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Ripple Marks

The Story Behind the Story

BY CHERYL LYN DYBAS

“Talking to the Animals”: Chemical Ecologists Translate the Language of the Sea

If Dr. Doolittle talked to the animals, it's more likely he was a chemical ecologist than a linguist, says scientist Mark Hay of the Georgia Institute of Technology in Atlanta. At least when it comes to the fauna (and flora) of the sea.

Chemical signals are the primary “language” used by ocean organisms. In an extrasensory perception of the deep, marine animals and plants react to other species, and to their environment, based on these cues.

Humans are poorly designed to understand such chemically driven interactions “because we sense the world primarily via visual and auditory input,” Hay says. “In contrast, many ocean species lack eyes and ears. They sense much of their world via chemical signals. In the sea, even species that do see and hear rely on chemical cues.”

Imagine walking along a bustling New York City street at night. Suddenly, the boulevard goes pitch black and deathly silent—permanently. How would you find food, a mate, or protect yourself against thieves and murderers? What if you had to rely on detecting chemicals produced by other people, and other animals, to survive?

“For ocean animals and plants, it's like that every minute of every day,” says Hay. For most marine species, chemical cues determine whether they consume,

fight with, run from, or mate with the creatures next to them—and whether they are eaten by, infected by, or overgrown by natural enemies.

Welcome to New York City...eerily silent and utterly dark...beneath the sea.

Dead ahead are the shapeshifters, marine denizens that use chemical messages to change their outward appearances. When the bloom-forming phytoplankton *Phaeocystis globosa* senses its next-door neighbors under attack by ciliates, which feast on small foods, it shifts shape and grows colonies too big for the ciliates to consume, states Hay in a 2009 paper in the *Annual Review of Marine Science*. When the phytoplankton's neighbors are attacked by copepods, which feed on larger foods, it suppresses colony formation and grows as single cells too small to interest the copepods.

“These shifts could alter energy flow, nutrient cycling, and patterns of carbon sequestration,” says Hay. “Chemical cues affect not only individual behavior and population-level processes, but also community organization and ecosystem function.”

What if you had to fly a plane over an area the size of Canada to locate a grocery store—with no “map” but a few simple fresh food molecules wafting through the air? Tube-nosed seabirds—storm-petrels,

albatrosses, petrels, shearwaters, and others—do exactly that. They use a chemical cue to track high-productivity pelagic areas, where they forage on zooplankton, fish, and squid. They're responding to the presence of dimethyl sulfide (DMS), produced when zooplankton attack blooms of phytoplankton, then excrete this substance. “At scales of thousands of square kilometers, DMS may function as an olfactory landscape,” says Hay, “indicating ocean areas where phytoplankton [and zooplankton] accumulate and where the search for prey should be most successful.”

To discover how chemical signals play a part in ocean ecosystem—and perhaps human—health, Hay and colleagues are studying why marine organisms produce and deploy chemical arsenals. Understanding substances that cloak seaweeds, for example, could allow scientists to adapt these compounds for use against microbial pathogens, HIV, cancer, and other human diseases.

As part of a long-term project supported by the National Institutes of Health, Hay and colleagues have analyzed compounds from more than 800 species in the waters around Fiji Islands like Yanuca. One species has emerged as a frontrunner in their investigations: the red seaweed *Callophycus serratus*. This alga is adept at fighting infections. As Hay's colleagues report in a



2009 paper in *Proceedings of the National Academy of Sciences*, chemical extracts from this alga fend off disease-causing microbes. The compounds are the largest group of algal antifungal chemical defenses reported to date.

"We're in effect 'listening in' on the fight between this red seaweed and a fungus trying to attack it," says Hay. "What we hear may allow us to translate the language of the sea into that of human biomedicine."

They may be tuning in for some time. *Callophycus serratus* manufactures at least 28 different bioactive compounds. Why would a single species of seaweed produce so many bioactive substances?

The compounds may all work together against a host of different enemies, says Hay. "Or they may have separate uses we don't yet comprehend."

Hay is busy deciphering. He and colleagues reveal in a 2009 paper in the *Journal of Organic Chemistry* that *Callophycus serratus* contains bromophycolides—in ocean-speak, chemicals that have shown promise as new treatments for infectious diseases.

Whether working along the shores of Yanuca Island, Fiji, or in the seas around Florida, Panama, or the Caribbean Islands, Hay is proving that we can interpret the language of marine organisms. "Knowing what's being communicated will provide a deeper understanding of marine systems," says Hay, "and improve our ability to serve as wise stewards of marine natural resources."

Along the way we might, in the vein of Dr. Doolittle, find out how the animals and plants of the ocean are faring, and with them, ourselves.

Better living through chemistry: marine animals and plants in the Fiji Islands—and around the world—"communicate" using chemical cues.
Photos courtesy Mark Hay



A rift in Ethiopia's Afar depression may herald the formation of a new ocean. Photo credit: University of Rochester



Earth's Oceans: And Ten More Were Six?

The Arctic. The Atlantic. The Indian. The Pacific. The Southern. The African?

Earth's sixth ocean may be in the process of forming—not in eons, but in less than a week.

In 2005, a 35-mile-long rift split apart the Afar depression in Ethiopia's desert. The depression, more properly called the Manda-Harraro nascent oceanic rift, lies at the junction of the Red Sea, the Gulf of Aden, and the Ethiopian rift system. The splitting of the Arabia, Somalia, and Nubia tectonic plates during the past 30 million years produced the 300-km-wide, 600-km-long depression. Some three million years ago, widespread faulting and volcanism in the Afar localized to a 10-km-wide, 60-km-long rift segment.

Geologists believed the 2005 rifting might be the beginning of a new ocean as two parts of the African continent move apart. Now scientists have confirmed that the volcanic processes beneath the Ethiopian rift are almost identical to those at the bottom of the world's seas, heralding the formation of what someday may be Earth's sixth ocean.

Unlike other rifts on Earth, however, Afar didn't open in a series of small earthquakes over an extended period of time. It tore open along its entire 35-mile-length in just days, according to Atalay Ayele of Addis Ababa University in Ethiopia and colleagues, who published their findings in a paper in the journal *Geophysical Research Letters (GRL)* in October 2009.

A volcano called Dabbahu at the northern end of the rift erupted in September 2005. Magma flowed up through the center of the rift and began "unzipping" it in both directions.

The finding overturns previously held notions of the processes at active volcanic boundaries. "We never thought a huge length of rift could break open at once," says Cindy Ebinger of the University of Rochester, a co-author of the *GRL* paper. "We now know that rift segments can rip open incredibly quickly."

Such sudden, large-scale rifting poses more serious hazards to those living nearby than would several smaller splits, she believes.

Since 2005, the researchers have installed seismometers and measured 12 similar, though less-intense, events.

Insights into the link between volcanoes and tectonic plates depend on observing such spreading center events, "difficult in the hostile and remote environment of the deep sea," write Ayele and colleagues in their paper. "Most of what we know about these events comes from the less than one percent of spreading centers that occur on land in Iceland, and in Afar."

Glacial landforms complicate the interpretation of spreading centers in Iceland, says Ayele, "and spreading ridges in the ocean are hidden under miles of water, making it a challenge for scientists to track more than one small section there."

Ethiopia is a unique rift laboratory, says Ayele, one that's on land. At least for now.

Seashells, Not Diamonds, A Long-Ago "Girl's Best Friend"

Diamonds are a girl's best friend, or so the saying goes.

The number of carats a diamond or other precious gem contains is a status symbol in today's world. Our jewelry, our clothes, our cars. All advertise our resources, and, perhaps, our social allegiances.

When did this human desire for adornment begin? Was there a long-ago ancestor who found something shiny on the ground, and started a fashion landslide?

A study by Abdeljalil Bouzouggar of the Institut National des Sciences de l'Archeologie et du Patrimoine in Morocco, Nick Barton of the University of Oxford in the United Kingdom, and colleagues shows that personal ornamentation began more than 80,000 years ago.

The researchers found beads made of shells in ancient caves in North Africa. Shell beads were common throughout the region until they fell out of use around 70,000 years ago.

Before Bouzouggar's and Barton's discovery, the shells were known from only a few scattered sites. "We can now document these at several North African locations, all of about the same age," says Barton.

The first appearance of explicitly symbolic objects in the archaeological record marks

an important stage in the emergence of modern social behavior in early humans, state Barton and colleagues in 2007 and 2009 papers published in *Proceedings of the National Academy of Sciences (PNAS)*. "Ornaments such as shell beads represent some of the earliest examples of this kind."

The researchers reported on examples of perforated *Nassarius gibbosulus* "sea snail" shell beads from the Grotte des Pigeons (Cave of Pigeons). Grotte des Pigeons is a large cave in eastern Morocco near the village of Taforalt, 40 km from the Mediterranean coast. The shells were found in sediments dated to some 82,000 years ago. "They had been transported a good distance from the marine environment in which they live, and had evidence of human alteration," says Barton.

The shells were strung together as necklaces or bracelets, had holes made by tools, and marks around the openings like those in items threaded on a string. The beads confirm evidence of similar ornamentation from other locations in North Africa and Southwest Asia.

The Grotte des Pigeons shells are of the same genus as those in beads from Blombos Cave in South Africa. "Wear patterns on the shells [from Grotte des Pigeons] imply that



some of them were suspended, and, as at Blombos, they were covered in red ochre," says Barton. These findings indicate an early distribution of bead-making in Africa and Southwest Asia. Shell beads there became a hot item at least 40 millennia before the appearance of similar jewelry in Europe.

The shells infer that people alive 80,000-plus years ago acted much like modern humans. "There has long been a question about the link between anatomically modern humans and behaviorally modern humans," says Barton. "These people may have looked like us, but did they behave the same?"

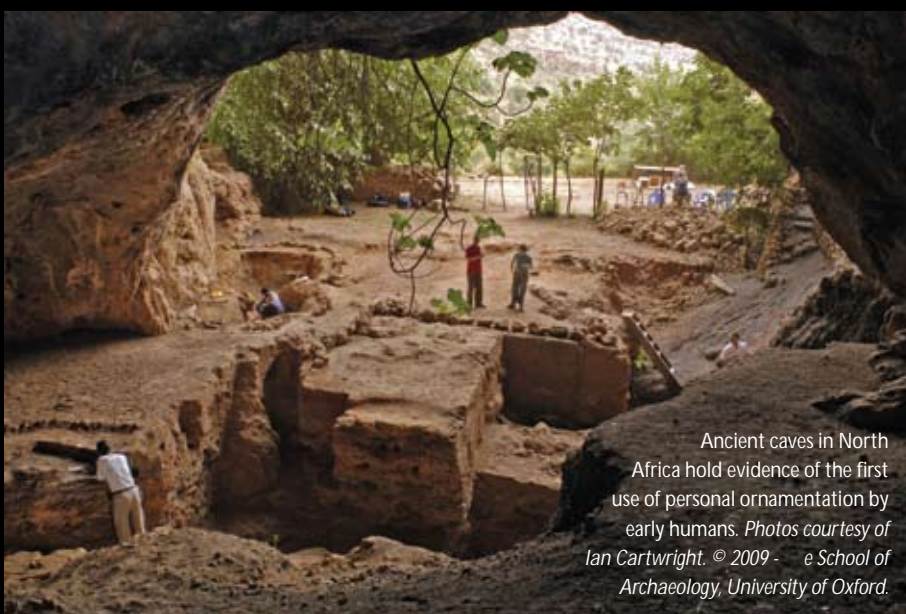
The shell beads suggest they did. Using symbolic items like beads to signal information about the wearer requires skills unique to modern humans, Barton believes, including well-developed language and an ability to understand abstract concepts.

"Whether used in isolation or integrated into complex arrangements, ornaments made of slightly modified natural objects often represent, by the direct link they establish with the natural world and the meaning attributed to them, quintessential symbolic items," write the researchers in *PNAS*.

Early shell jewelry has also been found in the Aviones cave and Anton rock shelter in Southeast Spain. Archaeologist Joao Zilhao of the University of Bristol in the United Kingdom reported in *PNAS* in January 2010, that shells at these sites date back some 50,000 years.

What shell beads signified remains an unknown. The beads may have been an insurance policy, a means of conveying shared access to resources, or of identifying oneself to members of another group.

Not so different from another modified natural object whose origins are in Africa: the diamond.



Ancient caves in North Africa hold evidence of the first use of personal ornamentation by early humans. Photos courtesy of Ian Cartwright. © 2009 - The School of Archaeology, University of Oxford.

We Are Stardust, We are Golden, Our Hearts Are Billion-Year-Old Carbon

Stardust, and a pairs of the heart. Musicians sing of them. Poets write of them. But what do stardust and the human heart actually have in common?

Geologist Nick Petford of Bournemouth University in the United Kingdom and cardiac radiologist Roger Patel of the nearby Royal Bournemouth Hospital may have found the answer. The early formation of planets, and how liquids travel into their centers, may be used to detect heart defects.

Planets like Earth have a solid core, says Petford, surrounded by liquid metal that circulates beneath the surface.

Working with geologist Tracy Rushmer at Macquarie University in Sydney, Australia, Petford developed a technique for importing images of rock slices into a software package, then running a fluid-flow simulation that looks at how liquid metal moves through rocks under pressure.

To simulate what happens in planet formation, Rushmer conducted experiments on samples of meteorites, relics from the birth of planets. The results established that molten iron can swirl through tiny fissures, and allowed fluid flow equations to be written. "Once you know how metal flows through cracks, you can develop computer simulations to see how fast it moves," says Petford.

Scientists didn't know how liquid traveled into such small spaces in rocks. "We thought it might be impossible that molten iron, for example, could flow through narrow channels and cracks and along edges," Petford says. "But not so."

Bringing geology to the emergency room, Petford teamed up with Patel to examine blood flow in the interstices of a Royal Bournemouth Hospital patient's diseased heart. Data from magnetic resonance imaging (MRI) were used to determine the fluid flow equations for the left atrium.

The aim was to model blood flow where a

potentially life-threatening clot was seen on an MRI scan.

Once allowances were made in the software for the different fluid viscosity and density of blood vs. liquid metal, the molten iron simulation model accurately predicted the clot's location.

"Using this flow analysis quantified what doctors had thought," says Patel. "The left atrial appendage is a relatively stagnant flow area in the heart. People with atrial fibrillation, for example, have left atrial appendages of variable size, shape, and blood stagnation. Imaging, then flow modeling, such individuals gives a better predictor of relative risk of clot formation, and perhaps risk of stroke."

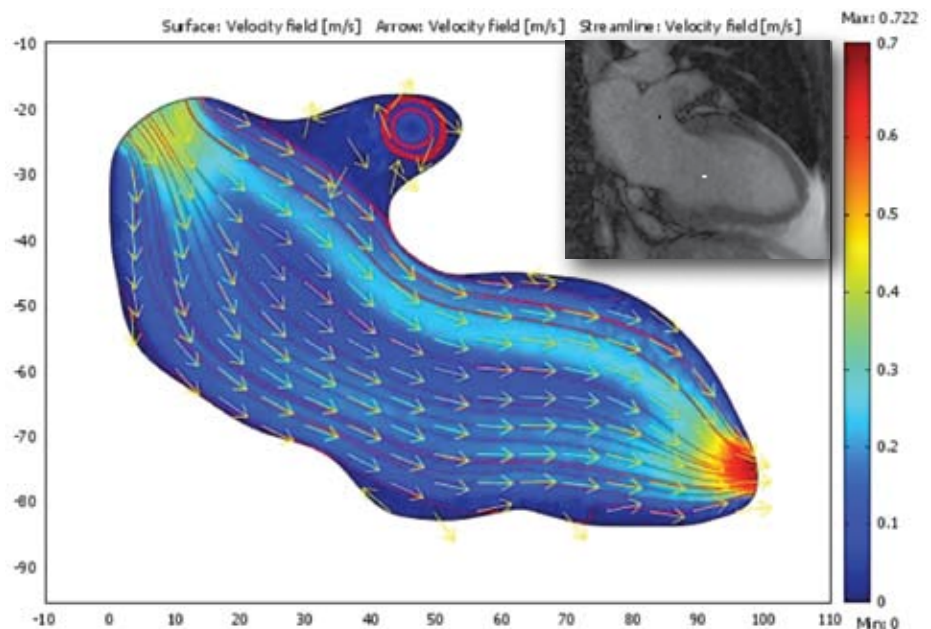
In the Royal Bournemouth Hospital patient, doctors suspected that there was an area of sluggish blood flow, but couldn't be sure where it was. By scanning the MRI images of the patient's heart into the fluid flow simulation, they were able to predict the clot's location.

"All vascular systems are different," says Patel. "Previous attempts to model the heart don't give information on what's happening in an individual patient, especially if his or her heart is irregular or deformed in some way. By using this new technology, we're able to produce an exact replica of what's going on in a patient's body."

Doctors hope the technology can be developed so it might be used routinely to analyze scans from heart patients. It will address the fact, say researchers, that blood is not a simple fluid and arteries are not simple tubes.

"This is a great example of knowledge transfer across disciplines that at first don't seem to have much in common, in this case geophysics and clinical medicine," says Petford. "Molten metal from meteorites has much to tell us about our own bodies."

Indeed, as songwriter Joni Mitchell sings, we are stardust, we are billion-year-old carbon.



Numerical model based on MRI image. The shape of the embayment is important as this is where stagnant blood is predicted (red circles). Inset: MRI scan of a human heart, showing a developing clot in the upper embayment. Courtesy of Nick Petford