Diving Into Marine Biotechnology
Your World/Our World describes the application of biotechnology to problems facing our world. We hope that you find it an interesting way to learn about science and engineering.

Development by:

Writing & Editing by:
The Writing Company, Cathryn M. Delude and Kenneth W. Mirvis, Ed.D.

Design by:
Snavely Associates, Ltd.

Illustrations by:
Patrick W. Britten

Science Advisor:
Judy Brown, University of Maryland Center for Marine Biotechnology

Science Reviewers:
Dr. Rita Colwell, Dr. Shaojian Du, Dr. William Jones, Dr. Dennis Maeder, Dr. Allen Place, Dr. Frank Robb, Dr. William Straube, Dr. John Stubblefield, Dr. Yonathon Zohar (University of Maryland Biotechnology Institute’s Center of Marine Biotechnology)

Special Thanks:
The PBA is grateful to the members of the Education Committee for their contributions:
John C. Campbell, SmithKline Beecham
Kathy Cattell, SmithKline Beecham
Cel M. Ciociola, PRIME, Inc.
Jeff Davidson, Pennsylvania Biotechnology Association
Alan Gardner, SmithKline Beecham
Anthony Green, Puresyn, Inc.
Mary Ann Mihaly Hegedus, Bioprocessing Resource Center
Linda C. Hendricks, SmithKline Beecham
Daniel M. Keller, Keller Broadcasting
Richard Kral
Colleen McAndrew, SmithKline Beecham
Barbara McHale, Gwynedd Mercy College
Jane Rae Merwin, The West Company
M. Kay Oluwole
Lois H. Peck, Philadelphia College of Pharmacy & Science
Jean L. Scholz, University of Pennsylvania
John Tedesco, Brandywine Consultants, Inc.
Adam Yorke, SmithKline Beecham
Laurence A. Weinberger, Esquire, Committee Chair

If you would like to make suggestions or comments about Your World/Our World, please contact us at:
Internet: 73150.1623@compuserve.com
or write to:
Pennsylvania Biotechnology Association
1524 W. College Avenue, Suite 206
State College, PA 16801
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**Question:**
What has the oldest, most numerous, most diverse, and least studied life forms on earth? What covers almost three-fourths of our planet but is our greatest untapped resource? Where do creatures thrive in temperatures of 121 °C (250 °F)? What could provide food to the starving people of the world but is having its supplies endangered by over-harvesting and pollution?

**Answer:** The sea, the sea, the beautiful, mysterious sea.

The sea remains mysterious because it is so hard to explore. It is wide, deep, and dark, with dangerous waves and icebergs on the surface and incredibly high pressures below. The ocean floor has mountains, canyons, and volcanoes, where temperatures range from below freezing to above boiling. Exploring these areas was impossible until we developed technologies such as deep-sea submersibles, scuba, sonar, lasers, videos, and satellites. Still, studying marine biology remains a challenge because so many creatures live in strange, inaccessible places, and we can’t keep them alive and thriving in the artificial conditions of a surface laboratory. Because of these difficulties, we have probably catalogued fewer than 5% of marine organisms, much less studied them in depth.

Fortunately, biotechnology opens a another window on marine life. It allows us to inspect organisms at a molecular and genetic level – and to do so quickly, before human activity reduces the incredible biodiversity of life in the sea.

Why is this study so valuable to us? Scientists have always found useful products produced by living plants and animals. The ocean environments are completely different from our own, and marine creatures probably produce a whole different set of useful products – a treasure chest full! Now researchers are looking to the sea for everything from a cure for cancer and AIDS to less-polluting industrial chemicals, and much, much more.

We are also improving our knowledge of the world at large by studying marine creatures. The microscopic life in the sea holds clues to the origin of life on earth – and to global cycles of oxygen, carbon, and nitrogen. Furthermore, we share many genes with marine organisms, so we can learn about ourselves by studying them. What helps them stay healthy may also help us. Likewise, what hurts them may harm us.

This issue of Your World/Our World shows how biotechnology is making the mysterious sea more understandable and useful to us, while also allowing us to protect its precious resources. So put on your snorkel and mask, and dive into our underwater biotechnology laboratory to explore this last earthly frontier.
Biotechnology and molecular biology can shed light on the innermost life processes of the organisms that live in the sea's deep, dark, inhospitable places. Here are a few techniques that give us a peek through that porthole.

**Proteins and Enzymes**

All organisms produce proteins to build cells and perform the functions of life. Certain proteins, called enzymes, carry out biochemical processes within cells.

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Scientists are studying these and other organisms for their scientific and medical value.

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**Top to bottom, left to right**

**Coral Reefs** are to the sea what tropical rain forests are to the land: teeming with species that may have medicinal value, yet vulnerable to destruction by human activity.

**Puffer Fish** secrete a deadly poison that scientists use to study neuromuscular transmission in people.

**Striped Bass** could help feed a hungry world. But they are declining in the wild, and they are hard to breed in fish farms. Genetic research may overcome these difficulties. (Pages 8 – 9.)

**The Sea Sponge** has defense mechanisms that could someday help you reduce inflammations, fight bacterial and fungal infections, and perhaps cure cancer. (Pages 6 – 7.)

**Sharks** live in a microbe-infested world, so they secrete a steroid disinfectant that kills germs on contact. Some sharks contain a substance “squalamine” that cuts off the blood supply to tumors and is being tested for treating cancer.

**Crabs and Shrimp** have molecules with many uses in every day life and science. (Page 7.)

**Sea Turtles** are exposed to chemicals that may interfere with their egg development. These chemicals may harm mammals as well. (Pages 10 – 11.)

**The Squid’s** nerve axons serve as a model system in neuroscience.

**Submersible Vessels** help us explore the deep and collect samples for further study. We can also learn about past climates and geological events on earth.

**Thermophiles** thrive near the volcanic heat of these deep-sea vents, and we might be able to use these unusual organisms for medicine and industry. (Pages 12 – 13.)
We use the proteins and enzymes as ingredients in everything from medicines to soap. Analyzing their chemistry teaches us about their roles in the organism’s biology – and their potential benefits to us.

**DNA and Genes**
DNA is the information molecule that tells each organism how to develop, giving each cell its special characteristics. DNA forms genes, which are sequences of codes that “spell out” the recipes for proteins. We can learn about a protein by analyzing its DNA sequence. In addition, we can study which genes become active in response to a threat from a predator, or a change in temperature and nutrients, or pollution. By tracking the molecular activity of marine organisms, scientists can study their interaction with the environment and gain insights into changes in global climate and pollution.

**Classification**
We classify organisms to tell how they are related to each other. Scientists used to focus on how organisms looked. If they looked similar, they were probably related. Genetic comparison gives us more accurate classifications. It relies on the fact that all organisms share some common genes, such as a gene involved in assembling proteins. Variations in that gene provide a yardstick for how closely organisms are related. This yardstick gives us a new panoramic view of the world’s “family tree.” It also gives us a shortcut to identifying unstudied marine organisms and screening them for useful products.

**PCR (polymerase chain reaction)**
Single fragments of DNA are too tiny to manipulate in the laboratory. They need to be amplified just as a stereo needs an amplifier to make a sound signal loud enough to hear. PCR is a way of making many exact copies or clones of a tiny section of DNA, which can be used for further research.

**Fermentation**
Scientists can insert a gene that produces a valuable marine protein into the DNA of an easy-to-grow bacterium like *E. coli* or a yeast cell. These “workhorse” microorganisms then reproduce in fermentors and act like mini-factories, churning out the protein. Fermentation allows us to produce the valuable natural products even when we cannot grow the whole organism – or when we do not want to harvest proteins from a rare creature living in a fragile marine ecosystem.

**Antibodies**
When a bacterium or virus invades your body, your immune system produces an antibody that latches onto that microbe to destroy it. Scientists use antibodies to “see” a hard-to-detect marine microbe: They tag the antibodies with special labels that identify the microbes when the antibodies lock onto their target.
Welcome to the ocean superstore, the showcase of many present and future products made from marine life. Most of these items weren’t actually taken directly from the sea. Rather they were, or will be, “inspired” by products found in the sea.

The Pharmacy Aisle

Our oldest medicines were leaves, flowers, and barks, and many modern drugs come from such natural products. Organisms produce proteins, hormones, starches, and other chemicals to help them survive in their environment. These products often have a different effect in human beings. For example, the rattlesnake’s poison contains chemicals that lower blood pressure in people. Until now, most products used for drugs came from the land rather than the sea. But that may soon change.

How do you find new medicines in the sea? One way is to follow clues of nature. For example, scientists noticed that a sponge from the coral reefs of the Pacific, Luffrariella variabilis, looks good enough to eat, but predators leave it alone. Maybe the sponge uses the tricks of land plants which can’t run away from their predators. They defend themselves by producing bad-tasting or toxic chemicals. Scientists tested this hypothesis by studying the sponge’s slimy secretion. Sure enough, it contains toxins that drive predators away – as well as a chemical that reduces inflammation in people. This chemical prevents the release of an “arachidonic” (ah-rak-id-on-ik) acid that plays a key role in the biochemical processes of pain and swelling. Aspirin also works by disrupting the production of this inflammatory acid. Scientists are adapting the chemical to develop new anti-inflammatory ointments for treating bee stings, poison ivy, arthritis, psoriasis, and gout.

Scientists also test the products of marine organisms to see if they stop infections, strengthen or weaken the immune system, or fight cancer. They are looking for clues to treat deadly infectious diseases such as AIDS, Ebola, and drug-resistant forms of tuberculosis.

As you can imagine, searching for new medicines in the vast ocean could take forever if you simply followed nature’s clues. Fortunately, genetic screening gives scientists a faster, more precise way to search. Suppose you find a species that produces a weak anti-cancer protein. Perhaps one of its cousins might produce a more potent protein. How can you find that cousin? In the old days, you would compare their physical structures. Today, you compare their genes. The more similar the genes are, the more likely they produce a product with similar functions. Computers can analyze millions of genes and target species with anti-cancer proteins. In this way, you can screen thousands of species to find the few that may be worth studying further. Scientists expect these methods will speed up our search for new medicines from the sea – and fill the pharmacy shelves.
Marine biologist Bill Jones explains how bacterium *Acinetobacter* helps clean up oil spills and degrease these shoe parts after they are taken from their molds.

**The Cleaning Aisle**
Check the labels of the soaps and detergents in this aisle. Most of them list surfactant as an ingredient. A surfactant reduces the surface tension of the water at the dirt’s surface, loosening the dirt so it can be washed away. Certain organisms produce natural soaps called biosurfactants. One marine microbe named *Acinetobacter* put on a great show following the 1989 Exxon Valdez oil spill off the Alaskan coast. Its biosurfactant loosened the oil from the sand and rock so the bacteria could break down the oil. Now, *Acinetobacter* is grown commercially to help clean up oil spills. It also has a potential job in another industry. The Nike shoe factory coats the molds for its running shoes with an oily compound so the plastic shoe parts won’t stick. Afterwards, the parts have to be cleaned. Rather than using chemical solvents to dissolve the grease, the company is experimenting with *Acinetobacter*, the environmentally friendly cleaner-upper.

**The All-Purpose Aisle**
Many of the foods and drugs in this superstore contain additives derived from shellfish. Their shells contain a long molecule called chitosan (kite–o–san) that is a kind of starch or polysaccharide. Chitosan is a molecule of many uses. It acts as a gel and thickening agent in foods like ice cream. It draws out impurities from substances, so it helps purify materials in research laboratories and treat drinking water. It absorbs fat, so it is used in alternative diet medicines. New research shows it breaks down the barriers between cells in the stomach and intestines, so it may be used to help your body absorb medicines more completely. It gets inside cells, so it may become a delivery vehicle for gene therapy, taking “repair” genes into a cell's DNA. It may also create a new type of adhesive that hardens under water. Dentists could use such an adhesive on braces and to glue teeth back into the jaw after being knocked out!

**GRIND & FIND**

Biotechnology allows us to sample and test huge numbers of marine organisms for useful products. Scientists then reproduce those products synthetically rather than harvesting them directly from the marine environment. Here’s the process for searching for medicinal proteins:

1. Extract the proteins produced by each organism that is sampled using a physical (perhaps grinding) or chemical procedure.
2. Test the proteins to see if they show activity against cancer cells, inflammations, and/or microbial infection.
3. Identify the genes that encode the active proteins, and search for other organisms with similar genes. Repeat steps 1 and 2 until the most effective protein is found.
4. Take a copy of the gene for the most effective protein and insert it into “workhorse” organisms. These workhorses then produce the protein when they are grown in large numbers. The proteins are grown first in a small flask, then the whole process is “scaled up,” and the proteins are grown in huge fermentation tanks.
5. Purify the active proteins from the fermentation process and prepare them into a final product.

Thousands of organisms are tested as in steps 1 & 2, but VERY FEW go through steps 3-5.

Photo by P.A. Shave, Marine Biology Laboratory

Mollusks helped cloak the ancient Phoenicians in their royal purple robes, thanks to a dye derived from their slime.
Fish for a Lifetime
An old saying goes, “Give people a fish and they can eat for a day. Teach them to fish and they can eat for a lifetime.” As the world’s population grows larger, the saying rings truer than ever. Fish provide a healthy, nutritious meal, but the ocean is so overfished that many nets come up empty. Pollution in the coastal waters where fish spawn (breed) has also reduced the supply of fish. Luckily, the aquaculture “fish farm” industry has come to the rescue, breeding food fish in captivity to increase their supply. Unfortunately, one popular and nutritious food fish – the striped bass – does not like life in the farm. It won’t spawn in captivity.

Scientists are learning why not by studying the zebrafish. This little fish zips around many household freshwater aquaria. The zebrafish is easy to breed in captivity and matures quickly, so it provides a wonderful model for studying both fish reproduction and developmental biology. Now it is also helping to solve the striped bass’s reproductive problems “down on the farm.”

Model Species: Different Stripes, Similar Genes
The zebrafish and the striped bass have different stripes, sizes, and life spans. Still, they are genetic cousins. They start out traveling the same developmental path, controlled by similar genes.

All vertebrates, from fish to humans, have a remarkably similar early development. That’s because we all have an almost identical set of “master genes” that govern early development. Scientists call these master genes homeodomain genes because they all share a very similar region, the homeodomain, in their sequences. (“Homeo” means “same” in Greek, and a “domain” is a kind of home). You can think of homeodomain genes as highways with toll booths. The highways (genes) are different, but they have an almost identical toll booth section (homeodomain region).

Homeodomain genes work like an electrical circuit breaker in a house, controlling the action of other genes further down the line.

One set of homeodomain genes controls the reproductive pathway. As species develop along this pathway, they acquire different reproductive characteristics. Fish spawn, birds lay eggs in a shell, and mammals have live births. Among fish species, further differences appear in the reproductive wiring. Somewhere down that reproductive circuit is a gene that gets switched off when a striped bass lives in captivity.
Scientists are trying to coax the striped bass to reproduce in captivity. If they can isolate the gene that switches off in the striped bass, they can transfer that gene into the zebrafish. By observing how that gene affects the zebrafish, scientists will learn more about how it behaves in striped bass.

Scientists already know that in captivity the striped bass does not release enough of a hormone, which is a molecule that acts like a messenger in the body. This particular hormone signals reproduction, so without enough of it, the fish does not breed. Now that scientists know more about the gene that encodes that hormone, they can mimic its function by increasing the hormone level in other ways. They are also trying to make striped bass spawn at an earlier age, and even to spawn year round instead of just once a year. Eventually, scientists hope to transfer the zebrafish’s natural switch gene into the striped bass to try to correct the reproductive problem from the start. Splicing the zebrafish gene into the site that gets “shut down” in captivity may allow the remaining reproductive circuitry to function as normal. If these efforts succeed, the world will have a much more dependable supply of healthy, nutritious food fish.

RISK BENEFIT

The aquaculture industry has transferred genes into fish to make them grow bigger than normal, to survive in waters colder than their natural habitats, and to resist disease. Scientists keep them in a closed system so they won’t breed with wild fish. What might happen if the fish escaped their farms? Is this a risk worth taking in order to provide more food for the world?

Crabby Detectives

Americans are eating more seafood these days. Naturally, the seafood industry has grown dramatically – and so has seafood fraud. Some merchants misrepresent common fish for more desirable, higher priced ones or they call soy-based products “crab meat.” Others sell illegal seafood, such as whale meat. Now, the same technology that brought DNA fingerprinting into the courtroom can help food inspectors detect the deception. They can take samples of the seafood, extract its DNA or the proteins encoded by the DNA, and find out what species it really is. Once again, biotechnology helps fight crime and protects the average citizen!

What advantage does aquaculture have over livestock farming for the environmental resources of a country? Consider the land, water, and feed required to raise farm animals, and the organic waste produced.
Sea turtles have to be clever to be fertile – so their species will survive. The hatchlings leave their nests on the sand and waddle into the waves to spend their lives at sea. When it’s time for the female to lay her average “litter” of over 100 eggs, she returns to her birthplace and builds a nest.

Trouble in the Nest
Things have gotten tougher for the turtle in recent years. Often, the female returns to her birthplace to lay her average “litter” of over 100 eggs, she returns to her birthplace and builds a nest.

Mother Nature’s Enzyme
When the temperature in the diamondback terrapin’s nest is above 30°C, all the hatchlings usually become females. Below 27°C, they will all be males. (The nests in the middle temperature range produce a mix.) Higher temperatures switch on a gene that produces an enzyme called aromatase. Aromatase converts a male hormone (androgen) into the female hormone estrogen. Estrogen tells the embryo to develop ovaries and become female. At cooler temperatures, the gene for aromatase is not switched on, so no estrogen is produced, and the embryos develop into males.

However, scientists found that some nests kept at the cooler temperature are producing females instead of males. To find out why, they coated some eggs in cool nests with estrogen. The eggs absorbed the estrogen and developed into females. Even though the embryo cells did not produce their own estrogen, the estrogen from the outside “environment” had the same effect as natural estrogen would have had.

Thus, changing the estrogen levels in the embryos overrides the natural temperature control that...
The debate about global warming is really heating up! If world temperatures really are rising, how might turtles be affected?

determines sex. Some scientists fear that pesticides and other chemicals in the environment may be jump-starting the estrogen reaction in the same way.

**Chemicals Mimicking Hormones**

Hormones are shaped like keys that can lock into a keyhole or receptor on the cell membrane. When a hormone locks into the receptor, it can send a message inside to the DNA. This message tells the DNA to turn on a certain gene, like turning on an ignition key to start an engine. It so happens that many human-made chemicals have a very similar shape to the estrogen molecule, so they “mimic” estrogen in a cell. There are at least 50 such chemicals that mimic estrogen. They are used in everything from agriculture to making plastic and paper, so they are just about everywhere in the environment.

These chemicals accumulate in animal tissue, where they can scramble the genetic instructions for the cells. This scrambling is especially bad in embryos, since fetal cells are extremely sensitive to the signals that tell them how to develop. In turtles, the effect is powerful enough to override the temperature control, producing too few males.

**The Human Connection**

Why should you care about the turtle’s fertility problems? Well, you may care about the survival of endangered species. If there aren’t enough males, the turtles will soon become extinct. But the turtle’s troubles may hit closer to home. Other species are exposed to the same chemicals in the environment. In our mammal cousin, the otter, the male reproductive organs decrease in size as the concentration of pesticides in their bodies increases. Perhaps these chemicals have overridden a mechanism in the development of otters. If so, could they be affecting other mammals? Some scientists suspect that human sperm counts have declined worldwide because of these chemicals. Research into these issues continues, and you can follow their development in the news.

One thing is clear: Biotechnology and molecular biology can help us understand how our bodies react to hormones and chemicals at a molecular level. Scientists have developed systems of cells that produce the same response to hormones as a whole organism. They can use these systems to test the effects of chemicals in the environment. By studying how turtles are affected, we may find out how to protect them – and the world at large – from the onslaught of estrogen-mimicking chemicals.

**The Dooming of a Species**

Below 27˚C, the embryos do not produce estrogen and should become males.

Estrogen-mimicking chemicals from the environment override the temperature control gene, so the embryos become female.

Without enough males, the species cannot survive.

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*Risk/Benefit*

We use so many products in our daily lives that contribute to estrogen-mimicking chemicals in the environment: paper, plastic, garden products... In addition, livestock is often given estrogen to stimulate growth, and we absorb that estrogen when we eat meat. Do the benefits we get from these products outweigh the harm we might be doing to other species and ourselves?
Come aboard a submersible as we sink into the freezing water toward the ocean floor. Our lights cut through the blackness and shine on weird creatures that get their energy from minerals in the water rather than sunlight. Up ahead looms a steaming chimney, spewing out sulfuric liquids from volcanic activity within the earth’s crust.

Inside the chimney walls, where it is 121°C (250°F) and the pressure is 200 times that at sea level, some microbes contentedly eat sulfur while others give off methane gas. How do they keep from getting cooked, not to mention crushed to death? And why do they choose to live there?

In fact, they like these conditions and would die in less extreme environments like our own. Indeed, their environment probably resembles our planet when life first began millions of years ago. We call microbes that still live in such extreme conditions extremophiles. The Greek word “philo” means “lover”. The ones that live in these hot vents are thermophiles. (“Thermós” means “hot” in Greek.)

Extra-Stable Enzymes

Extremophiles may be very useful to us because they produce enzymes that act as “survival suits” against extreme conditions.

All enzymes consist of building blocks called amino acids. Chemical bonds join these amino acids together into a three-dimensional shape, which allows the enzyme to interact with cells and molecules. Thus, the enzyme’s function depends on its structure. Extreme conditions, such as high temperature, acidity, or alkalinity, can break the bonds that stabilize an enzyme’s structure. When this happens, the enzyme no longer functions and may even fall apart. Enzymes from extremophiles, however, continue functioning partly because they have extra stabilizing bonds to hold them together.

This difference has great commercial significance, since we use enzymes to promote chemical reactions for industrial and commercial applications. For example, enzymes help convert corn syrup to sugar for soft drinks and improve the cleaning power of laundry detergents. Unfortunately, many enzymes stop working in the extremes of industrial processes. But the extremophile enzymes, outfitted with their extra-stable chemical bonds, keep on going... We learned just how useful the durable enzymes can be from the very first extremophile to be discovered, a thermophile that lives in the hot pools of Yellowstone National Park.

Hot Bugs in Yellowstone

No one thought it was possible for organisms to survive in boiling temperatures until a very surprised scientist discovered the bacterium Thermus aquaticus (for “hot water”)
The same volcanic forces form the Yellowstone hot pools and deep-sea vents, and the same extremophiles live in both places. Thus, although the hot pools are not marine (ocean water), marine biologists use Yellowstone as an extremophile laboratory because it is so much more accessible than deep-sea vents.

Scientists are studying the structure of other extremophile enzymes to learn more about their unique properties. They hope to find other amazing applications that will bring more technological breakthroughs. For example, extremophiles can protect and repair their DNA from heat and acid. Perhaps their enzymes can be tailored to protect us from DNA damage caused by toxic pollutants, radiation, and other harmful elements. This protection could prevent cancer and other diseases. So now, when scientists go “shopping” for new genes to develop medicines and industrial products, they check out the “catalog” of extremophile genes and proteins, and they look to the oceans!

Many extremophiles belong to a branch of life called Archaea. The word “Archaea” comes from the same root as “archaeology,” which is the study of ancient things. Scientists think that Archaea are so ancient that they evolved when the earth as we know it was still forming. But we did not know Archaea existed before scientists studied the Yellowstone hot pools. Once people began to look for such life forms, however, they found them everywhere, not just in extreme environments. In fact, Archaea may be the most common organisms in the ocean.

When Archaea were first discovered, scientists did not agree on how to classify them. Biotechnology solved the dispute. Analysis of their genes showed that about one half of their genes are completely unknown to us. Many of these unusual genes probably build their survival suits for their extreme environments.

Marine biologist Judy Brown collects samples from a hot pool in Yellowstone.
Sunny became interested in marine science when she was in middle school in China. “We lived on a harbor and I loved the beauty of the animals and the blue colors of the sea water,” Sunny muses. She planned to major in marine environmental science in college. However, her parents wanted her to become a doctor, so she studied pre-medicine with a major in biochemistry at the Nankai University in Tainjin. “In China it is traditional for parents to influence the career choices of their children,” Sunny laughs. “But I still wanted to follow my dream, so I accepted a graduate fellowship at the University of South Florida.”

Sunny earned her Ph.D. and now works in a research laboratory at the University of Maryland Biotechnology Institute’s Center of Marine Biotechnology. This research team uses biotechnology to study how global weather patterns such as El Niño contribute to the spread of cholera. Cholera is a life-threatening disease carried by a waterborne bacterium Vibrio cholerae. Cholera outbreaks often occur during the summer in areas near stagnant estuaries (bays). The El Niño weather pattern distributes more warm, moist air around the globe, affecting the circulation and temperatures of estuary waters. These changes may increase the numbers of V. cholerae and make them more deadly.

“People might not know that the cholera bacterium is in their water until the disease strikes,” Sunny explains. “That’s because it’s hard to detect using standard water quality tests. Sometimes the bacterium will not grow in cultures, so laboratories cannot detect it. Also, many strains don’t carry the form of the gene that causes disease. So even if we detect the bacterium, we still don’t know if it will cause disease. Luckily, we can use biotechnology to overcome these problems.” In one method, the scientists run water through a filter to collect all the bacteria. They attach specially tagged V. cholerae antibodies that allow them to detect that bacterium in the water. Then, they use PCR and other techniques to analyze this bacterium to see if it is a disease-causing strain.

Sunny’s team studies samples of V. cholerae collected from outbreak areas around the world. They isolate and culture disease-causing strains of the bacterium and compare their genetic structure to strains in other areas. This analysis may show that a disease-causing strain is moving into a new area. “If it is, we can warn the people there to take preventive measures, such as boiling or filtering their water,” Sunny explains. “We’re also trying to link the presence of V. cholerae in water samples with changes in the water’s characteristics, such as its salinity, temperature, and levels of plankton. We use satellite data to help get these measurements. It’s really cool to combine technology from space with genetic analysis of marine organisms to save human lives!”

This Coastal Zone Color Scanner image of the Bay of Bengal in India shows a plankton bloom associated with cholera outbreak.
ACTIVITY:

The ocean contains many environments that are completely different from our own: to start with, it’s salty. In many places, it’s way too cold for our comfort, but organisms from whales to algae to microbes call it “home sweet home.” Others find the high pressure at the ocean floor cozy. But extremophiles don’t just live in the sea. The chart to the right shows some of the places they like.

In this activity, you will recreate some of these extreme conditions and see how they affect the proteins in a “normophile” cell. You will use a cell that is big enough to see without special equipment: a chicken egg. Could this cell survive in an extreme environment?

Materials
- 5 raw eggs, cracked open carefully so the yolk remains intact
- 5 bowls or cups to hold the raw eggs and the liquids below

About 10 ml of the following:
- A 9% solution of salt (9 grams salt to 100 ml water);
- A 9% solution of bleach (pH 12)
- Vinegar (acetic acid, pH 4.5)
- Boiling water

Focus
How can you simulate the following extreme conditions: high salinity, alkalinity (high pH), acidity (low pH), extreme cold, and extreme heat?

Hypotheses
What do you think will happen to the proteins in a raw egg when they are exposed to those five extremes? Do you think the proteins can protect themselves from damage? Can they repair the damage once they are removed from the extreme condition?

Experiment and Find Out
Develop a way to test your hypotheses using the materials suggested. Write up your procedure, record your data, and develop a theory about the nature of normophile proteins.

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<th>Location</th>
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**Resources**

**Sail The Seas**
The 1998 World’s Fair in Lisbon, Portugal is devoted to the ocean. If you can’t make it to the fair, you can take a virtual trip and learn about the marine world along the way. Pick your travel plan to this permanent learning and entertainment center:

1) Fly by space shuttle and use remote sensing technology to study whale migration and the ecological system that supports this largest mammal on earth. You can also study the ocean’s weather: [www.seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/oceanography/](http://www.seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/oceanography/)

2) Sail across the ocean on the research vessel Eagle. Use navigational tools and research instruments to study whales. For terrific National Geographic images, visit: [chili.rt66.com/hrbmoore/NGSImages/NGS.html](http://chili.rt66.com/hrbmoore/NGSImages/NGS.html)

3) Submerge yourself in the Jason, an underwater exploration vessel that explores the deepest parts of our oceans. Visit hyperthermal vents, climb mountains and canyons, and see marine shows: [www.jasonproject.org](http://www.jasonproject.org)

4) For video clips of thermal action, see [www.pmel.noaa.gov/vents/geology/video.html](http://www.pmel.noaa.gov/vents/geology/video.html)

5) Lisbon at last! Once at the permanent virtual World’s Fair, follow a student guide to the Ocean Supermarket display of all the everyday products derived from the sea. Visit the world’s largest and most modern aquarium: [expo98.pt.pt.default.html](http://expo98.pt.pt.default.html)

**Go Surfin’!**
- Thermophiles: [whyfiles.news.wisc.edu/022critters/hot_bact.html](http://whyfiles.news.wisc.edu/022critters/hot_bact.html)
- Marine pharmacology: [wwwcsgc.uscd.edu/communication/MP.html](http://wwwcsgc.uscd.edu/communication/MP.html)
- National Cancer Institute’s Division of Natural Products “Cancer Web:” [www.graylab.ac.uk/cancernet/600733.html](http://www.graylab.ac.uk/cancernet/600733.html)
- Columbus Center for Marine Biotechnology: [www.columbuscenter.org](http://www.columbuscenter.org)
- Marine Biological Laboratory: [www.mbl.edu](http://www.mbl.edu)
- Woods Hole Oceanographic Institute: [www.whoi.edu](http://www.whoi.edu)
- National Ocean Science Bowl: [core.cast.msstate.edu/nosb.html](http://core.cast.msstate.edu/nosb.html)

**Beach Reading**
*Planet Ocean: Making Sense of Science Series,* by Brian Bett
*Start Exploring Oceans: Discover the Wonders of Life Underwater,* by D.M. Tyler and J.C. Tyler
*Underwater Wilderness: Life in America’s National Marine Sanctuaries and Reserves,* by Charles Seaborn
*Young Scientists Undersea,* by C. Pick

**Dear Students:**

This issue on marine biotechnology allows us to dip beneath the surface of our planet’s oceans and discover amazing worlds populated by a tremendous variety of fish, mammals, and microorganisms. We hope you enjoy exploring this world and learning about marine biotechnology research.

We hope that having a better understanding of the research taking place in this and other rapidly developing fields of biotechnology will encourage you to study science and mathematics. Perhaps you will select biotechnology as a career and help discover tomorrow’s science.

Sincerely,

Jeff Davidson
Executive Director, Pennsylvania Biotechnology Association

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