College of Natural Sciences and Mathematics

B715 Lederle Graduate Research Tower
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Interim Dean: Robert B. Hallock. Associate Dean for Undergraduate Advising: James F. Walker.

All departments in the College offer programs leading to the Bachelor of Science. All departments except Computer Science also offer programs leading to the Bachelor of Arts.

Students have great freedom in choosing a program of study and a major. However, some of the major programs require sequences of courses that can extend over seven or eight semesters. Students who do not consider this in their course selection during their first year may have to use a summer session or extra semesters to accommodate these sequences.

The Fields

The departments of the College of Natural Sciences and Mathematics encompass the disciplines which are essential to all fields of scientific research and application. They study the sciences of life, of the planet, of the universe. Information gained from research in chemistry and biology is essential to understanding the processes of life, from cells to organisms to ecosystems. Insights into planetary, climatic, and atmospheric functions come to us through physics, the geosciences, and astronomy. Mathematics and computer science provide models and tools for conducting such research. We use scientific and analytic methods and knowledge in our daily life and at all levels of education, as well as in advanced research.

Academic Advising Services

All students in the College are encouraged to meet regularly with an academic adviser. Faculty and staff advisers are available to assist students with questions or concerns that they have as they progress through their academic careers. This includes advice on course selection; departmental, College and University requirements; career guidance; assistance with academic problems; and referral information about other services.
Each department in the College has a chief undergraduate adviser who facilitates advising to students concerning the major. Advising regarding College requirements, general academic advising, and information concerning other academic matters (e.g., repeat options, repeat course substitutions, late course adds, late course drops, academic discipline) and programs within the College are handled through the Arts and Sciences Advising Center, in E-24 Machmer Hall. This office also houses the College Records Office.

Career Opportunities

Students majoring in the sciences and mathematics develop understandings of process and logical and analytic ability. These enable them to pursue a wide range of careers directly upon graduation, or following further professional or graduate education. Graduates of the College are in medicine and health sciences, industrial science and technology, administration, elementary and secondary teaching, law, software and systems development, environmental protection, regional planning, and university research and teaching.

Career and Field Experience Advising

Students are encouraged to explore the world beyond the University through internships, international study, and career planning. The Campus Career Network operates the College of Natural Sciences and Mathematics Career Planning and Field Experience Offices. Staff are available to help students make intelligent, well-informed career choices, and to provide opportunities to obtain experience through internships, cooperative education, and service learning programs.

College Foreign Language Requirement

All students in the College must demonstrate proficiency in a foreign language at the intermediate level, by one of the following methods:

a) Completion of a foreign language course at the fourth semester level (Intermediate II or Intermediate Intensive courses numbered 240-249). Intermediate II courses may be graded on a Pass/Fail basis.

b) Degree credit equivalent to such a course earned through an appropriate score on a College Board Foreign Language Achievement Test or a College Board Advanced Placement Test.

c) Proficiency demonstrated in a test designed by a University of Massachusetts language department, or a test administered and validated by a local faculty member if the language is not one offered by a department at the University.

d) Satisfactory completion in high school of either a fourth-level foreign language course, or of a third-level course in one language and a second-level course in another language.

e) Successful completion of one year in a high school in which English is not the language of instruction.

f) Successful completion of a semester or year’s study abroad program that leads to foreign language proficiency at the fourth semester (Intermediate II) level as approved by the appropriate language department.

Students who have not satisfied the Foreign Language requirement on admission to the College should select a foreign language course each term in residence until the requirement has been satisfied. The University offers sequences that satisfy this requirement in the following languages: Arabic, Chinese, French, German, Greek, Hebrew, Italian, Japanese, Latin, Polish, Portuguese, Russian, and Spanish. Students who have not yet completed the Foreign Language requirement may not apply their Pass/Fail option to foreign language courses numbered below 240.

Students who are certified by the Disability Services Office as having a significant hearing impairment that is seriously limiting to the auditory reception of language may fulfill the Foreign Language requirement either by demonstrating proficiency in American Sign Language at the intermediate level, or by completing two semesters (6 cr.) of foreign language, plus two courses (6 cr.) taught in English on the history, culture, or literature of non-English speaking countries or regions. These courses must be in addition to courses used to fulfill the General Education requirements, and may not be graded on a Pass/Fail basis. A list of courses that may be used in this manner is available from the Arts and Sciences Advising Office.

Students with a documented learning disability may submit a request for a foreign language modification to the Foreign Language Committee of Learning Disability Support Services (LDSS). For more detailed information about the petition process and required documentation, students should contact LDSS, tel. 545-4602.

College Requirement for the B.A.

In addition to the University requirements, the College Foreign Language requirement and the requirements of the major, all students pursuing a Bachelor of Arts must complete two courses in the College of Humanities and Fine Arts and/or the College of Social and Behavioral Sciences. These two courses may carry a General Education designation, but must be completed in addition to all courses applied to General Education requirements. The courses may not be graded on a Pass/Fail basis. Students may not apply to this requirement any practicum, independent study, thesis, or internship course, or any course below the 100 level. Students may petition the undergraduate dean to apply certain experimental, seminar, and special topics courses (courses with numbers ending in 90, 91-95, or 97).

College Requirement for the B.S.

In addition to completing the Foreign Language requirement, all students pursuing a Bachelor of Science in the College must earn a minimum of 60 credits in courses offered by the College and the Department of Psychology, or other approved related courses. These include credits earned to satisfy General Education and major requirements.

Note: A student whose primary major is not in Natural Sciences and Mathematics but who has a secondary major within the College will be exempt from the College’s Foreign Language Proficiency Requirement, but must complete all College requirements of the primary major. This exemption does not apply to Second Bachelor’s Degree Candidates.
Astronomy

Degrees: Bachelor of Science
Bachelor of Arts

Contact: Stephen Schneider, Chief Adviser
Office: 536 LGRC Tower B
Phone: 545-2076

Head, Department of Astronomy and Five College Chair: Ronald L. Snell. Professors Arny, Dent, Irvine, Kwan, Schloerb, Schneider, Skrutskie, Weinberg, Young; Associate Professors Kaiz, Tademaru; Assistant Professors Lowenthal, Wang, Yun; Research Professors Erickson, Predmore; Research Associate Professor Heyer; Research Assistant Professors Kanbur, Narayanan.

Other Astronomy faculty in the Five Colleges: Dennis, Dyar, Edwards, Greenstein, Lovell, Vesperini, White.

The Five College Department of Astronomy is administered jointly with Amherst, Hampshire, Mount Holyoke, and Smith colleges. The elementary courses for nonmajors are taught separately at each campus, but all advanced courses are given on a joint basis for students from the five participating institutions. Five College courses are identified in this catalog by ASTFC.

The Field

Astronomy is the study of the regions beyond the Earth: planets, moons, stars, galaxies, and the universe itself. Astronomers study these objects not only by observing them with telescopes and other instruments, but also with mathematical and computer models. Astronomers therefore make heavy use of physics, mathematics, and computer science.

Equipment used ranges from radio telescopes half a mile across and high speed computers to optical telescopes so big a truck could park on the mirror. The discipline ranges over many areas: radio astronomy; study of stars; their structure and evolution; origin of the universe and other astronomical systems; and the atmospheres and surfaces of planets.

The Major

B.A. Degree in Astronomy

The Bachelor of Arts degree is intended for students who want to explore the science of astronomy in depth, but who do not intend to pursue a professional career in the field. The coursework provides a thorough grounding in the physical sciences and develops the logic of applying physics, mathematics, and other sciences to the solution of astronomical questions. The degree is suitable for pre-med, pre-law, and other students who are interested in developing a rigorous ability to examine complex problems. It would also be appropriate as a nucleus of study for a career in secondary science education, or possibly planetarium or museum work. Astronomy also provides a good introduction to atmospheric physics and meteorology. The astronomy requirements represent only the backbone of the coursework that would be needed to pursue successfully one of these careers; the remainder of the courses should be planned with one's astronomy advisor.

Astronomy B.A. Requirements:
1. Introductory physics sequence: PHYSIC 171, 172, 283, 284 or 151, 152, and 261
2. Calculus sequence: MATH 131, 132, 233
3. Astronomy Elective—at least one of:
   - 114 Stars and Galaxies
   - 123 Planetary Science
4. Observational astronomy—at least one of:
   - 224 Stellar Astronomy
   - 225 Galactic and Extragalactic Astronomy
5. Writing requirement—at least one of:
   - PHYSIC 381 Writing in Physics
6. Astrophysics—at least one of:
   - 451 Astrophysics I: Stars and Stellar Evolution
   - 452 Astrophysics II: Galaxies
7. Astronomy Elective—at least one more course at the 220 level or higher
8. At least 15 credits (including the above courses) in astronomy or physics at the 200 level or above.
9. A minimum grade point average of 2.0 is required for astronomy courses.

B.S. Degree in Astronomy

The Bachelor of Science degree, intended for students who plan to follow a professional career track in astronomy or allied fields, normally leads to graduate school after completion of the degree. For students seriously interested in pursuing a research career in astronomy, a much more substantial background in physics and math is needed, which is reflected in these requirements.

Astronomy B.S. Requirements:
1. Introductory physics sequence for science majors: PHYSIC 171, 172, 283, and 284
2. Two more physics courses at the 400 level or higher
3. Calculus sequence and linear algebra: MATH 131, 132, 233, and 235
4. Math methods: PHYSIC 282 or MATH 431
5. Introductory astronomy:
   - 114 Stars and Galaxies
6. Writing requirement—at least one of:
   - 224 Stellar Astronomy
   - PHYSIC 381 Writing in Physics
7. Computational physics: PHYSIC 290S
8. Astrophysics sequence:
   - 451 Astrophysics I: Stars and Stellar Evolution
   - 452 Astrophysics II: Galaxies
9. Astronomy electives—at least two more courses at the 220 level or higher
10. A minimum grade point average of 2.0 is required for astronomy courses.

Independent study and honors work are encouraged for all majors. Opportunities for theoretical and observational work are available in cosmology, radio astronomy, planetary science, relativistic astrophysics, astronomical instrumentation, stellar astrophysics, and extragalactic astronomy. Local facilities available to qualified students include several optical and infrared telescopes of sizes 16, 18, and 24 inches, equipped with optical and infrared photometers, CCD cameras, and spectographs. Another local facility is the 14 m radio telescope at the Five College Radio Astronomy Observatory located at Quabbin Reservoir. The 14 m telescope has unique imaging capabilities at millimeter wavelengths that are exploited to study the physics and chemistry of galactic and extragalactic interstellar clouds, circumstellar envelopes, planetary atmospheres, and comets.

The University is leading a project, called the Two Micron All Sky Survey (2MASS), which is currently mapping the entire sky at infrared wavelengths for stars and galaxies as much as 50,000 times fainter than the previous survey carried out 25 years ago. The two 50-inch telescopes and cameras for 2MASS are located in Arizona and Chile. The University is also involved in a collaboration with Mexico to build the Large Millimeter Telescope (LMT), which when completed around the year 2004, will be the world’s largest millimeter wavelength telescope. The LMT is a 50-m diameter telescope of novel design which takes advantage of recent advances in structural design and active control of surfaces. The University is also participating in the Infrared and Optical Telescope Array (IOTA), a collaborative project with Harvard University, Smithsonian Astrophysical Observatory, the University of Wyoming, and MIT’s Lincoln Laboratories. IOTA’s emphasis is on the detection and imaging of faint astronomical sources at high angular resolution in the optical and infrared.

Opportunities for summer research internships are also available. Original publications have resulted from undergraduate research.
It is desirable that a student have a reading knowledge of French, German, Russian, or Spanish. Students are also urged to broaden their background by taking courses in geology, electronics, or other subjects after consultation with their adviser.

Career Opportunities

Most professional astronomers are employed by universities as researchers and teachers. The federal government also employs astronomers at the National Aeronautics and Space Administration, and the national observatories. The aerospace industry (Lockheed, Boeing, Grumman, etc.) and research and development firms also employ some astronomers. Most of these positions require a doctoral degree, but graduates with a bachelor’s degree may find openings on the staffs of observatories, planetariums, museums, and in government training programs. Astronomy also offers a good introduction to some areas of atmospheric physics and meteorology.

The Minor

Five astronomy courses (3 or 4 credits), excluding independent studies, as follows:
1) Two courses at the 100 level or above.
2) Three additional courses at the 200 level or above.

The Courses

(All courses carry 3 credits unless otherwise noted.)

100 Exploring the Universe (PS) (both sem)
For nonscience majors. Introductory survey of astronomy. How we learn about the Universe and what we already know of it, how it originated, evolves, and its ultimate fate. Emphasis on modern research in solar phenomena, stellar evolution (including white dwarfs, neutron stars, pulsars, and black holes) and galaxy studies (including quasars).

101 The Solar System (PS) (both sem)
For nonscience majors. Introduction to the physical characteristics of the earth, moon, planets, asteroids and comets—their motions and gravitational interactions. Recent discoveries of space probes relative to formation of the solar system and origin of life. Prerequisite: high school algebra.

103 Astronomical Observations (both sem) 1 cr
Multiple sections. For nonscience students. Introduction to the night sky, telescopes, astronomical events, and celestial maps. Visual and telescopic observations of the constellations, moon, planets, stars, and other interesting astronomical objects. Planetarium trip. Attendance required.

105 Weather and Our Atmosphere (PS) (2nd sem)

114 Stars and Galaxies (PS) (2nd sem) (ASTFC 14)
A freshman-level introductory course appropriate for science majors, engineering majors, and students with a strong precalculus background. Topics include: the observed properties of stars and the methods used to determine them, the structure and evolution of stars, the end-points of stellar evolution, our galaxy, the interstellar medium, external galaxies, quasars, and cosmology. Prerequisite: high school algebra.

191 Freshman Seminar (1st sem) 1 cr
Weekly class exploring the field of astronomy and its practice. Meetings may include observing sessions, projects with University telescopes, laboratory activities, and introductions to the latest topics of astronomical research. Intended primarily for first-year students considering an astronomy major or minor, but open to all undergraduates on a space-available basis.

215 History of Astronomy (ASTFC 15)
Astronomy and cosmology from earliest times, Egyptian, Babylonian, Greek, Islamic; the medieval universe; Middle Ages; Copernican revolution, the infinite universe; Newtonian universe; mechanistic universe of the 18th and 19th centuries. Gravitational theory; origin, structure, and evolution of stars and galaxies; developments in modern astronomy. Nontechnical; emphasis on history and cosmology.

220 Topics in Astronomy: Astronomy and Public Policy (2nd sem) (ASTFC 20)
Astronomical issues affecting our society explored in a seminar format. Each issue approached by posing a question based on a body of scientific evidence with potential consequences for human society. The answers to these questions investigated both on scientific and societal grounds. Scientific issues include the potential threat of collisions between the earth and other solar system bodies and the potential existence of extraterrestrial life. Prerequisite: 1 semester of a physical science.

223 Planetary Science (1st sem) (ASTFC 23)
Introductory course for physical science majors. Topics include planetary orbits, rotation and precession; gravitational and tidal interactions; interiors and atmospheres of the Jovian and terrestrial planets; surfaces of the terrestrial planets and satellites; asteroids, comets, planetary rings; origin and evolution of the planets. Prerequisites: 1 semester of calculus and 1 semester of a physical science.

224 Stellar Astronomy (1st sem) (ASTFC 24) 4 cr
Satisfies Junior Year Writing requirement. Computer and observational lab-based course on the observational determination of the fundamental properties of stars. An inquiry-based approach to learning scientific techniques, including hypothesis formation, pattern recognition, problem solving, data analysis, error analysis, conceptual modeling, numerical computation, and quantitative comparison between observation and theory. No previous computer programming experience required. Prerequisites: 1 semester of calculus, 1 semester of physics, introductory astronomy, and ENGLWP 112 or 113.

225 Galactic and Extragalactic Astronomy (ASTFC 25) 4 cr
The unsolved mystery of dark matter in the universe explored through an inquiry-based approach. Working with actual and simulated astronomical data and computer labs, students explore the topic both individually and in seminar discussions, ultimately presenting team research projects. Many of the pedagogical goals of ASTRON 224 and 225 are identical; students are therefore advised to take only one these courses. Prerequisites: 1 semester of calculus, 1 semester of physics, and introductory astronomy.
226 Cosmology (1st sem) (ASTFC 26)
Cosmological models and the relationship between models and observable parameters. Topics in current astronomy that bear upon cosmological problems, including background electromagnetic radiation, nucleosynthesis, dating methods, determinations of mean density of the universe; the Hubble constant, and tests of gravitational theories. Discussions of some questions concerning the foundations of cosmology and its future as a science. Prerequisites: 1 semester of calculus and 1 semester of a physical science.

335 Modern Astrophysics (2nd sem) (ASTFC 35)
How astronomers determine the nature and extent of the universe. Following the theme of the “Cosmic Distance Ladder,” an exploration of how our understanding of astrophysics allows us to evaluate the size of the observable universe. Topics include direct distance determinations in the solar system and nearby stars, spectroscopic distances of stars, star counts and the structure of our galaxy, Cepheid variables and the distances of galaxies, the Hubble Law and large-scale structure in the universe, and quasars and the Lyman-alpha forest. Prerequisites: Introductory Physics (131-132, 151-152, or 171-172), calculus through MATH 128, 132 or equivalent, and at least one prior astronomy or physics course at the 200 level or above.

337 Techniques of Optical and Infrared Astronomy (2nd sem) (ASTFC 37) 4 cr
With lab. Introduction to the techniques of gathering and analyzing astronomical data, particularly in the optical and infrared. Telescope design and optics. Instrumentation for imaging, photometry, and spectroscopy. Astronomical detectors. Computer graphics and image processing. Error analysis and curve fitting. Data analysis and astrophysical interpretation, with an emphasis on globular clusters. Prerequisites: ASTRON 224 or 225; 2 semesters of physics, and 2 semesters of calculus.

338 Techniques of Radio Astronomy (alt yrs) (ASTFC 38) 4 cr

451 Astrophysics I: Stars and Stellar Evolution (1st sem) (ASTFC 51) 4 cr
The application of physics to the understanding of astronomical phenomena. Physical principles governing the properties of stars, their formation and evolution: radiation laws and the determination of stellar temperatures and luminosities; Newton’s laws and the determination of stellar masses; hydrostatic equation and the thermodynamics of gas and radiation; nuclear fusion and stellar energy generation; physics of degenerate matter and the evolution of stars to white dwarfs, neutron stars or black holes; nucleosynthesis in supernova explosions; dynamics of mass transfer in binary systems; viscous accretion disks in star formation and x-ray binaries. Prerequisites: 4 semesters of physics, PHYSIC 421 or equivalent strongly recommended.

452 Astrophysics II: Galaxies (2nd sem) (ASTFC 52) 4 cr
The application of physics to the understanding of astronomical phenomena. Physical processes in the gaseous interstellar medium: photoionization in HII regions and planetary nebulae; shocks in supernova remnants and stellar jets; energy balance in molecular clouds. Dynamics of stellar systems: star clusters and the virial theorem; galaxy rotation and the presence of dark matter in the universe; spiral density waves. Quasars and active galactic nuclei: synchrotron radiation; accretion disks; supermassive black holes. Prerequisites: 4 semesters of physics, PHYSIC 421 or equivalent strongly recommended.

Biochemistry and Molecular Biology

Lederle GRC Towers

Degrees: Bachelor of Science
Bachelor of Arts

Contact: John H. Nordin
Office: 1228 LGRC Towers
Phone: 545-2461

Head of Department: Professor Lila Gierasch.
Professors Cheung, Fitzgerald-Hayes, Fournier, Jacobson, Mason, O’Brien, Slakey, Zimmerman; Associate Professors Cumberledge, Gross, Normanly, Schnell; Assistant Professor Hebert; Lecturer Pinkham; Research Faculty M. Cannon, Swain, Wu.

The Field

Biochemistry and Molecular Biology aim to understand the chemical and physical principles that make life occur as we know it. They examine biological processes from physical, chemical, and genetic perspectives and, as academic disciplines, have great overlap with many other fields in the chemical, medical, behavioral, and biological sciences. Their demonstrated impact on the health and well-being of humanity have increased dramatically in the last generation, making them subject areas of great interest to those students interested in pursuing a scientific career.

From investigations into the chemicals that constitute living organisms, the focus has broadened to increase our understanding of how biochemical reactions are integrated and regulated and how the genetic information stored in living organisms is expressed and controlled. Most recently, the goal of utilizing this knowledge in practical settings in medicine and agriculture has spawned an extremely productive academic enterprise and a world-wide biotechnology industry, both offering unbounded opportunities for making new discoveries.

The interconnectedness of scientific disciplines is especially apparent in biochemistry. Students whose interest spans the fields of both biology and chemistry are frequently attracted to this discipline. A strong high school background in mathematics, physics, chemistry, and biology is recommended.

The Major

The program for majors provides the foundation for applications in an ever-increasing array
of emerging and established areas such as medical genetic diagnostics, pharmaceutical design, neurobiology, bioinformatics, genomics, nanotechnology, and paleontology. Career opportunities for students trained in this discipline are vast. The highly integrated curriculum prepares students either for employment at the B.S. level or for further training in professional or graduate schools. Majors receive foundational instruction in chemistry, physics, biology, and mathematics, and begin their introduction to biochemistry in the sophomore year. The program also encourages students to engage in independent research work in faculty laboratories. A strong high school background in mathematics, physics, chemistry, and biology is recommended.

Requirements:

1. Three semesters of mathematics (two for the B.A. degree): 131, 132, and STATIS 501; or 135, 136 and STATIS 501; or 127, 128, Calculus for the Life Sciences and STATIS 501. MATH 233 may be substituted for STATIS 501 with permission of adviser. RES EC 211 can be substituted for STATIS 501.
2. Two or three semesters of general physics with lab sections: 131-134 or 151-154; 261/2.
3. Six semesters of chemistry including: 121, 122 General Chemistry for Majors or 111, 112 General Chemistry for Science Majors 265/7, 266/8 Organic Chemistry for Majors (recommended); or 261, 262 and 269 for non-majors 315 Quantitative Chemistry or 312 Analytical Chemistry 471 Elementary Physical Chemistry or 475, 476 Physical Chemistry
4. Three courses in biology: 100, 101 Introductory Biology I and II, and 283 General Genetics
5. Biochemistry core:
   285 Cell and Molecular Biology
   523, 524 General Biochemistry I, II
   526 Biochemistry Laboratory
   491H Senior Seminar
   591H Scientific Writing and Speaking
6. Advanced Course Requirements:
   B.S. Degree: Three semesters of advanced electives in the life sciences, physics, chemistry, or biochemistry in consultation with adviser. For students who qualify, these may be satisfied by research participation.
   B.A. Degree: One advanced course in the life sciences, physics, chemistry, or biochemistry. Departmental Honors: A student must, in addition to meeting the B.S. and University Honors requirements, write a thesis based on a research project.

Majors must obtain a grade of C or better in BIOL 100 and BIOL 101 for admission to BIOCHM 285. A grade of B/C or better in BIOCHM 285 is required for admission to BIOCHM 523.

Off-Campus Study

Selected programs administered by the International Programs Office allow students to obtain their four-year degree in Biochemistry and Molecular Biology and enjoy the benefits of a comprehensive liberal arts degree. Co-op internships are available at some laboratories in New England. These provide the student with an opportunity to gain valuable work experience in a research environment while earning academic credit.

Career Opportunities

The program in biochemistry trains students to be directly employable at the Bachelor’s degree level in a wide variety of fields. Graduates frequently find positions with major chemical and pharmaceutical and biotechnology companies, the food industry, scientific equipment suppliers, and various university, government, and medical research laboratories. Biochemistry majors are particularly well trained to undertake graduate work in biochemistry and in many areas related to the health sciences such as microbiology, cell or molecular biology, pharmacology, virology, physiology, nutrition, and environmental law. Biochemistry majors enjoy a high success rate in acceptance into medical and dental schools.

Five-Year Master’s Program

It is possible for departmental majors to earn a Master’s degree in Biochemistry and Molecular Biology in one year plus a summer, following completion of the B.S. degree in our program. Interested students should begin discussing their plans with their advisers as early as the sixth semester, in order to start making the appropriate course choices. All of the usual Graduate School regulations pertaining to study for the M.S. degree apply in this program, but with careful planning, the time required to obtain the degree will be less than usual. Six credits taken as an undergraduate can count towards the Master’s degree if they are in excess of these courses required for the Bachelor’s. An independent study project begun as an undergraduate is strongly recommended prior to admission to the M.S. Program. This program gives students helpful extra training before they enter the job market or apply to graduate or medical school.

Secondary Teacher Education

Students majoring in Biochemistry and Molecular Biology may obtain teacher certification for General Science, Chemistry or Biology. For the first two of these fields, no science courses beyond those already required for the major are needed. For Biology, one course in ecology and one course in human biology must be taken. Undergraduate students must achieve a passing score on the Communication and Literacy Skills Test of the Massachusetts Educator Certification Tests (MECT) prior to admission into professional preparation programs for educators. Each student in a program for which there is an MEET Subject Test must pass the appropriate subject area test as a prerequisite for enrolling in his or her practicum. To obtain information about these requirements and to enter the program, students should contact the Secondary Teacher Education Program (STEP) Advising Office, 121 Furcolo Hall, tel. 545-3497 or e-mail: stepadv@educ.umass.edu.

The Courses

(All courses carry 3 credits unless otherwise noted.)

(BIOL) 100 Introductory Biology I (BS) (1st sem) 4 cr
   Prospective Biochemistry and Molecular Biology majors are expected to enroll in this course. (See Biology.)

(BIOL) 101 Introductory Biology II (BS) (2nd sem) 4 cr
   Prospective Biochemistry and Molecular Biology majors are expected to enroll in this course. (See Biology.)

205 Introduction to Biochemistry (2nd sem)
285 Cell and Molecular Biology (both sem)
For sophomore-level majors in biology, microbiology, or biochemistry. Building upon concepts introduced in BIOL 100/101, consideration given to structure and function at the cellular, subcellular, and molecular levels. Equally divided between aspects of molecular biology and cellular biology. Prerequisites: BIOL 100 and 101; CHEM 111 and 112, or equivalent. Also listed as BIOL 285.

296 Independent Study (both sem) 1-6 cr
Individual laboratory research project under supervision of a faculty member. In unusual cases, research may be library rather than laboratory centered.

396 Independent Study (both sem) 1-6 cr
Lab. Individual laboratory project under supervision of a faculty member. In unusual cases, research may be library rather than laboratory centered.

420 Elementary Biochemistry (1st sem)
Not for Biochemistry majors. An elementary course, intended as part of sequence complementing BIOCHM 285. Survey of the structure and function of biological molecules, including carbohydrates, lipids, and proteins. Emphasis on relation to other life sciences. Topics include enzymology, special properties of biological membranes, hormones, vitamins, metabolic pathways, and biotransformation. Prerequisite: 1 semester of organic chemistry.

421 Elementary Biochemistry Laboratory (1st sem) 2 cr
Not for Biochemistry majors. Experiments using modern biochemical techniques. Quantitative measurement and calculations stressed. Major topics include spectrophotometry, chromatography, electrophoresis of proteins and DNA, properties of enzymes, immunochemistry, and DNA amplification by polymerase chain reaction. Prerequisite or corequisite: BIOCHM 420 or consent of instructor. Not for credit after BIOTCH 385 or BIOCHM 565.

491H Senior Honors Seminar (1st sem) 2 cr
Required for majors. Emphasis on an oral and written interpretation of current journal articles in selected fields of biochemistry. Partially fulfills Junior Year Writing requirement. Prerequisite: BIOCHM 524.

496 Independent Study (both sem) 1-6 cr
Individual laboratory research project under supervision of a faculty member. In unusual cases, research may be library rather than laboratory centered.

499Y Senior Honors (both sem)
Intensive laboratory research project under supervision of a faculty member. Permission of department required.

499T Senior Honors (both sem)
Continuation of the laboratory research project of BIOCHM 499Y. Thesis written at completion of the lab work. Prerequisite: BIOCHM 499Y.

523 General Biochemistry (1st sem)
Structure and function of biological molecules, especially proteins, lipids and carbohydrates. Important concepts include bioenergetics, biological catalysis, and metabolic pathways as interacting regulated systems. Prerequisites: 1 year of general chemistry, 1 year of organic chemistry or 2nd semester concurrently, and BIOCHM 285.

524 General Biochemistry (2nd sem)
An integrated presentation of the biochemistry and molecular biology of cellular interactions. Emphasis on accounting for complex cellular processes in terms of protein structure and regulation of gene expression. Topics include gene structures and techniques for studying them; replication; control of gene expression; post-translational processing; membrane associated energetics; behavior of transport systems; mechanisms of signal transduction; and interactions of cells with extracellular matrix and with other cells. Prerequisite: BIOCHM 523; BIOCHM 285 and BIOL 283, or comparable courses, strongly recommended.

526 Biochemistry Laboratory (both sem) 4 cr
Modern techniques in experimental biochemistry and molecular biology. Experiments include enzymology, protein purification, and gene expression and organization. Methods include spectrophotometry, polymerase chain reaction, DNA cloning, electrophoresis, protein detection by immunoblot, RNA hybridization, and computer analysis of DNA and protein sequence data. Manipulation of animal, plant, yeast, and bacterial systems. Prerequisite: BIOCHM 523. Second semester enrollment restricted to Biochemistry majors.

591H Scientific Writing and Speaking (2nd sem) 2 cr
Emphasizes development of skills in scientific writing and speaking, and critical reading of the literature. Work includes analyses of summaries, graphs, and figures taken from journal articles, and oral presentations by students. Incorporates group discussions and peer critiques. Partially fulfills the Junior Year Writing requirement. Requires concurrent enrollment in BIOCHM 526. Prerequisite: BIOCHM 523.

597, 697 Special Topics in Biochemistry
Topics of current interest include aspects of cellular development, recognition, and signaling; protein folding and targeting; pharmaceutical design; molecular biology and molecular genetics of animal, plant, and microbial systems; organelle biogenesis and function; biochemistry and molecular biology of RNA.
Biology

348 Morrill Science Center
Degree: Bachelor of Science
Bachelor of Arts

Contact: W. Brian O'Connor
Office: 348 Morrill Science Center
Phone: 545-2287

Chair of Department: Professor C.L. Woodcock, Gilbert L. Woodside Professor; Associate Chair: Professor G.A. Wyse. Director, Undergraduate Program: Professor W. B. O'Connor. Ray Ethan Torrey Professor of Botany and Constantine Gilgut Professor: P.K. Hepler. Professors Bemis, Bittman, Kaulenas, Klekowski, Kroodsma, Kunkel, Mulcahy, Murphey, Rubinstein, Schwartz, D. Searcy, Stuart, Walker; Associate Professors Alpert, Brained, Budnik, Connor, Coombs, Edwards, Godfrey, Kent, Ludlam, Nambu, Petersen, Phillis, Wadsworth, Zoeller; Assistant Professors Adkins, Brewer, Byers, Karlstrom, Podos, Qui, E. Walker; Lecturers Goodenough, K. Searcy, Smith; Adjunct Faculty Fite, McCormick, Shetty.

The Field

Biology is the science of life. The vast scope of its subject matter makes biology an extremely diverse field of study. This diversity stems not only from the tremendous variety of life forms with which we share our planet, but also from the multiple levels of organization available for biological investigation. Given an organism, a biologist might choose to investigate how it behaves, how it fits into its ecosystem, the mechanisms by which its genes shape its appearance, what its ancestors were like, how its cells divide, how it grows and develops, or how it derives energy from nourishment. Biological inquiry encompasses perspectives from the planetary to the submicroscopic.

The wide array of biological perspectives is reflected in the many subdisciplines of the field. Genetics, anatomy, physiology, ecology, ethology, botany, neurobiology, systematics, molecular biology, developmental biology, paleontology, and cell biology are just a few of the multitude of specializations that, taken together, compose biology. Given the plethora of approaches that coexist under the biological umbrella, a casual observer might believe that biology is an intellectually fragmented and diffuse endeavor. Fortunately, biology, in all of its glorious diversity, is unified by a few grand ideas. In particular, the theory of evolution provides a conceptual framework that draws together the far-flung threads of biological thought.

Like other scientists, biologists use the scientific method to develop explanations for the patterns and processes that they observe in the natural world. The practice of biology thus involves both systematic observation, often aided by sophisticated instruments, and experimentation. Biologists may work in laboratories or in the field; some of the best biological research combines data gathered in both settings.

Career Opportunities

For many biology majors, undergraduate studies are preliminary to the pursuit of an advanced degree that will lead to a career as a medical doctor, veterinarian, academic, or scientist. A graduate degree is not, however, required to pursue a career related to biology. A bachelor’s degree in biology can lead to employment in the large and growing biotechnology, health care, or pharmaceutical industries. Many openings in these dynamic, high-tech fields require a degree in the life sciences. Biology majors are likewise well prepared for careers as secondary-school science teachers. Certain government agencies, including the National Park Service and the Environmental Protection Agency, also regularly hire biology graduates, as do private environmental and conservation organizations. Employers of all types recognize that a person with a science degree is likely to be comfortable with logical, quantitative thinking.

The Major

The Biology major is open to all students with an interest in biology. The course requirements for the major emphasize fundamental scientific concepts while allowing students to tailor a program to their own interests. All majors are required to complete a core sequence that includes basic math and science courses and several key Biology courses. The elective portion of the degree is more flexible.

Transfers

Courses completed elsewhere and accepted for transfer credit may substitute for some required courses. A minimum of 25 credits, however, must be completed in the Department of Biology.

Course requirements

At least 65 credits, with a minimum grade of C required in each course taken for credit toward the Biological Science Core.

A. Math and Physical Sciences Core
(30 credits)
1. PHYSIC 131/133 and 132/134 Introductory Physics
2. CHEM 111 and 112 General Chemistry for Science and Engineering Majors
3. CHEM 261 and 262/269 Organic Chemistry/ Organic Lab for Non-Majors
4. Any two of the following: MATH 127 Calculus for the Life and Social Sciences I MATH 128 Calculus for the Life and Social Sciences II

B. Biological Science Core (35 credits)
1. BIOL 100, 101 Introductory Biology (C or higher in both courses required before additional Biology courses may be taken); 2. BIOL 312 Writing in Biology;
3. At least 25 additional credits in biological science courses numbered 200 or above. These credits must include:
   a) at least 13 credits in courses numbered 300 and above;
   b) at least one course related to plant biology and one course related to animal biology;
   c) at least two courses with a laboratory or field component;
   d) at least one course in each of four of the following five areas (a list of acceptable courses in each of the five areas is available in the Biology Undergraduate Office): Genetics and Molecular Biology Cellular Biology and Development Physiology Evolution and Biodiversity Ecology and Behavior.

The 25 additional credits may include up to three credits of Independent Study. In addition, the credits may include up to three credits of Undergraduate Teaching Practicum in a Biology Department course or three credits of Contractual Independent Study (i.e., an independent study project completed under the terms of a formal written contract and resulting in a written paper, poster presentation, or oral presentation).

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Honors

Students interested in graduating as Biology majors with Honors should contact Professor O’Connor for information on requirements.

The Minor

An undergraduate minor in Biology requires successful completion of the Biological Science Core courses. Seventeen credits total are required.

1. 100 and 101 Introductory Biology
2. Three of the five courses listed below:
   280 Evolution: Diversity of Life Through Time
   285 Cell and Molecular Biology
   283 General Genetics
   297A Introductory Physiology
   297B Introductory Ecology.

Other Information

The laboratory component of many Biology courses requires the examination and/or dissection of animals. For a description of the use of animals in a particular course, contact the course instructor or the Biology Undergraduate Office.

Biology may be selected as the area of primary concentration in the Science Major (see Science Major). Six Biology courses, including one from each of five specified areas, are required.

Students are encouraged to spend one or two semesters studying abroad. Study abroad offers a valuable opportunity for enrichment and to gain perspective on the field of biology.

Secondary Teacher Education

Students interested in teacher certification should contact the STEP Advising Office, 121 Furcolo Hall, tel. 545-4397 or e-mail: stepadv@educ.umass.edu.

Major in Pre-Medical or Pre-Dental Studies

Students are discouraged from majoring in Pre-Medical or Pre-Dental Studies, but the University does offer these majors. For information on major requirements, contact the Pre-Medical Advising Office, tel. 545-3674, or write to Prof. W. Brian O’Connor in the Biology Department. There is a section in this Catalog (under “Special Programs”) with information about undergraduate preparation for applying to medical or dental school.

The Courses

(All courses carry 3 credits unless otherwise noted)

100 Introductory Biology I (BS)
   (1st sem) 4 cr
   With lab. First semester of a full year course for majors in the life sciences. Lecture: introduction to biochemical basis of living systems, cell biology, mitosis and meiosis, principles of genetics, developmental biology. Lab selected exercises on such topics as enzymes, cell structure, photosynthesis, mitosis, genetics, and embryology. Required for biology majors.

101 Introductory Biology II (BS)
   (2nd sem) 4 cr
   With lab. Second semester of a full year course for majors in the life sciences. Lecture: introduction to animal physiology, survey of animals representing the diversity of life; plant and animal structure and physiology, evolution, and ecology. Lab: selected exercises on such topics as excretion, animal, plant anatomy and development, animal diversity, rat dissection, and ecology. Required for biology majors. Recommended prerequisite: BIOL 100.

102 Introductory Animal Biology for Non-Biological Science Majors (BS)
   (2nd sem) 4 cr
   With lab. Survey of cellular biology, genetics, human physiology, evolution, behavior, and ecology. Lab includes dissection of invertebrate and vertebrate groups. Students majoring in a biological science should take BIOL 100-101.

103 Plant Biology (BS) (1st sem) 4 cr
   With lab. For science majors and others who want an in-depth introduction to plants. Selected topics differ in each lecture section; one may emphasize evolutionary trends while another stresses form/function relationships. Labs include survey of major plant groups and aspects of anatomy, cytology, and physiology of flowering plants.

104 General Botany (BS) (both sem)
   For non-science majors; not for Biology major credit. An introduction to plant biology. Emphasis on flowering plants. Topics include cell and molecular biology, plant structure, growth, development, reproduction, and genetics.

105 Biology of Social Issues (BS) (both sem)
   For non-science majors; not for Biology major credit. Aspects of biology of current social concern: organic evolution as fact, fertility, embryogenesis, birth defects, genetic engineering, race, population growth, and other topics.

106 Human Biology (BS) (1st sem)
   For non-science or science majors; not for Biology major credit. Physiology of the major systems of the human body in health and disease. Intricacy of the human body; good health practices. Collateral issues include smoking, birth control, sexually transmitted diseases, nutrition, and physiological effects of drugs.

197A Introductory Neuroscience (2nd sem)
   A topical introduction to neuroscience through the examination of selected issues in the study of nervous systems. Emphasis on how brains work in terms of nerve cells, and of functional interaction of brain circuits. Topics include: neuron signaling, synapses, visual information processing, brain imaging, mechanisms of animal behavior, brain disease and disorders, learning, memory, and consciousness.

250 Sociobiology and Behavior (BS)
   For non-science or science majors; not for Biology major credit (see BIOL 550). Survey of contemporary studies of animal behavior, particularly to illustrate 1) the natural history, field-study based approach comprising the field of ethology, and 2) the more recent attempts at a synthesis with ecology and evolutionary biology, comprising the field of sociobiology. Broad, general approach; includes examples and studies from all levels of the animal kingdom. Emphasis on human implications.

263 Avian Field Studies I (2nd sem) 2 cr
   For non-science or science majors; not for Biology major credit. Weekly 7-9:30 a.m. field trips or laboratory study; one all-day trip to the coast. For those with an interest in field studies of birds (any level of competence). Emphasis on identification, sea-
283 General Genetics (both sem)
Introduction to genetics including Mendelian, cytoskeletal, molecular, developmental, and population genetics. Examples from a wide variety of organisms. Satisfies major requirements in Biology. Prerequisite: a grade of C or better in BIOL 100 and 101. Optional 1 credit lab.

284 Genetics Laboratory (both sem) 2 cr
Various classical and molecular genetic techniques using prokaryotic and eukaryotic systems. Laboratory projects include genetic mapping via recombination and P element-mediated mutagenesis in Drosophila, plasmid-mediated transformation of bacteria, yeast 2-hybrid assays for protein/protein interactions, and detection of human DNA polymorphisms. Also, bioinformatics tools to perform DNA and protein sequence similarity searches and characterize the organization of specific genes. Prerequisite: BIOL 283 (may be concurrent).

285 Cell and Molecular Biology (both sem)
Follows and builds upon concepts of cell structure and function introduced in BIOL 100. Emphasis upon cellular compartmentation, membrane structure and function, cytoskeleton, cell movement, and synthesis of nucleic acids and proteins. Prerequisites: a grade of C or better in BIOL 100 and 101; CHEM 111, 112.

297A Introductory Physiology (both sem)
The physiology of humans and other vertebrates on a system-by-system basis (e.g., circulatory, respiratory, digestive, etc.). Emphasis on understanding fundamental physiological concepts. Concentrates primarily on human physiology, but examples from other vertebrate animals used to illustrate some physiological phenomena. Prerequisite: a grade of C or better in BIOL 100 and 101.

297B Introductory Ecology (both sem)
The scope of ecology: how organisms cope with environmental challenges; population dynamics; species interactions of competition, predation, and mutualism; community ecology; biodiversity; biogeochemical cycles; selected topics in evolutionary and behavioral ecology. Basic concepts related to practical applications in harvesting, biological control, conservation, pollution, and global change. Prerequisite: a grade of C or better in BIOL 100 and 101 or BIOL 102 and 103.

297C Cellular and Molecular Biology Lab 2 cr
Basic laboratory methods in cell and molecular biology. Labs equally divided between cellular and molecular methods. Experiments include use of microscope, immunofluorescence, subcellular fractionation, and electrophoresis. Molecular methods include restriction enzyme, digestion, plasmid isolation, bacterial transformation, and polymerase chain reaction. Prerequisite: BIOL 285 or consent of instructor.

312 Writing in Biology (both sem) 2 cr
Satisfies Junior Year Writing requirement for Biology majors. Students write and revise short papers on subjects likely to be encountered by biologists. Class discussion of papers. Prerequisites: 3 biological science courses, for declared Biology majors only.

397 Neuroanatomy Laboratory
Lab. Modern approaches to the study of the nervous system, including immunofluorescence, receptor labeling, retrograde labeling, use of enhancer traps. All methods used in conjunction with computer-aided imaging techniques, including signal enhancement, morphometric analysis, and analysis of images acquired with laser confocal microscopy. Prerequisite: BIOL 100 or equivalent and consent of instructor.

397C Marine Vertebrates (2nd sem) 2 cr
An introduction to the biology of hagfishes, lampreys, sharks, bony fishes, turtles, lizards, snakes, birds, and mammals. Reviews structure, diversity, behavior, and ecology in an evolutionary framework.

421 Plant Ecology (1st sem) 4 cr
With lab. Principles of ecology, emphasizing plants. Students explore local habitats, collect and analyze original data, and write results in publication form. Topics include vegetation analysis, plant-plant and plant-animal interactions, ecosystem processes, and hypothesis testing. Prerequisite: an introductory biology or botany course or consent of instructor.

426 New England Flora (2nd sem)
Identification of New England plants in the lab and on field trips. Emphasis on the minimum terminology needed to identify plants and to use keys. Students learn to recognize the common plant families in the area. Prerequisite: introductory biology or consent of instructor.

485 Aquatic Vascular Plants (1st sem)
With weekly field trips. Identification of approximately 200 common vascular plants found in New England wetlands (fresh and salt). Topics include adaptations and ecology of aquatic plants, values of wetlands, and introduction to legal aspects, specifically the Massachusetts Wetlands Protection Act. Prerequisite: BIOL 426 or equivalent course in taxonomy.

504 Plant Morphology (2nd sem) 4 cr

511 Plant Physiology (1st sem) 4 cr
Lecture, lab. Structure and function of components of the plant cell, including the wall, membranes, vacuoles, various organelles, and the cytoskeleton. Characteristics of development at the molecular, tissue, and whole plant level, including genetic engineering. Current theories pertaining to how plants react to hormones, light, and daylength. Responses to stresses such as drought, temperature and touch, and the nature of plant defenses against...
521 Comparative Vertebrate Anatomy (both sem) 4 cr

With lab. Detailed approach to the structure and evolutionary relationships of vertebrates. Evolutionary and functional significance of structures in different groups. Lab involves evolutionary trends and specializations, experience in dissection. Prerequisite: BIOL 102, or BIOL 100 or 101.

522 Vertebrate Fossils and Evolution (alt yrs) 4 cr

Introduction to vertebrate history emphasizing fossil forms. Topics include: skeletal morphology and evolution, modes of life of extinct animals such as dinosaurs, faunal change over time, and relationships among the various groups of vertebrates. Lectures and lab at Amherst College Pratt Museum, with study of display and other fossil specimens. Prerequisite: introductory course in a biological science, geology, or physical anthropology.

523 Histology

With lab. The relation of cell, tissue, and organ microscopic structure to function. Discussion of major tissue types—epithelia, nerve, muscle and connective tissue. Lab includes light microscopic identification of various tissues and organ systems (primarily mammalian) and related electron micrographs. Prerequisite: BIOL 102 or BIOL 100-101.

524 Coastal Plant Ecology (alt 2nd sem)

Plants and processes that characterize the coastal zone (estuaries, salt marshes, maritime forests, grasslands, dune strand and beaches) including interaction of plants with geological factors. Human impact and planning also emphasized. Informal field trips to the coast. Prerequisites: general botany and any ecology course. Previous course in oceanography recommended.

526 Plant Geography (alt 2nd sem)

Principles of plant distribution, basic characteristics, and literature on vegetation of North America, with an overview of world vegetation. History of plant geography, mechanisms of plant dispersal, and development of plant communities in time and space. Emphasis on vegetation of New England. Prerequisites: introductory biology or introductory plant biology, and plant ecology or equivalent, or consent of instructor.

528 Principles of Evolution (alt 2nd sem)

Sources, fates, and importance of genetic variation; how these are influenced by the environment and how such information is gained. Organisms from each of the five kingdoms considered. Approach not mathematical, but knowledge of genetics required.

530 Biology of Invertebrates 4 cr

With lab. Field trips. Survey of structural and functional diversity, phylogeny, classification, ecology and development of the invertebrate phyla and “lower chordates.” Prerequisite: introductory biology.

534 Biological Limnology (1st sem) 4 cr

With lab, field trips. The community ecology of lakes and ponds with emphasis on primary productivity, eutrophication, relationships between environmental conditions and lake biota, and the role of competition and predation in determining the structure and succession of lake communities. Labs emphasize field techniques, identification of flora and invertebrate fauna, and analyses of plankton. Prerequisite: semester of biological science with lab.

537 Ecology (1st sem)

With lab, field trips. A broad survey of modern ecology from the evolution of the biosphere and the principles of ecosystems (including energy-flow and nutrient cycles) through features of terrestrial and aquatic habitats to the ecology of populations and population interactions (especially competition and predation) and patterns of biotic communities. Prerequisite: a life science course beyond the introductory level.

542 Ichthyology (1st sem) 4 cr

With lab. The biology and evolution of fishes with a focus on the structure and function of major living groups. Topics include an overview of evolution, systematics, and biogeography of recent and fossil fishes, functional anatomy of feeding and locomotory systems, reproduction and reproductive behavior, physiological adaptations to aquatic habitats, etc. Lab: anatomy, diversity, systematics and functional morphology of major lineages. Prerequisite: BIOL 521 or consent of instructor.

544 Ornithology (2nd sem) 4 cr

With lab. Avian systematics, phylogeny, behavior, ecology, etc. Lab includes bird identification, anatomy, censusing, field studies. Prerequisite: upper-level biology course or consent of instructor.

548 Mammalogy 4 cr (1st sem)

With lab. Lectures and readings on comparative biology and evolutionary relationships of mammalian groups. Lab involves detailed introduction to the New England mammalian fauna and study of selected representatives of other groups, emphasizing adaptation. Prerequisite: any life science course beyond the introductory level.

550 Animal Behavior (both sem)

For majors in biology, zoology, animal science, wildlife, fisheries, entomology, psychology, and related fields. Survey of recent developments emphasizing current research and its interpretations. Review of “classical” ethological approach and more recent developmental, physiological, ecological, and evolutionary approaches. Also developments, both experimental and theoretical, in sociobiology. Implications with respect to human behavior. Prerequisite: introductory biology or psychology course; or consent of instructor and at least sophomore level standing.

565 Human Physiology 4 cr

With lab. Physiology of organs and organ systems of vertebrates; circulatory, respiratory, digestive, excretory, reproductive, nervous, and endocrine systems. Prerequisites: BIOL 285 or equivalent and at least one semester of organic chemistry. (Non-majors may enroll in 564—lecture only—3 cr.)

567 Comparative Animal Physiology 4 cr

With lab. Students learn to analyze physiological systems and then apply these techniques in reverse to design imaginary animals. The physiology of vertebrates and invertebrates on a system-by-system basis. Comparisons between animals
within each system and adaptations to "extreme" environments emphasized. Projects involve designing an animal which incorporates elements of physiological systems from different animals. Prerequisites: a grade of C or better in BIOL 100, 101.

569 Endocrinology 4 cr
With lab. The role of hormones in the growth, metabolism and reproduction of vertebrates; mechanisms of hormone action, environmental and feedback control of secretion, and evolution of endocrine systems. Prerequisite: 500-level physiology course or consent of instructor. (Non-majors may enroll in 568—lecture only—3 cr.)

571 Biological Rhythms (2nd sem)
The formal, genetic, cell biological and physiological analysis of endogenous oscillations in plants and animals including their entrainment by light and in photoperiodism and orientation. Circadian, circatidal, and circannual rhythms emphasized. Prerequisite: BIOL 285 or equivalent.

572 Neurobiology (1st sem)
Biology of nerve cells and cellular interactions in nervous systems. Structural, functional, developmental, and biochemical approaches. Topics include neuronal anatomy and physiology, membrane potentials, synapses, development of neuronal connections, visual system, control of movement, and neural plasticity. Prerequisite: BIOL 523, 285; or BIOL 100 or 102 and PSYCH 330.

574 Cell Motility and the Cytoskeleton (alt yrs)
The molecular and cellular basis for motion of whole cells and cell organelles. Topics include muscle motility, ciliary motion, amoeboid movement, cytoplasmic streaming, nuclear migration, mitosis and membrane-cytoskeletal interactions. The assembly and regulation of microfilaments and microtubules. Prerequisite: biochemistry recommended.

580 Developmental Biology
Physiological and biochemical aspects of development. Labs include discussions, demonstrations, computer modeling and experimental work. Prerequisite: BIOL 285 or equivalent recommended.

581 Angiosperm Systematics (alt 2nd sem) 4 cr
With lab. History of angiosperm systematics, basic principles of evolutionary biology and phylogenetics, major systems of angiosperm classification, instructor's system. Survey of angiosperms and their economic botany on world scale.

597 Special Topics
Advanced Physiology: Communicating Current Research in Endocrine Physiology (A Community Service Learning Course) (2nd sem)
Estrogen actions in males and females from birth through old age. Estrogen biochemistry, and molecular mechanisms of action of this steroid. Current issues in endocrinology, including the role in which environmental contaminants may act as endocrine disrupters, physiological basis of sexual differences in the incidence of heart disease and Alzheimer's disease, mechanism by which estrogen prevents osteoporosis, and examination of the rationale for and risks of prophylactic antiestrogen administration to prevent breast cancer.

Genomics and Bioinformatics (2nd sem)
Lecture and computer exercises. Discussion of experimental techniques in genomics and theoretical and analytical approaches for handling genetic data, based on recent papers. Computer labs during normally scheduled course time use many of the current databases and computational tools of actual bioinformatics studies. Basic understanding of college-level algebra and Macintosh operating system required. Prerequisite: BIOL 283 or equivalent.

Aquatic Parasitology (2nd sem)
A survey course of the metazoan (nonprotist) internal and external parasites of aquatic organisms, both marine and freshwater. Morphology, reproductive biology, host-parasite relationships, pathology, and classification of parasites. Survey of a taxonomic group of parasites followed by a laboratory study of examples of the phylum. Prerequisites: An introductory biology course and any one of the following courses: BIOL 397C, 521 or 542, ENT 576, or W&FCON 470.

Plant Evolution (2nd sem)
Basic concepts and theories in micro- and macro-evolution of plants. Brief reviews of diversity of photosynthetic organisms and methodologies employed to investigate plant evolution. All recent developments in evolutionary genomics, evolutionary developmental biology, and evolutionary ecology of plants. Prerequisites: BIOL 100, 101, 280 and 283.

Vegetation of North America (1st sem)
Includes short field trips on campus. For undergraduate and graduate students in such disciplines as Biology (Ecology), Conservation Biology, Forestry and Wildlife, Landscape Architecture, and Natural Resource Studies. Covers the major plant communities—formations and associations—of North America. Introduction to the species composition and distribution of vegetation through readings, slides, species lists, and living and pressed specimens. A brief overview of the principles and history of vegetation science. Some background in plant ecology and a familiarity with the geography of North America required.
Chemistry

Degrees: Bachelor of Science
Bachelor of Arts

Contact: George Richason
Office: 701 LGRC Towers
Phone: 545-2292

Head of Department: Professor Paul M. Lahti.
Associate Head: Professor David J. Curran.
Professors Adams, Cade, Carpino, Day, Gierasch, Hixson, Jackson, Lillya, Maroney, Miller, Rausch, Richason, Stidham, Tyson, Uden, Wood, Zajicek; Associate Professors Auerbach, Bianconi, Chandler, Martin, Rotello, Thompson, Vining, Voigtman, Weis; Assistant Professors Kaltashov, Metz, Turner, Vachet, Venkataraman; Lecturers Botch, Samal, Whelan.

The Field

Chemistry occupies the central position among the sciences. Most phenomena in the biological and physical worlds which constitute our environment are ultimately explained in terms of the physical and chemical processes of molecules and atoms. The field, itself, is uncommonly broad, encompassing a number of subdisciplines, among which are physical chemistry, inorganic chemistry, organic chemistry, biological chemistry, and analytical chemistry. Working within these subdisciplines are chemists in such diverse areas as environmental chemistry, medicinal chemistry, neurochemistry, polymer chemistry, materials chemistry, and photobiology. A chemist may decide to specialize in one or more of the subdisciplines in order to pursue a particular interest.

Chemists can pursue their work on purely theoretical grounds, or on an experimental basis. An example of the former might be the physical chemist who seeks a mathematical model of the chemistry of the combustion process. On the other hand, inorganic and organic chemists seek ways to synthesize bioactive organic compounds containing metals to find new drugs to treat diseases. An analytical chemist might be involved in investigating new approaches to measuring the identities and amounts of drugs in body fluids. The mechanism of protein folding is a major concern to biological chemists. Often, in today’s laboratories, teams of various types of chemists are engaged with other scientists to find solutions to problems.

Chemists share a common core of knowledge and methodology, largely acquired during the first three years of undergraduate education. In the third and fourth years there is ample opportunity for the student to pursue appealing specialties within the sub-disciplines.

Career opportunities for the B.A. or B.S. chemist are many and varied. The industry which does not require chemists is unusual. There are many opportunities for chemists in government positions at the local, state, and national levels. In addition, chemists are engaged in a large number of related fields, including medicine, dentistry, law, secondary school education, administration, technical sales, scientific journalism, and illustrative arts.

The Major

The student chooses either the B.A. or the B.S. curriculum and may select from a wide range of courses within each option. These curricula are identical in the first two years. Both provide the opportunity for the pursuit of work in other areas, the B.A. more than the B.S. It is expected that, by the end of the second year, students, in consultation with a faculty adviser, will select the curriculum more suitable for their goals. A B.S. graduate whose program includes instrumental analysis and a full year of inorganic chemistry (and, starting with the class of 2005, BIOCHM 523) will be certified to the American Chemical Society.

Chemistry may be elected as the area of primary concentration in the Science major, an interdepartmental program administered by the Arts and Sciences Advising Services. The program of a student who wishes to major in Science/Chemistry must be approved by the Chemistry Department Chief Undergraduate Adviser. This major is acceptable for secondary school teaching.

UEA Junior Year Abroad Option

The Chemistry Department has a formal exchange arrangement with the School of Chemical Sciences at the University of East Anglia in Norwich, England. This exchange program allows students to obtain a four-year chemistry degree (B.A. or B.S.) and also enjoy the advantages of a year of education in England. The first and second year curriculum for the exchange program is the program listed for the B.A. and B.S. degrees. Information about this program may be obtained from the Chemistry Department Chief Undergraduate Adviser.

The Minor

The chemistry minor requires a minimum of 15 credits of chemistry courses numbered 200 or higher, exclusive of 291A Seminar, 388 B.S. Independent Research Project, 391A Writing in Chemistry, 496 Independent Study, and 499 Senior Honors.

Students petitioning for certification of completion of the minor requirements should present evidence of same (transcript or grade reports) to the Chemistry Department Chief Undergraduate Adviser.

Bachelor of Arts Curriculum

The B.A. curriculum requires the following courses. PHYSIC 261, 262 is recommended but not required. The upper-level chemistry requirement is three credits chosen from a list of courses available from the Chemistry Department. Where options exist, the option recommended is noted by an asterisk (*).

Freshman
Fall
CHEM 121* or 111 General Chemistry
MATH 135* or 131 Calculus I
Spring
CHEM 122* or 112 General Chemistry
MATH 136* or 132 Calculus II
PHYSIC 151/3 General Physics I with lab
Sophomore
Fall
CHEM 265/7* or 261 Organic Chemistry
MATH 233 Multivariate Calculus
PHYSIC 152/4 General Physics II with lab
Spring
241, 242 Descriptive Inorganic 266/8* or 262, 269 Organic 291A Undergraduate Seminar
Junior
Fall
391A Writing in Chemistry 475 Physical Chemistry
Spring
312* Analytical Chemistry or 315 (fall semester) Quantitative Analysis 476, 477 Physical Chemistry with lab
Senior
Upper-level chemistry requirement (3 credits)

Bachelor of Science Curriculum

The requirements of the first four quarters of the B.S. curriculum are identical to those of the B.A. curriculum. The program of the junior and senior years is given below. PHYSIC 171-174 and 283 may be substituted for PHYSIC 151-154 and 261/2. This substitution, along with completion of PHYSIC 284, 285 and 286, is encouraged for students interested in chemical physics. (Students who plan to complete the four-quarter physics sequence should take PHYSIC 171/3 in the first semester of the freshman year.) The upper-level chemistry requirements include an independent project done following the guidelines of the Undergraduate Research Coordinator plus a minimum of eight
credits of upper-level lecture and laboratory courses. Details of these requirements are available from the Chemistry Department. A student who completes this curriculum will be certified to the American Chemical Society if CHEM 513 (Instrumental Analysis) and CHEM 546 (Advanced Inorganic Chemistry) are included in the upper-level selections.

**Junior**

**Fall**
- 315 Quantitative Analysis 4 cr
- 391A Writing in Chemistry 4 cr
- 475 Physical Chemistry 4 cr
- PHYSIC 261, 262 General Physics III (may be taken in the sophomore year) 5 cr

**Spring**
- 476, 477 Physical Chemistry with lab 5 cr

**Senior**

Independent project 4 cr

Upper-level chemistry courses**

**A total of at least 8 credits of upper-level chemistry courses must be taken during the junior and senior years. The independent project is not included in this total.**

### The Courses

*(All courses carry 3 credits unless otherwise noted. A minimum grade of CD in prerequisite chemistry courses, or consent of the instructor, is required for enrollment in chemistry courses. Exceptions are CHEM 265 and 266, with C being required.)*

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>101</td>
<td>General Chemistry for Nonscience Majors (PS) (1st sem) 4 cr</td>
</tr>
<tr>
<td>102</td>
<td>General Chemistry for Nonscience Majors (PS) (2nd sem) 4 cr</td>
</tr>
<tr>
<td>110</td>
<td>General Chemistry (PSL) (1st sem) 4 cr</td>
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<tr>
<td>111</td>
<td>General Chemistry for Science and Engineering Majors (PSL) (both sem and summer) 4 cr</td>
</tr>
<tr>
<td>121</td>
<td>General Chemistry (PSL) (1st sem) 4 cr</td>
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<tr>
<td>122</td>
<td>General Chemistry (PSL) (2nd sem) 4 cr</td>
</tr>
<tr>
<td>241</td>
<td>Introductory Descriptive Inorganic Chemistry (2nd sem) 4 cr</td>
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<tr>
<td>242</td>
<td>Introductory Inorganic Chemistry Laboratory (2nd sem) 1 cr</td>
</tr>
<tr>
<td>250</td>
<td>Organic Chemistry (may not be offered ’01-’02) 4 cr</td>
</tr>
</tbody>
</table>

111 General Chemistry for Science and Engineering Majors (PSL) (both sem and summer) 4 cr
With lab. Basic principles of structure and reactivity. Microscopic nature of atoms and molecules; the macroscopic properties of chemical systems. Topics include stoichiometry, thermochemistry, atomic structure, molecular structure, properties of gases. Note: a maximum of 5 cr may be received for both CHEM 101 and CHEM 102, or 2 cr for either, if CHEM 111 is completed. Prerequisite: MATH 104 or equivalent. Computer fee.

121 General Chemistry (PSL) (1st sem) 4 cr
With lab. Same lecture material as 111. Prerequisite: secondary school chemistry; concurrent enrollment in MATH 135. Computer fee.

241 Introductory Descriptive Inorganic Chemistry (2nd sem)
Chemical periodicity, reaction behavior and structural interrelationships within the framework of a systematic treatment of the main group and transition elements. Prerequisite: CHEM 112 or 122.

250 Organic Chemistry (may not be offered ’01-’02)
A one-semester introduction to chemistry of organic compounds: alkanes, alkenes, alkynes, aromatic compounds, alky1 halides, alcohols, ethers, aldehydes and ketones, carboxylic acids and their derivatives, phenols, amines, fats, amino acids, carbohydrates. Emphasizes nomenclature, structure, synthesis, stereochemistry, mechanisms of organic reactions. Prerequisite: CHEM 111 or equivalent.

262 Organic Chemistry II for Non-majors (both sem)
A continuation of CHEM 261. Prerequisite: CHEM 261 or 265.

263, 264 Organic Lab I, II for Non-majors (summer) 1 cr
Experimental organic chemistry with emphasis on underlying physical principles. Separation and purification, synthesis, analysis, and identification of organic compounds, including spectroscopy. Microscale work predominates. Emphasis on safe laboratory practices and proper disposal of wastes. Concurrent enrollment in CHEM 261, 262 required.

265 Organic Chemistry I for Chemistry Majors (1st sem)
For majors and Commonwealth College students; others by instructor’s consent. Introduction to organic chemistry; structure of organic molecules, reactions of the principal functional groups, and basic theory. Emphasis on prediction of reaction products and rates using reaction mechanisms as a unifying principle. Prerequisite: one year of general chemistry or consent of instructor. Prerequisite: grade
of C or better in CHEM 112 or 122 or equivalent, or consent of instructor. Corequisite: CHEM 267.

266 Organic Chemistry II for Chemistry Majors (2nd sem)
A continuation of CHEM 265. Prerequisite: grade of C or better in CHEM 265 or consent of instructor.

267 Organic Chemistry Laboratory I for Majors (1st sem) 2 cr
Experimental organic chemistry with underlying physical principles: separation and purification, synthesis, and analysis, including spectroscopy. Identification of organic compounds and use of library resources. Work conducted on micro- and macroscales with emphasis on safe laboratory practice and proper disposal of wastes. Prerequisite or corequisite: CHEM 265.

268 Organic Chemistry Laboratory II for Majors (2nd sem) 2 cr
A continuation of CHEM 267. Corequisite: CHEM 266.

269 Organic Lab for Nonmajors (both sem) 2 cr
Experimental organic chemistry with emphasis on underlying physical principles. Separation and purification, synthesis, analysis, and identification of organic compounds, including spectroscopy. Microscale work predominates. Emphasis on safe laboratory practices and proper disposal of wastes. Prerequisite or corequisite: CHEM 262 or 266.

291A Undergraduate Seminar (2nd sem) 1 cr
Weekly lecture by guest scientist working in chemistry or chemically related field (research, teaching, administration, product development, sales, etc.) Brief reports. Prerequisite: CHEM 265 or 261 and concurrent enrollment in CHEM 266 or 262.

312 Analytical Chemistry (2nd sem) 4 cr
With lab. For nonchemistry majors and B.A. chemistry majors. Essential theory and practice of analytical chemistry and interpretation of data. Applications to fields other than chemistry (e.g., the health sciences); selected instrumental methods. Includes K-12 teaching experience. Prerequisite: CHEM 250, 262, or 266.

315 Quantitative Analysis (1st sem) 4 cr
With lab. Fundamental principles of quantitative analytical chemistry with practical inorganic and organic applications. Includes titrimetric methods, acid-base, complexometric and redox, plus separation, electrochemical, and spectroscopic techniques. Prerequisites: CHEM 262 and 264, or 266 and 268.

342 Inorganic Chemistry Lab (2nd sem) 2 cr
The synthesis of inorganic materials and their characterization using a variety of physical techniques. Topics include solid state and inert atmosphere techniques and compounds relevant to biological systems. Includes a class project. Prerequisite: CHEM 241 or consent of instructor.

369 Advanced Organic Chemistry Laboratory (2nd sem all yrs) 2 cr
A continuation of CHEM 268 or 269.

388 B.S. Independent Research Project (both sem)
Used to satisfy the B.S. independent project requirement. A research project, which may consist of laboratory work or theoretical work or both. Project and research director selected by student with consent of instructor and departmental Undergraduate Research Coordinator required. About 8–10 hours of independent work per week; in close consultation with research director, culminating in written and oral reports. A copy of the written report must be included in the student’s academic folder.

391A Seminar: Writing in Chemistry (1st sem)
Satisfies Junior Year Writing requirement. Develops written and oral communication skills. Emphasizes writing as a process. Covers letters, summaries, critiques, reports, articles, reviews, resumes, and proposals. Prerequisite: CHEM 266 or 262.

471 Elementary Physical Chemistry (1st sem)
For nonmajors. Principles of physical chemistry with emphasis on applications to biological systems: thermodynamics and kinetics applied to understanding protein and DNA structure and biological processes such as ligand binding, enzyme catalysis, and membrane transport. Prerequisities: CHEM 112; PHYSIC 132, MATH 132 or 128 (one year introductory chemistry, one year introductory physics, calculus through partial derivatives).

472 Elementary Physical Chemistry (not offered '01-'02)
For non-majors. Basic quantum mechanics and chemical bonding, statistical mechanics with applications to understanding the stability of macromolecules, principles of spectroscopy and diffraction with applications to understanding the structure and function of proteins and nucleic acids. Prerequisites: CHEM112; PHYSIC 132; MATH 132 or 128 (one year introductory chemistry, one year introductory physics, calculus through partial derivatives).

473 Physical Chemistry (not offered '01-'02)
For engineers. Introduction to thermodynamics and application to chemical phenomena; to chemical and phase equilibria and solutions; to statistical thermodynamics; to chemical kinetics, rate laws, analysis of rate processes, theories of reaction rates, complex reactions. Prerequisite: MATH 233 (knowledge of partial differentiation). Corequisites: PHYSIC 152, CHEM 315 or 312.

474 Physical Chemistry (not offered '01-'02)
For engineers. Introduction to quantum theory: Schroedinger equation, electronic structure of atoms and molecules. Elementary rotational and vibrational spectroscopy of molecules—microwave, infrared, Raman spectra—and nuclear magnetic resonance. Miscellaneous other topics. Prerequisite: CHEM 473.

475 Physical Chemistry (1st sem)
For majors. Introduction to thermodynamics and application to chemical phenomena; to chemical and phase equilibria and solutions; to statistical thermodynamics; to chemical kinetics, rate laws, analysis of rate processes, theories of reaction rates,
complex reactions. Prerequisite: MATH 233 (knowledge of partial differentiation). Corequisites: PHYSIC 152, CHEM 315 or 312.

476 Physical Chemistry (2nd sem)
For majors. Introduction to quantum theory; Schroedinger equation, electronic structure of atoms and molecules. Elementary rotational and vibrational spectroscopy of molecules (microwave, infrared, Raman spectra) and nuclear magnetic resonance. Miscellaneous other topics. Prerequisite: CHEM 475.

477 Physical Chemistry Lab (both sem) 2 cr
Experience in classical and modern physiochemical techniques applied to making meaningful chemical measurements. Pre-lab lecture. Part illustrates material offered in junior-level chemistry major physical chemistry lecture course; part is independent. Prerequisites: working knowledge of common analytical techniques or CHEM 315; MATH 233, PHYSIC 152; concurrent enrollment in CHEM 473, 474, 475, or 476.

478 Physical Chemistry Lab (not offered '01-'02) 2 cr
Experiments by arrangement. Tutorial development of experiments, introduction to scientific research. 1-4 reports. Prerequisite: CHEM 477.

489 Chemistry of Macromolecules (not offered '01-'02)
Synthetic and biological polymers discussed and contrasted. Topics include: chain polymerization; characterization of molecular weight and size distributions; protein and DNA sequence analysis; polymer solution thermodynamics and configurational statistics; rubber elasticity; helix-coil transition; the structure and stability of proteins and nucleic acids. Prerequisites: one year of organic and physical chemistry or equivalent and MATH 233.

496 Independent Study (both sem) 2-6 cr
Does not satisfy the B.S. independent research project requirement. Experimental or theoretical study that may involve lab or library work or a combination. Work supervised by faculty sponsor who determines direction of project nature, of reports required, and grade and credit awarded. Prerequisite: consent of instructor.

497 Special Topics 1-3 cr
Faculty member selects a topic of personal interest and discusses it in greater detail and rigor than is possible in normal curriculum. Consent of instructor required.

499Y Honors Research
An independent research project supervised by a professor chosen by student. Early in semester a thesis proposal is written, approved by a thesis committee and submitted to the Honors Office. About 3-4 hours of lab per week per credit. Continued as 499T subsequent semester. Prerequisites: faculty sponsor approval and 3.2 average.

499T Honors Thesis (both sem)
Lab. Continuation of CHEM 499Y in which experimental part of course is completed, thesis is written, oral presentation of the work given to the Thesis Committee, and accepted thesis presented to the Honors Office. Prerequisite: CHEM 499Y.

513 Instrumental Analysis (1st sem)
With lab. Theory and practical application of modern instrumental methods for chemical analyses. Atomic and molecular spectroscopy, electroanalytical chemistry, chromatography and mass spectrometry. Applications to real analytical problems. Prerequisites: CHEM 315 and 476 or consent of instructor.

515 Theory of Analytical Processes (1st sem)
Aspects of the theory underlying modern analytical chemistry. Topics treated in depth vary with instructor, but can include relevant aspects of quantitative analysis; essential signal processing for analytical techniques; chromatography and other separation procedures; optical spectroscopy and spectrometry; flow injection analysis; use of statistics for the analysis and treatment of data. Prerequisite: CHEM 315.

516 Chemical Microscopy 2-3 cr
Lab, with lecture. Theory and application of various optical techniques of microscopy, including bright field, dark field, phase contrast, polarization, fluorescence, and interferometry in both qualitative and quantitative analyses. Introduction to microspectrophotometry, quantitative stereochemistry, other uses of computer-interfaced optical microscopy. Prerequisite: CHEM 513 or consent of instructor.

519 Electronic Instrumentation for Scientists (2nd sem)
With lab. Analog and digital circuits. Electronically aided measurement. Concepts involving instrumentation. Data domain conversion circuits. Approaches to improve the signal-to-noise ratio. Hands-on hardwiring and computer circuit simulation in lab. Prerequisites: year of physics; at least three junior/senior courses in student’s major; consent of instructor.

546 Advanced Inorganic Chemistry (1st sem)
Basic atomic structure concepts; stereochemical principles and bonding models applied to main group and transition metal compounds and to the structure of solids. Includes elementary molecular orbital and ligand field theory, and kinetics and reaction mechanisms of d-block complexes. Descriptions of metal-metal bonded and organometallic systems. Structure and bonding principles applied to catalytic and biological system reactivity. Prerequisites: CHEM 241, 476.

551 Advanced Organic Chemistry (1st sem)
Mechanisms of some important organic reactions. Topics covered may include application of qualitative molecular orbital theory to pericyclic reactions, free radical chemistry, photochemistry, heterocyclic systems, cationic and anionic reactions. Prerequisite: one year of organic chemistry.

552 Spectroscopic Identification of Organic Compounds (1st sem)
Modern techniques for identification and structural analysis of organic compounds. Emphasis on the interpretation of spectra. Optional lab sections with opportunities to use spectroscopic facilities in the department, and to use spectroscopic techniques and procedures, such as nuclear-nuclear decoupling or 2-D NMR experiments (DEPT, COSY), spectral simulation and prediction, standard sample preparation methods. Prerequisites: CHEM 266 and 268 or equivalent. Completion of a two-semester physical chemistry course prior to enrollment strongly recommended. Students may enroll in the concurrent one-credit laboratory, CHEM 553, with consent of the instructor.
Computer Science

553 Spectroscopic Identification of Organic Compounds Laboratory (1st sem) 1 cr
Introduction to the use of UV-visible, infrared, nuclear magnetic resonance, and mass spectroscopy for identification and proof of structure of organic compounds. Work includes preparation of samples, operation of instruments and accessing the data from the literature including online sources like Beilstein Crossfire. Orientations to the University’s NMR and mass spectrometry laboratories. Identification of several unknown compounds. Prerequisites: one year of organic chemistry and concurrent (or previous) enrollment in CHEM 552. A year of physical chemistry recommended.

584 Advanced Physical Chemistry (1st sem)
Introduction to quantum mechanics and its application to chemical problems; electronic structure of atoms and molecules, molecular orbital theory, chemical bonding, potential energy surfaces, and molecular spectroscopy. Prerequisite: CHEM 476 or equivalent or consent of instructor.

585 Advanced Physical Chemistry (2nd sem)
Short review of thermodynamics. Introduction to statistical thermodynamics and its application to chemical problems. Statistical mechanical basis of thermodynamic behavior, e.g., entropy and attainment of equilibrium, and derivation of thermodynamic properties from basic microscopic description of molecules and solids, via quantum mechanics. Other topics may include gas imperfections, theory of liquids, adsorption, and molecular simulations. Prerequisite: CHEM 476 or equivalent or consent of instructor.

100 Computer Science Building

Degree: Bachelor of Science
Contact: Robert Moll, Undergraduate Program Director
Office: 100 Computer Science Building
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Web site: www.cs.umass.edu

Chair of Department: Professor James F. Kurose. Undergraduate Program Director: Associate Professor Robert Moll. Distinguished University Professors Croft, Rosenberg, Towsley; Professors Adron, Barto, Porcarke, Cohen, Graham, Hanson, Immerman, Lehner, Lesser, Osterweil, Poplestone, Ramamritham, Riseman, Russel, Spinelli, Wileden; Associate Professors Barrington, Grupen, McKinley, Moss, Sitaraman, Uitgo, Weems, Zilberstein; Assistant Professors Adler, Allan, Levine, Shenoy, Verts; Research Faculty Fagg, Jensen, Manamtha, Schultz, Woolf.

The Field

The Computer Science Department offers an undergraduate program leading to the Bachelor of Science degree (a Bachelor of Arts degree is not offered). Students admitted to the Computer Science major learn from and interact with faculty who are doing state-of-the-art research in computer science. Many Computer Science majors become involved in such research themselves during their junior and senior years. Students graduating with a Computer Science degree are well prepared to assume responsible and challenging positions in the computing profession or to continue their computer science education at the graduate level.

The Major

The Computer Science undergraduate program is intended to provide a solid foundation for students whose goals span a wide range of endeavors within the rapidly changing computing field. The Computer Science undergraduate program is built around a core of 11 computer science courses (total credits 40), 5 mathematics courses (total credits 17), and 2 physics courses (total credits 8). These courses supply the essential theory, concepts, and techniques in the major areas of computer science. To complement the breadth achieved by this core, majors must also complete at least three advanced technical elective courses in computer science or some related area.

Computer Science majors also must fulfill a Junior Year Writing requirement by taking CMPSCI 305 Social Issues in Computing. This course fulfills part of the distribution course credits required by the Colleges of Arts and Sciences.

Required Computer Science Courses
121 Introduction to Problem Solving with Computers
187 Programming with Data Structures
201 Architecture and Assembly Language
250 Introduction to Computation
287 Programming Language Paradigms
305 Social Issues in Computing
311 Introduction to Algorithms
320 Introduction to Software Engineering
377 Operating Systems
383 Artificial Intelligence

At least two from the following:
401 Formal Language Theory
445 Information Systems
453 Computer Networks
491A Compiler Techniques

Required Mathematics Courses

MATH 131 or 135 Calculus I
MATH 132 or 136 Calculus II
MATH 233 Multivariate Calculus
MATH 235 or 236 Introduction to Linear Algebra

One of the following courses (or another upper-level mathematics course approved by the academic advisor).

MATH 411 Introduction to Abstract Algebra I
MATH 421 Complex Variables
MATH 431 Ordinary Differential Equations for Scientists and Engineers
MATH 451 Numerical Analysis I
MATH 456 Mathematical Modelling
MATH 523 Introduction to Modern Analysis
STATIS 501 Methods of Applied Statistics
STATIS 515 Statistics I

Required Natural Sciences Courses

PHYSIC 151/3, 152/4 General Physics I & II
with labs

Computer Science Electives

Three further elective courses are required. At least one elective must be an advanced computer science course, numbered 400 or higher. Other electives from Mathematics or Electrical and Computer Engineering may be approved.

Notes: Computer Science majors are not permitted to use any course taken on a Pass/Fail
basis to fulfill the Computer Science core requirements (including Mathematics, Physics, and Computer Science concentration sequences). All courses used to satisfy the Computer Science Undergraduate Program requirements must be passed with a grade of C or better. Students receiving a grade of less than C in any such course must see the Computer Science Undergraduate Program Director as soon as possible. Finally, at least five courses numbered 311 or higher must be taken at the University.

Admission to the Major
While many freshmen are admitted directly into the Computer Science major when they apply for admission to the University, the major is restricted for students already on campus who wish to enter the program. Under these circumstances, admission criteria for the major are based principally upon the applicant’s performance in five predictor courses, which are required for the Computer Science degree: CMPSCI 121, 187, 201, and MATH 131-132 or 135-136. At the present time, the requirements for joining the major do not exclude any qualified students. Any student who gets a grade of C or better in each of the predictor courses is eligible for entry into the program. An application form may be obtained from the Computer Science Departmental office in room 100 Computer Science Building and should be returned there when completed. It is also necessary to include a current transcript with the completed application form.

The Minor
The Computer Science Department offers a minor in Computer Science. While the minor is most appropriate for students in math, science, engineering, or business, it is open to all students at the University. The nine courses that make up the minor provide a coherent introduction to the science of computing. These courses are: MATH 131-132 (or 135-136); CMPSCI 121, 187, 201, 250, 287, and two additional regular computer science courses, numbered 300 or higher, except CMPSCI 305 or courses designated to be for non-majors. Note: A grade of C or better is required in all courses used to satisfy the minor, including the preliminary courses. For more information on the minor, contact the Computer Science Undergraduate Program Director.

Career Opportunities

Students graduating with a Computer Science degree are well prepared for a professional career in industry or for graduate study. Careers are available in software, such as operating systems and compilers for computer manufacturers and software houses; in air traffic control; in space vehicle control; in patient monitoring for a hospital; in flight simulation for aircraft manufacturers; and in performing checking account, credit card, and other services for banks and businesses.

Introductory Courses

An increasing number of undergraduates, whatever their major, are finding it necessary to have the ability to use and/or program modern computing equipment. For these students the Department offers CMPSCI 102 Computers and Society, CMPSCI 105 Computer Literacy, CMPSCI 120 Introduction to Problem Solving with the Internet, and CMPSCI 121 Introduction to Problem Solving with Computers.

Students seeking a broad introduction to the use and programming of computers, with an emphasis on the social impact of computing and an overview of the uses of computers within various disciplines, will be interested in CMPSCI 102. CMPSCI 105 stresses the concepts and use of “applications programs” such as word processors, spreadsheets, and databases as well as computer programming for problem solving. CMPSCI 120 provides an introduction to practical problem solving on the Internet. This course requires some prior experience with computers. The Internet concepts and techniques that are presented in the course can be useful for students in any major. Finally, CMPSCI 121 provides the most in-depth material on problem solving and programming using the computer. CMPSCI 121 is a prerequisite to all upper-level Computer Science courses.

Some students entering the University will have already done work that can be applied to the Computer Science requirements. This work may be completed in high school, at another college or university, or through private study. Exemption from Computer Science requirements may be granted by the Undergraduate Program Director, according to guidelines described below. Acceptance of credits to be applied to the University general education requirements can be granted only by the Office of Transfer Affairs.

The most common exemptions are for CMPSCI 121 and 187, the introductory programming and data structures courses. Automatic exemption from both 121 and 187 is granted for a score of 4 or 5 on the AB Computer Science Advanced Placement exam, and in this case, 8 graduation credits are also awarded. Exemption from 121 only is granted for a score of 3 on either the AB or A exams. In this case 4 graduation credits are awarded. These exams are usually taken by students who have had several semesters of programming in high school.

Students who have done well in a good high school programming course, or who have supplemented their course work with private study, may qualify to take CMPSCI 187 without taking CMPSCI 121.

Some students will be able to demonstrate competence in the material of other courses, such as CMPSCI 201, Architecture and Assembly Language. Exemption for requirements such as these may be granted by the Undergraduate Program Director in consultation with the faculty. Similarly, transfer students should have their records evaluated by the Undergraduate Program Director to determine which of the Computer Science requirements they have satisfied.

The Courses

(All courses carry 3 credits unless otherwise noted. Students should check with the Department office for current information regarding which courses will be offered each semester.)

102 Computers and Society (R2) (both sem)

What computers are, how they are used, and how their use affects society. Origins of computing and the forces that brought it about. Essential hardware components of the computer. Introduction to basic programming methods using the JavaScript language. Use of computers in business, professions, art, and science, effect of the Information Superhighway. Social, political, and economic impact of computers on society: privacy, robotics, computers in political action. Use of computer required. Not open to CMPSCI majors or premajors.

105 Computer Literacy (R2) (both sem)

How computers can help solve problems efficiently and effectively. Broad introduction to hardware and software aspects
of microcomputers. Four application areas: word processing, spreadsheets, databases, and telecommunications (access to the Internet). Uses University microcomputer labs; weekly 90-minute lab sessions. Students more interested in programming should take CMPSCI 121. Prerequisites: reasonable high school math skills. Typing ability an important asset.

120 Introduction to Problem Solving with the Internet (R2) (both sem)
Basic skills needed to use the Internet. UNIX commands, e-mail management, listserv software, gophers, Usenet newsgroups, ftp file transfers, telnet sessions, www browsers, basic Web page design, and PGP-based cryptography. Relevant social and political topics: copyright law, First Amendment issues, computer security, personal privacy, electronic cash, commercialization, and bandwidth pricing strategies. Not intended for Computer Science majors. Programming experience not required. Prerequisites: some hands-on experience with PCs or MACs or UNIX.

121 Introduction to Problem Solving With Computers (R2) (both sem)
An introductory course in problem solving, using the programming language Java. Focuses on the fundamental concepts of problem solving and on computer implementation. Satisfactory completion is a prerequisite for all higher-level computer science courses. Use of computer required. Prerequisite: high school algebra and basic math skills (R1).

187 Programming with Data Structures (R2) (both sem) 4 cr
Advanced programming techniques in the Java language. Elementary techniques of software engineering: documentation, coding style, basic testing principles, and informal reasoning about correctness. The notion of an abstract data structure and various important data structures: stacks, queues, linked lists, tree-based structures, and hash tables. Use of object-oriented language constructs for encapsulation of data objects. Lecture, programming projects. Prerequisites: basic math skills and high school algebra (R1); CMPSCI 121 or equivalent.

195A Representing, Storing, and Retrieving Information
Recommended for First Year and Sophomore Non-Majors. The use of data in computer systems. Formats for representing text, sound, images, etc., as strings of bits. Basic information theory, use and limitations of file compression. Structured databases and how to use them. Information retrieval in heterogeneous environments such as the Web. XML as a language for defining new formats for representing data. Prerequisites: user-level familiarity with a modern operating system and some experience with application programs; Tier I math skills.

201 Architecture and Assembly Language (both sem) 4 cr
Introduction to computer organization and programming in assembly language. Various experiments performed using an 8086-based microcomputer system. Develops skills in programming bare or nearly bare machines. Use of computer required. Prerequisite: CMPSCI 187 or equivalent.

250 Introduction to Computation (both sem) 4 cr
Basic mathematical paradigms essential for computer science. Propositional and predicate calculus. Sets, formal languages, relations, and functions. Inductive definition, recursive algorithms, and mathematical induction. Elementary combinatorics. Basic definitions of graph theory. Finite-state machines, regular languages, equivalence of these, proving languages not regular. Prerequisite: CMPSCI 187 or consent of instructor. Corequisite: MATH 132 or 136 or equivalent.

287 Programming Language Paradigms (both sem) 4 cr

305 Social Issues in Computing (both sem)
Satisfies the Junior Year Writing requirement. The impact of computers on modern society. Prerequisites: CMPSCI major or premajor status; ENGLWP 112 or equivalent.

311 Introduction to Algorithms (both sem) 4 cr
The design and analysis of efficient algorithms for important computational problems. Emphasis on the relationships between algorithms and data structures and on measures of algorithmic efficiency. Sorting (heapsort, mergesort, quicksort), searching, graph algorithms. Experimental analysis of algorithms also emphasized. Use of computer required. Prerequisite: CMPSCI 250.

320 Introduction to Software Engineering (both sem) 4 cr
A study of the program development life cycle and fundamental ideas of good programming practices. Topics include software requirements, specifications, design, program structure and style, testing, and program management. An introduction to proof of correctness, data abstraction, and program validation. Use of computer required. Prerequisite: CMPSCI 287.

377 Operating Systems (both sem) 4 cr
The design and operation of modern computer operating systems. Review of capabilities of typical computer hardware. Topics include command language interpreter (the shell), processes, concurrency, interprocess communication, linking and loading, file systems, security, and protection. Programming projects in C++ and UNIX. Prerequisites: CMPSCI 187, 201.

383 Artificial Intelligence (both sem)
Fundamental concepts in machine intelligence. Techniques for search, learning, representation, control, and formal reasoning. Study of selected landmark AI systems. Introduction to planning, natural language processing, and common-sense reasoning. Programming projects in Lisp. Prerequisites: CMPSCI 250, 287.

401 Formal Language Theory (2nd sem)
Introduction to formal language theory. Topics include finite state languages, context-free languages, the relationship between language classes and formal machine models, the Turing Machine model of computation, theories of computability, resource-bounded models, and NP-completeness. Prerequisites: CMPSCI 250, 311 or equivalent.

445 Information Systems (1st sem)
Introduction to database systems. File organization, database system architectures,
520 Software Engineering: Synthesis and Development (1st sem)
Systematic processes for creating high-quality software systems: requirements analysis, formal specification and software design methods, software architecture, process definition, and test planning. Complements CMPSCI 521. Prerequisite: CMPSCI 320 or consent of instructor.

530 Programming Languages (2nd sem)
The skills required to design and implement programming languages. The motivations and costs for various language facilities; the descriptive tools required to compare and evaluate programming language designs. Prerequisites: CMPSCI 287, 320, 377. Corequisite: CMPSCI 401.

535 Computer Architecture (1st sem)
The various elements of computer systems with particular reference to the historical influence of certain real computers and the concepts behind them. Computers studied from different levels of abstraction, including logic level, component level, and system level. Topics include logic circuits, memory devices, virtual memory, arithmetic, pipelines, caches, I/O, and an introduction to parallel processing. Prerequisites: CMPSCI 250, 377.

570 Computer Vision (2nd sem)
Basic techniques in computer vision. The theoretical development of basic image processing operations and their efficient implementation as building blocks of a computer vision system. Topics include the image formation process and digital representation of images; image filtering; extraction of regions and edges; measurement of image features such as color, texture, and shape; hardware/software architectures for image processing; and recovery of motion and depth information from multiple images. Prerequisites: linear algebra and basic computer skills.

585 Natural Language Processing (1st sem)
Introduction to natural language processing including conceptual dependency, predictive parsing, knowledge-based inference generation, and language-oriented models of memory. The relationship between syntax and semantics. Various task orientations including narrative text comprehension, question answering, summarization, and interactive discourse. Prerequisite: CMPSCI 383 or consent of instructor.

589 Machine Learning (2nd sem)
Introduction to methods permitting machines to learn: decision tree induction, cover generation, candidate elimination, artificial neural networks, inductive logic programming. Bayesian, instance-based, reinforcement, apprentice, macro, and explanation-based learning. Use of computer required. Prerequisite: CMPSCI 383.
The primary objectives of geology are to understand the many complex processes that constantly change the earth and other terrestrial planets, and to decipher the history of the earth and terrestrial planets from the time of origin of the solar system to the present day. Achieving those objectives involves diverse activities. Geologists study active natural features such as coastlines, glaciers, lakes and rivers, and volcanoes. Geologic mapping of rocks, sediments, and other features is done to learn of past events and conditions, and field/laboratory studies are conducted to determine fundamental chemical and physical properties of minerals, rocks, sediments, and surface and ground waters. Finding and developing deposits of industrial minerals and rocks, metallic ores, gas and oil, and ground-water aquifers, as well as managing geologic hazards and toxic waste all require insight into geological relationships and processes. A great deal of research (especially in the department) studies the earth’s climate history from the perspective of both terrestrial and marine environments. Computer skills are also emphasized in the geosciences. Such activities add a strong practical flavor to the academic challenge.

### The Major

All students majoring in Geology are required to maintain a 2.0 average for all upper-division courses taken to fulfill degree requirements. The Junior Year Writing requirement is fulfilled by GEO 307 Geologic Writing.

**The B.A. degree program** is intended to provide a firm background in geology while allowing sufficient flexibility to pursue other areas as well. This degree is suitable for Pre-Law and Pre-Dent/Pre-Med students. Requirements include 15 credits of supporting science and mathematics, GEO 101 (or any other introductory geology course) plus GEO 131 and 201, and 21 credits of upper-division geology or physical geography courses (GEO 231 or courses numbered 300 and above) with a minimum of 15 credits in geology. Upper division courses should be selected in consultation with a geology adviser.

**B.S. Programs**

Two separate Bachelor of Science tracks are available. The Geology Track provides a strong background for students wishing professional careers in geology. Requirements include CHEM 111-112, MATH 127-128 or 131-132 or 135-136, and two semesters of Physics (131-134 or 151-154 or 171-174) or two semesters of Biology (100-101 or 102-103); most geology majors should elect MATH 131-132 or 135-136 and PHYSIC 151-154, but discussion with an adviser is strongly recommended. GEO 101 (or any other introductory geography course) plus GEO 131, and GEO 201, 231, 311, 321, 331, 431, and 445 make up the core of this option. An additional 12 credits in upper-division geology or physical geography courses numbered 300 or above, or in relevant supporting sciences or mathematics, are also required; the biology course used to satisfy University General Education requirements cannot be counted towards this requirement, and if courses from mathematics, physics, or chemistry are elected, they must be more advanced than the required courses listed above. All electives should be selected in consultation with a geology adviser. The department strongly recommends that candidates enhance their employability by acquiring practical field experience before they graduate.

**For the B.S. Degree, Earth Science Track**

The Earth Science Track is recommended to students interested in teaching at the secondary school level, or in pursuing graduate studies leading to the M.A.T. or M.Ed. degrees. The program requires completion of courses (some specified) comprising four blocks. The Basic Earth Science Block (13 cr) requires GEO 101, 103 and 131, ASTRON 100 and 105 (or GEO 354). The Supporting Sciences Block (23-24 cr) requires at least one course in biology (BIOL 100, 102, or 103), at least one course in calculus (MATH 127, 131, or 135), two semesters of chemistry (CHEM 111-112, or equivalent), and two semesters of physics (PHYSIC 131-134 or 151-154 or 171-174). The required courses in the Geology Block (15 cr) are GEO 201 (or 341), 231, 311, and 321. An Electives Block (9 cr) consists of upper-division courses in Geology or Physical Geography (courses numbered 300 and above). Students are encouraged to take an environmental geology or related course as part of the Electives Block.

**Teacher Certification:** Undergraduate students must achieve a passing score on the Communication and Literacy Skills Test of the Massachusetts Educator Certification Tests (MECT) prior to admission into professional preparation programs for educators. In addition to meeting other preparation program requirements, each student in a program for which there is an MECT Subject Test must pass the appropriate Subject Test as a prerequisite for enrollment in his or her practicum.

For further information about the procedures leading to teacher certification in Massachusetts, students should follow the guidelines in the Secondary Teacher Education Program (STEP) available at the School of Education.
Career Opportunities

A wide variety of employment opportunities are open to geologists. Most are employed in private industry by firms involved in environmental and engineering geology and groundwork, and in exploration for oil and mineral resources. A growing number of geology graduates obtain employment with federal or state geological surveys, or with agencies involved with the environment or with energy. Although government agencies and industrial firms hire some geologists with B.S. or B.A. degrees, these employers generally prefer geologists who have obtained the M.S. degree. Currently a few colleges and secondary schools also hire geologists.

The Minor

The minor in geology is flexible, so that it can complement the student’s major in the best possible manner. A student desiring to minor in geology must complete the following requirements:

1. GEO 101 The Earth, GEO 131 Experiencing Geology, and GEO 201 History of the Earth
2. 12 credits in upper-division geology courses (GEO 231 and courses numbered 300 and above), no more than 3 credits of which may be in Seminars, Special Problems, or Independent Study. Courses must be approved by one of the regular geology advisers.
3. All prerequisites for courses selected for the minor, both in geology and in supporting science and mathematics.

Note: All students minoring in Geology are required to maintain a 2.0 average for all upper-division courses taken to fulfill degree requirements.

The Courses

(All courses carry 3 credits unless otherwise noted.)

101 The Earth (PS) (both sem)
Co-registration in GEO 131 required. Nature and origin of the earth; volcanism; minerals and rocks; earthquakes; plate tectonics; mountain belts; geologic time scales; wave, river, glacial, and wind action in modification of landscape and atmosphere; the asteroid impact hypotheses; genesis of non-renewable resources, geologic basis for environmental decision making. Field excursions.

103 Introductory Oceanography (PS) (both sem)
The natural processes of the ocean, including earthquakes and volcanoes, the hydrologic cycle and weather, ocean circulation and the global energy balance, the carbon cycle and productivity, biodiversity and marine food webs, coastal dynamics. Also, global warming, sea-level rise, environmental degradation and the ocean system response to human activity and global change. Interactive class sessions, with considerable participation by students in problem solving, discussions, and demonstrations. Exams and grades based on teamwork as well as on individual performance. Students needing or wanting a laboratory component may register for GEO 131.

105 Dynamic Earth (PS)
Mountain building and plate tectonics; landscapes and the underlying rocks and structures; earth history; the role of earthquakes, volcanoes, coastlines, rivers, glaciers, and wind; natural hazards; survey of resources of water, energy, and minerals. Students needing or wanting a laboratory component may register for GEO 131.

109 The Nature of Mountains (PS)
The unique geologic setting and geologic history of many of Earth’s great mountains, including why they rise and why they ultimately fall. Focus on the geologic processes that give rise to mountains and the new insights into geologic process that can be gained from present-day mountains. The interaction between mountains and life on Earth, from earliest evolution to our modern fascination with, and exploitation of, mountainous environments. Fulfills the GEO 101 requirement for Geosciences and Earth Science majors. Students needing or wanting a laboratory component may register for GEO 131.

131 Experiencing Geology (L) (both sem) 1 cr
A practical approach to the Earth in the laboratory and field. Understanding rocks and minerals, reading topographic and geologic maps, investigating the geologic history of the Connecticut Valley, measuring stream flow and water quality. Prerequisite: GEO 100 or 101 or 103 or 105 or 285; may be taken concurrently.

191 Seminar
Reading the Earth: Scientific Methods and Geologic Field Excursions (1st sem)
Geology as seen and investigated in the field. Collecting and interpreting of basic geologic field data during weekly field excursions to localities in the Connecticut Valley and the adjacent mountains. Topics include: plate tectonics, the geologic history of western Massachusetts, surficial processes from rivers to glaciers to oceans, environmental geology, hydrogeology, predicting and preparing for geologic hazards.

201 History of the Earth (2nd sem) 4 cr
With lab. Subjects covered include geologic time, principles of stratigraphy and correlation, evolution and the fossil record, a review of plate tectonics, eustasy and isostasy, and the geologic evolution of the Earth with emphasis on the geologic history of North America. Prerequisite: introductory geology course, preferably GEO 101, or one semester of biology, or consent of instructor.

231 Geological Field Methods (2nd sem)
With outdoor lab. Understanding and interpreting topographic and geologic maps; using the Brunton compass and other surveying equipment; making reconnaissance maps; applications to environmental problems; describing rock units; measuring and correlating stratigraphic sections; compiling and producing bedrock maps. Prerequisites: either GEO 101 or 103 or 105 and GEO 131.

285 Environmental Geology (PS) (2nd sem)
With field trips. Principles of geology and hydrology applied to regional planning in conservation and land use. Ground and surface water resources, water pollution problems, slope stability and mass wasting, geological catastrophes with prevention planning. Environmental geology related to broader environmental and social problems. Participation in field trips. Prerequisite: introductory geology course. Students needing or wanting a laboratory component may register for GEO 131.

307 Geologic Writing
Geologic literature and writing in geology: abstracts, reports, research proposals and articles, topic reviews, theses; editing; style; map production; vitae; oral
presentation. Workshop component. Satisfies Junior Year Writing requirement. Prerequisite: GEO 331.

311 Mineralogy (1st sem) 4 cr
With lab. Systems in mineralogy, including crystallography, the physics and chemistry of minerals, the genesis of minerals, and determinative methods in mineralogy. Prerequisite: CHEM 111 (or concurrent enrollment) or consent of instructor.

321 Petrology (2nd sem) 4 cr
With lab. Genesis of igneous and metamorphic rocks in the earth’s crust and upper mantle. Experiment and theory applied to the interpretation of natural rock textures and their origin. Introduction to thermometry and barometry of rocks and rocks. Recognition of rocks and crystallization histories using the polarizing microscope. Prerequisite: GEO 311.

331 Geological Mapping (1st sem)
With lab. Mapping and interpretation of geologic relationships in the field. Preparation of geologic maps and interpretive cross-sections. Four or five mapping projects conducted jointly by the faculty and students. Weekend field trips. Prerequisite: GEO 231.

341 Invertebrate Paleontology (1st sem alt yrs) 4 cr
With lab. A systematic survey of the morphology (including functional morphology), evolution, stratigraphic occurrence, and ecological requirements of the major invertebrate groups, strongly emphasizing those groups with relatively complete fossil records. Elementary course in geology or zoology helpful.

415 Introduction to Geochemistry (1st sem alt yrs)
The origin, evolution, and maintenance of the Earth’s systems from a geochemical perspective. Some of the fundamental discoveries that have shaped our understanding of the planet: the principles of radiometric age dating; how the crust and mantle achieved their present composition; the power of stable isotopes in unraveling paleoenvironments; the biochemical processes that led to the present composition of the atmosphere and the ocean. Also, the cycling of major elements among the lithosphere, hydrosphere, atmosphere, and biosphere, with attention to those compounds having a major influence on global environmental conditions. Interactive class sessions with emphasis on collaboration in solving problems and completing projects. Prerequisite: 1 year of geology and chemistry or consent of instructor.

431 Structural Geology (2nd sem)
With lab. Description and analysis of deformation and deformation processes at scales ranging from minerals to mountain belts. Topics include: faults, folds, construction of cross-sections, interpretation of structural fabrics, stress, strain, plate tectonics, New England geology, and the geologic history of North America. Emphasis on three-dimensional visualization of geologic features and practical solutions to structural problems relevant to industry and research. Several short field trips (during lab) and one weekend field trip. Prerequisites: GEO 201 and 311 or consent of instructor.

439 Field Problems (both sem) 2-6 cr
Directed field study or research.

445 Sedimentology (1st sem)
With lab. Processes acting to form sediments; composition, structures, origin, and classification of sedimentary rocks. Field trips. Prerequisites: GEO 201, 231 and 311 or consent of instructor.

483 Environmental Evolution (both sem)
Earth’s environment from Archean times to the present; the planetary impact of the origin and evolution of life. Microbial communities, metabolic and cell evolution. International faculty accessible via the interactive lecture-electrowriter system. Class discussion and oral presentation. Limited to senior science majors.

485 Applied Environmental Geology (1st sem) 4 cr
With field trips. Basic concepts of environmental geology necessary for the practicing environmental professional. Emphasis on applications. Topics include: geology in planning and land-use decisions, environmental law, soils from geology and engineering perspectives, hydrologic processes, basic concepts in groundwater hydrology, contamination, and remediation technology. Prerequisites: introductory course in geology and at least one introductory course in another science or mathematics or consent of instructor.

515 X-ray Fluorescence Analysis (2nd sem) 2 cr
Theoretical and practical application of X-ray fluorescence analysis in determining major and trace element abundances in geological materials. Prerequisite: Analytical Geochemistry or consent of instructor.

517 Sedimentary Geochemistry (2nd sem alt yrs)
With lab, field trip. Applications of geochemistry to the study of modern sedimentary environments and sedimentary rocks. Geochemistry of carbonates and evaporites. Use of stable isotopes in paleoenvironmental analysis. Oxidation-reduction processes and their significance for iron formations. Geochemical transformations during burial of sedimentary sequences and the formation of petroleum. Prerequisite: GEO 445 or equivalent; college chemistry recommended.

519 Aqueous and Environmental Geochemistry (2nd sem alt yrs) 4 cr
With lab, field projects. The ways in which waters acquire their chemical composition during the hydrologic cycle. Focus on developing a working knowledge of thermodynamics and equilibria to investigate the origin of different aqueous systems and to understand the processes by which contaminants can be introduced and removed. Research projects investigating local streams and groundwater aquifers. Includes the use of sophisticated analytical instrumentation, principally ICP and ion chromatography, for acquiring original data. Prerequisites: CHEM 111, 112 and introductory geology or consent of instructor.

531 Tectonics (2nd sem alt yrs) 4 cr
With lab. All aspects of plate tectonics and plate tectonic processes. Past and present mechanisms creating the broader framework of global geology; mountain building, ocean-basin structure, continental drift, mantle processes, continental evolution, early history of the earth, structural geology of selected key regions of the globe. Prerequisites: GEO 431 and 321, or consent of instructor.

539 Advanced Geological Mapping (1st sem)
With lab. Complete series of operations required for publication of a geological map; field location and drawing of contacts, collection and interpretation of field
notes, data reduction, drafting, and methods of reproduction. Two afternoons per week in the field. Prerequisites: GEO 321 and 431 or equivalent training.

541 Paleoecology (2nd sem) 2 cr
Survey of theoretical paleontology, including functional morphology, large-scale changes in diversity, taphonomic modeling, and community changes through time. Prerequisite: GEO 341.

551 Geometrics (2nd sem alt yrs)
With lab. Design of geological experiments: the collection and analysis of quantitative data in geology.

560 Geomorphology (1st sem)
Field trips by arrangement. Earth surface processes and resulting landforms including physical and chemical weathering, hillslope, fluvial, eolian, coastal, glacial, and periglacial processes and their relationships to landforms. Term paper or project. Prerequisites: at least 12 credits in geology, physical geography, or related fields; first-year courses in physics and chemistry recommended.

563 Glacial Geology (1st sem) 4 cr
Field trips, lab. The origin and forms of glaciers; erosional and depositional processes and the recognition of erosional and constructional landforms. General Pleistocene history, stratigraphy, map interpretation.

567 Planetary Geology (2nd sem alt yrs)
Geology of the solar system. Emphasis on the solid bodies, age, sequence of events, compositions, surficial and internal geologic processes. Photogeologic mapping of selected portions of Moon and Mars using recent imagery from the space program. Consent of instructor required.

571 General Geophysics (1st sem)
With lab. The physics of the earth and the gravitational, magnetic, electrical, and seismic methods of geophysical exploration. Laboratory problems and computations. Prerequisites: GEO 331, 321; or consent of instructor.

573 Environmental Geophysics
Application of seismic, gravity, magnetic, and electrical methods used in geophysical exploration. Field techniques, data compilation, and basic interpretations used to support shallow subsurface studies and environmental or hydrologic programs. Includes laboratory and field problems.

575 Paleomagnetism (1st sem)
The magnetic field recorded in rocks. Rock magnetism, description of the earth's magnetic field, lab procedures, polar wandering paths. Application of paleomagnetism to geologic problems. Class participation required. Prerequisite: advanced standing in geology or consent of instructor.

583 Metalliferous Economic Geology (1st sem alt yrs)
Nature, origin, and distribution of metalliferous ore deposits in a tectonic, geochemical, and process framework. Petrological and geochemical criteria for the recognition of ore deposits, changes in character with metamorphism, mineral P-T stabilities, associations, wall rock alteration, and concentration mechanisms. Geochemistry of ore minerals and petrological affinities. Prerequisites: GEO 321, 331, or consent of instructor; 723 desirable.

587 Hydrogeology (2nd sem) 4 cr
With lab. An introduction to practical hydrogeology. Topics include the hydrologic cycle, aquifer properties and descriptive parameter, groundwater occurrence and movement, groundwater resource evaluation, aquifer analysis, field methods, relationship between geology and groundwater, and introduction to groundwater modeling. Emphasis on the application of hydrogeologic principles to field problems, development of field skills, and analysis of data including computer analysis. Prerequisite: GEO 101. Introductory calculus recommended but not required.

591 Volcanology
Systematic discussion of volcanic phenomena, types of eruptions, generation and emplacement of magma, products of volcanism, volcanic impact on humans, and the monitoring and forecasting of volcanic events. Case studies of individual volcanoes illustrate principles of volcanology; particular attention to Hawaiian, ocean-floor, and Cascade volcanism.

591G Granites and Rhyolites (1st sem)
Survey of the origin of granites, which make up much of the Earth's continental crust, and of their volcanic equivalent, rhyolites, which are erupted from the most explosive volcanoes on Earth. Topics include chemistry and physics of highly viscous magmas, their plate tectonic association, and economic importance. Prerequisite: GEO 321 or equivalent.

The following graduate courses are also open to undergraduates.

615 Organic and Biogeochemistry
The cycling and distribution of "life elements" (C,O,N,S,P) and compounds in modern and ancient marine and terrestrial settings. Emphasis on the transfer of compounds from the biota to their surroundings. Topics include: anthropogenic influence on biogeochemical cycles, importance of microbes in geochemistry, utility of biomarkers in reconstructing paleoecosystems and paleoenvironments. Prerequisite: one year of college chemistry or GEO 415 or consent of instructor. Organic Chemistry highly recommended.

621 Sedimentary Petrology (2nd sem)
With lab. Analysis of sedimentary structures; petrology of sandstones; heavy-mineral analysis and interpretation. Petrology of carbonate rocks. Prerequisite: GEO 445 or consent of instructor.

627 Clay Petrology (1st sem alt yrs)
With lab. Structure and composition of clay minerals; their formation in the weathering zone; mechanisms of transport and distribution in sedimentary environments; clay minerals in paleoenvironmental and paleoclimatic reconstructions; early and late-stage diagenesis of clays in marine and nonmarine environments. Prerequisite: GEO 445 or consent of instructor.

631 Brittle Fracture Analysis (1st sem alt yrs) 4 cr
With lab. Analysis of faults, joints, veins, and dike patterns using principles of continuum and fracture mechanics. A variety of analytical, statistical, computational, and field techniques used to detect and map past stress fields for tectonic, engineering, and economic applications.

633 Structural Geology of Metamorphic Rocks (1st sem alt yrs) 4 cr
With lab. Analysis of the geometry of intensely deformed rocks with emphasis on interpretation of structural features in the field. Prerequisite: GEO 431 or equivalent.

662 Advanced Geomorphology (2nd sem alt yrs) 2 cr
Selected topics and current problems in geomorphology. Prerequisite: GEO 560 or consent of instructor.
673 Earth Physics (2nd sem all yrs)
Introduction to the physics of the earth as determined from seismological, heat flow, gravity, and paleomagnetic data and their relationship to observed geological phenomena. Prerequisites: GEO 571 and consent of instructor.

687 Advanced Hydrogeology (1st sem)
Advanced groundwater hydrology and contaminant hydrogeology. Includes the application of field techniques, analysis of field data, and use of analytical and numerical models in the investigation of groundwater problems. Introduction to Visual MODFLOW and other groundwater models, including development of conceptual models from geologic data, laying out grids, handling boundaries, source and sinks, transience, calibration, and sensitivity. Prerequisite: GEO 587 or consent of instructor.

Geography

Degrees: Bachelor of Arts
Bachelor of Science

Contact: William McCoy
Office: 236 Morrill
Phone: 545-1535
Web site: www.geo.umass.edu

The Major

The substance of modern geography is based on our inherent sense of place and on the study of the spatial characteristics of the earth—and all that is found on it. This curiosity extends to both the physical content of earth space and to human behavior in response to that environment. Different cultures and groups place contrasting priorities on the kinds of environments and places in which they want to live. Geographers examine the forces that help to shape both attitudes and behavior with regard to the environment and location in space. Such studies help to explain changing patterns of human settlement—where people live, why they are located there, and how individuals and cultures perceive, organize spatially, and use the land around them. As a result, geography’s unique contribution involves an understanding of the spatial distributions, spatial relationships and spatial behavior involved in people-environment systems.

Geography has two main branches: Human geography is concerned with the spatial aspects of our existence—how and where people are distributed and how they perceive, use, and sustain their places on the earth’s surface. Human geographers work in fields such as resource management, environmental conservation and policy, urban and regional planning, transportation, and international business. Physical geography studies patterns among climates, land forms, vegetation, soils, and water. Physical geographers forecast the weather, manage land and water resources, and analyze and plan for use and protection of forests, rangelands, and wetlands.

For some students, a major in geography serves as a flexible foundation on which to build a broad-based liberal education. For others it serves as an appropriate preparation for further training in other fields such as urban and regional planning, business, cartography, and urban studies. For still others, who see themselves as professional geographers, it provides the first step in a professional training which will be continued at graduate school.

Study abroad is often especially appropriate for Geography majors. Students are encouraged to take advantage of opportunities to study abroad for one or two semesters.

Career Opportunities

A wide range of careers demanding knowledge of geographic concepts and mastery of geographic techniques are open in business, government, teaching, and cartography. Many opportunities are becoming available in the field of environmental management and planning. The Federal government will need additional personnel to work in programs such as regional development, environmental quality, and intelligence. Employment of geographers in state and local government is expected to expand, particularly in areas such as conservation, environmental quality, highway planning, and city, community, and regional planning and development. Private industry also is expected to employ increasing numbers of geographers for market research and location analysis. Graduates who have only the Bachelor’s degree in geography may find positions connected with making, interpreting, or analyzing maps; or in research, either working for government or industry. Others may obtain employment as research or teaching assistants in educational institutions while studying for advanced degrees. Some Bachelor’s degree holders do teach at the high school level, although in some states, the Master’s degree is becoming essential for high school teaching positions. Others earn library science degrees and become map librarians.

Many geographers have job titles such as cartographer, map analyst or regional planner, that describe their specialization. Others have titles that relate to the subject matter of their study, such as photo-intelligence specialist or climatological analyst. Still others have titles such as community or environmental planner, or market or business analyst.

Further training to open career doors may be either in geography or in other fields where geography can be applied, such as planning or business, or it can be totally unrelated to geography specifically, such as law and public administration. The critical point is for the stu-
dent, in consultation with a faculty adviser, to work out a solid program in geography and related fields which will sound out the various options.

The Minor

There are several options in the Geography minor. Each is consistent with the general structure of the discipline and its specific subfields and: a) provides students with exposure to fundamental concepts in the field; b) enables them to become familiar with the application of these concepts; and c) complements concepts and perspectives emphasized in the student’s declared major field of study. In practical terms the minor in geography enables students to acquire specific skills and competencies (e.g., cartography) which qualify them for employment with various federal, state, and local agencies. For those students interested in careers in teaching, the geography minor broadens their perspectives in the area of social studies education. In many cases the elected minor in a subfield of geography complements perspectives provided by the student’s academic major, and in doing so potentially enhances the scope of employment prospects.

The department expects students majoring in the following disciplines to be most interested in a minor in geography: Anthropology, Earth Systems, Economics, Education, Environmental Design, General Business and Finance, Geology, History, and Sociology.

Advising

Students are assigned an academic adviser in the same way Geography majors are assigned. Potential minors first consult with the Chief Undergraduate Adviser in Geography to determine possible options and relevant faculty. Students may choose an adviser from the faculty most closely involved with the minor option that they wish to take. The appropriate faculty member works with the student to design the minor program.

Requirements

A. Urban-Economic. 15 credits taken from the courses listed below

102 The Human Landscape
360 Economic Geography
362 Land Use Control
370 Urban Geography

One of the following three:

324 Environmental Perception
372 Social Problems in Metropolitan America
396 Independent Study: Urban Geography

B. Development Studies. 15 credits from courses listed below

100 Global Environmental Change or 102 The Human Landscape
Any four of the following:
320 Latin America
330 East Asia
332 Southeast Asia
360 Economic Geography
364 Development
370 Urban Geography
466 Rural Development and Change

C. Maps and Visualization (Cartography). 18 credits from courses listed below (18 credits are required to meet federal regulations for employment as cartographers).

100 Global Environmental Change or 102 The Human Landscape
350 Maps, History, and World View
352 Computer Cartography
397 Special Topics: Cartography
397A Desktop Publishing
594A Seminar: GIS (one seminar)

One upper-division geography course, either regional or systematic
One of the following three:
ENVDES 191 Graphic Communications
ART 271 Computing in the Fine Arts
FOREST 531 Aerial Photogrammetry

D. Physical-Environmental. 15 credits from courses listed below

100 Global Environmental Change or 101 The Earth
354 Climatology
362 Land Use Control
285 Environmental Geology
324 Environmental Perception
392E Earth System Science
491 Seminar: Water Resource Policy
510 Natural Hazards
560 Geomorphology
563 Glacial Geology

E. Appropriate variations of those above, approved by the student’s academic adviser. These variations must form a unified program in order to be approved. These involve 15 credits.

Prerequisites

All the minors have the Introductory course(s) GEO 100 and/or GEO 102 as prerequisites to subsequent courses. GEO 370 is prerequisite to GEO 372 and Independent Study in Urban Geography. GEO 362 is prerequisite to GEO 491 Seminar in Water Resource Policy.

Restrictions

Transfer credits. Maximum of 6 credits allowed. These must fit into the minors to be allowed.

No Pass/Fail courses are allowed in the minors. Independent Study/Practicum courses: maximum of 6 credits allowed. Relevant examples are listed in the above options. In general we expect students to take 3 credits of these at most.

The Courses

(All courses carry 3 credits unless otherwise noted.)

100 Global Environmental Change (PS) (2nd sem)

With lab. The natural relationships between the atmosphere, hydrosphere, biosphere, and lithosphere; human impact on the natural environment. Global environmental issues: global warming, sea-level rise, and ozone depletion in the stratosphere. Global changes of the past also studied to give perspective to forecasted changes. Includes writing exercises.

102 The Human Landscape (SBD) (both sem)

How people shape the world they live in. Themes and concepts of human geography through the current issues and large questions that guide them. Lectures, labs, and readings on the geographic aspects of cultural diversity, population issues—often as they relate to available resources and technology, states vs. nations, the global economy, issues of conservation and/or development, migration and urbanization, human impact on the environment, and how and why social disparities exist in the modern world.

250 Natural Disasters (I) (1st sem)

Introduction to catastrophic natural hazards and their effects on humans and their environment: volcanic eruptions, earthquakes, floods, droughts, hurricanes, catastrophic landslides. Management and relief of disasters; the damage they cause; prevention and prediction.

314 Writing in Geography (2nd sem)

Readings, lecture, group and individual tutorial, exercises, and peer review focusing on critical thinking and geographic writing.

320 Latin America (SBD) (2nd sem)

Survey of spatial and environmental changes of both cultural/human landscapes and physical/social regions. Emphasis on case studies of selected rural and urban
354 Climatology

Fundamentals of the earth/atmosphere energy balance, the hydrologic cycle, atmospheric motion, and the general circulation of the atmosphere. Regional and local climates. How climate affects people’s activities and how people influence climate. Climate change, its causes, and its effects. Prerequisite: introductory course in weather and climate (e.g., GEO 100 or ASTRON 105).

330 East Asia (2nd sem)

Geographic exploration of the historical evolution and contemporary development of social, cultural, and economic patterns and processes in East Asia focusing on China and Japan. Contemporary issues such as urbanization, population, economic development, and cultural change and continuity.

332 Southeast Asia (1st sem)

The historic and contemporary foundations of Southeast Asian human landscapes and society. How geopolitical, economic and social processes have fostered diasporic movements and redefined the local and global meanings of place, identity, and economy. These themes also examined through the processes of globalization, transnationalism, and transculturalism which connect Southeast Asia to Asian American communities in the U.S. Readings, discussions, video, and community-based projects in Western Massachussets enable students to study and experience the growing interconnectedness of people and places on both sides of the Pacific Rim.

340 Quantitative Methods (R2)

Methods of data analysis and visualization useful in geographic research. Descriptive and inferential statistics through linear regression and analysis of variance, with applications of quantitative methods to spatial data. Examples drawn from both human and physical geography. Extensive use of microcomputers.

352 Computer Mapping

Mapping projects through the use of software mapping packages. Students select their own final projects.

354 Climatology (1st sem)

360 Economic Geography (SBD) (2nd sem)

Economic activity around the world, from world market factories in Asia to industrial co-ops in Spain to households in the U.S. and Australia. Paid and unpaid labor, market and nonmarket transactions, capitalist and noncapitalist enterprises. Emphasis on economic diversity and agency.

362 Land Use and Society (SB) (1st sem)

The meaning of land in past and present societies, and the evolution of land involvement in land use management. Land use data and concepts: review of historical emergence of land use controls in response to social needs: current methods and issues of land use management in the U.S.

364 Development

Examines the geographic structure and process of social, economic, and environmental change associated with ‘development’ in the ‘Third World’. Issues addressed at a global and local scale include population, food production, and the Green Revolution, gender, population mobility and urbanization, and environmental costs of growth.

370 Urban Geography (SBD) (1st sem)

Survey of urban geographical analysis and the development of the world’s cities. Theoretical and methodological approaches of urban geography used to explore cities as they shape and are shaped by their social, cultural, economic, and physical contexts. Topics include pre-industrial cities, industrial cities, the evolution of American cities, and contemporary urban issues in both developed and developing countries.

372 Urban Issues (2nd sem)

Contemporary urban issues in Asia, Africa, and Latin America. Survey of the cities of Asia, Africa and Latin America as they have developed from traditional forms to modern metropolises housing three out of every five of the world’s urban dwellers. The role of culture, society, economy, and politics in shaping urban landscapes. Special topics include the persistence of traditional forms (both physical and social) in contemporary cities, the role of economic globalization in urbanization, and the impacts of contemporary urban planning and development strategies on urban form and functions.

392E Earth System Science (2nd sem)

420 The Human Impact on the Natural Environment (2nd sem)

444 Sense of Place and Environmental Perception

491A Disaster Planning and Emergency Management
half the course involves practical exercises, including seminar discussions, exercises, field visit, and collaborative project work. Recommended for juniors and seniors.

492W Geographic Films (2nd sem)
How film and video are used in geography to illustrate and analyze such topics as how individuals and cultures perceive and interact with the natural environment, form world views, and are attracted to particular kinds of environments; how environmental hazards such as drought, desertification, earthquakes, and tornadoes have an impact on human settlement, and how human migration has an environmental impact on new places ranging from frontier rain forests to the ecology of cities throughout the world.

494A American Indian Geographies
The transformations in the cultural, legal, and political geography of Native Americans over the last five hundred years, exploring changes in the spatial extent of lands, territories, and natural resources under Native American control or jurisdiction. How Euro-American colonialism resulted in changes to this land base and Native American control over natural resources. The importance of law, legislation, and court decisions in the changing legal and political geography of Native Americans. Differences in how Native Americans and Euro-Americans think about nature and land. Cultural differences between Indian and non-Indian over the meaning of nature and how nature should be used.

497S Indigenous Peoples and Conservation
Indigenous peoples’ conservation values and practices and their importance for global conservation. Emphasis on indigenous knowledge, cultural values, sacred places, community management of natural resources, and the role of indigenous peoples in the establishment and management of inhabited national parks and other protected areas.

498A Exploring the New England Landscape (1st sem) 6-9 cr
Helps students to gain a “sense of place” from the New England landscape. Emphasis on combining an experiential learning and discovery of “places” with an intellectual understanding of the forces—physical and human—that shape those places. The development of attachments to places and nature, and an appreciation of those complex layers of the past superimposed over them: the invisible landscapes of human history, folklore, and ecology.

510 Natural Hazards (1st sem)
Natural hazards as interaction of extreme geophysical events and the spatial organization of human activities. Topics include earthquakes, floods, drought, landslides, volcanic eruptions, hurricanes, and tornadoes. Policy and economic implications of hazards, risk assessment, hazard mapping. Some prior experience of scientific subjects recommended.

530 Population and Environment (1st sem)
Population-resource relationships in context of social science theory and debates over sustainability, theories of population change, political economy of resource degradation, institutional factors in resource management, and carrying capacity concepts applied to conditions in Africa, Asia, and Latin America.

560 Geomorphology (1st sem)
Earth surface processes and resulting landforms including physical and chemical weathering, hillslope, fluvial, eolian, coastal, glacial, and periglacial processes and their relationships to landforms. Term paper or project. Field trips by arrangement. Prerequisites: at least 12 credits in geology, physical geography, or related fields; first-year courses in physics and chemistry recommended.

591R Remote Sensing and Image Analysis
Hands-on introduction to applications of satellite remote sensing in the geosciences. Emphasis on image processing and analysis: georeferencing, radiometric and geometric enhancement, classification, multispectral, multitemporal, and Fourier methods.

594A Introduction to GIS
Hands-on introduction to fundamental concepts and methods of spatial information and analysis. Emphasis on developing skills using geographic information systems to solve typical spatial problems in the geosciences through regular exercises and a larger, final group project.

595A Advanced GIS
Project-based, intensive study of concepts and methods of spatial information, statistics, and analysis using ARC/INFO GIS. Emphasis on applying spatial analysis to complex problems in the geosciences using vector and raster data. Prerequisite: introductory GIS course or consent of instructor.

Earth Systems
Degree: Bachelor of Science
Contact: Robert DeConto
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Phone: 545-3426
Web site: www.umass.geo.edu

The Field
Global environmental changes require a comprehensive understanding of the earth’s major systems, and of the important ways in which these systems are linked. The major systems are the geosphere—processes of the Earth’s surface and interior; biosphere—life on land and in the sea; atmosphere—weather and climate; hydrosphere—water in the oceans, air, and on the continents; and cryosphere—snow and ice-covered regions, as well as the impact of human activities on these systems. The goal of earth system science is to obtain a scientific understanding of the entire earth system on a global scale. Recent studies of the continents, oceans, atmosphere, biosphere, and ice cover have revealed a far more complex and dynamic world than hitherto imagined.

In the past, diverse studies of volcanic activity, ocean chemistry, global climate, and biological processes would have been treated in isolation; we now recognize there are important links between them which themselves define new fields of study. Furthermore, the human population is no longer a passive spectator to earth processes, but an active participant on a worldwide scale. Human activity has become an agent of global change, depleting energy, mineral and water resources, altering rivers, coastlines and sedimentation patterns, polluting groundwater resources, and even changing the composition of the entire atmosphere, leading to climate changes with unforeseen and perhaps irreversible consequences. Distinguishing between natural changes, and the results of large-scale economic and technological activity, is a major challenge in earth system research.
The Major

The purpose of the Earth Systems degree is to provide students with a holistic understanding of the interactions of large-scale systems on Earth. The major is designed for students interested in the interface between Earth science and social science, and in issues related to the long-term management of the home planet. Potential applications lie in the areas of education, business, law, government, policy, and economics.

Requirements for the B.S. Degree

A. Supporting Sciences (7 courses; 24-27 credits total)

1. Two courses in Biology (BIOL 100-101, or 102-103, or 100 or 101 and 280, or equivalent)
2. Five courses in Physics, Chemistry, Mathematics, and Statistics, with at least one each in Physics, Chemistry and Math/Statistics (approved courses include: PHYSIC 131-133, 132-134, 151-153, 152-154, or equivalent; CHEM 111-112, or equivalent; MATH 127-128, 131-132, 135-136, or equivalent; STATIS 501; GEO 340, 551)

B. Earth Systems Core Courses (32 credits total)

101 The Earth (both sem)
102 The Human Landscape (both sem)
103 Introductory Oceanography (both sem)
131 Experiencing Geology (both sem)
201 History of the Earth (2nd sem)
231 Introductory Field Geology (2nd sem)
354 Climatology (1st sem)
392 Earth System Science (2nd sem)
415 Introduction to Geochemistry (1st sem)
420 Human Impact on the Natural Environment (2nd sem)
307 or 314 Junior Writing (2nd sem)

C. Electives—12 credits

Additional approved courses in Geology, Geography, Biology, Environmental Sciences, Computer Science, Forestry, Physics, Wildlife and Fisheries Biology, Anthropology, Plant and Soil Sciences, Resource Economics. Courses must be selected in consultation with an adviser.

Career Opportunities

Earth Systems majors will be well positioned to continue their studies at the graduate level in specializations related to earth science, geography, and environmental management, thereby enhancing their career potential.

The Courses

See descriptions under the Geology program for odd-numbered courses, and under the Geography program for even-numbered courses.

Mathematics and Statistics

1622 Lederle GRC Towers

Degrees: Bachelor of Science
Bachelor of Arts

Contact: Jon L. Sicks
Office: 1623C Lederle GRC Towers
Phone: 545-0510

Head of Department: Professor Donald F. St. Mary. Associate Head: Professor Jon L. Sicks; Administrative Coordinator: Lecturer Arline Norkin. Professors Avrunin, Berger, Buonaccorsi, Cattani, Connors, Cook, Eisenberg, Ellis, Fogarty, Gardner, Geman, Hayes, Horowitz, Hsieh, Humphreys, Kaplan, Knightly, Korwar, Kusner, M-C Ku, Liu, Manes, Meeks, Norman, Rosenkrantz, Stockton, Turkington, Williams; Associate Professors Borrego, Katsoulakis, Mirkovic, Pedit, Rudvalis, Whitaker; Assistant Professors Feng, Markman, Nahmod, Raphael, Sebastiani, Sottile, Tsimikas, Wong, Young; Visiting Assistant Professors Anderson, Caldararu, Hukovic, Reid, Stanislavova, Stefanov, Witherspoon, Xia, Xu.

The Field

Mathematics has traditionally been used to solve problems in science and engineering. Nowadays, its methods and techniques pervade almost every aspect of modern life, and individuals trained in mathematical sciences are much in demand throughout the country. Sophisticated mathematics called “tomography” is used to construct the pictures in CAT and MRI scans, the revolutionary new diagnostic techniques in medicine. Techniques from a relatively new branch of mathematics, “coding theory,” ensure that the quality of the music on a laser disk will not be affected if the disk is marred by scratches. Nobel Prize-winning work in economics, widely used for pricing stock options in financial markets, is in the area of mathematics called “non-linear partial differential equations.”

The field of statistics is concerned with methods for the analysis of data, the design of experiments, and surveys for data collection. This includes a combination of the theory of mathematical statistics and applications. Applications include choosing proper methods of analysis, interpretation of results, and training in the use of statistical packages. Statistics is widely used in business, industry, and government.

Students interested in majoring or minoring in mathematics should contact Professor
The Major

The beginning courses emphasize computational skills, problem solving, and the understanding of basic concepts. As students progress, they must solve problems that are less and less routine and more abstract or intricate. Some upper-level courses emphasize proofs and the understanding of abstract structures, while others emphasize advanced computational methods or the formulation and analysis of mathematical or statistical models of reality. A number of the courses involve the use of computers in a fundamental manner in the development of the material covered.

Specific requirements for a major in mathematics are given in 1-7 below. All courses used to satisfy these requirements must be completed with a passing grade, but not with a “P.” A cumulative quality point average of 2.00 is required in all Mathematics and Statistics courses taken.

1. Calculus: MATH 131-132 or MATH 135-136 and MATH 233 or MATH 245 or equivalent.
2. Introduction to Abstract Mathematics: MATH 300. Grade of C or better required. It is strongly advised that MATH 300 be taken by the end of the sophomore year and it is expected that it will be taken by the end of first semester of the junior year.
3. Computer Science: proficiency in a computer programming language. May be satisfied by MATH 236, CMPSCI 121, CMPSCI 187, ECE 242, or equivalent.
4. Linear Algebra: MATH 235 or MATH 236 or MATH 246.
6. Junior Year Writing: MATH 370 Writing in Mathematics.
7. Upper-Division Courses: Eight upper-division courses, of at least three credits each. These must include MATH 411 and MATH 523 and a pair of courses in which one is a prerequisite for the other. See list in Mathematics Information Leaflet, available in Departmental Advising Office, Lederle GRT 1521E, tel. 545-2282. At least four of these eight courses, including a pair in which one course is a prerequisite for the other, must be taken in the Department. At most two of the eight courses may be in fields other than mathematics and statistics. Courses taken in other departments must be approved by the Chief Undergraduate Adviser.

Honors Program

The Department also offers a program of study in mathematics leading to higher honors at graduation (i.e., magna cum laude or summa cum laude) at graduation. Prospective honors students are strongly advised to take MATH 300 as early as possible, as well as the honors sections which are offered throughout the calculus courses and MATH 236 (rather than MATH 235). For more information, consult the Chief Undergraduate Adviser, tel. 545-2282, Lederle GRT 1521E.

Mathematics Information Leaflet

Each year the department publishes, for its majors and other interested students, a Mathematics Information Leaflet which contains more detailed information on the requirements, suggested electives for students with various career interests, and other information of particular interest to mathematics majors. Copies of this leaflet, as well as answers to further questions about the undergraduate program, can be obtained from Professor Cook, the Chief Undergraduate Mathematics Adviser, in Room 1521E, Lederle GRC Towers, tel. 545-2282.

Career Opportunities

Abundant opportunities exist for individuals with the highly developed mathematical and statistical skills and problem-solving ability that the major provides. Modern high technology industrial firms are avidly seeking such individuals, especially those with knowledge of computers, statistics, and applied areas such as differential equations and numerical analysis. Many of the large governmental agencies employ people to work as statisticians or in other mathematical capacities.

Employment opportunities for mathematicians in business, industry, and government are many and varied. The habits of careful, analytic thought instilled by training in mathematics are valuable for managerial as well as for scientific careers. Mathematics/Statistics majors with courses in computer science and statistics compete favorably with majors in computer science or engineering for positions in computer-related industries.

There is a severe and growing shortage of qualified mathematics teachers in the nation’s secondary schools.

Students with an undergraduate major in mathematics often go on to graduate study in fields such as computer science, philosophy, operations research, statistics, biostatistics, and econometrics, or to professional schools in law or business.

For information on career opportunities contact the Chief Undergraduate Adviser, tel. 545-2282, Lederle GRT 1521E.

The Minor

Requirements

Specific requirements for a minor in Mathematics are given in 1-4 below. All courses used to satisfy these requirements must be completed with a passing grade, but not with a “P.” A cumulative quality point average of 2.00 is required in all Mathematics and Statistics courses taken.

1. Calculus: MATH 131-132 or MATH 135-136 and MATH 233 or MATH 245 or equivalent.
2. Computer Science: proficiency in a computer programming language. May be satisfied by MATH 236, CMPSCI 121, CMPSCI 187, ECE 242, or equivalent.
3. Linear Algebra: MATH 235 or MATH 236 or MATH 246.
4. Upper-Division Courses: four upper-division courses, of at least three credits each. At least two of these four courses must be taken in the Department. At most one of the four courses may be in a field other than mathematics and statistics. Any course taken in another department must be approved by Professor Cook, the Chief Undergraduate Adviser.

The Courses

The Department offers courses in mathematics and statistics for students with various interests and mathematical backgrounds. MATH 100 is a basic mathematics course which satisfies the General Education R1 requirement; it is not a pre-calculus course. The courses numbered 011, 101, 102, 103, and 104 are intended to assist the student in preparation for an introductory calculus course. MATH 127-128 is a calculus sequence for business and life and social science students. MATH 131-132 and MATH 135-136 are calculus sequences for students in fields such as mathematics, physics, chemistry, computer science, and engineering.
Mathematics

011 Elementary Algebra (R1) (both sem)
(cr not applicable toward graduation)
Beginning algebra enhanced with pre-algebra topics such as arithmetic, fractions, and word problems as needed. Topics include real numbers, linear equations and inequalities in one variable, polynomials, factoring, algebraic fractions, problem solving, systems of linear equations, rational and irrational numbers, and quadratic equations.

012 Elementary Algebra (R1) (for Stockbridge students) (both sem)
3 Stockbridge graduation credits, but 3 non-graduation University credits.
Beginning algebra enhanced with pre-algebra topics and word problems of particular interest to Stockbridge students. Topics include real numbers, linear equations and inequalities in one variable, polynomials, factoring, algebraic fractions, problem solving, systems of linear equations, rational and irrational numbers, and quadratic equations.

100 Basic Mathematics Skills for the Modern World (R1) (both sem)
Topics in mathematics that every educated person needs to know to process, evaluate, and understand the numerical and graphical information in our society. Applications of mathematics in problem solving, finance, probability, statistics, geometry, population growth. Note: This course does not cover the algebra and precalculus skills needed for calculus.

101 Precalculus Algebra with Functions and Graphs (both sem) 2 cr
First semester of the two-semester sequence MATH 101-102. Detailed, in-depth review of manipulative algebra; introduction to functions and graphs, including linear, quadratic, and rational functions. Prerequisite: MATH 011 or Placement Exam Part A score above 10. Students needing a less extensive review should register for MATH 104.

102 Analytic Geometry and Trigonometry (R1) (both sem) 2 cr
Second semester of the two-semester sequence MATH 101-102. Detailed treatment of analytic geometry, including conic sections and exponential and logarithmic functions. Same trigonometry as in MATH 104. Prerequisite: MATH 101.

103 Precalculus Trigonometry (1st sem) 1 cr
The trigonometry topics of MATH 104. Prerequisite: the equivalent of the algebra and geometry portions of MATH 104. (See also MATH 101, 102, 104.)

104 Algebra, Analytic Geometry, and Trigonometry (R1) (both sem)
One-semester review of manipulative algebra, introduction to functions, some topics in analytic geometry, and that portion of trigonometry needed for calculus. Prerequisite: MATH 011 or Placement Exam Part A score above 15. Students with a weak background should take the two-semester sequence MATH 101-102.

113 Mathematics for Elementary Teachers I (R2) (both sem)
Fundamental and relevant mathematics for prospective elementary school teachers, including whole numbers and place value operations with whole numbers, number theory, fractions, ratio and proportion, decimals, and percents. For Pre-Early Childhood and Pre-Elementary Education majors only. Prerequisite: MATH 011 or satisfaction of R1 requirement.

114 Mathematics for Elementary Teachers II (2nd sem)
Various topics that might enrich an elementary school mathematics program, including probability and statistics, the integers, rational and real numbers, clock arithmetic, diophantine equations, geometry and transformations, the metric system, relations and functions. For Pre-Early Childhood and Pre-Elementary Education majors only. Prerequisite: MATH 113.

121 Linear Methods and Probability for Business (R2) (both sem)
Linear equations and inequalities, matrices, linear programming with applications to business, probability and discrete random variables. Prerequisite: working knowledge of high school algebra and plane geometry.

127 Calculus for the Life and Social Sciences I (R2) (both sem)
Basic calculus with applications to problems in the life and social sciences. Functions and graphs, the derivative, techniques of differentiation, curve sketching, maximum-minimum problems, exponential and logarithmic functions, exponential growth and decay, and introduction to integration. Prerequisite: proficiency in high school algebra, including word problems. Honors sections available.

128 Calculus for the Life and Social Sciences II (R2) (both sem)
Continuation of MATH 127. Elementary techniques of integration, introduction to differential equations, applications to several mathematical models in the life and social sciences, partial derivatives, and some additional topics. Prerequisite: MATH 127.

131 Calculus I (R2) (both sem) 4 cr
Continuity, limits, and the derivative for algebraic, trigonometric, logarithmic, exponential, and inverse functions. Applications to physics, chemistry, and engineering. Students expected to have and use a Texas Instruments 86 graphics, programmable calculator. Prerequisites: high school algebra, plane geometry, trigonometry, and analytic geometry. Honors section available first semester.

132 Calculus II (R2) (both sem) 4 cr
The definite integral, techniques of integration, and applications to physics, chemistry, and engineering. Sequences, series, and power series. Taylor and MacLaurin series. Students expected to have and use a Texas Instruments 86 graphics, programmable calculator. Prerequisite: MATH 131 or equivalent. Honors section available.

135 Calculus I with Computer (R2) (1st sem) 4 cr
Calculus developed through its applications to population models, dynamical systems, optics, and physics. Techniques of differentiation of algebraic, trigonometric, exponential and logarithmic functions. Differential equations. Computers and MATHEMATICA software used to investigate ideas of calculus. No previous computer experience necessary. Prerequisite: high school algebra, plane geometry, trigonometry, and analytic geometry.

136 Calculus II with Computer (R2) (2nd sem) 4 cr
Continuation of MATH 135. Definition and applications of definite integral, techniques of integration, differential equations, infinite series, dynamical systems.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>233</td>
<td>Multivariate Calculus (R2) (both sem)</td>
<td>4 cr</td>
<td>Techniques of calculus in two and three dimensions. Vectors, partial derivatives, multiple integrals, line integrals. Prerequisite: MATH 132, or 136. Students expected to have and use a Texas Instruments 86 graphics, programmable calculator. Honors section available.</td>
</tr>
<tr>
<td>236</td>
<td>Linear Algebra with Computer Programming (R2) (2nd sem)</td>
<td>4 cr</td>
<td>Basic concepts of linear algebra. Enough of an array-oriented computer language such as APL, J, or MATHEMATICA to write programs that will solve systems of linear equations and related problems. Topics include those normally covered in MATH 235, with special effort to cover eigenvalues. Prerequisite or corequisite: MATH 132 or 136 or consent of instructor.</td>
</tr>
<tr>
<td>245</td>
<td>Multivariable Calculus, Linear Algebra, and Ordinary Differential Equations with Computer I (1st sem)</td>
<td>4 cr</td>
<td>Unified treatment of the subjects in a context of real-world applications. Computers used to investigate concepts. Vector spaces and linear transformations; Markov chains; cross products and determinants; eigenvalues and eigenvectors; algebraic solution of ordinary differential equations. MATH 245 and 246 together are an alternative to MATH 233, 235, and 431. Prerequisites: MATH 135-136 or MATH 131-132.</td>
</tr>
<tr>
<td>246</td>
<td>Multivariable Calculus, Linear Algebra, and Ordinary Differential Equations with Computer II (2nd sem)</td>
<td>4 cr</td>
<td>Continuation of MATH 245. Vector methods for ordinary differential equations; multivariable derivatives; optimization; Fourier series and Fourier transform; line and surface integrals; multiple integrals, volume, and probability; introduction to partial differential equations—all in a context of real-world applications. Computers used to investigate concepts. Prerequisite: MATH 245.</td>
</tr>
<tr>
<td>291</td>
<td>Seminar: Problem Solving (1st sem) 1 cr</td>
<td></td>
<td>A number of methods for solving problems; a wide variety of interesting and unusual problems. May be repeated for credit.</td>
</tr>
<tr>
<td>300</td>
<td>Fundamental Concepts of Mathematics (both sem)</td>
<td></td>
<td>Four to six topics, chosen from fields such as geometry, number theory, and the real numbers, with emphasis on precise definitions, examples, conjectures, theorems, and proof methods, including induction and contradiction. Prerequisite: MATH 132 or 136 or consent of instructor.</td>
</tr>
<tr>
<td>370</td>
<td>Writing in Mathematics (both sem)</td>
<td></td>
<td>Satisfies Junior Year Writing requirement. Develops research and writing skills in mathematics through peer review and revision. Students write on mathematical subject areas, prominent mathematicians, and famous mathematical problems. Prerequisites: MATH 300 and completion of College Writing (CW) requirement.</td>
</tr>
<tr>
<td>411</td>
<td>Introduction to Abstract Algebra I (both sem)</td>
<td></td>
<td>Introduction to groups, rings, fields, vector spaces, and related concepts. Emphasis on development of careful mathematical reasoning. Prerequisites: MATH 235 or 236; MATH 300 or consent of instructor.</td>
</tr>
<tr>
<td>412</td>
<td>Introduction to Modern Algebra II (2nd sem)</td>
<td></td>
<td>Continuation of MATH 411. Prerequisite: MATH 411.</td>
</tr>
<tr>
<td>421</td>
<td>Complex Variables (both sem)</td>
<td></td>
<td>Complex numbers and functions, analytic functions, complex integration, series, residues, conformal mappings. Applications: computation of real integrals, Dirichlet’s boundary value problem and its application to physics and engineering. Prerequisite: MATH 233.</td>
</tr>
<tr>
<td>425</td>
<td>Advanced Multivariate Calculus (both sem)</td>
<td></td>
<td>Calculus of several variables, Jacobians, implicit functions, inverse functions; multiple integrals, line and surface integrals, divergence theorem, Stokes’ theorem. Prerequisites: MATH 233 and MATH 235 or 236.</td>
</tr>
<tr>
<td>431</td>
<td>Ordinary Differential Equations for Scientists and Engineers (both sem)</td>
<td></td>
<td>Introduction to ordinary differential equations. First and second order linear differential equations, systems of linear differential equations. Laplace transform, numerical methods, applications. Prerequisite: MATH 132, or 136; corequisite: MATH 233.</td>
</tr>
<tr>
<td>455</td>
<td>Introduction to Discrete Structures (2nd sem)</td>
<td></td>
<td>Introduction to the wealth of pure mathematical and formal proofs. Discrete and continuous tools used to study discrete structures. Topics from algebraic coding theory, Boolean algebras, combinatorics, fields, finite state automata, graph theory, groups, number theory, and rings. Prerequisites: MATH 132 or 136, MATH 235/236 or CMPSCI 250.</td>
</tr>
<tr>
<td>461</td>
<td>Geometry I (1st sem)</td>
<td></td>
<td>Topics chosen from affine, projective, Euclidean, and non-Euclidean geometry. Highly recommended for prospective secondary school mathematics teachers. Prerequisite: MATH 235 or 236 and 300, or consent of instructor.</td>
</tr>
<tr>
<td>462</td>
<td>Geometry II (2nd sem)</td>
<td></td>
<td>A continuation of MATH 461. Prerequisite: MATH 461.</td>
</tr>
<tr>
<td>471</td>
<td>Number Theory</td>
<td></td>
<td>Basic properties of the positive integers including congruence arithmetic, the theory of prime numbers, quadratic reciprocity, and continued fractions. Theory applied to develop algorithms of computer science and to cryptography. Prerequisite: MATH 235 or 236.</td>
</tr>
<tr>
<td>475</td>
<td>History of Mathematics</td>
<td></td>
<td>History and development of mathematics from early Greeks to present day. Prerequisite: MATH 233.</td>
</tr>
<tr>
<td>491H</td>
<td>492H Honors Seminar (both sem) 1 cr</td>
<td></td>
<td>Content varies from term to term and with instructor. What modern mathematics is all about; an appreciation of mathematics as part of our cultural heritage. Students</td>
</tr>
</tbody>
</table>
solve specific problems and give class presentations. Outside speakers, films. When taken consecutively, 491H and 492H constitute one honors course.

503 Topics in Computer Connected Mathematics for Secondary Teachers (R2) (2nd sem)
Topics appropriate for secondary school mathematics courses using computers, focusing on algorithms, roundoff error, and graphics. Topics chosen from number theory, linear algebra, geometry, analysis, probability, and statistics. Prerequisites: MATH 233 and 235, plus working knowledge of some computer programming language.

511 Abstract Algebra I (1st sem)
Introduction to various topics in abstract algebra, such as groups, rings, and fields. A deeper and more advanced treatment than MATH 411. Prerequisites: MATH 233 or 235; MATH 300 or consent of instructor.

512 Abstract Algebra II (2nd sem)
A continuation of MATH 511.

523 Introduction to Modern Analysis (both sem)
Topics include intuitive set theory; equivalence relations; mathematical induction; integers and rational numbers; Dedekind completion; countability; sequences; topology of the reals and metric spaces; limits, continuity, differentiability, and integrability of functions. Prerequisites: MATH 233 and 235, plus working knowledge of some computer programming language.

534 Introduction to Partial Differential Equations (2nd sem)
Introduction to solution methods for partial differential equations. Topics: classification and canonical forms, characteristics, separation of variables and Fourier series, maximum principles, the energy method, Green’s functions, Fourier transforms. Prerequisites: MATH 233, MATH 235 or 236, and MATH 431 or 432.

545 Linear Algebra for Applied Mathematics (2nd sem)

551 Introduction to Scientific Computing (both sem)
Introduction to computational techniques used in science and industry. Topics selected from root-finding, interpolation, data fitting, linear systems, numerical integration, numerical solution of differential equations, and error analysis. Prerequisites: MATH 233 and 235, or consent of instructor, and knowledge of a scientific programming language.

552 Applications of Scientific Computing (2nd sem)
Introduction to the application of computational methods to models arising in science and engineering, concentrating mainly on the solution of partial differential equations. Topics include finite differences, finite elements, boundary value problems, Fast Fourier transforms. Prerequisite: MATH 551 or consent of instructor.

563 Introduction to Differential Geometry (2nd sem)
Study of curves and surfaces in 3-dimensional Euclidean space which may be defined by smooth functions. The “extrinsic” geometry of curves and surfaces (how they sit in space); the intrinsic geometry of surfaces; properties of a surface that may be determined without reference to the ambient Euclidean space; Geodesics, fundamental forms, principal curvature, convex surfaces, Gauss-Bonnet Theorem. Prerequisites: MATH 233 and MATH 235 or 236, or consent of instructor.

576 Introduction to Differential Geometry (2nd sem)
Study of curves and surfaces in 3-dimensional Euclidean space which may be defined by smooth functions. The “extrinsic” geometry of curves and surfaces (how they sit in space); the intrinsic geometry of surfaces; properties of a surface that may be determined without reference to the ambient Euclidean space; Geodesics, fundamental forms, principal curvature, convex surfaces, Gauss-Bonnet Theorem. Prerequisites: MATH 233 and MATH 235 or 236, or consent of instructor.

Statistics

There is no undergraduate major in statistics. The curriculum is intended for those who wish to prepare for graduate work in statistics and for those who require statistics as a basic preparation for their own discipline.

111 Elementary Statistics (R2) (both sem)
Descriptive statistics, elements of probability theory, and basic ideas of statistical inference. Topics include frequency distributions, measures of central tendency and dispersion, commonly occurring distributions (binomial, normal, etc.), estimation, and testing of hypotheses. Prerequisite: high school algebra.

140 Introduction to Statistics (R2) (both sem)
Basics of probability, random variables, binomial and normal distributions, central limit theorem, hypothesis testing, and simple linear regression.

501 Methods of Applied Statistics (R2) (both sem)
Statistical methods for research and experimental work, emphasizing practical issues; presentation of data, probability, sampling, hypothesis tests, parameter estimation, frequency data, regression, analysis of variance, design of experiments. Computer analysis of data (no computer experience necessary). A fast-paced course for students without extensive mathematical background. Prerequisite: high school algebra, Junior standing or higher.

505 Regression and Analysis of Variance (1st sem)
Applied statistics; including analysis of real data. Simple and multiple regression, including model fitting and selection, and diagnostics; one-way and n-way analysis of variance. Use of statistical packages (no computer experience necessary). Prerequisites: previous work in statistics, such as STATIS 501 or 516.

506 Design of Experiments (2nd sem)
Statistical considerations in planning, analysis, and interpretation of experiments; standard designs, e.g., factorials, block designs, Latin squares, and the associated analysis of variance; sample size determination; multiple comparisons; randomization; response surfaces. Computer analysis of data (no computer experience necessary). Prerequisite: previous work in statistics, such as STATIS 501 or 516.
Physics

1126 Lederle GRC Towers

Degrees: Bachelor of Science
Bachelor of Arts

Contact: Professor Edward Chang
Office: 223 Hasbrouck
Phone: 545-0586

Head of Department: Professor John Donoghue;
Undergraduate Program Director: Professor Chang. Professors Byron, Cook, Dubach, Gerace, Godowich, Guyer, Hallock, Hertzbach, Hicks, Holstein, Kofler, Kreisler, Langley, Machta, Mestre, Miskimen, Penchina, Pichanick, Rabin, Sastry, Swift, Wong; Associate Professors Candela, Kumar, Prokof'ev, Traschen, Walker; Assistant Professors Blaylock, Dallapiccola, Menon, Tuominen, Willcoq; Lecturers Hatch, Kastor, Papirio; Research Assistant Professors Dufresne, Leonard.

The Field

Physics is the basic science that underlies all of the physical sciences and influences most of the biological sciences. It treats matter, energy, and interactions at the fundamental level. Its subdisciplines include acoustics, optics, mechanics, thermodynamics, atomic physics, nuclear physics, condensed-matter physics, low-temperature physics, elementary-particle physics, plasma physics, astrophysics, biophysics, geophysics, relativity, and nonlinear dynamics. Physics is a laboratory-based science. Experiments reveal the observable properties of the natural world, and theories provide an understanding of the observations. Mathematics serves as the essential language for the analysis of experiment and theory.

The work physicists do can be classified as basic or applied. The scientist doing basic research typically works in a university or national laboratory, and is interested in learning about the fundamental processes of nature. The applied physicist wants to develop uses for knowledge through technological advances, and is employed most often in an industrial setting. Physicists usually choose to be either experimentalists or theorists. The experimenter uses apparatus designed to test hypotheses and theories, to make unexpected discoveries of new phenomena, or to develop new applications of ideas. The theorist uses that data to develop new explanations, hypotheses, or theories. Occasionally a particularly broad scientist can act as both experimentalist and theorist. Physicists may also use the computer to simulate a physical system and generate data from observations of the simulation in order to gain new insights into real systems.

Physics is a constantly changing science with aspects which sometimes cross over into other disciplines. Often a field becomes very exciting and physicists pursue it vigorously. After the fundamental principles are established, a particular field may be given over to another discipline for further exploration. Thus, much of the physics of yesterday is now regarded as part of chemistry or engineering. It is interesting to conjecture how the physics of today may evolve in the decades to come.

The Major

The Department of Physics has the faculty and facilities to provide unusually strong programs for students wishing to major in physics. The department offers a variety of courses and tracks; many options are available at the introductory level, in the core upper-division courses, and in the advanced electives. The three available tracks, Professional, Applied, and General, enable students to tailor the major to suit their goals. Whether the student plans to continue physics in graduate school, seek employment immediately after the B.S. degree, study other fields, or pursue other alternatives, an appropriate set of courses is available.

Courses for majors generally have low enrollments and so students are treated as individuals. The student-faculty ratio in the department is optimal; it is easy for a student to interact directly with the faculty and get extra help and advice.

Most faculty members are engaged in basic experimental or theoretical research in one of the following areas: atomic physics, condensed-matter physics, elementary-particle physics, nuclear physics, polymer physics, low-temperature physics, and nonlinear dynamics. Excellent facilities have been supplied by the University and are supported by several million dollars annually in federal research funds. This activity makes it possible to bring the frontiers of physics to the classroom and enables undergraduates to participate in original research activities. These opportunities can be found through independent study, the departmental honors program, or student employment during the summer or academic year.

The department has an active chapter of the Society of Physics Students (SPS), which allows the student to interact socially with student colleagues and faculty as well as to carry out interesting extracurricular physics activities. For example, there is a Five College Undergraduate Physics Colloquium that brings...
several nationally known speakers to the area each year. Traditionally, SPS members and faculty eat together in the dining commons before attending the evening lecture.

PHYSIC 171-174 and 283/285 are the recommended introductory courses and labs for students considering a major in physics. (Under certain circumstances, and with approval of an adviser, PHYSIC 151-154 may be substituted.)

Students intending to go on to graduate school in physics or closely related fields or simply desiring a complete set of courses in physics should follow the Professional Track. Those intending to take jobs immediately after receiving the B.S. degree, or who will go to graduate school in other areas, can choose one of two other tracks, Applied Track or General Track.

The latter two tracks include fewer Physics courses, but require that the student take a coherent program of courses (a concentration) from other departments together with our own. The details of the concentration must be worked out with an adviser from the department. The Applied Track is for majors interested in other technical subjects, for example, computing or engineering, while the General Track allows a concentration in non-technical areas, for example, finance, teaching, and science writing.

Core Courses (required for all tracks):
171/3 Physics I with Lab
172/4 Physics II with Lab
283 Physics III
284 Modern Physics I
285 Sophomore Lab I
286 Sophomore Lab II
381 Writing in Physics
MATH 131 Calculus I
MATH 132 Calculus II
MATH 233 Multivariate Calculus

Professional Track (B.S.):
282 Techniques of Theoretical Physics
290S Introduction to Computational Physics
421 Mechanics
422 Electricity and Magnetism
423 Statistical Physics
424 Modern Physics II
440 Intermediate Lab I
441 Intermediate Lab II
500-level lab or ASTRON 337
500-level course or ASTRON 451 or 452
MATH 431 Differential Equations

Applied Track (B.S.):
Two of 421, 422, 423 and 424
440 Intermediate Lab I
441 or a 500-level lab
Concentration in scientific/technical field(s), minimum 18 credits, developed in consultation with Physics adviser.

General Track (B.A.):
One of 421, 422, 423, or 424
440 or 500-level lab
Concentration in non-departmental field(s), minimum 18 credits, developed in consultation with Physics adviser.

A more detailed description of the programs for majors in both physics and astronomy is contained in the Handbook for Physics Majors. Copies may be obtained upon request from the Undergraduate Program Director.

Career Opportunities

Physics provides an excellent background for a wide variety of careers in science, and in science-related and technological fields. A survey of the department’s graduates has yielded the following information. About half of those responding are in science-related industrial jobs; half of these had received advanced degrees (M.S. or Ph.D.) before or during employment.

About one-third of the respondents are presently in graduate school or in academic positions following graduate school. One-tenth of those surveyed are in the medical professions, and another one-tenth are employed in other fields. Graduates are in a wide variety of professions. Some examples include a chemical engineer, a supervisor in charge of inspection techniques for nuclear power plants, a systems engineer in ship design, and a graduate student in oceanography. Several graduates are M.D.s or medical students. One of our former majors is now a Professor of Physics at the University of Massachusetts.

Industrial research and development is an appealing career opportunity; for this goal a highly laboratory-oriented physics curriculum is recommended. A master’s degree increases the number of opportunities in industry. For teaching at the secondary school level one needs also to complete the education courses necessary for certification. These courses can easily be fitted into a Physics major’s program, especially the General Track. For teaching at the community college level a master’s degree is usually the minimum requirement; at the college or university level (and for many research jobs in government or industrial laboratories) a Ph.D. is required.

Many students take courses in other sciences, in mathematics, or in engineering, in addition to their physics curriculum, to strengthen their industrial “marketability” or to prepare for graduate school in programs such as astronomy, biophysics, meteorology, geophysics, oceanography, computer science, polymer science, etc. The Applied and General tracks are particularly useful in this regard.

The undergraduate program of a physics major is frequently taken by individuals planning to apply to medical or dental school. Some medical professions, such as nuclear medicine and health physics, are directly related to physics. Physics can also be a reasonable preparation for law school. Patent law, for example, requires a technical background.

Few individuals with bachelor’s or advanced degrees in physics are unemployed or seriously underemployed. A physics education provides a broad background of fundamental principles and develops skills in solving complex problems, enabling effective contribution in many kinds of traditional and novel activities.

Material relating to job opportunities and graduate schools is kept up to date by the senior adviser.

The Minor

To satisfy the requirements for a minor in physics the student must complete 15 credits at the 200 level or above.

Courses for Nonmajors

The department offers a variety of courses for students with varied interests and needs. Introductory courses intended mainly for nonscience majors are PHYSIC 100, 114, 115, 116, 120, 125, and 139. (114 is of special interest to Communication Disorders majors, 115 to Music majors.) PHYSIC 131-134 are for life science majors; 151-154 are for majors in engineering, chemistry, and other physics sciences.

The Courses

(All courses carry three credits unless otherwise noted.)

Note: Credits may be earned for only one of the following courses in each line:

PHYSIC 131, 151, 171
PHYSIC 132, 152, 172
PHYSIC 133, 153, 173
PHYSIC 134, 154, 174.

100 Conceptual Physics (PS) (both sem)

The fundamental ideas of physics, a minimum of mathematics. Selected phenomena of everyday existence (motion, sound, electricity). Physics beyond the range of
our senses, the realm of atoms and nuclei (quantum physics), the universe (cosmology), high speed phenomena (relativity). For nonscience majors. PHYSIC 103 serves as an optional laboratory to accompany this course. Prerequisite: Basic Math Skills (R1) proficiency, or equivalent.

103 Conceptual Physics Laboratory (2nd sem) 1 cr
Lab experiments investigate topics in mechanics, waves, electricity, light, heat, and atomic and nuclear physics. Prerequisite: Basic Math Skills (R1) proficiency, or equivalent.

114 Theory of Sound with Applications to Speech and Hearing Science (PS) (2nd sem)
Fundamentals of wave motion, vibration of strings, sound waves, resonance, harmonic analysis, sound intensity and the decibel, physics of the ear and theories of hearing, physics of speech, elementary properties of microphones and speakers. Prerequisite to COMDIS 311, 312. For communication disorders majors; open to others.

115 Physics of Music (PS) (2nd sem)
Waves, the production and perception of sound, the physical basis of pitch, timbre, resonance, dissonance, and musical scales. Concepts applied to orchestral instruments and auditorium acoustics. Fundamentals of electronic sound reproduction and recording. Elementary algebra and powers of ten notation used.

116 Relativity (PS) (1st sem)
The nature of space and time from the viewpoint of the special theory of relativity. Historical perspective. A variety of paradoxes and puzzles including the twin paradox. The speed of light as an upper limit. Muon decay. Photons. Basic high school algebra and geometry required.

120 Big Bang to Black Holes (PS) (2nd sem)
The great 20th-century revolutions in scientific thought: Einstein’s Theory of Relativity and Quantum Mechanics, at a level appropriate for non-science majors. Relativity: spacetime and time dilation, blackholes, big-bang cosmology; Quantum Mechanics: uncertainty principle, wave-particle duality, and simple quantum systems. What constitutes a scientific theory. Collaborative work. Prerequisite: Basic Math Skills (R1).

125 Seeing the Light (PS) (1st sem)
An introductory course in light and vision. Optical instruments, photography, light in nature (rainbows, mirages), the human eye, visual perception (depth, color, optical illusions), interference, quantum effects, lasers and holograms. Designed for non-science majors with an interest in the physical and natural worlds. Strong emphasis on demonstration and experimental observation. Prerequisite: Basic Math Skills (R1).

131 Introductory Physics I (PS) (both sem)
Basic physical laws governing mechanics, heat, and sound; examples and applications from the biological sciences. Arithmetic, high school algebra, and basic trigonometry required. The recommended introductory physics course for majors in the biological sciences and related areas.

132 Introductory Physics II (PS) (both sem)
Basic principles of physics illustrated by example and demonstration, whenever possible, from the biological sciences. Topics: electricity, magnetism, radiation, optics, atomic structure of matter. Prerequisite: PHYSIC 131/133 or equivalent.

133 Introductory Physics Laboratory I (both sem) 1 cr
Laboratory for PHYSIC 131. Together, PHYSIC 131 and 133 replace PHYSIC 141 in the curriculum.

134 Introductory Physics Laboratory II (both sem) 1 cr
Laboratory for PHYSIC 132. Together, PHYSIC 132 and 134 replace PHYSIC 142 in the curriculum.

139 Introduction to Physics (PS) (1st sem)
A comprehensive introduction to physics. Discussion of fundamental principles: numerous examples of practical applications. Topics include forces, motion, energy, heat, fluids, electricity, magnetism, light, and the atom. High school algebra required and used freely. Intended for nursing, allied health, natural resources, and other majors interested in a quantitative one-semester course. Does not replace PHYSIC 131-134 for science majors.

151 General Physics I (PS) (both sem)

152 General Physics II (PS) (both sem)
Heat and thermodynamics. Fundamental principles of electricity and magnetism. Prerequisites: PHYSIC 151/153 and MATH 132.

153 General Physics Laboratory I (both sem) 1 cr
Laboratory for PHYSIC 151. Together, PHYSIC 151 and 153 replace PHYSIC 161 in the curriculum.

154 General Physics Laboratory II (both sem) 1 cr
Laboratory for PHYSIC 152. Together, PHYSIC 152 and 154 replace PHYSIC 162 in the curriculum.

171 Physics I (PS) (1st sem)
For engineering, mathematics, physics, and other science majors with interest in analytical science. Principles of mechanics, dynamics of particles and rigid bodies, conservation laws. Corequisite: MATH 131.

172 Physics II (PS) (2nd sem) 4 cr
Foundations of thermodynamics, fluids, waves, sound, and optics. Prerequisites: PHYSIC 151/153 or 171/173, MATH 131, or consent of instructor.

173 Physics Laboratory I (1st sem) 1 cr
Laboratory for PHYSIC 171. Together, PHYSIC 171 and 173 replace PHYSIC 181 in the curriculum.

174 Physics Laboratory II (2nd sem) 1 cr
Laboratory for PHYSIC 172. Together, PHYSIC 172 and 174 replace PHYSIC 182 in the curriculum.

185 Freshman Seminar (1st sem) 1 cr
Weekly seminar for freshman physics majors; open to all undergraduates. Current trends in physics. Modern topics at the research frontier in language suitable for beginners. Lecturers from the physics faculty; topics in each one’s specialty. Graded Pass/Fail.
186 Freshman Seminar (2nd sem) 1 cr
Continuation of PHYSIC 185.

196 Independent Study (both sem) 1-3 cr
Special projects; departmental sponsor required. See Professor Mullin for details.

261 General Physics III (2nd sem)
Wave physics and modern physics. Waves on a string, sound and electromagnetic waves, Ray and wave optics, reflection and refraction of light, optical instruments, interference and diffraction. The central ideas of 20th-century physics: relativity, photons, introduction to quantum physics, atoms, molecules, nuclei, and other modern topics as time permits. Prerequisites: PHYSIC 151-154, MATH 233, or equivalent.

262 General Physics Laboratory III (2nd sem) 1 cr
Laboratory for PHYSIC 261. Together, PHYSIC 261 and 262 replace PHYSIC 263 in the curriculum.

282 Techniques of Theoretical Physics (2nd sem)
The application of mathematical methods to problems in theoretical physics. A wide variety of techniques employing calculus. Introduction to complex numbers, matrices, vector calculus, Fourier series, and differential equations. Prerequisites: any introductory physics sequence; MATH 233, or consent of instructor.

283 Physics III (1st sem)
Electricity and magnetism. Emphasis on basic foundations of physics and techniques used to solve a wide range of problems. For engineering, math, physics, and other science majors with facility and interest in math and physics. Prerequisites: PHYSIC 151 or 171, MATH 132. Corequisite: MATH 233 or consent of instructor.

284 Modern Physics I (2nd sem)
Fourth term of 180-series Introductory Physics sequence. Survey of discoveries in physics in the 20th century; special relativity, prelude to quantum theory, principles of quantum mechanics with application to problems in one dimension. PHYSIC 284 and 424 constitute a full-year course in modern physics. Prerequisites: PHYSIC 171, 172, 283, or consent of instructor, MATH 233.

285 Sophomore Laboratory I (1st sem) 2 cr
First half of the experimental course for sophomore majors. Experiments on a range of topics in electricity and magnetism. Introduction to techniques for setting up a physics experiment and for obtaining and analyzing data. Corequisite: PHYSIC 283.

286 Sophomore Laboratory II (2nd sem) 2 cr

290S Introduction to Computational Physics (2nd sem) 2 cr
Hands-on, project-based course developing computational skills necessary to solve basic physics problems numerically. Tools include UNIX operating system, Internet, symbolic programming and visualization with Mathematica or Matlab, and programming with C or Java. Methods include differentiation, integration, root-solving, and data analysis. Prerequisites: PHYSIC 171, 172, and MATH 132.

296 Independent Study (both sem) 1-3 cr
Special projects; departmental sponsor required. Prerequisite: introductory physics. See Professor Chang for details.

354 Meteorology
Review of fundamental thermodynamics and physics of fluids. Application of physics to atmospheric science; development of weather patterns and characteristics including aerosols, droplet growth and dynamics, humidity, condensation and clouds, vertical stability, convection, wind patterns. Solar and terrestrial radiation balance, global circulation. Weather maps and charts, development and evolution of storms and isolated violent phenomena. Prerequisites: PHYSIC 151, 152 or equivalent, and MATH 233.

381 Writing in Physics (1st sem)
Seminar. Satisfies Junior Year Writing requirement for physics majors only. Several writing exercises illustrating the various modes of science writing. Subject matter based on modern research topics.

421 Mechanics (1st sem)

422 Electricity and Magnetism (2nd sem)
Vector calculus, electrostatics, Laplace’s equation, dielectric media, magnetostatics, time varying fields, Maxwell’s equations, electromagnetic waves. Prerequisites: introductory electricity and magnetism (PHYSIC 152, 283 or equivalent); MATH 233.

423 Statistical Physics and Thermodynamics (2nd sem)
Probabilistic treatment of systems of many particles, Concepts and laws of heat and thermodynamics, derived from a statistical approach. Microcanonical and canonical ensembles. Applications to classical and quantum gases, blackbody radiation, solids, magnetism, phase transitions, chemical reactions. Prerequisites: PHYSIC 284 and MATH 233, or consent of instructor.

424 Modern Physics II (1st sem)
Concluding half of full-year course in modern physics (PHYSIC 284 is first half). Quantum mechanics in three dimensions, and applications, particularly to atoms and nuclei. Prerequisite: PHYSIC 284.

440/1 Intermediate Laboratory (both sem) 2 cr ea
Modern and classic experiments performed with up-to-date techniques. Partially satisfies the lab requirement for physics majors. Course complements 400-level physics courses. Prerequisites: introductory physics with labs (PHYSIC 171-174, 283, 284, 285, 286, or equivalent), or consent of instructor.

496 Independent Study (both sem) 1-3 cr
Special projects in physics. Departmental sponsor required. Prerequisite: one or more 400-level physics courses. See Professor Mullin for details.

499Y Honors Research (both sem) 1-4 cr
Honors thesis research. Students work on an independent research project under
The Major

The Science major is intended for students with a general intellectual interest in natural sciences who do not wish to specialize or to go on to graduate work in a specific area of science. It can provide a valuable broad science background to an administrative position in science-related industries, or to a career as a science writer or illustrator. It is especially appropriate for students who intend to teach general science at the middle school level, or for those who want to pair a degree in Science with a program in Education to teach at the elementary school level. The Science major is not designed for students who wish to do graduate work in a specific area of science (for which a traditional departmental major would be appropriate), but is a very good choice as a second major or a second degree, or as preparation for teaching certification, graduate school, or professional school.

Each student is advised by the Science major adviser in the student’s concentration area (usually the department’s chief undergraduate adviser). The Science major adviser in the concentration area will be responsible for academic advising, approval of the program, and certification of completion of graduation requirements within the guidelines established by the Science major coordinating committee. This committee consists of the chief undergraduate advisers of the College departments, a representative of the Pre-Medical committee, and College Associate Dean for Advising (Arts and Sciences Advising Center, E24 Machmer Hall).

Requirements

A total of 60 science or mathematics credits must be completed, primarily from departments in the College of Natural Sciences and Mathematics. (These departments are Astronomy, Biochemistry and Molecular Biology, Biology, Chemistry, Computer Science, Geosciences, Mathematics and Statistics, and Physics.) The 60 credits must be distributed as follows:

A. Foundation Requirement (9 courses):

1. Plant and Animal Biology: One of the following two-course sequences:
   - BIOL 100 and 101 Introductory Biology I and II
   - BIOL 102 and 103 Introductory Animal Biology and Plant Biology
2. General Chemistry: One of the following two-course sequences:
   - CHEM 111 and 112 General Chemistry for Science and Engineering Majors
CHEM 121 and 122 General Chemistry for Chemistry Majors
Earth/Planetary Science: One of the following courses:
ASTRON 113 The Solar System
ASTRON 223 Planetary Science
GEO 101 The Earth
GEO 103 Introductory Oceanography
Mathematics, Statistics, Computer Science: One of the following two-course sequences:
MATH 127 and 128 Calculus I and II for the Life and Social Sciences
MATH 131 and 132 Calculus I and II for Science and Engineering
MATH 135 and 136 Calculus I and II with Computers
CMPSCI 121 Introduction to Problem Solving and CMPSCI 187 Programming with Data Structures
Statistics sequence approved by the Mathematics Department
Physics: Two-course introductory physics sequence with accompanying laboratories chosen from:
PHYSIC 131/133 and 132/134 Introductory Physics I and II/Laboratory I and II
PHYSIC 151/153 and 152/154 General Physics I and II/Laboratory I and II
PHYSIC 171/173 and 172/174 Physics I and II/Laboratory I and II.

B. Concentration Requirement
Each student selects a concentration area from among the programs offered in the College, which becomes part of the major designation. The permitted concentrations (and major designations) are: Astronomy (SCIAR), Biochemistry (SCIBC), Biology (SCIBIO), Chemistry (SCICHE), Computer Science (SCICS), Geology (SCICEO), Mathematics (SCIMTH), and Physics (SCIPHY). The concentration consists of at least 15 credits in courses numbered 200 and above. These should include the Junior Year Writing course for that area, and at least three other upper-division courses (courses numbered 300 and above). Some programs specify that particular courses must be taken, so it is important that each student consult with the departmental Science major adviser when planning the concentration.

C. Upper-Division Requirement
If the courses taken to meet the Concentration Requirement do not include at least 15 credits of courses numbered 300 or above, additional upper-division credits must be taken to reach at least 15 credits.

D. Additional Courses
If courses taken to meet all above requirements do not amount to 60 credits, the remaining credits must be from courses numbered 200 or above in the College of Natural Sciences and Mathematics, and may not include courses specifically intended for non-science majors.

Notes and Restrictions
1. The 60 required credits may include a maximum of six credits in courses numbered 200 and above from science-related fields in other schools or colleges on campus (Humanities and Fine Arts, Social and Behavioral Sciences, Education, Engineering, Food and Natural Resources, Management, Nursing, and Public Health and Health Sciences). The acceptable courses must be approved by the Science major coordinating committee. Some less obvious examples of such courses are HIST 432 and 433 U.S. Science and Technology I and II; PHIL 310 Intermediate Logic; PHIL 382 Philosophical Approaches to Science; PHIL 513 and 514 Mathematical Logic I and II; PSYCH 310 Sensation and Perception; and PSYCH 330 Physiological Psychology.
2. No course taken to satisfy the requirements of the major may be taken on a Pass/Fail basis. Colloquia and seminars that are offered as mandatory Pass/Fail may not be applied to the requirements of the major.
3. Individual departments may have minimum acceptable grades and/or averages for the concentration. Science majors must maintain at least a “C” average in the courses used to satisfy major requirements.
4. Although the Science major might usefully be part of a double major degree, the second major must be outside the College of Natural Sciences and Mathematics.