THE EARS OF WORMS, CRUSTACEANS AND ANTS.

BY JAMES WEIR, JR., M.D.

Some recent investigations and experiments, carried out in my laboratory, have shown me that many of the very lowest of animals possess the sense of hearing, and that some of them even possess the power of tonal discrimination, showing clearly, by their actions, that musical sounds are pleasing or disagreeable, as the case may be. In our own ears, sound waves are transmitted from the ear drums through the small bones of the middle ear, the so-called "stirrup," "hammer" and "anvil," on into the inner ear, where they strike a peculiar arrangement of microscopic plates resembling somewhat the ivory keys of a piano. These plates or plaques are called the plates of Corti, and each plate vibrates in unison with some particular number of sound waves. The range of true tonal or musical discrimination in the human ear ranges from notes produced by from about twenty-seven vibrations per second to notes produced by five or six thousand vibrations per second. Some ears are able to hear much lower or much higher notes, while in other ears, some of the plates of Corti that register the highest and lowest notes seem to be absent. Thus, in my own case, I am unable to hear the lowest note when the keyboard comprises or reaches the seventh C; again, in the case of a friend, he is unable to hear the highest note (A″), of the organ when the piccolo stop is drawn.

Supported by these facts, and by deductions derived from certain experiments which will be detailed further along in this paper, I have come to the conclusion that many of the lower animals are capable of hearing sounds whose vibrations are so many or so few to the second, that our ears are unable to perceive them.

The lowest sound that the human ear is able to detect, is produced, probably, by about twelve vibrations per second, while the highest reaches about thirty-five thousand vibrations per second. By experiment, I think that I have actually demonstrated the fact that ants hear sounds that are produced by vibrations exceeding sixty thousand per second.

In a former paper ("The Senses in the Lower Animals," North American Review, February, 1894), I showed that common angle worms not only possess the senses of touch, taste and smell, but that they also, (Darwin to the contrary, notwithstanding), possess the sense of sight to a certain extent being able to discriminate between light and darkness by means of exceedingly primitive ocelli or pseudo sight organs.

Further study of these creatures leads me to the conclusion that they likewise possess organs of hearing.

If I tap with a pencil on the surface of the earth in my vermicularium, or vessel containing worms, the little animals will soon emerge from their holes and cast themselves about on all sides, as if in search of the noise which has aroused them from their slumber. The schoolboy performs the same experiment when he pounds the earth in search of bait for his Saturday's fishing.

Darwin was perfectly well aware of this fact, but he attributed the movements of the worms to a sense of discomfort arising from vibrations transmitted through the earth and felt by them.

Now, if the third caudal or tail segment of a common angle worm be frozen, and a thin section of its lower surface be placed beneath a low-power lens, two oval, pinkish bodies lying immediately beneath, and adhe-

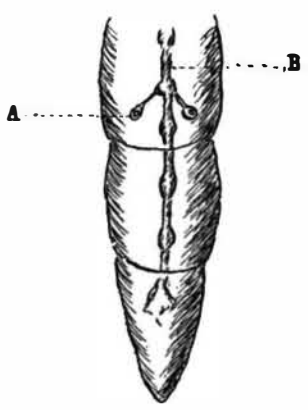

Fig. 1.

Auditory Organs of Earthworm (L. terrestris). A, auditory organ; B, noto chord.

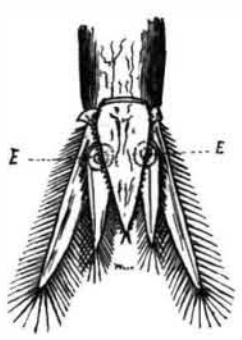

Fig. 2.

Tail of Shrimp, E, auditory organs (after Lubbock).

rent to the skin, can be readily made out. When the section is stained with eosin, these little organs become quite visible even to the naked eye. Two nerves start from these bodies, (one from each), and end in a ganglionic enlargement of the noto chord or central nerve.

If these bodies be removed and the worm be restored to the vermicularium, no amount of pounding will bring it from its hole during the day. Reasoning, by exclusion and by analogy, (the shrimp, not many steps higher than the worm, has its ears in its tail), I conclude that the bodies are organs of hearing, and that the worm actually hears the sound of the pencil's impact on the surface of its home.

The ears of ants are situated in their legs. If an ant's leg be examined, a curious enlargement of its canal will be at once observed. In the femur or thigh, the diameter of this canal is $\frac{1}{8000}$ of an inch, but when it enters the tibia it swells to the diameter of $\frac{1}{5000}$ of an inch, then contracts to $\frac{1}{700}$ of an inch, and then again, at the end of the tibia, expands to $\frac{1}{800}$ of an inch. At the upper sac, where it contracts, there is a conical, striated organ which bears some resemblance to the organ of Corti in our own ears. A special nerve arises in the sensorium, the terminal filaments of which are spread out over this peculiar conical body. The thin integument of the leg, where the canal is swollen or enlarged into sacs, forms a very efficient ear drum.

Experiments with tuning forks, whistles, etc., on ants, produced nothing definite, and I came to the conclusion that they did not hear sounds emanating from these instruments on account of the, to them, slow rate of vibration. I therefore resolved to construct an ap-

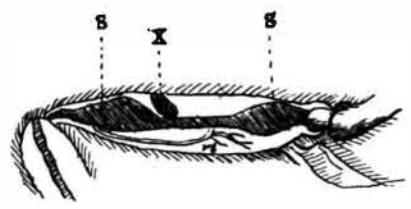

Fig. 3.

Tibia of Yellow Ant (L. flavus) slightly modified, from Lubbock. S S, swellings of large trachea; X, chordo tonal organ.

paratus that would, in my opinion, produce an extraordinary number of vibrations per second. With the assistance of a mechanical friend, by careful manipulation and after many failures, I made a wire, much thinner than a human hair, almost microscopic, in fact. This wire was tightly stretched between two pegs fastened in a board.

Taking the diameter of the wire, its tension, its length and the force of impact when I struck it with a small wooden hammer dressed in goldbeater's skin, we calculated that it would produce a sound having over 60,000 vibrations per second. Whether we were absolutely correct in our calculations, I am not prepared to state; yet I emphatically affirm that this instrument produced a remarkable effect on ants (L. niger) when any of them strayed near it and it was struck.

The behavior of the ants on such occasions was striking and peculiar. They would crouch down closely to the surface of the table, their antennæ moving rapidly and continuously; then, as though greatly alarmed, they would rush off at their greatest speed. I tried this experiment time and again, always with the same result. They were never alarmed when I struck guitar strings stretched between pegs; in fact, they went on their way without appearing to notice the sound at all.

The almost microscopic wire, when struck with the hammer, gave out no sound to my ears, though I listened intently. To the ants, however, it may have emitted, and probably did, a sound terrifying, startling, and alarming in its loudness and intensity. It sounded to them, perhaps, like the roar of some terrible monster, or like the awful peal, perhaps, of a hitherto unknown and unheard thunder. Some may contend that the ants were influenced solely by vibrations transmitted from the wire through the pegs to the board. If this were so, why were they not equally influenced by vibrations transmitted from guitar strings? The evidence seems to me to indicate and to prove conclusively that they were influenced by the sound of the wire vibrating many thousand times per second.

I am convinced that ants are deaf to all sounds heard by human ears, yet hear sounds that the ear of man is utterly incapable of detecting. That ants communicate with one another no one who has observed them will for one instant deny. A most careful and systematic search has revealed no vocal organs in ants such as the mammalia possess, consequently, if they communicate by sounds, they must produce them in some other way.

Many insects produce chirping noises by rasping two portions of their bodies, one against the other; the love songs of the grasshopper, cricket, katydid, etc., being made in this manner. I believe that the organs of sound in the ant are triangular spots on the upper surfaces of the third and fourth abdominal rings. These spots are finely ribbed, and when rubbed against the adjacent abdominal rings, as has been pointed out by Lubbock, must produce stridulation. From twelve to fifteen well-marked ribs or ridges will be found occupying a space about one-hundredth of an inch in length; and since we know that allied insects use a similar contrivance, (only it is situated in other portions of their bodies), for the purpose of producing sound, it is reasonable to presume that the ant does so likewise. Because we do not hear sounds produced by ants, is no reason for asserting that they do not make sounds, for, as I have explained, our ears can hear only sounds of so many vibrations; above and below a certain number of vibrations per second we are deaf.

A scientific note in Appleton's Popular Science Monthly, of recent date, states that certain observers distinctly heard ants making chirping or stridulating sounds, therefore it can be positively asserted that ants hear; for, if they have sound-producing organs, it necessarily follows that they have organs of hearing also.

At the bases of a lobster's antennæ are to be found two cul de sacs or pouches, one for each antenna. These are the creature's ears. The external covering or skin of these pouches is a continuation of the body covering, though somewhat modified in structure. In each pouch are always to be found several minute grains of sand, and these grains of sand play prominent rôles in the drama of audition, as experienced by the animal under discussion. The microscope shows that the floors of the ear pouches are papilomatous, or dotted thickly with minute papules or elevations, each surmounted by a hair. If one of these papules be examined with a high-power lens, a terminal nerve tuft will be found ensheathed in its thin walls; a microscopic nervule leads from it, together with thousands of its fellows, to the auditory nerve, which passes on into the sensorium. This description of a lobster's ears is derived from a careful study of fresh specimens, and is, I think, correct in all essential details.

In our own ears are to be found certain little stone-like bodies called "otoliths," which subserve a very useful purpose in audition. As I have stated above, small grains of sand are always to be found in the ears of lobsters; likewise, if the exuviæ or cast-off skins of lobsters be examined, minute sand grains will be found in the discarded ear pouches. These animals have discovered that these artificial otoliths increase their acuteness of hearing, therefore, manage to supply these adjuvants to audition from the ocean's bed.

A German scientist, Prof. Hassen, proved that they really do this by the following experiment, which I myself have likewise performed with complete success.

Taking advantage of the lobster's habit of exuviation, Hassen placed one, which was about to shed its skin, in a receptacle in which there was strained sea water, and in which there were no grains of sand. As soon as it had cast its old skin, he placed it in another basin of strained sea water, in which he had scattered some crystals of uric acid.

In a day or so he examined the ears of the lobster, and found in them certain crystals which, upon being tested, gave out the characteristic reaction of uric acid, thus showing that the lobster had sought out these unique otoliths, and had placed them in its ears.

Water is a good conductor of sound, and the lobster's ears are, therefore, very useful organs. It is warned by them of the approach of its enemy or its prey. I am convinced that it is able to hear any disturbance in the sand bed or rock bed of its house at the distance of two or three feet.

In 1889, while in New York, I procured some fine lobsters, and made them the subjects of careful study. After removing the eyes of one of them, I took a slender sliver or splinter of wood, and, drawing its point about over the sandy bottom of the tank in which the blind lobster was confined, could attract its attention, and occasion it to approach in the direction of the disturbance, when the point of the stick was two feet

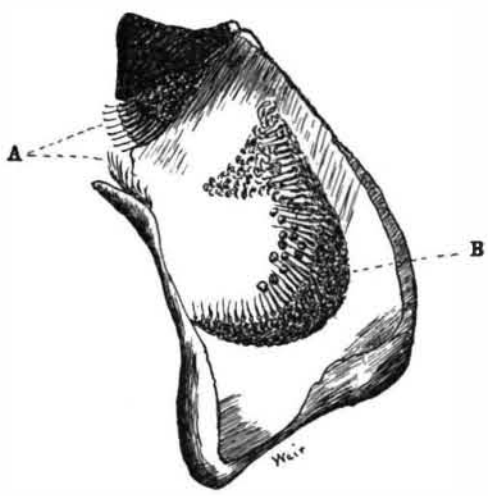

Fig. 4.

Ear of Lobster (modified from Farre). A, orifice; B, auditory hairs and sand grains ("otoliths").

away. When it had arrived within a short distance of the point of disturbance, it would rush forward and endeavor to seize the splinter with its claw.

A shrimp was placed in the tank and was observed as soon as it began to crawl. I am convinced that the lobster heard the footsteps of the shrimp, improbable as it may seem.

THE colors for signal lamps have been made the subject of a letter ballot by the Railway Signaling Club, with the following results: 26 for red (danger) and green (clear); 9 for red (danger) and white (clear); 3 for other arrangements. This represents a strong opinion in favor of the elimination of the white light for signals on the part of the men who manufacture and have charge of signal equipment.