

CHAPTER 1 THE HISTORY OF OCEANOGRAPHY

Key Concepts

Major Concept (I) *Scientists who study the oceans have many different scientific backgrounds. Essentially any scientific discipline can be applied to some sub-field of oceanography.*

Related or supporting concepts:

- Among the many different areas of science that are applied to the study of the oceans are:
 - 1) geology,
 - 2) physics,
 - 3) chemistry,
 - 4) atmospheric science,
 - 5) biology, and
 - 6) engineering
- Marine geologists study the sediments and rocks found on the sea floor and along coastlines. They also investigate the effects of volcanism associated with the formation of new oceanic crust at spreading centers, the destruction of old oceanic crust along trenches, and in areas such as the Hawaiian Islands.
- Geophysicists can investigate the occurrence of earthquakes in the oceans. They may also measure the gravity and magnetic properties of marine rocks to determine such things as the rate of sea floor spreading, the frequency of the reversal of Earth's magnetic field, and the distribution of mass in ocean basins.
- Physical oceanography relies heavily on physics and mathematics to study the propagation of waves, the motion of currents, the transmission of energy (such as sound, heat, and light) in water, and the nature of the tides, among other things.
- Chemists can apply their expertise to the analysis of seawater, the measurement of rates and effects of chemical reactions in the water, and the study of the composition of marine sediments and rocks.
- We now appreciate the fact that the oceans interact in complex, and very important, ways with the atmosphere to greatly influence global weather patterns. Conversely, circulation in the atmosphere plays a major role in driving surface currents and can trigger events such as El Niño that impact life in the sea and weather on land. Hence, atmospheric scientists can immerse themselves in oceans too.
- One of the most fundamental characteristics of the oceans is their role as a habitat for a tremendous variety of plants and animals. Consequently, marine biology is a major field of oceanographic study for reasons including pure scientific curiosity, investigation of possible applications to the medical field, and for harvesting food reserves to feed the planet's ever-increasing population.
- Engineers design equipment used to study the oceans, ships, and structures such as jetties, piers, breakwaters, and groins.

Major Concept (II) *Oceanographic study has historically concentrated on different areas, driven by the needs and interests of different nations at different periods of time.*

Major Concept (III) *Most of the interaction that early civilizations had with the oceans was the result of obtaining food or a desire to discover new lands and improve trade routes rather than to gain any general scientific knowledge.*

Related or supporting concepts:

- People are known to have sought food from the seas as early as the Paleolithic period when barbed spears or harpoons were developed.
- At the beginning of the Neolithic period, about 10,000 B.C., bone fishhooks were developed. Some time later during the Neolithic fish nets were first used.
- Copper fishhooks were used by 5000 B.C.

- The first recorded sea voyage was led by Pharaoh Snefru about 3200 B.C.
- The first recorded voyage of exploration was led by Hannu in 2750 B.C. The voyage sailed from Egypt to the southern edge of the Arabian Peninsula and the Red Sea.
- Extensive migration throughout the southwestern Pacific Ocean may have begun by 2500 B.C. This migration was relatively easy because of the short distance between islands.
- The Phoenician civilization was adept at sailing and navigation as early as 1200 B.C. They are known to have established trade routes throughout the Mediterranean Sea and northward into the Atlantic as far as Great Britain.
- The Phoenicians circumnavigated Africa in about 590 B.C.
- During this same period of time, from 1500–500 B.C., the boundaries of the Indian Ocean were being explored by Arab traders.
- Perhaps the most accomplished open ocean sailors of this time, again between about 1500–500 B.C., were the Polynesians who managed to travel over vast expanses of the Pacific Ocean basin to populate numerous island chains.
- The Polynesians colonized the Hawaiian Islands between A.D. 450 and 600. By the eighth century A.D. they had colonized every habitable island in a triangular region roughly twice the size of the United States from Hawaii on the north to New Zealand in the southwest and Easter Island in the east.
- Without the ability to determine latitude and longitude, and hence actual position on the globe, early explorers observed a variety of natural phenomena to help them in their travel when they were out of site of land. These included wind and wave patterns, their sense of smell, the location and pattern of clouds that would characteristically form over islands, and the sighting of birds that wouldn't stray too far from land.
- The Greeks called the Mediterranean Sea "Thalassa" and believed that it was surrounded by land, which in turn was surrounded by a great river called "Oceanus."
- Pytheas (c. 350–300 B.C.), a Greek geographer and explorer, made one of the first voyages from the Mediterranean to England and then north to Scotland, Germany, and Norway. Pytheas also recognized the relationship between the tides and the phases of the moon.
- Aristotle (c. 384–322 B.C.) studied the oceans as a scientist. He believed that they occupied low regions on the earth's surface, he recognized the cycling of water by evaporation from the sea surface followed eventually by condensation and return as rain, and he studied marine organisms.
- Eratosthenes (c. 264–194 B.C.) first calculated the circumference of the earth as 40,250 km, or 25,000 mi, (compared to current measurements of 40,067 km, or 24,881 mi on average). He also produced a map of the known world.
- Posidonius (c. 135–50 B.C.) reportedly measured an ocean depth of 1800 m, or 6000 ft.
- Pliny the Elder (c. A.D. 23–79) related phases of the moon to the tides and studied currents flowing through the Strait of Gibraltar.
- Ptolemy (c. A.D. 127–151) produced the first world atlas listing more than 8000 places by latitude and longitude. It was based on a major flaw however. He used a value of the circumference of the earth of 29,000 km (18,000 mi). This had the effect of shortening distances and made Columbus believe he had reached the eastern edge of Asia when he landed in the Americas.

Major Concept (IV) *During the Middle Ages, relatively little new knowledge was added to our understanding of the oceans. Despite this, however, advances continued to be made in shipbuilding, navigation, and piloting.*

Related or supporting concepts:

- Following the academic achievements of the Greeks and Romans, the Middle Ages were a period of roughly 1000 years of intellectual inactivity in the West.
- Practical problems related to the sea continued to be addressed during this time and there were significant improvements in:
 - a. ship design and building,
 - b. navigation, and
 - c. cartography (the design and making of maps).
- The Vikings are credited with extensive voyages throughout the North Atlantic during the time from 793–1066. These voyages were aided by a period of global warming that reduced the hazards of drifting ice in the North Atlantic.

- Additional important accomplishments of the Vikings include:
 - a. the colonization of Iceland in 871. As many as 12,000 immigrants eventually settled there.
 - b. Erik the Red (Erik Thorvaldsson) sailed west from Iceland in 982 and discovered Greenland.
 - c. Leif Eriksson (son of Erik the Red) sailed to North America in 1002, roughly 500 years before Columbus.
- At about this same time, Arab civilization was building on the knowledge of the Greeks and Romans to pioneer and improve trade routes throughout the Indian Ocean.
- The Arab El-Mas'ûdî (d. 956) first described the relationship between surface currents and monsoon winds in the Indian Ocean. Using this knowledge the Arabs pioneered regular trade routes across the Indian Ocean.
- Chinese junks sailed the same trade routes as the Arabs using crews of 200 to 300 during the 1200s.
- Charts during this time still lacked accurate lines of latitude and longitude. Consequently, they were not useful for navigation across large expanses of seawater and absolute location.
- Most charts were of near coastal waters, locating ports and noting distances between them. These charts were called “portolanos.” These charts included a mileage scale and notes on hazards to navigation but they did not have latitude and longitude.
- In the 13th century:
 - a. magnetic compass directions were added to maps (figure 1.6), and
 - b. Greek knowledge in the hands of the Arabs was translated into Latin and re-discovered by northern Europeans.
- The Venerable Bede (673–735) made observations of the tides along the British coast.
- By the 1300s Europeans had established successful trade routes, including some partial ocean crossings.
- By the end of the 1300s the desire for riches from new lands led wealthy individuals in Europe to finance long voyages of discovery to all the oceans of the world. A leader in this exploration was Prince Henry of Portugal (1394–1460), also known as Prince Henry the Navigator because he established a naval observatory for the teaching of navigation, astronomy, and cartography in about 1450.

Major Concept (V)

The 15th and 16th centuries were times of great global voyages of discovery. These were conducted primarily by northern Europeans.

Related or supporting concepts:

- The first voyages of discovery in the early 15th century were conducted by the Chinese. In seven voyages over 300 ships explored the Indian and Pacific oceans. The last of these voyages was in 1433, after which the Chinese concluded that other civilizations were not advanced enough to offer them anything and they voluntarily entered a period of isolation that would last 400 years.
- These voyages were the result of a desire to increase trade with known lands and discover new regions that might also prove to be financially rewarding.
- Bartholomeu Dias:
 - a. lived from about 1450–1500,
 - b. circumnavigated Africa sailing around the Cape of Good Hope into the Indian Ocean in 1487 in the first of the great voyages of discovery, and
 - c. was driven by his desire to find faster trade routes to the Far East.
- Christopher Columbus:
 - a. lived from 1451–1506,
 - b. made four voyages across the Atlantic intent on reaching the Far East, and
 - c. is credited with being the first European to see the New World.
- Vasco da Gama:
 - a. lived from about 1469–1524, and
 - b. followed in the path of Dias, journeying to India.
- Amerigo Vespucci:
 - a. lived from 1454–1512,
 - b. was an Italian explorer,
 - c. sailed several times to the New World between 1499–1504 on behalf of Spain and Portugal, and
 - d. believed South America was a distinct continent not attached to Asia.

- Martin Waldseemüller was a German cartographer who christened what we now call South America “America” in honor of Vespucci in 1507.
- Vasco Nuñez de Balboa:
 - a. lived from 1475–1519, and
 - b. is credited with first sighting the Pacific Ocean in 1513.
- Juan Ponce de León:
 - a. lived from about 1460–1521, and
 - b. discovered Florida and the Florida Current in 1513.
- Ferdinand Magellan:
 - a. lived from about 1480–1521,
 - b. left Spain in 1519 with five ships to cross the Atlantic and rounded the tip of South America in 1520 in search of a westward passage to the Spice Islands,
 - c. crossed the Pacific with three ships in 1520–21 and was killed in the Philippines in 1521.
 - d. one of his three ships, *Victoria*, continued around Africa and across the Indian Ocean to return home in 1522 completing the first circumnavigation of the globe, and
 - e. is also credited with determining the length of a degree of latitude and calculating the circumference of the earth.
- In the last half of the 16th century explorers sought new knowledge of, and trade routes across, northern routes.
- Sir Martin Frobisher:
 - a. lived from about 1535–94, and
 - b. led three voyages in search of a northwest passage across North America in the 1570s.
- Henry Hudson (d. 1611) followed Frobisher and sailed on four trips from 1607–1610.
- William Baffin
 - a. lived from 1584–1622, and
 - b. sought a northwest passage during two trips in 1615 and 1616.
- Sir Francis Drake:
 - a. lived from about 1540–96,
 - b. sailed on the *Golden Hind* to circumnavigate the globe in a voyage that lasted from 1577–80, and
 - c. returned with Spanish gold for Queen Elizabeth I.

Major Concept (VI) *Scientists in the 17th century were beginning to show an interest in the basics of Earth science.*

Related or supporting concepts:

- In the 15th and 16th centuries the scientific view of the oceans was still dominated by the work of Aristotle and Pliny.
- In the 17th century curiosity about the earth began to flourish. Scientists wrote papers and formed societies to discuss their findings.
- Johannes Kepler (1571–1630) studied planetary motion.
- Galileo Galilei (1564–1642) studied mass, weight, and acceleration.
- Sir Isaac Newton (1642–1727) wrote his *Principia* in 1687 in which he presented his law of gravity and the forces creating the tides were explained.
- Edmund Halley (1656–1742):
 - a. made a voyage in 1698 to study longitude and the variation of the compass, and
 - b. suggested that the age of the oceans could be calculated by measuring the rate at which rivers carry salt to the sea.
- Physicist John Joly followed Halley's suggestion and in 1899 reported an age of the oceans of 90–100 million years based on a calculation of the annual rate of addition of salt to the oceans. This proved to be far too young because he did not account for the recycling of salt, the incorporation of salt in marine sediments, or marine salt deposits.

Major Concept (VII) *The successful exploitation of the oceans for transportation and economical trade*

required the development of accurate navigational methods and detailed charts of land masses, prevailing winds, and surface currents.

Related or supporting concepts:

- Following the great voyages of discovery, there were new trade routes to be used routinely and distant colonies established. This required the construction of accurate charts and the improvement of navigational techniques.
- The science of the mapping of oceans and other large bodies of water for the purpose of improving navigation is called “hydrography.”
- The first hydrographic office was established in France as early as 1720.
- In 1795 Great Britain appointed an official hydrographer for the British navy.
- While latitude could be determined easily at sea by astronomical means, determining longitude accurately was a major problem for early navigators. Important milestones in determining longitude include:
 - a. Flemish astronomer Gemma Frisius noted the relationship between longitude and time as early as 1530.
 - b. In 1598 King Philip III of Spain offered a reward of 100,000 crowns to anyone who could make a clock that would keep accurate time at sea.
 - c. In 1714 Queen Anne of England offered a public reward and the British Parliament offered a reward of 20,000 pounds for a clock that would keep accurate time at sea.
 - d. John Harrison made four chronometers from 1735 to 1761, the fourth version in 1761 met the British Parliament's requirements for accuracy by losing only 51 seconds during an 81 day voyage.
 - e. In 1772 James Cook (1728–79) used John Harrison's chronometer to chart new regions of the Pacific Ocean.
- Some of the earliest extensive mapping of the oceans was carried out by James Cook in his voyages throughout the Pacific Ocean basin (figure 1.10). Cook compiled data covering such things as:
 - a. ocean depths,
 - b. prevailing wind directions,
 - c. characteristics of surface currents, and
 - d. water temperatures.
- The first chart of the Gulf Stream was made by Benjamin Franklin with help from his cousin Timothy Folger in 1769. Figure 1.11 in the text shows the detail of the current along the coast of the United States as well as the general clockwise circulation in the North Atlantic.
- The United States established a naval hydrographic office in 1830. This office was called the U.S. Naval Hydrographic Office and it still exists, although its name has been changed to the U.S. Naval Oceanographic Office.
- Matthew Maury was placed in charge of the U.S. Naval Hydrographic Office and began a career compiling data on the seas. Among his accomplishments are:
 - a. the founding of the Naval Depot of Charts,
 - b. publication of the first wind and currents charts of the North Atlantic in 1847,
 - c. construction of the first bathymetric chart of the North Atlantic with contours at 6000 ft intervals, and
 - d. the publication in 1855 of a comprehensive book called *The Physical Geography of the Sea*
- Maury’s careful compilation of current and wind directions along with recommended sailing routes are credited with reducing travel times between some ports by as much as a month.

Major Concept (VIII) *In the 19th century scientists began exploring the oceans in earnest. Scientific exploration was facilitated by accurate charts and ships’ crews skilled in navigation.*

Related or supporting concepts:

- One of the earliest scientific voyages was aboard the HMS *Beagle* with Charles Darwin as the ship naturalist.
- The *Beagle* expedition sailed from 1831–36.
- Darwin collected a variety of marine organisms for study and proposed an explanation for the progressive evolution of coral reefs into atolls.

- One of the leading marine biologists of the 19th century was Edward Forbes (1815–54). Forbes believed the oceans could be divided vertically into zones, each of which was home to a characteristic group of organisms. He suggested that there was no life below about 550 m (1800 ft) and hence the waters beneath this were called the “azoic” (no life) zone. We now know that organisms can be found at all depths.
- Forbes’ definition of an azoic zone was peculiar because:
 - a. Sir John Ross (1777–1856) recovered a variety of organisms by dredging the floor of Baffin Bay at a depth of over 1800 m (6000 ft), and
 - b. Sir James Clark Ross (1800–62), the nephew of Sir John Ross, recovered similar organisms in even deeper water off Antarctica.
- Christian Ehrenberg (1795–1876) concluded that the oceans were filled with microscopic life and that the skeletons from these organisms were continually supplying sediment to the sea floor.
- The extremely small plants and animals that drift freely in shallow water were first studied intensely by Johannes Müller. Müller was followed in this work by Victor Hensen who named these organisms “plankton” in 1887.
- The laying of transatlantic telegraph cables in the late 19th century made a better understanding of the oceans and the sea floor imperative.
- The British recovered a damaged cable from a depth of over 1500 m (5000 ft) that was covered with organisms.
- Wyville Thompson (1830–82) helped lead two expeditions that recovered organisms from the deep-sea floor:
 - a. in 1868 the *Lightning* recovered animals from a depth of 915 m (3000 ft), and
 - b. in 1869 and 1870 the *Porcupine* dredged animals from a depth of over 4300 m (14,000 ft).
- Wyville Thompson had his book *The Depths of the Sea* published in 1873.

Major Concept (IX) *It was also in the 19th century that one of the greatest scientific oceanographic expeditions was mounted, the Challenger expedition.*

Related or supporting concepts:

- The *Challenger* expedition was organized by the British Royal Society and the British Admiralty and sailed under the direction of Charles Wyville Thompson.
- Thompson’s assistant was a young geologist named John Murray (1841–1914).
- The charge given to Thompson was to travel throughout the ocean basins collecting all of the scientific information possible about the seas.
- The expedition lasted from December 21, 1872 until May 24, 1876; nearly three and one half years.
- The *Challenger* logged 110,840 km (68,890 mi). Its route is shown in figure 1.16.
- During the voyage:
 - a. ocean depth measurements were taken at 361 locations,
 - b. a maximum depth of 26,850 feet was discovered in the Marianas Trench in the western Pacific Ocean,
 - c. water samples were taken at various depths and analyzed for temperature and chemistry,
 - d. it was shown that the relative abundance of the major component ions of seawater remains constant regardless of where the sample is taken,
 - e. 4717 new species of marine organisms were discovered, and
 - f. deep water currents were investigated.
- Scientists worked for 20 years after the conclusion of the expedition cataloguing and analyzing all of the information that was collected.
- John Murray edited and wrote many of the *Challenger* reports after Thompson’s death. Murray is considered the first geological oceanographer.
- The success of the *Challenger* expedition encouraged other nations to mount expeditions including:
 - a. Norway’s exploration of the North Atlantic with the *Voringen* during the summers of 1876 to 1878,
 - b. Germany’s study of the Baltic and North seas with the SS *Pomerania* in 1871–72 and the *Crache* from 1881–84,
 - c. France’s expeditions using the *Travailleur* and *Talisman* in the 1880s,
 - d. Austria’s exploration of the Mediterranean and Red seas in the 1890s with the *Pola*,

- e. the United States' circumnavigation of the globe using the vessel *Enterprise* from 1883–86, and
- f. Russian and Italian expeditions between 1886–89.

Major Concept (X) *Late in the 19th century Fridtjof Nansen led a voyage to the Arctic to test his theories about surface circulation in Arctic waters. This was the beginning of the exploration of polar seas that continued into the early 20th century.*

Related or supporting concepts:

- Nansen was a Norwegian scientist who lived from 1861 to 1930. He was a zoologist by training but he had a particular interest in Arctic waters.
- Nansen designed a ship that could be frozen into the ice during winter months so that it would drift with the ice pack under the influence of surface circulation.
- The ship had a rounded bottom, rather than the traditional V-shape, so that the ice would lift it out of the water rather than crush it as it froze. It's hull was over 60 cm (2 ft) thick. The name of the ship was the *Fram* and it is shown in figure 1.17.
- The *Fram* was frozen into the ice for 35 months from 1893–96 and drifted with the ice pack around the pole.
- During this time measurements were taken of:
 - a. water depth, demonstrating that the Arctic was very deep rather than a shallow sea,
 - b. weather conditions,
 - c. water temperature and chemistry, and
 - d. characteristics of the periodic changes in numbers of plankton in the water.
- When it became apparent that the ship would not be carried over the Pole, Nansen left the ship on dog sled with one companion, F. H. Johansen, to attempt a 500 km (300 mi) trip to reach it. The ship was left under the command of its captain, Otto Sverdrup.
- Nansen was unable to reach the Pole due to inadequate supplies and fatigue. He and Johansen were forced to turn back and spent the winter of 1895–96 living off seals and walrus before being found in the early summer by a British expedition that brought them home.
- After breaking free from the ice, the *Fram* also returned to Norway in 1896.
- Nansen designed an instrument to collect deep water samples that is still used today. It is called a Nansen bottle in his honor.
- Nansen was awarded the Nobel Peace Prize in 1922 for his work with the League of Nations in resettling refugees from World War I.
- Otto Sverdrup used the *Fram* to explore and chart 100,000 square miles of what is now the Canadian Arctic during a four year voyage from 1898–1902.
- Roald Amundsen took the *Fram* to the Antarctic in 1911.
- Amundsen is also credited with the first traverse of a northwest passage entirely by water in a three year voyage (1903–1906) by sailing from Norway to Nome, Alaska.

Major Concept (XI) *The late 19th and early 20th centuries saw increased interest in the scientific study of the oceans to solve practical problems. This work often necessitated the design and construction of new instruments to make the needed measurements.*

Related or supporting concepts:

- As early as 1870, it was recognized that we needed to know more about the chemical and physical characteristics of the oceans to effectively deal with problems related to commercial fisheries.
- A tide-predicting machine was developed by Lord Kelvin (1824–1907), a British scientist, in 1872. This allowed the compilation of tide tables for different regions.
- In 1902 Germany, Russia, Great Britain, Holland, and the Scandinavian countries formed the International Council for the Exploration of the Sea (ICES) to coordinate and conduct research in the oceans and on fisheries.
- Deepwater circulation couldn't be studied until about 1910 when it became possible to identify individual water masses on the basis of their temperature and salinity characteristics. This could be

accomplished with the addition of specially designed thermometers to Nansen bottles and an improved technique for measuring salinity devised by Martin Knudsen (1871–1949).

- Water depth and sea floor bathymetry were not easily measured until the successful testing and use of an echo sounder during the *Meteor* expedition in 1925–27. The echo sounder emitted a pulse of sound and then timed how long it took for the sound to reflect from the sea floor and return to the ship. Knowing the velocity of sound in water, it was simple to determine depth from this two-way travel time.

Major Concept (XII) *In the early 20th century there was a great deal of interest in oceanography in the private sector that led to the creation of private institutions that would eventually become incorporated into universities. American government interest in oceanography blossomed at the federal level in the middle of the 20th century in response to World War II.*

Related or supporting concepts:

- Following the Civil War, there was less interest in gaining more information about physical oceanography (directions of winds, waves, and currents) because steam driven engines replaced sails and ships could easily choose their own course.
- Alexander Agassiz (1835–1910):
 - a. financed a number of marine biology expeditions,
 - b. was the scientific director of the first ship built specifically for marine exploration, the U.S. Fish Commission's *Albatross*, and
 - c. designed much of the equipment used to recover deep-sea organisms.
- The earliest oceanographic institution in the United States began shortly after the turn of the century. This was funded privately by Ellen B. Scripps and is now known as the Scripps Institution of Oceanography, located in La Jolla, California. It is presently affiliated with the University of California, San Diego.
- The Carnegie Institution funded a series of cruises in the early 20th century directed toward the investigation of Earth's magnetic field. It also supported a marine biological station.
- In 1927, the National Academy of Sciences recommended the creation of a permanent marine science laboratory on the east coast. This led to the establishment of the Woods Hole Oceanographic Institution in 1930. This was funded largely by the Rockefeller Foundation.
- Essentially all of the world's knowledge of oceanography was compiled in a textbook published in 1942 called *The Oceans*, by Harald U. Sverdrup, Martin W. Johnson, and Richard H. Fleming.
- World War II brought ocean science to the forefront of federal concern for military reasons. A variety of research endeavors were supported including:
 - a. prediction of wave and tide conditions for amphibious landings,
 - b. how explosives act in seawater,
 - c. accurate charting of coastlines, and
 - d. the propagation of sound in water in order to locate submarines.
- Following the war, oceanography became an important area for research that was well funded by a number of different government agencies including:
 - a. the National Science Foundation (NSF),
 - b. the Office of Naval Research (ONR), and
 - c. the Atomic Energy Commission (AEC).
- The federal government operates a number of research vessels through the National Oceanic and Atmospheric Administration (NOAA) and owns many other ships that are "on loan" to universities that operate them.

Major Concept (XIII) *Oceanography has grown into a major area of research in the last few decades with the development of new instrumentation and the construction of research vessels to conduct extensive expeditions in all of the world's ocean basins.*

Related or supporting concepts:

- Several international ventures were undertaken from the 1950s through the 1970s. These included:

- a. The International Geophysical Year (IGY) was observed in 1957–58. During this time marine geology and geophysics studies were carried out by sixty-seven different countries.
- b. An international program to explore the Indian Ocean took place in 1963–64.
- c. The 1970s were declared the International Decade of Ocean Exploration (IDOE).
- The 1960s were a period of time where there was a lot of development of new equipment and application of technology to oceanography. In this time:
 - a. research ships and submersibles were built for use by the federal government and universities,
 - b. the Deep Sea Drilling Program (DSDP) began to core and retrieve sea floor sediment and rock in 1968 using the drill ship *Glomar Challenger* (figure 1.20a), and
 - c. there was widespread use of electronics technology from the space program and computers on board research vessels.
- In the 1970s, there was a decline in the funds available for basic research. Despite this, instruments continued to be improved and the use of satellite technology to obtain basic data on the oceans began.
- The ten-year International Decade of Ocean Exploration (IDOE) occurred in the 1970s. This was a multi-nation effort to survey seabed resources, improve environmental forecasting, investigate coastal ecosystems, and modernize and standardize the collection, analysis, and use of marine data.
- In 1970, the National Oceanic and Atmospheric Administration (NOAA) was formed.
- The DSDP's drill ship *Glomar Challenger* was retired in 1983 after 15 years of service.

Major Concept (XIV) *In the future there will continue to be an increased emphasis on the study of the planet as a whole system. Now, and in the future, we must recognize that oceanographic studies need to be interdisciplinary in their nature due to the complexity of the problems we wish to investigate.*

Related or supporting concepts:

- Today's scientists see the earth as a complex of systems and subsystems acting as a whole.
- It used to be popular for scientists in different disciplines to research problems only from their narrow perspective. We know now that Earth is essentially a self-contained, complex environment where different processes interact and influence each other.
- Large-scale cooperative studies of global problems have increased in importance as:
 - a. scientists have realized that they need cooperation from people in other disciplines to study earth processes in ever greater detail,
 - b. the development of satellite technology has made it possible for the first time in history to gather very large scale data sets over short time periods, and
 - c. society as a whole has recognized the potential for human actions to radically alter global environmental conditions.
- Cooperative studies of this sort can be successfully carried out now because:
 - a. individual scientific disciplines have advanced to the point where we can begin to conduct meaningful interdisciplinary research,
 - b. we have the tools and methods available to acquire and analyze global data, and
 - c. global communication enables scientists to plan and monitor complex global programs.
- Examples of cooperative, large-scale studies include:
 - a. the World Ocean Circulation Experiment (WOCE) uses computers and chemical tracers to model the present state of the ocean and predict its evolution in response to long-term changes in the atmosphere,
 - b. the U.S. Joint Global Ocean Flux Study (JGOFS) studies the relationship between ocean plant production and solar radiation,
 - c. the Global Ocean Atmosphere-Land System (GOALS) studies the energy transfer between the atmosphere and the tropical oceans to better understand El Niño, and
 - d. the Ocean Drilling Program (ODP) and the Ridge Interdisciplinary Global Experiment (RIDGE) both explore the ocean floor and the margins of continents to better understand the structure of the sea floor and the relationship between geological processes and ocean chemistry.
- In 1983, the Deep Sea Drilling Program (DSDP) became the Ocean Drilling Program (ODP). With the retirement of the *Glomar Challenger* a new ship, the *JOIDES Resolution* (figure 1.20b), was built for ocean drilling under the ODP.

- Satellite monitoring of the oceans has enabled us to observe marine processes and measure marine characteristics over entire ocean basins. Some examples of major satellite programs include:
 - a. The first satellite launched to study the oceans was placed in orbit in 1978 and was called SEASAT. It had an operational lifetime of only a few months and was replaced by a military satellite called GEOSAT.
 - b. NASA's Nimbus-7 satellite, also launched in 1978, carried a sensor package called the Coastal Zone Color Scanner. It was used from 1978 to 1986 to measure levels of biological productivity in the ocean.
 - c. In 1985, the U.S. Navy Geodynamic Experimental Ocean Satellite (GEOSAT) was launched. While it was intended for military purposes, its orbit was later changed to replace the failed SEASAT. It was used from 1986 to 1990 to measure sea-level height to monitor ocean waves, changes in gravity and abrupt boundaries in the ocean caused by changes in salinity and temperature.
 - d. In 1992, the satellite TOPEX/Poseidon was launched to explore ocean circulation and interaction between the ocean and the atmosphere. This satellite is capable of measuring ocean surface elevations with an accuracy of less than 10 cm (4 in).
- Twenty-four nations have jointly recommended the development of a Global Ocean Observing System (GOOS) of satellites, buoy networks, and research vessels to improve our understanding of ocean processes and our ability to predict ocean events such as El Niño.
- An integral part of GOOS is a project called ARGO.
 - a. ARGO will deploy an array of 3000 independent instruments, or floats, by the year 2005. As of March 2003, 720 active floats have been deployed.
 - b. Each float will be programmed to dive to a depth of 2000 m (6560 ft) where it will remain for 10 to 14 days (figure 1.22b).
 - c. As the floats rise to the surface they will measure temperature and salinity. When it reaches the surface it will transmit the data to shore via satellite and then descend to 2000 m once again.
 - d. In this fashion, detailed profiles of temperature and salinity in the upper 2000 m of water will be obtained every 10 to 14 days.
- The United Nations designated 1998 as the Year of the Ocean. Goals included:
 - a. a comprehensive review of ocean policies and programs, and
 - b. raising public awareness of the importance of the oceans in human life and the impact human activities have on the oceans.
- Project NEPTUNE is an international research and education program scheduled to begin operations in 2007. It is part of a worldwide effort to develop regional, coastal, and global ocean observatories.
- The Office of Ocean Exploration (OOE) at NOAA was created in 2001 to encourage and fund new exploratory mission in the oceans as well as new technology to support such exploration.

Test Your Recall

Answer the following questions to test your understanding

FILL IN THE BLANK

1. The North Atlantic was crossed by the _____ during the Middle Ages.
2. Early information about the oceans was acquired primarily by _____ and _____.
3. The first extensive maps of ocean regions and surrounding continents were produced by the _____.
4. A _____ was an early chart used during the Middle Ages to find harbors along trade routes.
5. The first European to sight the Pacific Ocean was _____.
6. The great voyages of discovery occurred in the _____ and _____ centuries.

7. The *Golden Hind* was the name of _____ ship.
8. The Naval Depot of Charts was founded by _____.
9. The *Meteor* expedition concentrated on the _____ Ocean.
10. Fridtjof Nansen sailed on board the _____.

TRUE - FALSE

1. Scientific exploration of the oceans began with the Phoenicians.
2. The Polynesians are known to have navigated with the aid of charts made from sticks and shells.
3. Magellan sailed around the globe and returned to Spain in 1521.
4. The search for a northwest passage was driven by a desire to shorten the voyage to China from England and Europe.
5. Benjamin Franklin became interested in the Gulf Stream because of its affect on mail ships.
6. The *Challenger* expedition sailed under the leadership of Wyville Thompson.
7. The *Fram* was built with a specially deep, pointed keel for survival in the ice.
8. The scientific study of the oceans blossomed following WWII.
9. Following the *Challenger* expedition, it took another five years to analyze all of the data.
10. The *Meteor* expedition was a biological cruise.

MULTIPLE CHOICE

1. Early voyagers used a variety of observations to help guide them, including
 - a. their sense of smell.
 - b. cloud formations.
 - c. the appearance of birds.
 - d. the direction of waves.
 - e. all of the above.
2. This individual first calculated the circumference of the earth:
 - a. Pliny
 - b. Eratosthenes
 - c. Franklin
 - d. Ptolemy
 - e. Elvis
3. During the Middle Ages
 - a. scientific investigation of the seas increased.
 - b. the great depths of the oceans were first discovered.
 - c. shipbuilding technology improved.
 - d. the first circumnavigation of Africa was completed.
 - e. accurate maps with latitude and longitude appeared.
4. The explorer who first believed South America was a distinct continent was
 - a. Amerigo Vespucci.
 - b. Franco Americas.
 - c. Vasco d'Americ.
 - d. Bartholomeu Dias.
 - e. none of the above.
5. The *Challenger* expedition is credited with
 - a. discovering over 4700 new species of marine organisms.
 - b. measuring ocean depths greater than any previously found.
 - c. discovering that major component ions have a constant relative abundance.
 - d. sailing into and investigating all of the world's oceans.
 - e. all of the above.
6. Which of the following explorers used the *Fram*?
 - a. William Baffin
 - b. Fridtjof Nansen
 - c. Roald Amundsen
 - d. b and c
 - e. all of the above

7. While on the HMS *Beagle*, Charles Darwin studied
 - a. the variability of seawater salinity.
 - b. the vertical zonation of life in the seas.
 - c. the formation of atolls.
 - d. the westward intensification of surface currents.
 - e. the Gulf Stream.
8. The first serious study of the small animals and plants that populate surface waters was undertaken by
 - a. Edward Forbes.
 - b. Johannes Müller.
 - c. Aristotle.
 - d. Wyville Thompson.
 - e. Charles Darwin.
9. The first European credited with sighting the Pacific Ocean is
 - a. Vasco Nuñez de Balboa.
 - b. Bartholomeu Dias.
 - c. Christopher Columbus.
 - d. Martin Waldseemüller.
 - e. Ferdinand Magellan.
10. Oceanography in the 1970s
 - a. suffered from a decline in funding for basic research and the construction of ships.
 - b. was galvanized by the discovery of sea floor hydrothermal vents.
 - c. saw the development of more sophisticated submersibles.
 - d. benefited tremendously from the acquisition of satellite data.
 - e. all of the above.

Answer Key for Key Terms and Test Your Understanding

FILL IN THE BLANK

- | | |
|--------------------|-----------------------|
| 1. Vikings | 2. explorers, traders |
| 3. Greeks | 4. portolanos |
| 5. Balboa | 6. 15th, 16th |
| 7. Francis Drake's | 8. Maury |
| 9. Atlantic | 10. <i>Fram</i> |

TRUE - FALSE

1.F 2.T 3.F 4.T 5.T 6.T 7.F 8.T 9.F 10.F

MULTIPLE CHOICE

1.e 2.b 3.c 4.a 5.e 6.d 7.c 8.b 9.a 10.e