[Excerpted from Charles Michel de l'Epée, "How the Deaf and Dumb may be brought to understand, in some measure, what it is to hear, auribus audire" (1784), in John Pauncefort Arrowsmith, *The Art of Instructing the Infant Deaf and Dumb* (1819).]

How the Deaf and Dumb may be brought to understand, in some measure, what it is to hear, audibus audire

Charles Michel de l'Epée

In attempting to explain this article to the deaf and dumb, I go to work as follows: I direct a large pan to be brought and order it to be filled with water. The water being perfectly settled, I take an ivory ball, or something similar, and drop it perpendicularly in. I make my pupil observe the undulation produced in the water, which would be much greater in a pond or river; but the deaf and dumb having seen this undulatory motion in both, call it to mind very easily. Then I write down as follows: — 'I drop the ball into the water; the water being displaced, runs up and strikes the edge of the pan.' Not a word of this is unintelligible to my pupils. Next I take up a screen, or some thing similar, and flapping it in my hand, the curtains flutter and leaves of paper fly about. I blow upon the hands of one of my pupils with my mouth; and call all that air. Then I write down further: 'the room is full of air, as the pan is full of water: I strike upon the table, the air is displaced and strikes against the walls of the room, in the same manner as the water is displaced and strikes against the edges of the pan.' I now take out my alarum watch, and setting it properly, I make each of my pupils feel the little hammer which strikes against his finger with great rapidity.

I then tell him that we have all a little hammer in the ear; that the air being displaced in making its way towards the walls of the room, meets with our ear, which it enters, and causes the little hammer there to move in the same way that I make the corner of my handkerchief move with my breath. (This is the language I hold with them, and I think it right not to alter it here.)

After this I get a person who hears to stand with his face against the wall, and his back towards me, requesting him to turn round and come forward as soon as he hears me strike upon the table. I strike, and the rest is executed as agreed upon. I show that the air met with his ear, and having entered it, caused his little hammer to move, the sensation of which made him turn round and come forward.

I afterwards send the same person into another room: I strike and he comes back directly. I declare that the same operation has taken place in his ear, and served him for a signal to come back. It is thus we show that sound is propagated by means of undulating air. (We explain also why this propagation is slower than that of light.) As to what really takes place in the interior of the ear, anatomists will please recollect that we are addressing ourselves to persons who are deaf and dumb, consequently that physical exactness is out of the case.

The faculty of hearing, therefore, appears to them, an internal disposition of our ears, rendering us capable of sensations there, of which their own ears are incapable, because the door is shut so as to prevent the air from penetrating, or because they are without the little hammer to strike, or without the drum which it is to strike upon; and as they perceive that the stamping of the foot on the floor produces more or less motion at their feet, in proportion to the force of the stroke, so they conceive that the motion produced in our ears, is more or less felt in proportion to the degree of violence with which the air enters: they have nearly the same idea of it as of a wind blowing with more or less strength.

But as we can give no distinct idea of the difference of colours to a person born blind, neither can we give the deaf or dumb a distinct idea of the difference of sounds produced in our ears by the different articulation of letters.

[Reprinted courtesy of the author and *Nature Publishing*, Vol. 411, 10 May 2001.]

Spiny lobsters stick and slip to make sounds

Sheila Patek

Many anthropods are able to produce pulsed sounds by rubbing a hard pick over stiff macroscopic ridges[1], rather like dragging a stick over a washboard. Spiny lobsters (Palinuridae) also make pulsed sounds, and here I show that they generate these by virtue of a frictional 'stick-and-slip' mechanism that is more usually associated with bowed stringed instruments. By using this technique rather than a 'hard-washboard' mechanism, lobsters can produce strident warning sounds against predators throughout their moult cycle, including the period when their exoskeleton is softened and they are most susceptible to predation.

Palinurid lobsters produce a loud, abrasive sound (rasp) by rubbing a plectrum (a basal extension of each antenna) over a file (located on the antennular plate below the eyes)[2]. This rasp, which is composed of a series of sound pulses, is ostensibly similar to stridulation-based sounds made by crickets, for example, in which a sound pulse is produced when a hard pick (plectrum) hits a macroscopic ridge on the file[1]. However, lobsters produce sound pulses without impact between hard structures; instead, a soft-tissue plectrum rubs over microscopic shingles on the file.

The lobster plectrum and file suggest a frictional mechanism[3] that is analogous to the 'stick-and-slip' that occurs between the bow and string of stringed instruments[4]. In stringed instruments, friction causes the bow to stick momentarily and then to slip relative to the string many times during the course of a single sweep of the bow across the string. This unsteady movement of the bow relative to the string excites vibrations and produces sound. Although theoretically possible in biological systems[5], such a mechanism has not been found until now.

In the lobster stick-and-slip model, sliding friction between the plectrum and file surfaces would intermittently exceed static friction as the two rub together. The soft, elastic tissue of the plectrum resists compression and hence would store energy during the 'sticking' phase and release it during the 'slipping' phase. Each slip between the two surfaces would thus generate a sound pulse.

To test whether palinurid lobsters produce sound using such a stick-and-slip mechanism, I first measured the correlation between plectrum movement and sound production. Using the Caribbean spiny lobster *Panulirus argus*, I attached a motion detector to the plectrum and used a hydrophone to record rasps. Sound was generated only when the plectrum moved posteriorly against the anteriorly projecting shingles on the file. This posterior movement consisted of alternating still and sliding periods; sound pulses were produced only during the sliding movements (97 rasps; 6 lobsters). Using

---

[1] Ewing, A. W. *Arthropod Bioacoustics: Neurobiology and Behaviour* (Cornell Univ. Press, Ithaca, 1989).

[2] Phillips, B. F., Cobb, J. S. & George, R. W. in *The Biology and Management of Lobsters: Physiology and Behavior* (eds Cobb, J. S. & Phillips, B. F.) 1–82 (Academic, New York, 1980).

[3] Meyer-Rochow, V. B. & Penrose, J. D. *J. Exp. Marine Biol. Ecol.* 23, 191–209 (1976).

[4] Benade, A. H. *Fundamentals of Musical Acoustics* (Dover, New York, 1990).

[5] Fletcher, N. H. *Acoustic Systems in Biology* (Oxford Univ. Press, New York, 1992).

high-speed video analysis, I found that the frequency of shingle impacts was 19,000–28,000 Hz (5 rasps; 1 lobster), which far exceeds the average pulse rate (77 Hz; 139 rasps; 6 lobsters). This is inconsistent with a 'pick-and-washboard' mechanism, in which the pulse rate would be equal to the rate of ridge impact.

A single continuous muscle contraction should be sufficient to produce the series of stepped movements described here, just as a constant driven motion of a bow over a violin string produces repeated sticking and slipping[4]. Synchronous electromyographic, acoustic and plectrum-movement recordings showed that the promotor muscle[6] contracts tonically during the rasp (120 rasps; 6 lobsters). Thus, a single tonic muscle contraction generates a series of sound pulses. Furthermore, pulsed sound can be generated by manually dragging the plectrum over the file with a single pull. These results are further evidence for the presence of a stick-and-slip mechanism.

When attacked by predators, spiny lobsters produce rasps[3,7,8] which probably function as a startling deterrent[9]. Lobsters typically rely on their hardened exoskeletons for protection from attack, but they lack such protection when this is softened during the moult cycle[10]. Lobsters do not depend on the hard washboard structures typically used by arthropods to produce sound, but instead make use of frictional interactions between surfaces that do not need to be hard. They can therefore create loud sounds even with a softened exoskeleton during the moult cycle[11], deterring predators acoustically when their other structural defences are compromised.

---

[6] Paterson, N. F. *Ann. S. Afr. Mus.* 51, 1–232 (1968).
[7] Mulligan, B. E. & Fischer, R. B. *Crustaceana* 32, 185–199 (1977).
[8] Lindberg, R. G. *Univ. California Publ. Zool.* 59, 157–248 (1955).
[9] Masters, W. M. *Behav. Ecol. Sociobiol.* 5, 187–200 (1979).
[10] Aiken, D. E. in *The Biology and Management of Lobsters: Physiology and Behavior* (eds Cobb, J. S. & Phillips, B. F.) 91–163 (Academic, New York, 1980).
[11] Moulton, J. *Biol. Bull.* 113, 286–295 (1957).