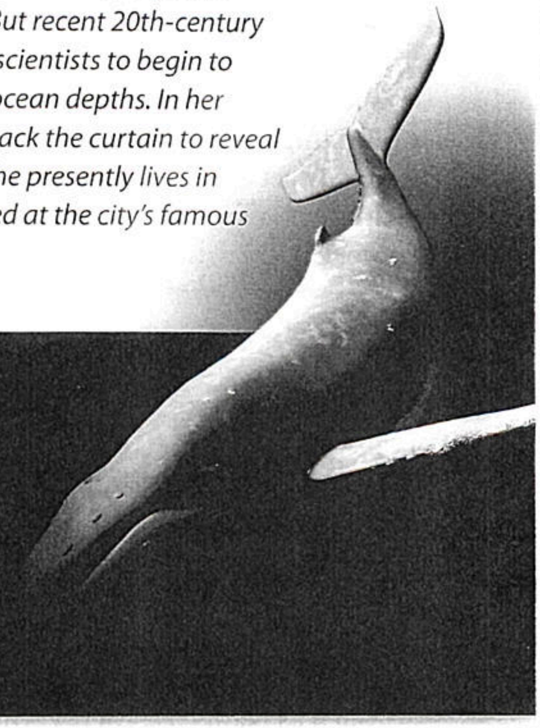
Background *For many years, it was nearly impossible to study life at the bottom of our oceans. Therefore, very little was known about deep-sea habitats. But recent 20th-century technological advances have allowed scientists to begin to discover surprising forms of life in the ocean depths. In her writing,* **Cheryl Bardoe** *likes to draw back the curtain to reveal how scientists explore the unknown. She presently lives in Chicago, Illinois, where she once worked at the city's famous Field Museum of Natural History.*



from
Living in the Dark

Science Article by Cheryl Bardoe

SETTING A PURPOSE As you read, notice how scientific study has altered past beliefs about Earth's oceans. Write down any questions you have while reading.

When a Whale Falls

Imagine the moment when a great blue whale, undernourished and exhausted from migrating, grunts out its last breath somewhere in the Pacific Ocean.

Then, as the pressure of the surrounding water squeezes the last air reserves from the whale's lungs, this massive creature begins to sink.

It plunges 700 feet (200 meters) through the ocean's top layer, the warm "sunlight zone" where algae kick-start life's food chain with photosynthesis. It drops another 2,600 feet (800 meters) through the cold twilight zone, where no plants live and fish have extra-large eyes to catch the faintest glimmers of sun. It descends down, down, down through 3,300 feet (1 kilometer) or more of the midnight zone. Here, temperatures hover close to freezing; deep-sea creatures must flash their own lights to break the darkness; and the weight of the water feels like about 500 bowling balls pressing in on every square inch of the whale's carcass.

The tiny flecks of dead plankton that are called marine snow may drift for months before reaching the ocean floor. But this great blue whale plummets so quickly that scavengers barely get a nibble. Its 160-ton carcass thumps down nearly intact, depositing as many nutrients as several thousand years' worth of marine snow—all in one fell swoop.

This **cache** of resources, called a whale fall, will become the center of a unique habitat. First, it attracts deep-sea scavengers. Hagfish—unsightly creatures also called slime eels—wriggle inside the carcass and begin to eat it from the inside out. Squat lobsters, sleeper sharks, and crabs tear at the whale's flesh and scatter crumbs into nearby sediments. Then mollusks colonize those sediments. Meanwhile, fantastical worms, slugs, and bacteria bore into the whale's bones to feast on fatty marrow.

cache
(kăsh) *n.* A *cache* is an amount of something that has been hidden away.

Finally come bacteria that transform the chemicals leaking out of the decaying bones into food for themselves and others. Much as plants use energy from the sun to make their own nourishment, these "chemosynthetic" bacteria use energy from chemical reactions to create the basic building blocks of life. Within months this whale carcass may support more than 40,000 creatures; it might keep this chemosynthetic ecosystem going for up to a century.

The living things that take up residence on this whale fall are similar to those that live near undersea **geysers** (called hydrothermal vents) or cracks that leak natural gas into the ocean (called cold seeps). Together, these three habitats have completely changed how scientists think about the basic rules for life.

geyser
(gī´zər) *n.* A *geyser* is a natural hot spring that shoots hot water and steam into the air.

Life Where Life Isn't Possible

For most of human history, the ocean's secrets have been beyond reach. Gazing across the water's rippling surface, who could have guessed what truly lay beneath? In the 1840s, British naturalist Edward Forbes dredged the Aegean Sea[1] 100 times to find out. The deeper his device went, the less it

1 **Aegean Sea** (ĭ-jē´ən sē): an arm of the Mediterranean Sea between Greece and Turkey.

dragged up, and Forbes concluded that nothing at all lived below 1,600 feet (500 meters) deep. This theory fit perfectly with what others had observed on land. If the extreme climates of the Arctic and high mountain peaks snuffed out life, then the cold, dark, deep sea must be empty too.

“Within months this whale carcass may support more than 40,000 creatures.”

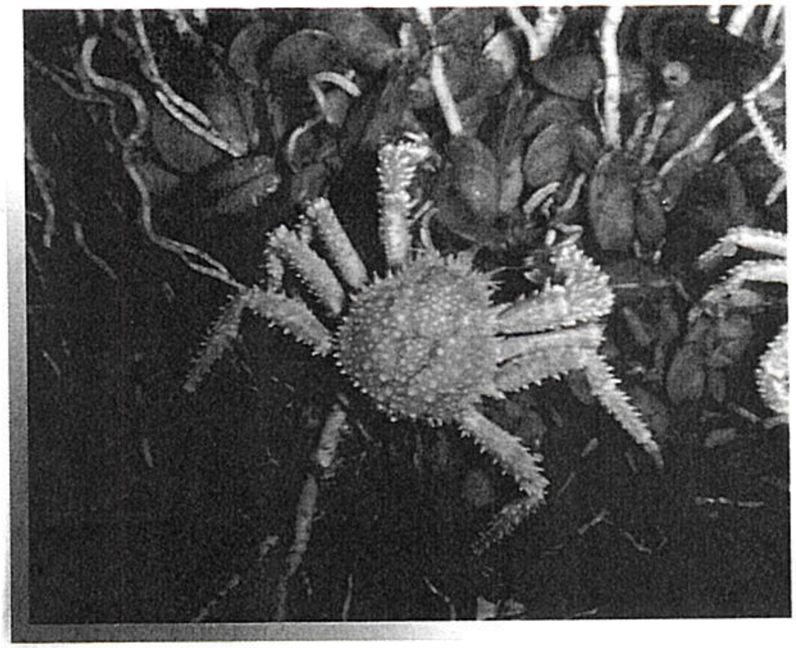
Over the next century, people challenged this theory. Corals were hauled up from 2,500 feet (750 meters) deep; starfish and oysters were gathered from 7,500 feet (2,300 meters). One expedition collected 4,700 new species from as deep as 16,000 feet (5,000 meters)—that's more than three miles underwater! Because photosynthesis isn't possible at such depths, scientists decided that marine snow provided the base of the food chain for these animals. Sure, they acknowledged, life was possible in the deep sea. But scientists assumed that life forms living off such scraps would be **meager**. And so they continued to believe that life couldn't survive in the most extreme ocean-floor conditions.

meager
(mē´gər) *adj.* If something is *meager,* it is small or deficient in quantity.

Then everything changed.

In 1977, a team of geologists squeezed into the research mini-sub called *Alvin,* hoping to confirm whether geysers (like Old Faithful in Yellowstone National Park) existed on the ocean floor. The hydrothermal vents were there, all right. So was a “Garden of Eden,”[2] as the scientists called it, of mussels, anemones, and 7-foot (2-meter) worms with crimson, feather-like plumes. The stunned researchers gathered samples and called biologists at the Woods Hole Oceanographic Institute (WHOI) in Massachusetts.

[2] **Garden of Eden:** the garden that was the first home of Adam and Eve according to the Bible.



On the sea floor, a spider crab, mussels, and worms are revealed by the light of a submersible vehicle.

"It was predicted that vents would exist," explains Santiago Herrera, a biologist currently working at WHOI. "What wasn't predicted was that there would be anything living there." Scientists had found an ecosystem that didn't rely on the sun for energy. Not only that, but its inhabitants were thriving in a place that would be toxic for any other known organism. Ideas about the origins and requirements for life on Earth were suddenly turned upside down.

Hydrothermal Vents

You can often find undersea volcanic activity where Earth's **tectonic** plates are pulling apart. As the planet's crust stretches thin, molten rock breaks through to create new crust. Meanwhile, water soaks into the crust through nearby cracks, dissolving rocks and heating up to temperatures of 660 degrees Fahrenheit (350 degrees Celsius) before rising again through a "chimney" on the ocean floor. When the mineral-rich, super-hot water from the geyser meets the oxygen-rich, frigid water of the deep sea, a chemical reaction is triggered that forms hydrogen sulfide. This smells like rotten eggs and looks like black smoke spewing into the ocean.

tectonic (tĕk-tŏn´ĭk) *adj.* If something is *tectonic*, it relates to the deformation of Earth's rocky crust.

Scientists now know that some bacteria release energy by breaking down these sulfides spewing from the geysers. These same bacteria then harness that energy to turn carbon dioxide and oxygen from the ocean water into sugars—that is, food energy. Ta-da! Here's the foundation for an entire deep-sea food chain.

These chemosynthetic bacteria may be food for other creatures themselves, or may live in symbiosis[3] with other deep-sea dwellers. The giant tube worms, for example, have no mouths or stomachs, but get their food by hosting billions of bacteria within their bodies. Many clams and mussels living near these vents get their food the same way.

Hydrothermal vents have been a constant source of surprises, ranging from the single-celled microbe that actually lives *inside* a vent (and tolerates temperatures of 250 degrees Fahrenheit, or 120 degrees Celsius) to the white crab with such furry arms that it was dubbed the "yeti crab."

Cold Seeps

Scientists discovered a second type of deep-sea chemosynthetic habitat in 1984. This time, bacteria were breaking down the hydrogen sulfide and methane that oozed from cracks in the ocean floor near Monterey Bay, California. Scientists have since identified three sources for these "cold seep" communities: large deposits of oil or natural gas beneath the seabed; deep trenches created by one tectonic plate sinking below another; and undersea landslides or erosion that expose chemical deposits in the seabed.

Cold seep communities play a major role in shaping Earth's climate, Herrera says. "If they did not exist, a lot of methane would end up in the atmosphere." Without bacteria breaking down methane from the ocean floor, this greenhouse gas[4] would escape from the ocean and make Earth warmer.

ectonic
tĕk-tŏn′ĭk) *adj.*
f something is *ectonic*, it relates to he deformation of Earth's rocky crust.

Cold seep habitats develop like those at hydrothermal vents do, but with different species. Chemosynthetic bacteria arrive first, forming large white mats on the sea floor. Crabs and shrimp come to scavenge dead bacteria, and mussels arrive that live with symbiotic bacteria. Over time, the

[3] **symbiosis** (sĭm′bē-ō′sĭs): a relationship between two living things that benefits both of them.

[4] **greenhouse gas:** a gas in the atmosphere that traps heat.

chemosynthetic bacteria produce a hard material called carbonate, which offers tube worms a firmer ground to grip than the muddy sea floor. Then tube worms build up their hard, protective branches, providing living space for even more organisms.

Whale Bones, Stepping Stones

So far, whales are the only animals we know of that can affect life on the ocean floor the same way shifting tectonic plates do. Besides their hefty size, whales are unique in that fats make up 60 percent of their bone weight. (For comparison, humans are born with almost no fat in their bones.) In life, this bone fat helps whales float and store energy. In death, these fats are **decomposed** by bacteria that give off hydrogen sulfide—sound familiar? Once the chemosynthetic community that lives off these sulfides is in full swing, whale falls host an average of 185 different species—the highest number yet observed in such deep-sea communities.

decompose (dē´kəm-pōz´) *v.* When things *decompose*, they decay and break down into their basic parts.

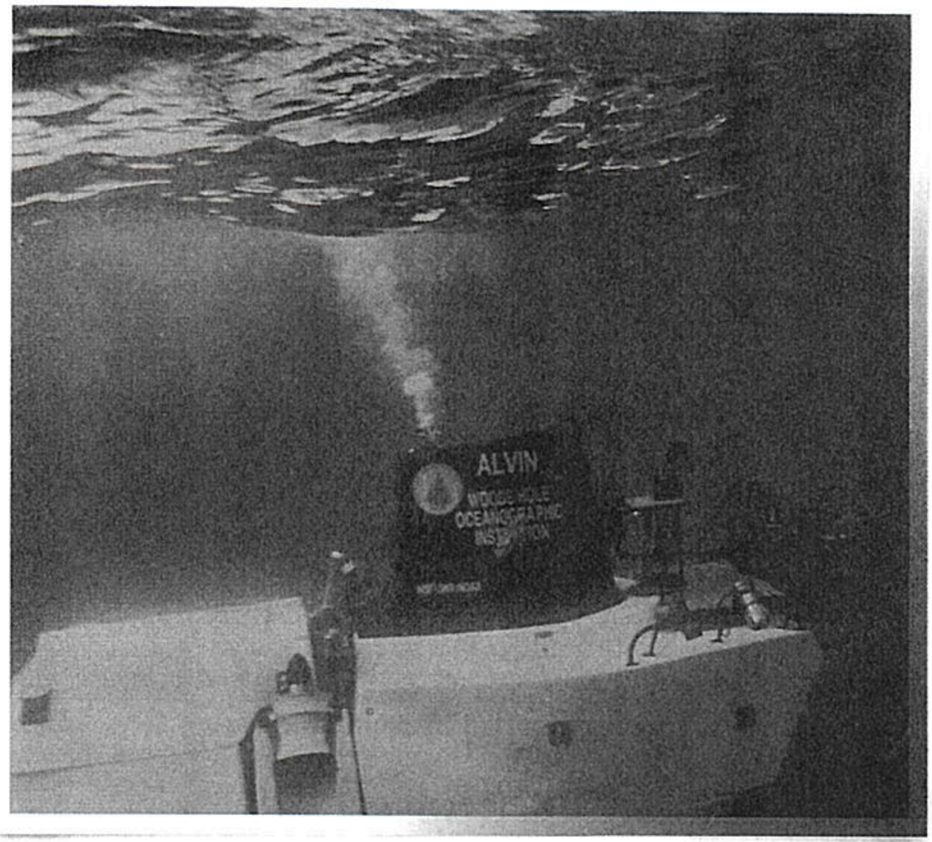
Whale falls might explain how species travel across vast ocean spaces from one hydrothermal vent or cold seep to the next. "There are specialists in each habitat, but there is also overlap," says Craig Smith, a professor at the University of Hawaii, who discovered the first whale fall in 1987. "Some species may use whale falls as stepping stones."

Smith says that seeing the same kinds of communities at hydrothermal vents, cold seeps, and whale falls shows us how connected the oceans really are. "The connectivity is across widespread spaces from seemingly isolated habitats."

At the Whims of the Waves

Thirty-five years have passed since the discovery of the first hydrothermal vent—but study of the deep sea has really just begun. The main obstacle is getting there.

Fieldwork in the ocean requires tremendous resources. For starters, scientists need a ship and a crew. Reaching a field site may take weeks at sea. Then scientists need high-tech equipment to open a window onto the watery world. Even if everything comes together, success is at the whims of weather and waves. Herrera remembers one expedition where an unmanned, remotely operated vehicle (called an ROV) drifted into the wrong place at the wrong time and was destroyed



The *Alvin* submersible begins its descent under water.

by the ship's propellers. "Every time you put something overboard on a ship," he says, "it's basically a miracle that you get it back."

Under such conditions, scientists must balance the thrill of discovery with persistence and patience. Smith knows what that's like. His team discovered the first whale fall at the tail end of the last *Alvin* dive on a research trip. "Within ten minutes of *Alvin's* return, we knew what we had," he says, "but we had to wait a year to get back and investigate it."

Fortunately, improvements in technology are giving scientists more ocean access than ever. In 2010, Herrera sailed to the Coral Triangle, near Indonesia. This is the most diverse marine ecosystem on the planet, and scientists wonder if the deep-sea communities underlying the coral reefs there might be the reason. Herrera was one of only a few scientists on the ship, but video footage of his ROV dives was transmitted to Massachusetts, Maryland, and Washington, plus Canada and Indonesia. Dozens of scientists worldwide witnessed and discussed the dives as if they were all present on the ship.

The goal of this expedition was to explore unseen waters and identify places worth returning to for in-depth research. Scientists saw far more than they expected. Monitoring video from most exploratory dives means watching hours of flat and empty (which is to say, boring) seabed scroll by, hoping to spot something exciting. But on this expedition, Herrera says, "we were never bored because we were constantly seeing amazing species. We suspect this is one of the areas of highest biodiversity[5] on Earth." Scientists will definitely be going back—just as soon as they can find the money to fund another expedition.

To date, scientists have identified more than 1,300 species in deep-sea chemosynthetic habitats. These organisms have introduced us to completely new ways of life and expanded our view of how adaptable life can be. Yet they raise as many questions as they answer. Smith predicts that scientists will find life popping up in even more surprising locations: "We haven't exhausted the list of processes that create these kinds of ecosystems."

The oceans cover 70 percent of Earth's surface, yet less than 5 percent of this resource has been explored. "This is definitely worth investing your whole life to study," Herrera says.

COLLABORATIVE DISCUSSION The author tells how scientists react to evidence that challenges ideas they had long accepted as possibilities. How have scientists reacted to the discoveries of deep-sea habitats? Talk about your ideas with other group members.

[5] **biodiversity:** the range of living things within an environment.

Analyze Structure

COMMON CORE RI 3, RI 5

Science writing usually presents relationships between events or ideas. Events can show **cause-and-effect relationships,** in which one event brings about, or causes, the other. The event that happens first is the **cause;** the one that follows is the **effect.**

Readers of science writing can grasp cause-and-effect relationships by thinking about what happens and why. One of the main clues readers can look for are **signal words.** Words or phrases that signal causes are *due to, because of,* or *since.* Words or phrases that signal effects are *as a result, therefore,* and *led to.* Sometimes the cause-and-effect relationship is not obvious, and readers must look deeper for **implied** causes and effects. This involves making inferences based on clues in the text.

Organizing information into a chart can help you to connect causes and effects. This chart shows a cause-and-effect chain based on ideas in the section "Cold Seeps" of the excerpt from "Living in the Dark."

Cause	▶ Effect	▶ Effect	▶ Effect
cold seep communities form	bacteria break down hydrogen sulfide and methane	methane can't escape from ocean floor	potential global warming is reduced

Reread lines 1–13 from the section "When a Whale Falls." Organize the information into a chart that shows a cause-and-effect chain.

Determine Central Ideas and Details

COMMON CORE RI 2, RI 3

Paraphrasing is the restating of information in your own words. When you read science texts, you may encounter complex ideas and new vocabulary. To check your understanding, use paraphrasing to restate the language in the text. For example, reread lines 33–40 of the excerpt from "Living in the Dark." Then read this paraphrase of the sentence comparing green plants and deep-sea bacteria:

> **Plants make their own food using the sun's energy, but these "chemosynthetic" bacteria use chemical energy to make food.**

Look back at lines 33–40 again. Tell what a "chemosynthetic ecosystem" is in your own words.

Analyzing the Text

COMMON CORE RI 1, RI 2, RI 3, RI 5, RI 6, W 1, W 4, W 8, W 10

Cite Text Evidence Support your responses with evidence from the text.

1. **Cause-Effect** What are the major effects of a giant whale's death on ocean life?
2. **Cause-Effect** Reread lines 87–97. Note the cause-and-effect connections in that paragraph. Paraphrase the information in the form of a chart that shows the cause-and-effect chain. Label the first box as "Cause" and complete it with this entry:
   Water soaks into cracks in Earth's stretched crust.
3. **Compare** What are the three types of habitats described in this article, and how are they alike?
4. **Interpret** Reread lines 104–109. How would you paraphrase the information in the first sentence of this paragraph?
5. **Cite Evidence** Reread lines 79–86 from the section "Life Where Life Isn't Possible." What ideas were "suddenly turned upside down," and why?
6. **Evaluate** Why might the author have decided to end the article using the scientist's quotation?

PERFORMANCE TASK

my WriteSmart

Writing Activity: Persuasive Essay Think about Santiago Herrera's statement at the end of the excerpt from "Living in the Dark." Why does he have that opinion? Why might someone else have a different opinion? Do you agree with Herrera's statement? Use your answers to those questions to write a one- to three-paragraph persuasive essay.

- In your introduction, state your opinion, or claim, clearly.
- In the rest of the essay, present valid reasons for your opinion and support them with evidence from the text and other sources that you can rely on.
- Try to present and refute one counterargument to your claim.