GEOLOGICAL AND ENVIRONMENTAL SCIENCES

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Courses given in Geological and Environmental Sciences have the subject code GES. For a complete list of subject codes, see Appendix B.

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

The program leading to the Bachelor of Science degree in Geological and Environmental Sciences (GES) provides the background for a wide variety of careers. It prepares students for employment or graduate studies in earth and environmental sciences, environmental engineering, land use planning, law, public service, teaching and other professions in which an understanding of the earth and a background in science can be important. The geological sciences are broad and include study of the Earth's history and the evolution of life; the oceans and atmosphere; the processes that shape the Earth's mountains, continents, and landscape; the chemistry and physics of earth materials and their interactions with each other and with water; and sources of water, economic minerals, metals, and fuels. Within GES, study of the environmental sciences emphasizes earth surface processes at present and in the future, particularly the ways in which humankind is affected by natural hazards such as volcanic eruptions and earthquakes and the ways in which we affect the planet and its viability by urban and agricultural development, contamination of natural waters, and depletion of resources.

An important emphasis of the B.S. program in GES is the study of earth processes and history in the natural laboratory of the field. Stanford University's location near the Pacific continental margin, the Sierra Nevada mountain range, and the San Andreas fault system provides a nearly unparalleled setting for field studies. At the same time, geological and environmental sciences deal quantitatively with processes on and in the earth and other planets, and with interactions between chemical, biological, and physical systems. The curriculum thus includes courses in chemistry, physics, and/or biology, and mathematics. The range of these requirements and experiences results in graduates with a broad range of skills.

The GES undergraduate major is designed to recognize the diversity of this field and to provide a great deal of flexibility, with a variety of course choices that should be made in consultation with a faculty adviser and/or the undergraduate program coordinator. The department also offers a specialized curriculum in Engineering Geology and Hydrogeology. Students whose educational objectives are within the scope of the department, but not encompassed in our predefined programs, may also design an independent curriculum with the help of a faculty adviser and approvals from the department chair and the undergraduate program director.

The Writing in the Major (WIM) requirement may be fulfilled by taking one of the following courses designated (WIM): GES 54Q, 55Q, 110, 131, 151, 152, or 185 along with the 1-unit WIM Project course, GES 190. Students choosing to take a course for WIM credit should consult with the instructor early in the quarter; additional writing-intensive work is assigned.

GES majors must complete at least 54 units which includes a core sequence of GES courses, a flexible series of electives, and at least 6 units of field research; or, GES majors may choose to follow the specialized curriculum for Engineering Geology and Hydrogeology. Subject to approval of the GES undergraduate program director, the 6-unit field research requirement may be satisfied by completion of a summer field course in geology at another university or by a faculty-directed field research project that involves learning and application of field techniques and the preparation of a written report. Up to 6 units of GES 198 or 199 may be counted toward the required 54 units if they are part of a research program leading to the preparation of an undergraduate thesis or an honors degree. GES 101 is also a required course, involving three weeks of off-campus field study prior to the start of classes in Autumn. In addition, students are required to choose a sequence of mathematics courses (10 units) and two sequences of courses in cognate sciences (7-10 units each or a total of 15-19 units). Substitutions or changes to these requirements may be requested through a formal petition to the undergraduate program director. Letter grades are required in all courses, if available.

COURSE SEQUENCE (80-91 UNITS TOTAL)

REQUIRED GEOLOGICAL & ENVIRONMENTAL SCIENCES (30-37 UNITS)

All of the following courses (17-18 units):

Course No. and Subject	*Units*
GES 1. Fundamentals of Geology	5
or GES 49N. Field Trip to Death Valley and Owens Valley	4
GES 2. Earth History	3
GES 4. Undergraduate Seminar (2 quarters)	2 (total)
GES 80. Earth Materials	4
GES 101. Environmental and Geological Field Studies	3
GES 190. Writing in the Major	1

Four of the following courses (13-19 units)

GES 90. Introduction to Geochemistry	3-4
GES 110. Structural Geology and Tectonics	5
GES 151. Sedimentary Geology and Petrography	4
GES 175. Science of Soils	4
or GES 130. Environmental Earth Sciences I	5
or GES 170. Environmental Geochemistry	4
GES 181. Igneous and Metamorphic Processes	3-5
or GES 185. Volcanology	3

REQUIRED SUPPORTING MATHEMATICS (10 UNITS)

Choose one of the following groups of mathematics courses. The third group is strongly recommended for students planning graduate study in science and engineering:

Course No. and Subject	*Units*
MATH 19. Calculus	3
MATH 20. Calculus	3

MATH 21. Calculus	4
or	
MATH 41. Calculus	5
MATH 42. Calculus	5
or	
MATH 51. Multivariate Mathematics	5
MATH 52. Multivariate Mathematics	5
or MATH 53. Multivariate Mathematics	5

REQUIRED SUPPORTING COGNATE SCIENCES (15-19 UNITS)

Choose sequences listed below from two of the following three fields of cognate sciences:

Chemistry (7-8 units):	
CHEM 31. Chemical Principles	4
or CHEM 31M. Chemical Principles with Application to Materials Technology	4
or CHEM 32. Frontiers of Chemical Science	5
CHEM 135. Physical Chemical Principles	3
or CHEM 171. Physical Chemistry	3
or GES 171. Geochemical Thermodynamics	3
Physics (8-9 units):	
PHYSICS 21. Mechanics and Heat	3
PHYSICS 22. Mechanics and Heat Lab	1
PHYSICS 23. Electricity and Optics	3
PHYSICS 24. Electricity and Optics Lab	1
or	
PHYSICS 51. Light and Heat	4
PHYSICS 52. Light and Heat Lab	1
PHYSICS 53. Mechanics	4
or	
PHYSICS 53. Mechanics	4
PHYSICS 55. Electricity and Magnetism	3
PHYSICS 56. Electricity and Magnetism Lab	1
Biology (8-10 units):	
BIOSCI 41. Genetics, Biochemistry, and Molecular Biology	5
BIOSCI 42. Cell Biology and Animal Physiology	5
or BIOSCI 43. Plant Biology, Evolution, and Ecology	5
or BIOSCI 101. Ecology	3

ELECTIVES (19 UNITS)

Majors must complete at least 19 additional units of GES courses numbered 90 through 290, not including GES 200 and 201. With approval of the Undergraduate Program Director, courses numbered 100 or above in other science and engineering fields may satisfy this requirement. A maximum of 3 of the required elective units may be taken in directed reading or non-required seminar courses.

FIELD RESEARCH (6 UNITS)

Majors must complete a 6-unit summer field course in geology at another university, or a faculty-directed field research project that involves learning and application of field techniques and the preparation of a written report.

ENGINEERING GEOLOGY AND HYDROGEOLOGY SPECIALIZED CURRICULUM

The Engineering Geology and Hydrogeology curriculum is intended for undergraduates interested in the application of geological and engineering data and principles to the study of rock, soil, and water to recognize and interpret geological and environmental factors affecting engineering structures and groundwater resources. Students learn to characterize and assess the risks associated with natural geological hazards, such as landslides and earthquakes, and with groundwater flow and contamination. The curriculum prepares students for graduate programs and professional careers in engineering, and environmental geology, geology, geotechnical engineering, and hydrogeology. Students interested in this curriculum should contact a faculty adviser: Professor Loague, Pollard, or Gorelick.

GES majors who elect the Engineering Geology and Hydrogeology curriculum are expected to complete a core course sequence and a set of courses in supporting sciences and mathematics. The core courses come from Earth Sciences and Engineering. Any substitutions for core courses must be approved by the faculty adviser and through a formal petition to the undergraduate program director. In addition, four elective courses, consistent with the core curriculum and required of all majors, are to be selected with the advice and consent of the adviser. Typically, electives are selected from the list below. Letter grades are required, if available, in all courses.

COURSE SEQUENCE (88-99 UNITS TOTAL)

REQUIRED GEOLOGICAL & ENVIRONMENTAL SCIENCES (34-37 UNITS)

Course No. and Subject	*Units*
GES 1. Fundamentals of Geology	5
GES 80. Earth Materials	4
GES 101. Environmental and Geological Field Studies	3
GES 111. Structural Geology and Rock Mechanics	3
or GES 215. Advanced Structural Geology and Rock Mechanics	3-5
GES 115. Engineering Geology Practice	3
GES 144. Fundamentals of GIS	4
GES 160. Statistical Methods for Earth and Environmental Sciences: General Introduction	4
or GES 161. Statistical Methods for the Earth and Environmental Sciences: Geostatistics	3-4
GES 190. Writing in the Major	1
GES 230. Physical Hydrogeology	5
GEOPHYS 190. Applied Geophysical Methods	3

REQUIRED ENGINEERING (20 UNITS)

CEE 101A. Mechanics of Materials	4
CEE 101B. Mechanics of Fluids	4
CEE 101C. Geotechnical Engineering	4
CS 106A. Programming Methodology	5
ENGR 14. Applied Mechanics: Statics	3

REQUIRED SUPPORTING SCIENCES AND MATHEMATICS (23 UNITS)

CHEM 31. Chemistry Principles	4
MATH 51. Multivariate Mathematics	5
MATH 52. Multivariate Mathematics	5
MATH 53. Multivariate Mathematics	5
PHYSICS 53. Mechanics	4

SUGGESTED ELECTIVES (11-19 UNITS)

Choose *four* courses from the following list or, with faculty approval, four related courses:

CEE 180. Structural Analysis	3
CEE 270. Movement, Fate, and Effects of Contaminants in Surface Waters and Groundwater	3
CEE 293. Foundation Engineering	3
CEE 296. Experimental Soil Mechanics	2
ENGR 30. Engineering Thermodynamics	3
ENGR 50. Introductory Science of Materials	4
ENGR 155A,B. Mathematical and Computational Methods	5
GEOPHYS 150. General Geophysics	4
GES 130. Environmental Earth Sciences I	5
GES 131. Environmental Earth Sciences II	5
GES 217. Characterization and Hydraulics of Rock Fracture	3
GES 231. Contaminant Hydrogeology	4
GES 235. Role of Fluids in Geologic Processes	3
GES 237. Surface and Near-Surface Hydrologic Response	4
MATH 103. Matrix Theory and its Applications	3
ME 80. Stress, Strain, and Strength	3

MINORS

A minor in Geological and Environmental Sciences consists of a small set of required courses, plus 12 elective units.

Required courses:

GES 1. Fundamentals of Geology
or GES 49N. Field Trip to Death Valley and Owens Valley
or GES 2. Earth History
or GES 130. Environmental Earth Sciences I
GES 80. Earth Materials
GES 101. Environmental and Geological Field Studies

A minimum of 12 additional units in GES courses, including three courses from the list below:

GES 8. The Oceans
GES 90. Introduction to Geochemistry
GES 110. Structural Geology
or GES 111. Structural Geology and Rock Mechanics
GES 130. Environmental Earth Sciences I
GES 131. Environmental Earth Sciences II

GES 144. Fundamentals of GIS
GES 151. Sedimentary Geology and Petrography
GES 152. Stratigraphy and Applied Paleontology
GES 170. Environmental Geochemistry
GES 175. Science of Soils
GES 181. Igneous and Metamorphic Processes
GES 185. Volcanology

All students pursuing a minor in GES are encouraged to take one of the freshman or sophomore seminars (courses with numbers 38-59) and to participate in the undergraduate seminar (GES 4). Up to 3 units of Stanford Introductory Seminar courses may be used in fulfilling the 12-unit requirement above.

Contact the GES department for further information. The variety of courses that may be used to satisfy the requirements should make it possible for students with a wide range of interests and backgrounds to complete a minor in GES.

HONORS PROGRAM

The Department of Geological and Environmental Sciences offers a program leading to the Bachelor of Science in Geological and Environmental Sciences with honors. The program provides an opportunity for independent study and research on a topic of special interest culminating in a written report. The honors program is open to all seniors with a grade point average (GPA) of at least 3.5 in Earth and Environmental Science courses and a minimum of 3.0 in all University course work. Modest financial support is available to help defray laboratory and field expenses incurred in conjunction with honors research. Students intending to pursue the honors program must submit an application to the department before the beginning of their senior year.

A student selects a research topic and prepares a research proposal in consultation with a faculty adviser of his or her choosing. Research undertaken for the honors program can be of a theoretical, field, or experimental nature, or a combination of these approaches.

Upon approval of the research proposal and formal entrance to the program, course credit for the honors research project and report preparation is assigned by the student's faculty adviser within the framework of GES 199; 3 units each quarter are assigned to the project for three quarters of the student's senior year for a total of 9 units. Research undertaken for the honors program cannot be used as a substitute for regularly required courses.

Both a written and an oral presentation of research results are required of honors students. A formal written report must be submitted to the student's research adviser no later than the fourth week of the student's final senior quarter. To graduate with honors, the report must be read, approved, and signed by the student's faculty adviser and a second member of the faculty. Before the end of the senior year, each honors candidate gives a public seminar on his or her research results.

COTERMINAL B.S. AND M.S. DEGREES

The coterminal B.S./M.S. program offers a special opportunity for students to pursue a graduate research experience and an M.S. degree concurrently with or subsequent to their B.S. studies. The master's degree may serve as an entrance professional degree in a number of subdisciplines within the earth sciences (for example, engineering geology and environmental geology). Alternatively, graduate course work and the master's research experience can provide an intermediate step prior to pursuit of the Ph.D. Regardless of their professional goal, coterminal B.S./M.S. students are treated as members of the graduate community and are expected to meet all of the standards set for regular M.S. students. Students should apply to the program after their seventh quarter (or after earning 105 units), but no later than their eleventh quarter. They are required to submit a coterminal program application to the GES department which includes a statement of purpose, a copy of their current Stanford transcript, official Graduate Record Examination scores, letters of recommendation from two members of the Stanford faculty (at least one of whom must be in this department), and a list of courses in which they intend to enroll to fulfill degree requirements. Each student must complete a thesis describing the results of his or her research. Specific research interests should be noted in the statement of purpose and discussed with a member of the GES faculty prior to submission of an application to the coterminal program.

Students must meet all requirements for both the B.S. and M.S. degrees. Students may either (1) complete 180 units required for the B.S. degree and then complete three full-time quarters for the M.S. degree, or (2) complete a total of fifteen quarters during which the requirements of the two degrees are fulfilled concurrently. The student has the option of receiving the B.S. degree upon completion of that degree's requirements, or receiving the B.S. and M.S. degrees concurrently at the completion of the master's program. Unit requirements for the coterminal program are a minimum of 180 units for the B.S. degree and a minimum of 45 units of course work at the 100 level or above for the M.S. degree. At least half of the courses used to satisfy the 45-unit requirement must be designated as being primarily for graduate students, normally at the 200 level or above. No more than 15 units of thesis research may be used to satisfy the 45-unit requirement. Further information about this program may be obtained from the GES office.

GRADUATE PROGRAMS

Graduate studies in the Department of Geological and Environmental Sciences (GES) involve academic course work and independent research. Students are prepared for careers as professional scientists in research or the application of the earth sciences to mineral, energy, and water resources. Programs lead to the M.S., Engineer, and Ph.D. degrees. Course programs in the areas of faculty interest are tailored to the student's needs and interests with the aid of his or her research adviser. Students are encouraged to include in their program courses offered in other departments in the School of Earth Sciences as well as in other departments in the University. Diplomas designate degrees in Geological and Environmental Sciences and may also indicate the following specialized fields of study: Geostatistics and Hydrogeology.

Admission—For admission to graduate work in the department, the applicant must have taken the Aptitude Test (verbal, quantitative, and analytical writing assessment) of the Graduate Record Examination. In keeping with University policy, applicants whose first language is not English must submit TOEFL (Test of English as a Foreign Language) scores from a test taken within the last 18 months. Individuals who have completed a B.S. or two-year M.S. program in the U.S. or other English-speaking country are not required to submit TOEFL scores. Previously admitted students who wish to change their degree objective from M.S. to Ph.D. must petition the GES Admissions Committee.

FIELDS WITH DIPLOMA DESIGNATION

Hydrogeology—The Hydrogeology program, which leads to an M.S., Engineer, or Ph.D. degree in GES, balances research in the purely scientific and applied aspects of groundwater resources and near-surface processes.

The program requires students to obtain a broad background in earth sciences and engineering. Students in the program must have a strong general scientific background in basic physics, chemistry, computer science, and mathematics, and a demonstrated aptitude for solving quantitative problems. They must complete a core curriculum involving courses in fluid mechanics, hydrogeology, hydrology, and water quality. A list of required and recommended courses is supplied upon request.

Geostatistics—The Geostatistics program leads to an M.S. or Ph.D. degree in GES. Strong interactions have been developed with faculty and students in the departments of Geophysics and Petroleum Engineering.

The program requires a geological background and a fair level of calculus and programming (Fortran and/or C++). Recent graduates have found jobs in the extractive (mining, oil) and environmental (EPA) fields.

MASTER OF SCIENCE

Objectives—The purpose of the master's program in Geological and Environmental Sciences is to continue a student's training in one of a broad range of earth science disciplines and to prepare students for either a professional career or doctoral studies.

Procedures—The graduate coordinator of the department appoints an academic adviser during registration with appropriate consideration of the student's background, interests, and professional goals. In consultation with the adviser, the student plans a program of course work for the first year. The student should select a thesis adviser within the first year of residence and submit to the thesis adviser a proposal for thesis research as soon as possible. The academic adviser supervises completion of the department requirements for the M.S. program (as outlined below) until the research proposal has been accepted; responsibility then passes to the thesis adviser. The student may change either thesis or academic advisers by mutual agreement and after approval of the graduate coordinator.

Requirements—The University's requirements for M.S. degrees are outlined in the "Graduate Degrees" section of this bulletin. Practical training (GES 385) may be required by some programs, with adviser approval, depending on the background of the student. Additional department requirements include the following:

1. A minimum of 45 units of course work at the 100 level or above.
   a. Half of the courses used to satisfy the 45-unit requirement must be intended as being primarily for graduate students, usually at the 200 level or above.
   b. No more than 15 units of thesis research may be used to satisfy the 45-unit requirement.
   c. Some students may be required to make up background deficiencies in addition to these basic requirements.
2. By the end of Winter Quarter of their first year in residence, students must complete at least three courses taught by a minimum of two different GES faculty members.
3. Each student must have a research adviser who is a faculty member in the department and is within the student's thesis topic area or specialized area of study.
4. Each student must complete a thesis describing his or her research. Thesis research should begin during the first year of study at Stanford and should be completed before the end of the second year of residence.
5. Early during the thesis research period, and after consultation with the student, the thesis adviser appoints a second reader for the thesis, who must be approved by the graduate coordinator; the thesis adviser is the first reader. The two readers jointly determine whether the thesis is acceptable for the M.S. degree in the department.

ENGINEER DEGREE

The Engineer degree is offered as an option for students in applied disciplines who wish to obtain a graduate education extending beyond that of an M.S., yet do not have the desire to conduct the research needed to obtain a Ph.D. A minimum of two years (six quarters) of graduate study is required. The candidate must complete 90 units of course work, no more than 10 of which may be applied to overcoming deficiencies in undergraduate training. The student must prepare a substantial thesis that meets the approval of the thesis adviser and the graduate coordinator.

DOCTOR OF PHILOSOPHY

Objectives—The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship, high attainment in a particular field of knowledge, and the ability to conduct independent research. To this end, the objectives of the doctoral program are to enable students to develop the skills needed to conduct original investigations in a particular discipline or set of disciplines in the earth sciences, to interpret the results, and to present the data and conclusions in a publishable manner.

Requirements—The University's requirements for the Ph.D. degree are outlined in the "Graduate Degrees" section of this bulletin. Practical training (GES 385) may be required by some programs, with adviser approval, depending on the background of the student. A summary of additional department requirements is presented below:

1. Ph.D. students must complete the required courses in their individual program or in their specialized area of study with a grade point average (GPA) of 3.0 (B) or higher, or demonstrate that they have completed the equivalents elsewhere. Ph.D. students must complete a minimum of four letter-grade courses of at least 3 units each from four different faculty members on the Academic Council in the University. By the end of Winter Quarter of their first year in residence, students must complete at least three courses taught by a minimum of two different GES faculty members.
2. Each student must qualify for candidacy for the Ph.D. by the end of the sixth quarter in residence, excluding summers. Department procedures require selection of a faculty thesis adviser, preparation of a written research proposal, approval of this proposal by the thesis adviser, selection of a committee for the Ph.D. qualifying examination, and approval of the membership by the graduate coordinator and chair of the department. The research examination consists of three parts: oral presentation of a research proposal, examination on the research proposal, and examination on subject matter relevant to the proposed research. The exam should be scheduled for prior to May 1, so that the outcome of the exam is known at the time of the annual spring evaluation of graduate students.
3. Upon qualifying for Ph.D. candidacy, the student and thesis adviser, who must be a department faculty member, choose a research committee that includes a minimum of two faculty members in the University in addition to the adviser. Annually, in the month of March or April, the candidate must organize a meeting of the research committee to present a brief progress report covering the past year.
4. Under the supervision of the research advisory committee, the candidate must prepare a doctoral dissertation that is a contribution to knowledge and is the result of independent research. The format of the dissertation must meet University guidelines. The student is strongly urged to prepare dissertation chapters that, in scientific content and format, are readily publishable.
5. The doctoral dissertation is defended in the University oral examination. The research adviser and two other members of the research committee are determined to be readers of the draft dissertation. The readers are charged to read the draft and to certify in writing to the department that it is adequate to serve as a basis for the University oral examination. Upon obtaining this written certification, the student is permitted to schedule the University oral examination.

Ph.D. MINOR

Candidates for the Ph.D. degree in other departments who wish to obtain a minor in Geological and Environmental Sciences must complete, with a GPA of 3.0 (B) or better, 20 units in the geosciences in lecture courses intended for graduate students. The selection of courses must be approved by the student's GES adviser and the department chair.

COURSES

(WIM) indicates that the course satisfies the Writing in the Major requirements. (AU) indicates that the course is subject to the University Activity Unit limitations (8 units maximum).

UNDERGRADUATE

GES 1. Fundamentals of Geology—For non-majors or prospective majors in Earth Systems or Geological and Environmental Sciences. Topics include: processes that shape the earth's landforms, produce the minerals and rocks that comprise the earth, create soils, deform the earth's crust, and move continents; surficial processes involving water, wind, and ice, and their role in erosion and in the production of sediment; processes acting within the earth's interior with an emphasis on global tectonics; how geologists determine the ages of rocks and geologic events; geologic hazards including earthquakes, volcanic eruptions, flooding, landslides, and their mitigation; and nonrenewable resources, energy, and environmental problems. One all-day field trip; weekly lab. Recommended: high school chemistry and physics. GER:2a

5 units, Aut (Surpless), Win (Ernst), Spr (McWilliams)

GES 2. Earth History—For non-majors and prospective Earth Systems or Geology majors. Overview of how the universe evolved from the creation of the elements to the origin of humans. The origin of the universe, our solar system, and Earth's atmosphere, oceans, and continents. The origin of life, the evolution of life from its earliest beginnings to the rise of metazoans and development of humans, and the relationship between geological and biological evolution. Future scenarios for earth, including human impact on earth systems and how human beings are modifying the atmosphere, oceans, and land. GER:2a

3 units, Win (Chamberlain)

GES 4. Undergraduate Seminar—For majors and prospective majors in Geological and Environmental Sciences. Topic changes each offering. May be repeated for credit.

1 unit, Aut (Mahood)

GES 7A,B. An Introduction to Wilderness Skills—Introduction to living, traveling, and working in the wilderness for those planning fieldwork in the backcountry. In-class topics: geological processes, land management, environmental ethics, first aid, animal tracking, and plant ecology. Four weekend outings focus on minimum impact backcountry skills including backcountry ski techniques, backpacking, caving, food preparation, orienteering, rock climbing, snow shelter building, and telemarking. Students research the geological history of trip locations and make short presentations on their findings. 7A emphasizes navigation on foot and rock climbing, and 7B emphasizes winter camping skills and backcountry skiing. Food, group, and major personal gear provided. Students provide own clothing. Fee for food and transportation. Preregistration required through OEP at http://www.stanford.edu/class/ges7/. (AU)

1 unit, Aut, Win (Bird)

GES 7C. Advanced Wilderness Skills—Introduction to mountaineering techniques and issues of interest to students experienced with outdoor travel. Fee for food and transportation. Preregistration required through OEP at http://www.stanford.edu/class/ges7/. (AU)

1 unit, Spr (Bird)

GES 8. The Oceans: An Introduction to the Marine Environment—For non-majors and prospective geology, earth systems, and environmental majors. Topics: topography and geology of the sea floor, evolution of ocean basins, the circulation of the ocean and atmosphere, the nature of sea water, waves, tides, and the history of the major ocean basins. The interface between continents and ocean basins, emphasizing estuaries, beaches, and continental shelves with California margin examples. The relationships between the distribution of inorganic constituents, ocean circulation, biologic productivity, and marine environments from deep sea to the coast. Required one-day field trip to measure and analyze waves and currents. GER:2a

3 units, Spr, Sum (Ingle)

GES 29N. The Outer Limits of Life—(Enroll in BIOSCI 29N.)

3 units, Win (Bohannan, Lowe)

GES 38N. The Worst Journey in the World: What Drives Polar Exploration?—Stanford Introductory Seminar. Preference to freshmen. Polar explorers spent months in isolation under the harshest conditions on Earth. Many explorers used this time to create a written record of scientific discovery and often dashed geographic hopes. The title of this seminar is taken from a book by Aspley Cherry-Gerard who in 1911 participated in a mid-winter sledding trip in Antarctica to recover Emperor penguin eggs from a remote cape on Ross Island. The accounts of this and other Antarctic and Arctic journeys. Focus is on the main scientific and geographic achievements. The class jointly authors an essay on common themes from discussions. Optional field trip into the high Sierra in December.

3 units (Dunbar) alternate years, given 2004-05

GES 39N. The Search for Life in the Solar System—Stanford Introductory Seminar. Current thinking on the origin of life and the search for life in the solar system and beyond. Topics: definitions of life, life as we know it, origins of life on Earth, contingency vs. necessity, Mars, Europa, interplanetary transfer of microorganisms, ethical issues in exploration, the evolution of complexity, and the Fermi paradox. Grading via student presentations and papers. GER:2a

3 units, Spr (Chyba) alternate years, not given 2004-05

GES 41N. El Niño: History and Predictability of a Global Climate Pacemaker—Stanford Introductory Seminar. Preference to freshmen. The coupled El Niño-Southern Oscillation (ENSO) system is the dominant source of interannual climate variability worldwide. The workings and impacts of El Niño through readings and analysis of primary climatic data. Topics: principles of air-sea interaction, mechanisms of El Niño, simple simulations of ENSO warm and cool events, teleconnected responses in California and the U.S., past El Niño disasters, future predictability of ENSO, and possible El Niño manifestations in a greenhouse world. Grading via class projects.

3 units (Dunbar) alternate years, given 2004-05

GES 42N. Early Life on Earth—Stanford Introductory Seminar. Preference to freshmen. The first billion years of earth history, with emphasis on the environments, conditions, and processes that led to the origin of life. The likelihood that life has evolved elsewhere in the solar system. The geologic record of the oldest preserved life forms, and the environments in which they lived. Term paper. Use of Stanford's rock collection containing the oldest evidence for life on earth. GER:2a

3 units (Lowe) alternate years, given 2004-05

GES 44N. A Transition to Sustainability? Development and Environment in the 21st Century—Stanford Introductory Seminar. Preference to freshmen. What will it take to meet the needs of the human population while preserving Earth's life support systems? Trends and transitions in population growth, resource consumption, and environmental conditions at regional and global scales. Approaches that can move the world towards sustainability in energy, industry, urbanization, living resources, air, and water. Students prepare a case study of sustainable development in the area of their choice. GER:2a

3 units, Spr (Matson) alternate years, not given 2004-05

GES 46N. The Beach—Stanford Introductory Seminar. Preference to freshmen. Open coast beaches represent one of the most complex and dynamic natural environments of Earth where ocean, atmosphere, and continent meet and interact on time scales of seconds to millennia. The beach environment and analysis in the field. Field work involves repeated measurement of waves, currents, and beach character, and sample collection at sites from Point Reyes to Monterey Bay, with the goals of assembling and analyzing a quantitative record of change. Required papers on a specific aspect of the beach environment. GER:2a

3 units, Win (Ingle) alternate years, not given 2004-05

GES 47N. Secrets in the Mud: A Look Into the Field of Paleoceanography—Stanford Introductory Seminar. Preference to freshmen. How oceans responded to natural perturbations helps predict and plan for the potential consequences of human-induced environmental changes. The types of information deduced from marine sediments about Earth's past environments. Lab projects: sediment sample preparation and analysis, description and interpretation of data, and oral and written presentation. One-day field trip.

3 units (Paytan) alternate years, given 2004-05

GES 48N. Volcanoes of the Eastern Sierra Nevada—Stanford Introductory Seminar. Preference to freshmen. Skills in researching primary sources in scientific literature and written and oral presentation of results. Topics: young volcanoes, hot springs, earthquake faults, glacial features, paleoclimatology, and saline lakes of the eastern Sierra Nevada. Four-day field trip over Memorial Day weekend. Term project is written as a chapter for a class-produced field trip guidebook. Oral presentation on the outcrop at the field trip stop described in the guidebook chapter. Camping and light hiking.

2 units (Mahood) alternate years, given 2004-05

GES 49N. Field Trip to Death Valley and Owens Valley—Stanford Introductory Seminar. Preference to freshmen. California's Death Valley and Owens Valley are natural laboratories for exploring a billion years of earth history: the sediments of ancient oceans, mountain building, recent earthquake faulting, glacial landscapes, and volcanic erup-

tions. Desert environments reveal prehistoric climate changes and historic human impacts. Six-day field trip to these areas during Spring Break. Term paper is written as a chapter for a field trip guidebook. Oral presentation on the outcrop at the field trip stop described in the guidebook chapter. The basics of plate tectonics and geology. Rock identification, reading topographic and geologic maps, and interpreting remote sensing imagery. Camping and moderate hiking required. GER:2a
4 units, Win (Mahood)

GES 50Q. The Coastal Zone Environment—Stanford Introductory Seminar. Preference to sophomores. The oceanographic, geological, and biological character of coastal zone environments, including continental shelves, estuaries, and coastal wetlands, with emphasis on San Francisco Bay. Five required field trips examine the estuarine and coastal environments of the Bay region, and agencies and facilities concerned with monitoring and management of these resources. Original research on a selected aspect of the coastal zone results in written and oral reports. Prerequisite: beginning course in Biology (e.g., BIOSCI 51), Chemistry (CHEM 30, 31), Earth Sciences (GES 1,2), or Earth Systems (EARTHSYS 10); willingness to get your feet cold, wet, and muddy. GER:2a
3 units, Aut (Ingle)

GES 52Q. Geologic Development of California—Stanford Introductory Seminar. Preference to sophomores, and to students who have completed introductory geology. Field-based study of the crustal evolution of California in post-Paleozoic time, and covering the geotectonic development of most of the state. Weekend field trips to the Eastern Coast Ranges (two days); Mount Shasta and the central Klamath Mountains (four days); Point Lobos and the Big Sur coast (two days). Camping and hiking. Term paper. GER:2a
5 units (Ernst) not given 2003-04

GES 53Q. In the Beginning: Theories of the Origin of the Earth, Solar System, and Universe—Stanford Introductory Seminar. Preference to sophomores. What happened in the first few seconds following the Big Bang? Where did all the elements in the periodic table come from? When and how did the Earth, Moon, and solar system form? When and where did life begin on Earth? The history and evolution of theories of the origin of the Earth, Moon, solar system, and the Universe. GER:2a
3 units, Win (McWilliams)

GES 54Q. California Landforms and Plate Tectonics—Stanford Introductory Seminar. Preference to sophomores. The forces of plate tectonics at work on the landscape of California. The principles of rock deformation are introduced with laboratory experiments. Landforms resulting from deformation of the earth are analyzed with digital and photographic images. Field trips relate these large-scale structures to the human perspective on the ground. Final paper involves literature research on active deformation and earthquakes in a region of the student's choice. GER:2a (Corequisite for WIM: 190.)
3 units, Aut (Miller)

GES 55Q. The California Gold Rush: Geologic Background and Environmental Impact—Stanford Introductory Seminar. Preference to sophomores, and to students who have completed introductory geology. Topics include: geologic processes that led to the concentration of gold in the river gravels and rocks of the Mother Lode region of California; and environmental impact of the Gold Rush due to population increase, mining operations, and high concentrations of arsenic and mercury in sediments from hard rock mining and milling operations. Field trip to the Mother Lode region. GER:2a (Corequisite for WIM: 190.)
3 units, Win (Bird)

GES 56Q. Changes in the Coastal Ocean: The View From Monterey and San Francisco Bays—Stanford Introductory Seminar. Preference to sophomores. Recent changes in the California Current, using Monterey Bay as an example. Current literature is an introduction to several principles of oceanography. Visits from researchers from MBARI, Hopkins, and UCSC. Optional field trip to MBARI and Monterey Bay.
3 units, Spr (Dunbar) alternate years, not given 2004-05

GES 57Q. How to Critically Read and Discuss Scientific Literature—Stanford Introductory Seminar. Preference to sophomores. Topics: how to approach the reading of scientific articles, and how to understand and evaluate the information contained in them through guided reading, and a review of such papers. GER:2a
3 units, Aut (Paytan)

GES 80. Earth Materials—Identification, classification, and interpretation of rock-forming minerals and the igneous, sedimentary, and metamorphic rocks they comprise. Rock cycles are related to earth systems. Lab work emphasizes use of the hand lens in making observations; overnight field trip demonstrates mineral and rock identification in the field, a variety of different pressure and temperature environments where minerals and rocks have formed, and genetic associations. Prerequisite: 1. Recommended: introductory chemistry.
4 units, Aut (Brown, Liou)

GES 81. Petrography Tutorial—Practice and instruction in identifying minerals and rocks using a petrographic microscope. One three-hour lab per week. Prerequisite: 80 or equivalent.
2 units, Spr (Miller)

GES 90. Introduction to Geochemistry—The chemistry of the solid earth and its atmosphere and oceans, emphasizing the processes that control the distribution of the elements in the earth over geological time and at present, and on the conceptual and analytical tools needed to explore these questions. The basics of geochemical thermodynamics and isotope geochemistry. The formation of the elements, crust, atmosphere and oceans, global geochemical cycles, and the interaction of geochemistry, biological evolution, and climate. Recommended: introductory chemistry.
3-4 units, Win (Stebbins)

GES 101. Environmental and Geological Field Studies in the Rocky Mountains—Introduction to research possibilities in the geological sciences. Field-based program from September 1-22. Weekly meetings on campus during Autumn Quarter. Field portion is based in the Greater Yellowstone/Teton and Bighorn Mountain region of Wyoming and Montana. Topics include the basics of structural geology and petrology, economic geology, glacial geology, regional western cordillera geology, paleoclimatology, chemical weathering and the carbon cycle, aqueous geochemistry, and environmental issues. Earth/environmental science questions in the Precambrian granitic and glacial terranes of the Wind Rivers of Wyoming, the Laramide fold/thrust belt of the Bighorn basin, and the mid-tertiary volcanic center of N.E. Yellowstone National Park. Research papers based on the results of fieldwork.
3 units, Aut (Chamberlain)

GES 110. Structural Geology and Tectonics—The basic theory, principles, and techniques used to interpret and measure structures in naturally deformed rocks. Topics: the properties, rheology, and mechanisms of deformation of rocks and minerals; techniques of data collection in the field; lab and computer analysis of structural data; geometry and development of faults and folds; interpretation of geologic maps and construction of geologic cross-sections; strain measurement and structural analysis of metamorphic tectonites; the evolution of mountain belts, formation of rift-related sedimentary basins, and development of strike-slip fault systems. Prerequisites: 1, calculus. Recommended: 80, 102. (Corequisite for WIM: GES 190)
5 units, Spr (Miller)

GES 111. Structural Geology and Rock Mechanics—(Same as CEE 195.) Introduction to a methodology for understanding tectonic processes and their structural products by combining quantitative field data with conceptual and mechanical models of rock deformation and flow. Topics include: modern mapping techniques using GPS; characterization of structures using differential geometry; dimensional analysis; kinematics of deformation; stress analysis; elasticity, brittle fracture and faulting; viscosity and flow of rock; modeling geological structures using continuum mechanics. Applications include the role of geological structures in the evolution of the earth's crust; the mitigation of geologic hazards; and

the flow of fluids in groundwater aquifers and hydrocarbon reservoirs. Prerequisites: 1, MATH 51, 52.
3 units, Aut (Pollard)

GES 115. Engineering Geology Practice—(Same as CEE 196.) The application of geologic fundamentals to the planning and design of civil engineering projects. Field exercises and case studies emphasize the impact of site geology on the planning, design, and construction of civil works such as buildings, foundations, transportation facilities, excavations, tunnels and underground storage space, and water supply facilities. Topics: Quaternary history and tectonics, formation and physical properties of surficial deposits, site investigation techniques, geologic hazards, and professional ethics. Prerequisite: GES 1 or consent of instructor.
3 units (Holzer) alternate years, given 2004-05

GES 130. Environmental Earth Sciences I: Soil Physics and Hydrology—First of a two-part sequence on surface and near-surface processes. Focus is on the waters of the Earth, their occurrence, distribution, circulation, and reaction with the environment. Topics: precipitation, evapotranspiration, infiltration and vadose zone, groundwater, surface water and streamflow generation, lakes, water supply and use, and water balance and flood frequency estimates. Current and classic theory in soil physics and hydrology. Urban, rangeland, and forested environments. Project throughout sequence involves the case study report. Students individually or in groups prepare and present a reconnaissance report. Field trips to project area and San Mateo County coast.
5 units, Aut (Loague)

GES 131. Environmental Earth Sciences II: Fluvial Systems and Landscape Evolution—Second part of sequence on surface and near-surface processes. Focus is on the materials of the Earth and hydrologically driven landscape processes. Topics: hillslope hydrology, weathering of rocks and soils, erosion, flow failures, mass wasting, and conceptual models of landscape evolution. Current and classic theory in geomorphology. Groups prepare and present a final case study report. Field trips to project area and San Mateo County coast. (Corequisite for WIM: GES 190)
5 units, Win (Loague)

GES 140. The Earth from Space: Introduction to Remote Sensing—(Enroll in GEOPHYS 140.)
3 units (Zebker) alternate years, given 2004-05

GES 141. Remote Sensing of the Oceans—(Enroll in EARTHSYS 141/241, GEOPHYS 141.)
4 units, Win (Arrigo) alternate years, not given 2004-05

GES 142. Remote Sensing of Land Use and Land Cover—(Same as EARTHSYS 142/242.) The use of satellite remote sensing to monitor land use and land cover, with emphasis on terrestrial changes. Topics include pre-processing data, biophysical properties of vegetation observable by satellite, accuracy assessment of maps derived from remote sensing, and methodologies to detect changes such as urbanization, deforestation, vegetation health, and wildfires.
4 units (Seto) alternate years, given 2004-05

GES 144. Fundamentals of Geographic Information Systems (GIS)—Analysis of digital geographic information using modern spatial data processing. Topics include conceptual models of geographic data, database development, integration of remote sensing with GIS, elementary spatial analysis, functions and applications of geographic information systems. Weekly computer-based lab sessions stress hands-on experience.
4 units, Spr (Seto)

GES 145/245. Understanding Energy Flow and Policy Issues: The Pacific Rim—(Same as EARTHSYS 145/245; graduate students register for 245.) Current and future Pacific Rim energy issues and their global context. Topics include basic energy resources, alternative sources, technological advances, environmental impacts, and geopolitics of energy.
3 units, Win (Graham, Howell)

GES 147. Controlling Climate Change in the 21st Century—(Enroll in EARTHSYS 147/247, BIOSCI 147/247.)
3 units (Schneider, Rosencranz) alternate years, given 2004-05

GES 151. Sedimentary Geology and Petrography: Depositional Systems—Topics: weathering, erosion and transportation, deposition, origins of sedimentary structures and textures, sediment composition, diagenesis, sedimentary facies, tectonics and sedimentation, and the characteristics of the major siliciclastic and carbonate depositional environments. Lab: methods of analysis of sediments in hand specimen and thin section. Field trips required. Prerequisites: 1. GER:2a (Corequisite for WIM: 190)
4 units, Win (Lowe, Graham)

GES 152. Stratigraphy and Applied Paleontology—The rudiments of interpreting sedimentary sequences. Emphasis is on the integration of paleontologic and sedimentologic evidence to reconstruct depositional environments, basin history, and paleo-oceanographic settings. The nature of the fossil record, the use of marine fossils for dating, correlation, and paleo-environmental and paleo-oceanographic reconstructions. Characteristic variations of modern and ancient biofacies and lithofacies. Biostratigraphy, magnetostratigraphy, and radiometric dating and correlation. Required research paper. Lectures supplemented by classic and current scientific literature. Weekly lab; two required field trips. Prerequisites: 1, 2. GER:2a (Corequisite for WIM: 190)
4 units, Spr (Ingle)

GES 159. Marine Chemistry—(Graduate students register for 259.) The oceans are in interactive contact with the atmosphere, biosphere, and lithosphere, and virtually all elements pass through the ocean at some point in their cycles. First-order processes that take place within the sea and affects its chemistry. What controls the distribution of chemical species in water and sediments? How long do elements spend in the ocean? How do marine chemical processes interact with ocean biological, geological, and physical processes? Prerequisite: 8 or consent of instructor.
2-4 units, Spr (Paytan)

GES 160. Statistical Methods for Earth and Environmental Sciences: General Introduction—Extracting information from data using statistical summaries and graphical visualization, statistical measures of association and correlation, distribution models, sampling, error estimation and confidence intervals, linear models and regression analysis, introduction to time-series and spatial data with geostatistics, applications including environmental monitoring, natural hazards, and experimental design. Either or both of 160 and 161 may be taken.
3-4 units, Aut (Switzer)

GES 161. Statistical Methods for the Earth and Environmental Sciences: Geostatistics—(Same as PETENG 161.) Statistical analysis and graphical display of data, common distribution models, sampling, and regression. The variogram as a tool for modeling spatial correlation; variogram estimation and modeling; introduction to spatial mapping and prediction with kriging; integration of remote sensing and other ancillary information using co-kriging models; spatial uncertainty; introduction to geostatistical software applied to large environmental, climatological, and reservoir engineering databases; emphasis is on practical use of geostatistical tools.
3-4 units, Win (Caers)

GES 164. Stable Isotopes—Light stable isotopes and their application to geological and geophysical problems. Isotopic systematics of hydrogen, carbon, nitrogen, oxygen, and sulfur; chemical and biogenic fractionation of light isotopes in the atmosphere, hydrosphere, and in minerals. Isotopic composition of water in the oceans. Paleothermometry and paleoclimatology. Isotope fractionation in igneous, sedimentary, and metamorphic rocks, and in ore-forming fluids. Prerequisite: 163 or consent of instructor.
3 units (Dunbar) alternate years, given 2004-05

GES 164L. Stable Isotopes Laboratory—Practical laboratory for GES 164.
2-3 units (Dunbar)

GES 165. Geochronology and Thermochronology—Principle applications to geological and geophysical problems. Topics: nuclear structure, isotope systematics, decay schemes for the principal nuclides used in earth sciences, equilibrium and disequilibrium, diffusion and transport phenomena, blocking (closure) of isotopic and magnetic systems, creation and annealing of fission tracks, neutron activation, a review of geologic timescales, chronostratigraphy, magnetostratigraphy, and cosmogenic exposure ages. Alpha counting, mass spectrometry by gas source, solid source, ion probe and accelerator methods. Fundamentals of K-Ar, Ar-Ar, Rb-Sr, U-Pb fission track (U+Th)/He, and cosmogenic isotope methods. Recommended: undergraduate calculus, chemistry, geology, and physics.
3 units (McWilliams) alternate years, given 2004-05

GES 165L. Geochronology and Thermochronology Laboratory—Practical laboratory for 165.
1-2 units (McWilliams) alternate years, given 2004-05

GES 166. Soil Chemistry—Practical and quantitative treatment of soil processes affecting chemical reactivity, transformation, retention, and bioavailability. The three primary areas of soil chemistry: inorganic and organic soil components, complex equilibria in soil solutions, and adsorption phenomena at the solid-water interface. The special considerations required for acid, saline, and wetland soils will be discussed.
3 units, Win (Fendorf) alternate years, not given 2004-05

GES 170. Environmental Geochemistry—Solid, aqueous, and gaseous phases comprising the environment, their natural compositional variations, and their chemical interactions. Contrast between natural sources of hazardous elements and compounds and the types and sources of anthropogenic contaminants and pollutants. Chemical and physical processes of weathering and soil formation. Chemical factors that affect the stability of solids and aqueous species under earth surface conditions. Processes that control the release, mobility, and fate of contaminants in natural waters and the roles that water and dissolved substances play in the physical behavior of rocks and soils. The scientific basis for evaluation of the impact of contaminants and the design of remediation strategies. Case studies. Prerequisite: 90 or consent of instructor.
4 units, Win (Brown)

GES 171. Geochemical Thermodynamics—Introduction to the application of chemical principles and concepts to geologic systems. The chemical behavior of fluids, minerals, and gases using simple equilibrium approaches to modeling the geochemical consequences of diagenetic, hydrothermal, metamorphic, and igneous processes. Topics: reversible thermodynamics, solution chemistry, mineral-solution equilibria, reaction kinetics, and the distribution and transport of elements by geologic processes. Prerequisite: 80.
3 units, Aut (Bird)

GES 175. Science of Soils—Physical, chemical, and biological processes within soil systems. Emphasis is on factors governing nutrient availability, plant growth/production, land-resource management, and pollution within soils.
4 units, Aut (Fendorf)

GES 181. Igneous and Metamorphic Processes—The origin of igneous and metamorphic rocks, emphasizing magmatic differentiation and subsolidus recrystallization processes and their imposed physiochemical and tectonic conditions. The physical properties of magmas, role of volatile components, applications of trace elements and isotopes to igneous processes, geodynamics, and evolution of the crust-mantle system modeling of crystal fractionation and partial melting, experimental data and phase diagrams, and relations of magma types to tectonic settings. Mineral paragenesis, phase relations, metamorphic reactions, fluid/rock interactions, P-T-time paths and their imposed tectonic settings. Lab hand-specimen and petrographic examinations of suites of igneous and metamorphic rocks. Graduate students may take without lab for 3 units. Prerequisites: 80, 90, or equivalents.
3-5 units (Liou) alternate years, given 2004-05

GES 182. Field Seminar on Continental-Margin Volcanism—For juniors, seniors, and graduate students in the earth sciences and archeology. One weekend-long, and two one-day field trips to study Cenozoic volcanism associated with subduction and with passage of the Mendocino Triple Junction off the west coast of California: Mt. Lassen/Mt. Shasta/Modoc Plateau; Clear Lake/Sonoma Volcanics; Pinnacles National Monument. Features visited and studied: andesite and basalt lavas, cinder cones, mixed magmas, blast deposit, debris avalanches, volcanic mudflows, hydrologic controls of springs in volcanic terrains, hydrothermal alteration and modern geothermal systems, Hg mineralization, obsidian source. Prep lectures, readings, and videos. Prerequisite: 1, 80 or equivalent.
2 units, Aut (Mahood) alternate years, not given 2004-05

GES 184. Field Seminar on Eastern Sierran Volcanism—For juniors, seniors, and graduate students in the earth sciences and archaeology. Four-day trip over Memorial Day weekend to study silicic and mafic volcanism associated with the western margin of the Basin and Range province: basaltic lavas and cinder cones erupted along normal faults bounding Owens Valley, Long Valley caldera, postcaldera rhyolite lavas, hydrothermal alteration and hot springs, Holocene rhyolite lavas of the Inyo and Mono Craters, volcanism of the Mono Basin with subaqueous basaltic eruptions, floating pumice blocks, and cryptodomes punching up lake sediments. If snow-level permits, silicic volcanism associated with the Bodie gold district. Prep lectures, readings, and videos. Prerequisite: 1, 80 or equivalent.
2 units, Spr (Mahood) alternate years, not given 2004-05

GES 185. Volcanology—For juniors, seniors, and beginning graduate students in the earth sciences and in archaeology. Two lecture-lab sessions per week. Lectures emphasize how volcanic landforms and deposits relate to the composition and physical properties of magmas and the modes of emplacement. Labs emphasize recognizing types of lavas and products of explosive eruptions. Volcanic hazards and the effects of eruptions on climate and the atmosphere; volcanic-hosted geothermal systems and mineral resources. Required four-day field trip over Memorial Day weekend to study silicic and mafic volcanism associated with the western margin of the Basin and Range province. Prerequisite: 1, 80 or equivalent (Corequisite for WIM: 190.)
3 units, Spr (Mahood) alternate years, not given 2004-05

GES 188. Archaeometry Seminar—(For undergraduates; see 288.)
1-2 units (Mahood) alternate years, given 2004-05

GES 189. Field Studies in Earth Systems—(Enroll in EARTHSYS 189, BIOSCI 206.)
5 units, Spr (Chiariello, Fendorf, Ackerly, Matson, Miller) alternate years, not given 2004-05

GES 190. WIM project—Students in a GES WIM course (54Q, 55Q, 110, 131, 151, 152, or 185) register for 190 using the section number of the appropriate faculty member.
1 unit, Aut, Win, Spr, Sum (Staff)

GES 192. Undergraduate Research in Geological and Environmental Sciences—Field-, lab-, or literature-based. Faculty supervision. Written reports.
1-10 units, Aut, Win, Spr, Sum (Staff)

GES 198. Special Problems in Geological and Environmental Sciences—Reading and instruction under faculty supervision. Written reports.
1-10 units, Aut, Win, Spr, Sum (Staff)

GES 199. Honors Program—Research on a topic of special interest. See "Undergraduate Honors Program" above.
3 units, Aut, Win, Spr, Sum (Staff)

GRADUATE

GES 200. Professional Development in Geoscience Education
1 unit, Aut, Spr (McWilliams)

GES 201. Science Course Design—(Same as CTL 201.) For students interested in an academic career and who anticipate designing science courses at the undergraduate or graduate level. Goal is to apply research on science learning to the design of effective course materials. Topics include syllabus design, course content and format decisions, assessment planning and grading, and strategies for teaching improvement.
2-3 units, Aut (Wright-Dunbar)

GES 202. Reservoir Geomechanics—(Enroll in GEOPHYS 202.)
3 units, Win (Zoback)

GES 205. Advanced Oceanography—For upper-division undergraduates and graduate students in the earth, biologic, and environmental sciences. Topical issues in marine science/oceanography. Topics vary each year following or anticipating research trends in oceanographic research. Focus is on links between the circulation and physics of the ocean with climate in the N. Pacific region, and marine ecologic responses. Participation by marine scientists from marine research groups and organizations including the Monterey Bay Aquarium Research Institute.
3 units, Aut (Dunbar)

GES 206. Antarctic Marine Geology—For upper-division undergraduates and graduate students. Intermediate and advanced topics in marine geology and geophysics, focusing on examples from the Antarctic continental margin and adjacent Southern Ocean. Topics: glaciers, icebergs, and sea ice as geologic agents (glacial and glacial marine sedimentology, Southern Ocean current systems and deep ocean sedimentation), Antarctic biostratigraphy and chronostratigraphy (continental margin evolution). Students interpret seismic lines and sediment core/well log data. Examples from a recent scientific drilling expedition to Prydz Bay, Antarctica. Up to two students may have an opportunity to study at sea in Antarctica during Winter Quarter.
3 units (Dunbar, Cooper) alternate years, given 2004-05

GES 210. Geologic Evolution of the Western U.S. Cordillera—For undergraduates and graduate students. Overview of the geology of the western states. The evolution of the mountain belt from its inception in the Precambrian to its contemporary history of extension and strike-slip faulting, based on the description, analysis, subduction, and interpretation of the rock record through time. The characteristic structural styles developed during crustal shortening, extension, and strike-slip tectonic regimes; tectonic controls on sedimentary basin formation; plate-margin magmatism and metamorphism; and the relation of plate motions to the land geologic record all provide insight into the crustal-scale processes and driving mechanisms common to mountain chains.
2-3 units, Win (Miller) alternate years, not given 2004-05

GES 211. Topics in Regional Geology and Tectonics
3 units (Miller) alternate years, given 2004-05

GES 215. Advanced Structural Geology and Rock Mechanics—(Same as CEE 297G.) Solutions to initial and boundary-value problems of continuum mechanics are integrated with quantitative field and laboratory data to develop conceptual and computational models for tectonic processes and the development of geological structures. Topics include: techniques for structural mapping and data analysis; differential geometry to characterize structures; dimensional analysis and scaling relations; kinematics of deformation and flow; traction and stress analysis; conservation laws; mechanical properties of rock (elasticity, viscosity, strength, friction, fracture toughness). Models formulated and solutions visualized using MATLAB. Prerequisites: 1, MATH 53, MATLAB or equivalent.
3-5 units, Aut (Pollard)

GES 216. Rock Fracture Mechanics—Principles and tools of elasticity theory and fracture mechanics are applied to the origins and physical behaviors of faults, dikes, joints, veins, solution surfaces, and other natural structures in rock. Field observations, engineering rock fracture mechanics, and the elastic theory of cracks. The role of natural fractures in brittle rock deformation, and fluid flow in the earth's crust with applications to crustal deformation, structural geology, petroleum geology, engineering, and hydrogeology. Prerequisite: 215 or equivalent.
5 units, Spr (Pollard) alternate years, not given 2004-05

GES 217. Faults, Fractures, and Fluid Flow—Process-based approach to rock failure; the microstructures and overall architectures of the failure products including faults, joints, solution seams, and types of deformation bands. Fluid flow properties of these structures are characterized with emphasis on sealing and transmitting of faults and their role in hydrocarbon flow, migration, and entrapment. Case studies of fracture characterization experiments in aquifers, oil and gas reservoirs, and waste repository sites. Guest speakers; weekend field trip. Prerequisite: first-year graduate student in Geological and Environmental Sciences, Geophysics, Petroleum Engineering, or equivalent.
3 units, Win (Aydin) alternate years, not given 2004-05

GES 219. Paleoceanography—For upper-division undergraduates and graduate students. How can we learn about the chemistry, circulation, biology, and geology of past oceans and why is this of interest? Evidence for substantial changes in earth's climate and surficial environment is contained in the sedimentary record. The fundamentals of gathering and interpreting this information in the context of understanding how earth processes functioned in the past and their relevance for the habitability of our planet in the future.
1-3 units, Win (Paytan) alternate years, not given 2004-05

GES 220. Terrestrial Biogeochemistry—(Enroll in BIOSCI 216.)
3 units (Vitousek) alternate years, given 2004-05

GES 221. The Origins of Life in the Solar System—Interdisciplinary seminar for upper-division undergraduates and graduate students in the physical and biological sciences. Current topics in exobiology and the origins of life from a planetary sciences perspective. Definitions of life and the origin of information; water, carbon, and energy; phylogenetic and fossil inferences about early life on Earth; the early terrestrial environment, including asteroid and comet impacts; prebiotic organic syntheses and the RNA world; panspermia; the search for life on Mars; Europa, including prospects for an ocean and speculative ecologies; upcoming spacecraft missions and mission planning; planetary protection, back contamination, and legal and ethical issues; and student suggested topics. Student presentations.
3 units (Chyba) alternate years, given 2004-05

GES 222. Planetary Systems: Dynamics and Origins—For students with a background in astronomy, earth sciences, geophysics, or physics. Motions of planets, moons, and small bodies; energy transport in planetary systems; meteorites and the constraints they provide on the formation of the solar system; asteroids and Kuiper belt objects; comets; planetary rings; planet formation; and extrasolar planets. In-class presentation of student papers.
3 units, Aut (Lissauer) alternate years, not given 2004-05

GES 223. Planetary Systems: Atmospheres, Surfaces, and Interiors—Focus is on physical processes, such as radiation transport, atmospheric dynamics, thermal convection, and volcanism, shaping the interiors, surfaces, and atmospheres of the major planets in the solar system. How these processes manifest themselves under various conditions in the solar system. Case study of the surface and atmosphere of Mars. Application of comparative planetary science to extrasolar planets and brown dwarfs. In-class presentation of student papers.
3 units, Win (Marley)

GES 225. Isotopes in Geological and Environmental Research—For upper-division undergraduates and graduate students. The applications of isotopic systems in geological, oceanographic, and environmental studies at low temperature. The use of isotopes as tracers for weathering rate, biogeochemical cycling, food-web structures, ecology, paleochemistry, provenance, circulation, and anthropogenic and extraterrestrial inputs. Emphasis is on developing skills in reading and evaluation of scientific papers, manuscript reviews, and proposal preparation. Prerequisite: 163, 164, or consent of instructor.
1-3 units (Paytan) alternate years, given 2004-05

GES 230. Physical Hydrogeology—(Same as CEE 260A.) Theory of underground water, analysis of field data and pumping tests, geologic groundwater environments, solution of field problems, groundwater modeling. Introduction to groundwater contaminant transport and unsaturated flow. Lab. Prerequisite: elementary calculus.
4 units, Aut (Gorelick)

GES 231. Contaminant Hydrogeology—(Same as CEE 260C.) For earth scientists and engineers. Environmental and water resource problems involving contaminated groundwater. The processes affecting contaminant migration through porous media including interactions between dissolved substances and solid media. Conceptual and quantitative treatment of advective-dispersive transport with reacting solutes. Predictive models of contaminant behavior controlled by local equilibrium and kinetics. Modern methods of contaminant transport simulation and optimal aquifer remediation. Prerequisite: 230 or CEE 260A or equivalent.
4 units, Spr (Gorelick)

GES 235. Role of Fluids in Geologic Processes—The principles governing groundwater flow and its interaction with crustal stress, heat flow, and chemical mass transport. Topography-driven flow of groundwater on a regional scale; compaction-driven flow in the sedimentary basin; development of anomalous fluid pressure; the role of fluid in tectonism; migration and entrapment of petroleum; density driven flow and thermal anomaly; formation of mineral deposits. Prerequisite: 230.
2-3 units (Hsieh) alternate years, given 2004-05

GES 236. Hydraulic and Tracer Tests for Groundwater Resource Evaluations—Theory and application of hydraulic and tracer tests to determine flow and the transport properties of aquifers. Analysis of well tests in single-layer aquifers and multiple aquifer-aquitard systems; water table conditions; anisotropy; double-porosity; effects due to wellbore storage, wellbore skin, aquifer boundaries, and heterogeneities such as faults and fracture zones; natural and forced gradient tracer tests.
2-3 units, Spr (Hsieh) alternate years, not given 2004-05

GES 237. Surface and Near-Surface Hydrologic Response—(Same as CEE 260B.) Quantitative review of process-based hydrology and geomorphology. Introduction to finite-difference and finite-element methods of numerical analysis. Topics: biometeorology, unsaturated and saturated subsurface fluid flow, overland and open channel flow, erosion and mass wasting, and physically-based simulation of coupled surface and near-surface hydrologic response and landscape evolution. Links hydrogeology, soil physics, and surface water hydrology.
4 units (Loague) alternate years, given 2004-05

GES 238. Soil Physics—Advanced. The physical and chemical properties of the soil solid phase, with emphasis on the transport, retention, and transformation of water, heat, gases, and solutes in the unsaturated subsurface. Agricultural systems. Field techniques and classic experiments demonstrated and reproduced in the lab. Prerequisite: elementary calculus.
4 units, Aut (Loague) alternate years, not given 2004-05

GES 239. Advanced Geomorphology—Advanced level, focusing on the surface/near-surface hydrologic processes governing landscape evolution. Topics: channel networks and landscape dissection. Current and classic theory. Case histories and experimental studies. Prerequisites: elementary calculus, 131.
4 units (Loague) alternate years, given 2004-05

GES 240. Geostatistics for Spatial Phenomena—(Same as PETENG 240.) Probabilistic modeling of spatial and/or time dependent phenomena. Kriging and cokriging for gridding and spatial interpolation. Integration of heterogeneous sources of information. Stochastic imaging of reservoir/field heterogeneities. Introduction to GSLIB software. Case studies from the oil and mining industry and environmental sciences. Prerequisites: introductory calculus and linear algebra, STATS 116, GES 161 or equivalent.
3-4 units, Win (Journel)

GES 241. Practice of Geostatistics and Seismic Data Integration—(Enroll in GEOPHYS 241, PETENG 241.)
3-4 units, Spr (Caers, Mukerji)

GES 242. Topics in Advanced Geostatistics—(Same as PETENG 242.) Conditional expectation theory and projections in Hilbert spaces; parametric versus non-parametric geostatistics; Boolean, Gaussian, fractal, indicator, and annealing approaches to stochastic imaging; multiple point statistics inference and reproduction; neural net geostatistics; Bayesian methods for data integration; techniques for upscaling hydrodynamic properties. May be repeated for credit. Prerequisites: 240, advanced calculus, Fortran/Unix.
3-4 units (Journel) alternate years, given 2004-05

GES 244. Modeling of 3D Geological Objects with Gocad—(Enroll in PETENG 244.)
3 units, Aut (Journel, Caumon)

GES 246. Reservoir Characterization and Flow Modeling with Outcrop Data—(Same as PETENG 246.) Project provides earth science students with an understanding of how to use outcrop observations in quantitative geological modeling and flow simulation, and addresses a specific reservoir management problem by studying a suitable outcrop analog (weekend field trip), constructing geostatistical reservoir models, and performing flow simulation. An introduction, through an applied example, to the relationship between the different disciplines. A different reservoir management question and outcrop analog is studied each year.
3 units, Aut (Aziz, Graham, Journel)

GES 249. Biological Markers—The fundamentals of understanding, interpreting, and applying biomarkers and their fingerprints. Biological markers (molecular fossils, biomarkers) are known from the Archean to the present as biologically derived carbon compounds that provide information on the paleoenvironment, geologic age and stratigraphy, thermal maturity, and diagenesis of sediments, rocks, and petroleum. Biomarker fingerprints are useful to monitor the environmental fate of petroleum and to map petroleum systems, and are key biogeochemical proxies for monitoringpaleoenvironmental conditions and changes. They have been a focus in the search for extraterrestrial life.
2-3 units, Win (Moldowan)

GES 250. Sedimentation Mechanics—The mechanics of sediment transport and deposition and the origins of sedimentary structures and textures as applied to interpreting ancient rock sequences. Dimensional analysis, fluid flow, drag, boundary layers, open channel flow, particle settling, erosion, sediment transport, sediment gravity flows, soft sediment deformation, and fluid escape. Field trip required.
4 units (Lowe) alternate years, given 2004-05

GES 251. Sedimentary Basins—Analysis of the depositional framework and tectonic evolution of sedimentary basins. Topics: tectonic and environmental controls on facies relations, synthesis of basin development through time in terms of depositional systems and tectonic settings. Weekend field trip required. Prerequisites: 110, 151.
3 units, Spr (Graham) alternate years, not given 2004-05

GES 252. Sedimentary Petrography—Siliciclastic sediments and sedimentary rocks. Research in modern sedimentary mineralogy and petrography and the relationship between the composition and texture of sediments and their provenance, tectonic settings, and diagenetic histories.Topics varies yearly. Prerequisite: 151 or equivalent.
4 units, Aut (Lowe) alternate years, not given 2004-05

GES 253. Petroleum Geology and Exploration—The origin and occurrence of hydrocarbons. Topics: thermal maturation history in hydrocarbon generation, significance of sedimentary and tectonic structural setting, principles of accumulation, and exploration techniques. Prerequisites: 110, 151. Recommended: GEOPHYS 184.
3 units (Graham) alternate years, given 2004-05

GES 255. Introduction to Micropaleontology—Microscopic marine fossils, including diatoms, ostracods, and radiolaria, with emphasis on foraminifera. The principles of classification, evolutionary trends, common genera, ecology, and environmental distribution of foraminifera. Application of planktonic and benthic foraminifera to interpretation of paleoenvironments, paleoceanographic and paleoclimatic analysis, and correlation of marine sequences. Paleoenvironmental and age analysis of an unknown microfossil sample serves as a term research project. Weekly lab.
5 units, Aut (Ingle) alternate years, not given 2004-05

GES 258. Introduction to Depositional Systems—The characteristics of the major sedimentary environments and their deposits in the geologic record, including alluvial fans, braided and meandering rivers, aeolian systems, deltas, open coasts, barred coasts, marine shelves, and deep-water systems. Emphasis is on subdivisions; morphology; the dynamics of modern systems; and the architectural organization and sedimentary structures, textures, and biological components of ancient deposits.
3 units (Lowe) alternate years, given 2004-05

GES 259. Marine Chemistry—(For graduate students; see 159.)
2-4 units, Spr (Paytan)

GES 260. Laboratory Methods in Organic Geochemistry—Knowledge of components in geochemical mixtures is useful to understand geological and environmental samples. The presence and relative abundance of these compounds provides information on the biological source, depositional environment, burial history, biodegradation, and toxicity of organic materials. Laboratory methods detect and quantify components of these mixtures. Basic understanding and hands-on experience of methods used for the separation and analysis of organic compounds in geologic samples: extraction, liquid chromatography, absorption by zeolites, gas chromatography and gas chromatography-mass spectrometry. Student samples considered as material for analysis. Recommended: 249.
2-3 units, Spr (Moldowan)

GES 261. Physics and Chemistry of Minerals and Mineral Surfaces—The concepts of symmetry and periodicity in crystals; the physical properties of crystals and their relationship to atomic-level structure; basic structure types; crystal chemistry and bonding in solids and their relative stability; the interaction of x-rays with solids and liquids (scattering and spectroscopy); structural variations in silicate glasses and liquids; UV-visible spectroscopy and the color of minerals; review of the mineralogy, crystal chemistry, and structures of selected rock-forming silicates and oxides; mineral surface and interface geochemistry.
4 units, Spr (Brown) alternate years, not given 2004-05

GES 262. Thermodynamics and Disorder in Minerals and Melts—The thermodynamic properties of crystalline, glassy, and molten silicates and oxides in light of microscopic information about short range structure and ordering. Measurements of bulk properties such as enthalpy, density, and their pressure and temperature derivatives, and structural determination by spectroscopies such as nuclear magnetic resonance and Mössbauer. Basic formulations for configurational entropy, heats of mixing in solid solutions, activities; and the energetics of exsolution, phase transitions, and nucleation. Quantitative models of silicate melt thermodynamics are related to atomic-scale views of structure. A general view of geothermometry and geobarometry. Prerequisites: introductory mineralogy and thermodynamics.
3 units (Stebbins) alternate years, given 2004-05

GES 264. Aquatic Chemistry—(Enroll in CEE 273.)
3 units, Aut (Leckie)

GES 265. Redox Processes in Soils and Sediments—Chemical and biologically mediated oxidation and reduction processes within soils, sediments, and surface/subsurface waters. Emphasis is on reactions and processes at the solid-water interface. Topics include electron transfer processes, dissimilatory metal reduction, redox reaction rates, alterations in mineralogy, and modifications in chemical behavior with changes in redox state.
3 units (Fendorf) alternate years, given 2004-05

GES 267. Solution-Mineral Equilibria: Theory—Procedures for calculating and evaluating the thermodynamic properties of reversible and irreversible reactions among rock-forming minerals and aqueous solutions in geologic systems. Emphasis is on the generation and utility of phase diagrams depicting solution-mineral interaction relevant to phase relations associated with weathering diagenetic, hydrothermal, and metamorphic processes, and the prediction of temperature, pressure, and the chemical potential of thermodynamic components compatible with observed mineralogic phase relations in geologic outcrops. Individual research topics. Prerequisite: 171.
3 units (Bird) alternate years, given 2004-05

GES 270. Petrologic Phase Equilibria—The principles of phase equilibrium determined by lab experimentation and thermochemical calculation, as applied to igneous and metamorphic petrology. Focus is on the underlying principles of classical thermodynamics which govern mineral equilibria. Introduction to phase relations, element partitioning, chemical kinetics, and order-disorder phenomena in geologic systems. Term paper optional.
4 units (Ernst) not given 2003-04

GES 275. Electron Probe Microanalytical Techniques—The practical and theoretical aspects of x-ray generation and detection, and the behavior of electron beams and x-rays in solids. The basic principles needed to quantitatively analyze chemically complex geological materials. Operation of the JEOL 733 electron microprobe and associated computer software for quantitatively analyzing materials. X-ray chemical mapping. Enrollment limited to 8.
2-3 units, Win (Jones)

GES 285. Petrogenesis of Crustal Magmatism—Radiogenic isotopes, stable isotopes, and trace elements applied to igneous processes; interaction of magmas with mantle and crust; convergent-margin magmatism; magmatism in extensional terrains; origins of rhyolites; residence times of magmas and magma chamber processes; granites as imperfect mirrors of their source regions; trace element modeling of igneous processes; trace element discriminant diagrams in tectonic analysis; sources of ore forming metals. Topics emphasize the interest of students. Prerequisite:181, or equivalent.
2 units, Aut (Mahood) alternate years, not given 2004-05

GES 287. Tectonics, Topography, and Climate Change—For upper-division undergraduates and graduate students. The links between tectonics and climate change with emphasis on the Cenozoic era. Focus is on terrestrial climate records and how they relate to large-scale tectonics of mountain belts. Topics include stable isotope geochemistry, geochronology, chemical weathering, stratigraphy of terrestrial rocks, paleofauna and flora, climate proxies and records, and Cenozoic tectonics. Guest speakers, student presentations, required field trip.
3 units, Win (Chamberlain) alternate years, not given 2004-05

GES 288. Archaeometry Seminar—(Undergraduates register for 188.) For upper-division undergraduates and graduate students. Introduction to the use of geochemical, geophysical, and remote sensing techniques as they apply to archaeology, emphasizing facilities available in the School of Earth Sciences.
1-2 units (Mahood) alternate years, given 2004-05

GES 290. Numerical Analysis of Geological Time Series—Seminar for graduate students interested in a variety of statistical tools appropriate for analysis of time series. Topics: Fourier transform techniques, singular spectrum analysis, evolutionary spectral analysis, and filtering. Prerequisite: some knowledge of UNIX.
3 units (Dunbar) alternate years, given 2004-05

GES 314. Structural Geology and Geomechanics—Research seminar. May be repeated for credit.
1 unit, Aut, Win, Spr, Sum (Staff)

GES 322A,B,C. Seminar in Biogeochemistry—Current topics. May be repeated for credit.
1-2 units, Aut, Win, Spr (Matson)

GES 323. Stanford at Sea—(Enroll in BIOHOPK 182H/323H, EARTHSYS 323.)
16 units (Block, Dunbar, Gilly, Micheli) alternate years, given 2004-05

GES 324. Seminar in Oceanography—Current topics. May be repeated for credit.
1-2 units, Aut, Win, Spr (Arrigo, Dunbar, Paytan)

GES 326. Isotopes and Biogeochemical Tracers in the Hydrological Cycle—Practical applications of environmental isotopes. The systematics of isotope fractionations and the distributions of isotopes in natural systems. Focus is on applications of isotopes for tracing waters, solutes, and biogeochemical reactions in hydrologic systems. Hydrological topics include tracing sources of ground and surface water, isotope hydrograph separations, groundwater influence on coastal systems, rock-water interactions, recharge rate, and groundwater dating. Biogeochemical topics include sources of contaminants, biogeochemical reaction mechanisms, nutrient sources and pathways, and food web studies.
3 units (Paytan, Kendall, Bullen) alternate years, given 2004-05

GES 327. The Glacial World—(Same as GEOPHYS 327.) The environmental changes that took place on Earth between the last glacial maximum (LGM) and the present. Focus is on the cause of the low atmospheric CO_2 concentrations characteristic of the LGM and what conditions explain these reduced CO_2 levels. How changes in sea level, marine primary production, ocean circulation, and elemental cycling may have contributed to past global changes.
2-3 units (Arrigo, Paytan) alternate years, given 2004-05

GES 329AB. Advanced Topics in Near-Surface Hydrologic Processes—Classic studies and current research in hydrology, geomorphology, and soil physics. Topics: nonpoint source groundwater contamination (agriculture), evapotranspiration, unsaturated fluid flow and solute transport, rainfall-runoff mechanisms, slope stability, restoration geomorphology.
1-2 units, Aut, Win (Loague)

GES 330A,B,C. Advanced Topics in Hydrogeology—Topics: questioning classic explanations of physical processes; coupled physical, chemical, and biological processes affecting heat and solute transport.
1-2 units, Aut, Win, Spr (Gorelick)

GES 332A,C. Seminar in Hydrogeology—Current topics. May be repeated for credit.
1 unit, Aut, Spr (Gorelick)

GES 333. Water Policy Seminar—(Enroll in CEE 333, IPER 333.)
1 unit, Spr (Freyberg)

GES 335. Special Topics in Earth Sciences Seminar—Suggested topics: gas hydrates, paleoproductivity, the glacial world, mass extinctions, the K/T boundary, hydrothermal vents, paleocirculation, warm climates in Earth's history, geomicrobiology, evaporite deposits. Guest speakers.
1-2 units (Paytan) alternate years, given 2004-05

GES 342A,B,C. Geostatistics—Classic results and current research. Topics based on interest and timeliness. May be repeated for credit.
1-2 units, Aut, Win, Spr (Journel)

GES 362. Silicate Glasses and Liquids—Current topics. May be repeated for credit.
2-3 units, by arrangement (Stebbins) alternate years, not given 2004-05

GES 385. Practical Experience in the Geosciences—On-the-job training in the geosciences. May include summer internship; emphasizes training in applied aspects of the geosciences, and technical, organizational, and communication dimensions. Meets INS requirements for F-1 curricular practical training.
1 unit, Aut, Win, Spr, Sum (Staff)

GES 399. Advanced Projects—Graduate research projects that lead to reports, papers, or other products during the quarter taken. On registration, students designate faculty member and agreed-upon units.
1-10 units, Aut, Win, Spr, Sum (Staff)

GES 400. Graduate Research—Faculty supervision. On registration, students should designate the appropriate faculty member and number of units as agreed upon.
1-15 units, Aut, Win, Spr, Sum (Staff)

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