Sonic history. Stanford archaeologist John Rick (*right*) is creating an acoustic map of prehistoric underground chambers in Peru.

Sound Science Maps Venetian Canals and Peruvian Ruins

Think of archaeologists out in the field and you probably picture them carrying shovels and sample bags—perhaps also a bullwhip if you're an Indiana Jones fan. But the newest generation of researchers may be as likely to wield sensitive microphones and recorders, according to several sessions in Paris devoted to archaeological acoustics.

Some are harnessing sound waves to reveal the invisible. Fantina Madricardo, a geologist at the Institute of Marine Science in Venice, Italy, presented a dramatically different map of her famous city's lagoon. Using a newly developed shallow-water sonar system, she and colleagues charted subtle differences in sediment density, tracing the contours of canals and structures buried for millennia beneath the shifting water. The sonar map led archaeologists to dig in places "where they did not think to look," Madricardo says. A previously undiscovered Roman brick embankment is now being unearthed. Because river deltas have been a favorite site for human occupation going back to Neolithic times, the method could reveal many more submerged artifacts elsewhere.

Other archaeological studies are turning to sound not as a tool but as an artifact itself. "Ancient soundscapes have been largely ignored by archaeology," says David Lubman, a veteran acoustical scientist who is now an industry consultant based in Westminster, California. One reason is that "sound is ephemeral," so reconstructing what an environment sounded like hundreds or even thousands of years ago is a daunting task. Then, he says, "comes the question of intentionality—how do you prove that people were aware of particular acoustic phenomena?"

For example, for about a decade, Lubman has argued that the Maya Temple of Kukulkan step pyramid in Chichen Itza, Mexico, was designed with sound in mind. In Paris, he convinced scientists in the audience that the temple's peculiar shape makes it reflect the sound of clapping back as a chirp that closely matches the call of the quetzal, a bird revered by the Maya. But few of his listeners agreed that the effect was deliberately built into the temple. "I do not believe it," says Jorge Cruz, an acoustics Ph.D. student at the Mexican National Polytechnic Institute in Mexico City.

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Listen to roaring tigers, snorting polar bears, a cracking mountain of ice, and more from Acoustics '08.

The question of intentionality may also arise from an ongoing study described by Miriam Kolar and Patty Huang, acoustics Ph.D. students at Stanford University in Palo Alto, California. As part of a team led by Stanford archaeologist John Rick, they are mapping the acoustic environment within the 3000-year-old labyrinthine galleries of Chavín de Huántar in the Peruvian highlands. Conch-shell trumpets previously discovered within the galleries indicate that the underground chambers were used for music and ritual ceremonies. The new work shows that the layout of the galleries creates reverberations that make it impossible to pinpoint sound sources. Rick hypothesizes that a ruling priest class exploited the disorienting acoustic effect to instill awe and fear. The study "is persuasive because it builds on evidence of performance in the space," says Christopher Scarre, an archaeologist at Durham University in the U.K.

In collaboration with Stanford composer John Chowning, the team plans to use its three-dimensional acoustic map of the galleries to create a virtual simulation of the rituals that took place at Chavín de Huántar. "In a couple of years, the galleries are going to be reinforced to prevent collapse, which will change their acoustics," says Kolar. "So this is really the last chance to preserve this ancient soundscape."

Ultrasound Uses in Medicine Heat Up

Hospitals have used ultrasound for decades to see fetuses and kidney stones without breaking a patient's skin. Now doctors' sonic toolkits are about to expand, as new ultrasound-based technologies are poised to probe the inner structure of bones and treat otherwise incurable cancers.

X-ray photography "only gives you the average density of the bone," says Pascal Laugier, a medical researcher at Université Pierre et Marie Curie in Paris. "To determine the quality of bone, you need to see its inner structure, and only ultrasound can reveal this." That information is particularly crucial in aging populations of the industrialized countries, where the burden of treating bone fractures from osteoporosis and falls has ballooned. As a bonus, ultrasonic devices require none of the radioisotopes or heavy shielding of x-ray machines.

The bone biophysicists gathered in Paris compared notes on the many problems with interpreting the ultrasonic sounds that propagate through the body's hardest material. A team led by Victor Humphrey, a physicist at the University of Southampton, U.K., presented an acoustic study of how bones heal after a break. Bones typically form a thick "callus" of tissue around fractures, cement the gap, and then reabsorb the callus. A bone's stage of healing can be quickly assessed, Humphrey reports, by transmitting ultrasound through the fracture—

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Snapshots From the Meeting >>

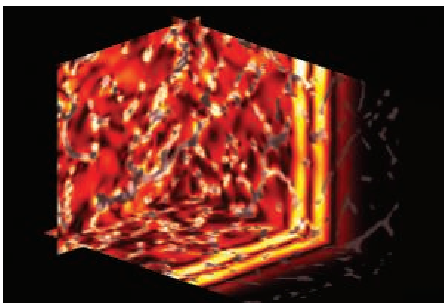
Sleepy talking. Slumped posture and bloodshot eyes are giveaways of extreme lack of sleep, but speech betrays fatigue, too. A team led by Suzanne Boyce, a linguist at the University of Cincinnati in Ohio, recorded people giving directions after a good night's rest and after 34 to 58 hours of sleep deprivation. By analyzing phonetic features of each person's speech—pauses and the loss of syllables—a computer spotted a pattern associated with drowsiness. "This work is very exciting," says Sarah Hawkins, a linguist at the University of Cambridge, U.K. "It promises to … not only help with practical applications such as detecting when machine operators like airline pilots are tired but will also give us greater insight into … how speech is produced."

How polar bears and tigers hear. The results of the first hearing tests of large carnivores were welcomed by conservationists eager to know the frequency ranges at which these animals can perceive human noise. A team led by Anne Bowles, a biologist at the Hubbs–Sea World Research Institute in San Diego, California, trained polar bears to respond to tones in order to receive a snack. The bears had a hearing range similar to that of humans, between 125 and 20,000 hertz. Meanwhile, tiger hearing was tested at Henry Doorly Zoo in Omaha, Nebraska. A team led by Edward Walsh, a physiologist at nearby Boys Town National Research Hospital in Omaha, analyzed the spectrum of tiger roars and also used electrodes to monitor brain activity in anesthetized tigers while playing a range of sounds. The results, says Walsh, support theories that tigers communicate with each other by infrasound, sound of lower frequency than most mammals perceive. "Confrontational roars" contain infrasonic energy, and other tigers can hear it, Walsh says. But such sounds are absent from the "territorial roars" that tigers use to maintain their vast domains. –J.B.

at least for long bones such as those in the arm. But one of the most medically important bones still defies ultrasound analysis. "We have not figured out the hip," says Laugier. "It has such complex geometry and diverse structure."

Cancer researchers discussed high-intensity focused ultrasound (HIFU) therapy, which focuses ultrasound beams on a single spot inside the body, such as the center of a tumor. The mechanical energy of the acoustic waves converts into heat, and the tissue dies in a sizzle. HIFU is already used to treat cancer in easily accessible tissue such as in the prostate and uterus, but the brain has so far been off-limits because the skull makes focusing the beams nearly impossible. The solution, says Mathias Fink, a physicist and medical researcher at the University of Paris, is "time-reversal acoustics," a strategy that uses echo patterns as a guide for focusing waves through a barrier. Fink has used the technique to successfully target brain tumors in animals.

As the hype for HIFU grows—it's widely used to treat cancer in China and is being evaluated in the United States and Europe—some scientists at the meeting urged caution. HIFU often generates transient microscopic bubbles that can boost the temperature of the surrounding tissue to potentially dangerous levels. "No simple way exists … to calculate temperature rise and therapeutic dose in tissue," says Peter Kaczkowski of the University of Washington, Seattle. The ultrasound engineer calls for more basic research on HIFU and better "regulatory oversight."



Bone probe. Passing ultrasonic waves through bone, as in this numerical simulation of a section of femur, reveals its inner structure.

Listening to Distant Ice Crack

Using satellites, scientists have kept a wary eye on the crumbling Antarctic ice shelf, tracking the movement of titanic chunks that break free. Now, using acoustic instruments designed to detect nuclear explosions, they are putting an ear to the ice as well.

Big breaks in the ice shelf over the past 2 decades have been dramatic, but it remains unclear whether they are due to global warming. That's partly because most cracks and breaks are too small to be seen from space. Getting a statistical handle on those smaller events, said polar scientists at the meeting, will help determine whether the rate of ice-shelf degradation stays within natural bounds or steadily increases.

The sound of an ice mountain cracking quickly dissipates through air and land, but it can propagate through water for thousands of kilometers. So Alexander Gavrilov and Binghui Li, marine acousticians at Curtin University of Technology in Perth, Australia, took advantage of a Cold War legacy: three hydrophone arrays in the Indian Ocean that listen for nuclear explosions as part of the Comprehensive Nuclear Test Ban Treaty. Each 2-kilometer-wide array reveals the direction of sounds; by triangulating data from the three stations, researchers can trace the location of the sound sources.

The first result is that the system works. "Antarctica is the major source of low-frequency noise in the Southern Ocean and southern parts of the Indian Ocean," Gavrilov reports. To confirm that these sounds originated from distant ice cracking, he and Li compared a year of the sounds with recordings from a hydrophone they installed on the Antarctic sea floor.

Next, the scientists focused on the dozen or so daily "cracking and breaking events" from the ice shelf that could be detected in the Indian Ocean data. Over the past 7 years, they found seasonal variation in the sounds but no significant increase—or decrease—over time. This is "good news," says Gavrilov, because the data set can be used as a baseline for monitoring the ice in coming years.

"Seismologists a decade ago would have never dreamed that these kinds of signals would be broadcast from the ice masses into the far fields of the world's oceans," says Douglas MacAyeal, a geophysicist at the University of Chicago in Illinois. But there may be limits to the interpretation of these acoustic signals. So far, says Ursula Schauer, a geophysicist at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany, scientists cannot use the sounds to calculate the volume of ice breaking off the shelves. "But this might be possible in the future with more sophisticated signal processing," she says. The study is a "major innovation," adds Terence Hughes, a glaciologist at the University of Maine, Orono, but more ears in the water are needed. "It should be employed all around Antarctica, not just in the Indian Ocean sector." –JOHN BOHANNON

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