PART ONE: Archaea

The life in an ocean wave

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The ocean is a rich soup of unknown microbes

THREE centuries ago, a scientist called Van Leeuwenhoek discovered that the sea contained some “little animals”, now known to be bacteria. But only recently has it been realised that the sea is awash with tiny, strange, life-forms.

Small as they are—bacteria are from 0.1 to a few microns long (a micron being a millionth of a metre)—microbes number in the thousands of trillions of trillions worldwide. This gives them a huge role in the chemistry of the planet. Their metabolism recycles energy and chemicals between the air and the oceans. At a recent conference on marine diversity, Farooq Azam, a microbiologist at the Scripps Institution of Oceanography, in La Jolla, California, declared that, without microbes, models of the ocean were “incomplete”.

Traditionally, the way to study microscopic ocean life has been to put a drop of seawater on to a plate coated with nutritious jelly and see what grew. But the problem with this—known as the “great plate count anomaly”—is that only a tiny fraction of what can be seen in the water can be grown. So in the late 1980s, Stephen Giovannoni at Oregon State University applied a new process that multiplies small amounts of DNA into quantities that can be analysed. He found lots that looked nothing like the genes of any of the cells that would grow on existing cultures. Genetic analysis suggested that 11 organisms, nine bacteria and two archaea, predominate in seawater.

The presence of the archaea was a particular surprise. These ancient, single-celled organisms, which are similar to bacteria, have mastered life in hostile conditions. It used to be thought that they were found only in extreme environments. David Karl, a microbiologist at the University of Hawaii, and Edward DeLong of the Monterey Bay Aquarium Research Institute in California, have since discovered that the sea is full of archaea. Close to the surface, archaea are outnumbered by bacteria, but below 150 metres their share starts to rise.

The pair have also found that life in the ocean wave is much stranger than had been imagined. Some bacteria are like tiny green plants that use conventional photosynthesis to generate energy from carbon dioxide, water and sunlight, expelling oxygen. Others have evolved variations of photosynthesis that do without the oxygen atoms bound into water molecules, or that use water but produce no oxygen. Some have developed unknown ways to make use of other chemicals dissolved in the water, such as organic matter from broken-down cells, or scraps of loose DNA that waft around in the sea. Archaea, which include species that thrive on salt or sulphuric acid, are even more baffling.

Understanding all these creatures will ultimately depend on being able to culture them, and watch them grow. This is hard if it is not known what they live on. To date only three of the 11 most abundant creatures have been successfully cultured. Last year, scientists managed to refine the culturing process to grow SAR-11 (so named because it was first identified in water from the Sargasso Sea), one of the commonest bacteria in the ocean. The next step will be to discover where it finds the carbon and energy that are the basic inputs to its metabolism. That will provide one more thread in the tangle of life far offshore.
PART TWO: Bioprospecting

Bioprospecting in nature fuels debate: Profits and stewardship at play

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PALO ALTO, Calif. - The creatures are known as “extremophiles,” and they earn the name: They live in toxic Superfund cleanup sites, boiling deep-sea rift vents, volcanic craters and polar glaciers — some of the planet’s harshest environments.

These single-celled creatures owe their hardiness to genes, and that has drawn the attention of a few biotech companies. The companies train the genes to mass produce industrial-strength enzymes for such products as better detergents, cleaner chemicals and more effective DNA fingerprints.

Such “bio-prospecting” efforts have huge potential for good. They just might make hazardous waste cleanup more affordable, reduce pollution and make better medicines if the microbes’ genetic durability can be exploited and controlled.

But tough questions are being raised as well — about the morality of allowing private companies to patent and profit from Mother Nature.

‘Conan the Bacterium’ a favorite

The extremophile candidates are numerous. There’s Deinoccus radiodurans, dubbed Conan the Bacterium by its legions of fans because it withstands 10,000 times the amount of radiation that would kill a human. Found on radiated food, it has a unique ability to repair broken DNA.

In Chile’s moonlike Atacama desert — one of Earth’s driest spots — lives another extremophile scientists say could give them clues to what life might look like on Mars.

And the Pentagon’s research arm, the Defense Advanced Research Projects Agency, is sponsoring experiments on genetically engineering extremophiles to extend the shelf life of blood-clotting platelets in extreme conditions. The idea is to help treat battlefield wounds.

Objections to such work often come from activists who complain that Third World countries aren’t properly compensated for microbes extracted from their deserts, mountains and sea shores.

“The concern with bio-prospecting is that the people who consider themselves to be the stewards of the biodiversity in a region often aren’t consulted or are ignored,” said Beth Burrows of the Edmonds Institute, a environmental nonprofit based in Edmonds, Wash.

Hawaii eyes moratorium

Native Hawaiians are angry over a deal between the University of Hawaii and a biotechnology company to share in potential profits gleaned from lava sludge. Now the Hawaiian Legislature is considering a moratorium on the transfer or sale of extremophiles found on public lands so environmental and profit-sharing issues can be worked out.

Antarctica is governed by an international treaty that vows to keep the continent open and free to scientists dedicated to peaceful pursuits. But some 92 patents have been filed in the United States and another 62 in Europe that claim ownership of biological property found there.

While such patent applications appear to be legal, “some scientists active in Antarctica worry about whether outright commercial exploitation and patents are within the spirit of the treaty,” said Sam Johnston, who co-wrote a report on the subject for the United Nations this year.

The Edmonds Institute sued the National Park Service in 1997 after it gave San Diego-based Diversa Corp. commercial rights to prospect for extremophiles in the fabled hot springs of Yellowstone National
Park. The prospecting, involving fees and royalties paid to the government, was ultimately approved by a judge on the condition that an extensive environmental review be completed.

The park service has defended the deal — which remains on hold pending the review — as a way for it to profit on scientific research without disrupting the park’s environment. Four decades ago, the park service wasn’t so financially savvy when a University of Wisconsin researcher discovered the extremophile *Thermus aquaticus* in a Yellowstone hotspring.

**Yellowstone gets no profit**

Today, that bacterium provides a key enzyme — polymerase — used for polymerase chain reaction, better known as PCR, a Noble Prize-winning DNA fingerprinting technique used widely by crime labs, hospitals and university researchers.

Yellowstone doesn’t receive any income from sales of the PCR enzyme, now a key tool in the $300 million-a-year DNA fingerprinting business.

The companies involved say that without the ability to patent extremophiles, they can’t make good on the many promises of this area of biotechnology.

David Estell, a researcher at Genencor International Inc., said bio-prospecting requires the collecting of just a few samples, which hardly disturbs the environment.

Genencor is one of the few profitable biotechnology companies in existence, earning $13 million in the first quarter of 2004 on $94 million in revenue.

**African enzymes in jeans**

Genencor has the genetic material of 15,000 strains of microbes stored in deep-freeze in Palo Alto and the Netherlands. It already has 11 industrial products on the market, and is using living material — enzymes and proteins, rather than fossil fuels — to develop cleaner and cheaper ways of making industrial chemicals.

For instance, Genencor takes a gene that gives a microbe alkaline resistance and uses it to create enzymes for laundry detergent. One enzyme is used in Tide detergent, another is used to give jeans a faded look.

Both are produced by extremophiles found thriving in highly alkaline lakes in East Africa and Kenya. The extremophile genes responsible for making these enzymes are genetically engineered into commonplace bacteria, which are then coaxed to grow by the trillions in giant brewers’ vats at Genencor’s nine factories around the world.

“The goal,” Estell said, “is make proteins do something they’ve never done before.”

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**Questions** (your answers should be very brief)

#1. If you try to culture a drop a seawater on a regular agar plate, will most of the microbes grow?

#2. What remarkable group of microorganisms includes species that thrive on salt or even sulphuric acid?

#3. *Deinococcus radiodurans* has what notable property?

#4. What commercially valuable extremophile was originally discovered in a hot spring at Yellowstone National Park?