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 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/theschool/economics/), Public Policy Studies (http://collegecatalog.uchicago.edu/theschool/publicpolicystudies/), and Environmental and Urban Studies (http://collegecatalog.uchicago.edu/theschool/environmentalstudies/), 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 13000 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

<table>
<thead>
<tr>
<th>CHEM 10100</th>
<th>&amp;</th>
<th>CHEM 10200</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 10100</td>
<td>Introductory General Chemistry I</td>
<td>AND</td>
</tr>
</tbody>
</table>

One of the following sequences: 200

<table>
<thead>
<tr>
<th>CHEM 11100-11200</th>
<th>CHEM 12100</th>
<th>&amp;</th>
<th>CHEM 12200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comprehensive General Chemistry I-II</td>
<td>Honors General Chemistry I</td>
<td>AND</td>
<td>Honors General Chemistry II</td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Units</td>
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</tr>
<tr>
<td>-------------------</td>
<td>--------------------------------------------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>MATH 13100-13200</td>
<td>Elementary Functions and Calculus I-II *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATH 15100-15200</td>
<td>Calculus I-II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATH 16100-16200</td>
<td>Honors Calculus I-II</td>
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</tr>
<tr>
<td>Both of the following: **</td>
<td>200</td>
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<tr>
<td>BIOS 20198</td>
<td>Biodiversity</td>
<td></td>
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<tr>
<td>GEOS 27300</td>
<td>Biological Evolution-Advanced %</td>
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</tr>
<tr>
<td>Total Units</td>
<td>Total Units</td>
<td>600</td>
<td></td>
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</table>

**MAJOR**

<table>
<thead>
<tr>
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<th>Course Title</th>
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<tbody>
<tr>
<td>ENSC 13300</td>
<td>The Atmosphere</td>
<td>100</td>
</tr>
<tr>
<td>ENSC 23800</td>
<td>Global Biogeochemical Cycles</td>
<td>100</td>
</tr>
<tr>
<td>ENSC 23900</td>
<td>Environmental Chemistry</td>
<td>100</td>
</tr>
<tr>
<td>ENSC 24400</td>
<td>Ecology and Conservation</td>
<td>100</td>
</tr>
<tr>
<td>CHEM 11300</td>
<td>Comprehensive General Chemistry III *</td>
<td>100</td>
</tr>
<tr>
<td>or CHEM 12300</td>
<td>Honors General Chemistry III</td>
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</tr>
<tr>
<td>One of the following:</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>PHYS 12100</td>
<td>General Physics I ‡</td>
<td></td>
</tr>
<tr>
<td>PHYS 13100</td>
<td>Mechanics</td>
<td></td>
</tr>
<tr>
<td>PHYS 14100</td>
<td>Honors Mechanics</td>
<td></td>
</tr>
<tr>
<td>One of the following:</td>
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<tr>
<td>MATH 18300</td>
<td>Mathematical Methods in the Physical Sciences I</td>
<td></td>
</tr>
<tr>
<td>MATH 20250</td>
<td>Abstract Linear Algebra</td>
<td></td>
</tr>
<tr>
<td>BIOS 20152</td>
<td>Introduction to Quantitative Modeling in Biology (Advanced)</td>
<td></td>
</tr>
<tr>
<td>or BIOS 20151</td>
<td>Introduction to Quantitative Modeling in Biology</td>
<td></td>
</tr>
<tr>
<td>MATH 13300</td>
<td>Elementary Functions and Calculus III *</td>
<td></td>
</tr>
<tr>
<td>MATH 15300</td>
<td>Calculus III</td>
<td></td>
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<tr>
<td>MATH 16300</td>
<td>Honors Calculus III</td>
<td></td>
</tr>
</tbody>
</table>

Eleven electives as follows: 1100

- Four courses designated ENSC or GEOS from List E-1: Physical and Biological 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, 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: Physical and Biological Sciences**

**Environmental Science**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>ENSC 21100</td>
<td>Energy: Science, Technology, and Human Usage</td>
<td>100</td>
</tr>
<tr>
<td>ENSC 23600</td>
<td>Chemical Oceanography</td>
<td>100</td>
</tr>
<tr>
<td>ENSC 23820</td>
<td>Biogeochemical Analysis in Terrestrial and Aquatic Ecosystems # Marine Biological Laboratory @</td>
<td>100</td>
</tr>
<tr>
<td>ENSC 24000</td>
<td>Geobiology</td>
<td>100</td>
</tr>
</tbody>
</table>
ENSC 24100 Ecology - Marine Biological Laboratory  
ENSC 24200 Methods in Microbial Ecology - Marine Biological Laboratory  
or ENSC 24500 Environmental Microbiology  
ENSC 24300 Roles of Animals in Ecosystems # Marine Biological Laboratory  
ENSC 25000 Biological Oceanography  
ENSC 28100 Quantitative Environmental Analyses # Marine Biological Laboratory  
ENSC 29700 Reading and Research in Environmental Science  
ENSC 29800 Independent Undergraduate Research in Environmental Sciences Marine Biological Laboratory  

* 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.  

^ This course is part of the Marine Biological Laboratory Spring Quarter Program. For more information, see 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  

Geophysical Sciences

GEOS 21000 Mineralogy  
GEOS 21400 Thermodynamics and Phase Change  
GEOS 22060 What Makes a Planet Habitable?  
GEOS 22200 Geochronology  
GEOS 22700 Analytical Techniques in Geochemistry  
GEOS 23205 Introductory Glaciology  
GEOS 24220 Climate Foundations  
GEOS 24230 Geophysical Fluid Dynamics: Foundations  
GEOS 24240 Geophysical Fluid Dynamics: Rotation and Stratification  
GEOS 24250 Geophysical Fluid Dynamics: Understanding the Motions of the Atmosphere and Oceans  
GEOS 24300 Paleoclimatology  
GEOS 25400 Intro to Numerical Techniques for Geophysical Sciences  
GEOS 26100 Phylogenetics and the Fossil Record  
GEOS 26300 Invertebrate Paleobiology and Evolution  
GEOS 28600 Earth and Planetary Surface Processes  

Chemistry

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

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>BIOS 20200</td>
<td>Introduction to Biochemistry</td>
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<tr>
<td>BIOS 23232</td>
<td>Ecology and Evolution in the Southwest</td>
<td>100</td>
</tr>
<tr>
<td>BIOS 23252</td>
<td>Field Ecology</td>
<td>100</td>
</tr>
<tr>
<td>BIOS 23254</td>
<td>Mammalian Ecology</td>
<td>100</td>
</tr>
<tr>
<td>BIOS 23258</td>
<td>Molecular Evolution I: Fundamentals and Principles</td>
<td>100</td>
</tr>
<tr>
<td>BIOS 23266</td>
<td>Evolutionary Adaptation</td>
<td>100</td>
</tr>
<tr>
<td>BIOS 23289</td>
<td>Marine Ecology</td>
<td>100</td>
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<tr>
<td>BIOS 23404</td>
<td>Reconstructing the Tree of Life: An Introduction to Phylogenetics</td>
<td>100</td>
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<tr>
<td>BIOS 23406</td>
<td>Biogeography</td>
<td>100</td>
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<tr>
<td>BIOS 25206</td>
<td>Fundamentals of Bacteria</td>
<td>100</td>
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<tr>
<td>BIOS 27720</td>
<td>Microbiomes Across Environments</td>
<td>100</td>
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<tr>
<td>BIOS 27723</td>
<td>Biodiversity and Genomics: Exploring the Marine Animal Diversity of Woods Hole Using Molecular Tools</td>
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</tr>
<tr>
<td>BIOS 27725</td>
<td>Biogeography and Distribution of Species %</td>
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### Physics

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>PHYS 12200</td>
<td>General Physics II ‡</td>
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<tr>
<td>PHYS 12300</td>
<td>General Physics III ‡</td>
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<tr>
<td>or PHYS 12400</td>
<td>General Physics III at MBL</td>
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</tr>
<tr>
<td>PHYS 13200</td>
<td>Electricity and Magnetism</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 13300</td>
<td>Waves, Optics, and Heat</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 14200</td>
<td>Honors Electricity and Magnetism</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 14300</td>
<td>Honors Waves, Optics, and Heat</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 18500</td>
<td>Intermediate Mechanics</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 22500</td>
<td>Intermediate Electricity and Magnetism I</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 22600</td>
<td>Electronics</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 22700</td>
<td>Intermediate Electricity and Magnetism II</td>
<td>100</td>
</tr>
</tbody>
</table>

* 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/mbl-september-courses (https://college.uchicago.edu/academics/mbl-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 (https://college.uchicago.edu/academics/spring-quarter-mbl/).

### List E-2: Social Sciences

#### Microeconomics Foundations

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>ECON 10000</td>
<td>Principles of Microeconomics</td>
<td>100</td>
</tr>
<tr>
<td>ECON 20000</td>
<td>The Elements of Economic Analysis I ^</td>
<td>100</td>
</tr>
<tr>
<td>ECON 20100</td>
<td>The Elements of Economic Analysis II ^</td>
<td>100</td>
</tr>
<tr>
<td>PBPL 20000</td>
<td>Economics for Public Policy</td>
<td>100</td>
</tr>
<tr>
<td>PP HA 32300</td>
<td>Principles of Microeconomics and Public Policy I ^</td>
<td>100</td>
</tr>
<tr>
<td>PP HA 32400</td>
<td>Principles of Microeconomics and Public Policy II ^</td>
<td>100</td>
</tr>
</tbody>
</table>

Other Social Science Electives

(Note that many courses below require microeconomics as a prerequisite)
ECON 10200  Principles of Macroeconomics  100  
ENST 23550  Urban Ecology and the Nature of Cities  100  
ENST 24102  Environmental Politics  100  
ENST 28220  Global Energy & Climate Challenge: Economics, Science & Policy  100  
PBPL 23100  Environmental Law  100  
PBPL 24701  U.S. Environmental Policy  100  
PBPL 26530  Environment, Agriculture, and Food: Economic and Policy Analysis  100  
PPHA 36921  Energy Economics and 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

**Mathematics**

<table>
<thead>
<tr>
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<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
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<td>MATH 15300</td>
<td>Calculus III</td>
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<td>or MATH 16300</td>
<td>Honors Calculus III</td>
<td>100</td>
</tr>
<tr>
<td>MATH 15910</td>
<td>Introduction to Proofs in Analysis</td>
<td>100</td>
</tr>
<tr>
<td>or STAT 24300</td>
<td>Numerical Linear Algebra</td>
<td>100</td>
</tr>
<tr>
<td>MATH 18300</td>
<td>Mathematical Methods in the Physical Sciences I</td>
<td>100</td>
</tr>
<tr>
<td>MATH 18400</td>
<td>Mathematical Methods in the Physical Sciences II</td>
<td>100</td>
</tr>
<tr>
<td>MATH 18500</td>
<td>Mathematical Methods in the Physical Sciences III</td>
<td>100</td>
</tr>
<tr>
<td>MATH 20300</td>
<td>Analysis in Rn I</td>
<td>100</td>
</tr>
<tr>
<td>MATH 20400</td>
<td>Analysis in Rn II</td>
<td>100</td>
</tr>
<tr>
<td>MATH 20500</td>
<td>Analysis in Rn III</td>
<td>100</td>
</tr>
<tr>
<td>MATH 21100</td>
<td>Basic Numerical Analysis</td>
<td>100</td>
</tr>
<tr>
<td>MATH 20250</td>
<td>Abstract Linear Algebra</td>
<td>100</td>
</tr>
<tr>
<td>BIOS 20152</td>
<td>Introduction to Quantitative Modeling in Biology (Advanced)</td>
<td>100</td>
</tr>
<tr>
<td>or BIOS 20151</td>
<td>Introduction to Quantitative Modeling in Biology</td>
<td>100</td>
</tr>
<tr>
<td>BIOS 26210</td>
<td>Mathematical Methods for Biological Sciences I</td>
<td>100</td>
</tr>
<tr>
<td>BIOS 26211</td>
<td>Mathematical Methods for Biological Sciences II</td>
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</table>

**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:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>PPHA 31200</td>
<td>Mathematical Statistics for Public Policy I</td>
<td>100</td>
</tr>
<tr>
<td>PPHA 31300</td>
<td>Mathematical Statistics for Public Policy II</td>
<td>100</td>
</tr>
<tr>
<td>STAT 22000</td>
<td>Statistical Methods and Applications</td>
<td>100</td>
</tr>
<tr>
<td>STAT 23400</td>
<td>Statistical Models and Methods</td>
<td>100</td>
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<tr>
<td>STAT 24400</td>
<td>Statistical Theory and Methods I</td>
<td>100</td>
</tr>
<tr>
<td>STAT 24500</td>
<td>Statistical Theory and Methods II</td>
<td>100</td>
</tr>
<tr>
<td>STAT 22400</td>
<td>Applied Regression Analysis</td>
<td>100</td>
</tr>
<tr>
<td>STAT 22600</td>
<td>Analysis of Categorical Data</td>
<td>100</td>
</tr>
<tr>
<td>STAT 26100</td>
<td>Time Dependent Data</td>
<td>100</td>
</tr>
<tr>
<td>PPHA 34600</td>
<td>Program Evaluation</td>
<td>100</td>
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</table>

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.

<table>
<thead>
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<tr>
<td>STAT 31900</td>
<td>Introduction to Causal Inference</td>
<td>100</td>
</tr>
<tr>
<td>STAT 35800</td>
<td>Statistical Applications</td>
<td>100</td>
</tr>
<tr>
<td>STAT 36900</td>
<td>Applied Longitudinal Data Analysis</td>
<td>100</td>
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</tbody>
</table>
Environmental Science

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.

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
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 Bacteria 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
ENST 21800 Economics and Environmental Policy 100
PPHA 32300 Principles of Microeconomics and Public Policy I 100
PPHA 32400 Principles of Microeconomics and 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.
Instructor(s): T. Shaw; N. Nakamura Terms Offered: Spring
Prerequisite(s): MATH 13100-MATH 13200
Equivalent Course(s): ENST 13300, 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, ENST 12300, 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
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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, ENST 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): Knowledge of physics or consent of instructor
Equivalent Course(s): GEOS 24705, GEOS 34705, ENST 24705, CEGU 24705

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 23600

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 23800, GEOS 33800

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): D. Archer Terms Offered: Autumn
Prerequisite(s): CHEM 11100-11200 or equivalent, and prior calculus course
Equivalent Course(s): GEOS 23900, ENST 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
Equivalent Course(s): GEOS 26600, GEOS 36600

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 27710, BIOS 27711, and BIOS 27712.
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 24300. Roles of Animals in Ecosystems - Marine Biological Laboratory. 100 Units.
This course addresses the question, How do animals, including man, affect the structure and function of ecosystems. The course takes an interdisciplinary approach focused on the interactions of animal diversity, migration patterns, population dynamics, and behavior with biogeochemical cycles, productivity, and transport of materials across ecosystems. This course is an elective option within the Semester in Environmental Science program at the Marine Biological Laboratory in Woods Hole, MA.
Instructor(s): Marine Biological Laboratory Staff
Terms Offered: Autumn
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 27715

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. Prerequisite(s): BIOS 20150, BIOS 20151 or BIOS 20152. Note(s): BIOS 20196 is identical to the previously offered BIOS 23251. Students who have taken BIOS 23251 should not enroll in BIOS 20196.
Equivalent Course(s): ENSC 24400
Instructor(s): C. Pfister, E. Larsen
Terms Offered: Autumn. L.
Prerequisite(s): BIOS 20151
Equivalent Course(s): BIOS 20196

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 36650, GEOS 26650

**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.
Terms Offered: Summer
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 25000. Biological Oceanography. 100 Units.**
This intensive four-week course addresses fundamental oceanographic processes that maintain and structure marine biodiversity and productivity, including physical oceanographic processes of dispersal and upwelling, environmental selection, biogeography, nutrient dynamics, primary production, and food web dynamics. Students will design an original research project during an initial week-long shore component at Marine Biological Laboratory (MBL) in Woods Hole, MA, and then address their own questions by collecting samples and data aboard Sea Education Association (SEA)'s oceanographic research sailing vessel, the SSV Corwith Cramer, on a 10-day offshore voyage. At sea students will deploy oceanographic instruments, interpret various data streams, and work as research teams and watch members as they navigate and sail the vessel. During a final week-long shore component at MBL, students will analyze and interpret the data they collected and present their results in written and oral reports.
Instructor(s): SEA Staff
Terms Offered: Spring
Prerequisite(s): Second-year standing or greater (or by consent)
Note(s): Course meets for three weeks (5-6 days/week, 8 hours per day) at Marine Biological Laboratories, in Woods Hole Massachusetts as part of the Spring Quarter at MBL. For more information see https://college.uchicago.edu/academics/mbl-spring-quarter-biology E.
Equivalent Course(s): BIOS 27751

**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
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 forcers - 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

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, BIOS 27714 or BIOS 27715.
Note(s): E.
Equivalent Course(s): BIOS 27712