Major Requirements and Course Descriptions

This is the Major Requirements and Course Descriptions section of the 1997-1999 University of Minnesota College of Biological Sciences Bulletin.
Course Numbers and Symbols—Courses primarily for freshmen and sophomores are numbered 1000 through 1998; for sophomores, juniors, and seniors, 3000 through 3998; for juniors, seniors, and graduate students, 5000 through 5998. Courses numbered 8000 and above are restricted to graduate students.

The following symbols are used throughout the descriptions:

- The comma, used in prerequisite listings, means “and.”
- § Credit will not be granted if credit has been received for the course listed after this symbol.
- ¶ Concurrent registration is required (or allowed) in the course listed after this symbol.
- # Approval of the instructor is required for registration.
- △ Approval of the department offering the course is required for registration.
- † All courses preceding this symbol must be completed before credit will be granted for any quarter of the sequence.

H Honors course.

Directed studies course numbers end in “970” and directed research in “990.”

Sequence courses, separated by hyphens (e.g., 3142-3143-3144), must be taken in the order listed.

Series courses, separated by commas (e.g., 1234, 1235, 1236), may be entered any quarter.

A prerequisite course listed by number only (e.g., prereq 5246) is in the same department as the course being described.

Prerequisites should be considered as guides. When a prerequisite is listed, an equivalent course may be substituted. Consult the course instructor for more information.

Biology (Biol)

Director of Undergraduate Studies—Kathryn Hanna

Biologists are concerned with the fundamental properties of living things, from the interactions of molecules unique to life through the maintenance and integration of organisms and the interactions of populations in space and time.

The biology program provides students with a broadly based, thorough undergraduate education in the biological sciences. Biology majors must complete the graduation requirements outlined under Admission Procedures and Degree Requirements. The distribution of the 16 additional upper division credits in the mathematical, biological, or physical sciences is determined by each student in consultation with the adviser. Students may request a faculty adviser from any of the departments of the college. A prospective major should begin general chemistry and mathematics coursework as early as possible.

Also, a bachelor of arts degree with a major in biology is available through the College of Liberal Arts. The core course requirements for this degree are the same as those for the B.S. through CBS. However, the B.A. student must fulfill the additional CLA requirements that are outlined in the College of Liberal Arts Bulletin.

A student interested in teaching biology at the secondary level should consult the College of Education and Human Development office for information about the specialized curriculum that is available.

General Education—Courses especially appropriate for non-science and non-biology majors include BioC 1401; Biol 1009, 1051, 1101, 1103, 1106, 1201, 3051, 3112, 5913; EEB 1019, 3001, 3361, 3111; GCB 3002, 3008, 3022; MicB 3103; PBio 1009, 1012.

Minor Requirements

Required Preparatory Courses—Biol 1009 or 1201, 1202, 1203

Minor Requirements—1) Minimum of 15 3xxx-5xxx cr chosen from courses carrying the following designators: BioC, Biol, EEB, GCB, MicB, NSc, PBio, Phsl.

2) One course about animals, Biol 1106 or 3011, and one course about plants, Biol 1103 or 3012/3812.

The minor program must be approved by an Office of Student Services adviser, 223 Snyder Hall. CBS majors and CLA biology and microbiology majors are not eligible for the minor.
Major Requirements

See Degree Requirements in the previous section for a description of residency requirements, liberal education, foreign language, and English communication requirements.

Mathematics—A three-quarter analytic geometry and calculus sequence (Math 1251-1252-1261 or equivalent). A two-quarter course sequence in statistics may be substituted for the third quarter of calculus (Stat 3011-3012 or Stat 5021).

Chemistry—Two quarters of general chemistry with lab (Chem 1051-1052 or equivalent) and two quarters of organic chemistry, with lab (Chem 3301-3302 with 3305-3306 or equivalent).

Physics—A full year course, with lab, that requires college-level mathematics as a prerequisite (Phys 1251-1252-1253 (1254 optional) or 1104-1105-1106 with 1107-1108-1109) or equivalent. By petition, a two-quarter sequence (Phys 1041-1042) plus an additional four to five credits of mathematics, statistics, computer programming, or physical science chosen in consultation with the major adviser may be substituted.

General and organismal biology—Choose one of the following sequences:

- (preferred) Biol 1201, 1202, 1203, plus one organismal course (3011 or 3012/3812 or 5013)
  - or Biol 1201-1202, 3011, 3012/3812, 5013
  - or Biol 1009, 3011, 3012/3812, 5013

Biology core—Each of the following:

- Biochemistry (BioC 3021 or 5331)
- Genetics (Biol 5003)
- Cell Biology (Biol 5004)
- Ecology and Evolution (Biol 3008/5841)
- 16 additional upper division credits in mathematics and/or physical and/or biological science (Phsl 3051 may not be used for this requirement)
- Lab or fieldwork in two additional upper division biological science courses. Credits earned may be used toward fulfilling the elective part of the major above. A list of acceptable courses follows:
  Biol 5125
  BioC 5025, 5990*
  EEB 5014, 5016, 5129, 5134, 5157, 5621, 5990*
  GCB 5015, 5030, 5605, 5990*
  MicB 5234, 5322, 5425, 5990*
  NSc 3105-3115, 5990*
  PBio 3109, 3201, 5103, 5105, 5107, 5111, 5132, 5231, 5990*

All CBS courses offered at the Lake Itasca Forestry and Biological Station are acceptable.

* An independent research project is strongly recommended for every student. To use one of the department Directed Research courses to satisfy one of the upper division lab or fieldwork requirements, students must complete a minimum of 4 credits under the 5990 course number. Biology majors may satisfy both of the lab/field course requirements through Directed Research only if 4 credits of 5990 are completed in each of two different labs. A maximum of 10 credits of 5990 will count toward the 16 upper division elective credits required for the biology major.

Biol Courses

Biol 1009. General Biology. (5 cr; for majors requiring a comprehensive survey of biology in one qtr; high school chemistry strongly recommended; pre-biology majors see Biol 1201, 1202, 1203; nonscience majors see 1201)

Biol 1009H. General Biology. (5 cr; prereq honors division or 3-4 yrs high school mathematics, high school chemistry or ∆)

For description, see 1009. For honors students or others with the requisite background who plan to major in a life science.

Biol 1051. Environmental Studies. (4 cr, §3051, §ES 1051)

Principles of ecology and current environmental issues, including air and water pollution, human population growth, toxic and hazardous wastes, urbanization, land use, biological diversity, energy, environmental health, conservation history, attitudes towards nature, environmental politics, and ethics. Meets environmental theme for liberal education curriculum.

Biol 1101. Heredity and Human Society. (4 cr, §GCB 3002; no cr if taken after 5003 or GCB 3022; for students in programs not directly related to biological sciences)

Principles of heredity and their social and cultural implications.

Biol 1103. General Botany. (5 cr, §3012, §3812; prereq 1009 or 1202; students who plan to major in biology in CLA or in any bioscience major in CBS should take 3012 or 3812)

Plant organization, function, growth and development, reproduction. Lab.

Biol 1106. General Zoology. (5 cr, §1806; prereq 1009 or 1202)

Survey of animal phyla; structure, function, behavior, adaptation, evolutionary relationships. Lab includes dissections.

Biol 1201. Evolutionary and Ecological Perspectives. (5 cr)

 Origins and foundations of modern evolutionary thought, putting evolutionary theory to work; evolution and ecology. Lab. Can be taken as a single course or as the first in the Biol 1201, 1202, 1203 sequence.
Biol 1202. Molecular and Cellular Perspectives. (5 cr, §1009; prereq 1201, Chem 1051 or equiv) Chemistry of living things, cell structure and transport, energy processing in cells, introduction to primary metabolism, molecular genetics, cell physiology, regulation of development. Lab.

Biol 1203. Organismal Adaptation and Diversity. (5 cr, §1103, §1106; prereq 1201, Chem 1051 or equiv or #) How plants, animals, and microbes adapt to similar environmental challenges, commonalities in these adaptations, evolutionary diversity of organisms. Lab includes dissections.

Biol 1941. Preparation for Graduate Programs in Biology. (1 cr; prereq #; S-N only) Study habits, time and money management, course participation, personal sacrifices.

Biol 1951, 1952, 1953. Biology Colloquium. (1 cr each; S-N only) Introduction to the diversity of biology through seminars, lab tours, undergraduate research, trips to Itasca Biological Station, and interaction with other biology students and faculty.

Biol 1960. Biology Colloquium Project. (1 cr; prereq §§1951 or §§1952 or §§1953; #; S-N only) Individual project or research supervised by a faculty sponsor.

Biol 1961. Careers in Biology. (1 cr; prereq 1951 or 1952 or 1953; S-N only) Exploration of career options in biological sciences. Introduction to career life planning techniques and decision-making skills. Interest, aptitude, and skills assessment. Preparation for an internship experience.

Biol 2003. Introduction to Computing in Biology. (2 cr; prereq 1009 or 1202 or equiv, declared biological sciences major; S-N only) Hands-on use of microcomputers to introduce students in biology to how computers can help them manipulate data, prepare graphs and graphics, perform literature searches, prepare posters and reports, and communicate with others through the use of the computer network.


Biol 3011. Animal Biology. (5 cr, §§1106, §§Phsl 3051; prereq 1009 or 1202, Chem 1052) Comparative physiology of various animal groups; coordination, movement, support, excretion, reproduction.

Biol 3012. Plant Biology. (5 cr, §§1103, §§3812; prereq 1009 or 1202, Chem 1052) Comparative physiology of various plant groups and physiological experiments and dissections.

Biol 3014. Human Anatomy and Physiology. (5 cr; prereq #; S-N only) Principles of anatomy and physiology, notation systems, and systems of the human body.

Biol 3017. Environmental Studies. (4 cr, §§1051, §§ES 1051; biological sciences students may not apply these credits toward the major) Principles of ecology and current environmental issues including air and water pollution, human population growth, toxic and hazardous wastes, urbanization, land use, biological diversity, energy, environmental health, conservation history, attitudes toward nature, environmental politics, and ethics. Meets environmental theme for liberal education curriculum.

Biol 3010. Introduction to Neuroscience I: Molecules to Madness. (4 cr, §§Nsc 3010, §§Phsl 3010; prereq 5004 or §§Biol 5004, BioC 3021 or BioC 5331; A-F only) Introduction to basic principles of cell and molecular neurobiology and nervous systems.

Biol 3012. Introduction to Neuroscience II: Biological Basis of Behavior. (4 cr, §§Phsl 3012, §§Nsc 3012; prereq 3010 or Nsc 3010 or Phsl 3010; A-F only) Organization of neural systems and subsystems underlying the sensory and motor aspects of behavior.

Biol 3015. Neurobiology Lab I. (1 cr, §§Nsc 3015, §§Phsl 3015; prereq 3010 or §§3105 or Nsc 3010 or §§Nsc 3015 or Phsl 3015 or §§Phsl 3010) Principles, methods, and laboratory exercises for investigating neural mechanisms and examining experimental evidence.

Biol 3011. Animal Biology. (4 cr, §§3011, §§Phsl 3051; prereq 1108, Chem 1052) Comparative physiology of various animal groups; coordination, movement, support, excretion, reproduction.

Biol 3012. Biological Rhythms and Timing Mechanisms. (4 cr; prereq 1009 or 1202 or #) Timing mechanisms and rhythms of organisms in physiological processes, ecological adaptation, and health; current hypotheses concerning their cellular and molecular nature. Individual projects.

Biol 3111. Neurobiology Lab II. (1 cr, §§Nsc 3115, §§Phsl 3115; prereq 3102 or §§3105 or Nsc 3012 or §§Nsc 3102 or Phsl 3012 or §§Phsl 3102) Principles, methods, and laboratory exercises for investigating neural mechanisms and examining experimental evidence.

Biol 340. History and Concepts in Biology. (2 cr per qtr; S-N only) Each quarter different faculty members lead groups of students in discussions on topics of current interest.

Biol 3960H. Undergraduate Seminar. (2 cr per qtr; S-N only) Oral reports on topics of current interest to biologists. Progress reports on laboratory and field research by students.

Biol 3980. Directed Instruction. (1-3 cr per qtr; S-N only) Leadership opportunities for upper division students wishing to assist with the Biology Colloquium. Application required.

Biol 5003. Genetics. (4 cr, §GCB 3022; prereq BioC 3021 or BioC 5331) Introduction to the nature of genetic information, its transmission from parents to offspring, its expression in cells and organisms, and its course in populations.


Biol 5125. Recombinant DNA Laboratory. (4 cr, §5825, §MicB 5425; prereq one college level course in biochemistry and one in genetics) Basic recombinant DNA techniques. Methods for growing, isolating, and purifying recombinant DNAs and cloning vectors.

Biol 5150. Introduction to Neuroscience. (3 cr, §NSc 5150, §Phs1 5150; prereq 3011 or equiv or Phs1 3055-3056, BioC 3021 or equiv or #) Survey of neuroscience from invertebrates to humans. Ion channels and membrane currents, neurotransmitters and signal transduction, neuroanatomy, sensory and motor systems, learning and memory, emotion, disease states, neural networks, development.

Biol 5931. Environmental Ethics and Citizenship. (4 cr; prereq 1051 or 3051 or EEB 3001 or #) Survey of theory and practice of environmental ethics and green politics in the United States and worldwide. Western and non-Western ethical principles and theories of human relationships with the environment.

Biol 5950. Special Topics in Biology. (1-5 cr per qtr) Courses Offered at Lake Itasca Forestry and Biological Station

Biol 3812. Plant Biology. (5 cr, §1103, §3012; prereq 1009 or 1202, Chem 1052, ∆) Plant diversity and evolution; structure and function of the plant cell and of the whole organism; growth and development of plants. Field trips.

Biol 5816. Field Biology Photography. (5 cr; prereq intro biology course, ∆; A-F only) Field photography techniques for documentation of insects, vertebrates, aquatic organisms and plants, and habitats of the Itasca area. Emphasis on general photographic principles and advanced techniques using flash, reversed lenses, and infra-red photoelectric tripping devices. On-site processing of color slides and black and white films. No previous processing experience required.

Biol 5825. Recombinant DNA Laboratory. (3 cr, §5125, §MicB 5425; prereq application, ∆) Basic recombinant DNA techniques. Methods for growing, isolating, and purifying recombinant DNAs and cloning vectors. Special application required.

Biol 5841. Ecology. (5 cr, §3008, §5041; prereq 1203 or 1103 or 1106 or 3011 or 3012 or 3812, Math 1142 or Math 1251, ∆; A-F only) Growth, structure, and evolution of populations. Pairwise biotic interactions between species and their effect on the diversity and structure of natural communities. Nutrient dynamics, function, productivity, and temporal stability of ecosystems. Field work at the Itasca station.

Biol 5850. Special Topics in Biology. (Cr ar, 1-10 per qtr; prereq ∆) Courses Offered in Denmark Through the Danish International Study Program (DIS)

Biol 3991. Marine Biology of European Coastal Waters. (4.5 cr; prereq 1 yr college biology incl lab, 1 college chemistry course, ∆) Marine biology, using Baltic and North Seas as focus. Biology of coastal waters, interactions between organisms and their environment, methods used by marine researchers to investigate biological systems. Students conduct simple experiments during field trips. Given in Copenhagen area, with study tour in northern and western Denmark.

Biol 3992. Biological Oceanography. (4.5 cr; prereq 1 yr college biology incl lab, 1 college chemistry course, ∆) Interaction among biology, physics, and chemistry in the ocean, with special reference to unique characteristics of North and Baltic Seas. Effects of light, temperature, salinity, density, pressure, and limiting chemical constituents on marine biological systems. Problems in fisheries management. Given in Denmark.

Biol 3993. Marine Biological Science Project. (9 cr; prereq 3991, 3992 or equiv, 1 yr college biology incl lab, 1 college chemistry course, ∆) Research project with practical field components. Students use scientific libraries of various research institutions, engage in discussions and seminars with leading Danish and German scientists, and conduct experiments on research ship and at Marine Biological Laboratory. Given in Denmark.

Biol 3994. Ecology and Human Impact in the North and Baltic Seas. (4.5 cr; prereq 1 yr of college biology incl lab, 1 college chemistry course, ∆) Ecosystems of North and Baltic Seas and how natural and human activities threaten their integrity. Given in Copenhagen area, with study tour in northern and western Denmark.


Biol 3996. Arctic Biology in Iceland. (4.5 cr; prereq 1 yr college biology incl lab, 1 college chemistry course, ∆) Field and classroom study. Geology; terrestrial biology, freshwater and marine biology/ecology; humans in the Arctic. Life under extreme conditions, Arctic vs. temperate and tropical waters, effects of biodiversity on evolution. Given in Iceland.
Biochemistry (BioC)

Director of Undergraduate Studies—Clare K. Woodward

Biochemists study molecules found in living organisms, particularly proteins, nucleic acids, lipids, and carbohydrates. The major in biochemistry is for students who plan to pursue graduate study in biochemistry or a related biological science, attend medical or veterinary school, or seek entry-level biochemical positions in industry. The biochemistry major differs from the chemistry major in that biochemistry emphasizes the integration of chemical principles into biological processes from molecular genetics to enzymology.

Biochemistry is an experimental science, and majors, especially those who plan to pursue graduate studies in the field, should become acquainted with laboratory research approaches beyond those introduced in the formal lab courses. Research options are available through BioC 5990 and the Honors Program. Students should start planning the research component of their major program as early as possible and should make arrangements during their junior year, in consultation with their adviser, for their senior research project.

Major Requirements

See Degree Requirements in the previous section for a description of residency, liberal education, foreign language, and English communication requirements.

Mathematics—A four-quarter analytic geometry and calculus sequence (Math 1251-1252-1261-3251 or equivalent).

Chemistry—Two quarters of general chemistry with lab (Chem 1051-1052 or equivalent); three quarters of organic chemistry, with labs (Chem 3301-3302-3303 with 3305-3306 or equivalent); a two quarter physical chemistry sequence (Chem 5501-5502 or 5534, 5535 (5533 is optional and requires Math 3252 as a prerequisite). A physical chemistry lab (5538 or 5540) is recommended but not required for those taking the three-quarter sequence.

Physics—A full year course, with lab, that requires college-level mathematics as a prerequisite (Phys 1251-1252-1253 (1254 optional) or 1104-1105-1106 with 1107-1108-1109) or equivalent.

Biochemistry majors are advised to select the 1251 calculus-based sequence. By petition, a two-quarter sequence (Phys 1041-1042) plus an additional four to five credits of mathematics, statistics, computer programming, or physical science chosen in consultation with the major adviser may be substituted.

General and organismal biology—Choose one of the following sequences:

- (preferred) Biol 1201, 1202, 1203
- or Biol 1201-1202, plus two courses from 3011, 3012/3812, 5013
- or Biol 1009, plus two courses from 3011, 3012/3812, 5013

Biology core—Each of the following:

- Genetics (Biol 5003)
- Cell Biology (Biol 5004)
- One 3xxx or 5xxx course from one of the following areas (credits may not count toward organismal biology requirement above nor toward the lab/field requirement below):
  a) Integrative/Organismal Biology/Physiology
  b) Ecology/Evolution/Systematics/Behavior (for a list of acceptable courses in these categories, see Biology Core course list on page 24)

- Lab or fieldwork in one additional upper division biological science course. A list of acceptable courses follows:
  Biol 3011, 3012/3812, 5013 (if not used to satisfy either the organismal biology requirement or the elective course in the core above)

- Bio 5125
- BioC 5990*
- EEB 5014, 5016, 5129, 5134, 5157, 5621, 5990*
- GCB 5015, 5030, 5605, 5990*
- MicB 5234, 5322, 5425, 5990*
- NSc 3105-3115, 5990*
- PBio 3109, 3201, 5103, 5105, 5107, 5111, 5132, 5231, 5990*

All CBS courses offered at the Lake Itasca Forestry and Biological Station are acceptable.

* An independent research project is strongly recommended for every student. To use one of the department Directed Research courses to satisfy the additional upper division lab or fieldwork requirement students must complete a minimum of 4 credits under the 5990 course number.
Biochemistry—Each of the following:

- BioC 3960—Research Topics in Biochemistry
- BioC 5025—Laboratory in Biochemistry
- BioC 5331—Structure, Catalysis, and Metabolism in Biological Systems
- BioC 5332—Energy and Signal Transduction in Biological Systems
- BioC 5333—Molecular Mechanisms of Gene Action

BioC Courses

BioC 1401. Elementary Biochemistry. (4 cr, §3001; prereq Chem 1001 or one qtr college chemistry)
Survey of biochemistry, beginning with a brief introduction to organic chemistry. For students who need general, non-intensive knowledge of the scope of biochemistry.

BioC 3021 (formerly Biol 5001). Biochemistry. (4 cr, §Biol 5001; prereq Biol 1009 or 1202, 8 cr organic chemistry)
Structure and function of proteins, nucleic acids, lipids, and carbohydrates; metabolism and regulation of metabolism; quantitative treatments of chemical equilibria, enzyme catalysis, and biochemicals of genetic information flow.

BioC 3960. Research Topics in Biochemistry. (1 cr; S-N only)
Lectures and discussions on current research in the department.

BioC 5025. Laboratory in Biochemistry. (2 cr; prereq 3021 or §3021 or 5331 or §5331)
Discussions of techniques and problem-solving approaches illustrated with lab experiments and demonstrations.

BioC 5301. Ecological Biochemistry. (3 cr; prereq 3021 or 5331 or #)
Biochemistry of environmental processes, including biochemistry of organismal interactions, biological responses to environmental stress, gene transfer in the environment, and effects and fate of environmental toxins.

BioC 5309. Biocatalysis and Biodegradation. (4 cr, §MicE 5309; prereq chemistry through organic chemistry, one course in biochemistry, microbiology, or advanced chemistry, knowledge of word processing and electronic mail; access to the World Wide Web and related Internet resources required; access to a college-level scientific library recommended)
A novel method for obtaining information on biocatalytic or biodegradation processes and pathways. Students verify and update existing Web pages in a database and develop Web pages for metabolic pathways for the degradation of environmental pollutants.

BioC 5331. Structure, Catalysis, and Metabolism in Biological Systems. (4 cr, §3021, §Biol 5001; prereq Biol 1009 or Biol 1202, 2 qtrs organic chemistry or #)
Structure and function of biological molecules, emphasizing protein structure, catalysis, and intermediary metabolism. Enzyme kinetics, thermodynamics, and the role of cofactors in catalysis.

BioC 5332. Energy and Signal Transduction in Biological Systems. (4 cr; prereq 5331 or #)
Biological membrane structure and membrane-associated proteins emphasized. Processes such as transport, oxidation/reduction, photosynthesis, electron transfer mechanisms, membrane receptors, signal transduction, and specific regulatory systems.

BioC 5333. Molecular Mechanisms of Gene Action. (4 cr; prereq 5332 or #)
Gene action mechanisms. Structure and function of nucleic acids and the regulatory process involved in gene expression from a biochemical point of view.

BioC 5352. Applied Microbial Biochemistry. (4 cr, §MicB 5352; prereq BioC 3021 or BioC 5331 or MicB 5321, intro microbiology course or #)
Biochemistry of microorganisms and enzymes of industrial interest. Overview of heterologous peptide overproduction by microorganisms and yeasts; polymer, antibiotic, organic acid, and amino acid production; genetics of industrially useful microorganisms; biological systems useful for biotransformations and environmental remediation; introduction to fermentation technology.

BioC 5418. Topics in Molecular Immunology. (4 cr; prereq MicB 5218; A-F only)
Molecular interactions among proteins and peptides involved in immune recognition.

BioC 5525. Physical Biochemistry: Solution Structure and Interactions of Biological Macromolecules. (4 cr, §Chem 5525, §MdBc 5525; prereq 5331 or equiv, 2 qtrs physical chemistry)
Physical chemistry of equilibrium, transport and scattering phenomena in solution, with application to proteins and nucleic acids. Intermolecular forces, macromolecular dynamics, conformational transitions, binding thermodynamics, methods for determining biopolymer size and shape, including sedimentation, diffusion, viscosity, electrophoresis, and scattering.

Fundamental spectroscopic principles, with emphasis on the development of magnetic resonance theory used in the study of biological macromolecules.

BioC 5527. Physical Biochemistry: Spectroscopic Methods II. (4 cr, §Chem 5527, §MdBc 5527; prereq 5526, 2 qtrs physical chemistry)
Applications of optical and magnetic resonance techniques to the study of structure and dynamics in proteins, lipids, nucleic acids, and synthetic analogs.

BioC 5528. Physical Biochemistry: Enzyme Kinetics. (4 cr, §Chem 5528, §MdBc 5528; prereq 5331 or 8001 or equiv, 2 qtrs physical chemistry)
Theory and application of steady-state and transient kinetics to the study of enzymes, enzyme systems, and cellular regulation.
BioC 5529. Protein Structure and Folding. (4 cr, §Chem 5529, §MdBc 5529; prereq 5331 or equiv, 1 qtr physical chemistry or §)
Protein structure, stability, folding and molecular modeling. Emphasis on results from X-ray crystallography, solution thermodynamics, NMR, computer graphics, and protein engineering.

BioC 5950. Special Topics. (1-5 cr; prereq #, Δ)

BioC 5970. Directed Studies. (Cr ar [10 cr max of 5970 or 5990 may count toward major requirements; prereq #, Δ; S-N only)
Individual study on selected topics, with emphasis on selected readings and use of scientific literature.

BioC 5990. Directed Research. (Cr ar [10 cr max of 5970 or 5990 may count toward major requirements; prereq #, Δ; S-N only)
Lab or field investigation of selected areas of research.

For Graduate Students Only
(For descriptions, see the Graduate School Bulletin)

BioC 8001. Advanced Biochemistry I: Protein Structure and Function
BioC 8002. Advanced Biochemistry II: Molecular Biology
BioC 8003. Advanced Biochemistry III: Regulation of Metabolism and Biological Processes
BioC 8094. Research and Literature Reports
BioC 8194. Graduate Seminar
BioC 8206. Cell Signaling and Metabolic Regulation
BioC 8213. Advanced Molecular Biology I
BioC 8214. Advanced Molecular Biology II
BioC 8230. Membrane Biochemistry
BioC 8290. Current Research Techniques
BioC 8990. Graduate Research

Ecology, Evolution, and Behavior (EEB)

Director of Undergraduate Studies—Richard Phillips
Ecologists study the evolutionary adaptations of plants and animals to the environment. The ecological perspective encompasses the growth and maintenance of populations and their interactions in communities, and the interrelationships among organisms and physical events in terrestrial and aquatic ecosystems. The behavioral biology perspective deals with adaptations to the environment, mechanisms of behavior, and the evolution of social systems.

The Department of Ecology, Evolution, and Behavior participates in teaching the core curriculum in biology and offers an undergraduate major in ecology, evolution, and behavior.

Major Requirements
See Degree Requirements in the previous section for a description of residency, liberal education, foreign language, and English communication requirements.

Mathematics—A three-quarter analytic geometry and calculus sequence (Math 1251-1252-1261 or equivalent). A two-quarter course sequence in statistics may be substituted for the third quarter of calculus (Stat 3011-3012 or Stat 5021).

Chemistry—Two quarters of general chemistry with lab (Chem 1051-1052 or equivalent) and two quarters of organic chemistry, with lab (Chem 3301-3302 with 3305-3306 or equivalent).

Physics—A full year course, with lab, that requires college-level mathematics as a prerequisite (Phys 1251-1252-1253 (1254 optional) or 1104-1105-1106 with 1107-1108-1109) or equivalent. By petition, a two-quarter sequence (Phys 1041-1042) plus an additional four to five credits of mathematics, statistics, computer programming, or physical science chosen in consultation with the major adviser may be substituted.

General and organismal biology—Choose one of the following sequences:
• (preferred) Biol 1201, 1202, 1203
• or Biol 1201-1202, plus two courses from 3011, 3012/3812, 5013
• or Biol 1009, plus two courses from 3011, 3012/3812, 5013

Biology core—
• One 3xxx or 5xxx course each from two of the three following areas (credits may not count toward organismal biology requirement above nor toward the EEB course requirements below):
  a) Biochemistry (needed for most of the courses listed in category b, which follows)
b) Genetics/Cell Biology/Development

(For a list of acceptable courses in these categories, see Biology Core Course List on page 24)

• Lab or fieldwork in one additional upper division biological science course. A list of acceptable courses follows. (This course may also satisfy a requirement for a Group I course in the EEB course requirements listed below.)
Biol 3011, 3012/3812, 5013 (if not used to satisfy any organismal biology requirement listed above)
Biol 5125
BioC 5025, 5990*
EEB 5014, 5016, 5129, 5134, 5157, 5621, 5990*
GCB 5015, 5030, 5605, 5990*
MicB 5234, 5322, 5425, 5990*
NSc 3105, 3115, 5990*
PBio 3109, 3201, 5103, 5105, 5107, 5111, 5132, 5231, 5990*

All CBS courses offered at the Lake Itasca Forestry and Biological Station are acceptable.

* An independent research project is strongly recommended for every student. To use one of the department Directed Research courses to satisfy one of the upper division lab or fieldwork requirements, students must complete a minimum of 4 credits under the 5990 course number.

Ecology, Evolution, and Behavior—one of the following:

• Biol 3008/5841—Ecology and Evolution
• EEB 3111/5811—Introduction to Animal Behavior
• EEB 5044—Evolution or 5064 The Process of Evolution
• EEB 5156—Comparative Animal Physiology (if not used to meet physiology requirement listed above)

Organismal Biology and Physiological Ecology

b) EEB 5129 and EEB 5134 plus either EEB 5014 or EEB 5016.
c) Internship or job involving 100 hours or more of data collection in the field and 50 or more hours of analysis of these data. Petitions for this option need to include a letter from the student describing duties and a letter from the employer/supervisor describing the educational components of the work that was performed as well as certifying that it had been completed.

• At least two courses from Group I (below). Appropriate courses from other departments may also be substituted by petition—see especially departments listed under Group II below. Courses in bold are courses that will meet the additional lab/field requirement listed above under biology core course requirements.

Recommended Courses, Group I:

Community Ecology and Paleoecology
EEB 5004—Earth System: Geosphere/Biosphere Interactions (4 cr)
EEB 5008—Quaternary Ecology (4 cr)
EEB 5014—Ecology of Vegetation (5 cr)
EEB 5016—Ecological Plant Geography (5 cr)

Population and Evolutionary Biology
EEB 5034—Population Genetics (3 cr)
EEB 5042—Quantitative Genetics (4 cr)
EEB 5044—Evolution (4 cr) (if not used to meet requirement c. above)
EEB 5051—Analysis of Populations (4 cr)
EEB 5052—Theoretical Population Ecology (5 cr)
EEB 5064—The Process of Evolution (4 cr) (if not used to meet requirement c. above)

Organismal Biology and Physiological Ecology
EEB 5122—Plant/Animal Interactions (4 cr)
EEB 5129—Mammalogy (5 cr)
EEB 5134—Introduction to Ornithology (5 cr)
EEB 5136—Ichthyology (4 cr)
EEB 5156—Comparative Animal Physiology (3 cr) (if not used to meet physiology requirement above)
EEB 5157—Animal Physiology Laboratory (3 cr)

Behavioral Biology
EEB 5321—Evolution of Social Behavior (4 cr)
EEB 5323—Mechanisms of Behavior (3 cr) (if not used to meet physiology requirement above)
EEB 5324—Evolution of Primate Social Behavior (3 cr)
EEB 5325—Behavioral Ecology (4 cr)

Limnology and Ecosystem Biology
EEB 5601—Limnology (4 cr)
EEB 5608—Ecosystems: Form and Function (4 cr)
EEB 5621—Limnology Laboratory (2 cr)
**Recommended Courses, Group II:**

Anthropology  
Climatology/Meteorology  
Earth Sciences  
Entomology  
Fisheries  
Forestry  
Mathematics  
Psychology  
Public Health  
Statistics  
Wildlife Biology

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**EEB Courses**

**EEB 1019. Our Changing Planet.** (4 cr; §Ast 1019, §Geo 1019)  
Interrelationships among Earth’s subsystems—solid earth, oceans, atmosphere, and biosphere—and solar and galactic super-systems. Interactions of the natural cycles, their rates and feedbacks, and human impacts.

**EEB 3001. Introduction to Ecology.** (4 cr; for students in programs not directly related to biological sciences)  
Basic concepts in ecology; organization, development, and functioning of ecosystems; population growth and regulation. Human impact on ecosystems.

**EEB 3111. Introduction to Animal Behavior.** (4 cr, §Biol 1009 or Biol 1201 or Biol 1202 or #)  
Causation, development, function, and evolution of animal behavior; emphasizes evolution of adaptive behavior, especially social behavior, in the natural environment.

**EEB 3361. Visions of Nature: The Natural World and Political Thought.** (4 cr, §CSCL 3361; biological sciences students may not apply these credits toward the major)  
Theories about the organization of nature and their significance for the development of ethics, religion, political and economic philosophy, civics, and environmentalism in Western and other civilizations.

**EEB 3960. Research Topics in Ecology and Behavioral Biology.** (1 cr per qtr; prerequisite #; S-N only)  
Individual study on selected topics or problems with emphasis on selected readings and use of scientific literature.

**EEB 5970. Directed Studies.** (Cr ar [10 cr max of 5970 or 5990 may count toward major requirement]; prerequisite #; S-N only)  
Individual study on selected topics or problems with emphasis on selected readings and use of scientific literature.

**EEB 5990. Directed Research.** (Cr ar [10 cr max of 5970 or 5990 may count toward major requirement]; prerequisite #; S-N only)  
Lab or field investigation of selected areas of research.

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**Community Ecology and Paleoecology**

**EEB 5004. Earth System: Geosphere/Biosphere Interactions.** (4 cr, §Geo 5631; prerequisite Geo 3202, 3301 or #)  
Interdisciplinary study of global change-forcing mechanisms, feedbacks, and dynamics on various time scales, using paleorecord to illustrate processes.

**EEB 5008. Quaternary Ecology.** (4 cr; prerequisite Biol 3008 or 5841 or #)  
Impact of changes in the physical and biological environment on plants and animals during the Quaternary Period. Changes in evolutionary rates, geographical distributions, community composition, and population sizes. Impact of prehistoric human culture on the environment, including ecosystem-level changes recorded in sedimentary sequences. Recent climatic changes. General principles of analysis and methods of investigation and interpretation.

**EEB 5014. Ecology of Vegetation.** (5 cr; prerequisite Biol 3008 or 5841, 1 qtr statistics or #)  
Methods of describing, sampling, and classifying vegetation; spatial and temporal variation of vegetation on landscapes; theory of structure and dynamics of plant communities. Field trips to local vegetation types; analysis of quantitative data.

**EEB 5016. Ecological Plant Geography.** (5 cr; prerequisite Biol 3008 or Biol 5841, P Bio 3201 or PBio 3201 or #)  
Vegetation regions of the world in general and North America in detail; ecological principles of plant distribution; interpretation of regional and temporal patterns in the distribution of vegetation and taxonomic groups. Field trips to floristic regions of Minnesota.

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**Population and Evolutionary Biology**

**EEB 5034. Population Genetics.** (3 cr; prerequisite basic genetics, one qtr calculus, familiarity with computer programming)  
Introduction to the genetic basis of evolutionary change, including population genetics, theory, techniques for Monte Carlo simulation of genetic evolution, and literature of experimental population genetics.

**EEB 5042. Quantitative Genetics.** (4 cr; prerequisite Biol 5003 or GCB 3002, course in statistics or #)  
Genetic basis of variation in traits that are continuous in distribution and influenced by genes and environment. Assessment of genetic variance and heritability of traits in populations. Prediction of response to selection.

**EEB 5044. Evolution.** (4 cr; prerequisite Biol 1106 or Biol 3011, Biol 1103 or Biol 3012 or Biol 3812)  
Evidence for and causes of biological evolution.
ECOLOGY, EVOLUTION, AND BEHAVIOR

EEB 5051. Analysis of Populations. (4 cr; prereq Biol 3008 or Biol 5841 or #)
Factors involved in the regulation, growth, and general dynamics of populations. Data needed to describe populations, population growth, population models, and regulatory mechanisms.

EEB 5052. Theoretical Population Ecology. (5 cr; prereq Biol 3008 or Biol 5841 or #)
Theories of population ecology, including models of growth and regulation of single populations and of interactions between populations, including competition, predation, mutualism; emphasizes assumptions and rationales of models and their predictions for dynamics, stability, and diversity of communities.

EEB 5064. The Process of Evolution. (4 cr; prereq Biol 3008 or Biol 5841 or #)
Mechanistic bases of evolution, including causes and consequences of natural selection, stochastic consequences of Mendelian segregation, and their combined influences on the structure of natural and captive populations. Lab exercises based on “Populus” computer simulation software.

Organismal Biology and Physiological Ecology

EEB 5122. Plant/Animal Interactions. (4 cr; prereq Biol 1106 or Biol 3011, Biol 1103 or Biol 3012 or Biol 3812, 10 cr biological sciences or #)
Herbivory, pollination, seed dispersal. Implications of interactions for plants and animals at organismal, population, and community levels. Coevolution

EEB 5129. Mammalogy. (5 cr, §FW 5129; prereq Biol 1106 or Biol 3011 or #)
Recent families and orders of mammals of the world and genera and species of mammals of North America, with emphasis on morphology, evolution, and zoogeographic history.

EEB 5134. Introduction to Ornithology. (5 cr; prereq Biol 1106 or Biol 3011)
Lab and field course in structure, classification, distribution, migration, habits, habitats, and identification of birds. Weekend trips.

EEB 5136. Ichthyology. (4 cr; prereq 15 cr incl Biol 1106 or Biol 3011)
Biology of fishes including development, systematics, anatomy, physiology, and ecology.

EEB 5156. Comparative Animal Physiology. (3 cr; prereq Biol 1106 or Biol 3011, Chem 3302 or #)
The passive organism-environment stresses and biological mechanisms by which they are counteracted.

EEB 5157. Animal Physiology Laboratory. (3 cr; prereq 5156 or 5323 or AnSci 3301 or Biol 3011 or Biol 3111 or Ent 5030 or FW 5459 or GCB 5114 or § in any course listed or #; A-F only)
Recording and analysis of bioelectric events, transduction of force and displacement into electrical signals, respirometry, spectrophotometry. Independent or team research projects required.

Behavior

EEB 5321. Evolution of Social Behavior. (4 cr; prereq Biol 1106 or Biol 3011 or #)
Current theories and concepts relating to mating systems, spacing systems, and cooperative behavior in animals.

EEB 5323. Mechanisms of Behavior. (3 cr; prereq 3111 or Biol 3011 or #; A-F only)
Neural and hormonal mechanisms that mediate adaptive behavior in invertebrate and vertebrate animals, using a series of well-studied examples to illustrate general principles.

EEB 5324. Evolution of Primate Social Behavior. (3 cr; prereq 3111 or 5811 or #)
Ecological factors that influence variation in the demography, social structure, and social behavior of non-human primates. Application of current evolutionary theory (e.g., kin selection, reciprocity) to the understanding of social behavior.

EEB 5325. Behavioral Ecology. (4 cr; prereq 3111 or 5321 or 5811 or Biol 3008 or Biol 5841 or #)
Evolutionary principles applied to the study of aggressive competition, mating systems, cooperation, and parental investment. Optimization models used to examine foraging strategies, predator/prey interactions, and territoriality. Evolution of sex, sexual selection, and dispersal.

Limnology and Ecosystem Ecology

EEB 5601. Limnology. (4 cr, §Geo 5601; prereq Chem 1052 or #)
Description and analysis of the events in lakes, reservoirs, and ponds, beginning with their origins and progressing through their physics, chemistry, and biology. Interrelationships of these parameters and effects of civilization on lakes.

EEB 5608. Ecosystems: Form and Function. (4 cr; prereq 5601 or Biol 3008 or Biol 5841 or equiv, an advanced course in writing such as Comp 3015 or 3027 or 3033 or 3085 or Rhet 3562, A)

EEB 5621. Limnology Laboratory. (2 cr, §Geol 5621; prereq 5601 or Geol 5601 or #)
Principal techniques for obtaining information about environmental conditions in lakes and streams. Procedures for measuring the abundance and population dynamics of aquatic organisms, with special emphasis on plankton. Field instruments, sampling devices, chemical analysis, microscopy, and analysis of data. One Saturday field trip.

EEB 5652. Community and Ecosystem Processes. (4 cr; prereq 2 qtrs calculus, Biol 3008 or 5841, one ecology course in populations or communities or ecosystems or #; A-F only)
Courses Offered at Lake Itasca Forestry and Biological Station

EEB 5811. Field Studies of Animal Behavior. (5 cr, §3111, §3811, §AnSc 3111; prereq general biology and an additional course in biology, Δ)
Survey of animal behavior in the natural environment emphasizing field projects using video and audio recording and analysis, audio playback, models, radio telemetry, design of observations, and individual marking.

EEB 5814. Plant Community Ecology. (5 cr; prereq ecology course, Δ; A-F only)
Communities represented in Itasca Park and vicinity, with emphasis on vegetation. Patterns of distribution of the communities, their interaction with the environment, and their dynamic relationships. Methods of community description and analysis.

EEB 5817. Vertebrate Ecology. (5 cr; prereq ecology course, Δ)
Field studies on vertebrate populations and their relationships to local environments. Habitat analysis and ecological research methods. Students work individually or as a team investigating factors influencing distribution and abundance of selected vertebrates in various habitats. Research-oriented course supplemented with lectures and field trips.

EEB 5834. Field Ornithology. (5 cr; prereq general biology course including study of zoology, Δ)
Emphasis on the breeding season, biology, and behavioral ecology of birds in the Itasca Park region. Field trips taken to a variety of habitats to learn bird identification and observe and practice techniques for conducting field studies. Lab sessions investigate family distinctions and species identification. Individual field projects.

EEB 5839. Field Studies in Mammalogy. (5 cr; prereq college-level biology course including study of animals or #, Δ; A-F only)
Identification, distributions, community interactions, ecophysiology, and population ecology.

Biol 5841. Ecology. (5 cr, §Biol 3008; prereq 1203 or 1103 or 1106 or 3011 or 3012 or 3812, Math 1142 or Math 1211 or Math 1251, Δ)
Growth, structure, and evolution of populations. Pairwise biotic interactions between species and their effect on the diversity and structure of natural communities. Nutrient dynamics, function, productivity, and temporal stability of ecosystems. Fieldwork at the Itasca station.

For Graduate Students Only
(For descriptions, see the Graduate School Bulletin)

EEB 8003. Ecological Modeling
EEB 8061. Social Systems
EEB 8300. Topics in Evolution
EEB 8390. Graduate Seminar
EEB 8391. Advanced Work in Ecology and Behavioral Biology
EEB 8400. Population Biology Seminar
EEB 8410. Community Ecology Seminar
EEB 8420. Population Biology Research Seminar
EEB 8430. Evolutionary Genetics Seminar
EEB 8500. Writing Research Proposals
EEB 8510. Behavioral Biology Seminar
EEB 8602. Advanced Limnology
EEB 8612. Winter Ecology
EEB 8990. Graduate Research

Interested students should also check the Courses on the Environment bulletin.

Genetics and Cell Biology (GCB)

Director of Undergraduate Studies—William Herman

Genetics is the study of inheritance, including molecular mechanisms of gene organization and expression, human genetics, and the behavior of genes in populations of organisms. Study in cell and developmental biology seeks to answer basic questions regarding organization, composition, function, and assembly of cells and cellular components, and their regulation during the processes of cellular growth and differentiation.

The GCB major provides special educational opportunities for undergraduate students through group discussion of current research problems and techniques, enhanced practical experience with relevant systems and methodology, additional advanced courses, and close interaction with faculty actively investigating contemporary problems and reviewing current literature in the field. The major prepares undergraduates for advanced study and for positions in the rapidly growing field of biotechnology and in medical, industrial, or other scientific laboratories.

Major Requirements

See Degree Requirements in the previous section for a description of residency, liberal education, foreign language, and English communication requirements.

Mathematics—A three-quarter analytic geometry and calculus sequence (Math 1251-1252-1261 or equivalent). A two-quarter course sequence in statistics may be substituted for the third quarter of calculus (Stat 3011-3012 or Stat 5021).
Chemistry—Two quarters of general chemistry with lab (Chem 1051-1052 or equivalent) and two quarters of organic chemistry, with lab (Chem 3301-3302 with 3305-3306 or equivalent).

Physics—A full year course, with lab, that requires college-level mathematics as a prerequisite (Phys 1251-1252-1253 (1254 optional) or 1104-1105-1106 with 1107-1108-1109) or equivalent. By petition, a two-quarter sequence (Phys 1041-1042) plus an additional four to five credits of mathematics, statistics, computer programming, or physical science chosen in consultation with the major adviser may be substituted.

General and organismal biology—Choose one of the following sequences:
- (preferred) Biol 1201, 1202, 1203, plus one organismal course (3011 or 3012/3812 or 5013)
- or Biol 1201-1202, 3011, 3012/3812, 5013
- or Biol 1009, 3011, 3012/3812, 5013

Biology core—Each of the following:
- Biochemistry (BioC 3021 or 5331)
- Genetics (Bio 5003)
- Cell Biology (Biol 5004)
- One course from the Ecology/Evolution/Behavior core course list (see page 24). If the course chosen is also listed under Area 3 for the GCB major, it will count towards the 27 required credits below.

GCB majors must complete 27 additional upper division credits in math or science, including:

a. GCB 3960 (1 cr) (Students should complete this course as soon as possible after they decide to major in GCB)

b. Biol 3950H (two quarters, 4 cr). The value of the undergraduate seminar is at least two-fold: (1) It permits students to meet in small groups and practice both oral and written communication; (2) it requires students to explore an aspect of biology in depth.

c. BioC 5025, Lab in Biochemistry (2 cr)
d. 20 additional credits in life sciences or physical science or mathematics or statistics or computer science, chosen in consultation with major adviser. The 20 credits must include two additional labs, totaling a minimum of 4 cr, one of which must be in GCB. (Biol 5125 may be considered a GCB course for purposes of this requirement.) Students should include GCB 5990, Directed Research, as one or both of these experiences. A minimum of 4 and a maximum of 8 credits of 5990 may be used towards the 20-credit total.

The 20 credits must include at least 3 credits from Area 1 and 3 credits from Area 2; but may include not more than 4 credits from Area 4:

**Area 1: Genetics**
Biol 5125—Recombinant DNA Laboratory (4 cr)*
or MicB 5425—Virology and Molecular Genetics Laboratory (3 cr)*
EEB 5033—Population and Quantitative Genetics (4 cr)
GCB 5024—Genetics of Development (4 cr)**
GCB 5030—Laboratory: Genetics (2 cr)*
GCB 5034—Intermediate Molecular Genetics (4 cr)
GCB 5043—Human Genetics (4 cr)
GCB 5073—Advanced Human Genetics (4 cr)**
PBio 5109—Molecular Genetics and Biochemistry of Yeasts and Filamentous Fungi (4 cr)**
Psy 5137—Introduction to Behavioral Genetics (4 cr) (prerequisites waived for CBS students)

**Area 2: Cell and Developmental Biology**
GCB 5015—Histology: Cell and Tissue Organization (5 cr)*
GCB 5035—Intermediate Cell Biology (4 cr)
GCB 5061—Developmental Biology (4 cr)
GCB 5114—General Physiology (4 cr)
GCB 5134—Endocrinology (4 cr)
GCB 5605—Cell Biology Laboratory (2 cr)*
MicB 5218—Immunology (3 cr)
PBio 5151—Plant Cell Biology (4 cr)**

* Lab courses.

** Courses taken primarily by graduate students; undergraduates should have excellent grades in Biol 5003 or Biol 5004.

**Area 3: Courses from other departments. (This list is not all-inclusive.)
BioC 5401—Metabolism and Regulation (3 cr)
Biol 5150—Introduction to Neuroscience (3 cr)
Chem 3100, 3101—Quantitative Analysis (5 cr)
Chem 3303—Elementary Organic Chemistry III (4 cr)
Chem 5501-5502—Elementary Physical Chemistry (6 cr)
CSci 3102—Introduction to PASCAL Programming (4 cr)
EEB 5044—Evolution (4 cr)
EVB 5064—The Process of Evolution (4 cr)
GCB 3008—The Biology of Cancer (3 cr)
Math 3251—Multivariable Differential Calculus (4 cr)
MicB 5218—Immunology (3 cr)
MicB 5321—Physiology of Bacteria (3 cr)
MicB 5424—Biology of Viruses (4 cr)
PBio 3131—Survey of Plant Physiology (4 cr)
PBio 5111—Plant Cell, Tissue, and Organ Development (5 cr)
Stat 5021—Statistical Analysis (5 cr)

**Area 4: History and Philosophy of Science**
Biol 5951—Social Uses of Biology (4 cr)
HSci 3202—History of Biology (Physiology and Cell Theory) (4 cr)
HSci 5242—The Darwinian Revolution (4 cr)
Phil 3601—Scientific Thought (4 cr)
Phil 5603—Philosophy of Science: Change (4 cr)
Phil 5607—Philosophy of Science: Biology (4 cr)
GCB Courses

GCB 3002. Human Genetics, Social Affairs. (3 cr [4 cr with term paper], §3022, §Biol 1101, §Biol 5003; for students in programs not directly related to biological sciences) Heredity and basic genetic mechanisms, with emphasis on humans. Relationship between human genetics and disease, family planning, gender, behavior, and race. Ethical/societal issues concerning human genetics and modern genetic technologies.


GCB 3022. Genetics. (4 cr, §Biol 5003; not for biology majors; prereq Biol 1009 or 1202) Mechanisms of heredity, their implications for biological populations, and applications to practical problems.

GCB 3960. Research Topics. (1 cr; prereq 15 cr biology; S-N only) Ongoing department faculty research. Introduces sophomores and juniors who are potential GCB majors to department faculty, various faculty research activities, and opportunities for GCB undergraduate research.

GCB 5015. Histology: Cell and Tissue Organization. (5 cr; prereq Biol 5004 or #) Structure and function of vertebrate tissues and organs. Lectures combine electron microscopy, light microscopy, physiology, and cell biology of higher animals. Labs concentrate on light microscopy of mammalian tissues.

GCB 5024. The Genetics of Development. (4 cr; prereq Biol 5003 or #) Current concepts and experimental approaches concerning the genetic basis of morphogenesis and metazoan development. Concentration on organisms amenable to genetic analysis, including certain prokaryotes and single-cell eukaryotes, nematodes, and Drosophila.

GCB 5030. Laboratory: Genetics. (2 cr; prereq 3022 or Biol 5003 or BioC 5333) Investigative approaches to analysis of genetic problems. Focus on a given organism or related group of organisms may differ from quarter to quarter.

GCB 5034. Intermediate Molecular Genetics. (4 cr; prereq Biol 5003, Biol 5004) Molecular genetics of prokaryotes and eukaryotes concentrating on the characterization and regulation of expression of genes, and the techniques used to study gene expression. For advanced bioscience undergraduates and graduate students outside of CBS programs.

GCB 5035. Intermediate Cell Biology. (4 cr; prereq Biol 5004 or #) Current literature in cell biology. Selected scientific papers illustrate new concepts in and experimental approaches to cell organization and function. Topics vary but include membranes, secretion, endocytosis, the cytoskeleton, and the nucleus.

GCB 5043. Human Genetics. (3 cr; prereq 3022 or Biol 5003 or #) Principles of human genetics at the molecular, cellular, individual, and population levels. Chromosomal and biochemical disorders; gene mapping; mutation and natural selection; variation in intelligence and behavior; genetic screening, counseling, and therapy.


GCB 5073. Advanced Human Genetics. (4 cr; prereq 5034 or #) Application of molecular, biochemical, chromosomal, and population genetics to human variation and disease. Abnormal chromosome number and structure; abnormal enzyme, structural protein, receptor and transport; inheritance patterns; behavioral genetics; genetic basis of common disease.

GCB 5114. General Physiology. (3 cr; prereq Biol 3011 or Biol 3111, Biol 5001 or BioC 3021 or BioC 5331, Phys 1109 or Phys 1253) Quantitative approach to the study of cell function, with emphasis on application of physical and chemical principles. Transport, electrical activity of cell membranes, and cell contractility.

GCB 5134. Endocrinology. (4 cr; prereq Biol 3011 or Biol 3111, Biol 5001 or BioC 3021 or BioC 5331 or #) Survey of structure and function of invertebrate and vertebrate endocrine systems.

GCB 5605. Cell Biology Laboratory. (2 cr; prereq Biol 5004 or Biol 5004 or #) Experimental approaches to cell structure, function, and replication, including microscopy, autoradiography, cell fractionation, and molecular and chemical analyses.

GCB 5970. Directed Studies. (Cr ar [10 cr max of 5970 or 5990 may count toward major requirement]; prereq #; ∆ S-N only) Individual study on selected topics or problems, with emphasis on selected readings and use of scientific literature.

GCB 5990. Directed Research. (Cr ar [10 cr max of 5970 or 5990 may count toward major requirement]; prereq #; ∆ S-N only) Laboratory or field investigation of selected areas of research.

For Graduate Students Only

(For descriptions, see the Graduate School Bulletin)

8131. Advanced Genetics I
8132. Advanced Genetics II
8148. Advanced Cell Biology I
8149. Advanced Cell Biology II
8213. Advanced Molecular Biology I
8214. Advanced Molecular Biology II
8900. Seminar
8910. Journal Clubs
8912. Genetic Counseling in Practice
8913. Psychosocial Issues in Genetic Counseling
8914. Ethical and Legal Issues in Genetic Counseling
8970. Directed Study
8990. Research
Molecular, Cellular, Developmental Biology and Genetics
8920. Special Topics
8950. Teaching Practicum
8970. Directed Studies
8990. Research

History of Science and Technology (HSci)

HSci 3201/5201, 3202/5202. History of Biology. (4 cr per qtr)
Scientific, philosophical, and social factors in the development of biology; changing styles of biological reasoning and changing relationships between biological and physical sciences. 3201/5201: Biology from antiquity through early modern period. 3202/5202: Biology in the 19th and 20th centuries.

HSci 5242. The Darwinian Revolution. (4 cr; prereq Biol 1009 or Biol 1101 or Biol 1202 or #)
Pre-Darwinian conceptions of nature; development and reception of Darwin’s theory of evolution by natural selection; broader context of the Darwinian revolution, including religious thought, political theory, and views about proper scientific methodology.

Microbiology (MicB)

Medical School

Director of Undergraduate Studies—
Palmer Rogers

The microbiology program prepares students for work as practicing microbiologists or for graduate work.

The field of microbiology embraces a multitude of areas of fundamental and applied research. Microbiologists have in common an interest in the basic role played by microbes, such as bacteria, fungi, and viruses, in the world in which we live. Microbiologists may be interested in basic biological mechanisms such as DNA replication or the regulation of protein synthesis, which are currently under study employing microorganisms. They may study fundamental issues concerning human and animal diseases such as the mechanisms of viral and bacteriological infection, immunity and autoimmune disease, and viral-induced cancer. Many aspects of agriculture are under investigation by microbiologists; among them are specific fungal and bacterial symbionts essential for maximum growth of certain plants, and bacteria and fungi essential for maintenance and production of natural soil fertility. Microbiologists are also active in many industrial and pharmaceutical fields involving production and discovery of new antibiotics; manufacture of cheese, beer, wine, and other foods; pasteurization in canning and food processing; and even decontamination of space vehicles.

Major Requirements

See Degree Requirements in the previous section for a description of residency, liberal education, foreign language, and English communication requirements.

Mathematics—A three-quarter analytic geometry and calculus sequence (Math 1251-1252-1261, or equivalent, or Math 1251-1252 and Stat 3011-3012 or Stat 5021).

Chemistry—Two quarters of general chemistry with lab (Chem 1051-1052 or equivalent), two quarters of organic chemistry with lab (Chem 3301-3302 with 3305-3306 or equivalent), and quantitative chemistry (Chem 3100-3101).

Physics—A full year course, with lab, that requires college-level mathematics as a prerequisite (Phys 1251-1252-1253 (1254 optional) or 1104-1105-1106 with 1107-1108-1109) or equivalent. By petition, a two-quarter sequence (Phys 1041-1042) plus an additional four to five credits of mathematics, statistics, computer programming, or physical science chosen in consultation with the major adviser may be substituted. Microbiology majors are advised to complete the 1251 series.

General and organismal biology—Choose one of the following sequences:
• (preferred) Biol 1201, 1202, 1203
• or Biol 1201-1202 plus one of the following: Biol 3011 or 3012/3812
• or Biol 1009 plus one of the following: Biol 3011 or 3012/3812

Biology core—Each of the following:
• Biochemistry (BioC 3021 or 5331)
• Genetics (BioI 5003 or GCB 3022)
• Microbiology (BioI 5013)
• Ecology or Microbial Ecology (BioI 3008/5841 or MicB 5611)
Microbiology—Each of the following:
- MicB 5900
- Four of the following: MicB 5218, 5232, 5321, 5322, 5424, 5611 (if not used to meet the ecology requirement above)
- Two of the following advanced microbiology lab courses: MicB 5234, 5322, 5425 or directed research. MicB 5990 (a minimum of 8 cr in one faculty lab is required to meet one of the lab course requirements). Directed research may be used to meet only one of the lab requirements. A directed research project is strongly recommended for every student.

Students planning to graduate with honors in microbiology must include specific courses in their program in addition to the college requirements. A listing of these courses may be obtained from the department office, 1460 Mayo Memorial Building (Minneapolis), or from the CBS Office of Student Services, 223 Snyder Hall (612/624-9717).

MICB COURSES

**MicB 3103.1 General Microbiology.** (5 cr, §5105, §Biol 5013, §VPB 3103; prereq soph with C avg in courses prereq to major sequence or jr with 10 cr chemistry, 5 cr biological sciences or #; not for biology majors) Morphology, physiology, taxonomy, and ecology of microbes. Applications of fundamental principles. Lab.

**Biol 5013.1 Microbiology.** (5 cr, §MicB 3103, §MicB 5105, §VPB 3103; prereq Biol 5001 or BioC 3021 or BioC 5331) Taxonomy, anatomy, physiology, biochemistry, and ecology of microbes. Molecular structure in relation to bacterial function. Lab.

**MicB 5105.1 Biology of Microorganisms.** (5 cr, §Biol 5013, §MicB 3103, §VPB 3103; prereq Biol 5001 or BioC 3021 or BioC 5331 or #) Taxonomy, anatomy, physiology, biochemistry, and ecology of microbes. Molecular structure in relation to bacterial function. Lab.

**MicB 5218. Immunology.** (3 cr; prereq Biol 5001 or BioC 3021 or BioC 5331) Cellular, protein, and genetic bases of humoral immunity; methods used to measure antibodies and antigens. T lymphocytes; interaction of T helper cells with B lymphocytes and other T cells in cell-mediated immunity. Clinical immunology: immunodeficiency, allergy, autoimmunity, and transplantation.

**MicB 5232. Medical Microbiology.** (3 cr; not open to med students; prereq 3103 or 5105 or Biol 5013, MicB 5218 or §MicB 5218) Pathogenic bacteria and fungi, mechanisms of pathogenicity and virulence; properties of microorganisms and their animal hosts that influence the outcome of host-parasite relations analyzed from genetic and metabolic view.

**MicB 5234.1 Immunology and Medical Microbiology Laboratory.** (3 cr; prereq 5218 or §5218, 5232 or §5232) Principles that determine the outcome of host-parasite interactions. Host defense and immunology methods, including immunohematological and microbiological methods used to diagnose infectious disease.

**MicB 5235. Microorganisms and Disease.** (3 cr, §5233; not open to microbiology majors; does not count toward the 16 upper division elective credits in the biology major; prereq 10 cr chemistry, 5 cr biological sciences or #) Nature of microorganisms, immunology, medical bacteriology, virology, mycology, and principles of disease control.

**MicB 5321. Physiology of Bacteria.** (3 cr; prereq 3103 or 5105 or Biol 5013 or VPB 3103, Biol 5001 or BioC 3021 or BioC 5331, 3 cr genetics) Chemical and physical organization of bacteria as related to function; growth; energy metabolism including oxidations and fermentations; nutritional requirements; antimicrobial agents; autotrophic mechanisms; microbial differentiation.

**MicB 5322. Microbial Diversity and Physiology Laboratory.** (3 cr; prereq 5321 or §5321 or equiv; A-F only) Isolation from natural sources and study of the physiology and metabolism of a wide variety of microorganisms such as Clostridium, yeast, Caulobacter, myxobacteria, Leptospira, photosynthetic bacteria, Bdellovibrio, and luminescent bacteria. Lab only.

**MicB 5352. Applied Microbial Biochemistry.** (4 cr, §BioC 5352; prereq BioC 3021 or BioC 5331 or MicB 5321, intro microbiology course or #) Biochemistry of microorganisms and enzymes of industrial interest. Overview of heterologous peptide overproduction by microorganisms and yeasts; polymer, antibiotic, organic acid, and amino acid production; genetics of industrially useful microorganisms; biological systems useful for biotransformations and environmental remediation; and fermentation technology.

**MicB 5424. Biology of Viruses.** (3 cr; prereq Biol 5003 and one of the following: Biol 5004 or Biol 5103 or MicB 5105) Structure, composition, and properties of bacterial, plant, and animal viruses; interaction with cells, and effects on host cell metabolism; biochemistry of viral replication; techniques for studying viruses and viral infections; and viral tumorigenesis.

**MicB 5425. Virology and Microbial Genetics Laboratory.** (3 cr, §Bio 5125; prereq 5424 or §5424, BioC 3021 or BioC 5331 or Biol 5001, GCB 3022 or Biol 5003) Techniques in virology and microbial genetics: animal cell culture, virus infectivity titrations, analysis of viral nucleic acids and proteins by radiolabeling, gel electrophoresis and blot hybridizations, cell transformation by tumor viruses and DNA, analysis and mapping of mutants in microorganisms.

**MicB 5611. Microbial Ecology.** (3 cr, §Soil 5605; prereq 3103 or 5105 or Biol 5103 or Soil 5610 or #) Interrelationship of microorganisms with terrestrial, aquatic, and organismal environments; survey of bacterial, fungal, and algal components of ecosystems; evolution and structure of microbial communities; population interactions within ecosystems; quantitative and habitat ecology; biogeochemical cycling; and biotechnical approaches to studying microbial ecology.

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1. Microscope required. Students may obtain use of microscope by purchasing two microscope cards from the bursar.
MicB 5900. Topics in Microbiology. (1 cr; prereq 5105 or Biol 5013; open to microbiology sr majors; A-F only)
Seminars on research programs, historical perspectives, significant emerging fields, professional societies and publications, and career opportunities.

MicB 5970. Directed Studies. (Cr ar [10 cr max of 5970 or 5990 may count toward major requirement]; prereq #, △; S-N only)
Individual study on selected topics or problems, with emphasis on selected readings and scientific literature.

MicB 5990. Directed Research. (Cr ar; prereq #, △; S-N only)
Lab or field investigation of selected areas of research.

For Graduate Students Only
(For descriptions, see the Graduate School Bulletin)

MicB 8110. Biology of Microorganisms
MicB 8112. Microbial Genetics
MicB 8231. Advanced Topics in Molecular Pathogenesis
MicB 8421. Virology and Tumor Biology
MicB 8990. Research in Microbiology
MIMP 8216. Frontiers of Immunology I: Molecular Immunology
MIMP 8217. Frontiers of Immunology II: Cellular Immunology
MIMP 8218. Frontiers of Immunology III: Clinical Immunology

Neuroscience (NSc)

Director of Undergraduate Studies—Richard Popple
The goal of neuroscience is to understand the brain and behavior, how we perceive, move, think and remember. Important aspects of the study of behavior can be examined at the level of individual nerve cells, their properties, and the ways they communicate with one another. Many aspects of the biological basis of behavior are studied by examining the specific functions of nervous systems and the behavior they produce. The major prepares undergraduates to pursue advanced studies in neuroscience; take a position in one of the many rapidly growing areas in the pharmaceutical, medical, or biotechnology industries; or to pursue a professional degree in medicine or psychology.

Major Requirements
See Degree Requirements in the previous section for a description of residency, liberal education, foreign language, and English communication requirements.

Mathematics—A three-quarter analytic geometry and calculus sequence (Math 1251-1252-1261 or equivalent). A two-quarter course sequence in statistics may be substituted for the third quarter of calculus (Stat 3011-3012 or Stat 5021).

Chemistry—Two quarters of general chemistry with lab (Chem 1051-1052 or equivalent) and two quarters of organic chemistry, with lab (Chem 3301-3302 with 3305-3306 or equivalent).

Physics—A full year course, with lab, that requires college-level mathematics as a prerequisite (Phys 1251-1252-1253 (1254 optional) or 1104-1105-1106 with 1107-1108-1109) or equivalent. By petition, a two-quarter sequence (Phys 1041-1042) plus an additional four to five credits of mathematics, statistics, computer programming, or physical science chosen in consultation with the major adviser may be substituted.

General and organismal biology—One of the following sequences:
• Biol 1201, 1202, 1203 and Biol 3011 or Phsl 3051 and the lab from either Biol 1106 or 3011
• Biol 1009 and Biol 3011 or 3051 and the lab from either Biol 1106 or 3011 and 3012/3812 or 5013

Biology core—each of the following:
• BioC 3021 or 5331 (Biochemistry)
• Biol 5003 (Genetics)
• Biol 5004 (Cell Biology)
One 3xxx or 5xxx course from one of the following areas:
• Integrative/Organismal Biology/Physiology (courses used to meet the organismal biology requirements above cannot also be used here)
• Ecology/Evolution/Systematics/Behavior (For a list of acceptable courses in these categories, see Biology Core Course List on page 24)
• Lab or fieldwork in one additional upper division biological science course. A list of acceptable courses follows. (This additional lab
MAJOR REQUIREMENTS AND COURSE DESCRIPTIONS

requirement may be satisfied by completing 4 cr or more of NSc 5990—see below.)

Biol 3012, 5013 (if not used to meet an organismal biology requirement above)

Biol 5125
BioC 5025, 5990*
EEB 5014, 5016, 5129, 5134, 5157, 5621, 5990*
GCB 5015, 5030, 5605, 5990*
MicB 5234, 5322, 5425, 5990*
NSc 5990*
PBio 3109, 3201, 5103, 5105, 5107, 5111, 5132, 5231, 5990*

All CBS courses offered at the Lake Itasca Forestry and Biological Station are acceptable.

Neuroscience—each of the following:
• Biol 3101—Introduction to Neuroscience I
• Biol 3102—Introduction to Neuroscience II
• Biol 3105—Neurobiology Lab I
• Biol 3115—Neurobiology Lab II
• NSc 5970 or 5990 (2 cr) Directed Studies or Directed Research

A minimum of 14 credits selected from Groups A-D, with at least one course from each group:

**Group A—Cell and Molecular Neurobiology**
NSc 5150—Introduction to Neuroscience
NSc 5444—Muscle Contraction
NSc 5460/5461—Cellular and Molecular Neuroscience

**Group B—Sensory and Motor Systems**
EEB 5323—Mechanisms of Behavior
NSc 5031—Perception
NSc 5034—Psychobiology of Vision
NSc 5480—Invertebrate Neurobiology
Psy 3031—Sensation and Perception
Psy 5036—Vision: Computational Theory to Neural Systems
Psy 5037—Psychology of Hearing
Psy 5038—Introduction to Neural Networks

**Group C—Behavior**
EEB 3111—Introduction to Animal Behavior
EEB 5321—Evolution of Social Behavior
EEB 5324—Evolution of Primate Social Behavior
EEB 5325—Behavioral Ecology
Psy 3051—Introduction to Cognitive Psychology
Psy 3061—Introduction to Biological Psychology

**Group D—History and Philosophy of Science**
HSci 3201/3202—History of Biology
HSci 5242—The Darwinian Revolution
Phil 3601—Scientific Thought
Phil 5607—Philosophy of the Biological Sciences

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**Plant Biology (PBio)**

**Director of Undergraduate Studies—**
Tom Soulen

Plant biologists study such varied topics as the structure, function, development, classification, evolution, worldwide distribution, and importance of plants ranging from algae and fungi to flowering plants; the molecular basis of plant evolution and development; the mechanisms through which plants convert light into chemical energy; the use of plants in the interpretation of the history and prehistory of the world; and the impact of plants on human civilizations.

The major in plant biology provides a comprehensive and well-balanced undergraduate education in biology, with a concentration in the plant sciences.

**Major Requirements**

See Degree Requirements in the previous section for a description of residency, liberal education, foreign language, and English communication requirements.

**Mathematics**—A three-quarter analytic geometry and calculus sequence (Math 1251-1252-1261 or equivalent). A two-quarter course sequence in statistics may be substituted for the third quarter of calculus (Stat 3011-3012 or Stat 5021).

**Chemistry**—Two quarters of general chemistry with lab (Chem 1051-1052 or equivalent) and two quarters of organic chemistry, with lab (Chem 3301-3302 with 3305-3306 or equivalent).

**Physics**—A full year course, with lab, that requires college-level mathematics as a prerequisite (Phys 1251-1252-1253 (1254 optional) or 1104-1105-1106 with 1107-1108-1109) or equivalent. By petition, a two-quarter sequence (Phys 1041-1042) plus an additional four to five credits of mathematics, statistics, computer programming, or physical science chosen in consultation with the major adviser may be substituted.

**General and organismal biology**—Choose one of the following sequences:
• (preferred) Biol 1201, 1202, 1203
• Biol 1009 plus either Biol 3011 or 5013
Biology core—One 3xxx or 5xxx course from three of the four following areas:

- Biochemistry
- Genetics/Cell Biology/Development
- Integrative/Organismal Biology/Physiology
- Ecology/Evolution/Systematics/Behavior

(For a list of acceptable courses in these categories, see Biology Core Course List on page 24)

- Lab or fieldwork in two additional upper division biological science courses. A list of acceptable courses follows. (One course may also satisfy a requirement for a lab course in the plant biology course requirements listed below.)

Biol 3011, 5013 (if not used to satisfy either the organismal biology or integrative/organismal biology requirements listed above)

Biol 5125
BioC 5025, 5990*
EEB 5014, 5016, 5129, 5621, 5990*
GCB 5015, 5030, 5605, 5990*
MicB 5234, 5322, 5425, 5990*
NSc 3105-3115, 5990*
PBio 3109, 3201, 5103, 5105, 5107, 5111, 5132, 5231, 5990*

All CBS courses offered at the Lake Itasca Forestry and Biological Station are acceptable.

* An independent research project is strongly recommended for every student. To use one of the department Directed Research courses to satisfy one of the upper division lab or fieldwork requirements, students must complete a minimum of 4 credits under the 5990 course number. A directed research project is strongly recommended for every student.

Plant biology—all of the following:

- Biol 1103 or 3012 or 3812
- Biol 3950H—Undergraduate Seminar (2 cr)
- 20 credits from groups A-E below, with at least one course each from groups A-D, including at least one course designated as a lab or field course, and no more than one course from group E (may not include courses used to complete the biology core course requirements above)

A. Plant Cell and Molecular Biology

GCB 5034—Intermediate Molecular Genetics (4 cr)
PBio 5109—Molecular Genetics and Biochemistry of Yeasts and Filamentous Fungi (4 cr)
PBio 5141—Plant Cell Biology (4 cr)
PBio 5186—Topics in Plant Biochemistry (3 cr)

B. Plant Physiology

PBio 3131/5131—Survey of Plant Physiology (4 cr)
PBio 5182—Plant Metabolism (3 cr)
PBio 5183—Water, Minerals, and Translocation (4 cr)
PBio 5184—Plant Growth and Development (3 cr)

C. Plant Structure/Diversity/Development

PBio 3109—Plant Anatomy (5 cr)*
PBio 5103—Algae, Fungi, Bryophytes (5 cr)*
PBio 5105—Morphology of Vascular Plants (5 cr)*
PBio 5107—Myology: Basidiomycetes (4 cr)*
PBio 5111—Plant Cell, Tissue, and Organ Development (5 cr)*
PBio 5231—Introduction to the Algae (5 cr)*
PBio 5811—Freshwater Algae (5 cr)*

D. Ecology/Systematics/Evolution

EEB 5014—Ecology of Vegetation (5 cr)*
EEB 5016—Ecological Plant Geography (5 cr)*
EEB 5122—Plant/Animal Interactions (4 cr)
PBio 3201—Introductory Plant Systematics (4 cr)*
PBio 5221—Plant Molecular Evolution (3 cr)
PBio 5801—Plains and Boreal Flora (5 cr)*

E. History and Philosophy of Science

HSci 3201/3202—History of Biology (4 cr each)
HSci 5242—The Darwinian Revolution (4 cr)
Phil 3601—Scientific Thought (4 cr)
Phil 5607—Philosophy of Science: Problems of the Biological Sciences (4 cr)

* Lab courses.

PBio Courses

PBio 1009. Minnesota Plant Life. (4 cr; suitable for nonmajors)
Identification of the more characteristic and conspicuous Minnesota plants, including many lower forms, with discussion of their basic distinctions, life cycles, habitat requirements, distribution, vegetation types, and ecological relations. Lectures, demonstrations, and six field trips.

PBio 1012. Plants Useful to Humans. (4 cr; for majors or nonmajors)
Roles that plants play and have played in human biological and cultural development. Lectures and demonstrations.

Biol 1103. General Botany. (5 cr, §Biol 3012, §Biol 3812; prereq Biol 1009 or Biol 1202; students who plan to major in biology in CLA or in any major in CBS should take 3012 or 3812)
Levels of organization of plants, plant function, plant growth and development, plant reproduction. Lab.

Biol 3012. Plant Biology. (5 cr, §Biol 1103, §Biol 3812; prereq Biol 1009 or Biol 1202; Chem 1052)
Plant diversity and evolution; structure and function of the plant cell and of the whole organism; and growth and development of plants. Lab.

PBio 3109. Plant Anatomy. (5 cr; prereq Biol 1103 or Biol 3012 or Biol 3812; offered alt yrs)
Structure and development of plants with special reference to vascular plants. Lab.

PBio 3131. Survey of Plant Physiology. (4 cr, §§131; prereq Biol 1103 or Biol 3012 or Biol 3812, Biol 5001 or BioC 3021 or BioC 5311)
Physiological principles underlying processes that occur in living plants, with emphasis on higher plants. Growth and development, mineral nutrition, transport, water relations, and metabolism, emphasizing photosynthesis and nitrogen assimilation. For lab, see 5132.
MAJOR REQUIREMENTS AND COURSE DESCRIPTIONS

PBio 3201. Introductory Plant Systematics. (4 cr; prereq Biol 1103 or Biol 3012 or Biol 3812)
Systematics of the flowering plants of the world. Ecology, geography, origins, and evolution of flowering plants; family characteristics; floral structure, function and evolution; pollination biology; methods of phylogenetic reconstruction; molecular evolution; taxonomic terms; and methods of collection and identification. Two field trips. Lab.

PBio 3960. Research Topics in Plant Biology. (1 cr; prereq Biol 1103 or Biol 3012 or Biol 3812; S-N only)
For undergraduates interested in plant biology. Lecture, discussion, and demonstration of faculty research interests.

PBio 5001. Basic Botany. (Cr ar; prereq Biol 1009 or Biol 1202, #, ∆)
For beginning graduate students who need to strengthen their botanical background.

PBio 5103. Algae, Fungi, and Bryophytes. (5 cr; prereq Biol 1103 or Biol 3012 or Biol 3812; offered when feasible)
Characteristics of groups, evolutionary relationships, life cycles, comparative morphology (including ultrastructure), comparative nutrition. Lab emphasizes living organisms and isolation of algae and fungi into culture.

PBio 5105. Morphology of Vascular Plants. (5 cr; prereq Biol 1103 or Biol 3012 or Biol 3812 or #; offered alt yrs)
Vascular plant morphology examined from an evolutionary perspective; vegetative and reproductive structures, life cycles. Extinct ancestors of vascular plants, ferns and lower plants, and gymnosperms and angiosperms (flowering plants). Lab.

PBio 5107. Mycology: Basidiomycetes. (4 cr; prereq 5103 or PlPa 5105 or equiv or intro microbiology or #)
Ecology, evolutionary relationships, systematics (taxonomy and nomenclature), morphology (including ultrastructure and life cycles of the basidiomycetes). Laboratories parallel lectures, with living and preserved representatives of the Uredinales, Auriculariales, Septobasidiales, Exobasidiales, Sporobolomyces, Ustilaginales, Tilletiales, Tremellales, Dacrymyctales, Tulasnellales, Aphyllophorales, Agaricales, and Gasteromycetes. Lab.

PBio 5109. Molecular Genetics and Biochemistry of Yeasts and Filamentous Fungi. (4 cr, §PlPa 5109; prereq one course each in genetics and biochemistry or #)
Chromosome structure and function, regulation of nuclear gene expression, mitochondrial gene organization and expression, membrane and organelle biogenesis, cell cycle regulation, morphogenesis, mating and reproduction, recombination and gene switching, spore formation and germination, viruses, plasmids, and toxins.

PBio 5111. Plant Cell, Tissue and Organ Development. (5 cr; prereq Biol 1103 or Biol 3012 or Biol 3812)
Microscopic structure of vascular plants; development in root, stem, and leaf. Lab.

PBio 5131. Survey of Plant Physiology. (4 cr, §3131; prereq BioC 3021 or BioC 5331 or Biol 5001, Biol 1103 or Biol 3012 or Biol 3812)
Physiological principles underlying processes that occur in living plants, with emphasis on higher plants. Growth and development, mineral nutrition, transport, water relations, and metabolism, emphasizing photosynthesis and nitrogen assimilation. Weekly discussion section.

PBio 5132. Plant Physiology Laboratory. (2 cr; prereq 3131 or §3131 or 5131 or §5131)
Lab to accompany 3131 or 5131.

5141. Plant Cell Biology. (4 cr; prereq Biol 5004 or equiv)
Structural, functional, developmental, and biochemical aspects of cellular components and processes specific to plants. Cell walls, dictyosome activity, plastids, plant cytoskeleton, modes of plant cytokinesis, cell-cell communication, lectins and cell recognition, vacuoles, and cytoplasmic streaming.

PBio 5182. Plant Metabolism. (3 cr; prereq 3131 or 5131 or equiv, course in biochemistry)
Plant metabolism; photosynthesis, respiration, and synthesis of macromolecules by plants. Structure-function relations at the plant, cell, and subcellular levels. Energy flow in the plant system and regulation of plant metabolism.

PBio 5183. Water, Minerals, and Translocation. (4 cr; prereq 3131 or 5131 or equiv)
Membrane phenomena and osmotic properties of cells. Uptake, movement, and loss of water in plants; effects of external factors. Translocation of organic substances. Absorption, distribution, and function of inorganic elements.

PBio 5184. Plant Growth and Development. (3 cr; prereq 3131 or 5131 or equiv)
Plant growth and development from germination to death, with emphasis on physiology, biochemistry, and molecular biology. Developmental processes related to mobilization of macromolecules during germination, cell division and extension during axis growth, photomorphogenesis, chloroplast and microbody ontogeny, flowering, fruit and seed formation, and senescence; how plant growth substances control these developments.

PBio 5186. Topics in Plant Biochemistry. (3 cr; prereq BioC 3021 or BioC 5331 or Biol 5001)
Biochemical processes unique to plants, with emphasis on structures of the macromolecules involved and the reactions and their regulation. Major topics: light reactions of photosynthesis, secondary metabolism, and carbohydrates. Minor topics: carbon dioxide fixation and nitrogen fixation.

PBio 5203. Herbarium Techniques. (1 cr; prereq 1099 or 3201 or equiv; S-N only)
Hands-on approach to museum curation procedures in the herbarium. Students are exposed to all aspects of herbarium management and assist with some curation of plant specimens.

PBio 5221. Plant Molecular Evolution. (3 cr; prereq Biol 5003 or GCB 3022)
Applications of molecular genetics to the study of the processes and products of evolution. Phylogenetic reconstruction, chromosomal evolution, multigene families, molecular aspects of morphological change, role of transposons in evolution, DNA sequence evolution, and measures of genetic diversity.
PBio 5231. Introduction to the Algae. (5 cr; prereq 10 cr in plant biology or biology or #; offered when feasible)
Structure, reproduction, and life histories of major algal divisions. Lab.

PBio 5960. Special Topics. (Cr ar; prereq #, Δ)
In-depth study of a specialized botanical topic.

PBio 5970. Directed Studies. (Cr ar [10 cr max of 5970 or 5990 may count toward major requirement]; prereq #, Δ; S-N only)
Individual study on selected topics or problems, with emphasis on selected readings and use of scientific literature.

PBio 5990. Directed Research. (Cr ar [10 cr max of 5970 or 5990 may count toward major requirement]; prereq #, Δ; S-N only)
Lab or field investigation of selected areas of research.

Courses Offered at Lake Itasca Forestry and Biological Station

Biol 3812. Plant Biology. (5 cr, §1103, §3012; prereq 1009 or 1202, Chem 1052, Δ)
Plant diversity and evolution; structure and function of the plant cell and of the whole organism; growth and development of plants. Field trips.

PBio 5801. Plains and Boreal Flora. (5 cr; prereq taxonomy course, Δ; offered when feasible)
Summer flowering plants and ferns of Minnesota, with particular reference to local flora. Identification by technical keys, important plant families, field recognition of common species, habitat preferences, and natural history and population biology of selected important species.

PBio 5811. Freshwater Algae. (5 cr; prereq 10 cr plant biology or biology or zoology or equiv, Δ; offered when feasible)
Morphology, systematics, and distribution of the local algal flora. Collection, preservation, enumeration, and culture techniques; identification of field collections using technical literature. Ecological implications of species interactions, algal associations, and indicator taxa.

PBio 5890. Research Problems. (1-5 cr per qtr; prereq Δ)
Individual research for undergraduates and graduates.

For Graduate Students Only
(For descriptions, see the Graduate School Bulletin)

PBio 8287. Plant Molecular Biology

PBio 8301. Pollen Morphology and Quaternary Palynology

PBio 8950. Seminar

PBio 8990. Research Problems

**Recommended Related Coursework**

The University offers a wide variety of life sciences courses in addition to those offered by CBS. To explore courses in related areas, students are encouraged to consult the bulletins of several colleges ( Colleges of Human Ecology, Liberal Arts, Natural Resources, and Agricultural, Food, and Environmental Sciences; Institute of Technology; School of Public Health). A complete list is available in the Directory of U of M Undergraduate Courses in Life Sciences Disciplines. This resource, in electronic and booklet form, is available in the Instructional Computing Center in 406 Biological Sciences Center. Biology majors may petition to use many of these courses to count toward the 16 credits of upper division science/math elective work required for the major. Courses are recommended in anatomy (CBN), agronomy and plant genetics (Agro), animal science (AnSc), anthropology (Anth), biophysics (BPhy), chemical engineering (ChEn), chemistry (Chem), computer science (CSci), entomology (Ent), fisheries and wildlife (FW), food science and nutrition (FScN), forest resources (FR), geology (Geo), history of medicine and science (HMed, HSci), horticultural science (Hort), laboratory medicine (LaMP), mathematics (Math), natural resources and environmental studies (NRES), pharmacology (Phcl), philosophy (Phil), physics (Phys), physiology (Phsl), plant pathology (PlPa), psychology (Psy), public health (PubH), soil science (Soil), statistics (Stat), veterinary biology (VB), and veterinary pathobiology (VPB).