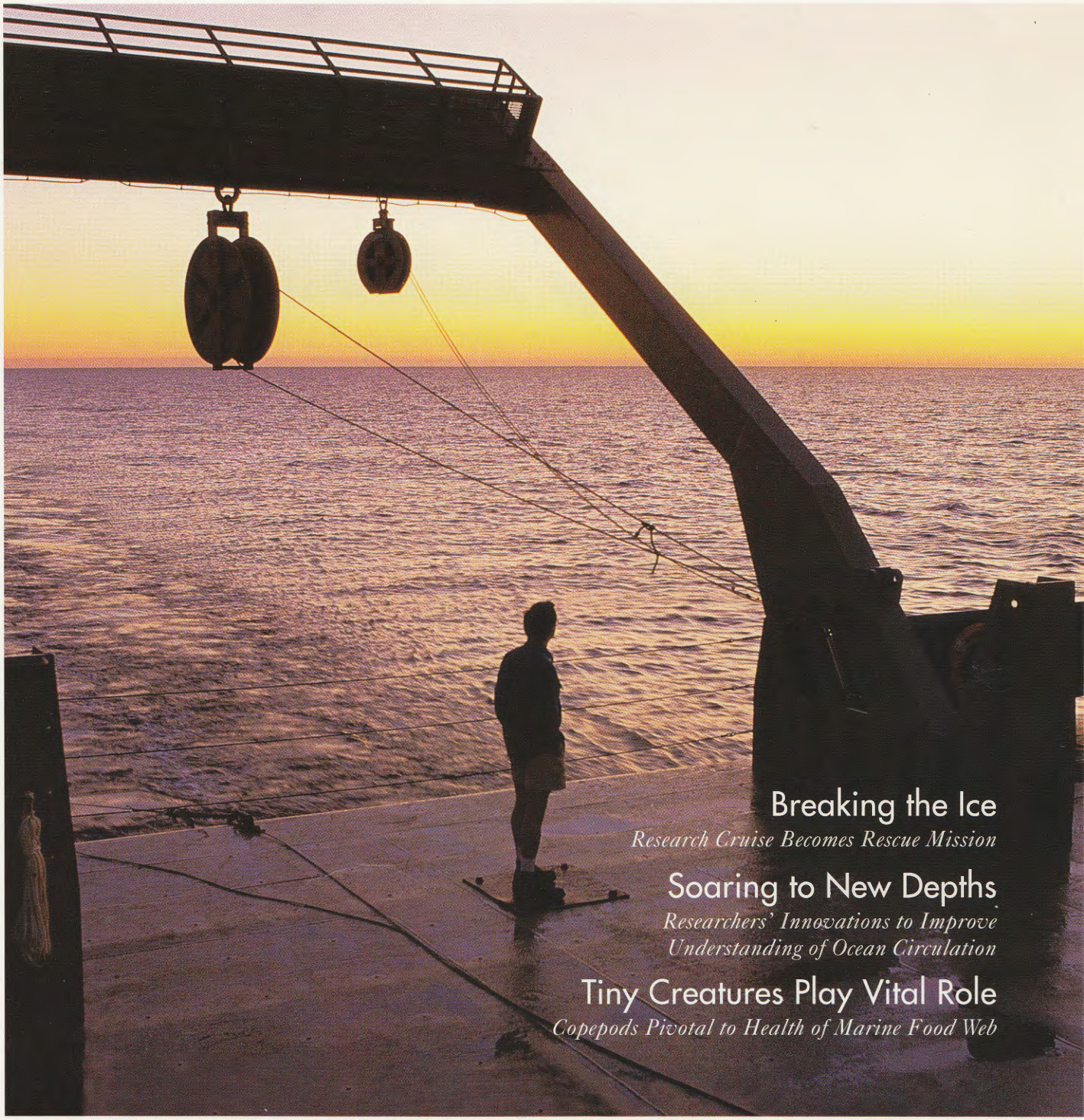
SCRIPPS INSTITUTION OF OCEANOGRAPHY

EXPLORATIONS

Global Discoveries for Tomorrow's World



Breaking the Ice

Research Cruise Becomes Rescue Mission

Soaring to New Depths

Researchers' Innovations to Improve Understanding of Ocean Circulation

Tiny Creatures Play Vital Role

Copepods Pivotal to Health of Marine Food Web

Volume 3, Number 4, Spring 1997
Annual Report Fiscal 1996
UNIVERSITY OF CALIFORNIA, SAN DIEGO

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Spring1997

Scripps Institution of Oceanography Explorations informs and educates the public, our alumni, the scientific community, and Scripps's friends about ongoing research and events. Explorations is mailed four times a year. Summer, fall, and spring we publish magazine editions, with the Scripps annual report included in the spring edition. Winter we produce a video edition.

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University of California, San Diego

SCRIPPS INSTITUTION OF OCEANOGRAPHY

EXPLORATIONS

Global Discoveries for Tomorrow's World

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Insert for Kids!
See center of magazine

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A Message from the Director

The past year was eventful for Scripps and certainly for me. I have a new appreciation for the demands placed on the director of Scripps Institution of Oceanography. Scripps continues to strengthen external connections and form strategic partnerships to meet the challenges of pursuing basic research and responding to the needs of society.

From its inception, oceanography has been global in scope. Scripps scientists travel the world conducting investigations of the atmosphere, the sea, and the earth below it. The institution has increased its number of international cooperative agreements to 27, adding four during the past year.

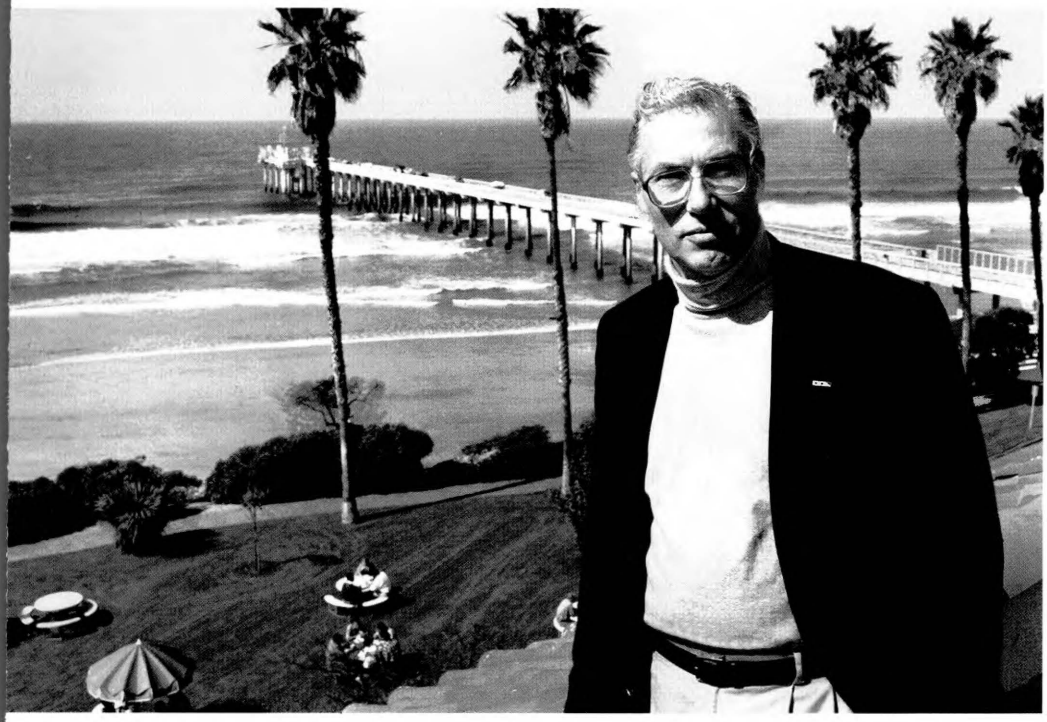
The Center for Clouds, Chemistry and Climate continues to lead large international programs. The Indian Ocean Experiment, with partners in nine nations, is in the advanced stages of planning. Scientists in this multi-agency (NSF, NASA, DOE, NOAA) program will look at the atmospheric and oceanic systems in the Indian Ocean to learn how anthropogenic emissions from southern Asia influence the equatorial marine troposphere. Scripps and Lamont Doherty Earth Observatory will lead the International Research Institute for Seasonal to Interannual Prediction to distribute climate forecasts to a worldwide group of agencies and policymakers. The global seismic network, Project IDA (International Deployment of Accelerometers), coordinates data-collecting instruments from 32 stations strategically placed around the globe. The resulting data are used for studies of earthquakes, the structure of the earth's interior, and other geophysical processes.

Scientists in the Scripps Center for Marine Biotechnology and Biomedicine (CMBB) apply chemical and molecular techniques to the study of marine life. These studies contribute to basic knowledge about the chemical makeup of marine organisms and enhance human health through the development of pharmaceutical agents. Efforts are under way to expand commercial participation in the CMBB program to ensure effective technology transfer.

The institution has strong ties to many federal agencies, and this year joined the NASA Goddard Space Flight Center to create the Joint Center for Observation System Science (JCOSS), which will expand activities between the

two institutions. The NOAA/University Consortium on the Ocean's Role in Climate, led by Scripps and the Lamont Doherty Earth Observatory, continues observations of ocean processes and modeling of climatically important variations.

The fifty-year partnership between Scripps and the Department of Defense has advanced knowledge of the world's oceans and developed technologies to ensure national security. The Acoustic Thermometry of Ocean Climate project scientists continue to monitor long-term temperature change in the global ocean by measuring travel times of signals transmitted from an underwater sound source. The resulting climate data are important in understanding the ocean's role in global change. The Office of Naval Research has linked the navy and the academic community and has been a primary source of construction funding for U.S. oceanographic vessels. Scripps's record of excellence in ship operations and seagoing science enabled us to benefit from that support; and, this past year we welcomed R/V *Roger Revelle* to the Scripps fleet.



The Scripps Development Office maintains a strong program building new community support for Scripps and strengthening ties to private foundations and corporations. The Scripps Oceanographic Society provides opportunities for interested persons to learn about and support our teaching, research, and outreach programs. In July, we celebrated the ground breaking for the W. M. Keck Center for Ocean/Atmosphere Research. A generous grant from the W. M. Keck Foundation resulted in Scripps securing funds from other private sources, including the David and Lucile Packard Foundation and the G. Unger Vetlesen Foundation, to create a center of excellence for an integrated approach to global environmental research.

We are particularly proud of our aquarium, which leads many of the institution's outreach efforts. The Birch Aquarium at Scripps functions as an informal marine education center offering a full range of public programs.

The realities of a shrinking federal resource base make the future of scientific research and environmental stewardship at Scripps more dependent on external connections and partnerships. Working together with current and future partners, we shall prevail in our efforts to deserve and maintain the position we hold as a leading oceanographic institution.

Wolfgang H. Berger
Interim Director, December 1996

ANNUAL REPORT 1996

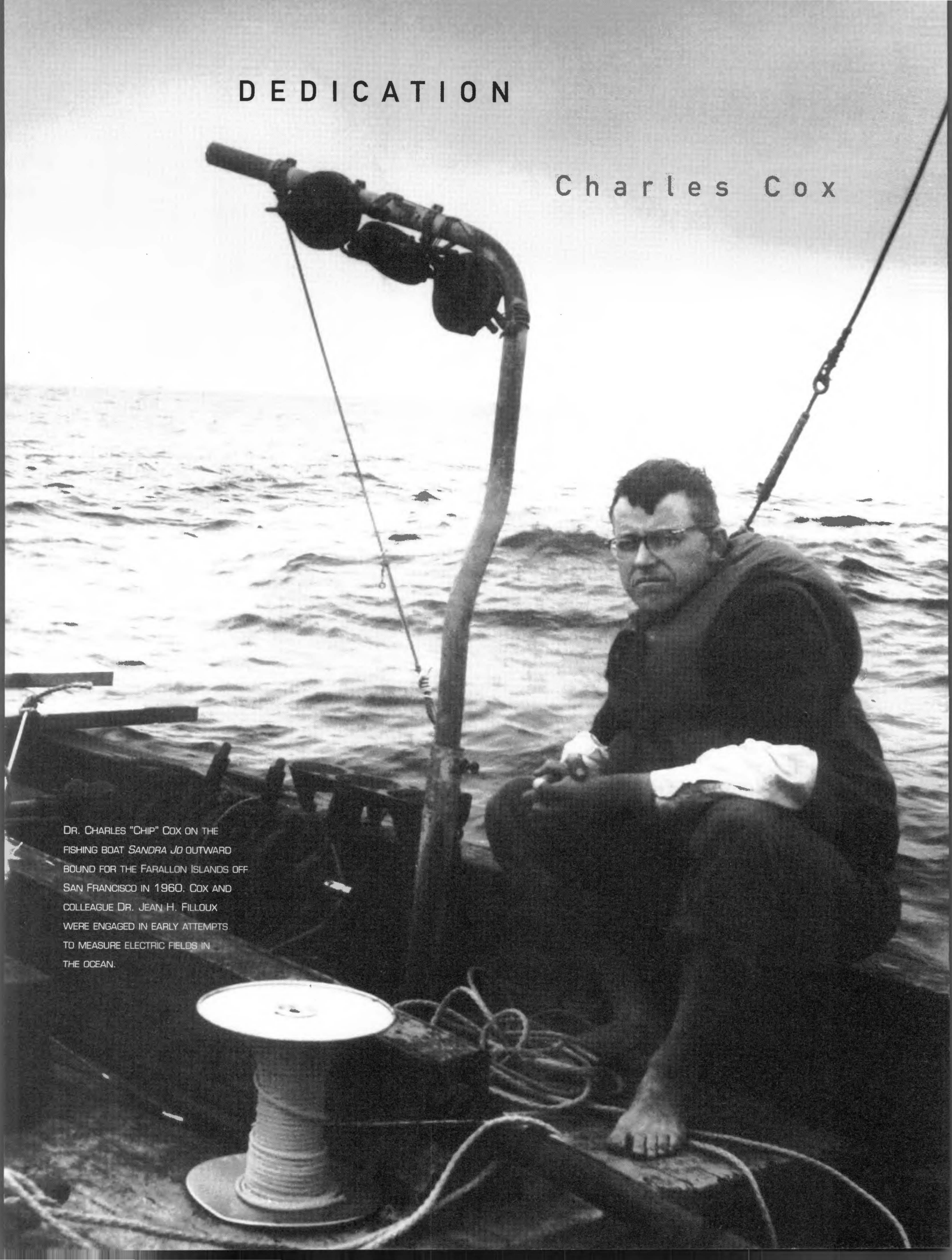
Global Discoveries for Tomorrow's World

Scripps Institution of Oceanography

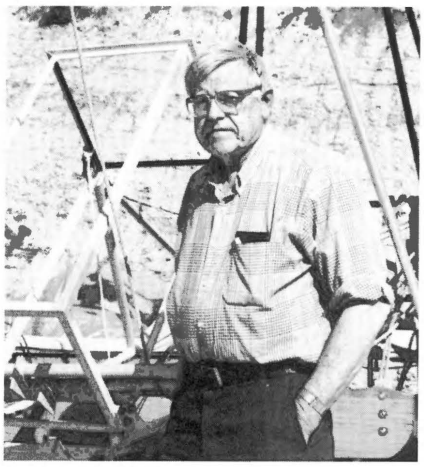
UCSD

DEDICATION

Charles Cox



DR. CHARLES "CHIP" COX ON THE FISHING BOAT *SANDRA JO* OUTWARD BOUND FOR THE FARALLON ISLANDS OFF SAN FRANCISCO IN 1960. COX AND COLLEAGUE DR. JEAN H. FILLOUX WERE ENGAGED IN EARLY ATTEMPTS TO MEASURE ELECTRIC FIELDS IN THE OCEAN.



A pioneer in marine physics, Professor Emeritus Charles S. "Chip" Cox is recognized for having made several fundamental contributions to geophysics, while infecting all those around him with boundless enthusiasm.

Cox began his love affair with the sea while growing up in Hawaii, where he built and sailed small boats. He received a scholarship to the California Institute of Technology and majored in physics, working on military rocket projects during the mid-1940s. In 1948, he came to Scripps as a graduate student, living aboard a 110-foot surplus navy sub-chaser that he used for commercial albacore fishing in the summers. Thus began a career full of innovations.

His thesis advisor, Walter Munk, had proposed a method to determine the distribution of sea-surface slopes by observing sun glitter. They worked together, taking aerial photographs over Hawaiian waters. Their results remain useful as a basis for interpretation of modern sea-surface studies, including remote-sensing instruments on satellites.

After graduation in 1955, Cox turned his attention to the generation of very short wind waves. He built a small wind-wave tank with an optical system that used the refraction of light beams through the water surface to make measurements, now a common practice. This led to a classic paper in 1958, in which he and colleagues demonstrated that longer waves feed energy directly to ripples, even in the absence of wind.

After joining the Scripps faculty in 1960, Cox and his student Hal Sandstrom made a theoretical study of how tidal currents flowing over seafloor mountains can generate internal waves. In 1963, Cox developed the first free-falling recording devices for measuring temperature fluctuations along a vertical path in the ocean. This technique, used to detect internal waves and turbulence, led to pioneering papers on oceanic microstructure and opened a new subdiscipline of oceanography to study mixing and heat flow.

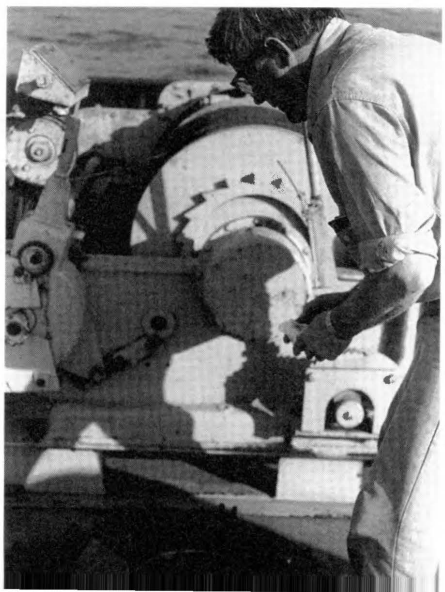
Working with his students, Jean H. Filloux, Jimmy Larsen, and Spahr Webb, Cox made early measurements of naturally occurring electric and magnetic field fluctuations at the bottom of the ocean. They built devices, called pressure transducers, to record these electrical interactions, descendants of which are used today for studying the structure of the ocean crust and upper mantle. They also developed methods to produce and detect the transmission of artificially generated electromagnetic fields that travel through and below the seafloor.

Along the way, Cox has been a postdoctoral researcher at the National Institute of Oceanography in England, a Fulbright scholar at the University of Tokyo, and a visiting professor at the Massachusetts Institute of Technology. He was elected a fellow of the American Geophysical Union (AGU) and received the 1992 Ewing Medal given by AGU and the U.S. Navy for leadership in geophysics. In 1996, he was elected to the prestigious National Academy of Sciences.

Throughout his career, Cox's approach has always been to look for problems that are soluble with new observations and then to proceed by developing both innovative sensors and theory to establish a foundation for those coming after him. Looking back at a lifetime at Scripps, he says, "Isn't this a wonderful place. I was just lucky, I fell into the right place at the right time and never left." During this time, he met and married his wife, Maryroth, and they had five children.

Currently, Cox is outfitting an 18-foot catamaran for close-up studies of sea-surface turbulence on extremely small scales using optical methods. Even after all these years, making new kinds of measurements and finding out greater detail are still what most interests him.

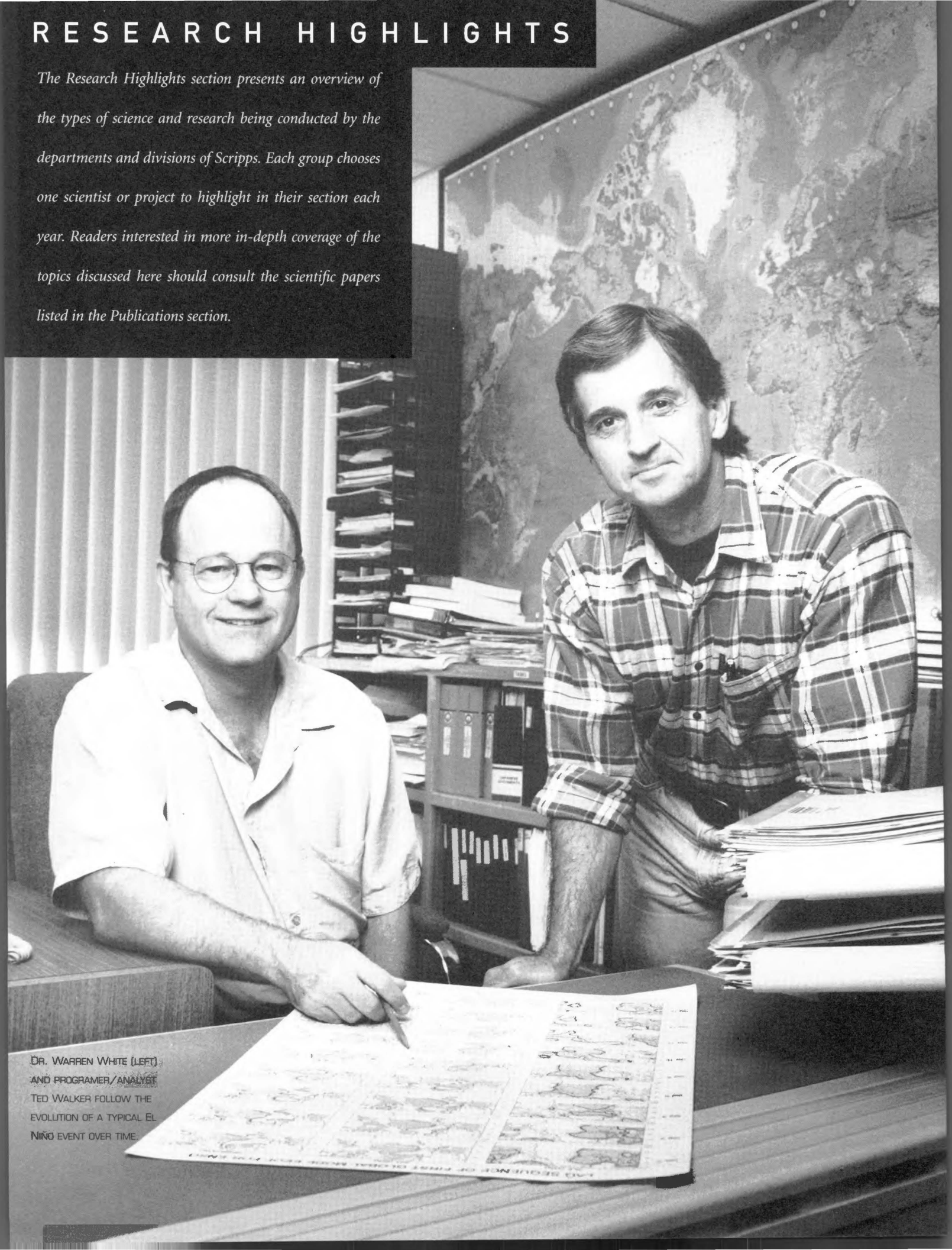
by Chuck Colgan



ABOVE: COX WITH EQUIPMENT DESIGNED TO MEASURE MILLIMETER-SCALE WAVELETS AND TURBULENCE AT THE AIR-SEA INTERFACE. RIGHT: COX, ABOARD R/V *E. B. SCRIPPS*, CIRCA 1984, WORKING WITH AN ANCHOR FOR AN OCEAN ELECTRIC FIELD DETECTOR.

RESEARCH HIGHLIGHTS

The Research Highlights section presents an overview of the types of science and research being conducted by the departments and divisions of Scripps. Each group chooses one scientist or project to highlight in their section each year. Readers interested in more in-depth coverage of the topics discussed here should consult the scientific papers listed in the Publications section.



DR. WARREN WHITE (LEFT) AND PROGRAMER/ANALYST TED WALKER FOLLOW THE EVOLUTION OF A TYPICAL EL NIÑO EVENT OVER TIME.

Climate Research Division

In the Climate Research Division (CRD), scientists study a broad range of phenomena spanning time scales from a few weeks to several decades. Research themes include diagnosing and predicting the natural variability of climate and understanding the consequences of man-made increases in the greenhouse effect. In the climate system interactions among the atmosphere, the seas, the land surface, and the world of living things are tightly joined. To understand these interactions, CRD brings a variety of expertise to bear through a team approach to research in areas including meteorology, oceanography, and hydrology.

Current research projects include developing coupled global ocean and atmosphere models, assessing the role of cloud-radiation feedbacks in climate change, unraveling the connections of the atmosphere and ocean to land surface hydrology, and modeling and predicting seasonal climate variability. CRD research combines the analysis of large observational data sets, the development of comprehensive numerical models of the climate system, and the use of satellite remote sensing capabilities for monitoring the entire planet. CRD scientists stress research on how global change impacts regional and transient phenomena, emphasizing those aspects of climate that are potentially predictable.

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Dr. Warren B. White, a research oceanographer, studies climate variability in global ocean circulation and its interaction with the overlying atmosphere. Currently, with Dr. Ray G. Peterson of PORD, White is investigating a physical phenomenon of the Southern Ocean described as an Antarctic Circumpolar Wave (ACW).

White became interested in the possible existence of the ACW after detecting an El Niño Southern Oscillation (ENSO) signal in the Southern Ocean. Normally, ENSO is thought of as an irregular cycle in the tropics, repeating every three to five years, during which tropical wind patterns and warm surface waters are displaced from east to west along the equator. This displacement is associated with corresponding displacements in the winds over the entire globe. Using a combination of satellite observations and in situ data, White has mapped interannual variations in sea-surface temperature (SST), atmospheric sea-level pressure, wind stress, and sea ice extent in the Southern Ocean, around Antarctica. These variations, or anomalies, propagate from west to east with the Antarctic Circumpolar Current with a cycle of approximately four years, moving at 5 to 10 cm per second and taking 8 to 10 years to propagate around Antarctica.

This eastward movement of cold and warm SST anomalies affects wind direction and the ice pack around Antarctica. As warmer water anomalies propagate, they cause poleward winds that push the Antarctic ice pack against the continent; as cooler water anomalies propagate, they cause winds to move equatorward, pushing the ice pack away from Antarctica. Within this cycle of variability the ACW is composed of two wavelengths around Antarctica, with warm and cool anomalies on opposite sides of each other.

The anomalies associated with the ACW originate in the western subtropical South Pacific and move south to east, where they merge with the Antarctic Circumpolar Current. As they propagate around the Southern Ocean they encounter eastern boundaries, such as the west coast of South America, where an offshoot of that anomaly travels equatorward, back into the subtropics and tropics. In this manner, the Southern Ocean receives influences from other oceans and acts as a conduit, transporting temperature anomalies and heat storage anomalies from one ocean to another. Prior to these findings, most scientists thought that the Southern Ocean could not influence the tropics.

White also has determined that the circulating sea-surface temperature anomalies affect the direction and strength of the atmospheric winds around Antarctica. The atmospheric feedback onto the ocean maintains the anomalies and prevents dissipation during circulation. The winds also change the speed of the ACW. If the anomalies relied only on the momentum of the circumpolar current, the ACW would take 12 years, rather than eight years, to make one complete circuit.

These data, satellite imagery, animations, and other scientific information can be accessed via the Joint Environmental Data Analysis (JEDA) home page on the Internet. The JEDA Center was established as a collaborative program between Scripps Institution and the National Oceanic and Atmospheric Administration to provide quality control on upper ocean temperature and salinity observations over the global ocean. The JEDA home page address is http://jedac.ucsd.edu/.

Geosciences Research Division

Scientists in the Geosciences Research Division (GRD) address the broad areas of the physical and chemical processes occurring in the earth's mantle and crust, especially in the seafloor, interactions between the ocean and atmosphere, and the reconstruction of ocean and climate history. They carry out detailed studies concerning marine geology, petrology, tectonics, geophysics, isotope geology, geochemistry, remote sensing, mantle and crustal evolution, fluid processes, climate history, global biogeochemical cycles, global change, microfossil evolution and systematics, and marine, atmospheric, and solar system chemistry.

Structural hydrogeologist Dr. Kevin M. Brown uses laboratory investigations and field-monitoring programs to study the interaction of fluid flow within actively deforming tectonic systems. In the saturated, brittle crust of the earth, an imbalance between both fluid production and drainage can lead to greatly elevated fluid pressures—or geopressures—in pores and fractures at depth. Such geopressures play a fundamental role in determining the state of stress and frictional properties among plate-boundary faults such as those found at subduction zones or in strike-slip fault zones.

Sediments and oceanic basements in active tectonic regions contain large amounts of water both in their pore spaces and as chemically bound water within minerals. According to Brown, water is mainly expelled in the shallow portions of the sediments by mechanical porosity reduction, with chemically controlled dehydration reactions becoming increasingly significant at depth just prior to the onset of major plate-boundary earthquakes. Water is released from minerals at depths where the permeability has already been greatly reduced to levels at which the water cannot easily escape from the system, resulting in the buildup of pressure.

High-pressure fluids can carry nearly the full weight of entire mountain belts, resulting in an almost frictionless basal shear zone beneath them. Brown argues that while tectonic compression generates mountain belts, the overall shape of a mountain belt's front is controlled by the friction across its base, and, ultimately, the production and migration of water in the deforming system.

Brown generates these fluids under laboratory conditions similar to those at depth. He is building a new type of flux meter to monitor and map the expulsion patterns of the water as it migrates out of the systems, carrying with it a suite of dissolved chemical components.

Of several different types of minerals very rich in water, the clay mineral smectite is a common constituent of sediments of faulted and altered oceanic basements and sediments. In the laboratory, Brown uses a heated high-pressure press to study how smectite dewaters under stresses and temperatures that correspond to intermediate crustal depths ranging from two to six kilometers. This process allows him to simultaneously study how the porosity and permeability of samples evolve as water is expelled from the minerals.

During the experiment, a disc-shaped sample of smectite is heated under stress, and fluids are pumped through the axis of the sample. A finely controlled flow-through system continually monitors the pressure drop across the sample and the composition of the fluid moving out of the sample. As the dehydration reactions proceed, the expelled fluid freshens by as much as 50%. The drop in pressure across the sample is monitored so that the investigators can couple the chemical changes to the permeability and physical properties of the specimen.

Observations made during shipboard drilling in subduction zones as well as surface manifestations of deep-sea vent activity indicate that water coming out of these systems is somewhat fresher than seawater. According to Brown, salinity measurements of water from these systems indicate that it is sometimes 20-50% fresher than the surrounding seawater. Brown thinks that overpressuring processes at depth similar to those he is reproducing in the laboratory may be responsible for production of this anomalous freshened pore water.

His research in this area has many practical applications, particularly in the seafloor oil-prospecting industry. Overpressure development also occurs in sedimentary basins, such as the gulf coast of the U.S. It happens that in the same zones in which fluids are being extruded from minerals, oil is being generated. As a result, oil companies are also interested in overpressure development, which is intimately linked with how the source regions defluidize, expelling oil, water, and gas.

DR. KEVIN BROWN USES A 30-TON PRESS IN AN EXPERIMENT TO TEST PHYSICAL PROPERTY CHANGES DURING HIGH-TEMPERATURE MINERAL DEHYDRATION REACTIONS.


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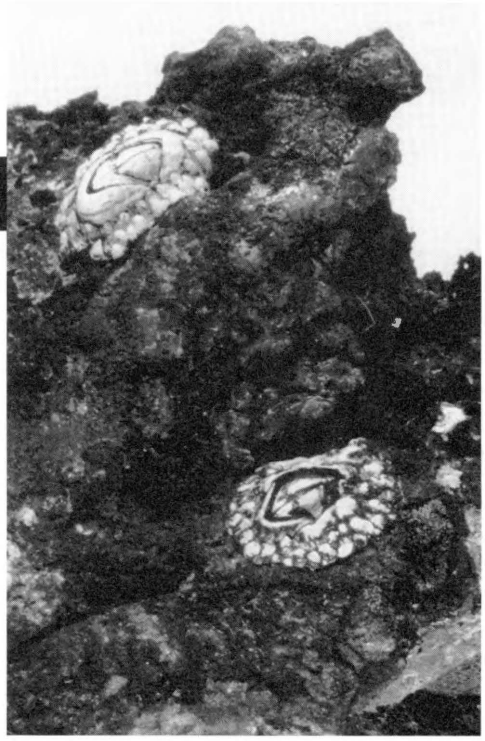
Marine Biology Research Division

Scientists in the Marine Biology Research Division (MBRD) investigate the taxonomic, ecological, physiological, cellular, biochemical, and genetic characteristics of marine bacteria, plants, and animals, and the fundamental processes affecting life and energy flow in marine ecosystems. They examine organisms in a variety of habitats including the deep sea, coastal ecosystems, and Antarctica.



TWO RECENTLY DESCRIBED BARNACLE SPECIES FROM THE LAU BASIN, TONGA.

Ongoing studies involve anatomy and mechanics of marine invertebrates, mechanisms of invertebrate egg and sperm interaction, and the symbiotic relationships between diverse bacteria species and their invertebrate and fish hosts. Also being studied is the large-scale and long-term potential effects of global change on the productivity and diversity of marine ecosystems and on the distribution and abundance of marine organisms. Several MBRD scientists also are closely aligned with Scripps's Center for Marine Biotechnology and Biomedicine.

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The fauna found thriving around deep-sea hydrothermal vents are one of the most exciting discoveries in the history of marine biology. Unknown to science less than a generation ago, these creatures are the focus of attention for a growing number of marine scientists. With deep-diving research submersibles such as *Alvin*—from which scientists first viewed hydrothermal vents on the East Pacific Rise—researchers are sampling an unexpected variety of organisms unique to these isolated and, until recently, inaccessible habitats.

Dr. William A. Newman specializes in *Cirripedia,* the subclass of crustaceans commonly known as barnacles. Over the past ten years, Newman has worked with Scripps's Dr. Robert R. Hessler and two foreign colleagues on barnacles collected from hydrothermal vent communities on the deep seafloor of the Pacific Ocean. A number of species, directly related to some of the earliest barnacles known from the fossil record, have been described and dated. These discoveries include *Neolepas,* the most primitive living Scalpellomorph, dating from the early Mesozoic; *Neoverruca,* an intermediate between the otherwise distinct groups Brachylepadomorpha and Scalpellomorpha, also early Mesozoic; *Eochionelasmus,* the most primitive living Balanomorph, late Mesozoic; and *Neobrachylepas,* dating from the middle Mesozoic. The latter is the sole surviving member of the Jurassic-Miocene Brachylepadomorpha, and represents a more primitive stock than previously known from the fossil record.

Most recently, Newman and a colleague described a new sessile barnacle, *Neobrachylepas relica.* Collected by the French research submersible *Nautile* during the BIOLAU Expedition to the Lau back-arc basin near Tonga, it is the first record of a living representative of the Brachylepadomorpha since the Miocene.

To establish the ages of such "living fossils," some of the newly described barnacles were examined for distinguishing characteristics during ontogeny, and these characteristics were compared with ancient species familiar from the fossil record. Newman disclosed that as the various developmental stages in individual species proceed from larvae to juvenile to adult, the evolutionary process of the whole group is recapitulated. Though traditionally disputed, the notion that ontogeny recapitulates phylogeny seems to hold surprisingly true for the species of barnacles described by Newman and his colleagues.

All of these genera survived the mass extinctions of the Cretaceous-Tertiary, when the dinosaurs and other groups vanished. Newman thinks that the survival of these barnacles is likely because of the refuge afforded them by hydrothermal vents.

Newman has also looked at other faunal groups found at deep-sea hydrothermal vents and noted a very high degree of endemism present in these isolated habitats. The endemics also are of high taxonomic ranks, in many cases well above the level of species. Indeed, among the groups of hydrothermal vent fauna new to science are whole families, some orders, and, in at least one case, a proposed new phylum. A general rule of biogeography states that the higher the taxonomic level of the endemism, the older the fauna. It is safe to conclude that these communities contain some of the oldest living groups of animals in the sea, and therefore provide researchers with glimpses into antiquity.

Marine Life Research Group

The Marine Life Research Group (MLRG) cooperates with two other agencies—the California Department of Fish and Game and the Southwest Fisheries Science Center of the National Marine Fisheries Service—in the California Cooperative Oceanic Fisheries Investigations (CalCOFI). This study of the California Current system provides one of the world's most complete time series of data (more than 40 years) from this important oceanic ecosystem, permitting scientists to examine variability in the physics, chemistry, ecology, and fisheries of this eastern boundary current system from the interannual scale, such as El Niño events, to decadal trends.

High-resolution analysis of sediment cores extends some data back in time for centuries, making possible the study of properties and processes over much longer time scales. The ongoing challenge to the collaborators is to incorporate new techniques, concepts, and societal concerns. For investigators outside the program, the CalCOFI cruises provide a platform for biological oceanographic studies and also a base of environmental data from which to interpret their specialized measurements.

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Dr. Ralf Goericke studies the physiological ecology of marine phytoplankton. In 1995 he embarked on two research cruises in the Arabian Sea in conjunction with the Joint Global Ocean Flux Study (JGOFS)—an international, multidisciplinary project to determine and understand carbon flux between the ocean and atmosphere and to develop a capability to predict the response of oceanic biogeochemical processes to human influences, especially global change on a worldwide scale.

The Arabian Sea was selected for this project in part because it is affected by severe physical forcing. The winds and ocean circulation change direction on a seasonal basis. In the winter the monsoons come from the northeast, and in the summer they come from the southwest. Some scientists think that this sea, as it exists today, might be used as a model system for other areas of the world's ocean if global change occurs.

Goericke's Arabian Sea research was focused on the effect of environmental factors on phytoplankton community structure and the growth rates of the different groups of microalgae. He is clarifying the factors that favor the development of a community dominated by large diatoms as opposed to small cyanobacteria. Goericke gathered data on distribution and growth rates of different groups of microalgae and will combine his chemical, physical, and other biological findings with data collected by other scientists.

Goericke observed high phytoplankton growth rates during the southwest and northeast monsoons. Large differences between growth rates of different groups of microalgae in the nutrient enriched surface layer were observed, even though they were impacted by the same factors. Goericke thinks the microalgae in the Arabian Sea were growing at their maximum rates, unrestrained by the availability of nutrients. However, they were restrained by their physiology, and rates differed significantly among the groups.

Goericke's study also uncovered a new niche of the photosynthetic picoplankter, *Prochlorococcus* sp. This very small prokaryotic organism—discovered only eight years ago—is usually found in the ocean's light enriched surface layers. In the Arabian Sea, Goericke discovered a prolific *Prochlorococcus* population thriving at the top of the oxygen minimum layer, which receives very little light and marks the transition from the oxygen-rich euphotic zone to suboxic waters. There the oxygen minimum layer begins at about 120 m and occurs as carbon, produced in the euphotic zone, sinks quickly and is degraded by microorganisms that use up all of the oxygen.

In similar environments this zone is inhabited only by photosynthetic bacteria, not by phytoplankton. In the Arabian Sea, *Prochlorococcus* are the only phytoplankton found at this level. Goericke suspects that this population is leading a photoheterotrophic life—the organisms gain some energy from the minimal light present but acquire carbon from the dissolved organic compounds in the water. He hopes to study similar populations in the eastern South Pacific in 1997.

Marine Physical Laboratory

Scientists in the Marine Physical Laboratory (MPL) apply knowledge of the ocean and its boundaries to the solution of problems in ocean acoustics, marine physics, marine geophysics, signal processing, and ocean technology.

Researchers in ocean acoustics quantify limitations the environment places on acoustic systems and how they affect the design, performance prediction, and operation of oceanographic systems. Scientists studying marine physics focus on the effects of the oceanic physical environment on undersea systems. They investigate large-scale eddy structures and small-scale internal waves and turbulence. MPL scientists also are interested in cloud cover and detection of surface and air targets through the marine atmosphere.

Marine geophysicists emphasize the basic physical processes and properties of the oceans, the substrate, and the ocean basins to clarify the environmental parameters affecting search, detection, and navigation systems. Research in signal processing encompasses all aspects of the collection, manipulation, and output of both analog and digital data including theoretical design, hardware fabrication, software development, and performance evaluation. Development of advanced ocean technology both for environmental measurement programs and for testing of new engineering concepts is another major MPL focus.

•

As MPL celebrated its 50th anniversary in 1996, it is appropriate to reflect on the many contributions to undersea technological development that have emerged from the laboratory since its establishment. One of the most significant of these is the Deep Tow project, launched more than 30 years ago under the guidance of Scripps Director Emeritus Dr. Fred N. Spiess. Currently working on the project is a team of MPL scientists, engineers, and technicians led by Spiess, Dr. John Hildebrand, and Dr. Christian de Moustier.

De Moustier was awarded funding from the National Science Foundation to help develop the latest generation of deep-tow technology. This new development is an instrument package called Fish 6, which is deployed at the end of an electromechanical cable to carry out fine-scale measurements near the seafloor to depths of 6000 meters. Fish 6 is based on knowledge acquired using the five previous generations of the system. It is distinguished by its greater use of digital technology to improve versatility and to facilitate the addition of new sensors as needed to fulfill specific scientific objectives.

At present, the sensors mounted on Fish 6 include a pair of 110-kHz side-looking sonars, a 4-kHz sub-bottom profiler, a 40-kHz obstacle avoidance sonar, a 12-kHz navigation sonar, a 23.5-kHz up-looking sonar, a CTD unit, a transmissometer, a magnetometer, a complement of still and TV cameras, and a 100-kHz multibeam echo sounder. The latter is a unique instrument developed by the Deep Tow group with funding from the Office of Naval Research. It provides fine-scale swath bathymetry and acoustic backscatter imagery of the bottom over a swath roughly 60 degrees wide in the deep ocean. De Moustier and his team have just begun work on the second prototype of this multibeam echo sounder that will have twice the coverage in area of the existing sonar.

The Deep Tow group works on a variety of deep sea exploration projects. In May and June, they used Fish 6 off the coast of southern California to search for World War II-vintage navy destroyers that had been scuttled in the early 1980s. In September, the group was aboard R/V *New Horizon* to perform geodetic research on the Juan de Fuca Ridge system off the Pacific Northwest coast. Scientists used an instrument package called the Control Vehicle, also designed and built by the group. This package is equipped with two thrusters to allow maneuvers away from the straight hang-down or tow positions along the deployment cable, a capability that is most effective in positioning instruments on the seafloor. It was originally designed to place instruments into boreholes made by the Deep Sea Drilling Program. It has been used to reoccupy benchmarks on the seafloor, to record measurements in exact locations, or to deploy corers on target.

The group is also assisting the U.S. Navy's Deep Submergence Group 1 with its deeply towed sidescan sonar technology, and is building a new tow fish for them. Concurrently, de Moustier leads STS's Shipboard Computer Group and Geological Data Center in assisting the Deep Submergence Group 1 with shipboard swath bathymetry capabilities, advising navy personnel, and coordinating the transfer of expertise from Scripps to the navy's operators. This service reflects a close relationship that has existed with the navy since MPL's founding a half century ago.

Neurobiology Unit

The survival, success, distribution, and ecological role of animals depend on sensing the environment, integrating, calculating, interpreting, and recognizing stimuli, and controlling adaptive behavior. The Neurobiology Unit (NU) is a group of several laboratories at Scripps that focus on the nervous systems, sense organs, and behavioral mechanisms of animals. NU scientists participate in the Center for Marine Biotechnology and Biomedicine and some are associated with the UC San Diego School of Medicine.

The taste system is a complex grouping of sensory cells and organs that is present in all vertebrates. Animals as diverse as fishes, salamanders, and mammals all possess a taste system essential to their survival. Research has shown that taste systems are usually organized very similarly among these very different groups.

Dr. Linda A. Barlow has been working with Dr. R. Glenn Northcutt on the vertebrate taste system and its development. According to Barlow, concentrating on the taste system allows her to ask questions about the development of the nervous system and sensory systems in general. She has been seeking answers to many questions: Where do taste buds come from initially? What causes them to form? Between the taste buds and the neurons, which dictates the contact? How do they connect?

The array of receptor organs found inside the mouths of vertebrates possesses receptor cells that are innervated by sensory neurons originating among the cranial nerves. During the embryonic development of a vertebrate, the sensory neurons face a remarkable challenge. They must send out an axon from the relatively remote distance where the developing brain is located. This axon must grow to reach the region of the mouth and there find a target cell—a taste bud—to innervate. Only in this way can a functional taste system develop.

To her surprise, Barlow has found that taste buds form without nerve contact, and she thinks that they actually dictate how nerves eventually grow to innervate them. She has begun to test how nerves might be finding their targets. Though a great deal is known about how nerve cells in other systems, such as sight, are able to find their targets, very little is known about how this takes place in the taste system.

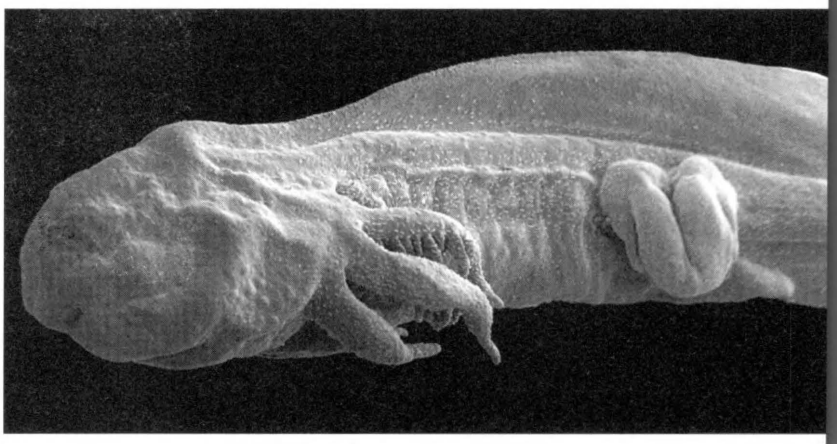
Barlow theorizes that there may be a progression of guidance cues, because the axons are quite remote from their targets. She suggests that perhaps the endoderm of the mouth secretes a substance that acts over a longer range to provide a gradient of information to the growing axons so that they come into the general area. Once axons reach the endoderm, they may locate specific target cells using molecules on the surface of the cells.

How axons find their targets in this field of cells, where taste buds are interspersed irregularly, is described by Barlow in two models. One is the local factor, which acts over a medium range of perhaps a few cell bodies, attracting the neuron directly to the target. In this scenario, the sensory axon grows, senses a chemical signal, and immediately innervates the cells at hand, which are the taste bud precursor cells.

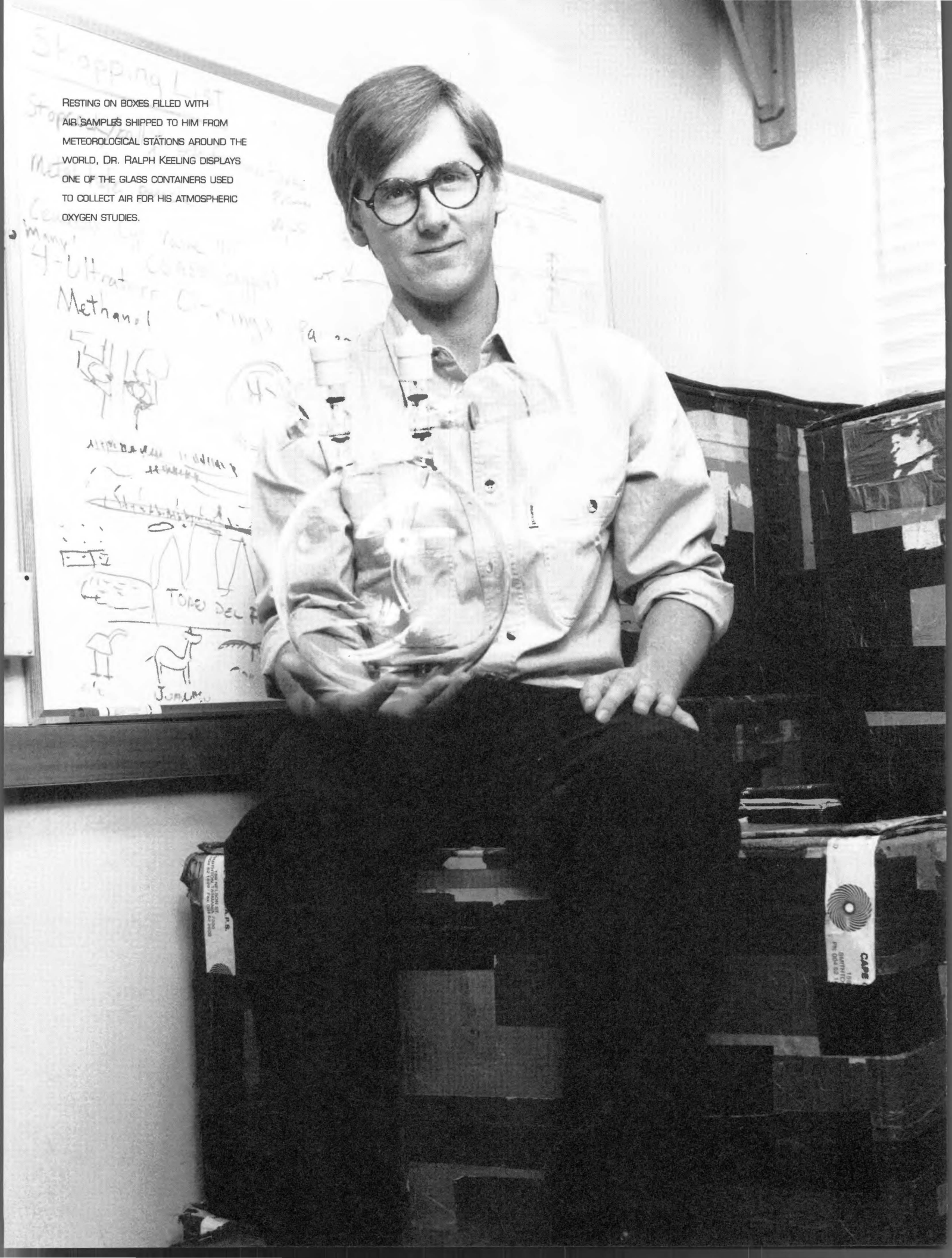
The other scenario is the pruning model, in which the neurons grow out and ramify widely. In this case, the taste buds might possess a trophic factor on their cell surfaces or one that covers a very short distance, and the sensory axons might actually compete for the precursor cells. Any neuron not innervating that particular region would then regress.

The problem Barlow sees is that the taste buds are not completely developed, and undetectable, when the sensory neurons arrive. She is most interested in finding a chemical marker that will allow detection of the taste bud precursor cell.

Which scenario describes the mystery of nerve cell-taste bud innervation, if indeed either does, remains a compelling question for Barlow, and the object of ongoing experimentation by the Northcutt team.



THIS EMBRYO OF THE AXOLOTL, *AMBYSTOMA MEXICANUM*, BEARS A GRAFT OF JAW TISSUE ON ITS SIDE. DR. LINDA BARLOW STUDIES SUCH TISSUE GRAFTS IN THESE SALAMANDERS TO DETERMINE HOW TASTE BUDS DEVELOP.



RESTING ON BOXES FILLED WITH AIR SAMPLES SHIPPED TO HIM FROM METEOROLOGICAL STATIONS AROUND THE WORLD, DR. RALPH KEELING DISPLAYS ONE OF THE GLASS CONTAINERS USED TO COLLECT AIR FOR HIS ATMOSPHERIC OXYGEN STUDIES.

Marine Research Division

Studies in the Marine Research Division (MRD) span the disciplines of biological oceanography, marine chemistry, and physical oceanography.

MRD scientists are investigating the large-scale circulation of the South Atlantic Ocean, studying the characteristics of the earth's earliest ocean and atmosphere, and elucidating the organic carbon cycling in the oligotrophic gyres of the North Atlantic and Pacific oceans.

They study theoretical and applied problems in marine optics, the geochemistry of borehole fluids, the natural products chemistry of marine invertebrates and marine bacteria, and the role of bioactive chemicals in the marine environment. Researchers also focus on the medical and pharmaceutical applications of marine organisms.

Several researchers at MRD are investigating the inhibition of red-tide dinoflagellate growth in California's Santa Cruz Harbor, and the performance of a breakwater at Fisherman's Wharf in San Francisco Bay. Other scientists at MRD concentrate on the Antarctic coastal ecosystem.

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By monitoring the concentrations and interrelationships of atmospheric gases, scientists seek to understand the mechanisms of global climate and answer questions concerning possible global warming.

Dr. Ralph Keeling measures atmospheric oxygen to clarify the roles of both oxygen and carbon dioxide in climate processes. Atmospheric carbon dioxide and oxygen are linked; changes in one are usually associated with changes of a similar—but opposite—magnitude in the other. Climate and CO_2 also are linked; each affects the other in a relationship that is synergistic and exhibits multiple feedback loops. Thus oxygen, through its relationship with carbon dioxide, is a marker for potential changes of global dimensions.

Since 1989, Keeling's research group has analyzed air samples from meteorological stations worldwide. They look at differences over time—on monthly and yearly scales—and at differences in samples from different geographical locations. They also chart seasonal changes in atmospheric oxygen levels. The changes they have observed, though mostly smaller than 1/100 of a percent, are nevertheless very interesting.

Human activity in recent decades has released greatly increased amounts of carbon dioxide into the atmosphere through the burning of fossil fuels and emissions from automobiles. However, CO_2 levels are not rising as fast as expected. Reasons for this are not clear, but scientists suspect a CO_2 sink somewhere in the carbon cycling process. Keeling's work suggests that both the oceans and land plants have been removing significant quantities of carbon dioxide from the atmosphere in the past few years.

Keeling has been a pioneer in the development of technology for measuring atmospheric gases. To conduct his investigations of atmospheric oxygen levels, he invented a special interferometer—a device in which light is passed through an air sample. Light passes more slowly through oxygen than it does through nitrogen, the other main constituent in air, so the oxygen content of a sample can thus be precisely measured by evaluating the speed of the light through the sample.

Keeling and student Andrew Manning modified a commercial instrument—smaller and less expensive than the interferometer—that will continuously record air sample measurements, eliminating the need to collect samples separately. Oxygen is attracted to a magnetic field; most gases are weakly repelled. Thus, the amount of oxygen in a sample is detected by its attraction to a magnetic field.

A mobile instrument that can be used on planes and ships has been created by Keeling and graduate student Britt Stephens. In the ultraviolet region of the spectrum, oxygen absorbs light. Ultraviolet light is shined through an air sample and the amount that passes through it is measured. The more oxygen in the sample, the less light will pass through.

Keeling is now developing an instrument to test levels of atmospheric argon, the third most abundant atmospheric gas, which can be used as a marker for rising ocean temperatures. Because argon is less soluble in warm water than in cold water, atmospheric levels of argon are driven by temperature change in the ocean. As the ocean warms, more argon will be displaced into the atmosphere. Thus, rising atmospheric argon levels indicate rising oceanic temperatures.

In other studies, Keeling and graduate student Helen Perks are investigating organic carbon in sediments as a proxy for paleoproductivity and paleoclimate. Samples from sediment cores are burned, and the amount of oxygen consumed indicates the carbon content of the sediment. Higher carbon content probably indicates a higher level of paleoproductivity related to changes in upwelling or winds at the sea surface.

Physical Oceanography Research Division

Scientists in the Physical Oceanography Research Division (PORD) study a range of observational and theoretical topics related to the physics of the ocean. Many of the PORD investigators hold joint appointments in other areas at Scripps, which provide for diverse research and cross-disciplinary communication.

Some PORD researchers study the large-scale circulation of the world's oceans or the specifics of smaller environments such as the continental shelf, marginal seas, straits, estuaries, or the surf zone of open shorelines. Others examine the interaction between the ocean and the atmosphere. Theoretical studies range from classical fluid dynamics problems to models of large-scale ocean circulation or the atmospheric marine boundary layer. PORD scientists also develop new sensors and measurement technology for ocean studies such as autonomous drifters, bottom pressure and electromagnetic sensors, and new versions of Acoustic Doppler Current Profilers.

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Dr. Janet Sprintall focuses on a program to track surface water temperatures along specific merchant shipping lines. The data she gathers will help to determine how heat is transported through the upper layers of the oceans and how ocean circulation changes over time.

The ocean has a large capacity for heat transport, and Sprintall is interested in how this impacts regional climate patterns. The mean and fluctuating heat balance in the ocean relies on three factors: air-sea flux, heat storage within the water column, and horizontal movement of heat by ocean currents. Sprintall charts how the balance of these factors varies over time.

Merchant ships serve as research vessels for Sprintall and her colleagues in this "ships of opportunity" program. At seasonal intervals, she and other researchers travel aboard several merchant ships continuously plying Pacific waters. These ships provide scientists an affordable and dependable mode for collecting data at sea, because scheduling time on oceanographic research vessels can be expensive and space limited because of the relatively small number of vessels in operation. Merchant ship operators also benefit because much of the data gathered helps improve the quality of their charts of general ocean circulation, and provides information on its variability.

During each cruise, Sprintall, or one of her colleagues, launches temperature probes known as expendable bathythermographs (XBTs) over closely spaced intervals of 10-40 kilometers. When deployed, each XBT is attached to the ship by a copper wire and an electric cable connected to a shipboard computer. The probe has a sensor in its head that continuously records temperature change to an approximate depth of 850 meters. Then the copper wire breaks and the probe is released.

Sprintall focuses on temperatures between the surface and the thermocline—a layer of water at which the temperature gradient is greater than overlying and underlying layers. The probe's entire drop is digitized to the computer screen, from which she determines the success of the drop in real time and analyzes significant features.

The regularity of the merchant lines and the relatively close spacing between drops allow Sprintall and others to measure temperature variability on seasonal, interannual, and eventually decadal intervals. These data are supplemented by less frequent deployments of expendable probes called XCTDs, which are used to estimate salinity, and by altimetric data from 10-day passes of the TOPEX/Poseidon satellite.

Sprintall is primarily interested in measurements in a small area of the southwestern Pacific banded by three shipping lines linking Australia, Fiji, and New Zealand. She began this study following an anomalously cold New Zealand winter in 1992 that caused damage to livestock and had disastrous economic consequences in the region. After analyzing five years of data, she determined that heat transported out of that area of the Pacific by ocean currents probably led to the aberrant weather patterns.

In other areas of the Pacific up to ten years of continuous measurements, including approximately 40,000 XBT casts, have been collected by scientists aboard ships of opportunity. Amassing decades of data along set shipping lines should provide a longer history and a more accurate understanding of how ocean circulation fluctuates over time.

DR. JANET SPRINTALL LAUNCHES AN EXPENDABLE BATHYTHERMOGRAPH (XBT) AT SEA. INSERT: A CLOSE-UP LOOK AT THE XBT TEMPERATURE PROBE.

Center for Coastal Studies

The Center for Coastal Studies (CCS) is an interdisciplinary research center focused on the physical and sedimentary processes along the coastlines of the world. Research at CCS concerns fluid-sediment interactions responsible for sand transport along beaches and over the continental shelf; processes affecting circulation of coastal waters, circulation in semi-enclosed seas, and in the straits that connect them to larger ocean basins; and coastal meteorology, surface gravity waves, and wave-induced currents in shallow water. CCS manages the Hydraulics Laboratory.

Recent CCS research has concerned beach or shelf processes in the Santa Barbara Channel, offshore of North Carolina and southern California, within San Francisco and San Diego bays, in the Nile Delta, and in the Indonesian Archipelago.

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Coastal bathymetry affects how sea and swell waves transform from a largely cyclic form in deep water to a highly nonlinear shape when they break in shallow water. These breaking waves, in turn, change the ocean bottom and beach by causing sediments to move from place to place. Studies of wave breaking and associated fluid motions, sediment transport, and nearshore ocean bathymetry are the focus of Dr. Thomas C. Lippmann's research.

Scientists traditionally study nearshore processes using groupings of fixed-point instruments—equipment secured in the sand or placed at fixed locations in the water—to record measurements of fluid motions and sediment response. Lippmann and colleagues have developed and use an alternative remote sensing approach based on video image processing techniques.

Complex changes occur in the nearshore within a few hundred meters of the shoreline. The energy from deep-water waves is transferred among frequencies across a wide spectrum, while interactions between wave field and bathymetry create a continuous feedback loop. The time scale of these changes can be as short as one second for fluid motions to years for bathymetric responses. Longshore distance scales can vary from meters to many kilometers. Because of these long spatial and temporal scales characteristic of the nonlinear, dynamic nature of the nearshore, conclusive sampling methods may require very long time series and nearly continuous measurement over a large field area.

Video monitoring combines the advantages of logistical ease and low cost deployment and maintenance with the capability of modifying and augmenting the sampling strategy at any time through the post-processing design of the imaged array. It also provides the opportunity to continue studies over long periods. Video can provide high resolution, closeup images, and extensive coverage of large areas at lower resolution.

Variability in light intensity can be related to geophysical features in an environment—for instance the location of breaking waves over a submerged sandbar. Time codes from a recorder can be synchronized with other data sources to provide an accurate time base, and images can be synchronized with ground-based coordinates for comparison with fixed in situ instrumentation.

Lippmann and colleagues have developed image processing techniques with a wide range of nearshore oceanic applications. Video techniques have proven useful in measuring wave variables, including incident wave period and phase. They have also provided the means to quantify processes including the spatial and temporal variation of the distribution of wave breaking across the surf zone, the sea-surface elevation at the shoreline through analysis of the swash run-up, and the surface water velocity within the surf zone through analysis of foam streaks.

Lippmann investigates the spatial and temporal variability of nearshore sandbar morphology using daily time exposure images of breaking waves. Positive correspondence between surveyed shoreline and the location of the white band associated with shore break has been documented. Lippmann and a colleague have shown that offshore bands of white separated from the shoreline by dark regions represent wave breaking over offshore sandbars. This information can aid in quantifying the location and morphology of submerged sandbar systems.

Lippmann also studies the behavior of nearshore sandbar systems in an ongoing long-term Coastal Sciences Program sponsored by the Office of Naval Research and the U.S. Geological Survey. Data so far indicate that transition from a one to two bar configuration is a natural progression, that extreme storms cause both immediate and subsequent changes to bar migration patterns, and that alongshore bar movement may be temporarily nonstationary even when it is spatially homogeneous over longer time periods.

Center for Marine Biotechnology and Biomedicine

The Center for Marine Biotechnology and Biomedicine (CMBB), housed at Scripps Institution of Oceanography, UC San Diego, is a campus-wide center dedicated to exploration of the biomedical and biotechnological resources found in the world's oceans. The center includes faculty and researchers from Scripps and other UC San Diego departments, including biology, chemistry, medicine, neuroscience, pediatrics, and pharmacology.

The CMBB program in marine biomedicine focuses on interactive projects with the UC San Diego School of Medicine and includes marine drug discovery (with an emphasis on cancer), marine pharmacology, physiology, neurobiology, and studies of the molecular events associated with reproduction.

CMBB scientists investigate new biotechnologies ranging from the special properties of deep-sea marine microbes to the genetic engineering of commercially important marine animals. Scientists within CMBB stress basic research, participate in student education, and provide support for the local biotechnology industry.

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Humans experience surprise and expectation; this can be proven through direct observation and measurement of human brain waves. Dr. Theodore H. Bullock and his research team want to know if other animals also perceive surprise and expectation in response to their environments. In his current research, he investigates the dynamic properties of brain waves in marine animals, including cartilaginous fishes (sharks and rays), bony fishes, cuttlefish (mollusks), and turtles.

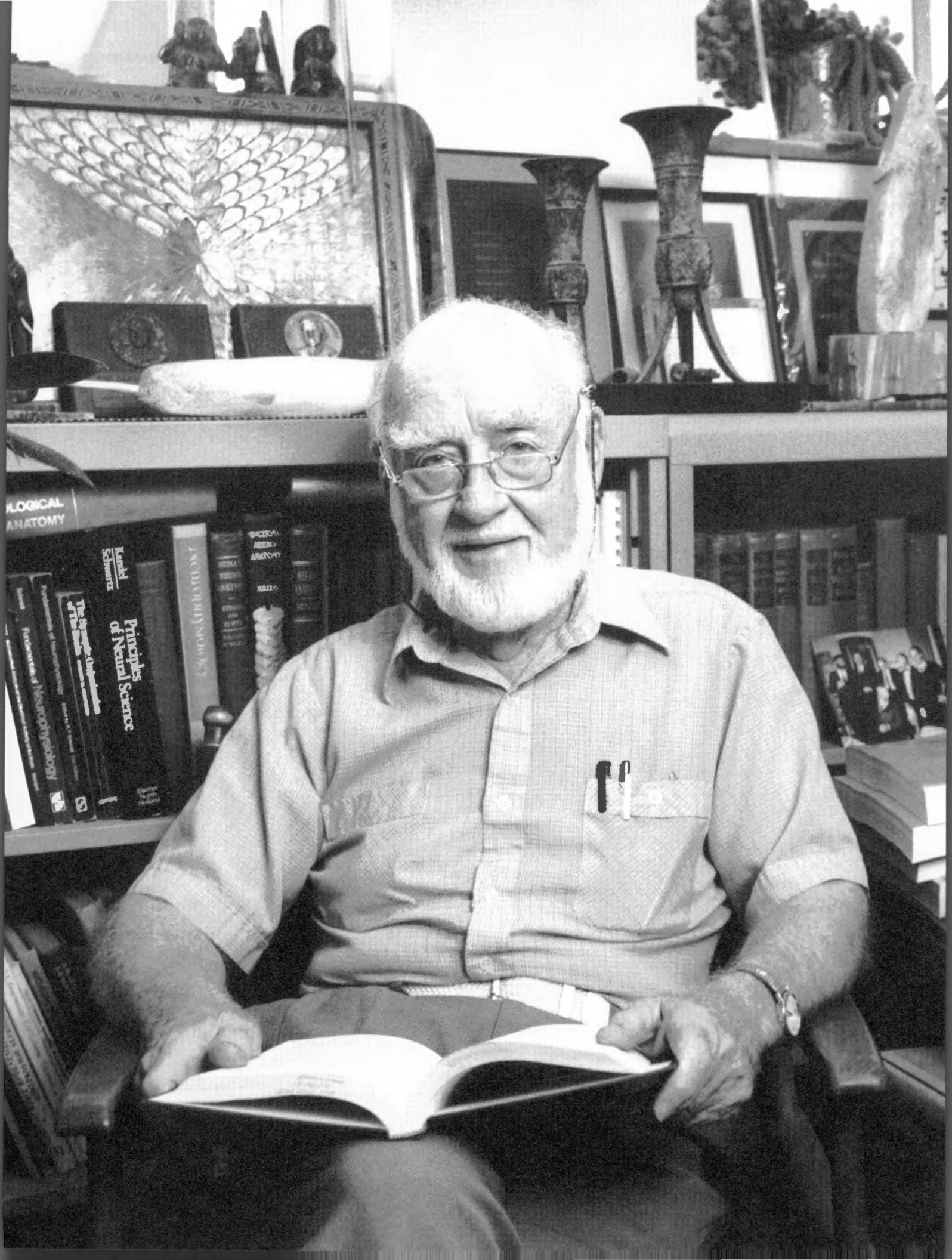
Specifically, he is interested in expectancy waves, which occur when an organism expects something to happen. These waves fall under the category of cognitive waves, found in humans when they are experiencing thought, surprise, or expectation. According to Bullock, fish make good research candidates because they produce a very clear, measurable brain wave when in a state of anticipation.

To measure brain activity, the subject is anesthetized, an electrode is placed on the midbrain, and a series of stimuli is delivered. These stimuli may be flashes of light, pulses of sound, or minuscule electrical pulses. The stimuli are repeated at a set rate called the Inter Stimuli Interval (ISI). After a specified number have been delivered, the next is omitted. In the absence of the stimulus, a brain wave occurs called the Omitted Stimulus Potential (OSP). Bullock has determined that the OSP occurs at a fixed time after the missing stimulus was due. For example, if the ISI is five flashes of light per second, following the last flash the OSP will occur 1/5 of a second later, plus a set latency period. If the ISI is six light flashes per second, the OSP will occur 1/6 of a second later, plus a set latency period. If no interruption occurs in the delivery of flashes, the OSP will not occur.

Through this research scientists have also detected an OSP in the retina, which means that this is an extremely low-level process in fishes. The data gathered in Bullock's research are providing the basis for future studies on the evolution of cognitive functions such as expectancy or surprise. To do this, scientists look at single cells of an organism's retina, midbrain, and forebrain. They measure each cell's reaction to the stimuli, and how the cells influence each other. Crucial to mapping the physiological evolution of fishes, reptiles, and mammals is the ability to record, trace, and understand their brain activities.

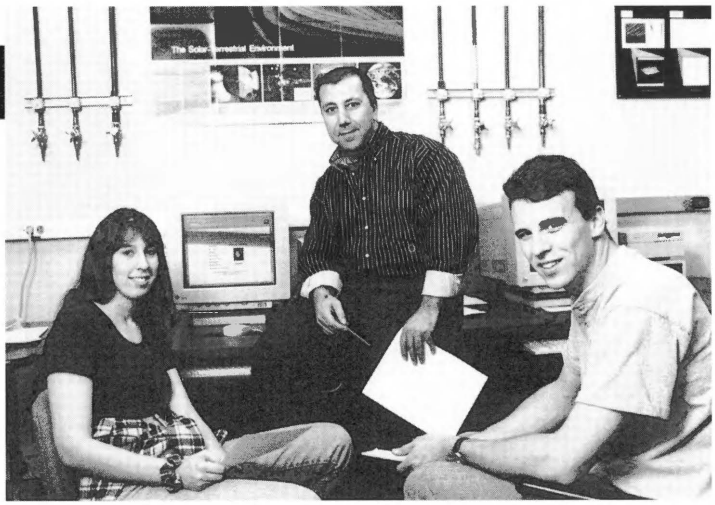
Bullock also is overseeing the work of graduate students and postdoctoral researchers in the laboratory of Dr. Walter F. Heiligenberg, a Scripps professor who died in 1994. A longtime friend and colleague of Heiligenberg, Bullock established the Heiligenberg Visiting Investigator Program. This allows scientists to come to Scripps for a few months to conduct research and serve as mentors for Heiligenberg's remaining students and postdoctoral researchers until they complete their studies. Expected to close in June 1997, this laboratory is famous for work being done to unravel the brain circuits used for analyzing sensory stimuli, measuring their time relations to less than a microsecond, and triggering the appropriate response using the electrosense, which is highly developed in some fishes.

DR. THEODORE H. BULLOCK PAUSES DURING WORK IN HIS SCRIPPS OFFICE.


LOGICAL
ANATOMY
Kandel
Schwartz
Principles of Neural Science

California Space Institute

The California Space Institute (CalSpace) is a multicampus research unit of the University of California, which supports space and Earth related sciences, education, and technology research. CalSpace maintains close ties with many departments both at UC San Diego and other UC campuses through scientific collaboration and joint faculty appointments. CalSpace researchers conduct both pure and applied research in interdisciplinary fields.



DR. NICK OMIDI (CENTER) POSES WITH JENNIFER LINVILLE AND BRIAN FARWELL, TWO OF HIS STUDENTS WHO CONTRIBUTED TO THE INTERNATIONAL SPACE PHYSICS CONSORTIUM'S INTERNET SITE, THE VISUAL LEARNING CENTER.

CalSpace scientists at UC San Diego are involved in research in many space-related fields. The main emphasis for some CalSpace researchers is on space plasma physics and planetary science. At Scripps, CalSpace researchers study the atmosphere and atmosphere-ocean interactions. These researchers have a growing interest in using space activities and accomplishments to stimulate and motivate students. University students at all levels may join in creating programs in this area.

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Dr. Nick Omidi's aim is to understand the physical processes that determine space weather and how changes in solar conditions influence it. To this end he creates computer models that simulate the region of space under investigation. These simulations are then compared to satellite observations to verify their accuracy and also to explain the underlying physical mechanisms. To date Omidi and colleagues have an almost 1:1 success rate in matching their simulations to observational data.

Omidi's research focuses on the physical processes that play an important role in the energy transfer from the solar wind or interplanetary space to the magnetosphere. The magnetosphere is formed as a result of the interactions between the solar wind and Earth's intrinsic magnetic field.

Solar wind is the engine that runs weather in space. Omidi describes one of the effects of solar wind on the magnetosphere as being similar to a jet traveling at supersonic speed and creating a shock wave; the solar wind creates a shock wave around the earth. Omidi studies the properties of this shock wave and how changes in the solar wind speed, or the direction of the magnetic field in the solar wind, modifies them.

Omidi and colleagues also are interested in understanding how the passage of plasma (solar wind) through the shock leads to its heating. In air, collisions between the molecules lead to shock heating, but in space, collisions are not a dominant process and are replaced by wave particle interactions. Electromagnetic waves generated at the shock are absorbed by the plasma that gets heated—a process he describes as being like putting a frozen dinner in a microwave oven.

Changes in the solar wind affect Earth/space weather, creating high energy radiation that can impact spacecraft, communications on Earth (that use the ionosphere), and disrupt Earth based power sources. With models he also can trace events backward into the past, something not possible with observational data.

Information relevant to solar system physics is available to anyone with Internet access, thanks to a program created by Omidi. Originally conceived for students at a UC campus to access the expertise of professors at any other UC campus, the concept grew to become a worldwide gateway for students.

In 1995, Omidi formed a group called the International Space Physics Education Consortium (ISPEC) that has designed a website called the Visual Learning Center. ISPEC organizes, consolidates, and validates materials already on the web and serves as a vehicle for disseminating both the latest theoretical information and experimental data in real-time mode. A direct line to the website from the spacecraft *Galileo,* which arrived at Jupiter in December 1995, made data available to Omidi's students (and others) by March 1996—information not available from conventional textbooks. To visit the Visual Learning Center website, use the address: http://ispec.ucsd.edu.

Institute of Geophysics and Planetary Physics

The Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics (IGPP) is located at Scripps and is strongly linked to the institution. This location is one of the branches of IGPP at the University of California and houses the systemwide office. Other IGPP branches are located at the Los Angeles and Riverside campuses and at the Los Alamos and Lawrence Livermore Laboratories. Both graduate and undergraduate students are involved in the many research programs at IGPP.

IGPP research at Scripps spans many disciplines, including seismology, space and terrestrial geodesy, geomagnetism, global seismic networks, fluid mechanics, marine acoustics, marine geophysics, geodynamics, space physics, nonlinear dynamics, and theoretical geophysics. IGPP operates a global network of seismic stations; several modern seismic arrays in places such as Saudi Arabia; Kyrgyzstan; Anza, California; and a permanent space geodesy network in California. Scientists at IGPP maintain a very active seagoing program including the measurement of absolute gravity on the seafloor, seafloor electromagnetic and seismic measurements, multichannel seismology, and the Acoustic Thermometry of Ocean Climate (ATOC) project.

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Dr. Bradley T. Werner and his research group apply the principles of physics, nonlinear dynamics, geomorphology, and computation to a new method for modeling nearshore processes, with the goal of making predictions regarding waves, currents, the shoreline, and bathymetry in the surf zone. Because this method applies general principles that govern nonlinear systems, they also are testing its application to the study of terrestrial landforms like sand dunes.

Nearshore processes can be characterized by two major features: they are nonlinear, or strongly coupled; and they are open, exhibiting nonequilibrium behavior with energy and material both entering and leaving the system. This complicated environment with large numbers of interacting elements (for example, the multitude of sand grains on a beach), presents severe challenges for modeling and prediction. The traditional approach is to start with the basic physics of sand grain motion, fluids, waves, and currents, and to formulate models of large scale nearshore processes and features, through a series of approximations.

Based on recent developments in nonlinear dynamics and complex systems, the group is developing models for these complicated, multivariable processes that have few variables and simple interactions. These models are based on the concept that nonlinear open systems have an internal selection mechanism for dominant variables and processes, and that their behavior often is nearly independent of small-scale (sand-grain level) physics.

Selection of dominant variables and processes in complex systems occurs through evolution toward an attractor. An attractor is a particular characteristic state toward which a system will evolve from a broad range of initial states. Variables that are slow to evolve dominate the dynamics of a complex system and its interaction with the external environment. The dynamics of the faster evolving variables are subordinate to the long-term dynamics of a complex system. Werner and his group are investigating the possibility that the dominant variables on a beach are the position of the shoreline and the crest of the sandbar, and that a predictive model for the evolution of these variables under a changing wave climate can be developed independent of small-scale sediment and fluid physics.

Practical applications of this simplified modeling include the abilities to incorporate three dimensions into the model, to work with less precise data, to identify and resolve important time scales, and to make quantifiable predictions for the dominant, large-scale variables of a system. Because of their simplicity, these models are more amenable to direct comparison with field data than are more spatially extensive, detailed measurements.

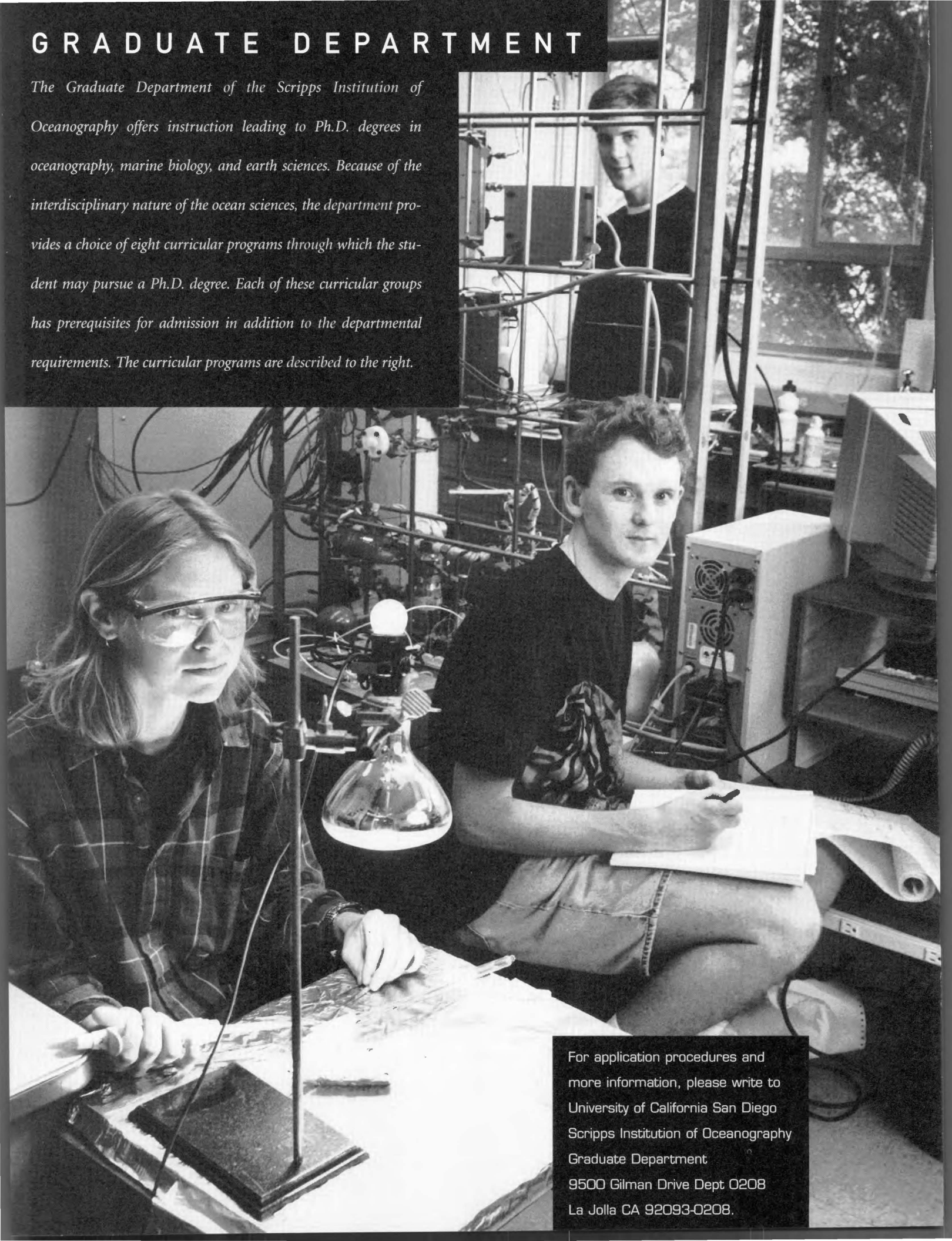
The complex systems modeling approach is being applied to subaqueous ripples, megaripples, beach cusps, surf zone waves, rip currents, sandbars, and shorelines. Field data from a nearshore experiment conducted by Werner's group are being used to test models for beach cusp formation. The results support the use of a simple model, but indicate that additional processes—such as tides and groundwater flow—play an important role in beach cusp dynamics.

They also are applying the complex systems approach to modeling the formation and evolution of sand dunes. They have found that a model for sand dunes in which slabs of sand are moved according to very basic rules can reproduce the range of observed categories of dunes. Results from this model indicate that sand dune crest positions are the dominant variables of a sand dune field.

Members of the group have constructed a model for the evolution of the orientation of sand dunes based solely on the behavior and interaction of dune crests. Within this model, a dune assumes a stable orientation under a given sequence of winds when the two ends of the dune crest migrate at the same speed (otherwise the crest would rotate). If the winds change, the rate of reorientation to a new stable position is smaller if the length of the crest is longer. Dunes with long crests, such as the linear dunes of Australia and Namibia, require up to ten thousand years to respond to even small shifts in wind direction. They hope to use the pattern of dune orientation in these areas to test for paleoclimatic shifts since the Last Glacial Maximum.

GRADUATE DEPARTMENT

The Graduate Department of the Scripps Institution of Oceanography offers instruction leading to Ph.D. degrees in oceanography, marine biology, and earth sciences. Because of the interdisciplinary nature of the ocean sciences, the department provides a choice of eight curricular programs through which the student may pursue a Ph.D. degree. Each of these curricular groups has prerequisites for admission in addition to the departmental requirements. The curricular programs are described to the right.



For application procedures and more information, please write to
University of California San Diego
Scripps Institution of Oceanography
Graduate Department
9500 Gilman Drive Dept 0208
La Jolla CA 92093-0208.

Curricular Programs

APPLIED OCEAN SCIENCES

This interdepartmental curriculum combines the resources of the Scripps Graduate Department with those of the Department of Applied Mechanics and Engineering Sciences and the Department of Electrical and Computer Engineering, on the UC San Diego campus.

Engineers gain a substantial education in oceanography, and oceanographers receive training in modern engineering. Instruction and basic research include the applied science of the sea, and structural, mechanical, material, electrical, and physiological problems within the ocean.

BIOLOGICAL OCEANOGRAPHY

In the biological oceanography curriculum, the interactions of marine organisms with the physical-chemical environment and with each other are studied. Research and instruction in this curriculum range from food-chain dynamics and community structure to taxonomy, behavior, physiology, biogeography, and physical-biological interactions.

FROM LEFT: GRADUATE STUDENTS HELEN PERKS, ANDREW MANNING, AND BRITT STEPHENS WORK IN THE LABORATORY OF DR. RALPH KEELING. MANNING AND STEPHENS HELPED CREATE NEW INSTRUMENTATION TO TEST ATMOSPHERIC OXYGEN. PERKS INVESTIGATES ORGANIC CARBON IN SEDIMENT CORES.

CLIMATE SCIENCES

The climate sciences curriculum 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 timescales and those induced by human activities, as well as paleoclimatic changes on time scales from centuries to millions of years. Examples of current research 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; and terrestrial and marine ecosystem response to global change.

GEOCHEMISTRY AND MARINE CHEMISTRY

The geochemistry and marine chemistry curriculum emphasizes the chemical and geochemical processes operating in the oceans, the solid earth, the atmosphere, marine organisms, polar ice sheets, lakes, meteorites, and the solar system. This program, designed for students with undergraduate majors in either chemistry or geology, features areas of advanced study and research that include the physical and inorganic chemistry of seawater; ocean circulation and mixing based on chemical and isotopic tracers; marine organic and natural products 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, sulfur, nitrogen, and other elements; isotope geochemistry of the solid earth and meteorites; atmospheric trace gas chemistry; paleoatmospheric composition recorded in polar ice cores and in sediments; and chemistry of lakes and other freshwater systems.

GEOLOGICAL SCIENCES

This curriculum applies observational, experimental, and theoretical methods to the understanding of the solid earth and solar system and how they relate to the ocean and atmosphere. Principal subprograms are marine geology and geophysics, tectonics, sedimentology, micropaleontology and paleoceanography, petrology and geochemistry, and isotope

geology. Expedition work at sea and field work on land are emphasized as essential complements to laboratory and theoretical studies.

GEOPHYSICS

Students in this curriculum study the physics of the solid earth, including the earth's magnetic field, the mechanics of tectonic processes, earthquakes and the waves they produce, the physics of the earth's interior, and mathematical methods for analyzing data and interpreting them in terms of models of the earth. The program emphasizes physical and mathematical approaches to geophysical research.

MARINE BIOLOGY

The marine biology curriculum emphasizes the basic biology of marine organisms—animals, plants, and prokaryotes. Research and teaching emphasize a broad range of biological disciplines, including molecular biology, microbiology, comparative physiology and biochemistry, developmental biology, neurobiology, biomechanics, evolution, systematics, behavior, and ecology.

PHYSICAL OCEANOGRAPHY

Studies in physical oceanography include observation, analysis, and theoretical interpretation of the general circulation of ocean currents and the transport of dissolved and suspended substances and heat; the distribution and variation of oceanic properties; the propagation of sound and electromagnetic energy in the ocean; and the properties and propagation of ocean waves.

Student Enrollment

In the fall of 1995, 38 new students were admitted to graduate study. Of these, 12 were in marine biology, 2 in geological sciences, 8 in geochemistry and marine chemistry, 1 in geophysics, 4 in physical oceanography, 6 in applied ocean sciences, and 5 in biological oceanography. The newest curricular group, climate sciences, began accepting students for fall 1996 matriculation. Enrollment at the beginning of the academic year was 188. UC San Diego awarded 20 Doctor of Philosophy degrees and 9 Master of Science degrees to the students listed in this section.

GRADUATE STUDENTS AND DEGREE RECIPIENTS

Doctor of Philosophy Degrees Awarded, with Titles of Dissertations

EARTH SCIENCES

Joydeep Bhattacharyya
"Three-dimensional Anelastic Structure of Earth."

Julie J. Dieu
"On the Formation of Cumulates, Characteristics of Oceanic Lithosphere, and the Process of Carbonatite Metasomatism: A Study of Ultramafic Xenoliths from South Pacific Islands."

Harold Gurrola
"Investigation of the Upper Mantle Transition Zone through Velocity Spectrum Stacking of Receiver Functions."

Paul D. Hartl
"High Resolution Magnetic Records in Pelagic Sediments: The Oligocene Geomagnetic Field, the Brunhes/Matuyama Geomagnetic Reversal, and Rock Magnetic Changes at the Eocene/Oligocene Boundary."

MARINE BIOLOGY

José A. Alves-Gomes
"The Phylogeny and Evolutionary History of the South American Electric Fishes (Order Gymnotiformes)."

Ellen Chi
"Studies of Pressure Adaptation and Pressure Regulation of Protein Abundance in the Deep-Sea Bacterium SS9."

Keith E. Korsmeyer
"A Study of Cardiovascular Function in Swimming Tuna."

OCEANOGRAPHY

Carole A. Bewley
"New Antifungal and Cytotoxic Cyclic Peptides and Studies of the Bacterial Symbionts of Lithistid Sponges."

Milton A. Garcés
"The Acoustics of Volcanic Explosions."

Michele Y. Morris
"Mean and Low Frequency Fluctuations in the Circulation of the Western/Central Pacific Ocean."

Peter M. Norris
"Radiatively Driven Convection in Marine Stratocumulus Clouds."

GRADUATE STUDENT KAREN CASCIOTTI AND RESEARCHER RICHARD COSSON USE A VAN VEEN GRAB IN THE SANTA BARBARA CHANNEL.

Adina Paytan
"Marine Barite, a Recorder of Oceanic Chemistry, Productivity and Circulation."

Britt Raubenheimer
"Waves in the Surf and Swash Zones."

Karl F. Rieder
"Influences of Surface Waves on the Open Ocean Wind Stress Vector."

Steven C. Sherwood
"The Maintenance of the Tropical Water Vapor Distribution."

Robert A. Sohn
"Oceanic Spreading Center Accretionary Process Studies with Ocean Bottom Seismometers."

Malcolm D. Stokes
"Ontogenetic Changes in the Morphology, Ecology and Locomotory Biomechanics of the Lancelet, *Branchiostoma floridae*."

Alfredo J. Torruella III
"The Fall Upper Ocean Heat Balance in the Northeast Pacific."

Pim van Meurs
"The Importance of Spatial Variabilities on the Decay of Near-Inertial Mixed Layer Currents: Theory, Observations and Modeling."

Sean M. Wiggins
"Hess Deep Rift Valley Structure from Seismic Tomography."

Master of Science Degrees

MARINE BIOLOGY

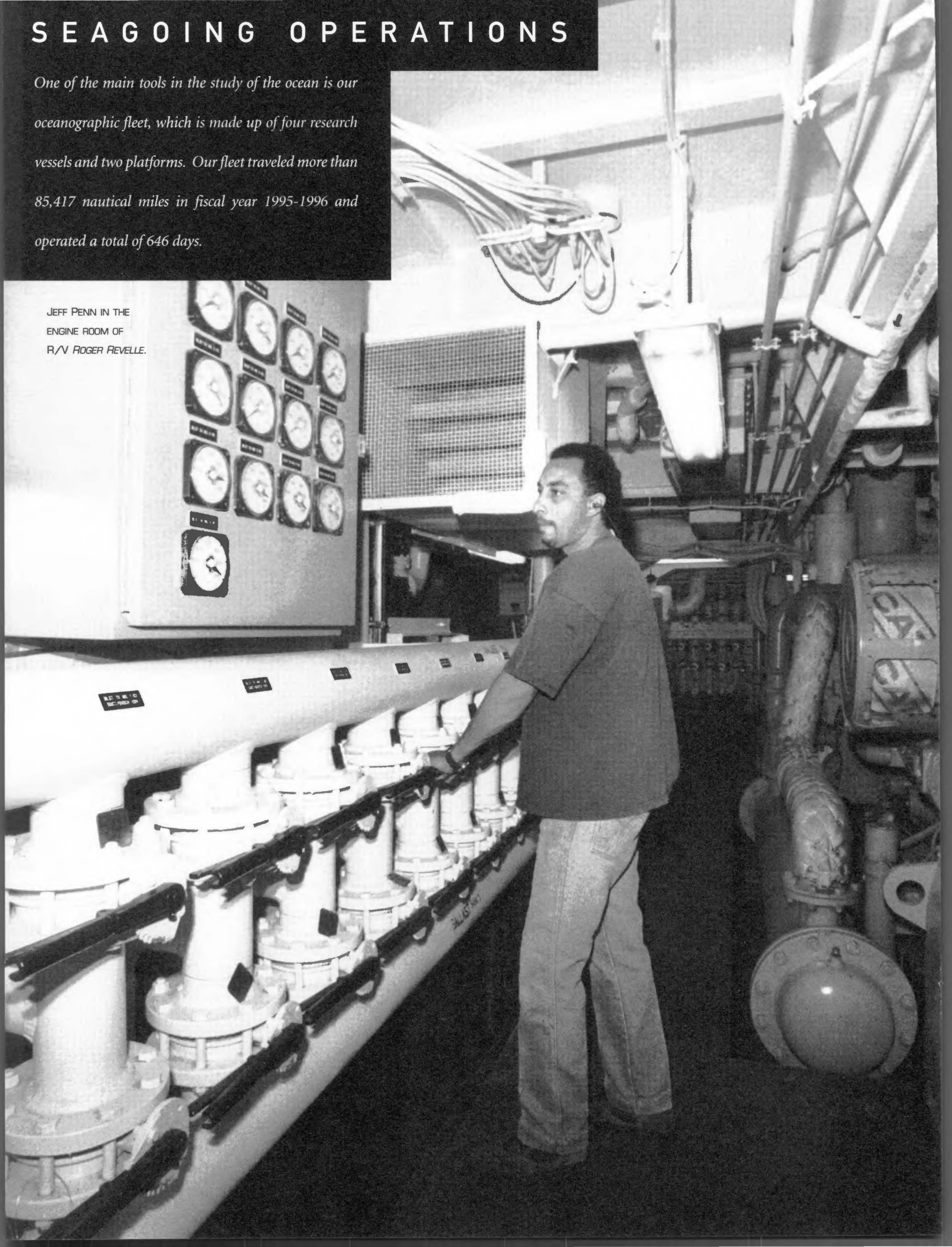
Vivian R. Casanas

OCEANOGRAPHY

Elizabeth D. Baker
Gregory T. Bullard
William C. Conant
Diana Lewis
Megan M. Hamilton
Hans E. Ramm
Laurence Sombardier
Constanze E. Weyenmeyer

SEAGOING OPERATIONS

One of the main tools in the study of the ocean is our oceanographic fleet, which is made up of four research vessels and two platforms. Our fleet traveled more than 85,417 nautical miles in fiscal year 1995-1996 and operated a total of 646 days.



JEFF PENN IN THE ENGINE ROOM OF R/V *ROGER REVELLE.*

R/V *Melville*

Eight chief scientists led 10 expedition legs aboard R/V *Melville* during the fiscal year 1995-1996. Research sites included the southern East Pacific Rise, waters off Mexico, northwest of Australia, south of New Zealand, and in the North and South Pacific. The research vessel worked throughout the southern and central regions of the Indian Ocean. Research activities included SeaBeam data collection, dredging, water sampling, Deep Tow operations, sea trials, OBS deployment, and seismology studies of the East Pacific Rise. Thomas Desjardins was captain. Relief captains were Eric Buck and Albert Arsenault.

Type	Oceanographic research
Yr. Built	1969 (refitted, 1992)
Yr. Acquired by Scripps	1969
Owner	U.S. Navy
Length	278'10"
Beam	46'
Draft, full	16'6"
Displacement, full (tons)	2,958
Cruising Speed (knots)	12
Range (nautical miles)	12,000
Crew	23
Scientific Party	38
Total Distance Traveled	53,068 nautical miles
Operating Days	280

Type	Oceanographic research
Yr. Built	1978 (refitted, 1996)
Yr. Acquired by Scripps	1978
Owner	University of California
Length	170'
Beam	36'
Draft, full	12'8"
Displacement, full (tons)	1,080
Cruising Speed (knots)	10
Range (nautical miles)	4,100
Crew	12
Scientific Party	17
Total Distance Traveled	17,901 nautical miles
Operating Days	177

R/V *New Horizon*

Fourteen chief scientists led 15 scientific explorations aboard R/V *New Horizon* during the 1995-1996 fiscal year. The ship underwent a mid-life refit during the first quarter of 1996. An extensive array of research and testing was conducted, including phytoplankton studies, column denitrification, Deep Tow operations, equipment recovery and testing, CalCOFI studies, gravity studies, coring, trawling, and benthic biology. The ship was used for one Scripps class cruise. Research destinations included the Juan de Fuca Ridge, the Southern California Bight, Los Angeles Harbor, Point Conception, and the waters off Hawaii, Santa Barbara, and San Diego. Other institutions conducting research aboard the ship included UC Santa Cruz, UC Santa Barbara, UC Irvine, University of Southern California, and the University of Hawaii. John Manion was captain. Curtis Johnson was relief.

R/V *Robert Gordon Sproul*

Twenty-eight chief scientists embarked on 46 research projects aboard R/V *Robert Gordon Sproul* during the 1995-1996 fiscal year. The ship traveled from the waters off San Diego to the Santa Barbara Channel, the Southern California Bight, Los Angeles Harbor, and the waters off Point Conception. Research efforts included ambient noise studies, biogeochemistry, clam collection, coring, euphausiid collection, optical system deployment, fish and larval sampling, coastal studies, MOCNESS biology, SeaSoar tests, CTD and mooring deployment, and a student cruise. Louis Zimm was captain. Relief captains were Thomas Desjardins, Wesley Hill, John Manion, and Christopher Curl.

Type	Oceanographic research
Yr. Built	1981
Yr. Acquired by Scripps	1984
Owner	University of California
Length	125'
Beam	32'
Draft, full	9'6"
Displacement, full (tons)	696
Cruising Speed (knots)	9
Range (nautical miles)	3,250
Crew	5
Scientific Party	12
Total Distance Traveled	12,308 nautical miles
Operating Days	126

R/P FLIP

R/P FLIP made five sea trips this year, supporting a variety of research projects. The projects included a highly successful 40 day NOAA wave study cruise to the Oregon coast, engineering trials, an operational test of the acoustic daylight system, and SWellEX 96, a major navy research program. Additionally, FLIP was the subject of a documentary film made in July 1995 and featured on the Discovery Channel. Four chief scientists led trips this year. Tom Golfinos was the senior floating lab crewman on FLIP throughout the year.

Type	Floating instrument platform
Yr. Built	1962
Yr. Acquired by Scripps	1962
Owner	U.S. Navy
Length	355'
Beam	20'
Draft, full	12'/300'
Displacement, full (long tons)	700
Cruising Speed (knots)	varies*
Range (nautical miles)	varies*
Crew	5
Scientific Party	11
Total Distance Towed	2,140 miles
Operating Days	63

R/P ORB

R/P ORB was not operated during the 1995-1996 fiscal year. In January 1996, the navy authorized the disposal of ORB.

Type	Oceanographic research buoy
Yr. Built	1967
Yr. Acquired by Scripps	1968
Owner	U.S. Navy
Length	69'
Beam	45'
Draft, full	fwd.4'10.5"/aft 5'4.5"
Displacement, full (tons)	325
Cruising Speed (knots)	varies*
Range (nautical miles)	varies*
Crew	5
Scientific Party	10
Total Distance Towed	0
Operating Days	0

* Depends on towing vessel.

FINANCIAL SUPPORT

Private gifts and grants to Scripps provided important support for a variety of programs during the past year. As Scripps prepares for its next century of discovery, philanthropy will play an increasingly critical role in funding research and education programs.

During fiscal 1995-1996, Scripps Institution of Oceanography received more private gifts and grants than in any previous year. Community support for Scripps continued to grow with the creation of new endowments, fellowships, and research funds. The total from pledges, gifts, grants, and gifts-in-kind was more than $14,800,000.

The W. M. Keck Foundation awarded Scripps a $4,750,000 grant to complete funding for the W. M. Keck Foundation Center for Ocean Atmosphere Research. The center will bring together leading global change research groups in an interdisciplinary setting. These facilities will provide scientists with the next generation of oceanographic, atmospheric, and satellite instrumentation necessary for quantifying global change processes.

Other gifts to the Keck center included a bequest from the estate of James G. Scripps, grandson of Scripps cofounder E. W. Scripps, and a grant from the G. Unger Vetlesen Foundation. The Scripps bequest will help to create the James G. and Marion B. Scripps Laboratory to house physical oceanographers and atmospheric scientists. In addition to the grant for the Keck Center, the Vetlesen Foundation also awarded Scripps a major grant for global change research.

The Henry L. and Grace Doherty Charitable Foundation awarded a challenge grant of up to $300,000 to fund endowed fellowships for first-year students at Scripps. Financial support for students during their first, critical year of graduate studies is a top priority for the institution. Scripps needs to raise an additional $600,000 to match the Doherty Foundation's challenge. During the first six months of the challenge, more than $300,000 in matching funds were raised. Pledges and donations to establish endowments for fellowships for first-year students were received from the Margaret T. Morris and J. W. Kieckhefer Foundations, Albert and Betty Boyer, Alan and Nora Jaffe, Bernard Ecker, Maurice and Charmaine Kaplan, and Peg Scripps Buzzelli. Scripps also received a bequest from the estate of Thomas Joseph Walsh to establish an endowed fellowship for first-year students. Walsh was a long-time employee of Scripps.

Other notable contributions during the past year included

- the donation of the swath boat *Chubasco* from Chubasco Charters, Inc.
- a grant from the David and Lucile Packard Foundation for operating support
- a grant from the Andrew W. Mellon Foundation to support research on beach formation
- a gift from the Robins Family Foundation for unrestricted support
- several grants from the Cecil H. and Ida M. Green Foundation for Earth Sciences to support the Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics
- a gift from Robert P. Scripps to support aquarium operations
- grants from the Los Angeles and San Diego Chapters of the ARCS Foundation for fellowships
- a gift from Alex and Diane Szekely to sponsor a tank at the aquarium

In March, members of the Scripps family joined over 250 friends of Scripps for the "Whale of a Gala" weekend dedicating a life-size, bronze whale exhibit in memory of E. W. "Ted" Scripps II. The sold-out gala raised more than $55,000 for the aquarium.

The SIO Associates supported the purchase of seafloor recorders at the Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics and provided startup funds for a research program at the Marine Physical Laboratory.

These are just a few of the many donations to Scripps during the year. The names of the donors are shown on the following pages.

Financial support from July 1, 1995 through June 30, 1996

INTERNATIONAL

National Center of Spatial Studies (France)

Japan Marine Science Technology Center (Japan)

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UNITED STATES

Agriculture, Department of
- Forestry Service

Commerce, Department of
- National Oceanic and Atmospheric Administration

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- Advanced Research Projects Agency
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  - Air Force Office of Scientific Research
- Army, Department of the
  - Army Corps of Engineers
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- U.S. Geological Survey

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- Department of Fish and Game
- Department of Water Resources

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MEMORIAL GIFTS

In memory of Dr. Robert S. Arthur, professor of oceanography
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In memory of Saul Bass
- Charlotte and William Hoyt

In memory of Edith Jessop DeWeese
- Mary Carlson
- Carol and Thomas Fairbairn
- Z. Pauline Gold
- Arthur and Elizabeth Jessop
- Mary and George Carter Jessop, Jr.
- Elizabeth Jessop Kelley
- Donald W. Leonard
- Jean L. May
- Members of Pi Beta Phi, Los Angeles-Santa Monica Alumnae Club
- Ann Thompson

In memory of Carl Eigenbrodt
- Mary and Don Carlson

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If you are interested in making a donation to the institution, please contact

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Scripps Institution of Oceanography

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CURRENT FUNDS

Agency	Expenditures for 94/95*	Percent of Total	Expenditures for 95/96*	Percent of Total
FEDERAL GOVERNMENT				
National Science Foundation	$23,130,799	23.14	$25,479,433	25.09
Defense, Department of	$12,420,827	12.43	$7,279,077	7.16
Navy, Department of the	$12,385,476	12.39	$15,833,011	15.59
Commerce, Department of	$7,800,596	7.80	$12,519,175	12.33
Health and Human Services, Department of	$6,913,466	6.92	$1,057,364	1.04
National Aeronautics and Space Administration	$4,214,791	4.22	$4,697,981	4.62
Interior, Department of the	$1,617,600	1.62	$1,789,555	1.76
Energy, Department of	$1,503,401	1.50	$1,975,165	1.94
Other/Including Federal Flowthru Funds	$8,706,694	8.71	$9,146,653	9.00
Total *Federal Government*	$78,693,650	78.74	$79,777,414	78.53
OTHER				
State General Funds	$15,199,587	15.21	$14,770,199	14.54
Private Gifts and Grants	$2,831,823	2.83	$2,205,690	2.17
Overhead Funds	$1,474,998	1.48	$2,249,603	2.21
State of California	$1,626,898	1.63	$1,701,416	1.67
Endowment Funds	$254,981	0.26	$767,970	0.76
University Funds	$211,946	0.21	$263,483	0.26
Local Government	$100,822	0.10	$136,348	0.13
Sales and Services	($309,055)	-0.31	($634,435)	-0.62
Reserves	($138,174)	-0.14	$356,621	0.35
Total *Current Funds Expenditures*	$99,947,477	100.00	$101,594,309	100.00

**Includes Overhead*

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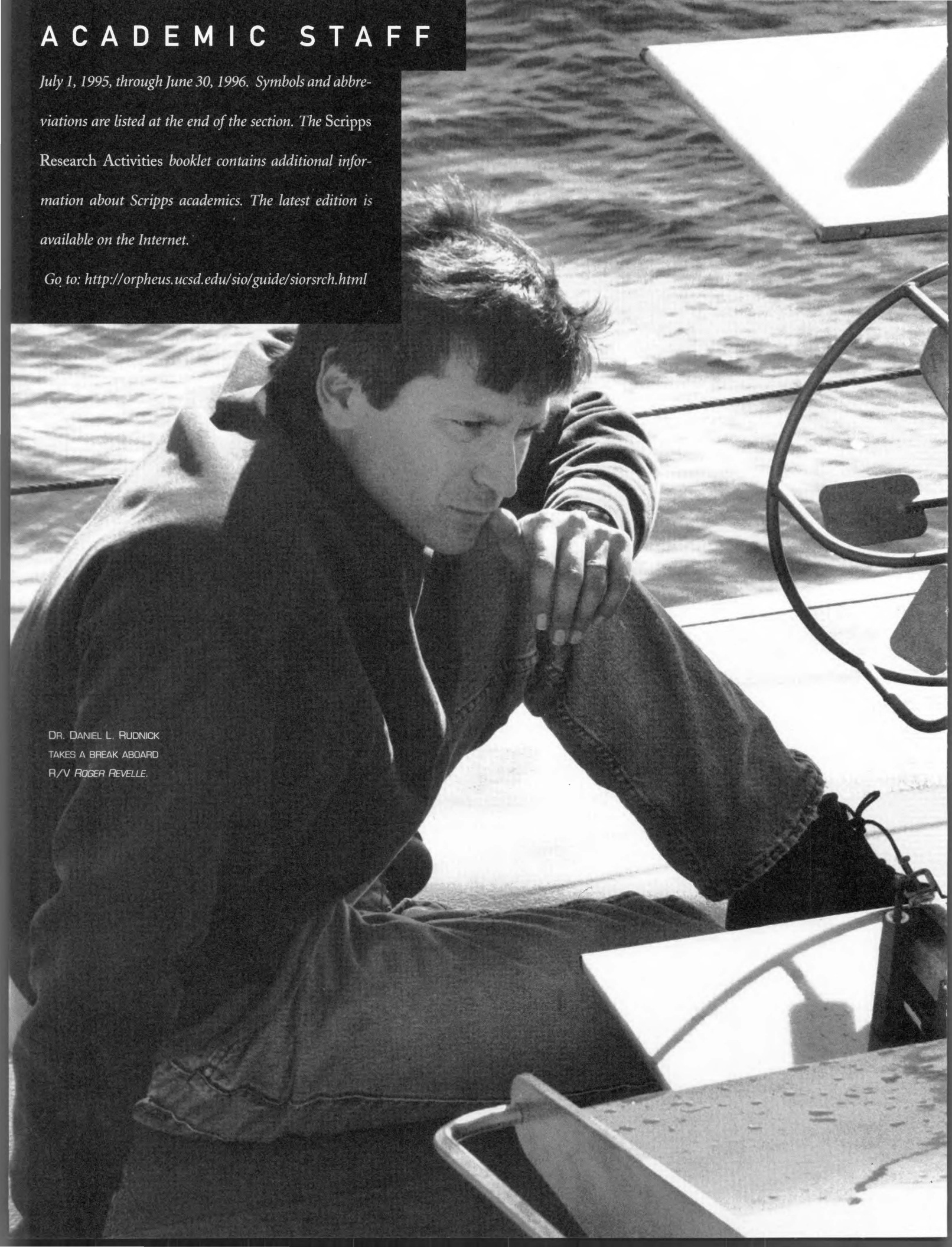
July 1, 1995, through June 30, 1996. Symbols and abbreviations are listed at the end of the section. The Scripps Research Activities *booklet contains additional information about Scripps academics. The latest edition is available on the Internet.*

Go to: http://orpheus.ucsd.edu/sio/guide/siorsrch.html



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AMES *Applied Mechanics and Engineering Sciences Department*
CMBB *Center for Marine Biotechnology and Biomedicine*
CRD *Climate Research Division*
CSI *California Space Institute*
CCS *Center for Coastal Studies*
DO *Director's Office*
D-SIO *Department of the Scripps Institution of Oceanography*
ECE *Electrical and Computer Engineering Department*
GRD *Geosciences Research Division*
IGPP *Institute of Geophysics and Planetary Physics*
MBRD *Marine Biology Research Division*
MLRG *Marine Life Research Group*
MPL *Marine Physical Laboratory*
MRD *Marine Research Division*
NU *Neurobiology Unit*
PORD *Physical Oceanography Research Division*
SGP *Sea Grant Program*
SOMTS *Ship Operations and Marine Technical Support*
STS *Shipboard Technical Support*

AWARDS & HONORS

GEORGE E. BACKUS
Awarded the degree of Docteur Honoris Causa at the Sorbonne, in Paris, France, by the Institut de Physique du Globe de Paris.

CHARLES S. COX
Elected a member of the National Academy of Sciences.

PAUL CRUTZEN
Honored by the Royal Swedish Academy of Sciences with the 1995 Nobel Prize in Chemistry.

WILLIAM H. FENICAL
Received the "Paul Scheuer Award" presented during the Gordon Research Conference on Marine Natural Products Chemistry.

EDWARD A. FRIEMAN
Honored with the Compass Distinguished Achievement Award for 1995 from the Marine Technology Society.

EDWARD D. GOLDBERG
Awarded the 1996 John H. Martin Medal of Excellence in Marine Sciences by the Hopkins Marine Station of Stanford University.

WILLIAM A. KUPERMAN
Awarded the Pioneers of Underwater Acoustics Medal from the Acoustical Society of America.

WALTER H. MUNK
Declared an honorary doctor of philosophy of the School of Sciences of the University of Crete in Greece.

WILLIAM A. NEWMAN
Honored with The Crustacean Society Research Excellence Award and was recognized at the society's annual meeting with a symposium entitled "New Frontiers in Barnacle Evolution."

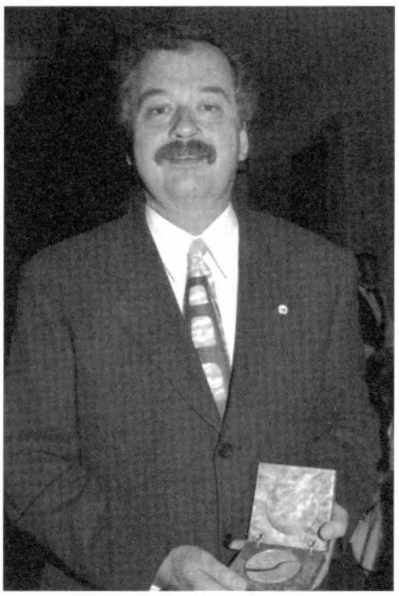
JOSEPH L. REID
Received The Henry Stommel Research Award from the Council of the American Meteorological Society.

SCRIPPS INSTITUTION
Faculty in oceanography voted #1 in quality by the National Research Council.

RICHARD J. SEYMOUR
Elevated to fellow within the American Society of Civil Engineers.

WILLIE J. SWANSON
Awarded the newly established Edward A. Frieman Director's Prize in recognition of an outstanding research paper by a Scripps graduate student.

BENJAMIN E. VOLCANI
Honored by Dow Corning Corporation in recognition of his pioneering work on silicon in biological systems.



DR. KENNETH BRINK.

CODY AWARD

The fourth Robert L. and Bettie P. Cody Award in Ocean Sciences was presented by Scripps to Dr. Kenneth Brink, a physical oceanographer at Woods Hole Oceanographic Institution.

Brink's research focuses on the response of waters over the continental shelf and their reaction to wind forcing. During his career, he has contributed to a variety of seagoing experiments as well as to theoretical research work. His work has yielded valuable scientific information about interdisciplinary coastal oceanography.

The biennial Cody Award, first presented in 1989, comprises a gold medal, a certificate, and a ten-thousand-dollar prize presented by Scripps. While at Scripps, the recipient presents a scientific lecture to his or her professional colleagues, and a public lecture.

Cody Awards honor outstanding scientific achievement in oceanography, marine biology, and the earth sciences.

The award was established by Mr. and Mrs. Robert L. Cody. Robert Cody's great aunt, Mary Bennett Ritter, was the wife of Scripps's first director, William E. Ritter.

PUBLICATIONS

The results of Scripps research are published in many different forms. These publications range from short contractual reports to long taxonomic descriptions. Scripps publications are distributed by subscription, exchange, or government contract. A listing of recent Scripps publications follows. Detailed information on the availability of each series is included. The bibliography of the Scripps Institution of Oceanography Contributions *for years 1982 through 1994 is now on the Internet. Searches can be conducted either by author or subject.*

Go to: http://orpheus.ucsd.edu/cgi-bin/sio/sio.search.pl

BULLETIN

The *Bulletin of the Scripps Institution of Oceanography* is an irregularly published series for lengthy, in-depth scientific papers written by Scripps scientists. For information about subscriptions and a list of volumes available, please write to

University of California Press
2120 Berkeley Way
Berkeley CA 94720.

The most recent volumes are listed below.

v.28 **Castellini**, Michael A., Randall W. **Davis** and Gerald L. **Kooyman**. Annual Cycles of Diving Behavior and Ecology of the Weddell Seal. 1992. 54p.

v.29 **Park**, **Taisoo**. Taxonomy and Distribution of the Marine Calanoid Copepod Family Euchaetidae. 1995. 203p.

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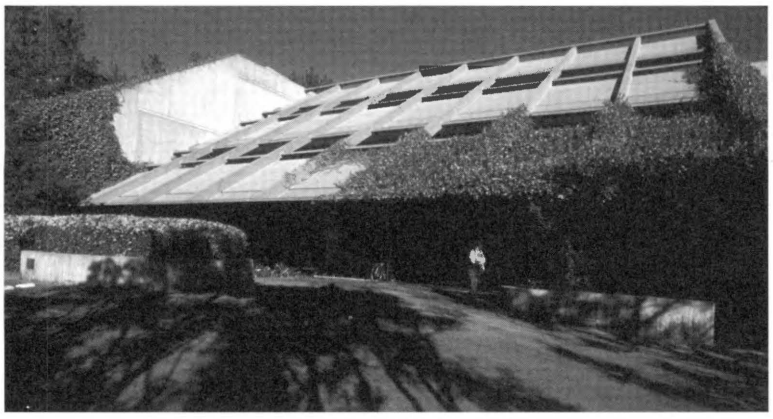

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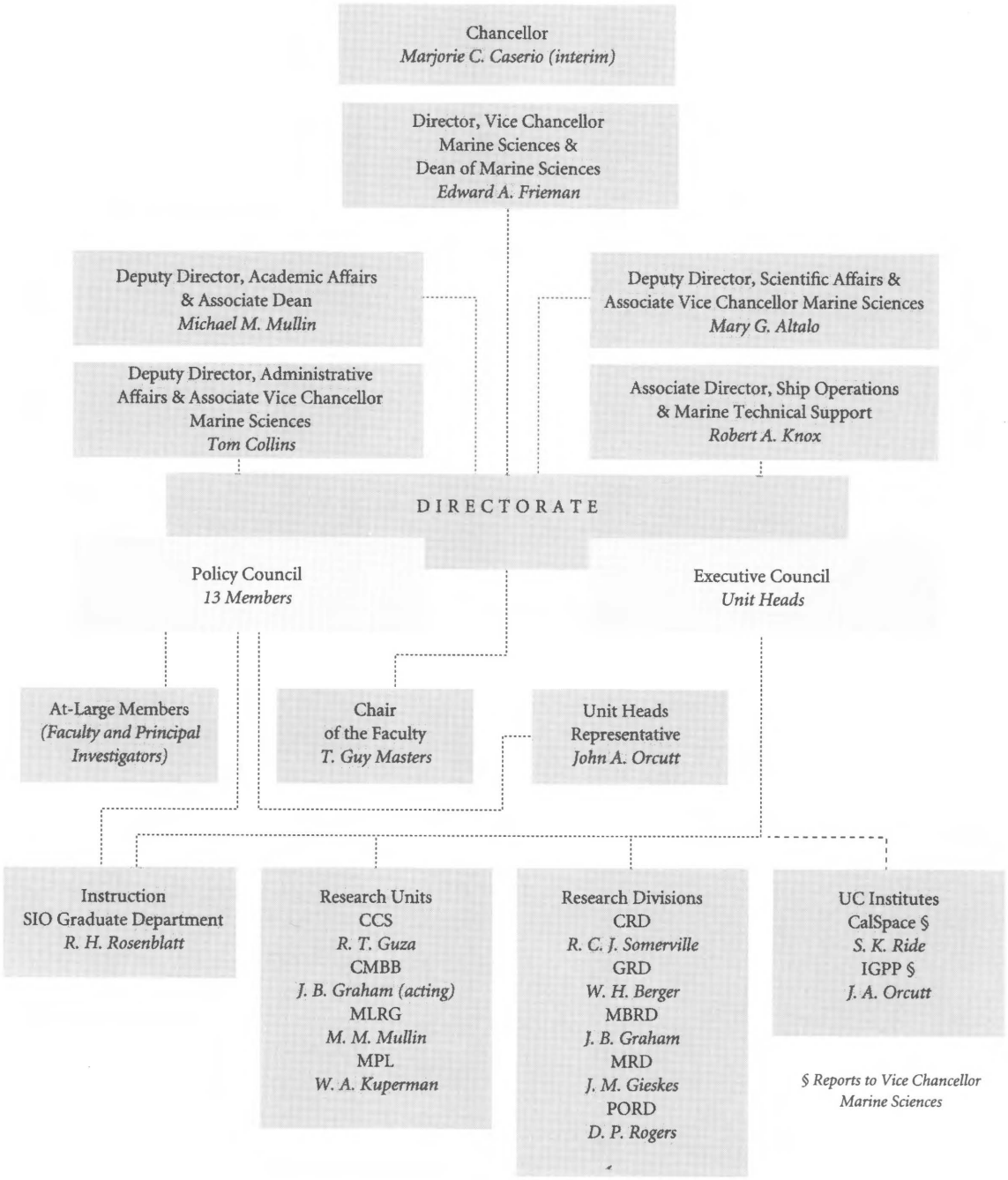

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(Left to right) Resident technician Tammy Koonce, research assistant Lynn Harris, and Dr. Lloyd A. Regier during vehicle deployment aboard R/V *Roger Revelle*.

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IN MEMORIAM

William F. Blankley
January 1996

William F. Blankley was a graduate student in Ralph Lewin's laboratory for five years. In 1971 he submitted a Ph.D. thesis on growth and calcification in coccolithophorids, in which he refuted the popular idea that the deposition of calcium carbonate in such planktonic algae was tied to photosynthesis and thus dependent on light. His conclusions were correct.

Thomas E. Bowman
August 1995

Tom Bowman came to Scripps in 1948 to study zooplankton and became the forerunner of Martin Johnson's students who embarked on analysis of CalCOFI samples starting in 1949. From 1955 until his death, he was curator of crustacea at the Smithsonian Institution.

MELVIN N. A. PETERSON

Rear Admiral Justin Langille
May 1996

Retired Rear Admiral Justin "Jack" Langille served as Scripps deputy director from 1982-1987. He graduated from the Naval Academy in 1946, and held a variety of sea commands and high-level research positions during his 38-year military career. He co-invented the military aircraft escape chute, an underwater work vehicle, and a shipboard helicopter landing computer. He was awarded the Legion of Merit, two Bronze Stars, the Meritorious Service Medal, and various campaign medals. After retiring from the military, he served as director of marine operations for the Hubbs-Sea World Research Institute Task Force for the Frontier-Challenger Expedition.

Melvin N. A. Peterson
September 1995

Mel Peterson joined Scripps in 1960 following completion of his doctoral dissertation in geology at Harvard University. He was a renowned sedimentologist. He was appointed chief scientist of the Deep Sea Drilling Project in 1967 and its director in 1971.

Diane Phillips
May 1996

Diane Phillips was a Scripps graduate student in the geochemistry and marine chemistry curricular group. She came to Scripps as a student in the fall of 1994, and her outgoing and personable character won her many friends among her colleagues.

Brenda Stoker
February 1996

Brenda Stoker started her career at UC San Diego in 1971 in the staff personnel office and transferred to the chemistry department in 1978. In 1981, she joined the Institute for Marine Research/Marine Research Division at Scripps, where she worked until leaving because of illness in December 1992. She worked with payroll/personnel and proposal preparation.