MERIDIAN

FALL 2006

R/V BANK OF BERMUDA ATLANTIC EXPLORER

FROM VISION TO REALITY

THE BIOLOGICAL STATION BECOMES THE BERMUDA INSTITUTE OF OCEAN SCIENCES

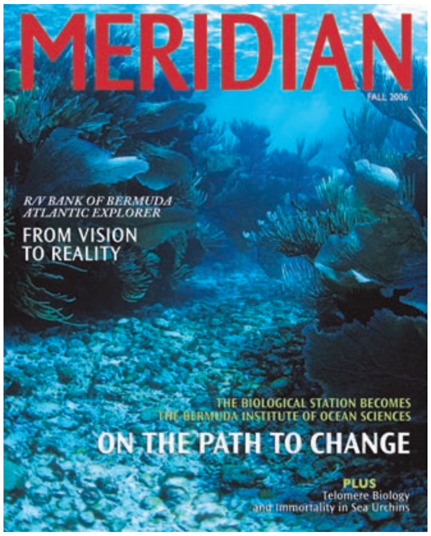
ON THE PATH TO CHANGE

PLUS

Telomere Biology and Immortality in Sea Urchins

Our Planet.

BIOS



ON THE COVER A pebble path through a field of sea fans and soft corals at North Rock. PHOTOGRAPH BY ALEX VENN

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BIOS is an independent marine science organization. It was founded in 1903 as the Bermuda Biological Station by scientists from Harvard and New York University to take advantage of Bermuda's ideal location for deep-ocean and coral reef research and education.

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Fall 2006

Dr. Tony Knap and Brian Duperrault, Chairman of the Board of Trustees of the Bermuda Institute of Ocean Sciences at the announcement of the name change.

A Letter From the Director

Well – it has been a great summer at the Bio Station. Our new 168-foot deep-ocean research vessel – the *Bank of Bermuda Atlantic Explorer* – has seen a busy schedule supporting our scientists in a variety of research endeavors in various locations throughout the Atlantic Ocean. It has also been a magnet for scientific explorers from around the world, who have journeyed to Bermuda to utilize one of the most advanced ocean-going vessels in the University-National Oceanographic Laboratory System (UNOLS) fleet. Its introduction to our array of scientific resources has exponentially grown our capability, keeping us firmly at the forefront of ocean science research.

As we introduce the *R/V Bank of Bermuda Atlantic Explorer* to many of you for the first time, we also launch ourselves into a new world with a change of name that is more than cosmetic. Since our inception in 1903, we have been known in various iterations as the Bermuda Biological Station, later completing the name by adding ‘for Research’, or simply being known in Bermuda as the ‘Bio Station’ or ‘BBSR’. We have long thought that the name simply did not reflect the breadth of the scientific and educational focus on our campus and our Board of Trustees decided earlier this year that it was time for a meaningful change. To that end, on September 5th, we announced to the community of Bermuda and to the oceanographic world that we were to be known in the future as the Bermuda Institute of Ocean Sciences (BIOS). With the vast array of scientific programs underway at BIOS, the name we have chosen reveals the expanding palette of work being undertaken.

And that change extends to this magazine, which we christen as *Meridian*. We thought a new name for the institution deserved a fresh approach to the primary communications effort dedicated to our BIOS family. We hope you enjoy the new look and would welcome your thoughts on its design and content.

As the world's attention focuses more and more on the question of climate change, Bermuda plays a larger global role in this field through the data collected in the deep ocean off the island, which provides the longest data set of continual measurements in the world. On every voyage undertaken by the *R/V Bank of Bermuda Atlantic Explorer*, unique insights are provided into the changing world around us. These time-series programmes are clearly the most measured long-term stations in the world and we have seen a change in the temperature of the ocean over this time. Over the past fifty years there have been changes in the temperature of the surface ocean – either human-induced and/or natural. In the deep waters off Bermuda we have measured a warming of one degree Celsius during that period. We are only now beginning to understand the implications of that warming trend to the oceans and the various life in it.

This role of the ocean in global warming and the uptake of carbon by the ocean led to the creation of the Risk Prediction Initiative (RPI), started twelve years ago by BIOS, in partnership with many re-insurers and insurers located in Bermuda and overseas. Just last October, BIOS / RPI hosted a meeting entitled *"Assessing, Modeling and Monitoring the Impacts of Extreme Climate Events"*, where thirty of the top tropical cyclone, wind, hail, rain and flood experts came to Bermuda to share their expertise with the insurance industry. Scientists from the Massachusetts Institute of Technology, University of Southern California, and other universities within the United States; from Germany, the United Kingdom, France, and Spain, to name but a few, came to Bermuda to take part in this timely meeting. A book based on this meeting is in the final stages of pre-publication.

In just the last month, BIOS has hosted a workshop on catastrophe modeling for twenty members of the insurance industry with instructors from Princeton University, the University of Rhode Island, the National Institute of Standards and Technology, and the University of Southern California. This has triggered the first step in establishing a Risk Institute at BIOS to provide educational opportunities for both Bermudians and non-Bermudians on modeling risk and the role of climate on the insurance industry business model. It is fair to say that Bermuda provides a perfect environment to bring the insurance and re-insurance industry together with the leading proponent of climate science, as we search together for answers to the perplexing questions that we encounter in our scientific realm.

The BIOS team is moving rapidly forward in developing a graduate school in conjunction with major university partners from the United States and the United Kingdom. I should have more to report to you early in 2007 on our progress. In the meantime, during 2006, we have hosted eleven undergraduate students from Princeton University; eighteen students from Duke University; eleven from Southampton University in the United Kingdom; fifteen from the University of Rhode Island; and, thirteen from Roger Williams University. Our two summer courses were attended by twenty-four undergraduate and graduate students from around the world. We also mentored six undergraduate interns during the summer and eight students this fall from universities throughout the United States. It has been a stellar year for our university-level programmes with more students engaged in the undergraduate curriculum than ever in the past.

We continue to expand our footprint in the community by offering more projects under the banner of the new Bermuda Ocean Education Programme. Included in this effort is the summer programme called Waterstart, which saw over seventy students involved in week-long immersions in the environment of the ocean, gaining a greater understanding of the science that underpins the effort to maintain a healthy planet. And coming in the first quarter of 2007 is *BIOS Explorer*, the successor to JASON. With a unique curriculum focused on the local Bermudian environment, *BIOS Explorer* will reach out to thousands of middle school students, working with teachers and children alike to integrate a meaningful field trip to BIOS into their environmental studies in the classroom. You will hear more about *BIOS Explorer* in the first quarter of the new-year.

As always, your financial commitment is vital to the future of BIOS. Whether an unrestricted gift, specific project support, or perhaps a legacy gift that ensures a growing endowment, your involvement with us is crucial to a strong future for the scientists and educators who have committed their lives to the pursuit of discovery that ultimately benefits us all. In advance, thanks so much for investing in healthy oceans for our children's sake.

Anthony H. Knap, PhD
President and Director

Engaging the Next Generation of Ocean Stewards

by Thomas L. Stephenson

Cris Todd and Kervin Moreno overlook the South Shore
PHOTOGRAPH BY ANTOINE HUNT

As you can glean in your reading of this first edition of *Meridian*, change is afoot throughout our institution. That's hardly new for this 103-year old organization, as the many scientists, researchers and educators through that time have adapted to the science and educational needs of the day and produced exceptional results that have stood the test of time. As an example, it's been over fifty years since the first hydrological measurements were made at Hydrostation 'S', located 15 nautical miles south of Bermuda. They constitute the longest set of consistent measurements in the world of ocean sciences. It's that constancy that interestingly enough underpins the change.

Our scientific explorers eagerly pursue new avenues of discovery while keeping a vigilant eye upon the steady accumulation of valuable data that informs them of trends that may impact their research. Our scientists are methodical, whether studying the specific effects an ecotoxin might have on a coral reef or perhaps gazing into a petri dish, as they culture a group of organisms in the hope of finding a new answer to the questions they pursue. They also lean back and dream the 'what if' not content with simply accepting the research norms that might be driving the science at that moment. The worked accomplished at BIOS is cutting-edge, precise, bold and ultimately focused on preserving the health of our oceans. As a supporter of BIOS you can be assured that you're investing in a noble endeavor.

We have donors that go back through many years and well into decades. They were inspired by the scientists and researchers, and ultimately the mission and vision articulated by the leadership of BIOS over the years. This support from Bermudian donors, and from others around the world, has helped to build an Institute that is at the forefront of training the next generation of marine scientists. As a donor, there is so much to choose from in considering whether a portion of your philanthropy should be directed to the work at BIOS.

You might decide to give annually to the unrestricted campaign which ignites the capacity of the institution to strive for extraordinary goals. In doing so, you ensure an infrastructure that is fiscally sound with the people and systems that an organization of this sort requires to not only be competitive, but to become the best at what it does. Or you may choose to give to a specific project that is close to your heart, one that inspires your interest in discovery or supports the work of our university-level educational team. Or you might grasp the opportunity to name a laboratory aboard the *R/V Bank of Bermuda Atlantic Explorer* or see your family crest fly from the bridge for an entire month, every year, as the vessel sails on one of its many voyages of discovery. Or you can be a part of growing our endowment through a legacy commitment that allows us to build upon the excellence being demonstrated daily by our faculty and scientific staff. As you might surmise, the opportunities to make a difference are bountiful. It rests with you to decide how you might like to measure your commitment.

We would like to offer one further possibility. BIOS has established a new project this year called Bermuda's Ocean Education Programme, designed to impact the children of Bermuda at the middle school level through senior high school. The mission is clear: to inspire in Bermudian students a lifelong passion to pursue learning in science, mathematics, and technology through exploration and discovery. We set out to achieve this vision in the following ways:

- BIOS Explorer for grades 6-9.
- Waterstart for grades 5-12.
- Marine Science Day, our annual open house for Bermuda's families.
- The Bermuda Programme, offering internships at BIOS for aspiring young scientists in their teens.
- An ongoing BIOS commitment to assisting teachers in the classroom with curriculum development and core teacher training.

As a donor – you, your company or your foundation – can be a part of this emerging commitment that BIOS has for our local community. As of this writing, we can count Butterfield Bank, the Bank of Bermuda Foundation, Shell Companies of Bermuda Limited, and ACE Group Limited as leading underwriters for this project. Along with the generosity of an anonymous private donor, we have begun to raise the necessary capital to deliver on our vision. With your help, we can ensure the future they inherit will include a greater understanding of their roles as stewards of the environment. The next generation will exist in a complex world, with no easy answers to the questions they will have to face. We at BIOS hope to inspire them to think more critically, more thoughtfully – and to recognize that they stand on the threshold of a new opportunity in a global community that prizes the educated young man and young woman. As a donor to Bermuda Ocean Education, you can be a integral part of that effort.

Contact us at (441) 297-1880, extension 113, to learn more about Bermuda Ocean Education

The R/V Bank of Bermuda Atlantic Explorer steams in to Ferry Reach.
PHOTOGRAPH BY JAMES WOOD

From Vision to Reality

Over the past two decades the waters off Bermuda have become a laboratory of ecosystem research. The number of scientists who desire to engage in marine research in the Atlantic Ocean and especially the Sargasso Sea guarantee that this increased scientific focus will continue. As a result, the trustees of the Bermuda Institute of Ocean Sciences (BIOS) determined that a larger and more capable vessel would be required to replace the current research vessel, the *Weatherbird II*. The *R/V Weatherbird II* had been brought to Bermuda and began its operation at BIOS in November, 1989. In late 2004, BIOS ship operations, and a group resident scientists, corporate members and trustees were tasked with providing options for replacing the *R/V Weatherbird II*. The *R/V Seward Johnson II* at Harbor Branch Oceanographic Institution, located in Ft. Pierce, Florida, was identified as a suitable replacement vessel. The size and capabilities of the *R/V Seward Johnson II*, a class III vessel, would alleviate the principle operational deficiencies associated with the *R/V Weatherbird II.*

The vessel was purchased in October of 2005 and was then configured and modified to better support the types of science activities conducted off Bermuda. The most extensive modification made was the fabrication of an integrated Conductivity, Temperature and Depth (CTD) cast garage and deployment/recovery station that would be capable of handling the 24-place CTD rosette package used for the Bermuda Atlantic Time Series (BATS) operations. The *R/V Seward Johnson II* was renamed and christened in March 2006, taking the name – *R/V Bank of Bermuda Atlantic Explorer* – representative of the primary sponsor, whose gift supported the purchase of the new scientific research vessel.

THE DAWN OF A NEW ERA

There were several other principle benefits of replacing the *R/V Weatherbird II* with the *R/V Bank of Bermuda Atlantic Explorer*. She is small enough to navigate Ferry Reach and berth at the new BIOS dock facility, but large enough to greatly improve seaworthiness and conduct science operations. Expanded deck space carries up to four 20-foot scientific vans and/or work boats simultaneously. She allows for the launching of larger scientific mooring buoys and instruments, along with providing more room for multi-investigator equipment. There is larger wet and dry laboratory space and greater stability for carrying more delicate instruments. In addition, there is greater science berthing capacity (up to 22 scientists) and larger lab space, providing a more conducive environment for education at the K-12, undergraduate and graduate levels.

Home port advantage of a suitable Class III vessel in Bermuda will serve to reduce overall University – National Oceanographic Laboratory System (UNOLS) fleet costs by reducing the number of transit and mobilization days and improving overall East Coast fleet efficiencies.

One of the major aims of the vessel being based at BIOS is to support funded science research in the oligotrophic subtropical gyre of the North Atlantic Ocean. This region is an important modulator of the oceanic cycling of biogeochemical (N, P) and radiatively (e.g., CO2) important elements, air-sea heat and salt transport, as well as climate. The ease of access to these deep waters has allowed the UNOLS vessel based at BIOS to significantly contribute to national as well as international efforts to improve our understanding of ocean processes and global issues. Factors such as climatic change, the complex interaction and feedback between climate phenomena, global warming, ocean biogeochemistry, and ecosystem variability and health can thus be studied. The Bermuda time-series activities are increasingly important for capturing unpredictable, larger-scale and lower-frequency climate variations associated with climate phenomena such as the North Atlantic Oscillation (NAO) and El Ni(o Southern Oscillation (ENSO).

PROGRAMME ENHANCEMENT AND DEVELOPMENT

The principal users of the *R/V Bank of Bermuda Atlantic Explorer* will continue to be the four ongoing oceanographic time-series operations: BATS, Hydrostation 'S' (HYDRO), the Oceanic Flux Programme (OFP) and the Bermuda Testbed Mooring (BTM). In addition to research directly supported by these grants, the time series programmes together provide seagoing opportunities for sample collection in support of a wide diversity of National Science Foundation (NSF)-funded research. BIOS ship operations collaborators include Woods Hole Oceanographic Institute, the University of California at Santa Barbara, and University of Miami Rosenstiel School of Marine and Atmospheric Science.

The enhanced capabilities of the *R/V Bank of Bermuda*


Sunrise on the Sargasso Sea
PHOTOGRAPH BY STUART HALEWOOD

Atlantic Explorer allows for development of courses specifically geared to training in shipboard methodology and technical training for the UNOLS fleet. The ship intends to continue in the tradition of the *R/V Weatherbird II*, as many undergraduate, graduate and post-graduate students have received training or conducted their research using the *R/V Weatherbird II*. The *R/V Bank of Bermuda Atlantic Explorer* will contribute significantly to improve the training and experience of young research scientists and technicians, through participation with oceanographic time-series programmes. BIOS ship operations hosts undergraduates from Duke University, University of Rhode Island, University of Southampton in England and a BIOS-hosted, NSF-funded Research Experience for Undergraduates (REU), designed to gain valuable first-hand scientific experience at sea.

In July this year, the new ship hosted its first cruise with the BIOS Educational Department's Waterstart Marine Science Internship Programme. Fifteen students from Bermuda, ages fourteen to eighteen years, participated on a hydro cruise, providing an opportunity for the teenagers to work alongside and watch the scientists at work collecting data. These cruises give students an opportunity to understand how the ship's officers, crew and technicians interact to make the process of science successful.

FUTURE OUTLOOK

Requests for time-series cruises to support collaborative and ancillary NSF-funded research continues to grow. Time-series measurements are a major focus of the U.S. and international Joint Global Ocean Flux Study (JGOFS) science plans. In the future, ocean time-series will be important components of ocean biogeochemical programmes and ocean observing networks supported by the National Science Foundation. The two NSF-funded stations, Bermuda and Hawaii, are central to national and international plans for a network of ocean time-series stations, and are being used as models for time-series research efforts by other countries. In addition, these two sites are important training and testing grounds for both the national and international efforts to study biogeochemical cycles in the ocean. In fact BIOS is the only Atlantic UNOLS vessel host institution that has accessibility to deep waters within a few hours steam of the dock.

BIOS has always sought to be at the forefront of scientific inquiry in the ocean sciences. From the small boats of the early 1920s, to the use of the 65-foot *R/V Weatherbird I* in the early '80s and the 115-foot *R/V Weatherbird II* until 2005, BIOS has always had a commitment to deep ocean research. The acquisition of the 168-foot *R/V Bank of Bermuda Atlantic Explorer* positions BIOS as one of the primary resources for our researchers and others with whom the Institute collaborates, and will allow the institution to expand its horizons, enhancing its scientific and educational missions. This ship will become a platform for educating the next generation of scientists, young men and women who are in our local school as well as and in colleges and universities around the world. We now have the means to be a significant force in the field of marine science.

Since the purchase of the *R/V Weatherbird II* in 1988, hundreds of researchers have logged thousands of days at sea, and have returned with an expanded comprehension of the ecology of the North Atlantic Ocean. The *R/V Bank of Bermuda Atlantic Explorer* will offer an even better platform for significant discovery over the next two decades and beyond. The new research ship is another example of Bermuda's commitment to ensuring healthy oceans for our children and for generations to come.

Designed to Meet the Needs of Ocean Research and Education

by Dr. Maureen H. Conte

Hamilton Town Crier Ed Christopher opens the christening ceremonies of the R/V Bank of Bermuda Atlantic Explorer in March 2006
PHOTOGRAPH BY MEREDITH ANDREWS

The arrival of the *R/V Bank of Bermuda Atlantic Explorer* in March 2006 launched a new era of greatly expanded oceanographic research and educational opportunities at the Bermuda Institute of Ocean Sciences (BIOS). When she arrived in Bermuda, the 168-foot ship – an intermediate class vessel operating as one of the U.S. University-National Oceanographic Laboratory System (UNOLS) research fleet – had just undergone a major six-month conversion at Lyons Shipyard in Norfolk, Virginia. She transitioned from primarily a submersible support vessel to a multi-purpose ship that will support the current and future needs of BIOS and of oceanographers from around the globe who study the northern Atlantic Ocean.

After a lively ship christening and brief celebration, the *R/V Bank of Bermuda Atlantic Explorer* and crew set out to work. The first cruise headed to the Bermuda Atlantic Time Series (BATS) site, where Woods Hole Oceanographic Institution scientists John Dacey and Deidre Toole installed a novel instrument in one of the refurbished main labs to measure dimethyl sulfide (DMS), a gas produced by phytoplankton, and known to be an important regulator of climate.

Following a short cruise to map currents off the Argus bank, I sailed next as Chief Scientist on the following cruise. Our mission was the 124th recovery and redeployment of the Oceanic Flux Programme (OFP) mooring, located near BATS. The OFP mooring is four kilometers long and outfitted with large funnel-shaped sediment traps that are designed to collect continuous, time-resolved samples of particles settling through the water column. The OFP, is one of the longest running time-series in oceanography. Initiated in 1978, the OFP, has produced a nearly continuous thirty-year record of how the quantity and composition of material exported from the surface to the deep ocean varies over time-scales of weeks to decades. Studying oceanic particle flux is important because settling particles are the primary energy supply for all life in the ocean's interior and their flux regulates the removal of carbon dioxide from the atmosphere and the cycling of nutrients and many other elements that are associated with biogenic debris. Additionally, the residual flux material that accumulates in seafloor sediments forms a detailed record of past ocean history. OFP researchers use information gleaned from microscopic and chemical studies of the recovered sediment trap material to elucidate how surface ocean processes and climate patterns control particle flux and its temporal variability.

> "One of the major shipyard conversions was a new bridge deck which provides direct line-of-sight visibility for all deck operations... The reconfigured layout provides for a study area, used to examine and process shipboard data, for science discussions, and to conduct lectures for sea-going educational programmes."

Analysis of this material has produced a time-series of changes in ocean biology and chemistry spanning almost thirty years. The OFP time-series, along with the Hydrostation 'S', BATS and the Bermuda Testbed Mooring (BTM) programmes are the primary, ongoing research programmes located near Bermuda that will be serviced by the *R/V Bank of Bermuda Atlantic Explorer*. Together, these time-series programmes, funded by the U.S. National Science Foundation (NSF), support approximately half of the ship's operations. The breadth of information gathered by the time-series programmes and the logistical support provided by BIOS, in turn, attract many other scientists to conduct their studies off Bermuda.

Recovery and deployment of deep-sea moorings such as the OFP mooring are complex, demanding deck operations that use the large A-frame and multiple winches in simultaneous coordination, but the *R/V Bank of Bermuda Atlantic Explorer* is made for the task. During the conversion, her bridge and deck layout were enlarged and expressly reconfigured to optimally accommodate the multiple winches that are needed for deployment of deep-sea moorings, autonomous vehicles and advanced over-the-side oceanographic equipment. The 01 deck (just above the main deck) also has a specialized winch and starboard A-frame for the electromechanical cable of the Conductivity, Temperature and Depth (CTD) cast, the ship's scientific workhorse. On the main deck, a weather garage houses the CTD and other large over-the-side equipment and provides a protected area for collecting water samples. The garage leads directly into a main lab equipped with sinks, lab benches and a filtered, clean air hood for shipboard sample processing. Two additional labs are located on the port side opposite the main lab and provide space for refrigerators and freezers, larger laboratory instrumentation requiring dry, climate-controlled conditions and permanent installation of measuring systems. Off these labs, a small fume hood room provides a ventilated area for use of chemicals and an environmental room accommodates operations that require controlled temperature and light conditions. In each lab, navigational information and meteorological and underway surface ocean data are displayed. These measurements are supported by instruments that are maintained by the BIOS marine technicians.

One of the major shipyard conversions of the *R/V Bank of Bermuda Atlantic Explorer* was fabrication of a new bridge deck located mid-ship. The new bridge provides direct line-of-sight visibility for all deck operations, of utmost importance for safety and smooth over-the-side operations. The relocation of the bridge deck provides new space for an atmospheric lab container to be placed forward on the 02 deck below, thus enabling air sampling to be conducted without contamination from the ship or exhaust stacks. The reconfigured bridge layout provides for a small, multipurpose study area, captain's office and marine tech electronics room and lab on that deck. The study area, equipped with computers and whiteboard, is used to examine and process shipboard data, for science discussions, and to conduct lectures for sea-going educational programmes.

The ship's larger deck and laboratory spaces, and ample berthing capacity, provides significantly better operational capabilities as compared with the *R/V Weatherbird II*. Berthing for ship's crew to allow for a three-man watch system is available if needed, and a spacious galley and crew work areas improves living and working conditions – leading to a better-equipped and less fatigued crew. The vessel's greater flexibility in deck equipment configuration and the ability to carry multiple winches, vans and work boats simultaneously, allows for multi-investigator cruises that were not possible using the *R/V Weatherbird II*. The ample lab spaces can accommodate multiple activities while also allowing for semi-permanent installation of instrumentation without interfering with other science activities. The larger ship size provides a more stable platform that allows larger and more delicate lab instruments to be carried and the better sea-keeping ability greatly improves the ability to conduct operations in high seas.

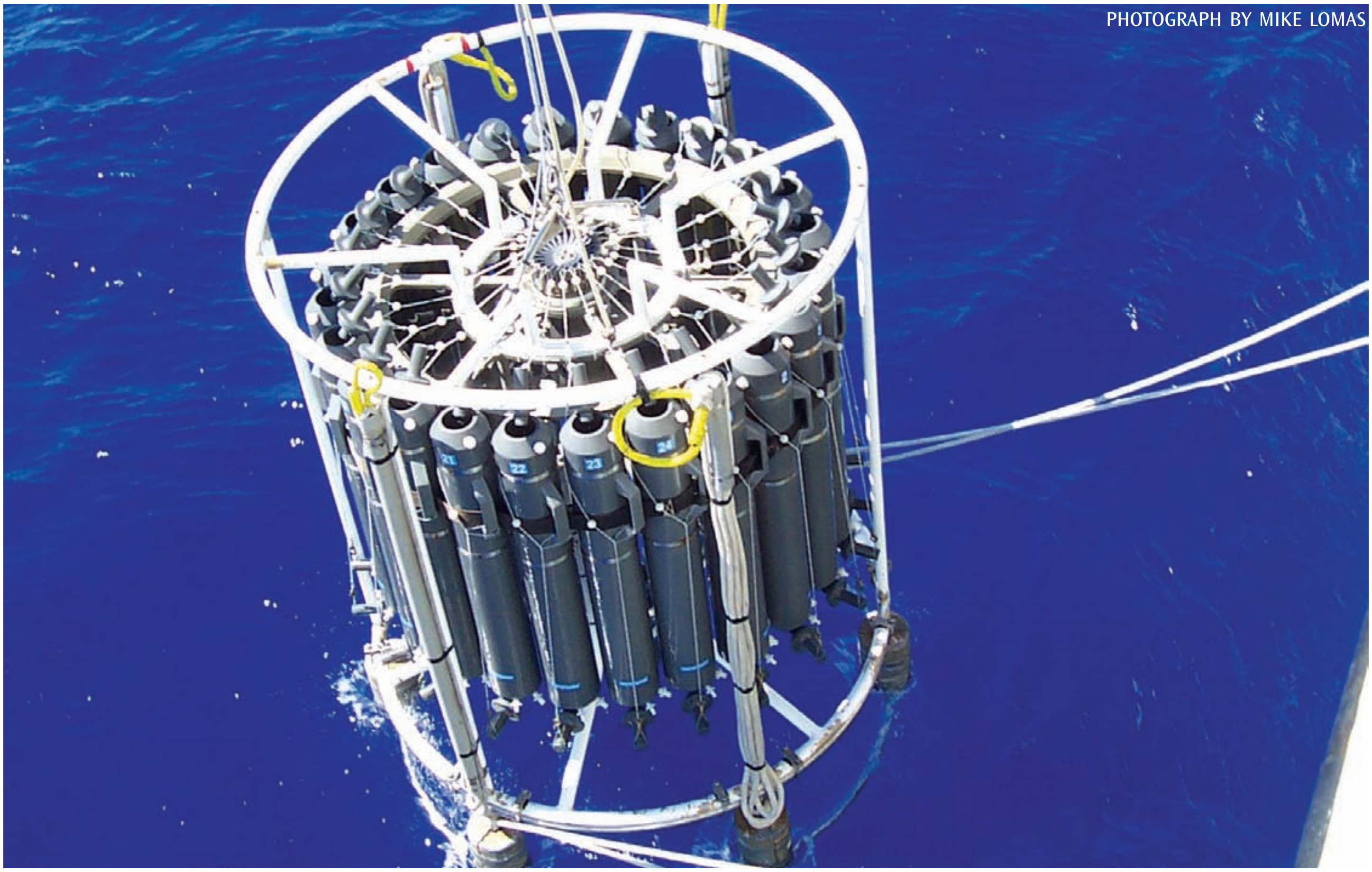
A major contribution to BIOS is the new educational capability made possible by the *R/V Bank of Bermuda Atlantic Explorer*. The large lab spaces and classroom area can easily accommodate groups of five to twenty for teaching and technical training, and the stability of the ship provides for an optimal teaching environment (i.e. fewer green faces). A berthing capacity of twenty-two scientists allows more students to participate in overnight and longer cruises. We at BIOS are currently developing new programs to fully exploit these new at-sea educational opportunities.

As we look to the future, it seems certain that oceanographic research will increasingly be conducted using a combination of sampling platforms including instruments deployed on moorings, autonomous vehicles such as gliders, and intensive ship-based operations. Scientific spaces on ships will need to house and service increasingly sophisticated over-the-side instrumentation and provide stable, climate-controlled conditions for at-sea experiments and fragile laboratory instrumentation. Multi-investigator research, often under the auspices of national initiatives, will demand increasing flexibility in accommodating diverse yet specialized requirements for deck and lab operations. As a BIOS scientist who has sailed on many research ships, I wholeheartedly welcome the new vessel and can say she is fully ready to serve the future needs of the oceanographic community as one of the best and most versatile intermediate-size ships in the U.S. fleet.

Dr. Maureen Conte is an Associate Research Scientist

The modified CTD garage and deployment/recovery station capable of handling the 24-place CTD rosette package used for BATS. (Top)

Education Coordinator Joanne Duyzer and student Elijah Simmons in the at-sea training room on a Waterstart Marine Science Internship Programme cruise. (Bottom)



PHOTOGRAPH BY MIKE LOMAS

Ocean Productivity

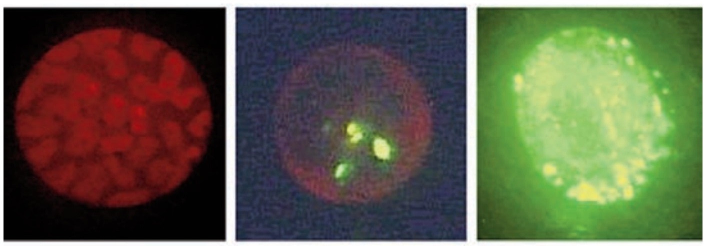
Organic Phosphorus in the Sargasso Sea

by Dr. Michael W. Lomas

A common goal of all biological oceanographers is to examine the distribution, abundance, and production of marine organisms and to obtain a basic understanding of the processes – biological, chemical or physical – controlling them. Despite over a century of biological oceanographic research we have only begun to scratch the surface of our understanding with regard to marine phytoplankton and bacteria. Such direct questions as what organisms are present and where they occur are difficult to answer. For example, it wasn't until twenty years ago that we identified the single most abundant plant species in the oceans, *Prochlorococcus marinus*, a single cell phytoplankton about 1/200th the thickness of a human hair. Ten years ago we identified a new domain of life called *Archaea*, a bacterial lineage that is genetically and physiologically very distinct from 'traditional' bacteria. Moreover, the metabolic activities of *Prochlorococcus* and other phytoplankton have a global impact as they account for about half of the global photosynthesis and are particularly important with respect to the long-term sequestration of carbon to the ocean interior. With limitations in our understanding at this basal level, perhaps it is not surprising that our ability to make future predictions about the state of the ocean carbon cycle is subject to very large uncertainties.

For over fifty years scientists at BIOS have been studying the Sargasso Sea, with the last decade seeing a significant increase in studies of microbial ecology and ecosystem function. These studies have shed light on previously unknown levels of bio-diversity, identified previously unknown pathways of light and carbon cycling in the ocean, and helped us to change long-standing paradigms about how the ocean ecosystem functioned. One such paradigm that appears to be changing for the subtropical North Atlantic Ocean surrounding Bermuda is that this ocean region may be limited by nutrient elements other than nitrogen. In marine phytoplankton, like terrestrial plants, carbon, nitrogen and phosphorus are the three most abundant elements, and sometimes nitrogen or phosphorus availability limits the growth of phytoplankton in the ocean. In the Sargasso Sea, dissolved inorganic phosphorus concentrations are very low, <5 parts per trillion, and vary only slightly from season-to-season. Despite these vanishingly low levels of inorganic phosphorus, rates of photosynthesis in the Sargasso Sea are as high as they are in the subtropical North Pacific where phosphate concentrations are ~100 parts per trillion.

So how can we explain this apparent paradox? One possible explanation, and the focus of a recently funded study, is that dissolved organic phosphorus (DOP) compounds, fifty-fold more abundant than inorganic phosphorus, are being assimilated within the Sargasso Sea to meet the phytoplankton demand.



Phytoplankton from the Sargasso Sea glow
'green' when utilizing dissolved organic phosphorus compounds

In fact, recent data from colleagues at the National Oceanography Center at Southampton suggests that there is a gradient of DOP compounds with higher concentrations in the regions 'upstream' from Bermuda. Not all phytoplankton species possess the ability to utilize DOP compounds, however, and this diversity in physiological capacity likely plays an important role in the biogeochemical patterns that we observe, as well as structuring the biological components of this ecosystem.

I, along with collaborators Sonya Dyhrman from Woods Hole Oceanographic Institution, and James Ammerman from Rutgers University, have been funded by the U.S. National Science Foundation to study the following questions: Are inorganic phosphorus concentrations in the Sargasso Sea limiting phytoplankton growth? Which DOP compounds are assimilated in the Sargasso Sea by phytoplankton, and what is the role of physiological diversity?

In May of 2006 we conducted a transect cruise from Bermuda to Puerto Rico with fourteen scientists and graduate students from four different institutions on BIOS's new research vessel the *R/V Bank of Bermuda Atlantic Explorer*. Along this transect, we sampled for inorganic phosphorus and DOP concentrations throughout the sunlit portion of the surface ocean, and probed single phytoplankton cells looking for evidence of DOP assimilation. We conducted manipulation experiments where we added phosphate and DOP and looked for changes in the assimilation of DOP by phytoplankton. We'll be repeating many of these measurements at the same stations in October of 2007 to determine if there is a seasonal pattern.

Our preliminary observations from this cruise suggest that patterns in DOP assimilation are driven primarily by patterns in phytoplankton abundance, as opposed to the commonly held belief that bacteria dominate the assimilation of dissolved organic compounds, even though the highest phytoplankton abundances are co-located with increased phosphate concentrations. Analysis of additional samples collected on this cruise is necessary, but these data strongly suggest that we may need to consider DOP as a primary nutrient for phytoplankton growth in the Sargasso Sea. Surprisingly, when we added phosphorus (both phosphate and DOP) in our manipulation experiments, there was no increase in total phytoplankton biomass. At first this seems contrary to our hypothesis, that phosphate is limiting phytoplankton growth, but we believe this lack of response was due to increased grazing pressure on phytoplankton. This outcome further highlights the need to develop methods that allow us to assess the physiological state of individual phytoplankton, thus separating organism responses, an inherent property, from ecosystem responses, an emergent property.

One such method that we are currently developing is the use of a fluorescent marker that can be quantified by our flow cytometer. This technique results in the accumulation of an insoluble green product in those phytoplankton (or bacteria) that are breaking down some DOP compounds. By measuring this 'greenness' over time, we can quantify how cells within a specific phytoplankton population are responding to changes in the environment, for example across natural phosphate gradients within the ocean, or to changes in our manipulation experiments. We plan to continue this 'single-cell' approach to biological oceanography with several additional projects in the works that would examine the interactive roles of iron and nitrogen in controlling growth of phytoplankton and the direct competition for nitrogen, phosphorus, and carbon between phytoplankton and bacteria.

Currently, within the U.S. and internationally, there are several very large science programs that are being developed around this process-oriented, single-cell approach to oceanography. With the purchase of the *R/V Bank of Bermuda Atlantic Explorer*, BIOS scientists (and our colleagues throughout the world) stand poised to take advantage of these new research programs and make large strides forward in our understanding of the changing ocean.

Dr. Michael W. Lomas is an Associate Research Scientist with BATS

Telomere Biology and Immortality in Sea Urchins

by Dr. Andrea Bodnar

Sea urchins have served as model animals for scientific research since the 1800's. They hold an important evolutionary position with respect to vertebrates and are more closely related to humans than many other model organisms. There is a large body of information about gene expression in the sea urchin and a number of genomic resources are available. Thus the sea urchin is an ideal organism for learning how pathways of genes and proteins regulate growth and development, with potentially profound implications for understanding human biology.

Because of their biological characteristics and recent technological developments, individual cell functions are particularly well understood in sea urchin embryos and are accessible to molecular, biochemical and cytological investigation.

In the Molecular Biology lab at the Bermuda Institute of Ocean Sciences we are using sea urchins as a model system to better understand the process of aging at a molecular level. In the Fall of 2003, we initiated a project to characterize the genetic differences in species of sea urchins which display a tremendous disparity in their natural lifespans. Our collaborator at Oregon State University, Thomas Ebert, recently reported that the red sea urchin of the Pacific (*Strongylocentrotus franciscanus*) is one of the earth's longest living animals, living in excess of 100 years, with no age-related decline in health or reproductive capacity. In contrast, the maximum lifespan of the common purple sea urchin of Bermuda, (*Lytechinus variegatus*), is estimated to be only 4 years. In an effort to understand the molecular mechanism underlying the differences in their longevity, we have investigated telomere biology in these long-lived and short-lived urchins.

Telomeres are repetitive DNA structures which cap the ends of chromosomes and play an essential role in maintaining genome stability. Telomeres shorten each time a cell divides and critically short telomeres signal the cell to permanently stop dividing. Therefore, the length of telomeres defines cellular lifespan. Some cells can re-build telomeres after cell division by activating an enzyme called telomerase which adds DNA back onto the chromosome ends. Telomere maintenance by telomerase is essential for continued cell division, immortality and the progression of cancer while telomere shortening results in cellular senescence and aging. In humans, telomerase is active in the early embryo but is switched off in most tissues as they develop. Without telomerase, telomeres shorten in numerous tissues throughout the human body with age. It is thought that this process of cellular aging caused by shortened telomeres contributes to many age-related degenerative diseases such as atherosclerosis, macular degeneration (a chronic disease of the eyes resulting in vision loss), impaired wound healing and impaired immune function. It is hypothesized that telomerase is turned off during human development to reduce the incidence of developing cancer, as a necessary step in the progression of most cancers is re-activation of telomerase.

Our results indicate sustained telomerase activity and maintenance of telomeres throughout the lifespans of both long- and short-lived species of sea urchins suggesting a lack of telomere-related aging. One might expect an increased incidence of cancer in long-lived species that do not repress telomerase activity but, remarkably, there are few reported cases of cancer in sea urchins and none in the long-lived species. This limited number is surprising given the intensity to which sea urchins have been studied as model organisms for the last century and the fact that some species, including *Strongylocentrotus franciscanus*, form the basis of a commercial fishing industry. This suggests that sea urchins rely on other mechanisms to prevent the formation of cancer, such as efficient cellular defense and repair mechanisms or efficient mechanisms to replace damaged cells.

> "...the red sea urchin of the Pacific is one of the earth's longest living animals, living in excess of 100 years with no age-related decline in health or reproductive capacity."

By comparing the biology of young and old, long-lived and short-lived sea urchins, we will begin to understand the molecular mechanisms which confer the tremendous longevity and resistance to acquiring cancer on different species of sea urchins. This information may eventually lead to identification of new targets for therapeutic intervention for age-related diseases.

Dr. Andrea Bodnar is a Senior Research Scientist in the Molecular Biology Laboratory

Mangrove trees grow in sheltered bays and have large prop roots which shelter a vast array of marine life, particularly juvenile fish. Mangroves are a disappearing habitat in Bermuda and many parts of the world. This shot was taken in Walsingham Pond looking up through overhanging branches and prop roots.

PHOTOGRAPH BY ALEX VENN

Ivy League

by Carol Gould

This June, a partnership between Princeton University and the Bermuda Institute of Ocean Sciences (BIOS) brought fifteen Princeton sophmores to Bermuda to study Marine Biology. Funded in part by Princeton's Environmental Institute

(PEI) and the President's Sophomore Initiative, the students spent the month here in Bermuda taking a rigorous lab and field course that will translate into a full course credit at Princeton.

The students enjoyed lectures from veteran BIOS teacher and coral researcher Samantha de Putron, cephalopod specialist James Wood, doctoral candidate Kim Holtzer, who led a lab on sea grass, and course TA Abel Valdevia, as well as Princeton Professor James Gould, who focused on marine animals and ecosystems. The course is unusual in that it is a hybrid between Dr. de Putron's popular Coral Reef Ecology class and a broader overview of the biology of other marine systems, all packaged into an intensive four-week time frame.

The wide range of the material and its concentration made the experience a rigorous one, but the students found the field work thrilling, and even fun. The difference between the neat pre-packaged labs they had taken previously and real-world, real-time research both intrigued and awed them. BIOS's facilities offer unparalleled access to Bermuda's wealth of varied ecosystems, from North Rock's intricate coral reef communities and wave-pounded rocky shore environment to Walsingham Pond's mangroves, whose submerged roots provide toeholds for countless invertebrate and algal species. Samples from each ecosystem, brought back to Scott Lab, yielded dozens of species, some newly recorded on the island.

Lectures also covered man-made (anthropogenic) changes that affect ocean communities, such as sewage and heavy metal pollution, and ocean warming. Several of the students who plan to go into public policy work found this concrete example of anthropogenic disturbance fascinating, and a possible basis for work in the public sector. Others hope to return next year as interns to assist BIOS staff in their research, forming the basis for their own Princeton Senior Thesis projects.

Next summer will bring a new group of Princeton sophomores, both for this course and an additional one in Oceanography, to be led by Princeton Geology professor Danny Sigman.

Carol Gould is the Author of The Remarkable Life of William Beebe: Explorer and Naturalist and the wife of Dr. James Gould

Princeton University students with Professor James Gould of Princeton University (top right) and BIOS scientist Dr. Samantha de Putron (second row, far right)

A Legacy of Caring for Bermuda

Since becoming a member of the Board of Trustees of BIOS in 1969, Idwal Wyn Hughes or Walwyn, as he is familiarly known, enjoys the longest tenure as a trustee of the institution. This steadfast dependability is one of Walwyn's hallmarks, as is his legacy of service to Bermuda. With his wife Betsy, Senator Hughes has been at the forefront of ensuring a sound environemnt for the island community of Bermuda.

Senator Hughes is an entomologist by training and a retired civil servant, and has been a long time proponent of environmental issues. He served many years as Director of Agriculture in Bermuda before becoming the Permanent Secretary of the Ministry of the Environment and then, the Ministry of Finance. Senator Hughes was appointed to the Senate in 1996, and continues to serve in that capacity.

Throughout his long and distinguished service to BIOS, Senator Hughes says he has always tried to represent the Bermuda perspective on the Board. "I was familiar with the Station from the time I joined the staff of the Bermuda Department of Agriculture in 1954 as a newly graduated entomologist and a good friend of Bill Sutcliff, the Director of BBSR at that time. I actually joined the Board of Trustees in the spring of 1969 – the same year that Wolfgang Sterrer became Director. I replaced Mr. Louis Mowbray on the Board, who was Curator of the Aquarium and had himself served as a trustee. I have been there ever since as Vice President, now Vice Chairman, having served with eight different Chairmen and three Directors."

Senator Hughes champions BIOS as a leader in research in ocean sciences research, committed to the protection and preservation of our environment. "Much of the work at BIOS over the period in which I have been involved has been hugely beneficial to Bermuda, such as the hydrogeological studies of the 50's and 60's, which enabled Bermuda to develop a ground water extraction programme; the Inshore Water Study of the 70's, which set the base line for so much of the inshore quality studies of today; and, the air quality programmes which have reassured Bermudians of the quality of their environment."

Senator Hughes attributes his staunch support of the Institute with his uncommon commitment on behalf of the local environment. "Having being educated in the natural sciences and worked most of my life as a public servant in these fields in Bermuda, I have always seen BIOS as a wonderful asset for this island. The research conducted at the institution covers a wide range of ocean sciences. For over one hundred years, our island has benefited from the work of the scientific team, as has the wider global community. The Institute's accomplishments have raised our island's profile internationally and provided training and employment opportunities in ocean sciences for many young Bermudians."

When asked what educational and research programmes most interest him, Senator Hughes replied, "Those which have a local bias, such as the Inshore Waters Study of the 1970's, the various coral reef studies of today and the great work done on the geology and hydrology of the island, which has had such an important impact on our fresh water resources."

In his role as a trustee, Senator Hughes hopes the BIOS scientific team will encourage the community to gain a better understanding and awareness of our natural environment, believing it will positively impact the lives of young people. "Betsey and I believe that summer programmes like the ones being led by J.P. Skinner are building on this success, as are the periodic lectures, open-houses and other outreach programmes. All of these efforts will help in getting the message out about the vital importance of caring for our island habitat and promoting a greater understanding of the fragility of both our land and marine environments."

When ask to consider the direction for the future of BIOS, Senator Hughes stated he believes the trend at research institutions is geared toward large, multi-discipline programmes, where he considers the significant financial resources for science to be. He adds, "With our deep ocean location and new research vessel, the *R/V Bank of Bermuda Atlantic Explorer*, BIOS should be well placed to take advantage of this trend."

However at the same time, he maintains an interest in preserving a place, and funding to support, the scientist working by himself or herself, or with a small team. He believes pursuing basic research in the biological sciences, which he sees as the foundation of BIOS over its long and distinguished history, should be maintained and enhanced.

"The BIOS of today is well known and respected by Bermudians and a great scientific resource for the Government and people of Bermuda. That is very satisfying to Betsey and me."

A Life of Commitment to Education

Bermudian Katherine Watson joined the BIOS Board of Trustees in November of 2003. From the beginning of her tenure with BIOS, she has worked in the trenches to raise money and awareness for the many educational and scientific endeavors of the Institute. Having been involved in volunteer and fund-raising work for many diverse charities, Mrs. Watson explains that her dedication toward BIOS stems from a common lifelong passion. "My husband Peter and I have been dedicated supporters of BIOS for many years. We have always been conscientious about the environment, as well as trying to gain a better understanding of our natural surroundings. As a family, our holidays have generally been outdoor activities, and this legacy carries on with our sons, so when asked several years ago to be on the Board of Trustee of BIOS, I was thrilled at the prospect."

Mrs.Watson has an extraordinary history of assisting non-profits throughout the island. Mrs. Watson has served on the Council on Alcohol and Drug Abuse Executive Committee, is a past chairman of The Council Partners Fundraising Campaign and a past governor of The Council Partners Charitable Trust. Currently she is on the committee of protectors of The Council Partners Endowment Trust and also Chairman of The Duperreault Fellowship Committee.

With this long record of service, rich in support of the community of Bermuda, Mrs. Watson is the ideal champion for BIOS's renewed educational efforts with the Bermuda Ocean Education Programme. The programme targets areas where BIOS can best serve the needs of middle school to high school students, their teachers and their parents. The goal is to inspire Bermudian students to embark upon a lifelong pursuit of learning. By encouraging a greater interest in science, math, and technology the Institute hopes to galvanize a greater interest in, and concern for, the environment surrounding Bermuda in this and future generations.

Mrs. Watson believes she can be a catalyst in reaching this goal: "During my time as a trustee I have come to fully appreciate what an intellectually stimulating organization BIOS is. I consistently come away with new knowledge of ocean sciences, renewed enthusiasm toward the preservation of the environment, and profound hope in the continued protection of our oceans by the next generation."

She explains her commitment to education on the island stems from having co-owned a large pre-school for sixteen years. In part, that's why she is committed to helping BIOS build a vibrant Bermuda Ocean Education Programme. "The programme is a wonderful opportunity to provide school children of all ages the chance to explore and better understand the natural environment that surrounds them," she said. Among those programmes is *BIOS Explorer*, the next generation of JASON for middle school children, as well as research projects for junior and senior school students, who have the unique opportunity to live on-campus during the summer and be young scientists in the Waterstart Marine Science Internship Programme. The Bermuda Ocean Education Programme also offers ocean science curriculum assistance to teachers in the classroom. All of these programmes support Mrs. Watson's belief that, "it is vital that the youth of Bermuda have a long-term understanding and appreciation of our fragile ecosystem. They will soon be the stewards of this precious resource. They must be prepared by society to accept that responsibility."

When asked about her son Matthew, who interned at BIOS in 2004, Mrs. Watson explains, "Our son was an environmental studies major at college and spent a summer volunteering under Dr. Ross Jones in the Marine Environment Programme. Among others, one particular project of note was producing a DVD with other interns on the Institute's Remote Operated Vehicle (ROV). It was a wonderful and exciting opportunity for him to get 'hands on' experience. He was already an experienced diver so he enjoyed applying that expertise as well. He now has a keen appreciation for the constant hours of lab work that is required to be a successful scientist in a research environment. He has taken that work ethic into his own field of endeavor."

With such a varied and dedicated background in philanthropy we asked what she would say to encourage others about taking a role in non-profit organizations: "I would encourage everyone to volunteer at a charity of their choice not only because of the skills they may be able to offer, but also because of what they will inevitably take away from the organization, including meeting a diverse group of committed people that share a similar interest. People give of their time and talents for many reasons, whether by helping Bermuda's ocean, youth, or social concerns. I would stress, it is vital to find the right match. It is also extremely important to commit the time needed to fulfill the goals of the organizations they have chosen."

BIOS has been extremely fortunate to have that commitment of both time, energy and support from Kathy and her husband Peter, who in many roles, have been so important to the community of Bermuda. We look forward to their continued involvement and influence in the future.

Endowing the Future of Science Research

Over the last fifteen years, BIOS has been ably served by one of its most dedicated trustees, Raymond Moore. Better known as Ray, he has provided clear guidance to staff and trustee alike in a myriad of different ways. He and his wife Diana have also invested wisely in the scientific and educational mission of the Institute over the years. They have always been steady contributors in meeting the unrestricted needs of the institution and have continually sought to underwrite the work of dedicated scientists who toil in endeavors that are often unappreciated. He's always had a great interest in the realm of science but it was the law where he found his passion.

"I qualified as a lawyer in 1952 and went straight out to Hong Kong. It seemed the place to be, especially after the war. There were very few western lawyers in Hong Kong at the time and I became the Hong Kong lawyer for a number of the major pharmaceutical companies. They included companies like Merck, which was just then developing the first synthesized diuretic. This got me very interested in pharmaceuticals and from there in genetics."

Mr. Moore has a special interest in the field of genetics and the work of several scientists that have been in residence at BIOS. "When I came to Bermuda, genetics was still a new science and I was fortunate to have acquired more than the usual layman's knowledge of it. After I became a Trustee, I discovered that the Bio Station, as we called it at that time, was engaged in genetic-related research through Dr. Hank Trapido-Rosenthal. It looked exciting as well as a meaningful to the scientific mission of the place. Hank and I became friends and from that emerged the personal interest in financing the research that he and others were doing."

To that end, Ray and Diana Moore have established a significant endowment, one of the largest ever funded in the history of BIOS. And the reason for doing so he says: "It was involved in the science which Hank was doing that enabled me to develop my interest. Alas, the science of genetics has progressed to the point that a layman cannot keep up. The discovery of the molecular structure of DNA has raised far more questions than it answered and I now find it very hard to understand most of the articles in *Nature* and *Scientific American* in this field."

Dr. Trapido-Rosenthal is now at the University of Hawaii, but Mr. Moore remains excited about the future at BIOS. "I find what Dr. Andrea Bodnar and Dr. Alex Venn (the researchers who followed Dr. Trapido-Rosenthal) are doing in the molecular biology laboratory fascinating and their intellect and enthusiasm encourages me to remain involved in helping with this research. Diana and I are just happy that our endowment support for BIOS helps to finance this important research in the field of molecular biology."

But it just wasn't money that Mr. Moore brought to the equation. He has been instrumental over the years in establishing relationships with other organizations interested in doing joint research with BIOS in this and other fields. He and Diana have had an abiding interest in the young students who journey to Bermuda to take coursework in the ocean sciences, and have assisted in raising funds for overseas students from all walks of life to attend BIOS summer courses.

His advice to those who are looking to expand their philanthropy: "Only support what you are genuinely interested in; otherwise any donation is just that, and does not enlarge the mind."

He believes the future of BIOS is resilient and the science practiced at the Institute to be compelling. What does he hope for BIOS: "Well of course I hope they have a strong endowment. In this world of growing competition for a diminishing public sector dollar, building an endowment is just absolutely critical for any long-term success. With a strong endowment you can develop a future free of the vagaries of searching for money that you need just to survive from year-to-year."

He went on to say, "Having a large endowment, and a fully-fledged graduate degree-granting programme with partner universities from around the world would just be perfect."

Ray and Diana Moore are tremendous role models to emulate. They place their energies and resources into those things they care about. We are fortunate to have them as members of the BIOS family.

Our Planet. Our Oceans.

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The 103-year history of achievement at the Bermuda Institute of Ocean Sciences would not be possible without the support of the donors who are part of the BIOS community. Year after year, BIOS Annual Fund donors have provided truly significant support for marine research and education.

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