Elaborate

Part 1: The Nature of Science

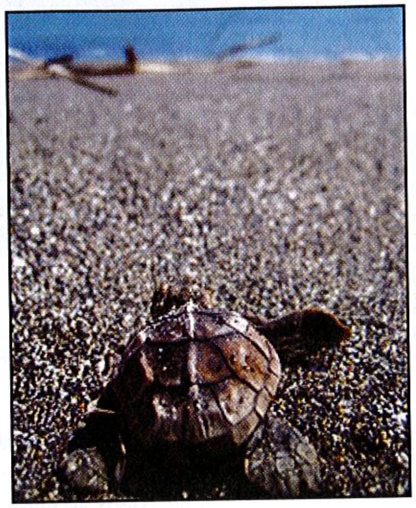

FIGURE 4.12. A Hawksbill Turtle hatchling heads for the ocean.

Have you ever watched fireworks and wondered how people have figured out how to create beautiful colors and patterns in the sky? Have you considered why the sky is blue or how a sea turtle, only minutes old, knows which way to crawl across the sand to reach the ocean? If you have ever asked questions like these, then you know what it is like to be curious about the natural world. Scientists ask questions, or inquire, all the time and begin a process of investigation that leads to discoveries, answers to their questions, and opportunities to ask additional questions. This process is known as **scientific inquiry**.

Scientific inquiry is a cyclical process. All scientists, students, and citizens use their senses (i.e., touch, taste, smell, sight, and hearing) to collect information, or **observations**, about the natural world. Observations are based on what our senses tell us. When scientists collect and record their observations they create **data**. One single observation is a *datum*, the plural is *data*. Data are presented in many different forms, including graphs, charts, tables, pictures, maps, and other ways of communicating information such as multimedia presentations, animations, and technology tools.

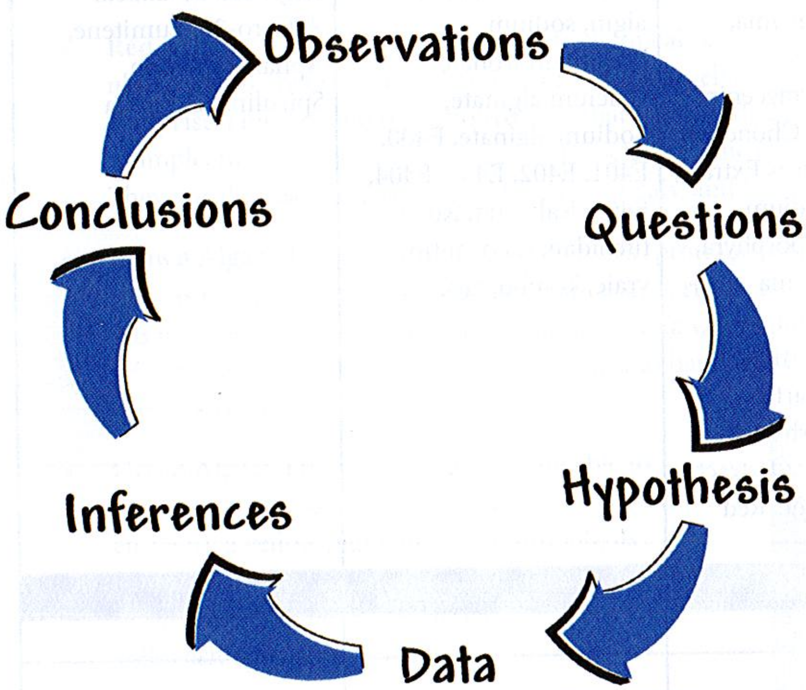

FIGURE 4.13. The process of scientific inquiry is a circular process. Scientists are constantly searching for the answers to new questions that arise in the course of scientific study.

Scientific tools help scientists collect data, as an extension of human senses. For example, a microscope extends our ability to see small organisms and a telescope gives us the ability to see farther away. Without these tools we would not be able to make astute observations and collect detailed data about materials that are very small or very far away.

Data usually fit into one of two categories, depending on how they are collected. Data recorded as measurements are called **quantitative data**. Scientists use the internationally recognized metric system to record quantitative data. For example, instruments such as thermometers, temperature probes, or satellites can measure the kinetic energy of molecules to quantitatively derive temperature. Satellites and tools allow scientists and students to identify the distance that migrating marine mammals travel over time.

FIGURE 4.14. Tiger Sharks are found in Earth's Equatorial Regions. One of the world's largest sharks, these dangerous scavengers can grow to be more than 7 meters (~23 feet) in length.

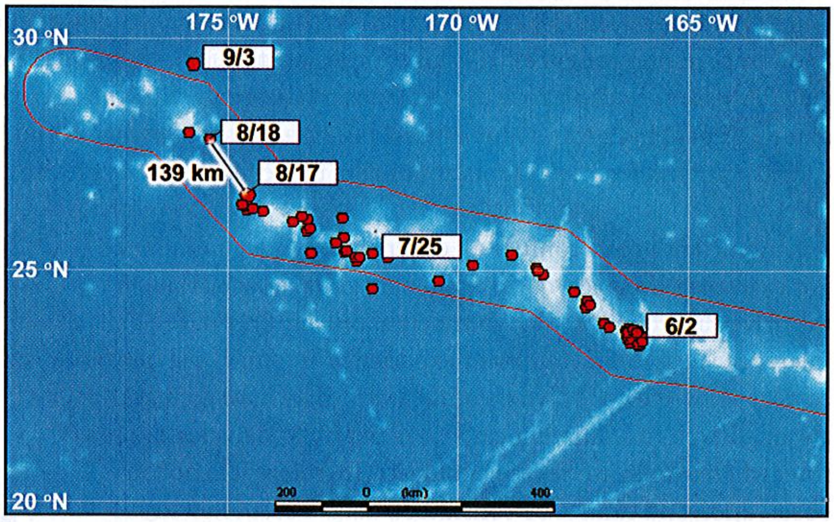

FIGURE 4.15. One individual Tiger Shark track over several months is presented at the *Signals of Spring* website.

The Tiger Shark tracked in the map on the right traveled 139 kilometers (~86 miles) in one day between August 17 and 18.

Data recorded as descriptions are referred to as **qualitative data**. A qualitative observation of the same data is: "The Tiger Shark generally moved in a westward direction during the summer". This is a statement based on the data, but it does not involve measurement. Other qualitative data could be a description of the habitat of the animal at a particular time or what the animal looks like. Quantitative and qualitative observations are both useful and are used together by scientists.

Qualitative data: Quality means property (e.g., appearance, taste, smell, texture).

Quantitative data: Quantity means measurement (e.g., temperature, length, height, cost, levels).

Let's practice to help clarify the difference.

8. Indicate whether each statement is qualitative or quantitative.

   a. The summer forest fire burned a kilometer of forest in several days.
   b. The shell of a diatom looks like shattered glass when observed under a precise microscope.
   c. The leaves on the tree, from top to bottom, are bright red.
   d. Our graduating class has over 700 students, and 60% of them are on the honor roll.
   e. The room is 6 meters x 9 meters.
   f. The sky gets darker over a period of time.
   g. This new yogurt I tried earlier today has a flavor that I find tastes sweet.
   h. More than two feet of snow fell in Washington, D.C., on February 10, 2010.
   i. The Loggerhead Sea Turtle traveled north northeast on Thursday.
   j. The Northern Elephant Seal dove 50 meters on its last dive.

Once scientists collect data they try to find a logical explanation to a question or situation based on their past knowledge and experience. This kind of explanation is an **inference**. A scientist might analyze the Tiger Shark data discussed above along with some observation data illustrating current fish movements. She may infer that the Tiger Shark traveled northeast because it was following its food supply. Inferences help scientists draw conclusions and form questions about data that can become the focus of scientific inquiry.

It is important not to confuse an observation with an inference. For example, when you observe your neighbor's car parked in the driveway, you infer that your neighbor is in the house. This inference is based on your prior experience and may well be correct. However, the owners of the home may have gone for a walk, driven in a different car, or taken public transportation somewhere. Your inference is not fact. Therefore it is not an observation and cannot be considered data. Most often in the *Marine Science: The Dynamic Ocean* animal tracking activities you will perform, your observations will be right on track. Then you will analyze all of your data. You will draw inferences about why your animal is responding the way it is to its environment at the time and moving in a certain direction. Then you will use this information, combining your observations and prior knowledge to support your ideas. Acting like a scientist in the *Marine Science: The Dynamic Ocean* program will give you practice in the process of scientific inquiry.

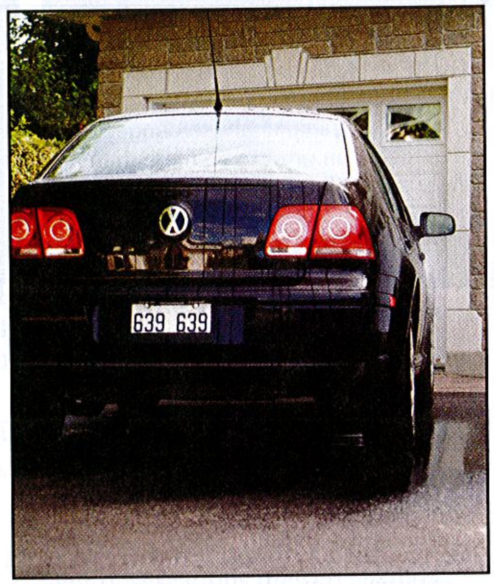

FIGURE 4.16. A car in the driveway suggests someone is home. This statement is an inference.

9. Look at the picture (FIGURE 4.17) and indicate whether each statement below is an observation or an inference.

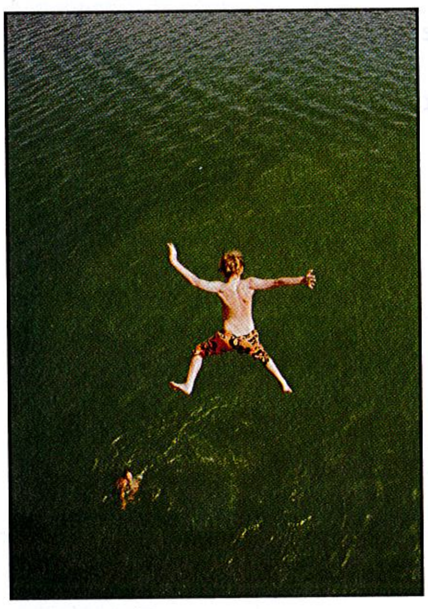
FIGURE 4.17.

a. The boy jumped.
b. The boy is above the water.
c. It is a warm day.
d. He jumped out of a helicopter.
e. The water is a greenish color.
f. There is someone else in the water.
g. It will hurt when he hits the water.
h. The boy is having fun.
i. The boy is scared.
j. He has red hair.
k. The boy was pushed off a diving board.
l. The water is deep.
m. The other person jumped into the water.

10. Write an example of an inference not listed.

11. Write an example of an observation not listed.

Observations and inferences help scientists formulate a testable idea about their scientific question, called a **hypothesis**. To test a hypothesis, scientists set up a procedure or an **experiment**. They must clearly record their procedures, so that other scientists or researchers can repeat them exactly. Experiments result in more data, which scientists will analyze to help form **conclusions** that support, fail to support, or contradict their hypothesis. Inevitably, every time a scientist investigates something, it leads to more questions. Even a hypothesis that is not supported is valuable in science because it sparks additional questions.

You learned in Lesson 1: Diving Into Ocean Ecosystems that scientists use satellite tracking to learn about marine organisms and ecosystems. In the Lessons that follow, you will view various data sets and make observations. You will use your knowledge of marine ecosystems and ocean processes to analyze data and draw conclusions to potentially support or refute your hypothesis. These experiences will model how scientists engage in scientific inquiry to make discoveries about the ocean.

Many people believe that science is made up of boring facts that are set in stone. In fact, science is a very imaginative process. It can be creative as well. For example, scientific concepts may be applied to a new problem for designing solutions and systems, a process called **engineering**.

Science and engineering constantly require new ideas to learn about our world. Science is also always changing—there are plenty of ideas that were once believed to be true but those ideas have changed. Consider, for example, that scientists of the past used to believe that the Sun revolved around the Earth, or that nothing could live in the deep sea. Through investigation and exploration, data collection and inference, scientists have collected evidence that refute *these* hypotheses, but new questions about the solar system and deep oceans are being studied. It is important that scientists share recent and accurate findings with the public and with government agencies. From scientific results, we are then able to make informed decisions that protect the ocean and its resources.

The following statements describe the nature of science:

- Science is based on observations and inferences about the natural world.
- Science is creative.
- There is a relationship between science and culture.
- Scientific ideas are subject to change.

Marine scientists come from all different backgrounds and cultures and work in every country across the globe. They come from small villages to large cities, and, with their unique perspective on the world, each individual provides a valuable point of view and perhaps a creative way of thinking about a scientific question. In other words, they bring their culture, beliefs, and expertise into a scientific discussion or exploration at the onset. Their unique perspectives take a more creative and complete look at a world that is totally integrated on many levels. Scientists from around the globe gather at conferences and meetings to discuss the conclusions of specific investigations. They share new ideas about finding the answers to problems and the technologies needed to collect data. Although anyone can pursue a career in the ocean sciences, these careers take commitment, hard work, and years of study.

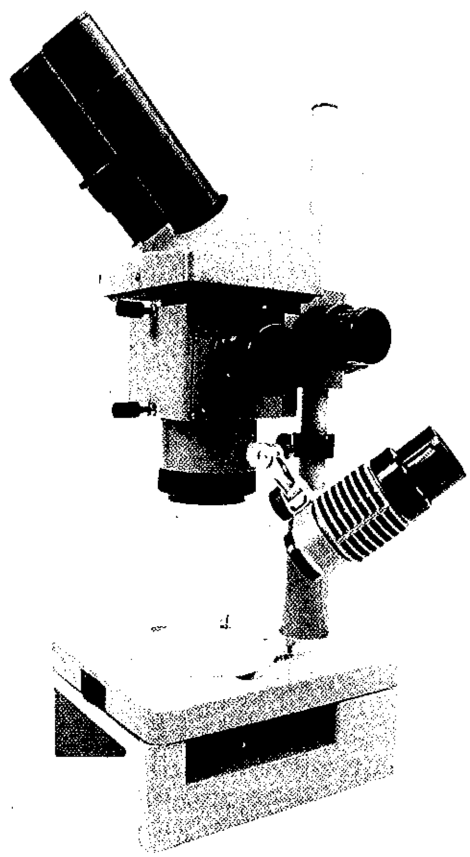

FIGURE 4.18. A microscope is an iconic tool scientists use to make compelling observations.

Western scientific knowledge and indigenous scientific knowledge are examples of perspectives that drive science. Groups of people that are native to a certain place for thousands of years are known as **indigenous** peoples. Other indigenous groups in the United States are Alaska Natives (such as Athabascan and Inuit), Native Hawaiian, and Native American (such as Sioux, Shinnecock, and Navajo). Indigenous peoples around the world understand changes in their environments through many generations of careful observation. Indigenous scientific knowledge is practical knowledge passed on from generation to generation. Most indigenous cultures dictate reverence for Earth's natural environments, and have lived sustainably within specific environments for thousands of years. Indigenous ways of knowing are an important perspective within the scientific community.

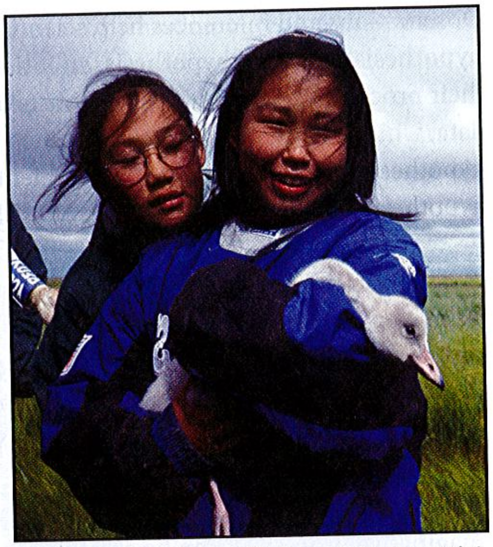

FIGURE 4.19. Alaska Native students assist Western scientists with bird banding.

Today's understandings about the ocean are the result of scientists from diverse backgrounds working together or valuing others' work, engaged in scientific inquiry. Because there is one ocean, it is natural that scientists from all over the world study its features and processes. In recent years, more people from diverse races, cultures, genders, and backgrounds have become scientists. The scientific community will benefit from the diversity of scientists and our understanding of the natural world will continue to grow as this trend continues.

The following images show scientists of different backgrounds working together on the same expedition. This NOAA expedition, entitled *Lophelia II: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks*, took place in 2009.

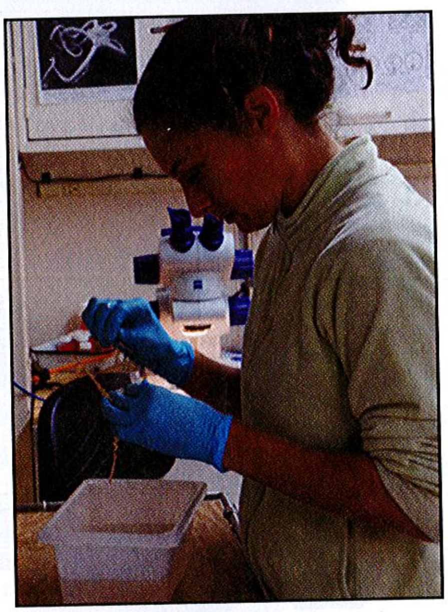

FIGURE 4.20. A scientist takes a tissue sample of a coral for genetic analysis. From this analysis, she and other scientists can make observations and inferences.

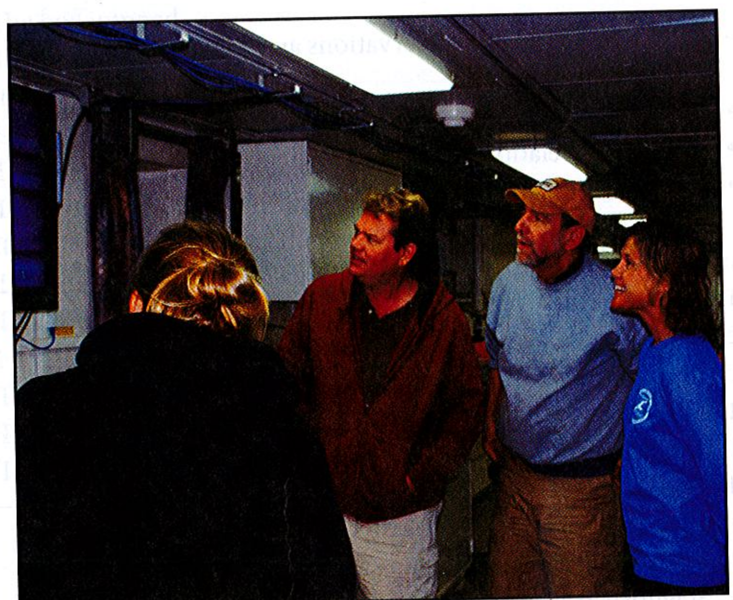

FIGURE 4.21. Scientists on a ship work together and watch as seafloor imagery appears on the monitor in the research vessel's main lab.

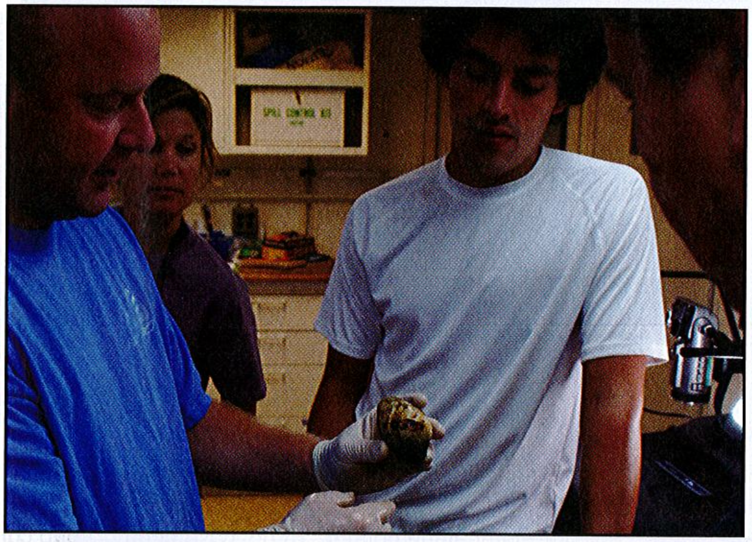

FIGURE 4.22. The team of scientists observes and discusses a biological sample.

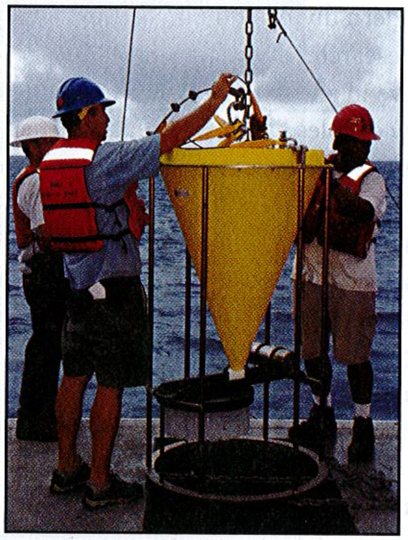

FIGURE 4.23. Sediment traps are deployed from the stern of the ship. These tools will capture samples of the seafloor for analysis.

Part 2: Innovative Ocean Technologies

See Page 694 for how to access e-Tools.

View the ***Ocean Technologies Videos*** from the e-Tools.

Video 1 (0:53) | Video 2 (1:08) | Video 3 (1:04) | Video 4 (0:31) | Video 5 (0:39) | e-Tools

FIGURE 4.24. Screenshots of ***Ocean Technolgies Videos***.

View several of the videos from the *Lophelia II* and other expeditions. Pay close attention to the remarkable technologies used by the scientists. Note that some of the underwater videos may appear a bit dark and grainy.

12. Give at least two examples of how scientists from different perspectives and disciplines work together.

The types of ocean exploration technologies shown in the videos were the dream of marine scientists and explorers for centuries. It is only over the past 50 years that explorers' fantasies have become reality, yet scientists estimate that 95% of the ocean has still not been explored in any great detail. Current technology allows scientists to explore depths and distances that were never before accessible. The technologies now available to an ocean technician or researcher include huge oceangoing vessels that serve as research stations and floating homes for scientists who embark on expeditions lasting for a few days to several months at a time. These ships carry computer systems, navigation and communication systems, research equipment, and full laboratories where scientists can conduct their research, and technicians and staff can assure safe voyages.

Modern diving equipment plays a major role in research. It gives scientists the freedom to move in and explore marine. Diving technology now enables humans to reach deeper than 40 meters (>130 feet) beneath the surface. When investigating beyond the safe depths for diving equipment, scientists use pressure-controlled chambers called **submersibles**. Submersibles are now widely used to allow humans or data collection tools, such as cameras or sensors, to explore deep ocean ecosystems. Submersibles in which humans travel are called human occupied vehicles, or **HOVs**. Some of the most famous oceanic discoveries, including life seen in hydrothermal vent communities, are a result of work in HOVs. These vehicles, however, are not as versatile as unmanned vehicles. The United States also maintains an undersea laboratory located off the coast in the Florida Keys National Marine Sanctuary about 20 meters (~66 feet) below the surface. From the decks of ships or from shore, other scientist teams can send out unmanned equipment called remotely operated vehicles (**ROV**s), or autonomous underwater vehicles (**AUV**s). ROVs are connected to ships through a cable, or **tether,** whereas AUVs are not limited in this way. AUVs are self-guided by computers, allowing them to reach extremely deep water and wider geographic areas than ROVs. They can even be used during bad weather. Both ROVs and AUVs are equipped with a variety of sensors that allow them to observe physical and biological features of the ocean.

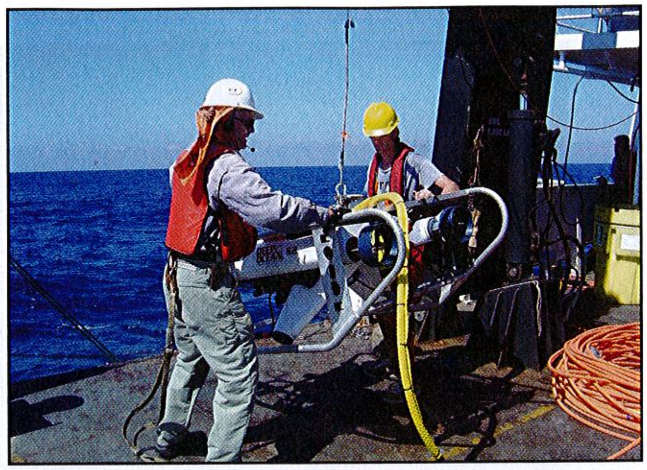

FIGURE 4.25. Scientists prepare to launch an ROV. Advantages of ROVs over submersibles are that there is less risk to humans, less cost, and much more time can be spent at the bottom. ROVs have been used to conduct research in a wide range of environments—from the tropics to the poles.

See Page 694 for how to access e-Tools.

View the ***Aquarius Video*** (3:14) from the e-Tools.

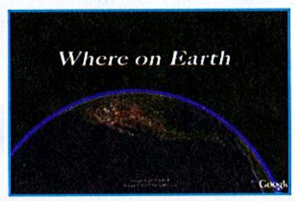

FIGURE 4.26 Screenshot of the ***Aquarius Video***.

e-Tools

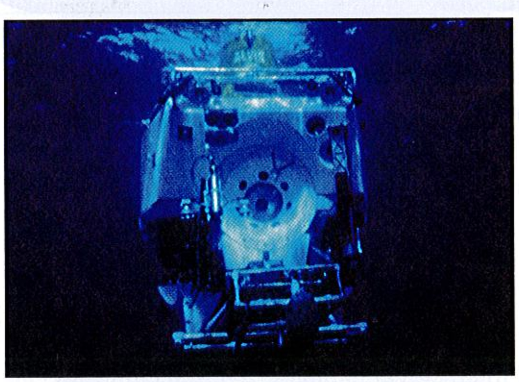

FIGURE 4.27. *Alvin*, arguably the most successful research submersible, can dive up to 4,500 meters (~14,764 feet). For many years it has performed underwater tasks and taken extensive photographs. It can stay underwater for up to 3 days.

In addition to these fascinating technologies, scientists use a wide range of observational tools to monitor Earth's processes. Many of these devices are used onboard research vessels and submersibles, while others collect data from thousands of miles above the surface of the ocean. Satellites house instruments that provide remote-sensing data, helping scientists to understand sea surface temperatures, currents, changes in food availability, pollution, flooding, the location of animals, and more of the activities on the planet. Ocean-observing systems (OOSs) combine satellite data along with observations from land, air, and ocean-based sensors such as those on ships, buoys, and aircrafts. These systems provide us with a great deal of data, which are processed by computers in laboratories onshore. Satellites are an extremely important tool for understanding ocean ecosystems, which you will discover in the Lessons to follow.