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BIODIVERSITY
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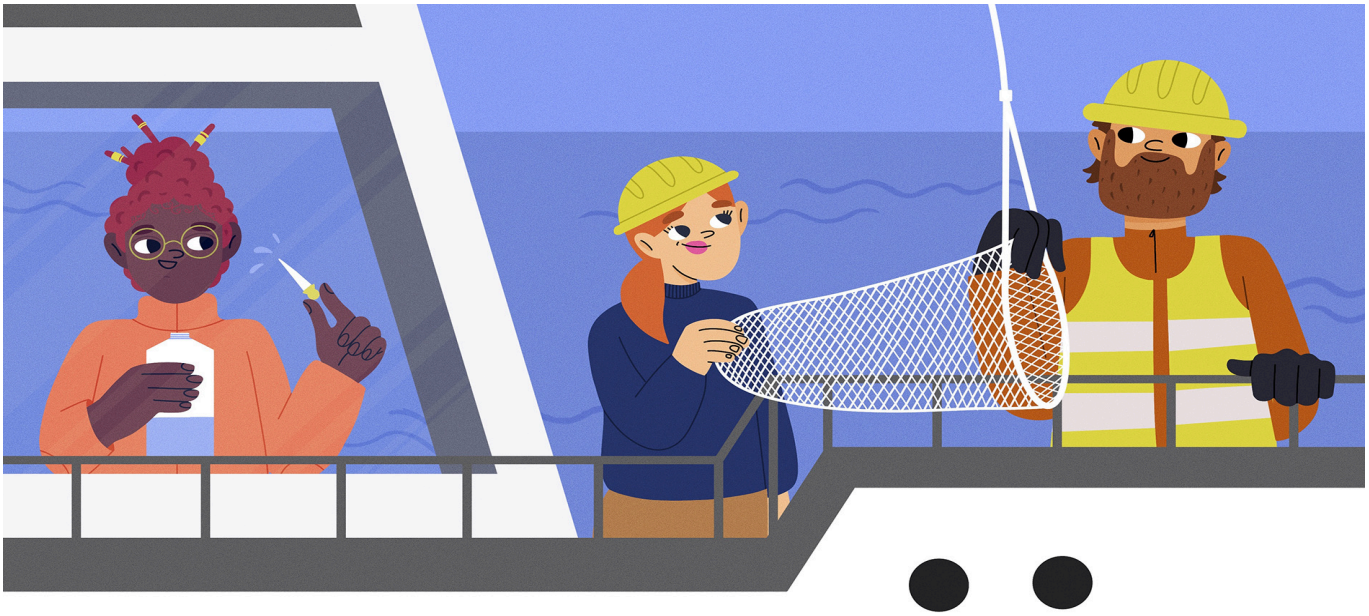

ALL ABOARD! BEHIND THE SCENES OF A SCIENTIFIC RESEARCH CRUISE

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YOUNG REVIEWERS:

ERIC
AGE: 10

GEMMA
AGE: 8

From our climate to the air we breathe, the ocean influences the world around us. Scientists are always looking for new ways to explore and study the ocean. One way we do this is by going on specially designed ships that allow us to study the deep sea, far from land. On our latest expedition aboard the Research Vessel Sally Ride, we went out 300 miles into the North Pacific Ocean for a week. We used some of the most important ocean science tools to catch tiny marine animals, collect water from some of the deepest depths, uncover mysteries of oceans past, and study how desert dust feeds marine animals today.

WHY DO SCIENTISTS GO ON RESEARCH CRUISES?

When we think about the ocean, most of us think of crashing waves and animals like whales and dolphins. The ocean covers 70% of our planet's surface and is incredibly important to the Earth and human

CLIMATE

The weather conditions of a place over a long period of time.

life. It helps determine our weather and **climate**, and it absorbs some of the gasses that cause climate change [1]. Fish from the ocean feed billions of people every day [2]. We rely on the ocean for so much that it is important to understand how it works and how humans are changing it. Scientists have lots of tools for studying the ocean. We can use satellites to look at the ocean from space, and we can study the ocean from the coast. These methods give us a good idea about the ocean's edges, but we also need ways to study the deep ocean, far away from land. To do so, scientists go to sea on specially designed ships with science tools for collecting all kinds of information. These research expeditions can be days or even months long.

AEROSOL

Small liquid or gas particles suspended in a gas. Here, this gas is air.

Come aboard our expedition! Here is a look into our voyage on board the Research Vessel Sally Ride in the North Pacific Ocean. You can learn what we did at sea and how we used four important tools to study the ocean: the CTD, the multicorer, the tow, and **aerosol** samplers (Figure 1).

Figure 1

This illustration of our ship at sea shows various parts of the ocean and how we use our equipment to study them. It shows a net tow dragging through the water, a multicorer collecting marine sediment (or mud), a CTD collecting seawater, and a Hi-Vol air sampler collecting aerosols at the front of the ship. The ship is about 73 m (238 feet) long. Take a virtual tour of the ship here, and visit this site to learn more about our day-to-day activities on the ship.

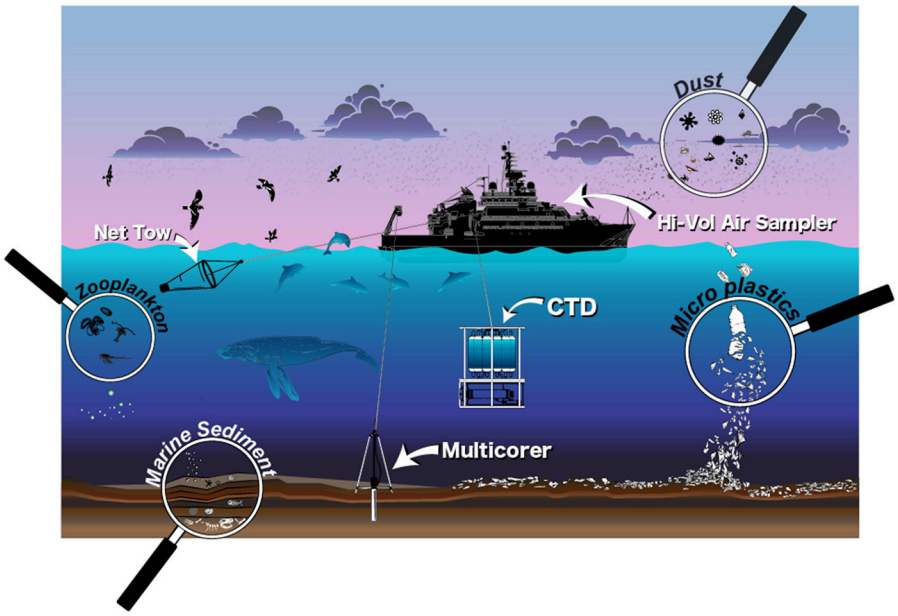

Figure 1

THE CTD: DIVING INTO THE DEEP OCEAN

CONDUCTIVITY

How easy it is for electricity to pass through a material. In the ocean, we use conductivity to measure how salty seawater is.

The CTD is named after three things it measures. "C" is for **conductivity** (how salty seawater is), "T" is for temperature (how hot or cold seawater is), and "D" is for depth (how deep the CTD has sunk). A CTD is shaped like a giant can with lots of smaller tubes inside it. It carries water samplers and electronic sensors [3]. We lower the CTD off the side of the ship, and as it sinks, it collects both samples and information (Figure 2A). We can also add more tools to the CTD to measure things like how much sunlight there is, how many living things there are, and

how cloudy the water is. All this information is sent back up to the ship for the scientists to use.

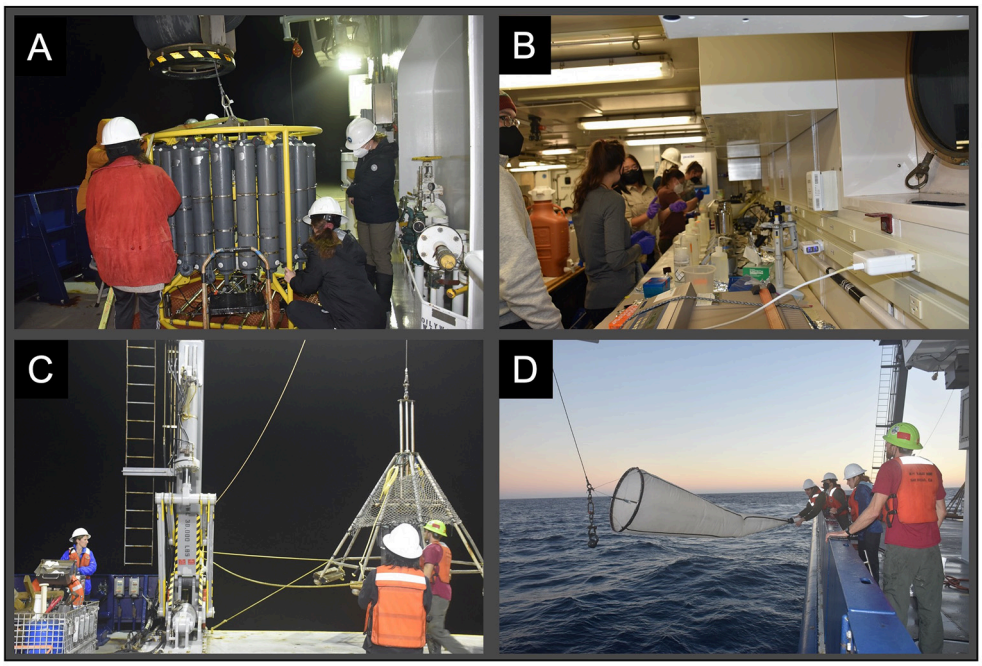

Figure 2

Science at sea. **(A)** Scientists prepare the CTD to collect seawater. **(B)** Kaycie leads a team collecting microbes from seawater. **(C)** Cate uses a multicorer to collect deep sea mud. **(D)** Annie sends out the net tow to sample plankton.

The water samplers are bottles that can be opened and closed deep in the ocean using electronics on the ship. The water samples allow us to measure what makes up ocean water and what lives in it. By filtering the water, we can look at particles of dust, DNA and nutrients (Figure 2B). Just for fun, we decorated styrofoam and sent it down to the deep ocean on the CTD! The weight of the ocean above it squeezed all of the air out of the styrofoam and made it a lot smaller (Figures 3A,B).

We use information from the CTD to answer important questions about what happens in the ocean. On our cruise, Linqing used water from the CTD to explore how ocean water moves around. Tricia used the CTD to look at how food is recycled in the ocean (Figure 3C). Kaycie used the CTD to study how **microbes**, or tiny organisms, get energy from the food they eat. We sent the CTD down more than 4,500 m (14,764 feet) below the ocean's surface.

MICROBES

Living things that are too small to see with just your eyes.

CORING: COLLECTING DEEP OCEAN MUD

We have a time machine aboard. It does not carry us physically into the past, but we can use it to see what Earth was like long ago. Our time machine is a multicorer (Figure 2C). It collects mud from the seafloor that accumulated over the past centuries of ocean history [4]. The seafloor is constantly being rained on by mud carried into

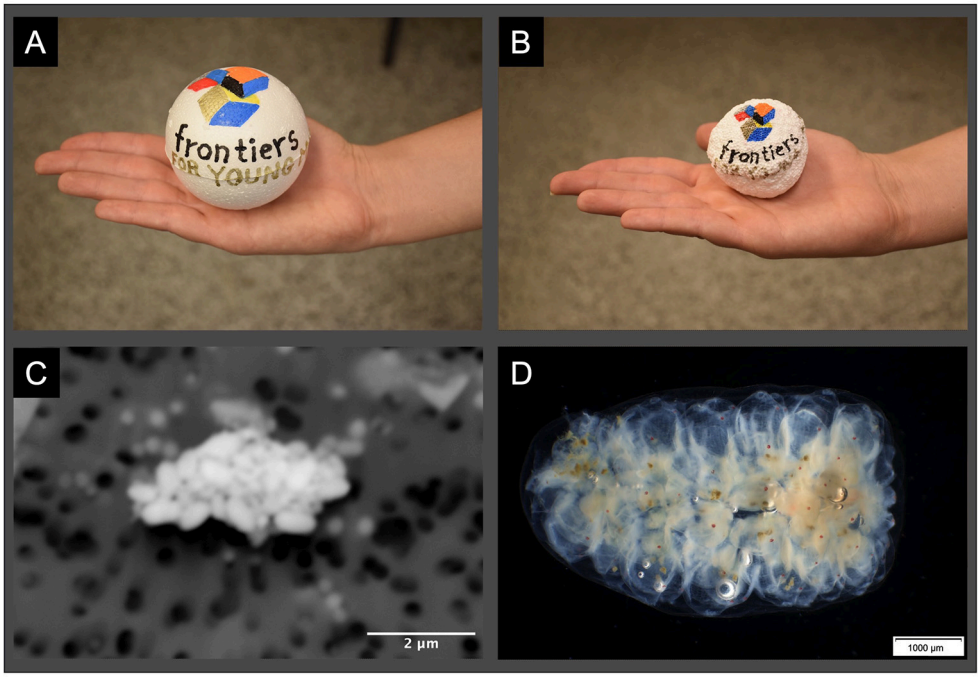

Figure 3

Figure 3

Some of the fun things scientists see at sea. A styrofoam ball **(A)** before and **(B)** after it is sent down to the deep ocean on the CTD. The ball shrank to about 2/3 of its original size because of the enormous pressure created by the weight of the ocean above it. **(C)** A microscope image of crystals that form in dead organisms as they are broken down in the ocean. **(D)** A microscope image of a pyrosome, or a type of squishy zooplankton, captured by a net tow. Scale bars for **(C)** and **(D)** are in micrometers (µm; 1/1,000 of a mm or about 1/70 the width of an average human hair).

the sea by rivers, dust, pollen, and ash blown from land, and dead organisms that sink from the sea surface. All this stuff settles on the ocean bottom every hour of every day. As the centuries pass, the layers of mud thicken, preserving the history of fires, floods, and land life swept into the sea. The mud obtained by the multicorer tells the story of Earth's past.

How does the multicorer work? It looks like a moon lander with four legs supporting a triangular structure attached to the ship with a cable. Heavy weights slowly shove eight plastic tubes into the seabed. The device is then hauled back to the ship with a cable. Each tube is sealed by spring-loaded doors to preserve the mud inside. The tubes of mud are called cores.

The layers in the cores capture information about how humans are changing the world. Looking back at what Earth was like long ago helps us predict how the Earth might change in the future. On our cruise, Cate is using cores to find out how much of the plastic that humans throw away ends up on the seafloor. She will compare the mud now to mud from decades ago, to see how it has changed. The cores are like a fat book of Earth's history—a time machine to our past.

ZOOPLANKTON

A category of ocean animals that mostly drift along with ocean currents. Zooplankton include everything from big jellyfish to tiny larvae.

TOWS: CATCHING LITTLE ANIMALS IN OUR NET

We do not care only about ocean mud and ocean water—we also care about ocean life! We use a net tow (Figure 2D) to catch **zooplankton**, which are small ocean animals that mostly drift along with ocean

currents [5]. Most zooplankton are so tiny that you need a microscope to see them well (Figure 3D). Some zooplankton, like jellyfish, are bigger. Zooplankton are an important part of the ocean's food web because they get eaten by fish and other animals. Lots of large animals like tuna, squid, and crabs start out as plankton before they get big, while others remain tiny their whole lives.

The tow looks like a net that you might use to catch fish in a stream, but ours is so big that it takes a full team of scientists to use. Its holes are much smaller than a fishing net's holes, so zooplankton will not float through. We hang the tow off the side of the ship into the water. We then move the boat forward, so the tow catches the zooplankton swimming through the water. After a few minutes, we bring the net back to the ship to see what we caught. We have a microscope on the ship to see what the tiny zooplankton look like. We also store some of the zooplankton to study back on land.

We collect zooplankton to answer all sorts of questions: How do plankton change over time? Are large or small plankton more common? What do plankton eat and where does it come from? On our cruise, Annie collected zooplankton to help answer some of these questions. Some of the zooplankton also end up in the Scripps' Collections, where they will sit on shelves like library books alongside samples over 100 years old!

AEROSOL SAMPLING: COLLECTING DUST FROM OCEAN AIR

Did you know that plankton get food from the sky? Although you might not be able to see it, there are billions of tiny pieces of rock floating around in the air all around you [6]. These little particles are called dust. Around 500 million tons of dust fall into the ocean each year, bringing with it nutrients like iron that many organisms, like **phytoplankton**, need to live. This dust comes from all over the world, including the Sahara Desert in Africa and glaciers in Alaska. It floats with the wind until it eventually falls into the ocean, where it can be used by animals. The amount of dust that enters the ocean changes depending on what is happening on land. Dust helps determine how much life is in the ocean, which can affect global climate by adding or removing gasses from our **atmosphere**.

PHYTOPLANKTON

Microscopic organisms that live in water and get their energy from the sun, just like plants do on land.

ATMOSPHERE

The layer of gases that surround our planet.

Onboard the ship, Emmet studied dust by sucking lots of air through a filter that catches the dust. To do this, he used a type of aerosol sampler called a Hi-Vol air sampler. Back on land in his lab, he can learn a lot about this dust. He hopes to learn more about the amazing ways that air transports nutrients around the world, even if we cannot see it with our eyes.

HOW CAN I GO TO SEA?

There are all sorts of ways to become a scientist who goes to sea. The scientists on our cruise are from five different countries. They studied various college subjects—chemistry, biology, physics, anthropology, and even art! Some of them have always wanted to study the ocean, and some did other things before becoming ocean scientists. We all worked really hard and prepared a lot so that we could deal with the challenges of being at sea. Some of the problems we overcame during our cruise were people getting sick, tools breaking, and experiments not working the way we expected. To get a taste of what it is like to be a scientist at sea, explore websites (like this one) about ocean science. You can also get out and explore near where you live, from a park to a stream to a city block. To become a scientist, you need a sense of wonder and you must pay attention to little details, write everything down, and notice changes that happen over time. Above all, have fun!

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AUTHOR CONTRIBUTIONS

TL, EN, DZ, RV, and RN conceptualized and planned this work. EN and DC created figures. All authors wrote and revised sections of the manuscript.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ERIC, AGE: 10
Hello, my name is Eric, I am Brazilian. I am 10 years old. I am in the fifth grade at school. I like to run, sports (swimming, capoeira, football, biking), to play games, play violin, go to the beach and play with my cat Crystal. Not only that, but I also like space and robots.

GEMMA, AGE: 8
My favorite subject is science and I love almost everything related to the ocean. I am an avid reader of science, mystery, and fantasy books. I read National Geographic Kids and enjoy playing around with their app. I am also interested in Thea and Geronimo Stilton books. I have a special liking for those with jokes and games at the end or the ones that you can help them solve the mystery with the given clues.

AUTHORS

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Tricia Light is a marine chemist and Ph.D. candidate at the Scripps Institution of Oceanography in San Diego, California. She studies how crystals in seawater and ocean mud can help us understand the relationship between life in the ocean and climate change. In her free time, she loves hiking, swimming, and spending time outside. *tlight@ucsd.edu

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Emmet is a geochemist/artist/community organizer and Ph.D. student at the Scripps Institution of Oceanography, where he studies the intersection of earth science and human health. He is interested in how modern human activities such as agriculture and mining affect natural cycles on the Earth's surface, and how these systems then affect human communities, particularly marginalized communities. He loves cactus flowers and thinking about how magnificent the Earth is.

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Dongran Zhai is an oceanic climatologist and Ph.D. candidate at University of California, Santa Cruz. She is working on observing and understanding changes in global ocean chlorophyll over time. She uses observations from satellite ocean color data and simulations from models. She loves cooking and baking!

RUTH VARNER
Ruth Varner is a biological oceanographer and M.S. student at the Scripps Institution of Oceanography in San Diego, California. Ruth is interested in investigating how microbes can influence the growth of organisms in extreme environments. Her current research focuses on the mechanisms that underlie how organisms called halophic archaea interact with microalgae to allow them to grow in some of the world's saltiest environments. In her spare time, she loves reading, running, and exploring the world around her.

KAYCIE B. LANPHER
Kaycie B. Lanpher is a marine microbiologist and chemist at the Scripps Institution of Oceanography at the University of California San Diego. She studies how marine microbes, such as bacteria and phytoplankton, are impacted by the marine environment and control the chemistry of the ocean. She studies these interactions from coastal beaches to the middle of the ocean. She got her Ph.D. in ocean sciences and loves to travel the world, meet new people, and learn about different cultures. When she is not working, Dr. Lanpher enjoys rock climbing, knitting, and playing soccer.

DANTE CAPONE
Dante Capone is a biological oceanography Ph.D. student at the Scripps Institution of Oceanography in San Diego, California. Dante's research explores what plankton can tell us about how the oceans are changing. He is especially interested in how California's recent megafires might be affecting the ecosystem off the coast. Outside of his studies, he runs for the San Diego Track Club Elite group and enjoys making art and sourdough bread.

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Natalia Erazo is a marine microbiologist and Ph.D. candidate at the Scripps Institution of Oceanography in San Diego, California. Natalia studies how microbes are responding to climate change and pollution. She is interested in conservation policy, climate change adaptation and mitigation, and works with women-led fisheries on seafood sustainability and how to better protect marine ecosystems. She loves swimming, diving, and sailing.

RICHARD NORRIS

Richard Norris is a paleontologist at the Scripps Institution of Oceanography in San Diego, California. He is interested in the impact of past environmental change on ocean life. Lately he has been using microscopic fish teeth and bones to understand how the abundance of reef fish keeps corals healthy. The tiny fossils he extracts from ocean mud tell lots of neat stories about how people have changed the world. He enjoys traveling the deserts, looking at birds, and making jam and a warm scone!