately following this section.

The department's large collections of plants (Dudley Herbarium), fish, reptiles, and amphibians, as well as smaller collections of birds, mammals, and invertebrates, are housed at the California Academy of Sciences in San Francisco, where they, and extensive collections of the academy, are available to those interested in the systematics of these groups. Entomological collections, restricted to those being used in particular research projects, are housed in the Herrin Laboratories. No general collections are maintained except for teaching purposes.

The Falconer Biology Library in Herrin Hall (http://library.stanford.edu/depts/falconer) contains over 1,200 current subscriptions and an extensive collection of monographs and reference works. A specialized library is maintained at the Hopkins Marine Station.

## UNDERGRADUATE PROGRAMS IN BIOLOGY

### ADVISING

Members of the Biology faculty are available for advising on such academic matters as choice of courses, research, suggested readings, and career plans. The student services office maintains a current list of faculty advisers, advising schedules, and research interests.

The student services office staff and BioBridge, the department's peer advising group, are prepared to answer questions on administrative matters, such as requirements for the major, approved out-of-department electives, transfer course evaluations, and petition procedures. This office also distributes the department's *Bachelor of Science Handbook*, which delineates policies and requirements, as well as other department forms and information handouts.

Each undergraduate interested in the Biology major is required to select a department faculty adviser as part of the major declaration process. Students who plan to attend medical or graduate school, enroll in the honors or coterminal programs, take courses at Hopkins Marine Station, or attend one of the overseas campuses may find their faculty adviser particularly helpful.

### TRANSFER STUDENTS

Because of differences between Stanford undergraduate courses and prerequisites and those of many other institutions, transfer students may face problems not encountered by entering freshmen. Transfer students are urged to visit the student services office in Gilbert 108 during transfer orientation to obtain information on course credit evaluations. Course catalogs, syllabi, and/or lecture notes from the former institution are necessary in the evaluation and accreditation process. Transfer students are encouraged to find a faculty adviser soon after arrival.

All transfer courses intended to fulfill department requirements must be evaluated on Evaluation of Course Content forms available in the student services office or downloadable at http://biology.stanford.edu/student_resources/eval_course_content.pdf; these forms are kept in the student's file. This department procedure is in addition to the Registrar's process of having units earned at other institutions transferred for Stanford credit that appear on the Stanford transcript.

The department authorizes transfer credit only for courses whose content parallels the Stanford courses and that have comparable prerequisites (not merely a comparable course title). To substitute a course taken elsewhere for an upper-division Stanford course, course content must be approved by a department faculty member teaching in the area of the course. Submit as complete a course description as practical (including prerequisites and their descriptions) using the Evaluation of Course Content form available in the student services office before taking an off-campus course. Students must provide

exams, reading lists, term papers, and other materials for the evaluation. Credit is not allowed for projects for which the student was paid, nor is credit allowed for work of a purely technical or clinical nature. Academic performance is verified upon receipt of the official transcript.

## REQUIREMENTS FOR PREHEALTH PROFESSIONS

Students who are not biology majors should take at least BIO 41, 42, 43, 44X, 44Y, and such upper-division electives as may be recommended by Undergraduate Advising and Research.

## BACHELOR OF SCIENCE IN BIOLOGY

The undergraduate major in Biology serves as preparation for professional careers, including medicine, dentistry, veterinary sciences, teaching, consulting, research, and field studies.

### REQUIREMENTS

Candidates for the general Biology B.S. degree must complete:

*Core Courses*—must be taken for a letter grade, including Writing in the Major courses:

| *Subject and Catalog Number* | *Units* |
|---|---|
| BIO 41 | 5 |
| BIO 42 | 5 |
| BIO or BIOHOPK 43 | 5 |
| BIO 44X | 4 |
| BIO or BIOHOPK 44Y* may be replaced by 4 units of BIOHOPK 175H | 4 |

* BIO 44Y not required if completing honors program. Failure to complete honors program results in student being required to complete BIO 44Y.

*Required Foundational Breadth Courses*—two courses may be taken credit/no credit:

| *Subject and Catalog Number* | *Units* |
|---|---|
| CHEM 31A,B, or 31X | 8 or 4 |
| CHEM 33, 35, 36, 130*, 131 | 18 |
| CHEM 135 or 171 | 3 |
| PHYSICS 21, 22, 23, 24 or 41, 43, 45 or 28, 29 | 8-12 |
| MATH 19, 20, 21 or 41, 42 | 10 |
| One additional Foundational Breadth Course from this list: | |
| BIOHOPK 174H** | 3 |
| BIO/STATS 141** | 4-5 |
| CS 106A or 106X | 3-5 |
| MATH 51 or beyond | 5 |
| STATS 60/PSYCH 10 | 5 |

* May be substituted with MATH 100 or beyond if student is interested in the field of ecology and evolutionary biology.

** If taken to fulfill the foundational breadth requirement, these courses do not count toward the 24 elective unit requirement.

*Electives*—24 units required. Electives must be 100-level or above and selected from the offerings in the Department of Biology, Hopkins Marine Station, or from the list of approved out-of-department electives in the student services office or by downloading http://biology.stanford.edu/student_resources/out_of_dept_electives.pdf. Up to 6 units of teaching and research are allowed and up to 6 units can be taken credit/no credit. Stanford Introductory Seminars may not be used to fulfill this requirement.

Elective courses are typically taken during the junior and senior year and should include a total of 24 elective units beyond the core. The courses making up these units must include at least one course from at least three of the following four central menu areas. The rest of the 24 units can include more courses from this central menu, other Biology or Hopkins Marine Station courses, courses listed on the approved out-of-department elective list, or advanced courses for which menu courses are prerequisites. A complete central menu course listing including inactive and alternate year courses is available in the student services office or by downloading http://biology.stanford.edu/student_resources/central_menu.pdf.

Active central menu courses are:

*Molecular*

BIO 104. Advanced Molecular Biology
BIO 113. Fundamentals of Molecular Evolution[3]
BIO 118. Genetic Analysis of Biological Processes[1]
BIO 133. Genetics of Prokaryotes[1]
BIO 134. Replication of DNA[1]
BIO 160A. Developmental Biology and Signal Transduction I[1]
BIO 160B. Developmental Biology and Signal Transduction II[1]
BIO 188. Biochemistry I
BIO 189. Biochemistry II
BIO 230. Molecular and Cellular Immunology[1]
CBIO 101. Cancer Biology[1]
CEE 274A. Environmental Microbiology I

1. *Cell/Developmental*

BIO 118. Genetic Analysis of Biological Processes[1]
BIO 129A. Cellular Dynamics I: Cell Motility and Adhesion
BIO 129B. Cellular Dynamics II: Building a Cell
BIO 133. Genetics of Prokaryotes[1]
BIO 134. Replication of DNA[1]
BIO 137. Plant Genetics[1]
BIO 154. Molecular and Cellular Neurobiology[2]
BIO 158. Developmental Neurobiology[2]
BIO 160A. Developmental Biology and Signal Transduction I[1]
BIO 160B. Developmental Biology and Signal Transduction II[1]
BIO 230. Molecular and Cellular Immunology[1]
CBIO 101. Cancer Biology[1]
CEE 274A. Environmental Microbiology I

2. *Organismal*

BIO 112. Human Physiology
BIO 153. Cellular Neuroscience
BIO 154. Molecular and Cellular Neurobiology[2]
BIO 158. Developmental Neurobiology[2]
BIO 163. Neural Systems and Behavior
BIO 213. Biology of Viruses
BIOHOPK 161H. Invertebrate Zoology
BIOHOPK 162H. Comparative Animal Physiology
BIOHOPK 167H. Nerve, Muscle, and Synapse
BIOHOPK 169H. Neurobiology and Behavior
BIOHOPK 171H. Ecological and Evolutionary Physiology
MI 185. Topics in Microbiology

3. *Ecology and Evolution*

BIO 101. Ecology
BIO 113. Fundamentals of Molecular Evolution
BIO 121. Biogeography
BIO 136. Evolutionary Paleobiology
BIO 143. Evolution
BIO 144. Conservation Biology
BIO 145. Behavioral Ecology
BIO 185. Evolution of Reproductive Social Behavior
BIOHOPK 163H. Oceanic Biology
BIOHOPK 172H. Marine Ecology
CEE 274A. Environmental Microbiology I

1. May be used to satisfy either area I or area II requirement.
2. May be used to satisfy either area II or area III requirement
3. May be used to satisfy either area I or area IV requirement.
4. May be used to satisfy either area III or area IV requirement.
5. May be used to satisfy either area I or area II or area IV requirement.

No more than 6 units from any combination of individual instruction courses (BIO 198, 198X, 199, 199X, 290, 290X, 291, 300, 300X; BIOHOPK 175H, 198H, 199H, 290H, or 300H) may be applied toward the total number of elective units. No more than 6 units applied toward the elective unit requirement may be taken CR/NC.

Students intending to pursue research careers in biology, especially in ecology, population genetics, or theoretical biology, should be aware that MATH 19, 20, 21, or MATH 41, 42 are minimum mathematics requirements for the B.S. degree in Biology. Substantial additional training in mathematics, including differential equations, linear algebra, and probability theory, is often highly advisable. Students should consult the Biology faculty to discuss individual needs.

Additionally, even though only two or three quarters of physics

are required, students should be aware that many graduate and professional schools (for example, Medicine and Education) require a year of general physics with lab. Biology majors are therefore advised to take the year-long physics sequence PHYSICS 21, 22, 23, 24, 25, 26 if they plan to attend graduate or medical school.

For students considering study at Hopkins Marine Station during the junior or senior year, or an overseas program, the department recommends fulfilling as many University General Education Requirements as possible in the first two years at Stanford.

## HOPKINS MARINE STATION

For more information on the Hopkins Marine Station, see the "Hopkins Marine Station" section of this bulletin. Full descriptions of Hopkins Marine courses are listed in the "Courses in Biology, Hopkins Marine Station" section of this bulletin. The following Hopkins Marine Station courses may be used toward the Biology degree requirements:

*Core—*

BIOHOPK 43. Plant Biology, Evolution, and Ecology (equivalent to BIO 43)

BIOHOPK 44Y. Core Experimental Laboratory, equivalent to BIO 44Y

BIOHOPK 175H. Problems in Marine Ecology and Ecophysiology (can be used in place of BIO 44Y)*

* 4 units count toward the BIO 44Y requirement, with the remaining units counting as research/teaching under the upper-division elective requirement

*Electives—*

BIOHOPK 161H. Invertebrate Zoology (central menu area 3)

BIOHOPK 162H. Comparative Animal Physiology (central menu area 3)

BIOHOPK 163H. Oceanic Biology (central menu area 4)

BIOHOPK 164H. Marine Botany

BIOHOPK 166H. Molecular Ecology

BIOHOPK 167H. Nerve, Muscle, and Synapse (central menu area 3)

BIOHOPK 168H. Molecular Ecology Data Analysis

BIOHOPK 170H. Topics in Marine Biology

BIOHOPK 171H. Ecological and Evolutionary Physiology (central menu area 3)

BIOHOPK 172H. Marine Ecology (central menu area 4)

BIOHOPK 173H. Marine Conservation Biology

BIOHOPK 174H. Experimental Design and Probability

BIOHOPK 178H. Polar Biology

BIOHOPK 182H. Stanford at Sea (6 units maximum)

BIOHOPK 184H. Holistic Biology: Monterey Bay and the Sea of Cortez (6 units maximum)

BIOHOPK 185H. Ecology and Conservation of Kelp Forest Ecology

BIOHOPK 187H. Sensory Ecology

BIOHOPK 188H. Experimental Sensory Ecology

BIOHOPK 274. Hopkins Microbiology Course (6 units maximum)

BIOHOPK 277H. Biomechanics, Ecological Physiology, and Genetics of Intertidal Communities

BIOHOPK 310H. Intertidal Natural History

*Research and/or Teaching (maximum 6 units combined)—*

BIOHOPK 175H. Problems in Marine Ecology and Ecophysiology

BIOHOPK 198H. Directed Instruction or Teaching

BIOHOPK 199H. Undergraduate Research

BIOHOPK 290H. Teaching of Biological Science

BIOHOPK 300H. Research

See Biology degree requirements above for further information. Many of the Hopkins Marine Station courses may be used to fulfill department major requirements.

## TYPICAL SCHEDULE FOR A FOUR-YEAR PROGRAM

### FIRST YEAR

| *Subject and Catalog Number* | *Qtr. and Units* | | |
|---|---|---|---|
| | A | W | S |
| CHEM 31X*, 33, 35, 36. Chemical Principles and Organic Chemistry | 4 | 4 | 7 |
| MATH 19, 20, 21. Calculus and Analytic Geometry | 3 | 3 | 4 |
| Freshman requirements, seminars, or GERs | 8 | 8 | 6 |
| Totals | 15 | 15 | 17 |

* This schedule varies slightly if the student takes CHEM 31A,B.

### SECOND YEAR

| | | | |
|---|---|---|---|
| BIO 41. Principles of Biology* | 5 | | |
| BIO 42. Principles of Biology* | | 5 | |
| BIO *or* BIOHOPK 43. Principles of Biology* | | | 5 |
| BIO 44X. Core Experimental Laboratory | | 4 | |
| BIO *or* BIOHOPK 44Y. Core Experimental Laboratory | | | 4 |
| CHEM 130, 131, 135 (or 171). Organic and Physical Chemistry | 8 | 3 | |
| General Education Requirements or electives | 3 | 5 | 8 |
| Totals | 16 | 17 | 17 |

* Letter grade only.

### THIRD YEAR

| | | | |
|---|---|---|---|
| PHYSICS 21, 22, 23, 24. Introductory Physics | 4 | 4 | |
| General Education Requirements or electives | 11 | 11 | 11 |
| Totals | 15 | 15 | 11 |

### FOURTH YEAR

| | | | |
|---|---|---|---|
| Electives | 15 | 15 | 15 |

## FIELDS OF STUDY

In addition to the undergraduate major program described above, the department offers these six fields of study for students wishing to concentrate their studies in particular areas of biology:

Biochemistry and Biophysics

4. Ecology and Evolution
5. Marine Biology
6. Microbes and Immunity
7. Molecular and Cellular Biology
8. Neurobiology

These fields of study are declared on Axess; they appear on the transcript but not on the diploma. Candidates for the B.S. degree in Biology with a field of study are expected to complete the departmental honors program as well as the set of requirements outlined below. Students in a field of study must have their checklist signed by their advisers and submitted to the student services office by the end of junior year. Students may petition in advance for the substitution of either equivalent or more advanced courses using the General Petition, available in the student services office or by downloading http://biology.stanford.edu/student_resources/general_petition.pdf.

## BIOCHEMISTRY AND BIOPHYSICS

Core Courses (must be taken for a letter grade):

| *Subject and Catalog Number* | *Units* |
|---|---|
| BIO 41 | 5 |
| BIO 42 | 5 |
| BIO *or* BIOHOPK 43 | 5 |
| Writing in the Major (one of the following): | |
| BIO 44X | 4 |
| BIO *or* BIOHOPK 44Y | 4 |
| BIO 145* | 4 |
| BIOHOPK175H* | 10 |

* These courses can also be used to count toward the elective requirement.

Required Foundational Breadth Courses (two courses may be taken credit/no credit):

| | |
|---|---|
| CHEM 31A,B *or* 31X | 8 or 4 |
| CHEM 33, 35, 36, 130 | 15 |
| CHEM 135 *or* 171 | 3 |
| PHYSICS 41, 43, 45 | 12 |
| MATH 51, 52 | 10 |
| STATS 60 *or* BIO 141 | 5 or 4-5 |

Required Biology Courses (must be taken for a letter grade):

| | |
|---|---|
| BIO 104 | 3 |
| BIO 118 | 5 |
| BIO 129A or 129B | 4 |
| BIO 188 | 3 |

Approved Biochemistry and Biophysics Courses (three of the following; must be taken for a letter grade):

| | |
|---|---|
| APPPHYS 192 | 3 |
| BIOMEDIN 210 | 3 |
| BIO 152/MCP 222 | 3 |
| BIO 154 | 4 |
| CHEM 232/CHEMENG 452 | 3 |
| MCP 256 | 4 |

*Electives*—7 units required. Electives must be 100-level or above and chosen from the offerings in the Department of Biology, Hopkins Marine Station, or from the list of approved out-of-department electives. Up to 6 units of teaching and research are allowed. Only one course can be taken credit/no credit.

*Research Requirement*—Admission to the departmental honors program; 10 units of BIO 199, 199X, or BIOHOPK 199H; poster or oral presentation; and honors thesis. Only research units from BIO or BIOHOPK are permitted.

### ECOLOGY AND EVOLUTION

Core Courses (must be taken for a letter grade):

| *Subject and Catalog Number* | *Units* |
|---|---|
| BIO 41 | 5 |
| BIO 42 | 5 |
| BIO *or* BIOHOPK 43 | 5 |
| BIO 101 *or* BIOHOPK 172H | 3 or 5 |

Writing in the Major (one of the following):

| | |
|---|---|
| BIO 44X | 4 |
| BIO or BIOHOPK 44Y | 4 |
| BIO 145* | 4 |
| BIO 185* | 4 |
| BIOHOPK 175H | 10 |

* This course can also be used to count toward the elective requirement.

Required Foundational Breadth Courses (two courses may be taken credit/no credit):

| | |
|---|---|
| CHEM 31A,B *or* 31X | 8 or 4 |
| CHEM 33, 35, 36 | 11 |
| PHYSICS 21, 22, 23, 24 *or* 41, 43, 45 or 28, 29 | 8 or 12 |
| MATH 41, 42 | 10 |

Required Evolutionary Biology Course (one of the following; must be taken for a letter grade):

| | |
|---|---|
| BIO 113/244 | 4 |
| BIO 136 | 4 |
| BIO 143 | 3 |
| BIOHOPK 166H | 5 |

Required Quantitative Methods Course (one of the following; must be taken for a letter grade):

| | |
|---|---|
| BIO 141 | 4-5 |
| BIO 221 | 4 |
| BIOHOPK 174H | 3 |
| CS 106A or 106X | 3-5 |
| STATS 60 or beyond | 5 |

*Electives*—30 units required. Only one course can be taken credit/no credit. Electives must be from this approved list: BIO 102, 117, 118, 121, 124, 125, 139, 144, 145, 146, 147, 175, 183, 184, 185, 215, 216; BIOHOPK 163H, 171H; CHEM 130, 131; EARTHSYS 144/EESS 164; EESS 134, 158; GES 123, 240; OSPAUSTL 10*, 20*, 30*.

* Only 2 units can count.

*Research Requirement*—Admission to the departmental honors program; 10 units of BIO 199, 199X, or BIOHOPK 199H; poster or oral presentation; and honors thesis. Only research units from BIO or BIOHOPK are permitted.

### MARINE BIOLOGY

Core Courses (must be taken for a letter grade):

| *Subject and Catalog Number* | *Units* |
|---|---|
| BIO 41 | 5 |
| BIO 42 | 5 |
| BIO *or* BIOHOPK 43 | 5 |

Writing in the Major (one of the following):

| | |
|---|---|
| BIO 44X | 4 |
| BIO *or* BIOHOPK 44Y | 4 |
| BIO 145 | 4 |
| BIO 185 | 3 |
| BIOHOPK 175H* | 10 |

* This courses can also be used to count toward the approved courses.

Required Foundational Breadth Courses (two courses may be taken credit/no credit):

| | |
|---|---|
| CHEM 31A,B or 31X | 8 or 4 |
| CHEM 33, 35, 36, 130, 131 | 18 |
| PHYSICS 21, 22, 23, 24 *or* 41, 43, 45 | 8 or 12 |
| MATH 41, 42 *or* 19, 20, 21 | 10 |
| STATS 60 *or* BIO 141 *or* BIOHOPK 174H | 5 or 4-5 or 3 |

Required Biology Courses (must be taken for a letter grade):

| | |
|---|---|
| BIO 101 | 3 |
| BIO 118 | 5 |
| BIO 143 | 3 |

Approved courses (three of the following; must be taken for a letter grade):

| | |
|---|---|
| BIOHOPK 161H | 5 |
| BIOHOPK 162H *or* 171H | 5-8 or 4 |
| BIOHOPK 163H | 4 |
| BIOHOPK 166H | 5 |
| BIOHOPK 172H | 5 |

Approved courses (one of the following; must be taken for a letter grade):

| | |
|---|---|
| BIOHOPK 175H | 10 |
| BIOHOPK 182H | 16 |

*Research Requirement*—Admission to the departmental honors program; 10 units of BIO 199, 199X, or BIOHOPK 199H; poster or oral presentation; and honors thesis. Only research units from BIO or BIOHOPK are permitted.

### MICROBES AND IMMUNITY

Core Courses (must be taken for a letter grade):

| *Subject and Catalog Number* | *Units* |
|---|---|
| BIO 41 | 5 |
| BIO 42 | 5 |
| BIO *or* BIOHOPK 43 | 5 |

Writing in the Major and Introduction to Laboratory Science (one of the following):

| | |
|---|---|
| BIO 44X | 4 |
| BIO *or* BIOHOPK 44Y | 4 |
| BIOHOPK 175H* | 10 |

* This course can also be used to count toward the elective requirement.

Required Foundational Breadth Courses (two courses may be taken credit/no credit):

| | |
|---|---|
| CHEM 31A,B or 31X | 8 or 4 |
| CHEM 33, 35, 36, 130, 131 | 18 |
| PHYSICS 21, 22, 23, 24 *or* 41, 43, 45 | 8 or 12 |
| MATH 19, 20, 21 *or* 41, 42 | 10 |
| BIO 141* *or* BIOHOPK 174H* | 4-5 or 3 |

* This course cannot also be used to count toward the elective requirement.

Required Courses in Microbiology, Immunology, Molecular Evolution (four of the following; must be taken for a letter grade):

| | |
|---|---|
| BIO 113 | 4 |
| BIO 133 | 4 |
| BIO 177 | 3 |
| BIO 213 | 4-5 |
| BIO 230 | 9-12 |
| BIOHOPK 274 | 4 |
| CEE 177 | 3 |
| CEE 274A | 3 |
| CEE 274B | 3 |
| CEE 274D | 3 |
| MI 104 | 3 |
| MI 211 | 3 |
| MI 212 | |

Required Course in Reading Scientific Literature (one of the following, must be taken for a letter grade):

| | |
|---|---|
| BIO 178 | 3 |
| MI 185 | 3 |

*Electives*—12 units required. Electives must be 100-level or above and selected from the offerings in the Department of Biology, Hopkins Marine Station, or from the list of approved out-of-department electives. Up to 6 units of teaching and research are allowed. Only one course can be taken credit/no credit.

*Research Requirement*—Admission to the departmental honors program; 10 units of BIO 199, 199X, or BIOHOPK 199H; poster or oral presentation; and honors thesis. Only research units from BIO or BIOHOPK are permitted.

### MOLECULAR AND CELL BIOLOGY

Core Courses (must be taken for a letter grade):

| *Subject and Catalog Number* | *Units* |
|---|---|
| BIO 41 | 5 |
| BIO 42 | 5 |
| BIO or BIOHOPK 43 | 5 |

Writing in the Major (one of the following):

| | |
|---|---|
| BIO 44X | 4 |
| BIO or BIOHOPK 44Y | 4 |
| BIO 145* | 4 |
| BIOHOPK175H* | 10 |

* These courses can also be used to count toward the elective requirement.

Required Foundational Breadth Courses (two courses may be taken credit/no credit):

| | |
|---|---|
| CHEM 31A,B or 31X | 8 or 4 |
| CHEM 33, 35, 36, 130, 131 | 18 |
| CHEM 135 or 171 | 3 |
| PHYSICS 21, 22, 23, 24 or 41, 43, 45 | 8 or 12 |
| MATH 41, 42 or 19, 20, 21 | 10 |
| STATS 60 or BIO 141* | 5 or 4-5 |

* This course cannot also be used to count toward the elective requirement.

Required Biology Courses (must be taken for a letter grade):

| | |
|---|---|
| BIO 104 | 3 |
| BIO 118 | 5 |
| BIO 129A, 129B | 8 |
| *or* BIO 160A, 160B | 8 |

*Electives*—15 units required. Electives must be 100-level or above and selected from the offerings in the Department of Biology, Hopkins Marine Station, or from the list of approved out-of-department electives. Up to 6 units of teaching and research are allowed. Only one course can be taken credit/no credit.

*Research Requirement*—Admission to the departmental honors program; 10 units of BIO 199, 199X, or BIOHOPK 199H; poster or oral presentation; and honors thesis. Only research units from BIO or BIOHOPK are permitted.

### NEUROBIOLOGY

Core Courses (must be taken for a letter grade):

| *Subject and Catalog Number* | *Units* |
|---|---|
| BIO 41 | 5 |
| BIO 42 | 5 |
| BIO or BIOHOPK 43 | 5 |

Writing in the Major (one of the following):

| | |
|---|---|
| BIO 44X | 4 |
| BIO or BIOHOPK 44Y | 4 |
| BIO 145* | 4 |
| BIOHOPK175H* | 10 |

* These courses can also be used to count toward the elective requirement.

Required Foundational Breadth Courses (two courses may be taken credit/no credit):

| | |
|---|---|
| CHEM 31A,B or 31X | 8 or 4 |
| CHEM 33, 35, 36, 130, 131 | 18 |
| PHYSICS 21, 22, 23, 24 or 41, 43, 45 | 8 or 12 |
| MATH 41, 42 or 19, 20, 21 | 10 |
| STATS 60 or BIO 141* | 5 or 4-5 |

* This course cannot also be used to count toward the elective requirement.

Required Biology Courses (must be taken for a letter grade):

| | |
|---|---|
| BIO 118 or 104 | 5 or 3 |
| BIO 129A or 129B or 160A or 160B | 4 |
| BIO 150 or 163 | 5 or 4 |
| BIO 154 | 4 |
| BIO 158 | 4 |

*Electives*—15 units required. Electives must be at the 100-level or above and selected from the offerings in the Department of Biology, Hopkins Marine Station, or from the list of approved out-of-department electives. Up to 6 units of teaching and/or research are allowed. Only one course can be taken credit/no credit.

*Research Requirement*—Admission to the departmental honors program; 10 units of BIO 199, 199X, or BIOHOPK 199H; poster or oral presentation; and honors thesis. Only research units from BIO or BIOHOPK are permitted.

For further information on the fields of study, including detailed descriptions of their requirements and deadlines, see http://biology.stanford.edu/programs.html.

### HONORS

To graduate with departmental honors, a student must:

Submit an honors petition proposal to the department's undergraduate research coordinator by the fifth Friday of the quarter, two quarters prior to graduation. For instance, students graduating Spring Quarter must submit petitions no later than mid-Autumn Quarter.

9. Complete at least 10 units of an approved research project in BIO 199, 199X, or BIOHOPK 199H. Only research units from BIO or BIOHOPK are permitted.
10. Obtain at least a 3.0 (B) grade point average (GPA) in all Biology major requirements taken at Stanford (foundational breadth, core, and elective courses). Grades earned from teaching (BIO or BIOHOPK 290 and BIO 291) and research (BIOHOPK 175H, 199H; BIO 199, 199X) are not computed into this GPA.
11. If graduating in June, participate in the Biology Honors Symposium by presenting a poster or giving an oral presentation. The symposium is usually at the end of May. If graduating Autumn, Winter, or Summer Quarter, produce a poster.
12. Complete and submit, by the end of the quarter of graduation, two signed and bound copies of an honors thesis approved by at least two readers (one of whom must be from the faculty of the Department of Biology and both must be Academic Council members). In addition, students must submit two copies of the honors thesis abstract (one paper copy and one electronic copy), which include student name, thesis title, research sponsor, and sponsor's department.

Further information on the honors program is available in the office of the undergraduate research coordinator in Gilbert 118, as well as on the web at http://biohonors.stanford.edu. Questions should be directed to the undergraduate research coordinator, Dr. Angela Lee (angelee@stanford.edu, 650-723-3767, Gilbert 118).

## MINOR IN BIOLOGY

Students interested in the minor in Biology must declare the minor and submit their course plan online via Axess no later than two quarters prior to the student's intended quarter of degree conferral. The Biology minor requires a minimum of six courses meeting the following criteria:

All courses must be taken for a letter grade.

13. All courses must be worth 3 or more units.
14. All courses, other than the Biology Core (41, 42, 43), must be at or above the 100-level. Stanford Introductory Seminars may not be used to fulfill the minor requirements.
15. Courses used to fulfill the minor may not be used to fulfill any other department degree requirements (minor or major).
16. At least one course from the Biology Core (41, 42 or 43) must be taken.
17. The Biology Core Laboratory (BIO 44X and BIO 44Y) does not count towards the minor.
18. Courses must be chosen from the offerings of the Department of Biology or the Hopkins Marine Station, or from the list of approved out-of-department electives (available in the student services office or downloadable at http://biology.stanford.edu/student_resources/out_of_dept_electives.pdf).
19. Elective credit for research (BIO 199 or BIOHOPK 199H) is limited to a maximum of 3 units.

## COTERMINAL B.S. AND M.S. DEGREES IN BIOLOGY

The Department of Biology admits a limited number of undergraduates to the coterminal B.S. and M.S. degree program in Biology. Current Stanford students may apply to the program after they have earned a minimum of 120 units toward graduation (UTG) and at least one quarter prior to conferring the undergraduate degree; for example, if a student expects to have the B.S. conferred in Spring Quarter, the student must apply no later than the third week of Winter Quarter. The application includes a statement of purpose, an

unofficial Stanford transcript, official GRE score print-out, two letters of recommendation from faculty members in this department (if two such letters are not available, a letter from someone outside the department can be used in lieu of one of those), a program proposal listing the courses in which they intend to enroll to fulfill degree requirements, a course transfer form, and an application fee of $50. Students must meet all requirements except the electives for the B.S. degree, and all requirements for the M.S. degree in Biology. Unit requirements for a coterminal program are 180 units for the bachelor's degree and 45 units for the master's degree.

Coterminal students are permitted to use course work taken up to two quarters immediately prior to their first graduate quarter toward their graduate degree.

For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/shared/publications.htm#Coterm.

# GRADUATE PROGRAMS IN BIOLOGY

## TEACHING CREDENTIALS

For information concerning the requirements for teaching credentials, consult the "School of Education" section of this bulletin or address an inquiry to the Credential Administrator, School of Education.

## MASTER OF SCIENCE IN BIOLOGY

For information on the University's basic requirements for the M.S. degree, see the "Graduate Degrees" section of this bulletin.

The M.S. degree program offers general or specialized study to individuals seeking biologically oriented course work, and to undergraduate science majors wishing to increase or update their science background or obtain advanced research experience. Students who have majored in related fields are eligible to apply. However, course work equivalent to the Stanford B.S. in Biology is recommended. The M.S. program does not have an M.S. with thesis option.

### ADMISSIONS

The department only accepts M.S. program applications from matriculated Stanford students.

### GENERAL REQUIREMENTS

The M.S. program consists of Department of Biology and/or Hopkins Marine Station course work, approved out-of-department electives, and foundational breadth courses totaling at least 45 units at or above the 100-level, distributed as follows:

A minimum of 23 of the 45 units must be courses designated primarily for graduate students (200-level or higher).

20. A minimum of 36 units must be chosen from the offerings in the Department of Biology (BIO), Hopkins Marine Station (BIOHOPK), the list of approved out-of-department electives, foundational breadth courses, and/or research and teaching.
    a. a maximum of 18 of the 36 units may be a combination of Biology research, directed reading, and/or teaching (BIO 198, 198X, 290, 290X, 291, 300, 300X; BIOHOPK 175H, 176H, 198H, 290H, or 300H).
    b. a maximum of 9 units may be foundational breadth courses in chemistry, mathematics, statistics, computer science, and/or physics beyond the level required for the undergraduate degree in Biology and at least at the 100-level.
21. The remaining 9 units may be other Stanford course work relevant to a student's professional development. Students are required to petition for courses that fall into this category using the General Petition form, available in the student services office or downloadable at http://biology.stanford.edu/student_resources/general_petition. pdf.

Each candidate designs a coherent program of study in consultation with her or his department adviser. Although there are no specific courses required, program proposals must adhere to department parameters.

A program proposal, signed by the student's adviser and approved by the chair of the M.S. committee, must be filed by the third week of the first quarter of enrollment. Students may take only 6 units CR/NC and must receive a grade of 'B-' or better in all courses taken for the degree.

## DOCTOR OF PHILOSOPHY IN BIOLOGY

For information on the University's basic requirements for the Ph.D. degree, see the "Graduate Degrees" section of this bulletin. Training for a Ph.D. in Biology is focused on learning skills required for being a successful research scientist and teacher, including how to ask important questions and then devise and carry out experiments to answer these questions. Students work closely with an established adviser and meet regularly with a committee of faculty members to ensure that they understand the importance of diverse perspectives on experimental questions and approaches. Students learn how to evaluate critically pertinent original literature to stay abreast of scientific progress in their areas of interest. They also learn how to make professional presentations, write manuscripts for publication, and become effective teachers.

### ADMISSIONS

*Preparation for Graduate Study*—Students seeking entrance to graduate study in Biology ordinarily should have the equivalent of an undergraduate major in Biology at Stanford. However, students from other disciplines, particularly the physical sciences, are also encouraged to apply. Such students are advised at the time of initial registration on how they should complete background training during the first year of graduate study. In addition to the usual basic undergraduate courses in biology, it is recommended that preparation for graduate work include courses in chemistry through organic chemistry, general physics, and mathematics through calculus.

*Application, Admission, and Financial Aid*—Prospective graduate students should apply online at http://gradadmissions.stanford.edu. The department's program is divided into three separate tracks: ecology/evolution/population biology; integrative/organismal; and molecular/cellular/developmental/genetic/plant. Included in these tracks is the option to conduct research at Hopkins Marine Station. These concentrations are reported to the department; they are not declared on Axess.

Applicants are required to take the Graduate Record Examination (GRE) general test. The GRE subject test is not required. Applicants should plan on taking the GRE at least one month prior to the application deadline to ensure that official scores are available when applications are evaluated.

Admission to the Ph.D. program is competitive, and in recent years it has been possible to offer admission to only 10 percent of the applicants.

Qualified applicants should apply for nationally competitive predoctoral fellowships, especially those from the National Science Foundation.

Admitted students are typically offered financial support in the form of Stanford Graduate Fellowships, research assistantships, NIH traineeships, or Biology fellowships.

### GENERAL REQUIREMENTS

The following requirements must be completed by all students:

Course work is planned in consultation with an advising committee assigned for a student's track. In addition, students must take a course on the ethical conduct of research: BIO 312 for the ecology/evolution/population biology track; MED 255 for the integrative/organismal and molecular/cellular/ developmental/genetic/plant tracks.

22. Teaching experience and training are part of the graduate curriculum. Each student assists in teaching one course in the department's core lecture (41, 42, or 43) or lab (44X, 44Y) series, and a second course that can be either a core course or other Biology or Hopkins Marine Station course. Three quarters of teaching are required for ecology, evolution, and population biology students.
23. Graduate seminars devoted to current literature and research in particular fields of biology are an important means of attaining professional perspective and competence. Seminars are presented under individual course listings or are announced by the various research groups. Topics of current biological interest are presented

by speakers from Stanford and other institutions. During the first year of study, graduate students are required to attend seminars and make one formal seminar presentation which must be evaluated by a minimum of two faculty members.

24. By June 1, each first-year student is expected to have selected a lab in which to perform dissertation research and to have been accepted by the faculty member in charge. Students and faculty must wait until April 1 to discuss the choice of a dissertation lab.
25. During the second year, students are required to write a dissertation proposal which is evaluated by a committee of three faculty (the dissertation advising committee) in an oral presentation. Advancement to candidacy depends on satisfactory completion of the dissertation proposal.
26. Third year and beyond: each student must meet with the advising committee at the beginning of the third year, and each year thereafter prior to the end of the Spring Quarter. Advanced students are required to meet with their committee at least twice a year.
27. Residency requirement: a minimum of 135 units of graduate registration is required of each candidate.
28. The doctoral dissertation must be presented to an oral examination committee comprised of at least five faculty members. In addition, the final dissertation must be approved by the student's reading committee, comprised of at least three faculty members and by a graduate degree progress officer in the Registrar's Office. Upon completion of this final requirement, a student is eligible for conferral of the degree.

### TRACK SPECIFIC REQUIREMENTS

In addition to the general requirements listed above, students must also complete requirements within their track.

*Molecular, Cellular, Developmental, Genetic, and Plant Track—*

*First year:*

c. *advising committee:* shortly after arrival, each entering student meets with the first-year advising committee. The committee reviews the student's previous academic work and current goals and advises the student on a program of Stanford courses, some of which may be required and others recommended. Completion of the core curriculum (below) is required of all students.

d. *core curriculum:** students are required to take the following courses for a letter grade, unless previous course work has fulfilled these requirements:

BIO 203. Advanced Genetics
BIO 214. Advanced Cell Biology
BIO 301. Frontiers in Biology: satisfies first-year talk requirement; must be taken Autumn and Winter quarters.

One of the following:

BIOC/SBIO 241. Biological Macromolecules
BIOC 201. Advanced Molecular Biology
CSB 210. Signal Transduction Pathways and Networks
MCP 256. How Cells Work: Energetics, Compartments, and Coupling in Cell Biology

Three additional courses in the student's area of interest, or as advised by committee.

e. *Lab rotations:** first-year students are required to complete rotations in three different laboratories. The first rotation must be in a lab in the Department of Biology.

* Written petitions for exemptions to core curriculum and lab rotation requirements are considered by the advising committee and the chair of the graduate studies committee. Approval is contingent upon special circumstances and is not routinely granted.

2. *Second year:* Each student must pass a qualifying exam.

f. *dissertation proposal:* during Winter and Spring quarters of the second year, the student must prepare a dissertation proposal that outlines the student's projected dissertation research, including an expert assessment of the current literature. An oral examination is held after submission of the proposal to the dissertation advising committee. The student's adviser is a silent member of the examination committee; the other members of the dissertation advising committee can provide feedback. Advancement to candidacy is contingent upon completion of the dissertation proposal and oral exam. The written proposal is due by March 31 and the oral defense must take place no later than May 1. Failure to complete these requirements on schedule results in formal warnings and eventual dismissal from the program.

3. *Third year and beyond:*

g. *dissertation and dissertation defense:* a completed draft of the dissertation must be turned in to the student's oral examination committee at least one month before the oral exam is scheduled to take place. See University guidelines for the composition of this committee in the "Graduate Degrees" section of this bulletin.

*Integrative/Organismal Track—*

*First year:*

h. *advising committee:* shortly after arrival, each entering student meets with the first-year advising committee. The committee reviews the student's previous academic work and current goals and advises the student on a program of Stanford courses, some of which may be required and others recommended.

i. *core curriculum*: Students are required to take BIO 306, Current Topics in Integrative and Organismal Biology. Students specializing in integrative biology may also be asked to take appropriate graduate-level courses such as DBIO 210; MCP 215; NBIO 206, 216; or PSYCH 228.

j. *first-year paper:* students must submit a paper that is evaluated by the advising committee before the end of Spring Quarter of the first year. This paper should be a step toward the development of a dissertation proposal and may consist of an analysis of new data or a literature review and synthesis. The first-year paper must be evaluated by a minimum of two faculty members.

29. *Second year:*

k. *dissertation proposal:* during Spring quarter of the second year, the student must prepare a dissertation proposal that outlines the student's projected dissertation research, including an expert assessment of the current literature. An oral examination is held after submission of the proposal to the dissertation advising committee comprised of three faculty members. Advancement to candidacy depends on completion of the dissertation proposal and oral exam. The written proposal is due by May 15, and the oral defense must take place no later than June 15. Failure to complete these requirements on schedule will result in formal warnings and eventual dismissal from the program.

30. *Third year and beyond:*

l. *dissertation and dissertation defense:* a completed draft of the dissertation must be turned in to the student's oral examination committee at least one month before the oral exam is scheduled to take place. See University guidelines for the composition of this committee in the "Graduate Degrees" section of this bulletin.

*Ecology, Evolution, and Population Biology Track—*

*First year:*

m. *advising committee:* each entering student is assigned a first-year advising committee whose function is to develop a schedule of required and recommended courses and to meet once each quarter with the student during the first year.

n. *core curriculum:* Students are required to take BIO 302, 303, 304, Current Topics and Concepts in Population Biology, Ecology, and Evolution.

o. *first-year paper:* each student must submit a paper that is evaluated by the advising committee before the end of Spring Quarter of the first year. This paper should be a step toward the development of a dissertation proposal and may consist of an analysis of new data or a literature review and synthesis. The first-year paper must be evaluated by a minimum of two faculty members.

31. *Second year:*

p. *dissertation proposal:* during Spring quarter of the second year, the student must prepare a dissertation proposal that outlines the student's projected dissertation research, including an expert assessment of the current literature. An oral examination is held after submission of the proposal to the dissertation advising committee comprised of three faculty members. Advancement to candidacy depends on completion of the dissertation proposal and oral exam. The written proposal is due by May 15, and the oral defense must take place no later than June 15. Failure to complete these requirements on schedule will result in formal warnings and eventual dismissal from the program.

32. *Third year and beyond:*

q. *dissertation and dissertation defense:* a completed draft of the dissertation must be turned in to the student's oral examination committee at least one month before the oral exam is scheduled to take place. See University guidelines for the composition of this committee in the "Graduate Degrees" section of this bulletin.

# BIOLOGY (BIO) COURSES

For information on undergraduate and graduate programs in the Department of Biology, see the "Biology," section of this bulletin. Course and laboratory instruction in the Department of Biology conforms to the "Policy on the Use of Vertebrate Animals in Teaching Activities," the text of which is available at http://www.stanford.edu/dept/DoR/rph/8-2.html. See the "Biology, Hopkins Marine Station Courses" section of this bulletin for additional offerings of interest.

## UNDERGRADUATE COURSES IN BIOLOGY

**BIO 1. Human Evolution and Environment**
Human genetic and cultural evolution and how people interact with their environments, from the ancestors of Australopithecus to current events. Issues include race, gender, and intelligence; pesticide and antibiotic resistance; abortion and contraception; ecosystem services; environmental economics and ethics; the evolution of religion; climate change; population growth and overconsumption; origins and spread of ideas and technologies; and the distribution of political and economic power. GER:DB-NatSci

*3 units, Spr (Ehrlich, P)*

**BIO 2. Current Research Topics in Biology**
Primarily for sophomores interested in majoring in Biology. Weekly seminars by faculty: molecular biology and genetics; theory and mathematics in biology; ecology, physiology, and the environment; molecular and cellular aspects of neurobiology, immunology, and developmental biology; biological chemistry; behavioral biology; and evolution. May be repeated for credit.

*1 unit, Aut (Riepel, A), Win (Riepel, A)*

**BIO 13N. Environmental Problems and Solutions**
Stanford Introductory Seminar. Preference to freshmen. Students do independent investigations of current environmental problems, analyzing differing views of them and discussing possible solutions. Each student gives two seminar presentations and leads two seminar discussions. Short, documented position papers are written for policy makers. GER:DB-NatSci

*3 units, Spr (Ehrlich, P)*

**BIO 14N. Plants and Civilization**
Stanford Introductory Seminar. Preference to freshmen. The role of plants in the development of civilization. Topics: the use of forests, woodlands, and grazing lands; centers of origins and spread of crops; viticulture, and wine and beer making; the spice route and the age of exploration; the use of plants as medicine; the global spread of weeds; engineering plants for the future; the importance of tea, coffee, chocolate, sugar, potatoes, natural dyes, and rubber in societal affairs and change. GER:DB-NatSci

*3 units, Win (Mooney, H)*

**BIO 15N. Environmental Literacy**
Stanford Introductory Seminar. Preference to freshmen. Lack of public understanding of the details of most environmental problems is cited as a cause of environmental deterioration. Good citizenship requires literacy about the elements of the scientific and decision making processes that accompany most environmental issues: what can happen, what are the odds, how can the credibility of sources of expertise be assessed, which components of environmental debates deal with factual and theoretical issues, and which are political value judgments? GER:DB-NatSci

*3 units, Win (Schneider, S)*

**BIO 20. Introduction to Brain and Behavior**
(Same as HUMBIO 21.) Evolutionary principles to understand how the brain regulates behavior, described in physiological terms, and is influenced by behavioral interactions. Topics include neuron structure and function, transmission of neural information, anatomy and physiology of sensory and motor systems, regulation of body states, the biological basis of learning and memory, and behavioral abnormalities. GER:DB-NatSci

*3 units, Aut (Fernald, R), alternate years, not given next year*

**BIO 25N. Biogeography of Disease**
Stanford Introductory Seminar. Preference to freshmen. Geographic distribution of disease. Biotic interactions among vectors, hosts, and environment. Influence of climatic and environmental change on spread and virulence of disease. Human and animal diseases. Primary literature. GER:DB-NatSci

*3 units, Aut (Hadly, E)*

**BIO 25Q. The Molecular Basis of Genetic Disease**
Stanford Introductory Seminar. Preference to sophomores. Focus is on two genetic diseases resulting from the production of protein molecules that are unable to fold into their native conformations, called conformational diseases: cystic fibrosis and amyotrophic lateral sclerosis or Lou Gehrig's disease. Hypotheses and controversies surrounding the molecular basis of these disorders, and implications for novel therapeutics. Readings from research literature. GER:DB-NatSci

*3 units, Spr (Kopito, R)*

**BIO 26N. Maintenance of the Genome**
Stanford Introductory Seminar. Preference to freshmen. Focus is on DNA repair systems which scan the genome to ensure genomic stability in the face of natural endogenous threats to DNA and those due to radiation and chemicals in the external environment. Redundancy of the genetic message ensured by complementary DNA strands facilitates recovery of information when one of the strands is altered. Predisposition to cancer often implicates a defective DNA repair gene. Relevance for oncology, aging, developmental biology, environmental health, and neurobiology. GER:DB-NatSci

*3 units, Spr (Hanawalt, P)*

**BIO 30. Frontiers in Marine Science**
The diversity of marine environments and their inhabitants; physical ocenaography; near shore and pelagic ecology; adaptations to aquatic life and extreme conditions; and global change, conservation, and the effects of human activity. Field trip to Stanford's Hopkins Marine Station; taught by Hopkins faculty.

*2 units, Aut (Denny, M; Micheli, F; Somero, G)*

**BIO 31Q. Ants: Behavior, Ecology, and Evolution**
Stanford Introductory Seminar. Preference to sophomores. Behavior: the organization of colonies, how they operate without central control, how they resemble other complex systems like brains. Ecology: how populations of colonies change, comparing the ecology of a species in SW American desert and invasive Argentine ants. Evolution: why are there so many species of ants; how are they alike, how do they differ, and why? Ants as the theme for exploring how to do research in animal behavior, ecology, and evolution. Research project will be on the invasive Argentine ant: its distribution on campus, foraging trails, and nest structure.

*3 units, Spr (Gordon, D)*

**BIO 33N. Conservation Science and Practice**
Stanford Introductory Seminar. Preference to freshmen. Interdisciplinary. The science and art of conservation today. The forces that are driving change in Earth's atmosphere, lands, waters, and variety of life forms. Which broad dimensions of the biosphere, and which elements of ecosystems, most merit protection? The

prospects for, and challenges in, making conservation economically attractive and commonplace. Field trip; project. GER:DB-NatSci

*3 units, Spr (Daily, G)*

**BIO 41. Genetics, Biochemistry, and Molecular Biology**

First of a three part sequence, preferably taken in the sophomore year. Emphasis is on macromolecules (proteins, lipids, carbohydrates, and nucleic acids) and how their structure relates to function and higher order assembly; molecular biology, genome structure and dynamics, gene expression from transcription to translation. Biology majors must take course for a letter grade. Prerequisites: CHEM 31X (or 31A and B), 33, 35; MATH 19, 20, 21, or 41, 42. (Note that these prerequisites were inadvertently omitted from the printed Stanford Bulletin.) GER:DB-NatSci

*5 units, Aut (Simoni, R; Bergmann, D)*

**BIO 42. Cell Biology and Animal Physiology**

Second of a three part sequence, preferably taken in the sophomore year. Cell structure and function; principles of animal physiology (immunology, renal, cardiovascular, sensory, motor physiology, and endocrinology); neurobiology from cellular basis to neural regulation of physiology. Biology majors must take course for a letter grade. Prerequisites: CHEM 31X (or 31A and B), 33, 35; MATH 19, 20, 21, or 41, 42. (Note that these prerequisites were inadvertently omitted from the printed Stanford Bulletin.) GER:DB-NatSci

*5 units, Win (Cyert, M; Jones, P; Heller, C; Sapolsky, R)*

**BIO 43. Plant Biology, Evolution, and Ecology**

Third of a three part sequence, preferably taken in the sophomore year. Principles of evolution: macro- and microevolution and population genetics. Ecology: the principles underlying the exchanges of mass and energy between organisms and their environments; population, community, and ecosystem ecology; populations, evolution, and global change. Equivalent to BIOHOPK 43. Biology majors must take course for a letter grade. Prerequisites: CHEM 31X (or 31A and B), 33, 35; MATH 19, 20, 21, or 41, 42. (Note that these prerequisites were inadvertently omitted from the printed Stanford Bulletin.) GER:DB-NatSci

*5 units, Spr (Petrov, D; Gordon, D; Mudgett, M)*

**BIO 44X. Core Experimental Laboratory**

Two quarters of lab projects provide a working familiarity with the concepts, organisms, and techniques of modern biological research. Emphasis is on experimental design, analysis of data, and written and oral presentation of the experiments. Lab fee. Prerequisites: CHEM 31X, or 31A,B, and 33. Recommended: statistics, and concurrent enrollment in Biology or Human Biology core; 44X,Y should be taken sequentially in same year. 44Y equivalent to BIOHOPK 44Y.

*4 units, Win (Malladi, S)*

**BIO 44Y. Core Experimental Laboratory**

Two quarters of lab projects provide a working familiarity with the concepts, organisms, and techniques of modern biological research. Emphasis is on experimental design, analysis of data, and written and oral presentation of the experiments. Lab fee. Prerequisites: CHEM 31X, or 31A,B, and 33. Recommended: statistics, and concurrent enrollment in Biology or Human Biology core; 44X,Y should be taken sequentially in same year. 44Y equivalent to BIOHOPK 44Y.

*4 units, Spr (Malladi, S)*

**BIO 96A. Jasper Ridge Docent Training**

Two quarter preparation for Stanford and community students to join the Jasper Ridge education program. Multidisciplinary environmental education; hands-on field research. Field ecology and the natural history of plants and animals, archaeology, geology, hydrology, land management, and research projects of the preserve presented by faculty, local experts, and staff. Participants lead research-focused educational tours, assist with classes, and attend continuing education classes available to members of the JRBP community after the course.

*4 units, Win (Dirzo, R; Wilber, C)*

**BIO 96B. Jasper Ridge Biological Preserve Docent Training Program**

Two quarter preparation for Stanford and community students to join the Jasper Ridge education program. Multidisciplinary environmental education; hands-on field research. Field ecology and the natural history of plants and animals, archaeology, geology, hydrology, land management, and research projects of the preserve presented by faculty, local experts, and staff. Participants lead research-focused educational tours, assist with classes, and attend continuing education classes available to members of the JRBP community after the course.

*4 units, Spr (Dirzo, R; Wilber, C)*

**BIO 101. Ecology**

The principles of ecology. Topics: interactions of organisms with their environment, dynamics of populations, species interactions, structure and dynamics of ecological communities, biodiversity. Prerequisite: 43, or consent of instructor. Recommended: statistics. GER:DB-NatSci

*3 units, Aut (Dirzo, R; Vitousek, P)*

**BIO 102. Demography: Health, Development, Environment**

(Same as HUMBIO 119.) Demographic methods and their application to understanding and projecting changes in human infant, child, and adult mortality and health, fertility, population, sex ratios, and demographic transitions. Progress in human development, capabilities, and freedoms. Relationships between population and environment. Prerequisites: numeracy and basic statistics; Biology or Human Biology core; or consent of instructor. GER:DB-SocSci

*3 units, Spr (Tuljapurkar, S)*

**BIO 104. Advanced Molecular Biology**

(Same as BIO 200.) Molecular mechanisms that govern the replication, recombination, and expression of eukaryotic genomes. Topics: DNA replication, DNA recombination, gene transcription, RNA splicing, regulation of gene expression, protein synthesis, and protein folding. Prerequisite: Biology core. GER:DB-NatSci

*5 units, Win (Frydman, J; Gozani, O)*

**BIO 106. Human Origins**

(Same as ANTHRO 6, ANTHRO 206, HUMBIO 6.) The human fossil record from the first non-human primates in the late Cretaceous or early Paleocene, 80-65 million years ago, to the anatomically modern people in the late Pleistocene, between 100,000 to 50,000 B.C.E. Emphasis is on broad evolutionary trends and the natural selective forces behind them. GER:DB-NatSci

*5 units, Win (Klein, R)*

**BIO 109A. The Human Genome and Disease**

(Same as BIO 209A, HUMBIO 158.) The variability of the human genome and the role of genomic information in research, drug discovery, and human health. Concepts and interpretations of genomic markers in medical research and real life applications. Human genomes in diverse populations. Original contributions from thought leaders in academia and industry and interaction between students and guest lecturers. GER:DB-NatSci

*3 units, Win (Heller, R)*

**BIO 109B. The Human Genome and Disease: Genetic Diversity and Personalized Medicine**

(Same as BIO 209B.) Continuation of 109A/209A. Genetic drift: the path of human predecessors out of Africa to Europe and then either through Asia to Australia or through northern Russia to Alaska down to the W. Coast of the Americas. Support for this idea through the histocompatibility genes and genetic sequences that predispose people to diseases. Guest lectures from academia and pharmaceutical companies. Prerequisite: Biology or Human Biology core. GER:DB-NatSci

*3 units, Spr (Heller, R)*

**BIO 112. Human Physiology**

(Same as BIO 212, HUMBIO 133.) The functioning of organ systems emphasizing mechanisms of control and regulation. Topics: structure and function of endocrine and central nervous systems, cardiovascular physiology, respiration, salt and water balance, exercise, and gastrointestinal physiology. Prerequisite: Biology or Human Biology core. GER:DB-NatSci

*4 units, Win (Garza, D)*

**BIO 113. Fundamentals of Molecular Evolution**

(Same as BIO 244.) The inference of key molecular evolutionary processes from DNA and protein sequences. Topics include random genetic drift, coalescent models, effects and tests of natural selection, combined effects of linkage and natural selection, codon bias and

genome evolution. Prerequisites: Biology core or graduate standing in any department, and consent of instructor. GER:DB-NatSci

*4 units, not given this year*

**BIO 114. Field Course on Tropical Biogeochemistry: Amazon as Case Study**

(Same as EARTHSYS 114.) Post-field seminar for students who went on the two-week field trip to the Amazon in September with Brazilian students under Professor Martinelli of the University of São Paulo and Stanford Latin American Studies. Land use changes over the last 30 years including the conversion of natural forest for cattle ranching and soy beans in the Amazon, the largest continuous area of tropical forests on Earth with the greatest number of plant and animal species. In English.

*3 units, not given this year*

**BIO 117. Biology and Global Change**

(Same as EARTHSYS 111, EESS 111.) The biological causes and consequences of anthropogenic and natural changes in the atmosphere, oceans, and terrestrial and freshwater ecosystems. Topics: glacial cycles and marine circulation, greenhouse gases and climate change, tropical deforestation and species extinctions, and human population growth and resource use. Prerequisite: Biology or Human Biology core or graduate standing. GER:DB-NatSci

*4 units, Win (Vitousek, P; Arrigo, K)*

**BIO 118. Genetic Analysis of Biological Processes**

(Same as BIO 218.) Genetic principles and their experimental applications. Emphasis is on the identification and use of mutations to study cellular function. Prerequisite: Biology core. GER:DB-NatSci

*5 units, Spr (Staff)*

**BIO 121. Biogeography**

Global distributions of organisms through the Phanerozoic, with emphasis on historical causes. Topics: plate tectonics, island biogeography, climatic change, dispersal, vicariance, ecology of invasions, extinction, gradients, diversity. GER:DB-NatSci

*3 units, Spr (Hadly, E), alternate years, not given next year*

**BIO 125. Ecosystems of California**

The diversity and functioning of California ecosystems through time and how human beings have impacted and managed them. Prerequisite: 43, HUMBIO 2A, or EARTHSYS 10. GER:DB-NatSci

*3 units, Spr (Mooney, H)*

**BIO 129A. Cellular Dynamics I: Cell Motility and Adhesion**

Cell motility emphasizing role of actin assembly and dynamics coupling actin organization to cell movement. Interaction of cells with extracellular matrix, and remodelling of extracellular matrix in development and disease. Directed cell migration by chemotaxis (neuronal path-finding, immune cells). Cell-cell adhesion, formation of intercellular junctions and mechanisms regulating cell-cell interactions in development and diseases. Experimental logic, methods, problem solving, and interpretation of results. Students present research papers. Prerequisite: Biology core. GER:DB-NatSci

*4 units, not given this year*

**BIO 129B. Cellular Dynamics II: Building a Cell**

Principles of cell organization; how common biochemical pathways are modified to generate diversity in cell structure and function. Roles of actin and microtubule cytoskeletons in cellular architecture. Mechanisms of protein sorting and trafficking, and protein modules and switches in regulating cell polarity. Yeast to polarized epithelial cells and neurons. Experimental logic, methods, problem solving, and interpretation of results. Students present research papers. Prerequisite: Biology core. Recommended: 129A. GER:DB-NatSci

*4 units, not given this year*

**BIO 130. Current Issues in Paleoanthropology**

(Same as ANTHRO 162C, ANTHRO 262C.) Current issues in fossil, archaeological, and genetic evidence for human evolution. Topics chosen by participants. May be repeated for credit.

*1 unit, Aut (DeGusta, D), Win (DeGusta, D), Spr (DeGusta, D)*

**BIO 132. Advanced Imaging Lab in Biophysics**

(Same as BIO 232, BIOPHYS 232, MCP 232.) Laboratory and lectures. Advanced microscopy and imaging, emphasizing hands-on experience with state-of-the-art techniques. Students construct and operate working apparatus. Topics include microscope optics, Koehler illumination, contrast-generating mechanisms (bright/dark field, fluorescence, phase contrast, differential interference contrast), and resolution limits. Laboratory topics vary by year, but include single-molecule fluorescence, fluorescence resonance energy transfer, confocal microscopy, two-photon microscopy, and optical trapping. Limited enrollment. Recommended: basic physics, Biology core or equivalent, and consent of instructor. GER:DB-NatSci

*4 units, Spr (Block, S; Schnitzer, M; Smith, S; Stearns, T)*

**BIO 133. Genetics of Prokaryotes**

Genetic approaches for understanding cellular processes in bacteria, including metabolism, adaptive and stress responses, signal transduction, gene expression, genetic exchange and recombination, chromosome dynamics and evolution, cell division, motility, surface attachment, and developmental responses. Emphasis is on the power of effectively combining genetics with biochemistry, microscopy, and genomics. Prerequisite: Biology core. GER:DB-NatSci

*4 units, Aut (Burkholder, W; Campbell, A), alternate years, not given next year*

**BIO 134. Replication of DNA**

Seminar. Modes of DNA replication and their control in prokaryotes and eukaryotes. Structures, properties, and functions of DNA polymerases and associated factors. Emphasis is on experimental approaches and their limitations. Current research literature. Students prepare journal club style report and lead class discussions. Enrollment limited to 20 advanced undergraduates. Prerequisite: Biology core. Recommended: 118. GER:DB-NatSci

*3 units, Win (Burkholder, W)*

**BIO 135. Biological Clocks**

(Same as HUMBIO 186.) The biological basis for endogenous timekeeping in organisms from flies to human beings. How biological clocks are constructed at the molecular, tissue, and behavioral levels; how these clocks interact with other physiological systems and allow animals to anticipate changes in their environment. Applications of circadian rhythm principles to treating human disorders and diseases such as cancer. Prerequisite: Biology or Human Biology core, or consent of instructor. GER:DB-NatSci

*3 units, not given this year*

**BIO 136. Evolutionary Paleobiology**

A paleontological approach to evolutionary theory. History of life, speciation, heterochrony, evolutionary constraint, coevolution, macroevolution, Cambrian Explosion, mass extinctions, taphonomy, life on land, life in the sea, life in the air. GER:DB-NatSci

*4 units, not given this year*

**BIO 137. Plant Genetics**

(Same as BIO 237.) Gene analysis, mutagenesis, transposable elements; developmental genetics of flowering and embryo development; biochemical genetics of plant metabolism; scientific and societal lessons from transgenic plants. Prerequisite: Biology core or consent of instructor. GER:DB-NatSci

*3-4 units, Spr (Walbot, V)*

**BIO 139. Biology of Birds**

How birds interact with their environments and each other, emphasizing studies that had impact in the fields of population biology, community ecology, and evolution. Local bird communities. Emphasis is on field research. Enrollment limited to 20. Prerequisites: 43 or equivalent, and consent of instructor. Recommended: birding experience. GER:DB-NatSci

*3 units, Spr (Root, T), alternate years, not given next year*

**BIO 140. Population Biology of Butterflies**

Field work on Euphydryas populations under study on campus and elsewhere in California. Course offered as participation in research when conditions permit; decisions not made until Winter Quarter. Prerequisites: 43 and consent of instructor.

*2-5 units, not given this year*

**BIO 141. Biostatistics**

(Same as STATS 141.) Introductory statistical methods for biological data: describing data (numerical and graphical summaries); introduction to probability; and statistical inference (hypothesis tests and confidence intervals). Intermediate statistical methods: comparing groups (analysis of variance); analyzing associations (linear and logistic regression); and methods for categorical data (contingency tables and odds ratio). Course content

integrated with statistical computing in R. See http://www-stat.stanford.edu/~rag/stat141/. GER:DB-Math

*4-5 units, Aut (Boik, J; Rogosa, D)*

**BIO 143. Evolution**
(Same as BIO 243.) The basic facts and principles of the evolution of all life. The logic of and evidence for the correctness of Darwin's argument for evolution by natural selection. How Mendelian genetics was integrated into evolutionary thinking. The integration of physiological and ecological perspectives into the study of evolutionary adaptation within species. Species formation and evolutionary divergence among species. Patterns of evolution over long time scales. GER:DB-NatSci

*3 units, Aut (Watt, W)*

**BIO 144. Conservation Biology**
(Same as HUMBIO 112.) Principles and application of the science of preserving biological diversity. Topics: sources of endangerment of diversity; the Endangered Species Act; conservation concepts and techniques at the population, community, and landscape levels; reserve design and management; conflict mediation. 4 units if taken with a service learning component. Prerequisite: BIO 101, or BIO 43 or HUMBIO 2A with consent of instructor. GER:DB-NatSci

*3-4 units, Win (Boggs, C; Launer, A)*

**BIO 145. Behavioral Ecology**
(Same as BIO 245.) Animal behavior from an evolutionary and ecological perspective. Topics: foraging, territoriality, reproductive behavior, social groups. Lecture/seminar format; seminars include discussion of journal articles. Independent research projects. Prerequisites: Biology or Human Biology core, or consent of instructor. Recommended: statistics. GER:DB-NatSci

*4 units, alternate years, not given this year*

**BIO 146. Population Studies**
Series of talks by distinguished speakers introducing approaches to population and resource studies.

*1 unit, Win (Tuljapurkar, S)*

**BIO 147. Controlling Climate Change in the 21st Century**
(Same as BIO 247, EARTHSYS 147, EARTHSYS 247, HUMBIO 116.) Global climate change science, impacts, and response strategies. Topics: scientific understanding of the climate system; modeling future climate change; global and regional climate impacts and vulnerability; mitigation and adaptation approaches; the international climate policy challenge; and decarbonization of energy and transportation systems. GER:DB-NatSci

*3 units, Win (Schneider, S; Mastrandrea, M), alternate years, not given next year*

**BIO 149. The Neurobiology of Sleep**
(Same as BIO 249, HUMBIO 161. Graduate students register for 249.) Preference to seniors and graduate students. The neurochemistry and neurophysiology of changes in brain activity and conscious awareness associated with changes in the sleep/wake state. Behavioral and neurobiological phenomena including sleep regulation, sleep homeostasis, circadian rhythms, sleep disorders, sleep function, and the molecular biology of sleep. Enrollment limited to 16. GER:DB-NatSci

*4 units, Win (Heller, C)*

**BIO 150. Human Behavioral Biology**
(Same as BIO 250, HUMBIO 160.) Multidisciplinary. How to approach complex normal and abnormal behaviors through biology. How to integrate disciplines including sociobiology, ethology, neuroscience, and endocrinology to examine behaviors such as aggression, sexual behavior, language use, and mental illness. GER:DB-NatSci

*5 units, alternate years, not given this year*

**BIO 151. Mechanisms of Neuron Death**
For Biology majors with background in neuroscience. Cell and molecular biology of neuron death during neurological disease. Topics: the amyloid diseases (Alzheimer's), prion diseases (kuru and Creutzfeldt-Jakob), oxygen radical diseases (Parkinson's and ALS), triplet repeat diseases (Huntington's), and AIDS-related dementia. Student presentations. Enrollment limited to 15; application required. GER:DB-NatSci

*3 units, Aut (Sapolsky, R)*

**BIO 152. Imaging: Biological Light Microscopy**
(Same as MCP 222, NBIO 222.) Survey of instruments which use light and other radiation for analysis of cells in biological and medical research. Topics: basic light microscopy through confocal fluorescence and video/digital image processing. Lectures on physical principles; involves partial assembly and extensive use of lab instruments. Lab. Prerequisites: some college physics, Biology core. GER:DB-NatSci

*3 units, alternate years, not given this year*

**BIO 153. Cellular Neuroscience: Cell Signaling and Behavior**
(Same as PSYCH 120.) Neural interactions underlying behavior. Prerequisites: PSYCH 1 or basic biology. GER:DB-NatSci

*4 units, not given this year*

**BIO 154. Molecular and Cellular Neurobiology**
(Same as BIO 254, NBIO 254.) For advanced undergraduates and graduate students. Cellular and molecular mechanisms in the organization and functions of the nervous system. Topics: wiring of the neuronal circuit, synapse structure and synaptic transmission, signal transduction in the nervous system, sensory systems, molecular basis of behavior including learning and memory, molecular pathogenesis of neurological diseases. Prerequisite for undergraduates: Biology core or equivalent, or consent of instructors. GER:DB-NatSci

*4 units, Aut (Luo, L; Shen, K; Clandinin, T), alternate years, not given next year*

**BIO 157. Plant Biochemistry**
(Same as BIO 257.) The biochemistry of plants relevant to their physiology and cell biology. Topics include: the biosynthesis, assembly, function, and regulation of cell walls; lipids; pigments; photoreceptors; transporters; and the response of plants to pathogens and stresses. Prerequisite: Biology core or equivalent, or consent of instructors. GER:DB-NatSci

*3-4 units, Spr (Mudgett, M), alternate years, not given next year*

**BIO 158. Developmental Neurobiology**
For advanced undergraduates and coterminal students. The principles of nervous system development from the molecular control of patterning, cell-cell interactions, and trophic factors to the level of neural systems and the role of experience in influencing brain structure and function. Topics: neural induction and patterning cell lineage, neurogenesis, neuronal migration, axonal pathfinding, synapse elimination, the role of activity, critical periods, and the development of behavior. Prerequisite: BIO 42 or equivalent. GER:DB-NatSci

*4 units, Spr (McConnell, S; Shen, K; Garner, C), alternate years, not given next year*

**BIO 160A. Developmental Biology and Signal Transduction I**
Focus is on the molecular mechanisms underlying the generation of diverse cell types and tissues during embryonic and post-embryonic animal development. The role of cell-cell communication in controlling key developmental decisions. Embryonic axis formation, cell fate specification, regulation of tissue and animal size, tissue regeneration, and the evolution of developmental mechanisms. Experimental logic and methods of research in developmental biology. Discussions of research papers. Prerequisite: Biology core or consent of instructor. GER:DB-NatSci

*4 units, Win (Simon, M)*

**BIO 160B. Developmental Biology and Signal Transduction II**
Continuation of BIO 160A. Focus is on the molecular mechanisms underlying the generation of diverse cell types and tissues during embryonic and post-embryonic animal development. The role of cell-cell communication in controlling key developmental decisions. Embryonic axis formation, cell fate specification, regulation of tissue and animal size, tissue regeneration, and the evolution of developmental mechanisms. Experimental logic and methods of research in developmental biology. Discussions of research papers. Prerequisites: Biology Core and BIO 160A, or consent of instructor. GER:DB-NatSci

*4 units, Spr (Simon, M)*

**BIO 161. Molecular Basis of Biological Communication**
Across molecular, cellular, organismal and communal biological scales, communication among elements of a system is required for its function. The molecules and logic at the heart of communication

at levels from the interactions between cells in a developing body to how organisms perceive and respond to their physical environment and the organisms around them; how these systems normally work and how failures in communication result in and from disease. Current research literature. Prerequisites: BIO 41, 42. Recommended: BIO 160A, 129A.

*4 units, Spr (Bergmann, D), alternate years, not given next year*

**BIO 163. Neural Systems and Behavior**

(Same as BIO 263, HUMBIO 163.) The field of neuroethology and its vertebrate and invertebrate model systems. Research-oriented. Readings include reviews and original papers. How animal brains compare; how neural circuits are adapted to species-typical behavior; and how the sensory worlds of different species represent the world. Prerequisites: BIO 42, HUMBIO 4A, or equivalents. GER:DB-NatSci

*4 units, alternate years, not given this year*

**BIO 164. Biosphere-Atmosphere Interactions**

(Same as BIO 264.) Physiological, ecological, and physical aspects of ecosystem function, emphasizing how ecosystems influence and are influenced by the atmosphere. Prerequisites: 42, 43; or consent of instructor. GER:DB-NatSci

*4 units, Win (Field, C; Berry, J), alternate years, not given next year*

**BIO 165. Cellular and Molecular Therapeutic Approaches to Neurological Disorders**

(Same as BIO 265.) Current therapeutic research for neurological conditions, including stroke, epilepsy, neurodegenerative disorders, depression, anxiety, and aging. Sources include primary literature. Guest lecturers.

*1 unit, Win (Sorrells, S)*

**BIO 166. Fanual Analysis: Animal Remains for the Archaeologist**

(Same as ANTHRO 113, ANTHRO 213, BIO 266.) The analysis of fossil animal bones and shells to illuminate the behavior and ecology of prehistoric collectors, especially ancient humans. Theoretical and methodoloigcal issues. The identification, counting, and measuring of fossil bones and shells. Labs. Methods of numerical analysis.

*5 units, Spr (Klein, R)*

**BIO 175. Tropical Ecology and Conservation**

Field trip to a field station at Los Tuxtlas, Mexico; lectures at Stanford. How to address scientific questions concerning ecology and conservation. Field trip includes natural history observations and group research projects. Symposium based on project results. Recommended: 43, 101, and 141 or STATS 60. GER:DB-NatSci

*5 units, Spr (Dirzo, R)*

**BIO 177. Plant/Microbe Interactions**

(Same as BIO 277.) Plant pathology and plant symbiosis.Topics include: prokaryotic and eukaryotic pathogens; molecular, genetic, and cellular basis for microbial pathogenicity and host defense; genetics and cell biology of nitrogen-fixing symbiosis and for mycorrhizal associations. Evolutionary context. Prerequisites: Biology core and two or more upper division courses in genetics, molecular biology, or biochemistry. Recommended: plant genetics or plant biochemistry.

*3 units, alternate years, not given this year*

**BIO 178. Microbiology Literature**

(Same as BIO 278.) Critical reading of the research literature in prokaryotic genetics and molecular biology. For advanced undergraduates and first or second year graduate students. Classic and foundational papers in microbiology and molecular biology; more recent literature on prokaryotic biochemistry, genomics, pathogenesis, and cell biology. Prerequisites: Biology Core and two upper-division courses in genetics, molecular biology, or biochemistry.

*3 units, Win (Long, S)*

**BIO 180. Fundamentals of Sustainable Agriculture**

(Same as BIO 280, EARTHSYS 180, EARTHSYS 280.) Ecological, economic, and social dimensions of sustainable agriculture in the context of a growing world population. Focus is on management and technological approaches, and historical content of agricultural growth and change, organic agriculture, soil and water resource management, nutrient and pest management, biotechnology, ecosystem services, and climate change. GER:DB-NatSci

*3 units, Spr (Naylor, R), alternate years, not given next year*

**BIO 183. Theoretical Population Genetics**

(Same as BIO 283.) Models in population genetics and evolution. Selection, random drift, gene linkage, migration, and inbreeding, and their influence on the evolution of gene frequencies and chromosome structure. Models are related to DNA sequence evolution. Prerequisites: calculus and linear algebra, or consent of instructor.

*3 units, not given this year*

**BIO 185. Evolution of Reproductive Social Behavior**

(Same as BIO 285.) Seminar. Controversies surounding theory and data for the evolution of sex, gender, and sexuality. Issues include the critique of Darwin's theory of sexual selection, and the accuracy of the metaphor of universal selfishness and sexual conflict in biological nature. Readings include Evolution's Rainbow and The Genial Gene, and primary literature. GER:DB-NatSci

*3 units, Aut (Roughgarden, J), alternate years, not given next year*

**BIO 188. Biochemistry I**

(Same as BIO 288, CHEMENG 181, CHEMENG 281, CHEM 181. CHEMENG offerings formerly listed as 188/288.) Chemistry of major families of biomolecules including proteins, nucleic acids, carbohydrates, lipids, and cofactors. Structural and mechanistic analysis of properties of proteins including molecular recognition, catalysis, signal transduction, membrane transport, and harvesting of energy from light. Molecular evolution. Prerequisites: CHEM 135 or 171. GER:DB-NatSci

*3 units, Win (Zare, R; Altman, D)*

**BIO 189. Biochemistry II**

(Same as BIO 289, CHEMENG 183, CHEMENG 283, CHEM 183. CHEMENG offerings formerly listed as 189/289.) Metabolism. Glycolysis, gluconeogenesis, citric acid cycle, oxidative phosphorylation, pentose phosphate pathway, glycogen metabolism, fatty acid metabolism, protein degradation and amino acid catabolism, protein translation and amino acid biosynthesis, nucleotide biosynthesis, DNA replication, recombination and repair, lipid and steroid biosynthesis. Medical consequences of impaired metabolism. Therapeutic intervention of metabolism. Prerequisite: BIO 188/288 or CHEM 181 or CHEMENG 181/281 (formerly 188/288). GER:DB-NatSci

*3 units, Spr (Dunn, A)*

**BIO 191. Research in Bird Biology**

Field research in ornithology emphasizing ecological relationships. Projects involve research, planned and carried out by the student in consultation with the instructor. Results are written in publication format. Enrollment limited. Prerequisites: 43, concurrent or subsequent enrollment in 139, and consent of instructor.

*1-4 units, Win (Root, T), Spr (Root, T)*

**BIO 193. Undergraduate Journal Club**

Weekly discussion, led by students and facilitated by faculty, for reading scientific literature and presenting papers. Prerequisites: Biology core and consent of instructor. Recommended: 199 or 199X.

*1 unit, not given this year*

**BIO 198. Directed Reading in Biology**

Individually arranged under supervision of members of the faculty.

*1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)*

**BIO 198X. Out-of-Department Directed Reading**

Individually arranged under the supervision of members of the faculty. Credit for work arranged with out-of-department faculty is restricted to Biology majors and requires department approval. See http://biohonors.stanford.edu for information and petitions. May be repeated for credit.

*1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)*

**BIO 199. Advanced Research Laboratory in Experimental Biology**

Individual research taken by arrangement with in-department instructors. See http://biohonors.stanford.edu for information on research sponsors, units, and credit for summer research. May be repeated for credit.

*1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)*

**BIO 199X. Out-of-Department Advanced Research Laboratory in Experimental Biology**
Individual research by arrangement with out-of-department instructors. Credit for 199X is restricted to declared Biology majors and requires department approval. See http://biohonors.stanford.edu for information on research sponsors, units, petitions, deadlines, credit for summer research, and out-of-Stanford research. May be repeated for credit.

*1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)*

# GRADUATE COURSES IN BIOLOGY

Primarily for graduate students; undergraduates may enroll with consent of instructor.

**BIO 200. Advanced Molecular Biology**
(Same as BIO 104.) Molecular mechanisms that govern the replication, recombination, and expression of eukaryotic genomes. Topics: DNA replication, DNA recombination, gene transcription, RNA splicing, regulation of gene expression, protein synthesis, and protein folding. Prerequisite: Biology core.

*5 units, Win (Frydman, J; Gozani, O)*

**BIO 203. Advanced Genetics**
(Same as DBIO 203, GENE 203.) For graduate students in Bioscience programs; may be appropriate for graduate students in other programs. The genetic toolbox. Examples of analytic methods, genetic manipulation, genome analysis, and human genetics. Emphasis is on use of genetic tools in dissecting complex biological pathways, developmental processes, and regulatory systems. Faculty-led discussion sections with evaluation of papers. Students with minimal experience in genetics should prepare by working out problems in college level textbooks.

*4 units, Aut (Stearns, T; Barsh, G; Sidow, A)*

**BIO 205. DNA Repair and Genomic Stability**
Interactions of endogenous and environmental mutagens with cellular DNA. Cellular responses to damaged DNA including molecular mechanisms for DNA repair, translesion DNA synthesis, and genetic recombination. Inducible repair responses and error-prone mechanisms. Human hereditary diseases that predispose to cancer. Relationships of DNA repair to mutagenesis, carcinogenesis, aging, and human genetic disease. Current research literature. Prerequisites: 41 and 118, or consent of instructor.

*3 units, Spr (Hanawalt, P)*

**BIO 206. Field Studies in Earth Systems**
(Same as EARTHSYS 189.) For advanced upper-division undergraduates and graduate students. Field-based, focusing on the components and processes by which terrestrial ecosystems function. Topics from biology, chemistry, ecology, geology, and soil science. Lecture, field, and lab studies emphasize standard field techniques, experimental design, analysis of data, and written and oral presentation. Small team projects test the original questions in the functioning of natural ecosystems. Admission by application; see Axess. Prerequisites: BIO 141 or EESS 160 (formerly GES 160), or equivalent.

*5 units, Spr (Chiariello, N; Dirzo, R; Field, C; Fendorf, S; Freyberg, D; Matson, P), alternate years, not given next year*

**BIO 207. Life and Death of Proteins**
How proteins are made and degraded in the cell. Discussion of primary literature. Case studies follow the evolution of scientific ideas, and evaluate how different experimental approaches contribute to our understanding of a biological problem. Topics: protein folding and assembly, mechanisms of chaperone action, sorting into organelles and the ubiquitin-proteasome pathway. Enrollment limited to 20.

*3 units, Spr (Frydman, J)*

**BIO 209A. The Human Genome and Disease**
(Same as BIO 109A, HUMBIO 158.) The variability of the human genome and the role of genomic information in research, drug discovery, and human health. Concepts and interpretations of genomic markers in medical research and real life applications. Human genomes in diverse populations. Original contributions from thought leaders in academia and industry and interaction between students and guest lecturers.

*3 units, Win (Heller, R)*

**BIO 209B. The Human Genome and Disease: Genetic Diversity and Personalized Medicine**
(Same as BIO 109B.) Continuation of 109A/209A. Genetic drift: the path of human predecessors out of Africa to Europe and then either through Asia to Australia or through northern Russia to Alaska down to the W. Coast of the Americas. Support for this idea through the histocompatibility genes and genetic sequences that predispose people to diseases. Guest lectures from academia and pharmaceutical companies. Prerequisite: Biology or Human Biology core.

*3 units, Spr (Heller, R)*

**BIO 212. Human Physiology**
(Same as BIO 112, HUMBIO 133.) The functioning of organ systems emphasizing mechanisms of control and regulation. Topics: structure and function of endocrine and central nervous systems, cardiovascular physiology, respiration, salt and water balance, exercise, and gastrointestinal physiology. Prerequisite: Biology or Human Biology core.

*4 units, Win (Garza, D)*

**BIO 213. Biology of Viruses**
Principles of virus growth, genetics, architecture, and assembly. The relation of temperate viruses and other episomes to the host cell. Prerequisite: Biology core. Recommended: 118.

*3 units, Win (Campbell, A)*

**BIO 214. Advanced Cell Biology**
(Same as BIOC 224.) For Ph.D. students. Current research on cell structure, function, and dynamics. Topics include complex cell phenomena such as cell division, apoptosis, compartmentalization, transport and trafficking, motility and adhesion, differentiation, and multicellularity. Current papers from the primary literature. Prerequisite for advanced undergraduates: BIO 129A,B, and consent of instructor.

*2-5 units, Win (Kopito, R; Pfeffer, S; Nelson, W; Theriot, J; Straight, A)*

**BIO 215. Biochemical Evolution**
Biochemical viewpoints on the evolutionary process. Topics: prebiotic biochemistry and the origins of life; adaptive organization of metabolism; enzyme polymorphisms and other biochemical aspects of population genetics; macromolecular phylogeny and protein clocks. Prerequisites: Biology core or substantial equivalent.

*3 units, Win (Watt, W)*

**BIO 216. Terrestrial Biogeochemistry**
Nutrient cycling and the regulation of primary and secondary production in terrestrial, freshwater, and marine ecosystems; land-water and biosphere-atmosphere interactions; global element cycles and their regulation; human effects on biogeochemical cycles. Prerequisite: graduate standing in science or engineering; consent of instructor for undergraduates or coterminal students.

*3 units, Spr (Vitousek, P), alternate years, not given next year*

**BIO 217. Neuronal Biophysics**
Biophysical descriptions and mechanisms of passive and excitable membranes, ion channels and pumps, action potential propagation, and synaptic transmission. Introduction to dynamics of single neurons and neuronal networks. Emphasis is on the experimental basis for modern research applications. Interdisciplinary aspects of biology and physics. Literature, problem sets, and student presentations. Prerequisites: undergraduate physics, calculus, and biology.

*4 units, Win (Schnitzer, M)*

**BIO 218. Genetic Analysis of Biological Processes**
(Same as BIO 118.) Genetic principles and their experimental applications. Emphasis is on the identification and use of mutations to study cellular function. Prerequisite: Biology core.

*5 units, Spr (Staff)*

**BIO 222. Exploring Neural Circuits**
Seminar. The logic of how neural circuits control behavior; how neural circuits are assembled during development and modified by experience. Emphasis is on primary literature. Topics include: neurons as information processing units; simple and complex circuits underlying sensory information processing and motor control; and development and plasticity of neural circuits. Advanced undergraduates with background in physical science, engineering,

and biology may apply to enroll. Recommended: background in neuroscience.

*3 units, not given this year*

**BIO 223. Stochastic and Nonlinear Dynamics**
(Same as APPPHYS 223.) Theoretical analysis of dynamical processes: dynamical systems, stochastic processes, and spatiotemporal dynamics. Motivations and applications from biology and physics. Qualitative approaches, asymptotics, and multiple scale analysis. Prerequisites: ordinary and partial differential equations, complex analysis, and probability or statistical physics.

*3 units, alternate years, not given this year*

**BIO 230. Molecular and Cellular Immunology**
For graduate students and advanced undergraduates. Components of the immune system: structure and functions of antibody molecules; cellular basis of immunity and its regulation; molecular biology and biochemistry of antigen receptors and signaling pathways; genetic control of immunity and disease susceptibility. Emphasis is on key experimental approaches. Prerequisite for undergraduates: Biology or Human Biology core, or consent of instructor.

*4 units, Aut (Jones, P)*

**BIO 230A. Molecular and Cellular Immunology Literature Review**
Supplement to 230. Corequisite: 230.

*1 unit, Aut (Staff)*

**BIO 231. Evolution of Life Histories**
Life histories as descriptions of reproduction, survival, and growth over the lives of individuals. Theoretical approaches to the dynamics and evolution of life histories and of populations with different life histories. Experimental data on natural populations and methods for their analysis.

*3 units, Spr (Tuljapurkar, S), alternate years, not given next year*

**BIO 232. Advanced Imaging Lab in Biophysics**
(Same as BIO 132, BIOPHYS 232, MCP 232.) Laboratory and lectures. Advanced microscopy and imaging, emphasizing hands-on experience with state-of-the-art techniques. Students construct and operate working apparatus. Topics include microscope optics, Koehler illumination, contrast-generating mechanisms (bright/dark field, fluorescence, phase contrast, differential interference contrast), and resolution limits. Laboratory topics vary by year, but include single-molecule fluorescence, fluorescence resonance energy transfer, confocal microscopy, two-photon microscopy, and optical trapping. Limited enrollment. Recommended: basic physics, Biology core or equivalent, and consent of instructor.

*4 units, Spr (Block, S; Schnitzer, M; Smith, S; Stearns, T)*

**BIO 235. Challenges for Biodiversity Conservation in Latin America**
The largest megadiversity countries including Brazil and México. The conceptual basis of biodiversity conservation. Case studies. Topics include: habitat loss, threatened species, and hotspots; threats to the Amazon, Atlantic forest, Pantanal, and cerrado; impact of hunting; and the conflict between protected areas and parks.

*3 units, Aut (Galetti, M)*

**BIO 237. Plant Genetics**
(Same as BIO 137.) Gene analysis, mutagenesis, transposable elements; developmental genetics of flowering and embryo development; biochemical genetics of plant metabolism; scientific and societal lessons from transgenic plants. Prerequisite: Biology core or consent of instructor.

*3-4 units, Spr (Walbot, V)*

**BIO 243. Evolution**
(Same as BIO 143.) The basic facts and principles of the evolution of all life. The logic of and evidence for the correctness of Darwin's argument for evolution by natural selection. How Mendelian genetics was integrated into evolutionary thinking. The integration of physiological and ecological perspectives into the study of evolutionary adaptation within species. Species formation and evolutionary divergence among species. Patterns of evolution over long time scales.

*3 units, Aut (Watt, W)*

**BIO 244. Fundamentals of Molecular Evolution**
(Same as BIO 113.) The inference of key molecular evolutionary processes from DNA and protein sequences. Topics include random genetic drift, coalescent models, effects and tests of natural selection, combined effects of linkage and natural selection, codon bias and genome evolution. Prerequisites: Biology core or graduate standing in any department, and consent of instructor.

*4 units, not given this year*

**BIO 245. Behavioral Ecology**
(Same as BIO 145.) Animal behavior from an evolutionary and ecological perspective. Topics: foraging, territoriality, reproductive behavior, social groups. Lecture/seminar format; seminars include discussion of journal articles. Independent research projects. Prerequisites: Biology or Human Biology core, or consent of instructor. Recommended: statistics.

*4 units, alternate years, not given this year*

**BIO 247. Controlling Climate Change in the 21st Century**
(Same as BIO 147, EARTHSYS 147, EARTHSYS 247, HUMBIO 116.) Global climate change science, impacts, and response strategies. Topics: scientific understanding of the climate system; modeling future climate change; global and regional climate impacts and vulnerability; mitigation and adaptation approaches; the international climate policy challenge; and decarbonization of energy and transportation systems.

*3 units, Win (Schneider, S; Mastrandrea, M), alternate years, not given next year*

**BIO 249. The Neurobiology of Sleep**
(Same as BIO 149, HUMBIO 161. Graduate students register for 249.) Preference to seniors and graduate students. The neurochemistry and neurophysiology of changes in brain activity and conscious awareness associated with changes in the sleep/wake state. Behavioral and neurobiological phenomena including sleep regulation, sleep homeostasis, circadian rhythms, sleep disorders, sleep function, and the molecular biology of sleep. Enrollment limited to 16.

*4 units, Win (Heller, C)*

**BIO 250. Human Behavioral Biology**
(Same as BIO 150, HUMBIO 160.) Multidisciplinary. How to approach complex normal and abnormal behaviors through biology. How to integrate disciplines including sociobiology, ethology, neuroscience, and endocrinology to examine behaviors such as aggression, sexual behavior, language use, and mental illness.

*5 units, alternate years, not given this year*

**BIO 254. Molecular and Cellular Neurobiology**
(Same as BIO 154, NBIO 254.) For advanced undergraduates and graduate students. Cellular and molecular mechanisms in the organization and functions of the nervous system. Topics: wiring of the neuronal circuit, synapse structure and synaptic transmission, signal transduction in the nervous system, sensory systems, molecular basis of behavior including learning and memory, molecular pathogenesis of neurological diseases. Prerequisite for undergraduates: Biology core or equivalent, or consent of instructors.

*5 units, Aut (Luo, L; Shen, K; Clandinin, T), alternate years, not given next year*

**BIO 257. Plant Biochemistry**
(Same as BIO 157.) The biochemistry of plants relevant to their physiology and cell biology. The biosynthesis, assembly, function, and regulation of cell walls; lipids; pigments; photoreceptors; transporters; and the response of plants to pathogens and stresses. Prerequisite: Biology core or equivalent, or consent of instructors.

*3-4 units, Spr (Mudgett, M), alternate years, not given next year*

**BIO 258. Neural Development**
For Ph.D. students. Seminar; students also attend BIO 158 lectures. Topics: neural induction and patterning, cell lineage, neurogenesis, neuronal migration, axonal pathfinding, synapse elimination, the role of activity, critical periods, and the development of behavior.

*4 units, Spr (McConnell, S; Shen, K; Garner, C), alternate years, not given next year*

**BIO 263. Neural Systems and Behavior**
(Same as BIO 163, HUMBIO 163.) The field of neuroethology and its vertebrate and invertebrate model systems. Research-oriented. Readings include reviews and original papers. How animal brains compare; how neural circuits are adapted to species-typical behavior; and how the sensory worlds of different species represent the world.

Prerequisites: BIO 42, HUMBIO 4A, or equivalents.

*4 units, alternate years, not given this year*

**BIO 264. Biosphere-Atmosphere Interactions**

(Same as BIO 164.) Physiological, ecological, and physical aspects of ecosystem function. How ecosystems influence and are influenced by the atmosphere. Prerequisites: 42, 43; or consent of instructor.

*4 units, Win (Field, C; Berry, J), alternate years, not given next year*

**BIO 265. Cellular and Molecular Therapeutic Approaches to Neurological Disorders**

(Same as BIO 165.) Current therapeutic research for neurological conditions, including stroke, epilepsy, neurodegenerative disorders, depression, anxiety, and aging. Sources include primary literature. Guest lecturers.

*1 unit, Win (Sorrells, S)*

**BIO 266. Fanual Analysis: Animal Remains for the Archaeologist**

(Same as ANTHRO 113, ANTHRO 213, BIO 166.) The analysis of fossil animal bones and shells to illuminate the behavior and ecology of prehistoric collectors, especially ancient humans. Theoretical and methodoloigcal issues. The identification, counting, and measuring of fossil bones and shells. Labs. Methods of numerical analysis.

*5 units, Spr (Klein, R)*

**BIO 267. Molecular Mechanisms of Neurodegenerative Disease**

(Same as NENS 267.) The epidemic of neurodegenerative disorders such as Alzheimer's and Parkinson's disease occasioned by an aging human population. Genetic, molecular, and cellular mechanisms. Clinical aspects through case presentations.

*4 units, not given this year*

**BIO 274S. Hopkins Microbiology Course**

(Same as BIOHOPK 274, CEE 274S, EESS 253S. Formerly GES 274S.) Four-week, intensive. The interplay between molecular, physiological, ecological, evolutionary, and geochemical processes that constitute, cause, and maintain microbial diversity. How to isolate key microorganisms driving marine biological and geochemical diversity, interpret culture-independent molecular characterization of microbial species, and predict causes and consequences. Laboratory component: what constitutes physiological and metabolic microbial diversity; how evolutionary and ecological processes diversify individual cells into physiologically heterogeneous populations; and the principles of interactions between individuals, their population, and other biological entities in a dynamically changing microbial ecosystem. Prerequisites: CEE 274A,B, or equivalents.

*9-12 units, Sum (Spormann, A; Francis, C)*

**BIO 277. Plant/Microbe Interactions**

(Same as BIO 177.) Plant pathology and plant symbiosis.Topics include: prokaryotic and eukaryotic pathogens; molecular, genetic, and cellular basis for microbial pathogenicity and host defense; genetics and cell biology of nitrogen-fixing symbiosis and for mycorrhizal associations. Evolutionary context. Prerequisites: Biology core and two or more upper division courses in genetics, molecular biology, or biochemistry. Recommended: plant genetics or plant biochemistry.

*3 units, alternate years, not given this year*

**BIO 278. Microbiology Literature**

(Same as BIO 178.) Critical reading of the research literature in prokaryotic genetics and molecular biology. For advanced undergraduates and first or second year graduate students. Classic and foundational papers in microbiology and molecular biology; more recent literature on prokaryotic biochemistry, genomics, pathogenesis, and cell biology. Prerequisites: Biology Core and two upper-division courses in genetics, molecular biology, or biochemistry.

*3 units, Win (Long, S)*

**BIO 280. Fundamentals of Sustainable Agriculture**

(Same as BIO 180, EARTHSYS 180, EARTHSYS 280.) Ecological, economic, and social dimensions of sustainable agriculture in the context of a growing world population. Focus is on management and technological approaches, and historical content of agricultural growth and change, organic agriculture, soil and water resource management, nutrient and pest management, biotechnology, ecosystem services, and climate change.

*3 units, Spr (Naylor, R), alternate years, not given next year*

**BIO 283. Theoretical Population Genetics**

(Same as BIO 183.) Models in population genetics and evolution. Selection, random drift, gene linkage, migration, and inbreeding, and their influence on the evolution of gene frequencies and chromosome structure. Models are related to DNA sequence evolution. Prerequisites: calculus and linear algebra, or consent of instructor.

*3 units, not given this year*

**BIO 285. Evolution of Reproductive Social Behavior**

(Same as BIO 185.) Seminar. Controversies surounding theory and data for the evolution of sex, gender, and sexuality. Issues include the critique of Darwin's theory of sexual selection, and the accuracy of the metaphor of universal selfishness and sexual conflict in biological nature. Readings include Evolution's Rainbow and The Genial Gene, and primary literature.

*3 units, Aut (Roughgarden, J), alternate years, not given next year*

**BIO 288. Biochemistry I**

(Same as BIO 188, CHEMENG 181, CHEMENG 281, CHEM 181. CHEMENG offerings formerly listed as 188/288.) Chemistry of major families of biomolecules including proteins, nucleic acids, carbohydrates, lipids, and cofactors. Structural and mechanistic analysis of properties of proteins including molecular recognition, catalysis, signal transduction, membrane transport, and harvesting of energy from light. Molecular evolution. Prerequisites: CHEM 135 or 171.

*3 units, Win (Zare, R; Altman, D)*

**BIO 289. Biochemistry II**

(Same as BIO 189, CHEMENG 183, CHEMENG 283, CHEM 183. CHEMENG offerings formerly listed as 189/289.) Metabolism. Glycolysis, gluconeogenesis, citric acid cycle, oxidative phosphorylation, pentose phosphate pathway, glycogen metabolism, fatty acid metabolism, protein degradation and amino acid catabolism, protein translation and amino acid biosynthesis, nucleotide biosynthesis, DNA replication, recombination and repair, lipid and steroid biosynthesis. Medical consequences of impaired metabolism. Therapeutic intervention of metabolism. Prerequisite: BIO 188/288 or CHEM 181 or CHEMENG 181/281 (formerly 188/288).

*3 units, Spr (Dunn, A)*

**BIO 290. Teaching of Biology**

Open to upper-division undergraduates and graduate students. Practical experience in teaching lab biology or serving as an assistant in a lecture course. May be repeated for credit. Prerequisite: consent of instructor.

*1-5 units, Aut (Staff), Win (Staff), Spr (Staff)*

**BIO 290X. Out-of-Department Teaching**

May be repeated for credit. Prerequisite: consent of instructor.

*1-5 units, Aut (Staff), Win (Staff), Spr (Staff)*

**BIO 291. Development and Teaching of Core Experimental Laboratories**

Preparation for teaching the core experimental courses (44X and 44Y). Emphasis is on lab, speaking, and writing skills. Focus is on updating the lab to meet the changing technical needs of the students. Must be taken prior to teaching either of the above courses. May be repeated for credit. Prerequisite: selection by instructor.

*1-2 units, Aut (Staff), Win (Malladi, S)*

**BIO 294. Cellular Biophysics**

(Same as APPPHYS 294.) Physical biology of dynamical and mechanical processes in cells. Emphasis is on qualitative understanding of biological functions through quantitative analysis and simple mathematical models. Sensory transduction, signaling, adaptation, switches, molecular motors, actin and microtubules, motility, and circadian clocks. Prerequisites: differential equations and introductory statistical mechanics.

*3 units, alternate years, not given this year*

**BIO 300. Graduate Research**

For graduate students only. Individual research by arrangement with in-department instructors.

*1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)*

**BIO 300X. Out-of-Department Graduate Research**
Individual research by arrangement with out-of-department instructors. Master's students: credit for work arranged with out-of-department instructors is restricted to Biology students and requires approved department petition. See http://biohonors.stanford.edu for information on research sponsors, units, petitions, deadlines, credit for summer research, and out-of-Stanford research. May be repeated for credit.

*1-15 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)*

**BIO 301. Frontiers in Biology**
Limited to and required of first-year Ph.D. students in molecular, cellular, and developmental biology. Current research in molecular, cellular, and developmental biology emphasizing primary research literature. Held in conjunction with the department's Monday seminar series. Students and faculty meet weekly before the seminar for a student presentation and discussion of upcoming papers.

*1-3 units, Aut (Bergmann, D; Gozani, O), Win (Bergmann, D; Gozani, O)*

**BIO 302. Current Topics and Concepts in Population Biology, Ecology, and Evolution**
Required of first-year graduate students in population biology, and ecology and evolution; open to all graduate students. Major conceptual issues and developing topics.

*1 unit, Aut (Watt, W)*

**BIO 303. Current Topics and Concepts in Population Biology, Ecology, and Evolution**
Required of first-year graduate students in population biology, and ecology and evolution; open to all graduate students. Major conceptual issues and developing topics.

*1 unit, Win (Watt, W)*

**BIO 304. Current Topics and Concepts in Population Biology, Ecology, and Evolution**
Required of first-year graduate students in population biology, and ecology and evolution; open to all graduate students. Major conceptual issues and developing topics.

*1 unit, Spr (Watt, W)*

**BIO 306. Current Topics in Integrative Organismal Biology**
Limited to and required of graduate students doing research in this field. At Hopkins Marine Station.

*1 unit, Aut (Heller, C; Sapolsky, R; Fernald, R)*

**BIO 312. Ethical Issues in Ecology and Evolutionary Biology**
Focus is on ethical issues addressed in Donald Kennedy's Academic Duty and others of importance to academics and scientists in the fields of ecology, behavior, and evolutionary biology. Discussions led by faculty and outside guests. Satisfies ethics course requirement for ecology and evolutionary biology. Prerequisite: graduate standing in the ecology and evolutionary biology or marine program, or consent of instructor.

*1 unit, Aut (Ehrlich, P)*

**BIO 315. Seminar in Biochemical Evolution**
Literature review and discussion of current topics in biochemical evolution and molecular evolutionary genetics. Prerequisite: consent of instructor.

*1-3 units, Spr (Watt, W)*

**BIO 325. The Evolution of Body Size**
(Same as GES 325.) The influence of organism size on evolutionary and ecological patterns and processes. Focus is on integration of theoretical principles, observations of living organisms, and data from the fossil record. What are the physiological and ecological correlates of body size? Is there an optimum size? Do organisms tend to evolve to larger size? Does productivity control the size distribution of consumers? Does size affect the likelihood of extinction or speciation? How does size scale from the genome to the phenotype? How is metabolic rate involved in evolution of body size? What is the influence of geographic area on maximum body size?

*2 units, not given this year*

**BIO 342. Plant Biology Seminar**
Topics announced at the beginning of each quarter. Current literature. May be repeated for credit. See http://carnegiedpb.stanford.edu/seminars/seminars.php.

*1-3 units, Aut (Walbot, V), Win (Walbot, V), Spr (Walbot, V)*

**BIO 344. Advanced Seminar in Cellular Biology**
Enrollment limited to graduate students directly associated with departmental research groups working in cell biology.

*1 unit, Aut, Win, Spr (Burkholder, W; Cyert, M; Fang, G; Frydman, J; Kopito, R; Stearns, T)*

**BIO 346. Advanced Seminar on Prokaryotic Molecular Biology**
Enrollment limited to graduate students associated with departmental research groups in genetics or molecular biology.

*1 unit, Aut, Win, Spr (Long, S; Campbell, A; Spormann, A; Grossman, A; Burkholder, W; Yanofsky, C)*

**BIO 358. Advanced Topics in Biology**
Restricted to doctoral and medical students in neurobiology labs. May be repeated for credit.

*1 unit, Aut (Fernald, R; Luo, L; McConnell, S; Shen, K), Win (Fernald, R; Luo, L; McConnell, S; Shen, K), Spr (Fernald, R; Luo, L; McConnell, S; Shen, K), Sum (Staff)*

**BIO 383. Seminar in Population Genetics**
Literature review, research, and current problems in the theory and practice of population genetics and molecular evolution. Prerequisite: consent of instructor.

*1-3 units, not given this year*

**BIO 384. Theoretical Ecology**
Recent and classical research papers in ecology, and presentation of work in progress by participants. Prerequisite: consent of instructor.

*1-3 units, Aut (Roughgarden, J), Win (Roughgarden, J), Spr (Roughgarden, J)*

**BIO 385. Speaking About Science**
Communication about science occurs in settings such as presenting scientific work to an audience of peers, communicating difficult concepts in a classroom, or describing a new finding to a reporter. Focus is on practice in speaking about science, emphasizing strategies for making difficult ideas easy to understand and integrating visual aids into oral presentations. Limited to Ph.D. students.

*2 units, alternate years, not given this year*

**BIO 388. Communication and Leadership Skills**
(Same as IPER 210.) Focus is on delivering information to policy makers and the lay public. How to speak to the media, Congress, and the general public; how to write op-eds and articles; how to package ideas including titles, abstracts, and CVs; how to survive peer review, the promotion process, and give a job talk; and how to be a responsible science advocate.

*2 units, Spr (Root, T)*

**BIO 459. Frontiers in Interdisciplinary Biosciences**
(Same as BIOC 459, BIOE 459, CHEMENG 459, CHEM 459, PSYCH 459.) Students register through their affiliated department; otherwise register for CHEMENG 459. For specialists and non-specialists. Sponsored by the Stanford BioX Program. Three seminars per quarter address scientific and technical themes related to interdisciplinary approaches in bioengineering, medicine, and the chemical, physical, and biological sciences. Leading investigators from Stanford and the world present breakthroughs and endeavors that cut across core disciplines. Pre-seminars introduce basic concepts and background for non-experts. Registered students attend all pre-seminars; others welcome. See http://biox.stanford.edu/courses/459.html. Recommended: basic mathematics, biology, chemistry, and physics.

*1 unit, Aut, Win, Spr (Robertson, C)*

## OVERSEAS STUDIES COURSES IN BIOLOGY

For course descriptions and additional offerings, see the respective "Overseas Studies" courses section of this bulletin or http://bosp.stanford.edu. Students should consult their program's student services office for applicability of Overseas Studies courses to a major or minor program.

## AUSTRALIA BIOLOGY COURSES

**OSPAUSTL 10. Coral Reef Ecosystems**
*3 units, Aut (Hoegh-Guldberg, O; Ward, S; Arrigo, K)*

**OSPAUSTL 20. Coastal Resource Management**
*3 units, Aut (Johnstone, R)*

**OSPAUSTL 30. Coastal Forest Ecosystems**
*3 units, Aut (Hall, J)*

## SANTIAGO BIOLOGY COURSES

**OSPSANTG 85. Marine Ecology of Chile and the South Pacific**
*5 units, Spr (Palma, A)*