A chrysalis stridulating by means of instrument on inside of cocoon.*)

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(With 5 figures).

One day toward the end of September 1944 at Peitaiho Beach, North China (39° 47' N 119° 27' E), I heard from some (false) acacia (or locust) shrubs (*Robinia pseudacacia* L.) a stridulating sound produced at a somewhat slower rate than the grasshopper calls usually heard there. Also the tone was more hissing. I found that it came from a spot where a medium sized parasitic wasp was sitting boring into a somewhat swollen part of an acacia twig about 1 cm thick. The swollen part looked like a twig gall, about 5 cm long, shaped as the one half of a longitudinally cut cigar, but apparently lying entirely under the bark (Fig. 1). The sound continued until the wasp flew away.

Seeing no reason why a parasitic wasp should stridulate, I marked the spot in order to cut out the gall occasionally later. However, a few days later I was attracted by the same sound from two closely adjacent similar galls on another acacia scrub. This time no wasp was seen, although the sound did not cease.

Putting the finger on one of the galls I found that it was soft like paper. I cut it open at the edge and found within it a yellow Lepidopterous larva *Eligma narcissus* Cr. (Family *Noctuidae*), very commonly seen

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feeding on *Ailanthus altissima* Swingle. It is yellow with black cross lines, has between each pair of lines 1—2 cross rows of black dots, and possesses on the black lines some long light hairs.

When the larva was taken out, the sound ceased. When it was put back, the sound started again. I could not make sure from which of the two cocoons it came, and so I cut open the other one.

It contained a brown pupa in violent motion. The isolated pupa, however, though violently wriggling its hind part from side to side, gave no sound. As soon as it was placed again in the cocoon (which had been only cut along its one margin), some noise was again heard but not as loud as before. It appeared to come from the lower part of the cocoon.

I removed the cocoon and found at the lower end of its inside wall a horizontal row of 11 vertical white ridges; the outer about 3, the inner about 7 mm long. That looked like a stridulation rasp (Fig. 2). Looking for the scraper organ at the hind end of the chrysalis I actually found it there on its back (Figs. 3 and 4).

Evidently I had re-placed the chrysalis in the cocoon in a wrong position. It should be placed with the back facing the cocoon wall and with the front facing the bark. As a matter of fact it is also shaped in accordance with this, being flat toward the tree and rounded toward the cocoon wall.

When I brought the removed cocoon and chrysalis to my house and placed them on a table, I could satisfactorily ascertain, that when the cocoon was placed over the chrysalis, the characteristic stridulation was produced only when the chrysalis was placed with back upwards, whereas a faint and uncharacteristic sound was produced when it was placed with front upwards. The method of stridulation was thus clearly demonstrated.

The abdomen moves rhythmically from side to side,

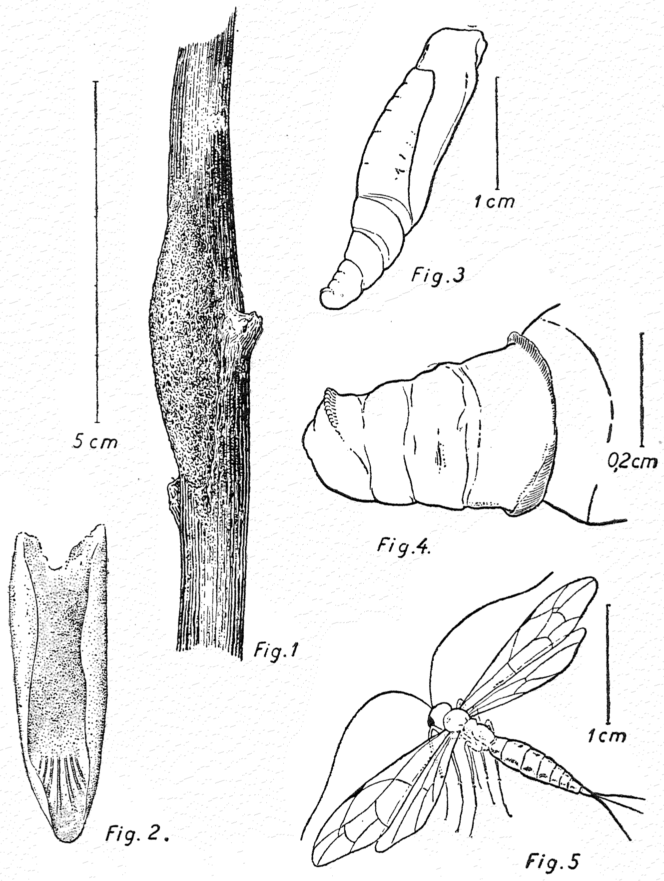

Fig. 1: Cocoon of *Eligma narcissus* Cr. on a twig.

Fig. 2: Inside of cocoon with rasp. Fig. 3: The chrysalis.

Fig. 4: Hind part of chrysalis with scraper organ.

Fig. 5: The parasitic wasp (*Pimpla* sp.).

The drawings are made by Mr. Poul H. Winther: Fig. 1, directly; the other figures, on the basis of drawings in pencil by Claire Hirschberg-Taschdjian, B. Sc., Peking.

and as there is no extra space within the cocoon, these movements invariably bring about the rhythmic stridulation.

To me this was a new and striking observation, because I knew of no stridulations produced in insects by means other than friction of one part of the body against another part (*Orthoptera, Hemiptera, Lepidoptera, Coleoptera*). It is true that *Anobium* beetles and some termite soldiers produce sounds by tapping their head against external objects, but the manufacturing of a real sound instrument by the insect itself, appeared to me something particularly remarkable.

After it has thus been established *how* the stridulation is produced, the next question is: *When* is it produced? As already mentioned, it was heard in the absence of any external stimulation other than the presence of a larva in an adjoining cocoon. That in this case the movements of the larva caused the chrysalis to stridulate, becomes very likely, if not certain, from the following observations on a cocoon-building larva.

In order to study how the cocoon with its remarkable resemblance to the bark and the remarkable stridulating instrument, was constructed, I collected a large larva crawling on a wall and placed it on an *Ailanthus* branch in my laboratory. It had obviously left the nearby larva-infested *Ailanthus,* and was in search of a suitable place to build its cocoon. For although many larvae had built cocoons on the *Ailanthus* trunks, which were full of them, others seemed to have wandered about a great deal before starting to build. There was for instance no *Ailanthus* within 10 m or more of one of the acacias on which cocoons were found. And the larvae appeared not to feed on acacia leaves.

Such larvae as I have observed in the process of making cocoons, all started in the evening, and worked throughout the night, so I had to study the building of the cocoon partly by lamp light at intervals during the night. One larva which had just started to build its cocoon on a big *Ailanthus* trunk in the free at about 6 p. m., had disappeared shortly after and had possibly been snatched away by a cuckoo which just then happened to visit the locality on autumn migration. So it may be of some protective value for this rather conspicuously coloured larva to work by night, and later to be camouflaged in an apparent gall. When feeding by day on the leaves the larvae are not easily detected.

The larva starts its work sitting with head turned towards the top of the tree and builds up on each side of it a thin wall. The two walls are about 1 cm apart and incline obliquely outwards. Minute pieces of bark, on an average $\frac{1}{2}$ mm in diameter, are gnawed loose from the bark, often with visible exertion, and one by one spun together to form the rising walls. How each minute piece is added, can be easily studied with a magnifying glass, the larva being in no way detained from its work by close inspection. It builds up the two walls at the same time, alternately bending to the right and to the left to place its bark-particles. Yet it may go a few times successively to one side and then a few to the other side, the alternation left-right left-right not being followed rigidly.

Now, in the case of the larva studied in the laboratory, it had ascended the stem until it came to where there already was a cocoon with a chrysalis that had stridulated whenever I had touched the cocoon. Here it paused and started building immediately to the left of the cocoon already present.

The cocoons are often found closely adjacent, and it seems that larvae prefer to build where there are already other cocoons. Whether they are attracted by the material already freely available for building — for they use bark particles from the neighbouring cocoon — or by the stridulation which is heard as soon as they touch it, is difficult to decide. I believe it is the easily available material that attracts them.

Now, the larva in question caused the neighbouring chrysalis to stridulate every time it built on the right side where its wall was standing on the neighbour cocoon, whereas the latter became silent every time the building larva moved to work on to the left side wall. This very clearly shows that the stridulation was produced whenever the cocoon was mechanically stimulated.

In the free this was seen to occur when neighbouring larvae move and when a parasitic wasp settles on it.

Later during the construction of the cocoon the larva is seen to have turned round working with head down. Later again when the upper edges of the two walls are being brought together and the cocoon closed, it can again be seen working with head turned toward zenith.

The rasp is visible from without during the later stages of the construction, but eventually so much tapestry is placed on the inside that the cocoon ceases to be transparent. It takes a whole night to build up a cocoon.

So much as to *how* and *when* this stridulation occurs. I shall relate in the following some observations which suggest *why* it occurs, or rather what biological significance it has.

When the stridulation was heard in the open by day, I almost invariably found that it was caused by a parasitic wasp trying to bore through the cocoon. This was experienced repeatedly, and on various days and occasions. Only in a few cases is it caused by movements of other larvae, because these build their cocoons at night; and those having built the preceding night will be quiet and about to pupate.

It might be suggested that the stridulation serves to scare away the parasitic wasps. But the wasps I saw

— and they all appeared to belong to the same species with the common characteristic trait that the two sides of the sheath of the ovipositor stood straight out during oviposition — were not scared away. It is of course possible that the survival value of the stridulation should be sought in connection with some parasites which I have not observed, or which may even be extinct now. However, the parasitic wasps I saw were scared away by the approach of a third organism attracted by the stridulation, in casu me. Ordinarily it may be by the approach of a bird, attracted by the sound, and which may even in cases devour the parasites.

One wasp was seen repeatedly to try to pierce a cocoon in an awkward way with an apparently broken ovipositor. It is possible that the latter is occasionally broken through the violent movements of the stridulating chrysalis, in which not only the abdomen moves from side to side but the whole body is in violent motion; anyway, when the cocoon is opened. The movements may thus have a small additional survival value of their own.

Although any kind of mechanical stimulation of the cocoon brings about the stridulation, and although the parasitic wasps observed by me were not scared away by the stridulation, it is of course quite possible that the biological significance of the stridulation is to scare away such enemies as the parasitic wasps. Poisonous snakes succumb to the secretary bird, the mangouste, the hedgehog, etc., but no one would on these grounds deny the defensive value in general of the poisonous fangs of snakes.

Fascinating is the problem of the evolution of this extraordinary stridulation arrangement. It may be elucidated by looking for it in related forms.

Three cocoons into which the wasp had certainly had time enough to deposit its egg before leaving, stridulated the same day later when I touched them, but later they did not respond, and were collected. 31 such silent chrysalises were collected. Indeed the silent cocoons were perhaps in majority, and I believe they all contained parasites. 4 female and 1 male wasps hatched from them before $^{26}/_{10}$; another 5 females and 4 males before $^{23}/_{7}$ 1945. The genus is *Pimpla* as kindly determined from my specimens by Dr. V. F. Perkins at the British Museum (Fig. 5), but the species is uncertain.

Like most biological objects the rasp ridges vary in number. Out of 18 cocoons 15 had 10—13 ridges; 1 had 14; 1, 18; and one poorly developed one, only 8. The smallest ridges on each side are often very low and difficult to distinguish. Also sometimes 2 ridges may be confluent, in which case the counting of numbers are somewhat arbitrary.

Stridulation was heard as late as $^{27}/_{10}$ in cocoons kept in the laboratory. Two had not yet hatched $^{23}/_{7}$ 1945.

The larvae seem to use their hairs to put on the inside of the cocoon. One had built its cocoon on a wooden box. The one that had built a new cocoon after being robbed by me of the one it had already made, on $^{5}/_{10}$ stridulated in its new cocoon. It later hatched a moth. A pupa within a cocoon cut open at the side, stridulated one night incessantly. One or two days after I found that the pupa in the neighbouring cocoon had hatched, and I found the moth in the room. At least some of the cocoons delivered moths already in the autumn (in unheated room).

Postscript.

After this paper had been delivered for publication, a paper by Hinton has appeared (Trans. Roy. Entomol. Soc. 97. 3rd Dec. 1946, pp. 473—496) from which I learn (p. 475) that "a few Lepidopterous pupae which are enclosed in cocoons stridulate (to scare off enemies?). For instance, the pupa of an Oriental Hesperid, *Gangara thyrsis* Fabricius, makes a loud hissing noise by moving so that its roughened proboscis rubs the walls of ridged grooves on the ninth and tenth abdominal segments. This species also makes a loud rattling noise by rubbing its body against the surface of its pupal cell, as does a British Agrotid, *Pseudoips bicolorana* Fuessly, by rubbing its abdominal setae against the walls of its parchment-like cocoon." Also (p. 494) that the pupa of *Oryctes rhinoceros* L. has been heard to stridulate (Gravely in Rec. Indian Mus. 11, 1915, pp. 483—539) by means of the structures now described by Hinton (loc. cit.), also in various other beetle pupae, as gin-traps. The two jaws of such gin-traps are formed by toothed or smooth plates or ridges on the posterior margin of one segment and the anterior margin of the segment immediately behind. They may be single or paired; between one pair of segments only, or between several pairs; median or lateral, according to the way the pupa moves when stimulated. They are supposed to grip palpi, legs or other appendages of enemies the attack of which make the pupa wriggle.

Whereas stridulation have thus been observed in pupae other than that of *Eligma narcissus* Cr., with or without cocoons, the existence of a veritable scraper organ playing on a veritable rasp on the cocoon, is to my knowledge unknown.

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