

MILES DOWN! OCEANOGRAPHY THROUGH HISTORY

The history of oceanography is an international story of invention, individual adventure, and exploration that remains little-known.

This exhibition presents an historical overview, using timelines, text, photographs, and profiles of oceanographic expeditions and individual scientists from around the world.

Image: Colette Kerry

From water's edge, the oceans are as mysterious as the stars. In the 21st century, deep-sea exploration – like space exploration - is no longer a fantastic idea, but a fact of scientific life. How did we move below the surface to study the depths of the sea? This exhibition tells the story of curious humans posing questions about the oceans and developing the tools and technology to move miles down to explore the sea. The oceans that cover 71% of the world's surface hide complex worlds within their depths. How ocean waters behave, what creatures inhabit the seas, what lies on the ocean floors, what makes up seawater: these are the questions that underlie the scientific study of the oceans - the science of oceanography.

Oceanography is the scientific study of the oceans as complex, interrelated systems. It is a mixed science that combines many different approaches to understanding the watery portion of our planet.

Physics explores the physical properties of the oceans, the currents and waves. It's a study of matter and energy and the relation between them.

Chemistry is concerned with the properties, composition, and structure of substances in the oceans and the changes they undergo when they combine or react.

The geology of the seafloor explores the earth's history, composition, structure and processes.

Biology studies the organisms that live in the oceans, zoology looks at animal life and botany looks at plant life.

In turn, oceanography adds knowledge to other branches of science such as climatology, meteorology, and general science. Increasingly, oceanography overlaps with atmospheric and space sciences, engineering, and research technology.

Scientists began to organize the study of the oceans as complex, interrelated systems in the late 1800s.

Oceanography's practical origins

Thousands of years before formal oceanography, people observed the world's oceans, and knew practical things about waves, currents, fish, whales, and other sea creatures. Their knowledge of coastal waters enabled them to build boats, go fishing, and navigate to trade with or settle other lands.

Image: Micronesian and Polynesian navigators (<http://www.janeresture.com/navigators/index.htm>)

Image: Early navigators followed the movements of birds; dawn and dusk flight paths pointed the way to land. (<http://www.janeresture.com/navigators/index.htm>)

Image: Low lying cloud formation above an atoll (<http://www.janeresture.com/navigators/index.htm>)

Image: An early stick chart from Micronesia shows the waves and currents around the islands which are represented by shells (<http://www.janeresture.com/navigators/index.htm>)

By the 15th century, people began to study the oceans more formally, driven by the search for wealth and by human curiosity. Fishermen and whalers, merchants and traders, navigators and colonizers, philosophers and scientists all faced the need to survive in an extreme environment. Some sailed across huge, threatening oceans looking for isolated new lands. They defined the outlines of land and sea in the process. Others looked for what lives beneath the surface.

Seeking to understand the sea's behavior, these practical sea folk had the same questions that both ancient philosophers and modern marine scientists ask: How do ocean waters behave? What creatures inhabit the seas? What lies on the ocean floors? How deep?

Fishermen sought abundant fishing grounds, studying the oceans for a practical reason: to find fish.

Images: These medieval woodcuts shows an abundance of edible fish, crayfish and lobsters near fishing vessels. Courtesy Medieval Woodcuts Clipart Collection at Godecookery.com

Seeking New Lands

Over thousands of years, sea traders laid down the outlines of geography: where the oceans and lands of the world intersect.

Navigators and explorers sought new lands to trade with, conquer, colonize, or settle. Many of these lands were isolated by huge oceans. We now know that ancient seafarers voyaged farther and more often than we realized. Australia, for example, was settled by long-distance voyages from South Asia in about 50,000 BC.

Image: Genoese nautical chart of the world, 1457 (http://academic.emporia.edu/aberjame/map/h_map/h_map.htm)

Image: A 16th century portolan of the Mediterranean and Black Seas, by Placido Oliva, represents a new type of navigational chart that emerged in the 13th century. Geography and Map Division, Library of Congress

Merchants and traders wanted good routes to cross the seas – the quickest routes that held the least peril of losing ships, lives, and cargoes. Wealth through trade meant understanding the ocean: How do we get where we want to go? How do wind and water interact? Where did currents speed up voyages, or slow them down?

Other seafaring areas were the Mediterranean and Middle East, The Pacific and Atlantic oceans, and the Far East, where the Chinese discovered the magnetic compass, which came to Europe about 900 AD.

Using this direction-finding device, Europeans entered a “Golden Age” of exploration around 1450 AD and spent the next three hundred years voyaging for trade and acquiring land. These navigators gathered basic data onto charts for getting around the oceans. By the beginning of the 18th century, we knew the basic outlines of land and sea the world over.

Image: As redrawn from Claudius Ptolemy’s first world atlas of 127-151 AD, this 1482 map shows the concept of the world and its oceans that guided the Age of Exploration. Thacher Collection, Rare Book & Special Collections Division, Library of Congress

Ancient Theories of the Oceans

In ancient times, Greek and Roman philosophers - the early scientists - studied the oceans as part of their inquiries into the physical world. This learning provides some of the foundations for modern ocean science.

Aristotle (384-322 BC) included ideas about the sea's origins in his work *Meteorologica*. He described a cycle of rainfall and evaporation, proven by the fact that the sea does not dry up. Aristotle's observations of the oceans and marine species were influential for centuries, and rediscovered in Renaissance Europe.

The Greeks calculated the shape and circumference of earth. They too speculated about what lives deeper beneath the ocean's surface.

The Roman naturalist Pliny (1st century AD) had ideas about tides and salinity. He listed the known marine species in his work *Natural History*, which summarized all that the Romans knew about the natural world.

Image: Aristotle stamp. The Greek philosopher Aristotle was an influential observer of the sea and earth.

Image: A page from the 1472 printing of Pliny's *Natural History*. Rich book owners (this appears to have belonged to the powerful Medici family) could have their printed texts hand-illuminated, now with very detailed illustrations. Notice among naturalistic figures of insects and aquatic creatures is the figure of an artist. (http://www.princeton.edu/~his291/Pliny_1.html)

In Europe, little substantial marine science was done between Pliny's time and the Renaissance, fourteen hundred years later. But the Arab world preserved much of the early knowledge.

Image: During the so-called Dark Ages, Arab geographers such as Muhammad al-Idrisi (1100-1165) continued to work on defining the world. Al-Idrisi's spherical world map (1154) was used by Renaissance-era ocean explorers. Note that south is at top.

Myths to Explain the Ocean's Mysteries

Throughout time, people have created mythologies to explain the mysteries of ocean behavior. These myths combine imagination, poetry, and spiritual beliefs. Today, in many parts of the world, people continue to honor the oceans as places where spirit resides.

The Deep: Realm of Imagination

The ancient Greeks placed goddesses, gods, and monsters throughout the universe, including the sea. These supernatural beings interacted with humans and animals in dramatic ways, creating natural phenomena of land, sea, and sky.

The Greeks passed along their religion (along with their scientific findings) to the ancient Romans. Through the Romans, these ideas spread across the western world.

The Deep: Realm of Gods

The Olympian god Poseidon (Roman Neptune) and Amphitrite, a daughter of Nereus and Doris, were the chief Greek water deities.

The Deep: Realm of Monsters

Old tales of sea serpents and other fishy monsters were sometimes exaggerated descriptions of real animals, such as the giant squid. Other creatures were imaginary, but before deep ocean science, who could say these did not live in the sea?

Image: Mythical Satyrus marinus - a sea-going merman satyr. Part man, part goat, part fish. In: "Specula physico-mathematico-historica" by Johann Zahn.1696 NOAA Library Collection

Image: mermaid

Image: Neptune, God of the Sea (<http://www.crystalinks.com/neptunerome.html>)

Image: The giant squid may be the basis for tales of sea monsters since Homer's *Odyssey* to Jules Verne's *20,000 Leagues Under the Sea*, fixed the squid as a monster in readers' minds. © The Mariners' Museum, Newport News, VA

Ancient Beliefs Persist Today

Mazu was a 10th-century Chinese Taoist, Lin Moniang, who used her spiritual powers to aid fishermen and sailors. After her death she became known as the Goddess of the Sea, or Heavenly Mother (Tianhou). A thousand years later, people maintain a vital Mazu culture through ceremonies at her home temple in Meizhou Bay, Fujian, on China's southeast coast, and throughout China, Taiwan, and other parts of Asia.

Ocean mythology can be seen in age-old customs. Seafarers continue old practices such as ceremonially naming boats while offering a libation to the sea; painting eyes on the bows so the boat can see where it is going; and buying (or placating) the wind by placing a coin under the mast of a sailboat.

Image: Mazu, Goddess of the Sea, is honored in many places today (China.cn.org)

Image: Mazu ceremony (chinaplanner.com)

Image: Maltese fishermen paint eyes on the bows of their boats. Courtesy Philippe Plisson.

Early Seemarks in Marine Science

Starting in the 18th century, scientists began to build upon the practical ocean knowledge gathered by earlier seafarers and natural philosophers. They studied seawater's chemistry and salinity. They continued to take soundings to determine ocean depth, and to collect and study marine species. They charted currents and winds, whale and fish populations. Each study led to even more questions about the seas, and how all these elements – winds, waves, currents, depth, and species – fit together.

Image: Dredge of 1750. In the mid-18th century, dredging for science, not just for food, began with Otho Frederick Müller.

Image: sifting deposit NOAA Photo Library

Image: Sounding by hand continued to be a foundation of oceanography through the early 1900s, especially alongshore as illustrated here in L'Océan by J. Thoulet, 1904. Courtesy NOAA Picture Library.

Individual scientists pursued marine studies at an even greater pace during the 19th century. Notable discoveries hinted at the complexity of ocean systems. This era culminated in the 1870s voyage of HMS *Challenger*, which marks the beginning of modern scientific oceanography. The expedition's team used many scientific disciplines to achieve a fuller view of the oceans.

Image: HMS *Challenger* was a 226-foot-long warship with a 30-foot beam, (69 meters long with a 9-meter beam). The vessel was modified to accommodate scientists and equipment: most of the guns were removed, and cabins and a laboratory were added. The auxiliary engine of 1,200 horsepower was particularly important. It controlled the vessel's movements during dredging, sounding and trawling. A steam winch of 18 horsepower helped pull up the trawls and dredges. NOAA Photo Library

Timeline

235 BC – 415 AD

The ancient Greeks and Romans list species of marine animals, calculate the circumference of the earth, and theorize about the hydrological cycle and salinity; sailors routinely take soundings of depth

Image: Aristotle

700-1200 AD

Viking sailors sample bottom sediments and take depth soundings, measuring by fathoms (1.83 meters or 6 feet), the distance between a man's outstretched arms (a measure still used today)

Image: Sounding by hand continued to be a foundation of oceanography through the early 1900s, especially alongshore as illustrated here in L'Océan by J. Thoulet, 1904. Courtesy NOAA Picture Library.

500-1000 AD

In Europe's Dark Ages, the theories of the ancients are forgotten after the fall of Greek and Roman civilizations, but the knowledge is preserved in the Arab countries. Sailors' practical knowledge continues to grow, as does scientific learning about the sea in the Middle East, China, and India

Image: Arab vessel

15th -18th centuries

The long voyages of Europe's Golden Age of Exploration produce maps to serve commerce and science and determine that all the oceans are connected

Image: Oliva's 16th century portolan. Courtesy Geography and Map Division, Library of Congress

15th century

The French first use the term "océanographie," but the word vanishes again until the 1870s

1520 and 1580

First circumnavigations of the world's oceans

1711-1725

Luigi Marsigli (Italy) publishes *Histoire Physique de la Mer*, the first book devoted to marine science (based upon his 1680s studies of the Bosphorus, where he discovered that currents between the Black Sea and Mediterranean are caused by different water densities)

Image: The Bosphorous straits today, courtesy Philippe Plisson.

1700s

Vitus Bering and others undertake Russian voyages of exploration to Northwest America and the Arctic

Image: Bering stamp.jpg

1736

Carolus Linnaeus (Sweden) develops a classification system for plants and animals, advancing scientific collection

1768-1779

The explorer James Cook (Britain) and naturalists gather data during expeditions to the Pacific and South Seas; measure winds, currents, temperatures; locate and map New Zealand, Australia, the Great Barrier Reef, and the Hawaiian Islands. Cook's voyages are sometimes called the first scientific oceanographic expeditions

Image: Whale fishery. Published accounts of Cook's voyages included views of ocean activity around the world.

1769

Benjamin Franklin (America) collects data to indicate the presence of the Atlantic Gulf Stream, in order to speed up postal services; also demonstrates relationships between weather and sea, a foundation for further studies

Image: Franklin.

1818

Sir John Ross (Britain) hauls up marine specimens from more than a mile (2.2km) deep in the Arctic

1831-1836

Charles Darwin (Britain) sails as unpaid naturalist / geologist on the voyage of HMS *Beagle*; develops theory on formation of coral reefs. His collections and observations lead to his theory of evolution, encouraging the search for living fossils and "missing evolutionary links" in the sea

Image: HMS Beagle

1832

James Rennell (Britain) publishes *An Investigation of the Currents of the Atlantic Ocean*

1839-1842

Wilkes Expedition (America), the U.S. Exploring Expedition, performs extensive studies in the Pacific Ocean, making great advances in hydrographic charts

Image: Wilkes small boat. Alfred Agate recorded the experiences of the Wilkes expedition in sketches and watercolors. Courtesy US Navy, Naval Historical Center

1839-1843

Sir James Ross' (Britain) expedition to south polar seas locates magnetic south pole and dredges life from deep sea

Images: Antarctic 1838. A French expedition under Dumont D'Urville also explored the south polar seas. Courtesy NOAA Picture Library

1843

Edward Forbes (Britain) states that there is no life in the deep sea below 300 fathoms (1800 feet or 548 m); debate on this "azoic zone" continues until about 1860

Image: Forbes' cartoon of dredging.

1841-1861

Matthew F. Maury (America) compiles vessels' wind and current data for improving navigation charts; creates whale chart based on ships' logbooks

Image: Maury's Gulf Stream chart of 1858, public domain

1849

US Coast Survey discovers presence of the continental shelf and slope

1853

The International Marine Conference in Brussels is the first international scientific meeting devoted to the oceans

Image: Understanding weather at sea motivated much 19th-century ocean science. Threatening waterspouts, or *trombes*, from *Les Meteores*, 1869;

Courtesy NOAA Photo Library

M. F. Maury publishes *The Physical Geography of the Sea*

Image: M.F. Maury

Image: chart by Maury

1860s

Growing interest in deep sea studies; scientists find organisms living at 1200 m (3,940 feet or 656 fathoms)

First marine biological station founded at Naples by Anton Dohrn (Italy), followed by a laboratory at Villefranche sur Mer (France) in 1882

Image: Villefranche sur Mer

Image: Anton Dohrn

1872-1876

HMS *Challenger* expedition (Britain) under naturalists Sir Wyville Thomson (Scotland) and John Murray (Canada) performs oceans research

worldwide; fifty volumes of results are published beginning in 1880, ushering in new era of science

Image: HMS Challenger

Charles Darwin and The Sea (1831-1859)

Early marine biologists had the thrill of discovering a huge variety of life forms in the oceans. They looked into how species can thrive in environments so different from those on land.

Charles Darwin sailed as naturalist and geologist on the voyages of HMS *Beagle* between 1831 and 1836. He systematically collected fossils, plants, and animals, resulting in tons of material for him and other scientists to study back home. His marine observations led him to propose a theory on how coral reefs form. Digesting this material, over the next several decades, resulted in his theory of evolution (eventually published as *On the Origin of Species by Natural Selection* in 1859).

Among Darwin's many legacies, his influential theory of evolution encouraged other scientists to search for living fossils and "missing evolutionary links" in the sea. This gave a great boost to marine science.

Image: Aboard HMS *Beagle* between 1831-1836, Charles Darwin observed and collected marine specimens that would help him develop his theory of evolution.

Image: The Kelp Forest and Other Mysteries "The number of living creatures of all Orders, whose existence intimately depends on the kelp, is wonderful. A great volume might be written, describing the inhabitants of one of these beds of sea-weed..." Charles Darwin, *The Voyage of the Beagle*, 1845 Courtesy NOAA Photo Library

Defining Land and Sea in 19th Century America

America in the early 19th century was a young country developing its overseas trade. To encourage shipping and marine commerce, officials needed more information on winds, currents, navigation routes, and the hazardous margins where land and sea meet. So the government funded surveys to study sea conditions and faraway lands. Such surveys helped ensure the success of American trade. The young U.S. Navy also found better ocean knowledge to be strategically important.

Image: Disaster at sea. In 1846, while conducting Gulf Stream studies to aid the speed and safety of shipping, the Coast Survey Brig PETER G. WASHINGTON was wrecked in a hurricane with the loss of 11 crew members – including Lieutenant Commanding George M. Bache, head of the expedition. Courtesy NOAA Picture Library

The U.S. Exploring Expedition, 1838-1842

In 1838, the U.S. Exploring Expedition went to sea on its assigned task: to survey and explore all around the world. Its goals included improving America's commercial interests in maritime trade, sealing, and whaling. The expedition also hoped to show that the American nation was mature enough to undertake an enormous scientific endeavor.

The expedition did not meet these lofty goals. Organizational chaos and an unsuccessful collaboration between its Navy scientists and civilian naturalists compromised the results. After almost four years of extensive (and costly) voyaging, and many setbacks including the loss of two ships, the fleet of Navy ships straggled back. Collections were lost or destroyed. Further funding for the study and publication of results was hard to obtain.

Yet the Wilkes Expedition (as it is also called, after its commander Naval Lieutenant Charles Wilkes) did achieve many significant results. Its ships explored the Pacific Ocean and South Seas and advanced hydrographic charting – a particular interest of Charles Wilkes. It added to the growing understanding of the oceans and the natural history, ethnography, and geography of the world.

Image: The Wilkes Expedition determined the existence of Antarctica. Courtesy U.S. Navy, Naval Historical Center

Maury: Pathfinder of the Seas (1841-1861)

Sometimes it takes an energetic administrator to advance a science. So it was with Matthew F. Maury, head of the U.S. Navy's Depot of Charts and Instruments.

For twenty years beginning in 1841, Maury sought to improve navigation charts for the benefit of trade. He compiled data on winds, currents, whales, and weather, using notes from vessels' logbooks. He also sent blank charts along on voyages so that ships' crews could record data. Maury's efforts to gather ocean information advanced marine science as well as trade. He issued "sailing instructions" that enabled ship masters to shorten their voyages by days or weeks by altering their routes.

Along with Britain's Edward Forbes, Maury organized the first international scientific meeting devoted to the oceans: the International Marine Conference in Brussels in 1853, which focused on weather.

Maury's 1855 book, *The Physical Geography of the Sea*, remains a landmark in marine science.

Image: Maury's 1851 whale chart, based on the logs of whaling ships, added to knowledge of how commercially valuable whale species were distributed. Library of Congress image

The U.S. Coast Survey (1807 ->)

For hundreds of years, people surveyed waterways so that vessels could navigate them smoothly. One early technique was taking soundings – measuring the depth of water with a weighted device – which provided essential information for charting coasts, harbors, and rivers, and for mapping underwater hazards.

Because coastal waters are the most hazardous for shipping, charting the coasts became a significant public enterprise in 19th century America. The government's U.S. Coast Survey (founded in 1807) also studied the Atlantic's Gulf Stream. By combining marine-science methods already in use - depth soundings, temperature readings, measurements of current direction and speed, and sampling the bottom sediments - the Coast Survey created a comprehensive hydrographic study that served as a model for other studies.

In 1849 the Coast Survey found something as important as gold in California, discovered that same year. Soundings revealed the continental slope and shelf – the shallow areas near continents that are formed by sediments washing down from rivers. Averaging about 430 feet deep (with the edge of the shelf found at from 66 to 1,800 feet deep) the shelves support abundant marine life and contain minerals. This stunning finding influenced the course of marine geology, biology, and hydrography.

Image: diagram of continental shelf, eastern North America

Image: Today we can see the shallow continental shelves from space, as orbiting satellites take sophisticated “snapshots” of land and sea. This image of Hurricane Floyd (1999) reveals sediment suspended along the U.S. continental shelf. Courtesy NASA.

Life in the Deep Sea?

In the early 1800s, many European naturalists held the theory that the deep sea was dense, dark, cold – and lifeless. Therefore it was not worth exploring. In any case, technical limitations prevented looking too far below the ocean's surface.

A British naturalist, Edward Forbes, proposed his theory of the azoic (lifeless) zone in the 1840s: no biological life could exist in the deep sea below the 300-fathom line - that is, deeper than (1800 feet or 548 meters).

But was the deep sea really lifeless? Scientists had gathered some evidence of deep-sea life even before Forbes stated his azoic theory. Notably, Sir John Ross dredged specimens from Arctic deep-sea in 1818, and his nephew Sir James Ross repeated the experiment near Antarctic in the late 1830s. The debate on the limits of marine life continued through the late 1850s, when ideas changed completely: the deep sea had considerable life.

Edward Forbes and the Azoic Zone (1843-1868)

Known as a brilliant botanist, zoologist and geologist, Edward Forbes turned to studying the distribution of sea life. In 1843, based on dredge studies, he stated a theory that the deep sea must be azoic, or lifeless, below 300 fathoms (1800 feet or 548 meters).

This theory prompted other scientists to look for abyssal animals. But despite occasional retrievals of living finds, the azoic zone idea persisted for a long time. Finally, a broken telegraph cable brought up from 1200 fathoms down on the Mediterranean sea bed was found to be covered with sea life – proving that life did exist deep in the sea.

Image: Ryder Bay, Antarctica from the RRS James Clark Ross, 2005. Photo: Jean McNeil

Image: deep dredge, NOAA Photo Library

Image: deep sea creatures, NOAA Photo Library

20,000 Leagues Under the Sea (1869)

Visionary French writer Jules Verne wrote a hugely popular book, *Twenty Thousand Leagues Under the Sea*, in 1869. His fiction anticipates real scientific advances. Verne described technical innovations such as the deep-sea submarine and food made from sea life. But his explorers see no life in the deep ocean. (Real-life scientists, by this time, were seeing evidence of marine species thriving deep beneath the surface).

Image: Captain Nemo regards a giant octopus through the viewing window of Verne's fictional deep--sea submarine. Courtesy NOAA Photo Library

The Beginnings of Deep-Sea Exploration

After Darwin published his theory of evolution in 1859, the investigation of marine life turned to the deep sea - soon regarded as the “cradle of life.” Scientists searched there for living fossils, or missing evolutionary links. They also studied the sea floor and its life to prepare to lay communications cables between continents.

We now know that the deep sea is the largest habitat on earth. Life has been found at depths that 19th century scientists could only dream of sampling. But even after more than 150 years of exploration, there is still much we don't know about fish and other creatures that live in the abyssal sea.

A Boost from Evolutionary Theory (1859)

British naturalist Charles Darwin's theory of evolution (published in *The Origin of Species* in 1859) overturned long-held ideas about the emergence of life on planet Earth. It also suggested that the marine environment changed more slowly than the land, and that idea prompted other scientists to investigate marine life. Perhaps ancient forms of life – living fossils and “missing evolutionary links” – might be found in the sea.

Soon, scientists' view of the deep sea had shifted permanently. No longer a lifeless abyss, the sea was the cradle of life itself.

Image: laying the transatlantic cable 1857-1858, Burndy Library

Image: The *Great Eastern* cable laying ship 1866-66, Corbis (http://www.pbs.org/wgbh/amex/cable/peoplevents/e_second.html)

The Royal Society (1868-1871)

Britain's Royal Society, founded in 1660, represented the interests of science. Its interest in any scientific endeavor guaranteed prestige, and, often, persuaded the government to fund it. Scientists made great advances once the Royal Society began to support investigation of the deep sea. This also happened in other European countries such as the Scandinavian nations, Germany, and France, which all had scientific societies. The Europeans' pursuit of ocean science for knowledge's sake contrasted with the practical approach of the Americans at that time.

Throughout the 19th century, the Royal Society funded several expeditions to explore the deep sea. A series of short cruises into waters off Scotland in 1868-1871 brought up an abundance of marine animals from as deep as 2400 fathoms (14,400 feet or 4,390 meters). This work, led by scientists Charles Wyville Thomson and Dr. William B. Carpenter, added to Britain's scientific and political prestige.

Finally, the Royal Society decided that it was important to collect enough data to confirm British scientists' deep-sea hypotheses. This led to the landmark oceanographic voyage of HMS *Challenger* and the era of modern oceanography.

Image: Wyville Thomson's *The Depths of the Sea* recorded the results of deep-sea work supported by the Royal Society. Courtesy NOAA, Rare Books Collection.

Image: Bishop John Wilkins, founder and first Secretary of The Royal Society (http://www.bishopwilkins.co.uk/html/john_wilkins.html)

The Voyage of HMS *Challenger*, 1872-1876

Oceanography's emergence as a distinct science is marked by the worldwide voyage of the HMS *Challenger* between 1872 and 1876. A converted British warship, *Challenger* was equipped with the latest scientific gear to study the deep ocean.

In December 1872, the *Challenger* expedition set out from England with a simple but enormous mission: To sail the globe and survey all aspects of the deep sea. Four years later, the ship had visited all the world's oceans except the Arctic Ocean, and had traveled almost 69,000 nautical miles (127,000 km). The expedition's work built upon dozens of marine-science endeavors undertaken since the 1840s. But its scope far exceeded earlier studies.

Image: HMS *Challenger* was a 226-foot-long warship with a 30-foot beam, (69 meters long with a 9-meter beam). The vessel was modified to accommodate scientists and equipment: most of the guns were removed, and cabins and a laboratory were added. The auxiliary engine of 1,200 horsepower was particularly important. It controlled the vessel's movements during dredging, sounding and trawling. A steam winch of 18 horsepower helped pull up the trawls and dredges. NOAA Photo Library

The Men of HMS *Challenger*

Aboard the *Challenger* were five scientists and an artist, making up the civilian scientific staff, as well as a naval crew of experienced officers and men to run the vessel.

The Royal Society chose naturalist Sir Charles Wyville Thomson (Scotland) to head the expedition, assisted by John Murray of Canada. (Later, Murray became director of the *Challenger* office, so his name and Thomson's are most closely linked with the expedition.) Henry Nottidge Mosley and Rudolf von Willmöes – Suhm, also naturalists, and John Young Buchanan, a chemist, rounded out the scientific staff. James John Wild served as expedition artist and secretary.

The ship's officers (appointed by the Admiralty) included Captain George Nares in command, and Lt. Thomas Tizard as navigator. Many of the crew members, professional Royal Navy mariners, also assisted with the work of the scientific "stations" – supplying the considerable manpower needed to haul back dredges and nets, assisted by a steam winch, and sorting the finds.

Image: HMS *Challenger* crew, October 1874 (<http://19thcenturyscience.org/HMSC/HMSC-Reports/1885-Narrative/htm/doc.html>)

The Route

Challenger's expedition was not a straightforward long-distance voyage, but a voyage between “stations” in various parts of the ocean. At each station, the crew performed scientific work. There were 362 scientific stations made on the voyage.

The expedition began with four crossings of the north and south Atlantic, followed by two months at Cape Town, South Africa. In January 1874, the ship entered the Antarctic Ocean for the southern summer, but the cold, rough seas and icebergs interfered with their work. Buchanan took water temperature and salinity measurements, but physics and chemistry were not a primary focus.

Challenger sailed to Australia, then into the Pacific, and on to Fiji, and New Zealand, the Malay Peninsula, and South China Sea. January of 1875 found her in Hong Kong, from where she moved on to Japan, the eastern Pacific, and several Pacific crossings. The new year of 1876 dawned at Cape Horn, then *Challenger* sailed via the Falkland Islands, across the Atlantic for a fifth time, to the Cape Verdes and home to England after three and a half years.

Image: HMS Challenger tracks, Maps 1, 2 & 3 - 13317, 13318, 13319 (http://aadc-maps.aad.gov.au/aadc/mapcat/gis_maps.cfm)

The Methods

Challenger's scientists and crew used several methods for studying the ocean. They measured water temperature at the surface and at depth using submersible thermometers. They dredged up samples of marine animals, plants, and sediments from the bottom. With trawls and nets, they collected fish and other animals. They took soundings, with weighted devices, to gauge the ocean's depth.

Using these methods, the *Challenger* expedition found undersea mountain chains, collected more than 4,700 previously unknown sea animals and plants from various depths, and sounded the deep Marianas Trench, at 8,185 meters (almost 5.1 miles deep). While the work emphasized biology, scientists also examined the chemistry and density of seawater, and analyzed sediments dredged up from the sea floor.

The Scientific Method at Sea

By the late 19th century, the scientific method had developed into a useful tool. It offers an organized structure within which to pursue questions about the oceans.

The scientific method involves a series of steps. First, observe the phenomenon being studied, and develop a hypothesis. Next, devise more observations and experiments to test the preliminary idea. If the hypothesis holds true when tested, scientists adopt it as theory or "law." If it is contradicted by the facts, it is modified and tested again – or even thrown away.

Scientists often return to "proven" scientific theories with additional evidence that may support or contradict them.

For example, *Challenger's* scientists re-examined the "primordial slime" called *Bathybius*. When first discovered, it was thought to hold a clue to the origins of life in the sea. But upon examining new samples, scientists found that the slime was actually a chemical by-product (calcium sulfate) formed in a reaction between sea water and the alcohol preservative used for mineral specimens!

Life at Sea

Crammed onto a vessel just 226 feet long that also carried everything needed for life and work for several years, *Challenger's* crew and scientists faced discomfort as well as the hazards of life at sea. Despite the steam winch, hauling nets and dredges was very heavy work. One sailor was killed by the whiplash of a line and block that came loose from a dredge. Many were injured just doing their daily work.

During the 3 and a half year voyage, expedition members also suffered illnesses, both major and minor; two drowned, one committed suicide, two went mad, and one man was poisoned. The young German naturalist, Rudolf von Willmões – Suhm, died from erysipelas, a skin infection.

The expedition also offered the excitement of new discoveries, interesting ports of call where the crew could replenish water and supplies, and the fascination of being at sea.

Image: HMS *Challenger* was equipped with the most modern scientific equipment available. Conducting experiments and collecting specimens at sea is necessarily expensive, requiring special equipment as well as a good vessel. The *Challenger* expedition was funded by the British Admiralty (Royal Navy) and the Royal Society, Britain's scientific academy.

Image: Sea thermometers measure water temperature, which, combined with salinity, determines the density of seawater. Density indicates where different masses of water lie and flow. Temperature and salinity, as essential oceanographic data, are still recorded regularly on most scientific voyages.

NOAA Photo Library

Image: Challenger trawl

Image: Scientists' workroom aboard HMS *Challenger*. NOAA Photo Library

Challenger's Results

Once back in England, it took scientists almost twenty years to sort and examine the specimens and materials collected during *Challenger's* cruise. Seventy-six specialists studied portions of the collections. Thirteen thousand different kinds of plants and animals, more than 1,400 water samples, and hundreds of sea-floor deposits were analyzed.

Eventually, fifty volumes of findings were published, first under the supervision of Sir Wyville Thomson and later under Dr. (Sir) John Murray. The *Challenger* reports (published between 1880 and 1895) remain a landmark of marine science, recording in detail all knowledge of the deep sea at that time. For decades afterwards, oceanographers worked to fill in the substantial framework created by the *Challenger* expedition.

Image: Challenger Bathytroctes (<http://www.hmsc.19thcenturyscience.org/>)

Image: Challenger's soundings (<http://www.hmsc.19thcenturyscience.org/>)

Image: Bathymetrical Chart of the Oceans showing the "Deeps," according to Sir John Murray (<http://www.hmsc.19thcenturyscience.org/>)

***Challenger's* Results**

The many exciting scientific discoveries made aboard *Challenger* greatly advanced marine science. Among the most significant outcomes, scientists found that there was no depth limit to life on the sea floor. They found an amazing abundance of marine organisms at various depths. One trawl, in the South Atlantic off Argentina, brought up almost 500 specimens representing 127 species, more than a hundred of them new to science. Altogether, *Challenger's* scientists found more than 4,700 new marine species.

Some old ideas were put to rest, too. The non-discovery of “missing evolutionary links” in the deep sea was in itself noteworthy.

The *Challenger* expedition fathomed the deepest parts of the ocean, sounding more than 5 miles down at the Marianas Trench – now known to be the deepest part of the ocean. And *Challenger* was the first steam vessel to cross the Antarctic Circle.

Image: Challenger deep sea fishes (<http://www.hmsc.19thcenturyscience.org/>)

Image: Challenger coral (<http://www.hmsc.19thcenturyscience.org/>)

Image: Challenger seafloor sediments (<http://www.hmsc.19thcenturyscience.org/>)

Image: Sargasso fish (<http://www.hmsc.19thcenturyscience.org/>)

National Expeditions: The Foundations of Oceanography, 1880 - 1940

Other nations, inspired by the *Challenger* expedition, sent out oceanographic missions in the 1880s through the 1930s. Many made exciting discoveries and advanced the technology needed to study the sea. Altogether, they began to tie information together into the emerging picture of oceans as complex, dynamic systems.

In the early years of the 20th century, oceanographers flourished with the support of governments that saw strategic advantages in knowing more about the seas.

Scientists from the United Kingdom, Europe, and the United States undertook most of the world's ocean surveys at this time. This was primarily because oceanography is expensive. Governments and wealthy individuals in those countries were interested in ocean science questions, and funded scientific expeditions to seek answers.

But when nations have other concerns, ocean science lags. World War One – the Great War – interrupted many oceanographic studies. But it also prompted new areas of investigation, such as underwater sound.

Image: Das Meer 1888, NOAA Photo Library

Image: Belgica 5th March 1898 (<http://www.exmaroffshore.com/Belgica.htm>)

The Costs of Oceanography

Oceanographers and marine scientists need specialized vessels and tools to perform their studies. It adds up to a costly science.

Ships are critical as the foundation for work at sea, as are support boats (and, today, remote underwater vehicles) for exploring below the surface. Vessels need trained crews to run them. Also essential are up-to-date research equipment and shipboard laboratories for analyzing data. And, of course, the scientists themselves require specialized training and good salaries. Then there are the substantial costs of fuel and provisions for a long voyage.

Since scientists don't spend all their time at sea, they also need laboratories and offices on shore. There they conduct data analysis - and plan the next voyages.

Prince Albert of Monaco

In the 1880s, Prince Albert the First of Monaco, who had a lifelong interest in marine science, began to make scientific expeditions aboard his own well-equipped yachts. His work at sea expanded to include colleagues from other nations, continuing until the outbreak of World War One. Among his comprehensive studies were the drift patterns of Atlantic currents and the biology of mid-water fish. The Prince's legacy includes an oceanographic museum at Monaco and marine institute in Paris, both opened in the early 20th century and still active today.

Fridtjof Nansen and the Norwegian North Polar Expedition

Norwegian scientist Fridtjof Nansen suspected that currents and winds caused an eastward drift around the North Pole. He proved this in 1893-1896 by undertaking a tough voyage in the specially built ice ship *Fram*. Deliberately frozen into the polar ice, the *Fram*, Nansen, and a crew of thirteen drifted for almost three years. Their voyage showed that the polar sea was full of moving pack ice, but no continental land mass. Soundings proved that it was not shallow, as believed, but actually very deep. They also studied electricity in the air, water temperature and salinity, meteorology, and biology.

Image: boat plans for *Belgica* (<http://www.exmaroffshore.com/Belgica.htm>)

Image: Under Roald Amundsen the sturdy ship *Fram* went on to explore the Antarctic seas, but her earlier work in the Arctic is also a landmark of oceanography. NOAA Photo Library.

Image: The well-equipped research vessel *Blake* cruised for the US Coast and Geodetic Survey from 1874-1905 doing Gulf Stream studies. NOAA Photo Library

The Russian Expeditions aboard *Vitiaz* and *Yermak*

Russia has an eminent history of oceanographic study dating back earlier than the 18th century. But for a long time Russian science was shrouded by secrecy and political competition, so it is not as well known as science in other nations.

Following the path of the Russian ship *Vitiaz*, which made ocean observations in the 1870s, the *Vitiaz II* circled the globe from 1886 to 1889 observing ocean temperature and density. Under the command of Admiral S.O. Makarov, this landmark voyage set the stage for later Russian efforts to study the deep sea. It first discovered undersea volcanoes and hot springs on the floor of the Red Sea – a finding often credited to oceanographers of the 1970s.

In the 1890s the Russian icebreaker *Yermak* opened up new areas of the Arctic for study. By the end of the 20th century, Russian scientists had a comprehensive view of Arctic ecosystems that could be brought together with the western scientists' work to understand this critical area of the world ocean.

Image: Built in 1899, the *Yermak* was one of the first true icebreakers, built to move through sea ice and opening new areas of the Arctic to Russian exploration. Image courtesy Ecoshelf [<http://www.ecoshelf.ru/>]

Scandinavian Scientists and the Dynamic Ocean

Fishing was a lifeline to the Scandinavian countries of Norway, Sweden, Denmark and Finland, so ocean research there tended to support the fisheries.

Scandinavian scientists advanced physical oceanography when they found that plankton (microscopic marine life) is a biological “marker” for water masses, just as temperature and salinity are physical and chemical markers. Water masses influence currents, so these plankton studies added to a dynamic picture of the sea in motion.

Another important question was how ocean currents and water masses (hydrography) relate to the abundance of fish (biology). Norway’s 1910 Atlantic Ocean Expedition aboard the research vessel *Michael Sars* was an international effort to gather essential information about North Atlantic sea creatures. Led by chief scientist Johan Hjort, hydrographic studies were carried out by Fridtjof Nansen, Bjorn Helland Hansen, and others. Eventually, Hjort stated that fish abundance was related to available food. This principle sounds elementary today, but needed to be proven by science first.

The Danish government sponsored a significant long-term study by Johannes Schmidt to find the spawning grounds of European and American eels, an important near-shore fishery. Interrupted by World War One, Schmidt eventually identified the mid-Atlantic as the area where these fish populations originated.

Image: The common Atlantic grenadier, *Nezumia aequalis*, was illustrated in Johan Hjort and John Murray’s book *The Depths of the Ocean*, 1912.

Public domain [wikimedia commons]

Bridging Nations through ICES fisheries research

Late in the 19th century, European fishing regions saw smaller catches. Some suspected a human impact, in addition to natural shifts in fish populations. As human populations grew, so did the demand for fish. So fishermen used more efficient boats and nets to bring in huge catches. But over time, the catches declined. Marine scientists took up the question of why fish abundance changes.

Image: Early 20th century fishing (http://www.clupea.net/fleets/Ger_driftnet/Ger_driftnet_hist.html)

Image: Herring catch (http://www.clupea.net/fleets/Ger_driftnet/Ger_driftnet_hist.html)

Image: Trawler nets (http://www.clupea.net/fleets/Ger_driftnet/Ger_driftnet_hist.html)

Image: Packing herring in a barrel (http://www.clupea.net/fleets/Ger_driftnet/Ger_driftnet_hist.html)

In 1902, several European countries joined together to cooperate in and promote fisheries research, in order to ensure fish for everyone in the future. The organization ICES (the International Council on the Exploration of the Sea) began by coordinating simultaneous hydrographical studies. Eventually this work linked currents and water masses, fish life cycles and migration, and the availability of plankton as food for larval fish: all essential to understanding fisheries.

Today, ICES continues to coordinate marine research in the North Atlantic and adjacent seas. It distributes results to policy makers and promotes marine research in general. Scientists around the world have adopted the “ICES model” of studying a body of water over a long period of time.

Image: ICES nations in 1902 included Russia, Germany, the Netherlands, Great Britain, and the Scandinavian nations
Part of the Vegesack herring fleet (http://www.clupea.net/fleets/Ger_driftnet/Ger_driftnet_hist.html)

The German Antarctic and Atlantic Expeditions

The German Antarctic Expedition of 1911-1912 achieved the first basic studies of the Antarctic Ocean. The German scientists, on their way to the southern ocean, also took temperature and salinity measurements from north to south in the Atlantic, creating an essential hydrographic study.

In the mid-1920s, scientists with the German Atlantic Expedition aboard the *Meteor* set out to extract gold from seawater, in order to pay war debts. The scientists found only a small percentage of the gold they expected. But they did take seawater samples for chemical analysis and charted temperature and salinity.

They also mapped a continuous ridge along the mid-Atlantic sea floor by using the relatively new sonic depth finder, based on the echo sounder device. This technology was developed before and during World War One, as a way of detecting icebergs and military submarines.

Under physical oceanographer Dr. Alfred Merz, whose interest was in deep ocean circulation, *Meteor*'s comprehensive studies over huge areas of the North Atlantic resulted in a fuller picture of this ocean basin.

Image: The German Atlantic Expedition aboard the *Meteor*, 1925. NOAA Photo Library

Image: A scientist sends Dr. Merz' current meter over the side of the ship *Meteor* to gauge current and ocean circulation. NOAA Photo Library

The International Ice Patrol, Currents, and Echo Sounders

Once again, commercial and military needs both played a role in the next major developments of ocean technology.

The fearful shipping hazards posed by icebergs on the busy North Atlantic seaways were dramatized by the sinking of the passenger steamer *Titanic* in 1912. The International Ice Patrol (a 16-nation effort begun in 1914) first tracked icebergs by observing them from patrol vessels and reporting them to other shipping. Later, the Patrol drew upon marine science by using Helland-Hansen's dynamic technique: predicting ocean currents so that vessels could avoid the worst iceberg areas.

Images: Icepatrol map and Iceberg as seen from today's ice patrol airplanes. Ice still poses a hazard to North Atlantic shipping. Both Courtesy US Coast Guard

Canadian Reginald Fessenden had developed an Iceberg Detector and Echo Depth Sounder – an underwater sound-oscillation device that sends sound towards a solid object and measures the time it takes for the echo to return. This was altered into a submarine detector and used by British warships and French submarines against the German U-Boat force during World War One. Germany also developed an echo-sounding device for undersea warfare, later used for marine science.

Today's Ice Patrol technology includes airplanes, radar and loran, as well as underwater sound equipment.

Image: *Seneca* 1914.jpg Sailors on one of the first International Ice Patrol vessels, the US Revenue Cutter *Seneca*. Courtesy US Coast Guard

The Great War and Oceanography

The outbreak of war among European nations interrupted ocean research. Submarine warfare required a quick response. Developing military uses for the new echo sounder required data on sea floor profiles and sediments, temperature and salinity. Scientists redirected their work towards physical oceanography, rather than marine biology, during these years.

Dutch Geologists Take Core Samples Around Indonesia

In a trip to the Indonesian seas in 1929-1930, scientists aboard the Dutch vessel *Willibrord Snellius* pioneered a new technique. Using an explosive bottom sampler called the Piggot gun, they brought up a 6-foot core of marine sediment for analysis.

This core-sampling technique and its later refinements opened up huge advances in marine geology

Image: German UC-1 class submarine (<http://www.answers.com/topic/submarine?cat=technology>)

Image: Crew working with a hydraulic corer from the deck of R/V Bear in 1954, a direct inheritance of earlier marine coring work done by Dutch geologists. Copyright Woods Hole Oceanographic Institution

Image: After the First World War, oceanography provided the basis for international projects such as the development of sound technology, shown in use aboard R/V Chain in 1967 Copyright Woods Hole Oceanographic Institution

Visionary Scientists

The energies of key individuals advance scientific knowledge. Many visionary scientists pursued ocean research in the late 19th and 20th centuries, often working cooperatively with scientists from other nations. They developed new techniques and research questions. Many worked within large institutions and governments, because of the high costs of ocean science. The need to train new scientists led to the founding of many great oceanographic institutions.

Ocean scientists also dealt with political concerns. Whether a result of institutional or international politics, issues of money and power have frequently steered the course of investigations carried out at sea.

In addition to scientists profiled elsewhere in the exhibit, here are a few of the visionary scientists who made substantial contributions to oceanography in the 19th and 20th centuries.

Image: Prince Albert consults with Arctic scientists aboard his research vessel, 1906. NOAA photo Library

Image: Prince Albert and whale. NOAA photo Library

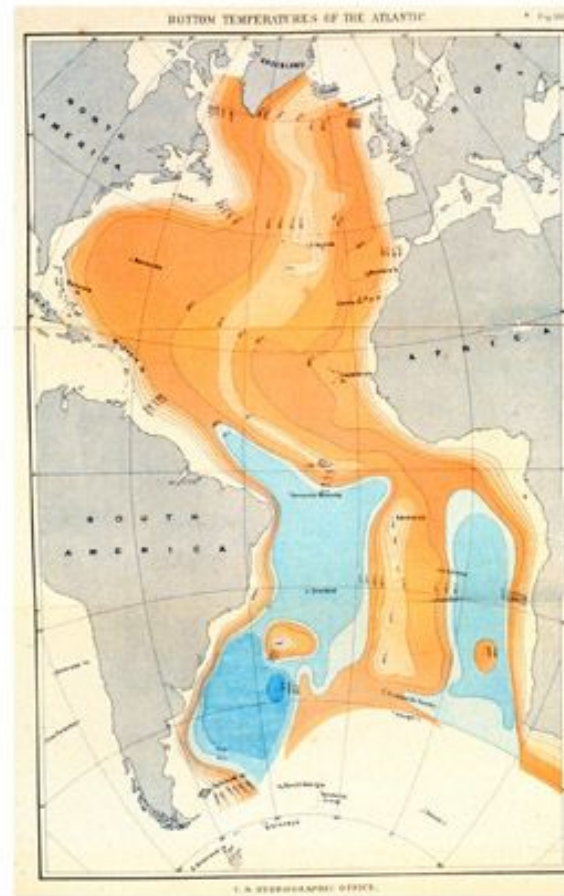


Spencer Fullerton Baird (1823-1887)

An energetic American zoologist, Baird served for many influential years (1850-1887) at the Smithsonian Institution, establishing the National Museum and later becoming Secretary. Concurrently, he was appointed head of the new U.S. Fish Commission in 1871. The Marine Biological Laboratory he established at Woods Hole, Massachusetts has evolved into a major oceanographic institution, and under his direction the research vessel *Albatross* performed studies of fisheries and coastal ecology. Baird's scientific work had a very broad range, from birds and reptiles to marine biology, and he published over 1,000 articles and books.

Alexander Agassiz (1835-1910)

A naturalist, Alexander Agassiz began oceanographic studies in 1877 and led American oceanographic work aboard the *Blake* in the Atlantic. Agassiz was also an industrialist. Some of his profits later supported Harvard's Museum of Comparative Zoology, which had been founded by his father Louis Agassiz.



The elder Agassiz was a renowned geologist and zoologist whose teaching method - direct studies from nature - greatly influenced the development of science in America.

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Image: Spencer Fullerton Baird, NOAA Photo Library

Image: Alexander Agassiz, NOAA Photo Library

Image: Blake bottom temperature chart. In 1888, Agassiz published "Three Cruises of the Blake. This map of bottom temperatures combines temperature data obtained by the Blake with earlier Challenger readings. NOAA Photo Library



Reginald Fessenden

Widely known today for making the first radio broadcast in 1906, Canadian Reginald Fessenden invented over a hundred patentable devices. While employed at the Submarine Signal Company of Boston, Fessenden designed an underwater sound oscillator (left). It was successfully tested in 1914, and became the basis for the echo sounder, the Iceberg Detector, and the sonic depth profiler - devices that re-shaped our knowledge of the underwater environment and sea floor.



Henry Bigelow

Bigelow (above), a student of the legendary Alexander Agassiz, was inspired by the ICES method to perform long-term studies of a single body of water: the biologically rich Gulf of Maine. Over several decades, Bigelow ran studies on fish, plankton, and hydrography, resulting in a fuller understanding of the gulf.

Victor Hensen

Hensen was a German physiologist who coined the term plankton for the simplest forms of marine life, those minute animals and plants that drift through the water and provide essential food for larger organisms. He led a significant study of Atlantic plankton in 1899.

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Image: Reginald Fessenden with his electric oscillator, around 1914, from a Scientific American article. NOAA Photo Library

Image: Henry Bigelow, NOAA Photo Library

Alfred Wegener

In 1912, German geophysicist Alfred Wegener proposed an idea that contradicted much of what scientists believed about the world: that the continents are not fixed in location, but have moved over millennia to their present locations. Wegener based his idea on much older scientific speculations, adding evidence from paleontology that Brazil and western Africa must have been connected at one time. A heated debate continued for decades. In the 1960s new techniques and new evidence from sea-floor spreading and paleomagnetism emerged to support the concept of continental drift, and to expand it to plate tectonic theory.

Image: Alfred Wegener 1880-1930. Courtesy NASA

Image: Bands of fossil evidence found across continents were one of Alfred Wegener's clues to continental drift, now refined as the theory of plate tectonics. Map from *This Dynamic Earth*, Courtesy U.S. Geological Survey

Popularizing Ocean Discoveries

Today, landlubbers have many ways to satisfy their curiosity about the oceans. Over the last century, ocean scientists have shared their discoveries at marine aquaria and exhibits, through popular television programs, books, and films. It's become possible to explore the underwater world recreationally using snorkel or SCUBA gear. Or one can go as a tourist, on a vessel equipped for viewing. The underwater realm continues to inspire creative artists, as it has since antiquity. Photographers, painters, writers, and musicians draw from the oceans' inspiration and share their visions with the world.

Image: Moon over sea

Aquaria and Oceanographic Museums

Growing interest in the sea led to the world's first public aquarium, opening in London in 1853. Once better techniques for keeping fish alive were developed in the 1870s, aquaria spread across Europe - and eventually around the world.

At the turn of the 20th century, the “Scientist Prince” Albert I of Monaco set up a pioneering Oceanographic Museum (with its own aquarium) and also founded an Oceanographic Institute in Paris; both still flourish. Today, marine institutes in Africa, Asia, the Middle East, Australia and New Zealand, Europe and Russia, South America and the Caribbean, and North America provide specialized training and offer public programs to share the results of their work.

Image: Marcel Camia's 1930s poster of the Oceanographic Museum of Monaco depicts its far-ranging scientific interests and displays.
Courtesy Oceanographic Museum of Monaco, NOAA Photo Library

Expositions and Fairs

A prime attraction at the 1933 Century of Progress Exposition in Chicago was Otis Barton's invention, the bathysphere. In this apparatus – essentially a steel sphere tied by cable to a ship on the surface – naturalist Dr. William Beebe and engineer Barton dove many times, reaching a record depth of 3,028 feet (923 meters) off Bermuda in 1934. Beebe recounted their trips into the deep ocean in many articles and books, exciting public imagination with the richness of marine life.

Image: William Beebe in the bathysphere he pioneered with Otis Barton, ca. 1934. Courtesy Wildlife Conservation Society.

Diving In! Access to the Depths

Since ancient times people have explored underwater by holding the breath. We extended underwater time and range by capturing surface air in diving bells or going underwater in self-contained vessels. In the 19th century, the diving helmet and suit became practical, and a form of SCUBA (self-contained underwater breathing apparatus) was invented.

Scuba opened the underwater realm to recreation as well as science and warfare.

Image: Hardhat diver, NOAA Photo Library

In the mid-20th century a major innovation changed self-contained diving: the Aqua-Lung. In 1943 Jacques-Yves Cousteau and engineer Emile Gagnan created a regulator that automatically supplied compressed air when a diver breathed in. Marketed commercially beginning in France in 1946, the Aqua-Lung was carried on the diver's back and used with an insulating suit. This combination freed divers to explore without being tethered to a vessel. A new world opened up.

Image: Aqualung, 18th century concept; NOAA Photo Library

Image: diver underwater

Miles Down and Ever Deeper!

Vessel diving continued to be an important means of studying the deep. Otis Barton went deeper and deeper in his bathysphere, reaching 4,200 feet (1280 meters) in 1948. In 1960 the bathyscaphe *Trieste* – a self-contained, self-propelled diving vessel designed by August Piccard – reached the deepest part of the ocean. In it, Jacques Piccard and Lt. Don Walsh descended 35,820 feet (10,918 meters, or more than 6-3/4 miles) at the Marianas Trench, southwest of Guam in the Pacific.

Deep ocean submersibles developed from the bathyscaphe to be more maneuverable. The first of these, *Alvin*, was built in 1964 and so far has made more than 4,200 dives. *Alvin* is well known for exploring newly discovered hydrothermal vents in the 1970s. It also took scientists down to survey the deep-ocean wreck site of RMS *Titanic* in 1986.

Living in the Deep

Vessel diving was extended by creating below-water habitats where divers could live for up to a month at a time while venturing out on scuba expeditions. Jacques Cousteau supervised the first experiment, Conshelf One, in 1962, followed by several other habitats (Conshelf Two and Three, Sealab I and II) in the mid-1960s.

Image: *Alvin*, Woods Hole Oceanographic Institution

Image: At the USSR's Gelendzhik lab in the late 1960s, American scientists examine a Russian-style sealab. Courtesy WHOI Archives, Copyright Woods Hole Oceanographic Institution

Jacques Cousteau (1910-1997)

The name Jacques-Yves Cousteau came to mean “oceans” to millions of people between the 1950s and the 1990s. The long-time director of the Oceanographic Museum in Monaco popularized ocean science. Over the course of 60 years in ocean work, Cousteau was a serious scientist, naval officer, undersea inventor, writer, and a global icon who opened the doors to the ocean and passionately defended the seas.

Film and Television

With scuba gear, photographers could go beneath the surface starting in the 1950s. Films and television broadcasts featuring underwater footage became hugely popular. Jacques Cousteau was a pioneer of underwater films and documentaries, beginning during World War Two. His film “The Silent World” won top prize at the Cannes Film Festival 1956. His television series, “The Undersea World of Jacques Cousteau,” started a long run in 1968 and was followed by other series. Enormously popular, it featured his vessel *Calypso* on world-roaming adventures in defense of nature.

Underwater images are now so common that it’s easy to forget the magic of those first glimpses of the “silent world,” just a few decades ago.

Image: Jacques Cousteau aboard ship with oceanographic equipment, around 1963 Courtesy WHOI Archives, Copyright Woods Hole Oceanographic Institution

Image: Cousteau’s research vessel *Calypso* was synonymous with ocean exploration; the diving saucer was photographed when *Calypso* visited Woods Hole Oceanographic Institution in 1959. WHOI Archives, Copyright Woods Hole Oceanographic Institution

The Written Word

While the 19th century French writer Jules Verne had a perennial hit in his fantastic book *Twenty Thousand Leagues Under the Sea*, the 20th century brought additional classics on the ocean. Scientist Rachel Carson published *The Sea Around Us* and *The Edge of the Sea* in the 1950s. This award-winning ocean biography combined science with lyrical writing to explain the formation, evolution, and life of the oceans. Bestsellers in 29 languages, these books brought world attention to the ocean.

Music

Musicians and composers have long taken inspiration from the sea. Traditional music includes sea-related work and folk songs from all cultures. Popular and classical composers express the inspiration of the sea in more formal ways.

Today's recording technology creates a different realm of "sea music." Incorporating underwater sounds like the song of the humpback whale has been popular for decades. There are now underwater music festivals that use the acoustics of the ocean and offer underwater broadcasts to audiences of snorkelers and SCUBA divers – a total musical immersion.

Image: Popular books about the ocean were lavishly illustrated before the era of photography, as in Mattias Schleiden's book *Das Meer* (The Sea), published in Germany in 1888. Jacket of "Das Meer" by M.J. Schleiden, 1804-1881.

Image: "Meerkrebse" in: "Das Meer" by M. J. Schleiden, 1804-1881. P. 464.

Art and Photography

Artists and sculptors have always depicted the sea, its mythological and natural inhabitants, in thousands of ways. Underwater exploration offered artists new subjects. Exotic marine animals like whales and dolphins, once known to only a few seafarers, became better known and therefore more popular in art.

Development of underwater cameras began in the 19th century, and made a huge advance with SCUBA gear after the Second World War. While underwater is still the most challenging realm for photography, the resulting images have been enormously popular.

Image: Today, scientists and artists alike use underwater cameras to create images like this Arctic jelly, “captured” on film by a scientist with the National Undersea Research Program. NOAA Photo Library

Image: Mary Jane Brush created this painting, “Exploring the Deep Boulder Reefs,” as part of a Marine Sanctuary program. Courtesy Stellwagen Bank National Marine Sanctuaries, NOAA

Late 20th Century Oceanography in the International Arena

World events of the mid and late 20th century forced cooperation between navies and scientists, a collaboration now typical for oceanography.

World War Two required all the world's navies to know more about the sea. Physical oceanographers studied waves, weather, and surf conditions so that armed forces could plan amphibious landings, contributing to the knowledge of ocean climatology.

After the war, the intensifying Cold War between the USSR and the US moved to the deep sea. The United States responded to the threat of submarine warfare with the Soviet Union by funding major oceanographic and military research on the submarine environment. Soviet scientists competed with their own studies, although with fewer resources. Threatening maneuvers between Soviet missile-carrying subs and American attack submarines continued through the 1980s, when treaties began to reduce nuclear arms.

Ocean science also focused on geology and geophysics as the idea of continental drift was examined. International efforts became important in this era.

Image: Colette Kerry

Behind the Iron Curtain

Russia, and the Soviet Union, has a long and eminent tradition of oceanographic study that includes substantial 18th and 19th century expeditions and polar work. After the Second World War, however, Russian scientific activity was shrouded by competition and political suspicion between East and West. One renowned example of Soviet oceanographic studies lies in the research vessel *Vitiaz III* (now a museum ship in Kaliningrad), which made many voyages between 1949 and 1979. Soviet and international scientists studied ocean trenches, abyssal fauna, oil and gas deposits, ore formation and nodules.

Also driven by Cold War concerns, Soviet scientists turned to studying the Arctic region, antisubmarine acoustics, and ocean surveys, and to modernizing their oceanographic research fleet.

Image: Built in Germany in 1939, the *Vitiaz* sailed for the Soviet Academy of Science. It is today part of the Museum of the World Ocean in Kaliningrad.

The United States Navy

The focus on antisubmarine warfare made navy funds available to hundreds of American scientists and institutions for widespread ocean surveys. Sonar, ocean acoustics, underwater weapons, and conventional and nuclear submarines that could run quietly all developed quickly. The Navy improved the bathyscaph, built a deep sea piloted submersible (*Alvin*) in 1964, and began to test undersea robots in the 1960s. These contributed to exciting new discoveries in geology, as well as to continuing Cold War submarine warfare.

Image: Alvin, early in its career; Woods Hole Oceanographic Institution

Image: Alvin dive, Woods Hole Oceanographic Institution

Image: Alvin spotlights the ocean floor, Woods Hole Oceanographic Institution

The International Geophysical Year and the Geophysical Revolution

Focus on the geology of the deep sea had some revolutionary results. The coordinated projects of the International Geophysical Year (1957-1958) involved scientists from 67 nations in studies of the solar-terrestrial environment. Work on deep ocean currents and factors affecting deep sea mining, the deep sea bed, and seismic activity along the mid-ocean ridges contributed greatly to plate tectonic and sea floor spreading theories.

Accepted by the end of the 1960s, plate tectonic theory and sea floor spreading represented a revolutionary new look at a dynamic earth. The rigid plates of the earth's crust are mobile, so land changes position over time.

Image: IGY Cruise. Aboard R/V Atlantis, two scientists working on International Geophysical Year Projects in 1957. WHOI Archives, Copyright Woods Hole Oceanographic Institution.

Cooperative Science

Marine science flourished around the world after World War Two. Outside the USSR and US, it was far less influenced by the military. Scientific cooperation among nations has also been important. The International Geophysical Year (1957-1958) was one of many enterprises that took hold in the late 1950s and 1960s. Organizations such as NATO's Science Committee (now Science for Peace & Security), the Scientific Committee on Oceanic Research (SCOR), and UNESCO's Intergovernmental Oceanographic Commission (IOC) continue to foster interdisciplinary, international science today. The International Polar Year of 2007-2009 creates another opportunity for coordinated scientific investigations of the polar seas and environment.

Image: The Polarstern docked on ice © Hannes Grobe/Alfred-Wegener-Institut

The Age of Technology

Today, we have many new techniques and tools to study the oceans. Satellite imaging, computer analysis and instant data transmission, radar, and deep-sea remotely operated vehicles are just some examples. These technologies improve both the quantity and the quality of scientific information. Technology has pushed the boundaries of ocean exploration miles deep.

Image: Arctic mooring, Woods Hole Oceanographic Institution

Recent Discoveries

Remotely operated vehicles (ROVs) make it possible to explore parts of the sea floor that would be too difficult to reach in a manned submersible. The ROV extends the reach of scientists on the ocean surface or in submersibles or underwater environments, enabling them to “walk around” at great depths.

Discoveries made or investigated by deep submersibles have literally changed our view of the oceans to include volcanic activity and hydrothermal vents rich in mineral deposits, black smokers (undersea geysers that shoot out dark water), deep sea vents with organisms that thrive at high-temperatures, and other phenomena. Similarly, underwater vehicles open up the possibility of deep-sea mining for minerals.

Image: Underwater hydrothermal vents

Image: an underwater remotely operated vehicle

Image: Alvin, Woods Hole Oceanographic Institution

Image: A serpulid, photographed on the deep sea floor from inside submersible ALVIN. Copyright Woods Hole Oceanographic Institution.

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Current Initiatives in Oceanography

The boundaries of ocean exploration seem to expand daily. So does the significance of ocean science as we continue to learn about the critical earth processes that take place in the oceans - over 70 per cent of the world's surface.

Image: Satellite image of the sands and seaweed in the Bahamas

(http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=10318)

The emergence of oceanography brought together many branches of science and applied them to the oceans.

Image: Juvenile Pacific Herring, *Clupea pallasii* -schools of herring in Saanich Inlet, VENUS
(http://www.venus.uvic.ca/data/galleries/still/saanich_inlet/ropos/detail_demo14.html)

Today, oceanography contributes to a holistic systems science that sees all earth's phenomena as interrelated. The oceans are inseparable from the atmosphere and the land. The oceans' role in climate change, the Arctic and Antarctic regions, seafloor mapping, and the status of marine life are among current initiatives in oceanography.

Despite more and better data, we still know just a fraction of all there is to be learned about the oceans.

Image: Earth, as seen from a weather satellite, late 20th century. The ability to view weather systems of the entire globe at a moment in time has contributed enormously to our ability to forecast © Science Museum/Science and Society Picture Library

Census of Marine Life

The 21st century Census of Marine Life, an international effort to track and map all living beings in the world's oceans (conducted between 2000 and 2010), continues the efforts of 19th and 20th century marine scientists to examine the creatures of the sea.

Image: jellyfish

Climate and Arctic Studies

Deep-ocean circulation patterns govern the planet's climate. The traditional oceanographic studies of water temperature, depth, and salinity, which define water masses and drive their circulation, are as important as ever. Oceans data from the Arctic Ocean is especially critical to understanding changes in earth's climate everywhere.

The Birth of a New Ocean

A 37-mile long fissure in the Afar desert of northeast Ethiopia is the sign of a process that will tear the desert off the African continent, resulting in the formation of a new sea to fill the gap – in a million years' time.

Image from WHOI, ice camp: Studying surface heat exchange in the Arctic at the ice camp in 1998, photo by Carin Ashjian, copyright Woods Hole Oceanographic Institution.

Ocean Frontiers

Medicine, climate, public health, and hydrology are among the many new frontiers of ocean information to be explored in the years to come. Deep sea mining, medicines using marine material, and food fish are among the commercial interests on the frontiers of the ocean.

The more oceanography is done, the greater scientific basis exists for international projects in the shared oceans.

Image: Colette Kerry