

ENVIRONMENTAL SCIENCE

Department Website: <http://geosci.uchicago.edu>

PROGRAM OF STUDY

The Department of the Geophysical Sciences offers a BS degree in Environmental Science. The program is intended for students whose interests fall at the intersection of biology, chemistry, and earth sciences, and is designed to prepare them to enter a variety of interdisciplinary fields in the environmental sciences, including the interface of environmental science and public policy. Students are given the opportunity to study such topics as the biogeochemical cycles, environmental chemistry, microbiology, ecology, the chemistry and dynamics of the ocean and atmosphere, climate change, and environmentally relevant aspects of economics and policy. Students are encouraged to participate in the Semester in Environmental Science at the Marine Biological Laboratory, and undergraduate research is also strongly encouraged.

PROGRAM REQUIREMENTS FOR THE BS IN ENVIRONMENTAL SCIENCE

The requirements for the BS degree in Environmental Science involve completion of:

- six required courses that fulfill general education requirements for the physical sciences, biological sciences, and mathematics
- seven required science or mathematics courses
- eleven elective courses pertinent to the major from the electives lists below, which must include
 - four courses designated ENSC or GEOS
 - one course in Statistics, and two more in any of Mathematics, Statistics, or Computing
 - one to three courses in Social Science/Public Policy

Candidates for the BS in Environmental Science complete a year of chemistry, a year of mathematics (including Calculus I-II), and a year of biology (ENSC 24400 Ecology and Conservation, GEOS 27300 Biological Evolution-Advanced, and BIOS 20198 Biodiversity), as well as PHYS 13100 Mechanics or the equivalent. (Note that some advanced chemistry courses require further physics as a prerequisite.)

Students are encouraged to begin discipline-specific courses as early as possible. Required disciplinary courses include ENSC 13300 The Atmosphere, ENSC 23800 Global Biogeochemical Cycles, and ENSC 24400 Ecology and Conservation. (Note that ENSC 23800 Global Biogeochemical Cycles is typically offered every other year.) Of ENSC/GEOS science electives, one can be a field course, and one may be ENSC 29700 Reading and Research in Environmental Science. Students participating in the Semester in Environmental Science receive credit for four courses in environmental science (as explained in list E-1 Environmental and Geophysical Sciences below).

The major is designed to be flexible enough to accommodate students whose primary interests cover various aspects of environmental science. Sample course schedules below give examples of course plans appropriate to students focusing on climatology, conservation, and biogeochemistry. Students with a focus on policy questions may take up to three courses in social science/public policy. These courses are available through undergraduate programs in Economics (<http://collegecatalog.uchicago.edu/thecollege/economics/>), Public Policy Studies (<http://collegecatalog.uchicago.edu/thecollege/publicpolicystudies/>), and E ([http://collegecatalog.uchicago.edu/thecollege/environmentalstudies/environment, Geography, and Urbanization](http://collegecatalog.uchicago.edu/thecollege/environmentalstudies/environment,Geography,andUrbanization) (<http://collegecatalog.uchicago.edu/thecollege/cegu/>), or through the Harris School of Public Policy (<http://collegecatalog.uchicago.edu/harrispublicpolicy/courses/>).

Because analysis of data and mathematical modeling are fundamental to environmental science, the major requires six courses in quantitative methods: a year of mathematics, one course in statistics, and two additional courses in mathematics, statistics, or computing.

Note that while students taking calculus through the more introductory MATH 13000s sequence are encouraged to complete the third quarter of calculus, MATH 13300 Elementary Functions and Calculus III, in the higher tracks Calculus III (e.g., MATH 15300 Calculus III) is not specifically required or recommended, as the first two courses offer a sufficiently comprehensive calculus training for students to move on to other courses. Depending on the choice of electives, students may credit as many as nine Mathematics/Statistics/Computing courses toward the major.

SUMMARY OF REQUIREMENTS FOR THE BS IN ENVIRONMENTAL SCIENCE

GENERAL EDUCATION

One of the following sequences:

200

CHEM 10100 & CHEM 10200	Introductory General Chemistry I and Introductory General Chemistry II
CHEM 11100-11200	Comprehensive General Chemistry I-II *

CHEM 12100 & CHEM 12200	Honors General Chemistry I and Honors General Chemistry II	
One of the following sequences:		200
MATH 13100-13200	Elementary Functions and Calculus I-II *	
MATH 15100-15200	Calculus I-II	
MATH 16100-16200	Honors Calculus I-II	
Both of the following: **		200
BIOS 20198	Biodiversity	
GEOS 27300	Biological Evolution-Advanced %	
Total Units		600
MAJOR		
ENSC 13300	The Atmosphere	100
ENSC 23800	Global Biogeochemical Cycles	100
ENSC 23900	Environmental Chemistry	100
ENSC 24400	Ecology and Conservation	100
CHEM 11300 or CHEM 12300	Comprehensive General Chemistry III * Honors General Chemistry III	100
One of the following:		100
PHYS 12100	General Physics I * †	
PHYS 13100	Mechanics	
PHYS 14100	Honors Mechanics	
One of the following:		100
MATH 18300	Mathematical Methods in the Physical Sciences I	
MATH 20250	Abstract Linear Algebra	
BIOS 20152 or BIOS 20151	Introduction to Quantitative Modeling in Biology (Advanced) Introduction to Quantitative Modeling in Biology	
MATH 13300	Elementary Functions and Calculus III *	
MATH 15300	Calculus III	
MATH 16300	Honors Calculus III	
Eleven electives as follows:		1100
Four courses from List E-1: Environmental and Geophysical Sciences		
One course from List E-2: Social Sciences		
Three courses from List E-3: Computational Sciences, of which one must be under the heading of Statistics		
Three more courses from any of the elective lists (E-1, E-2, E-3, or E-4), but only up to two of these may be from List E-2: Social Sciences		
Total Units		1800

* Credit may be granted by examination.

** Only students majoring in Environmental Science or Geophysical Sciences may use this pairing toward the general education requirement in the Biological Sciences. Environmental Science and Geophysical Sciences majors can take these courses without the BIOS prerequisites (BIOS 20150-20151/20152) unless they pursue a double major in Biological Sciences. They are expected to show competency in mathematical modeling of biological phenomena covered in BIOS 20151/20152.

† PHYS 13100 or PHYS 14100 are the preferred courses. PHYS 12100 is allowable on a case-by-case basis but may not provide adequate preparation to allow for enrollment in higher level PHYS courses. Additionally, PHYS 12100 has a prerequisite of a year of Chemistry. Special petition to the department counselor is required for PHYS 12100 approval.

% Biological Evolution-Advanced has several cross-listings. Environmental Sciences majors *must* register for it under the GEOS 27300 listing.

LISTS OF ELECTIVE COURSES

LIST E-1: ENVIRONMENTAL AND GEOPHYSICAL SCIENCES

Environmental Science

ENSC 21100	Energy: Science, Technology, and Human Usage	100
ENSC 23600	Chemical Oceanography	100

ENSC 23820	Biogeochemical Analysis in Terrestrial and Aquatic Ecosystems # Marine Biological Laboratory [@]	100
ENSC 24000	Geobiology	100
ENSC 24100	Ecology - Marine Biological Laboratory [@]	100
ENSC 24200 or ENSC 24500	Methods in Microbial Ecology - Marine Biological Laboratory [@] Environmental Microbiology	100
ENSC 24300	Roles of Animals in Ecosystems # Marine Biological Laboratory [@]	100
ENSC 24550	Global Change Microbiology	100
ENSC 24800	Climate Systems Engineering	100
ENSC 25000	Biological Oceanography [^]	100
ENSC 29700	Reading and Research in Environmental Science	100
ENSC 29800	Independent Undergraduate Research in Environmental Sciences Marine Biological Laboratory [@]	100

[@] This course is part of the Semester in Environmental Science/Marine Biological Laboratory. Admission to the Semester in Environmental Science program is by application, which must be received by the MBL generally in March of the year preceding the start of the semester. Admissions decisions will generally be sent in April. Note that these courses start at the beginning of September, typically four weeks prior to the start of the College's Autumn Quarter, and are completed by the end of Autumn Quarter. More information on the course content and the application process, and deadlines can be found at college.uchicago.edu/academics/semester-environmental-science. (<https://college.uchicago.edu/academics/semester-environmental-science/>)

[^] This course is part of the Marine Biological Laboratory Spring Quarter Program. For more information, see college.uchicago.edu/academics/spring-quarter-mbl (<https://college.uchicago.edu/academics/spring-quarter-mbl/>).

Field Courses in Environmental Science

The department sponsors field trips that range in length from one day to several weeks. Shorter field trips typically form part of lecture-based courses and are offered each year. (The trips are open to all students and faculty if space permits.) Longer trips are designed as undergraduate field courses, and one such course may be used as an elective science course for the major. Destinations of field courses have recently included Baja California and the Bahamas. (http://collegecatalog.uchicago.edu/thecollege/geophysicalsciences/#_msocom_1)

ENSC 29002	Field Course in Modern and Ancient Environments	100
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Geophysical Sciences

GEOS 21000	Mineralogy	100
GEOS 21400	Thermodynamics and Phase Change	100
GEOS 22060	What Makes a Planet Habitable?	100
GEOS 22200	Geochronology	100
GEOS 22700	Analytical Techniques in Geochemistry	100
GEOS 23205	The Cryosphere: Glaciers and Ice Sheets	100
GEOS 24220	Climate Foundations	100
GEOS 24230	Geophysical Fluid Dynamics: Foundations	100
GEOS 24240	Geophysical Fluid Dynamics: Rotation and Stratification	100
GEOS 24250	Geophysical Fluid Dynamics: Understanding the Motions of the Atmosphere and Oceans	100
GEOS 24300	Paleoclimatology	100
GEOS 25400	Intro to Numerical Techniques for Geophysical Sciences	100
GEOS 25460	Practical AI Methods in Data and Modeling for Weather and Climate	100
GEOS 25500	Scientific machine learning for climate and chaos	100
GEOS 26100	Phylogenetics and the Fossil Record	100
GEOS 26300	Invertebrate Paleobiology and Evolution	100
GEOS 26310	Quantitative Paleontology I: Specimen-Based Analysis of the Fossil Record	100
GEOS 28600	Earth and Planetary Surface Processes	100

LIST E-2: SOCIAL SCIENCES

Microeconomics Foundations

Students may take one of the following:

ECON 10000	Principles of Microeconomics	100
ECON 20000	The Elements of Economic Analysis I *	100
ECON 20100	The Elements of Economic Analysis II *	100
PBPL 20000	Economics for Public Policy	100
PPHA 32300	Principles of Microeconomics for Public Policy I *	100
PPHA 32400	Principles of Microeconomics for Public Policy II *	100

Other Social Science Electives

(Note that many courses below require microeconomics as a prerequisite)

ECON 10200	Principles of Macroeconomics	100
PBPL 23100	Environmental Law	100
PBPL 24701	U.S. Environmental Policy	100
PPHA 36930	Environmental Economics: Theory and Applications	100
PPHA 38900	Environmental Science/Policy	100

* Must be taken in sequence

LIST E-3: COMPUTATIONAL SCIENCES

Semester in Environmental Science/MBL

ENSC 28100	Quantitative Environmental Analyses # Marine Biological Laboratory *	100
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Mathematics

MATH 15300	Calculus III	100
or MATH 16300	Honors Calculus III	
MATH 15910	Introduction to Proofs in Analysis	100
or STAT 24300	Numerical Linear Algebra	
MATH 18300	Mathematical Methods in the Physical Sciences I	100
MATH 18400	Mathematical Methods in the Physical Sciences II	100
MATH 18500	Mathematical Methods in the Physical Sciences III	100
MATH 20300	Analysis in R^n I	100
MATH 20400	Analysis in R^n II	100
MATH 20500	Analysis in R^n III	100
MATH 21100	Basic Numerical Analysis	100
MATH 20250	Abstract Linear Algebra	100
BIOS 20152	Introduction to Quantitative Modeling in Biology (Advanced)	100
or BIOS 20151	Introduction to Quantitative Modeling in Biology	
BIOS 26210	Mathematical Methods for Biological Sciences I	100
BIOS 26211	Mathematical Methods for Biological Sciences II	100
BIOS 26405	Predictive Biology: Learning from Data in Microbiomes	100

Statistics

Students may take any course in statistics at the 22000 level or higher, but recommended courses are shown below. Some courses require one of the first three as a prerequisite.

Students may take one of the following:

PPHA 31200	Mathematical Statistics for Public Policy I ^{‡ ~ ^}	100
PPHA 31300	Mathematical Statistics for Public Policy II ^{‡ ~ ^}	100
STAT 22000	Statistical Methods and Applications ^{§§ ^}	100
STAT 23400	Statistical Models and Methods ^{‡‡ ^}	100
STAT 24400	Statistical Theory and Methods I [§]	100
STAT 24500	Statistical Theory and Methods II [§]	100
STAT 22400	Applied Regression Analysis	100
STAT 22600	Analysis of Categorical Data	100
STAT 26100	Time Dependent Data	100

PPHA 34600	Program Evaluation	100
The 30000 (and above) level courses listed below are a joint offering of the Department of Statistics and the Department of Public Health Sciences, and may be suitable for Environmental Science majors.		
STAT 31900	Introduction to Causal Inference	100
STAT 35800	Statistical Applications	100
STAT 36900	Applied Longitudinal Data Analysis	100
Computing		
CMSC 14100	Introduction to Computer Science I	100
CMSC 14200	Introduction to Computer Science II	100
CMSC 23710	Scientific Visualization	100
Geographic Information Systems		
GISC 28200	Spatial Analysis Methods in Geographic Information Systems	100
GISC 28300	Topics in Geographic Information Science	100
GISC 28702	Introduction to GIS and Spatial Analysis	100

* This course is part of the Semester in Environmental Science/Marine Biological Laboratory. Admission to the Semester in Environmental Science program is by application, which must be received by the MBL generally in March of the year preceding the start of the semester. Admissions decisions will generally be sent in April. Note that these courses start at the beginning of September, typically four weeks prior to the start of the College's Autumn Quarter and are completed by the end of Autumn Quarter. More information on the course content and the application process, and deadlines can be found at college.uchicago.edu/academics/semester-environmental-science. (<https://college.uchicago.edu/academics/semester-environmental-science/>)

‡ Must be taken as a sequence

~ PPHA 31200 and PPHA 31300 each count as 100 credits and can be taken individually.

‡‡ Higher programming component than STAT 22000

§ Recommended for advanced students. Must be taken as a sequence to be credited. STAT 24400-24500 have no prerequisite, but it is possible to take both STAT 23400 and STAT 24400-24500.

§§ AP credit for STAT 22000 does not count toward the major requirements. Students with AP credit for STAT 22000 should plan to take at least three other courses from List E-3: Computational Sciences, one of which must be under the heading of Statistics.

^ Students may only receive credit for one of these four courses.

LIST E-4: PHYSICAL AND BIOLOGICAL SCIENCES

Chemistry

CHEM 20100	Inorganic Chemistry	100
CHEM 20200	Organometallic Chemistry	100
CHEM 22000	Organic Chemistry I	100
CHEM 22100	Organic Chemistry II	100
CHEM 22200	Organic Chemistry III	100
CHEM 23300	Introduction to Chemical Biology *	100
CHEM 26100	Introductory Quantum Mechanics **	100
CHEM 26200	Thermodynamics	100
CHEM 26300	Chemical Kinetics and Dynamics	100

Biology and Ecology***

BIOS 20200	Introduction to Biochemistry	100
BIOS 23232	Ecology and Evolution in the Southwest	100
BIOS 23252	Field Ecology	100
BIOS 23254	Mammalian Ecology	100
BIOS 23258	Molecular Evolution I: Fundamentals and Principles	100
BIOS 23266	Evolutionary Adaptation	100
BIOS 23289	Marine Ecology	100
BIOS 23404	Reconstructing the Tree of Life: An Introduction to Phylogenetics	100
BIOS 23406	Biogeography	100
BIOS 25206	Fundamentals of Bacteriology	100

BIOS 26405	Predictive Biology: Learning from Data in Microbiomes	100
BIOS 27720	Microbiomes Across Environments [%]	100
BIOS 27723	Biodiversity and Genomics: Exploring the Marine Animal Diversity of Woods Hole Using Molecular Tools [%]	100
BIOS 27725	Biogeography and Distribution of Species [%]	100
Physics		
PHYS 12200	General Physics II [‡]	100
PHYS 12300 or PHYS 12400	General Physics III ^{‡ ^} General Physics III at MBL	100
PHYS 13200	Electricity and Magnetism	100
PHYS 13300	Waves, Optics, and Heat	100
PHYS 14200	Honors Electricity and Magnetism	100
PHYS 14300	Honors Waves, Optics, and Heat	100
PHYS 18500	Intermediate Mechanics	100
PHYS 22500	Intermediate Electricity and Magnetism I	100
PHYS 22600	Electronics	100
PHYS 22700	Intermediate Electricity and Magnetism II	100

* Enrollment in CHEM 23300 requires a grade of C or higher in CHEM 22200 or 23200

** Prerequisites include MATH 18500 and PHYS 13300

*** ENSC majors can take these courses without the BIOS prerequisites (20150-20151) unless they pursue a double major in biology. Students are expected to show competency in the mathematical modeling of biological phenomena covered in BIOS 20151.

‡ PHYS 13200-13300 or PHYS 14200-14300 are the preferred sequences. PHYS 12200-12300 is allowable on a case-by-case basis but may not provide adequate preparation to allow for enrollment in higher-level PHYS courses. Special petition to the department counselor is required for PHYS 12100-12200-12300 approval.

% This course is part of the Marine Biological Laboratory September Courses. For more information, see college.uchicago.edu/academics/mbi-september-courses/.

^ PHYS 12400 is part of the Marine Biological Laboratory Spring Quarter Program. For more information, see college.uchicago.edu/academics/spring-quarter-mbl/.

GRADING

Students majoring in Environmental Science must receive quality grades in all courses taken to meet requirements in the major.

HONORS

The BS degree with honors is awarded to students who meet the following requirements: (1) a GPA of 3.25 or higher in the major and of 3.0 or higher overall; (2) completion of a paper based on original research, supervised and approved by a faculty member in geophysical sciences; (3) an oral presentation of the thesis research. All theses will be examined by the supervisor and a second reader from the faculty. Manuscript drafts will generally be due in the sixth week of the quarter in which the student will graduate (fifth week in Summer Quarter), and final manuscripts and oral presentations in the eighth week (seventh week in Summer Quarter).

Students are strongly encouraged to reach out to potential faculty supervisors no later than their third year, since theses generally arise out of research projects already begun with faculty members. When a thesis topic is determined, students should notify the undergraduate adviser of their intent to complete a thesis and confirm their eligibility. ENSC 29700 Reading and Research in Environmental Science can be devoted to the preparation of the required paper; however, students using this course to meet a requirement in the major must take it for a quality grade.

Students who wish to submit a single paper to meet the honors requirement in Environmental Science and the BA paper requirement in another major should discuss their proposals with the undergraduate advisers from both programs no later than the end of third year. Certain requirements must be met. A consent form, to be signed by the undergraduate advisers, is available from the College adviser. It must be completed and returned to the College adviser by the end of Autumn Quarter of the student's year of graduation.

SAMPLE BS PROGRAMS

Each student will design an individual plan of course work, choosing from a wide range of selections that take advantage of rich offerings from a variety of subdisciplines. The sample programs that appear below

are merely for the purpose of illustration; many other variations would be possible. NOTE: Courses that meet general education requirements and are required for the major are not listed.

Environmental Geochemistry

ENSC 23820	Biogeochemical Analysis in Terrestrial and Aquatic Ecosystems # Marine Biological Laboratory	100
ENSC 28100	Quantitative Environmental Analyses # Marine Biological Laboratory	100
ENSC 29800	Independent Undergraduate Research in Environmental Sciences Marine Biological Laboratory	100
BIOS 20200	Introduction to Biochemistry	100
BIOS 26210	Mathematical Methods for Biological Sciences I	100
BIOS 26211	Mathematical Methods for Biological Sciences II	100
CHEM 22000	Organic Chemistry I	100
CHEM 22100	Organic Chemistry II	100
PBPL 20000	Economics for Public Policy	100
STAT 22000	Statistical Methods and Applications	100

Environmental Microbiology

ENSC 23820	Biogeochemical Analysis in Terrestrial and Aquatic Ecosystems # Marine Biological Laboratory	100
ENSC 24000	Geobiology	100
ENSC 24100	Ecology - Marine Biological Laboratory	100
ENSC 24200	Methods in Microbial Ecology - Marine Biological Laboratory	100
ENSC 24500	Environmental Microbiology	100
ENSC 29800	Independent Undergraduate Research in Environmental Sciences Marine Biological Laboratory	100
BIOS 23404	Reconstructing the Tree of Life: An Introduction to Phylogenetics	100
BIOS 25206	Fundamentals of Bacteriology	100
BIOS 26210	Mathematical Methods for Biological Sciences I	100
BIOS 26211	Mathematical Methods for Biological Sciences II	100
PBPL 20000	Economics for Public Policy	100
STAT 22000	Statistical Methods and Applications	100

Environmental Science and Public Policy

ENSC 21100	Energy: Science, Technology, and Human Usage	100
ENSC 29002	Field Course in Modern and Ancient Environments	100
BIOS 23406	Biogeography	100
PPHA 32300	Principles of Microeconomics for Public Policy I	100
PPHA 32400	Principles of Microeconomics for Public Policy II	100
STAT 22400	Applied Regression Analysis	100

ENVIRONMENTAL SCIENCE COURSES

ENSC 13300. The Atmosphere. 100 Units.

This course introduces the physics, chemistry, and phenomenology of the Earth's atmosphere, with an emphasis on the fundamental science that underlies atmospheric behavior and climate. Topics include (1) atmospheric composition, evolution, and structure; (2) solar and terrestrial radiation in the atmospheric energy balance; (3) the role of water in determining atmospheric structure; and (4) wind systems, including the global circulation, and weather systems. Preference will be given to Geosci and Environmental Sci majors/prospective majors. If you are a prospective major, please include this information in your consent request.

Instructor(s): T. Shaw; N. Nakamura, P. Hassanzadeh
Terms Offered: Spring

Prerequisite(s): MATH 13100-MATH 13200

Equivalent Course(s): GEOS 13300

ENSC 13400. Global Warming: Understanding the Forecast. 100 Units.

The future of human civilization depends on its ability to avoid, or adapt to, climate change associated with fossil-fuel (carbon) emissions. With so much at stake, it is important that citizens of the world understand the science which forms the foundation of what is understood about global climate change. The learning objectives of this course are to develop understanding of: (1) the historical and pre-historical records of global climate change, (2) the Earth's carbon budget, (3) how the greenhouse effect determines temperature in Earth's atmosphere and at the land and sea surface, (4) how climate projections are made, and (5) how present-day activities, both in the scientific research realm and in the socio-economic/political realm are shaping what will happen in the future.

Course activity is partitioned into lectures (given by the course instructor), weekly laboratory-section activity (run by graduate teaching assistants), outside reading, and occasional homework. Assessment leading to a course grade will focus primarily on student performance in completing laboratory exercises and on a midterm and final exam. (L)

Instructor(s): D. MacAyeal Terms Offered: Autumn

Equivalent Course(s): PHSC 13400, GEOS 13400

ENSC 13410. Global Warming: Understanding the Forecast (Flipped Class) 100 Units.

This course presents the science behind the forecast of global warming to enable the student to evaluate the likelihood and potential severity of anthropogenic climate change in the coming centuries. It includes an overview of the physics of the greenhouse effect, including comparisons with Venus and Mars; predictions and reliability of climate model forecasts of the greenhouse world. This course is part of the College Course Cluster program, Climate Change, Culture, and Society. This course covers the same material as PHSC 13400, but is organized using a flipped classroom approach in order to increase student engagement and learning.

Instructor(s): D. Abbot Terms Offered: Autumn Spring

Prerequisite(s): Some knowledge of chemistry or physics helpful.

Equivalent Course(s): GEOS 13410, PHSC 13410

ENSC 21100. Energy: Science, Technology, and Human Usage. 100 Units.

This course covers the technologies by which humans appropriate energy for industrial and societal use, from steam turbines to internal combustion engines to photovoltaics. We also discuss the physics and economics of the resulting human energy system: fuel sources and relationship to energy flows in the Earth system; and modeling and simulation of energy production and use. Our goal is to provide a technical foundation for students interested in careers in the energy industry or in energy policy. Field trips required to major energy converters (e.g., coal-fired and nuclear power plants, oil refinery, biogas digester) and users (e.g., steel, fertilizer production). This course is part of the College Course Cluster program: Climate Change, Culture and Society.

Instructor(s): E. Moyer Terms Offered: Spring

Prerequisite(s): Completion of General Education Physical Sciences Sequence (physics is most relevant) and 2 Quarters of Calculus is recommended.

Equivalent Course(s): CEGU 24705, GEOS 24705, CCSG 20500, GEOS 34705

ENSC 23600. Chemical Oceanography. 100 Units.

This course explores the chemistry of the ocean system and its variations in space and time. The oceans play an essential role in most (bio)geochemical cycles, interacting in various ways with the atmosphere, sediments, and crust. These interactions can be understood through studying the geochemical and isotopic properties of the ocean, its inputs and outputs, and its evolution as recorded in marine sediments and sedimentary rocks. Topics include: the marine carbon cycle, nutrient cycling, chemical sediments, and hydrothermal systems.

Instructor(s): C. Blättler Terms Offered: Spring

Prerequisite(s): Completion of one of the following Chemistry Sequences: CHEM 10100-10200-11300 Introductory General Chemistry I-II; Comprehensive General Chemistry III or CHEM 11100-11200-11300 Comprehensive General Chemistry I-II-III or CHEM 12100-12200-12300 Honors General Chemistry I-II-III AND either GEOS 13100 or GEOS 13200.

Equivalent Course(s): GEOS 33600, GEOS 23600, CHEM 13600

ENSC 23800. Global Biogeochemical Cycles. 100 Units.

This survey course covers the geochemistry of the surface of the Earth, focusing on biological and geological processes that shape the distributions of chemical species in the atmosphere, oceans, and terrestrial habitats. Budgets and cycles of carbon, nitrogen, oxygen, phosphorous, and sulfur are discussed, as well as chemical fundamentals of metabolism, weathering, acid-base and dissolution equilibria, and isotopic fractionation. The course examines the central role that life plays in maintaining the chemical disequilibria that characterize Earth's surface environments. The course also explores biogeochemical cycles change (or resist change) over time, as well as the relationships between geochemistry, biological (including human) activity, and Earth's climate.

Instructor(s): J. Waldbauer Terms Offered: Spring

Prerequisite(s): CHEM 11100-11200 or consent of instructor

Equivalent Course(s): GEOS 33800, GEOS 23800

ENSC 23820. Biogeochemical Analysis in Terrestrial and Aquatic Ecosystems # Marine Biological Laboratory. 100 Units.

This course examines the interface of biological processes with chemical processes in ecological systems. Course content emphasizes aquatic chemistry and the role of microbes in the cycling of nitrogen, carbon, and other elements. Effects of global changes on chemical cycling are emphasized.

Instructor(s): Marine Biological Laboratory Staff. Terms Offered: Autumn. L.

Prerequisite(s): Consent only. Admission by application to the Semester in Environmental Science program at the Marine Biological Laboratory in Woods Hole, MA; concurrent registration in BIOS 27710 and BIOS 27712 along with one of BIOS 27713, BIOS 27714 or BIOS 27715.

Note(s): E.

Equivalent Course(s): BIOS 27711

ENSC 23900. Environmental Chemistry. 100 Units.

The focus of this course is the fundamental science underlying issues of local and regional scale pollution. In particular, the lifetimes of important pollutants in the air, water, and soils are examined by considering the roles played by photochemistry, surface chemistry, biological processes, and dispersal into the surrounding environment. Specific topics include urban air quality, water quality, long-lived organic toxins, heavy metals, and indoor air pollution. Control measures are also considered. This course is part of the College Course Cluster program: Climate Change, Culture, and Society.

Instructor(s): C. Blättler Terms Offered: Autumn

Prerequisite(s): CHEM 11100-11200 or equivalent, and prior calculus course

Equivalent Course(s): GEOS 23900, GEOS 33900

ENSC 24000. Geobiology. 100 Units.

Geobiology seeks to elucidate the interactions between life and its environments that have shaped the coevolution of the Earth and the biosphere. The course will explore the ways in which biological processes affect the environment and how the evolutionary trajectories of organisms have in turn been influenced by environmental change. In order to reconstruct the history of these processes, we will examine the imprints they leave on both the rock record and on the genomic makeup of living organisms. The metabolism and evolution of microorganisms, and the biogeochemistry they drive, will be a major emphasis.

Instructor(s): M. Coleman, J. Waldbauer

Prerequisite(s): GEOS 13100-13200-13300 or college-level cell & molecular biology

Equivalent Course(s): GEOS 36600, GEOS 26600

ENSC 24100. Ecology - Marine Biological Laboratory. 100 Units.

This course examines the structure and functioning of terrestrial and aquatic ecosystems including the application of basic principles of community and ecosystem ecology. The course also examines contemporary environmental problems such as the impacts of global and local environmental change on community composition and food webs within forest, grassland, marsh and nearshore coastal ecosystems on Cape Cod. This course examines the structure and functioning of terrestrial and aquatic ecosystems including the application of basic principles of community and ecosystem ecology. The course also examines contemporary environmental problems such as the impacts of global and local environmental change on community composition and food webs within forest, grassland, marsh and nearshore coastal ecosystems on Cape Cod.

Instructor(s): Marine Biological Laboratory Staff Terms Offered: Autumn. L.

Prerequisite(s): Consent only. Admission by application to the Semester in Environmental Science program at the Marine Biological Laboratory in Woods Hole, MA; concurrent registration in BIOS 27711 and BIOS 27712 along with one of BIOS 27713, BIOS 27714 or BIOS 27715.

Note(s): E.

Equivalent Course(s): BIOS 27710

ENSC 24200. Methods in Microbial Ecology - Marine Biological Laboratory. 100 Units.

This course explores the biology of microbes found in the environment, including relationships with the physical, chemical, and biotic elements of their environment. Emphasis is placed on understanding the science underlying the various methodologies used in the study of these organisms and systems. In the laboratory, students will work with the latest techniques to measure microbial biomass, activity, extracellular enzymes, and biogeochemical processes. Students are also introduced to molecular methods for assessing microbial genomic diversity.

Instructor(s): Marine Biological Laboratory Staff Terms Offered: Autumn. L.

Prerequisite(s): Consent only. Admission by application to the Semester in Environmental Science program at the Marine Biological Laboratory in Woods Hole, MA; concurrent registration in BIOS 27710, BIOS 27711 and BIOS 27712.

Note(s): E.

Equivalent Course(s): BIOS 27714

ENSC 24400. Ecology and Conservation. 100 Units.

This course focuses on the contribution of ecological theory to the understanding of current issues in conservation biology. We emphasize quantitative methods and their use for applied problems in ecology (e.g., risk of extinction, impact of harvesting, role of species interaction, analysis of global change). Course material is drawn mostly from current primary literature; lab and field components complement concepts taught through lecture.

Instructor(s): Autumn: C. Pfister, E. Larsen. Spring: L. Carley, E. Larsen Terms Offered: Autumn Spring. L.

Prerequisite(s): Overnight field trip required.

Equivalent Course(s): BIOS 20196

ENSC 24450. Marine Resource Use and Conservation- at Marine Biological Laboratory. 100 Units.

Students will learn about coastal and marine resource use and examine threats to ecosystem biodiversity and conservation exploring examples in the Cape Cod region and discussing global case studies. The course will review various methods and uses of aquaculture and mariculture for promoting the blue economy, their potential consequences, but also potential to mitigate climate change and nutrient pollution. We will also review the role of restoration in promoting ecosystem recovery and conservation. Field trips will include visits to local shellfish and finfish hatcheries, ongoing restoration projects, and conservation organizations. The course is organized

into focused two- to four-day modules that include lectures, discussions of papers, field trips, and field and lab activities.

Instructor(s): MBL SES Staff Terms Offered: Autumn. Offered as part of the Semester in Environmental Science (SES) at MBL in Woods Hole, MA

Prerequisite(s): Consent only. Admission by application to the Semester in Environmental Science program at the Marine Biological Laboratory in Woods Hole, MA

Equivalent Course(s): BIOS 27717

ENSC 24500. Environmental Microbiology. 100 Units.

The objective of this course is to understand how microorganisms alter the geochemistry of their environment. The course will cover fundamental principles of microbial growth, metabolism, genetics, diversity, and ecology, as well as methods used to study microbial communities and activities. It will emphasize microbial roles in elemental cycling, bioremediation, climate, and ecosystem health in a variety of environments including aquatic, soil, sediment, and engineered systems.

Instructor(s): M. Coleman Terms Offered: Autumn

Prerequisite(s): CHEM 11100-11200 and BIOS 20186, BIOS 20197, or BIOS 20198

Equivalent Course(s): GEOS 26650, GEOS 36650

ENSC 24550. Global Change Microbiology. 100 Units.

This course will examine the fundamental ecophysiological and evolutionary mechanisms that govern how microbes respond to global change across diverse ecosystems. Emphasis will be placed on adaptive and non-adaptive responses across levels of biological organization - from genes and cells to populations and ecosystems - under individual and compounded climate stressors. Lectures will introduce and synthesize advanced concepts in microbial ecophysiology and biogeochemistry, providing the foundation for linking microbial processes to ecosystem-scale feedbacks. Class discussions will center on primary literature that investigates the interplay between climatic factors and microbial community dynamics.

Instructor(s): L. Reji

Prerequisite(s): GEOS 26650/36650, ENSC 24500, or consent of the instructor

Equivalent Course(s): GEOS 26700, GEOS 36660

ENSC 24600. Marine Ecosystems: From Microbiomes, to Conservation, Climate & Beyond. 100 Units.

This course is designed for rising 2nd years with interests in microbiology, the environment, and society. More specifically, the course is designed for students considering a science major, as well as non-majors, who are looking for broad exposure to geosciences, environmental and climate science, microbiology, molecular biology, and the intersection between society and science. Students will study coastal marine habitats, connectivity to ocean and climate, dynamics of microbial community structure, and marine conservation alongside gaining experience on laboratory microbiome science and environmental field work. Students will gain firsthand experience with the types of microbes that influence climate and that impact health through laboratory experiments on culturing and analyzing microbes in 'pristine' and highly impacted coastal ecosystems. Methods to be learned include plating, epifluorescence microscopy, flow cytometry, DNA extraction, and sequencing. Lectures will cover marine microbiology, CO₂ sequestration (natural and engineered), geochemistry, coastal and open ocean habitat structure, and links to climate and the climate crisis. We will also address equity issues in marine conservation and the climate crisis. While all field work will be coastal, students will also learn about the open ocean due to the key linkages of water masses as well as climate feedback.

Instructor(s): A. Worden Terms Offered: Summer. L. September term. This course will be given at Marine Biological Laboratories, Woods Hole, Massachusetts. E.

Equivalent Course(s): BIOS 27726

ENSC 24800. Climate Systems Engineering. 100 Units.

How might humans use geoscience and engineering to intervene in the climate system with the goal of limiting the impacts of historical carbon emissions? Climate Systems Engineering is the intersection of Climate Systems Science and Systems Engineering. Topics will include (1) solar geoengineering with a focus on stratospheric aerosols, (2) open-system carbon removal such as the addition of alkalinity to soils or directly to the ocean, and (3) local interventions to reduce glacial melting; along with crosscuts on (4) systems engineering and (5) policy implications. Foundational knowledge of climate-related geoscience is a required prerequisite. About a third of class time will be devoted to student presentations and discussion. Class work includes problem sets, peer-graded technical micro-essays, and a collaborative project.

Instructor(s): D. Keith Terms Offered: Autumn

Prerequisite(s): GEOS 13300 The Atmosphere is required. GEOS 24220 Climate Foundations is strongly recommended.

Equivalent Course(s): GEOS 24800, GEOS 34800

ENSC 25100. Methods and Concepts in Oceanography- at Marine Biological Laboratory. 100 Units.

This immersive course provides students with a thorough introduction to the core methodologies and concepts in oceanographic research. Over a 10-week period, with 3 hours of class each week, students will explore the dynamic systems that shape our oceans and the cutting-edge techniques used to study them. The course combines engaging lectures, hands-on laboratory work, and field work aboard a coastal research vessel to offer a comprehensive introduction to biological oceanography, physical oceanography, biogeochemistry, marine ecology, and the ever-changing nature of our oceans. Students will gain practical experience in key

laboratory, field, and ship-board oceanographic techniques, including microscopy, molecular methods like PCR and sequencing, ocean sampling methods such as water column profiling using CTD casts and Niskin bottle grabs, and sediment grabs. Additionally, they will delve into the physical processes that drive ocean circulation, major oceanographic features, the role of primary and secondary production and the microbial loop in marine ecosystems, and the impact of climate change and human activities on ocean health. Throughout the course, students will actively participate in discussions, lab work, and field activities. They will be evaluated based on their engagement, performance in practical sessions, quizzes, and a final project report that synthesizes their learning and research findings.

Instructor(s): Marine Biological Laboratory Staff Terms Offered: Autumn. Offered as part of the Semester in Environmental Science (SES) at MBL in Woods Hole, MA. E.

Prerequisite(s): Consent only. Admission by application to the Semester in Environmental Science program at the Marine Biological Laboratory in Woods Hole, MA; concurrent registration in BIOS 27710, BIOS 27711 and BIOS 27712.

Equivalent Course(s): BIOS 27716

ENSC 25500. Coastal Watersheds. 100 Units.

Estuarine ecosystems are strongly influenced by terrestrial inputs, and changes in the quantity and quality of water flowing from land into these ecosystems are altering their function. This course examines how human activities on land alter flow of water and water-borne materials from coastal watersheds to adjoining estuaries. Field work focusing on local watershed-estuary systems will explore how changes in land use have increased nutrient inputs to Cape Cod estuaries, and how the estuarine ecosystems have changed as a consequence. Activities will include sampling of groundwater and surface water; laboratory analyses of nutrient content and other parameters that help diagnose human impacts; and estimation of nutrient input rates (using field-based calculations as well modeling techniques) to different estuaries. This course fosters fundamental understanding of principles in watershed hydrology and biogeochemistry as well as advanced exploration of coupling between terrestrial and aquatic systems.

Instructor(s): Marine Biological Laboratory Staff Terms Offered: Autumn. Offered as part of the Semester in Environmental Science (SES) at MBL in Woods Hole, MA. E.

Prerequisite(s): Consent only. Admission by application to the Semester in Environmental Science program at the Marine Biological Laboratory in Woods Hole, MA;

ENSC 28100. Quantitative Environmental Analyses # Marine Biological Laboratory. 100 Units.

This course emphasizes the application of quantitative methods to answering ecological questions. Students apply mathematical modeling approaches to simulating biological and chemical phenomena in terrestrial and marine ecosystems.

Instructor(s): Marine Biological Laboratory Staff Terms Offered: Autumn. L.

Prerequisite(s): Consent Only. Admission by application to the Semester in Environmental Science program at the Marine Biological Laboratory in Woods Hole, MA; concurrent registration in BIOS 27710, BIOS 27711 and BIOS 27712.

Note(s): E.

Equivalent Course(s): BIOS 27713

ENSC 29002. Field Course in Modern and Ancient Environments. 100 Units.

This course, in its many iterations, has had consistent aims: to provide students with hands-on experience of the processes that produce sedimentary rocks, exposure to standard field methods and fieldwork safety, and experience in developing and conducting an original research project. We consider biological as well as physical processes of sediment production, dispersal, accumulation, and post-depositional modification, and methods of paleoenvironmental analysis. We give significant attention to humans as geological agents: field areas today almost always exhibit legacy and/or ongoing effects from human activities. This year we explore the theme of Coasts and Coastal Resilience, using Lake Michigan shorelines as exemplars of coastal responses to key forcings - water (wave) regime, water level, and sediment supply - on societally relevant time scales. The spectrum of environments will include built structures such as seawalls, jetties, and hardened shorelines, and both natural and engineered "soft" shorelines. We will meet on Tuesdays and Thursdays 3:30-5:00, with approximately half devoted to lectures and discussion, and the other half to labs, which will be either indoors (using research wave tanks in Hinds) or outdoors (using nearby segments of the Lake Michigan shoreline). A day-long Saturday field excursion is also possible.

Instructor(s): S. Kidwell Terms Offered: Spring

Prerequisite(s): GEOS 13100 and 13200 recommended; contact instructor

Equivalent Course(s): GEOS 29002, CHST 29002

ENSC 29700. Reading and Research in Environmental Science. 100 Units.

Independent study; regular meetings with Geophysical Sciences faculty member required. Register by section corresponding to faculty supervisor.

Terms Offered: Autumn Spring Summer Winter

Prerequisite(s): Consent of instructor and departmental counselor

Note(s): Students are required to submit the College Reading and Research Course Form. Available to nonmajors for P/F grading. Must be taken for a quality grade when used to meet a requirement in the major.

ENSC 29800. Independent Undergraduate Research in Environmental Sciences Marine Biological Laboratory. 100 Units.

This course is the culmination of the Semester in Environmental Science at the Marine Biological Laboratory. An independent research project, on a topic in aquatic or terrestrial ecosystem ecology, is required. Students will participate in a seminar for scientific communication as well as submit a final paper on their project.

Instructor(s): Marine Biological Laboratory Staff Terms Offered: Autumn. L.

Prerequisite(s): Consent only. Admission by application to the Semester in Environmental Science program at the Marine Biological Laboratory in Woods Hole, MA; concurrent registration in BIOS 27710 and BIOS 27711 along with one of BIOS 27713 or BIOS 27714.

Note(s): E.

Equivalent Course(s): BIOS 27712

