So What's Different? Exploring the Ocean Then and Now

Focus: History of Ocean Exploration

Grade Level: 9-12

Focus Question: How have the technologies used to explore and collect basic oceanographic data such as depth, water chemistry, temperature, and organisms changed since the HMS *Challenger* expedition in the late 1800's?

Learning Objectives

Students will be able to understand some of the challenges that ocean explorers faced in the past, and how today's ocean explorers, through the use of new technologies, have dealt with some of those challenges.

Students will understand and appreciate that some of the earlier technologies used in ocean exploration have changed significantly, and some have changed very little.

Students will compare and contrast the modern research vessel R/V *Atlantis* and its tools and technologies with those used by the HMS *Challenger* in the 19th century.

Materials: Student worksheet, internet access, foot-long lengths of rope ½" and ¾" inch in diameter and of two kinds: one made of nylon and one made of hemp or natural fiber, small scale(s) to weigh the rope

Audio/Visual Materials: None

Teaching Time: Two to three 45-minute class periods

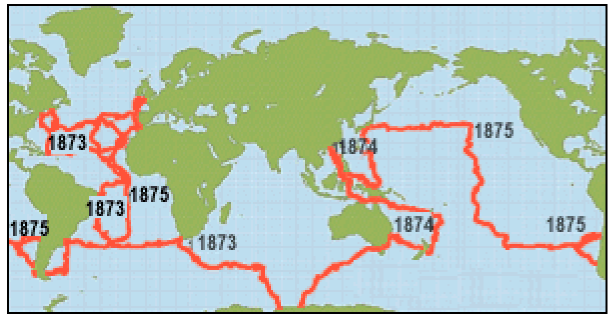
Seating Arrangement: Groups of 2-3 students

Maximum Number of Students: None

Keywords:
- HMS *Challenger*
- Sounding
- Trawl
- Suction sampler
- CTD
- Fauna
- Taxonomy

The HMS *Challenger* Voyage

(Note: All quotations and line drawings related to HMS Challenger are taken directly from the Challenger volumes, unless otherwise noted.)



The historic voyage of the British ship HMS *Challenger*, conducted between 1872-1876, is considered to be the first expedition undertaken specifically to conduct oceanographic research. At a time when knowledge began to be equated with power, the deep ocean was one of the great frontiers that man had yet to conquer. The *Challenger* had the specific assignment from the British government "to investigate the physical and biological conditions of the great Ocean Basins."

The sciences had been very active in the years leading up to the *Challenger* expedition, and there was a lot of interest in the oceans. For example,

* Some features of the ocean floor were known, such as the Atlantic Ridge, but the general features of the ocean floor were unknown. The deepest depth yet known was less than 3,000 fathoms (18,000 feet). The *Challenger* expedition discovered many new topographic features, and reached depths up to 4,500 fathoms.

* The composition of the ocean floor was of great interest to scientists. It was already known that the ocean floor was generally more dense than the continental masses, but the exact composition was unknown.

* There was some question about the existence of life at great depths (below 1,000 fathoms). An earlier expedition in the Indian Ocean claimed to find such deep life, but there was some question about its validity. So there was great interest in deep ocean biology and the question of how such life would get food and oxygen.

* Some scientists believed that the deep oceans were a refuge for the "extinct" fossils, such as trilobites and ammonites. Ironically, one such "extinct" fossil, the coelacanth was indeed hidden in the deep ocean until the 1940's when one was fished out of the ocean off Madagascar.

* Surface ocean currents were generally understood, but there was little known about sub-surface and deep ocean currents.

* The temperature, salinity and other properties of water at all depths were of interest, especially at the ocean bottom. It was generally assumed that the temperature at the ocean floor would be about 4°C or 39° F, the temperature of maximum density. Small variations in this maximum density temperature were of great interest to physicists who study the way that the maximum density point varies with solutes.

* The Antarctic region below about 60°S was unknown, although scientists had determined from global weather patterns that there was a large continent near the South Pole. Thus a portion of the expedition was spent in high Southern latitudes.

The *Challenger* was originally a military vessel, and had to be outfitted to support an extended oceanographic expedition. Fifteen of her 17 guns were removed to make room for laboratory space, storage space, and the samples that would be collected. Five scientists, one artist, 23 officers and 243 sailors comprised the *Challenger's* crew. Their around-the-globe voyage covered almost 69,000 nautical miles and gathered data on temperature, currents, water chemistry, marine organisms, and bottom deposits at 362 oceanographic stations. At these stations, the following tasks were undertaken to the best of the crew's ability:

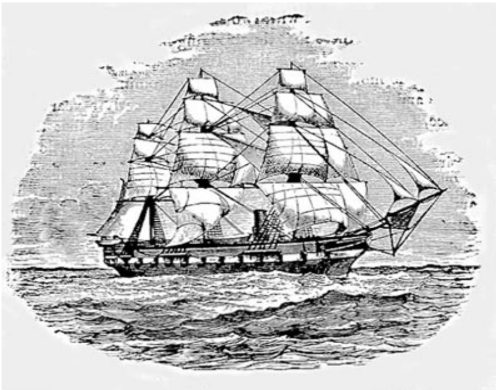
- The depth was determined by using an instrument called a Baillie sounding device (pictured at right): a rod and weighted sinkers were attached to a line, which was marked in intervals. The sinkers disengaged when the device hit bottom, at which time a sediment sample was retrieved.
- A sample of the bottom averaging from 1 ounce to 1 pound in weight was recovered by means of the sounding instrument (mentioned above) .
- A sample of bottom water was procured for chemical and physical examination. The bottom temperature was recorded.
- At most stations, a sample of the bottom fauna was procured by means of the dredge or trawl.
- At most stations, the fauna of the surface and of intermediate depths was examined by the use of tow nets.
- At most stations, a series of temperature observations was made at different depths from the surface to the bottom.
- At many stations, water samples were obtained from different depths.
- In all cases, atmospheric and other meteorological conditions were carefully observed and noted.
- The direction and rate of the surface current was determined.
- At a few stations, an attempt was made to ascertain the direction and rate of movement of the water at different depths.

Position determination and position-keeping were of obvious importance in this expedition. For depth determination, it was important to maintain position so that the sounding equipment would be as vertical as possible. The *Challenger* had coal-fired propulsion, which provided a way to stay on station much more accurately than using sails only. During the cruise, a donkey engine was also used to raise the cable during dredging. For great depths this was essential as the rope cable had a net weight in water of about 8 lb. per fathom.

The *Challenger* carried 144 miles of rope for sounding (determining the depth of the ocean) and 12.5 miles of piano wire for lowering sampling gear. Although the ship was thought to be well-equipped for its expedition, some equipment was found to be indispensable, while other gear was not. Storage racks were extremely valuable in holding bottles of all shapes and sizes, and "common fish globes were especially useful on board ship for containing live animals in water, washing the contents of nets into, and all similar purposes." A slate and plate glass aquarium set up on deck proved to be a failure because the constant sloshing (due to the ship rolling) and weight of the water led to the weakening of the structure, and the aquarium leaked. Although the ship was equipped with a harpoon gun in the hopes of obtaining a cetacean specimen, it did not have a whale boat or a crew that knew about whaling operations. A gun or small harpoon that could be used from the bow of the ship would have proved more useful, and was available at the time of the voyage. Lobster pots and shrimp nets were also supplied on board, but the often short durations of the port calls were not conducive to their use.

The scientific results of the voyage were published in a 50-volume, 29,500-page report that took 23 years to compile. More than 100 scientists, acknowledged world experts in each area, assisted in analyzing the samples resulting from the voyage. Specialists in every branch of science studied the collections and data and assisted in producing the reports. The findings were deemed "the greatest advance in the knowledge of our planet since the celebrated discoveries of the fifteenth and sixteenth centuries." Many of the detailed drawings of flora and fauna provide much of the basis of modern marine biology.

When the *Challenger* expedition is compared to a modern day oceanographic expedition, it is evident how much technological and scientific progress has been made in the field of oceanography. At the same time, this comparison is telling of how little certain tools and technologies have changed in the last 130 years.



HMS *Challenger*

At sea in the late 1800's

226 feet in length

Carried over 200 people,
including six scientists

All male crew

Powered by wind, with auxiliary steam-powered 1,200 hp motor

A donkey engine was used for raising probes

Position determination by astronomical observations and dead reckoning

Depth determination by sounding lines

Military vessel converted to research vessel

Expedition Duration: 4 years

R/V *Atlantis*

At sea today

274 feet in length

Carries up to 60 people,
including 24 scientists

Male and female crew

Powered by diesel-electric

Electric winch motors

Global Positioning System

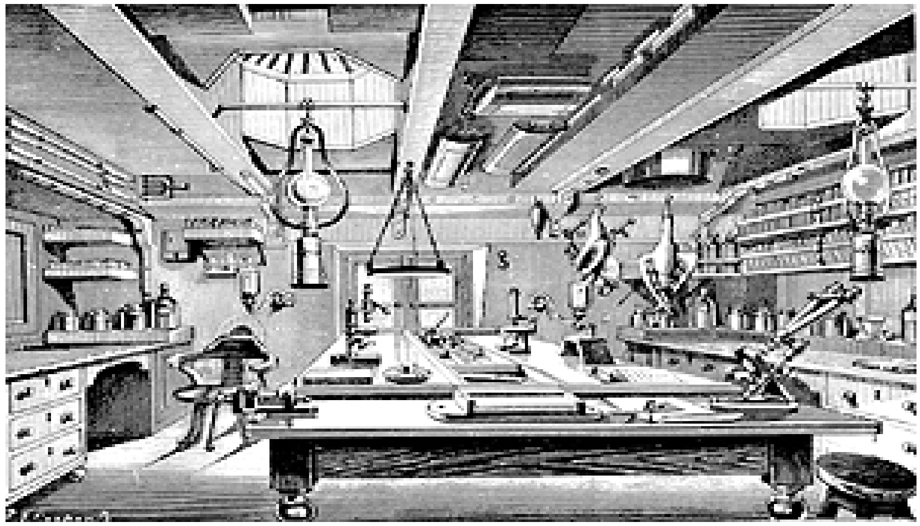
Depth sonar and multibeam mapping technologies

General purpose vessel designed to support undersea technologies such as submersibles

Expedition Duration: weeks at a time

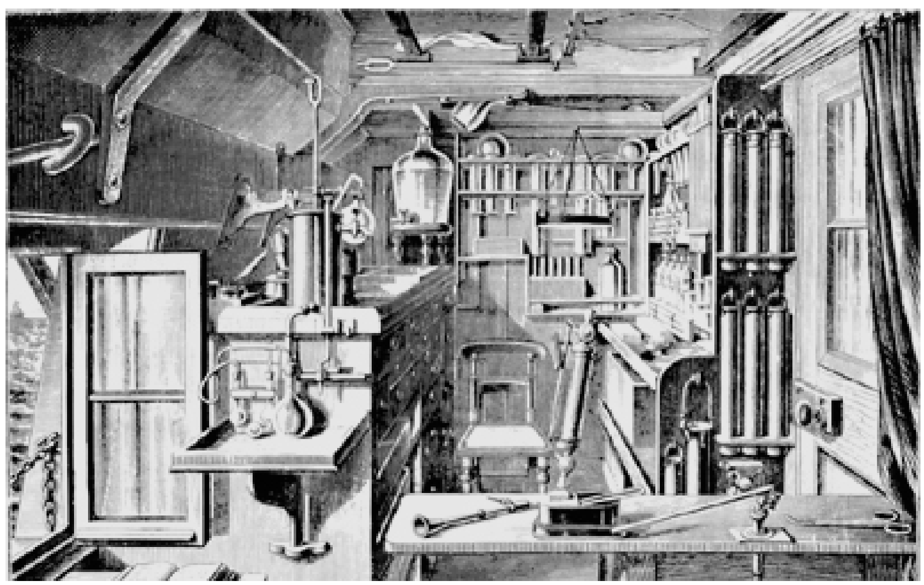
Laboratories On Board - HMS *Challenger*

The natural history laboratory on the *Challenger* was outfitted with microscopes and “all the necessary apparatus and arrangements for skinning, mounting, and preparing specimens in all ways, and for dissecting and injecting.” The sides of the room were lined with two dressers containing drawers with zinc linings that provided airtight and damp-proof spaces. Specimens were preserved in “spirit” and stored in bottles of all shapes and sizes. The spirit was stored in the section of the ship that previously housed ammunition.



***Challenger's* Natural History Lab**

A sample from the *Challenger*. **Photo courtesy of Birch Aquarium at Scripps.**



***Challenger's* Chemistry Lab**

Challenger also housed a chemistry lab which was used for analyzing the atmospheric gases dissolved in sea water.

Laboratories On Board - R/V *Atlantis*

The *Atlantis's* main laboratory is equipped with two large sinks, an uncontaminated seawater system, refrigerator/freezer, fume hood, and three freezers. A constant display of cruise parameters is visible, including water temperature, conductivity, time, the ship's position, and updates on the submersible dives. There are also several computers and a printer. In addition to *Atlantis's* Main Laboratory, the vessel houses a temperature-controlled Biological/Analytical Laboratory, which is designed to be isolated from the rest of the laboratory spaces to control contamination. Also on board is a Hydro Laboratory for working on underwater vehicles, a Wet Laboratory, a computer laboratory and other scientific spaces used for storage.

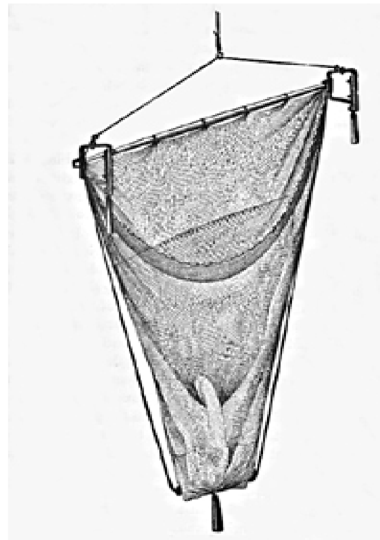
***Atlantis's* Main Lab**

***Atlantis's* Wet Lab**

Collecting the Organisms - *Challenger's* Sampling Gear

Trawls, which are nets towed behind a boat to collect organisms, have been used by fishermen for centuries. The type of trawl used by researchers is determined by the type of organisms they wish to collect and/or which part of the water column they are interested in sampling.

The *Challenger* crew employed a trawl of "the ordinary pattern" lined with fine linen or cotton that was changed after every haul. Lead weights of 28 pounds each were hung across the top beam to ensure that the trawl dragged across the bottom.



***Challenger's* Deep-Sea Trawl**

In the 1870's, science at sea was not without its difficulties. The following excerpt from the *Challenger* volumes describes a trawl that was put over the side at 9:00 a.m. to a depth of 11,700 feet. (*Something to think about: What might this task entail on the part of the crew?)* It took eight hours for this single sampling event to be completed, when it could be done today in about an hour.

> "The trawl was hauled in at 5 p.m. The beam was broken through the middle, and otherwise strangely torn and crushed, by the combined action of the of the pressure to which it had been subjected, and the strain of pulling it up rapidly through three miles of water. The wood was driven in and compressed so as to reduce the diameter of the beam by half an inch, and the knots projected a quarter of an inch on all sides."

***Challenger's* Shallow Water Dredge**

The dredge, different from the trawl in that it was weighted and dragged along the bottom in order to dig into the sediment, sampled substrate and the creatures that inhabited it. The one pictured at left was made of an iron frame and a sack lined with finely meshed cloth to catch the skimmings. The swabs on the bottom of the dredge were designed to catch animals that may have been missed by the dredge if it became clogged with mud.

Long days at sea also brought apathy on the part of *Challenger's* crew, who came to call the dredging procedure "drudging."

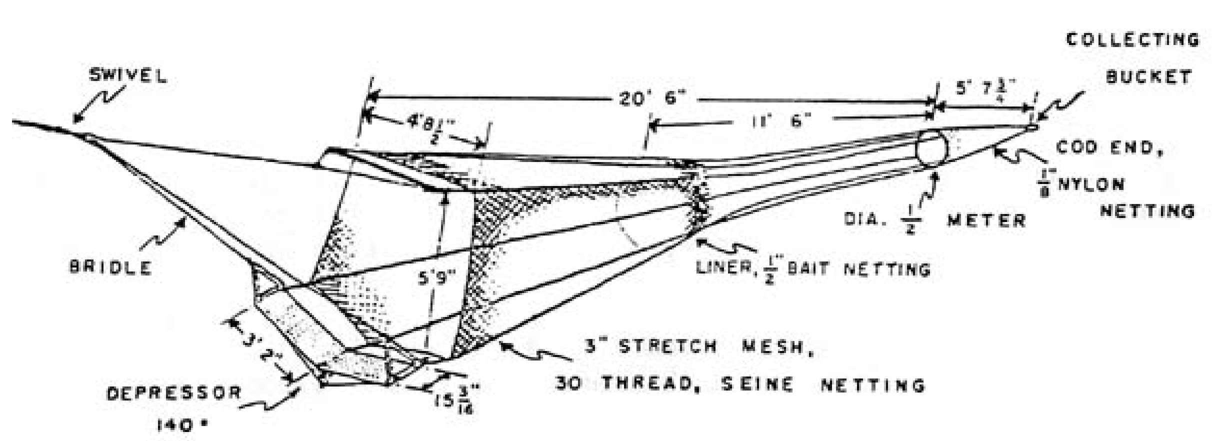
> "At first, when the dredge came up, every man and boy who could possibly slip away, crowded 'round it, to see what had been fished up...Gradually, as the novelty of the thing wore off, the crowd became smaller and smaller, until at last only the scientific staff, and perhaps one or two other officers besides the one on duty, awaited the arrival of the net on the dredging bridge."

The expedition lost a number of dredges. One advantage of using simple materials such as rope was that the men on board could fabricate new devices or make on-site repairs as required.

Collecting the Organisms - Modern Sampling Gear

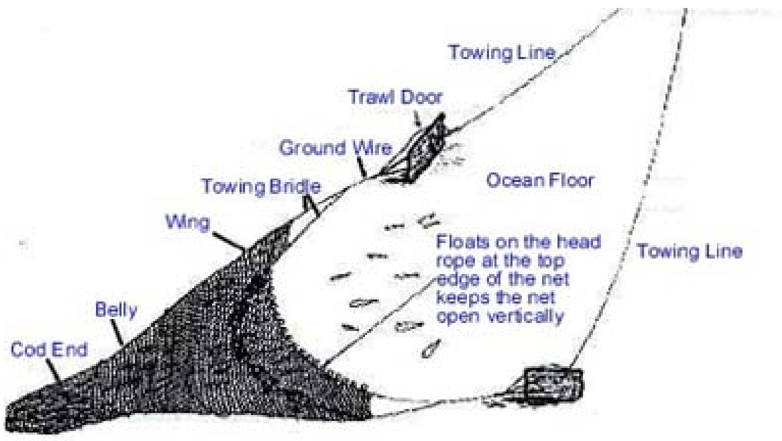
Modern trawls can be divided into three categories based on where they sample the water column - surface, midwater, and bottom. They may be divided further by their design, and the materials used in their construction.

The Isaacs-Kidd Midwater Trawl is used to collect marine life from the midwater zone—a region of the ocean that extends from 660 ft to 3,300 ft down. The midwater region is especially



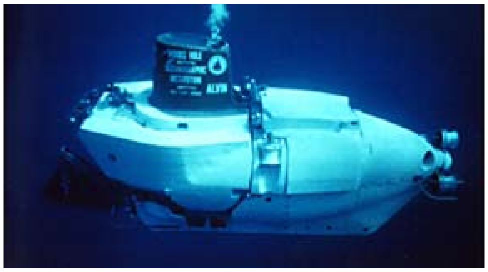
important because the creatures that inhabit it constitute the majority of the world's seafood. Understanding the ecology of midwater organisms and their vast environment can provide us with better information to manage these important natural resources and prevent their overexploitation. (*Something to think about: What must these nets be able to do in order to sample from specific depths?)*

During the last several decades, scientists have discovered that if they use a high frequency echosounder, which essentially is a sophisticated type of sonar, they can identify specific species in the midwater zone based on the organisms' acoustic images, or reflections.



The otter trawl (at left) can be used for sampling in both deep and shallow water depths. The heavy wooden doors at the front of the trawl help to keep the mouth of the net open to catch organisms swimming at or near the ocean floor. Winches are usually used to haul the trawl up from mid-depth or the sea floor.

Other Modern Sampling Techniques



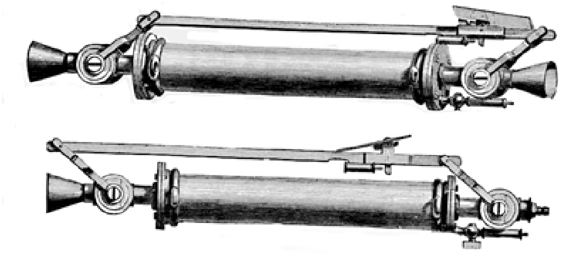
With the development of technologies such as the Woods Hole Oceanographic Institute's submersible Alvin (at right), selectivity has been added to undersea sampling abilities. The submersible's manipulator arm and suction sampler are often capable of choosing individual samples that a scientist is interested in.

The suction sampler pictured at left is one of the tools used to collect large, semi-fragile zooplankton from a Remotely Operated Vehicle or manned submersible. The system is, in effect, an underwater vacuum that collects animals under gentle suction and deposits them into a 6-liter (1.5 gal) canister.

The lid of each canister consists of an intake and exhaust door. The exhaust door is preceded by a fine mesh screen that prevents the animals from leaving the bucket. The spring-loaded canister doors are open only when directly beneath the suction head, and are closed automatically when the canister is rotated from beneath the suction head. A total of 12 canisters are rotated on a large aluminum carousel, allowing each canister to collect separate specimens.

Water Sampling Tools - *Challenger's* Buchanan Water Sampler

One of the challenges faced by the scientists on board *Challenger* was being able to collect sea water from a specific depth. John Buchanan, *Challenger's* chemist, invented this water sampler that bears his name. Similar to the procedures used today, this instrument was attached to a line in an open position and when it was at the desired depth (measured by keeping track of markings drawn on the line at regular intervals), a metal weight called a "messenger" was sent down the line, tripping the bottle closed. It was then hauled in and the water analyzed.



Buchanan Water Sampler

Taking the Ocean's Temperature -- *Challenger's* Thermometer

The Miller-Casella protected thermometer was the primary tool used on board the *Challenger* for measuring subsurface temperature. It consisted of a U-shaped tube with a small and a large bulb on either end. The large bulb and a portion of the tube was filled with a solution of creosote in alcohol, and the smaller bulb and another portion of the tube was filled with the same solution, its vapor, and air that was slightly compressed. Mercury filled the central part of the U-shaped tube, and the entire instrument was enclosed in a copper case when in use.

Although there were apparently hundreds of successful temperature recordings taken during the voyage, there were several problems with this type of thermometer. Problems included: strength of enclosure, compression of mercury, glass (with changes in reading). The scales were etched onto glass and attached alongside the thermometer, but were prone to movement when retrieving the instrument from the depths. The thermometers were very small (9 inches) in order to reduce friction, but the small size made the indices very difficult to read. It was not possible to read them to more than a quarter of a degree, an important factor when the deep ocean region being sampled experiences subtle variations in temperature.

The most problematic issue by far was the effect of pressure on the thermometers. Since different thermometers were used and the stems were not of the same thickness, the *Challenger* scientists developed corrections for each thermometer. In addition to the Miller-Casella thermometer, they also had a pressure-sensing thermometer (piezometer) and an electrical resistance thermometer, but at the time these were recent inventions, and not considered reliable for extensive use.

The scientists questioned the validity of their own corrections, which they thought were too large, but continued taking the measurements. After the expedition, it was shown that despite their lack of confidence, the effects of pressure were true, but quite small, and the scientists were ultimately accurate in their assessment of general oceanic temperatures.

The pressure of the deep left these thermometers broken.

Water Sampling Tools - Today's Hydrocast

A hydrocast: a CTD with Water Sampling Bottles on a Rosette

One type of water sampling system used today is an electronic measuring device called a CTD (conductivity, temperature, depth) which takes measurements at predetermined depths (e.g. Every three meters over a distance of 1,000 meters). The device's primary function is to detect how the conductivity (how well the water transmits electricity) and temperature of the water column changes relative to depth. This information is valuable because the salinity **(DEF)** of the seawater can be derived from these two variables. The CTD may be deployed by itself or, if water samples are desired, a set of sampling bottles can be attached to it on a "rosette" or carousel. Together, these tools are called a "hydrocast." The sampling bottles can collect water at different depths of the cast.

Sometimes, the metal frame is attached to a conducting wire and lowered into the water. Information is sent back to the ship along the wire while the instrument is lowered (downcast) to a depth specified by the scientist and then brought back (upcast) to the surface. In other cases, the CTD can store the data collected in its memory, which can be downloaded and analyzed at a later time.

Analyzing information about the water's physical parameters, gives scientists insight into how the ocean "functions" over certain temporal and spatial scales. Scientists can also make inferences about the occurrence of certain biological processes, such as the growth of algae, based on physical oceanographic features. Knowledge like this can, in turn, lead scientists to a better understanding of such factors as species distribution, abundance, and productivity in particular areas of the ocean.

There have been many changes and improvements to ocean technology in the past century. However, the one constant that has been invaluable to research, regardless of tools and procedures, is our ability to learn by using five senses along with judgment, reason, and intuition. This human component of oceanographic research was as effective in past centuries as it is today.

Learning Procedure:

1. Discuss with students the history of ocean exploration or have them visit http://www.oceanexplorer.noaa.gov/history/history.html

2. Convey to the students that the *Challenger* expedition is often considered the first oceanographic research cruise. Explain that much of the taxonomy that *Challenger* scientists described forms the basis of modern marine biology, and that these findings sparked the interest of the public in marine science. As a Directed Reading Assignment, have students read the "Introduction to the HMS *Challenger* and R/V *Atlantis* Voyages" (pages 2-12). Students should note all the things they understood, and underline those things they did not understand.

3. Some of the main research tasks were to sample the bottom, sample the fauna, ascertain depth, and determine temperature. Stimulate student's thinking by having them speculate about the problems encountered as the scientists attempted to conduct their research on the *Challenger* expedition. Have the students write or discuss suggestions for how they might solve them. After discussion about the problems and possible solutions, have the students read about how the research was conducted and how the problems were addressed.

Students should be encouraged to generate their own probing questions as they read through the material. Some suggested problems encountered by the *Challenger* scientists and questions include:

A. Problem: how might one have collected a true sample of bottom sediments and living organisms? What instruments were used and what were some of the challenges? How did that differ from what instrumentation is used now?

Answer "Then" *Challenger*: See page 8 to learn about trawls and dredges
Answer "Now" *Atlantis*: See pages 9-10 to learn about sampling today

B. Problem: How might one have sampled and analyzed water at different depths? What kinds of devices were used then and now?
Answer "Then" *Challenger*: See page 10
Answer "Now" *Atlantis*: See page 12

C. Problem: What were some of the adverse effects of pressure at depths experienced by the *Challenger*?

Answer: One difficulty related to use of thermometers: see page 11

4. Hand out the History of Ocean Exploration Student Worksheet and have students work in small groups to answer the questions on a separate piece of paper. Print and hand out the pages depicting the deck plans of the R/V *Atlantis* and HMS *Challenger* needed for Question #2 on the worksheet. *Note on Printing: The Challenger deck plans are easier to read if the enlargement or zoom tool is used, and then they are printed out on 8.5"x14" paper.* Have each student take a turn noting a comparison between the deck plans, and rate their answers on a scale of 1 to 3, with

one being a general, easy observation and 3 being a well-thought out, detailed observation. List all observations on the board. Hand out the pieces of rope to each group, and have a scale available for them to use when working through Question #5 on the Student Worksheet.

5. Wrap up by discussing students' answers and ask them the following question: Were the scientific contributions made by the *Challenger* expedition more or less important than those being made today? Why? Ask them to support their opinions. Emphasize that science is a constantly evolving process and that humans have always been, and will continue to be driven by a spirit of exploration.

6. Engage the students in a discussion or debate about using "tried and true" technologies versus cutting-edge innovations in ocean exploration. What are the pros and cons of each decision? Use the example of using rope versus wire with the instruments on the *Challenger*.

Note from Dr. David Bossard: The "conservative" choice of equipment should be understood in context of the need to "make do" for long periods of time. This tends to argue for the tried and true. For example, sailors had long experience with rope and in fact could readily splice it or even fabricate it from scratch if necessary. Wire cable, especially in the lengths required (about 5 miles in some cases) may have weight/quality/handling limitations at that time.

Evaluation:
Have students explain some of the differences and similarities of the tools and technologies used in oceanographic research in the 1870's and today.

Have students pretend they are part of the *Challenger* crew and write a letter to send "home" that tells about a difficulty they are experiencing with an instrument.

The BRIDGE Connection: On the main site (http://www.vims.edu/bridge) navigation bar, click on Ocean Science Topics, then Human Activities, Heritage, Maritime Heritage.

The "Me" Connection: Ask students what they can learn about the "spirit of exploration" shown by the *Challenger* crew, and ask them how they could apply it to their own lives. Ask them how the gathering of oceanographic data such as temperature and organisms benefits them? Discuss weather forecasting, medicines from the sea, food sources, etc.

Ask students to imagine that they are a scientist on board the *Challenger*. Tell them that a very exciting discovery has just been made: a species of fish that no one recognizes has just been brought up in the trawl! Have each student contribute a sentence or two (orally) that describes what might happen next on deck. Answers can be editorial, factual, emotional, etc.

Connections to Other Subjects: History, Social Studies, English, Technology, Mathematics

Extensions:
1. Have students compare the *Challenger* expedition with other oceanographic expeditions, i.e. Matthew Fontaine Maury's voyages in the mid-1800's, the *Blake*, or others. Comparisons could

be made between research, purpose of the expedition, areas traversed, length of voyage, and ship details.

2. Using the Ocean Explorer website at www.oceanexplorer.noaa.gov and other sources for their research, ask students to write a short essay on some of the challenges faced by oceanographic researchers working at sea today.

3. Sounding was an important component of the *Challenger* expedition. However, the process evolved during the voyage, and is too complex to include in this introductory lesson. Try to answer the question: How would you measure the depth of the ocean, and how would you ensure that the measurements were accurate?

Answer "Then:" (a) required a mechanical way to mark the bottom (b) required station-keeping to prevent ship drift so the cable would be as vertical as possible (this was a major use of the engines since sails could not reliably maintain position). Use the publications listed in the Resources section for more information.

Answer "Now:" depth sonar (use the web to find a simple explanation).

Resources:

Ocean Explorer Website
http://www.oceanexplorer.noaa.gov

At Sea with the Scientifics: The Challenger Letters of Joseph Matkin, edited by Philip F. Rehbock, University of Hawaii Press, Honolulu, 1992. (Available from Amazon.com)

The Voyage of the Challenger, by Eric Linklater, Doubleday and Company, Inc., New York, 1972. (Available from Amazon.com)

The Voyage of the *Challenger*
http://life.bio.sunysb.edu/marinebio/challenger.html

Oceans On Line
http://www.oceansonline.com/challenger_ex.htm

NOAA's Coast and Geodetic Survey Historic Image Collection
http://www.photolib.noaa.gov/historic/c&gs/oceanography.html

The Natural History Museum (London, England)
http://www.nhm.ac.uk/museum/tempexhib/voyages/challenger_map.html

Challenger Society for Marine Science
http://www.soc.soton.ad.uk/OTHERS/CSMS

NOVA Chronology of Deep Sea Exploration
http://cgi.pbs.org/wgbh/nova/abyss/frontier/discoveries.html

Historical Oceanography
http://www-ocean.tamu.edu/~wormuth/hist.html

History of Marine Biology
http://www.meer.org/mbhist.htm

National Science Education Standards:

Content Standard A: Science As Inquiry

- Understandings about scientific inquiry

Content Standard E: Science and Technology

- Understanding about science and technology

Content Standard G: History and Nature of Science

- Nature of scientific knowledge
- Historical perspectives

This lesson may also be used to meet Curriculum Standards for Social Studies related to science, technology and society.

STUDENT WORKSHEET

History of Ocean Exploration

1. There have been discussions among historians about the *Challenger's* use of tools and instrumentation being conservative in the sense that some of the cutting-edge technologies that were available during the years of the voyage were not used. For example, for trawling and dredging, rope was used instead of wire. List and support some reasons one might be used as opposed to the other, and discuss your list with group members and the rest of the class. Why do you think the *Challenger* crew was cautious in the use of new technology?

2. Examine the pages that depict the deck plans of the R/V *Atlantis* and the HMS *Challenger*. On the *Atlantis,* what purpose does the A- Frame serve? Compare and contrast the plans, addressing the following general topic areas: layout of the ship, relative size of lab and storage spaces, general design of the ship, and equipment used on the ship.

3. Why were "common fish globes" (what we call "fish bowls") so useful on the *Challenger*?

4. The *Challenger's* expedition leader, Charles Wyville Thomson, noted that "animals of all the marine invertebrate groups, and probably fishes also, exist over the whole of the floor of the ocean." Study the pictures of the gear used to sample organisms to determine why he felt he couldn't say *definitively* that fishes existed over the entire ocean floor.

5. The *Challenger* carried 144 miles of rope to be used in its research. Why do you think so much rope was required? You should have two different pieces of rope: one made of modern nylon and one made of hemp, or natural fiber. Examine them closely and write down any observations. Record their weights. How much rope would it take to conduct a sounding at 253 fathoms (1 fathom = 6 feet)? Make comparisons of the hemp and nylon rope when they are wet and dry. Determine their weight when they are wet. What do you think were some of the challenges faced by the *Challenger* crew in working with the rope made of natural fiber?

6. Imagine that you are an organism living in the ocean, and that you are observing either the *Challenger's* trawl sampling the bottom, *or* the submersible Alvin from the R/V *Atlantis*. Write one or two paragraphs describing what you are seeing from the point of view of the organism you have chosen.