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CHAPTER 1

Discovering the Oceans

Throughout history, men and women have been drawn to the sea. In ancient times, people felt the same desire you and I feel today, the urge to stand and gaze upon the ocean. Then, as now, the ocean meant different things to different people. For the hungry, the sea was a source of abundant food: fish and lobsters, seals and seaweeds, whales and shrimp. For the audacious, the ocean was a route to faraway lands, an avenue of commerce and conquest. For the bereaved, the ocean epitomized grief: the oblivion into which their loved ones sailed, never to return, or the source of waves that consumed their villages. For the lucky, the sea was a source of pleasure and recreation.

These historical perspectives persist, but if you go down to the shore today and stare out to sea, your perspective is likely tempered by a modern point of view. With our recently acquired ability to travel into space, we now see the earth and its oceans as a whole (figure 1.1). Using satellite cameras we can locate storms and guide ships out of harm's way. We can count the phytoplankton that fuel the fisheries and direct fishermen to fertile grounds. Our sensors detect climatic anomalies as they begin, allowing us to predict their consequences. These are exciting times for humankind's interactions with the sea.

But this new perspective has two dangers. First, our capacity to see the entire earth can foster a sense of arrogance. It is easy to forget that the ability to observe is only the first step toward the ability to understand and control. As we learn how the ocean works, we must be careful to note the limits of our knowledge. Second, the grand view from space has the tendency to diminish our sense of personal contact. Awe-inspiring as it is, figure 1.1 cannot convey the infinite expanse of the ocean at night when viewed from the deck of a small ship, the tang of salt on an ocean breeze, the crash of a breaking wave, or the shiver of water against your skin. To arrive eventually at a full appreciation of earth's seas, we first need to anchor our perspective in human experience. To that end, we retrace the steps of our ancestors and explore the arduous path by which human society discovered the oceans. In this chapter, we have time only for an outline of the full journey—a mad dash through history. So, brace yourself as we begin with legends.

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Figure 1.1. Earth from space. A photograph of the western hemisphere from the Visible Earth project at NASA (visibleearth.nasa.gov/view_detail.php?id=2429).

Ancient Myths

In many cultures, myths of the sea tell mostly of destruction. From the islands of the Pacific to the coasts of Central America, India, and the Middle East, when the ancient gods were displeased with men or women, they often chose the ocean rather than fire or wind as the instrument of their wrath. In the Bible, for instance, forty days and forty nights of rain caused the sea to rise and wipe the earth clean, sparing only Noah and those on his ark. Similar legends of earth-cleansing floods are common among civilizations in the Middle East. The Babylonians, for example, had a flood myth similar to that of the Bible, with a

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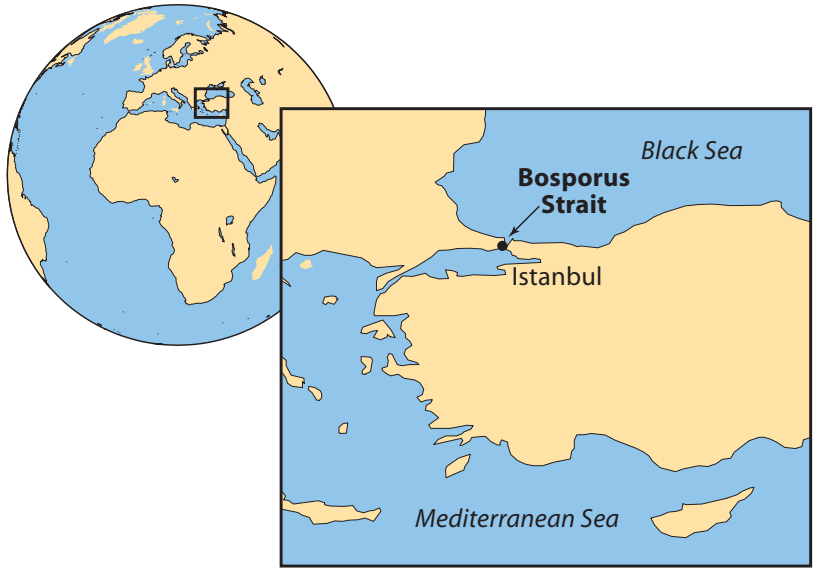

Figure 1.2. The Bosporus Strait, in what is now Turkey, separates the Black Sea from the Mediterranean Sea. Before the strait opened, the Black Sea was a freshwater lake.

man named Utnapishtim playing the role of Noah. Likewise, the Sumerians had King Ziusudra.

Given this ubiquitous mythical reference to floods, some historians have suggested that there are historical bases for these tales. For example, legends of a great flood among coastal Indians of the Pacific Northwest may refer to tsunamis (tidal waves) caused by earthquakes, and the flood myths of Pacific islanders may describe waves resulting from volcanic eruptions.

A potential, although controversial, source of the Middle Eastern flood legends concerns the Black Sea. Today, the Black Sea is connected to the Mediterranean Sea by the Bosporus Strait, a narrow passage adjacent to Istanbul (figure 1.2). However, about ten thousand years ago at the end of the last Ice Age, a sill (essentially an earthen dam) closed the Bosporus, and the Black Sea was a freshwater lake. As the glaciers receded and earth's climate warmed, the level of the Black Sea dropped due to evaporation, while the level of the Mediterranean rose as the world's oceans absorbed the water from melting ice. Eventually, the Mediterranean broke through the sill separating it from the Black Sea, and the consequent flooding would have been catastrophic to the villages along the Black Sea's coast—an event worthy of a legend.

Regardless of their precise origin, the flood myths convey the mystery and fear that tinged ancient encounters with the sea.

Commerce and Expansion

For all its destructive potential, the ocean has always tempted humans to risk its dangers in search of food and rapid transport. Boats built of wood and reeds traveled the waters of the Nile River in Egypt as long ago as 4000 BC, and many ancient civilizations of the Middle East used boats for fishing and coastal commerce. In particular, the Phoenicians were adventuresome merchants and adept sailors. In the first and second millennium BC, they developed

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a complex web of trade routes around the Mediterranean, and sailed as far north as the British Isles, trading for tin to use in making bronze. Similarly, in the Far East, coastal commerce using sampans and junks flourished in China. In the Arctic, the Inuit developed sea-going kayaks and umiaks, capable vessels from which they could hunt walrus and whales.[1] The indigenous people of Chile, Peru, and Ecuador used small reed boats and large rafts for fishing and commerce.

In fact, some anthropologists suggest that the expansion of humans into North and South America occurred most rapidly not by land, but rather by sea. Experts agree that humans spread from Asia into North America after the last Ice Age, and have long assumed that humans spread throughout North America before subsequently expanding to Central and South America. It has recently been proposed, however, that the leading edge of this expansion was not through the middle of the continent, but rather along its western shore as groups used small boats to travel south. For example, a village at Monte Verde on the coast of Chile probably dates back to at least 15,000 BC, a time when humans were only beginning to populate central North America. Clearly, from very early times, our fear of the ocean has competed with—and often lost to—our urge to go exploring in boats.

Perhaps the best example of this wanderlust is the spread of humanity to islands in the Pacific. Starting in the Philippines about five thousand years ago, modern humans rapidly expanded their range in the open expanse of the Pacific Ocean. By 1600 BC they had reached New Guinea and the nearby Bismarck Archipelago. Forced onward by population growth, Polynesians next sailed to Samoa around 1200 BC, and by 500 AD, they had traveled all the way to Hawai'i and Easter Island (figure 1.3).

It is clear that this expansion was not the accidental result of a few fisher folk being blown offshore and ending up on other islands. Hawai'i, for example, was settled by sailors traveling from the Marquesas across 3700 kilometers (2300 miles) of open ocean. That monumental leap required ocean-going outrigger canoes large enough to carry not only people but also the plants and animals of their culture. And finding Hawai'i required exceptional working knowledge of navigation and the sea. Each step in the Polynesian expansion involved skill, planning, and a group effort.

Even for the Polynesians, however, there were limitations. They sailed from one island to another within a circumscribed area of the Pacific, but this expansion was constrained by the availability of uninhabited islands. As well planned and skillfully executed as they were, Polynesian expeditions were incapable of invading previously occupied mainland territory. For instance, if prehistoric Polynesians reached South America—the next step east from Easter Island—their numbers were far too small to gain a foothold among the indigenous people who had arrived millennia before. Thus, despite their sailing prowess, the Polynesians could not move beyond the Pacific, and as a result, they had no knowledge of the entirety of the world ocean.

[1] Kayaks are small one- or two-person boats constructed from skins stretched over a wooden frame. The skins form a deck, so that when the occupants are settled into their cockpits, the boat is watertight both top and bottom. Kayaks are propelled by two-bladed paddles. In contrast, umiaks are larger skin-covered boats with no upper deck. They are capable of holding twenty people or more and much gear, and are propelled by oars, paddles, or sails.

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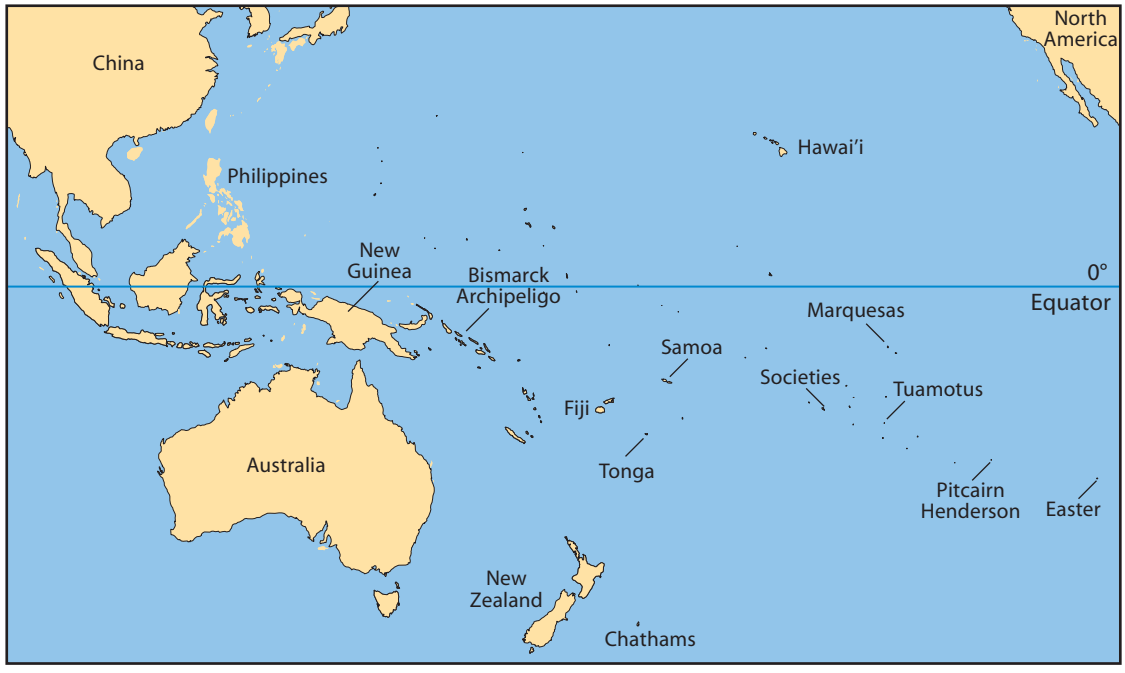

Figure 1.3. Islands of the Pacific, the realm into which the Polynesians expanded. Monte Verde, on the coast of Chile—site of a village dating back nearly 15,000 years—is 3600 kilometers southeast of Easter Island.

The course of Polynesian exploration in the Pacific was mirrored by that of the Vikings in the northern Atlantic. In the first few centuries AD, the climate in Scandinavia was unusually warm, allowing crops to flourish and populations to grow. As the countryside filled up, Norwegians and Danes looked for opportunities elsewhere. Utilizing their superior shipbuilding technology, the Vikings sent raiding parties eastward along the rivers of Russia and southward along the coasts of Europe, at times ranging as far as Constantinople (now Istanbul). These raids significantly impacted European history. For example, William the Conqueror defeated the English at the Battle of Hastings in 1066—the sole successful invasion of the British Isles—in large part because the English troops were exhausted from doing battle a month before with Viking invaders.[2]

In addition to raiding established societies, the Vikings undertook an island-hopping expansion westward into uninhabited territory (figure 1.4), first to the Orkney, Shetland, and Faeroe Islands (around 800 AD), then to Iceland (by 874 AD) and southern Greenland (in about 980 AD). Ships plying the trade routes between Iceland and Greenland were occasionally blown off course, and one of these (captained by Bjarni Herjolfsson in 986 AD) sighted a forested coast to the west of Greenland. Spurred on by the lure of abundant timber, which had become scarce in Greenland, Leif Ericsson bought Herjolfsson's boat and formed an expedition to explore this new land. Ericsson and his crews, accompanied by women and livestock, traveled along the coast of Baffin Island and Labrador and built a small outpost at L'Anse aux Meadows in Newfoundland. However, they skirmished with the local Indians, and in light of the prospect of

[2] William himself was the descendant of Vikings who settled in Normandy.

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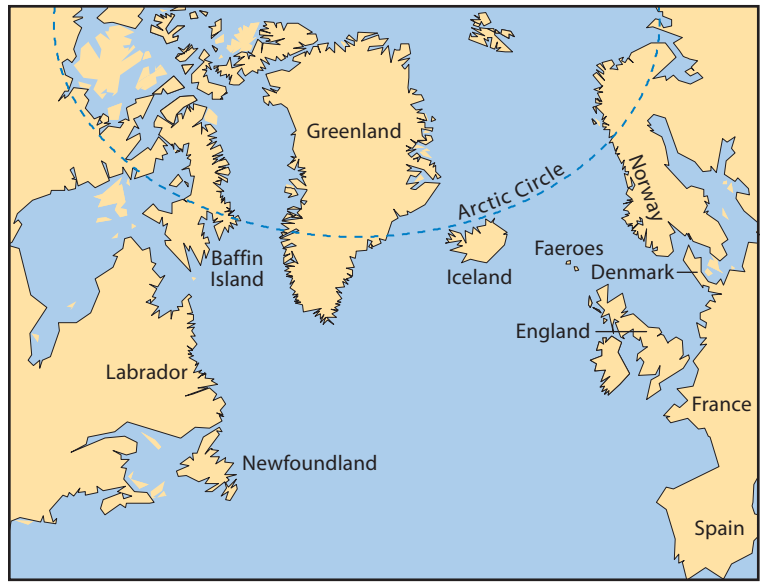

Figure 1.4. The realm of the Vikings.

continued conflict, the Vikings abandoned their attempt to colonize the New World.

Like the Polynesians, the Vikings explored the ocean not out of a thirst for knowledge, but rather in response to the demands of population growth and commerce. And, like the Polynesians, they were stymied in their expansion by the overwhelming size of indigenous populations. Viking travels were thereby limited, and they never developed an understanding of the scope of the world ocean.

In summary, as a result of its expanding population, by 1000 AD, humankind had dipped its toes into each of earth's seas. Many cultures used coastal waters for fishing and commerce, and the Polynesians and Vikings traveled a few open-ocean routes. But our knowledge of the sea was piecemeal: we hadn't truly discovered the ocean. That achievement resulted from a different journey, one that began with the Greeks.

Science and the Greeks

Growth of Greek civilization marked the beginning of abstract scientific thought. Whereas the Chinese, Egyptians, and Babylonians were masters of technology and astronomy, the Greeks were masters of concept. This distinction is evident in the way the different civilizations viewed the world. Early Chinese maps, for instance, give detailed information regarding the disposition of armies and the location of rivers and cities in the Middle Kingdom, but they show nothing beyond China's boundaries. In contrast, by 2500 years ago, the Greeks were actively speculating on the shape of the entire earth.

In fact, their speculations were highly logical and specific. For example, Aristotle (384–322 BC), the famous Greek scientist and philosopher, deduced that earth was a sphere, an assumption he based on four observations. First, there

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was the appearance of ships as they sailed into the distance. If the earth were flat, a ship sailing toward the horizon would appear smaller and smaller until it vanished from view. Instead, ships descended into the horizon, their hulls disappearing first, then their masts, suggesting that the surface of the water (and thus, of the earth) was curved.

The same logic applies from the perspective of the ship: as it travels away from shore, the coastline descends into the horizon. This perspective led Aristotle to note that stars appear and disappear on the horizon as one travels north or south, further evidence of earth's spherical shape.

Lunar eclipses provided a third clue. It was apparent from simple observations that the moon is a sphere. For instance, as the moon goes through its phases, the line separating dark from light changes shape as it travels across the moon's face. It is curved when the moon is a crescent, and straight when the moon is half full: what one would expect for a sphere lit from different angles. Shadows similarly reveal the shape of the earth. During a lunar eclipse, the shadow of the earth falling on the moon is always curved, as it should be if earth is a sphere.

And finally, there was the matter of aesthetics. To Greek mathematicians, the sphere was the perfect shape, the only object uniform about its center. The sun was clearly spherical, as was the moon. Why should the earth be any less perfect?

Acceptance of the earth as a sphere immediately led Greek scientists to two important questions: how big is the sphere, and where on its surface is Greece? In an extraordinary example of cultural genius, they devised answers to both.

In the fourth century BC, Alexander the Great (a pupil of Aristotle's) conquered much of the known world, sending many of the treasures he obtained to his museum in Alexandria, near the mouth of the Nile. After Alexander's death, the museum was supported by the royal rulers of Egypt and continued to acquire and catalog the fruits of civilization. To that end, it established a "think tank" (Euclid and Archimedes worked there, among others) and a vast library. The second Librarian of Alexandria, a man named Eratosthenes (ca. 276–196 BC), took it upon himself not only to accumulate the written knowledge of the world (as any good librarian would), but also to synthesize that knowledge. One of the things he contemplated was the size of the earth.

It came to Eratosthenes' attention that each year a notable event occurred in the city of Syene, due south of Alexandria. At noon on the summer solstice—the day of the year when the sun is highest in the sky—sunlight shone directly down into the wells at Syene, indicating that the sun was precisely overhead. Eratosthenes found this curious. In Alexandria there were vertical stone pillars called gnomons. If the sun were also directly overhead in Alexandria, the gnomons would not cast a shadow, but at noon on the summer solstice, shadows persisted. Clearly the angle at which sunlight approached the ground differed between Alexandria and Syene.

Enter the notion of a spherical earth (figure 1.5). Eratosthenes deduced that the difference in the angle of sunlight resulted from the different locations of Alexandria and Syene. At noon on the summer solstice, Syene (near the present-day city of Aswan) was at a point on earth directly under the sun, whereas Alexandria, north of Syene, was at a point on earth's curve where a vertical gnomon pointed off at an angle. Eratosthenes' genius was to use this realization to measure the size of the earth.

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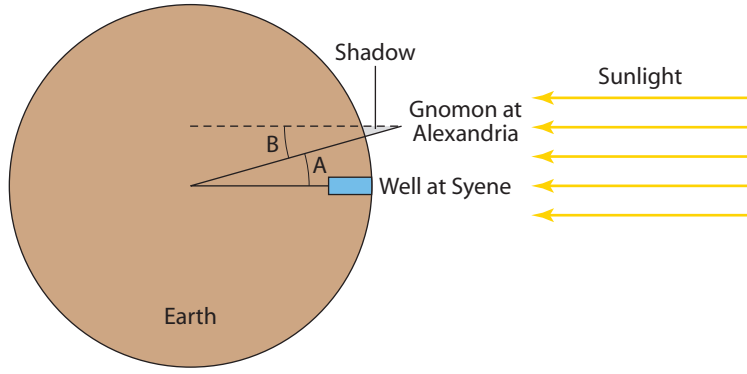

Figure 1.5. Eratosthenes' scheme for calculating the size of the earth. Angles *A* and *B* are equal.

To do so, he needed two measurements. First, he had to measure the angle between Alexandria and Syene (angle *A* in figure 1.5). This was easily done. Noting that angle *A* equals angle *B*, Eratosthenes realized he could use the shadow cast by a gnomon to measure the angle between Alexandria and Syene. At noon on the solstice, he wandered over to the nearest gnomon, measured its height and the length of its shadow, and used geometry to calculate first angle *B*, and then angle *A*. It turned out to be 7.12°, almost exactly 1/50 of an entire circle. This angle in turn meant that the distance from Syene to Alexandria was 1/50 the entire distance around the earth. Thus, if Eratosthenes could measure the distance from Syene to Alexandria, he could measure the earth's circumference.

Surprisingly, Eratosthenes didn't even need to leave home to measure the distance from Syene to Alexandria. As Librarian, he was privy to all sorts of information, including the fact that caravans of camels typically required 50 days to travel from Syene to Alexandria. It was common knowledge in those times that camels can travel 100 stadia per day, so he calculated that the distance from Syene to Alexandria is approximately $50 \times 100 = 5000$ stadia.

Now, a *stadium* is a measure of length used by the Greeks—a common foot race was one stadium in length, which set the size of a standard running track and eventually led to the current use of the term "stadium." Current archeological estimates suggest that one stadium is roughly 0.185 kilometers. Thus, in present-day units, Eratosthenes calculated that the distance from Syene to Alexandria was 925 kilometers. Multiplying by 50, he then estimated that the earth's circumference was approximately 46,250 kilometers.

This calculation is extraordinary. The current estimate of earth's circumference is 40,008 kilometers, only about 13% smaller than the distance Eratosthenes calculated 2300 years ago. One Greek, scratching his head in an ancient library, collecting a few facts from camel drivers and gnomons and making a simple calculation, measured the earth with astounding precision.

The Greeks' understanding of the earth did not stop there. In Eratosthenes' time, Greeks used a primitive version of latitude and longitude to locate points on earth's surface. In the beginning, the basis for this coordinate system was a line drawn east to west through the island of Rhodes (just south of Greece), essentially a line placed across the middle of the Greek empire. Parallel lines could then be drawn to the north and south, each expressing a line of more-or-less constant climate. These parallels—called *climata* or *klimata*—served as the basis for present-day lines of latitude.

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Originally, the climata were not equally spaced; as indices of climate, unequally spaced lines sufficed. But as civilization became more complex and more cities needed to be located on maps, the informal system of climata became unworkable, and a new, more uniform system gradually evolved. Hipparchus (ca. 190–120 BC) placed the climata at uniform distances and added lines running north-south to form a grid. To standardize the angular distances between points on earth, he borrowed a tradition from Babylonian astronomers and divided the circle into 360 degrees. Thus, Hipparchus invented the modern coordinate system of geography, complete with units, and of equal importance, his system was popularized by the Greek author, Claudius Ptolemy (ca. 90–168 AD).

Ptolemy excelled not at creating new knowledge, but rather at sorting and chronicling existing knowledge, which he did superbly. In two books, the *Almagest* ("The Greatest") and *Geography*, he recorded his best estimate of all knowledge of mathematics, science, and geography, and introduced a few innovations, such as dividing each degree of latitude or longitude into 60 minutes, and each minute, in turn, into 60 seconds. As their titles suggest, Ptolemy's books were a tour de force, and they became the standard references of his day.

Although Ptolemy successfully recorded much of the Greeks' knowledge, he was not infallible, and one of his mistakes had historical consequences. For reasons that are unclear, Ptolemy did not accept Eratosthenes' estimate for the size of the earth and instead chose a value calculated by another Greek scientist, Poseidonius. Unfortunately, Poseidonius had proposed that the circumference of the earth was 30,000 kilometers, 25% smaller than the actual value. By accepting Poseidonius's figure, Ptolemy assumed the earth was considerably smaller than it actually is.

Compounding this mistake, Ptolemy also thought that Asia extended to the east substantially farther than it really does. With an undersized earth and an oversized Asia, Ptolemy's globe had no room for features such as North and South America or a large Pacific Ocean. In fact, by Ptolemy's estimate, Asia extended so far east that it came close to wrapping around the earth and touching Europe. The mistaken idea that the east coast of Asia was but a short distance west of Europe eventually led to Christopher Columbus's voyage to the New World, but that lucky miscalculation was far in the future. In the interim, the Dark Ages descended on Europe.

The Dark Ages

The notion of a spherical earth survived the Roman absorption of Greek culture, but it was nearly lost to Western civilization with the fall of the Roman Empire. In 391, for instance, Christian mobs overran the library at Alexandria and burned its invaluable contents. Copies of a few books, Ptolemy's *Almagest* and *Geography* among them, had been translated into Arabic and disseminated, and thereby survived, but it would be nearly a thousand years before the Greeks' insights resurfaced in the West.

During the Middle Ages, knowledge of the earth in Western civilization was governed more by Christian doctrine than by scientific inquiry. Maps were drawn not as an expression of reality, but rather to match the dictates of the Bible. For example, the earth was deemed flat, with Jerusalem at its center. The Mediterranean

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Sea derived its name from its assumed location: the "middle of the earth." Surrounding the known lands of the earth was a mysterious ocean, unknown and—to a medieval culture closed in on itself—largely unknowable. Thus, for nearly 700 years after the sacking of Alexandria, knowledge of the ocean stagnated.

The Mongol Empire and the Role of Commerce

Although Christianity was largely responsible for the suppression of science in the Middle Ages, it also facilitated events that eventually brought the science of geography back to life. Beginning in 1096 AD with the First Crusade, Christian European society periodically waged war on the Muslim Middle East. This and subsequent crusades primarily sought recapture of the Holy Land for Christianity, but ancillary consequences abounded. For example, in traveling to and from the Holy Land and in governing the areas they conquered, the crusaders came into contact with Middle Eastern culture. As so often happens, the culture of the conquerors had less impact on the culture of the conquered than vice versa. Christian soldiers acquired a taste for intriguing riches available in the region—silk cloth, perfumes, and exotic spices—and soon active trade passed between the two cultures. Silks and spices from Asia arrived overland in the Middle East, where local traders acted as middlemen, selling to the highest bidders from the West.

This commerce had two major effects. First, the desire for silks, perfumes, and spices in Western culture gradually spiraled into an addiction. In an ancient analogy to the current commerce in oil, aspects of European society became dependent on commercial ties to the Middle East. Second, commerce opened Western eyes to the existence of Asian cultures. Although Europeans bought goods from the Arabs, they realized those goods came from powerful and intriguing civilizations farther to the east.

Events in China soon strengthened the interaction between Europe and Asia. In 1214 AD, Genghis Khan and his army captured Beijing, solidifying their hold on the Mongol Empire. For the next 154 years, the Mongols ruled all of the Far East.

The Mongol Empire impacted European history largely through commerce. In their administration of the Empire, the Mongols maintained the overland trade routes between China and the Middle East. Trade flourished, and the ready flow of goods heightened Europe's dependence on Asian goods.

The existence of safe routes of trade also made it possible for Europeans to travel to the Far East. Perhaps the most famous and influential of these travelers was Marco Polo (1254–1324 AD), a merchant from Venice. In the company of his father and brother, Polo traveled the Silk Road across the high Hindu Kush to China and spent 24 years at the right hand of Kublai Khan, Genghis's son. He acted as a military adviser to the Mongols during the siege of Saianfu, served as a court diplomat in Yunnan, and returned from the East as the escort for a princess betrothed to a Persian king. In his version of these events, Polo sailed home in a fleet of fourteen ships, accompanied by 600 courtiers and sailors, and was paid in jewels. He was subsequently captured in a sea battle between Venice and Genoa, and spent several months in prison, where a cellmate

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named Rustichello recorded his stories. Published in 1299, the *Travels of Marco Polo* was an instant success, and the book sparked Europe's interest in the Orient.

No empire lasts, however, and the burgeoning interaction between Europe and the Mongol Empire collapsed in 1368 AD when peasants in China overthrew the Mongols and established the Ming dynasty. In the wake of this revolution, overland trade routes with the West deteriorated, and the flow of silks, perfumes, spices, and cultural information declined. Flow ceased altogether when the Turks captured Constantinople in 1453.

European Exploration

Our story now splits in two as China and Europe follow separate paths. We begin with Europe.

The collapse of overland trade between China and Europe occurred at an auspicious time. The late 1300s saw the flowering of the Renaissance; Europe opened its eyes to scientific inquiry, and bits and pieces of Greek knowledge resurfaced, among them the works of Ptolemy, now translated into Latin from the Arabic in which they had rested for nearly a thousand years. With Ptolemy's vision of the earth at hand, European sailors were emboldened to extend their reach, searching for a sea route to the Far East to replace the defunct paths over land.

Two routes beckoned. First, because of Ptolemy's underestimation of earth's size, sailing west from Europe to reach Asia seemed possible—possible, but not easy, because this sort of transoceanic voyage could not be done in increments. Sailing halfway across the ocean and then turning back would be pointless; unless one sailed all the way across, there was no monetary profit in the venture and therefore little reason to go.

In contrast, the second route could be accomplished piece by piece. For centuries, Europeans had been trading with the coastal inhabitants of northern Africa. If these maritime trade routes could be extended south along Africa's west coast, perhaps someone would eventually find a southern tip of the continent and, from there, a route to the East. And, unlike a blind voyage across the ocean, this coastal route promised commercial returns for incremental journeys. Traveling an extra hundred miles down the African coast held the promise of perhaps finding the golden route to India. But even if a ship's captain didn't accomplish that goal, he could at least buy slaves or ivory to make the trip worthwhile.

What was needed, then, was a source of financial incentive and a mechanism to track the incremental progress. These two requirements were combined in one man: Prince Henry of Portugal, known as Henry the Navigator. Born in 1394, Henry was the third son of King John. He therefore had little hope of rising to the throne, and after a brief career in the army, he shifted his energies to exploration.

At that time, people assumed earth's equatorial region presented an impenetrable barrier. It was common knowledge that, as one sailed south along the coast of Africa, the climate steadily grew hotter. Surely, they concluded, at some tropical latitude the air must become too hot to breathe and man could go no farther. Conventional wisdom set this limit at Cape Bojador (the "bulging cape") in what is now Western Sahara, latitude 26° North (figure 1.6).

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Figure 1.6. Only when the "barrier" of Cape Bojador was breached could exploration progress toward the Cape of Good Hope.

Henry was determined to break that barrier. Between 1424 and 1434, he funded fifteen unsuccessful expeditions to Africa, a record of failure that would have daunted most entrepreneurs. But Henry persisted, and finally found a captain willing to sail past Cape Bojador. When that captain, Gil Eannes, turned the Cape in 1434, the impenetrable barrier collapsed, and the rush to India was on. Bit by bit, with Henry's support, the Portuguese worked their way down the African continent, mapping the coast and buying slaves as they went.

Prince Henry died in 1460, but by then the mechanism of progress was clear, and the quest continued after his death. Lopo Gonçalves crossed the equator in 1473. Nearly three decades after Henry's death, in 1488, captain Bartolomeu Dias and his crew were blown off course during a journey to southern Africa and, fighting their way back to land, found that they had rounded the Cape of Good Hope (although at the time they called it the "cape of storms") and with it the southern tip of Africa (figure 1.6). Dias pushed on another 500 miles to the east, far enough to know that the route to the north and to India was indeed open. But facing mutiny from his crew, he was forced to return to Portugal. Ten years later, Vasco da Gama completed the route, arriving in India on May 22, 1498.

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In opening a sea route to India, the Portuguese accomplished more than first meets the eye. Yes, the route to India was a huge commercial success. It assured trade between Europe and the Orient in the face of any turmoil that might close the routes through the Middle East, and the Dutch quickly followed the Portuguese in exploring this new realm of commerce. But even more importantly, Portuguese exploration expanded Europe's perspective on the world as a whole. Until Dias rounded the Cape of Good Hope, it was possible for geographers and sailors to think of the Atlantic and Indian Oceans as separate. Suddenly, in European minds, two small oceans became one. And this amalgamation was accomplished not by chance, but by concerted exploration. In essence, Portuguese exploration opened the world's oceans to discovery. And this new perspective on discovery, not the physical fact of rounding the Cape of Good Hope, fundamentally changed humankind's interaction with the ocean.

Chinese Exploration

Let's now pick up the second thread of our story, and return to China. We have already seen that Polynesians and Vikings, the greatest of ancient seafarers, never mapped the world despite their travels to far-flung islands. The story is similar for the Chinese. Shortly after the fall of the Mongol Empire and the rise of the Ming Dynasty in the late 1300s, a court eunuch named Zheng He initiated a series of expeditions to impress the world with the might and wealth of China. Known as the Admiral of the Triple Treasure, Zheng He (or Chêng Ho, depending on your preference in phonetic spelling) oversaw the formation of a fleet of ships such as the world had never seen. The largest vessel, the Treasure Ship, was 135 meters long, with 9 masts and a beam of 55 meters. Even the smallest ships in the fleet were large by the standards of the day—55 meters long, with 5 masts.

Every year between 1405 and 1433, Zheng's fleet sailed to islands south of China (Java and Sumatra) and on into the Indian Ocean. By 1421 (when Henry the Navigator was still a young man and 77 years before Vasco da Gama's famous voyage), the Chinese had reached India, Arabia, and even Zanzibar in Africa (figure 1.7).

Unlike the Portuguese, who arrived in India with thoughts of spices and the slave trade, the Chinese desired to demonstrate the superiority of China by handing out gifts. Thus, the Treasure Ship carried treasure *from* China *to* the rest of the world to dazzle natives with the majesty of the Middle Kingdom. And who would not be impressed? The largest of the treasure fleets consisted of 317 ships and more than 30,000 crew members. Even the most world-wise Arab trader would be awed by a fleet of more than 300 gigantic ships sailing over the horizon.

But, as with the travels of the Polynesians and Vikings, the voyages of the Chinese treasure fleets sought commerce rather than discovery. As exemplified by their trade in silks, perfumes, and spices, China had for centuries been involved in commerce with virtually all the known world. Thus, in sailing into the Indian Ocean, they simply used new routes to visit old trading partners in known places. The Chinese, too, lacked the impetus to sail into the unknown.

When Zheng's patron, the emperor Yung Lo, died in 1424, Zheng's power declined, and the treasure expeditions were doomed. Soon after the last

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Figure 1.7. Zheng He's route from China to India and Africa.

voyage in 1433, China turned in upon itself. The Great Wall, begun piecemeal in earlier dynasties, was consolidated to keep foreigners out, and it became a crime for anyone in China to leave. The path to Chinese discovery was closed.

The New World and Beyond

We now return to European explorations and pick up that thread of our story with Christopher Columbus (1451?–1506). Born in Genoa, Italy, Columbus was a sailor with grand aspirations. He focused his energies on Ptolemy's suggestion that Asia might lie a short journey west of Europe, and in 1488, Columbus and his younger brother Bartolomeo proposed to the rulers of Portugal that an expedition should be funded to explore that route.

Unfortunately, the timing of their proposition coincided with the return of Bartolmeu Dias from his triumphant rounding of the Cape of Good Hope; in fact, Columbus was on the dock when Dias returned. With a southern route to India within their grasp, the Portuguese were understandably reluctant to fund a chancy voyage to the west.

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Frustrated in Portugal, the Columbus brothers spent the next four years peddling their "Enterprise of the Indies" among the courts of Europe. Finally, in 1492, they acquired funding from Ferdinand and Isabella, rulers of Spain, and Christopher set forth with three ships (the *Niña*, the *Pinta*, and the *Santa María*) for a voyage into the unknown.

The plan was simple. The best maps of the day (based largely on Ptolemy's view of the earth) suggested that Europe and Asia were closest at the latitude of the Canary Islands, off the coast of North Africa (about 28° North). Thus, Columbus sailed south to the Canaries and then turned west. Thirty-three days later, on October 12, a lookout on the *Pinta* sighted the island of San Salvador. After a brief tour of the Caribbean islands, including Cuba and Hispaniola, Columbus sailed north to the latitude of the Azores (about 38° North) and then turned eastward and returned to Spain.

Following so quickly on the heels of Dias's rounding the Cape of Good Hope, Columbus's expedition electrified Europe. The dual discoveries, in 1488 of a route around Africa and in 1492 of a route to the New World, strongly justified the European strategy of discovery, and other voyages soon followed.

Columbus himself made three more voyages to the New World, but a flood of other expeditions eclipsed his efforts. The Spanish quickly established colonies on the islands of the Caribbean and at various points on the Caribbean coasts of Central, South, and North America. The Portuguese followed suit in present-day Brazil, and the English, Dutch, and French sent colonial expeditions to the Atlantic seaboard of North America.

Although the lure of commercial exploitation drove much of the European invasion of the New World, discovery continued to play an important role. For example, in 1513, stories told by Panamanian Indians suggested to Vasco Nuñez Balboa that a great body of water could be found across the Darien mountains. Intrigued by this lead, Balboa marched across the Isthmus of Panama, and with 190 Spaniards, several hundred native guides, and much effort, he reached the Pacific Ocean near what is now Panama City. It would take a few years for the Spanish to realize the true enormity of Balboa's discovery, but, 89 years after Prince Henry the Navigator sent out his first expedition, the last of the great oceans was finally on the map.

Balboa's discovery of the Pacific led to an enduring, although somewhat misleading, bit of terminology. The Isthmus of Panama runs roughly east to west, with the Caribbean Sea, Balboa's starting point, to its north (figure 1.8). As a result, when Balboa first sighted the Pacific, he was facing south, and he dubbed his discovery the "Southern Sea," a name still in use, as when we refer to places such as Tahiti and Samoa as "South Sea Islands."

In 1519, Ferdinand Magellan (1480?–1521) led the next great voyage of discovery, a five-ship expedition to circumnavigate the earth in search of spices. Mirroring the voyage of Dias in Africa 31 years earlier, Magellan (a native of Portugal, but sailing for Spain) sailed south along the east coast of South America searching for a passage to the west and to the spice islands. Time and again he and his crew probed rivers and bays with no luck. Finally, in an arduous journey of 334 miles and 38 days, Magellan worked his way through the narrow straits that now bear his name, and entered the Southern Sea (figure 1.9).

Whereas Dias had fallen back after rounding the tip of Africa, Magellan continued on. Taking advantage of a lucky absence of storms in the ocean he described as "pacific," Magellan reached the Philippines in 1521. His crew

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Figure 1.8. From the Isthmus of Panama, the Pacific Ocean lies to the south.

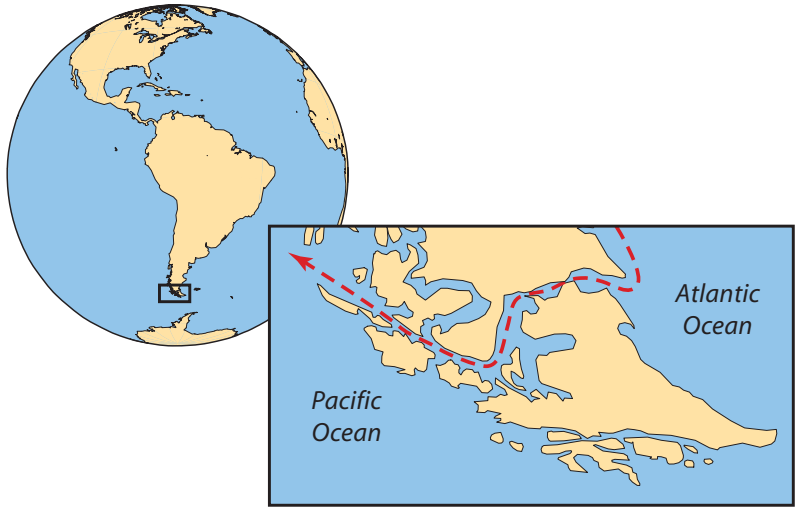

Figure 1.9. The sailing route through the Strait of Magellan. The numerous missteps involved in the original voyage are not shown.

arrived in India later that year, and from there, they retraced Gama's route, arriving back in Spain in 1522.

Magellan's expedition proved that the earth was a sphere: one could continuously sail westward and arrive back at one's starting point. But by 1522 that was almost a foregone conclusion. In fact, when Magellan arrived in the Philippines from the east, his largest problem was not to find a path into the unknown, rather it was to avoid the Portuguese and Dutch who had arrived in the Philippines after using Gama's route from the west. The Portuguese would soon set up trade with China and Japan. Thus, by the mid-1500s, European voyages of discovery had opened the entire globe to ship-borne commerce.

It is interesting to note that success as an explorer had few rewards for those who pioneered new routes. Adept as he was as a sailor, Columbus had limited

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abilities as a cartographer and administrator. In the face of growing evidence to the contrary, he continued to insist to his dying day that he had discovered the islands of Japan, and that a sea route past them would lead to Asia. The colonies that Columbus attempted to establish on his voyages failed, at least in part because he left his son in charge while he himself searched for the path to China. And Columbus began the atrocious tradition of enslaving local Indians. His record as an administrator was so abominable that at one point Columbus was sent back to Spain in shackles. Balboa fared even worse. Shortly after his discovery of the Southern Sea, Balboa was accused of plotting to become emperor of Peru, and he was beheaded. Magellan, too, did not live to reap the benefits from his exploration. In fact, he did not even complete the circumnavigation for which he is famous. While intervening in a local conflict in the Philippines, he was wounded by poison arrows and died. Only 18 of his original crew of about 250 were on the sole remaining ship that made it back to Spain.

Discovery continued apace after these early explorers. Driven by a lust for gold, silver, and spices, and facilitated by military technology and the death of the natives from smallpox, Spanish, Portuguese, British, and French colonists succeeded where the Polynesians and Vikings had failed, spreading their hegemony across North and South America. The coastline of the New World was quickly mapped, and explorers investigated the remaining pockets of unknown ocean.

Perhaps the greatest of this second generation of explorers was Captain James Cook (1728–79) of the British Navy, who, in three grand voyages, mapped much of the Pacific Ocean. In the process he "discovered" Hawai'i, surveyed the west coast of North America from Oregon to Alaska, and surveyed the east coast of Australia. (It wasn't until 1801 that Matthew Flinders, another British explorer, discovered that Australia was a continent, not just a series of islands.) Cook's success stemmed in part from new technology. The first explorer with access to an accurate clock—chronometer Number 4, invented by John Harrison—Cook could fix his longitude without having to come ashore to make astronomical sightings. In 1775, Cook crossed the Antarctic Circle and circumnavigated Antarctica, probing the boundaries of the ice, but he never got close enough to land to see the last of the continents. Not until 1820 did Fabian Bellingshausen sight Antarctica, but he too could not penetrate the ice surrounding the continent to make landfall. Mankind first set foot on Antarctica in 1838 when Dumont D'Urville landed on a small island off the Antarctic Peninsula. It was thought at that time that Antarctica was two continents, separated by a deep gash and overlaid with ice. The unity of the continent was not definitively established until the International Geophysical Year of 1957–58.

At the other end of the earth, numerous expeditions (mostly by the British) explored the Arctic, searching for the Northwest Passage, a hypothetical sea path around the northern end of North America: a route to counter the Spanish land routes across Central America. Martin Frobisher, Henry Hudson, and William Baffin all captained multiple expeditions, to no avail. The frustration of Arctic exploration is apparent in the fact that Hudson and his son died when they were set adrift by a mutinous crew, who preferred to head home rather than spend another winter in the North. Finally, in 1906, the Norwegian Roald Amundsen and his ship *Gjøa* took advantage of favorable ice conditions and, in

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an arduous voyage, navigated the Northwest Passage. Rumors of solid land in the midst of the Arctic Ocean ("Crocker Land") persisted until 1926, when Amundsen and his companions, Lincoln Ellsworth, Umberto Nobile, and Hjalmar Riiser-Larsen, flew the lighter-than-air ship *Norge* over the Pole, sighting nothing but ice and water.

From our vantage point in the twenty-first century, it is easy to look back at the heroic era of ocean exploration and think of it as ancient history. But it is important to realize how recent our knowledge is. For example, my parents were children when Amundsen flew over the North Pole, and I was in grade school when we found out that Antarctica was a single continent, not two. We have had only a single lifetime to contemplate the complete map of the earth.

Biology and the Oceans

As informative as it is, that map is far from the full story. Discovery of the oceans has involved much more than just mapping their shape and size. What plants and animals live in the sea? Where are they found and in what abundance? How do they survive? To begin to answer these questions, we need to move beyond maps and trace the history of the study of oceanic biology, a story that intertwines threads of commerce, war, and science. We begin with science and the history of diving.

Diving

Humanity's first contact with life in the seas occurred in shallow water along the coast where people could dive to the bottom and tides periodically uncovered the seafloor. Nearshore organisms played a large role in ancient commerce: fish, shellfish, and seaweeds were used for food, for example, and indigo, a precious purple dye, was extracted from shallow-water marine snails. Scientific description of the often-slimy marine organisms began with Aristotle, who aptly noted that one "must not recoil with childish aversion from the examination of the humbler animals. In all things of nature, there is something of the marvelous."

In contrast to shallow-water plants and animals, which were familiar because of their accessibility, the plants and animals of the deep remained largely unknown to the ancients. Deep-living organisms could be caught occasionally in nets and on hooks, but until the invention of an apparatus for delivering air to a submerged human, scientific observation of these organisms in their native habitat was impossible.

A variety of diving apparatuses have been invented over the years. One of the earliest was devised by Leonardo da Vinci, consisting of a leather helmet that covered the diver's head and a tube that connected the diver to air at the water's surface. As with many of Leonardo's ideas, this diving helmet, although innovative, was not practical. Unless the diver were within a foot or two of the surface, water pressure pushing in on his chest would prevent him from inhaling, and the "dead space" of the tube would mean that even if he could inhale he would simply be re-breathing the same air as it moved back and forth in the tube.

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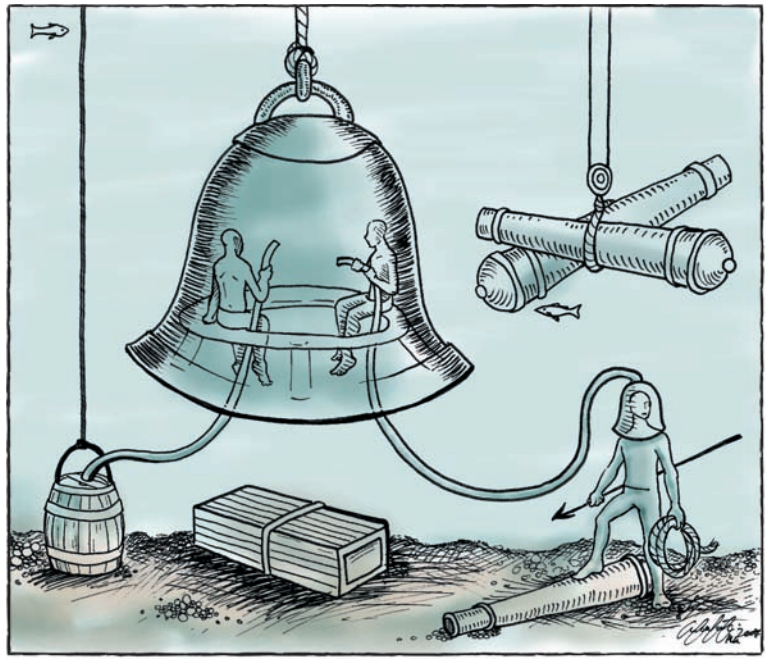

Figure 1.10. Edmund Halley's diving bell. Redrawn from M. W. Denny and J. L. Nelson (2006), *Conversations with Marco Polo* (Xlibris, Philadelphia, PA).

A more practical apparatus was designed in 1691 by Edmund Halley, the Halley of Halley's Comet. A watertight, weighted wooden bell suspended in the water received air periodically from weighted barrels lowered from the surface (figure 1.10). This diving bell was put to use salvaging cannons and other valuable objects from ships sunk in shallow water. The helmet-and-tube apparatus shown in the figure would suffer the same problems faced by da Vinci's helmet, although pressurized air would flow to the diver if his head were higher than the water level in the bell.

A truly practical diving apparatus appeared in the 1800s with the advent of the "hard-hat" diving suit. Originally built in England by Augustus Siebe in 1837, the apparatus consisted of a rigid helmet that enclosed the diver's head and an inflatable canvas suit. Air was pumped from the surface to the helmet, which in essence formed a small, personal version of Halley's diving bell. Updated versions of this apparatus are still used today for shallow-water salvage operations.

Although the hard-hat diving suit allowed divers to spend substantial time underwater, the air hose connected to the surface restricted the divers' mobility and thereby hampered their ability to observe and explore. Jacques Cousteau and Emile Gagnan solved this problem in 1943 with their invention of a regulator that made self-contained underwater breathing apparatus—scuba—practical. Carrying a tank of compressed air on their backs, scuba divers can move freely through the marine environment, and much of what we know about life in the shallow oceans is due to the use of this apparatus. Judicious use of different mixtures of gases allows scuba divers to reach depths of several hundred feet.

(continued)

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