

Voyager

F O R K I D S O F A L L A G E S

By Memorie Yasuda



DID YOU EVER WONDER what makes you different from your best friend? Why does she have brown eyes and you have blue? And maybe in a silly moment, you even wondered why you weren't a frog, jellyfish, or cat. Well, it's your cells that make you who you are and a jellyfish what it is.

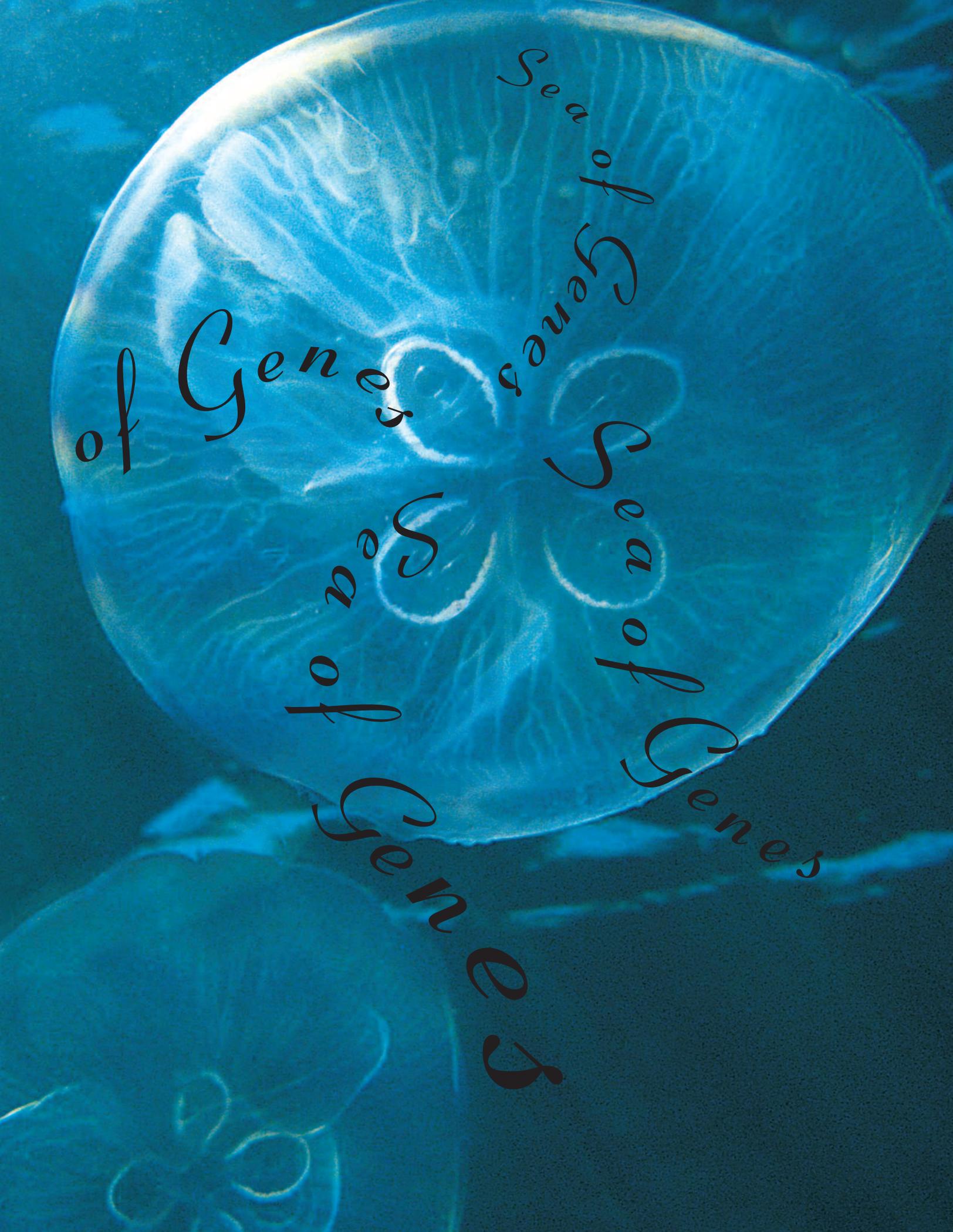
The genes are the instructions for making all of the estimated 100 million living organisms on Earth! Genes make sure that new cells match whether they belong to a human, banana, sea slug, bacterium, or frog.

Genes are inherited by each new generation of living thing. They are passed from cell to cell when cells divide or multiply and organisms grow. And they are passed from one generation to the next when organisms reproduce. Over long periods of time, they have been passed from generation of generation as living things as they evolved to meet unique challenges presented by the ever-changing conditions on Earth.

Genomics is the study of an organism's genome and the use of genes. It deals with the systematic use of genome information to provide answers in areas such as medicine, agriculture, and the environment. To understand the importance of genomes and genomics, we have to begin with the basics of biology.

Sea

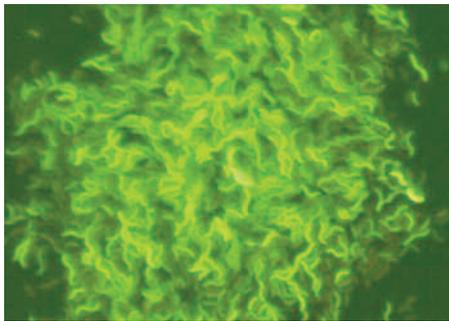




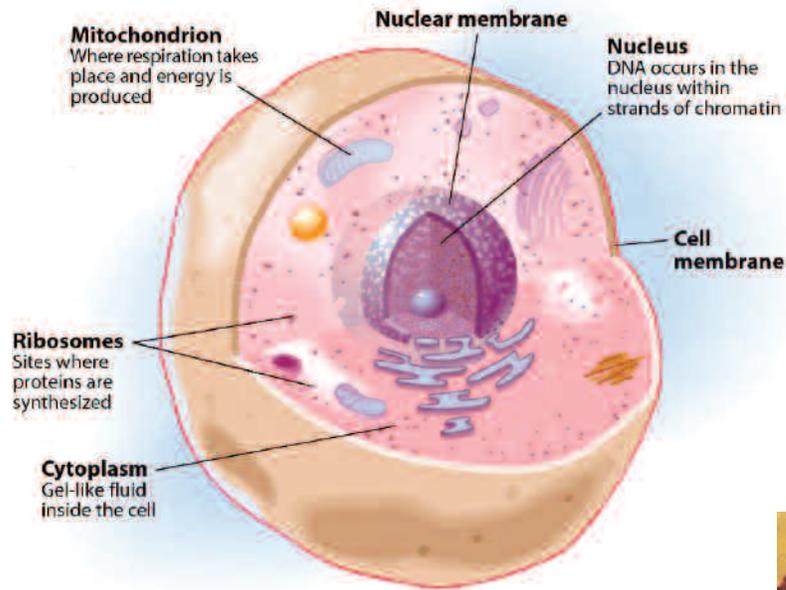
of Genes
Sea of Genes
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Sea of Genes

THE CELL

ALL LIVING THINGS consist of one or more microscopic cells. Bacteria and many other organisms consist of only a single cell, while plants and animals are made up of many cells of different types. Each cell works like a tiny factory within a larger functioning city that represents an entire body. The entire body of an organism relies on close coordination between the many factories or cells within it to function. Special processes go on inside each cell to produce all the materials needed for life, whether it's a plant, animal, fungus, bacterium, or you.



The bacterium *Vibrio cholerae*



DNA: The Chemical Instructions of Life

WITHIN EACH CELL, there is a special chemical compound called DNA, or deoxyribonucleic acid. DNA contains the cell's set of instructions for making all of the proteins needed by an organism. The 2 percent of DNA that makes proteins are called genes.

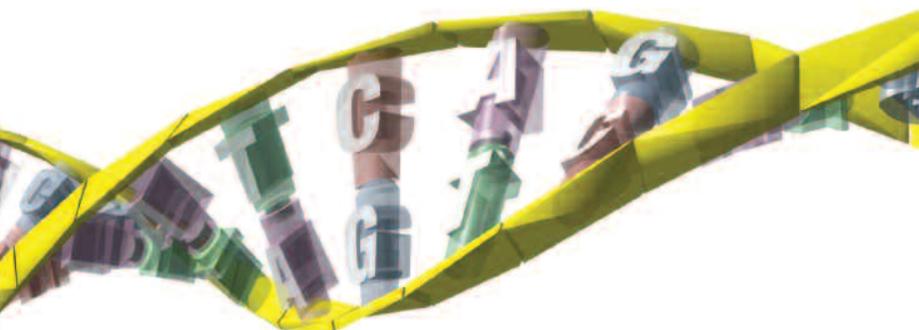
DNA tells cells how to build, fix, and operate themselves over a lifetime. It coordinates the production of proteins that control all of the processes that go on within and outside of each cell. Proteins signal the start of processes that take the body of living things through major stages of life from germination to going to seed, transforming from larva to adult, and being a kid to growing old. They regulate everything down to the smallest detail including replacing the nearly nine pounds of skin cells that each person loses each year.



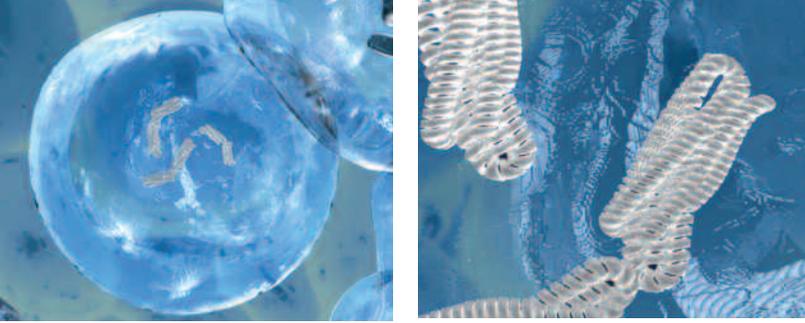
Chromosomes

DNA is stored in a compartment within each cell called the nucleus, except for the cells of bacteria and archaea. The nucleus in turn contains structures called chromatin or chromosomes.

Chromatin and chromosomes are made up of DNA and other materials that support its structure.



The building blocks of DNA



BUILDING BLOCKS OF DNA: A, T, C, and G

DNA LOOKS LIKE AN EXTREMELY LONG, spiral-shaped chain of chemical building blocks called bases. DNA is made up of just four bases. These four bases are adenine (A), thymine (T), cytosine (C), and guanine (G).

GENOME: The Entire Set of DNA in a Cell

INSTEAD OF USING WORDS ON PAPER, an organism's building instructions are encoded in long chemical chains of DNA. Human DNA is arranged in 23 pairs of chromosomes in the nucleus of single cells. Some organisms like bacteria often have just one chromosome, while others like a fern have as many as 630. The genome refers to all of the DNA in a cell, no matter how many separate chromosomes there might be.

In human cells, more than three billion pairs of blocks are linked in DNA. Two blocks are connected side by side, forming each rung of the spiral ladder. You would think that the largest number of bases would belong to the largest creature on Earth, but so far, scientists have determined that a small organism called *Amoeba dubia* possesses the most rungs—670 billion!

A copy of DNA is passed from cell to cell when they divide or combine. With the invention of the microscope, scientists could see that chromosomes were passed between cells when they divided or combined. Right before cells divide in a process called mitosis, they make a duplicate copy so that each resulting cell can have its own copy after cell division.

In the 1950s, scientists proved that traits from cell to cell and from generation to generation of living things are passed in DNA. In 1953, American James Watson and British Francis Crick discovered the shape and structure of the DNA molecule. More recently, the contributions to this discovery by another British scientist named Rosalind Franklin have been recognized.

The order of the blocks A, T, C, and G or the genome sequence of DNA for each species gives each living thing its general and unique characteristics. Like words in a book, the types and order of the blocks in DNA instruct parts of your body to do very specific things.

Artist's renderings of cells and genes.

THE HUMAN GENOME PROJECT

In 1990, scientists embarked on a large project called the Human Genome Project, which was completed in 2003. They set out to find the exact sequence of C, A, G, and T building blocks in human DNA and found it to be three billion blocks long! We now know that similar organisms tend to have a high percentage of genes in common. Individual people differ by just a hundredth of a percent of their genes. Humans share 98 percent of their genes with their closest cousins the chimpanzees, and even 50 percent with the fruit fly.

Because DNA is inherited, related people have similar DNA. It's the DNA that gives relatives common traits such as similar body features, predisposition to disease, and even some personality traits.

Until recently, scientists couldn't store and process all of the information in the genome because computers didn't have enough storage space or couldn't compute fast enough. Today, experts in computing and biology work together and Scripps scientists such as Terry Gaasterland use both skills in a new field called bioinformatics.

Within time, the genomes of other living organisms such as mice, fruit flies, bananas, and marine bacteria will be mapped. This information will help scientists cure diseases, improve crops, solve environmental problems, and much more.

MARINE GENES AT SCRIPPS

With the help of genomics, scientists now have the tools to unlock the biochemical secrets stored in the genes of countless plants, animals, and single-celled organisms that live in the ocean.

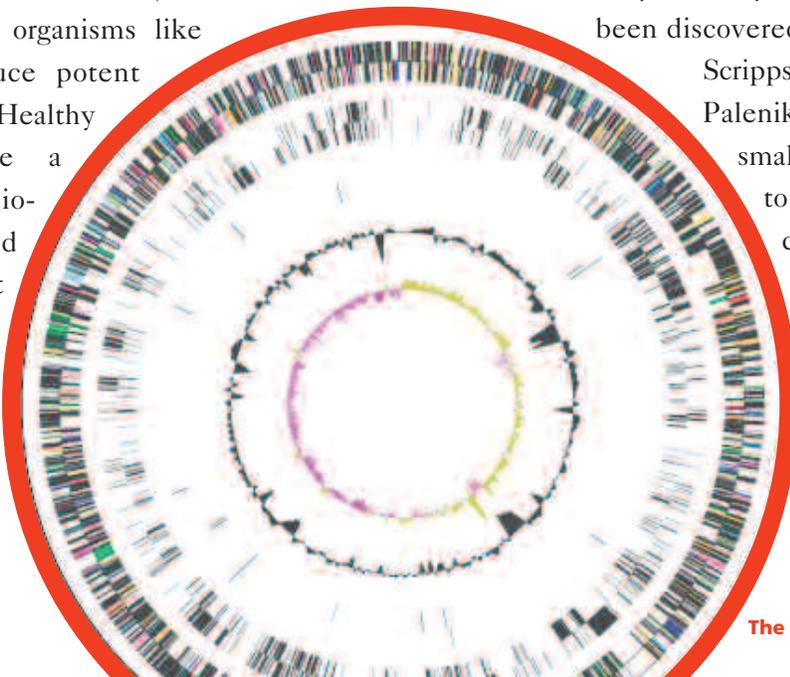
The genes of each organism allow it to produce chemicals that give it unique advantages to survive in a specific environment. For instance, some marine plankton and the bacteria that live within an anglerfish's lure produce a phosphorescent glow like a light stick. In other cases, small and defenseless-looking organisms like coral polyps produce potent toxins for defense. Healthy organisms produce a wide array of biochemicals to defend themselves against one another and their environment.

Many of these biochemicals may be useful for peo-

ple. In Dr. William Fenical's lab at Scripps, he's discovered a chemical toxin produced by a coral that prevents cancer from growing while another toxin prevents skin allergies. Genes make the production of these valuable biochemicals possible.

The most useful of the marine organisms may turn out to be bacteria that live everywhere in the ocean. These microscopic, single-celled organisms are the most abundant and versatile forms of life in the ocean, yet many of them haven't even been discovered.

Scripps scientists like Dr. Brian Palenik wonder whether very small bacteria can be used to perform big tasks like clean up excess carbon dioxide in the atmosphere. Dr. Palenik studies a marine bacterium called *Synechococcus*. Like a plant, this bacterium is



The *Synechococcus* genome map.

capable of photosynthesis, which is a plant's ability to incorporate the Sun's energy into chemical compounds such as sugar. When

Synechococcus conducts photosynthesis, it produces oxygen and uses up carbon dioxide

in seawater, making more room for this gas to be drawn out of the atmosphere and into seawater. Scientists like Dr. Palenik are trying to find safe ways to reduce carbon dioxide in the atmosphere to offset problems caused by excess carbon dioxide added by human activity. Humans have added so much extra carbon dioxide into the atmosphere that Earth's climate is changing in undesirable ways. If scientists find out how a bacterium like *Synechococcus* works, can the combined powers of bacteria be used to clean the atmosphere? Dr. Palenik is peeking at the genome of these bacteria to try to answer that question. By looking at the genes of an unusual group of bacteria, scientists have recently found that these organisms differ from all other bacteria.

This group of bacteria-like single-celled organisms is now classified in the domain archaea. They live

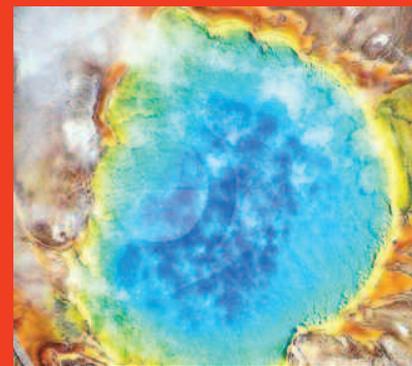
in the hottest and saltiest edges of the ocean, underneath frozen polar ice, near hydrothermal vents, and even in the deepest, darkest depths of the sea. To top that off, archaeans have an unusual skill—they can sustain life where there is no sunlight, unlike almost all other life on Earth.

THE FUTURE

Some scientists estimate that there are more than a million different kinds of bacteria in one gram of soil with maybe as many as five million trillion trillion total individuals on Earth! That's more bacteria than the number of stars in the Milky Way. How many bacteria could there be in one ton of seawater? Scientists believe that there is more than previously thought—possibly even more than in soil.

Today, microbe-rich soils and diverse marine habitats like coral reefs are being degraded at a rapid rate. At least some of our biochemical treasure chests and planetary medicine cabinets are in danger of extinction within our lifetime. The loss of one kind of living thing is also the loss of its unique genes and capabilities. That's one of the many reasons why we must protect the ocean and its inhabitants—even those we don't see.

Whether conservation, genomics, or bioinformatics, an array of exciting careers await today's young people.



Top, Cyanobacteria grow in the hot waters of thermal springs such as this one in Yellowstone National Park.

Middle, Bacteria glow inside an anglerfish's retractable lure, which helps attract prey.

Bottom, Colonies of microbes called snottites living in sulfite acid inside a cave.



Synechococcus



Methanopyrus kandleri bacterium