

ECHOLOLOCATION

THE ACOUSTICAL SOCIETY OF AMERICA (ASA)

The Acoustical Society of America is dedicated to increasing and advancing the knowledge of acoustics – the science of sound. ASA includes physicists, engineers, biologists, psychologists, geophysicists and scientists who work in music, speech, architecture, medicine, bioacoustics, noise control and oceanography. This diversity of topics, along with the opportunities provided for the exchange of knowledge and points of view, is one of the Society's strongest assets. Whether it is the study of humpback whale songs, the design of concert halls, the study of music and musical instruments or a wide range of sound-related studies, they will be investigated by ASA members.

THE OPTICAL SOCIETY (OSA)

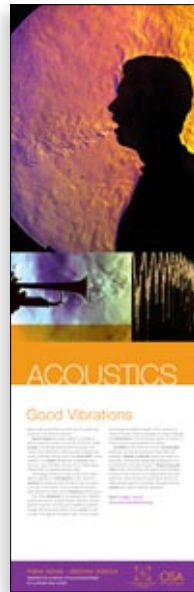
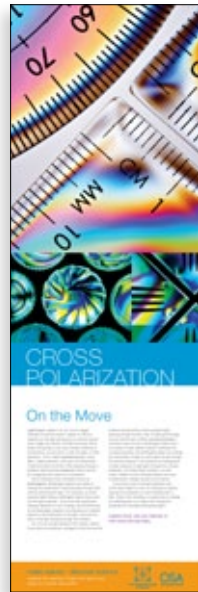
Founded in 1916, OSA brings together optics and photonics scientists, engineers, educators and business leaders. OSA is dedicated to providing its members and the scientific community with educational resources that support technical and professional development. OSA's publications, events and services help to advance the science of light by addressing the ongoing need for shared knowledge and innovation. The Society's commitment to excellence and continuing education is the driving force behind all its initiatives.

THE OSA FOUNDATION

Inspiring the next generation of scientists and engineers

The future's great scientists are among the children of today and tomorrow. These children live and study around the world. Some have the resources and support needed to succeed, but many others do not. The OSA Foundation believes all students should have access to quality education resources and everyone should have the opportunity to explore scientific studies and career paths.

The Foundation focuses on advancing youth science education by providing students with access to science educators and learning materials through interactive classroom and extracurricular activities. To learn more about the Foundation and its funded programs or to request support for your program, please visit www.OSA-Foundation.org, e-mail foundation@osa.org or call +1.202.416.1421.



This poster series was created by the Acoustical Society of America and The Optical Society.

Special thanks to the following volunteers for donating their time and expertise to this poster and guidebook:

- Wendy Adams, Acoustical Society of America
- Whitlow Au, Hawaii Institute of Marine Biology
- Freddie Bell-Berti, St. Johns University
- Kelly Benoit-Bird, Oregon State University
- Robin Cleveland, Boston University
- Judy Dubno, Medical University of South Carolina
- Geoffrey Edelmann, United States Naval Research Laboratory
- Pamela Harght, BAi, LLC
- Dan Ludwigsen, Kettering University
- Thomas Moore, Rollins College
- Cynthia Moss, University of Maryland
- Charles Schmid, Acoustical Society of America
- Victor Sparrow, Pennsylvania State University

Nature's SONAR!

ANIMALS, LIKE PEOPLE, USE SOUNDS TO COMMUNICATE WITH EACH OTHER AND TO FIND THEIR WAY AROUND THEIR ENVIRONMENTS.

Bats and dolphins even depend on the sounds they make to “see” when there is not much light. These animals send out short and very loud sound pulses- like snaps - and listen for the echoes from these pulses to return so they know how far they are from the wall of a cave or the bottom of the ocean. The use of **echoes** to find objects in the environment is called **echolocation**. Using echolocation, thousands of bats can fly around a dark cave, all sending out pulses, without bumping into each other!

Bats and dolphins use echolocation, also known as **sonar**, to find food. By listening to echoes of their sonar sounds, dolphins can find fish buried in the sand, and bats can find flying moths. But, some moths are able to hear the sonar sounds of the approaching bat and make their escape. Similarly, some fish are able to hear the dolphin sonar sounds and avoid capture.

Some blind people use sonar by listening to the echoes from the taps of their canes to help them determine how far they are away from a wall. Sonar originated as an abbreviation for “SOund Navigation and Ranging,” the **acoustic** method developed in World Wars I and II for locating submarines. Sonar is now a widely used method for finding objects in the ocean.

Acoustics is the science of sound. Acousticians study how sounds are produced, transmitted, and perceived. Scientists and Engineers who study animal bioacoustics and underwater acoustics focus on how sound is produced, the acoustic signals that are generated, and how listeners understand these signals.

Definitions

ECHOES

Reflections or repetitions of sound waves. Echoes can be produced and heard by clapping hands or shouting in a large empty room with hard walls or in a cave.

ECHOLOCATION

The method used to detect objects by producing a specific sound and listening for its echo.

SONAR

SOund Navigation and Ranging, is the process of listening to specific sounds to determine where objects are located. In active sonar, a sound is transmitted and the listener uses its echo to locate objects. In passive sonar, the listener uses the sounds emitted directly from the source of the sounds.

SPEED OF SOUND

The speed at which sound travels. This is very important for scientists who study sound. In air sound travels 343 meters in 1 second (767 miles per hour), but in water sound travels 1500 meters in 1 second (3350 miles per hour). Compare these speeds to cars traveling on the highway at 65 miles per hour.

FREQUENCY

The number of times a vibrating object oscillates (moves back and forth) in one second. Fast movements produce high frequency sound (high pitch/ tone), but slow movements mean the frequency (pitch/tone) is low.

SOUND SOURCE

Whatever object makes the sound. All of these are sources of sound: two hands clapping together, a person speaking or singing, a submarine echolocating, a radio playing, birds chirping, ocean waves crashing on the beach.

Echolocation Activities

SPEED OF SOUND

Here's what you do:

- Stand 200 yards (that's two football fields) or further from the goal post or backstop while a friend stays there. Have your friend hit a rock against the metal post (goal post or backstop). Listen and watch. Do you hear the sound at the same time that you see the rock hit the post?

Other things to try:

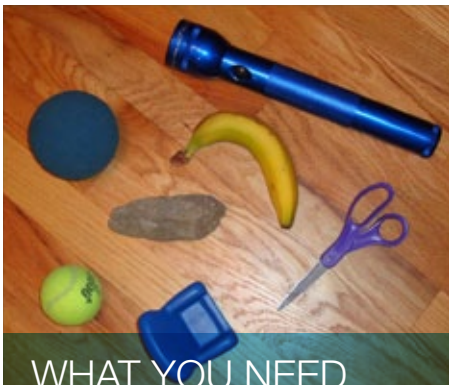
- Why do you think coaches tell sprinters to take off as soon as they see the smoke leave the gun rather than waiting until they hear the shot?
- Next time you see lightening, count how long it takes to hear the thunder. Every 5 seconds means the lightening is a mile away from you. If you count 10 seconds before you hear the thunder, the lightening was 2 miles away.



WHAT YOU NEED

- At least 2 people
- Very large field with a goal post, backstop or metal fence post.
- A rock

IDENTIFICATION FROM A DISTANCE



WHAT YOU NEED

- At least 2 people
- Objects 2 inches in detail or larger – (ex: tennis ball, nerf ball, scissors, banana)

Here's what you do:

- Have a friend stand 100 yards from you (that's one football field). *At this distance – using echolocation – a dolphin can identify small fish (6 inches in length).*
- Hold up one object at a time and have your friend identify the mystery objects.
- Move 20 yards closer to your friend and hold all the objects up again – in the same order each time. Keep moving in 20 yards at a time until you meet up. At what point was your friend able to identify each object?

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TEACHERS: find lesson plan details for these and other activities at <http://www.exploresound.org>

FAST FACT Many blind people use echolocation to get around!

Echolocation Activities

FISH FINDING GAME

Here's what you do:

- Have one person be the dolphin, four people will be objects and three will be fish.
 - › The dolphin **must** keep their eyes closed (no cheating!!).
 - › Objects are to lay, sit or stand in one place.
 - › Fish move around *slowly* winding in and out of objects.
- The dolphin tries to locate a fish.
 - › The dolphin makes a noise, “beep” and any object or fish in front of the dolphin is required to respond.
 - › Objects will say “object”
 - › Fish will say “fish”
- Once the dolphin touches a fish
 - › The tagged fish becomes the dolphin
 - › The objects and fish switch

WHAT YOU NEED

- At least 8 people

Now try this:

- Have the dolphin “beep” continuously. Does this make it easier or harder to find the fish?

Other things to try:

- If the dolphin is having trouble locating fish or if the fish are misbehaving, have the fish move one step per beep or simply have them stand still

3-D LOCATION

WHAT YOU NEED

- Thread or fine string
- Small objects up to 1 inch in size (buttons work)
- Tape
- Flashlight
- Completely dark room



Here's what you do:

- Tie each object to different lengths of thread (6 inches to 4 feet in length).
- Attach the threads to the ceiling in random locations throughout the room.
- Adjust the flashlight so that it has a very narrow beam.
- Turn out the lights and have a friend try to locate the objects using the flashlight. *Bats and Dolphins have to search around **and up** and down to find food!*

Cindy Moss

CINDY MOSS WORKS IN A PLACE CALLED THE “BATLAB.” In the Batlab, her research laboratory at the University of Maryland, Cindy and her graduate and undergraduate assistants are studying the way free-flying animals use echolocation to locate objects in the environment. Sometimes, this means they hang worms from strings for bats to locate and eat as they fly around the room. On other days, when working with a colleague studying hearing in insects, they might put a praying mantis and a bat in the Batlab together to observe their methods of detecting each other!

Observing bats and animals is made easier by the methods Cindy and her team have developed. They placed high-speed cameras and microphones on the walls and floor of the lab, which lets them track the bats in 3D. From the images and sounds recorded in the Batlab, the scientists create animations that they slow down to get insight into the bats’ behavior (bats fly at about 3 meters per second). They were able to see that bats aim their “sonar” like a flashlight, beaming it around the room to find their prey.

How did Cindy end up in the Batlab? Her interest in science started when she was very young. She used to explore the woods near her house, and bring home frogs, tadpoles

and turtles to observe. As she got older, she was interested in languages and art, too. As an undergraduate at Hampshire College and the University of Massachusetts, she started studying psychology and zoology, and the mix of the two. Her Ph.D. work at Brown University and post-doctorate work in Germany got her more into neurobiology in general and bats in particular. Bat echolocation research has taken her into the study of acoustics.

Her advice to aspiring young students is to imagine that you are a scientist already. Ask questions, then design, plan and carry out projects that will help you find the answers. You may discover interests you didn’t even know you had.

You can find Batlab movies and videos at www.bsos.umd.edu/psyc/batlab/movies.html.



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Whitlow Au

WHITLOW AU IS A RESEARCHER at the Hawaii Institute of Marine Biology, an institute of the University of Hawaii. His research focuses on marine bioacoustics, which covers just about anything in the oceans that you can use acoustics to study.

Whit puts acoustic recorders on the ocean bottom, along the coastline, to measure animal sounds where they occur. These recorders are run by small computers, which run on a “duty cycle” that turns them on and off to save power and collect data for months at a time. As most marine mammals tend to stay close to the coastline, this method works well for capturing the sounds of dolphins, smaller whales, fish, snapping shrimps and other organisms in coral reefs.

How did Whit end up in such a cool job? He studied electrical engineering while an under-

graduate at the University of Hawaii, a field that allows for many different careers. He knew he wanted to live in Hawaii and do research, and found that marine bioacoustics would allow him to do just that. It has also allowed him to travel to research and conference locations around the world, including New Zealand, Iceland, the Netherlands, Denmark, Moscow, Rome and Beijing!

In his over 35 years in this field, Whit has discovered a lot about dolphin sounds, and considers his work a continual game, trying to understand dolphin SONAR. He says his most memorable discovery was finding that dolphins produce very high intensity, high frequency (loud, high pitched) sounds in the wild. Because dolphins were previously monitored in tanks, only lower frequencies and amplitudes had been recorded. But Whit’s recorders out in



Whitlow Au and fellow researchers transport a dolphin at the Hawaii institute of Marine Biology.

the bay were finding unbelievable results that many other scientists had a hard time accepting. In fact, his first paper on dolphin SONAR was rejected.

Reviewers and other scientists thought Whit had measured incorrectly, as his numbers were so surprising. But Whit had stumbled upon a new concept: dolphins adjust their sound's volume and frequency to suit their environment. In fact, the difference in the tank versus the open sea was about 40 decibels, or 100 times louder! So Whit decided to try again, and wrote a paper proving his methodology, making sure to include lots of examples and lab calibration data. He even borrowed a hydrophone from another researcher to show that his results were not due to a problem with his own equipment. The paper was accepted in 1974.

By the time Whit published his book, *The SONAR of Dolphins*, in 1993, it was widely accepted by scientists. His other professional highlights include winning his first silver medal in bioacoustics, and being elected President of the Acoustical Society of America.

If you want to be a scientist, Whit says, you must like to study! He has had a lot of fun working in a field that encourages you to learn as much as you can. And if you have a high degree of curiosity, you'll have fun as a scientist, and you can take whatever the world throws at you.



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Kelly Benoit-Bird



Oregon State University oceanographer Kelly Benoit-Bird uses acoustics to “observe” undersea marine communities

THE SOUNDS OF SCIENCE Kelly Benoit-Bird is a marine scientist at Oregon State University who studies how animals in the vast oceans of the world interact with each other – and she does it most of the time without even looking at them. What Kelly does is use acoustics to bounce sound waves off these marine creatures to determine their size, their movements in the water, and how many of them there might be.

Already in her young career, her studies have taken her around the world. Kelly has studied the voracious Humboldt squid off Mexico, researched the feeding habits of sea birds and fur seals in the frigid northern waters of the Bering Sea, and analyzed marine communities in a deep undersea fjord off the spectacular coast of New Zealand.

Her experiences are extraordinary considering Kelly is the first member of her family to have attended college. She already has received prestigious awards from the MacArthur Foundation, the White House, the Office of Naval Research and the Acoustical Society of America for her research.

“If you ask my parents, they’ll tell you that I knew in elementary school that I would somehow end up doing something that related to oceans,” she said with a laugh. “Of course, I had no idea then what a marine scientist was, or whether you could make a career out of it. And the idea of using acoustics to study animals would never have entered my mind.”

As it turns out, Kelly Benoit-Bird not only uses sound waves as a tool to study marine creatures, she is very good at it. Two years ago, she developed a technique that would allow scientists aboard a ship to locate squid on sonar, which is a lot more difficult than it sounds. Squid, you see, don’t have bones or swim bladders, so there is little for a signal to “bounce off” and create an acoustical image. So Kelly developed an analysis approach that uses multiple frequencies or pitches of sound—and it works like a charm.

Why is that important? For one reason, many whale species love to eat squid, but it had been difficult, if not impossible, to estimate how many squid are in a certain location. And many scientists thought whales couldn’t use

“echolocation” to hunt for squid for the same reason acoustics had previously failed. Now scientists are looking at how the whales themselves use multiple frequencies to locate prey.

Kelly also has made important discoveries about how spinner dolphins off Hawaii hunt for food, using acoustics to track their movements through the water that are so sophisticated, it would put a synchronized swim team to shame. The dolphins in these groups themselves use sounds higher in frequency than humans can hear to communicate with each other to maintain their elaborate formations and synchronize their feeding behavior.

“Technology is really advancing rapidly,” the Oregon State University scientist said, “and it can open up a lot of doors to scientists. Luckily, I’m not intimidated by technology and trying new things. My dad was a mechanic and when I was growing up, I was always in his garage helping him, so I learned how to tinker.”

That mechanical ability also encouraged her to use new computer software to track the ballet-like moves of the dolphins and share the information with other scientists and students on her web site. Kelly also has an artistic side, however. She draws her own illustrations of marine creatures for the journal articles and book chapters she writes.

“Everyone should choose a career that they are passionate about,” Kelly said. “Being a scientist can be a lot of hard work, but if it’s something you love doing, it’s worth every minute. For me – it’s about the animals. I love learning why they do the things they do and how they survive in a world hidden from our view.”

—KELLY BENOIT-BIRD



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JOBS IN ACOUSTICS

Acousticians include engineers, physicists, speech and hearing scientists, architects, biologists, psychologists, linguists, mathematicians, oceanographers, computer scientists, and musicians.

ANIMAL BIOACOUSTICS

The study of how animals make and hear sounds. Animal bioacoustics also includes the use of sound to study and detect animals when they make sounds and the use of SONAR to monitor the presence of plankton and fish.

UNDERWATER ACOUSTICS

The study of natural and man-made underwater sounds. Scientists study how sounds are made and travel in the underwater environment.

Additional Resources

For Students, Teachers and Parents

EXPLORING THE SCIENCE OF SOUND

www.exploresound.org

This fun educational website contains resources for teachers, parents and kids.

- Classroom materials,
- games for kids, and
- career profiles of acousticians.
- Aimed at kids of all ages.

New materials are being added weekly.

Keep checking back for new ideas!

WORLD ACCESS FOR THE BLIND

www.worldaccessfortheblind.org

Resources and information for the blind.

Daniel Kish trains blind individuals how to use echolocation to navigate the world – including mountain biking!

DALLAS SYMPHONY ORCHESTRA FOR KIDS

www.dsokids.com

Contains resources about musical instruments

- Listen to a large range of instruments.
- Nicely put together, straightforward inquiry activities for teachers
- Elementary level.

DISCOVERY OF SOUND IN THE SEA

www.dosits.org

This is a very rich website with a range of education materials.

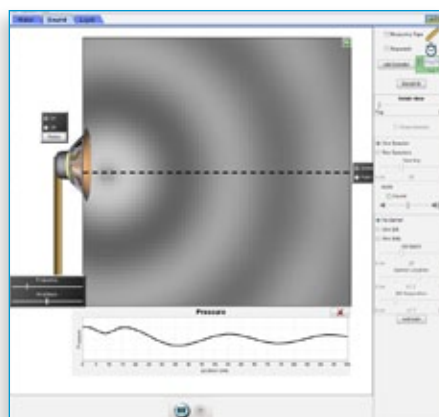
- Appropriate for all ages.
- Recordings of animal sounds and video.
- Teacher materials with extensions for all grade levels.
- Scientist profiles, and
- Lots of information about studying sounds in the sea.

PhET INTERACTIVE SIMULATIONS

<http://PhET.colorado.edu>

Suite of over 100, high quality, educationally effective, simulations about science.

- Appropriate for all ages.
- Includes activities for teachers.
- Simulations that relate to acoustics include:
 - » Sound,
 - » Wave on a String,
 - » Wave Interference, and
 - » Fourier: Making Waves



ACOUSTICS EDUCATION/OUTREACH

<http://AcousticalSociety.org>

The Acoustical Society's website has Education and Outreach resources including:

- Listen to Sounds
- Information on the science of acoustics
- Info on scholarships, prizes and grants
- Directory of graduate education in acoustics
- Career information on acoustics

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The Optics Discovery Kit was created by volunteer members of the Optical Society of America. The kit is part of the Society's youth education outreach programming. To request more information about OSA and other educational materials, please contact the OSA Education programming staff at: opticseducation@osa.org.

OSA Educational Resources ... *Exploring the Science of Light*

—Image courtesy of Ryan Gallagher: www.kineticphotography

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