BIOLOGY

Courses offered by the Department of Biology are listed under the subject code BIO on the (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=BIO&filter-catalognumber-BIO=on) Stanford Bulletin's (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=BIO&filter-catalognumber-BIO=on) ExploreCourses web site (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=BIO&filter-catalognumber-BIO=on).

The department provides:

- a major program leading to the B.S. degree
- a minor program
- a coterminal program leading to the M.S. degree
- a doctoral program leading to the Ph.D. degree, and
- courses designed for the non-major.

Mission of the Undergraduate Program in Biology

The mission of the undergraduate program in Biology is to provide students with in-depth knowledge in the discipline, from molecular biology to ecology. Students in the program learn to think and analyze information critically, to draw connections among the different areas of biology, and to communicate their ideas effectively to the scientific community. The major exposes students to the scientific process through a set of core courses and electives from a range of subdisciplines. The Biology major serves as preparation for professional careers, including medicine, dentistry, veterinary sciences, teaching, consulting, research, and field studies.

Learning Outcomes (Undergraduate)

The department expects undergraduate majors in the program to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. Students are expected to demonstrate:

1. the ability to use discipline-specific tools and content knowledge to analyze and interpret scientific data, to evaluate the significance of the data, and to articulate conclusions supportable by the data.
2. the ability, independently and collaboratively, to formulate testable scientific hypotheses and to design approaches to obtain data to test the respective hypotheses.
3. the ability to communicate content understanding and research outcomes effectively using various media.

Mission of the Graduate Program in 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 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.

The training for a Ph.D. in Biology is focused on learning skills required to be 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 advisor 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 in order 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.

Learning Outcomes (Graduate)

The purpose of the master's program is to further develop knowledge and skills in Biology and to prepare students for a professional career or doctoral studies. This is achieved through completion of courses, in the primary field as well as related areas, and experience with independent work and specialization.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research and analysis in Biology. Through completion of advanced course work and rigorous skills training, the doctoral program prepares students to make original contributions to the knowledge of Biology and to interpret and present the results of such research.

Facilities

The offices, labs, and personnel of the Department of Biology are located in the Anne T. and Robert M. Bass Biology Research, Gilbert Biological Sciences, James H. Clark Center, ChEM-H and the Wu Tsai Neurosciences Institute, and Jerry Yang and Akiko Yamazaki Environment and Energy (Y2E2) buildings. Along with the Carnegie Institution of Washington all are on the main campus. Jasper Ridge Biological Preserve (JRBP) is located near Stanford University's campus in the eastern foothills of the Santa Cruz Mountains. Hopkins Marine Station is on Monterey Bay in Pacific Grove.

Jasper Ridge Biological 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 the JRBP (http://jrbp.stanford.edu) web site.

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 "Hopkins Marine Station" section of this bulletin.

The Robin Li and Melissa Ma Science Library (http://library.stanford.edu/libraries/science/about/), located in the Sapp Center for Science Teaching and Learning, supports research and teaching for the Department of Biology and other related disciplines. A specialized library is maintained at Hopkins Marine Station.

Biology Course Numbering System

The department uses the following course numbering system:

Number	Level
000-099	Introductory and Foundations
100-199	Undergraduate
200-299	Advanced Undergraduate, Coterminal and PhD
300+	PhD

Bachelor of Science in Biology

The undergraduate major in Biology can serve as a stepping-stone for a wide variety of career opportunities. For students planning to attend medical, dental, or veterinary school, or graduate school in biological and applied sciences, the biology major provides a strong foundation in the basic life sciences. This foundation of knowledge, plus laboratory experience, also prepares students well for research and technical positions in universities, government, and industry.

While a major in Biology provides an excellent background for these technical careers, it can also serve as a valuable and satisfying focus of a liberal arts education for those not planning careers in science-related fields. An understanding of basic biological principles is of increasing importance in today's world. A knowledgeable and concerned citizenry is the best guarantee that these issues will be resolved most effectively. Finally, an understanding of the processes of life can heighten our perception and appreciation of the world around us, in terms of its beauty, variety, and uniqueness.

How to Declare a Major in Biology

Each undergraduate interested in the Biology major is required to select a department faculty advisor as part of the major declaration process.

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 advisors, advising availability, and research interests.

The student services staff and BioBridge (https://biology.stanford.edu/academics/undergraduate-program/advising/biobridge-peer-advising/), 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 (https://biology.stanford.edu/academics/undergraduate-program/forms/), which delineates policies and requirements, as well as other department forms and informational handouts.

Degree Requirements

Candidates for the general Biology B.S. degree must complete the following requirements, which ranges from 88-102 total units. There is also an option to add honors to the major, regardless of whether a student wishes to complete the general major or a specific field of study. Honors requirements are explained in detail in the "Honors (https://exploredegrees.stanford.edu/schoolofhumanitiesandsciences/biology/#honorstext)" tab. Requirements for specific fields of study are explained in the Fields of Study (p. 3) section below.

Course Requirements

Students with a field of study should consult their advisor for courses in Foundations, Foundational Breadth and Electives.

		Units
Introductory		**4**
Complete one course from (see Departmental website for current Introductory Seminars and THINK options to substitute for BIO 60-series courses):		
BIO 60	Problem solving in infectious disease	
BIO 61	Science as a Creative Process	
BIO 62	Microbiology Experiments	
Foundational		
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	
BIO 82	Genetics	
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 85	Evolution	
BIO 86	Cell Biology	
Foundational Lab		
BIO 45	Introduction to Laboratory Research in Cell and Molecular Biology	
BIO 46	Introduction to Research in Ecology and Evolutionary Biology	
or BIO 47	Introduction to Research in Ecology and Evolutionary Biology	
or BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	
Foundational Breadth		**33-47**
Chemistry		
(One course from this section may be taken credit/no credit)		
The following CHEM courses are required:		
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 33	Structure and Reactivity of Organic Molecules	
CHEM 121	Understanding the Natural and Unnatural World through Chemistry	
Mathematics		
Select one of the following options:		5-10
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications (or beyond)	
CME 100	Vector Calculus for Engineers	
Physics		
Select one of the following Series:		
PHYSICS 20 Series		
PHYSICS 21	Mechanics, Fluids, and Heat	
PHYSICS 22	Mechanics, Fluids, and Heat Laboratory	
PHYSICS 23	Electricity, Magnetism, and Optics	
PHYSICS 24	Electricity, Magnetism, and Optics Laboratory	
PHYSICS 40 Series		
PHYSICS 41	Mechanics	
PHYSICS 43	Electricity and Magnetism	
PHYSICS 45	Light and Heat	
Statistics		
Select one of the following courses:		
BIO/STATS 141	Biostatistics [1]	
BIOHOPK 174H	Experimental Design and Probability [1]	
STATS 60	Introduction to Statistical Methods: Precalculus	
Electives		**23**
See addtional information for how to complete electives.		
Writing In the Major (WIM)		
Complete one course from:		
BIO 46	Introduction to Research in Ecology and Evolutionary Biology	

BIO 47	Introduction to Research in Ecology and Evolutionary Biology	
BIO 168	Explorations in Stem Cell Biology	
BIO 196A	Biology Senior Reflection	
BIO 199W	Senior Honors Thesis: How to Effectively Write About Scientific Research	
BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	
BIOHOPK 175H	Marine Science and Conservation in a Changing World	
Total Units		65-84

1 If taken to fulfill the foundational breadth requirement, these courses do not count toward the 23 elective unit requirement.

Fields of Study

In addition to the undergraduate general major, the department offers the following seven fields of study for students wishing to concentrate their studies in particular areas of biology. These fields of study are declared on Axess at the time of the major declaration; they appear on both the transcript and on the diploma.

Biochemistry and Biophysics

Candidates for the Biochemistry and Biophysics field of study must complete the following, as well WIM requirement above, for a total ranging from 90-102 units:

Foundational Courses

(must be taken for a letter grade):

		Units
All of the following:		16
BIO 82	Genetics	
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 86	Cell Biology	
Select 1 of the following:		4
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	
BIO 85	Evolution	

Required Foundational Breadth Courses

(One course from this section may be taken credit/no credit):

		Units
Chemistry		
The following CHEM courses are required:		
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	5-10
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 121	Understanding the Natural and Unnatural World through Chemistry	5
Mathematics		
Select one of the following options:		5-10
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications (or beyond)	
CME 100	Vector Calculus for Engineers	
Physics		
PHYSICS 40 Series		12
PHYSICS 41	Mechanics	
PHYSICS 43	Electricity and Magnetism	
PHYSICS 45	Light and Heat	
Statistics		
Select one of the following courses:		3-5
BIO/STATS 141	Biostatistics [1]	
BIOHOPK 174H	Experimental Design and Probability [1]	
STATS 60	Introduction to Statistical Methods: Precalculus	
Total Units		35-47

1 If taken to fulfill the foundational breadth requirement, these courses do not count toward the 23 elective unit requirement.

Electives

23 units required. Students must take the 3 required courses listed, as well as three courses in Biochemistry and Biophysics from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
3 Required Courses:		
CHEM 141	The Chemical Principles of Life I	4
CHEM 143	The Chemical Principles of Life II	4
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	5
or CME 100	Vector Calculus for Engineers	
Select three of the following:		9-13
APPPHYS 236	Biology by the Numbers	
APPPHYS 294	Cellular Biophysics	
BIO 126	Introduction to Biophysics	
BIO 132	Advanced Imaging Lab in Biophysics	
BIO 152	Imaging: Biological Light Microscopy	
BIO 154	Molecular and Cellular Neurobiology	
BIO 214	Advanced Cell Biology	
BIOE 101	Systems Biology	
BIOE 103	Systems Physiology and Design	
BIOE 220	Introduction to Imaging and Image-based Human Anatomy	
BIOE 231	Protein Engineering	
BIOE 241	Biological Macromolecules	
BIOMEDIN 210	Modeling Biomedical Systems	
BIOPHYS 241	Biological Macromolecules	
BIOPHYS 242	Methods in Molecular Biophysics	
CHEM 183	Biochemistry II	
CHEM 184	Biological Chemistry Laboratory	
CHEM 185	Biophysical Chemistry	
CS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
CSB 210	Cell Signaling	
CSB 220	Chemistry of Biological Processes	
EE 236A	Modern Optics	

MCP 256	How Cells Work: Energetics, Compartments, and Coupling in Cell Biology	
PHYSICS 105	Intermediate Physics Laboratory I: Analog Electronics	
STATS 191	Introduction to Applied Statistics	

Computational Biology

Candidates for the Computational Biology field of study must complete the following, as well as the WIM requirement above, for a total ranging from 90-102 units:

Required Foundational Breadth Courses

(One course from this section may be taken credit/no credit):

		Units
Chemistry		
The following CHEM courses are required:		
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	5-10
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 33	Structure and Reactivity of Organic Molecules	5
Mathematics		
CHEM 121	Understanding the Natural and Unnatural World through Chemistry	5
Select one of the following options:		5-10
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications (or beyond)	
CME 100	Vector Calculus for Engineers	
Physics		
Select one of the following Series:		10-12
PHYSICS 20 Series		
PHYSICS 21	Mechanics, Fluids, and Heat	
PHYSICS 22	Mechanics, Fluids, and Heat Laboratory	
PHYSICS 23	Electricity, Magnetism, and Optics	
PHYSICS 24	Electricity, Magnetism, and Optics Laboratory	
PHYSICS 40 Series		
PHYSICS 41	Mechanics	
PHYSICS 43	Electricity and Magnetism	
PHYSICS 45	Light and Heat	
Statistics		
The following course is required:		5
BIO/STATS 141	Biostatistics [1]	
Total Units		35-47

1 If taken to fulfill the foundational breadth requirement, this course cannot count toward the 23 elective unit requirement.

Electives

23 units required. Students must take the 2 required courses listed, as well as three courses in Computational Biology from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
2 Required Courses:		
CS 106A	Programming Methodology	3-5
or CS 106B	Programming Abstractions	
or CS 106X	Programming Abstractions	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	5
or CME 100	Vector Calculus for Engineers	
Select three of the following:		9-13
APPPHYS 315	Methods in Computational Biology	
BIO 126	Introduction to Biophysics	
BIO 182	Modeling Cultural Evolution	
BIO 183	Theoretical Population Genetics	
BIO 268	Statistical and Machine Learning Methods for Genomics	
BIODS 215	Topics in Biomedical Data Science: Large-scale inference	
BIOE 101	Systems Biology	
BIOE 103	Systems Physiology and Design	
BIOE 212	Introduction to Biomedical Informatics Research Methodology	
BIOMEDIN 215	Data Science for Medicine	
BIOMEDIN 217	Translational Bioinformatics	
CS 235	Computational Methods for Biomedical Image Analysis and Interpretation	
CS 270	Modeling Biomedical Systems	
CS 271	Artificial Intelligence in Healthcare	
CS 272	Introduction to Biomedical Informatics Research Methodology	
CS 273A	The Human Genome Source Code	
CS 273B	Deep Learning in Genomics and Biomedicine	
CS 273C	Cloud Computing for Biology and Healthcare	
CS 274	Representations and Algorithms for Computational Molecular Biology	
CS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
GENE 211	Genomics	
IMMUNOL 206	Introduction to Applied Computational Tools in Immunology	
IMMUNOL 207	Essential Methods in Computational and Systems Immunology	
STATS 215	Statistical Models in Biology	

Ecology and Evolution

Candidates for the Ecology and Evolution field of study must complete the following, as well as the WIM requirement above, for a total ranging from 88-102 units:

Foundational Courses

(must be taken for a letter grade):

		Units
All of the following:		12
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175	Marine Science and Conservation in a Changing World	

BIO 82	Genetics	
BIO 85	Evolution	
Select 2 of the following:		8
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 86	Cell Biology	

Electives

23 units required. Students must take five courses in Ecology and Evolution from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
Select 5 of the following:		15-23
BIO 105A	Ecology and Natural History of Jasper Ridge Biological Preserve	
BIO 105B	Ecology and Natural History of Jasper Ridge Biological Preserve	
BIO 113	Fundamentals of Molecular Evolution	
BIO 116	Ecology of the Hawaiian Islands	
BIO 117	Biology and Global Change	
BIO 121	ORNITHOLOGY	
BIO 129	Fundamentals and Frontiers in Plant Biology	
BIO 130	Ecosystems of California	
BIO 138	Ecosystem Services: Frontiers in the Science of Valuing Nature	
BIO 140	The Science of Extreme Life of the Sea	
BIO 144	Conservation Biology: A Latin American Perspective	
BIO 145	Ecology and Evolution of Animal Behavior	
BIO 147	Ecosystem Ecology and Biogeochemistry	
BIO 150	Human Behavioral Biology	
BIO 161	Organismal Biology Lab	
BIO 172	Ecological Dynamics: Theory and Applications	
BIO 174	Human Skeletal Anatomy	
BIO 176	The Developmental Basis of Animal Body Plan Evolution	
BIO 178	Microbiology Literature	
BIO 182	Modeling Cultural Evolution	
BIO 183	Theoretical Population Genetics	
BIO 221	ORNITHOLOGY	
BIO 227	Foundations of Community Ecology	
BIOHOPK 161H	Invertebrate Zoology	
BIOHOPK 163H	Oceanic Biology	
BIOHOPK 173H	Marine Conservation Biology	
BIOHOPK 174H	Experimental Design and Probability	
BIOHOPK 182H	Stanford at Sea	
BIOHOPK 187H	Sensory Ecology	
BIOHOPK 268H	Disease Ecology: from parasites evolution to the socio-economic impacts of pathogens on nations	
EARTHSYS 128	Evolution of Terrestrial Ecosystems	
EARTHSYS 142	Remote Sensing of Land	
EARTHSYS 144	Fundamentals of Geographic Information Science (GIS)	
EARTHSYS 158	Geomicrobiology	
OSPAUSTL 10	Coral Reef Ecosystems	

1. Only 6 units can be counted from BIOHOPK 182H.
2. OSPAUSTL 10, 28, 32 count as 2 units each for a total of 6 units toward electives.

Marine Biology

Candidates for the Marine Biology field of study must complete the following, as well as the WIM requirement above, for a total ranging from 88-102 units:

Foundational Courses

(must be taken for a letter grade):

		Units
All of the following:		12
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175	Marine Science and Conservation in a Changing World	
BIO 82	Genetics	
BIO 85	Evolution	
Select 2 of the following:		8
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 86	Cell Biology	

Electives

23 units required. Students must take five courses in Marine Biology from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
Select 5 of the following:		15-23
BIO 116	Ecology of the Hawaiian Islands	
BIO 136	Macroevolution	
BIO 153	Cellular Neuroscience: Cell Signaling and Behavior	
BIOHOPK 150H	Ecological Mechanics	
BIOHOPK 173H	Marine Conservation Biology	
BIOHOPK 177H	Dynamics and Management of Marine Populations	
BIOHOPK 179H	Physiological Ecology of Marine Megafauna	
BIOHOPK 182H	Stanford at Sea	
BIOHOPK 185H	Ecology and Conservation of Kelp Forest Communities	
BIOHOPK 187H	Sensory Ecology	
EARTHSYS 117	Earth Sciences of the Hawaiian Islands	
EARTHSYS 118	Heritage, Environment, and Sovereignty in Hawaii	
OSPAUSTL 10	Coral Reef Ecosystems	

1. Only 6 units can be counted from BIOHOPK 182H.
2. OSPAUSTL 10, 28, 32 count as 2 units each for a total of 6 units toward electives. Together, these courses count as two courses toward the Marine Biology requirement.

Microbes and Immunity

Candidates for the Microbes and Immunity field of study must complete the following, as well as the WIM requirement above, for a total ranging from 88-102 units:

Electives

23 units required. Students must take the 3 required courses listed, as well as two courses in Microbiology and Immunology from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
3 Required Courses:		
BIO 178	Microbiology Literature (offered in 2019-20)	3
or		
MI 185	Topics in Microbiology	
CHEM 141	The Chemical Principles of Life I	4
CHEM 143	The Chemical Principles of Life II	4
Select two of the following:		4-8
BIO 119	Evolution of Marine Ecosystems	
BIO 120	Prokaryotic Biology - A Quantitative Approach	
BIO 132	Advanced Imaging Lab in Biophysics	
BIO 177	Plant Microbe Interaction	
BIO 178	Microbiology Literature	
BIO 180	Microbial Physiology	
BIO 230	Molecular and Cellular Immunology	
BIOHOPK 274	Hopkins Microbiology Course	
CEE 177	Aquatic Chemistry and Biology	
CEE 274A	Environmental Microbiology I	
CEE 274B	Microbial Bioenergy Systems	
CEE 274D	Pathogens and Disinfection	
CEE 274P	Environmental Health Microbiology Lab	
EARTHSYS 158	Geomicrobiology	
IMMUNOL 201	Advanced Immunology I	
IMMUNOL 202	Advanced Immunology II	
IMMUNOL 206	Introduction to Applied Computational Tools in Immunology	
IMMUNOL 209	Translational Immunology	
IMMUNOL 275	Tumor Immunology	
IMMUNOL 286	Neuroimmunity	
MI 185	Topics in Microbiology	
MI 210	Advanced Pathogenesis of Bacteria, Viruses, and Eukaryotic Parasites	

Molecular, Cellular, and Developmental Biology

Candidates for the Molecular, Cellular, and Developmental Biology field of study must complete the following, as well as the WIM requirement above, for a total ranging from 88-102 units:

Foundational Courses

(must be taken for a letter grade):

		Units
All of the following:		16
BIO 82	Genetics	
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 86	Cell Biology	
Select 1 of the following:		4
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	
BIO 85	Evolution	

Electives

23 units required. Students must take the 3 required courses listed, as well as two courses in Molecular, Cellular, and Developmental Biology from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
3 Required Courses:		
BIO 158	Developmental Neurobiology	4
or BIO 160	Developmental Biology	
CHEM 141	The Chemical Principles of Life I	4
CHEM 143	The Chemical Principles of Life II	4
Select two of the following:		5-10
BIO 110	The Chromatin-Regulated Genome	
BIO 124	Topics in Cancer Biology	
BIO 154	Molecular and Cellular Neurobiology	
BIO 158	Developmental Neurobiology	
BIO 160	Developmental Biology	
BIO 168	Explorations in Stem Cell Biology	
BIO 171	Principles of Cell Cycle Control	
BIO 177	Plant Microbe Interaction	
BIOE 101	Systems Biology	
BIOE 283	Mechanotransduction in Cells and Tissues	
BIOHOPK 155H	Developmental Biology and Evolution	
BIOPHYS 242	Methods in Molecular Biophysics	
CBIO 243	Principles of Cancer Systems Biology	
CS 273A	The Human Genome Source Code	
CS 273B	Deep Learning in Genomics and Biomedicine	
CS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
CSB 210	Cell Signaling	
DBIO 210	Developmental Biology	
GENE 211	Genomics	
GENE 235	C. Elegans Genetics	
NBIO 258	Information and Signaling Mechanisms in Neurons and Circuits	
STEMREM 201A	Stem Cells and Human Development: From Embryo to Cell Lineage Determination	
STEMREM 202	Stem Cells and Translational Medicine	

Neurobiology

Candidates for the Neurobiology field of study must complete the following, as well as the WIM requirement above, for a total ranging from 88-102 units:

Foundational Courses

(must be taken for a letter grade):

		Units
All of the following:		16
BIO 82	Genetics	
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 86	Cell Biology	
Select 1 of the following:		4
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	
BIO 85	Evolution	

Electives

23 units required. Students must take the 5 required courses listed. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
5 Required Courses:		
BIO 149	The Neurobiology of Sleep	4-6
or BIO 150	Human Behavioral Biology	
or NBIO 206	The Nervous System	
BIO 154	Molecular and Cellular Neurobiology	4
BIO 158	Developmental Neurobiology	4
CHEM 141	The Chemical Principles of Life I	4
CHEM 143	The Chemical Principles of Life II	4

Additional Information

Electives

23 units required, distributed as follows:

- Biology (BIO) or Hopkins Marine Station (BIOHOPK) courses numbered 100 or above.
- Approved out-of-department electives (https://drive.google.com/file/d/11dF9EHqjeWCweNzA6IkfHdtm4LNHl6o_/view/?usp=sharing) (list also available in the student services office).
- One course applied toward the elective unit requirement may be taken CR/NC.
- BIO 168, BIO 196A, and BIO 199W can also count toward the elective requirement.
- No more than 6 units from any combination of these courses may be applied toward the total number of elective units:

		Units
BIO 196A	Biology Senior Reflection	3
BIO 196B	Biology Senior Reflection	3
BIO 196C	Biology Senior Reflection	3
BIO 198	Directed Reading in Biology	1-15
BIO 198X	Out-of-Department Directed Reading	1-15
BIO 199	Advanced Research Laboratory in Experimental Biology	1-15
BIO 199W	Senior Honors Thesis: How to Effectively Write About Scientific Research	3
BIO 199X	Out-of-Department Advanced Research Laboratory in Experimental Biology	1-15
BIO 290	Teaching Practicum in Biology	1-5
BIO 291	Development and Teaching of Core Experimental Laboratories	1-2
BIO 296	Teaching and Learning in Biology	1
BIOHOPK 198H	Directed Instruction or Reading	1-15
BIOHOPK 199H	Undergraduate Research	1-15
BIOHOPK 290H	Teaching Practicum in Biology	1-15

Typical Schedule for a Four-Year Program

First Year	Units		
	Autumn	Winter	Spring
Chemical Principles I (CHEM 31A)	5		
Calculus (MATH 19)	3		
Freshman requirements, seminars, or WAYS	8		
Chemical Principles II (CHEM 31B)		5	
Calculus (MATH 20)		3	
Problem solving in infectious disease (BIO 60)		4	
Freshman requirements, seminars, or WAYS		4	
Structure and Reactivity of Organic Molecules (CHEM 33)			5
Calculus (MATH 21)			4
Introduction to Statistical Methods: Precalculus (STATS 60)			5
Freshman requirements, seminars, or WAYS			4
Year Total:	16	16	18

Second Year	Units		
	Autumn	Winter	Spring
Genetics (BIO 82)	4		
WAYS, PWR	8		
Understanding the Natural and Unnatural World through Chemistry (CHEM 121)	5		
Biochemistry & Molecular Biology (BIO 83)		4	
Physiology (BIO 84)		4	
Introduction to Laboratory Research in Cell and Molecular Biology (BIO 45)		4	
WAYS		4	
Cell Biology (BIO 86)			4
Introduction to Research in Ecology and Evolutionary Biology (BIO 47)			4
WAYS			3
Biology Electives			3
Year Total:	17	16	14

Third Year	Units		
	Autumn	Winter	Spring
Abroad			
Evolution (BIO 85)		4	
Electives		4	
WAYS		4	
Electives			7
Year Total:		12	7

Fourth Year	Units		
	Autumn	Winter	Spring
Electives	3		
Mechanics, Fluids, and Heat (PHYSICS 21)	4		
Mechanics, Fluids, and Heat Laboratory (PHYSICS 22)	1		
Electives		3	
Electricity, Magnetism, and Optics (PHYSICS 23)		4	
Electricity, Magnetism, and Optics Laboratory (PHYSICS 24)		1	
Electives			3
Year Total:	8	8	3

Total Units in Sequence: 135

1 This schedule varies slightly if the student takes CHEM 31M in place of CHEM 31A & CHEM 31B.

2 The schedule varies slightly depending on which 5 Bio Foundations courses the student chooses to take, and if any of them will be taken at Hopkins Marine Station.

Honors

To graduate with departmental honors, a student must conduct an independent research project typically over the course of at least one year; projects are started no later than Autumn or Winter Quarter of the junior year. Research must be done in a Biology Department lab or a lab in another department for which the student has obtained prior approval. Administrative steps include:

1. Submit an approved honors proposal to the department's student services office two quarters prior to graduation. For instance, students graduating Spring Quarter must submit petitions no later than Autumn Quarter of the same academic year.
2. Complete at least 10 units of an approved research project in from the same lab. Students conducting research in a lab outside of the department of Biology must submit an Out of Department Research Petition (https://biology.stanford.edu/academics/undergraduate-research/research/) either before they start their research, or if research was started prior to declaring the Biology major, as soon as their major declaration is approved. Only research units from BIO or BIOHOPK are counted toward the 10 unit requirement:

		Units
BIO 199	Advanced Research Laboratory in Experimental Biology	1-15
BIO 199X	Out-of-Department Advanced Research Laboratory in Experimental Biology	1-15
BIOHOPK 199H	Undergraduate Research	1-15

3. Obtain at least a 3.0 (B) grade point average (GPA) in all Biology major requirements taken at Stanford (foundational, breadth, and elective courses). Grades earned from these teaching and research are not computed into this GPA:

		Units
BIO 198	Directed Reading in Biology	1-15
BIO 198X	Out-of-Department Directed Reading	1-15
BIO 199	Advanced Research Laboratory in Experimental Biology	1-15
BIO 199X	Out-of-Department Advanced Research Laboratory in Experimental Biology	1-15
BIO 290	Teaching Practicum in Biology	1-5
BIO 291	Development and Teaching of Core Experimental Laboratories	1-2
BIO 296	Teaching and Learning in Biology	1
BIOHOPK 199H	Undergraduate Research	1-15
BIOHOPK 290H	Teaching Practicum in Biology	1-15

4. If graduating in Spring, participate in the annual Achauer Undergraduate Biology Honors Symposium by presenting a poster or giving an oral presentation. The symposium is typically held at the end of May. Students graduating in Autumn, Winter, or Summer Quarter must produce a poster in the quarter in which they graduate to be displayed at the symposium, however their attendance is optional.
5. Complete and, by the published deadline within the quarter graduation is expected, submit online an honors thesis approved by at least two readers. At least one reader must be from the faculty of the Department of Biology, and both readers must be Academic Council members. The title page of the honors thesis must include student name, thesis title, name and department of research sponsor, and name and department of second reader. Students must submit this page with original ink signatures to the student services office by the published deadline for the quarter in which graduation is expected.

Further information on the honors program is available on the Honors Program and Undergraduate Research in Biology (https://biology.stanford.edu/academics/undergraduate-program/honors-program/) web site.

Fields of Study

In addition to the undergraduate general major, the department offers the following seven fields of study for students wishing to concentrate their studies in particular areas of biology:

1. Biochemistry and Biophysics
2. Computational Biology
3. Ecology and Evolution
4. Marine Biology
5. Microbes and Immunity
6. Molecular, Cellular, and Developmental Biology
7. Neurobiology

These fields of study are declared on Axess at the time of the major declaration; they appear on both the transcript and on the diploma.

Writing in the Major for the B.S. Degree in Biology with a Field of Study

Students must take one of the following courses to fulfill the Writing in the Major requirement in Biology:

		Units
BIO 46	Introduction to Research in Ecology and Evolutionary Biology	
BIO 47	Introduction to Research in Ecology and Evolutionary Biology	
BIO 168	Explorations in Stem Cell Biology	
BIO 196A	Biology Senior Reflection	
BIO 199W	Senior Honors Thesis: How to Effectively Write About Scientific Research	
BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	
BIOHOPK 175H	Marine Science and Conservation in a Changing World	

Note: BIO 168, BIO 196A,and BIO 199W can also count toward the elective requirement.

Biochemistry and Biophysics

Candidates for the Biochemistry and Biophysics field of study must complete the following, as well WIM requirement above, for a total ranging from 90-102 units:

Introductory Course

(must be taken for a letter grade; see Departmental (https://biology.stanford.edu/academics/undergraduate-program/biology-undergraduate-major/)website for current Introductory Seminars and THINK options to substitute for BIO 60-series courses):

		Units
Select one of the following:		4
BIO 60	Problem solving in infectious disease	

BIO 61	Science as a Creative Process	
BIO 62	Microbiology Experiments	

Foundational Courses

(must be taken for a letter grade):

		Units
All of the following:		16
BIO 82	Genetics	
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 86	Cell Biology	
Select 1 of the following:		4
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	
BIO 85	Evolution	

Foundational Lab Courses

		Units
Two Courses Required:		
BIO 45	Introduction to Laboratory Research in Cell and Molecular Biology	4
BIO 46	Introduction to Research in Ecology and Evolutionary Biology	4-5
or BIO 47	Introduction to Research in Ecology and Evolutionary Biology	
or BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	

Required Foundational Breadth Courses

(One course from this section may be taken credit/no credit):

		Units
Chemistry		
The following CHEM courses are required:		
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	5-10
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 121	Understanding the Natural and Unnatural World through Chemistry	5
Mathematics		
Select one of the following options:		5-10
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications (or beyond)	
CME 100	Vector Calculus for Engineers	
Physics		
PHYSICS 40 Series		12
PHYSICS 41	Mechanics	
PHYSICS 43	Electricity and Magnetism	
PHYSICS 45	Light and Heat	
Statistics		
Select one of the following courses:		3-5
BIO/STATS 141	Biostatistics [1]	
BIOHOPK 174H	Experimental Design and Probability [1]	
STATS 60	Introduction to Statistical Methods: Precalculus	
Total Units		35-47

1 If taken to fulfill the foundational breadth requirement, these courses do not count toward the 23 elective unit requirement.

Electives

23 units required. Students must take the 3 required courses listed, as well as three courses in Biochemistry and Biophysics from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
3 Required Courses:		
CHEM 141	The Chemical Principles of Life I	4
CHEM 143	The Chemical Principles of Life II	4
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	5
or CME 100	Vector Calculus for Engineers	
Select three of the following:		9-13
APPPHYS 236	Biology by the Numbers	
APPPHYS 294	Cellular Biophysics	
BIO 126	Introduction to Biophysics	
BIO 132	Advanced Imaging Lab in Biophysics	
BIO 152	Imaging: Biological Light Microscopy	
BIO 154	Molecular and Cellular Neurobiology	
BIO 214	Advanced Cell Biology	
BIOE 101	Systems Biology	
BIOE 103	Systems Physiology and Design	
BIOE 220	Introduction to Imaging and Image-based Human Anatomy	
BIOE 231	Protein Engineering	
BIOE 241	Biological Macromolecules	
BIOMEDIN 210	Modeling Biomedical Systems	
BIOPHYS 241	Biological Macromolecules	
BIOPHYS 242	Methods in Molecular Biophysics	
CHEM 183	Biochemistry II	
CHEM 184	Biological Chemistry Laboratory	
CHEM 185	Biophysical Chemistry	
CS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
CSB 210	Cell Signaling	
CSB 220	Chemistry of Biological Processes	
EE 236A	Modern Optics	
MCP 256	How Cells Work: Energetics, Compartments, and Coupling in Cell Biology	
PHYSICS 105	Intermediate Physics Laboratory I: Analog Electronics	
STATS 191	Introduction to Applied Statistics	

Computational Biology

Candidates for the Computational Biology field of study must complete the following, as well as the WIM requirement above, for a total ranging from 90-102 units:

Introductory Course

(must be taken for a letter grade; see Departmental (https://biology.stanford.edu/academics/undergraduate-program/biology-undergraduate-major/)website for current Introductory Seminars and THINK options to substitute for BIO 60-series courses):

		Units
Select one of the following:		4
BIO 60	Problem solving in infectious disease	
BIO 61	Science as a Creative Process	
BIO 62	Microbiology Experiments	

Foundational Courses

(must be taken for a letter grade):

		Units
Select 5 of the following:		20
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175	Marine Science and Conservation in a Changing World	
BIO 82	Genetics	
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 85	Evolution	
BIO 86	Cell Biology	

Foundational Lab Courses

		Units
Two Courses Required:		
BIO 45	Introduction to Laboratory Research in Cell and Molecular Biology	4
BIO 46	Introduction to Research in Ecology and Evolutionary Biology	4-5
or BIO 47	Introduction to Research in Ecology and Evolutionary Biology	
or BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	

Required Foundational Breadth Courses

(One course from this section may be taken credit/no credit):

		Units
Chemistry		
The following CHEM courses are required:		
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	5-10
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 33	Structure and Reactivity of Organic Molecules	5
Mathematics		
CHEM 121	Understanding the Natural and Unnatural World through Chemistry	5
Select one of the following options:		5-10
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications (or beyond)	
CME 100	Vector Calculus for Engineers	
Physics		
Select one of the following Series:		10-12
PHYSICS 20 Series		
PHYSICS 21	Mechanics, Fluids, and Heat	
PHYSICS 22	Mechanics, Fluids, and Heat Laboratory	
PHYSICS 23	Electricity, Magnetism, and Optics	
PHYSICS 24	Electricity, Magnetism, and Optics Laboratory	
PHYSICS 40 Series		
PHYSICS 41	Mechanics	
PHYSICS 43	Electricity and Magnetism	
PHYSICS 45	Light and Heat	
Statistics		
The following course is required:		5
BIO/STATS 141	Biostatistics [1]	
Total Units		35-47

1 If taken to fulfill the foundational breadth requirement, this course cannot count toward the 23 elective unit requirement.

Electives

23 units required. Students must take the 2 required courses listed, as well as three courses in Computational Biology from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
2 Required Courses:		
CS 106A	Programming Methodology	3-5
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	5
or CME 100	Vector Calculus for Engineers	
Select three of the following:		9-13
APPPHYS 315	Methods in Computational Biology	
BIO 126	Introduction to Biophysics	
BIO 182	Modeling Cultural Evolution	
BIO 183	Theoretical Population Genetics	
BIO 268	Statistical and Machine Learning Methods for Genomics	
BIODS 215	Topics in Biomedical Data Science: Large-scale inference	
BIOE 101	Systems Biology	
BIOE 103	Systems Physiology and Design	
BIOE 212	Introduction to Biomedical Informatics Research Methodology	
BIOMEDIN 215	Data Science for Medicine	
BIOMEDIN 217	Translational Bioinformatics	
CS 235	Computational Methods for Biomedical Image Analysis and Interpretation	
CS 270	Modeling Biomedical Systems	
CS 271	Artificial Intelligence in Healthcare	

CS 272	Introduction to Biomedical Informatics Research Methodology	
CS 273A	The Human Genome Source Code	
CS 273B	Deep Learning in Genomics and Biomedicine	
CS 273C	Cloud Computing for Biology and Healthcare	
CS 274	Representations and Algorithms for Computational Molecular Biology	
CS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
GENE 211	Genomics	
IMMUNOL 206	Introduction to Applied Computational Tools in Immunology	
IMMUNOL 207	Essential Methods in Computational and Systems Immunology	
STATS 215	Statistical Models in Biology	

Ecology and Evolution

Candidates for the Ecology and Evolution field of study must complete the following, as well as the WIM requirement above, for a total ranging from 88-102 units:

Introductory Course

(must be taken for a letter grade; see Departmental (https://biology.stanford.edu/academics/undergraduate-program/biology-undergraduate-major/)website for current Introductory Seminars and THINK options to substitute for BIO 60-series courses):

		Units
Select one of the following:		4
BIO 60	Problem solving in infectious disease	
BIO 61	Science as a Creative Process	
BIO 62	Microbiology Experiments	

Foundational Courses

(must be taken for a letter grade):

		Units
All of the following:		12
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175	Marine Science and Conservation in a Changing World	
BIO 82	Genetics	
BIO 85	Evolution	
Select 2 of the following:		8
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 86	Cell Biology	

Foundational Lab Courses

		Units
Two Courses Required:		
BIO 45	Introduction to Laboratory Research in Cell and Molecular Biology	4
BIO 46	Introduction to Research in Ecology and Evolutionary Biology	4-5
or BIO 47	Introduction to Research in Ecology and Evolutionary Biology	
or BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	

Required Foundational Breadth Courses

(One course from this section may be taken credit/no credit):

		Units
Chemistry		
The following CHEM courses are required:		
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	5-10
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 121	Understanding the Natural and Unnatural World through Chemistry	5
Mathematics		
Select one of the following options:		5-10
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications (or beyond)	
CME 100	Vector Calculus for Engineers	
Physics		
Select one of the following Series:		10-12
PHYSICS 20 Series		
PHYSICS 21	Mechanics, Fluids, and Heat	
PHYSICS 22	Mechanics, Fluids, and Heat Laboratory	
PHYSICS 23	Electricity, Magnetism, and Optics	
PHYSICS 24	Electricity, Magnetism, and Optics Laboratory	
PHYSICS 40 Series		
PHYSICS 41	Mechanics	
PHYSICS 43	Electricity and Magnetism	
PHYSICS 45	Light and Heat	
Statistics		
Select one of the following courses:		3-5
BIO/STATS 141	Biostatistics [1]	
BIOHOPK 174H	Experimental Design and Probability [1]	
STATS 60	Introduction to Statistical Methods: Precalculus	
Total Units		33-47

1 If taken to fulfill the foundational breadth requirement, these courses do not count toward the 23 elective unit requirement.

Electives

23 units required. Students must take five courses in Ecology and Evolution from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
Select 5 of the following:		15-23
BIO 105A	Ecology and Natural History of Jasper Ridge Biological Preserve	

BIO 105B	Ecology and Natural History of Jasper Ridge Biological Preserve
BIO 113	Fundamentals of Molecular Evolution
BIO 116	Ecology of the Hawaiian Islands
BIO 117	Biology and Global Change
BIO 121	ORNITHOLOGY
BIO 129	Fundamentals and Frontiers in Plant Biology
BIO 130	Ecosystems of California
BIO 138	Ecosystem Services: Frontiers in the Science of Valuing Nature
BIO 140	The Science of Extreme Life of the Sea
BIO 144	Conservation Biology: A Latin American Perspective
BIO 145	Ecology and Evolution of Animal Behavior
BIO 147	Ecosystem Ecology and Biogeochemistry
BIO 150	Human Behavioral Biology
BIO 161	Organismal Biology Lab
BIO 172	Ecological Dynamics: Theory and Applications
BIO 174	Human Skeletal Anatomy
BIO 176	The Developmental Basis of Animal Body Plan Evolution
BIO 178	Microbiology Literature
BIO 182	Modeling Cultural Evolution
BIO 183	Theoretical Population Genetics
BIO 221	ORNITHOLOGY
BIO 227	Foundations of Community Ecology
BIOHOPK 161H	Invertebrate Zoology
BIOHOPK 163H	Oceanic Biology
BIOHOPK 173H	Marine Conservation Biology
BIOHOPK 174H	Experimental Design and Probability
BIOHOPK 182H	Stanford at Sea
BIOHOPK 187H	Sensory Ecology
BIOHOPK 268H	Disease Ecology: from parasites evolution to the socio-economic impacts of pathogens on nations
EARTHSYS 128	Evolution of Terrestrial Ecosystems
EARTHSYS 142	Remote Sensing of Land
EARTHSYS 144	Fundamentals of Geographic Information Science (GIS)
EARTHSYS 158	Geomicrobiology
OSPAUSTL 10	Coral Reef Ecosystems

1. Only 6 units can be counted from BIOHOPK 182H.
2. OSPAUSTL 10, 28, 32 count as 2 units each for a total of 6 units toward electives.

Marine Biology

Candidates for the Marine Biology field of study must complete the following, as well as the WIM requirement above, for a total ranging from 88-102 units:

Introductory Course

(must be taken for a letter grade; see Departmental (https://biology.stanford.edu/academics/undergraduate-program/biology-undergraduate-major/)website for current Introductory Seminars and THINK options to substitute for BIO 60-series courses):

		Units
Select one of the following:		4
BIO 60	Problem solving in infectious disease	
BIO 61	Science as a Creative Process	
BIO 62	Microbiology Experiments	

Foundational Courses

(must be taken for a letter grade):

		Units
All of the following:		12
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175	Marine Science and Conservation in a Changing World	
BIO 82	Genetics	
BIO 85	Evolution	
Select 2 of the following:		8
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 86	Cell Biology	

Foundational Lab Courses

		Units
Two Courses Required:		
BIO 45	Introduction to Laboratory Research in Cell and Molecular Biology	4
BIO 46	Introduction to Research in Ecology and Evolutionary Biology	4-5
or BIO 47	Introduction to Research in Ecology and Evolutionary Biology	
or BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	

Required Foundational Breadth Courses

(One course from this section may be taken credit/no credit):

		Units
Chemistry		
The following CHEM courses are required:		
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	5-10
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 121	Understanding the Natural and Unnatural World through Chemistry	5
Mathematics		
Select one of the following options:		5-10
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications (or beyond)	
CME 100	Vector Calculus for Engineers	
Physics		
Select one of the following Series:		10-12
PHYSICS 20 Series		
PHYSICS 21	Mechanics, Fluids, and Heat	

PHYSICS 22	Mechanics, Fluids, and Heat Laboratory	
PHYSICS 23	Electricity, Magnetism, and Optics	
PHYSICS 24	Electricity, Magnetism, and Optics Laboratory	
PHYSICS 40 Series		
PHYSICS 41	Mechanics	
PHYSICS 43	Electricity and Magnetism	
PHYSICS 45	Light and Heat	
Statistics		
Select one of the following courses:		3-5
BIO/STATS 141	Biostatistics [1]	
BIOHOPK 174H	Experimental Design and Probability [1]	
STATS 60	Introduction to Statistical Methods: Precalculus	
Total Units		33-47

1 If taken to fulfill the foundational breadth requirement, these courses do not count toward the 23 elective unit requirement.

Electives

23 units required. Students must take five courses in Marine Biology from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
Select 5 of the following:		15-23
BIO 116	Ecology of the Hawaiian Islands	
BIO 136	Macroevolution	
BIO 153	Cellular Neuroscience: Cell Signaling and Behavior	
BIOHOPK 150H	Ecological Mechanics	
BIOHOPK 173H	Marine Conservation Biology	
BIOHOPK 177H	Dynamics and Management of Marine Populations	
BIOHOPK 179H	Physiological Ecology of Marine Megafauna	
BIOHOPK 182H	Stanford at Sea	
BIOHOPK 185H	Ecology and Conservation of Kelp Forest Communities	
BIOHOPK 187H	Sensory Ecology	
EARTHSYS 117	Earth Sciences of the Hawaiian Islands	
EARTHSYS 118	Heritage, Environment, and Sovereignty in Hawaii	
OSPAUSTL 10	Coral Reef Ecosystems	

1 Only 6 units can be counted from BIOHOPK 182H.

2 OSPAUSTL 10, 28, 32 count as 2 units each for a total of 6 units toward electives. Together, these courses count as two courses toward the Marine Biology requirement.

Microbes and Immunity

Candidates for the Microbes and Immunity field of study must complete the following, as well as the WIM requirement above, for a total ranging from 88-102 units:

Introductory Course

(must be taken for a letter grade; see Departmental (https://biology.stanford.edu/academics/undergraduate-program/biology-undergraduate-major/)website for current Introductory Seminars and THINK options to substitute for BIO 60-series courses):

		Units
Select one of the following:		4
BIO 60	Problem solving in infectious disease	
BIO 61	Science as a Creative Process	
BIO 62	Microbiology Experiments	

Foundational Courses

(must be taken for a letter grade):

		Units
Select 5 of the following:		20
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175	Marine Science and Conservation in a Changing World	
BIO 82	Genetics	
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
or BIOHOPK 84	Physiology	
BIO 85	Evolution	
or BIOHOPK 85	Evolution	
BIO 86	Cell Biology	

Foundational Lab Courses

		Units
Two Courses Required:		
BIO 45	Introduction to Laboratory Research in Cell and Molecular Biology	4
BIO 46	Introduction to Research in Ecology and Evolutionary Biology	4-5
or BIO 47	Introduction to Research in Ecology and Evolutionary Biology	
or BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	

Required Foundational Breadth Courses

(One course from this section may be taken credit/no credit):

		Units
Chemistry		
The following CHEM courses are required:		
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	5-10
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 121	Understanding the Natural and Unnatural World through Chemistry	5
Mathematics		
Select one of the following options:		5-10
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications (or beyond)	
CME 100	Vector Calculus for Engineers	

Physics		
Select one of the following Series:		10-12
PHYSICS 20 Series		
PHYSICS 21	Mechanics, Fluids, and Heat	
PHYSICS 22	Mechanics, Fluids, and Heat Laboratory	
PHYSICS 23	Electricity, Magnetism, and Optics	
PHYSICS 24	Electricity, Magnetism, and Optics Laboratory	
PHYSICS 40 Series		
PHYSICS 41	Mechanics	
PHYSICS 43	Electricity and Magnetism	
PHYSICS 45	Light and Heat	
Statistics		
Select one of the following courses:		3-5
BIO/STATS 141	Biostatistics [1]	
BIOHOPK 174H	Experimental Design and Probability [1]	
STATS 60	Introduction to Statistical Methods: Precalculus	
Total Units		33-47

1 If taken to fulfill the foundational breadth requirement, these courses do not count toward the 23 elective unit requirement.

Electives

23 units required. Students must take the 3 required courses listed, as well as two courses in Microbiology and Immunology from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
3 Required Courses:		
BIO 178	Microbiology Literature	3
or		
MI 185	Topics in Microbiology	
CHEM 141	The Chemical Principles of Life I	4
CHEM 143	The Chemical Principles of Life II	4
Select two of the following:		4-8
BIO 119	Evolution of Marine Ecosystems	
BIO 120	Prokaryotic Biology - A Quantitative Approach	
BIO 132	Advanced Imaging Lab in Biophysics	
BIO 177	Plant Microbe Interaction	
BIO 178	Microbiology Literature	
BIO 180	Microbial Physiology	
BIO 230	Molecular and Cellular Immunology	
BIOHOPK 274	Hopkins Microbiology Course	
CEE 177	Aquatic Chemistry and Biology	
CEE 274A	Environmental Microbiology I	
CEE 274B	Microbial Bioenergy Systems	
CEE 274D	Pathogens and Disinfection	
CEE 274P	Environmental Health Microbiology Lab	
EARTHSYS 158	Geomicrobiology	
IMMUNOL 201	Advanced Immunology I	
IMMUNOL 202	Advanced Immunology II	
IMMUNOL 206	Introduction to Applied Computational Tools in Immunology	
IMMUNOL 209	Translational Immunology	
IMMUNOL 275	Tumor Immunology	
IMMUNOL 286	Neuroimmunity	
MI 185	Topics in Microbiology	
MI 210	Advanced Pathogenesis of Bacteria, Viruses, and Eukaryotic Parasites	

Molecular, Cellular, and Developmental Biology

Candidates for the Molecular, Cellular, and Developmental Biology field of study must complete the following, as well as the WIM requirement above, for a total ranging from 88-102 units:

Introductory Course

(must be taken for a letter grade; see Departmental (https://biology.stanford.edu/academics/undergraduate-program/biology-undergraduate-major/)website for current Introductory Seminars and THINK options to substitute for BIO 60-series courses):

		Units
Select one of the following:		4
BIO 60	Problem solving in infectious disease	
BIO 61	Science as a Creative Process	
BIO 62	Microbiology Experiments	

Foundational Courses

(must be taken for a letter grade):

		Units
All of the following:		16
BIO 82	Genetics	
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 86	Cell Biology	
Select 1 of the following:		4
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	
BIO 85	Evolution	

Foundational Lab Courses

		Units
Two Courses Required:		
BIO 45	Introduction to Laboratory Research in Cell and Molecular Biology	4
BIO 46	Introduction to Research in Ecology and Evolutionary Biology	4-5
or BIO 47	Introduction to Research in Ecology and Evolutionary Biology	
or BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	

Required Foundational Breadth Courses

(One course from this section may be taken credit/no credit):

		Units
Chemistry		
The following CHEM courses are required:		

CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	5-10
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 121	Understanding the Natural and Unnatural World through Chemistry	5
Mathematics		
Select one of the following options:		5-10
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications (or beyond)	
CME 100	Vector Calculus for Engineers	
Physics		
Select one of the following Series:		10-12
PHYSICS 20 Series		
PHYSICS 21	Mechanics, Fluids, and Heat	
PHYSICS 22	Mechanics, Fluids, and Heat Laboratory	
PHYSICS 23	Electricity, Magnetism, and Optics	
PHYSICS 24	Electricity, Magnetism, and Optics Laboratory	
PHYSICS 40 Series		
PHYSICS 41	Mechanics	
PHYSICS 43	Electricity and Magnetism	
PHYSICS 45	Light and Heat	
Statistics		
Select one of the following courses:		3-5
BIO/STATS 141	Biostatistics [1]	
BIOHOPK 174H	Experimental Design and Probability [1]	
STATS 60	Introduction to Statistical Methods: Precalculus	
Total Units		33-47

1 If taken to fulfill the foundational breadth requirement, these courses do not count toward the 23 elective unit requirement.

Electives

23 units required. Students must take the 3 required courses listed, as well as two courses in Molecular, Cellular, and Developmental Biology from the approved list. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
3 Required Courses:		
BIO 158	Developmental Neurobiology	4
or BIO 160	Developmental Biology	
CHEM 141	The Chemical Principles of Life I	4
CHEM 143	The Chemical Principles of Life II	4
Select two of the following:		5-10
BIO 110	The Chromatin-Regulated Genome	
BIO 124	Topics in Cancer Biology	
BIO 154	Molecular and Cellular Neurobiology	
BIO 158	Developmental Neurobiology	
BIO 160	Developmental Biology	
BIO 168	Explorations in Stem Cell Biology	
BIO 171	Principles of Cell Cycle Control	
BIO 177	Plant Microbe Interaction	
BIOE 101	Systems Biology	
BIOE 283	Mechanotransduction in Cells and Tissues	
BIOHOPK 155H	Developmental Biology and Evolution	
BIOPHYS 242	Methods in Molecular Biophysics	
CBIO 243	Principles of Cancer Systems Biology	
CS 273A	The Human Genome Source Code	
CS 273B	Deep Learning in Genomics and Biomedicine	
CS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
CSB 210	Cell Signaling	
DBIO 210	Developmental Biology	
GENE 211	Genomics	
GENE 235	C. Elegans Genetics	
NBIO 258	Information and Signaling Mechanisms in Neurons and Circuits	
STEMREM 201A	Stem Cells and Human Development: From Embryo to Cell Lineage Determination	
STEMREM 202	Stem Cells and Translational Medicine	

Neurobiology

Candidates for the Neurobiology field of study must complete the following, as well as the WIM requirement above, for a total ranging from 88-102 units:

Introductory Course

(must be taken for a letter grade; see Departmental (https://biology.stanford.edu/academics/undergraduate-program/biology-undergraduate-major/)website for current Introductory Seminars and THINK options to substitute for BIO 60-series courses):

		Units
Select one of the following:		4
BIO 60	Problem solving in infectious disease	
BIO 61	Science as a Creative Process	
BIO 62	Microbiology Experiments	

Foundational Courses

(must be taken for a letter grade):

		Units
All of the following:		16
BIO 82	Genetics	
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
BIO 86	Cell Biology	
Select 1 of the following:		4
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	
BIO 85	Evolution	

Foundational Lab Courses

		Units
Two Courses Required:		
BIO 45	Introduction to Laboratory Research in Cell and Molecular Biology	4

BIO 46	Introduction to Research in Ecology and Evolutionary Biology	4-5
or BIO 47	Introduction to Research in Ecology and Evolutionary Biology	
or BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	

Required Foundational Breadth Courses

(One course from this section may be taken credit/no credit):

		Units
Chemistry		
The following CHEM courses are required:		
CHEM 31A & CHEM 31B	Chemical Principles I and Chemical Principles II	5-10
or CHEM 31M	Chemical Principles: From Molecules to Solids	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 121	Understanding the Natural and Unnatural World through Chemistry	5
Mathematics		
Select one of the following options:		5-10
MATH 19 & MATH 20 & MATH 21	Calculus and Calculus and Calculus	
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications (or beyond)	
CME 100	Vector Calculus for Engineers	
Physics		
Select one of the following Series:		10-12
PHYSICS 20 Series		
PHYSICS 21	Mechanics, Fluids, and Heat	
PHYSICS 22	Mechanics, Fluids, and Heat Laboratory	
PHYSICS 23	Electricity, Magnetism, and Optics	
PHYSICS 24	Electricity, Magnetism, and Optics Laboratory	
PHYSICS 40 Series		
PHYSICS 41	Mechanics	
PHYSICS 43	Electricity and Magnetism	
PHYSICS 45	Light and Heat	
Statistics		
Select one of the following courses:		3-5
BIO/STATS 141	Biostatistics [1]	
BIOHOPK 174H	Experimental Design and Probability [1]	
STATS 60	Introduction to Statistical Methods: Precalculus	
Total Units		33-47

1 If taken to fulfill the foundational breadth requirement, these courses do not count toward the 23 elective unit requirement.

Electives

23 units required. Students must take the 5 required courses listed. The remainder of the 23 units of electives may be any BIO or BIOHOPK course at the 100-level or above, 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.

		Units
5 Required Courses:		
BIO 149	The Neurobiology of Sleep	4-6
or BIO 150	Human Behavioral Biology	
or BIO 161	Organismal Biology Lab	
or NBIO 206	The Nervous System	
BIO 158	Developmental Neurobiology	4
or BIO 204	Neuroplasticity: From Synapses to Behavior	
BIO 126	Introduction to Biophysics	3-4
or BIO 154	Molecular and Cellular Neurobiology	
or BIO 267	Molecular Mechanisms of Neurodegenerative Disease	
CHEM 141	The Chemical Principles of Life I	4
CHEM 143	The Chemical Principles of Life II	4

Hopkins Marine Station

For additional information, see the "Biology, Hopkins Marine Station (http://exploredegrees.stanford.edu/schoolofhumanitiesandsciences/biologyhopkinsmarinestation/)" section of this bulletin or the Hopkins Marine Station web site (http://hopkins.stanford.edu).

Courses offered by the Department of Biology are listed under the subject code BIOHOPK on the (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=BIOHOPK&filter-catalognumber-BIOHOPK=on) Stanford Bulletin's (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=BIO&filter-catalognumber-BIO=on) ExploreCourses web site (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=BIO&filter-catalognumber-BIO=on).

Summer Program at Hopkins Marine Station

The summer program is open to advanced undergraduate, graduate students, and postdoctoral students, and to teachers whose biological backgrounds, teaching, or research activities can benefit from a summer's study of marine life. Applications, deadlines, and further information are available at http://hopkins.stanford.edu.

Courses

Courses at Hopkins Marine Station can satisfy many requirements, from Ways to major and minor requirements in departments housed in the Schools of Engineering, Humanities and Sciences, and Earth Sciences. Students are encouraged to check with their department's student services office to see which courses at Hopkins may be used to fulfill major or minor requirements.

Students may go to Hopkins as early as Spring Quarter in the sophomore year, and can also go in the junior and/or senior year to take elective courses. The following Hopkins Marine Station courses may be used toward the Biology degree requirements:

Foundations and Foundational Labs

		Units
BIOHOPK 81	Introduction to Ecology	4
BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	5
BIOHOPK 175H	Marine Science and Conservation in a Changing World	16

Electives

		Units
BIOHOPK 150H	Ecological Mechanics	3
BIOHOPK 152H	Physiology of Global Change	2

BIOHOPK 153H	Current Topics and Concepts in Quantitative Fish Dynamics and Fisheries Management	1
BIOHOPK 154H	Animal Diversity: An Introduction to Evolution of Animal Form and Function from Larvae to Adults	7
BIOHOPK 155H	Developmental Biology and Evolution	4
BIOHOPK 156H	Hands-On Neurobiology: Structure, Function and Development	6
BIOHOPK 160H	Developmental Biology in the Ocean: Diverse Embryonic & Larval Strategies of marine invertebrates	5-8
BIOHOPK 161H	Invertebrate Zoology	5
BIOHOPK 162H	Comparative Animal Physiology	5
BIOHOPK 163H	Oceanic Biology	4
BIOHOPK 165H	The Extreme Life of the Sea	3
BIOHOPK 166H	Molecular Ecology	5
BIOHOPK 167H	Nerve, Muscle, and Synapse	5
BIOHOPK 168H	Disease Ecology: from parasites evolution to the socio-economic impacts of pathogens on nations	3
BIOHOPK 173H	Marine Conservation Biology	4
BIOHOPK 173HA	Marine Conservation Biology - Seminar and Discussion Only	1-2
BIOHOPK 174H	Experimental Design and Probability	3
BIOHOPK 177H	Dynamics and Management of Marine Populations	4
BIOHOPK 179H	Physiological Ecology of Marine Megafauna	3
BIOHOPK 181H	Physiology of Global Change	2
BIOHOPK 182H	Stanford at Sea (only 6 units may count towards the major)	16
BIOHOPK 184H	Holistic Biology (only 6 units may count towards the major)	16
BIOHOPK 185H	Ecology and Conservation of Kelp Forest Communities	5
BIOHOPK 187H	Sensory Ecology	4
BIOHOPK 264H	POPULATION GENOMICS	1-2
BIOHOPK 274	Hopkins Microbiology Course	9-12

Research and/or Teaching (maximum 6 units combined)

		Units
BIOHOPK 198H	Directed Instruction or Reading	1-15
BIOHOPK 199H	Undergraduate Research	1-15
BIOHOPK 290H	Teaching Practicum in Biology	1-15
BIOHOPK 300H	Research	1-15

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

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.
- All courses must be worth or approved for 3 or more units.
- At least 3 courses must be taken at the 100-level or higher. The only courses below 100 that are allowable are BIO/BIOHOPK courses at the 60- and 80- level, and OSPAUSTL 10, 28, or 32. Note: OSPAUSTL 10, 28, 32 together count as 2 courses toward the minor.
- Courses used to fulfill the minor may not be used to fulfill any other department degree requirements (minor or major).
- Stanford Introductory Seminars may not be used to fulfill the minor requirements.
- All courses must be chosen from the offerings of the Department of Biology or the Hopkins Marine Station, or from the list of a (https://stanford.box.com/v/OODEMinor/)pproved out-of-department electives for the minor (https://drive.google.com/file/d/1c1ZypomL3W-M9I3a5kf2kfdPbPWysZOw/view/?usp=sharing). Any approved out of department elective must be approved for at least 3 units.
- At least two courses from the Biology Foundations must be taken:

		Units
BIO 81	Introduction to Ecology	4
or BIOHOPK 81	Introduction to Ecology	
or BIOHOPK 175H	Marine Science and Conservation in a Changing World	
BIO 82	Genetics	4
BIO 83	Biochemistry & Molecular Biology	4
BIO 84	Physiology	4
BIO 85	Evolution	4
BIO 86	Cell Biology	4

- A third Bio Foundations course may be taken OR students may take one introductory Biology course from the following list:

		Units
BIO 60	Problem solving in infectious disease	4
BIO 61	Science as a Creative Process	4
BIO 62	Microbiology Experiments	4

- The Biology Core Laboratory courses do not count towards the minor:

		Units
BIO 45	Introduction to Laboratory Research in Cell and Molecular Biology	4
BIO 46	Introduction to Research in Ecology and Evolutionary Biology	4
BIO 47	Introduction to Research in Ecology and Evolutionary Biology	4
BIOHOPK 47	Introduction to Research in Ecology and Ecological Physiology	5
BIOHOPK 175H	Marine Science and Conservation in a Changing World	16

- If taken for at least 3 units, independent research conducted in a Biology lab may count as 1 course. Note: Research done in a non-Biology lab cannot be counted toward the minor. Directed reading, either in department or out of the department, also cannot count toward the minor.

		Units
BIO 199	Advanced Research Laboratory in Experimental Biology	1-15
BIOHOPK 199H	Undergraduate Research	1-15
Not allowable:		
BIO 198	Directed Reading in Biology	
BIO 198X	Out-of-Department Directed Reading	
BIO 199X	Out-of-Department Advanced Research Laboratory in Experimental Biology	

Master of Science in Biology

For information on the University's basic requirements for the M.S. degree, see the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin. Students considering this degree option should meet with staff in the student services office prior to applying.

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, but course work equivalent to the preparation of a Stanford B.S. in Biology may be required in addition to the general requirements. This includes course work in biology, chemistry, physics and mathematics. 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:

1. undergraduates wishing to pursue a coterminal M.S. degree.
2. graduate students from other Stanford programs wishing to pursue an M.S. degree.
3. current Biology Ph.D. students wishing to discontinue the Ph.D. program with an M.S. degree.

Undergraduates must apply in Autumn Quarter to begin the program in Spring Quarter or in Spring Quarter to begin the program the following Autumn or Winter Quarter. Graduate students may apply by the third week of any academic quarter.

Required application materials

1. Completed Coterminal Online Application (https://applyweb.com/stanterm/)
2. A statement of purpose which explains why the student wishes to enter the program and what the student plans to accomplish while in the program. The statement should also supply information about the student's science capabilities if his or her undergraduate academic record does not accurately reflect them.
3. Unofficial Stanford transcript.
4. Two letters of recommendation, preferably from Biology faculty members in this department. If two such letters are not available, letters from faculty familiar with the student's ability to succeed in a graduate science curriculum are acceptable.
5. Application fee: an application fee is charged to all students regardless of outcome; application fee is applied directly to students' accounts.

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (http://exploredegrees.stanford.edu/cotermdegrees/)" section. University requirements for the master's degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken three quarters prior to the first graduate quarter, or later, are eligible for consideration for transfer to the graduate career. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate advisor be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

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 (with the exception of BIO 196 A, B, & C), distributed as follows:

1. A minimum of 23 of the 45 units must be courses designated primarily for graduate students.
2. A minimum of 36 units must be chosen from the offerings in the Department of Biology (BIO) (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&catalog=&page=0&q=BIO&filter-catalognumber-BIO=on), Hopkins Marine Station (BIOHOPK) (http://explorecourses.stanford.edu/CourseSearch/search/?view=catalog&page=0&catalog=&q=biohopk&collapse=), the list of approved out-of-department electives (https://stanford.app.box.com/v/out-of-department-electives/), research, teaching and/or foundational breadth courses.

		Units
BIO 198	Directed Reading in Biology	1-15
BIO 198X	Out-of-Department Directed Reading	1-15
BIO 290	Teaching Practicum in Biology	1-5
BIO 291	Development and Teaching of Core Experimental Laboratories	1-2
BIO 300	Graduate Research	1-10
BIO 300X	Out-of-Department Graduate Research	1-10
BIOHOPK 198H	Directed Instruction or Reading	1-15
BIOHOPK 290H	Teaching Practicum in Biology	1-15
BIOHOPK 300H	Research	1-15

   a. a maximum of 18 units may be a combination of Biology research, directed reading and/or teaching:
   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.
3. No more than 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 (https://stanford.app.box.com/v/general-petition/).

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

In addition to the unit requirements outlined above, students must adhere to the following:

1. A program proposal, signed by the student's advisor and approved by the chair of the M.S. committee, must be filed by the third week of the first quarter of enrollment. A revised program proposal is required to be filed whenever there are changes to a student's previously approved program proposal.
2. Students may take only 6 units CR/NC.

3. Students must maintain a GPA of 3.0 or higher.
4. Students must receive a grade of 'B-' or better in all courses taken for the degree.

Students not meeting these minimum requirements are subject to departmental academic review and/or dismissal.

The department's Master of Science Handbook (listed on the department website (https://biology.stanford.edu/academics/coterminal-masters-program/forms/)) has additional information about the program, University policy, and the department.

Doctor of Philosophy in Biology

For information on the University's basic requirements for the Ph.D. degree, see the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/)" section of this bulletin. The 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 in order 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

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 must apply via Stanford's online graduate application (http://gradadmissions.stanford.edu/).

The training for a Ph.D. in Biology is focused on helping students achieve their goals of being a successful research scientist and teacher, at the highest level. Students work closely with an established adviser and meet regularly with a committee of faculty members to facilitate their progress. The Biology Ph.D. program is part of the larger Biosciences (https://biosciences.stanford.edu/) community of Ph.D. programs at Stanford, which includes Ph.D. programs in Stanford School of Medicine.

There are three tracks within the Biology Ph.D. program: 1) Cellular, Molecular and Organismal Biology, 2) Ecology and Evolution, and 3) Hopkins Marine Station. All are focused on excellence in research and teaching in their respective areas; where there are differences between the tracks, they are indicated in the links below.

Applicants are not required to take the Graduate Record Examination (GRE) general test nor the GRE subject test, but applicants who have taken either of these exams may choose to report their scores.

Admission to the Ph.D. program is competitive and in recent years it has been possible to offer admission to approximately 9-10 percent of the applicants.

Applicants who are eligible should apply for nationally competitive predoctoral fellowships, especially those offered by 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

All students must be enrolled in exactly 10 units during autumn, winter, spring and summer quarters until reaching Terminal Graduate Registration (TGR) status and are required to pass all courses in which they are enrolled. Students must earn a grade of 'B-' or better in all courses applicable to the degree that are taken for a letter grade.Satisfactory completion of each year's general and track specific requirements listed below is required for satisfactory progress towards the degree. Students not making satisfactory degree progress are subject to departmental academic review and/or dismissal.

1. **First year advising**
   Each entering student meets with their Biology First Year Facilitator (BFF) within the first two weeks of Autumn Quarter, Winter Quarter, Spring Quarter. Students in the Eco/Evo track must also meet with their first-year advising committee during this time. 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 listed below under "Track Specific Requirements" is required of all students.
2. **Ethics**
   Students must take a course on the ethical conduct of research. One of the two following courses should be taken in the first year of the program:

		Units
MED 255	The Responsible Conduct of Research (Required for all CMOB students)	1
OR		
BIO 313	Ethics in the Anthropocene (BIO 313 is intended for Ecology/Evolution and Hopkins students only.)	1

3. **Teaching**
   Teaching experience and training are part of the graduate curriculum. Each student assists in teaching one course in
   a. the intro/foundational level (BIO 40s, 60s, and 80s level courses). *Note:* Hopkins students complete at least one TA requirement on campus during the first year. Any remaining TA requirements can be completed at Hopkins.

		Units
BIO 45	Introduction to Laboratory Research in Cell and Molecular Biology (Formerly 44X)	4
BIO 46	Introduction to Research in Ecology and Evolutionary Biology (Formerly 44Y)	4
BIO 47	Introduction to Research in Ecology and Evolutionary Biology (Formerly 44Y)	4
BIO 60	Problem solving in infectious disease	4
BIO 61	Science as a Creative Process	4
BIO 62	Microbiology Experiments	4
BIO 81	Introduction to Ecology	4
BIOHOPK 81	Introduction to Ecology	4
BIO 82	Genetics	4
BIO 83	Biochemistry & Molecular Biology	4
BIO 84	Physiology	4
BIOHOPK 84	Physiology	4
BIO 85	Evolution	4

BIOHOPK 85	Evolution	4
BIO 86	Cell Biology	4

b. and a second course that can be either an intro/foundational course or other Biology or Hopkins Marine Station course.

c. The opportunities to gain teaching experience and training in specific courses are assigned using the departmental matching system during the Spring and Summer quarters prior to the next academic year.

4. **Seminars**
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 Biology faculty members.
5. **Fellowship application**
All eligible first year students must apply for a National Science Foundation (NSF) Graduate Research Fellowship.
6. **Advisor/lab selection**
By June 1, each first-year student is required to have selected a lab in which to perform dissertation research and to have been accepted by the faculty member in charge.
7. **Qualifying exam and admission to candidacy**
During the second year, students are required to write a dissertation proposal which is evaluated by a committee of faculty (the dissertation proposal committee) in an oral presentation. Track-specific deadlines are listed below. All students must be admitted to candidacy by the end of their second year. This is contingent upon satisfactory completion of course work, all first and second year requirements, the dissertation proposal and the University's requirements for candidacy outlined in the "Candidacy (http://exploredegrees.stanford.edu/graduatedegrees/#doctoraltext)" section of this bulletin; additional details may also be found in the Biology Ph.D. Handbook (https://stanford.box.com/v/PhDHandbook/). If a student does not meet the requirements for admission to candidacy by the end of the second year, the student is subject to dismissal from the Ph.D. program.
8. **Committee meetings**
Students must meet regularly with their advising committees. For more details, see the Biology Ph.D. Handbook (https://stanford.box.com/v/PhDHandbook/).
9. **Individual Development Plan meetings**
Students must meet once a year with their adviser by August 1 of that academic year. For more details, see the Biology Ph.D. Handbook (https://stanford.box.com/v/PhDHandbook/).
10. **Publishable manuscript**
Each student must complete one publishable manuscript (paper) for which s/he is the major contributor.
11. **Residency requirement**
Graduate students are expected to maintain a significant physical presence on campus unless the degree program has granted an exception, for example to conduct field work (GAP 3.1.1 (https://gap.stanford.edu/handbooks/gap-handbook/chapter-3/subchapter-1/page-3-1-1/)). Unless permission is granted by the department (for example, for field work) enrolled graduate students must maintain a significant physical presence on campus throughout each quarter a student is enrolled. A minimum of 135 units of graduate registration is required of each candidate at the time of graduation.
12. **Doctoral dissertation**
A substantial draft of the dissertation must be submitted to the student's oral examination committee at least one month before the oral exam is scheduled to take place. The dissertation must be presented to an oral examination committee (http://exploredegrees.stanford.edu/graduatedegrees/#doctoraltext) comprised of at least five faculty members. In addition, the final written dissertation must be approved by the student's reading committee (http://exploredegrees.stanford.edu/graduatedegrees/#doctoraltext) (a minimum of three approved faculty), and submitted to 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 concentration. 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.

Cellular, Molecular, and Organismal Biology (CMOB)

1. Courses: Students are required to take the following courses prior to Spring Quarter of the 4th year, except for the required first year courses as noted:

		Units
BIOS 200	Foundations in Experimental Biology (must be taken Autumn quarter of the first year)	5
BIO 301	Frontiers in Biology (satisfies first-year seminar requirement; must be taken Autumn quarter of first year)	1-3
One additional course in each of the four scientific areas decided upon by the student and the advising committee [1]		
1. Cell Biology		
2. Biology of Molecules		
3. Genetics/Genomics		
4. Quantitative Methods		

2. Lab Rotations*:* First-year students are required to do their first rotation in the lab of a Department of Biology faculty member for at least five weeks. The total rotation time in labs of Department of Biology faculty must be at least ten weeks. Students are encouraged to do at least two rotations in the Department of Biology.
3. Two-part qualifying exam: Each student must pass the exam in their second year.
   a. *Dissertation proposal:* During Autumn Quarter of the second year, the student must prepare a written dissertation proposal that outlines the student's projected dissertation research, including an expert assessment of the current literature; deadline is November 1.
   b. *Oral examination:* Held after submission of the written proposal to the dissertation proposal committee. It is an evaluation of the student's ability to summarize the field of study, generate a working hypothesis, develop a degree plan that could be completed in 3-4 years, understand the logic of experimental design, develop a decision tree based on (all) possible results of experiments and draw conclusions and adapt hypotheses depending on results. Deadline is November 15.
4. Seminar Presentation: The seminar requirement is fulfilled by presenting a minimum of a 30-minute talk. The student must arrange for at least two faculty members from the Department of Biology to attend the seminar and evaluate the presentation. Evaluation consists of meeting with each faculty member within one week following the seminar to obtain comments. If the faculty members approve the presentation, they sign the form at this time. In some

cases, they may require an additional talk before signing. The Seminar Evaluation form must be submitted to the student services office no later than June 1 of year three in the program.

[1] Up to two of these courses may be "mini courses" in the Biosciences (BIOS).

Ecology and Evolution

1. Courses: Students are required to take the following courses in their first year:

		Units
BIO 302	Current Topics and Concepts in Population Biology, Ecology, and Evolution	1
BIO 303	Current Topics and Concepts in Population Biology, Ecology, and Evolution	1
BIO 304	Current Topics and Concepts in Population Biology, Ecology, and Evolution	1
Students specializing in ecology and evolution may be required to take additional courses as advised by committee.		

2. Lab Rotations: EcoEvo Ph.D. students may rotate with and select as the primary Ph.D. adviser any faculty member with a primary appointment in one of the Biosciences Home Programs. While rotations are not required in order to choose the primary adviser, they are certainly possible. Many students collaborate with faculty in addition to their primary adviser in order to increase breadth and depth. This is usually accomplished with the advice and encouragement of the primary Ph.D. adviser.
3. First-year paper*:* The paper should be read, commented upon and agreed to as satisfactory by two EcoEvo faculty by June 1. This can be satisfied in a number of ways which all involve new writing, undertaken since entering the Stanford program. These may include:
   a. A new draft research manuscript (a previously published paper is not acceptable).
   b. Some other piece of new writing, such as a review paper from a course, or an initial literature review of a potential thesis topic. In this case the paper should ordinarily be not less than 10 double-spaced pages in usual sized font, and not more than 10 single spaced pages, plus references. It should be written in the style of a standard scientific paper.
4. Two-part qualifying exam: Each student must pass the exam in their second year.

   a. *Dissertation proposal:* During Spring Quarter of the second year, the student must prepare a written dissertation proposal that outlines the student's projected dissertation research, including an expert assessment of the current literature; deadline is June 1.
   b. *Oral examination:* Held after submission of the written proposal to the dissertation proposal committee. The student should prepare a presentation of the goals of the thesis, typically including preliminary data, models, etc. as appropriate which are relevant to at least the first goal, and should be prepared thereafter to discuss questions raised by the committee in professional scientific depth. Deadline is June 15.

Students are strongly encouraged to speak directly with their adviser and committee if they have specific questions or concerns regarding the format and content of the written proposal and/or procedures for the oral examination

Hopkins Marine Station

1. Courses: Students are required to take the following courses prior to Spring Quarter of the fourth year, except for the required first year courses as noted:

		Units
Seminar series (student should make selection in consultation with their advisor)		
BIO 301	Frontiers in Biology	1-3
OR		
BIO 302	Current Topics and Concepts in Population Biology, Ecology, and Evolution	1
BIO 303	Current Topics and Concepts in Population Biology, Ecology, and Evolution	1
BIO 304	Current Topics and Concepts in Population Biology, Ecology, and Evolution	1
Two additional Hopkins Marine Station courses (BIOHOPK). These may include BIOS mini courses offered at Hopkins.		
Students may also be required to take a set of courses to be determined by the advising committee.		

2. Lab Rotations: As with all students in the Biology Department, Hopkins Ph.D. students may rotate with and select as the primary Ph.D. adviser any faculty member with a primary appointment in one of the Biosciences home programs. In order to increase breadth and depth, many Hopkins students rotate through labs on main campus during their first year before moving to Hopkins, and continue to collaborate with faculty in addition to their primary adviser at Hopkins. This is usually accomplished with the advice and encouragement of the primary Ph.D. adviser.
3. First-Year Paper: The paper should be read, commented upon and agreed to as satisfactory by two faculty by June 1. 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. This can be satisfied in a number of ways that all involve new writing, undertaken since entering the Stanford program. These may include:
   a. A new draft research manuscript; a previously published paper is not acceptable because it may have received much editorial modification in the review process.
   b. Some other piece of new writing, such as a review paper from a course, or an initial literature review of a potential thesis topic. In this case the paper should ordinarily be not less than 10 or more than 20 double-spaced pages in usual sized font, plus references. It should be written in the style of a standard scientific paper.
4. Two-part qualifying exam: Each student must pass the exam in their second year. Students at Hopkins have the option of following the process of either the CMOB or Eco/Evo tracks (see above).
5. Graduate Student Symposium: All second- and fourth-year students are required to present at an annual student symposium (typically in February).
   a. Second-Year Students: The first half of the symposium gives second-year graduate students a forum to present plans for their graduate work. Because each student's research is different, there is no one-size-fits-all plan for these talks. But in general, these 20 minute presentations are meant to answer the questions: "What broad area of marine biology am I pursuing for my Ph.D.? What is known about this now? What am I planning broadly to contribute? What preliminary or initial data do I have?"
   b. Fourth-Year Students: The presentation for fourth-year students comes in two parts:
      i. Each student prepares a written overview of their doctoral research, including progress to date and plans for the final

thesis. The document should be single spaced, 11-point (or larger) font, and should not exceed 3 pages (including figures and tables, but excluding references). In addition to this research overview, each student submits an up-to-date CV, and the research overview and CV should be submitted no later than one week before the symposium date. This deadline gives a panel of judges time to review the documents prior to the symposium. Please combine the research statement and CV into a single PDF file, and email it to both the director and associate director.

ii. In the second half of the symposium, each fourth-year student presents to the judges and a general audience a 20-minute report on their Ph.D. research. Along with the written research overview, this is intended to give each student a chance to pull together their data and analyses to date, lay out initial conclusions, and explore what they mean in the context of their overall research interests and goals. As with the research overviews, these talks give students a chance to concentrate on what progress they have made along the complex path of their Ph.D., and what they are particularly excited about. Laying out plans for finishing the thesis should be a part of these talks, but should not be the main topic.

iii. After the symposium, the judges meet to choose the most outstanding combination of research statement and oral presentation. This student receives the Lederberg Award.

Note: Written petitions for exemptions to requirements are considered by a student's Advising Committee and the Graduate Studies Committee Chair. Approval is contingent on special circumstances and is not routinely granted.

COVID-19 Policies

On July 30, the Academic Senate adopted grading policies effective for all undergraduate and graduate programs, excepting the professional Graduate School of Business, School of Law, and the School of Medicine M.D. Program. For a complete list of those and other academic policies relating to the pandemic, see the "COVID-19 and Academic Continuity (http://exploredegrees.stanford.edu/covid-19-policy-changes/#tempdepttemplatetabtext)" section of this bulletin.

The Senate decided that all undergraduate and graduate courses offered for a letter grade must also offer students the option of taking the course for a “credit” or “no credit” grade and recommended that deans, departments, and programs consider adopting local policies to count courses taken for a “credit” or “satisfactory” grade toward the fulfillment of degree-program requirements and/or alter program requirements as appropriate.

Undergraduate Degree Requirements

Grading

The Department of Biology counts all courses taken in academic year 2020-21 with a grade of 'CR' (credit) or 'S' (satisfactory) towards satisfaction of undergraduate degree requirements that otherwise require a letter grade.

Graduate Degree Requirements

Grading

The Department of Biology counts all courses taken in academic year 2020-21 with a grade of 'CR' (credit) or 'S' (satisfactory) towards satisfaction of undergraduate degree requirements that otherwise require a letter grade.

Other Graduate Policies

Students entering the program during the 2020-21 academic year are allowed to rotate in a non-Biology department lab during their first rotation.

Graduate Advising Expectations

The Department of Biology is committed to providing academic advising in support of graduate student scholarly and professional development. When most effective, this advising relationship entails collaborative and sustained engagement by both the advisor and the advisee.

All first-year Biology graduate students have an assigned a Biology First-Year Facilitator (BFF). Faculty mentorship in the BFF program is focused on helping students integrate into the department culture through non-judgmental advocacy. BFFs support students as they manage their lab rotations and chose appropriate coursework. Emphasis is placed on cultivating a supportive relationship between faculty and student during what is often a stressful period of transition. The student services office (SSO) and the Director of Graduate Studies (DGS) have primary responsibility for ensuring students fulfill departmental requirements (coursework, TAships) and submit the appropriate forms on time.

Course Advising Workshops are organized to assist students in the selection of classes for the next quarter. The workshop consists of student, faculty, and SSO representatives who can advise on appropriate coursework to take. Students and faculty establish a course of study, taking into consideration: (1) area of specialization; (2) training in accessory areas such as language, math, physical sciences and computer science; and (3) breadth in biology.

Graduate students are expected to select a thesis advisor before the end of the first year of the program. Students are encouraged to work collaboratively with their advisors to establish a dissertation project and form a Dissertation Reading Committee. Advancement to doctoral candidacy is expected to occur during the second year of the program.

Thesis advisers are expected to meet with graduate students at least once each year to discuss and help develop the students' Individual Development Plans (IDP). Additionally, advisers and students should meet on a regular basis throughout the year to discuss the student's professional development in key areas such as selecting courses, designing and conducting research, developing teaching pedagogy, navigating policies and degree requirements, and exploring academic opportunities and professional pathways.

Graduate students are active contributors to the advising relationship. They should proactively seek academic and professional guidance and take responsibility for informing themselves of policies and degree requirements for the Biology Ph.D. program.

As a best practice, advising expectations should be periodically discussed and reviewed to ensure mutual understanding. Both the advisor and the advisee are expected to maintain professionalism and integrity.

Academic progress and student completion of program requirements and milestones are monitored by the program director and staff, and are discussed by faculty at an annual meeting devoted to assessing graduate student progress. A detailed description of the program's requirements, milestones, and advising expectations are listed in the Biology Ph.D. Student Handbook, found on the program web site.

The Director of Graduate Studies (DGS) is available during office hours and by appointment. In addition, each Autumn the DGS meets with each cohort of graduate students to discuss what aspects of the Ph.D. program areas warrant improvement. Together with the DGS, the Graduate Studies Committee acts as a mechanism to address these concerns and update advising policies. The committee is formed from faculty and student representatives of CMOB, EcoEvo, and Hopkins tracks.

Additionally, the program adheres to the advising guidelines and responsibilities listed by the Office of the Vice Provost for Graduate Education (https://vpge.stanford.edu/academic-guidance/advising-mentoring/) (VPGE) and in the Graduate Academic Policies (https://gap.stanford.edu/handbooks/gap-handbook/chapter-3/subchapter-3/page-3-3-1/) (GAP).

Emeriti Professors: Paul R. Ehrlich, David Epel, Philip C. Hanawalt, Patricia P. Jones, Donald Kennedy, Harold A. Mooney, W. James Nelson, Peter Ray, Joan Roughgarden, Robert D. Simoni, George N. Somero, Ward B. Watt, Norman K. Wessells, Dow O. Woodward

Emeritus Professor (Teaching): Carol L. Boggs

Chair: Martha S. Cyert

Director of Graduate Studies: Jose R. Dinneny

Director of Undergraduate Studies: Tadashi Fukami

Professors: Dominique Bergmann, Barbara A. Block, Steven M. Block, Larry B. Crowder, Martha S. Cyert, Gretchen C. Daily, Giulio De Leo, Mark W. Denny, Rodolfo Dirzo, Marcus W. Feldman, Russell D. Fernald, Christopher B. Field, Judith Frydman, William F. Gilly, Deborah M. Gordon, Or Gozani, Elizabeth A. Hadly, H. Craig Heller, Christine Jacobs-Wagner, Richard G. Klein, Ron R. Kopito, Sharon R. Long, Liqun Luo, Susan K. McConnell, Fiorenza Micheli, Mary Beth Mudgett, Stephen R. Palumbi, Dmitri Petrov, Jonathan Pritchard, Noah A. Rosenberg, Robert M. Sapolsky, Mark J. Schnitzer, Carla J. Shatz, Kang Shen, Michael A. Simon, Tim P. Stearns, Marc Tessier-Lavigne, Stuart H. Thompson, Alice Ting, Shripad Tuljapurkar, Peter Vitousek, Virginia Walbot

Professor (Research): Anthony Barnosky

Associate Professors: Xiaoke Chen, Jose R. Dinneny, Hunter B. Fraser, Tadashi Fukami, Christopher Lowe, Ashby Morrison, Kabir Peay, M. Kristy Red-Horse, Jan M. Skotheim

Associate Professor (Research): Mary Hynes

Assistant Professors: Jonas B. Cremer, Scott J. Dixon, Jessica L. Feldman, Jeremy A. Goldbogen, Erin Mordecai, Lauren O'Connell, Molly Schumer

Courtesy Emeritus Professor: Kathryn Barton

Courtesy Professors: Joseph Berry, Devaki Bhaya, Carlos D. Bustamante, Daniel Fisher, Arthur R. Grossman, Joseph S. Lipsick, Alfred Spormann, Irving Weissman

Courtesy Associate Professors: David Ehrhardt, Jonathan Payne, Sue Rhee, Zhiyong Wang

Courtesy Assistant Professor: Paula V. Welander

Lecturers: Daria Hekmat-Scafe, Jamie Imam, Waheeda Khalfan, Shyamala D. Malladi, Jesse E. D. Miller, Andrew Todhunter,

Librarian: Michael Newman

Overseas Studies Courses in Biology

The Bing Overseas Studies Program (http://bosp.stanford.edu) (BOSP) manages Stanford international and domestic study away programs for Stanford undergraduates. Students should consult their department or program's student services office for applicability of Overseas Studies courses to a major or minor program.

The BOSP course search site (https://undergrad.stanford.edu/programs/bosp/explore/search-courses/) displays courses, locations, and quarters relevant to specific majors.

For course descriptions and additional offerings, see the listings in the Stanford Bulletin's ExploreCourses (http://explorecourses.stanford.edu) or Bing Overseas Studies (http://bosp.stanford.edu).

Due to COVID-19, all BOSP programs have been suspended for Autumn Quarter 2020-21. All courses and quarters of operation are subject to change.

		Units
BIO 121	ORNITHOLOGY	3
BIOE 103	Systems Physiology and Design	4
OSPAUSTL 10	Coral Reef Ecosystems	3
OSPAUSTL 28	Terrestrial Ecology and Conservation	3
OSPAUSTL 32	Coastal Ecosystems	3

Courses

BIO 2N. Ecology and Evolution of Infectious Disease in a Changing World. 3 Units.
This seminar will explore the ways in which anthropogenic change, climate change, habitat destruction, land use change, and species invasions effects the ecology and evolution of infectious diseases. Topics will include infectious diseases of humans, wildlife, livestock, and crops, effects of disease on threatened species, disease spillover, emerging diseases, and the role of disease in natural systems. Course will be taught through a combination of popular and scientific readings, discussion, and lecture. .

BIO 3. Frontiers in Marine Biology. 1 Unit.
An introduction to contemporary research in marine biology, including ecology, conservation biology, environmental toxicology, behavior, biomechanics, evolution, neurobiology, and molecular biology. Emphasis is on new discoveries and the technologies used to make them. Weekly lectures by faculty from the Hopkins Marine Station.

BIO 3N. Views of a Changing Sea: Literature & Science. 3 Units.
The state of a changing world ocean, particularly in the eastern Pacific, will be examined through historical and contemporary fiction, non-fiction and scientific publications. Issues will include harvest and mariculture fisheries, land-sea interactions and oceanic climate change in both surface and deep waters.

BIO 6N. Ocean Conservation: Pathways to Solutions. 3 Units.
We will learn how to design pathways to solutions by integrating social sciences and governance into our case studies. We will address both conventional (fisheries management, reducing the impacts of global shipping, marine protected areas) and emerging research and management approaches (marine spatial planning, dynamic ocean management, environmental DNA). Oceans are facing long-term challenges, like overfishing and pollution that we know how to solve, and emerging challenges, like climate change and ocean plastics, for which solutions are more elusive. Ultimately to achieve long-term sustainability, solutions have to work for both people and the planet. These puzzles offer challenging complex systems problems that will require our best interdisciplinary thinking to solve.

BIO 7N. Conservation Photography. 3 Units.
Introduction to the field of conservation photography and the strategic use of visual communication in addressing issues concerning the environment and conservation. Students will be introduced to basic digital photography, digital image processing, and the theory and application of photographic techniques. Case studies of conservation issues will be examined through photographs and multimedia platforms including images, video, and audio. Lectures, tutorials, demonstrations, and optional field trips will culminate in the production of individual and group projects.

BIO 8N. Human Origins. 3 Units.
A survey of the anatomical and behavioral evidence for human evolution and of the increasingly important information from molecular genetics. Emphasis on the split between the human and chimpanzee lines 6-7 million years ago, the appearance of the australopiths by 4.1 million years ago, the emergence of the genus Homo about 2.5 million years ago, the spread of Homo from Africa 1.7-1.6 million years ago, the subsequent divergence of Homo into different species on different continents, and the expansion of fully modern humans (Homo sapiens) from Africa about 50,000 years ago to replace the Neanderthals and other non-modern Eurasians.

BIO 8S. Introduction to Human Physiology. 4 Units.
Normal functioning and pathophysiology of major organ systems: nervous, respiratory, cardiovascular, renal, digestive, and endocrine. Additional topics include integrative physiology, clinical case studies, and applications in genomics-based personalized medicine.

BIO 10N. Using Physics to Explain Biology: Mechanistic Approaches to Plankton Ecology. 3 Units.
People often think of physics and biology as entirely separate scientific pursuits, but in fact the two can be productively combined. All plants and animals live in a physical environment, and the laws of physics that govern that environment often determine how organisms function and interact. In this seminar, we will explore the confluence of physics and biology through an in-depth look at how phytoplankton and zooplankton -- the small algae and animals that form the base of the oceans' food web -- are affected by the physical properties of their watery world. You will be amazed by our ability to explain the ecology of these organisms, and how important that ecology is to life on earth.

BIO 12N. Sensory Ecology of Marine Animals. 3 Units.
Animals living in the oceans experience a highly varied range of environmental stimuli. An aquatic lifestyle requires an equally rich range of sensory adaptations, including some that are totally foreign to us. In this course we will examine sensory system in marine animals from both an environmental and behavioral perspective and from the point of view of neuroscience and information systems engineering.

BIO 16. Conservation Storytelling: Pre-course for BOSP South Africa. 1 Unit.
Limited to students admitted to the BOSP South Africa overseas seminar. Through 5 workshop meetings, students will develop and pitch story ideas, form teams in which a writer and a photographer agree to collaborate on a story, and conduct background research prior to departing for South Africa.

BIO 16N. Island Ecology. 3 Units.
Preference to freshmen. How ecologists think about the world. Focus is on the Hawaiian Islands: origin, geology, climate, evolution and ecology of flora and fauna, and ecosystems. The reasons for the concentration of threatened and endangered species in Hawaii, the scientific basis for their protection and recovery. How knowledge of island ecosystems can contribute to ecology and conservation biology on continents.

BIO 19S. Science of Covid-19. 4 Units.
This course is designed to help students apply knowledge from an introductory high school biology course to problems related to Covid-19. We will examine how the virus SARS-CoV-2 attacks the human body, how the immune system responds, how testing works, and how this information can be used to design drugs and vaccines to halt the spread of the virus. There has been an explosion of research papers and many claims in the media about the virus. We will evaluate the claims critically and explore the underlying science by reading a few selected papers.

BIO 24N. Visions of Paradise: Garden Design. 3 Units.
Through literature readings and field trips to local gardens learn the principles and esthetics of classic garden designs: Italian Renaissance, botanical teaching, Japanese, English cottage, and others. Design a personal vision of paradise with details of species, visual and scent impact, water features, and hardscape. Open your eyes to a new appreciation of the world of plants and learn some physiology and genetics that explains the specific properties of individual species.

BIO 25Q. Cystic fibrosis: from medical conundrum to precision medicine success story. 3 Units.
The class will explore cystic fibrosis (CF), the most prevalent fatal genetic disease in the US, as a scientific and medical whodunit. Through reading and discussion of medical and scientific literature, we will tackle questions that include: how was life expectancy with CF increased from weeks to decades without understanding the disease mechanism? Why is the disease so prevalent? Is there an advantage to being a carrier? Is CF a single disease or a continuum of physiological variation; or- what is a disease? How did research into CF lead to discovery of the underlying cause of most other genetic diseases as well? Through critical reading of the scientific and medical literature, class discussion, field trips and meetings with genetic counselors, caregivers, patients, physicians and researchers, we will work to build a deep understanding of this disease, from the biochemical basis to the current controversies over pathogenic mechanisms, treatment strategies and the ethics and economics of genetic testing and astronomical drug costs.

BIO 27S. Evolution: From DNA to Dinosaurs. 3 Units.
This course centers on the fundamental idea of evolution, which impacts fields as disparate as genetics to paleontology. You will learn about the history of evolutionary thought, including Darwin¿s idea of evolution by natural selection, and explore evolutionary timescales both small and large. Topics include population genetics, genomics, molecular evolution, evolutionary forces, formation of new species, evolutionary divergences in the history of life, and evidence of evolution, including patterns from DNA and the fossil record.

BIO 28S. Molecular Genetics and Biotechnology. 3 Units.
This course covers the fundamentals of molecular genetics, including principles of how genes work, how gene expression is regulated in both prokaryotes and eukaryotes, and how signals are passed from cells to cells that are far away. We will also explore key advances in biotechnology, including cloning, sequencing, and next-generation sequencing, and discuss case studies involving cancer, Huntington¿s Disease, and more.

BIO 30. Ecology for Everyone. 4 Units.
Ecology is the science of interactions and the changes they generate. This project-based course links individual behavior, population growth, species interactions, and ecosystem function. Introduction to measurement, observation, experimental design and hypothesis testing in field projects. The goal is to learn to think analytically about everyday ecological processes, including those that you participate in, which involve bacteria, fungi, plants, animals and humans. The course uses basic statistics to analyze data; there are no math prerequisites except arithmetic. Open to everyone, including those who may be headed for more advanced courses in ecology and environmental science. The online version will meet synchronously and involve preparation outside of class for interactive discussions during class time. We will organize field projects that you can do wherever you are. Projects begin in the first week of the quarter. For questions please contact Prof. Gordon at dmgordon@stanford.edu.

BIO 35. Sustainability and Civilization. 1 Unit.
Our civilization faces enormous sustainability challenges, and meeting them will require all of the considerable talent and vision of the rising generation. The unsustainability of the carbon-based energy regime underpinning the global economy has become increasingly apparent, and much of the biological world, as well as our own species, is at risk from human activity. The international political order has proven less stable than many twentieth-century observers expected, and both economic and cultural systems have suffered increasing shocks in recent decades. Science and technology have made enormous advances, but the resulting increases in our power to affect the world carry risks, as well as potential solutions. Some of these properties of modern societies, moreover, have contributed to the rise of the global pandemic, whose widespread effects remind us of the fragility of our knowledge-dependent civilization. This one-unit, online course will bring together faculty from across the entire University to address sustainability broadly conceived. Speakers will survey the range of threats facing us, explore potential solutions, and engage our next generation of future leaders in live discussion about these pressing issues.

BIO 35N. Climate change ecology: Is it too late?. 3 Units.
This Introductory Seminar will explore the consequences of climate change on ecological communities, focusing on two emerging concepts: "disequilibrium," which emphasizes that it can take long time for communities to respond to climate change because of species interactions, and "historical contingency," which proposes that the order in which species invade and disappear as communities re-assemble in response to climate change will determine which species will persist. The seminar will involve lecture, discussion, writing, and visit to Jasper Ridge Biological Preserve.

BIO 45. Introduction to Laboratory Research in Cell and Molecular Biology. 4 Units.
Investigate yeast strains that are engineered to express the human tumor suppressor protein, p53, and use modern molecular methods to identify the functional consequences of p53 mutations isolated from tumor cells. Learn about the protein's role as Guardian of the Genome through lectures and by reading and discussing journal articles. Use molecular visualization programs to examine the structure of normal and mutant p53 proteins. Learn about the assays used to study the ability of mutant p53 to direct expression of several reporter genes. During guided reflection, investigate further and identify what could be wrong with the p53 mutants you have been studying. Learn how to ask a question, test a hypothesis, conduct experiments and analyze data, and present your findings through a team oral presentation, as well as a scientific poster. Although there are no pre-requisites to enroll in this class, it will be helpful if you have already taken or are concurrently enrolled in the appropriate Biology Foundation classes (or HumBio core classes). Additionally, it will also be helpful if you have already taken CHEM 31M, or 31A & B.

BIO 46. Introduction to Research in Ecology and Evolutionary Biology. 4 Units.
The goal of this course is to develop an understanding of how to conduct biological research, using topics in Ecology as practical examples. This includes the complete scientific process: assessing background literature, generating testable hypotheses, learning techniques for data collection, analyzing data using appropriate statistical methods, and writing and sharing results. To build these skills, this course focuses on the microorganisms associated with lichen epiphytes and their interactions with air pollution and other environmental variables. Students, working in teams, develop novel research hypotheses and execute the necessary experiments and measurements to test these hypotheses. Because the course will be online this year, we will analyze data collected in previous years rather than conducting field and lab experiments in person. In addition, students will learn how to manipulate, visualize, and analyze data in R. The capstone of the course is a research paper in the style of a peer-reviewed journal article, as well as an educational video designed for a general audience that communicates research findings. IMPORTANT NOTE: Students who require BIO 46 to satisfy the WIM requirement for the Biology major MUST take this course for a letter grade (except in 2020-21).

BIO 47. Introduction to Research in Ecology and Evolutionary Biology. 4 Units.
The goal of this course is to develop an understanding of how to conduct biological research, using a topic in Ecology, Evolutionary Biology, and Plant Biology as a practical example. This includes the complete scientific process: assessing background literature, generating testable hypotheses, learning techniques for field- and lab- based data collection, analyzing data using appropriate statistical methods and finally writing and sharing the results. To build these skills, this course focuses on nectar microbes at Stanfords nearby Jasper Ridge Biological Preserve. Students, working in teams, will develop novel research hypotheses and do the necessary data analyses to test these hypotheses. The capstone of the course is a research paper written in the style of a peer-reviewed journal article as well as an oral defense of students research findings. Because the course will be offered online this year, we will analyze the data collected in previous years rather than conduct field and lab experiments in person. Although there are no pre-requisites to enroll in the class, it will be helpful if you have already taken BIO 81 or are concurrently enrolled in or have already taken the relevant HumBio core class. Note: Satisfies WIM in Biology.

BIO 50S. Introduction to Cancer Biology. 3 Units.
Introduction to the molecular basis of cancer. This course will examine the biological processes that are disrupted in cancer, such as DNA repair, cell cycle control and signaling pathways, as well as the science behind some current treatments. Prerequisites: general biology.

BIO 51S. The Gene: The History and Science of our Genetic Code. 3 Units.
This discussion-based course will use the novel ¿The gene¿ by Siddhartha Mukherjee and other selected readings to explore the science behind our genetic code. We will cover topics such as regulation of gene expression, inheritance, genetic testing, manipulation of the genome, and the relationship between genetics and identity. Prerequisites: Instructor consent, AP Biology Recommended.

BIO 52. I, Scientist: Diversity Improves the Scientific Practice. 1 Unit.
Disciplinary priorities, research agendas, and innovations are determined by the diversity of participants and problem-solving is more successful with a broad range of approaches. Using case studies in scientific research, we propose to use these insights to help our students learn why a diverse scientific community leads to better discovery and improves the relevance of science to society. Our premise is that a diverse set of perspectives will impact not only how we learn science, but how we do science.
Same as: CSRE 52H

BIO 53. Conservation Photography. 3 Units.
Introduction to the field of conservation photography and the strategic use of visual communication in addressing issues concerning the environment and conservation. Students will be introduced to basic digital photography, digital image processing, and the theory and application of photographic techniques. Case studies of conservation issues will be examined through photographs and multimedia platforms including images, video, and audio. Lectures, tutorials, demonstrations, and optional field trips will culminate in the production of individual and group projects. This course is identical to Bio 7N, so students enrolled in the former should not take this course. Open to undergraduates and graduate students. Students must have access to a DSLR camera and lenses - we can accept up to 20 students who can share 10 course-provided cameras and lenses, by application. Application for camera use: https://forms.gle/1yAD3my8GoDseXw59.

BIO 57. THE STATE OF HUMANS AND THE PLANET. 4 Units.
How does human well-being affect their environment and the reverse? The goals of this course are to examine ways of measuring human and environmental well-being, their main interactions now and in the next several decades, and to identify challenges and gaps in our knowledge.

BIO 60. Problem solving in infectious disease. 4 Units.
Why is Lyme disease spreading? How does HIV become drug resistant? How do other animals affect our disease risk? In BIO 60 students will examine actual case studies to experience how different scientific approaches are used to battle infectious disease. They will evaluate information presented in the popular media and the scientific literature, and will directly participate in the scientific process through hands-on collection, documentation and analyses of authentic scientific data. Students will cultivate their scientific curiosity by discovering the natural world with a Foldscope, the `origami paper microscope¿ (https://microcosmos.foldscope.com). Students will build critical thinking skills by creating hypotheses, and designing experiments that pertain to problems in infectious disease. Students will work in teams to expand their thinking and will practice communicating science to different audiences.

BIO 61. Science as a Creative Process. 4 Units.
What is the process of science, and why does creativity matter? We'll delve deeply into the applicability of science in addressing a vast range of real-world problems. This course is designed to teach the scientific method as it's actually practiced by working scientists. It will cover how to ask a well-posed question, how to design a good experiment, how to collect and interpret quantitative data, how to recover from error, and how to communicate findings. Facts matter! Course topics will include experimental design, statistics and statistical significance, formulating appropriate controls, modeling, peer review, and more. The course will incorporate a significant hands-on component featuring device fabrication, testing, and measurement. Among other "Dorm Science" activities, we'll be distributing Arduino microcontroller kits and electronic sensors, then use these items, along with other materials, to complete a variety of group and individual projects outside the classroom. The final course assignment will be to develop and write a scientific grant proposal to test a student-selected myth or scientific controversy. Although helpful, no prior experience with electronics or computer programming is required. Recommended for freshmen.
Same as: APPPHYS 61

BIO 62. Microbiology Experiments. 4 Units.
Micro-X is an on-ramp course in which we explore classic to modern bacteriology experiments with a focus on design and logic. Bacterial biochemistry, structure, metabolism, and genetics are covered in lecture. The lab includes microbial culture, microscopic examination, and bacteriophage discovery and characterization. Enrollment limited; application required. Apply at https://forms.gle/x37kwXvJxvQmN1sA6 by December 3rd to get preference for enrollment.

BIO 81. Introduction to Ecology. 4 Units.
This course will introduce you to the first principles of the science of ecology, the study of interactions between organisms and their environment. Prerequisites: None.

BIO 82. Genetics. 4 Units.
The focus of the course is on the basic mechanisms underlying the transmission of genetic information and on the use of genetic analysis to study biological and medical questions. Major topics will include: (1) the use of existing genetic variation in humans and other species to identify genes that play an important role in determining traits and disease-susceptibility, (2) the analysis of mutations in model organisms and their use in the investigation of biological processes and questions and (3) using genetic information for diagnosis and the potential for genetic manipulations to treat disease. Prerequisites: None, but BIO 83 is recommended. For 2021, Live Zoom lectures will be recorded and posted on Canvas for students with conflicts. Attendance at a discussion section held once a week is mandatory. For logistical questions about the course, please contact Waheeda Khalfan (wkhalfan@stanford.edu).

BIO 83. Biochemistry & Molecular Biology. 4 Units.
Introduction to the molecular and biochemical basis of life. Lecture topics include the structure and function of proteins, nucleic acids, lipids and carbohydrates, energy metabolism, signal transduction, epigenetics and DNA repair. The course will also consider how defects in these processes cause disease. Prerequisites: None.

BIO 84. Physiology. 4 Units.
The focus of Physiology is on understanding how organisms tackle the physical challenges of life on Earth. This course will provide an overview of animal and plant physiology and teach an understanding of how organisms maintain homeostasis, respond to environmental cues and coordinate behaviors across multiples tissues and organ systems. We will examine the structure and function of organs and organ systems and how those systems are controlled and regulated to maintain homeostasis. Control and regulation requires information as does the ability to respond to environmental stimuli, so we will give special consideration to hormonal and neural information systems. We will also be concerned with the interactions and integration of the activities of the different organ systems we study. Prerequisites: none. For 2021, Live Zoom lectures will be recorded and posted on Canvas for students with conflicts. Attendance at a discussion section held once a week is mandatory. There will be no exams in the course. For logistical questions about the course, please contact Waheeda Khalfan (wkhalfan@stanford.edu).

BIO 85. Evolution. 4 Units.
Understanding evolution is key to understanding the diversity of life on earth. We will be focusing on the fundamental principles of evolutionary biology from natural and sexual selection to the formation of new species. To understand these concepts we will delve into the mechanisms that underlie them. The course will also link these fundamental processes to important contemporary evolutionary topics such as the evolution of behavior, life history evolution, and human evolution. Prerequisites: BIO 60 or 61 or 62 or equivalent; recommended: BIO 82, or permission of instructor.

BIO 86. Cell Biology. 4 Units.
This course will focus on the basic structures inside cells and how they execute cellular functions. Topics include organelles, membrane trafficking, the cytoskeleton, cell division, and signal transduction. Classic and recent primary literature will be incorporated into lectures with an emphasis on state of the art experimental approaches. Prerequisites: BIO 83 is highly recommended.

BIO 89SI. Evolutionary Medicine. 2 Units.
Why are body systems prone to disease? This course will explore theories about the evolutionary basis of diseases, including cancer, diabetes, and psychiatric disease. Students with a background in genetics, physiology, and evolution will synthesize these fields to better understand human health and disease. The course will involve readings from and discussions about the primary literature.

BIO 102. Ecosystem Ecology and Biogeochemistry. 3 Units.
An introduction to ecosystem ecology and terrestrial biogeochemistry. This course will focus on the dynamics of carbon and other biologically essential elements in the Earth System, on spatial scales from local to global.

BIO 103. HUMAN AND PLANET HEALTH. 2 Units.
Two of the biggest challenges humanity has to face - promoting human health and halting environmental degradation ¿ are strongly linked. The emerging field of Planetary Health recognizes these inter-linkages and promotes creative, interdisciplinary solutions that protect human health and the health of the ecosystems on which we depend. Through a series of lectures and case-study discussions, students will develop an in-depth understanding of the ¿Planetary Health¿ concept, its foundation, goals, priority areas of action, methods of investigation, and the most relevant immediate challenges.
Same as: BIO 203

BIO 104. Advance Molecular Biology: Epigenetics and Proteostasis. 5 Units.
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 or BIO 83 (BIO 82 and 86 are strongly recommended).
Same as: BIO 200

BIO 105A. Ecology and Natural History of Jasper Ridge Biological Preserve. 4 Units.
Ecology and Natural History of Jasper Ridge Biological Preserve an upper-division course, aims to help student learn ecology and natural history using a ¿living laboratory¿, the Jasper Ridge Preserve. The course¿s central goal is that, as a community of learning, we examine ¿via introductory discussions, followed by hands-on experiences in the field¿ the scientific basis of: ecological research, archaeology, edaphology, geology, hydrology, species interactions, land management, and multidisciplinary environmental education. The 10 sessions that compose the academic program are led by the instructors, faculty (world-experts on the themes of each session), and JRBP staff. In addition, this class trains students to become JRBP Docents that therefore join the Jasper Ridge education affiliates community. nnAfter completing this course and as new affiliates of Jasper Ridge, participants will be able to lead research-focused educational tours, assist with classes and research, and attend continuing education activities available to members of the JRBP community.
Same as: EARTHSYS 105A

BIO 105B. Ecology and Natural History of Jasper Ridge Biological Preserve. 4 Units.
Ecology and Natural History of Jasper Ridge Biological Preserve an upper-division course, aims to help students learn ecology and natural history using a living laboratory, the Jasper Ridge Preserve. The course's central goal is that, as a community of learning, we examine via introductory discussions, followed by hands-on experiences in the field, the scientific basis of: ecological research, archaeology, edaphology, geology, hydrology, species interactions, land management, and multidisciplinary environmental education. The 10 sessions that compose the academic program are led by the instructors, faculty (world-experts on the themes of each session), and JRBP staff. In addition, this class trains students to become JRBP Docents that therefore join the Jasper Ridge education affiliates community. After completing this course, and as new affiliates of Jasper Ridge, participants will be able to lead research-focused educational tours, assist with classes and research, and attend continuing education activities available to members of the JRBP community.
Same as: EARTHSYS 105B

BIO 109A. Building Blocks for Chronic Disease. 3 Units.
Researchers have come a long way in developing therapies for chronic disease but a gap remains between current solutions and the ability to address the disease in full. This course provides an overview to the underlying biology of many of these diseases and how they may connect to each other. A "think outside of the box" approach to drug discovery is needed to bridge such a gap in solutions, and this course teaches the building blocks for that approach. Could Legoland provide the answer? This is a guest lecture series with original contributions from prominent thought leaders in academia and industry. Interaction between students and guest lecturers is expected. Students with a major, minor or coterm in Biology: 109A/209A or 109B/209B may count toward degree program but not both.
Same as: BIOC 109A, BIOC 209A, HUMBIO 158

BIO 109B. Advances in Therapeutic Development: Neuronal Signaling and Immunology. 3 Units.
This is a seminar course focused on teaching students about novel research and applications in the fields of neuroscience and immunology. The course will cover topics that range from the neuronal pathways in opioid addiction and the mechanics of pain, to advances in immunotherapy. Students will engage with diverse material from leading neuroscience and cancer immunotherapy experts in the Bay Area. Guest lecturers will visit from both academia and neighboring pharmaceutical/biotechnology companies. Active participation is required. Prerequisite: Biology or Human Biology core. Students with a major, minor or coterm in Biology: 109A/209A or 109B/209B may count toward degree program, but not both.
Same as: BIOC 109B

BIO 110. The Chromatin-Regulated Genome. 3 Units.
Maintenance of the genome is a prerequisite for life. In eukaryotes, all DNA-templated processes are tightly connected to chromatin structure and function. This course will explore epigenetic and chromatin regulation of cellular processes related to aging, cancer, stem cell pluripotency, metabolic homeostasis, and development. Course material integrates current literature with a foundational review of histone modifications and nucleosome composition in epigenetic inheritance, transcription, replication, cell division and DNA damage responses. Prerequisite: BIO 41 or BIO 83 or consent of instructor.
Same as: BIO 210

BIO 112. Human Physiology. 4 Units.
Human physiology will be examined by organ systems: cardiovascular, respiratory, renal, gastrointestinal and endocrine. Molecular and cell biology and signaling principles that underlie organ development, pathophysiology and opportunities for regenerative medicine are discussed, as well as integrative control mechanisms and fetal development. Prerequisite: Human Biology core or Biology Foundations or equivalent or consent of instructor.
Same as: HUMBIO 133

BIO 113. Fundamentals of Molecular Evolution. 4 Units.
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 BIO 82, 85 or graduate standing in any department, and consent of instructor.
Same as: BIO 244

BIO 114. bioBUDS (Building Up Developing Scientists): Science In & Beyond the Lab. 2 Units.
Your unique knowledge, experiences, and goals to enhance our collective understanding of life around us. BUDS aims to expand the idea of what it means to be a scientist and aid in the process of becoming community-driven scientists in and beyond the lab. We will spotlight graduate students and associations from historically underrepresented groups for their perspectives on research and broader STEM careers. All journal clubs and workshops are open to all students regardless of department affiliation, experience-level, or field.

BIO 115. The Hidden Kingdom - Evolution, Ecology and Diversity of Fungi. 4 Units.
Fungi are critical, yet often hidden, components of the biosphere. They regulate decomposition, are primary partners in plant symbiosis and strongly impact agriculture and economics. Students will explore the fascinating world of fungal biology, ecology and evolution via lecture, lab, field exercises and Saturday field trips that will provide traditional and molecular experiences in the collection, analysis and industrial use of diverse fungi. Students will chose an environmental niche, collect and identify resident fungi, and hypothesize about their community relationship. Prerequisite: BIO 81, 85 recommended.
Same as: BIO 239

BIO 116. Ecology of the Hawaiian Islands. 4 Units.
Terrestrial and marine ecology and conservation biology of the Hawaiian Archipelago. Taught in the field in Hawaii as part of quarter-long sequence of courses including Earth Sciences and Anthropology. Topics include ecological succession, plant-soil interactions, conservation biology, biological invasions and ecosystem consequences, and coral reef ecology. Restricted to students accepted into the Earth Systems of Hawaii Program.
Same as: EARTHSYS 116

BIO 117. Biology and Global Change. 4 Units.
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 BIO 81 or graduate standing.
Same as: EARTHSYS 111, EARTHSYS 217, ESS 111

BIO 119. Evolution of Marine Ecosystems. 3-4 Units.
Life originally evolved in the ocean. When, why, and how did the major transitions occur in the history of marine life? What triggered the rapid evolution and diversification of animals in the Cambrian, after more than 3.5 billion years of Earth's history? What caused Earth's major mass extinction events? How do ancient extinction events compare to current threats to marine ecosystems? How has the evolution of primary producers impacted animals, and how has animal evolution impacted primary producers? In this course, we will review the latest evidence regarding these major questions in the history of marine ecosystems. We will develop familiarity with the most common groups of marine animal fossils. We will also conduct original analyses of paleontological data, developing skills both in the framing and testing of scientific hypotheses and in data analysis and presentation.
Same as: EARTHSYS 122, GEOLSCI 123, GEOLSCI 223B

BIO 120. Prokaryotic Biology - A Quantitative Approach. 3 Units.
To live, microbes have to successfully coordinate various cellular processes, in line with available resources and what environmental conditions demand. This course introduces quantitative advances in understanding this coordination and their consequences across scales: from molecular biology via growth to population dynamics and ecology. Dry lab sessions complement lectures to introduce computational approaches. Python based analysis tools will be introduced. Prerequisite: MATH 51 or MATH 19, 20,21. Recommended: microbiology (e.g. BIO 62 or 162) and molecular biology/biochemistry/genetics courses (e.g. BIO 82 or 83) and basic familiarity with coding.
Same as: BIO 220

BIO 121. ORNITHOLOGY. 3 Units.
Advanced undergraduate survey of ornithology, introducing students to the biology of birds and giving them to tools to use birds as model systems for research. Topics will include avian evolution, physiology, adaptations, behavior, and ecology. Focus throughout on identification of California birds and applications to current bird conservation issues. Course will include lectures and a field component which will expose students to standard avian research techniques such as mistnetting, banding, and point count surveys. Prerequisite: BIO 81 or BIO 105 or instructor approval.
Same as: BIO 221

BIO 124. Topics in Cancer Biology. 3 Units.
This discussion-based course will explore the scientific tools used to study the molecular and genetic basis of cancer and to develop treatments for this disease. Topics covered may include cancer models, traditional and targeted cancer therapies, and the development of resistance to treatment. Students will develop skills in critical reading of primary research articles and will also complete a final project. Prerequisites: Human Biology core or BIO 82, 83, 86, or with permission of instructor.

BIO 126. Introduction to Biophysics. 3-4 Units.
Core course appropriate for advanced undergraduate students and graduate students with prior knowledge of calculus and a college physics course. Introduction to how physical principles offer insights into modern biology, with regard to the structural, dynamical, and functional organization of biological systems. Topics include the roles of free energy, diffusion, electromotive forces, non-equilibrium dynamics, and information in fundamental biological processes.
Same as: APPPHYS 205, BIO 226

BIO 129. Fundamentals and Frontiers in Plant Biology. 3 Units.
This course will serve as a primer for all levels of graduate, co-term, and upper-level undergraduates interested in learning about the fundamental aspects of plant biology, the latest advances in tools, techniques, and theories that link basic science with translational science and applications for solving major societal challenges of today and tomorrow. In addition, this course will serve to introduce the breadth of plant research on campus and help solidify a cohort of students interested in plant biology.
Same as: BIO 229

BIO 130. Ecosystems of California. 4 Units.
California is home to a huge diversity of ecosystem types and processes. This course provides an introduction to the natural history, systematics, and ecosystem ecology of California ecosystems, based on a combination of lectures, student-led projects, and weekend field trips. Ecosystems to be explored will range from coasts to mountains and from desert to wetlands. Requirements include three essays and participation in three field trips (of six options).
Same as: EARTHSYS 130A

BIO 132. Advanced Imaging Lab in Biophysics. 4 Units.
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, microendoscopy, and optical trapping. Limited enrollment. Recommended: basic physics, basic cell biology, and consent of instructor.
Same as: APPPHYS 232, BIO 232, BIOPHYS 232, GENE 232

BIO 134. Molecular and cellular analysis of human cancer cell lines. 4 Units.
This laboratory course will use cultured mammalian cells to study whether drug treatment can restore function to mutant versions of the tumor suppressor p53. Students will perform a variety of cellular and molecular techniques, including RT-PCR and immunofluorescence, to test certain abilities of their mutant in the presence and absence of the drug. The project will culminate with student-designed experiments testing a functional aspect of p53 and presentation of the results for both expert and lay audiences. Strongly suggested prerequisite: BIO 45, BIO 82, 83, 86.

BIO 135. Neuroethology. 3 Units.
Neuroethology is the study of the neural basis of animal behavior. We will explore the neural mechanisms of natural behaviors in a diverse set of organisms. Topics include molecular mechanisms of nervous system function, predator-prey interactions, social behavior, and other complex behaviors like learning and memory, navigation, and communication. Assessment includes group oral presentations of scientific papers, weekly homework prompts that lead into a mini grant proposal, and scientific writing and communication with the broader public on a neuroethological topic. Prerequisites: BIO 84.
Same as: BIO 235

BIO 136. Macroevolution. 3 Units.
The course will focus on the macroevolution of animals. We will be exploring how paleobiology and developmental biology/genomics have contributed to our understanding of the origins of animals, and how patterns of evolution and extinction have shaped the diversity of animal forms we observe today.
Same as: BIO 236, GEOLSCI 136, GEOLSCI 236

BIO 137. Plant Genetics. 3-4 Units.
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. Satisfies WIM in Biology.

BIO 138. Ecosystem Services: Frontiers in the Science of Valuing Nature. 3 Units.
This course explores the science of valuing nature, beginning with its historical origins and then a primary focus on its recent development and frontiers. The principal aim of the course is to enable new research and real-world applications of InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) tools and approaches. We will discuss the interconnections between people and nature and key research frontiers, such as in the realms of biodiversity, resilience, human health, poverty alleviation, and sustainable development. The science we¿ll explore is in the service of decisions, and we will use examples from real life to illustrate why this science is so critical to informing why, where, how, and how much people need nature. Prerequisite. Basic to intermediate GIS skills are required (including working with raster, vector and tabular data; loading and editing rasters, shapefiles, and tables into a GIS; understanding coordinate systems; and performing basic raster math).
Same as: BIO 238, EARTHSYS 139, EARTHSYS 239

BIO 140. The Science of Extreme Life of the Sea. 3 Units.
Covers the way marine animals and plants live in extreme environments by examining morphological, ecological, and genetic adaptations to low temperature, high heat, deep water, etc. We also cover extreme lifestyles such as fast swimming, small and large body size, and novel reproductive systems. Lecture material is punctuated with a series of tutorials on narrative writing skills in science, especially creative non-fiction, memoirs, braided essays and short fiction. The goal is to integrate quantitative thinking about the life sciences with creative writing that brings facts to life. Prerequisites: core courses in biology, creative writing, environmental sciences or engineering. Two lectures back to back on Tuesdays with a Writing Intermezzo between.

BIO 141. Biostatistics. 5 Units.
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.
Same as: STATS 141

BIO 142. Molecular Geomicrobiology Laboratory. 3-4 Units.
In this course, students will be studying the biosynthesis of cyclic lipid biomarkers, molecules that are produced by modern microbes that can be preserved in rocks that are over a billion years old and which geologist use as molecular fossils. Students will be tasked with identifying potential biomarker lipid synthesis genes in environmental genomic databases, expressing those genes in a model bacterial expression system in the lab, and then analyzing the lipid products that are produced. The overall goal is for students to experience the scientific research process including generating hypotheses, testing these hypotheses in laboratory experiments, and communicating their results through a publication style paper. Prerequisites: BIO83 and CHEM 121 or permission of the instructor.
Same as: EARTHSYS 143, ESS 143, ESS 243

BIO 144. Conservation Biology: A Latin American Perspective. 3 Units.
Principles and application of the science of preserving biological diversity. Conceptually, this course is designed to explore the major components relevant to the conservation of biodiversity, as exemplified by the Latin American region. The conceptual frameworks and principles, however, should be generally applicable, and provide insights for all regions of the world. All students will be expected to conduct a literature research exercise leading to a written report, addressing a topic of their choosing, derived from any of the themes discussed in class. Prerequisite: BIO 101 or BIO 43 or HUMBIO 2A or BIO 81 and 84 or consent of instructor.
Same as: BIO 234, HUMBIO 112

BIO 145. Ecology and Evolution of Animal Behavior. 3 Units.
Ecological and evolutionary perspectives on animal behavior, with an emphasis on social and collective behavior. This is a project-based course in a lecture/seminar format. Seminars will be based on discussion of journal articles. Independent research projects on the behavior of animals on campus. Prerequisites: Biology or Human Biology core or BIO 81 and 85 or consent of instructor; Biology/ES 30. Recommended: statistics.
Same as: BIO 245

BIO 146. Genes and Disease. 3 Units.
Students in this course will uncover key principles of genetics and molecular biology through investigation of case studies of human disease and novel therapeutic approaches in development. This course will require close reading and discussion of primary literature and will emphasize and support the development of critical skills in scientific communication. Students will utilize a variety of mediums to convey scientific information to a range of audiences in a series of projects completed during the quarter. Prerequisites: BIO 82, 83 and 86 or equivalent.

BIO 147. Ecosystem Ecology and Biogeochemistry. 3 Units.
An introduction to ecosystem ecology and terrestrial biogeochemistry. This course will focus on the dynamics of carbon and other biologically essential elements in the Earth System, on spatial scales from local to global. Prerequisites: Biology 117, Earth Systems 111, or graduate standing.
Same as: BIO 240, EARTHSYS 147, EARTHSYS 247

BIO 148. Evolution of Terrestrial Ecosystems. 4 Units.
The what, when, where, and how do we know it regarding life on land through time. Fossil plants, fungi, invertebrates, and vertebrates (yes, dinosaurs) are all covered, including how all of those components interact with each other and with changing climates, continental drift, atmospheric composition, and environmental perturbations like glaciation and mass extinction. The course involves both lecture and lab components. Graduate students registering at the 200-level are expected to write a term paper, but can opt out of some labs where appropriate.
Same as: BIO 228, EARTHSYS 128, GEOLSCI 128, GEOLSCI 228

BIO 149. The Neurobiology of Sleep. 4 Units.
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. nnPreference to seniors and graduate students. nnEnrollment limited to 16.
Same as: BIO 249, HUMBIO 161, PSYC 149, PSYC 261

BIO 150. Human Behavioral Biology. 5 Units.
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.
Same as: HUMBIO 160

BIO 151. Mechanisms of Neuron Death. 3 Units.
For undergraduates with backgrounds 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. Assessment based on in-class participation and short weekly papers. Enrollment limited to 15; application required. Apply at https://forms.gle/UE8EcQi3jS6do31a7 by 4:30pm on Wednesday, September 9, 2020.

BIO 152. Imaging: Biological Light Microscopy. 3 Units.
This intensive laboratory and discussion course will provide participants with the theoretical and practical knowledge to utilize emerging imaging technologies based on light microscopy. Topics include microscope optics, resolution limits, Köhler illumination, confocal fluorescence, two-photon, TIRF, FRET, photobleaching, super-resolution (SIM, STED, STORM/PALM), tissue clearing/CLARITY/light-sheet microscopy, and live-cell imaging. Applications include using fluorescent probes to analyze subcellular localization and live cell-translocation dynamics. We will be using a flipped classroom for the course in that students will watch iBiology lectures before class, and class time will be used for engaging in extensive discussion. Lab portion involves extensive in-class use of microscopes in the CSIF and NMS core microscopy facilities.
Same as: MCP 222

BIO 153. Cellular Neuroscience: Cell Signaling and Behavior. 4 Units.
Neural interactions underlying behavior. Prerequisites: PSYCH 1 or basic biology.
Same as: PSYCH 120

BIO 154. Molecular and Cellular Neurobiology. 4 Units.
For advanced undergraduate 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. Highly recommended: BioCore or BIO 82, 83, 86, or consent of instructor.

BIO 155. Cell and Developmental Biology of Plants. 3 Units.
In this course we will learn how plants are built at different organizational scales from the cell, tissue, organ and organ system level. We will also learn about the experimental methods used to study plants at these different organizational levels and how to interpret and evaluate experiments that use such methods. Broadly relevant skills that will be cultivated in the course include: evaluating primarily literature, identifying gaps in knowledge, formulating research questions and designing new experimental strategies. Prerequisites: BIO 80 series.
Same as: BIO 255

BIO 156. California Wildfires: Forest Fire Ecology, Management, and Policy. 3 Units.
Widespread wildfires have become an annual occurrence throughout California with massive implications for both the natural world and human society. The impacts of these fires are likely to grow with further climate change and land-use intensification. This class will take an interdisciplinary perspective on forest fires including the physiological, environmental, and social implications of the fires themselves, as well as the result of wildfire policy on nature and human beings, with a particular focus on equity of impacts across class and racial lines.

BIO 158. Developmental Neurobiology. 4 Units.
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. Prerequisites: BIO 82, 83, 84, 86.
Same as: BIO 258

BIO 160. Developmental Biology. 4 Units.
This course will cover the molecular mechanisms underlying the generation of diverse cell types and tissues during embryonic and post-embryonic animal development. Topics include the role of cell-cell communication in controlling developmental decisions, the organization and patterning of large groups of cells via morphogen signaling, the specification of individual cell types, and the role of stem cells in development. The course emphasizes the experimental logic and methods of research in developmental biology and includes discussions of research papers.

BIO 161. Organismal Biology Lab. 4 Units.
This laboratory is a genuine research experience course where students contribute to original research in a field of organismal biology. This year, the course will focus on the physiology of chemical defenses in poisonous amphibians through three modules. In the first module focusing on chemistry, students will work with metabolomics data to interpret and visualize chemical signatures of poison frog defense. In the second module focusing on physiology, students will learn to analyze gene expression differences in various tissues from RNA sequencing data. In the third module focusing on ecology, students will learn to analyze animal diet and foraging strategies through metabarcoding. Finally, students will integrate these datasets together for an organismal perspective on chemical defenses. Students will work collaboratively to analyze data and will learn to communicate their findings clearly through oral and written formats.

BIO 162. Mechanisms of Tissue Regeneration. 3 Units.
Many organisms possess a remarkable ability to repair and regenerate damaged organs and tissues. This course will explore the cellular and developmental mechanisms used to achieve regeneration. Students will learn the basic developmental and cellular mechanisms underlying the original formation of organs during normal development and how these mechanisms are modified during the regenerative process. The course will also consider how our expanding knowledge of regeneration mechanisms could be used to promote medically useful regeneration in humans. The course will involve extensive reading and analysis of primary literature. Prerequisites: BIO 86 and BIO160 or by consent of instructor.

BIO 168. Explorations in Stem Cell Biology. 3 Units.
A discussion-based course for advanced undergraduates. The purpose of this course is to introduce students to key topics in stem cell biology and foster the development of strong scientific writing skills. We will review and discuss some landmark and current primary literature in the stem cell field. Topics will include embryonic and adult stem cells, cellular reprogramming and stem cells in disease and regenerative medicine. Students will present a current research paper in their preferred stem cell topic area and compose a novel research proposal. Prerequisites: Biology or Human Biology core or BIO 82, 83, 86. Satisfies WIM in Biology.

BIO 171. Principles of Cell Cycle Control. 3 Units.
Genetic analysis of the key regulatory circuits governing the control of cell division. Illustration of key principles that can be generalized to other synthetic and natural biological circuits. Focus on tractable model organisms; growth control; irreversible biochemical switches; chromosome duplication; mitosis; DNA damage checkpoints; MAPK pathway-cell cycle interface; oncogenesis. Analysis of classic and current primary literature.
Same as: BIO 271, CSB 271

BIO 172. Ecological Dynamics: Theory and Applications. 4 Units.
Structured population models with age and phenotypic variation. Integral population models, model fitting and dynamics. Fitness and dynamic heterogeneity. Examples from natural populations (sheep, roe deer, plants, birds). Graduate students will be responsible for additional problem sets. Prerequisites: calculus and linear algebra.
Same as: BIO 272

BIO 173. Chemical Biology. 3 Units.
Chemical biology is an integrative discipline that seeks to apply chemical tools and approaches to understand biology. This course will introduce students to various methods and approaches used in this field, with an emphasis on the use of natural products and synthetic small molecules as probes of biological function. Specific examples will be used to illustrate the ramifications of chemical biology with molecular, cell and developmental biology. The interaction between disease and drug discovery will be considered in detail. Prerequisites: BIO 83, and BIO 82 and/or BIO 84.

BIO 174. Human Skeletal Anatomy. 5 Units.
Study of the human skeleton (a. k. a. human osteology), as it bears on other disciplines, including medicine, forensics, archaeology, and paleoanthropology (human evolution). Basic bone biology, anatomy, and development, emphasizing hands-on examination and identification of human skeletal parts, their implications for determining an individual's age, sex, geographic origin, and health status, and for the evolutionary history of our species. Three hours of lecture and at least three hours of supervised and independent study in the lab each week.
Same as: ANTHRO 175, ANTHRO 275, BIO 274, HUMBIO 180

BIO 175. Collective Behavior and Distributed Intelligence. 3 Units.
This course will explore possibilities for student research projects based on presentations of faculty research. We will cover a broad range of topics within the general area of collective behavior, both natural and artificial. Students will build on faculty presentations to develop proposals for future projects.
Same as: SYMSYS 275

BIO 176. The Developmental Basis of Animal Body Plan Evolution. 4 Units.
Animals are grouped into phyla with defined organizational characteristics such as multicellularity, axis organization, and nervous system organization, as well as morphological novelties such as eyes, limbs and segments. This course explores the developmental and molecular origins of there animal innovations. Offered alternate years. Prerequisites: None.
Same as: BIO 276

BIO 177. Plant Microbe Interaction. 3 Units.
Molecular basis of plant symbiosis and pathogenesis. Topics include mechanisms of recognition and signaling between microbes and plant hosts, with examples such as the role of small molecules, secreted peptides, and signal transduction pathways in symbiotic or pathogenic interactions. Readings include landmark papers together with readings in the contemporary literature. Prerequisites: Biology core and two or more upper division courses in genetics, molecular biology, or biochemistry. Recommended: plant genetics or plant biochemistry.
Same as: BIO 277

BIO 178. Microbiology Literature. 3 Units.
For advanced undergraduates and first-year graduate students. Critical reading of the research literature in prokaryotic genetics and molecular biology, with particular applications to the study of major human pathogens. Classic and foundational papers in pathogenesis, genetics, and molecular biology; recent literature on bacterial pathogens such as Salmonella, Vibrio, and/or Yersinia. Diverse experimental approaches: biochemistry, genomics, pathogenesis, and cell biology. Prerequisites: Declared Biology majors must have taken BIO 82 (Genetics) and BIO 83 (Biochemistry). Enrollment for undergraduates is limited to Biology majors in junior or senior year. Co-term or Ph.D. students in basic life sciences departments such as Biology, Bioengineering, and Genetics may also enroll in BIO 278. Apply at https://forms.gle/4NTtcBdWYMqRFvGc9.
Same as: BIO 278

BIO 179. Integrated Valuation of Ecosystem Services and Tradeoffs. 1-3 Unit.
This course explores the science of valuing nature, through two interwoven pathways. One is biophysical, focused on human dependence and impacts on Earth¿s life-support systems. If well managed, lands, waters, and biodiversity yield a flow of vital benefits that sustain and fulfill human life. A wild bee buzzes through a farm, pollinating vegetables as it goes. Nearby, wetlands remove chemicals from the farm¿s runoff, protecting a source of drinking water. In parklands at a city¿s edge, kids play and adults walk and talk, their exposure to nature promoting physical activity and improved mental health. The trees help maintain a favorable climate, locally and globally. We¿ll develop a framework and practical tools for quantifying this stream of benefits from nature to people.nThe second pathway is social, economic, and philosophical, weaving through concepts of well-being, human development, and conservation ¿ and the ethics and effects of their pursuit. We will look back, ahead into the future, and inward, taking a global view and considering diverse cultural perspectives. Our discussions will be situated in the context of the COVID-19 pandemic, movements for racial justice and socioeconomic equity, and efforts to enable people and nature to thrive in cities and countries worldwide.nAll of the science we¿ll explore is in service of decisions. We will dive into real-world examples to see how science can inform why, where, how, and how much people need nature. We will learn the basics of the InVEST tools (for Integrated Valuation of Ecosystem Services and Tradeoffs) to quantify benefits of nature, the equitability in access to these benefits, and the transformation of policy, finance, management, and practice to sustain and enhance them. nThe course is intended for diverse, advanced students, with interests in research and in moving from science to action for a more just and sustainable world. The instructors aim to provide an enjoyable and productive opportunity to connect ¿ remotely and yet with a lot of heart as well as intellectual drive and commitment, bringing empathy, flexibility and hopefully some humor to the day-to-day challenges we are all facing in different difficult ways. Prerequisite: Basic to intermediate GIS (Geographic Information Systems) skills are necessary. We will help with these, but not teach GIS specifically in class. Basic skills include, for example: working with raster, vector and tabular data; loading rasters, shapefiles, and tables into a GIS; changing the symbology of rasters and shapefiles in your chosen GIS; editing raster and shapefile attribute tables; understanding coordinate systems and how to re-project layers; looking at individual raster cell values; and performing basic raster math.
Same as: BIO 279

BIO 180. Microbial Physiology. 3 Units.
Introduction to the physiology of microbes including cellular structure, transcription and translation, growth and metabolism, mechanisms for stress resistance and the formation of microbial communities. These topics will be covered in relation to the evolution of early life on Earth, ancient ecosystems, and the interpretation of the rock record. Recommended: introductory biology and chemistry.
Same as: EARTHSYS 255, ESS 255, GEOLSCI 233A

BIO 182. Modeling Cultural Evolution. 3 Units.
Seminar. Quantitative models for the evolution of socially transmitted traits. Rates of change of learned traits in populations and patterns of cultural diversity as a function of innovation and cultural transmission. Learning in constant and changing environments. Possible avenues for gene-culture coevolution.
Same as: BIO 282

BIO 183. Theoretical Population Genetics. 3 Units.
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.
Same as: BIO 283

BIO 187. Mathematical Population Biology. 3 Units.
Mathematical models in population biology, in biological areas including demography, ecology, epidemiology, evolution, and genetics. Mathematical approaches include techniques in areas such as combinatorics, differential equations, dynamical systems, linear algebra, probability, and stochastic processes. Math 50 or 60 series is required, and at least two of (Bio 81, Bio 82, Bio 85) are strongly recommended.
Same as: CME 187

BIO 193. Interdisciplinary Approaches to Human Health Research. 1 Unit.
For undergraduate students participating in the Stanford ChEM-H Undergraduate Scholars Program. This course will expose students to interdisciplinary research questions and approaches that span chemistry, engineering, biology, and medicine. Focus is on the development and practice of scientific reading, writing, and presentation skills intended to complement hands-on laboratory research. Students will read scientific articles, write research proposals, make posters, and give presentations.
Same as: BIOE 193, CHEM 193, CHEMENG 193

BIO 196A. Biology Senior Reflection. 3 Units.
Capstone course series for seniors. Creative, self-reflective and scientifically relevant projects conceived, produced and exhibited over the course of three quarters. Explore scientific content of personal interest through creative forms including but not limited to writing, music, fine arts, performing arts, photography, film or new media. A written essay on the creative process and scientific significance of the selected topic will accompany the creative work. Completed projects may be included in a creative portfolio. Required enrollment in 196A,B,C. Satisfies WIM in Biology. May be repeat for credit.

BIO 196B. Biology Senior Reflection. 3 Units.
Capstone course series for seniors. Creative, self-reflective and scientifically relevant projects conceived, produced and exhibited over the course of three quarters. Explore scientific content of personal interest through creative forms including but not limited to writing, music, fine arts, performing arts, photography, film or new media. A written essay on the creative process and scientific significance of the selected topic will accompany the creative work. Completed projects may be included in a creative portfolio. Required enrollment in 196A,B,C. May be repeat for credit.

BIO 196C. Biology Senior Reflection. 3 Units.
Capstone course series for seniors. Creative, self-reflective and scientifically relevant projects conceived, produced and exhibited over the course of three quarters. Explore scientific content of personal interest through creative forms including but not limited to writing, music, fine arts, performing arts, photography, film or new media. A written essay on the creative process and scientific significance of the selected topic will accompany the creative work. Completed projects may be included in a creative portfolio. Required enrollment in 196A,B,C. May be repeat for credit.

BIO 198. Directed Reading in Biology. 1-15 Unit.
Individually arranged under the supervision of members of the faculty.

BIO 198X. Out-of-Department Directed Reading. 1-15 Unit.
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 https://biology.stanford.edu/academics/undergraduate-research/directed-reading for information and petitions. May be repeated for credit.

BIO 199. Advanced Research Laboratory in Experimental Biology. 1-15 Unit.
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.

BIO 199W. Senior Honors Thesis: How to Effectively Write About Scientific Research. 3 Units.
The goal of this class is to train students in effective scientific communication. It is designed to serve students working on their senior honors research to help facilitate the completion of their honors thesis. Topics covered will include elevator pitches, creating and improving the sections of the thesis, oral presentations and posters in the context of students¿ individual research projects. Emphasis will be on building and practicing the skills for 1) completing your thesis, poster and presentations and 2) gaining a conceptual understanding of effective scientific writing and communication that will be applicable more broadly. Satisfies the WIM requirement in Biology.

BIO 199X. Out-of-Department Advanced Research Laboratory in Experimental Biology. 1-15 Unit.
Individual research by arrangement with out-of-department instructors. Credit for 199X is restricted to declared Biology majors and requires department approval. See https://biology.stanford.edu/academics/undergraduate-research/research for information on research sponsors, units, petitions, deadlines, credit for summer research, and out-of-Stanford research. May be repeated for credit.

BIO 200. Advance Molecular Biology: Epigenetics and Proteostasis. 5 Units.
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 or BIO 83 (BIO 82 and 86 are strongly recommended).
Same as: BIO 104

BIO 202. Ecological Statistics. 3 Units.
Intended for graduate students (and advanced undergraduates in special circumstances with consent of instructors) in biology and related environmental sciences, this course is an introduction to statistical methods for ecological data analysis, using the programming language R. The course will have lectures, discussions, and independent research projects using the students¿ own data or simulated or publicly available data.

BIO 203. HUMAN AND PLANET HEALTH. 2 Units.
Two of the biggest challenges humanity has to face - promoting human health and halting environmental degradation ¿ are strongly linked. The emerging field of Planetary Health recognizes these inter-linkages and promotes creative, interdisciplinary solutions that protect human health and the health of the ecosystems on which we depend. Through a series of lectures and case-study discussions, students will develop an in-depth understanding of the ¿Planetary Health¿ concept, its foundation, goals, priority areas of action, methods of investigation, and the most relevant immediate challenges.
Same as: BIO 103

BIO 204. Neuroplasticity: From Synapses to Behavior. 3 Units.
This course will focus on neuroplasticity from a broad perspective, from molecular cellular mechanism to its involvement in behavior and diseases. Emphasis will be on: a) molecular and cellular mechanisms underlying various forms of neuroplasticity; b) the neuroplasticity during brain development; c) the neuroplasticity in adult brain with respect to learning and memory; and d) maladaptive neuroplasticity in neurodegenerative disease and drug addiction. This course is designed for Ph.D. students from both the Biology and Neuroscience programs. Open to advanced undergraduates by consent of instructor.

BIO 208. Spanish in Science/Science in Spanish. 2 Units.
For graduate and undergraduate students interested in the natural sciences and the Spanish language. Students will acquire the ability to communicate in Spanish using scientific language and will enhance their ability to read scientific literature written in Spanish. Emphasis on the development of science in Spanish-speaking countries or regions. Course is conducted in Spanish and intended for students pursuing degrees in the sciences, particularly disciplines such as ecology, environmental science, sustainability, resource management, anthropology, and archeology.
Same as: EARTHSYS 207, LATINAM 207

BIO 210. The Chromatin-Regulated Genome. 3 Units.
Maintenance of the genome is a prerequisite for life. In eukaryotes, all DNA-templated processes are tightly connected to chromatin structure and function. This course will explore epigenetic and chromatin regulation of cellular processes related to aging, cancer, stem cell pluripotency, metabolic homeostasis, and development. Course material integrates current literature with a foundational review of histone modifications and nucleosome composition in epigenetic inheritance, transcription, replication, cell division and DNA damage responses. Prerequisite: BIO 41 or BIO 83 or consent of instructor.
Same as: BIO 110

BIO 211. Proteostasis: From Basic Principles to Aging and Neurodegeneration. 3 Units.
The control of cellular protein homeostasis, also called Proteostasis, is emerging as the central cellular process controlling the stability, function and quality control of the proteome and central to our understanding of a vast range of diseases. The proteostasis machinery maintains the function of destabilized and mutant proteins; assists the degradation of damaged and aggregated proteins and monitors the health of the proteome, adjusting it in response to environmental or metabolic stresses. Proteostasis disfunction is linked to diseases ranging from neurodegeneration to aging.nThis class will introduce students to the exciting cutting edge discoveries in this field through presentations by leaders in the field and discussions of primary literature illustrating how understanding proteostasis can be leveraged to understand fundamental biological processes, such as evolution and aging and to ameliorate a wide range of diseases.

BIO 214. Advanced Cell Biology. 4 Units.
For Ph.D. students. Taught from the current literature on cell structure, function, and dynamics. Topics include complex cell phenomena such as cell division, apoptosis, signaling, compartmentalization, transport and trafficking, motility and adhesion, and differentiation. Weekly reading of current papers from the primary literature. Advanced undergraduates may participate with the permission of the Course Director.
Same as: BIOC 224, MCP 221

BIO 220. Prokaryotic Biology - A Quantitative Approach. 3 Units.
To live, microbes have to successfully coordinate various cellular processes, in line with available resources and what environmental conditions demand. This course introduces quantitative advances in understanding this coordination and their consequences across scales: from molecular biology via growth to population dynamics and ecology. Dry lab sessions complement lectures to introduce computational approaches. Python based analysis tools will be introduced. Prerequisite: MATH 51 or MATH 19, 20,21. Recommended: microbiology (e.g. BIO 62 or 162) and molecular biology/biochemistry/genetics courses (e.g. BIO 82 or 83) and basic familiarity with coding.
Same as: BIO 120

BIO 221. ORNITHOLOGY. 3 Units.
Advanced undergraduate survey of ornithology, introducing students to the biology of birds and giving them to tools to use birds as model systems for research. Topics will include avian evolution, physiology, adaptations, behavior, and ecology. Focus throughout on identification of California birds and applications to current bird conservation issues. Course will include lectures and a field component which will expose students to standard avian research techniques such as mistnetting, banding, and point count surveys. Prerequisite: BIO 81 or BIO 105 or instructor approval.
Same as: BIO 121

BIO 222. Exploring Neural Circuits. 3 Units.
Seminar. This course focuses on the logic of how neural circuits process information and control behavior, as well as 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, motor control, and cognitive function; and development and plasticity of neural circuits. Advanced undergraduates and graduate students with background in physical science, engineering, and biology may apply to enroll. Enrollment is by application only. Recommended: background in neuroscience.

BIO 223. Stochastic and Nonlinear Dynamics. 3 Units.
Theoretical analysis of dynamical processes: dynamical systems, stochastic processes, and spatiotemporal dynamics. Motivations and applications from biology and physics. Emphasis is on methods including qualitative approaches, asymptotics, and multiple scale analysis. Prerequisites: ordinary and partial differential equations, complex analysis, and probability or statistical physics.
Same as: APPPHYS 223, BIOE 213, PHYSICS 223

BIO 226. Introduction to Biophysics. 3-4 Units.
Core course appropriate for advanced undergraduate students and graduate students with prior knowledge of calculus and a college physics course. Introduction to how physical principles offer insights into modern biology, with regard to the structural, dynamical, and functional organization of biological systems. Topics include the roles of free energy, diffusion, electromotive forces, non-equilibrium dynamics, and information in fundamental biological processes.
Same as: APPPHYS 205, BIO 126

BIO 227. Foundations of Community Ecology. 3 Units.
Discussion of classic papers in community ecology (Forbes, Clements, Gleason, Grinnell, Lindeman, Preston, Elton, Hutchinson, May, MacArthur, Odum, Connell, Paine, Tilman, etc.) and contemporary papers on related topics, to develop historical perspectives to understand current issues and identify future directions. Prerequisite for undergraduates: consent of instructor.

BIO 228. Evolution of Terrestrial Ecosystems. 4 Units.
The what, when, where, and how do we know it regarding life on land through time. Fossil plants, fungi, invertebrates, and vertebrates (yes, dinosaurs) are all covered, including how all of those components interact with each other and with changing climates, continental drift, atmospheric composition, and environmental perturbations like glaciation and mass extinction. The course involves both lecture and lab components. Graduate students registering at the 200-level are expected to write a term paper, but can opt out of some labs where appropriate.
Same as: BIO 148, EARTHSYS 128, GEOLSCI 128, GEOLSCI 228

BIO 229. Fundamentals and Frontiers in Plant Biology. 3 Units.
This course will serve as a primer for all levels of graduate, co-term, and upper-level undergraduates interested in learning about the fundamental aspects of plant biology, the latest advances in tools, techniques, and theories that link basic science with translational science and applications for solving major societal challenges of today and tomorrow. In addition, this course will serve to introduce the breadth of plant research on campus and help solidify a cohort of students interested in plant biology.
Same as: BIO 129

BIO 230. Molecular and Cellular Immunology. 4 Units.
Mechanisms of immune responses in health and disease. Innate and adaptive immunity; development of the immune system; molecular biology, structure, and function of antibodies and T-cell receptors; cellular basis and regulation of immune responses; infectious diseases and vaccines; allergy, inflammation, and autoimmunity. COVID-19 will be featured as a major example. Lectures and discussion in class and in sections. For upper class undergraduate and graduate students who have not had an introductory immunology course. Prerequisites for undergraduates: Biology Core, Human Biology Core, or BIO 83 and 86, or consent of instructor. For graduate students: College-level molecular biology, biochemistry, and cell biology, or consent of instructor.

BIO 230A. Molecular and Cellular Immunology Literature Review. 1 Unit.
Special discussion section for graduate students. Supplement to BIO 230. Pre- or corequisite: BIO 230 or other introductory immunology course.

BIO 231. Structural Equation Modeling for Ecologists. 1 Unit.
We will focus on learning to use structural equation modeling (SEM) as a technique for ecological inference. Class will include short lectures, paper discussions, and SEM coding workshops in R. Meetings will generally last only 60 minutes.

BIO 232. Advanced Imaging Lab in Biophysics. 4 Units.
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, microendoscopy, and optical trapping. Limited enrollment. Recommended: basic physics, basic cell biology, and consent of instructor.
Same as: APPPHYS 232, BIO 132, BIOPHYS 232, GENE 232

BIO 234. Conservation Biology: A Latin American Perspective. 3 Units.
Principles and application of the science of preserving biological diversity. Conceptually, this course is designed to explore the major components relevant to the conservation of biodiversity, as exemplified by the Latin American region. The conceptual frameworks and principles, however, should be generally applicable, and provide insights for all regions of the world. All students will be expected to conduct a literature research exercise leading to a written report, addressing a topic of their choosing, derived from any of the themes discussed in class. Prerequisite: BIO 101 or BIO 43 or HUMBIO 2A or BIO 81 and 84 or consent of instructor.
Same as: BIO 144, HUMBIO 112

BIO 235. Neuroethology. 3 Units.
Neuroethology is the study of the neural basis of animal behavior. We will explore the neural mechanisms of natural behaviors in a diverse set of organisms. Topics include molecular mechanisms of nervous system function, predator-prey interactions, social behavior, and other complex behaviors like learning and memory, navigation, and communication. Assessment includes group oral presentations of scientific papers, weekly homework prompts that lead into a mini grant proposal, and scientific writing and communication with the broader public on a neuroethological topic. Prerequisites: BIO 84.
Same as: BIO 135

BIO 236. Macroevolution. 3 Units.
The course will focus on the macroevolution of animals. We will be exploring how paleobiology and developmental biology/genomics have contributed to our understanding of the origins of animals, and how patterns of evolution and extinction have shaped the diversity of animal forms we observe today.
Same as: BIO 136, GEOLSCI 136, GEOLSCI 236

BIO 238. Ecosystem Services: Frontiers in the Science of Valuing Nature. 3 Units.
This course explores the science of valuing nature, beginning with its historical origins and then a primary focus on its recent development and frontiers. The principal aim of the course is to enable new research and real-world applications of InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) tools and approaches. We will discuss the interconnections between people and nature and key research frontiers, such as in the realms of biodiversity, resilience, human health, poverty alleviation, and sustainable development. The science we¿ll explore is in the service of decisions, and we will use examples from real life to illustrate why this science is so critical to informing why, where, how, and how much people need nature. Prerequisite. Basic to intermediate GIS skills are required (including working with raster, vector and tabular data; loading and editing rasters, shapefiles, and tables into a GIS; understanding coordinate systems; and performing basic raster math).
Same as: BIO 138, EARTHSYS 139, EARTHSYS 239

BIO 239. The Hidden Kingdom - Evolution, Ecology and Diversity of Fungi. 4 Units.
Fungi are critical, yet often hidden, components of the biosphere. They regulate decomposition, are primary partners in plant symbiosis and strongly impact agriculture and economics. Students will explore the fascinating world of fungal biology, ecology and evolution via lecture, lab, field exercises and Saturday field trips that will provide traditional and molecular experiences in the collection, analysis and industrial use of diverse fungi. Students will chose an environmental niche, collect and identify resident fungi, and hypothesize about their community relationship. Prerequisite: BIO 81, 85 recommended.
Same as: BIO 115

BIO 240. Ecosystem Ecology and Biogeochemistry. 3 Units.
An introduction to ecosystem ecology and terrestrial biogeochemistry. This course will focus on the dynamics of carbon and other biologically essential elements in the Earth System, on spatial scales from local to global. Prerequisites: Biology 117, Earth Systems 111, or graduate standing.
Same as: BIO 147, EARTHSYS 147, EARTHSYS 247

BIO 244. Fundamentals of Molecular Evolution. 4 Units.
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 BIO 82, 85 or graduate standing in any department, and consent of instructor.
Same as: BIO 113

BIO 245. Ecology and Evolution of Animal Behavior. 3 Units.
Ecological and evolutionary perspectives on animal behavior, with an emphasis on social and collective behavior. This is a project-based course in a lecture/seminar format. Seminars will be based on discussion of journal articles. Independent research projects on the behavior of animals on campus. Prerequisites: Biology or Human Biology core or BIO 81 and 85 or consent of instructor; Biology/ES 30. Recommended: statistics.
Same as: BIO 145

BIO 247. Genomic approaches to the study of human disease. 3 Units.
This course will cover a range of genetic and genomic approaches to studying human phenotypic variation and disease. We will discuss the genetic basis of Mendelian and complex diseases, as well as clinical applications including prenatal testing, and pediatric and cancer diagnostics. The course will include lectures as well as critical reading and discussion of the primary literature. Prerequisite: BIO 82 or equivalent. Open to advanced undergraduate students.
Same as: GENE 247

BIO 249. The Neurobiology of Sleep. 4 Units.
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. nnPreference to seniors and graduate students. nnEnrollment limited to 16.
Same as: BIO 149, HUMBIO 161, PSYC 149, PSYC 261

BIO 251. Quantitative Evolutionary Dynamics and Genomics. 3 Units.
The genomics revolution has fueled a renewed push to model evolutionary processes in quantitative terms. This course will provide an introduction to quantitative evolutionary modeling through the lens of statistical physics. Topics will range from the foundations of theoretical population genetics to experimental evolution of laboratory microbes. Course work will involve a mixture of pencil-and-paper math, writing basic computer simulations, and downloading and manipulating DNA sequence data from published datasets. This course is intended for upper level physics and math students with no biology background, as well as biology students who are comfortable with differential equations and probability.
Same as: APPPHYS 237

BIO 254. Molecular and Cellular Neurobiology. 3-5 Units.
For graduate students. Includes lectures for BIO 154. 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.
Same as: NBIO 254

BIO 255. Cell and Developmental Biology of Plants. 3 Units.
In this course we will learn how plants are built at different organizational scales from the cell, tissue, organ and organ system level. We will also learn about the experimental methods used to study plants at these different organizational levels and how to interpret and evaluate experiments that use such methods. Broadly relevant skills that will be cultivated in the course include: evaluating primarily literature, identifying gaps in knowledge, formulating research questions and designing new experimental strategies. Prerequisites: BIO 80 series.
Same as: BIO 155

BIO 258. Developmental Neurobiology. 4 Units.
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. Prerequisites: BIO 82, 83, 84, 86.
Same as: BIO 158

BIO 267. Molecular Mechanisms of Neurodegenerative Disease. 4 Units.
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.nnnThis class is open to both graduate and undergraduate students, but requires sufficient backgrounds in college level genetics, cell biology and biochemistry. Undergraduates who are interested are required to contact the course director first.
Same as: GENE 267, NENS 267

BIO 268. Statistical and Machine Learning Methods for Genomics. 3 Units.
Introduction to statistical and computational methods for genomics. Sample topics include: expectation maximization, hidden Markov model, Markov chain Monte Carlo, ensemble learning, probabilistic graphical models, kernel methods and other modern machine learning paradigms. Rationales and techniques illustrated with existing implementations used in population genetics, disease association, and functional regulatory genomics studies. Instruction includes lectures and discussion of readings from primary literature. Homework and projects require implementing some of the algorithms and using existing toolkits for analysis of genomic datasets.
Same as: BIOMEDIN 245, CS 373, STATS 345

BIO 271. Principles of Cell Cycle Control. 3 Units.
Genetic analysis of the key regulatory circuits governing the control of cell division. Illustration of key principles that can be generalized to other synthetic and natural biological circuits. Focus on tractable model organisms; growth control; irreversible biochemical switches; chromosome duplication; mitosis; DNA damage checkpoints; MAPK pathway-cell cycle interface; oncogenesis. Analysis of classic and current primary literature.
Same as: BIO 171, CSB 271

BIO 272. Ecological Dynamics: Theory and Applications. 4 Units.
Structured population models with age and phenotypic variation. Integral population models, model fitting and dynamics. Fitness and dynamic heterogeneity. Examples from natural populations (sheep, roe deer, plants, birds). Graduate students will be responsible for additional problem sets. Prerequisites: calculus and linear algebra.
Same as: BIO 172

BIO 273A. Environmental Microbiology I. 3 Units.
Basics of microbiology and biochemistry. The biochemical and biophysical principles of biochemical reactions, energetics, and mechanisms of energy conservation. Diversity of microbial catabolism, flow of organic matter in nature: the carbon cycle, and biogeochemical cycles. Bacterial physiology, phylogeny, and the ecology of microbes in soil and marine sediments, bacterial adhesion, and biofilm formation. Microbes in the degradation of pollutants. Prerequisites: CHEM 33,CHEM 121 (formerly CHEM 35), and BIOSCI 83, CHEMENG 181, or equivalents.
Same as: CEE 274A, CHEMENG 174, CHEMENG 274

BIO 273B. Microbial Bioenergy Systems. 3 Units.
Introduction to microbial metabolic pathways and to the pathway logic with a special focus on microbial bioenergy systems. The first part of the course emphasizes the metabolic and biochemical principles of pathways, whereas the second part is more specifically directed toward using this knowledge to understand existing systems and to design innovative microbial bioenergy systems for biofuel, biorefinery, and environmental applications. There also is an emphasis on the implications of rerouting of energy and reducing equivalents for the fitness and ecology of the organism. Prerequisites: CHEMENG 174 or 181 and organic chemistry, or equivalents.
Same as: CEE 274B, CHEMENG 456

BIO 274. Human Skeletal Anatomy. 5 Units.
Study of the human skeleton (a. k. a. human osteology), as it bears on other disciplines, including medicine, forensics, archaeology, and paleoanthropology (human evolution). Basic bone biology, anatomy, and development, emphasizing hands-on examination and identification of human skeletal parts, their implications for determining an individual's age, sex, geographic origin, and health status, and for the evolutionary history of our species. Three hours of lecture and at least three hours of supervised and independent study in the lab each week.
Same as: ANTHRO 175, ANTHRO 275, BIO 174, HUMBIO 180

BIO 274S. Hopkins Microbiology Course. 3-12 Units.
(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 and CEE 274B, or equivalents.
Same as: BIOHOPK 274, CEE 274S, ESS 253S

BIO 276. The Developmental Basis of Animal Body Plan Evolution. 4 Units.
Animals are grouped into phyla with defined organizational characteristics such as multicellularity, axis organization, and nervous system organization, as well as morphological novelties such as eyes, limbs and segments. This course explores the developmental and molecular origins of there animal innovations. Offered alternate years. Prerequisites: None.
Same as: BIO 176

BIO 277. Plant Microbe Interaction. 3 Units.
Molecular basis of plant symbiosis and pathogenesis. Topics include mechanisms of recognition and signaling between microbes and plant hosts, with examples such as the role of small molecules, secreted peptides, and signal transduction pathways in symbiotic or pathogenic interactions. Readings include landmark papers together with readings in the contemporary literature. Prerequisites: Biology core and two or more upper division courses in genetics, molecular biology, or biochemistry. Recommended: plant genetics or plant biochemistry.
Same as: BIO 177

BIO 278. Microbiology Literature. 3 Units.
For advanced undergraduates and first-year graduate students. Critical reading of the research literature in prokaryotic genetics and molecular biology, with particular applications to the study of major human pathogens. Classic and foundational papers in pathogenesis, genetics, and molecular biology; recent literature on bacterial pathogens such as Salmonella, Vibrio, and/or Yersinia. Diverse experimental approaches: biochemistry, genomics, pathogenesis, and cell biology. Prerequisites: Declared Biology majors must have taken BIO 82 (Genetics) and BIO 83 (Biochemistry). Enrollment for undergraduates is limited to Biology majors in junior or senior year. Co-term or Ph.D. students in basic life sciences departments such as Biology, Bioengineering, and Genetics may also enroll in BIO 278. Apply at https://forms.gle/4NTtcBdWYMqRFvGc9.
Same as: BIO 178

BIO 279. Integrated Valuation of Ecosystem Services and Tradeoffs. 1-3 Unit.
This course explores the science of valuing nature, through two interwoven pathways. One is biophysical, focused on human dependence and impacts on Earth¿s life-support systems. If well managed, lands, waters, and biodiversity yield a flow of vital benefits that sustain and fulfill human life. A wild bee buzzes through a farm, pollinating vegetables as it goes. Nearby, wetlands remove chemicals from the farm¿s runoff, protecting a source of drinking water. In parklands at a city¿s edge, kids play and adults walk and talk, their exposure to nature promoting physical activity and improved mental health. The trees help maintain a favorable climate, locally and globally. We¿ll develop a framework and practical tools for quantifying this stream of benefits from nature to people.nThe second pathway is social, economic, and philosophical, weaving through concepts of well-being, human development, and conservation ¿ and the ethics and effects of their pursuit. We will look back, ahead into the future, and inward, taking a global view and considering diverse cultural perspectives. Our discussions will be situated in the context of the COVID-19 pandemic, movements for racial justice and socioeconomic equity, and efforts to enable people and nature to thrive in cities and countries worldwide.nAll of the science we¿ll explore is in service of decisions. We will dive into real-world examples to see how science can inform why, where, how, and how much people need nature. We will learn the basics of the InVEST tools (for Integrated Valuation of Ecosystem Services and Tradeoffs) to quantify benefits of nature, the equitability in access to these benefits, and the transformation of policy, finance, management, and practice to sustain and enhance them. nThe course is intended for diverse, advanced students, with interests in research and in moving from science to action for a more just and sustainable world. The instructors aim to provide an enjoyable and productive opportunity to connect ¿ remotely and yet with a lot of heart as well as intellectual drive and commitment, bringing empathy, flexibility and hopefully some humor to the day-to-day challenges we are all facing in different difficult ways. Prerequisite: Basic to intermediate GIS (Geographic Information Systems) skills are necessary. We will help with these, but not teach GIS specifically in class. Basic skills include, for example: working with raster, vector and tabular data; loading rasters, shapefiles, and tables into a GIS; changing the symbology of rasters and shapefiles in your chosen GIS; editing raster and shapefile attribute tables; understanding coordinate systems and how to re-project layers; looking at individual raster cell values; and performing basic raster math.
Same as: BIO 179

BIO 282. Modeling Cultural Evolution. 3 Units.
Seminar. Quantitative models for the evolution of socially transmitted traits. Rates of change of learned traits in populations and patterns of cultural diversity as a function of innovation and cultural transmission. Learning in constant and changing environments. Possible avenues for gene-culture coevolution.
Same as: BIO 182

BIO 283. Theoretical Population Genetics. 3 Units.
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.
Same as: BIO 183

BIO 287A. Advanced Topics in Mathematical Evolutionary Biology. 3 Units.
Focused examination of specific topics in mathematical evolutionary biology. Course themes may include: mathematical properties of statistics used in human population genetics, mathematics of evolutionary trees, and the intersection of population genetics and phylogenetics.

BIO 290. Teaching Practicum in Biology. 1-5 Unit.
Open to upper-division undergraduates and graduate students. Practical, supervised teaching experience in a biology lab or lecture course. Training often includes attending lectures, initiating and planning discussion sections, and assisting in the preparation course materials. May be repeated for credit.nPrerequisite: consent of instructor.

BIO 291. Development and Teaching of Core Experimental Laboratories. 1-2 Unit.
Development and Teaching of Core Experimental LaboratoriesnPreparation for teaching the core experimental lab courses (45 and 47). Emphasis is on practicing the lab, speaking, and writing skills. Taken simultaneously while teaching (for BIO 45) or during the previous quarter (for teaching BIO 47). May be repeated for credit. Meeting times TBD.

BIO 292. Curricular Practical Training. 1 Unit.
This course is required for international students who are participating in professional internships in organizations (e.g. research institutes, education, medicine, business, policy) with a focus in the biological sciences. Students will be engaged in on-the-job training under the guidance of experienced, on-site supervisors. This course meets the requirements for curricular practical training (CPT) for students with F-1D/S status. Prior to the internship, students are required to submit a concise report detailing the proposed project and work activities. After the internship, students are required to submit a summary of the work completed, skills learned, and reflection of the professional growth gained as a result of the internship. This course may be repeated for credit. Prerequisite: Qualified offer of employment and consent of advisor.

BIO 294. Cellular Biophysics. 3 Units.
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.
Same as: APPPHYS 294, BIOPHYS 294

BIO 296. Teaching and Learning in Biology. 1 Unit.
This course provides students teaching in the Department of Biology with basic training, support, and professional development in their teaching roles. Topics include student engagement, assessment, feedback and more. Should be taken concurrently with the first teaching position.

BIO 299. Biology PhD Lab Rotation. 1-10 Unit.
Limited to first year Biology PhD students. Lab rotations with Biosciences faculty.

BIO 300. Graduate Research. 1-10 Unit.
For graduate students only. Individual research by arrangement with in-department instructors.

BIO 300X. Out-of-Department Graduate Research. 1-10 Unit.
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 more information. May be repeated for credit.

BIO 301. Frontiers in Biology. 1-3 Unit.
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.

BIO 302. Current Topics and Concepts in Population Biology, Ecology, and Evolution. 1 Unit.
Required of first-year PhD students in population biology, and ecology and evolution. Major conceptual issues and developing topics. This course isnnopen only to Biology PhD students and is not open to auditors.".

BIO 303. Current Topics and Concepts in Population Biology, Ecology, and Evolution. 1 Unit.
Required of first-year PhD students in population biology, and ecology and evolution. Major conceptual issues and developing topics. This course isnnopen only to Biology PhD students and is not open to auditors.".

BIO 304. Current Topics and Concepts in Population Biology, Ecology, and Evolution. 1 Unit.
Required of first-year PhD students in population biology, and ecology and evolution. Major conceptual issues and developing topics. This course is open only to Biology PhD students and is not open to auditors.

BIO 305. Managing Your PhD. 1 Unit.
The course will focus on 5 themes for effectively managing your PhD: professionalism, scholarship, well-being, community-engagement and career development. We will meet every other week and have an active discussion-based class meeting for 2 hours. At the end of the quarter students and instructors will co-organize a departmental half-day workshop on a particular topic relevant to the topics covered in the class.

BIO 313. Ethics in the Anthropocene. 1 Unit.
Today, in the Anthropocene, humankind impacts the environment on a massive scale, with severe outcomes for species, ecosystems, and landscapes. The consequences of this impact raise many ethical questions, with new dilemmas forcing us to consider new moral values and re-consider old ones. In this course, we will become acquainted with environmental and conservation ethics and philosophy, and acquire the toolkit of concepts and ideas that will allow us to tackle the current environmental ethical debates. We will explore the role of ethics in the environmental and conservation sciences by discussing the philosophical foundations for moral values in the Anthropocene, as well as by examining practical current-day issues, such as reintroductions, invasive species and conservation advocacy.

BIO 315. Becoming a Resilient Scientist. 1 Unit.
This is a virtual six-part NIH-sponsored workshop that aims to build resilience in the face of obstacles commonly encountered in research. Students and facilitators will participate in a series of webinars and small group discussions on topics, such as emotional intelligence, self-advocacy, feedback resilience, and mentoring relationships.

BIO 329. Matrix Methods for Dynamic Models and Data Analysis. 1 Unit.
Types of matrices in dynamic & stochastic models, covariances, rectangular data, networks. Spectral theorem, asymptotics, stability theory, Nonnegative matrices, ergodicity, Markov chains. Hermitian, covariance, SVD. Perturbation theory. Random matrix products, Lyapunov exponents. Open to Ph.D. students in Biology. Prerequisites: Calculus (AP level) required. Some knowledge of linear algebra, R, preferred.

BIO 330. Stochastic Methods for Simulation, Dynamics and Data Analysis. 1 Unit.
Markov chains: ergodicity, CLT, passage times, absorption. Simulation: random numbers, chains. Poisson processes: applications and simulation. Time series models. MCMC essentials. Open to Ph.D. students in Biology. Prerequisites: Calculus (AP level) and basic linear algebra required. Facility with linear algebra, R, preferred.

BIO 332. Evolutionary Genomics. 2 Units.
We will read classic and modern papers relevant to evolutionary genomics, and discuss. We will cover a broad range of topics, methods, and species.

BIO 342. Plant Biology Seminar. 1-3 Unit.
Topics in plant biology presented at a weekly seminar. Topics announced at the beginning of each quarter. Current literature. May be repeated for credit. See https://dpb.carnegiescience.edu/events.

BIO 346. Advanced Seminar in Microbial Molecular Biology. 1 Unit.
Enrollment limited to PhD students associated with departmental research groups in genetics or molecular biology.
Same as: CSB 346, GENE 346

BIO 355. Coral Reefs of the Western Pacific: Interdisciplinary Perspectives, Emerging Crises, and Solutions. 1 Unit.
This new graduate-level course focusses on the complex interplay of biology, physics, chemistry, and human activities that both promotes and limits the development of coral reefs. We will examine the ecology of these biodiverse systems as well as the service they provide in terms of rapid nutrient recycling, coastal protection, and maintenance of large populations of fish. New advances in our understanding of coral reefs will be highlighted, including the role of climate variability and micro- and mesoscale fluid flow in controlling reef growth and persistence, the physiology, genomics, and physics underpinning thermal resilience in corals, contributing and mitigating factors involved in the current decline of coral reefs, ocean acidification, fishing, reef-scale trophic modeling, ecological interactions and trophic cascades, and reefs as part of complex seascapes and linkages with other marine ecosystems. The course will conclude with an analysis of science to policy case studies and future opportunities. The faculty leaders collectively have over 100 years of field experience working in coral reefs of the Pacific and despite our forced online teaching and learning format will endeavor to bring the coral reef field experience to life for this class.
Same as: BIOHOPK 355, CEE 363I, ESS 355

BIO 380. Career Exploration and Planning. 1 Unit.
Thinking about and planning for life beyond graduate school is one of the most anxiety-provoking activities students face. In this course, students will share their personal stories and dilemmas about career decisions, discuss various career options with a PhD in life sciences, and learn to design their own path. There will be three career panels with invited guests from various career tracks, including research, teaching, administration, industry, startup, investment, law, journalism, policy, and more. Open to Biology PhD students in year 3 or beyond. The class will meet at Carnegie Institution for Science's conference room building 600, located at 260 Panama St, Stanford, CA 94305.

BIO 383. Seminar in Population Genetics. 1-3 Unit.
Literature review, research, and current problems in the theory and practice of population genetics and molecular evolution. May be repeated for credit. Prerequisite: consent of instructor.

BIO 384. Theoretical Ecology. 1-3 Unit.
Recent and classical research papers in ecology, and presentation of work in progress by participants. Prerequisite: consent of instructor.

BIO 386. Conservation and Population Genomics. 1 Unit.
This once a week reading and discussion group will focus on adaptive capacity: how fast and how well species, populations and individual organisms react to climate change. A rapid change in environment imposes strong changes in ecological communities. Phenotypic plasticity can change physiology or morphology, patterns of natural selection can alter gene frequencies, demographic changes can shift species ranges, changes in species interactions can change communities in species composition. This seminar will explore what we know about adaptive capacity of different communities and different species. How fast can adaptation happen? How much can adaptation `solve¿ the problems generated by climate change? How do we measure adaptive capacity? We will pull readings from the literature and structure this topic into sections. Students will present their own or published work on adaptive capacity to provide examples and frame questions. At the end, we will design an international zoom symposium to highlight, define and articulate the role that adaptive capacity can play in managing and protecting complex ecosystems in the face of climate change.

BIO 459. Frontiers in Interdisciplinary Biosciences. 1 Unit.
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.
Same as: BIOC 459, BIOE 459, CHEM 459, CHEMENG 459, PSYCH 459

BIO 802. TGR Dissertation. 0 Units.
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