XVIII.—*On a Possible Stridulating Organ in the Mosquito. (Anopheles maculipennis, Meig.)* By A. E. SHIPLEY, M.A., and EDWIN WILSON, F.E.S. *Communicated by Sir JOHN MURRAY, K.C.B. (With a Plate.)*

(Read 3rd March 1902. Issued separately 24th April 1902.)

At the base of the wings of *Anopheles maculipennis*, Meig, is a small quadrilateral area (fig. 2, Plate) which has escaped the notice of the systematist, since the nervures in which he is interested lie almost entirely beyond the area in question, and which has escaped the notice of the morphologist, because it presents to him but a confused outline of meaningless ridges and intervening depressions of no structural importance. If, however, the well-preserved wing of a mosquito, whilst still attached to the thorax, be examined, a very curious apparatus can be made out, lying across the centre of the said quadrilateral area which is bounded posteriorly by the alula.* This apparatus lies at about equal distances from the anterior and the posterior edge of the wing, and divides the base of the wings roughly into two halves.

The arrangement of the apparatus is not quite constant in different specimens; details vary, but the following points can in all cases be made out. It should, however, be mentioned that the apparatus is very minute; that it lies very close to the thorax, hence, if the wings be cut off, it is almost certainly destroyed, and thus there is small chance of seeing it in a detached wing; that it is only visible when the wings are extended, a position in which it is not always easy to mount the insect; and finally, that when the wings are at rest and folded back over the abdomen, the details of the apparatus are obscured and become confused in a mass of ridges and furrows, from which they can hardly be disentangled by the eye. The presence of the striated scales on some of the ridges of this part of the wing still further serves to obscure the parts in question.

The structure of the apparatus is very complex, but can be easily realised from an inspection of fig. 1, Plate, which represents the right half of the thorax of *Anopheles maculipennis* with the base of the right wing and the right halter. To bring out the structures of the parts in question, we have coloured them, and it will be seen at a glance that they fall into two series, an anterior one, which we have coloured blue, and a posterior set of structures, which we have coloured yellow.

The anterior system consists of a slightly movable bar A, which covers a thickening in the tissue of the wing. This last-named ultimately passes into the sub-costal nervure. The bar extends from the articulation of the wing to the humeral

* NUTTALL and SHIPLEY, *J. Hygiene*, i., 1901, p. 474.

cross-nervure,* and, as we have stated, we consider it to be slightly movable. On its hinder, free edge the bar carries a series of thirteen to fifteen well-marked teeth, which, under certain circumstances, rasp across a series of ridges borne on the second part of the system, which we now proceed to describe.

This is coloured yellow in our Plate. It consists primarily of a chitinous blade B, shaped something like a butcher's knife, which is ridged on its upper surface with thirteen to fifteen sharply-defined elevations placed slightly obliquely. It is against these ridges that the teeth of the bar mentioned above rasp. The relative position of the bar and the blade is not constant. The latter is usually lying partly under the former, but at times it is free from it, and it seems as though it were hinged at the handle and can oscillate through a few degrees, around an axis at the base of the proximal end. But it cannot rotate very far. A little way behind the back of the blade is an upstanding flange of the membranous tissue of the wing, which we have called the trough C. This trough catches and holds the blade, and prevents the latter being thrown too far back.

It is worthy of note that the wing area between C and A, over which the blade travels, is quite smooth and entirely free from the minute hairs or prominences which cover the rest of the wing. A similar freedom from these processes is found beneath the next region of the apparatus to be described, and this, in our opinion, is also slightly movable. These are the only two regions of the entire wing which are quite smooth and free from hairs.

The base of the blade or handle is held in position partly by being clamped by the overlying bar A, and partly by a chitinous flap of the wing marked H in our figure. Underneath this is a knob or process which may act as a fulcrum on which the knife rotates.

Running from the extreme proximal end of the knife handle to the posterior inner angle of the wing are a series of sclerites of irregular outline, roughly recalling in shape a number of knuckle bones. The most distal of these, D, seems to send a process into a hollow at the extreme base of the knife, and may very probably serve to throw the latter in, and out of, gear. The middle sclerite E seems to be articulated with the proximal F by a very distinct joint, and the proximal runs into the thorax, just ventral to the scutellum, and forms the attachment of the wing to the body at the posterior edge.

The bases of the middle sclerites are overshadowed by a flange G¹ which is supported by the thickened ridge G which forms the outer limit of the squama.

It must be remembered that the attachment of the wing is not in one horizontal plane, but the line of junction has a slightly oblique course. The posterior edge of the base of the wing is slightly dorsal to that of the anterior end of the same. Hence it seems probable that, as the wings are raised and depressed, there will be a shearing action between the slightly movable toothed bar A and the ridged blade

* *Vide* NUTTALL and SHIPLEY, *J. Hygiene*, i., 1901, p. 475.

B, and we think that this movement of these two ridged surfaces, one on the other, is responsible for some of the characteristic buzzing of the mosquito.

The exact cause of the note of a mosquito has been a matter of much dispute. The following extract from a paper published last January by one of us, in collaboration with Dr G. H. F. NUTTALL, describes some experiments made last year at Cambridge on this subject :—

‘ According to HOWARD* the sound during flight is “apparently produced, as with flies and other dipterous insects, not by the rapid vibration of the wings, but by the vibrations of a chitinous process in the large tracheæ just behind the thoracic spiracles. These vibrations are produced by the air during respiration.” He furthermore states that the sound produced in its flight is higher in *Culex* than it is in *Anopheles*, adding that “the villain in the play has usually a bass voice.”

‘ Our experiments do not support HOWARD’s assertion with regard to the wing not producing a note, for we have found by cutting off more and more of the wing that the sound decreased in volume, the note rising progressively. When the wing was cut off quite closely, a very high-pitched note of slight intensity remained, this, as we supposed, being produced by an internal apparatus such as HOWARD indicates. It may, however, be due to respiratory movements which are exaggerated through the efforts at flight. The sound is not produced by the insect in repose. We found that the males gave a higher-pitched note than the females, and that the note was higher in both sexes when they had fed; the greater the meal, the higher the note. Of four unfed females, three gave notes within a quarter of a tone of 264 (*i.e.* of 240 to 270 vibrations), the fourth female gave an abnormally low note of about 175 vibrations. Four other females were arranged in the order of the distension of the abdomen by food, the last being largely distended; these gave notes corresponding roughly to 264—281—297—317 vibrations, or according to the musical scale, the notes :

‘ Three unfed males gave exactly the same note, viz. corresponding to 880 vibrations ; immediately after feeding one gave the note A#, another which had fed well B♭. The unfed males were more closely concordant than the unfed females, the latter varying over about a semitone. Mr J. W. CAPSTICK, M.A., Fellow of Trinity College, Cambridge, to whom we are greatly indebted for making these ear determinations for us by means of tuning-forks, was not certain that the note given by the males was not one of 440 vibrations. Overtones were obviously strong, and it sounded at times as if there were a faint note of 440 vibrations overshadowed by a strong one of 880.

* *Mosquitoes*, by L. O. HOWARD. New York : M'Clure, Phillips & Co., 1901, p. 14.

‘The obvious explanation of the higher note given off by the males is that their wings are markedly narrower and shorter than those of the females. Although a female *Culex pipiens* gave a higher-pitched note than a female *A. maculipennis*, we are not at all sure that it was not simply due to the smaller size of the former insect. The male of this species of *Culex* certainly gave a higher-pitched note than the female.’*

In the experiments described above, the note increased in pitch as the wings were shortened, until a very short stump was left. As long as these stumps were left on the body, a note was heard. These stumps would certainly include the stridulating apparatus figured on Plate, which lies very close to the thorax at the base of the wings. Dr NUTTALL assures us that when these stumps were removed, all perceptible sound ceased. Thus it appears, that as long as the very small portion of the wing which includes the stridulating organ remains on the body, a note is heard, but when this be removed no sound is perceived. This is evidence that the sound proceeds from the base of the wings, and not from the spiracles or other parts of the thorax.

Mons. J. PEREZ† has carefully gone into the question of the production of sound in the Diptera. He shows, experimentally, that the stigmata take no part in the production of sound. “Les causes du bourdonnement résident certainement dans les ailes.” He, too, points out that if the wings are cut short the note becomes more acute, until the ‘timbre’ resembles that of certain interruptors which break, and make an electric conductor. This sound we should attribute to the stridulator described above. Mons. PEREZ definitely states that both in the Diptera and in the Hymenoptera, the buzzing is due to two causes, “l’une, les vibrations dont l’articulation de l’aile est le siège et qui constituent le vrai bourdonnement; l’autre, le frottement des ailes contre l’air, effet qui modifie plus or moins le premier.” The apparatus we have described is, we believe, the mechanism by means of which his first vibrations are produced.

In the same periodical‡ Mons. JOUSSET DE BELLESME confirms the statement that both Dipterous and Hymenopterous insects emit two sounds, one deep and one acute, and states that the latter is usually the octave of the former. It is this double note which gives rise to the peculiar buzzing associated with these two orders of insects. Mons. DE BELLESME, like Mons. PEREZ, discards the view that acute sounds are due to any action of the issuing air in the stigmata, and attributes it to the vibrations of the pieces of the thorax which support the wing, and which are moved by the muscles of flight. It is usually stated that these muscles are not inserted into the wing, but into the sides of the thorax, to which the wing is so attached, that when the lateral walls of this part of the body are deformed by the action of the muscles, the wings move up and down. But whether this be the case or not, it is clear that the vibrations of the sides of the thorax caused by the muscles of flight—and causing the vibrations of the wing—will synchronise in number with these wing vibrations, and will give forth the same note. The existence of the higher note—‘usually the octave’ of the one produced by

* *J. Hygiene*, ii., 1902, 77 f.

† *C. R. Ac. Paris*, lxxxvii., 1878, p. 378.

‡ *Ibid.*, p. 535.

the wing vibrations—is unexplained by this view. It is, however, easily explicable if such a stridulating organ as we have described at the base of the wing in *Anopheles maculipennis* be found in other Diptera and in Hymenopterous insects.

On Plate we have thought it well to figure the upper surface of the halter as seen under a high magnification. The drawing shows the hinge on which the halter quivers, the basal-papilla-plate, as WEINLAND * calls it, and the same author's 'skapale'-papilla-plate of the upper side. The papillæ of the basal-papilla-plate are continued on to its under surface, and only a few are shown in our drawing.

There is little doubt that the main functions of the halteres is that of balancing and orientating the insect. They may, however, have some secondary function; in some flies they are known to vibrate with extreme rapidity. It is just possible that in these rapid vibrations the papillæ of the concave surface rubbing against those of the convex basal plate may produce a note. As long ago as 1764, VON GLEICHEN-RUSSWORM † observed that when the halteres of the common house-fly are removed, the amount of the buzzing is diminished. This, however, in all probability, is due to the diminished activity of the wings. On the other hand, Mr STANLEY J. GARDINER informs us that he has noticed that mosquitoes still continue to give forth a faint note even when their wings are quite at rest, and this may possibly be caused by the halteres.

* *Zeitschr. wiss. Zool.*, li., 1891, p. 55.

† *Geschichte der gemeinen Stubenfliege*, Nuremberg, 1764.

[EXPLANATION.

EXPLANATION OF PLATE.

FIG. 1. Right half of thorax of *Anopheles maculipennis*, Meig, with base of right wing and right halter. Magnified about 90-100.

FIG. 2. The same magnified about 15 to show the area which bears the stridulator. This is coloured blue.

- A. Toothed bar.
- A¹. The teeth which rasp on the ridges borne by B.
- B. Blade bearing the ridges R.
- C. Trough which limits the movements of B.
- D. Distal chitinous sclerite bearing a claw which works in.
- D¹. The hollow at the base of B.
- E. Intermediate sclerite between D and F.
- E¹. Hinge between E and F.
- F. Proximal sclerite which is inserted into the thorax beneath the scutellum
- F¹. Process on F.
- G. Thickened edge of squama.
- G¹. Fold of squama overhanging E and D.
- H. Process of chitin which overhangs the base of the blade.
- K. Distal end of halter.
- L. Concave area covered with papillæ.
- M. Knob.
- M¹. Hinge.
- N. Papillæ on knob.

SHIPLEY AND WILSON: STRIDULATING ORGAN IN THE MOSQUITO