A DEMONSTRATION OF THE LOCATION OF AUDITORY ORGANS IN CERTAIN ORTHOPTERA.

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Although the organs associated with the tympana in the front tibiæ of Tettigoniidæ and Gryllidæ are called auditory organs, there seems to be little experimental evidence to show that they are organs of hearing or that these insects can hear at all. It is assumed that such organs are auditory in function because by structure they seem to be well fitted for that purpose. These sense organs, in common with so-called auditory organs in other insects, are characterized by the presence of minute peg-shaped structures known as auditory-pegs or *scolopalæ*. Among the crickets and katydids, only the species having stridulatory organs possess also the tympanal organs. Snodgrass (1) sums up the situation by saying that the principle argument in favor of their auditory nature is "if they are not ears, what are they."

Much has been written pro and con on the subject of whether insects can hear. Forel (2) after experimenting with various kinds of sounds concludes that with few exceptions, insects do not hear but that they are remarkably sensitive, through their tactile organs, to mechanical vibrations of the ground or objects on which they are resting. He states that only crickets and several other Orthoptera appear to perceive sounds. More recently a number of workers have demonstrated that certain Lepidoptera are able to detect sounds. Turner and Schwarz (3) working with Catocala moths and Turner (4) working with several Saturniidæ concluded that these moths could detect sounds. Minnich (5) experimenting with larvæ of *Vanessa antiopa* and Abbott (6) with Datana caterpillars found that these larvæ reacted to sounds but failed to do so when the body hairs were loaded with water or other substances.

The fact that certain species of singing Orthoptera synchronize their notes, seems to me conclusive evidence that they can hear each other. Such a simultaneous sounding of notes could hardly be a matter of accident. Neither is it an auditory illusion as some writers have claimed. Allard (7) has demonstrated this, I think, conclusively.

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Synchronized stridulation is exhibited by a number of species of Orthoptera. The snowy tree cricket, *Oecanthus niveus*, De Geer, is perhaps the best known example. During the past summer I observed synchronization in two local species of Tettigoniidæ. While studying the songs of these insects I was impressed with the idea that here was excellent material for testing the auditory powers of the tympanal organs on the front tibiæ. Accordingly I set about collecting males of all such species as were available in this locality.

The first species collected was *Amblycorypha rotundifolia brachyptera* Ball (*A. iselyi* Caudell), a short winged katydid inhabiting the prairies. This insect starts singing in the afternoon and as evening approaches the number of singers increase. The song is a series of 20 to 30 short metallic rasps at the rate of 4 per second (at 67° F.). Each series of notes last about 5 to 7 seconds and is followed by a period of rest of about 5 seconds.

The synchronism exhibited by the ten males which I placed in one cage was almost perfect. The song of the group was continuous and as each individual started its series of notes anew it would fall in with the general cadence. It was only by detecting slight variations in the quality and volume of the chorus that one could be aware of the pauses in the individual songs.

After observing the song of the whole group for two nights I removed four males to another cage at some distance from the first and with a small scissors cut off their front tibiæ close to the femora. For the two following nights only one of the mutilated katydids was heard singing at one time. On the third night two sang more or less continuously. The notes were not synchronized except as they happened to sound together at times. The two males happened to have slightly different normal rates so that if they started their series of notes in unison they would usually be sounding them alternately at the close. I observed 36 consecutive periods when both males were singing at once and of these there were only two when the notes did not interfere at some time, during the period. Following these observations I went back to the cage of normal insects and listened carefully to four singers for ten minutes. During this time there were only two short intervals during which a few notes were sounded out of cadence as one of the singers began a series of notes.

In order to be doubly sure that my senses did not deceive me I requested someone who had no knowledge of the experiment to listen for a few minutes at each cage to see if they could detect any difference in the songs. This observer noted at once that the song was rhythmical and synchronized in the first cage but not in the second.

The katydids in both cages continued to live for a few weeks and their songs were observed many times but always with same results. At times as many as three of the mutilated males could be heard singing at once, with a still greater confusion of notes.

I next collected a number of snowy tree crickets (*Oecanthus niveus*, De Geer) and caged them in two lots. The song of this species is a clear whistling note rhythmically repeated for an indefinite period. After waiting a few days to see that both cages contained willing singers, I amputated the front tibiæ of one lot and removed their cage from the vicinity of the other lot. The results were essentially the same as with the preceding species. When only two of the mutilated males were singing at once the effect was that of being synchronous at regular intervals separated by periods during which the notes sounded alternately. This effect is produced by any two sets of rhythmically repeated sounds having a slightly different frequency. Each cricket sang at its own individual rate uninfluenced by the song of others in the same cage. When three or more mutilated males were singing at once an utter confusion of notes resulted so that the rhythmical quality of their songs was entirely obscured.

The song of the normal tree crickets in the other cage presented a striking contrast. Each individual sounded its notes in unison with the others, as if a single cricket were singing.

The third insect I experimented with, the Nebraska conehead, (*Neoconocephalus nebrascensis*, Bruner) proved to be the most remarkable synchronist of all. The song consists of a series of rasping buzzing notes each lasting a little over a second and separated by about equal intervals of silence. The length of the notes and their low frequency makes this species an easy one to study. At a temperature of 76° F. there were only 23 to 24 notes per minute. I have observed them in the field synchronizing their notes at a distance of 20 paces.

I used only four males for my experiments with this species. It is rather difficult to collect for it sings only at night and each specimen has to be captured by careful stalking while it is singing. The four cone-heads were placed in individual cages and separated into two lots, which were kept out of hearing range of each other. After testing both lots for synchronism, which proved to be perfect, the front tibiæ of one lot were removed.

On the second evening after this operation both cone-heads were singing with a very conspicuous lack of coordination. For about a minute at a time the notes of the two individuals would sound alternately, then gradually one song, would catch up with the other so that for another similar period the notes would sound simultaneously.

At the same time the normal cone-heads in the other two cages were keeping up perfect synchronism. Sometimes one note could be observed to start a fraction of a second ahead of the other but never once did I hear them entirely separated.

The removal of the front tibiæ of the insects used in these experiments did not seem to affect their general health in any way. Those operated on lived as long as the normal ones. Among the jumping Orthoptera the loss of one or more legs is apparently a matter of small consequence. They will voluntarily kick off one or both hind legs in order to escape when captured.

Conclusions.

The species of Gryllidæ and Tettigoniidæ which practice synchronized stridulation are able to do so by virtue of auditory organs located in the front tibiæ or tarsi. The foregoing experiments confirm the theory that the tympanal organs of the front tibiæ are auditory organs, an assumption based on the circumstantial evidence of their structure and the fact that they are present only in stridulating species.

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