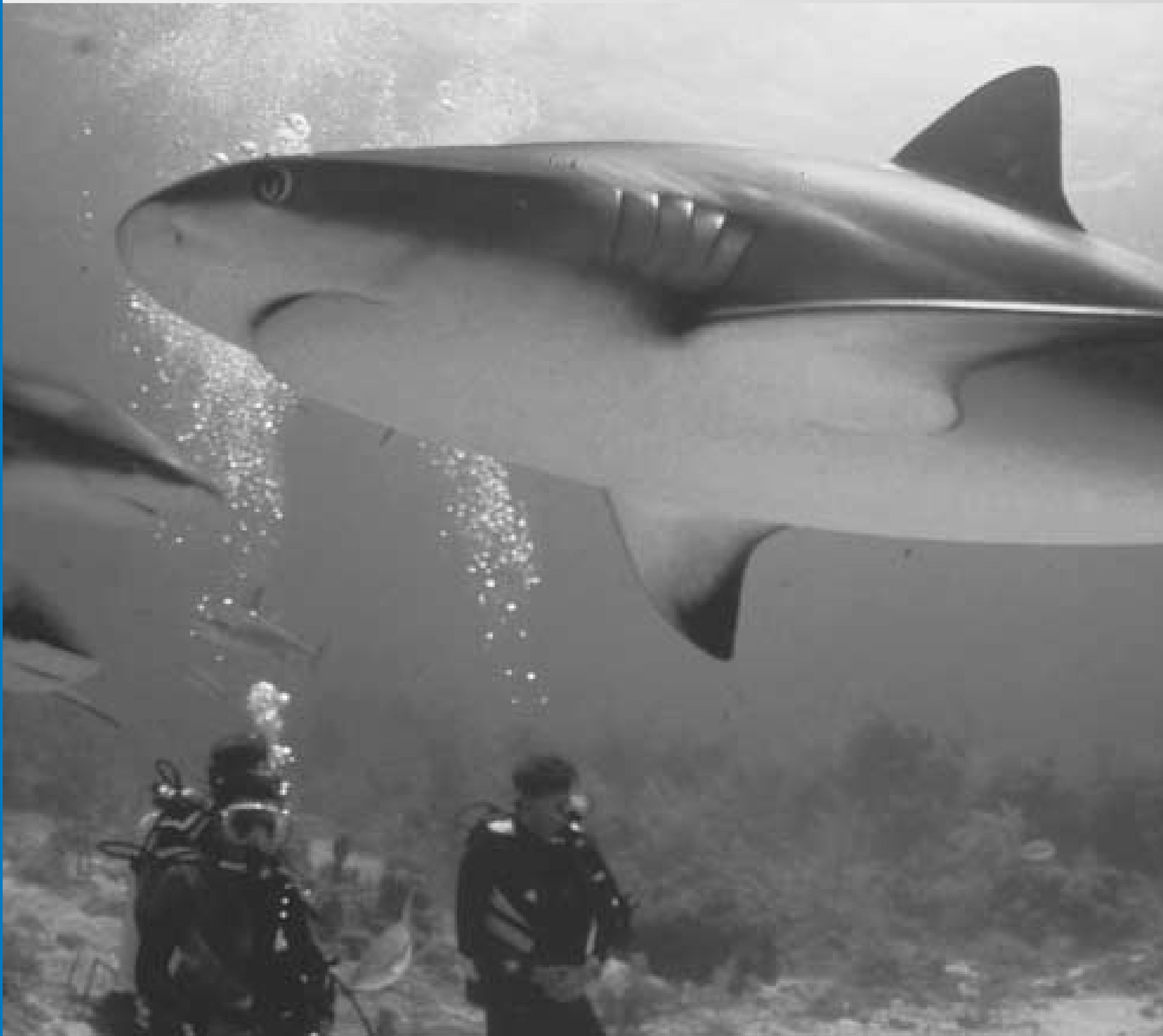
UNIT 1 INTRODUCTION TO MARINE SCIENCE



CHAPTER 1 *Exploring the Oceans*

CHAPTER 2 *Marine Scientists at Work*

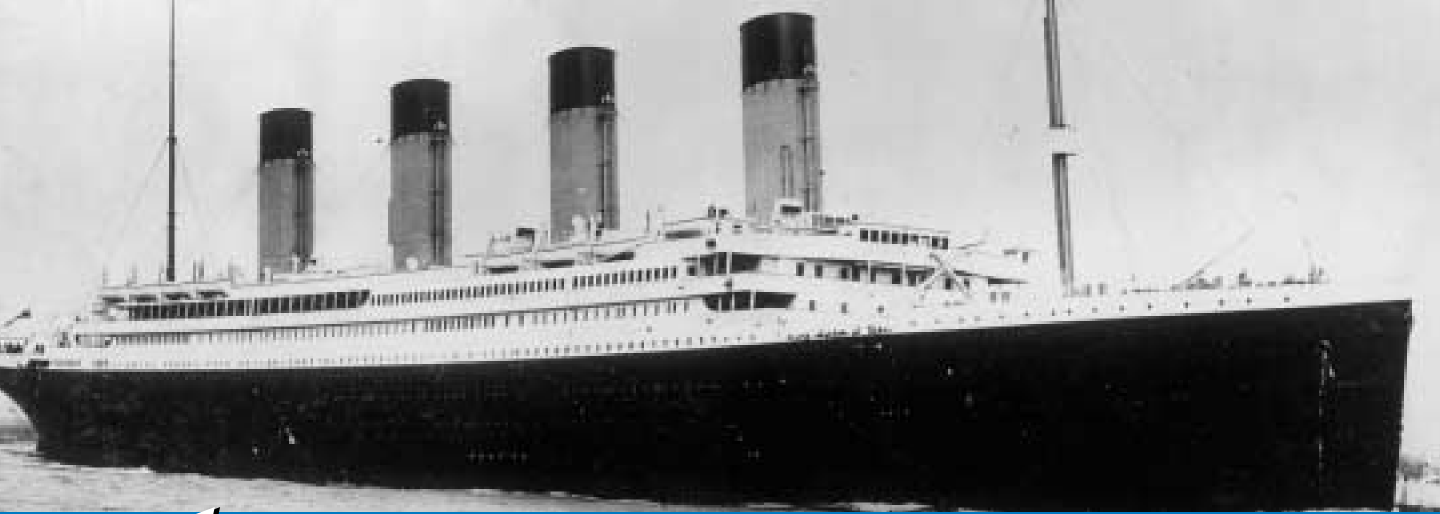
CHAPTER 3 *Marine Environments*

The ocean has been called one of the last frontiers on Earth. People have sailed the seas for thousands of years. Yet we actually know more about the surface of the moon than we know about the bottom of the sea.

In Chapter 1, you will begin your study of marine science by examining the history of ocean exploration.

In Chapter 2, you will learn about the process scientists use in their work. Discoveries in marine science are made by scientists who work in the field and in laboratories.

Most life on Earth is in the ocean, which contains a variety of environments. In Chapter 3, you will learn about the characteristics and inhabitants of these diverse marine environments.



1 Exploring the Oceans

When you have completed this chapter, you should be able to:

EXPLAIN what happened to the *Titanic* when it hit the iceberg.

DISCUSS some of the important people and discoveries in the field of oceanography.

DESCRIBE some of the important events and developments in the history of ocean exploration.

On April 14, 1912, at twenty minutes to midnight, a magnificent passenger ship, the R.M.S. *Titanic,* struck an iceberg in the North Atlantic, 564 kilometers (km) southeast of Newfoundland, Canada. This huge ship—at 269 meters, almost as long as three football fields—was making its maiden voyage, a trip from Southampton, England, to New York. After it struck the iceberg, water poured into the ship. As it took on more and more water, the ship's bow, or front, gradually moved below the frigid surface of the ocean. By twenty minutes past two on that dark night, the great ship assumed an almost vertical position in the water, with the stern, or back, of the ship pointing skyward. Within a few more minutes, the ship sank beneath the Atlantic's surface.

For more than seven decades, the *Titanic* lay on the bottom of the ocean, its grave unmarked. In 1985, the *Titanic's* resting place was found. The technology developed in the years since the ship sank played a crucial role in its discovery. In this chapter, you will discover how science and technology have been used to increase our understanding and knowledge of the ocean.

1.1 THE "UNSINKABLE" SHIP

The sinking of the *Titanic* was among the worst human disasters that ever occurred at sea. Of the 2224 passengers on board the ship, 1513 drowned. Most of the victims were swept into the freezing water when the ship upended. The 711 people who survived in lifeboats were later picked up by rescue ships that responded to the *Titanic's* distress signals.

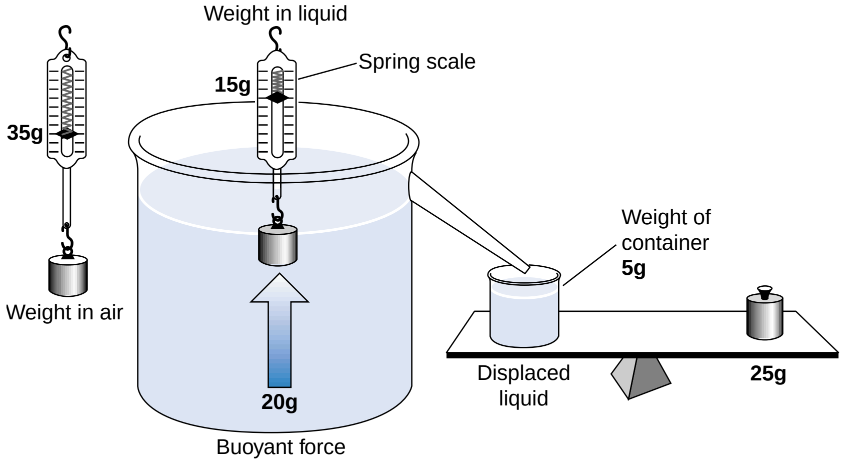
Shipbuilders described the *Titanic* as "unsinkable" because it had 16 watertight compartments designed to keep the ship afloat. The builders were so convinced that their "giant floating palace" could not sink, that they provided only 20 lifeboats with a total capacity of 1178 seats—not enough for everyone on the huge vessel. Ironically, Captain E. J. Smith, who went down with his ship, said, "I cannot conceive of any vital disaster happening to this vessel."

Buoyancy

Why were the builders and the captain of this ship so wrong? All large ships, like the *Titanic,* have hulls made of steel. You may already know that a steel anchor sinks to the bottom of the ocean. Why do some objects sink, while others float? The Greek scientist Archimedes, who lived from 287 to 212 B.C., discovered that floating objects are supported by an upward force called **buoyancy**. According to legend, Archimedes suddenly discovered the nature of this force while taking a bath. He jumped out of the tub and ran through the street yelling, "Eureka, eureka!," meaning "I found it."

Archimedes discovered that (1) the buoyant force on any object is equal to the weight of the liquid that the object displaces, or pushes aside; and (2) a body immersed in a liquid seems to lose weight, and the apparent loss in weight is equal to the weight of the liquid displaced. These observations are known as **Archimedes' principle**, and are shown in Figure 1-1 on page 6. The word equation for Archimedes' principle can be summarized as follows: buoyant force = weight of liquid displaced = loss of weight in liquid. For example, as shown in Figure 1-1, 20 grams of buoyant force of liquid = 20 grams of weight of liquid displaced (25g mass – 5g container weight) = 20 grams of apparent loss in weight (35g weight in

Figure 1-1 An illustration of Archimedes' principle: buoyant force = weight of liquid displaced = loss of weight in liquid.



air – 15g weight in water). Another way of expressing this principle is: buoyant force = weight of object in air – weight of object in liquid. Thus, buoyant force = 35 grams – 15 grams = 20 grams (the apparent loss in weight).

A ship floats because it is constructed with many air-filled compartments. Air, as you know, weighs less than water. Thus, the weight of air and steel in the ship is less than the weight of the water displaced by the ship, so the ship floats. An anchor sinks because it weighs more than the water it displaces. The *Titanic* sank almost three hours after it collided with the iceberg. At that time, experts believed that the impact of the collision caused a huge gash in the ship's hull that punctured a number of watertight compartments. The ship filled with water. In time, the combined weight of the water and weight of the ship became greater than the buoyant force supporting the ship, thereby causing the ship to sink.

The *Titanic* sank to the ocean floor in water that was about 3600 meters deep. For years, oceanographers searched in vain for the *Titanic*. In 1985, it was finally located. Finding the *Titanic* was a triumph in the use of modern technology. How was this lost ship located? What is left of its remains? Before we answer these questions, we need to learn more about the history of ocean exploration that led to this discovery.

1.1 Section Review

1. Why do some objects sink while others float?

2. What damage did people first think caused the *Titanic's* sinking?
3. What is the relationship between a buoyant object and the water it displaces?

1.2 VOYAGES OF DISCOVERY

Since early times, oceans were used for transport and travel. Merchants found that it was often cheaper to transport cargo by sea than by land. Human settlements sprang up along the sea or along waterways that led to the sea. The earliest boats were log rafts and canoes made from hollowed tree trunks. These small crafts were powered by people using paddles or oars.

The first sailing vessels were probably made about 3000 B.C. Powered by the wind, a sailboat could move faster and travel farther offshore than other types of small boats. By using sailing vessels, people became seafarers, and the ocean became a highway for trade.

The earliest recorded trade routes were established by the Phoenicians, about 2000 B.C. The Phoenicians were skilled seafarers who lived in the coastal area of the Mediterranean where present-day Syria and Lebanon are located. By 700 B.C., the Phoenicians had sailed completely around Africa. By A.D. 150, they had sailed north to present-day Great Britain and the North Sea. In that year, based on knowledge gained from the Phoenicians' voyages, the Greek geographer Ptolemy prepared a fairly accurate map of the world.

After the fall of the Roman Empire and the decline of civilization in the Mediterranean, seafaring and sea exploration almost came to a halt—with one major exception. The Vikings, a Norse people living in the region now known as Norway, Sweden, and Denmark, invaded and plundered much of Europe. Raiding voyages were even made as far away as North Africa and North America.

Why were the Vikings such successful seafarers? Part of the answer is that the ships they built were superior to anything afloat at the time. The remains of several Viking vessels have been excavated and reconstructed by marine archeologists. Viking ships were about 15 to 30 meters long, made almost entirely of oak, and powered by sails and oars. The main sail powered the boat when the winds were strong. In times when no winds blew, 32 people rowing together could move the ship quickly through the water. Its flattened bottom allowed the ship to move safely through even shallow water, where other ships would have run aground.

The era of Viking exploration lasted from about A.D. 800 to 1100. During this period, the Vikings discovered new lands. They landed in Greenland by A.D. 1000. Shortly thereafter, they landed in Newfoundland, on the eastern coast of Canada. The Viking era came to an end during the middle of the so-called Dark Ages.

The end of the Dark Ages signaled a rebirth in the exploration of the seas. Expeditions were mounted to discover new trading routes. In 1488, the Portuguese navigator Bartholomeu Dias (1450–1500) sailed around the southern tip of Africa, which was later named the Cape of Good Hope. In 1492, Christopher Columbus set sail from Spain looking for a new route to India by traveling west. He crossed the Atlantic and landed in what is now the Bahamas in the Caribbean. On three subsequent voyages, he reached the coasts of what are now called Central America and South America.

Other navigators and explorers followed Columbus. In 1497, John Cabot sailed from England to explore the coast of North America. He mapped the coast from Labrador to as far south as the present-day state of Delaware. The Italian navigator Amerigo Vespucci, upon landing on the continent of North America, was the first person to realize that this land was not part of Asia. He named the land "Mundus Novus," Latin for "New World." On later voyages, Vespucci explored the coasts of present-day Argentina and Uruguay. Vespucci was responsible for exploring more than 9600 km of coastline in the New World. Mapmakers in Europe named the continents of the New World the "Americas" in his honor.

Word of the Americas spread, beginning a new wave of exploration. In 1513, the Spanish explorer Vasco Núñez de Balboa traveled across Panama and saw "el Mar del Sud," the South Sea—later to be called the Pacific Ocean.

Ferdinand Magellan (1480–1521), a Portuguese navigator, was the first person to attempt to **circumnavigate**, or sail completely around, the Earth. (See Figure 1-2.) In 1519, Magellan sailed west from Spain with five ships and 290 men. The journey was to take three years to complete. In 1522, only one ship with 18 surviving sailors made it home to Spain. (Magellan was not one of the sur-

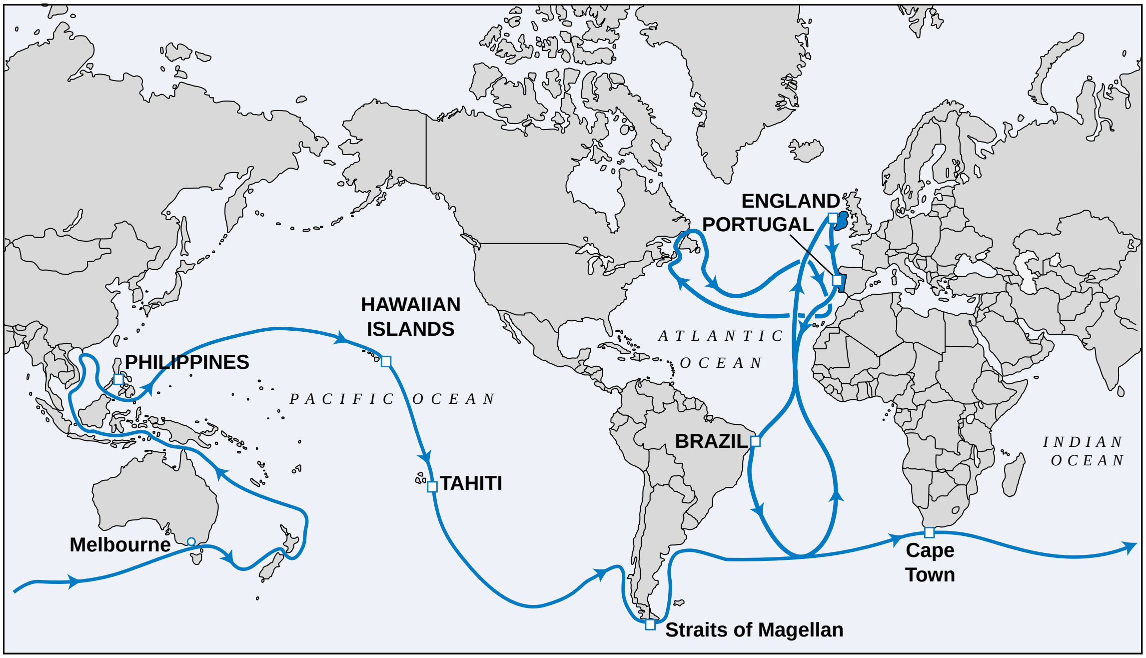


Figure 1-2 Magellan's path in his voyage around the world.

vivors; he was killed in the Philippine Islands. Most of the initial crew were killed in shipwrecks, in mutinous fights, and by disease.)

During the 1500s and 1600s, explorers and navigators continued to map the coastline of the Americas. In 1524, the Italian navigator Giovanni da Verrazano explored the coast of North America from Georgia to Massachusetts. Between 1534 and 1541, Jacques Cartier, a French explorer, traveled along the St. Lawrence River and the eastern coast of Canada. From 1607 to 1611, Henry Hudson, an English navigator commanding a Dutch ship, explored and mapped the river that was later to be named in his honor. During the next 100 years, further coastal explorations resulted in more detailed and accurate maps of the oceans and the coastlines that bordered them.

The spirit of adventure, the quest for discoveries, and the hope of untold riches were the motivating forces behind these navigators and explorers. By the middle of the eighteenth century, much was known about the geography of the ocean. However, scientific knowledge of the ocean was lacking. How deep is the sea? What causes ocean currents? What natural resources does the ocean contain? There were many scientific questions about the ocean that the early explorers did not answer. Another kind of explorer, the scientist, was beginning to uncover the answer to these kinds of questions. Scientific exploration of the oceans followed the work of the explorers and navigators.

1.2 Section Review

1. Why are many early settlements situated along coasts?
2. What special characteristics did Viking ships have?
3. How did Magellan's voyage prove that Earth is round?

1.3 SCIENTIFIC EXPLORATION

Scientific exploration of the oceans began in the mid-1700s with the voyages of Captain James Cook, a British navigator and explorer. On his first voyage, Cook explored the South Pacific in search of a southern continent. Although Cook was not trained as a physician, he was very concerned with the health of his crew. On his long voyages, Cook observed that when the crew ate citrus fruits—oranges, lemons, and limes—they did not develop scurvy. Scurvy is a very serious disease that killed a number of sailors on earlier voyages. Cook made sure that the crew ate a varied diet that included citrus fruits. As a result, on Cook's first voyage, only one sailor out of a total crew of 118 died. Today we know that scurvy is caused by a lack of vitamin C in the diet. This vitamin is found in citrus fruits. So Captain Cook's observations protected the health of his crew, even though he did not understand the reasons why eating citrus fruits worked. (His work proved that, through careful observation, scientific discoveries can be made by nonscientists.)

Being a skilled astronomer, Cook made important astronomical observations. Cook used his knowledge of latitude and longitude to determine his location and he was able to map many islands in the South Pacific. Unfortunately, he did not complete his dream of finding the southern continent of Australia. His life came to an untimely end when he was killed while exploring in Hawaii.

The American statesman Benjamin Franklin (1706–1790) also made several important scientific contributions. For example, he experimented with electricity and invented a heating device. According to popular history, while serving as U.S. postmaster general in 1770, Franklin wanted to find out why mail delivery from Europe to the American colonies took longer than mail delivery from the colonies to Europe. Since all mail traveled by ship, Franklin asked whalers about their experience. In this way, he learned about a water current that moved up along the east coast from the Gulf of Mexico. Franklin had a map drawn of this ocean current, which he called the Gulf Stream; the current flows northeast, then turns and heads east across the Atlantic Ocean. Franklin reasoned that if ships heading west from Europe to the colonies got caught in the Gulf Stream, they would be moving against the current, and therefore the trip would take longer than for ships that were traveling east with the current. Modern oceanographers marvel at the accuracy of Franklin's map of the Gulf Stream, considering the fact that he was not trained as an oceanographer and hardly spent any time at sea.

Scientific exploration of the ocean accelerated greatly in the nineteenth century. In 1831, a British sailing vessel, the H.M.S. *Beagle,* sailed for the western coast of South America on a mission to map the coastline and collect biological specimens. On board was Charles Darwin (1809–1882), the ship's naturalist. During a 5-year period, Darwin collected and observed animals and plants that lived in South America. He also visited the Galápagos Islands, located 965 km off the coast of Ecuador. On these islands, Darwin discovered unique animal species, including the giant tortoise and the marine iguana. In 1859, Darwin published his famous book, *On the Origin of Species by Natural Selection.*

The Beginning of Oceanography

By the middle of the 1800s, a wealth of scientific information on ocean depth, ocean currents, and winds had been collected by ships at sea. An American naval officer, Matthew Fontaine Maury (1806–1873), analyzed the data collected from ships' logbooks. In 1855, Maury published one of the first books on physical oceanography, *The Physical Geography of the Sea.* This book proved to be a valuable guide in navigation for shipmasters and a good reference text because of the technical information it contained.

DISCOVERY

A Highway for Cultural Dispersion

On April 28, 1947, the Norwegian sailor and adventurer Thor Heyerdahl (1914–2002) set sail from the coast of Peru on board the *Kon-Tiki*, a raft made of balsa wood (see photo). Exactly 101 days later, he ran aground on a reef near the island of Tahiti—6935 km away. Heyerdahl wrote about his epic voyage in an adventure book called *Kon-Tiki,* which became an international bestseller. The purpose of Heyerdahl's expedition was to confirm his theory that inhabitants of South America, such as the Peruvian Indians, were capable of crossing the Pacific Ocean to populate the Polynesian islands—centuries before Christopher Columbus dared to cross the much smaller Atlantic Ocean.

Heyerdahl's theory that some ancient human cultures were dispersed across oceans to distant shores—just as driftwood floats on ocean currents to faraway beaches—was put to the test again in 1970. He built a papyrus reed boat, called *Ra* after the Egyptian sun god. Heyerdahl successfully sailed his papyrus boat across the Atlantic Ocean, from the west coast of North Africa to the Caribbean islands, to show that ancient Egyptians could have done the same. Heyerdahl wanted to prove that the Egyptians might have introduced pyramid-building techniques to the Mayan Indians of Central America.

Today, most scholars who study human cultures and societies do not endorse Heyerdahl's theory that all cultural similarities between peoples on distant continents are the result of oceanic dispersion. Instead, they rely on linguistic, archaeological, and genetic evidence to understand cultural similarities between distant peoples. Still, Heyerdahl's efforts were valuable for confirming some ideas about ancient seafaring peoples. Thousands of years ago, similar long-distance voyages across the open ocean did enable the dispersal of people, and their cultures, throughout the widely scattered islands of the Pacific.

QUESTIONS

1. Compare and contrast the main purposes and destinations of the *Kon-Tiki* and *Ra* voyages.
2. Why did Heyerdahl cross the oceans on primitive sailing vessels rather than on modern boats?
3. In what way were Heyerdahl's voyages valuable for an understanding of early ocean travel and cultural dispersion?

However, there was so much more to learn about the oceans. Countries began to mount ocean expeditions devoted exclusively to gathering information in a scientific way. One of the most successful was the voyage of H.M.S. *Challenger.* This British sailing vessel was redesigned into a laboratory ship. From 1873 to 1876, the *Challenger* crossed the major oceans while carrying out a host of scientific tests. For example, water samples were taken and analyzed chemically. Sediments were dredged up from the ocean bottom and studied. Recordings of temperature and pressure were made at many depths in the water column. More than 4700 new species of marine organisms were discovered, described, and cataloged. Data on tides, currents, and wave action were also collected. Enough scientific information was compiled to fill a 50-volume *Challenger Report.* The *Challenger Report* was the most comprehensive study ever completed in the field of oceanography. The organizer of the *Challenger* expedition and the director of research was British zoologist Sir Charles Wyville Thompson. Because of his work, Sir Charles Thompson is credited by many as being the "founder of oceanography."

Many oceanographic expeditions followed. From 1893 to 1896, a Norwegian vessel, the *Fram,* explored the relatively unknown Arctic Ocean. On board was the Norwegian explorer and scientist Fridtjof Nansen (1861–1930), who invented a water-sampling bottle. This device, named the **Nansen bottle** in his honor, is still in use today. (See Figure 1-3.) It is used to collect water samples from different depths in the water column.

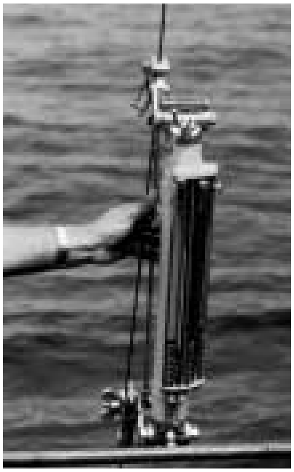


Figure 1-3 The Nansen bottle is used to collect water samples.

By the early 1900s, much of the ocean floor remained unmapped. In 1925, a German research ship, the *Meteor,* cruised the South Atlantic for 25 months. Using a new device called **sonar** (***so***und ***na***vigation ***r***anging), which emits and receives sounds, the *Meteor* took continuous readings of the seafloor. The map that was prepared from these sonar readings revealed a seafloor that had many varying depths and features.

In the late 1940s, the study of the world's oceans expanded rapidly. Many countries launched their own oceanographic vessels, and some countries cooperated in joint ventures of exploration. Expensive oceanographic vessels, staffed by marine biologists and oceanographers, were built to learn more about the oceans. Research facilities were founded that conducted both field and laboratory experiments in marine biology and oceanography.

1.3 Section Review

1. Describe Benjamin Franklin's contributions to the field of oceanography.
2. Why is Sir Charles Thompson considered by many to be the "founder of oceanography"?
3. What do navigators and explorers have in common with scientists?

1.4 EXPLORING INNER SPACE

The early explorers and navigators, on their voyages of discovery, mapped the oceans of the world, increasing our knowledge of the geography of Earth's surface. The world that is found beneath the ocean's surface, called **inner space**, also caught the human imagination. Underwater exploration paralleled the voyages of discovery being made on the surface.

The earliest records of underwater exploration show that the ancient Greeks dove for ornamental shells thousands of years ago. Unfortunately, a diver's vision is blurred underwater; objects cannot be sharply seen. By 2500 B.C., when glass was developed, divers made crude face masks that contained two small pieces of flat glass. The ability to see underwater improved dramatically with the use of such a face mask.

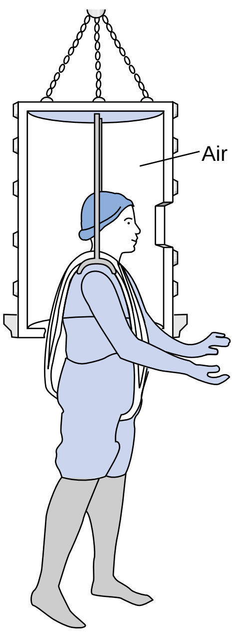


Figure 1-4 Early diving chambers held a supply of air in a barrel.

In the Mediterranean Sea, the ancient Greeks dove for pearls, sponges, and black coral. The Greek historian Herodotus (484–425 B.C.) wrote about Persian divers who rescued treasures from their own ships that had been sunk by the Greeks. Early divers also took part in military operations. The Greek poet Homer said that divers were used during the Trojan Wars, which took place between 1194 and 1184 B.C. And it was said that the Macedonian king Alexander the Great (356–323 B.C.) descended into the sea inside a special container to watch the destruction of enemy fortifications.

Diving Devices

How were early divers able to remain underwater for extended periods of time? A device called a **diving chamber** was used. The diving chamber contained a supply of air. (See Figure 1-4.) Halley's chamber, developed by Edmond Halley (1656–1742), was able to hold a larger supply of air than did the earlier diving chambers. This device had a reserve air supply in a barrel, connected by a hose to the chamber.

Underwater movement in diving chambers was awkward and limited. In time, a more suitable apparatus called a **diving suit** was developed. The diving suit was made of watertight canvas and had a heavy metal helmet, or hard-hat. Weighted boots enabled the diver to walk on the ocean bottom. Air was pumped from the surface through a tube and into the helmet. (See Figure 1-5.) The hard-hat diving suit was a great improvement over the diving chamber. During the era of the diving suit, the sponge industry flourished because the divers could work alone for long periods of time underwater. The diving suit even protected the diver from cold temperatures. However, there was one major disadvantage. The diver had limited movement underwater because of the necessary air hose to the surface.

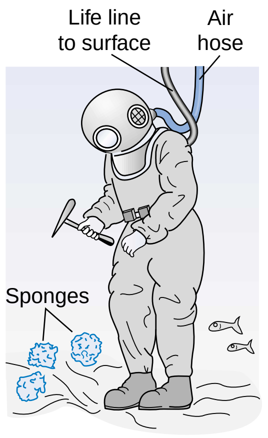


Figure 1-5 The diving suit had a helmet and heavy boots; air was pumped from the surface through a tube.

Divers knew that they could increase their time and mobility underwater if they carried their air supply along with them. In 1808, Friedrich von Drieberg invented a device that had a supply of air strapped to the diver's back. But it could be used for only short periods of time. In 1865, French engineer Benoit Rouquayrol and French naval officer Auguste Denayrouze invented a breathing device that contained compressed air. Their device was worn around the waist.

It remained for French ocean explorer Captain Jacques-Yves Cousteau and French engineer Émile Gagnan to improve this underwater breathing apparatus to make it more efficient. In 1943, Cousteau and Gagnan invented the modern **aqua-lung**, which is a tank of compressed air that is strapped to the diver's back. (See Figure 1-6.) The diver breathes air from the tank through a mouthpiece device called a *regulator*. The regulator (which is connected by a hose to the tank) adjusts the air in the tank to the correct pressure that a diver can safely breathe at any given depth. The aqua-lung is also called a **scuba tank**. Scuba is an acronym that stands for ***s***elf-***c***ontained ***u***nderwater ***b***reathing ***a***pparatus.

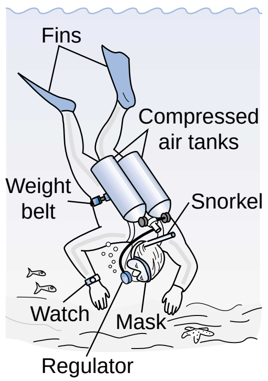


Figure 1-6 The modern aqua-lung, or scuba tank, allows a diver greater mobility and more time underwater than did earlier diving devices.

Diving Vessels

The scientists who explore outer space are called *astronauts*. Scientists who explore inner space are called **aquanauts.** Using scuba gear, scientists can explore the ocean. However, using this type of equipment has its limitations. The average depth of the ocean is about 3600 meters. The deepest dive made by a scuba diver is only about 135 meters. Because of the great water pressure, the depth to which a scuba diver can descend is severely limited.

Only a specially constructed steel chamber can protect human explorers at great depth. In 1934, the American oceanographer Dr. William Beebe reached a depth of about 1000 meters in a round steel chamber called a **bathysphere** (derived from the Greek word *bathos,* meaning "deep"), which had a thick glass porthole for viewing and room for only two people. It was attached to a ship on the surface by a length of very strong cable.

Later, in the 1950s, the Swiss father-and-son team of Auguste and Jacques Piccard developed a much deeper diving vessel called the **bathyscaphe.** On January 23, 1960, Jacques Piccard made the deepest dive ever recorded in his bathyscaphe. Named *Trieste,* the vessel descended to a depth of 10,852 meters into the Mariana Trench in the Pacific Ocean. This undersea trench, the deepest known on Earth, is deeper than Mount Everest is tall. It took more than four hours to make the trip to the bottom.

Beebe and Piccard were pioneers in the use of underwater vessels for scientific research. Since the 1960s, many underwater vehicles have been developed for the scientific exploration of the ocean. These small, research submarines, such as the "souscoup" invented by Cousteau, are called **submersibles**.

Modern Submersibles

A submersible that has logged more than 1000 dives is the *Alvin,* shown in Figure 1-7. This self-propelled submersible can carry a crew of three and has been used on a variety of missions. For example, in 1966, the *Alvin* recovered a hydrogen bomb in 1830 meters of water. The bomb fell from a bomber that had crashed in the ocean off the coast of Spain. Floodlights are used to illuminate the darkness at great depths, and the *Alvin* uses mechanical arms to pick up objects from the seafloor. In addition, the *Alvin* has been used to investigate hydrothermal vent communities along the mid-Atlantic Ridge (see Chapter 16), and has photographed living organisms at depths of more than 3900 meters.

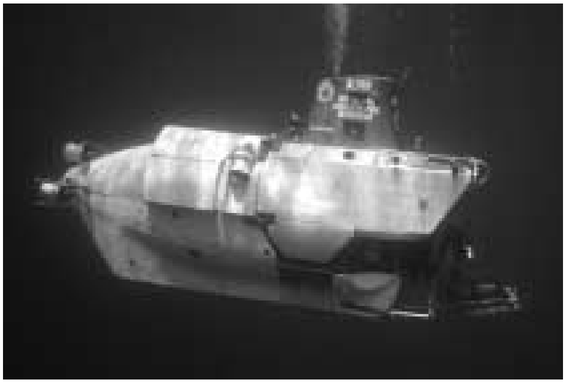


Figure 1-7 The *Alvin* submersible has been used for research on more than 1000 deep dives.

With each passing year, humans are exploring more of the ocean depths. In 1979, American scientist Dr. Sylvia Earle set a record for the deepest dive. She made a solo dive to a depth of 380 meters off the Hawaiian coast. In this magnificent effort, Dr. Earle wore a special "space-age" dive suit, illustrated in Figure 1-8. This high-tech suit was named the *Jim suit* in honor of Earle's colleague, diver Jim Jarratt. It is in many ways like a diver's own personal submersible. The suit is made from the durable metal titanium and is strong enough to protect the diver from the crushing effects of great pressure. Although it contains its own air supply, the suit must remain connected by cable to a ship that is on the surface.

Oceanographers are also exploring the ocean using **robots**. Robot vehicles do not carry any people on board. One important undersea robot is the *Jason*. The *Jason* is about two meters long. It is controlled by computers and is packed with lights, cameras, and scientific sensors. The *Jason* is tethered, or connected, to a sled that is suspended by cables from a surface ship, or to a submersible (such as the *Alvin*). Among other tasks, the *Jason* was used to explore the Gulf of California, 1.5 km below the surface of the sea. Photographs from the *Jason* revealed an alien world of unusual creatures and geological formations.

The technology of underwater explorations is changing rapidly. Untethered robots also have been developed and are now being used. One such robot, called the *Deep Drone*, is a remotely operated vehicle (ROV) that is designed to locate and recover objects on the deep ocean floor. By using robots to explore the world beneath the sea, researchers have increased our knowledge of the ocean floor and its inhabitants. With every dive made by a robot, a new region

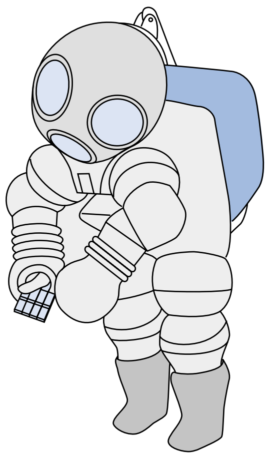


Figure 1-8 The *Jim suit* can withstand the crushing pressure of the ocean depths.

yields its secrets to the probing camera eye. Like the ancient explorers and navigators, the modern-day aquanauts are also making voyages of discovery.

1.4 Section Review

1. How did ancient people explore the undersea world?
2. What advantages do submersibles have over scuba gear?
3. What advantages do robots have over submersibles?

1.5 FINDING THE *TITANIC*

Scientific discoveries are often made by teams of people working together. On September 1, 1985, a joint United States–French expedition located the *Titanic* about 560 km southeast of Newfoundland, Canada. The ship was lying on the seafloor, covered by more than 3600 meters of water. Using advanced technology, marine scientists Dr. Robert D. Ballard and Jean-Louis Michel of the United States–French team searched the area where the *Titanic* was believed to have sunk. As their ships crisscrossed the target area, sonar was beamed from the sea surface to the bottom to help pinpoint the wreck. A robot vehicle called the *Argo,* which contained side-scan sonar and video cameras, searched along the ocean floor. The *Argo* was tethered to the support ship at the surface.

The first video pictures of the *Titanic* lasted only a few minutes. They showed a rusting steel hull of the ship that was remarkably well preserved and covered by a thin film of sediment. On subsequent dives, the team used the search vehicle *Argo* to pass over the *Titanic* to photograph the whole wreck. The video pictures showed that the ship had broken into two parts, with the halves lying about 600 meters apart. A great deal of debris was scattered on the seafloor between the two sections. The bow of the great ship was buried about 15 meters into the mud and sediment. Part of the *Titanic's* stern, lying exposed on the ocean floor, is shown in Figure 1-9.

To get a closer look at the wreck, the submersible *Alvin* was used. Tethered to the *Alvin* was the *Jason*. Signals sent from the scientists aboard the *Alvin* directed the *Jason* into and around the *Titanic*. No

Figure 1-9 Part of the *Titanic's* rusting hull and railing are shown here in a photograph taken by a robot vehicle more than three kilometers deep in the North Atlantic.

remains of passengers could be found. All dead organic matter, including the wooden deck and fixtures, had long since been eaten by marine organisms. Out of respect for the victims of this disaster, the discoverers of the *Titanic* made no attempt to raise the hull or any of the objects found with it.

However, the video pictures they took provided important information. They did not show the huge gash in the ship that was once believed to have been the cause of the ship's sinking. Instead, they showed that several steel plates were dented. Another United States–French research team, in 1996, used sonar to examine the part of the bow that was buried in mud. They discovered a series of six narrow openings along the right side of the hull. Based on the new evidence, marine scientists discovered that the collision with the iceberg tore the hull in several places, breaking the steel rivets that held together the steel plates covering the ship. The compartments inside the ship's hull had watertight **bulkheads**, or walls. But water poured in over the bulkheads, flooding 6 out of 16 compartments in succession, in much the same way that water runs over the sections of an ice cube tray when you tilt it as you fill it. Eventually, the ship held enough water to cause it to sink.

Often, something good comes from tragedy. In this case, reforms were instituted after the *Titanic* sank. All ocean liners are now required to provide sufficient lifeboats to accommodate everyone on board in case of emergency. The sea-lanes used in the winter by ships sailing in the North Atlantic were moved farther south. An International Ice Patrol was also established to locate and monitor drifting icebergs. But these reforms were paid for at a very high price indeed.

1.5 Section Review

1. How was the *Titanic* finally located?
2. Can a ship truly be made unsinkable? Why or why not?
3. What actually caused the sinking of the *Titanic*?

Laboratory Investigation 1

Making Ocean Water

PROBLEM: How can we make seawater for an aquarium?

SKILLS: Using a graduated cylinder; using a triple-beam balance.

MATERIALS: 1000-mL graduated cylinder, large beaker, triple-beam balance, sea salts, spatula, labels, stirrer.

PROCEDURE

1. Fill the graduated cylinder to the 1000-mL mark with tap water.
2. Pour the tap water from the graduated cylinder into a 1000-mL beaker or large container.
3. Set up your triple-beam balance to measure out the sea salts. Use the diagram in Figure 1-10 as a guide. Begin by moving all three riders on the three scales to the notches at the far left.
4. Check that the scale is balanced. The pointer should be at the zero mark. If the pointer is off-center, turn the counterweight screw located under the pan until it comes into balance.
5. Place a piece of paper on the pan to hold the salts. Since the paper has weight (mass), you need to bring the scale back into balance by moving the smallest rider until it balances.

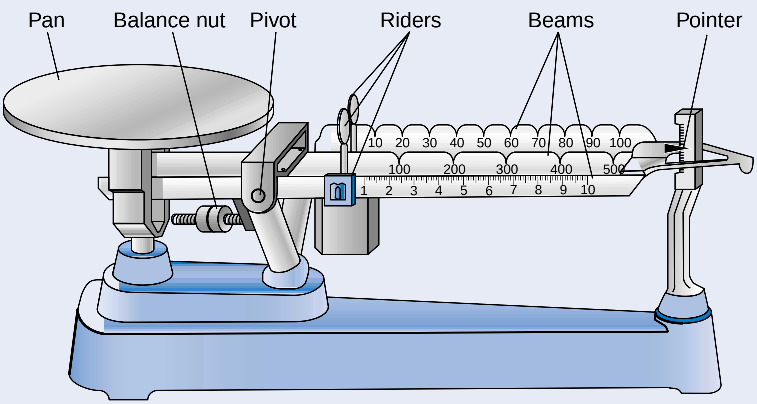


Figure 1-10 A triple-beam balance.

6. Weigh out 35 grams of salt. Move the middle rider to the 30-gram mark and then move the lowest rider up to 5 grams.
7. Use the spatula to put sea salts on the paper. Keep adding the sea salts until the scale comes into balance at the zero mark.
8. Carefully transfer the sea salts from the pan into the jar containing the 1000 mL of tap water. Stir. Label the jar Artificial Seawater 3.5%, and put your name and the date on it.
9. Tap water contains chlorine, which may be harmful to living things in your aquarium. Let the container of seawater stand uncovered overnight. This will de-chlorinate the water (the chlorine gas leaves the water) before it is poured into your tank.

OBSERVATIONS AND ANALYSES

1. A student measured out 350 grams of salt. How much tap water would have to be added to make ocean water containing 3.5% salt?
2. Why should artificial seawater sit overnight before being poured into an aquarium tank?
3. Why is it important to balance the scale before using it?

Chapter 1 Review

Answer the following questions on a separate sheet of paper.

Vocabulary

The following list contains all the boldface terms in this chapter.

aqua-lung, aquanauts, Archimedes' principle, bathyscaphe, bathysphere, bulkheads, buoyancy, circumnavigate, diving chamber, diving suit, inner space, Nansen bottle, robots, scuba tank, sonar, submersibles

Fill In

Use one of the vocabulary terms listed above to complete each sentence.

1. Floating objects are supported by a force called ________.

2. Magellan attempted to ________ Earth by ship.

3. A ________ device uses sound to make readings of the seafloor.

4. Modern divers breathe compressed air from an ________.

5. Diving vessels such as the *Alvin* are types of ________.

Think and Write

Use the information in this chapter to respond to these items.

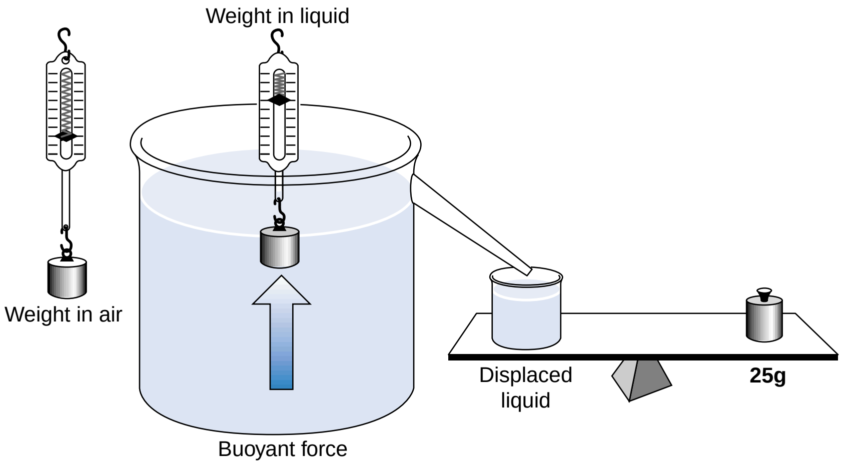
6. Describe the advantages of the diving suit over the diving chamber. How is the aqua-lung superior to both of these?

7. What were some of the factors that motivated the early ocean explorers? How were they similar to those of ocean explorers today?

8. The *Titanic* was the largest passenger ship built at its time. Explain how its particular construction enabled it to float—and to sink—according to Archimedes' principle.

Inquiry

Base your answers to questions 9 through 12 on the diagram below, which shows an experiment that a student performed in order to measure the buoyant force on a submerged object.



Results of the student's experiment are recorded in the following data table.

Weight of collecting can or beaker	5 grams
Weight of metal object in air	35 grams
Weight of the collecting can plus water	25 grams

9. What is the weight of the displaced liquid?
10. What is the apparent weight of the submerged object?
11. What is the buoyant force on the submerged object, as measured in grams?
12. Describe the relationship between a submerged object and the liquid it displaces.

Multiple Choice

Choose the response that best completes the sentence or answers the question.

13. The *Titanic* sank after it hit an iceberg because *a.* the buoyant force on the ship was greater than the weight of the ship *b.* the buoyant force on the ship was less than the weight of the ship *c.* the weight of the ice pushed the ship below the surface, filling it with water *d.* the ship had too many passengers and not enough lifeboats.

14. The ancient seafarers used the ocean primarily for *a.* shipping and trading *b.* scientific exploration *c.* underwater research *d.* recreational travel.

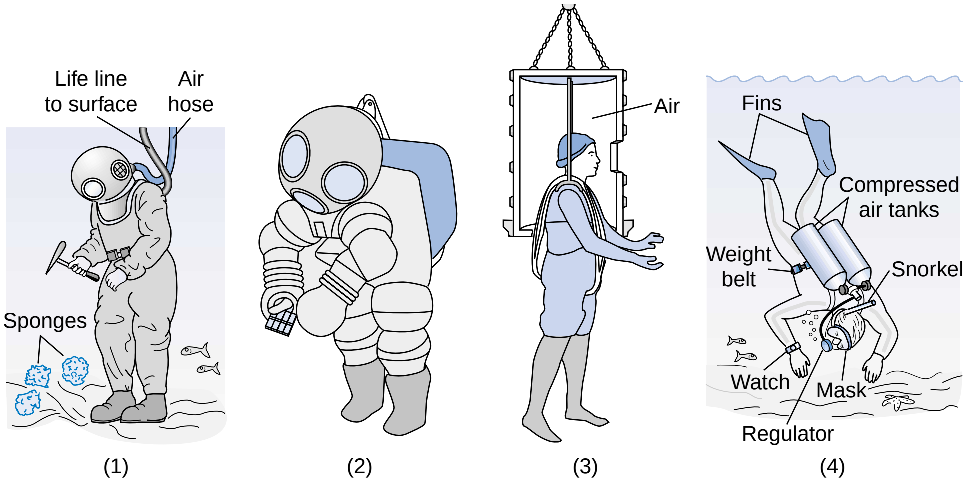
15. A coral stone placed in a saltwater tank caused the water to overflow. The weight of the coral stone underwater was 20 grams. The weight of the displaced liquid was 25 grams. What was the weight of the coral stone in the air? *a.* 20 grams *b.* 25 grams *c.* 35 grams *d.* 45 grams

16. The best explanation for the failure to find all sunken ships is that *a.* sunken ships cannot be found in very deep water *b.* the technology to find ships is too primitive c. the ocean is too vast and largely unexplored *d.* sunken ships completely decay underwater.

17. The founder of the science of oceanography is considered to be *a.* Sir Charles Thompson *b.* Captain James Cook *c.* Christopher Columbus *d.* Benjamin Franklin.

18. An important advantage that a submersible has over scuba gear is that the submersible can *a.* be used to observe the environment *b.* have greater maneuverability *c.* collect items from coral reefs *d.* be used at greater depths.

Base your answers to questions 19 and 20 on the different diving devices shown below and on your knowledge of marine science.



19. What is the proper sequence for the development and use of the diving devices shown (going from past to present)?
a. 1, 2, 3, 4 *b.* 4, 3, 2, 1 *c.* 3, 1, 4, 2 *d.* 2, 1, 3, 4

20. A diver using which device can descend to the greatest depths? *a.* 1 *b.* 2 *c.* 3 *d.* 4

21. An example of a vessel that is a submersible is the
a. *Challenger* *b.* *Alvin* *c.* *Beagle* *d.* *Meteor.*

22. The scientist responsible for locating the *Titanic* was
a. Sylvia Earle *b.* Charles Darwin *c.* Robert Ballard
d. Jacques Piccard.

23. The co-inventor of the modern aqua-lung was
a. Fridtjof Nansen *b.* Sylvia Earle *c.* Edmond Halley
d. Jacques-Yves Cousteau.

Research/Activity

Write a report about a known shipwreck. Include the causes for the shipwreck and your impressions of what the experience must have been like.