EXTREME 2004

Exploring the Deep Frontier

Produced by the
University of Delaware College of Marine Studies
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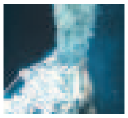
What's Inside

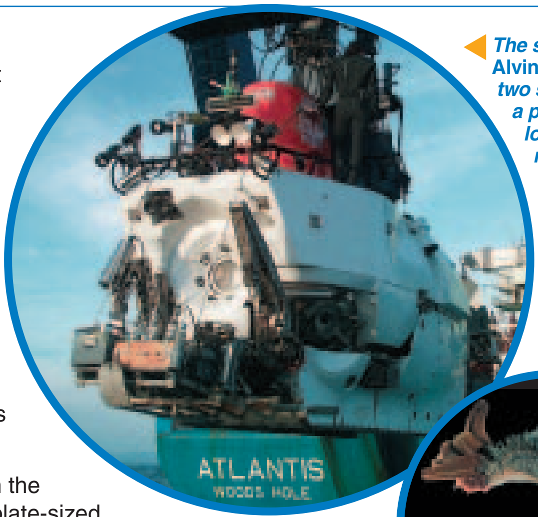


Geology: Find out what a hydrothermal vent is and how it forms.

Biology: Take a look at some of the strange creatures that inhabit the deep.

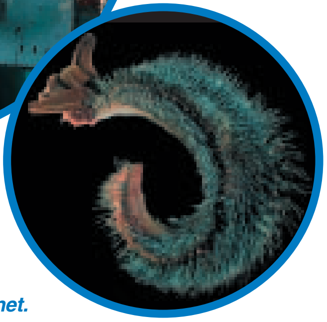
Technology: Learn more about the submersible *Alvin* and the history of deep-sea research.

The ocean's greatest depths once were believed to support only a few organisms. But in the past 25 years, intrepid explorers, diving to the seafloor in high-tech submersibles, have disproved that notion. They have discovered that a number of unusual creatures inhabit some areas of the deep sea — at underwater geysers called *hydrothermal vents*.



The submersible Alvin, *with a crew of two scientists and a pilot inside, is lowered from the research vessel* Atlantis *into the Pacific Ocean.*

Here, over a mile beneath the ocean's surface, live dinner-plate-sized clams reeking of sulfur, towering tubeworms resembling giant lipsticks, ghost-white crabs prowling for prey, pinkish eel-like fish, and the microscopic bacteria that hold together this strange web of life.



The Pompeii worm, which lives at hydrothermal vents, is one of the most heat-tolerant animals on the planet.

Currently, scientists are exploring hydrothermal vent sites to learn more about this "extreme" environment and its unique community of organisms. After all, vent dwellers thrive under some of the most demanding conditions on the planet. They live in a world of total darkness. They are constantly bathed in toxic water that rockets out of the vents. And while most of the deep sea is just above freezing, the water erupting from the vents is super-hot, up to 360°C (680°F)!

What's more, the atmospheric pressure exerted on these organisms from the vast ocean above them is more than 250 times the pressure we feel on land.

How can these creatures survive such harsh conditions? Researchers involved in *Extreme 2004: Exploring the Deep Frontier* are searching for the answers and invite you to join them in their adventure to the deep.

Turn the page and learn more about hydrothermal vents, the creatures that inhabit them, the technology that makes deep-sea research possible, and the discoveries that marine scientists are making. Let's dive in!

An eelpout swims over a bed of tubeworms and a vent crab.
Photo by Dr. Richard A. Lutz & Andrew Reed

Dive Mission

On November 30, a research team led by University of Delaware marine scientist Craig Cary will set sail from Manzanillo, Mexico, on the 21-day expedition *Extreme 2004: Exploring the Deep Frontier*.

Dr. Craig Cary

They will live aboard the 274-foot research vessel *Atlantis* and dive to the depths in the submersible *Alvin.*

Their mission will be to explore one of the most demanding environments on the planet: hydrothermal vents. These underwater geysers erupt at cracks in the Earth's crust, where new seafloor is being born.

The scientists will be working to learn more about *biocomplexity,* the complex interplay between vent organisms and their environment. Biologists, chemists, and geologists will all be working together to better understand how the strange life at the vents can function in their hostile environment of extreme temperature, toxic chemicals, high pressure, and darkness.

Using tools borrowed from the Human Genome Project, the scientists will examine creatures such as the Pompeii worm, which can survive temperatures up to 80°C (176°F).

For daily logs, photos, and videos of the scientists' activities, dive into this Web site:

www.ocean.udel.edu/extreme2004

Explore the Mysteries of the Sea
Discover New Worlds
www.ocean.udel.edu/extreme2004

Geology of the Ocean Floor

To someone who can't swim, the "deep sea" may be just above ankle level in the ocean. So what do scientists mean when they refer to the "deep sea"?

The ocean floor is divided into three major areas: the continental shelf, the continental slope, and the deep ocean basin.

The continental shelf extends underwater from each of the major land masses. It's the submerged portion of the continents. The shelf has features similar to those we see on land, including hills, ridges, and canyons.

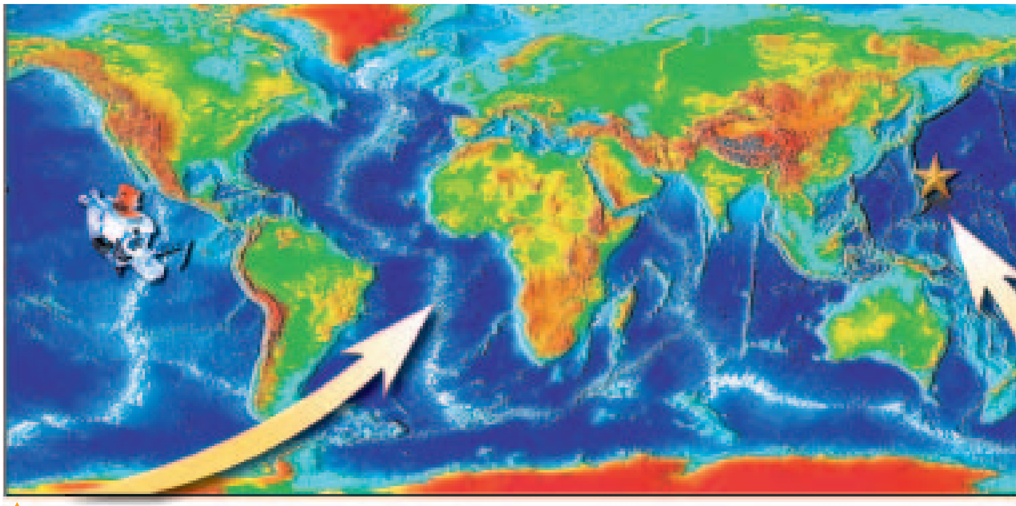
On the map to your right, the continental shelf is the light-blue area that edges the continents. The shelf varies in size. It may be virtually non-existent in some areas; elsewhere it may extend a great distance from shore. The shelf's average distance is about 64 kilometers (40 mi).

It is beyond the continental shelf that the "deep sea" begins. The shelf ends at a depth of about 200 meters (660 ft), giving way to the steeper continental slope, which descends about 3,700 meters (12,000 ft) to the deep ocean basin.

Here, the ocean floor deepens sharply and its features resemble those on land, only on a much larger scale, with great plains and mountains. In fact, the Earth's longest mountain range is underwater. Over 56,000 kilometers (35,000 mi) long, this mountain range, called the Mid-Ocean Ridge system, snakes around the globe.

The Mid-Ocean Ridge marks one of the most geologically active areas on Earth. It is where the planet's crustal plates are moving apart. It is where new seafloor is being born, giving rise to hydrothermal vents and volcanoes.

Adapted from NOAA



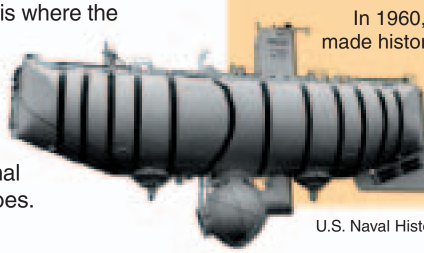
Did you know that the Earth's longest mountain range is underwater? The Mid-Ocean Ridge system, shown above snaking its way between the continents, is more than 56,000 kilometers (35,000 mi) long. It marks the areas where the Earth's crustal plates are moving apart. This is where most hydrothermal vents are located. The Extreme 2004 dive site, marked above by the submersible Alvin, *is in an active vent field in the Pacific Ocean west of Costa Rica.*

How Deep Is the Ocean?

The Mariana Trench is a depression in the Pacific Ocean, east of the Mariana Islands. It is 1,554 miles long and averages 44 miles wide. Within it, about 210 miles southwest of Guam, lies the deepest known point on Earth. Named the "Challenger Deep" for the British survey ship *Challenger II* that located it in 1951, this underwater gorge plunges to a depth of nearly 7 miles!

In 1960, Jacques Piccard and Navy Lt. Donald Walsh made history when they descended in the U.S. Navy bathyscaphe *Trieste* (left) to the bottom of the Mariana Trench. The divers were housed in the sphere at the bottom of the sub.

Students, can you convert the measurements into metric units?

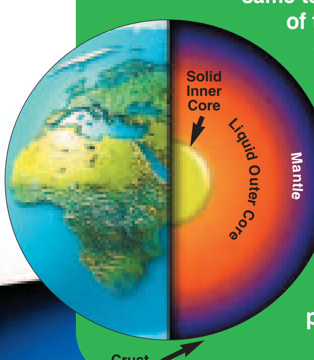


U.S. Naval Historical Center Photograph

Earth's Moving Crust Spawns Vents, Volcanoes & Quakes

Understanding where hydrothermal vents occur requires a closer look at the Earth's structure and the forces at work deep within the planet.

The deeper you go inside the Earth, the hotter it gets. Scientists have calculated that the Earth's inner core — a solid sphere composed primarily of iron — is about 5,500° C (10,000° F). That's about the same temperature as the surface of the sun. The solid inner core is about 2,400 kilometers (1,500 mi) in diameter. It is surrounded by a liquid outer core about 2,225 kilometers (1,380 mi) thick.



Bordering the liquid outer core is the mantle, which is composed of hot, molten rock called *magma.* The churning of the magma generates pressure on the Earth's surface layer, or crust. The crust is very thin and brittle compared to the other layers. It ranges in thickness from only about 3 kilometers (2 mi) in some areas of the ocean floor to some 120 kilometers (75 mi) deep under mountains on the continents.

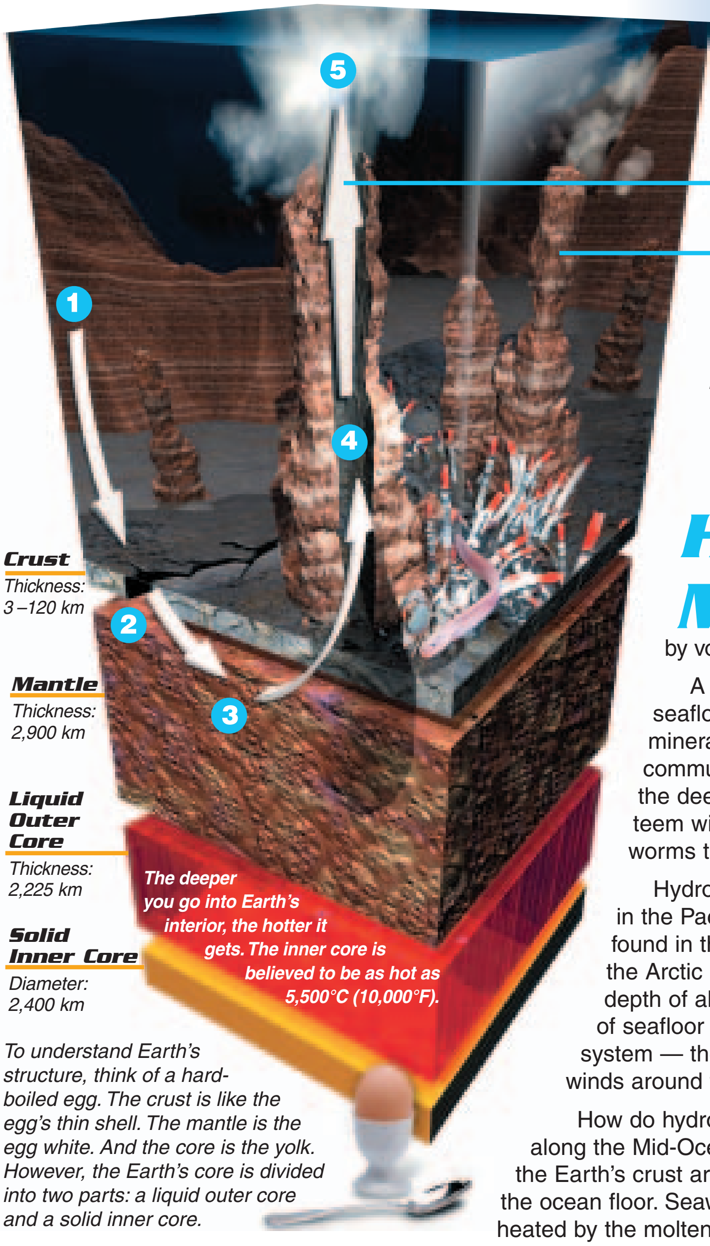
According to the theory of plate tectonics, the Earth's crust is made up of about a dozen plates on which the continents and the oceans rest. These plates are continually shifting because the surface beneath them — the hot, magma-filled mantle — is moving slowly like a conveyor belt, driven by the heat in the Earth's core. The plates currently move about a centimeter (0.5 in) to 15 centimeters (6 in) per year in different directions (see map at right).

The Earth's tectonic plates can move apart, collide, or slide past each other. The Mid-Ocean Ridge system — the Earth's underwater mountain range — marks where the plates are moving apart. As the plates part, the seafloor cracks. Cold seawater seeps deep down into these cracks, becomes super-heated by magma, and then gushes back out into the ocean, forming hydrothermal vents.

As the plates move farther apart, magma from the Earth's interior percolates up to fill the gap, sometimes causing earthquakes and the eruption of undersea volcanoes. This process, called *seafloor spreading,* is how new seafloor is formed.

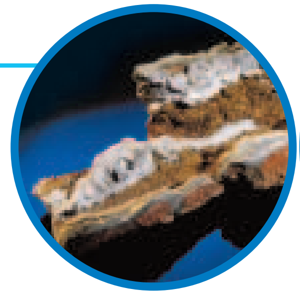
The Earth's size is constant, so as the crust expands through seafloor spreading in one area, crust must be swallowed up elsewhere. Crust is destroyed when the edge of one tectonic plate is forced under-

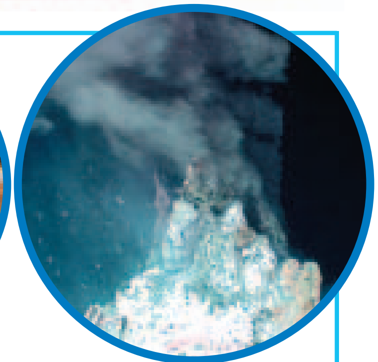
Exploring the Deep Frontier



To understand Earth's structure, think of a hard-boiled egg. The crust is like the egg's thin shell. The mantle is the egg white. And the core is the yolk. However, the Earth's core is divided into two parts: a liquid outer core and a solid inner core.

This is the inside of a vent chimney. The shimmering gold material is the mineral pyrite, or "fool's gold." The orange areas are oxidized iron.





Hydrothermal Vents

Many of us are familiar with "Old Faithful" in Yellowstone National Park. This famous geyser erupts several times a day. It spouts a column of water heated by volcanic rock deep within the Earth's crust.

A hydrothermal vent is a geyser on the seafloor. It continuously gushes super-hot, mineral-rich water that supports a diverse community of organisms. Although most of the deep sea is sparsely populated, vent sites teem with a fascinating array of life, from tube-worms taller than you to ghost-white crabs.

Hydrothermal vents were discovered in 1977 in the Pacific Ocean. Since then, they have been found in the Atlantic, Indian, and most recently, the Arctic Ocean. Most occur at an average depth of about 2,100 meters (7,000 ft) in areas of seafloor spreading along the Mid-Ocean Ridge system — the underwater mountain chain that winds around the globe.

How do hydrothermal vents form? In some areas along the Mid-Ocean Ridge, the huge plates that form the Earth's crust are moving apart, causing deep cracks in the ocean floor. Seawater seeps into these openings and is heated by the molten rock, or *magma,* beneath the crust. As the water heats up, it rises.

When this "hot spring" gushes out into the ocean, its temperature may be as high as 360° C (680° F). Yet this water does not boil because it is under so much pressure from the tremendous weight of the ocean above.

Chimneys top some vents. These smokestacks are formed from dissolved metals that precipitate out (form into particles) when the super-hot vent water meets the surrounding sea-water, which is only a few degrees above freezing.

Geologists are intrigued by how rapidly vent chimneys grow — as much as a whopping 30 centimeters (12 in) a day! "Godzilla," a vent chimney in the Pacific off the Oregon coast, reached the height of a 15-story building before it toppled and has since been rebuilding. In 2000, University of Washington scientists discovered even taller chimneys, up to 55 meters high (180 ft), in the "Lost City" vent field in the Atlantic Ocean.

There are many reasons why scientists want to learn more about hydrothermal vents. Besides providing habitat for an intriguing community of life, these underwater geysers are believed to play an important role in the ocean's temperature, chemistry, and circulation patterns.

How Does a Vent Work?

1 As the Earth's crustal plates move apart, the ocean floor cracks. Cold seawater seeps deep down into the openings.

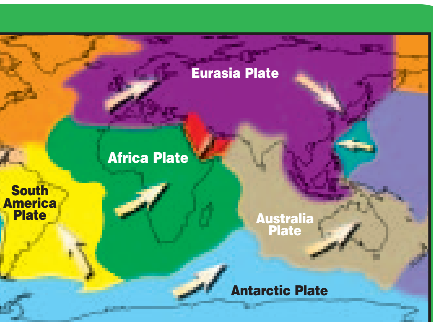
2 The seawater is heated by molten rock in the Earth's mantle, below the crust. As the water heats, chemical reactions occur. Oxygen, magnesium, potassium, and other minerals are removed from the seawater.

3 The deeper the fluid goes, the hotter it gets. Copper, zinc, iron, and sulfur from the crust dissolve into the fluid. The super-heated fluid, now laden with dissolved metals, rises.

4 As the hot fluid gushes out onto the ocean floor, it meets cold, oxygen-rich seawater, which spurs more chemical reactions. Hydrogen sulfide (a compound toxic to most organisms) forms, and minerals "rain out" from the fluid. These minerals build the vent chimneys.

5 "Black smokers," represented in this illustration, spew hot fluid (360°C) filled with metals (mostly iron) and sulfur, which combine to form black minerals called metal sulfides. These compounds give the smoker its black color.

"White smokers" release fluid more slowly and are cooler (250° – 300°C) than their cousins. The fluid contains compounds of barium, calcium, and silicon, which are white.



Adapted from NOAA

▲ This map shows the major tectonic plates that make up the Earth's crust and the directions in which they are moving.

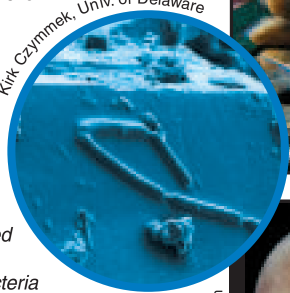
neath another. This dynamic process is called *subduction.* It results in earthquakes, volcanoes, and the formation of deep ocean trenches.

Presently, the Pacific Ocean basin is shrinking as other ocean basins expand. There are so many volcanoes along the perimeter of the Pacific Ocean basin the area is known as the "Ring of Fire."

Biology of Deep-Sea Life

They can withstand a broad range of temperatures, bathe in — and in many cases — even eat, toxic chemicals, bear the weight of the ocean on their shoulders, and never see the light of day. Such is the life of many of the organisms that inhabit hydrothermal vent sites!

These creatures, from microscopic bacteria to towering tubeworms, thrive under some of the most demanding conditions on the planet. And what further distinguishes them from other life on Earth is their energy source. This is the only complex ecosystem known to live on energy from chemicals from the Earth rather than energy from the sun.



Kirk Czymmek, Univ. of Delaware

Magnified view of vent bacteria on the surface of pyrite. The cylinder-shaped bacteria are 4 microns long.

Do hydrothermal vents, and microbes, lie beneath the frozen surface of Europa, one of Jupiter's moons?

On land and in the upper layer of the ocean, the food chain is based on photosynthesis, the process by which green plants use sunlight to make food and energy. A by-product of this process is oxygen. In fact, tiny plants in the ocean generate a lot of the oxygen we breathe through photosynthesis.

However, at deep-sea vents, where the sun's rays never reach, microbes get their energy from chemicals within the Earth itself — a process called *chemosynthesis.*

Bacteria Play Mighty Role

The hydrogen sulfide and other chemicals that rocket out of the vents would be poisonous to most organisms. But exotic animals flourish here thanks to unique adaptations. Some also have a special relationship with the tiniest vent life: bacteria.

While vent crabs and fish prey on other animals for food, other vent dwellers depend on bacteria for survival because the microbes can convert the toxic chemicals released by the vents into food and energy. Thus, some vent dwellers must either consume bacteria or harbor bacteria in their bodies so that the microbes can make food for them.

For example, tubeworms have no mouth, eyes, or stomach ("gut"). Their survival depends on a *symbiotic* relationship with the billions of bacteria that live inside them. These bacteria convert the chemicals rocketing out of the vents into worm fuel.

Frontiers of Science

Scientists are particularly interested in vent bacteria because these primitive

William Lange/WHOI

Hydrothermal vents are home to a diversity of marine life. How many different animals can you identify in this photo?

NASA/JPL/Caltech

microbes can withstand high temperature and pressure, giving them many valuable uses in industry. For example, some bacteria can convert harmful chemicals to safer forms, making them ideal for cleaning up oil spills and hazardous waste.

Scientists are also curious about the deep sea's tiniest life because these organisms are among the oldest on Earth. In fact, an ancient life form — Archaea ("ark-ee-uh") — has been found at vent sites. Previously, these microscopic organisms had been discovered in another "extreme environment": hot springs in Yellowstone National Park.

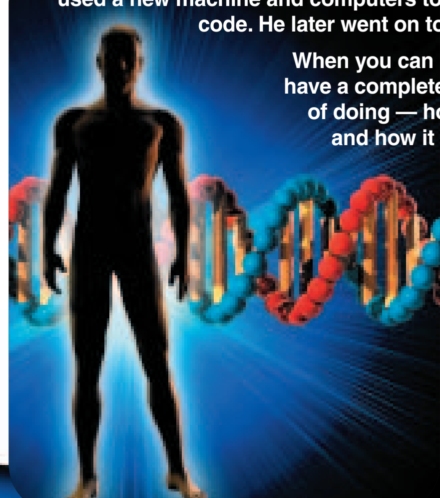
Some astrobiologists speculate that if there is life on other planets, it might be vent bacteria. Europa, one of Jupiter's moons, is covered in ice. Recent findings suggest that portions of the ice move, which is strong evidence that liquid water lies beneath it. The water may be maintained in its liquid state by hydrothermal vents. If vents exist on Europa, vent bacteria might live there, too!

Sorting Out the Code of Life: GENOMICS!

In 1994, it was the germ that causes the flu. In 2000, it was human beings. Then mice, rice, and, in early 2004, dogs. Call it a map, a diagram, a pattern, a problem, a miracle: it's genomics.

Genes make each of us what we are. Each cell in our bodies contains our genome, a code of 3.5 billion letters contained in the protein DNA. Sequencing DNA means figuring out what order the letters appear in — their sequence. In the past, geneticists studied genes one at a time. Today, scientists study the whole code, a situation comparable to getting a complete story, rather than using individual words to try to figure out a plot.

How do you sequence DNA when such gigantic numbers are involved? If you figured out one letter per second, it would take you longer than a century to sequence a human's DNA, says J. Craig Venter. He's the scientist who first sequenced a genome, the *Haemophilus influenzae* bacterium, which can cause ear infections, in 1994. He used a new machine and computers to do the job of identifying each letter in the code. He later went on to be the first to sequence the human genome.

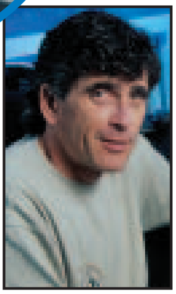


When you can read the genome sequence of any organism, you have a complete catalog of everything that organism is capable of doing — how it functions, the nutrients it needs to grow, and how it senses its environment.

Scientists are constantly adding to a catalog of genomes that have been sequenced by Dr. Venter and others. Extreme 2004 scientists will "blast" the microbes they find at the hydrothermal vents. This means they'll try to match the microbes' DNA to those in the catalog on the way to sequencing their genomes. This is important not just "because it's there" — for the sake of discovering something new — but because new bacteria have the potential to help us find new medicines, fuel sources, and even foods.

Below the Pompeii worm's feathery red gills is a structure that resembles a ball of yarn when it's not in use: the buccal feeding tube. The worm extends this tube to eat bacteria that grow in long filaments.

Deep-Sea Vents Harbor Earth's Hottest Animal



Steven Billups

Dr. Craig Cary

In 1998, University of Delaware marine biologist Craig Cary and his colleagues made international headlines when they determined that the vent-dwelling Pompeii worm is the most heat-tolerant animal on Earth, able to survive a bath as hot as 176°F.

While some bacteria thrive at higher temperatures, the Pompeii worm ranks as the most heat-tolerant among complex life forms. The former record holder was the Sahara Desert ant, at 131°F.

Discovered in the early 1980s by French scientists, the Pompeii worm *(Alvinella pompejana)* is about 4 inches long with tentacle-like, scarlet gills on its head. A gray "fleece" of bacteria covers the worm's back.

The worm gets its name from the Roman city of Pompeii, which was destroyed during an eruption of Mount Vesuvius in 79 A.D. The *Alvinella* in the worm's scientific name stems from the submersible *Alvin*.

"The Pompeii worm makes paper-like tube colonies attached to hydrothermal vent chimneys," says Dr. Cary. "While the very hottest water shoots out the top of the chimneys, these structures are so porous that hot water also seeps out the chimney sides and through the worm's tube home."

The worm also displays a remarkably broad temperature gradient along its hairy body. By inserting a temperature probe called "the Mosquito," from the submersible *Alvin* into the worm's tube, Dr. Cary found that the worm's rear end sits in water as hot as 176° F, while its gill-covered head, which often pokes out of the worm's tube home, rests in much cooler water, only about 72° F.

During the Extreme 2004 expedition, Dr. Cary and his team from the University of Delaware College of Marine Studies and Dr. Alison Murray and her research group from the Desert Research Institute in Reno, Nevada, will be working together to learn more about the Pompeii worm's incredible heat tolerance by studying the bacteria that live right on its back.

Dr. Alison Murray

"We're working to apply new genomics technologies to learn how these bacteria deal with the hydrothermal vent environment they inhabit in association with the worm," Dr. Murray says.

Using tools borrowed from the Human Genome Project, such as DNA sequencers, the scientists will be working to access all the genetic information tied up in the bacteria — their DNA code, or "road map of life," as Dr. Murray refers to it.

"Yet just as a road map has many more routes than are necessary for getting from one destination to another, a microorganism's genome can code for many, many pathways for carrying out its daily requirements," she explains. "The route that's actually taken on that road map represents the genes that are 'expressed,' or 'turned on,' at any given time. That's what we're looking for."

Dr. Murray says this information will help address key questions about the sources of energy and food the bacteria use. The gene expression profile also can reveal other intriguing information, such as the genes involved in heat tolerance, metal detoxification, and cell-to-cell communication.

The Pompeii worm and its bacteria are of interest to industry, as well as the scientific community, because they may yield a variety of products and applications, from new pharmaceuticals to enzymes capable of operating in hot, corrosive, high-pressure environments. Such enzymes can help dislodge oil inside wells, convert cornstarch to sugar, process food and drugs, and support a number of other industrial processes by speeding up chemical reactions.

The gray "hair" on the Pompeii worm's back is actually bacteria.

Creatures of the Deep

As they descend to the deep ocean floor, marine scientists might encounter any number of bizarre organisms illuminated in their submersible's headlights. These photos are a few of the deep-sea dwellers that UD marine scientists have seen en route to vent sites over 2,500 meters (1.5 mi) down.

Fangtooth. **Food is scarce in the deep sea. Deep-sea fish typically have big mouths, long sharp teeth, and stretchy stomachs to catch prey in the dark and swallow it whole. This ferocious-looking fish is called "fangtooth." It grows to a length of about 25 centimeters (10 in).**

Dragonfish. **Many deep-sea fish rely on bioluminescent (light-producing) organs to find a mate and lure prey. This fish has a long chin barbel that glows in the dark.**

Deep-Sea Octopus. **Hair-like projections ("cirri") line the webbed arms of this octopus. These projections may help it sense food in the darkness. This species is equipped with paddle-like fins to help it swim.**

Students, can you convert the temperatures on this page from Fahrenheit to Celsius?

Exploring the Deep

Throughout history, scientists have relied on a number of specialized tools to measure, map, and view the ocean's depths. These are a few highlights.

One of the first instruments used to investigate the sea bottom was the *sounding weight.* Viking sailors took measurements of ocean depth and sampled seafloor sediments with this device, which consisted of a lead weight with a hollow bottom attached to a line. Once the weight reached the ocean floor and collected a sample of the seabed, the line was hauled back aboard ship and measured in the distance between a sailor's outstretched arms — a 1.83-meter (6 ft) unit called a *fathom.* This term is still used today for nautical depth.

Cornelius van Drebel, a Dutch inventor, is credited by many historians with building the first submarine. His underwater vessel consisted of a wooden frame sheathed in leather. Oars extending out the sides propelled the craft through the water, at depths up to 4.6 meters (15 ft). The oar openings were sealed with tight-fitting leather flaps. Drebel tested the sub in the Thames River in England between 1620 and 1624. King James I is said to have taken a short ride in the craft.

From 1872 to 1876, a landmark ocean study was undertaken by British scientists aboard HMS *Challenger,* a sailing vessel that was redesigned into a laboratory ship. The *Challenger* expedition covered 127,653 kilometers (68,890 nautical miles) and is credited with providing the first real view of major seafloor features such as the deep ocean basins. The researchers used wire-line soundings to determine depths and collected hundreds of water, sediment, and biological samples from all the oceans except the Arctic. They discovered more than 4,700 new species of marine life, including deep-sea organisms.

Divers do a final safety check of Alvin's *hatch before the crew inside begins the descent to the seafloor.*

On the deck of the research vessel Atlantis, *marine scientists Craig Cary and Julie Robidart examine a vent chimney sample collected by* Alvin.

Deep-sea exploration advanced dramatically in the 1900s with a series of inventions, ranging from *sonar* — a system for detecting the presence of objects underwater through the use of sound — to manned submersibles such as *Alvin.*

Owned by the U.S. Navy and operated by the Woods Hole Oceanographic Institution, *Alvin* can carry a crew of one pilot and two scientists to a depth of 4,500 meters (14,764 ft). The sub is equipped with lights, cameras, computers, and highly maneuverable arms for collecting samples in the dark ocean's depths.

In the future, with the expanded use of fiber optics, high-tech sensors, and robotics, marine scientists hope to observe and monitor well-defined marine systems from the lab versus out of a porthole.

Currently, a team of researchers from several U.S. and Canadian institutes is developing the NEPTUNE project, a plan for installing 3,000 kilometers (1,864 mi) of fiber-optic cable on Juan de Fuca Plate, a tectonic plate in the northeast Pacific. Between 30 and 50 experimental sites will be established at nodes along the cable. They will provide real-time ocean data and imagery to shore-based Internet sites, as well as interactive control over robotic vehicles on site. The system is expected to be in operation in 2007.

Getting to the Bottom of It: The Ocean

Because of the tremendous pressure, the depth to which a diver can descend without special equipment is severely limited. The deepest recorded dive by a skin diver is 127 meters (417 ft). The deepest recorded dive by a scuba diver is 282 meters (925 ft).

Revolutionary new diving suits, such as the "Jim suit," enable divers to reach depths of about 600 meters (2,000 ft). Some suits feature thruster packs to boost a diver to different locations underwater.

To visit even greater depths, deep-sea explorers must rely on specially constructed steel chambers to protect them. In 1934, American oceanographer William Beebe and engineer Otis Barton were lowered to about 1,000 meters (3,280 ft) in a round steel chamber called a *bathysphere,* which was attached to a ship on the surface by a long cable. During the dive, Beebe peered out of a porthole and reported his observations by telephone to a colleague, Miss Hollister, on the surface.

In 1948, Swiss physicist Auguste Piccard began testing a much deeper-diving vessel he invented called the *bathyscaphe.* (This word is derived from the Greek words *bathos* — "deep" and *scaphos* — "ship.") On an unpiloted dive in the Cape Verde Islands, his invention, named *FNRS 2,* withstood the pressure on it at 1,402 meters (4,600 ft), but its float was severely damaged by heavy waves after the dive.

In the 1950s, Jacques Piccard joined his father in building new and improved bathyscaphes including *Trieste,* which dived to 3,139 meters (10,300 ft) in field trials. The U.S. Navy acquired *Trieste* in 1958 and equipped it with a new cabin to enable it to reach deep ocean trenches. In 1960, Jacques Piccard and Navy Lieutenant Donald Walsh descended in it to the deepest known point on Earth — the Challenger Deep in the Mariana Trench. The two men made the deepest dive in history: 10,915 meters (35,810 ft).

NOAA

In 1960, Jacques Piccard (top) and Donald Walsh made history when they descended in the bathyscaphe Trieste to the bottom of the Mariana Trench.

Today, scientists are making exciting discoveries about the ocean floor, thanks to deep-sea submersibles such as *Alvin.* Operated by the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts, this three-person sub made its first dive in 1964. Since then, *Alvin* has made more than 4,000 dives to an average depth of 2,079 meters (6,820 ft).

***Alvin* has conducted a wide variety of missions, from discovering giant tubeworms in the Pacific Ocean near the Galápagos Islands, to surveying the wreck of HMS *Titanic* in the Atlantic Ocean. The sub once was attacked by a swordfish, which became trapped between two pieces of the sub's fiberglass skin. The fish was brought back to the surface and cooked for dinner!**

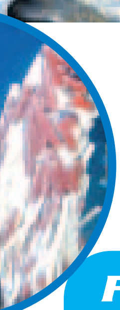
Plans now are under way for a new *Alvin.* The new sub, slated for completion in 2008, will reach more than 99% of the seafloor, diving to depths of 6,500 meters (21,320 ft).

Exploring the Deep Frontier

The 83-meter (274-foot) research vessel Atlantis *is the platform from which* Alvin *operates.* Atlantis *can carry up to 60 people, including crew, scientists, and technicians. The ship features hangars for* Alvin *and ROVs (remotely operated vehicles), portable labs, a machine shop, library, laundry, and inflatable rescue boats.*

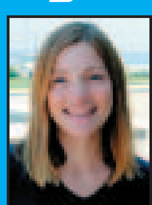
Tools of the Trade

The submersible Alvin *is equipped with clawed arms called manipulators that are used by the pilot to collect scientific specimens and samples and place them in the sub's collecting basket.*



Alvin*'s pilot navigates the submersible along the seafloor. It's very cramped inside the sub, which typically carries two scientific observers in addition to the pilot. The scientists sit with their legs alongside each other while the pilot sits on a tiny padded bench. A typical dive lasts eight hours.*

Frequently Asked Questions About Alvin



Liz McCliment

Liz McCliment, a Ph.D. student at the University of Delaware College of Marine Studies, answers your questions about working in the sub Alvin.

Q. What's it feel like when you're descending?

A. You actually sense very little motion inside the sub, except when you're bobbing on the surface. Mostly, you can tell you're descending by the color of the water outside your porthole. It gets dark pretty quickly — within about 10 minutes.

Q. How long does it take to get to the ocean bottom?

A. About one to two hours, depending on how deep you're going. You usually work for four hours or so on the bottom before ascending. A typical dive generally lasts eight hours.

Q. Do you have to wear anything special in the sub?

A. It gets very cold in the sub. The temperature of the water is just above freezing, so you have to bring a few layers of wool or cotton clothing, including extra pairs of socks. You cannot wear shoes, jewelry, or any synthetic material (like nylon or Lycra) in the sub. Shoes would just get in the way. Jewelry might scratch *Alvin*'s window. Synthetic clothes are not permitted for fire safety reasons.

Q. How much room do you have in the sub?

A. It's very cramped. There's enough room for two scientists to sit with their legs alongside each other, and the pilot to crouch on a tiny padded bench. If you want to stretch out, it is possible for one (short) person to stand up with their head in the hatch. You also spend a lot of time laying on your side or stomach, looking out your porthole, operating your equipment and conducting experiments.

Q. What do you have for lunch in *Alvin*?

A. There's a traditional lunch served to the scientists and crew on a dive: one peanut butter and jelly sandwich, one "mystery meat" sandwich, a candy bar, and a piece of fruit. Since you're generally very busy and lose track of time while you're working, you tend to eat when you're in transit between sites!

Facts about Alvin

How did Alvin get its name?

Alvin is owned by the U.S. Navy and operated as a national oceanographic facility by the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts. The sub was christened in 1964. The Deep Submergence Group at Woods Hole named *Alvin.* It was both a contraction of their colleague Allyn Vine's name (he worked tirelessly to make the submersible a reality) and a reference to the popular cartoon chipmunk.

How big is Alvin?

The sub (its official title is "Deep Submergence Vehicle") is about 23 feet long and 12 feet high. The 6.5-foot-diameter sphere in which the scientists work is made of titanium.

What equipment does Alvin have?

Its tools include sonar, a computer/data display/recording system, video cameras, a telephone, a magnetometer, and more. *Alvin* has two long, clawed arms called manipulators that are used to collect scientific specimens and place them in the sub's collecting basket.

Alvin Statistics

Length: 23.3 feet
Beam: 8.5 feet
Height: 12 feet
Draft: 7.5 feet
Gross Weight: 35,200 pounds
Operating Depth: 14,764 feet
Cruising Speed: 0.5 knot
Maximum Speed: 2 knots
Max. Cruising Range: 3 miles
Payload: 1,500 pounds
Normal Dive Duration: 6 – 10 hours
Life Support: 216 man-hours (72 hours x 3 persons)
Complement: 1 pilot, 2 observers

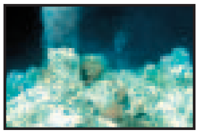
Students, can you convert the measurements on this page into metric units?

Dive Deeper!

This eight-page resource guide is designed to serve as a brief introduction to the deep sea and hydrothermal vents. Additional information including photos, video clips, journals, and other news from the Extreme 2004 expedition can be found on our Web site: **www.ocean.udel.edu/extreme2004.**

The following list of suggested classroom activities and resources may help expand your deep-sea learning experience. Use it as a starting point to your own voyage of discovery!

Two divers help steady the submersible Alvin *as it is lowered into the Pacific from the research vessel* Atlantis.



Geology

Word Definition

Here are some terms to define:

continental shelf
continental slope
deep ocean basin
hydrothermal vent
mantle
Mid-Ocean Ridge
plate tectonics
seafloor spreading
subduction
"Ring of Fire"

Math Activities

Let's test your knowledge of the metric system. Convert the British units of measure in the "How Deep Is the Ocean?" article in the Geology section to metric units.

Can you calculate what the atmospheric pressure is at the Earth's deepest known point, at the bottom of the Mariana Trench?

Extra-Credit Essay Topics

Why are hydrothermal vents important?

How does Old Faithful geyser work? Compare it to a hydrothermal vent.

Biology

Word Definition

Here are some terms to define:

Archaea
biocomplexity
chemosynthesis
genomics
microbe
Pompeii
photosynthesis
sulfur
symbiosis
tubeworm

Go Fish!

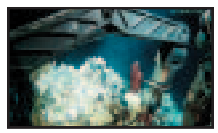
Many deep-sea fish look monstrous! Your mission is to find pictures and descriptions of at least five different deep-sea fish. What special adaptations do these fish have for living in their demanding environment?

Extra-Credit Essay Topics

Compare and contrast photosynthesis and chemosynthesis.

The HMS *Challenger* expedition covered nearly 70,000 miles at sea and discovered many new marine organisms. Tell us about the expedition and some of its key findings.

Technology



Word Definition

Here are some terms to define:

bathyscaphe
bathysphere
fiber optics
HMS *Challenger*
"Jim suit"
ROV
scuba
sonar
submersible
Trieste

Design a Submersible

A new *Alvin* now is being designed. If you could design a submersible, what would it look like and what special capabilities would it have? Sketch it!

Extra-Credit Essay Topics

Jason is used in deep-sea research. Do some research and tell us all about it.

What other scientific tools are revolutionizing our study of the ocean?

Resources

Many excellent resources were used to develop this guide and may help you in your search for more information.

Web Sites

The Bridge — Sea Grant Ocean Sciences Education Center
www.vims.edu/bridge

Jones & Bartlett Publishers — *Invitation to Oceanography* by Paul Pinet
www.jbpub.com/oceanlink2e

"Deep Sea Vents: Science at the Extreme"
www.nationalgeographic.com/ngm/0010/feature6

"Neptune's Web: Get the Facts on Oceanography"
pao.cnmoc.navy.mil/Educate/Neptune/Neptune.htm

NOAA Ocean Exloration Program
http://oceanexplorer.noaa.gov

Nova Online — "Into the Abyss"
www.pbs.org/wgbh/nova/abyss

Smithsonian Institution's 'Ocean Planet"
seawifs.gsfc.nasa.gov/ocean_planet.html

U.S. Geological Survey — *This Dynamic Earth: The Story of Plate Tectonics* by W. J. Kious and Robert Tilling
pubs.usgs.gov/publications/text/dynamic.html

U.S. Naval Historical Center
www.history.navy.mil/index.html

Woods Hole Oceanographic Institution "Dive and Discover" Expeditions
www.divediscover.whoi.edu

Books & Magazines

Davidson, Keay, and A. R. Williams. "Under Our Skin: Hot Theories on the Center of the Earth." *National Geographic* 189, No. 1 (Jan. 1996): 100–112.

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Earle, Sylvia A., and Al Geddings. 1980. *Exploring the Deep Frontier: The Adventure of Man in the Sea.* National Geographic Society.

Greene, Thomas F. 1998. *Marine Science.* New York: Amsco School Publications.

Lemonick, Michael D. "The Last Frontier." *Time,* Aug. 14, 1995, 52–60.

Van Dover, Cindy Lee. 2000. *The Ecology of Deep-Sea Hydrothermal Vents.* Princeton University Press.

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For more information about the University of Delaware's "Extreme 2004" deep-sea expedition, dive into *www.ocean.udel.edu/extreme2004.* To learn about past and future adventures involving University of Delaware marine scientists, please visit *www.ocean.udel.edu/expeditions.*

This publication was produced by the University of Delaware Marine Public Education Office: Tracey Bryant, editor; David Barczak, art director; Pamela Donnelly, production manager. Contributing writer: Karen Romano Young.

For information about other educational publications and programs from the University of Delaware College of Marine Studies and Delaware Sea Grant, visit us on-line at *www.ocean.udel.edu.* Or contact University of Delaware, Marine Public Education Office, 222 S. Chapel Street, Newark, DE 19716-3530. Phone: (302) 831-8083. E-mail: *MarineCom@udel.edu.*

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Visit us at www.ocean.udel.edu/extreme2004

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