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# Where We Are Now, Where We Are Going: Scripps Science in Two Centuries

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Scripps Institution of Oceanography shares its centennial year with innovators who changed the twentieth century and our ability to navigate it; the founding of the Ford Motor Company and the first flight of the Wright brothers in Kitty Hawk, North Carolina, also occurred in 1903.

Automobiles and airplanes have dramatically evolved over 100 years, and Scripps science is much different today than it was in the summer of 1903, when William E. Ritter and a handful of his students began studying marine life in San Diego Bay.

Scripps quickly became a multidisciplinary institution, researching and teaching all of the subjects pertinent to the oceans—physics, chemistry, biology, and geology. Scripps had few formal curricular—or geographical—constraints inhibiting research initiatives, and studies soon extended to such areas as volcanology, seismology, atmospheric science, and climate science. Today, Scripps is more like an earth science research center than a traditional ocean institution.

Its foundation of twentieth-century achievements has positioned Scripps to meet the even more profound interdisciplinary challenges of the twenty-first century. Indeed, Scripps, at 100, is at a turning point.

Our established competence in ocean and earth science is the principal asset we can invest in the future—though this principal asset is at risk, as Scripps faces its worst financial crisis since the Great Depression. That alone will force change, but there is a more profound reason for change. The earth itself changed profoundly in the last century, and ocean and earth science are changing in response. So to ask where Scripps is going, we must ask where *science* has been and where it is going.

## Exploration Then and Now

Toward the end of the fifteenth century, Prince Henry the Navigator sent Portugal's ships to the Atlantic shores of South America and Africa to seek commercial wealth through superior geographic knowledge. This initiated a grand age of European exploration. The great explorers were sea captains whose goal was to find new trade routes by completing maps of the world's oceans. Beginning in the seventeenth century, science played an important role in motivating explorations. The British and French science academies were important driving forces behind the largest of the eighteenth-century expeditions.

In the nineteenth century, scientific exploration was becoming the principal goal of exploration, with the voyages of *Beagle* and *Challenger* as prime examples. The last of the primarily geographic explorers were pressing toward the North and South poles, the last of the earth's uncharted territories, as the twentieth century began.

In the twentieth century, we moved beyond our own planet and went to the moon. On the way, we saw the earth from space for the first time, blue and inviting, alone in the black immensity of space. In the decades that followed, we flew in and above the earth's atmosphere, photographed the entire land surface, probed the deepest ocean trenches, charted the ocean's currents, mapped the entire ocean floor by satellite, and studied the movements of the earth's core. Everywhere we looked we found life, even in and below hydrothermal vents at the bottom of the ocean. Our spacecraft went to all the planets in the solar system but one. With the help of modern technology, we can visit any point on the earth. Nowhere on the earth's surface is there a virgin place, unvisited, uninspected.

As the twenty-first century begins, the very nature of exploration is being transformed. We are now more closely, deeply observing our world and the changes being wrought in our midst.

Humans have always modified their environment to better suit their needs. But over the last half century, such alterations have assumed global proportions. As a result, our advanced civilization is spending more and more of its time and treasure coping with the unintended by-products of its activities—air and water pollution, ecosystem decline, biological invasions, chemical contamination, and radiation. Humans now appropriate more than half the fresh water circulating in the hydrological cycle and fix more nitrogen than nature itself does. Air pollution has gone global and is changing the climate. The escape of chlorine and bromine compounds into the stratosphere created an Antarctic ozone hole. Industrial activity brought

*Scripps campus as seen from the Ellen Browning Scripps Memorial Pier in the mid-1990s.*

atmospheric greenhouse gases to the highest concentrations in the past half-million years. This will cause a warming of the global climate throughout the present century. The sea level will rise, and there will be unknown effects on the fresh water cycle, the distributions of plants and animals, and the propagation of human disease. The time scale for many of the changes being wrought by man is tens of years—one which strains the capacity of human institutions to adapt.

Humans are changing the earth, so earth science is changing out of necessity.

In addition to continuing to study eons past, earth science must now also cope with understanding the next hundred years, aiming to make useful forecasts of what the future may have in store. Understanding one scientific discipline is no longer enough. We must weave rigorous, single-minded disciplinary thought into an interdisciplinary panorama of the earth as it is today.

With the new capacity to map the genomes of all organisms, and the emerging interest in elucidating the collective behavior of nonlinearly interacting gene networks, biology is becoming an information science. The great divide between reductionist molecular biology and holistic ecology is on its way to being bridged as genetic techniques promise to establish rigorous measures of biodiversity and information technology promises to make holistic perceptions rigorous.

As the biological divide is bridged, there is the promise of a grand convergence with earth system science evolving along a parallel track. The fusion of Earth science, modern biology, and information technology will lead to a continuous awareness of earth's systems and their interactions with the human environment. Such integration will strengthen our disaster responses and our ability to manage a sustainable environment and cope with climate change. Achieving an integrated, continuous awareness will require a new organization of human, scientific, and technological systems:

- an intimate connection between observations, modeling, and support of decision making
- interdisciplinary research relating physical, biological, and human systems
- sustained and integrated observing systems that transcend traditional disciplinary boundaries
- assessment capabilities for integrating scientific knowledge into effective decision support systems
- connecting research, education, and public communication

## Scripps Science in the Twenty-First Century

The grand convergence is beginning to happen at Scripps. Here are some examples of the latest ways the institution is integrating its interdisciplinary and technological assets toward increased interconnectedness.

The Cecil H. and Ida M. Green Institute for Geophysics and Planetary Physics (IGPP) has led Scripps into the modern world of information technology, from its satellite downlink station in 1978 to its leadership in the creation of the first environmental seismological sensornets and its partnership with the University of California's California Institute for Telecommunications and Information Technology (Cal(IT)$^2$), now undertaking advanced data visualization. IGPP has been the lead player in the Southern California Earthquake Consortium's seismic network for more than ten years, and Scripps and IGPP will play an important role in the recently approved National Science Foundation project, Ocean Observatories Initiative, as well as the EarthScope USArray and Plate Boundary Observatory projects.

The Center for Marine Genomics at Scripps, the world's first center devoted to marine bioinformatics,

promises to lead Scripps into the burgeoning frontier of information technology's convergence with biology. Scripps biologists are beginning to bridge the divide between molecular biology and ecology with the establishment of the Center for Marine Biodiversity and Conservation (CMBC) at Scripps, which will work synergistically with the genomics center. Physical and biological oceanographers across the campus are collaborating to develop new measurement technologies.

Scripps is assembling integrated global observing capabilities, using space observations, robotic underwater vehicles, and acoustic methods to probe the oceans. The new Center for Observations, Modeling, and Prediction at Scripps (COMPAS) is using its half teraflop computing capacity to process circulation and climate models using real-time ocean data. The Center for Atmospheric Sciences at Scripps is constructing a fleet of unpiloted vehicles to make Pacific-wide measurements of atmospheric chemistry and aerosols, working in cooperation with the University of California, San Diego's earth observatory, which will make land-based measurements in California and develop a new generation of measuring instruments. Scripps climate scientists are installing a network of stream gauges in California's watersheds that will take advantage of communications technology developed for the seismological system. Our climate scientists also are working with the University of California, Berkeley social scientists to develop forecasts of the impacts of climate change on the Sierra Nevada snowpack, water availability, stream flows, hydroelectric power, wildfires, and agriculture. The California Cooperative Oceanic Fisheries Investigation (CalCOFI), which has taken extensive biological and physical measurements every year since 1949, may be the world's first long-term integrated ocean observing system. Scripps scientists took the lead in organizing a southern California consortium for coastal ocean observations and are planning to integrate CalCOFI into an eventual system for the entire California Current. The Southern California Coastal Ocean Observing System will integrate coastal observation programs in the Southern California Bight for scientific purposes and for the benefit of society.

In support of decision making, Scripps originated the UC Revelle Program on Climate Science and Policy to connect Scripps research with social and policy scientists across the University of California. Scripps is working actively with UCSD's Graduate School of International Relations and Pacific Studies, Graduate Management School, and departments of economics, political science, and history to develop a stronger presence in environmental policy studies on campus.

Scripps is innovating new educational enterprises while offering leading Ph.D. programs in ocean, atmospheric, geological, and biological sciences. The Center for Marine Biomedicine and Biotechnology at Scripps offers a unique medical scientist M.D./Ph.D. training program in conjunction with the UCSD School of Medicine. CMBC plans to educate graduate students in both natural and social science. It is possible that in the future, Scripps, like medical schools, will train both basic scientists and clinicians—only these clinicians' "patients" will be ecosystems, and the cures will be policy, not pharmaceuticals.

## The Roles and Responsibilities of Science

My term as director of Scripps began as the twentieth century was coming to a close. Bridging two centuries, my role is to work cooperatively with scientists and administrators at Scripps to chart the institution's future course, acknowledging the outstanding lineage of scientific leaders that have brought the institution this far.

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In the face of such a challenge, and observing the beginnings of tremendous change and innovation in this new century, I have been pondering—and asking my scientific colleagues—several abiding questions:

- Will we, the global community, humanity emerge at the end of this century at peace with ourselves and with nature?
- Can we reconcile our development goals with the environmental limits of the planet?
- Will we learn how to govern society and nature together?

As a global society, we have a responsibility to feed, house, clothe, educate, employ, and provide a peaceful existence for a world population half again as large as the one today, while remaining in equilibrium with the environmental and ecological systems that sustain all life. How we do so remains to be seen. Yet I firmly believe that Scripps can neither deny its ability nor shirk its responsibility to address the most profound issues facing our emerging global civilization.

The Oceans 2003 conference, which will gather numerous science and technology societies in San Diego in September, itself speaks to a broad, far-reaching interconnectedness, to the great integration of knowledge that is occurring within earth science. In honor of that gathering, and the Scripps centennial celebration, this issue of *Oceanography* is devoted to the creation of Scripps science from numerous disciplinary and historical points of view. As you read about where we have been and where we are now, I hope you'll also come away with a sense of all the scientific potential at Scripps today. The upcoming century of exploration is sure to be as eventful and innovative as the last.