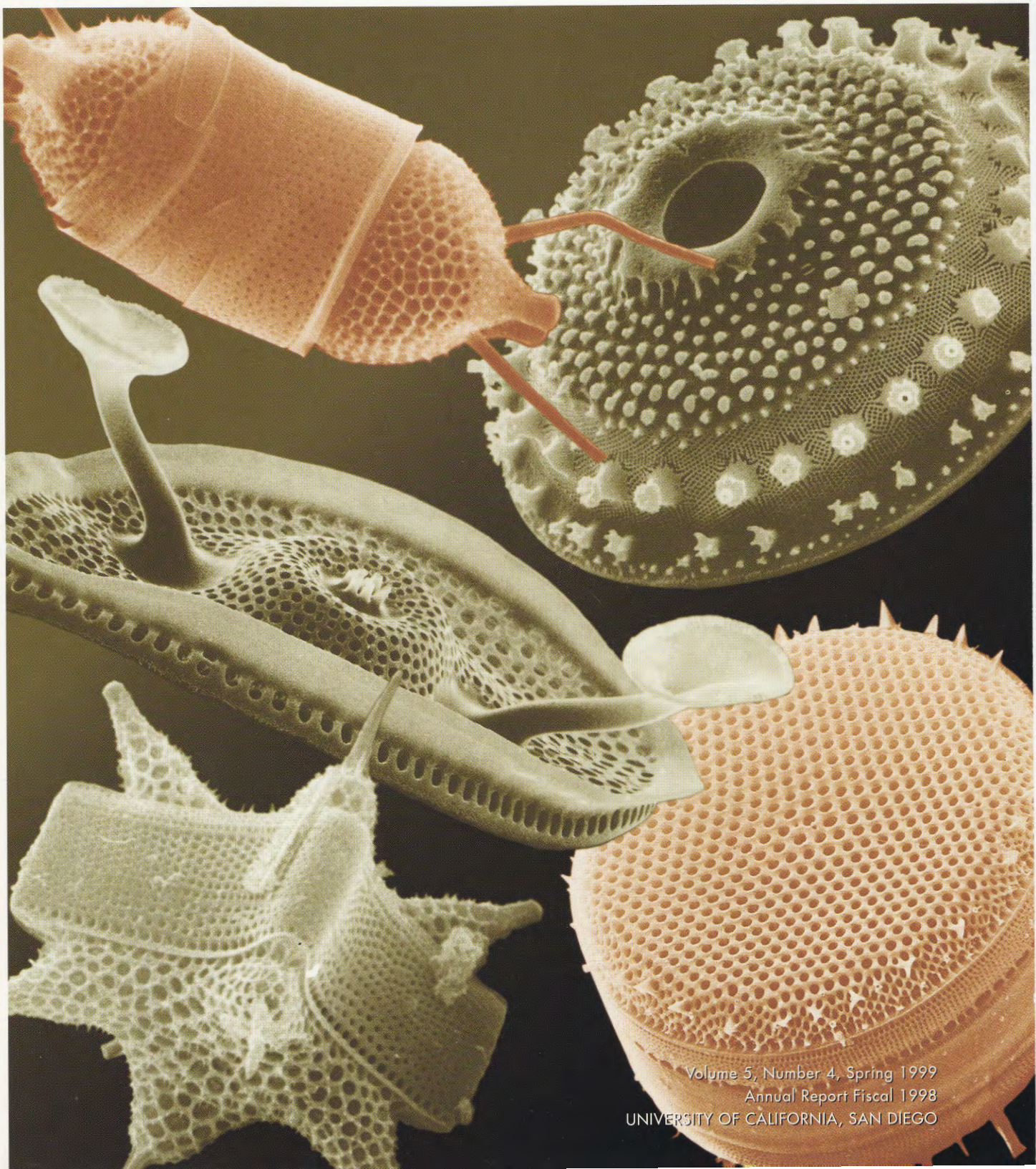
SCRIPPS INSTITUTION OF OCEANOGRAPHY

EXPLORATIONS

Global Discoveries for Tomorrow's World



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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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SCRIPPS INSTITUTION OF OCEANOGRAPHY

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Global Discoveries for Tomorrow's World

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A New Golden Age for Science

The Berlin Wall came down ten years ago. Almost immediately, concern was voiced that, without the rationale of national security, American science would inevitably decline. The Superconducting Supercollider and the Space Station came under attack, and the supercollider was canceled. Questions concerning the priorities and competence of the scientific community were raised. Would scientists forsake their expensive inventions and pay attention to human needs neglected during the cold war? Could universities manage interdisciplinary research and teaching and adjust to new global realities as industry had done?

You don't hear these refrains as often today. It has become quite clear that, far from being in decline, science is on the verge of a new golden age. There are several reasons for this. Powerful new concepts, computational techniques, and instrumentation have enriched the scientific disciplines. More scientists are at work in more countries around the world than there were even ten years ago. And they communicate in powerful new ways, sharing entire data sets in seconds. Scientific problems are solved, applications are invented, and interdisciplinary frontiers are crossed with unprecedented rapidity.

We will soon be able to undertake projects of hitherto inconceivable breadth. Nowhere is this truer than in the earth and ocean sciences. A true integration of the physics, chemistry, and biology of the oceans lies just over the horizon. Awareness of the earth as an interacting system of natural and human processes and a comprehensive understanding of human impact on our natural environment will ultimately follow.

These realizations may arrive just in time, for we oceanographers know how urgent it is to address such critical issues as global climate change, the sustainability of marine ecosystems, the increasing human impact on our coastal regions, and the ocean's role in human health.

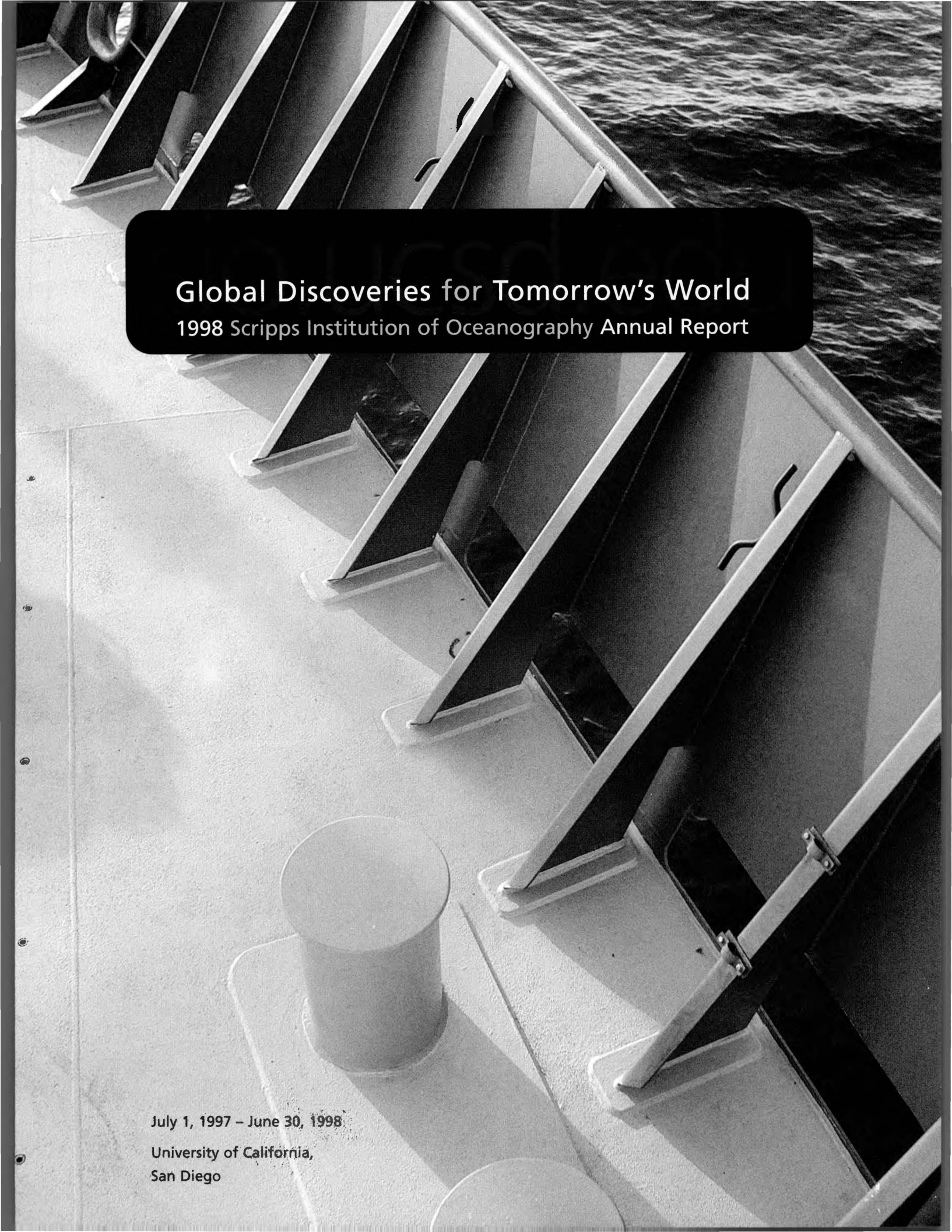
While we begin to see what needs to be, and can be, done, we do not yet know how to organize for the task. How will we build the global networks of cooperating institutions that our new ways of interdisciplinary thought require? How will we forge intimate links to the users of the emerging knowledge—in industry, government, and education?

We do have reason to hope. The World Ocean Circulation Experiment described in this issue stands as one proof that scientists around the world can organize cooperatively, and that governments can agree to support scientists to achieve results that no one of them, nor their institutions, could achieve alone. This current collaboration has produced a comprehensive picture of ocean circulation never before seen.

Scripps is proud to have played a part. We look forward to the next steps in developing and implementing an Integrated Global Observing Strategy—one that links physics, chemistry, and biology; joins observations from space with those made on and under the surface; and knits together the oceans, land, and atmosphere in a single intellectual panorama.

Charles Kennel

Charles F. Kennel
Director, Scripps Institution of Oceanography



Global Discoveries for Tomorrow's World

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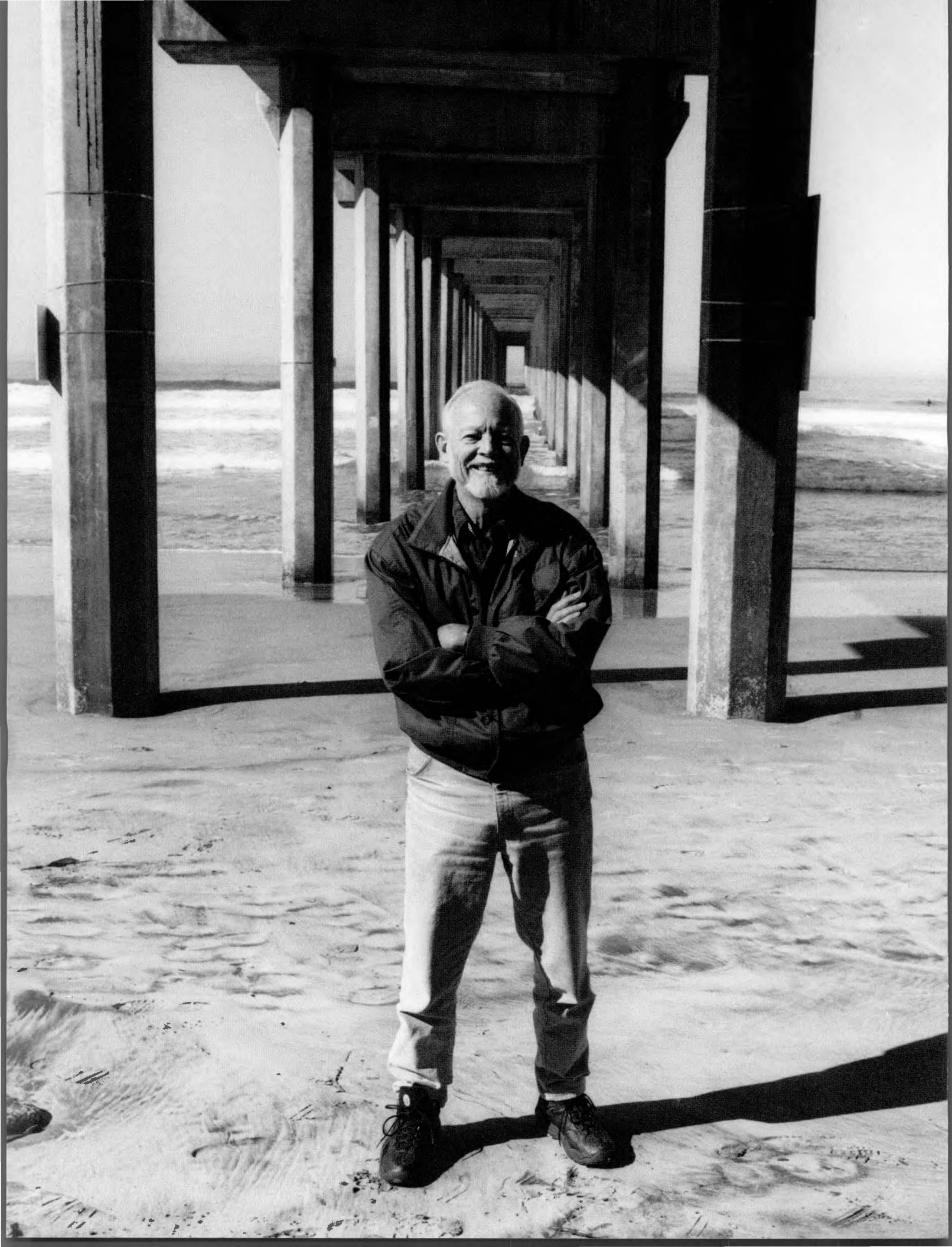


Doug Inman

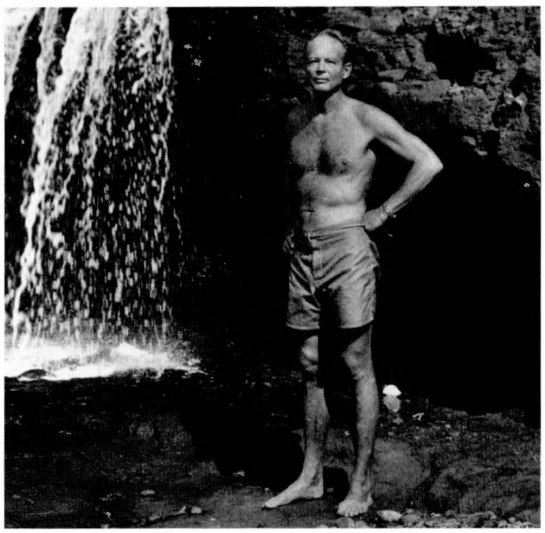
Shortly after World War II, a new wave of beach assaults commenced at Scripps Institution of Oceanography. Launched by Douglas L. Inman, a former Marine Corps major, these weren't military actions, but rather the onset of a lifelong campaign conducted on shorelines worldwide to understand and forecast the movements of waves, currents, and sand.

During his quest, Inman, now both an emeritus and research professor, founded the field of beach and nearshore processes and created the prestigious Center for Coastal Studies at Scripps. He pioneered quantitative methodologies and electronic instruments for coastal research and formulated mathematical models that are now fundamental to knowledge of beach erosion and wave dynamics. His actions, as both a scientist and advocate, have helped preserve beaches, lagoons, and harbors around the world.

By introducing the principles of physics and fluid mechanics to marine geology, Inman created a unique research program concentrating on shore processes. With collaborators, he formulated the first numerical models of sand transport, designed the first electronic data loggers to measure breaking waves, and created systems for data telemetry. Under his direction, scientists and students defined the actions of rip currents, edge waves, and the transport of sand. They developed new strategies and modern instruments for beach experiments and assessed controls for coastal processes, testing the designs of jetties, breakwaters, and sand-transfer systems. These diverse investigations have resulted in numerous applications in coastal management, engineering, and harbor planning.

Inman was born in Guam on July 7, 1921, into a military family that traveled around the world. He received a bachelor's degree in physics from San Diego State University (SDSU) in 1942 and the following year did graduate work in electronics at Harvard University and the Massachusetts Institute of Technology. Then came the war and four years of military service.

Returning to San Diego, Inman became an instructor at SDSU and then enrolled in the first class in the newly established oceanography graduate program at Scripps. He received master's and doctoral degrees, joined the faculty in 1953, and became a professor in 1965. He established Scripps's Hydraulics Laboratory and was the founding director of the Center for Coastal Studies.



Doug Inman, Scripps Beach, 1998 (opposite page) and 1977 (this page)

Foremost among Inman's concepts is the "littoral cell," defined as a section of coastline containing the sources, transport paths, and sinks of sediments. A "budget of sediment" is calculated for each cell along the coast and used to evaluate erosion, the damming of river sources, placement of shoreline barriers, and the silting and dredging of harbors. The concept has been applied successfully in all types of coastal areas.

Inman has advised local, state, and national agencies, and has lectured and consulted in South America, China, the Middle East, Italy, Turkey, and throughout Southeast Asia. He has fostered delicate collaborations between Israeli and Egyptian scientists and was among the first American scientists to visit China after U.S. relations were reestablished in the late 1970s. Both the U.S. Navy and the Army Corps of Engineers have relied heavily upon Inman's advice on coastal projects.

In 1961, Inman was appointed a Guggenheim Fellow. The American Society of Civil Engineers presented him the 1988 International Coastal Engineering Award. In 1989, he received an Ocean Science Educator Award from the Office of Naval Research. He is a Fellow of the Geological Society of America and the American Association for the Advancement of Science.

A member of the Scripps community since the 1950s, Inman has numerous colleagues and students who have become longtime friends and neighbors. Many remember fondly his first wife, Ruth, who was active in Oceanids and the UC San Diego International Center, and who died in 1978. He later married Patricia Masters, a marine chemist and archeology researcher at Scripps, and they reside with their son, Bryce, in La Jolla.

For nearly 50 years, Inman's tenacious genius and his support of several generations of graduate students and collaborators have created most of today's basic knowledge of beach processes. Asked for the most pivotal event in his long career at Scripps, Inman simply states, "When they asked me to stay."

BY CHUCK COLGAN

RESEARCH HIGHLIGHTS

More information on individual departments can be found at

http://www.sio.ucsd.edu/res_groups

BY MARIO C. AGUILERA AND JENNIFER E. CHUNG

The Research Highlights include a summary of current scientific activities at Scripps. Each department, division, center, and research unit or group is represented by a general overview of the activities of its scientists and by a detailed highlight of one scientist or project. Highlighted scientists have been selected by their departments for this recognition.

Readers interested in more in-depth coverage of the topics discussed here should consult the scientific papers listed in the Publications section.

CALIFORNIA SPACE INSTITUTE

CENTER FOR ATMOSPHERIC SCIENCES

CENTER FOR COASTAL STUDIES

CENTER FOR MARINE BIOTECHNOLOGY AND BIOMEDICINE

CLIMATE RESEARCH DIVISION

GEOSCIENCES RESEARCH DIVISION

INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS

MARINE BIOLOGY RESEARCH DIVISION

MARINE LIFE RESEARCH GROUP

MARINE PHYSICAL LABORATORY

MARINE RESEARCH DIVISION

NEUROBIOLOGY UNIT

PHYSICAL OCEANOGRAPHY RESEARCH DIVISION

FACING PAGE
Experimental marine geophysicist Spahr Webb of the Marine Physical Laboratory examines an ocean bottom seismometer.

California Space Institute

The California Space Institute (CalSpace), a multicampus research unit of the University of California, supports space and earth sciences, education, and technology. CalSpace maintains close ties with many departments at UC San Diego and other UC campuses through scientific collaboration and joint faculty appointments.

CalSpace scientists conduct pure and applied research in various interdisciplinary, space-related fields. Many CalSpace researchers emphasize the atmosphere and atmosphere-ocean interactions. Some scientists study space plasma physics and planetary science, while others investigate the earth's environment using remote sensing from satellites. CalSpace activities also include student teams working on projects with museums and governmental agencies.

Dr. John Roads is involved in several projects focused on understanding the global hydrologic cycle, which describes how water is evaporated from the ocean and land, transported by the atmosphere, returned to Earth as rain or snow, transmitted by rivers and groundwater, and stored in the ocean and land.

Roads is involved in the Continental-scale International Project (GCIP), a major global hydrology project that is part of the Global Energy and Water Cycle Experiment (GEWEX). GCIP is a multiagency program begun in 1991 to study the complex land-atmosphere-ocean interactions influencing the hydrologic cycle in the Mississippi River basin.

The Mississippi River basin, which stretches east from the Rocky Mountains to the Appalachian Mountains and south from the Canadian border to the Gulf of Mexico, is one of the largest and most heavily instrumented continental basins in the world. It was selected as the first GEWEX study site because it is monitored by extensive modern hydrological and meteorological observing systems, such as wind profilers and Doppler radars.

Roads analyzes equations from numerical models and numerical analyses of the hydrologic cycle and then compares these equations to quantities derived from direct observations, including satellite observations. The precision with which precipitation is balanced by evaporation in the hydrologic cycle equation gives him an idea of the model's accuracy. In an ideal model the values are balanced. Roads indicated there is still a long way to go before an accurate numerical analysis will be available.

Though GCIP scientists focus on the Mississippi River basin, their interests are global. Using GCIP data, Roads can check the validity of climate models. By bridging the gap between small- and large-scale climate models, global climate predictions will eventually become more accurate.

"Right now, we can validate predictions with observations that we have on weekly to seasonal to interannual timescales. When we do this, we notice discrepancies. As these model discrepancies or errors decrease because of better parameterizations, we can become more confident about large-scale climate model simulations," said Roads.

The refinement of modeling skills is important in order to predict slight variations in the hydrologic cycle. For example, Roads is investigating the accuracy of large-scale predictions of the hydrologic cycle when carbon dioxide is increased in the model atmosphere. Carbon dioxide is largely responsible for the hypothesized greenhouse effect that may cause global warming.

"If present trends continue, this enhanced greenhouse effect should become more apparent in the 21st century," said Roads. "We need to better understand the consequences of such changes on our hydrologic cycle."

GCIP's Mississippi River basin program has inspired the development of similar projects with global applications in Europe, Asia, the Amazon, and Canada. "GCIP is a prototype study for global hydrology in the 21st century," said Roads. "GCIP was the first, developed the standard research program for this type of research, and still remains the leader."

Center for Atmospheric Sciences

Researchers in the Center for Atmospheric Sciences (CAS) focus on fundamental investigations of the atmosphere related to large-scale climate change. Their analyses include a balance of field experiments, satellite observations, and computer modeling. Investigators use surface observatories, aircraft, and ships, as well as remote sensing by satellites. CAS scientists employ regional and global models of the atmosphere to interpret observations and to understand and predict changes in climate patterns. Areas of research within CAS include the climate feedback process, water vapor and clouds, and tropospheric aerosol and trace gas science.

Clouds are coming under increased scientific scrutiny because of mounting evidence of their fundamental role in Earth's climate.

Scripps meteorologist Dr. Guang J. Zhang is working to improve global and regional climate models—used around the world to predict changes in climate—by incorporating the effects of clouds and convection, an atmospheric process that produces thunderstorms.

"The interaction of clouds and climate is one of the major sources of uncertainty in predicting climate change," said Zhang. "If we don't understand clouds well, then our understanding of other issues will be severely hampered.

"Once we are able to predict fairly accurately the amount of clouds and their radiative properties, we expect that the climate models will be more dependable. That's the uncertainty now. We don't know enough about what the clouds are doing in climate change," said Zhang.

Clouds have the two-fold function of cooling and heating Earth. They cool by reflecting the Sun's radiation back into space, and they heat by absorbing radiation and transferring heat to Earth's surface. This dual behavior makes them difficult to analyze and model.

In addition to clouds, Zhang studies the complex interaction between convection and large-scale atmospheric circulation. In 1995 Zhang and a colleague at the Canadian Climate Center developed a new method of representing convection in global climate models. The following year the technique was integrated into the Community Climate Model 3, which was coordinated by the National Center for Atmospheric Research and used throughout the research world for understanding climate prediction. Their new technique led to improvements in simulating precipitation, surface evaporation, and surface wind activity.

Zhang also has improved scientific understanding of the dynamics of evaporation in tropical seas. Using data collected during a three-year period from an array of instrumented buoys in the tropics, Zhang analyzed how evaporation links with factors such as sea-surface temperature, wind speed, and atmospheric water vapor.

"What I found is that evaporation doesn't necessarily increase with sea-surface temperature, as previously perceived," said Zhang.

Zhang found that surface wind speed helps decide the rate of evaporation. In certain cases high sea-surface temperature translates into weaker surface winds. This, in turn, results in a lower ventilation mechanism and, hence, lower evaporation.

"So it's not just that sea-surface temperature translates into evaporation, although temperature has a lot to do with it," said Zhang.

Center for Coastal Studies

Scientists in the Center for Coastal Studies (CCS) focus on observing and modeling the physical and sedimentary processes that occur along the coastlines of the world. Ongoing research at CCS concerns surf zone hydrodynamics, fluid-sediment interactions responsible for sand transport along beaches, circulation in coastal waters and bays, propagation of surface waves across continental shelves, and coastal meteorology. CCS personnel also manage the Scripps Hydraulics Laboratory.

Recent CCS research sites include the Santa Barbara Channel, San Ignacio Lagoon in Mexico, San Francisco and San Diego Bays, and beaches and continental shelves in North Carolina and southern California.

Using the keen eye and analytical tools of a physicist, Dr. Myrl C. Hendershott describes ocean currents, waves, and tides in regions near the coastline.

Hendershott, graduate student James Lerczak, and Dr. Clinton D. Winant recently concluded a comprehensive study of ocean internal waves off Mission Beach, California. Just as traditional ocean surface waves propagate at the interface between water and air, two media of different densities, ocean internal waves propagate because deeper water is denser than water closer to the surface.

To analyze the internal waves coming toward Mission Beach, they used acoustic Doppler current profilers. These instruments continuously measure water velocity throughout the water column by comparing the frequency of sound waves sent out by the instrument with the frequency of the sound waves scattered back to the instrument by the minute particles that move with the water.

These instruments produce a vertical profile of currents about once every minute. An array of profilers spanning the nearshore region from depths of about 50 feet (15 m) at a few hundred yards from the coast, to 1,640 feet (500 m) at approximately 6 miles (10 km) offshore, was left in the water for six-week intervals during a two-year period.

"These have proven to be very interesting data; there were surprises there," said Hendershott. "We expected the internal waves to grow larger as they propagated toward the shore until they entered very shallow water. Instead we were surprised to see the internal waves kept getting smaller toward the shore as they passed through the instrument array. It's as though we are looking at an internal surf zone where the waves decay very rapidly near the shore."

The researchers focus on understanding how much energy the internal wave field puts into other kinds of motion near the coast. This information may have implications for water circulated from the ocean bottom to the top. Hendershott and Lerczak are now collaborating with other researchers to clarify some of the biological implications of these water motions.

CCS researchers and engineers, including Hendershott, have designed a new version of a traditional instrument, the surface drifter, a freely floating platform that moves with the surface water. The new drifter uses global positioning system technology to pinpoint its position to within a few meters and relays that position to a shore station every few seconds.

"Drifters with such precise positioning allow us to see horizontal motions that you can't measure with any other instrument," said Hendershott. "Now that drifters are able to record their position so accurately and frequently, I think we might really see some new things in nearshore waters."

Hendershott plans to combine these drifters with information from the Doppler profilers. "Ideally we would put that internal wave array back out in the Mission Beach area where we have results we understand, and then put out the drifters in the middle to see how the internal wave field is involved in moving fluid elements horizontally," said Hendershott. "Nearshore motions caused by internal waves could be as important as what we expect from other mechanisms, including wind-driven currents and big rip currents."

FACING PAGE

Physicist Myrl Hendershott (right) and graduate student James Lerczak check the readiness of an acoustic Doppler current profiler prior to deployment.

Center for Marine Biotechnology and Biomedicine

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

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

CMBB researchers investigate new biotechnologies ranging from the special properties of deep-sea marine microbes to the genetic engineering of commercially important marine animals. They also provide research support for the local biotechnology industries.

Dr. A. Aristides Yayanos has spent his career examining the properties of deep-sea microorganisms, primarily bacteria, that live in marine canyons and trenches more than 32,800 feet (10,000 m) deep. Limited food supply and extreme high and low temperatures are fundamental forces that affect the existence of these little-studied microorganisms. They must also contend with deep-sea pressure, one of the least understood forces on Earth and one of the main focuses of Yayanos's research.

"For the study of deep-sea life and bacteria in the oceans, you shouldn't look at just the temperature or the pressure of the environment; you have to look at both. I think that's the real take-home message from my work," said Yayanos. "Temperature and pressure interact in complex ways that we don't fully understand."

Yayanos's research addresses how temperature-pressure forces affect samples of organisms as they are retrieved from the deep sea for laboratory study. For example, three bacterial species that live at around 16,000 feet (5,000 m), each one located in a different part of the world's ocean with varying temperatures, will respond dissimilarly to surface decompression.

The levels of an enzyme in one deep-sea bacterium could be enhanced by pressure, while levels of the same enzyme in another bacterium might be inhibited by it. Adding to this complexity is nutrition, which can modify how an organism responds to pressure.

Because deep-sea microorganisms are never exposed to sunlight, fluorescent and ultraviolet laboratory light threaten the viability of deep-sea samples. Yayanos addresses this problem in his research by designing a variety of tools and instruments, including pressure vessels, to collect and transport samples from the field and maintain them for research in the laboratory. He also has designed six pressure-retaining animal traps that retrieve organisms from depths exceeding 9,800 feet (3,000 m).

"I catch deep-sea animals such as amphipods, not to study them, but to study the bacteria they contain," said Yayanos.

Yayanos recently published a comprehensive review of the problems and issues facing deep-sea microbiology, and the potential benefits of future investigations.

His research has even been of use to groups studying the feasibility of placing dredged and radioactive wastes in the deep ocean.

Yayanos will continue to target temperature and pressure and how, together, they influence the physiology of bacteria. Ultimately, these investigations could produce answers to questions about the physiological limits for life on Earth. That information, Yayanos believes, might one day be useful to researchers investigating the possibilities of life on other planets.

"These deep-sea pressure environments can tell us about the distribution of life on Earth, even in places we haven't sampled but where we could possibly find organisms," said Yayanos. "This approach could also show in a plausible way where other forms of life might exist in conditions that may not be found on Earth. So this kind of reasoning has importance for people looking for life on other planets."

Climate Research Division

In the Climate Research Division (CRD), scientists study phenomena spanning time scales from weeks to decades. They identify and predict the natural variability of climate and the consequences of man-made increases in the greenhouse effect. In the climate system, interactions among the atmosphere, the seas, the land, and the world of living things are tightly joined. To understand these interactions, CRD researchers use a team approach to research in areas including meteorology, oceanography, and hydrology.

CRD researchers develop coupled global ocean and atmosphere models, assess the role of cloud/radiation feedbacks in climate change, explore the connections of the atmosphere and ocean to land surface hydrology, and model and predict seasonal to decadal climate variability. They focus on how global change impacts regional and transient phenomena, emphasizing those aspects of climate that are potentially predictable.

The scientific mission of meteorologist and climate researcher, Dr. Richard C. J. Somerville, is to publicize scientific evidence supporting the strong probability that human activities can clearly influence climate. Global climate change has gone from a question of "if," Somerville said, to a question of "how much" and "how soon."

He stated that it is now the task of climate researchers to remove the uncertainties of how these changes may alter the planet.

"For centuries, and even millennia, people have been passive spectators in the big natural pageant of climate change," said Somerville. "Now, because we have been adding greenhouse gases like methane, nitrous oxide, and carbon dioxide to the atmosphere, we are moving out of the audience and up onto the stage."

Using theoretical tools and computer models, Somerville specializes in improving the global climate models scientists use to predict changes that will occur in the coming decades and centuries.

Somerville recently translated the complex issues of climate change for the public in his book, *The Forgiving Air.* He also contributes to international debates on climate change, most recently during the international global climate summit in Buenos Aires in November 1998. He also leads an annual teacher training program on the science of global change in Aspen, Colorado.

In his encounters with the public, Somerville frequently comes across people who question long-range climate prediction. If we can predict tomorrow's weather fairly accurately, they ask, what keeps us from being able to predict the climate of 2100 or 2150?

The answer is that there is no easy answer.

"Climate is complicated. It's not just a question of adding greenhouse gases and seeing how they warm the world, end of story. Things change," said Somerville.

The ocean, the atmosphere, radiation emitted from the Sun, and natural and man-made pollutants mix with one another and influence each other in the convoluted combination of forces that make up climate.

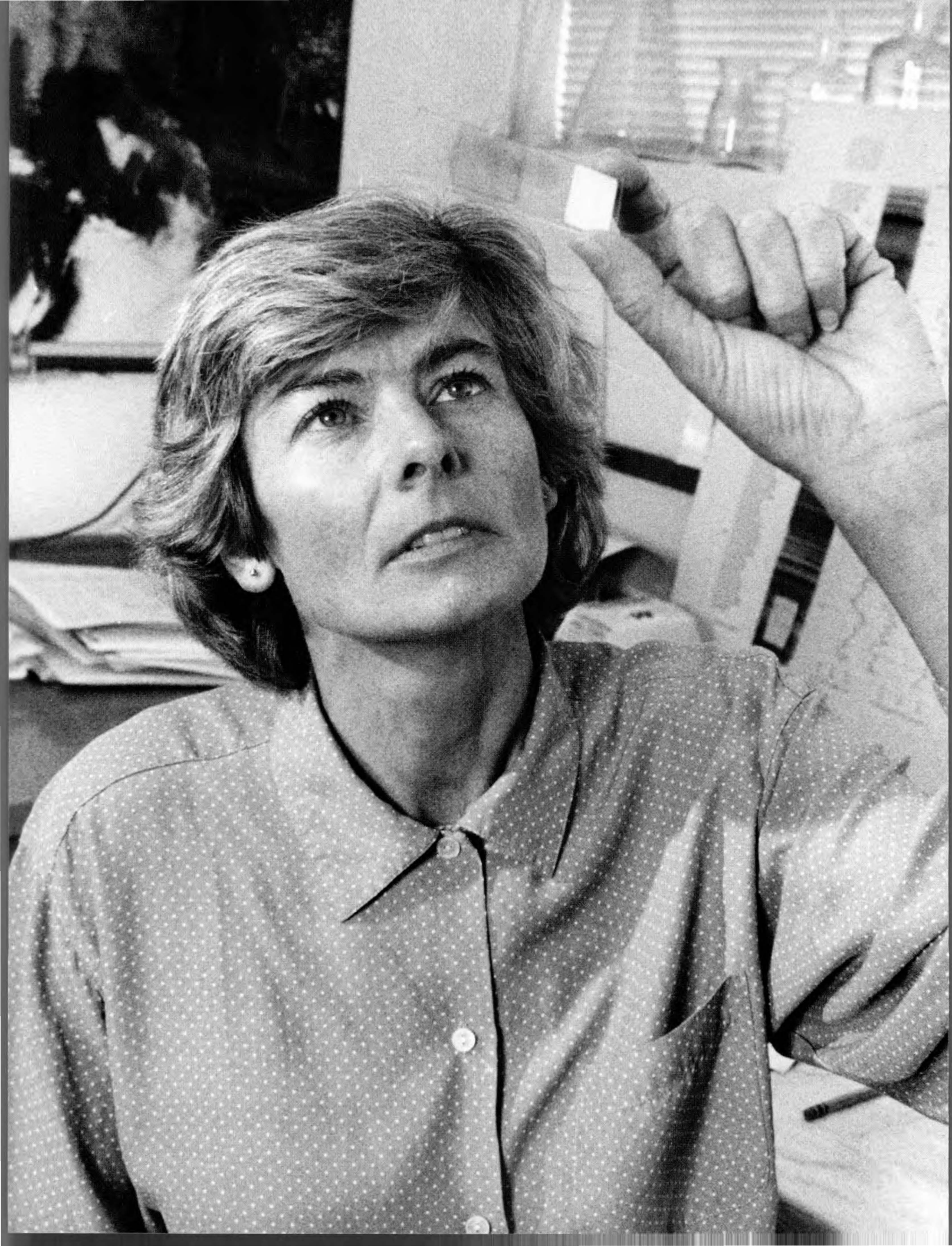
Clouds, Somerville's specialty, are responsible for cooling the planet by reflecting about 30 percent of the Sun's radiation that reaches Earth. But clouds also heat Earth because they absorb Earth's outgoing radiation and redirect a portion back down to the planet. The complex composition of clouds, plus their varying shapes and sizes, makes them difficult to study, and even more difficult to incorporate with other atmospheric effects in global climate models.

For six years, Somerville has been conducting studies of clouds and climate at the Department of Energy's Atmospheric Radiation Measurement (ARM) sites in Oklahoma and Kansas. Here, researchers measure radiation, wind, humidity, evaporation, and a host of factors in an experimental testing area. Scientists use data from ARM to refine global climate models.

Somerville's current research is focused on studying the microscopic characteristics of clouds.

"One of the things that has been suggested by our work is the fundamental importance of the microphysical mechanisms within clouds," said Somerville. "A large component of how much clouds reflect or absorb sunlight depends on the details of the tiny water droplets in them. Are they liquid or ice? Are they large or small?"

Somerville has also started using probabilistic modeling rather than deterministic modeling. Instead of looking at data and determining why there was a certain percentage of clouds in a given area, he will question the mathematical probability that a certain cloud distribution will occur.



Geosciences Research Division

Scientific activity within the Geosciences Research Division (GRD) addresses a wide range of topics in the earth, ocean, and atmospheric sciences. GRD scientists study the physical and chemical processes of the earth's mantle, crust, ocean, and atmosphere. They carry out detailed investigations in marine geology, petrology, paleomagnetism, tectonics, geophysics, isotope geology, geochemistry, and mantle and crustal evolution. GRD scientists also study fluid processes, climate history, global biogeochemical cycles, global change, microfossil evolution and systematics, ocean tracers, and atmospheric and solar system chemistry.

FACING PAGE
Geosciences researcher Carina Lange selects a mounted plankton sample for examination under the microscope.

The unicellular marine algae known as diatoms represent a fundamental food source for planktonic marine animals. For Dr. Carina B. Lange, diatoms are a vital tool in the investigation of historical climate records. These records, in turn, can be used to help scientists understand how diatoms and other silica-phytoplankton might be affected by future climate change.

Diatoms, a major component of the planktonic algae, are enclosed by two shell halves made largely of silica, which fit together like a petri dish. When diatoms die their siliceous shells settle through the water column and become a part of the seafloor sediments. Lange obtains clues about how diatom numbers and composition have fluctuated and how climate has influenced their growth and depletion.

Lange uses sediment traps, large funnel-shaped collecting cones, to capture diatom frustules (the siliceous shells of the dead organisms) on their way to the seafloor. The sediment traps also collect sedimenting particles and other oceanic material into a set of cups at the bottom of the cone. Several sediment traps are deployed simultaneously at different water depths.

In the laboratory, Lange inventories each sample under the microscope. She notes the various kinds of particles present, their colors and textures, and the types of planktonic organisms represented.

"In some coastal areas, like the Santa Barbara Basin, we can follow changes in the diatom population and extrapolate them to correlate with climate data for any given year. By analyzing the biological components, plus quartz, clay, and other materials, we can deduce whether there was a spring bloom of diatoms, what happened during summer, and how winter rains influenced diatom growth," said Lange.

Diatom records are one type of proxy used in combination with other data—such as organic carbon determination and tree-ring analysis—to investigate large, abrupt climate changes such as El Niño events.

"Any one of these proxies by itself may point to an event such as an El Niño that might have affected the California coast in the past, but when you put all the data together the historical record becomes clearer," said Lange.

"Over the years I've become an expert in diatom taxonomy, and I get samples sent to me from all over the world. One of the main things I teach my students is that they have to be very careful about identification, because each diatom species can be said to carry a particular ecological and biogeographical signal. If I misidentify a sample, I could mislead people by saying something about the ecology that isn't right."

In one project, Lange is reconstructing the history of El Niño and flood events by using samples collected from the Santa Barbara Basin. In another project she is comparing open-ocean upwelling systems in the equatorial Atlantic Ocean with coastal upwelling systems off Africa. In a third project she is investigating wind-transported diatom skeletons that originate in Sahara Desert oases and are carried across the Atlantic Ocean to Central and South America.

Institute of Geophysics and Planetary Physics

The Cecil H. and Ida M. Green Institute of Geophysics and Planetary Physics (IGPP) is located at and strongly linked to Scripps. This branch is part of the University of California IGPP and houses the systemwide office.

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, and Anza, California; and a permanent space geodesy network in California. IGPP scientists maintain an 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.

In 1979, T. Guy Masters was one of the first scientists to study the structure of the earth using data from Project IDA, a new network of worldwide seismology stations. The IDA network gives Scripps researchers access to hundreds of digital seismic recordings, allowing new types of seismic research to be done.

Today, Masters continues to use data from the network, which he calls "an inverted telescope." Instead of looking outward into space, global seismologists like Masters use the network to look inside the earth. He likens the seismographic recording data to medical tomography, in which instruments around a patient's head send and receive X rays to pinpoint the location of a lesion.

"Seismic tomography is similar in that we have earthquake waves, instead of X rays. The variations in the time it takes for these waves to travel through the earth can be used to pinpoint anomalous material," said Masters.

In 20 years of using global seismographic information, advances in recording and computing technology have given Masters and his colleagues the power to make finely detailed maps of the earth's inner structure.

"We're now at the point where we know the gross features of the earth quite well," said Masters. "The explosion of data from the [IDA] network and improved computing ability have made it so nobody disputes some of the key features of the earth's inner core and mantle. Ten years ago half the seismologists were disputing these results."

While seismologists have provided key pictures of the earth, geophysicists in related disciplines have also made fundamental advances. Masters is leading efforts to link scientists in areas such as mineral physics and geodynamics, in order to develop a viable, integrated model of the earth's geological processes. Masters stresses that collaboration among researchers may hasten results such as being able to accurately model movements of crustal plates, answer questions about subduction zones (where plates meet and descend into the earth), and understand issues of thermal energy movement, called convection.

Masters is grappling with the difficult task of developing procedures that allow researchers in a discipline with its own scientific language to understand and interface with those in another discipline with different methods.

For more than 30 years seismologists have argued that a fundamental principle of the earth is that there is a significant transfer of mass continually occurring between the upper and lower mantle layers. Geochemists, on the other hand, generally believe the opposite is true. They argue that the geochemical evidence shows that there must be little exchange between the mantles.

"We've got a lot more work to do in developing a model of how the earth functions, but we've got to begin somewhere, and integrating the geophysical models into one is a start. We can gain a more thorough understanding by integrating these disciplines," said Masters. "This business of having differences with geochemists is just one example of what can happen when disciplines don't talk to each other."

Marine Biology Research Division

Scientists in the Marine Biology Research Division (MBRD) investigate the taxonomic, geographical, ecological, physiological, cellular, biochemical, and genetic characteristics of marine bacteria, protozoa, 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.

Some of the ongoing studies involve the anatomy and mechanics of marine invertebrates, microbial metabolism of metals, mechanisms of invertebrate egg and sperm interaction, developmental evolution of chordates, and the symbiotic relationships between diverse bacteria species and their invertebrate and fish hosts.

Dr. Robert E. Shadwick, professor of marine biology, is taking an engineering approach to several problems in his study of the physiology and mechanics of fish locomotion.

"We're trying to figure out how fishes use their muscles to swim, which is not a trivial issue," said Shadwick. "In fact, the entire muscle system of fish is poorly understood because their muscle blocks are extremely complex structures that are nested together along their bodies."

Scientists can directly measure the force of a terrestrial animal's impact on the ground and relate this to muscle power production. Fishes, however, are much more difficult to study because swimming lacks this type of recordable impact.

To monitor locomotion, Shadwick's team uses a variety of tools and devices. In one study they place electrodes in fish muscle to measure the timing of muscles being activated sequentially along the fishes' bodies as they swim. This information is synchronized to video images to determine how changes in the shape of the undulating bodies relate to the muscle activity recorded.

Shadwick's group uses a new instrument to measure the lengthening and shortening of muscle blocks along the bodies of swimming fishes. By sending ultrasound pulses between pairs of electrodes placed in the muscle, researchers can determine when the muscle is contracting, and predict when, in each tailbeat cycle, the muscle is producing force.

Shadwick and Dr. Stephen Katz have recorded preliminary findings in a multiyear study of tuna locomotion. The body shape of tuna facilitates their high-speed swimming. The main muscles used in swimming are located in the middle section of a tuna's body, which tapers to a narrow peduncle anterior to a large crescent-shaped tail fin that functions as a natural hydrofoil. The puzzle of the tuna is that the muscle is located in the center of the body, yet the tail produces the motion and thrust for swimming.

In other fishes, like trout and mackerel, muscles used in swimming are distributed more uniformly along the body. When the muscles shorten, they cause local bending and this generates undulations along the entire body.

Shadwick and Katz have been able to confirm by direct measurement that tuna power their swimming by projecting muscle force from the midbody back to the tail fin through connective tissue, something that has long been predicted. "When the muscles in front shorten, they are not causing local shape changes; they are actually causing motion at more posterior sites," said Shadwick. "The focus of power and thrust is at the tail, but the power plant is up front."

Shadwick and his colleagues would like to use their analyzed data as stepping stones to an integrated model of aquatic locomotion that couples internal and external forces. They hope their research will aid in the design of an unmanned, untethered, maneuverable underwater vehicle, which uses a fish-like mode of propulsion.

Marine Life Research Group

Scientists in the Marine Life Research Group (MLRG) cooperate with 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 (nearly 50 years) from an oceanic ecosystem. Scientists examine variability in the physics, chemistry, ecology, and fisheries of this eastern boundary current system from the annual scale, to the interannual scale (such as El Niño events), to multidecadal trends. High-resolution analyses of sediment cores extend some data back in time for centuries, enabling long timescale studies.

For investigators outside of the program, CalCOFI cruises provide a platform for biological oceanographic studies and also a base of environmental data from which to interpret their specialized measurements.

Because the scientific community received early warnings of the 1997-1998 El Niño's arrival, many researchers, including Dr. Thomas L. Hayward, were prepared to sample the changes it precipitated. Under his management, CalCOFI increased its regular ocean monitoring program from quarterly to monthly cruises.

Hayward focuses on understanding the distribution of phytoplankton biomass in the ocean. For the past fifteen years, his research has focused on the California Current, where he studies the relationships between the physical structure of the ocean—including circulation patterns, temperature, and salinity—and the distribution of chlorophyll.

Hayward describes spatial patterns of chlorophyll (an index of phytoplankton abundance) and how they change over time. He strives to understand the causes of these changes. Also, he is attempting to separate natural variability in the ocean from human-influenced changes and pinpoint whether these are the products of local sources or large-scale effects, such as global warming.

"The reason we're asking questions about change in the ocean is for wise policy management," said Hayward. "It is absolutely critical to have that information for effective management—if we can't identify the cause of changes, we can't effectively manage. Before embarking on an expensive remediation project, for example, it's important to understand what's really causing that change."

Although half of his time is spent in an administrative position managing the research activities of CalCOFI, Hayward often works in the field, observing and describing changes.

Because the phytoplankton distribution is highly variable and difficult to sample, one of Hayward's aims is to develop different approaches for observing these patterns. His group recently designed a new tool for doing this within the CalCOFI program. The Continuous Underway Data Logging System (CUDLS) has proven valuable for describing small-scale patterns of chlorophyll and the surrounding environment.

During CalCOFI monitoring cruises, water is pumped into an onboard laboratory. The water passes over CUDLS's sensors, which measure temperature, salinity, and chlorophyll fluorescence. The CUDLS computer records the information, along with the ship's position, to produce maps of surface chlorophyll abundance. Hayward recently coauthored an article describing the strong connection between the pattern of ocean circulation and the chlorophyll distribution and how this relationship changes over time.

Hayward and his colleagues in CalCOFI are especially interested in changes resulting from the recent El Niño.

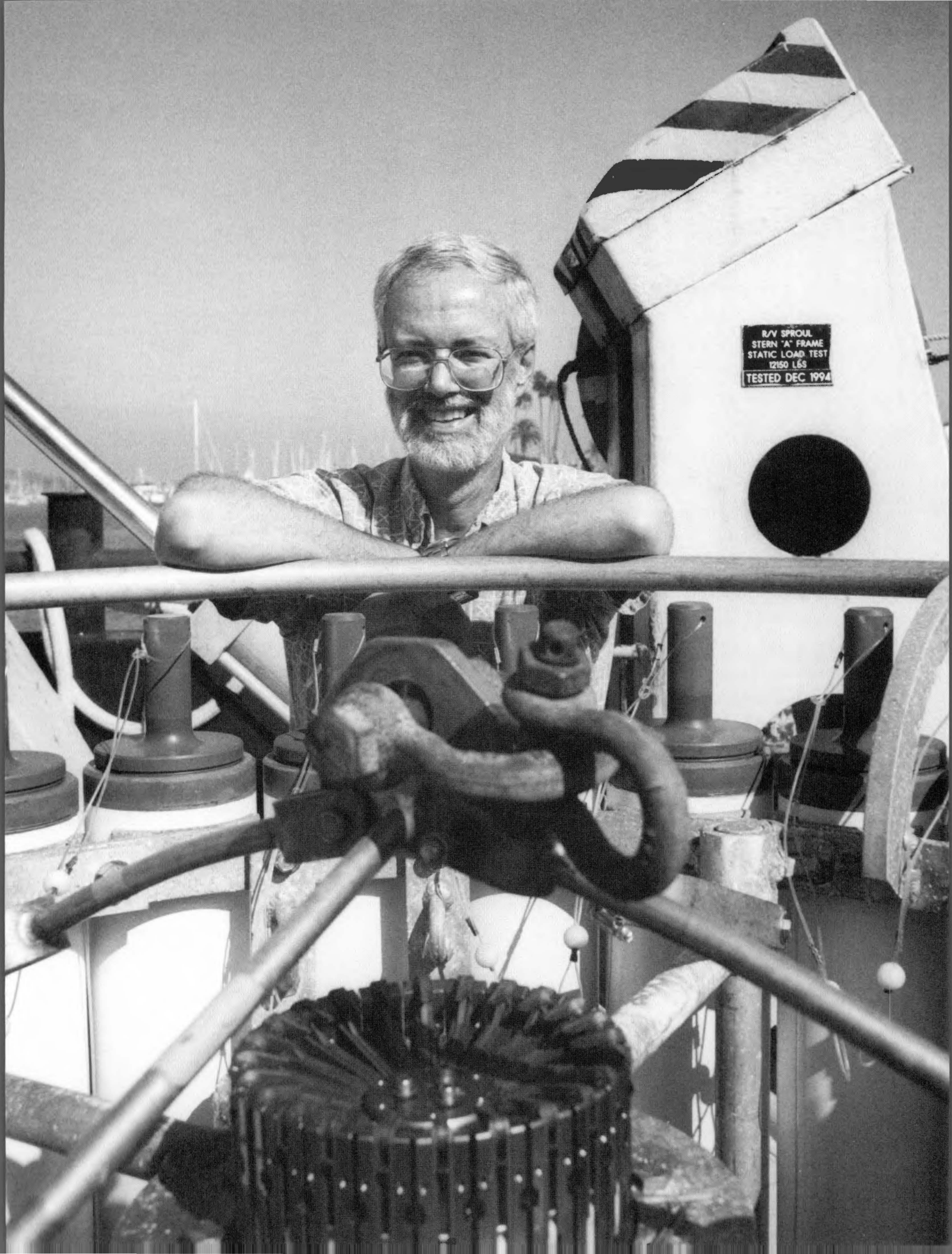
"With the early warnings we were able to see how rapidly the oceanographic structure can change," said Hayward. "We've also been surprised by the way the biological structure of the ocean is coupled with its physical structure."

The lowest macrozooplankton biomass ever measured during nearly a half century of CalCOFI monitoring was observed during the event. The warm, nutrient-poor surface layer of the California Current extended deeper than normal, and the California Current's low-salinity core moved offshore.

"One of the things that makes this region so exciting to study as we approach the 50th year of CalCOFI is the fact that we have a much larger historical context in which to consider new observations," said Hayward. "Eventually the goal is to improve our ability to predict biological changes that are going to happen off our coast."

FACING PAGE

Biological oceanographer Thomas Hayward prepares a CTD rosette for deployment from Scripps's R/V *Robert Gordon Sproul*.


R/V SPROUL
STERN "A" FRAME
STATIC LOAD TEST
12150 LBS
TESTED DEC 1994

Marine Physical Laboratory

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

Researchers in ocean acoustics quantify environmental limitations on acoustic systems and study how these affect design and operation of oceanographic systems. Scientists investigating marine physics focus on the ocean environment and its effect on undersea systems. Marine geophysicists study the earth beneath the sea and clarify the environmental parameters affecting search, detection, and navigation systems. Research in signal processing includes the collection, manipulation, and output of both analog and digital data. MPL scientists develop advanced ocean technology both for environmental measurement programs and for testing of new engineering concepts.

Dr. Spahr C. Webb, an experimental marine geophysicist, and his colleagues in MPL use sensitive ocean bottom seismometers (OBSs) to collect and measure earthquake data. Improvements in instrumentation and technology allow them to investigate the earth's structure with unprecedented precision.

OBS recordings reveal the mechanisms of large earthquakes along fault systems at the boundaries of oceanic plates and of smaller earthquakes caused by volcanic eruptions at seafloor spreading centers. Even the smallest events caused by contraction and movement under hydrothermal vent fields at ocean ridge crests can be studied using OBS technology.

Webb has spent the past 15 years turning OBSs into powerful, reliable instruments that are also affordable.

"I've been working with two excellent engineers at Scripps for many years," said Webb. "Tom Deaton has helped me develop these sensors into instruments that collect data over very long periods of time with very low noise levels and power requirements. Jacques Lemire has developed the construction technology needed to make them affordable. The more affordable OBSs become, the more of them you can have in the field. Resolution is dependent on the number of deployed instruments."

In the 1980s, OBSs could record only a few weeks of seismic data at one time. Now Webb's instruments can record more than a year's worth of data.

Leaving the instruments out longer and recording a large number of earthquake events results in much higher resolution data. The researchers are then able to locate the anomalies of the earth's structure more accurately.

The seismometers consist of 5,000 components and are built in two parts: a sensor that measures ground motion and a recording package that collects and stores data using a precise clock.

The invention of low-cost, high-capacity storage disk drives has had a significant impact on Webb's research. Each OBS carries two nine-gigabyte drives, a significant gain from the four-gigabyte drives Webb used four years ago and the one-half gigabyte optical disk drives used a few years before that. In 1984, the instruments used a 0.04-gigabyte tape drive.

In a current experiment, Webb and Scripps colleagues Robert Sohn and Wayne Crawford deployed 24 OBSs at the Juan de Fuca Ridge over the huge Axial Volcano. When the study concludes, Webb's team will have collected nearly 400 gigabytes of data on disk. Using complex computer algorithms, they will scan the disks for earthquake events.

Webb's group will scrutinize the larger earthquakes to determine how the volcano interacts with the ridge, to map the hydrothermal vents and heat sources, and to analyze the tectonic mechanisms and strains on the fault system.

"The ability to record continuously has been a real boon," said Webb. "We don't miss events, and there just aren't any questions about what we are looking at."

Marine Research Division

The Marine Research Division (MRD) encompasses the disciplines of marine chemistry and biological oceanography.

MRD scientists study variations of atmospheric oxygen with time and their relationship to the global carbon cycle and climate change, marine pollution and environmental issues, interstitial water chemistry of deep-sea cores, the geochemistry of nearshore sediments, and extraterrestrial geochemistry and chemistry related to the origin of life.

The bio-optics group uses optical methods to study the distributions of biological pigments and photosynthesis by phytoplankton in Antarctic, Arctic, and California coastal waters. Other MRD biologists focus on biological rhythms, sensory biology, and algae in snow. They also maintain long-term plankton records.

The marine natural products groups study the chemical ecology of marine organisms and the chemistry of marine microbes and invertebrates, from which potentially useful pharmaceuticals have been discovered. They also investigate the chemistry involved in symbioses between invertebrates and microbes.

As it becomes more difficult to locate new drugs from terrestrial sources, some scientists are turning their attention to the oceans. By taking advantage of collaborations with specialists in pharmacology and cellular biology, Dr. John Faulkner, professor of marine chemistry, has discovered and identified a number of chemicals from marine invertebrates that might eventually be used to combat cancer, AIDS, and other diseases.

Many of the chemicals studied by Faulkner's research group were obtained from marine sponges, which are rich in bioactive compounds. "Sponges appear to have survived for 500 million years, and during that period they have evolved strong chemical defenses that have contributed to their survival," said Faulkner.

In a recent collaboration with researchers at UC San Diego's Department of Pharmacology, two of Faulkner's colleagues, Dr. Cordula Hopman and graduate student Chris Blackburn, have discovered the first inhibitor of kinesin motor proteins ever found. These motor proteins are responsible for the transport of chromosomes, organelles, and vesicles along the microtubule network within the cell. Adociasulfate-2, produced by a marine sponge of the genus *Haliclona,* inhibits kinesin by binding at the site normally occupied by the microtubule. This stops normal cellular function and cell division, resulting in cell death. The research has potential applications in cancer chemotherapy.

"A number of clinically useful antitumor agents act by inhibiting the assembly or disassembly of microtubules. The problem is that both tumor and normal cells have the same kind of microtubules. In contrast, there are many different motor proteins. By inhibiting specific classes of motor proteins, we hope to find a more selective anticancer agent."

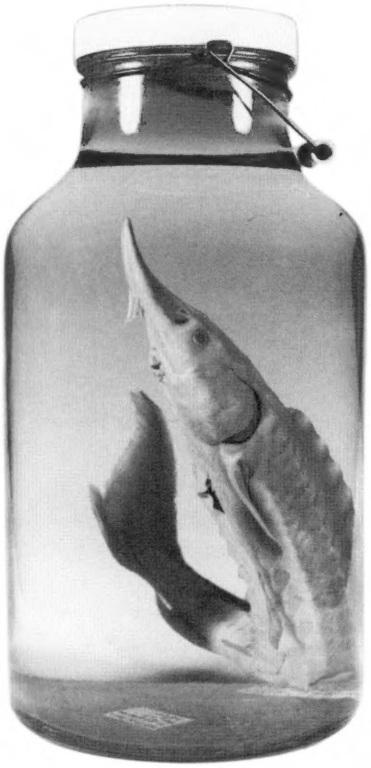
Faulkner is also collaborating with scientists at the Salk Institute in La Jolla to search for inhibitors of the enzyme HIV-1 integrase, which, along with the reverse transcriptase and protease enzymes, is required for the replication of the HIV virus in a host cell. Integrase is the enzyme responsible for inserting cDNA, which is produced by reverse transcriptase, into the chromosomal DNA of the infected host cell. This results in the infected cell producing new viral material. Inhibition of HIV-1 integrase would block viral replication.

Drugs that inhibit protease and reverse transcriptase are generally used in a "cocktail" to treat AIDS patients. The addition of an integrase inhibitor to this cocktail could make existing drug therapy more effective. There are currently no commercially available inhibitors of integrase. Dr. Venkata Macherla in Faulkner's group, using an extract provided by a colleague, recently identified a chemical compound that inhibits integrase and also inhibits HIV replication in vivo. "Although this compound is not spectacularly active, it is relatively selective and helps to demonstrate that integrase inhibitors can indeed be used to inhibit live viruses," said Faulkner.

The purpose of Faulkner's research program is twofold. "In addition to discovering new drugs, we want to learn something about cellular biology," Faulkner said. "By using marine natural products to inhibit specific enzymes and receptors within the cell or block specific stages in the cell cycle, we hope to map out biochemical events that occur within the cell."

Neurobiology Unit

An animal's role in its survival, distribution, and ecology depends on its ability to sense the environment; to integrate, calculate, interpret, and recognize stimuli; and to control adaptive behavior. The Neurobiology Unit (NU) includes several laboratories at Scripps dedicated to the nervous systems, sense organs, and behavioral mechanisms of animals. NU scientists also participate in the Center for Marine Biotechnology and Biomedicine, and some are associated with the UC San Diego School of Medicine.



Specimen of the sturgeon, *Acipenser stellatus*

The sensitive hair cells inside the inner ear are a key component of the human hearing system. Damage to these delicate hairs can result in significant and permanent hearing loss.

A research project begun at Scripps may one day give the scientific community clues for a greater understanding of how human hair cells develop and function.

Dr. Melissa A. Gibbs began groundbreaking research on the development of sensory systems in fishes while working as a postdoctoral researcher with Scripps professor of neurosciences Dr. R. Glenn Northcutt. Gibbs and Northcutt continue collaboration on the project to investigate the mechanosensory receptors in fishes, which function similarly to hair cells in human ears.

Gibbs began by looking at the embryonic development of the lateral-line system in fishes, a fundamental sensory unit made up of mechanical and electrical sensory components. Unlike human hair cells, which are hidden inside the inner ear, the lateral line of fishes is near the surface of the body. With the lateral-line receptors, fishes can sense which way water is flowing, whether there is a predator or prey nearby, and movements of other fish in a school.

Gibbs's project centers on sturgeon, bottom-dwelling fish, including some that are primarily known for producing eggs that are processed into caviar.

"We know where the lateral line develops in amphibians and in teleosts, but we don't know where it develops in the sturgeon, which falls in between on the evolutionary continuum," said Gibbs. "So we have this gap. We think of the sturgeon as a missing piece of the puzzle."

The project, in which they hope to pinpoint which embryonic tissues give rise to the lateral-line system, is composed of three parts.

Because so little is known about sturgeon, during the first phase of the project Gibbs studied their basic developmental anatomy. She documented how six placodes, the embryonic precursors of sensory systems, appear on the skin and begin to elongate, eventually evolving into the mechanoreceptors and electroreceptors of the lateral-line system.

In the second phase, Gibbs is investigating two major embryonic tissue types to discover from which the lateral-line receptors originate: the dorsal lateral placodes or the neural crest (a multipurpose cell type). In her study of this developmental process, she injects a fluorescent dye into the area where the receptor cells originate. Using a microscope with which she can visualize fluorescence, she is able to track the glowing migration of cells that ultimately become the receptor cells.

During the third part of the project, Gibbs will focus on the role of the neural crest tissue in inducing the development of the receptors. Does the neural crest directly contribute to the growth of the lateral-line receptors? Or does it support the cells remotely without directly contributing to their growth?

Gibbs hopes the answers to these questions may help researchers draw similar conclusions about how hair cells develop in the human ear.

"Mechanoreceptors in sturgeon are like hair cells in the inner ear," said Gibbs. "But it's difficult to study inner-ear cells because they are so deep inside the ear. Hopefully this work in sturgeon is helping us to understand how both of these areas develop."

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 PORD investigators hold joint appointments in other areas at Scripps, which provide for cross-disciplinary research and 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 technologies for ocean studies—such as autonomous drifters and bottom-pressure and electromagnetic sensors—and new versions of acoustic Doppler current profilers.

Dr. Ray G. Peterson first began investigating the currents and water properties of the Southern Ocean as a graduate student. Today the Scripps oceanographer is still devoted to studying this area and its relation to global climate.

Peterson and Scripps colleague Dr. Warren B. White study anomalies (variations) between currently recorded values and long-term averages for various climate data in the Southern Ocean. Three years ago they made the landmark discovery of an Antarctic Circumpolar Wave (ACW), a two-wavelength set of surface temperature anomalies that travels around the southern hemisphere in unison with anomalies that occur in the atmosphere and ice fields.

"The Southern Ocean," said Peterson, "is an ideal natural laboratory for studying interactions between the ocean and atmosphere because the direct feedbacks between the two can be maintained around the world without continental interruption."

According to Peterson, basic aspects of the ACW remain to be determined, including its depth. To address this question, Peterson and colleagues at Scripps measure the temperature structure of the upper kilometer of the ocean several times a year across the Drake Passage, a strait that connects the South Atlantic and South Pacific Oceans. In other studies, Peterson and colleagues use bottom-pressure gauges placed on either side of the Drake Passage to monitor changes in the circumpolar current and its relation to the atmosphere.

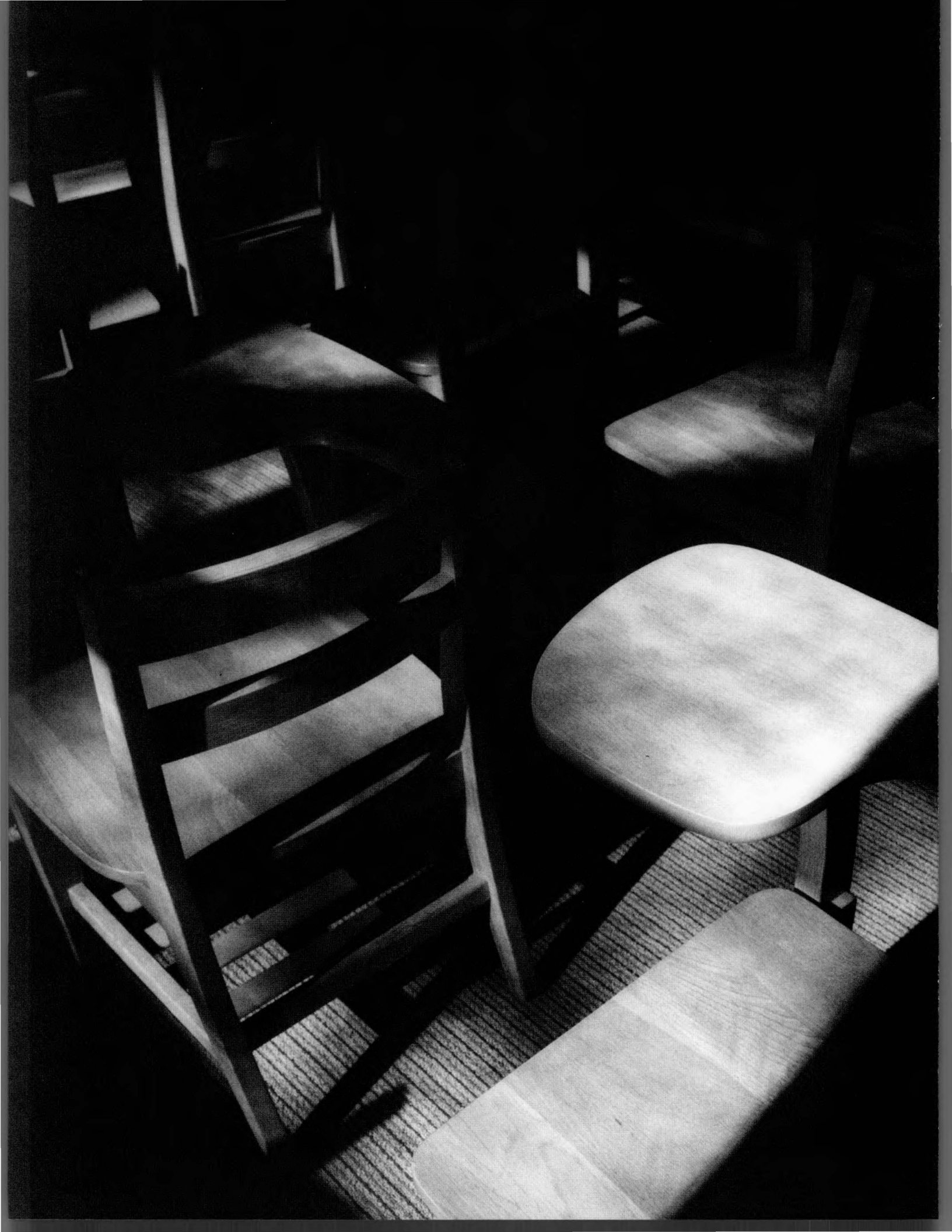
In their most recent research, Peterson and White have discovered a direct physical link between the ACW and El Niño phenomena in the western Pacific. Using oceanic temperature data and several types of atmospheric data, they found that sea-surface temperature anomalies form within a large region north of New Zealand in response to the atmospheric circulation changes that accompany warm and cool phases of the El Niño/La Niña cycle on the equator.

Once they are established, the oceanic anomalies move southward into the Southern Ocean, then eastward around the world with the ACW. Offshoots of the ACW propagate north into the South Atlantic and Indian Oceans. This appears to affect local climate, such as rainfall variations over Argentina and Uruguay.

The portions of the ACW that spread into the Indian Ocean continue to the tropics and move eastward to arrive at the Pacific Ocean ahead of an El Niño/La Niña phase, approximately six to eight years after first appearing in the South Pacific.

"What we're seeing is that the El Niño/La Niña cycle in the equatorial Pacific excites changes in the subtropical ocean that go around the world via the ACW to possibly help generate the next El Niño or La Niña," said Peterson. "We know that a vigorous coupling between the ocean and atmosphere, made possible by the circumpolar continuity of the Southern Ocean, is critical."

New questions have emerged about how the ACW, with its associated advances and retreats in sea ice extent around Antarctica, may be connected with interannual changes observed in Southern Ocean ecological systems. Peterson is now collaborating with biologists to study changes in marine life, such as krill, salps, and copepods, that correlate with passing phases of the ACW.



GRADUATE DEPARTMENT

An overview of the Scripps graduate program can be found on the Web at

http://www-siograddept.ucsd.edu/

The Graduate Department of 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 on the following pages.

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 Science This interdepartmental program is concerned with human exploration of the sea. The program combines the interests of faculty members of the Scripps Graduate Department and UC San Diego Departments of Applied Mechanics and Engineering Sciences and Electrical and Computer Engineering to produce oceanographers knowledgeable about modern engineering and instrumentation and marine-oriented engineering scientists familiar with the oceans. Instruction and research include the structural, mechanical, material, electrical, and physiological problems of operating within the ocean, and the applied environmental science of the sea.

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 web dynamics and community structure to systematics, behavior, biogeography, and physical-biological interactions.

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

Geological Sciences This curriculum applies observational, experimental, and theoretical methods to the understanding of the solid earth and the solar system and how they relate to the ocean and the 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 This curriculum educates the student about 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 course work, seminars, and research on all aspects of the biology of marine organisms. Teaching and research focusing on both prokaryotes and eukaryotes encompass the disciplines of cell and molecular biology, biochemistry, developmental biology, physiology, biomechanics, genetics, ecology, and evolutionary biology.

Marine Chemistry and Geochemistry Marine chemistry and geochemistry emphasizes the chemical and geochemical processes operating in the oceans, the atmosphere, or in other environments, and includes the subdiscipline of marine natural product chemistry. Education and research in this curriculum combine field observations with laboratory and/or modeling projects. Studies of natural systems are often multidisciplinary and integrate chemical concepts and techniques with information about physical, geological, or biological processes, including the effects of human activity. Students in this curricular group are encouraged to explore interdisciplinary collaborations to accomplish their research goals.

Physical Oceanography Physical oceanography is concerned with how water moves and mixes in the ocean, and how water carries and distributes dissolved chemicals, nutrients, plankton, sediments, and pollutants. Physical oceanography is a branch of applied physics focusing on understanding, modeling, and predicting ocean processes using mathematics and fluid mechanics. The discipline is increasingly intertwined with atmospheric and climate studies; understanding the energy and momentum transfer through the seas and across their boundaries is a major goal of all these fields. Physical oceanography includes the study of estuaries and lakes and also encompasses the study of large bodies of water on other planets and moons (for example, Europa).

Student Enrollment In the fall of 1997, 33 new students were admitted to graduate study. Of these, 4 were in applied ocean sciences, 7 in biological oceanography, 2 in climate sciences, 3 in geological sciences, 4 in geophysics, 6 in marine biology, 6 in marine chemistry and geochemistry, and 1 in physical oceanography. Enrollment at the beginning of the academic year was 171. UC San Diego awarded 27 doctor of philosophy degrees and 3 master of science degrees to the students listed in this section.

Degree Recipients

Doctor of Philosophy Degrees Awarded, with Titles of Dissertations

EARTH SCIENCES

Paul S. Earle
"Imaging the Earth's Seismic Response and Small-Scale Structure of the Deep Mantle and Core from PKP and PKKP Scattered Energy."

Tina G. Fitts
"The Dynamics and Implications of Stress-Induced Smectite Dehydration."

Jeffrey A. Hanson
"Seismic and Hydroacoustic Investigations near Ascension Island."

Stuart G. Johnson
"Applications of Global Seismic Tomography and Analysis of Variational Methods for the Solution of the Linearly Attenuating Frequency Domain Wave Equation."

Stephen J. Mojzsis
"Ancient Sediments of Earth and Mars."

Alyssa M. Peleo-Alampay
"Miocene and Oligocene Calcareous Nannofossils: Biochronology and Paleoceanography."

Michael A. Ravine
"Investigations into Aspects of Mantle Viscosity and Dynamics."

Jeffrey R. Ridgway
"The Development of a Deep-Towed Gravity Meter, and its Use in Marine Geophysical Surveys of Offshore Southern California and an Airborne Laser Altimeter Survey of Long Valley, California."

Hermanus J. A. van Avendonk
"An Investigation of the Crustal Structure of the Clipperton Transform Area Using 3D Seismic Tomography."

Xueyun Sharon Wang
"Stability of Genetic Informational Molecules under Geological Conditions."

Mara M. Yale
"Modeling Upper Mantle Rheology with Numerical Experiments and Mapping Gravity with Satellite Altimetry."

MARINE BIOLOGY

Lakshmi N. Chilukuri
"The Effect of Pressure on DNA-Binding Proteins from Piezosensitive and Piezophilic Bacteria."

Paul D. Jöbsis
"Muscle Oxygenation and Blood Flow during Submersion in Ducks *(Anas platyrhynchos)* and Seals *(Phoca vitulina)*."

Andrea Torrence Knower
"Biomechanics of Thunniform Swimming: Electromyography, Kinematics, and Caudal Tendon Function in the Yellowfin Tuna *Thunnus albacares* and the Skipjack Tuna *Katsuwonus pelamis*."

Patrick J. Krug
"Chemical and Larval Ecology of Opisthobranch Molluscs: Variable Development Modes and Settlement Cues for Larvae of *Alderia modesta*."

Richard G. LeDuc
"A Systematic Study of the Delphinidae (Mammalia: Cetacea) Using Cytochrome *B* Sequences."

Jennifer C. Nauen
"The Biomechanics of Two Aquatic Defense Systems: 1. The Scaling of Tail-Flip Kinematics and Force Production by the California Spiny Lobster *Panulirus interruptus* 2. Shear Sensitivity and Interspecific Variation in Flow-Stimulated Dinoflagellate Bioluminescence."

Greg K. Szulgit
"Mechanical Investigations of the Mutable Collagenous Tissues of the Echinoderms, *Eucidaris tribuloides, Cucumaria frondosa,* and *Parastichopus parvimensis*."

OCEANOGRAPHY

David B. Chadwick
"Tidal Exchange at the Bay-Ocean Boundary."

Chad L. Epifanio
"Acoustic Daylight: Passive Acoustic Imaging Using Ambient Noise."

Karin A. Forney
"Patterns of Variability and Environmental Models of Relative Abundance for California Cetaceans."

Kelly M. Jenkins
"Chemical Investigations of Marine Filamentous and Zoosporic Fungi and Studies in Marine Microbial Chemical Ecology."

Timothy J. Lueker
"The Ratio of the First and Second Dissociation Constants of Carbonic Acid Determined from the Concentration of Carbon Dioxide in Gas and Seawater at Equilibrium."

Sue E. Moore
"Cetacean Habitats in the Alaskan Arctic."

Axayácatl Rocha-Olivares
"Molecular Evolution, Systematics, Zoogeography and Levels of Intraspecific Genetic Differentiation in the Species of the Antitropical Subgenus *Sebastomus, Sebastes* (Scorpaeniformes, Teleostei) Using Mitochondrial DNA Sequence Data."

Eric J. Terrill
"Acoustic Measurements of Air Entrainment by Breaking Waves."

George M. Watters
"Models of Parasitism and Hyperparasitism on *Paralomis spinosissima*."

Master of Science Degrees Awarded

EARTH SCIENCES

Rosanne M. Nikolaidis

MARINE BIOLOGY

Mark A. Pospesel

OCEANOGRAPHY

Kimberly A. Brown


NEW HORIZON
CF 1506 XS
ROBERT GORDON SPROUL

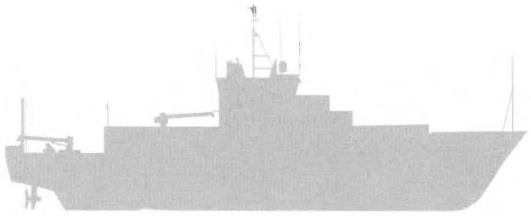
SEAGOING OPERATIONS

More information about ship operations can be found on the Web at

http://sio.ucsd.edu/supp_groups/shipsked/index.html

The Scripps oceanographic fleet is at the hub of the institution's research efforts. Four research vessels and one platform provide this important support. Our ships traveled an estimated 118,514 nautical miles in fiscal year 1998 and operated a total of 1,069 days.

FACING PAGE
Scripps research vessels moored at the Nimitz Marine Facility



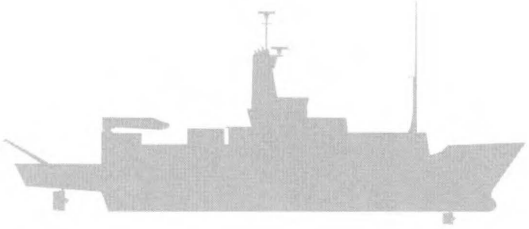
R/V *Roger Revelle*

R/V *Roger Revelle* supported 14 research cruises with 13 chief scientists. Research activities included SEA BEAM mapping, blue whale studies, sea trials, and sample and data collection on behalf of the U.S. Joint Global Ocean Flux Survey. Research was conducted off Hawaii, in Monterey Bay, and in the South Pacific. Other institutions that conducted research aboard R/V *Roger Revelle* during fiscal 1998 included University of Maryland, UC Santa Barbara, UC Santa Cruz, Texas A&M University, Massachusetts Institute of Technology, Woods Hole Oceanographic Institution, University of Hawaii, Oregon State University, and Duke University. Thomas Desjardins was captain. Albert Arsenault was relief captain.

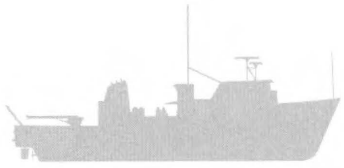
Type	Oceanographic research
Yr. Built	1996
Yr. Acquired by Scripps	1996
Owner	U.S. Navy
Length	275′
Beam	52′6″
Draft, full	17′
Displacement, full (tons)	3,350
Cruising Speed (knots)	12.5
Range (nautical miles)	13,000 @ 10 knots
Crew	22
Scientific Party	37
Total Distance Traveled	45,111 nautical miles
Operating Days	333

R/V *Melville*

Twelve chief scientists led 12 cruises aboard R/V *Melville* during the fiscal year 1998. Research sites included areas in the South Pacific, Gulf of Alaska, and off the coasts of northern California, southern California, and South America. Research activities included SEA BEAM data collection, marine geology studies, gravity surveys, dredging activities, biology studies, and Deep Tow operations. R/V *Melville* was used for research by several other institutions during the year, including State University of New York, Lamont-Doherty Earth Observatory, Woods Hole Oceanographic Institution, University of Hawaii, and Duke University. Eric Buck was captain. Christopher Curl was relief captain.



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 @ 10 knots
Crew	23
Scientific Party	38
Total Distance Traveled	42,568 nautical miles (estimated)
Operating Days	333



R/V *New Horizon*

Fifteen chief scientists led 20 cruises aboard R/V *New Horizon* during the 1998 fiscal year. An extensive array of research and testing was conducted, including benthic biology studies, dredging and coring, Deep Tow surveys, physical and geological oceanography studies, CalCOFI data collection, and vent-animal studies. A student cruise also was conducted. Research destinations included Tanner Banks off the coast of San Diego, the Southern California Bight, and the waters off Mexico, southern California, and central California. Other institutions conducting research aboard the ship included the Monterey Bay Aquarium and its affiliated research institute, UC Santa Barbara, Harvard University, and University of Hawaii. John Manion was captain. Relief captains were Christopher Curl, David Murline, and Curtis Johnson.

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	15,648 nautical miles
Operating Days	222

R/V *Robert Gordon Sproul*

During the 1998 fiscal year, 21 chief scientists embarked on 50 cruises aboard R/V *Robert Gordon Sproul,* which was used much of the year to support research off the San Diego coast. The ship also traveled to the Santa Barbara Channel, the Columbia River, and the waters off Point Conception, British Columbia, and the Pacific Northwest. Research efforts included acoustical and optical studies, equipment tests, benthic biology studies, animal collection, instrument recovery and deployments, internal bore studies, El Niño studies, glider tests, student training, and estuary studies. Other universities and organizations conducting research aboard R/V *Robert Gordon Sproul* included University of Washington, Woods Hole Oceanographic Institution, University of Southern California, and UC Santa Barbara. Louis Zimm was captain. Relief captains were David Murline, James Potts, and Murray Stein.

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	15,187 nautical miles
Operating Days	181

R/P FLIP

R/P FLIP was towed to sea five times in fiscal 1998 to support four research projects. The projects included a high-frequency fluctuation experiment, whale vocalization studies, a research equipment test, and acoustic research studies in the Santa Barbara Channel. Tom Golfinos was the officer in charge 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	745 miles
Operating Days	46

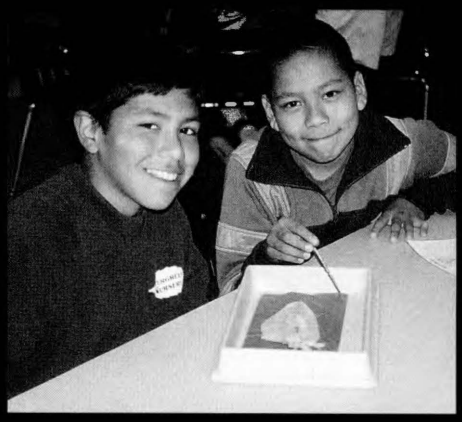
* Dictated by the towing vessel.

BIRCH AQUARIUM AT SCRIPPS

For further information about the Birch Aquarium, call 619/534-FISH or visit our Web site at

http://www-aquarium.ucsd.edu

The Birch Aquarium at Scripps celebrated the first five years in its new facility in 1998. During this time, aquarium personnel focused on establishing a foundation of quality exhibits and education programs that advanced the aquarium's threefold mission: to provide ocean science education, to interpret Scripps research, and to promote ocean conservation. During its fifth year, the Birch Aquarium received acclaim for professional success, faced challenges as the facility and its operations matured, and pursued opportunities to expand community programs.



Birch Aquarium Statistics Fiscal 1998

On-site visitors
367,923 (including 43,609 school children)

Public education activities
115, with 3,601 participants

Summer Learning Adventures
59 sessions, with 994 participants

Outreach program participants
282 programs for 8,850 students K-14
6 in-service workshops for 175 teachers
38 charity programs for 1,832 participants
15 fairs reaching 183,075 in attendance

341 programs reaching 193,932 total

Scripps Oceanographic Society
6,157 memberships

Volunteer hours
25,397
(with an additional 31 volunteers in Scripps research)

Staff members
56 career (10 part-time), and 26 by-agreement

Earned income
$2,334,155

Gifts, grants, and in-kind donations
$572,010

Operating expenses
$2,420,199

Acclaim

In recognition of its high professional standards and excellence in operations, the Birch Aquarium was accredited this year by the American Zoo and Aquarium Association, joining an elite group of 31 accredited aquariums nationwide.

The aquarium's animal propagation program continued to draw national attention. Aquarists provided specimens born and raised at the Birch Aquarium to more than 25 other facilities, with the potbellied seahorse *(Hippocampus abdominalis)* drawing the most requests. New reserve tanks and improvements to the warm-water supply enhanced the aquarium's coral propagation capabilities, and aquarium staff shared coral specimens with five other facilities during the year.

The National Environmental Education and Training Foundation ranked the aquarium-developed curriculum *Forecasting the Future: Exploring the Evidence for Global Climate Change* as number one in the country among global climate change curricula. It was developed through an ongoing collaboration with the Center for Clouds, Chemistry and Climate at Scripps.

Challenges

After five years of husbandry experience maintaining the giant kelp forest tank, aquarium staff renovated this centerpiece exhibit. The process included draining the tank, replacing the ten-ton acrylic window, fabricating more naturalistic rock work, and making plumbing improvements to increase water flow for kelp health. KelpCam, a new interactive exhibit, offers four underwater camera views of microhabitats within the kelp forest tank.

The aquarium offered more interactive programming to the public. A new program, Hands-on Science Stations, provided weekend audiences the opportunity for close observation of scientific specimens and the chance to use research tools. Whether examining krill under a video microscope, searching for life in a kelp holdfast, or experiencing the texture of shark skin, families were encouraged to learn together under the guidance of trained aquarium volunteers.

Opportunities

Outreach into the community attained new levels. In its first full year of operation, the aquarium's Planet Earth Express van took programs to almost 11,000 participants throughout southern California—engaging students, teachers, seniors, and hospital patients in the excitement of learning about the ocean. In addition, the aquarium reached more than 183,000 people by making Planet Earth Express available at community fairs and expositions.

The 1997-1998 El Niño presented a timely opportunity to convey Scripps research to the public. Aquarium staff installed an informative exhibit, *El Niño: A Pacific Ocean Phenomenon with Global Effects,* and updated the exhibit throughout the year. As part of the aquarium's Meet the Scientist lecture series, Scripps researcher Dan Cayan presented a first-hand account of tracking the most recent El Niño event. El Niño also was among the initial topics of Take-home Science, a series of informative aquarium publications that address current issues in oceanographic science.

Visitors to the Birch Aquarium enjoy the giant kelp forest tank, renovated this year (above). These two students are representative of 8,850 others who enjoyed aquarium outreach programs in their classrooms (facing page).

FINANCIAL SUPPORT

Information about the Scripps Oceanographic Society can be found on the Web at

http://www-sos.ucsd.edu/

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

FACING PAGE
Scripps's W. M. Keck Ocean Atmosphere Research Building under construction

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

R. Lawrance Bailey
Director of Development
Scripps Institution of Oceanography
9500 Gilman Drive Dept 0210
La Jolla CA 92093-0210

619/534-7171

During the 1998 fiscal year Scripps Institution of Oceanography received approximately $3.4 million in pledges, gifts, grants, and gifts-in-kind, and was named the beneficiary of a $1 million planned gift.

The largest gift, a bequest from the estate of Robert L. Cody, created the Robert L. and Bettie P. Cody Centennial Endowment Fund, which provides unrestricted support for the institution. The bequest also provided additional funds to the William E. and Mary B. Ritter Memorial Chair in Oceanography. During his lifetime Cody, along with his wife, Bettie, funded the William E. and Mary B. Ritter Memorial Fellowship and the Robert L. and Bettie P. Cody Award, in addition to the Ritter Chair. Cody, who died in 1996, was the grandnephew of Mary B. Ritter, wife of Scripps founding director William Ritter.

The G. Unger Vetlesen Foundation continued its support of global change research at Scripps for the tenth consecutive year. Vetlesen Foundation grants have provided seed funding for a number of innovative research projects and matching funds to secure federal research support.

In addition, the Vetlesen Foundation helped fund the Edward A. Frieman Endowed Chair in Global Observation Research. Ellen Revelle Eckis provided a challenge match gift, which afforded a vehicle for other donors to participate and was instrumental in completing funding for the chair honoring Frieman, director of Scripps from 1986 to 1996.

The Scripps Institution of Oceanography Associates program was reorganized during the past year and renamed the Scripps Oceanographic Society. Members of the society provide invaluable unrestricted annual support to the institution. Last year, gifts from society members totaled more than $170,000.

The top level membership category is the E. W. Scripps Associates, composed of institution supporters who contribute $1,000 per year. Membership in this group rose from fifteen members when the program was created in 1992 to more than seventy members in 1997. E. W. Scripps Associates contributed to special projects throughout the year and funded a graduate fellowship and a laboratory on the pier. The associates hosted an awards dinner in January honoring Peggy and Peter Preuss (Leadership Award), Scripps ecologist Paul Dayton (Community Outreach Award), and Ellen Revelle Eckis (Benefactor of the Year).

In May, the Charmaine and Maurice Kaplan Laboratory for Cancer Drug Discovery was dedicated at the Scripps Center for Marine Biotechnology and Biomedicine. At a celebration dinner that evening, the Kaplans received the *Amici cum Laude* award in recognition of their financial and volunteer support of Scripps during the past five years.

David C. DeLaCour, who created a $1 million charitable remainder annuity trust to benefit Scripps in 1996, created an additional $1 million trust that will provide unrestricted funds for the Birch Aquarium at Scripps.

Other notable contributions during the past year included

- A gift from Robert P. Scripps to support aquarium operations,
- Grants from the Los Angeles and San Diego Chapters of the ARCS Foundation for graduate fellowships, and
- A grant from the Quest for Truth Foundation to support the establishment of an earth reference model at Scripps.

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

FINANCIAL SUPPORT FOR 7/1/97 – 6/30/98

FEDERAL, STATE, AND CITY AGENCIES

United States

Agriculture, Department of
- Forestry Service

Commerce, Department of
- National Oceanic and Atmospheric Administration

Defense, Department of
- Air Force, Department of the
  - Air Force Office of Scientific Research
  - Defense Special Weapons Agency
- Navy, Department of the
  - Naval Postgraduate School
  - Naval Research and Development
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  - Office of Naval Research

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National Science Foundation

North Atlantic Treaty Organization

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The Resources Agency of California
- Department of Boating and Waterways
- Department of Fish and Game
- Department of Water Resources

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AGIP Petroleum Co.

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Current Funds

FEDERAL FUNDS	1997/1998	Percent of Total
National Science Foundation	$31,350,330	30.48
Department of the Navy	$20,467,960	19.90
National Oceanic and Atmospheric Administration	$8,237,556	8.01
National Aeronautics and Space Administration	$4,339,551	4.28
Department of the Interior	$2,144,042	2.08
Department of Energy	$1,883,697	1.83
Department of Health and Human Services	$1,299,665	1.26
Department of Defense	$1,273,499	1.24
Other, (including Federal Flowthru)	$5,612,021	5.46
TOTAL Federal	**$76,668,321**	**74.54**
OTHER		
State General Funds	$17,726,193	17.24
Private Gifts and Grants	$4,312,654	4.19
Overhead Funds	$2,533,429	2.46
State of California	$1,871,378	1.82
Endowments	$917,920	0.89
University Funds	$284,309	0.28
Sales, Services & Reserves	($1,461,092)	-1.42
TOTAL Other	**$26,184,791**	**25.46**
TOTAL EXPENDITURES	**$102,853,112**	**100.00**

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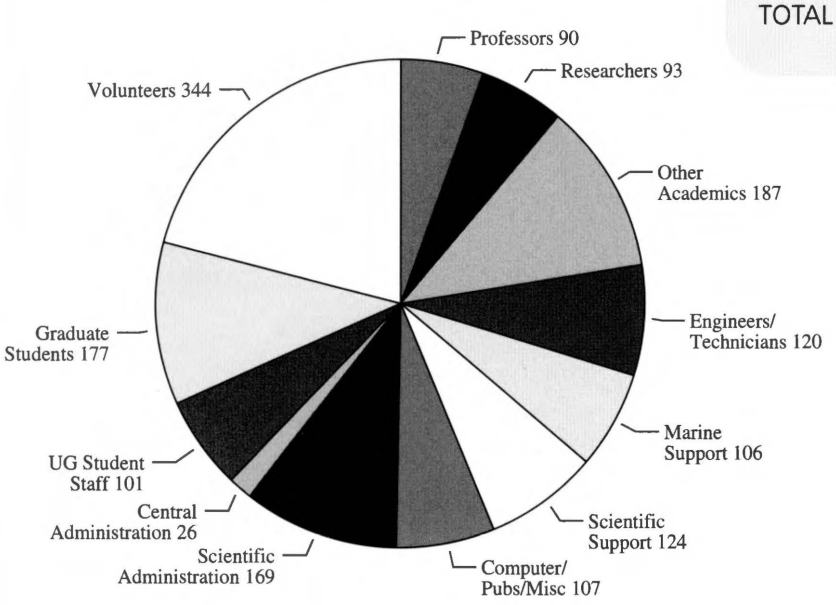

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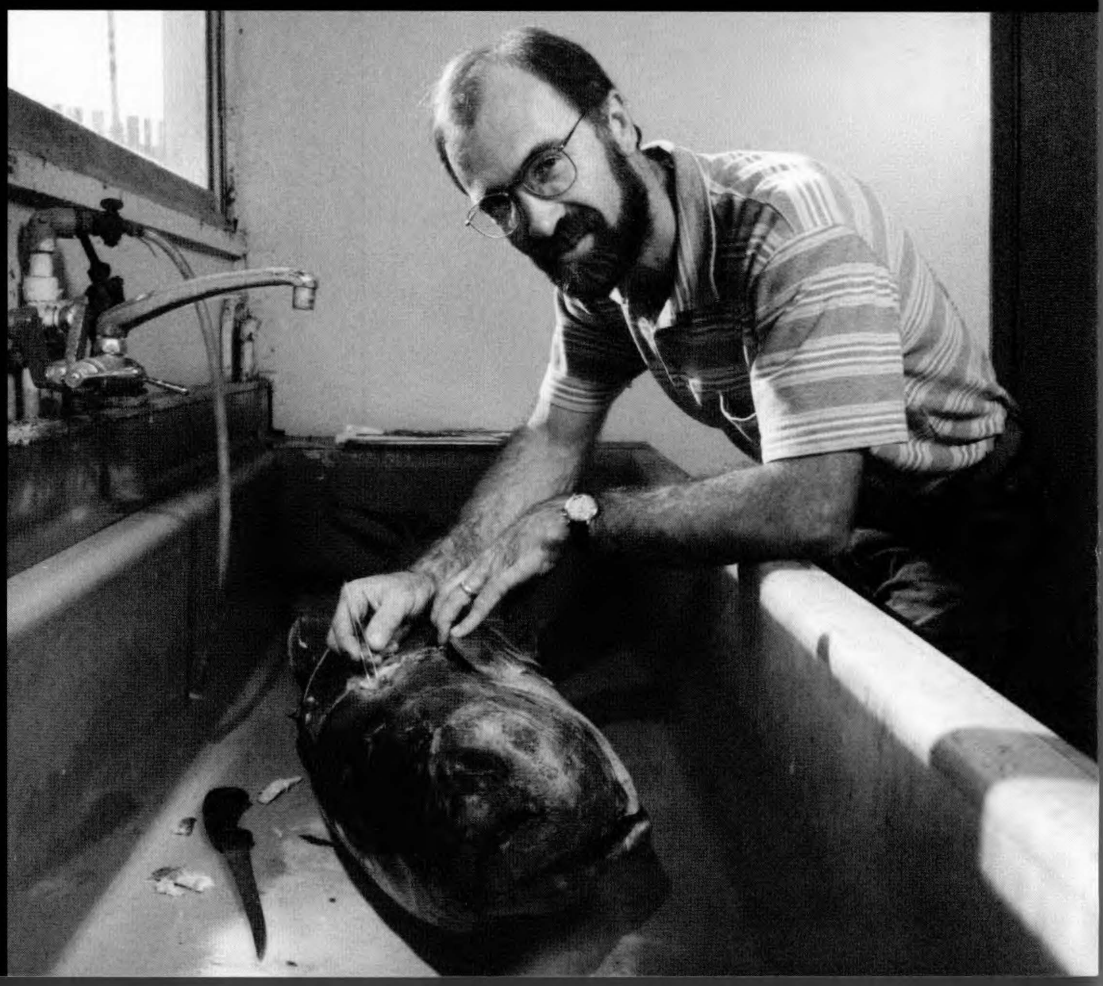
Marine Biology Research Division scientist Robert Shadwick extracts a tissue sample from a bigeye tuna, *Thunnus obesus*.



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■ **Qinyun Zhang,** GRD, Geology

✖ **Xin Zhang,** PORD, Physical Oceanography

Meng Zhou, MBRD, Coastal Oceanography

◗ **Alberto Zirino,** MRD, Oceanography

Mark A. Zumberge, IGPP, Physics

● Adjunct Professor Series

✷ Cecil H. & Ida Green Scholar

▲ Alderson Chair

◆ Emeritus

❖ Emeritus, on site

★ Faculty, Department of SIO

✱ John D. Isaacs Chair (returns to SIO 7/1/00)

✖ Postgraduate Research Scientist

✚ Ritter Chair

■ Visiting/Postdoctoral Scholar

◗ Non-Salaried, Affiliated elsewhere

✣ Member of SIO Faculty

AMES	*Applied Mechanics and Engineering Sciences Department*
CAS	*Center for Atmospheric Sciences*
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	*Scripps Institution of Oceanography Graduate Department*
ECE	*Electrical and Computer Engineering Department*
GRD	*Geosciences Research Division*
IGPP	*Institute of Geophysics and Planetary Physics*
INLS	*Institute for Nonlinear Science*
MBRD	*Marine Biology Research Division*
MLRG	*Marine Life Research Group*
MPL	*Marine Physical Laboratory*
MRD	*Marine Research Division*
NU	*Neurobiology Unit*
Physics	*Physics Department*
PORD	*Physical Oceanography Research Division*
SGP	*Sea Grant Program*
SOMTS	*Ship Operations and Marine Technical Support*
STS	*Shipboard Technical Support*

AWARDS & HONORS

Wolfgang H. Berger received the Steinmann Medal, the highest honor bestowed by Germany's largest geologic association, for his career-long leadership in paleoceanographic research.

Michael J. Buckingham won the Acoustical Society of America's Science Writing Award for Professionals in Acoustics for a paper in *Scientific American*.

Steven C. Cande was elected a Fellow of the American Geophysical Union.

Russ E. Davis received the Huntsman Award from Canada's Bedford Institute of Oceanography for his "contributions to the development of observational and theoretical tools for the exploration of the ocean."

Paul K. Dayton received the annual E.W. Scripps Associates Award for Community Outreach.

Grant B. Deane was awarded the A. B. Wood Medal and Prize from the United Kingdom's Institute of Acoustics for distinguished contributions to acoustics applications.

Jean H. Filloux was elected a Fellow of the American Geophysical Union.

Holly K. Given was appointed to the United Nations Provisional Technical Secretariat of the Preparatory Commission for the Comprehensive Nuclear Test Ban Treaty in Vienna, Austria.

Charles David Keeling received a "special achievement award" from Vice President Al Gore for 40 years of outstanding scientific research in monitoring atmospheric carbon dioxide.

Ralph F. Keeling received the Rosenstiel Award in Oceanographic Science for "distinguished contribution to oceanographic sciences."

Charles F. Kennel was the first winner of the European Geophysical Society's Hannes Alfvén Award for his "authoritative contributions to space plasma physics."

Walter H. Munk received Honorary Membership in the Royal Meteorological Society.

Robert L. Parker was awarded the Royal Astronomical Society's Gold Medal, its highest honor, for his outstanding contributions to theoretical geophysics.

Veerabhadran Ramanathan received the Volvo Environment Prize for pioneering work related to the greenhouse effect and for predicting the nature of future changes in the world climate.

John G. Sclater was awarded a Guggenheim Fellowship, which will allow him to work with international colleagues to study the history of plate tectonics underneath the Indian Ocean and to demonstrate how the plates move.

Ray F. Weiss was elected a Fellow of the American Geophysical Union.

Birch Aquarium at Scripps was granted accreditation by and membership in the American Zoo and Aquarium Association (AZA).

PUBLICATIONS

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The results of Scripps research are published in many different forms. These publications range from short contractual reports to long taxonomic descriptions. A listing of recent Scripps publications follows. Information on the availability of each series is included.

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The second-floor patio of the Scripps Library provides a retreat for quiet contemplation.

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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

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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.

v.30 **Gruber,** Nicolas, and Charles D. **Keeling.** Seasonal carbon cycling in the Sargasso Sea near Bermuda. In press. 96p.

CALCOFI PUBLICATIONS

The work of the California Cooperative Oceanic Fisheries Investigations (CalCOFI), in which Scripps Institution of Oceanography, the California Department of Fish and Game, and the National Marine Fisheries Service cooperate, is published in a variety of formats. Peer-reviewed scientific articles are published annually in the *California Cooperative Oceanic Fisheries Investigations Reports.* Maps of physical, chemical, climatological, and biological factors measured by CalCOFI researchers during the program's 49-year history are published irregularly in the *California Cooperative Oceanic Fisheries Investigations Atlas* series. Data reports, containing the processed data from specific cruises carried out under CalCOFI sponsorship, are published irregularly in the SIO Reference Series. To obtain copies of any of these CalCOFI publications, write to

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CONTRIBUTIONS

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The articles listed below were published in the 1997 volume and may also be found in the publications cited. Information about a specific reprint can be obtained by writing directly to the Scripps author in care of

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9500 Gilman Drive
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Directory of academic marine programs in California. Third edition. Publication Number E-005. 1993. 82p.

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Biennial report of completed projects 1994-1997. Report Number R-044. 1998. 200p.

California Sea Grant Program directory 1998-2000. Report Number R-043. 1998. 38p.

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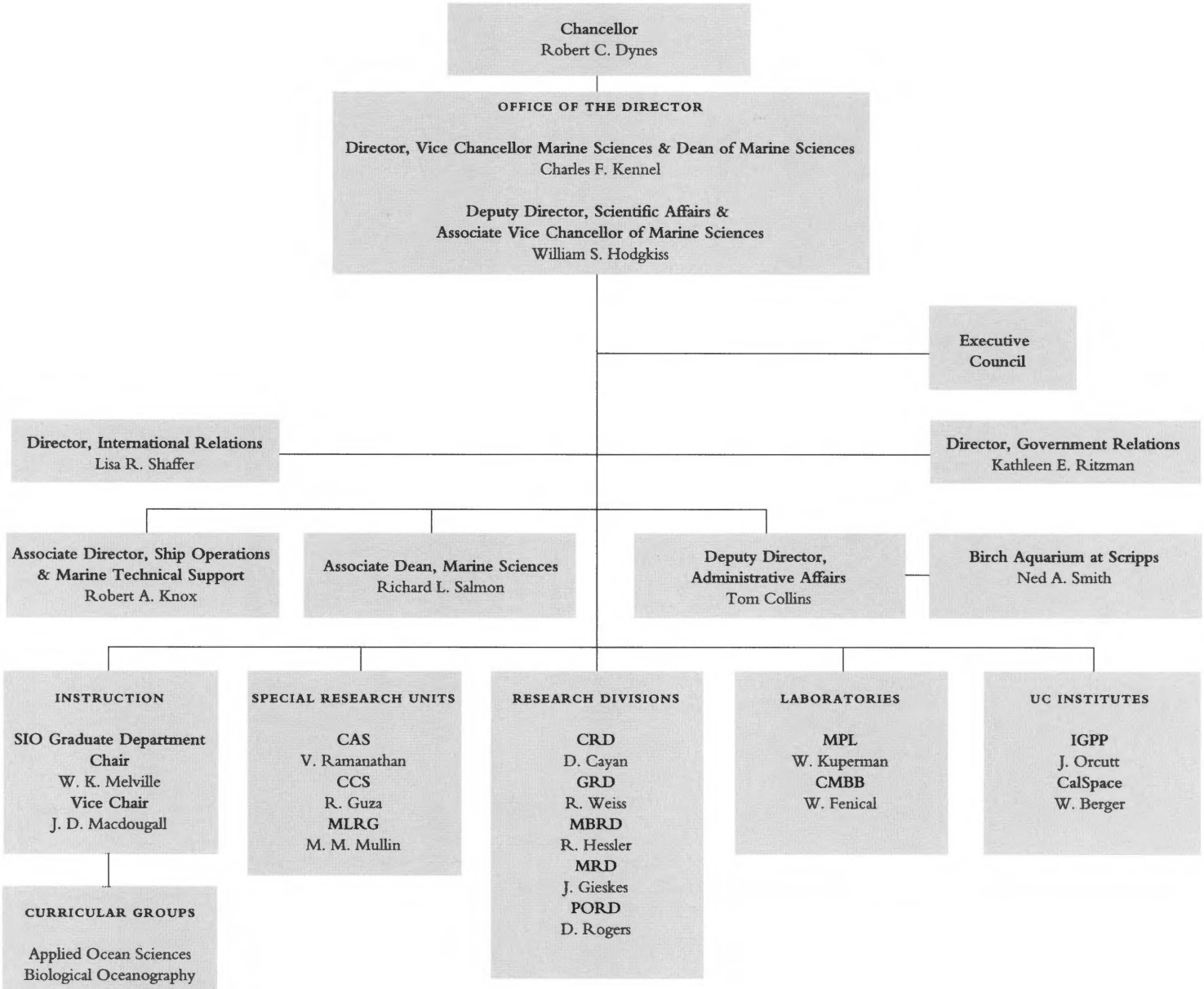

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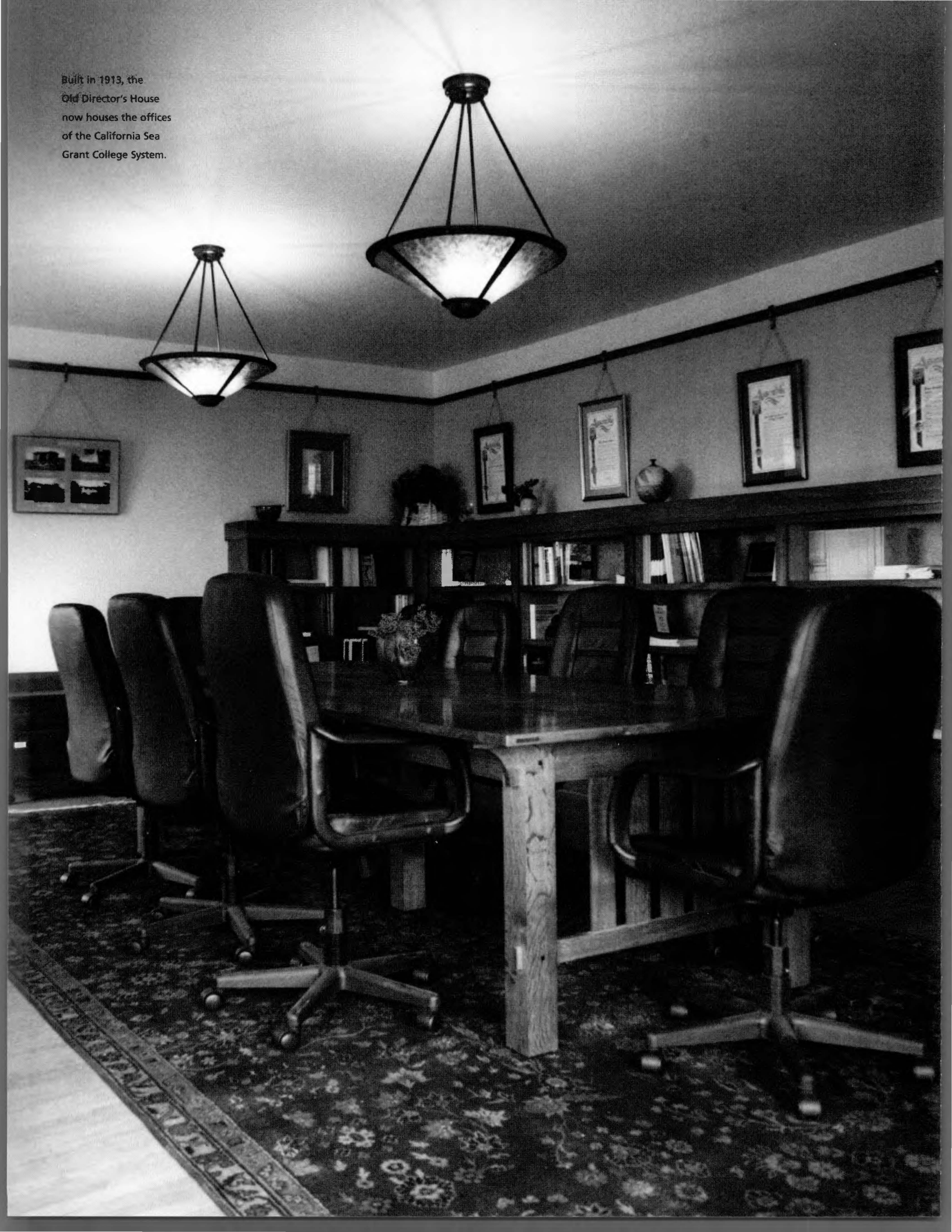

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In Memoriam

Philbrook Cushing
August 1997
Philbrook Cushing came to the Marine Physical Laboratory (MPL) in 1959 and started going to sea shortly thereafter as a lead engineer. His major seagoing expedition at MPL was the deployment in 1969 of the unmanned version of FLIP, the SPAR (Seagoing Platform for Acoustic Research). He was a senior development engineer when he left MPL in 1972.

Edwin L. Hamilton
January 1998
Edwin L. Hamilton served as a research associate and adjunct professor at Scripps and assisted a generation of graduate students in the fields of physical and acoustic properties of sediments. He worked on the joint Scripps-U.S. Navy Electronics Laboratory Mid-Pacific Expedition, which focused on seafloor topography, tectonics, and sedimentary processes.

Donna Hawkins
August 1997
Donna Hawkins was a staff member in the Geosciences Research Division and Deep Sea Drilling Project, where she worked with the Sediment Data Bank. For the Deep Sea Drilling Project she also worked as manager of the igneous rock and magnetic databases.

George William Hohnhaus
April 1998
George William Hohnhaus served on every major Scripps expedition from 1954 until his retirement in 1975. During an expedition aboard *Horizon* a new seamount was discovered and named Hohnhaus Seamount in his honor.

Cashie Parkhill Kieckhefer
August 1997
Cashie Parkhill Kieckhefer joined Scripps in 1978 as an employee of the SIO Department office. She befriended and encouraged many graduate students in her two years here.

Delpha Dean McGowan
September 1997
Delpha Dean McGowan worked at Scripps as a staff research associate through the 1960s and 1970s. She did data reduction for various researchers. She was one of the first two women to go out on a Scripps ship as a regular working member of the scientific party.

Richard J. Smith
August 1997
Richard J. Smith joined the Marine Physical Laboratory in 1951 and served as a member of the lab's electronics shop and as a principal electronics technician until his retirement in 1975.

Earl Squier
May 1998
Earl Squier started his 34-year career at Scripps in 1947 working with electronics as an engineer. He retired as a senior development engineer at the Marine Physical Laboratory.

Thomas J. Wiley Jr.
January 1998
Thomas J. Wiley Jr. worked at Scripps many years ago as the public relations administrator for the Deep Sea Drilling Project.

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