BIOLOGY

Courses offered by the Department of Biology are listed under the subject code BIO on the Stanford Bulletin's ExploreCourses web site.

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 Gilbert Biological Sciences, Herrin Laboratories, Herrin Hall, James H. Clark Center, Lorry I. Lokey Laboratory, 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 (http://exploredegrees.stanford.edu/schoolofhumanitiesandsciences/biology/%20/schoolofhumanitiesandsciences/biologyhopkinsmarinestation)" section of this bulletin.

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

The 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.

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://stanford.app.box.com/v/bs-handbook), which delineates policies and requirements, as well as other department forms and informational handouts.

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

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. 4)" tab.

Introductory Course

(must be taken for a letter grade):

		Units
Select one of the following:		4
BIO 60	Introduction to Problem Solving in Biology	
BIO 61	Science as a Creative Process	
BIO 62	Experimental strategy and the bacterial world	

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	
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	Ecology and Ecological Physiology	

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 31X	Chemical Principles Accelerated	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 35	Organic Chemistry of Bioactive Molecules	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 and Differential Calculus of Several Variables (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, distributed as follows:

- Biology (BIO) or Hopkins Marine Station (BIOHOPK) courses numbered 100 or above.
- Approved out-of-department electives (https://stanford.app.box.com/v/out-of-department-electives) (list also available in the student services office).
- 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 197WA	Senior Writing Project: The Personal Essay in Biology	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 of Biology	1-5
BIO 291	Development and Teaching of Core Experimental Laboratories	1-2
BIO 296	TA Training in Biology	1
BIOHOPK 198H	Directed Instruction or Reading	1-15
BIOHOPK 199H	Undergraduate Research	1-15
BIOHOPK 290H	Teaching of Biological Science	1-15

- One course applied toward the elective unit requirement may be taken CR/NC.

Writing in the Major

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

BIO 46	Introduction to Research in Ecology and Evolutionary Biology
BIO 47	Introduction to Research in Ecology and Evolutionary Biology
BIO 107	Human Physiology Laboratory
BIO 137	Plant Genetics
BIO 168	Explorations in Stem Cell Biology
BIO 196A	Biology Senior Reflection
BIO 197WA	Senior Writing Project: The Personal Essay in Biology
BIO 199W	Senior Honors Thesis: How to Effectively Write About Scientific Research
BIOHOPK 47	Ecology and Ecological Physiology
BIOHOPK 172H	Marine Ecology: From Organisms to Ecosystems

Note: BIO 107, BIO 137, BIO 168, BIO 196A, BIO 197WA, BIO 199W, and BIOHOPK 172H can also count toward the elective requirement.

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
Introduction to Problem Solving in Biology (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		
Organic Chemistry of Bioactive Molecules (CHEM 35)	5		
WAYS, PWR	8		
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 31X 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 mid-Autumn Quarter.
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://stanford.app.box.com/v/198x-199x-petition) 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 teaching and research are not computed into this GPA:

		Ur
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 of Biology	1-5
BIO 291	Development and Teaching of Core Experimental Laboratories	1-2
BIO 296	TA Training in Biology	1
BIOHOPK 199H	Undergraduate Research	1-15
BIOHOPK 290H	Teaching of Biological Science	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 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.
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 in the student services office in Gilbert 108, as well as 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:

BIO 46	Introduction to Research in Ecology and Evolutionary Biology
BIO 47	Introduction to Research in Ecology and Evolutionary Biology
BIO 107	Human Physiology Laboratory
BIO 137	Plant Genetics
BIO 168	Explorations in Stem Cell Biology
BIO 196A	Biology Senior Reflection
BIO 197WA	Senior Writing Project: The Personal Essay in Biology
BIO 199W	Senior Honors Thesis: How to Effectively Write About Scientific Research
BIOHOPK 47	Ecology and Ecological Physiology
BIOHOPK 172H	Marine Ecology: From Organisms to Ecosystems

Note: BIO 107, BIO 137, BIO 168, BIO 196A, BIO 197WA, BIO 199W, and BIOHOPK 172H 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):

		Units
Select one of the following:		4
BIO 60	Introduction to Problem Solving in Biology	
BIO 61	Science as a Creative Process	
BIO 62	Experimental strategy and the bacterial world	

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	

or BIOHOPK 84	Physiology	
BIO 86	Cell Biology	
Select 1 of the following:		4
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
BIO 85	Evolution	
or BIOHOPK 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	Ecology and Ecological Physiology	

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 31X	Chemical Principles Accelerated	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 35	Organic Chemistry of Bioactive Molecules	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 and Differential Calculus of Several Variables (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 and Differential Calculus of Several Variables	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 211	Biophysics of Multi-cellular Systems and Amorphous Computing	
BIOE 220	Introduction to Imaging and Image-based Human Anatomy	
BIOE 231	Protein Engineering	
BIOE 241	Biological Macromolecules	
BIOMEDIN 210	Modeling Biomedical Systems: Ontology, Terminology, Problem Solving	
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):

		Units
Select one of the following:		4
BIO 60	Introduction to Problem Solving in Biology	
BIO 61	Science as a Creative Process	
BIO 62	Experimental strategy and the bacterial world	

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	
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	Ecology and Ecological Physiology	

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 31X	Chemical Principles Accelerated	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 35	Organic Chemistry of Bioactive Molecules	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 and Differential Calculus of Several Variables (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 and Differential Calculus of Several Variables	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	
BIOE 101	Systems Biology	
BIOE 115	Computational Modeling of Microbial Communities	
BIOE 211	Biophysics of Multi-cellular Systems and Amorphous Computing	
BIOMEDIN 217	Translational Bioinformatics	
CS 273A	The Human Genome Source Code	
CS 279	Computational Biology: Structure and Organization of Biomolecules and Cells	
IMMUNOL 206	Introduction to Applied Computational Tools in Immunology	
IMMUNOL 207	Essential Methods in Computational and Systems Immunology	
STATS 155	Statistical Methods in Computational Genetics	

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):

		Units
Select one of the following:		4
BIO 60	Introduction to Problem Solving in Biology	
BIO 61	Science as a Creative Process	
BIO 62	Experimental strategy and the bacterial world	

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	
BIO 82	Genetics	
BIO 85	Evolution	
or BIOHOPK 85	Evolution	
Select 2 of the following:		8
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
or BIOHOPK 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	Ecology and Ecological Physiology	

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 31X	Chemical Principles Accelerated	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 35	Organic Chemistry of Bioactive Molecules	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 and Differential Calculus of Several Variables (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 118	Genetic Analysis of Biological Processes	
BIO 137	Plant Genetics	
BIO 138	Ecosystem Services: Frontiers in the Science of Valuing Nature	
BIO 144	Conservation Biology: A Latin American Perspective	
BIO 145	Ecology and Evolution of Animal Behavior	
BIO 146	Population Studies	
BIO 174	Human Skeletal Anatomy	
BIO 182	Modeling Cultural Evolution	
BIO 183	Theoretical Population Genetics	
BIOHOPK 161H	Invertebrate Zoology	
BIOHOPK 163H	Oceanic Biology	
BIOHOPK 172H	Marine Ecology: From Organisms to Ecosystems	
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	
OSPAUSTL 25	Freshwater Systems	
OSPAUSTL 30	Coastal Forest Ecosystems	

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

[2] OSPAUSTL 10, 25, 30 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):

		Units
Select one of the following:		4
BIO 60	Introduction to Problem Solving in Biology	
BIO 61	Science as a Creative Process	
BIO 62	Experimental strategy and the bacterial world	

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	
BIO 82	Genetics	
BIO 85	Evolution	
or BIOHOPK 85	Evolution	
Select 2 of the following:		8
BIO 83	Biochemistry & Molecular Biology	
BIO 84	Physiology	
or BIOHOPK 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	Ecology and Ecological Physiology	

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 31X	Chemical Principles Accelerated	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 35	Organic Chemistry of Bioactive Molecules	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 and Differential Calculus of Several Variables (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	
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	
OSPAUSTL 25	Freshwater Systems	
OSPAUSTL 30	Coastal Forest Ecosystems	

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

[2] OSPAUSTL 10, 25, 30 count as 2 units each for a total of 6 units toward electives.

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):

		Units
Select one of the following:		4
BIO 60	Introduction to Problem Solving in Biology	

BIO 61	Science as a Creative Process
BIO 62	Experimental strategy and the bacterial world

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	
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	Ecology and Ecological Physiology	

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 31X	Chemical Principles Accelerated	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 35	Organic Chemistry of Bioactive Molecules	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 and Differential Calculus of Several Variables (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 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	
BIOE 115	Computational Modeling of Microbial Communities	
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	
EARTHSYS 158	Geomicrobiology	
HUMBIO 155H	Humans and Viruses I	
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 120	Bacteria in Health and Disease	
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):

		Units
Select one of the following:		4
BIO 60	Introduction to Problem Solving in Biology	
BIO 61	Science as a Creative Process	
BIO 62	Experimental strategy and the bacterial world	

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	
or BIOHOPK 84	Physiology	
BIO 86	Cell Biology	
Select 1 of the following:		4
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
BIO 85	Evolution	
or BIOHOPK 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	Ecology and Ecological Physiology	

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 31X	Chemical Principles Accelerated	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 35	Organic Chemistry of Bioactive Molecules	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 and Differential Calculus of Several Variables (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	Chromatin Regulation of the Genome	
BIO 118	Genetic Analysis of Biological Processes	
BIO 124	Topics in Cancer Biology	
BIO 137	Plant Genetics	
BIO 154	Molecular and Cellular Neurobiology	
BIO 156	Epigenetics	
BIO 158	Developmental Neurobiology	
BIO 160	Developmental Biology	
BIO 167	Insulin and carbohydrate metabolism in health and disease a history of advances 1850 to current	
BIO 168	Explorations in Stem Cell Biology	
BIO 171	Principles of Cell Cycle Control	
BIO 177	Plant Microbe Interaction	
BIOE 101	Systems Biology	
BIOE 211	Biophysics of Multi-cellular Systems and Amorphous Computing	
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	
GENE 210	Genomics and Personalized Medicine	
GENE 211	Genomics	
GENE 235	C. Elegans Genetics	
NBIO 258	Information and Signaling Mechanisms in Neurons and Circuits	

STEMREM 201	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):

		Units
Select one of the following:		4
BIO 60	Introduction to Problem Solving in Biology	
BIO 61	Science as a Creative Process	
BIO 62	Experimental strategy and the bacterial world	

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	
or BIOHOPK 84	Physiology	
BIO 86	Cell Biology	
Select 1 of the following:		4
BIO 81	Introduction to Ecology	
or BIOHOPK 81	Introduction to Ecology	
BIO 85	Evolution	
or BIOHOPK 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	Ecology and Ecological Physiology	

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 31X	Chemical Principles Accelerated	
CHEM 33	Structure and Reactivity of Organic Molecules	5
CHEM 35	Organic Chemistry of Bioactive Molecules	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 and Differential Calculus of Several Variables (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	4-8
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

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 Stanford Bulletin's ExploreCourses web site.

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 the Natural Sciences GER 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:

Core

		Units
BIOHOPK 43	Plant Biology, Evolution, and Ecology	5
BIOHOPK 47	Ecology and Ecological Physiology (formerly BIOHOPK 44Y)	5

Electives

		Units
BIOHOPK 150H	Ecological Mechanics	3
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 172H	Marine Ecology: From Organisms to Ecosystems	5
BIOHOPK 173H	Marine Conservation Biology	4
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 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 189H	Sustainability and Marine Ecosystems	3
BIOHOPK 264H	POPULATION GENOMICS	1-2
BIOHOPK 274	Hopkins Microbiology Course	9-12
BIOHOPK 275H	Synthesis in Ecology	2

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 of Biological Science	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.
- All courses, other than BIO/BIOHOPK 81, BIO 82, BIO 83, BIO/BIOHOPK 84, BIO/BIOHOPK 85, BIO 86, OSPAUSTL 10, 25, or 30 must be at or above the 100-level. Stanford Introductory Seminars may not be used to fulfill the minor requirements. Note: OSPAUSTL 10, 25, 30 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).
- Courses must be chosen from the offerings of the Department of Biology or the Hopkins Marine Station, or from the list of approved out-of-department electives for the minor (https://stanford.box.com/v/OODEMinor). 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	
BIO 82	Genetics	4
BIO 83	Biochemistry & Molecular Biology	4
BIO 84	Physiology	4
or BIOHOPK 84	Physiology	
BIO 85	Evolution	4
or BIOHOPK 85	Evolution	
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	Introduction to Problem Solving in Biology	4
BIO 61	Science as a Creative Process	4
BIO 62	Experimental strategy and the bacterial world	3

- 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	Ecology and Ecological Physiology	5

- 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 is:		
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 mid-January to start the program in Spring, Autumn, or the following 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 adviser 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, distributed as follows:

1. A minimum of 23 of the 45 units must be courses designated primarily for graduate students (generally 200-level or higher, but not always).
2. A minimum of 36 units must be chosen from the offerings in the Department of Biology (BIO), Hopkins Marine Station (BIOHOPK), the list of approved out-of-department electives (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 of 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 of Biological Science	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 (https://stanford.box.com/s/js5ul8e1istcmgkqbsdmrc93g29926aj) 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 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.

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 advisor and meet regularly with a committee of faculty members to facilitate their progress. The Biology PhD program is part of the larger Biosciences (https://biosciences.stanford.edu) community of PhD programs at Stanford, which includes PhD programs in Stanford School of Medicine.

There are three tracks within the Biology PhD program: 1) Cell, 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 required to take the Graduate Record Examination (GRE) general test. The GRE subject test is not required. Applicants should plan on taking the GRE at least one month prior to the application deadline to ensure that official scores are available when applications are evaluated.

Admission to the Ph.D. program is competitive and in recent years it has been possible to offer admission to 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 the first-year advising committee within the first two weeks of Autumn Quarter, Winter Quarter and by May 15 of Spring Quarter. 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. This course should be taken in the first year of the program.

		Units
MED 255	The Responsible Conduct of Research	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)

		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	Introduction to Problem Solving in Biology	4
BIO 61	Science as a Creative Process	4
BIO 62	Experimental strategy and the bacterial world	3
BIO 81	Introduction to Ecology	4
BIO 82	Genetics	4
BIO 83	Biochemistry & Molecular Biology	4
BIO 84	Physiology	4
BIO 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

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 May 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. 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 PhD Handbook (https://stanford.box.com/v/PhDHandbook).
9. **Individual Development Plan meetings**
   Students must meet once a year with their advisor. For more details, see the Biology PhD 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**
    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 and Winter quarters 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.

[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. First-year paper*:* The paper should be read, commented upon and agreed to as satisfactory by two EcoEvo faculty by May 15. 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.

3. 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 May 15.
    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.

Emeriti Professors: Bruce S. Baker, Winslow R. Briggs, Allan M. Campbell, Paul R. Ehrlich, David Epel, Donald Kennedy, Harold A. Mooney, Peter Ray, Joan Roughgarden, Robert D. Simoni, George N. Somero, Ward B. Watt, Norman K. Wessells, Dow O. Woodward, Charles Yanofsky

Emeritus Professor (Research): R. Paul Levine

Emeritus Professor (Teaching): Carol L. Boggs

Chair: Tim P. Stearns

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, Philip C. Hanawalt, H. Craig Heller, Patricia P. Jones, Richard G. Klein, Ron R. Kopito, Sharon R. Long, Liqun Luo, Susan K. McConnell, Fiorenza Micheli, Mary Beth Mudgett, W. James Nelson, Stephen R. Palumbi, Dmitri Petrov, Jonathan Pritchard, Noah A. Rosenberg, Robert M. Sapolsky, Carla J. Shatz, Kang Shen, Michael A. Simon, Tim P. Stearns, Marc Tessier-Lavigne, Alice Ting, Stuart H. Thompson, Shripad Tuljapurkar, Peter Vitousek, Virginia Walbot

Associate Professors: Hunter B. Fraser, Tadashi Fukami, Christopher Lowe, Mark J. Schnitzer, Jan M. Skotheim

Associate Professor (Research): Mary Hynes

Assistant Professors: Xiaoke Chen, Scott J. Dixon, Jessica L. Feldman, Jeremy A. Goldbogen, Erin Mordecai, Ashby Morrison, Lauren O'Connell, Kabir Peay, M. Kristy Red-Horse

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

Courtesy Associate Professors: Kathryn Barton, José R. Dinneny, David Ehrhardt, Jonathan Payne, Sue Rhee, Zhiyong Wang

Courtesy Assistant Professor: Paula V. Welander

Lecturers: Jessica Coyle, Daria Hekmat-Scafe, Jamie Imam, Waheeda Khalfan, Shyamala D. Malladi, Patricia Seawell, Andrew Todhunter, James Watanabe

Librarian: Michael Newman

Overseas Studies Courses in Biology

The Bing Overseas Studies Program (http://bosp.stanford.edu) manages Stanford study abroad 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 Bing Overseas Studies 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).

		Units
OSPAUSTL 10	Coral Reef Ecosystems	3
OSPAUSTL 25	Freshwater Systems	3
OSPAUSTL 30	Coastal Forest Ecosystems	3