PHYSIOLOGICAL VARIATION IN THE SNOWY TREE-CRICKET, OECANTHUS NIVEUS DE GEER.*

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One of the most copied mistakes in entomological literature is one which was made by C. V. Riley and other writers of his time, on the oviposition of the Snowy Tree-cricket (*Oecanthus niveus* De Geer). At that time many entomologists did not clearly distinguish between the two species, which in the eastern states are commonly associated in raspberry and blackberry bushes. The more common species in such situations is *Oecanthus nigricornis* Walker, which deposits its eggs in conspicuous rows in the berry canes, while *O. niveus* places its eggs singly by the side of the leaf axils, where they easily escape observation. Riley (1) figured the eggs of the former species under the name of the latter. This error has been copied many times and can still be found in new publications at least as recently as 1918.

Observations by several entomologists have led to a correct understanding of the habits of the two species. Packard (2) gives an account of *O. niveus* depositing its eggs singly in elm bark, but did not question the validity of Riley's statement. Houghton (3) (4) in 1904, reared *O. niveus* from singly deposited eggs in plum bark and in 1909 reared *O. nigricornis* from eggs deposited in rows in elder. Parrott (5) in 1909, showed by cage experiments that *O. niveus* preferred apple to raspberry for oviposition and that *O. nigricornis* was responsible for the rows of eggs in raspberry and blackberry canes. Parrott and Fulton (6) in 1913, describe and illustrate the eggs of *O. niveus*, as they are deposited on raspberry and blackberry, in the thickened cortex by the side of the leaf axils, rarely at other points, and never extending into the pith, (Fig. 1, B). The insect is here following the same method, which it uses on apple and other trees, that of depositing the eggs singly in the bark,

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but on berry canes and other thin barked plants the cortical layer is not thick enough for their purpose except at the leaf axils. *O. nigricornis* prefers to oviposit in close set rows in pithy plants and the eggs lie in a slanting direction, imbedded in the pith, (Fig. 1, A). When this species occasionally oviposits on a woody plant, such as apple, it places the eggs in the young twigs in the same manner.

Shortly after the writer moved to Corvallis, Oregon, he was called upon to identify some tree-cricket eggs deposited in a raspberry cane in a long compact row, exactly as described above for *O. nigricornis*. Without hesitation he named them as such. The piece of cane was not thrown away and on the following day, June 13, four young crickets were found with it. An examination of these specimens revealed not young *O. nigricornis*, but something identical with the first instar *O. niveus* as observed in the east. It was something of a surprise to the writer to have his firmly established conceptions about the oviposition of tree-crickets so rudely upset. The only possible explanation seemed to be that this was a new species closely related to *O. niveus*. Curiously enough, the known species most closely related to *O. niveus*, namely *O. angustipennis* Fitch and *O. exclamationis* Davis, both have egg laying habits very similar to the first species. So far as known the habit of placing the eggs in rows in the pith was confined to the closely related species *O. nigricornis* Walker, *O. quadripunctatus* Beutenmuller and *O. pini* Beutenmuller.

This type of oviposition, i. e., rows of eggs in the pith, was found very commonly among raspberries, blackberries and loganberries in western Oregon. No eggs could be found deposited after the method of *O. niveus* on such plants, i. e., singly by the leaf axils. An examination of prune and apple trees showed that they also contained tree-cricket eggs, deposited singly in the bark in the same manner employed by *O. niveus* on these trees in New York State.

Two Races of *Oecanthus niveus* in Oregon.

In late summer, when the tree crickets had matured, it became apparent that the crickets, which were so numerous on berries as well as those found on prune and apple trees, were practically identical with the *O. niveus* of the east. Series of specimens collected both from bushes and trees were carefully and minutely compared with each other and with specimens of *O. niveus* from Geneva, New York. No morphological or color characters could be found which would separate any one group from the others.

Observations on the song of the Oregon tree crickets showed that they had the intermittent, rhythmical, whistling notes characteristic of *O. niveus* in the east, but in this connection a most remarkable situation was found—in that those living in the fruit trees had a frequency of notes almost twice as great as those living on the berry bushes. This difference could not be accounted for on the basis of temperature or other environmental factors.

It seemed evident that there were two races of the Snowy Tree-cricket in Oregon, one living on berry bushes and the other on fruit trees. The writer set out to make a more detailed study of the life habits and ecological distribution of each form and to see if they retained their habits if transferred from one environment to the other.

For convenience in describing further the habits of the two races they will be designated as *O. niveus* A for the arboreal form and *O. niveus* B for those living in bushes.

Ecological Distribution.

The *O. niveus* of the eastern states is not only found on a great variety of trees, but is also a regular inhabitant of berry bushes and many other low shrubs.

O. niveus A is strictly arboreal. In the vicinity of Corvallis, Oregon, this form is most common on prune and apple and in the native growths of white ash and Gary Oak. I have also heard it singing in cherry, maple and poplar trees. It is usually more abundant among the higher branches and could be heard singing in the tops of quite large trees. The only berry bushes I have found it in were tall, coarse blackberries growing under trees.

O. niveus B is preeminently a bush inhabiting form. It is very common on loganberry and raspberry, and to a somewhat less extent, on blackberry. It occurs abundantly in the wild rose thickets, which are so common in the Willamette Valley. It is widely distributed though not abundant, among the brake ferns and associated plants in old burned areas in the Coast Range.

At the edge of a deciduous woods where there is a scrubby growth of young trees and bushes the ecological ranges of the two forms come together, but the extent of such contact is relatively small. Occasionally in such places both races may be heard singing in the same bush or small tree.

In this connection it is interesting to note that *Oecanthus nigricornis*, which is the most common inhabitant of berry bushes in the east, is not found in such situations in western Oregon. The closely related species or western variety, *O. argentinus* Saussure, is rarely found on berry bushes. Its distribution is usually confined to medium sized weeds in open fields and prairies.

Oviposition.

The eggs of *O. niveus* A are placed singly in the bark of trees, (Fig. 1, C). In prune and ash trees they were found in branches from one to three inches in diameter. On ash trees they were usually located near side branches where the bark is somewhat thickened and rough. Eggs found on a vertical or sloping branch were most often located above the puncture, but there is considerable variability on this point. On horizontal or sloping branches, 75 per cent or more were located on the lower side. The females evidently prefer to work head downward on the lower side of a branch. Our observations on the species at Geneva, New York, show that the females there usually oviposit head uppermost on the upper side of a branch. A pellet of excrement is often used by *O. niveus* A to stop up the hole after the egg is deposited, as is the case in the eastern states. In cage experiments with form A, it was later found that plugs of chewed bark were sometimes used. This we have never observed in the eastern form.

The eggs of *O. niveus* B are placed in compact rows with the eggs all slanting across the pith, (Fig. 1, A). Most rows average about one egg per millimeter, but occasionally they are more scattered. The number of holes per row varies from 2 to 40. Rows of 10 to 20 are common. In vertical stalks the eggs usually extend downward from the point of oviposition, or in other words, the female works head uppermost, which is at variance with race A, but agrees with *O. niveus* in New York and Iowa. On horizontal or sloping branches most of the punctures are drilled on the underside. This habit agrees with race A, but in the east *O. niveus* usually oviposits on the upper side of a branch. After depositing the egg, race B covers the puncture with chewed bark, removed from a point just above the hole. The resulting scar is used as a starting point for the next drilling operation. This habit is exactly like that of *O. nigricornis*, which differs from race B in its oviposition only in its decided preference for the upper side of a stalk.

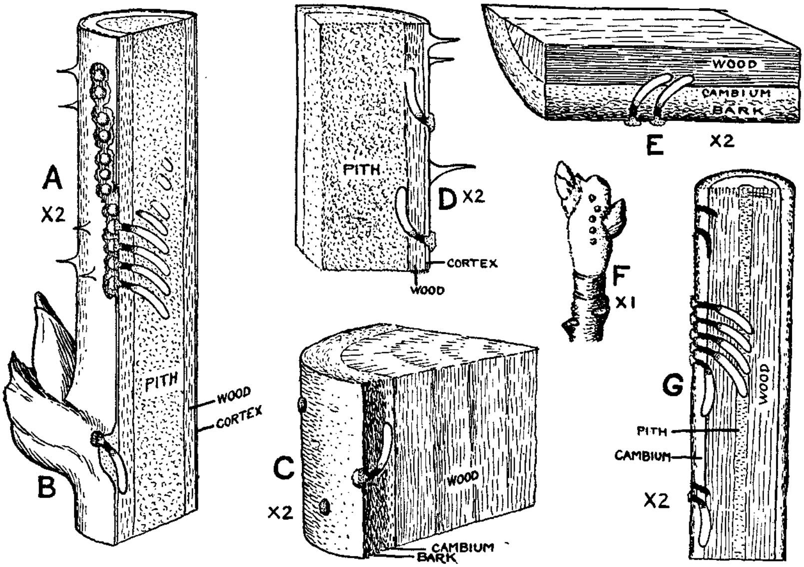

Fig. 1. Methods of oviposition used by varieties of *Oecanthus niveus*. A, Normal method of *O. niveus* B, and also *O. nigricornis*, in raspberry and other pithy plant stems. B, Normal method of *O. niveus* on raspberry in the eastern states. C, Normal method of *O. niveus* A on branches of trees. D, Forced oviposition of race A on blackberry, (Exp. A, 2). E, Forced oviposition of race B on apple branch. (Exp. B 10 and B 11). F, Oviposition of race B in green growth at tip of a side spur, when confined on an apple branch. (Exp. B 1 to B 5, Sept. 7). G, Oviposition of race B in hard watershoot of apple when given choice between that and a larger branch. (Exp. B 16).

The eggs of the two races of *O. niveus* in Oregon show no differences in the ornamentation of the cap at the cephalic end. Series of fifty of each kind showed slight relative differences in the total length and length of the cap. The average measurements in mm. are as follows: Race A, length, 3.16, width .67, length of cap .50, width of cap .52. Race B, length 3.01, width .68, length of cap .40, width of cap .52.

Oviposition Experiments with Oecanthus niveus, A.

Exper. No. of Female	Caged on September 9	September 14	September 22	October 24
A 1	Apple 14 mm. diam. Loganberry 6 mm. diam. (indoors)		25 eggs in apple. All placed singly in bark. No eggs on loganberry.	
A 2	Loganberry 3 mm. and 6 mm. diameter. (indoors)		24 eggs in larger cane, all imbedded in cortex and wood. Transferred to blackberry. 9 mm. diameter.	Cricket alive. 13 eggs all in cortex and wood.
A 3	Apple branch 20 mm. diameter with 2 small side spurs.	Several punctures observed.		Cricket dead. 14 eggs in bark, all but 2 on under side.
A 4	Loganberry cane close to ground.	No punctures on loganberry. Transferred to prune 20 mm. diameter.	Cricket alive. Punctures observed but not counted.	Cricket dead. 23 eggs deposited singly in bark. All but 4 on under side of branch.
A 5		Loganberry, 6 mm. diam.	Cricket alive.	Cricket dead. No eggs.
A 6		Loganberry, 7 mm. diam.	Cricket alive.	Cricket dead. No eggs.
A 7		Loganberry, 8 mm. diam.	Cricket alive.	Cricket dead. No eggs.
A 8		Grape, 5 mm. diam.	Cricket alive.	Cricket dead. No eggs.
A 9		On apple, watershoots. 5 and 8 mm. diam.	Cricket alive.	Cricket dead. No eggs.

OVIPOSITION EXPERIMENTS WITH OECANTHUS NIVEUS, B.

Exp. No. of Female	August 29	September 7	September 14	October 24
B 1, B 2, B 3, B 4, and B 5.	Apple branch 20 mm. diameter with small side spurs.	5 eggs in pith of green growth at tip of side spur. 2 incomplete punctures in large branch. Transf. to ornamental rose.	Row of 8 eggs in twig of 2–3 mm. diam. All in pith. 3 others in wood of larger twigs. Transf. to loganberry. 5–10 mm. diam.	Crickets dead. 95 eggs in 23 compact rows of 2 to 9 eggs. All but 8 in larger branch. All imbedded in pith.
B 6, B 7	Prune branch 20 mm. diameter. No side spurs.	No eggs. No punctures. Transf. to grape, 5 mm. diameter, present year's growth.	Compact row of 7 eggs, all slanting across pith. 7 incomplete punctures.	
B 8	Prune branch 16 mm. diameter. No side spurs.	No eggs. No punctures. Transf. to apple watershoots.	Crickets dead. No eggs.	
B 9	Prune branch 25 mm. diameter, with side spurs.	No eggs. No punctures. Transf. to loganberry.	Compact row of 10 eggs. All in pith.	
B10, B11		Apple branch 30 mm. diameter, with watershoot 4 mm. diameter.		Crickets dead. Row of 8 eggs in watershoot. Underside of large branch with 18 eggs.
B12, B13, B14		Wild rose, various sizes snowberry, 5 mm. diam. (indoors)	20 eggs in 3 mm. branch of wild rose. In 4 compact rows. All imbedded in pith.	
B 15		Apple branch 16 mm. diameter. Loganberry 6 mm. diam. (indoors)	(Sept. 22) 45 eggs in loganberry in 4 compact rows of 7, 9, 12 and 17 eggs. All imbedded in pith.	
B 16		1 apple branch 12 mm. diameter. With side spurs. (indoors)	(Sept. 22) No eggs. 4 incomplete punctures in spurs which had become dry. Trans. to apple branch 16 mm., watersprout, 6 mm.	Cricket dead. 22 eggs in sprout. Rows of 2, 4, 4, 8. Four single eggs in cambium. All imbedded in wood and pith.

Oviposition Experiments.

A series of experiments were carried out to determine the effect of transferring the two races from their normal host plants to those of the other form.

The insects were collected from pure stands of each race as determined by the character of vegetation, by the songs of the males and by the presence of eggs deposited in the characteristic manner. Race B was taken from loganberries and race A from apple, prune and oak trees. At the time the experiments were started the tree crickets had been mature about a month and had fully formed eggs in the body. All of them were fed on aphids during the experiments. They were caged on growing plants except where it is indicated that the experiment was performed indoors. The cages were made to surround a portion of a branch without cutting it off.

Notes on Oviposition Experiments.

A1. Of 25 eggs, all but two are directed upward from the puncture. Most of the holes are plugged with chewed bark, but some were plugged with excrement.

A2. On loganberry. Only four of the 24 eggs were placed at the side of leaf axils after the manner of *O. niveus* in the east, except that in these cases the eggs extended upward from the puncture. The other eggs were imbedded partly in cortex and partly in the underlying woody layer. Some of them reached the pith but none extended into it.

On blackberry.—Seven eggs and three empty punctures were found at leaf axils. Six eggs and numerous partially completed punctures were found in various other parts of the bark. The soft cortical layer was only about a half millimeter thick, so that most of the eggs were imbedded in the underlying woody layer, which was about a millimeter thick. Two eggs extended partly into the pith and one was almost entirely in the pith, but in these cases the eggs lay just under the woody layer and parallel to it, (Fig. 1, D), instead of slanting across the pith as when deposited by form B.

B1 to B5. In the first cage these females refused to oviposit in the large apple branch. A row of five eggs was found in the green terminal growth of a side spur, (Fig. 1, F).

The crickets were then confined on ornamental rose on twigs varying from 10 mm. in diameter to very small ones. Numerous attempts were made by the crickets to bore through the wood of the larger twigs, but apparently it was too hard for all the punctures terminated in the wood. Three eggs were found in holes which did not reach the pith. The only rows of eggs were in a small terminal twig; a row of five where the twig was 3 mm. in diameter and a row of three where it measured 2 mm.

After transfer to loganberry this same series of females deposited 95 eggs in the characteristic manner.

B10 and B11. These crickets were in a cage which included an apple branch 30 mm. in diameter and a small apple watershoot 4 mm. in diameter. Many attempts had been made to oviposit in the shoot, but few were successful. Most of the punctures were incomplete and terminated in the wood. There were two rows of 4 and 5 incomplete punctures besides several single ones. At the end of one of these rows, an egg had been deposited and toward the smaller end of the shoot there was a row of 8 eggs, all of which extended across the narrow pith. Apparently this watershoot was too hard for oviposition. The green tip was not included in the cage.

Twelve eggs were found in the bark on the underside of the large branch. These were placed in the usual slanting position with the distal ends imbedded in the wood. There were two sets of two placed one in front of the other about 1 mm. apart, as if forming an incomplete row, (Fig. 1. E).

B16. This female was given a choice of an apple branch of 16 mm. diameter and an apple watershoot of 6 mm. diameter. The 22 eggs were all placed in the shoot. All but four were imbedded in the wood and narrow pithy core. This wood was apparently almost too hard for the purpose and in six cases had turned the ovipositor so that the hole extended along the cambium layer parallel to the surface. In four of these holes eggs had been deposited and in such cases the position of the egg was like that of form A (Fig. 1, G). This was evidently due to force of circumstances and not from choice, but it shows that the habit of placing eggs singly in the bark could possibly have originated from the habit of placing them in rows in the pith. Of the four eggs mentioned, three were placed singly and the other was at the bottom of a row.

Summary of Oviposition Experiments.

Race A.

1. The females oviposited readily in the bark of prune and apple branches.

2. Females confined on grape and small apple shoots and most of those on loganberry canes, did not oviposit at all.

3. One female deposited eggs in loganberry and blackberry but in this case she placed the eggs in the cortex and woody layer in as near the normal manner as the physical character of the plant would permit, (Fig. 1, D).

Race B.

1. The females oviposited readily in loganberry and wild rose, placing the eggs in the pith in compact rows.

2. On ornamental rose, grape, and apple watershoots the same method of oviposition was used or attempted, but on these

plants the wood was a little too hard for drilling, as shown by the numerous partially completed punctures.

3. Four females confined on prune branches, (16–25 mm. diam.) did not oviposit at all. One of these was transferred to loganberry and it began oviposition on the following night.

4. Twelve eggs were deposited in the bark of an apple branch, where the only alternative was a watershoot which was too woody to be drilled into easily. The eggs did not lie nearly parallel to the surface as those of race A, but slanted at a forty-five degree angle and the distal ends were imbedded in the wood, (Fig. 1, E).

Song.

As mentioned before, the songs of the two forms of *Oecanthus niveus* in Oregon are very different. A more detailed study of the stridulation was made in order to make comparisons with the same species in the east.

The song of *O. niveus* has probably been written about more than that of any other American insect. By many writers it is considered the most musical of all insect sounds. It exhibits the interesting phenomenon of synchronism and has been much discussed in past numbers of the *American Naturalist* with reference to the relation between frequency of notes and temperature.

The stridulating organ of the tree cricket consists of a transverse vein near the base of the wing, which bears minute teeth on the underside. This is scraped by a thickening on the inner edge of the opposite wing. When the tree cricket sings it raises its wings perpendicularly over the back and vibrates them in a transverse direction. In the case of *Oecanthus niveus*, the vibrations are interrupted at regular intervals so that the song is a rhythmically repeated, whistling note.

Frequency of Notes and Temperature.

No study of the frequency of notes can be made without considering the temperature for the rate varies directly with the temperature. This relation of wing movement to temperature is present in all singing insects which the writer has observed, but only with those species whose song has a rhythmical beat, which is indefinitely repeated, can an accurate study of the correlation be made. In 1897, such a study was recorded by

Dolbear (7) who reduced the temperature correlation to an algebraic formula. He did not name the species of cricket but from his description of the song it was evident to later workers that he was dealing with the snowy tree cricket. A year later C. A. and E. A. Bessey (8), published a more detailed account with a graph made from a large number of records taken

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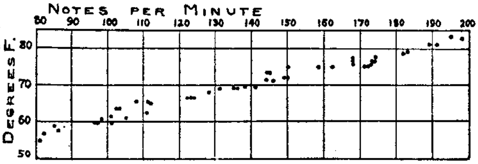

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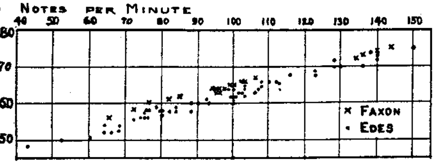

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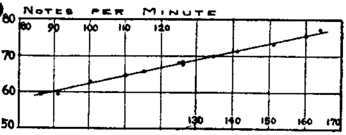

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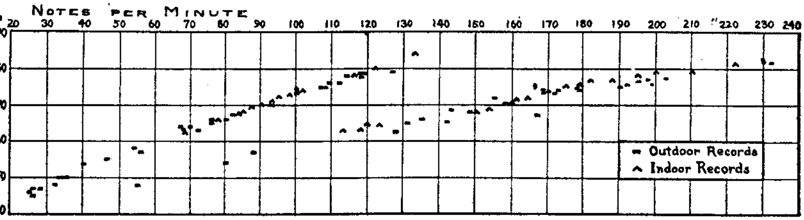

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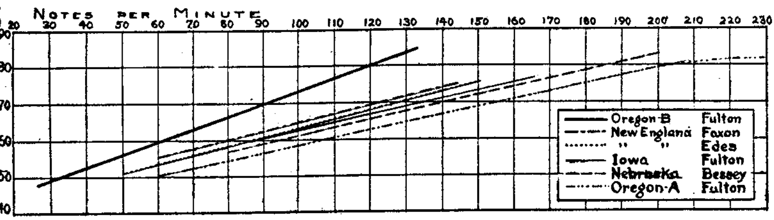

Fig. 2. Records of song of *O. niveus* taken by C. A. and E. A. Bessey in Nebraska.
Fig. 3. Records of song of *O. niveus* taken by Edes and Faxon in New England.
Fig. 4. Records of song of the two races of *O. niveus* in Oregon.
Fig. 5. Records of the song of one individual *O. niveus* taken indoors in Iowa.
Fig. 6. Comparison of graphs made from records shown in Figs. 2, 3, 4, and 5.

in Nebraska, (Fig. 2). Soon after that another article appeared by Edes (9) with a chart of observations made by himself and Faxon independently, (Fig. 3). Although both workers lived in New England the counts taken by the latter averaged a few notes less at the same temperatures. Edes states that his own records might have been more accurate if the thermometer had been on the same side of the house as the bush in which the crickets were singing.

Comparison of the Song of *O. niveus* A and B.

Numerous observations at various temperatures on the songs of the two races of *O. niveus* in Oregon, both out-of-doors and in the laboratory, are recorded in Fig. 4. It can be seen from this that there is a wide range of difference between the songs of the two forms. For instance, at 70° F., race A stridulates at a rate of about 160 notes per minute, while race B has only 90 notes per minute. Such a difference as this can not be accounted for by any physical difference in the environment. Actual cage experiments show that the males of each form retain the same relative difference, regardless of surroundings. During several years of observation on these crickets, in many situations, I have never heard one which seemed to be intermediate between the two forms in regard to song.

Another slight difference in the method of singing was observed one night when the temperature had gone down to 48° F., which is near the lower limit of the singing range of the cricket. The slight quaver in the note, which is noticeable even at higher temperatures, was then so reduced in speed that the undulations of sound came no faster than I could count. In the case of race B, each note consisted of a series of four brief phases. This was observed for several individuals. By throwing a flashlight on the singing insect it could be plainly seen that the wings rubbed past each other four times for each note. In the case of race A the notes were noticeably shorter and observations on several individuals showed that this form made only three strokes of the wings per note.

Causes of Variation in Charted Data.

In charting the data on the song of the tree cricket, the points do not line up in a regular curve, but will be found scattered within rather narrow limits. In other words, all observations made at the same temperature do not agree. Shull (10), in attempting to find some factor other than temperature which might influence the frequency of notes, investigated the relation of wing length to rate of chirping and found no correlation.

He concluded that the variations were probably due to humidity, individuality and physiological state.

In my work on the tree cricket song I tried to discover some of the sources of error. An accurate thermometer should be used, preferably one with fractions of degrees marked. Records taken out of doors are not accurate for the reason that the temperature varies slightly from place to place and from time to time. In taking a record it is not possible to have the thermometer close to the cricket for it stops singing at a slight disturbance. I found that under the foliage of loganberries it was often a degree colder than just above if a slight breeze was blowing in the evening. The tops of apple trees would be sometimes two degrees warmer than near the ground. On one night the temperature was found to fluctuate over a range of nearly four degrees F. within a few minutes. In a rising or falling temperature there will be an error, for the temperature of the cricket will not rise or fall at the same rate as the thermometer.

Aside from error in temperature I believe that the greatest cause for irregularities in the song charts is slight individual variations. There is no doubt but that some males have a rate of stridulation slightly higher or lower than the average. I had one cricket confined in a cage in the house that was noticeably slower, about five notes per minute, than the others when it sang alone. When more than one cricket is singing in the same room, they assume a common rate and all sound their notes together in perfect harmony. The rate of such a chorus would depend to some extent on the individuals that composed it.

Fig. 5 shows a series of observations taken on one male cricket in a room. Records were taken only when the temperature was holding fairly constant. The bulb of the thermometer touched the side of the cage in which the cricket was confined. Each count was carried on for three consecutive minutes to avoid error in counting. Even in this case there is some fluctuation from a straight line, but it is much more regular than a chart of observations made out-of-doors on various individuals. It is possible that the element of fatigue may cause some variation in the frequency, but I have not had access to equipment necessary to determine this point.

Synchronism.

There seems to me no doubt about the synchronism in the song of the Snowy Tree-cricket, although it has been questioned by some, who claim that an auditory illusion is responsible for the belief that the notes of neighboring crickets are sounded simultaneously. As Allard (11) (12) has pointed out, there are other insects having an intermittent, rhythmical song which do not give such an effect, because they do not synchronize their notes. Not all of the Snowy Tree-crickets in an orchard or berry patch will have their notes perfectly synchronized, although on warm evenings there are times when the chorus seems to come very close to this condition. In a single tree or among any group of crickets that are not more than a few yards apart, the singers usually keep up a perfect synchronism. On very cool evenings, near the lower temperature range of stridulation, synchronism becomes imperfect or almost lacking. The phenomenon can be best observed with caged crickets indoors. When one male is singing and another begins the second one will make a few weak notes until it can catch the proper rhythm and then its notes sound simultaneously with the other.

Comparison of Song of *O. niveus* in the East and West.

If the graphs made from the stridulation records of the two races of *O. niveus* in Oregon are compared with those made by the Besseys and Edes, it can be seen that both forms differ from the same species in the east in regard to song, (Fig. 6). Also it can be seen that the Besseys' records, which were taken in Nebraska, differ slightly from those of Edes and Faxon, which were taken in New England. Barring errors by the use of a defective thermometer, it would appear that *O. niveus* in Nebraska sings faster than it does in New England and that race A in Oregon sings still faster.

Humidity.

One might suppose from this that the humidity of the air which in general increases from west to east during the summer, might be responsible for this difference. Shull (10) thought that humidity influenced the rate of chirping, but admitted that the evidence on the point was not conclusive. The writer has one observation on this point. Two crickets were confined indoors where the temperature was kept fairly constant, one in a cage consisting of ordinary fly screen on all sides, and with no green plants inside, while the other was confined in a lamp chimney with a cotton plug in the top and many fresh green leaves inside. Moisture was condensed over the inside of the glass, showing that the atmosphere within was saturated.

The cricket in the lamp chimney did not chirp often, probably on account of the abnormal conditions in the cage, but on one occasion it sang for a time and its notes synchronized with those of the cricket in the wire cage. When each was permitted to sing alone, the rate was the same. The relative humidity of the air in the room was only 54% as determined by a sling psychrometer (dry bulb 66¾° F., wet bulb, 55¾° F.). This experiment was not tried on other crickets, but it shows that the effect of humidity on the rate of stridulation could at most not be greater than individual differences between crickets.

In the summer of 1923, the writer succeeded in taking to Oregon alive, two male crickets collected on apple in Ohio and two males collected on scrub oaks at Grand Canyon, Arizona. These were placed in separate cages in the same room with two males of the Oregon race A. When this lot was observed after dark, none of the usual synchronism of notes could be heard, but instead there was a confusion of sound, resulting from the crickets of each locality singing at somewhat different rates. One of the Arizona crickets was a most persistent singer and would be the first to start after they were stopped by a disturbance. An Ohio cricket would then apparently attempt to start in unison, but after a few notes would lose cadence and stop. After several such attempts it would sing independently at a somewhat slower rate. Counts of the three species taken within a half hour, with the temperature of the room holding close to 71° F., gave the following: Ohio 130, Arizona 140, Oregon A, 155.

This observation and the comparison of the song records taken by different workers in widely separated parts of the country, indicate that the average frequency of notes in the song of the Snowy Tree-cricket is not the same in all localities and that this variation is not dependent on the local physical conditions of the environment.

Crossing.

A male of race B was confined with a female of race A, and two males of A were confined with females of race B. Although these cages were examined frequently at night, no mating was observed for any of the three pairs. However, the cages could not be kept under constant observation and since few cases of mating were observed in the other cages where the sexes of the same race were confined together, it is entirely possible that crossing occurred. The females were already fertilized before capture. The writer had planned to start crossing experiments another year with immature crickets, but departure from the state prevented the carrying out of these plans.

Even if crossing did take place between individuals of the two races confined in a cage, it would not be a frequent occurence in nature because of the sharply limited ecological distribution. As stated before, the two races occur on the same plants only at the dividing line between deciduous forest or orchard and areas of low bushes.

Geographical Distribution.

Oecanthus niveus is the most widely distributed of all our native tree-crickets. It occurs over most of the North American continent from Maine, Ontario and British Columbia, southward. It is not common in southeastern U. S. and has never been recorded from Florida. It occurs in Cuba and is recorded from Guatemala and several widely separated points in Mexico. Besides having studied the species in New York and Oregon, the writer has made limited observations on its habits in Ohio, Iowa, Colorado and Arizona. The egg laying habits, both on trees and berry bushes, are essentially the same in New York, Ohio and Iowa. At the Grand Canyon, Arizona, the species was found living in junipers and small oaks, but no eggs were found. A few song records taken in Ohio agree with those taken by Edes and Faxon in New England. Records taken in Iowa, Colorado and Arizona occupy a middle ground near those taken by the Besseys in Nebraska. In no other place besides Oregon has the writer found any evidence of the existence of two races. It would be interesting to have for comparison some knowledge of the habits of the species in Cuba and Mexico.

The race A of *Oecanthus niveus* in Oregon does not differ greatly in song or egg laying habits from the same species in the east. Since the song of the species varies slightly in different parts of the country, it seems likely that there might also be slight geographical variations in other habits and that race A merges by gradual stages with the *O. niveus* of the central and eastern states.

Race B, however, is something more distinct. If its differences from the other form were morphological rather than physiological, it would constitute a separate species. It can be called a physiological variety. I have never observed it anywhere except in Oregon west of the Cascades. There it is widely distributed and is most abundant in the valleys, but is also found in burned areas in the Coast Range and lower Cascades. The race undoubtedly occurs also in western Washington, where conditions are practically identical to western Oregon. I believe that it also occurs in eastern Oregon and Washington in the Columbia and Snake River valleys. This assumption is based on tree-cricket eggs found at Walla Walla, Washington. They were in rather large wild rose bushes and were deposited in rows like the eggs of race B in western Oregon. They did not appear to be eggs of *O. argentinus*, which sometimes oviposits in small rose bushes, but usually in pithy weeds.

Other Examples of Physiological Varieties.

There have come to my attention, a few instances described in literature, of varieties of a species having a distinct difference in habits accompanied by slight or no morphological characters of separation. No doubt there are other cases scattered through the literature. I believe that a more intimate acquaintance with the habits of widely distributed species will show that such physiological varieties are not uncommon among insects.

I will describe briefly a few of the more striking examples. Howard (13) gave an interesting account of a fly, *Parexorista cheloniae*, which is parasitic on the Brown-tail Moth. The species exists both in America and Europe and is apparently identical in the two places, but the American race seems to be without defence against the poisonous barbed hairs of the caterpillar. The European race has become adapted to the Brown-tail physiologically and parasitizes it with impunity.

The European race was brought to America and colonized by thousands. It was found that they hybridized with the native race and after a few generations, with greatly diluted European blood, were no longer immune to the Brown-tail hairs.

Patch and Wood (14) have worked out the life history of the Blueberry Maggot, which is considered to be a small race of the ordinary apple maggot, *Rhagoletis pomonella*. There appears to be no difference between the two races except in size, but the food habits of the two are very distinct.

Among the Orthoptera, several instances have been described of varieties having a different song. Allard (15) states that "very marked differences of stridulation may characterize certain species in different parts of their range." He described differences in the song and other habits of the common field cricket, *Gryllus assimilis*, an extremely variable species morphologically. In New England, the song consists of intermittent chirps, while in northern Georgia a race occurs which has a prolonged, trilling note.

In the case of the Striped Ground Cricket, *Nemobius fasciatus* De Geer, also an extremely variable species, Allard (16) has discovered in Massachusetts two singing forms in the same locality, but having a different ecological distribution. One race occupies the dry, grassy upland fields and pastures and sings with a high pitched, prolonged trill. In damp marshy ground in fields and pastures, this race is replaced almost entirely by pure colonies of a form having brief intermittent notes. Only where wet and dry conditions overlap is there a noticeable intermingling of the two forms.

The writer has also found a race of the same species living on damp ground near Ames, Iowa, which appears to fit the description of Allard's intermittent singer. This was found only in grassy places near streams. An examination of a series taken from a pure colony of this form showed no characters to separate it from the common form. The song of the low ground race could be imitated by rubbing the edge of a fine-toothed comb lightly with the finger in short strokes. At 77° F. one of these crickets chirped from 24 to 30 times in ten seconds. There was no constant rhythm to the song and the frequency varied with different individuals, some chirping as much as 40 times in ten seconds. I watched a male singing and it appeared to make just one comparatively slow stroke of the wings per note.

Caged specimens of this race were observed to sing only in the manner described.

The song of the common form of *Nemobius fasciatus* is very different in quality and much louder. It has a very rapid wing movement and each stroke produces a sharp chirping note. The frequency is much faster than one can count at ordinary temperatures, and the song seems to be one prolonged note, having a distinct, tinkling quality.

At Mt. Pleasant, Iowa, in the southeastern part of the state, the writer found another differently singing variety of *N. fasciatus*, occuring in woods. This race was paler and more reddish in color than the common form, but some individuals of the pale color had the ordinary type of song. The song of this woodland variety differed only in the frequency of chirps which seemed to be just about half that of the common form. The notes were slow enough to be easily counted on cool days and even at higher temperature could be easily estimated by tapping a paper with a pencil in the same cadence and then counting the dots made in a certain period of time. At about 70° F. the frequency was close to five chirps per second. Male specimens of the woodland form, as well as the common form, were confined in separate cages with females. They always stridulated in their characteristic manner, but each form was found to have two songs. What might be termed the calling song was the one most commonly heard and is the song which I have described for each form. In it there was a constant cadence or rhythm which varied only with the temperature. When first starting to sing or when the male was actively courting the female, a slower frequency of chirps with less regular intervals, was used by each form, but the same comparative difference between the two forms was retained. At about 70° F., the common *N. fasciatus* would start chirping about 4 or 5 notes per second, but soon the speed would increase a little and then suddenly break into the regular tinkling song. The woodland form would chirp about twice per second in its preliminary song and then abruptly change to about five notes per second. If a female came near a calling mate, he would change to the slower song and follow her about with a nervous jerking of the body. At such times the song would be very irregular, varying both in loudness and frequency.

The woodland race of *N. fasciatus* was not found near Ames, nor was the lowland race found at Mt. Pleasant. In woods at Ames, only the song of the typical form was heard, as was also the case in low places along streams near Mt. Pleasant.

Summary and Conclusions.

1. Two races of *Oecanthus niveus* DeGeer are found in Oregon, which differ only in their habits. One form lives in bushes and the other in trees.

2. The habits of the tree inhabiting race differ but slightly from those of the same species in the eastern states.

3. The bush inhabiting form in Oregon is a distinct physiological variety.

4. The characteristic song and oviposition habits of the two forms of *Oecanthus niveus* in Oregon remain fixed when the adults of one form are confined to the normal environment of the other form.

5. The females of each form select plants for egg laying, which best meet the requirements of their characteristic mode of oviposition. This probably is the main factor in determining their ecological distribution.

6. The average frequency of notes in the song of *Oecanthus niveus*, at the same temperature, varies in different parts of the country. Slight individual variations in frequency occur in any one locality, but such differences are modified to synchronize the notes when more than one cricket is singing. Individuals brought together from certain widely separated parts of the continent find it difficult or impossible to synchronize the notes on account of the greater difference in frequency.

7. Physiological varieties of other species of insects have been recorded in literature. Among the Orthoptera, there are several species which have one or more varieties differing in type of song.

8. Three singing forms of *Nemobius fasciatus* are present in Iowa. The common form is found in all open fields and pastures. In the southeastern portion of the state, a different form is found in woodlands. In central Iowa a still different form occurs in low places.

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BOOK REVIEWS.

A General Textbook of Entomology. Including the Anatomy, Physiology, Development and Classification of Insects. By A. D. Imms, M. A., D. Sc., Chief Entomologist, Rothamsted Experimental Station. New York, E. P. Dutton and Co., Publishers.

The author of this important contribution to the literature of Entomology has attempted with a high degree of success to present a world wide survey of entomology in its different phases and while the student in any special field may not find all that he may wish on his particular subject, he will be able to secure a very comprehensive view of widely diverse branches.

The work is profusely illustrated with figures, many of which are new and many drawn from the works of well known authors. American students will find many of our familiar economic species treated in considerable detail, but will especially appreciate the bringing together of so large a mass of information concerning the important species of foreign lands.

H. O.

Anatomy and Physiology of the Honeybee. By R. E. Snodgrass. McGraw-Hill Book Company, 1925.

In this gem of morphological exposition Mr. Snodgrass has brought together all the main items of our present knowledge of the anatomy and physiology of the honeybee. The outstanding feature is the series of illustrations which are drawn in a boldness of contrasting white and black beyond the daring of an ordinary artist. Figures 70, 72, 74 and 75 are among the very best illustrations in morphological literature. With this gift of illustrative ability the volume shows Mr. Snodgrass' other ability of simple philosophical organization of the subject matter which gets the great amount of technical information across to the reader.

The subject is taken up in a series of chapters on the systems of organs and ends in two chapters on embryology and metamorphosis. The latter chapters, with that on the fat body and the oenocytes, are those most needed in present literature and are the high points in the whole presentation of the subject. The discussions of bee physiology give the reader practically all that is known on the subject and show how very little is really known positively on insect physiology. It shows that this is the great open field in Entomology which must be explored before this science can advance much farther.

C. H. K.