

OR – 102

SOSUS: Listening to the Ocean

A. The oceans of Earth cover more than 70 percent of the planet's surface, yet, until quite recently, we knew less about their depths than we did about the surface of the Moon. Distant as it is, the Moon has been far more accessible to study because astronomers long have been able to look at its surface, first with the naked eye and then with the telescope—both instruments that focus light. And, with telescopes tuned to different wavelengths of light, modern astronomers can not only analyze Earth's atmosphere, but also determine the temperature and composition of the Sun or other stars many hundreds of light-years away. Until the twentieth century, however, no analogous instruments were available for the study of Earth's oceans: Light, which can travel trillions of miles through the vast vacuum of space, cannot penetrate very far in seawater.

B. Curious investigators long have been fascinated by sound and the way it travels in water. As early as 1490, Leonardo da Vinci observed: "If you cause your ship to stop and place the head of a long tube in the water and place the outer extremity to your ear, you will hear ships at a great distance from you." In 1687, the first mathematical theory of sound propagation was published by Sir Isaac Newton in his *Philosophiæ Naturalis Principia Mathematica*. Investigators were measuring the speed of sound in air beginning in the mid-seventeenth century, but it was not until 1826 that Daniel Colladon, a Swiss physicist, and Charles Sturm, a French mathematician, accurately measured its speed in water. Using a long tube to listen underwater (as da Vinci had suggested), they recorded how fast the sound of a submerged bell traveled across Lake Geneva. Their result, 1,435 meters (1,569 yards) per second in water of 1.8 degrees Celsius (35 degrees Fahrenheit)—was only 3 meters per second off from the speed accepted today. What these investigators demonstrated was that water — whether fresh or salt— is an excellent medium for sound, transmitting it almost five times faster than its speed in air.

C. In 1877 and 1878, the British scientist John William Strutt, third Baron Rayleigh, published his two-volume seminal work, *The Theory of Sound*, often regarded as marking the beginning of the modern study of acoustics. The recipient of the Nobel Prize for Physics in 1904 for his successful isolation of the element argon, Lord Rayleigh made key discoveries in the fields of acoustics and optics that are critical to the theory of wave propagation in fluids. Among other things, Lord Rayleigh was the first to describe a sound wave as a mathematical equation (the basis of all theoretical work on acoustics) and the first to describe how small particles in the atmosphere scatter certain wavelengths of sunlight, a principle that also applies to the behavior of sound waves in water.

D. A number of factors influence how far sound travels underwater and how long it lasts. For one, particles in seawater can reflect, scatter, and absorb certain frequencies of sound — just as certain wavelengths of light may be reflected, scattered, and absorbed by specific types of particles in the atmosphere. Seawater absorbs 30 times the amount of sound absorbed by distilled water, with specific chemicals (such as magnesium sulfate and boric acid) damping out certain frequencies of sound. Researchers also learned that low-frequency sounds, whose long wavelengths generally pass over tiny particles, tend to travel farther without loss through absorption or scattering. Further work on the effects of salinity, temperature, and pressure on the speed of sound has yielded fascinating insights into the structure of the ocean. Speaking generally, the ocean is divided into horizontal layers in which sound speed is influenced more greatly by temperature in the upper regions and by pressure in the lower depths. At the surface is a sun-warmed upper layer, the actual temperature and thickness of which varies with the season. At mid-latitudes, this layer tends to be isothermal, that is, the temperature tends to be uniform throughout the layer because the water is well mixed by the action of waves, winds, and convection currents; a sound signal moving down through this layer tends to travel at an almost constant speed. Next comes a transitional layer called the thermocline, in which temperature drops steadily with depth; as the temperature falls, so does the speed of sound.

E. The U.S. Navy was quick to appreciate the usefulness of low-frequency sound and the deep sound channel in extending the range at which it could detect submarines. In great secrecy during the 1950s, the U.S. Navy launched project that went by the code name Jezebel; it would later come to be known as the Sound Surveillance System (SOSUS). The system involved arrays of underwater microphones, called hydrophones, that were placed on the ocean bottom and connected by cables to onshore processing centers. With SOSUS deployed in both deep and shallow waters along both coasts of North America and the British West Indies, the U.S. Navy not only could detect submarines in much of the northern hemisphere, it also could distinguish how many propellers a submarine had, whether it was conventional or nuclear, and sometimes even the class of sub.

F. The realization that SOSUS could be used to listen to whales also was made by Christopher Clark, a biological acoustician at Cornell University, when he first visited a SOSUS station in 1992. When Clark looked at the graphic representations of sound, scrolling 24 hours day, every day, he saw the voice patterns of blue, finback, minke, and humpback whales. He also could hear the sounds. Using a SOSUS receiver in the West Indies, he could hear whales that were 1,770 kilometers (1,100 miles) away. Whales are the biggest of Earth's creatures. The blue whale, for example, can be 100 feet long and weigh as many tons. Yet these animals also are remarkably elusive. Scientists wish to observe blue time and position them on a map. Moreover, they can track not just one whale at a time, but many creatures simultaneously throughout the North Atlantic and the eastern North Pacific. They also can learn to distinguish whale calls. For example, Fox and colleagues have detected changes in the calls of finback whales during different seasons and have found that blue whales in different regions of the Pacific ocean have different calls. Whales firsthand must wait in their ships for the whales to surface. A few whales have been tracked briefly in the wild this way but not for very great distances, and much about them remains unknown. Using the SOSUS stations, scientists can track the whales in real time and position them on a map. Moreover, they can track not just one whale at a time, but many creatures simultaneously throughout the North Atlantic and the eastern North Pacific. They also can learn to distinguish whale calls. For example, Fox and colleagues have detected changes in the calls of finback whales during different seasons and have found that blue whales in different regions of the Pacific Ocean have different calls.

G. SOSUS, with its vast reach, also has proved instrumental in obtaining information crucial to our understanding of Earth's weather and climate. Specifically, the system has enabled researchers to begin making ocean temperature measurements on a global scale — measurements that are keys to puzzling out the workings of heat transfer between the ocean and the atmosphere. The ocean plays an enormous role in determining air temperature the heat capacity in only the upper few meters of ocean is thought to be equal to all of the heat in the entire atmosphere. For sound waves traveling horizontally in the ocean, speed is largely a function of temperature. Thus, the travel time of a wave of sound between two points is a sensitive indicator of the average temperature along its path. Transmitting sound in numerous directions through the deep sound channel can give scientists measurements spanning vast areas of the globe. Thousands of sound paths in the ocean could be pieced together into a map of global ocean temperatures and, by repeating measurements along the same paths overtimes, scientists could track changes in temperature over months or years.

H. Researchers also are using other acoustic techniques to monitor climate. Oceanographer Jeff Nystuen at the University of Washington, for example, has explored the use of sound to measure rainfall over the ocean. Monitoring changing global rainfall patterns undoubtedly will contribute to understanding major climate change as well as the weather phenomenon known as El Nino. Since 1985, Nystuen has used hydrophones to listen to rain over the ocean, acoustically measuring not only the rainfall rate but also the rainfall type, from drizzle to thunderstorms. By using the sound of rain underwater as a "natural" rain gauge, the measurement of rainfall over the oceans will become available to climatologists.

Questions 1-4

Do the following statements agree with the information given in Passage?

In boxes 1-4 on your answer sheet, write

TRUE if the statement agrees with the information

FALSE if the statement contradicts the information

NOT GIVEN if the information is not given in the passage

1. In the past, difficulties of research carried out on Moon were much easier than that of now.
2. The same light technology used in the investigation of the moon can be employed in the field of the ocean.
3. Research on the depth of ocean by the method of the sound-wave is more time-consuming.
4. Hydrophones technology is able to detect the category of precipitation.

Questions 5-8

The reading Passage has seven paragraphs A-H.

Which paragraph contains the following information?

Write the correct letter A-H, in boxes 5-8 on your answer sheet.

NB You may use any letter more than once

5. Elements affect sound transmission in the ocean.
6. Relationship between global climate and ocean temperature
7. Examples of how sound technology help people research ocean and creatures in it
8. Sound transmission underwater is similar to that of light in any condition.

Questions 9-13

Choose the correct letter, A, B, C or D.

Write your answers in boxes 9-13 on your answer sheet.

9. Who of the followings is dedicated to the research of rate of sound?
 - A. Leonardo da Vinci
 - B. Isaac Newton
 - C. John William Strutt
 - D. Charles Sturm
10. Who explained that the theory of light or sound wavelength is significant in water?
 - A. Lord Rayleigh
 - B. John William Strutt
 - C. Charles Sturm
 - D. Christopher Clark
11. According to Fox and colleagues, in what pattern does the change of finback whale calls happen
 - A. Change in various seasons
 - B. Change in various days
 - C. Change in different months
 - D. Change in different years
12. In which way does the SOSUS technology inspect whales?
 - A. Track all kinds of whales in the ocean
 - B. Track bunches of whales at the same time
 - C. Track only finback whale in the ocean
 - D. Track whales by using multiple appliances or devices
13. What could scientists inspect via monitoring along a repeated route?
 - A. Temperature of the surface passed
 - B. Temperature of the deepest ocean floor
 - C. Variation of temperature
 - D. Fixed data of temperature

Answers – OR 102

1. TRUE

2. FALSE

3. NOT GIVEN

4. TRUE

5. D

6. G

7. F

8. D

9. D

10. A

11. A

12. B

13. C

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