INTRODUCTION

> They that go down to the sea in ships, that do business in great waters; these see the works of the Lord, and his wonders in the deep.
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> —*Psalm 107:23–24*

At a time when most think of outer space as the final frontier, we must remember that a great deal of unfinished business remains here on earth. As robots crawl on the surface of Mars, as spacecraft exit our solar system, and as the orbiting Hubble Space Telescope pushes back the edge of the visible universe, we must remember that most of our own planet has still never been seen by human eyes.

It seems ironic that we know more about impact craters on the far side of the moon than about the longest and largest mountain range on earth. It is amazing that astronauts walked on the surface of the moon before any person saw those earthbound peaks. But it remains a fact that human beings crossed a quarter million miles of space to visit our nearest celestial neighbor before penetrating just two miles deep into the earth's own waters to explore the Midocean Ridge. And it would be hard to imagine a more significant part of our planet to investigate—a chain of volcanic mountains 42,000 miles long where most of the earth's solid surface was born, and where vast volcanic landscapes continue to emerge.

After the historic moon landings, humankind sent probes to the far reaches of our solar system and witnessed amazing, otherworldly scenes and events. Yet perhaps the most affecting image of all those ever returned from space was captured in 1968, when astronauts aboard Apollo 8, on their way to orbit the moon, turned their cameras back on their home planet and revealed it for what it is—a majestic blue-green marble suspended in a cold black void. From that day forward, our world seemed more fragile and finite than ever before. Despite the huge dimensions of the universe, our little planet suddenly became more impressive—a precious jewel.

That picture from Apollo 8 also revealed the vastness of the earth's oceans. We had all been taught that water covers 71 percent of the earth's surface, but now we had a stark visual representation of that figure. Great swaths of solid blue showed more powerfully than ever just how much more of the planet remained to be explored. This new view of our home did not mean that we should cease to wonder about the heavens. Someday, perhaps, astronauts will walk on Mars. But clearly it is the earth where, for at least the foreseeable future, the vast majority of the human race will live out their lives. And for this reason the oceans of the world must receive greater attention than they do at present.

Actually, the figure we so often see quoted—71 percent of the earth's surface—understates the oceans' importance. If you consider instead three-dimensional *volumes,* our landlubbers' share of the planet shrinks even more toward insignificance: less than 1 percent of the total. We and all other creatures that walk, slither, burrow, or fly occupy only a thin layer of soil and air, whereas marine life roams through the oceans' full volume. Most of that enormous volume, roughly 330 million cubic miles, lies deep below the familiar surface. That upper sunlit layer, by one estimate, contains only 2 or 3 percent of the total space available to life. The other 97 percent of the earth's biosphere—the volume of space in which life exists—lies deep beneath the water's surface, where sunlight never penetrates. It is a world that humans rarely glimpse, a realm of eternal darkness.

This hidden deep-sea environment dwarfs all other earthly habitats combined. It is the ultimate reservoir from which life everywhere draws sustenance—a fact we should keep in mind in this age of growing populations and pressure on resources. The planet's entire water supply cycles through the oceans. Some of it evaporates into the atmosphere and returns in rain and rivers; the rest sinks beneath the seafloor and returns through deep-ocean hot springs. The deep sea, in fact, seems to be the planet's central clearinghouse for nutrients and minerals essential to life. It is also a haven for tens of millions of species by some estimates, most of which have never been seen—a greater diversity of animals than in any other ecosystem. The first life on earth may well have started on the deep seafloor. Certainly dry land was colonized by a few life forms that came out of the ocean—one branch of which eventually evolved into our own species. We need to keep in better touch.

Until recently, it was impossible to study the deep ocean directly. To view what lies in the depths of the sea requires us to enter a world in many ways more alien than Mars. Try to imagine, if you will, what ancient mariners must have felt as they left the safety of their settlements and ventured out on the constantly shifting watery surface. What must have gone through their minds as the land's silhouette sank slowly toward the horizon and the color of the sea changed from greenish brown to the transparent blue of the open ocean? With no land in sight, they must have gazed down as far as they could see and tried to picture how deep the ocean was and what lay on its floor—if it had one. At times it must have seemed like a bottomless pit, at other times a ghoulish graveyard of lost souls where great monsters lived. The surface of the sea was to be crossed and recrossed as quickly as possible. To linger was to tempt violent forces controlled by the gods.

Yet even from the earliest historical records, we know of rare individuals who dove repeatedly beneath the surface. Often they went looking for valuable objects: ornamental shells, pearls, or sponges. The first efforts took the bravest divers only a short distance, probably just over 100 feet while holding their breath. Other schemes, such as breathing through reeds or from air-filled bags, would not have extended this depth. By the sixteenth century, diving bells allowed people to stay underwater longer: they could swim to the bell to breathe air trapped underneath it rather than return all the way to the surface. Later, other devices—including pressurized or armored suits, heavy metal helmets, and compressed air supplied through hoses from the surface—allowed at least one diver to reach 500 feet or so by the 1930s. For most, however, the limit remained between 200 and 300 feet, the maximum that compressed air would usually permit. Beyond that depth, so much oxygen accumulates in the blood that it quickly becomes poisonous. Divers who repeatedly went deeper than 200 feet sometimes breathed heliox, a mixture of oxygen and helium.

To protect us from the unforgiving pressures of the deep, engineers began building submarines. Inside their sturdy shells, occupants breathed air at a safe pressure of 1 atmosphere, the same as we breathe on the surface. But even a submarine will collapse under extreme deep-ocean pressures. Today's nuclear submarines can dive only 1,500 feet below the surface, slightly more than one-tenth the average depth of the world's oceans. Ninety percent of the total ocean volume remains beyond their limit.

It was 1930 when a biologist named William Beebe and his engineering colleague Otis Barton sealed themselves into a new kind of diving craft, an invention that finally allowed humans to penetrate beyond the shallow sunlit layer of the sea. They took their first deep plunge off the island of Bermuda, and it is here that my history of deep-sea exploration begins.

From those mile-deep waters, full of many surprises, the narrative traces a moving frontier, continually pushed back by new technology. It proceeds in three parts. In Part I it recalls the early, heroic days of magnificent men and their diving machines. Those dreamers pursued a difficult quest for greater depth and better mobility. Science then was largely incidental—something that happened along the way. In terms of technical ingenuity and human bravery, this part of the story is every bit as amazing as the history of early aviation. Yet many of these individuals, and the deep-diving vehicles that they built and tested, are not well known.

It was not until the 1970s that deep-diving manned submersibles were able to reach the Midocean Ridge and begin making major contributions to a wide range of scientific questions. A burst of discoveries followed in short order. Several of those discoveries profoundly changed whole fields of science, and their implications are still not fully understood. For example, biologists may now be seeing—in the strange communities of microbes and animals that live around deep volcanic vents—clues to the origin of life on earth. No one even knew that these communities existed before explorers began diving to the bottom in submersibles.

Part II follows the teams of scientists who learned how to use those machines to their best advantage, often in tense rivalry with other groups. In terms of scientific achievement, this era was every bit as important for the earth sciences as the race into space was for astronomy. In fact, some of these deep-sea missions began to complement space exploration.

Meanwhile new kinds of deep-diving craft continued to drive back frontiers. Technology again plays a leading role in Part III, most notably in the race to find the *Titanic.* This part of the book introduces a new paradigm for deep-sea exploration. The advances described in the final chapters may allow either you or your children to join a mission someday—not merely as distant observers but as active participants.

It would have been impossible to write a comprehensive history and still keep the book manageable. The contents are of necessity highly selective—more and more so as the history progresses. However, I spent almost as much time compiling the suggestions for further reading as I did writing the chapters themselves, and in that listing I have indeed tried to be comprehensive. A great deal of the knowledge we have gained from the use of deep-diving vehicles appears in those references. Although technology drives the narrative, scientific results dominate the Further Reading section. I believe that this is the first time such a list has been attempted.

Although the actors change as the story evolves, one presence haunts this book from beginning to end: the ocean itself. Entering the deep, black abyss presents unique challenges for which humans must carefully prepare if they wish to survive—and this, sadly, has not always been possible. It is an unforgiving environment, both harsh and strangely beautiful, that few who have not experienced it firsthand can fully appreciate.

First of all, the abyss is dark. And that darkness seems much more oppressive than the blackest chamber inside any cavern on land. Even the most powerful searchlights don't penetrate very far in the deep abyss—typically only tens of feet. One reason is that suspended particles scatter the light. Another is that water itself is far less transparent than air; it absorbs and scatters light. The ocean also swallows other types of electromagnetic radiation, including radio signals. That is why many vehicles described in this story dangle from tethers. Inside those tethers, copper wires or fiber optic strands transmit signals that would dissipate and die if broadcast into open water. (Another strategy for deep-sea communication relies on sound waves, which travel through water much farther than light, but also much more slowly.)

A second challenge we must merely endure: the abyss is cold. The temperature near the bottom in very deep water typically hovers just four degrees above freezing, and submersibles rarely have much insulation. Since water absorbs heat more quickly than air, the cold down below seems to penetrate a diving capsule far more quickly than it would penetrate, say, a control van up above, on the deck of the mother ship.

And finally, the abyss clamps down with crushing pressure on anything that enters it. This force is like air pressure on land, except that water is much heavier than air. At sea level on land, we don't even notice 1 atmosphere of pressure, about 15 pounds per square inch—the weight of the earth's blanket of air. Yet any vessel that dives below the ocean's surface adds, in effect, 1 more atmosphere for every 33 feet it descends—the weight of the water above the craft. As a submersible goes down, the pressure on its hull keeps increasing: 30 atmospheres at 1,000 feet, 300 atmospheres at 10,000 feet, and so on. In the deepest part of the ocean, nearly seven miles down, it's about 1,200 atmospheres—18,000 pounds per square inch. A square-inch column of lead would crush down on your body with equal force if it were 3,600 feet tall.

Fish that live in the deep don't feel the pressure, because they are filled with water from their own environment. It has already been compressed by abyssal pressure as much as water can be (which is not much). A diving craft, however, is a hollow chamber, rudely displacing the water around it. That chamber must withstand the full brunt of deep-sea pressure—thousands of pounds per square inch. If seawater with that much pressure behind it ever finds a way to break inside, it explodes through the hole with laserlike intensity. A human body would be sliced in two by a sheet of invading water, or drilled clean through by a narrow (even a pinhole) stream, or crushed to a shapeless blob by a total implosion. The thought of such a leak actually comforted William Beebe, when it first occurred to him at a depth no living human had ever reached. "There was no possible chance of being drowned," he wrote, "for the first few drops would have shot through flesh and bone like steel bullets."

It was into such a terrifying environment—dark, cold, and mercilessly crushing—that the first twentieth-century explorers ventured. The vehicle for their daring plunge? A simple tethered sphere.