Scripps Institution of Oceanography

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Steven C. Cande, Ph.D., *Marine Geophysics*
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Catherine G. Constable, Ph.D., *Geophysics*
Paul J. Crutzen, Ph.D., *Atmospheric Chemistry*
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Horst Felbeck, Dr. rer. nat., *Marine Biology*
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Carl H. Gibson, Ph.D., *Engineering Physics and Oceanography*
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William S. Hodgkiss, Ph.D., *Electrical Engineering*
Nicholas D. Holland, Ph.D., *Marine Biology*
Glenn R. Ierley, Ph.D., *Geophysics*
Jeremy B.C. Jackson, Ph.D., *Marine Biology and Geology*
Miriam Kastner, Ph.D., *Earth Sciences*
Charles D. Keeling, Ph.D., *Oceanography*
Ralph F. Keeling, Ph.D., *Geochemistry*
Charles F. Kennel, Ph.D., *Physics, Vice Chancellor of Marine Sciences and Director of Scripps Institution of Oceanography*
Nancy Knowlton, Ph.D., *Marine Biology*
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Devendra Lal, Ph.D., *Nuclear Geophysics*
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Paola Cessi, Ph.D., *Oceanography*
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Philip A. Hastings, Ph.D., *Marine Biology*
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Adjunct Professors

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Andrew E. Dizon, Ph.D., *Marine Biology*
Konstantine P. Georgakakos, Sc.D., *Hydrology*
John R. Hunter, Ph.D., *Marine Biology*
William F. Perrin, Ph.D., *Marine Biology*
Paul E. Smith, Ph.D., *Biological Oceanography*

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Bruce D. Cornuelle, Ph.D., *Research Oceanographer*
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Hugh Bradner, Ph.D., *Professor Emeritus, MAE*
Theodore H. Bullock, Ph.D., *Professor Emeritus, Neurosciences*
Juan C. Lasheras, Ph.D., *Professor, MAE*
Paul A. Libby, Ph.D., *Professor Emeritus, MAE*
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R. Glenn Northcutt, Ph.D., *Neurosciences*
Sutanu Sarkar, Ph.D., *Professor, MAE*

The graduate department of Scripps Institution of Oceanography offers instruction leading to Ph.D. degrees in oceanography, marine biology, and earth sciences. Although students are not admitted specifically for an M.S. degree, it is possible to obtain an M.S. on the way to completing the Ph.D. program. A graduate student's work normally will be concentrated in one of the curricular programs within the department: applied ocean science, biological oceanography, climate sciences, geosciences, geophysics, marine biology, marine chemistry and geochemistry, and physical oceanography.

No undergraduate major is offered in the department though most courses in the department are open to enrollment for qualified undergraduate students with the consent of the instructor. The UCSD Earth Sciences Undergraduate Program offers an earth sciences major leading to a B.S. or a combined B.S./M.S. degree. The interdisciplinary nature of research in marine and earth sciences is emphasized; students are encouraged to take courses from various UCSD departments, and to consider interdisciplinary research projects.

The Curricular Programs

Applied Ocean Science is a multidisciplinary program focused on the application of advanced technology to ocean exploration and observation. AOS students perform research in marine acoustics, optics, electromagnetics, geophysics, ecology, sediment transport, coastal processes, physical oceanography, and air-sea interaction. The emphasis is on the resolution of key scientific issues through novel technological development. The science focus of the Scripps AOS program is complemented by parallel Applied Ocean Science programs in both the Mechanical and Aerospace Engineering (MAE) and Electrical and Computer Engineering (ECE) departments. Students have access to professors, courses, and research facilities across all three departments.

Biological Oceanography is concerned with the interactions of populations of marine organisms with one another and with their physical and chemical environment. Because these interactions are frequently complex, and because the concepts and techniques used are drawn from many fields, biological oceanography is, of necessity, interdisciplinary. Therefore, studies in physical oceanography, marine chemistry, marine geology, and several biological areas are pertinent.

Research is conducted on space/time scales ranging from short-term interactions between individual organisms (mm., sec.) to interdecadal variation in widely dispersed populations. The techniques used in these investigations are diverse, and can include field observation and manipulations, experimentation in the laboratory, and mathematical modeling.

Research topics include primary and secondary productivity and nutrient regeneration, fishery biology and management, community ecology of benthic and pelagic organisms, population dynamics, habitat changes and disruptions, systematics and biogeography, population genetics and evolution, and behavior as it affects distribution. Development and testing of new tools (molecular, optical, acoustic), design of sampling programs, and statistical/mathematical analyses of data also are significant activities.

Climate Sciences concerns the study of the climate system of the earth with emphasis on the physical, dynamical, and chemical interactions of the atmosphere, ocean, land, ice, and the terrestrial and marine biospheres. The program encompasses changes on seasonal to interannual time scales and those induced by human activities, as well as paleoclimatic changes on time scales from centuries to millions of years. Examples of current research activities include: interannual climate variability; physics and dynamics of El Niño; studies of present and future changes in the chemical composition of the atmosphere in relation to global warming and ozone depletion; effects of cloud and cloud feedbacks in the climate system; paleoclimate reconstructions from ice cores, banded corals, tree-rings, and deep-sea sediments; the origin of ice ages; air-sea interactions; climate theory; terrestrial and marine ecosystem response to global change.

Geosciences emphasizes the application of general principles of geology, geochemistry, and geophysics to problems in the marine and terrestrial environments of the Earth. Graduate students routinely participate in expeditions at sea and on land and many doctoral theses evolve from these experiences.

Research areas in the geological sciences include: the origin and evolution of the ocean-atmosphere system and global climate; geology, geochemistry, and geophysics of oceanic crustal

rocks and near-shore environments; tectonic and structural evolution of the oceans, plate margins, and back-arc basins; the role of fluids in the crust; chemistry of rare gases in active volcanoes; the use of natural nuclear processes for understanding physical and chemical processes in the Earth; paleomagnetic applications in geology and geophysics.

Geophysics emphasizes the application of general principles of mathematics and experimental physics to fundamental problems of the oceans, oceanic and continental lithosphere, and crust and deep interior of the Earth. Research interests of the group include: observational and theoretical studies of electric and magnetic fields in the oceans and on the land; paleomagnetism; theoretical seismology with special emphasis on the structure of the Earth from free-oscillation and body wave studies; broadband observational seismology, including ocean bottom and multichannel seismology; earthquake source mechanisms; the measurements of slow crustal deformations using satellite and observatory methods on continents and in the oceans; marine geodynamics and tectonophysics; gravity measurements; geophysical inverse theory; magnetohydrodynamics of the core of the Earth; geophysical instrumentation for oceanic and continental geophysical measurements; acoustic propagation in the oceans.

Marine Biology is the study of marine organisms. It is concerned with evolutionary, organismic, genetic, physiological, and biochemical processes in these organisms, and the relationship between them and their biotic and physical environment. Marine biology encompasses several major areas of modern biology, and is interpreted by understanding the physical and chemical dynamics of the oceans. Faculty research focuses on microbiology, photobiology, high pressure biology, deep-sea biology, developmental biology, genetics, biomechanisms, comparative biochemistry and physiology, behavior, ecology, biogeography, and evolution of marine prokaryotes and eukaryotes. Processes ranging from the fertilization of sea urchin eggs to the role of bacteria in marine food web dynamics are under study in over twenty independent research laboratories.

Marine Chemistry and Geochemistry concerns chemical and geochemical processes operating in a broad range of study areas: the oceans, the solid earth, the atmosphere, marine organisms, polar ice sheets, lakes, meteorites, and the solar system.

Areas of advanced study and research include the physical and inorganic chemistry of seawater; ocean circulation and mixing based on chemical and isotopic tracers; marine organic and natural products chemistry; marine bioinorganic chemistry; geochemical interactions of sediments with seawater and interstitial waters; geochemistries of volcanic and geothermal phenomena; chemical exchanges between the ocean and the atmosphere; geochemical cycles of carbon, oxygen, sulfur, nitrogen, and other elements; isotopic geochemistry of the solid earth and meteorites; atmospheric trace gas chemistry; paleoatmospheric composition recorded in polar ice cores, corals and sediments; and chemistry of lakes and other freshwater systems.

Studies are typically interdisciplinary and involve integration of chemical concepts with information about the physical, biological, or geological processes that influence natural systems. Students in the marine chemistry and geochemistry curricular group are encouraged to explore these links.

Physical Oceanography is the field of study that deals with mechanisms of energy transfer through the sea and across its boundaries, and with the physical interactions of the sea with its surroundings, especially including the influence of the seas on the climate of the atmosphere. Research activities within this curricular group are both observational and theoretical and include: study of the general circulation of the oceans, including the relations of ocean currents to driving forces and constraints of the ocean basins; fluctuations of currents, and the transport of properties; the mechanisms of transport of energy, momentum, and physical substances within the sea and across its boundaries; properties of wind waves, internal waves, tsunami and planetary waves; the thermodynamic description of the sea as a system not in equilibrium; optical and acoustic properties of the sea; and the influence of surf on near-shore currents and the transport of sediments.

Requirements for Admission

Candidates for admission should have a bachelor's or master's degree in one of the physical, biological, or earth sciences; degrees in mathematics or engineering science are also accepted. A scholastic average of B or better in upper-division courses, or prior graduate study, is required. The student's preparation should include:

(1) mathematics through differential and integral calculus

(2) physics, one year with laboratory (the course should stress the fundamentals of mechanics, electricity, magnetism, optics, and thermodynamics, and should use calculus in its exposition)

(3) chemistry, one year with laboratory

(4) an additional year of physics, chemistry, or mathematics

(5) all applicants are required to submit scores from the general test of the Graduate Record Examinations (GRE) given by the Educational Testing Service of Princeton, New Jersey. Marine biology applicants must also submit scores of the GRE biology (or biochemistry, cell, and molecular biology) subject test.

All international applicants whose native language is not English and whose undergraduate education was conducted in a language other than English must take the TOEFL and submit their test scores to the UCSD Office of Graduate Admissions.

Specific additional requirements for admission to the various curricular programs are as follows:

Applied Ocean Science—Students are admissible with a strong background in physical science, engineering science, or mathematics. Three years of physics or applicable engineering and three years of mathematics at college level are expected.

Biological Oceanography—Two years of chemistry, including general and organic chemistry, and a year of general biology are required. Physical chemistry requiring calculus may be substituted for physics requiring calculus where a more elementary physics course was taken. Zoology or botany may be substituted for general biology. Preparation should also include a course in general geology and at least one course in each of the following categories: systematics (e.g., invertebrate zoology), population biology (e.g., ecology), functional biology (e.g., physiology). In special cases, other advanced courses in mathematics or natural sciences may be substituted. Biological oceanography applicants are encouraged, but not required, to submit scores of the biology subject test of the GRE.

Climate Sciences—Students are admissible if they satisfy the requirements of the physical oceanography, geophysics, or marine chemistry and geochemistry curricular programs. Biology and geology majors may also be admissible if the Scripps faculty feel that they have a sufficiently strong background in mathematics and physical science.

Geosciences—A major in one of the earth sciences and undergraduate physical chemistry and calculus are required. Preparation beyond the minimum requirements in mathematics, physics, and chemistry is strongly recommended.

Geophysics—A major in physics or mathematics, or equivalent training, is required.

Marine Biology—A major in one of the biological sciences (or equivalent), with basic course work in botany, microbiology, or zoology; two years of chemistry, including organic chemistry, is required. Training in one or more of the following areas is strongly recommended: cellular biology, molecular biology, comparative physiology, genetics, developmental biology, ecology, evolutionary biology, vertebrate and invertebrate zoology, microbiology, and/or botany. Biochemistry and physical chemistry will be expected of students in experimental biology, although the student may, if necessary, enroll in these courses at UCSD after admission.

Marine Chemistry and Geochemistry—A major in chemistry, geology, biochemistry, or related field, is required.

Physical Oceanography—A major in a physical science, including three years of physics and mathematics, is required.

Special consideration occasionally can be given to candidates with outstanding records who do not meet all required preadmission criteria.

Programs of Study

Programs of study vary widely among the curricular groups, but generally first-year students are expected to enroll in core courses that cover physical, geological, chemical, and biological oceanography and in other courses recommended by the student's faculty adviser. Then, by the end of the first year, students usually select a particular area of focus and choose a major professor. As students advance beyond the first year, they begin to function effectively as research assistants or, in some cases, as teaching assistants. During their third to fifth year they are working toward writing their dissertations.

The interdisciplinary nature of research in marine and earth sciences is emphasized; students are encouraged to take courses in several programs and departments, and to select research problems of interdisciplinary character. The curricular programs of study are as follows:

Applied Ocean Science—The AOS academic program is designed to provide both a broad background and a core technical base to support the diverse interests and activities of the students. Early participation in an ongoing research project is encouraged. However, specialization and focus on a specific thesis topic is not required until the second or third year of the program. Required courses include SIO 214A Introduction to Fluid Mechanics, SIO 221A Analysis of Physical Oceanographic Data, and the two-quarter Wave Physics sequence SIO 202A–B. Two of the four SIO introductory courses (SIO 210, 240, 260, 280), must be completed during the first year, with the remaining two required prior to passing the doctoral qualifying exam at the end of the third year. In addition, the applied math sequence SIO 203 A–B or MAE 294 A–B is taken in either the first or second year of study. The AOS Seminar (SIO 208) serves as a communications bridge across the program; enrollment in this seminar is required during the student's entire period of study. Beyond these core classes, the majority of each student's academic program is tailored to individual interests. The AOS departmental examination, held at the end of the first year, is based on the core technical courses SIO 214A, SIO 221A, SIO 202A–B, and two of the four introductory courses (chosen by the student). The exam has both oral and written components.

Biological Oceanography—The student will be expected to be familiar with the material presented in the following courses: SIO 210, 240, 260, 270 or 270A, 275A or 277, 280, 290, and at least one of SIO 271, 274, 282, 284, or 294. Other course work ordinarily will be recommended by the student's advisory committee, usually including 278 (or equivalent participatory seminar) one quarter of each year, a course in introductory parametric statistics, and at least one advanced-level course in physical, chemical, or geological oceanography. Participation in an oceanographic cruise (minimum of two weeks' duration) and service as a teaching assistant (one quarter) are required. Individual advisers and/or doctoral committees may require foreign languages or computer programming languages of individual candidates.

Climate Sciences—The emphasis of this curricular group is on education through interdisciplinary research. All students are responsible for the fundamental material in the following "core" courses: SIO 210, 217A-B-C, 260. Students are also expected to supplement their backgrounds with additional fundamental courses, including, for most Climate Sciences students, at least one additional quarter of fluid dynamics. These additional course(s) will be chosen in consultation with the students' advisors. Students are also required to participate actively in at least two quarters of seminar courses designed to complement and stimulate individual research. Though the group stresses interactions across disciplines, students will specialize in a particular subdiscipline or track that will be chosen by the student following discussions with a 3-person faculty advisory committee soon after arrival. Examples of current tracks include: (1) atmospheric/ocean/climate dynamics and physics; (2) atmospheric chemistry (emphasizing climatic interactions); and (3) paleoclimate studies. Additional course requirements for these tracks will be tailored to the needs of the individual student. It is possible that some of these tracks will be similar to those recommended by other curricular groups such as Physical Oceanography or Applied Ocean Science.

Geosciences—The geosciences curriculum consists of a series of core courses and a series of research focus courses. All students whether pursuing an earth sciences or an oceanography degree are responsible for material in the core courses: Marine Geology (SIO 240), Marine Chemistry (SIO 260), and Physical Oceanography (SIO 210) during their first year of study. The research courses are selected from three themes: Geochemistry, Paleoclimate and Earth History, and Geology and Geophysics. A total of four research courses are required during the first year of study, with at least one from each theme. Additional courses offered by other curricular programs (e.g., geophysics, marine chemistry, and geochemistry) can be selected and scheduled depending on the student's background and interests any time during the student's career at SIO. A three-member faculty advisory committee is assigned to each student to help select the research and additional courses to be taken. Each student is also encouraged to participate in the Special Topics seminars (SIO 249) every quarter during the first two years of gradu-

ate study. Students wishing to graduate with an oceanography degree are also responsible for the material in SIO 280 (Biological Oceanography). Normally, students will take a comprehensive oral departmental examination near the end of their third quarter of residence. The qualifying examination will be given before the end of the third year.

Geophysics—There is no single course of study appropriate to the geophysics curriculum; instead, the individual interests of the student will permit, in consultation with the adviser, a choice of course work in seismology, geomagnetism, etc., although the content of certain core courses is usually taken during most of the first year. In the summer or early fall quarter following that year each student will be given written and oral departmental examinations, which are intended to cover the student's formal training. A brief presentation of possible research interests will also be expected at this exam.

Geosciences/Geophysics Track—For those students whose interests fall between the programs provided by the geosciences and the geophysics curricular groups, these groups are jointly offering a separate program and departmental examination. Such students would be admitted either to the geosciences or geophysics curricular group, but could declare their interest in a geosciences/geophysics track early in their first year. If they did so, they would take a departmental exam (at the end of spring quarter of their first year) which would be conducted by a committee with members from both curricular groups, and focusing on the student's ability to integrate material relevant to the subject. The expected courses would include those geosciences/geophysics courses appropriate to this specialization.

Marine Biology—Entering graduate students will be expected to gain research experience in one or more laboratories during their first year. In the spring term of their first year at SIO, students will take a departmental exam consisting of a presentation of their first-year research in the form of a paper and short talk to the curricular group, followed by a meeting with their first-year advisory committee. In this exam they also will be expected to demonstrate competence in the material covered in the following courses: SIO 210, 260, 280, 290 as well as any other course work recommended by the advisory committee. After their first year all students are expected to enroll and actively participate in at least one seminar course (SIO 278, 296, or equivalent) per year to provide in-depth knowledge and reading in selected areas, and to provide practice presenting scientific material. In addition to the seminar requirement discussed above, second-year students will present their research in a special Marine Biology mini-symposium, held in spring quarter; students in the third year and beyond are expected to participate in the research presentation class (SIO 291) each year. The curricular group coordinator, in consultation with the Ph.D. advisory committee, may waive specific course requirements in individual cases.

Marine Chemistry and Geochemistry—Students in this curricular group are required to take SIO 210, 260, and either SIO 280 or a suitable geosciences course (e.g. SIO 240) in their first year at SIO. Students in this curriculum are also expected to take additional SIO and UCSD courses; the exact choice of such courses will depend on the student's research interests and should be made in consultation with a faculty adviser.

Physical Oceanography—The physical oceanography curriculum combines a comprehensive program of coursework with individually tailored specialization to meet student needs. Students will demonstrate proficiency in foundation courses required for all subdisciplines of physical oceanography (SIO 203A-B, 214A, 212A), as well as additional courses appropriate to their specialization or interdisciplinary interest. Presently defined "tracks" in the curriculum are (i) Observational Physical Oceanography, (ii) Theoretical Physical Oceanography, and (iii) the Atmospheric/Ocean Climate System. All tracks are similar in the entry-year Fall Quarter, diverging as students become more familiar with the field and in their interests. A faculty Curriculum Advisory Committee meets with students to tailor tracks to individual needs, or to create new tracks as appropriate. In any track, the total body of required knowledge is equivalent to 16 four-unit courses, of which about 12 are covered during the first year. As part of the overall requirement, tracks include a breadth component of 2 or more four-unit courses in other oceanographic disciplines. These might come from the SIO core courses in other disciplines (SIO 240, 260, 280) or from related graduate level courses taught at UCSD.

Language Requirements

The department has no formal language requirements. Within the department, some curricular programs may require demonstration of ability to use certain foreign languages pertinent to a student's research. All students must be proficient in English.

Departmental and Qualifying Examinations

Doctoral candidates normally will be required to take a departmental examination not later than early in the second year of study. The examination will be oral and/or written depending on the curricular group. The student will be required to demonstrate, in a quantitative and analytical manner, comprehension of required subject material and of the pertinent interactions of physical, chemical, biological, or geological factors.

When the student has passed the departmental examination, and has completed an appropriate period of additional study, the department will recommend appointment of a doctoral committee which will supervise the student's performance and reporting of his or her research. The doctoral committee must be formed before the student may proceed to the qualifying examination.

The doctoral committee will determine the student's qualifications for independent research by means of a qualifying examination, which will be administered no later than the end of the third year. The nature of the qualifying examination varies between curricular groups. In biological oceanography, marine biology, geosciences, physical oceanography, applied ocean science, and climate sciences the student will be expected to describe his or her proposed thesis research and satisfy the committee, in an oral examination, as to mastery of this and related topics. In marine chemistry and geochemistry the student, in an oral examination, is required to present and defend a single research proposition in his or her specialized area. The student also is required to provide a written summary of the research proposition, with references, prior to the examination. In geophysics, the student presents an original research problem, in the form of a written proposition, to the doctoral committee. The student's oral presentation and defense of this proposition completes the examination.

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Dissertation

A requirement for the Ph.D. degree is the submission of a dissertation and a final examination in which the thesis is publicly defended. We encourage students to publish appropriate parts of their theses in the scientific literature. Individual chapters may be published as research articles prior to completion of the dissertation.

Departmental Ph.D. Time Limit Policies

Students must complete a qualifying examination by the end of three years, and must be advanced to candidacy for the Ph.D. degree by the end of four years. Total university support may not exceed seven years and total registered time at UCSD may not exceed eight years.

Special Financial Assistance and Fellowships

In addition to teaching assistantships, and graduate student researcher positions, fellowships, traineeships, and other awards available on a campus-wide competitive basis, the department has available a certain number of fellowships and graduate student researcher positions supported from research grants and contracts, or from industrial contributions.

COURSES

LOWER-DIVISION

87. Freshman Seminar (1)
The Freshman Seminar Program is designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small setting. Topics vary from quarter to quarter. Enrollment is limited to 15–20 students, with preference given to entering freshmen. (P/NP grades only.) SIO Staff (F,W,S)

UPPER-DIVISION

198. Directed Group Study (2-4)
Directed group study on a topic or in a field not included in the regular department curricula, by special arrangement with a faculty member. (P/NP grades only.) *Prerequisite: consent of instructor.* Staff (F,W,S)

199. Special Studies (2 or 4)
Independent reading or research on a problem by special arrangement with a faculty member. (P/NP grades only.) *Prerequisite: consent of instructor.*

GRADUATE

200A. Computational Ocean Acoustics and Signal Processing I (4)
Overview of ocean acoustics. Acoustics Wave Equation with some analytic solution techniques. Ray Methods. Introduction to Spectral and Normal Modes methods. Introduction to beamforming including matched field processing. Computer programs will be constructed on all subjects covered. *Prerequisites: basic physics and familiarity with differential equations and some linear algebra.* Kuperman (F)

200B. Computational Ocean Acoustics and Signal Processing II (4)
Continuation of SIO 200A. Range dependent propagation models including adiabatic and coupled mode models and parabolic equations. More advanced topics in matched field processing. *Prerequisite: SIO 200A.* Kuperman (W)

200C. Computational Ocean Acoustics and Signal Processing III (4)
Continuation of SIO 200B. Modeling interference such as ambient noise. Time domain methods. Matched field tomography, nonlinear optimization methods, and geophysical inversion. *Prerequisite: SIO 200B.* Kuperman (S)

201. Geological Record of Climate Change (4)
Introduction to geological archives; the tools for paleoclimate reconstruction and a sampling of important issues from the geological record, including the development of "greenhouse" and "icehouse" worlds, the origin and evolution of glacial cycles, and the origin of "millennial scale" climate variability. *Prerequisite: chemistry and physics required for graduate admission to SIO, ERTH 101 or equivalent, or consent of instructor.* Charles (W)

202 A-B. Fundamentals of Wave Physics (4-4)
This two-quarter sequence is designed to introduce a broad background of students to basic principles of wave physics, including generation, propagation, dispersion, refraction, diffraction, reflection, waveguides, etc. A variety of wave motions of environmental relevance, including acoustic, ocean surface and internal (SIO 202A), optical and seismic (SIO 202B) are used to illustrate these principles. In-class experiments, data collection, and analysis exercises are incorporated. *Prerequisites: calculus and partial differential equations*. Buckingham, Kuperman, Stramski, Melville, Hildebrand, Dorman (W)

203A-B-C. Methods of Applied Analysis (4-4-4)
Methods of analysis with emphasis on physical applications, including: complex analysis, Fourier methods, Sturm-Liousville theory, boundary value problems and Green's function techniques, Frobenius' method, special functions, steepest descents, multiple scales, WKB methods, asymptotic expansions, variational methods, Wiener-Hopf techniques, Galerkin methods. *Prerequisites: Math. 110 and 120A, or consent of instructors.* Cessi, Ierley, Young (F,W,S)

204A. Advanced Acoustics I (4)
Boundary value problems in vibrating systems, wave propagation in strings, bars, and plates. Fundamentals of acoustical transducers. *Prerequisite: concurrent registration in ECE 145AL recommended.* Hildebrand (F)

204B. Advanced Acoustics II (4)
Theory of radiation, transmission and scattering of sound with special application to ocean acoustics. *Prerequisites: concurrent registration in ECE 145BL recommended; SIO 204A or consent of instructor.* Buckingham (W)

204C. Advanced Acoustics III (4)
Signal processing in underwater acoustics. Theory and hardwave embodiments. *Prerequisites: concurrent registration in ECE 145CL recommended; SIO 204B or consent of instructor.* Buckingham (S)

205. Applied Nonparametric Statistics (4)
Methods of nonparametric statistical analysis. sampling, and experimental design with emphasis on those procedures particularly useful in field studies. Designed to supplement an introductory parametric statistics course. Offered in alternate years. *Prerequisites: elementary statistics or consent of instructor.* Venrick (S)

207A. Digital Signal Processing I (4)
Sampling: A/D and D/A conversion, discrete linear system theory, z-transforms; digital filters, recursive and nonrecursive designs, quantization effects; fast Fourier transforms, windowing, high speed correlation and convoluting; discrete random signals; finite word length effects. *Prerequisite: ECE 109, 153, or consent of instructor.* (S/U grades permitted.) Hodgkiss (F)

207B. Digital Signal Processing II (4)
Power spectrum estimation; homomorphic signal processing; applications to: speech, radar/sonar, picture, biomedical, and geophysical data processing. *Prerequisite: SIO 207A or consent of instructor.* (S/U grades permitted.) Hodgkiss (W)

207C. Digital Signal Processing III (4)
Single and multichannel data processing in a time varying environment; adaptive filters; high resolution spectral estimation; linear prediction; adaptive beamforming. *Prerequisite: SIO 207A-B or consent of instructor*. (S/U grades permitted.) Hodgkiss (S)

207D. Array Processing (4)
The coherent processing of data collected from sensors distributed in space for signal enhancement and noise rejection or wavefield directionality estimation. Conventional and adaptive beamforming. Sparse array design techniques. Applications to ocean acoustics and marine geophysics. *Prerequisite: SIO 207A or equivalent*. (S/U grades permitted.) Hodgkiss, Dorman (F)

208. Seminar in Applied Ocean Sciences (1)
Topics in applied ocean sciences. One hour seminar. (S/U grades only). Staff (F,W,S)

209. Special Topics (1-4)
Within the next few years, lectures on various special subjects will be offered by members of the staff. The emphasis will be on topics that reveal the interdependence of the biological, chemical, geological, and physical processes operating in the oceans. (S/U grades permitted.) Staff (F,W,S)

210. Physical Oceanography (4)
Physical description of the sea; physical properties of seawater, methods and measurements, boundary processes, regional oceanography. *Prerequisites: the mathematics and physics required for admission to the graduate curriculum in the Scripps Institution of Oceanography (see text), or consent of instructor.* Hendershott, Talley (F)

211A-B. Ocean Waves (4-4)
Propagation and dynamics of waves in the ocean including the effects of stratification, rotation, topography, wind, and nonlinearity. *Prerequisites: for SIO 211B, SIO 211A and SIO 214A, or consent of instructor.* Guza, Hendershott, Melville, Salmon, (W,S)

212A-B. Geophysical Fluid Dynamics (4-4)
The equations of motion for rotating stratified flow and their application to the atmospheric and oceanic dynamics; Ekman layer dynamics, potential vorticity dynamics, the quasigeostrophic approximation, theories of the wind-driven oceanic circulation, theories of the atmospheric Hadley circulation, geostrophic adjustment, and baroclinic instability. *Prerequisite: SIO 214A or consent of instructor.* Cessi, Young (W,S)

213. Ocean Turbulence and Mixing (4)
Mixing mechanisms, their identification, description, and modeling. Introduction to turbulence, semi-empirical theories, importance of coherent structures, effects of stratification and rotation on turbulent structure, entrainment and mixing. Cross-listed with MAE 214B. (S/U grades permitted.) Armi (S)

214A. Introduction to Fluid Mechanics (4)
A survey of classical problems in fluid mechanics and approximate techniques of analysis. Topics include conservation equations, straight laminar flows, low and high Reynolds number laminar flow, stability of laminar flows, turbulent flow. *Prerequisite: partial differential equations.* Winant, Melville, Young, Armi (F,W)

214B. Environmental Fluid Dynamics (4)
Single-layer flows with a free surface, two-layer flows including exchange flows in harbors, estuaries, seas, and buildings. Continuously stratified flows with meteorological and oceanographic applications. Topographic effects, plumes, jets, and thermals. Cross-listed with MAE 224. *Prerequisite: introductory graduate level course in fluid mechanics.* (S/U grades permitted.) Armi (F)

215. Introduction to Atmospheric Radiative Transfer (4)
Introduces elementary concepts in electromagnetism and quantum mechanics to explain scattering, absorption and emission by gases, aerosols, and clouds. Elegant analytical solutions to the transfer equation will be employed in conjunction with satellite and laboratory measurements to consider phenomena such as the CO_2 greenhouse effect, albedo effect of clouds, color of the skies, and atmospheric radiative cooling. *Prerequisites: undergraduate courses in physics and differential calculus.* Ramanathan (S)

216. Introduction to the Physics of Complex Systems (4)
Emergent complex behavior in nonlinear, dissipative, open dynamical systems will be investigated by studying fundamental properties and their manifestation in examples drawn from the physical and biological sciences. Topics to include fractals, chaos, self-organization, artificial life, and neural networks. *Prerequisites: basic solid and fluid mechanics, mathematics through PDEs, and computer programming skills.* (S/U grades permitted.) Werner (W)

217A. Atmospheric and Climate Sciences I (4)
Thermodynamics and statics of dry and moist air, atmospheric composition, Earth radiation budget, vertical structure of the atmosphere, global energy balance, thermodynamic feedbacks in the climate system. *Prerequisites: undergraduate general physics and mathematics through differential equations.* (S/U grades permitted.) Somerville (F)

217B. Atmospheric and Climate Sciences II (4)
Structure of midlatitude synoptic systems; equations of motion, scale analysis, elementary applications and wave solutions; baroclinic instability theory; atmospheric general circulation and energetics; tropical dynamics; relationships between atmospheric dynamics, CO_2 clouds, precipitation, and other weather and climate phenomena. *Prerequisite: SIO 217A.* J. Norris (W)

217C. Atmospheric and Climate Sciences III (4)
Physical and dynamical processes that determine climate and climate change; role of aerosols; water vapor; CO_2 and other greenhouse gases; cloud-radiative interactions; atmospheric general circulation; role of convection; tropical climate including El Niño. *Prerequisites: SIO 217A and 217B or equivalent background.* Ramanathan (S)

219. Special Topics in Physical Oceanography (1-4)
Example topics are case histories and methods in physical oceanography, theories of the ocean circulation, numerical methods in large-scale ocean and atmospheric models, and natural electromagnetic phenomena in the earth and the oceans. (S/U grades permitted.) Staff (F,W,S)

220. Observations of Large-Scale Ocean Circulation (4)
General circulation of the oceans; tropical, subtropical, and high-latitude current systems of the Atlantic, Indian, and Pacific Oceans and marginal seas; ocean heat flux and thermohaline circulations; observational basis of large-scale dynamics. *Prerequisite: SIO 210.* (S/U grades permitted.) Roemmich (S)

221A. Analysis of Physical Oceanographic Data (A) (4)
Fundamental elements of analysis of geophysical and oceanographic time series, including sampling problems, least squares techniques, spectral analysis, interpretation of series, design of experiments. *Prerequisite: consent of instructor.* Guza, Pinkel (F)

221B. Analysis of Physical Oceanographic Data (B) (4)
Techniques for analysis of physical oceanographic data involving many simultaneous processes including probability densities, sampling errors, spectral analysis, empirical orthogonal functions, correlation, linear estimation, objective mapping. Prerequisite: SIO 221A or consent of instructor. (S/U grades permitted.) Davis, Rudnick (W)

222. Underwater Bioacoustics (4)
Introductory course to familiarize a broad spectrum of participants to underwater sound and its relationship to underwater animals. Basic physics of sound propagation. use of sound to study underwater animals and, the sounds made by the animals themselves for echolocation and communication will be covered. *Prerequisite: consent of instructor*, (S/U grades permitted Jaffe (W)

223. Geophysical Data Analysis (4)
Design of geophysical experiments and analysis of geophysical measurements, interpretation of geophysical time series; sampling, least squares, spectrum analysis. Staff (W)

224. Internal Constitution of the Earth (4)
An examination of current knowledge about the composition and state of the earth's interior revealed by geophysical observations. Seismic velocity and mass density distributions; equations of state; phase changes; energy balance and temperatures; constraints on composition from extraterrestrial samples and exposed rocks; spherical and aspherical variations of properties. *Prerequisites: calculus and differential equations, basic chemistry and physics, or consent of instructor.* Staff (S)

225. Physics of Earth Materials (4)
Mathematics and physics of continuous media, focusing on geophysical problems. Topics include deformation, stress, conservation laws, elasticity, attenuation, viscoelasticity, fracture mechanics, and porous media. *Prerequisite: consent of instructor.* Staff (F)

226. Introduction to Marine Geophysics (4)
Methods of exploration geophysics with emphasis on those useful at sea. Magnetic and gravitational potential field methods, multi-beam echo sounding reflection and refraction seismology will be covered. Recent papers from the literature will also be read and discussed. *Prerequisites: differential equations; at least one geology course.* (S/U grades permitted.) Dorman, Hildebrand (W)

227A. Introduction to Seismology (4)
Introduction to seismometers and seismograms; stress and strain; potentials and the wave equation; geometrical ray theory and travel times in layered media; representation of seismic sources; WKBJ and synthetic seismograms; seismic hazards and other applications of seismology. *Prerequisite: consent of instructor.* (S/U grades permitted.) Staff (F)

227B. Advanced Seismology I (4)
Introduction to low-frequency digital data; continuum mechanics and the equations of motion; free oscillation solutions; construction of Earth models; excitation of free-oscillations and source mechanism retrieval; array processing of long-period data; modelling aspherical structure; surface waves. *Prerequisite: consent of instructor.* (S/U grades permitted.) Staff (W)

227C. Advanced Seismology II (4)
High-frequency wave propagation; methods for computing synthetic seismograms including WKBJ, reflectivity and finite differences; body-wave spectra; attenuation of body waves; source physics; reflection and refraction seismology; seismic tomography. *Prerequisite: consent of instructor.* (S/U grades permitted.) Staff (S)

229. Gravity and Geomagnetism (4)
Introduction to potential theory, with applications to gravity and geomagnetism. Topics include the geoid, spherical harmonics, Laplace's equation, the Dirichlet problem on a sphere, and Fourier methods. Gravity anomalies and geomagnetic field modeling and sources are discussed; also paleomagnetic observations. *Prerequisites: advanced calculus, differential equations, complex variables, and familiarity with Maxwell's equations, or consent of instructor.* (S/U grades permitted.) C. Constable, Parker (F)

230. Introduction to Inverse Theory (4)
Solution of linear and nonlinear inverse problems in geophysics by optimization techniques such as norm minimization and linear programming. Construction of models by regularization; inference by bounding functionals. Illustrations from gravity, geomagnetism, and seismology. *Prerequisite: consent of instructor.* (S/U grades permitted.) Parker (W)

232. Environmental Geophysics (4)
A field-based course on the geophysical techniques employed in modern environmental surveys for ground water studies, contaminant and hazard assessment, soil and foundation evaluation, and archaeology. Includes shallow seismic, electrical, and ground

penetrating radar methods. Seminars describing equipment and procedures will be followed by field trips, and the resulting data reduced and interpreted under supervision. *Prerequisite: consent of instructor.* S. Constable, Harding (S)

234. Geodynamics (4)
A general course on the dynamics and kinematics of the solid earth based on the text of Turcotte and Schubert. Topics include plate tectonics, heat flow, lithospheric cooling, flexure, viscous flow, global gravity, crustal structure, and other related topics. *Prerequisite: familiarity with partial differential equations and Fourier transforms.* (S/U grades permitted.) Sandwell (W)

235. Geodesy (4)
An introduction to the science and technology of determining the Earth's shape and gravity field with emphasis on applying this knowledge to geophysical problems. We will discuss both terrestrial measurement methods and the newer space-geodetic techniques. Additional topics include geometric and gravimetric geodesy, geodetic astronomy, and adjustment procedures, with special attention to the determination of crustal deformation. *Prerequisite: consent of instructor.* (S/U grades permitted.) Agnew, Bock (W)

236. Satellite Remote Sensing (4)
A general course on physical principles of remote sensing based on the text by Rees. Topics include: orbit geometries and platforms; propagation, reflection, and emission of electromagnetic waves; electro-optical systems; passive microwave systems, ranging systems; and scattering techniques such as SAR. *Prerequisite: consent of instructor.* (S/U grades permitted.) Sandwell (F)

237A. Introduction to Ocean Optics (4)
Overview of ocean optics. Concepts in radiometry. Inherent and apparent optical properties. Radiative transfer equation. Light absorption and scattering by seawater constituents. Optics of air-water interface. Light fields within and leaving the ocean. Optics of marine particles. Measurement methods and instrumentation. *Prerequisites: basic physics and differential calculus, or consent of instructor.* Stramski (F)

237B. Ocean Color Remote Sensing (4)
Overview of ocean color satellite missions. Concepts in radiometry. Inherent and apparent optical properties. Radiative transfer equation. Solar radiation and elements of atmospheric optics. Propagation of light across the sea surface and within the ocean. Light absorption and scattering by seawater. Water-leaving radiance and remote-sensing reflectance. Ocean color algorithms and applications. *Prerequisites: basic physics and differential calculus, or consent of instructor.* (S/U grades permitted.) Stramski (F)

237C. Optical-Biological Interactions in the Ocean (4)
A discussion class with emphasis on the interaction of light with marine plankton. Topics will include light absorption, fluorescence, and scattering by phytoplankton and effects of growth conditions on phytoplankton optical properties. Classic and contemporary papers dealing with these topics will be discussed. *Prerequisites: basic physics and biology, or consent of instructor.* (S/U grades only.) Stramski (F)

239. Special Topics in Geophysics (1-4)
Special course offerings by staff and visiting scientists. Example topics are seismic source theory, geophysical prospecting methods, dislocation theory and seismic mechanisms, tectonic interpretation of geodetic data, and dynamo theory. (S/U grades permitted.) Staff (F,W,S)

240. Marine Geology (4)
Introduction to the geomorphology, sedimentation, stratigraphy, vulcanism, structural geology, tectonics, and geological history of the oceans. *Prerequisites: the physics and chemistry required for admission to the graduate curriculum in SIO, and ES 101 or equivalent, or consent of instructor.* Staff (W)

241. Seminar in Hydrogeology and Tectonics (2)
Introduction to the role that fluids play in the physical development of active tectonic systems. Discussions will focus on the nature of the processes controlling fluid flow through the Earth's crust and the dynamic interaction of fluid migration and faulting. *Prerequisite: ES 101 or equivalent.* (S/U grades permitted.) Brown (S)

243. Marine Paleoecology (4)
Paleoecology of marine plankton, nekton, and benthos. Patterns and changes in marine communities and ecosystems over geological time in relation to changes in the physical, chemical, and geological environment and biotic interactions. The preservation filter and inference of ecological processes from fossils and biogeochemical proxies. Biotic interchanges, incumbency, escalation and trends, mass extinctions, and recovery. Lectures, seminar discussion, laboratory, and field trips. *Prerequisites: bachelor's degree in science or consent of instructor; open to undergraduates with completion of ERTH 104 and either BIEB 130 or BIEB 140, or equivalent.* Jackson, Staff (W)

244. Shape and Structure of the Ocean Floor (4)
Description and explanation of the structural geomorphology of oceanic crust, and of the tectonic and volcanic processes responsible for it. Description and interpretation of deep-sea sedimentary landforms (e.g., deep-sea fans, drifts, bedforms) and of the bottom currents that shape them. Offered in alternate years. *Prerequisite: any previous graduate/undergraduate earth science or geology course*. Lonsdale (S)

245. Seminar in Marine Sediment Geochemistry (2)
Chemical paleoceanography will be the focus, emphasis, on seawater and/or sediment chemical and isotopic records; discussions will concentrate on some of the following istopic systems: Li, B, C, O, S, Sr, and Nd, and on select chemical tracers such as Cd and Ir; on the marine phases that most reliably record seawater chemical and isotope compositions; and on diagenetic problems, how to identify and deal with them. *Prerequisite: SIO 260 and consent of instructor.* (Offered in alternate years.) (S/U grades permitted.) Kastner (S)

246. Global Tectonics and Basin Formation (4)
Plate tectonics of the crust and upper mantle, examining a variety of environments from ridge crests to continental margins, including plate interiors, with an emphasis on basin formation in these tectonic settings. *Prerequisite: graduate standing*. Cande, Driscoll (F)

247. Rock Magnetism and Paleomagnetism (4)
Rock magnetism and acquisition of magnetic remanence in geological materials as well as laboratory procedures and data analysis (isolating remanence components and statistical approaches). The paleomagnetic literature will be used to illustrate applications in geological and geophysical problems. *Prerequisites: one year each of college-level physics and geology; mathematics through calculus.* (S/U grades permitted.) Tauxe (W)

249. Special Topics in Marine Geology (1-4)
Special course offerings by staff and visiting scientists. (S/U grades permitted.) Staff (F,W,S)

252. Isotope Geochemistry (4)
Radioactive and stable isotope studies in geology and geochemistry, including geochronology, isotopes as tracers of magmatic processes, cosmic ray produced isotopes as tracers in the crust and weathering cycle, isotopic evolution of the crust and mantle. Offered in alternate years. Conjoined with ES 144. *Prerequisite: SIO entrance requirements or consent of instructor.* (S/U grades permitted.) Macdougall, Lal (S)

256A. Introduction to Field Geology (4)
Mapping and interpretation of geologic units and structures in the field. Field observations at the surface are related to theory and extrapolated to three dimensions. Field work is done on weekends in local areas; field data are discussed and evaluated through applicable geologic principles in the laboratory. Conjoined with ERTH 162A. *Prerequisites: consent of instructor; to be taken concurrently with SIO 256L.* Brown, Castillo (W)

256L. Structural Analysis for Field Geology (4)
Principles of stratigraphy and structural geology applicable to field geologic studies. Discussion and laboratory exercises. Conjoined with ERTH 162L. *Prerequisites: consent of instructor; to be taken concurrently with SIO 256A.* Brown, Castillo (W)

257. Seminar in Petrology (4)
Discussion of current research in petrology and mineralogy. (S/U grades permitted.) Hawkins (W)

259. Atmospheric Geochemistry (4)
Topics in this introductory course include: structure and composition of the atmosphere; chemistry and isotopes of natural and man-made carbon-, nitrogen-, and sulfur-bearing trace gases; ozone and hydroxyl radical; halogenated gases; air-sea exchange; aerosols; climatic effects. (S/U grades permitted.) Wahlen, Weiss (W)

260. Marine Chemistry (4)
Chemical description of the sea; the distribution of chemical species in the world oceans, and their relationships to physical, biological, and geological processes. Aluwihare, Barbeau, R. Keeling (W)

261. Energetics and Kinetics in Marine Systems (4)
This course teaches the physical chemical principles that control chemistry in marine systems. After a basic introduction to thermodynamics and its application to an understanding of the marine environment, the emphasis will be on the study of a variety of kinetic processes. *Prerequisites: undergraduate chemistry equivalent to UCSD Chemistry 6 sequence, SIO 260.* Dickson (S)

262. Seminar in Marine Natural Products (1)
Students will give seminars on current research topics in marine natural products chemistry. *Prerequisite: consent of instructors.* (S/U grades only.) Fenical (F,W,S)

263. Aqueous Chemistry (4)
This course emphasizes the chemical principles that control basic aqueous chemistry in marine systems. The focus will be to show that the geochemistry of the various elements in sea water and biological systems can be understood as a consequence of basic general chemical concepts such as electron structure, chemical bonding, and group and periodic properties. *Prerequisite: undergraduate chemistry equivalent to UCSD Chemistry 6 sequence.* Dickson (F)

265. Chemical Ecology of Marine Organisms (4)
An outline of the organic chemicals from marine organisms with special reference to their function in the marine environment. The differences between terrestrial and marine natural products will be stressed. *Prerequisite: basic organic chemistry.* Fenical (W)

268. Seminar in Geochemistry and Marine Chemistry (1)
Student seminars on topics related to geochemistry and the chemistry of the marine environment. (S/U grades only.) Dickson (W)

269. Special Topics in Marine Chemistry (1-4)
Special course offerings by staff and visiting scientists. (S/U grades permitted.) Staff (F,W,S)

270. Pelagic Ecology (4)
An analysis of the concepts and theories used to explain the biological events observed in the water column. Alternate years. *Prerequisites: SIO 210, 280, or consent of instructor.* Checkley, Ohman (S)

270A. Fisheries Oceanography (4)
Aspects of marine ecology relevant to the reproduction, survival, and distribution of commercially important marine species. Alternate years only. *Prerequisites: SIO 210 and 280, or consent of instructor.* (S/U grades only.) Checkley (S)

271. Marine Zooplankton (4)
Lectures and laboratories treating the morphological, behavioral, and life history variations of the principal phyla of planktonic invertebrates and heterotrophic protists. Constraints of life at low Reynolds numbers; principles of allometry; growth processes of heterotrophic organisms. *Prerequisite: SIO 280 or consent of instructor.* (S/U grades permitted.) Ohman (S)

272. Biogeography (3)
A lecture course concerning the origin, development, and perpetuation of distributional patterns with emphasis on benthic marine organisms. Newman (W)

273A. Professional Ethics in Science (2)
A seminar on the historical and contemporary ethics and ethos of scientific research, based on published documents. Given in alternate years. Dayton (S)

273B. Science and Marine Environmental Policy (2)
Lectures by the instructor, visiting lecturers, and class discussions focusing on how scientists can help policy makers transform scientific understanding into policy. Topics will emphasize conservation, fisheries management, and pollution issues. Given in alternate years. Dayton (S)

274. Marine Arthropods (5)
Lectures and laboratories on the natural history, morphology, taxonomy and phylogeny of arthropods with emphasis on marine forms. Alternate years. *Prerequisite: consent of instructor.* Hessler, Newman (W)

275A. Benthic Ecology (4)
Evolution and maintenance of benthic communities from the terrestrial margins to the deep sea. Special emphasis will be placed on physical and biological scaling and processes determining patterns of distribution and abundance; interrelationships between community structure and population phenomena, including trophic relationships, reproductive and recruitment patterns, succession, and life history biology. Offered in alternate years with SIO 275B. *Prerequisite: consent of instructor; open to undergraduates.* (S/U grades permitted.) Levin, Dayton, Sala (S)

275B. Natural History of Coastal Habitats (4)
Two three-hour laboratories per week, three four-six day field trips to sites from Mexico to Monterey Bay. Several one-day field trips to local habitats including lagoons, sand and rock intertidal habitats, areas of marine fossils, and areas with migrating birds. Format of course variable depending on student interests. Alternate years with 275A. *Prerequisites: open to undergraduates with consent of instructor and completion of BIEB 130, Introductory Marine Ecology.* (S/U grades permitted.) Dayton (W)

276. Quantitative Theory of Populations and Communities (4)
An introduction to the quantitative tools and conceptual issues underlying the study of the dynamics and structure of ecological systems. *Prerequisite: calculus (three quarters) or consent of instructor.* (S/U grades permitted.) Sugihara, Deriso (F)

277. Deep-Sea Biology (4)
The ecology, zoogeography, taxonomy, and evolution of deep-sea organisms, with emphasis on the benthos. Offered alternate years. *Prerequisite: consent of instructor.* (S/U grades only.) Levin, K. Smith j (W)

278. Seminar in Ocean Biosciences (2)
Presentations of reports, review of literature, and discussion of current research in the marine biological and oceanographic sciences. (S/U grades permitted.) Staff (F,W,S)

279. Special Topics in Biological Oceanography (1-4)
(S/U grades permitted.) Staff (F,W,S)

280. Biological Oceanography (4)
The biology and ecology of marine plankton, nekton, and benthos. Emphasis will be on processes regulating species, community, and ecosystem patterns and changes, including productivity, trophic relationships and species interactions with the physical, chemical, and geological environment. One or more field trips. *Prerequisite: bachelor's degree in science or consent of instructor.* Franks or Checkley, Levin (F)

281. Environmental Physiology and Biochemistry of Marine Organisms (4)
Biochemical mechanisms of adaptation of organisms to the marine environment. Special emphasis is on the effects of pressure, temperature, salinity, oxygen, and light on the physiology and biochemistry. Conjoined with BIBC 130. *Prerequisites: adequate training in biochemistry and biology and consent of instructor.* Felbeck (W)

282. Phytoplankton Diversity (4)
Molecular, biochemical, ecological, and evolutionary perspectives on the diversity of eukaryotic and prokaryotic phytoplankton. *Prerequisite: consent of instructor.* Palenik (W)

283. Marine Biodiversity (4)
The origins, maintenance, collapse and restoration of diversity in the sea, discussed from both ecological and evolutionary perspectives. *Prerequisite: consent of instructor.* (S/U grades permitted). Knowlton (S)

284. Invertebrate Zoology (5)
Invertebrate zoology covering all of the major and minor phyla: phylogeny, anatomy, physiology and natural history. Lecture and laboratory demonstrations. *Prerequisite: consent of instructors; no audits. Holland, Hessler* (W)

285. Physical-Biological Interactions (4)
Physical and biological processes affecting growth and patchiness of plankton. Concepts and equations from physical oceanography will be presented and explored in a biological context. Ideas will be treated both theoretically and with examples from the literature. *Prerequisites: introductory calculus and SIO 210, or consent of instructor.* Franks (S)

287A. Marine Microbial Ecology (4)
Recent developments in the study of marine bacteria. Emphasis will be on biochemical and physiological adaptations of marine bacteria to the ocean environment. Bacterial metabolism, growth, and death will also be discussed in the context of trophic interactions and flows of material and energy in marine ecosystems. Molecular biology techniques used in the study of bacterial ecology will also be discussed. *Prerequisite: consent of instructor.* (S/U grades permitted.) Azam (F)

287B. Microbial Physiology (4)
Prokaryotic microbial physiology will be discussed primarily from a biochemical standpoint with emphasis on mechanism. Topics will vary from year to year but will include the following themes: Central Metabolism. Bioenergetics, Biosynthesis, Regulation, Differentiation. Prokaryotic Structure-Function Relationships, *Prerequisites: BiBC100 or BIBC 102 or equivalent*. Haygood, Saier (S).

288. Environmental Microbiology Laboratory (4)
This course emphasizes advanced techniques and theory in environmental microbiology. Students will perform experiments concerning (a) enrichment of diverse microbes (b) microbial enumeration and identification (c) metabolic and physiochemical adaptations, and (d) biotechnology, along with an independent project. *Prerequisite: consent of instructors,* Bartlett, Brahamsha, Haygood, Tebo (S)

289. Introduction to Quantitative Marine Ecology and Evolution (4)
An introduction to basic questions and problems in quantitative ecology with emphasis on marine organisms: spatial and temporal patterns, population dynamics and the behavior of higher order systems, multispecies populations and communities, and population genetics and life histories. *Prerequisites: some undergraduate mathematics and ecology will be assumed; or consent of instructor.* Burton, Jackson, Sala, Sugihara

290. Marine Biology (4)
An introduction to the field of marine biology, especially to the diversity of marine organisms at all taxonomic levels and their adaptations to the marine environment. *Prerequisite: graduate standing*. Palenik and Staff (W)

291. Biology Graduate Research Presentations (1)
Graduate students in the biological sciences present their research in a seminar or poster format. Class participants and instructors provide written feedback on the presentations. Required of third-year and beyond marine biology curricular group students during spring quarter. Open to all SIO graduate students. (S/U grades only.) Tebo, Haygood, Latz (S)

292. Scientific Communication (2)
Forms of scientific communication, practical exercise in scientific writing and short oral communication and in criticism and editing; preparation of illustrations, preparation of proposals; scientific societies and the

history of scientific communication. Examples from any field of science, most commonly biology, marine biology, ecology, and neuroscience. *Prerequisite: graduate status in science.* (S/U grades only.) Yayanos, Staff (S)

294. Biology of Fishes (5)
The comparative evolution, morphology, physiology, and ecology of fishes. Special emphasis on local and deep-sea and pelagic forms in laboratory. *Prerequisite: graduate standing or consent of instructor.* Hastings (S)

296. Special Topics in Marine Biology (1-5)
Example topics are reproduction in marine animals, adaptation to marine environments, larval biology, marine fisheries, macromolecular evolution, physical chemical topics in physiology, philosophy of science. (S/U grades permitted.) Staff (F,W,S)

297. Marine Biology Seminar (1)
Lectures given by visiting scientists and resident staff and students. (S/U grades only.) Staff (F,W,S)

298. Special Studies in Marine Sciences (1-4)
Reading and laboratory study of special topics under the direction of a faculty member. Exact subject matter to be arranged in individual cases. *Prerequisite: graduate standing.* (S/U grades permitted.) Staff (F,W,S)

299. Research (1-12)
(S/U grades permitted.) Staff (F,W,S)