

SOME TEMPERATURE RESPONSES OF NYMPHS OF
LOCUSTA MIGRATORIA MIGRATORIOIDES (R. & F.),
 WITH SPECIAL REFERENCE TO AGGREGATION

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INTRODUCTION

It is characteristic of locusts in the field that they form basking groups; in these groups hundreds of individuals collect in sunlit places and remain relatively quiescent. Poikilothermal animals generally show an increase of activity with rising temperature up to conditions that produce stupor, but the quiescence of basking locusts at high temperatures is not due to heat stupor, for the hoppers (nymphs) are still in a very reactive state, so that basking was for long considered as an anomaly. It was described by Kennedy (1939, 1945) as a negative thermokinesis superimposed upon the normal positive thermokinesis in insects moving in a close patchwork of temperatures. The group formation might be due to each individual reacting independently to the patchwork of temperatures, or it might be complicated by the insects reacting to each other. Ellis (1953), working on the interaction of hoppers in a uniform field, concluded that although mutual attraction did exist in older hoppers, the effects of simple physical features of the environment were more important. Such environmental effects have not hitherto been investigated in the laboratory, and the present work is an attempt to fill the gap to some extent. Gregarious hoppers of *Locusta migratoria migratorioides* (R. & F.) were used in the experiments.

EXPERIMENTS WITH A TEMPERATURE GRADIENT

Since it was apparent from field observations (Shumakov, 1940; Clark, 1949; Régnier, 1931) that hoppers of various locust species tended to remain stationary at certain places in a patchy temperature field, an attempt was made to determine whether or not they showed a restricted temperature preference. It should be understood that the word 'preference' is not used here to imply any conscious choice on the part of locusts, but to mean that a locust remained for a relatively longer period at one temperature than at any other. The only previous work in this field was that of Bodenheimer (1929) on *Schistocerca gregaria* Forsk., Parker (1924) on *Camnula pellucida* Scudder and Rubtzov (1935) on a number of Asian grasshoppers. Thus only Bodenheimer worked on what is generally regarded as a locust, and his experiments were not strictly comparable with the present ones on *Locusta* because he used large numbers of hoppers at a time instead of single individuals. The work of all the above authors was criticized by Gunn (1934) for lack of control of humidity and convection currents and for disregard of differences between air and floor temperatures.

Apparatus and methods

The apparatus used in the temperature-preference experiments was that used by Gunn (1934). The temperature at the cold end was maintained not by the method illustrated by Gunn but by a lagged box which surrounded the air inlet, and which could be filled with ice or water. In the experiments on first-instar hoppers, the box was ice-filled, but for later instars tap water was found to be sufficiently cold. A period of at least 3 hr. was always allowed for the gradient to become stable before any experiments were started. In this way, day-to-day variation in the temperature of the gradient was minimized. Thus, although the experiments were carried out in a cold room over almost a whole year the temperature at the cold end varied only from 9 to 11° C. for the first-instar hoppers, and from 16 to 21° C. for the later instars, while temperatures at the hot end varied only between 37 and 42° C. for all the instars. When it was observed that hoppers preconditioned at higher temperatures showed a higher preference, the temperature of the hot end was increased to about 45° C., varying from 41 to 45° C. The middle thermometers showed hardly any variation throughout.

Except in the case of fifth-instar hoppers in dry conditions, the air passing through the apparatus had in all cases a dew-point at 16° C., the air being passed through water before entering the chamber. For the experiment with dry air the water was replaced by calcium chloride and the dew-point was below 3° C., the lower limit of the apparatus used. The direction of air flow was reversed after each individual test, the rate of flow being 200 c.c./min. in each direction. The apparatus was arranged parallel with the only window in the room, which faced north, so there was no question of the hoppers being exposed to strongly directional light along the length of the chamber.

Hoppers were tested singly because of their tendency to aggregate in a uniform field (Ellis, 1953). Results obtained if large numbers had been used might have been due to such aggregation rather than a true response to temperature. Further, owing to the relatively small size of the chamber, it was not thought advisable to use more than one hopper at a time because artificial groups might have formed as a result of the size limitations of the enclosing space, particularly in the later instars. Bodenheimer (1929) found this to be the case and was forced to modify his experiments. In practice it did not appear that the size of the gradient influenced the movement of the single animals, even in the fifth instar, except, of course, at each end.

It was originally intended to follow Gunn's method of leaving each insect in the gradient until it had remained in one spot for a given time. Preliminary experiments showed that hoppers sometimes did not sit still for more than a few minutes at a time throughout a whole day, and also, when kept in for such long periods, they became progressively more active. The best method was found to be to keep each hopper in the chamber for only half an hour; it was then replaced by another. The position of the hopper in the chamber was plotted every minute, taking the position of the cervical joint for reference. The total time spent stationary at each temperature was summed at the end of a series of experiments and the results plotted as

histograms. In expressing the results it has not been considered advisable to attempt to show temperatures more accurately than at intervals of 5°C ., since the head was often at one temperature and the abdomen at another.

Five thermometers were inserted into the apparatus through holes at equal intervals along the length of the gradient. Hoppers of the first three instars were introduced with equal frequency through each of these holes. No apparent disturbance of temperatures within the apparatus resulted from this method of introduction. Because of their larger size, hoppers of the fourth and fifth instars could not be introduced in this way, but they were put in equally frequently from either end of the chamber. The disturbance in this case was greater, but conditions became stable within a few minutes and the effect was, in any case, quite local.

Results

One hundred first-instar hoppers preconditioned over-night at 20°C . showed a peak at $30\text{--}35^{\circ}\text{C}$. in the histogram of time spent stationary (Fig. 1). A second peak shown at the lower end was due to the hoppers becoming physiologically trapped at temperatures below 15°C . Male and female hoppers gave similar results. Even hoppers less than 1 day old, of which fifty were tested, showed a definite tendency to remain longer at temperatures between 30 and 35°C . These hoppers had never before been subjected to temperatures in excess of 20°C . except during incubation of the eggs.

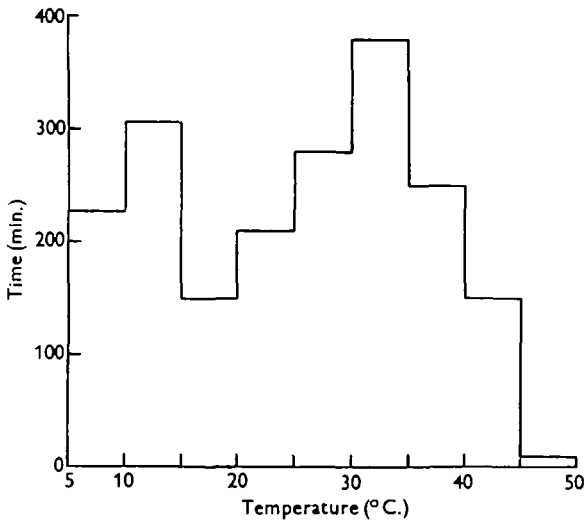


Fig. 1. Temperature preference of first-instar hoppers.

It was possible to find the rate of movement of the hoppers from their new starting point at the beginning of each minute. The results (Fig. 2), based on observations on 227 first-instar hoppers and not counting the time spent stationary, showed a steady increase in the rate of walking from 5 to 20°C .; above this the rate fell off. This latter fact was correlated with the inactivity of the hoppers from 25°C .

to nearly 40° C., and between these temperatures even those that were walking did so more slowly. The mode of recording was unsuitable for showing the increase in activity at temperatures over 40° C. because the hoppers became very excited and moved mainly by hopping instead of walking.

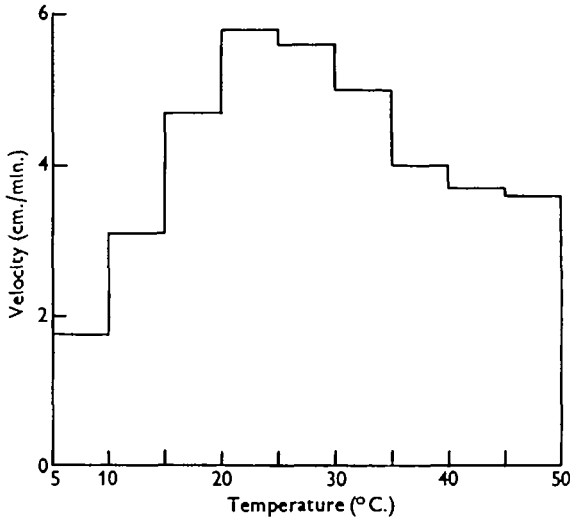


Fig. 2. Rate of movement of first-instar hoppers in the temperature gradient.

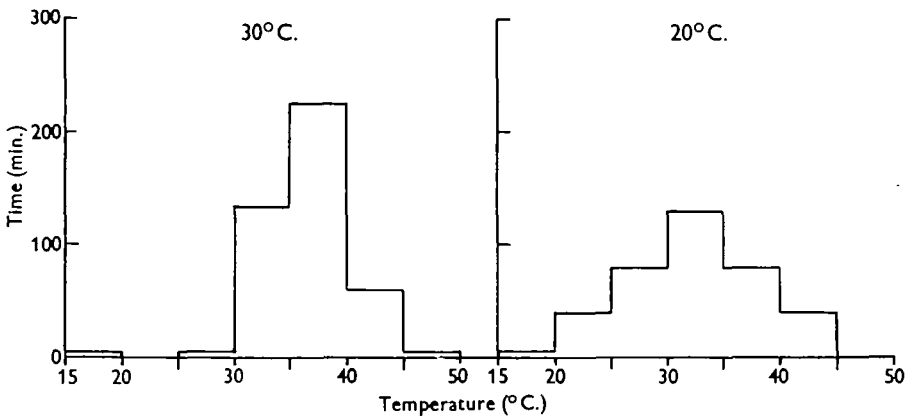


Fig. 3. Temperature preference of fifth-instar hoppers preconditioned at 20° C. and 30° C.

The later instars were tested in much smaller numbers, thirty hoppers of each being used. All the instars, when preconditioned at 20–25° C., showed a preference at 30–35° C. The fourth and fifth instars were also tested after preconditioning for some 3 hr. at about 35° C. In these cases, the range of temperatures at which hoppers remained stationary was much reduced. Thus fifth-instar hoppers only remained for 8 min. (less than 2% of the total time stationary) outside the range

30–45° C., whereas those preconditioned at 20–25° C. showed a normal distribution over the range 20–45° C. Furthermore, the hoppers remained longer at higher temperatures when the preconditioning temperature was higher, the peak in the histogram for preconditioning at 30° C. being at 35–40° C. (Fig. 3). For fifth-instar hoppers preconditioned at 20–25° C., the mean temperature was 32.4° C., while for those preconditioned at 35° C. it was 36.6° C. The difference was significant ($p < 0.01$).

A comparison of fifth-instar hoppers preconditioned at 35° C. in wet and in dry conditions showed peaks in both cases at 35–40° C. The mean preferred temperature was 36.6° C. in the wet and 37.1° C. in the dry conditions; the difference between the two cases was possibly significant statistically ($0.01 < P < 0.05$), although only 0.5° C. Such a difference is of doubtful significance biologically, and it indicated that the range of humidity at any one time throughout the temperature gradient and due to it was not likely to influence the results to any large extent.

Discussion

The results obtained here are at variance with those of Bodenheimer who found that the temperature preferred by *Schistocerca* increased through the instars from 30.1 to 36.7° C. Herter (1923, 1924) claimed to have shown that in *Formica rufa* L., the preference increased with the external temperature, and Bodenheimer & Schenkin (1928) had similar results for a number of insects. Bodenheimer stated that the differences which he observed in *Schistocerca* were not due to this cause, but to differences in the physiological states of the insects. He did not give the preconditioning temperatures, but merely indicated the month of the experiment, which is inadequate. All these experiments are open to the criticisms raised by Gunn (1934) that floor and air temperature in Herter's apparatus, which Bodenheimer used, were different and that the latter varied with the external temperature. Since the thermometers in the apparatus were influenced by both air and floor temperatures, a small insect, reacting possibly to floor rather than air temperature, would appear to alter its preferred temperature in correlation with room temperature. This lays the results of Herter open to suspicion and may also account for the variation from instar to instar which Bodenheimer found. His difference between young and old adults might well be physiological. It has been shown here that for *Locusta* there is no substantial difference in preference from instar to instar with similar preconditioning, but that increased preconditioning temperature leads to a rise in the preferred temperature. Gunn & Hopf (1942), using entirely different methods, showed the importance of preconditioning temperatures in the temperature responses of *Ptinus tectus*. Gunn's temperature gradient is not open to the criticisms levelled at Herter's 'Temperaturorgel', and the hoppers were all bred under similar conditions prior to the preconditioning period of 3 hr. Preconditioning took place in a room separate from that containing the gradient, this latter room being thermostatically controlled to 19° C. Broadly speaking, the range of temperature preference found here for *Locusta* agrees well with that obtained by Bodenheimer for *Schistocerca*, being about 30–35° C.

It has already been remarked that the mean result in dry air was slightly higher than that in moist air, the difference being considered of doubtful biological significance. However, it might be expected that in dry air the temperature preference would be increased, since it was shown by Bodenheimer (1929) that the body temperature of *Schistocerca* at about 40° C. was 3 or 4° C. lower in dry air than in moist. Thus for body temperatures to be similar in the two cases, the preference, measured as the temperature of the apparatus, would be slightly higher in dry than in moist conditions. On the other hand, if the insect reacts positively to dry air (Kennedy, 1937) a higher preferred temperature might be expected in moist air (Gunn & Cosway, 1938). The small effect in the present experiments may be due to the two components acting in opposite directions.

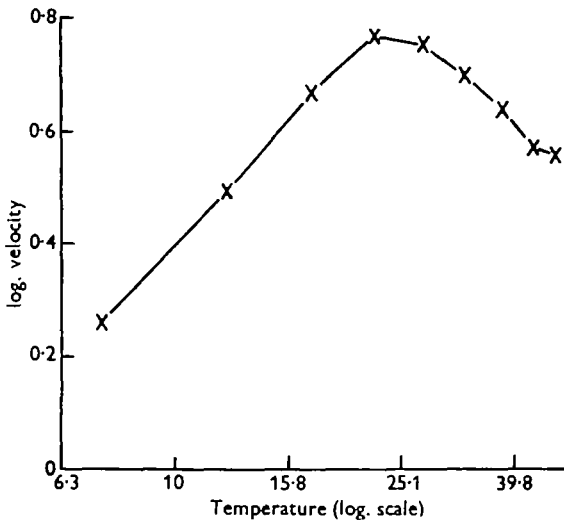


Fig. 4. Results shown in Fig. 2 plotted as logarithms, showing the applicability of Bělehrádek's formula.

The rate of movement of first-instar hoppers in the gradient was plotted as a logarithm against the logarithm of the temperature (Fig. 4). A straight line from 10 to 25° C. showed that the data for this range agreed closely with Bělehrádek's (1930) formula $v = \frac{a}{x} b$. The temperature coefficient for the range given and based on this formula is 1.06, showing a good agreement with Krogh's (1914) linear relation $yt = k$. Above 25° C., the curve, like the histogram, falls off.

These results are in general agreement with the views of Kennedy (1939) who stated (p. 504): '... negative thermokinesis, on theoretical grounds, could only be the dominant reaction in the field between 20 and 40° C. Below 20° C. weak positive thermokinesis would appear and above 40° C. it would supervene strongly.' The results given here provide quantitative data to support Kennedy's ideas for the lower temperatures, but they do so by using a different method of assessing activity. He used the proportion of time spent in motion, while here the speed of motion is

used. The manner of obtaining the results makes them unsuitable for showing the increase in activity at high temperatures because of the different form which the activity takes.

Bodenheimer (1929), Parker (1930) and Hussein (1937) studied the activity of locusts in a uniformly heated chamber the temperature of which was steadily changed. Under these conditions, all three authors found that the insects exhibited a continuous positive thermokinesis up to fatal temperatures. It is not obvious why there should be this difference between these results and those of Kennedy (1939) and the present work. The difference could be related to the post-prandial state of the hoppers, which, however, is not fully documented, or to the purely temporal temperature changes of the earlier experiments compared with the combination of spatial and temporal changes involved here.

EXPERIMENTS ON GROUP FORMATION

Apparatus

Twelve-litre cylindrical cages with metal bases and celluloid walls were used in the next series of experiments. The floor of such a cage was 20 cm. in diameter, and on it were drawn in chalk two concentric circles of 8 and 15 cm. diameter, giving inner, middle and outer floor areas in the ratio 4:10:11 approximately. By placing one of these cages on a trough of hot water (60° C.), 20 cm. in diameter, the whole of the bottom of the cage was uniformly heated. If, instead of a large trough, a beaker 6 cm. in diameter, filled with water at the same temperature as before, was placed centrally under the cage, the centre of the cage floor was warmed while the remainder was not, except for some conduction away from the centre.

Results

The tests were carried out with first-instar hoppers. In the 12 l. cages, hoppers normally climb the walls on the side towards the light. Counts of the distribution of the hoppers on the unheated floor showed that there was a marked edge-effect, the number in the outer area always exceeding the total number on the rest of the floor. This was not a sign of aggregation but was due to the wall-climbing.

Use of the large trough resulted in loss of the tendency to climb because of the more suitable temperature of the floor, so that the walls were almost entirely vacated and the whole population of the cage was on the floor. Again, a marked edge-effect was obtained because of the hoppers falling from the walls (Table 1). This was not true grouping and, although a tendency to group was sometimes observed, distribution of the hoppers was usually uniform except for the edge-effect. When the small beaker was used instead of the trough, a very marked group was invariably formed in the centre of the cage within 15 min. (figures in heavy type in Table 1). These groups were so dense on some occasions as to make accurate counting impossible. Similar results were obtained in complete darkness when no visual responses were possible (Table 2).

Discussion

These experiments made it quite clear that the formation of groups depended less on interaction between the hoppers than on the nature of the environment, hoppers collecting on the warmest available spots. Ellis (1953), working on the attraction of hoppers to one another, came to a similar conclusion. When in the present experiments there was a uniform temperature field, large groups were not formed, whereas the hot patch at the same temperature as the uniform field resulted in marked grouping. Hoppers, both younger and older than 3 days from hatching, were tested, because Ellis found no attraction between hoppers less than 3 days old. Groups were formed in both cases with the restricted temperature field.

Table 1. Group formation in first-instar hoppers

Normal				Floor temp. even				Floor temp. patchy				Age in days
S.	O.	M.	I.	S.	O.	M.	I.	S.	O.	M.	I.	
52	37	14	16	7	54	34	13	19	32	30	36	2
51	37	23	7	3	57	47	9	24	26	20	40	2
34	48	17	6	2	86	15	4	15	27	22	47	2
21	35	3	1	0	50	14	9	4	8	4	50	9
10	52	8	1	1	47	12	2	4	17	4	46	9
6	46	8	1	1	64	2	2	2	16	4	50	9
9	52	57	3	1	16	35	16	—	—	—	—	8
35	70	26	5	0	32	47	64	—	—	—	—	6
332	75	23	10	59	127	141	113	—	—	—	—	2
14	32	8	4	—	—	—	—	2	25	5	44	11
34	22	3	0	—	—	—	—	21	5	2	35	7
108	43	7	2	—	—	—	—	78	28	8	28	5
13	48	10	4	—	—	—	—	3	9	4	59	11
26	33	8	1	—	—	—	—	2	2	0	64	7
86	50	8	3	—	—	—	—	10	6	11	120	5
6	46	8	3	—	—	—	—	5	31	8	19	8
30	67	25	14	—	—	—	—	22	38	17	51	6
302	76	49	13	—	—	—	—	220	97	52	71	2
8	45	9	5	—	—	—	—	7	16	9	37	8
33	53	36	11	—	—	—	—	20	25	24	64	6
288	80	58	14	—	—	—	—	188	77	37	138	2

S. = sides, O., M., I. = outer, mid and inner areas of floor. Area O:M:I = 11:10:4.

The experiments further suggest that, in the actual formation of the groups, it is the surface temperatures rather than body or air temperatures which are of importance initially. The hoppers might react to surface temperatures by way of sense organs on the tarsi or antennae (Geist, 1928).

BASKING GROUPS

The formation of basking groups in gregarious locust hoppers is a constant feature of the daily cycle of behaviour in the field, groups normally being formed in the morning and evening immediately after the descent from, and before the ascent to, the roosting sites. All field workers have indicated that basking takes place at temperatures below that at which marching occurs. Thus Allan (1933) found that basking in *Locusta* occurred below 82° F. (28° C.) and persisted all day if the air temperature did not exceed this, and that at higher temperatures the hoppers

marched. Predtechenskii (1935), working on *Schistocerca*, found that basking took place from 22 to 32° C. and marching from 32 to 40° C., and Fraenkel (in Bodenheimer, 1929) regarded 27° C. as about the temperature at which basking gave place to marching. Again in *Locusta*, Shumakov (1940) observed basking up to 43° C. and marching above this. Observations of other authors made it quite clear that basking groups were formed in the warmest available situations (Kennedy, 1939). Clark (1949) gave an example of basking above ground-level when the ground was cold due to recent rain. Records by Johnston (in Johnston & Buxton, 1949) of hoppers of *Nomadacris*, and by Régnier (1931) and Fraenkel (in Bodenheimer, 1929) of those of *Schistocerca* basking on stones and other bare surfaces exposed to the

Table 2. *Group formation in first-instar hoppers in darkness*

Normal				Floor temp. patchy				Age in days
S.	O.	M.	I.	S.	O.	M.	I.	
9	22	12	4	7	6	3	48	5
71	70	18	6	25	66	10	64	3
31	30	11	4	3	8	7	58	8
119	68	41	16	37	36	49	122	4
10	46	26	7	1	6	8	74	8
136	55	33	20	34	40	50	120	4

sun, may similarly be interpreted as 'choice' of the warmest available situations. The experiments on group formation described above were not comparable with basking-group formation in the field, since they were not carried out in the presence of radiant heat from above. Taken with the variability of the temperatures for basking given by other authors, they suggest, however, that group formation is not correlated with a particular temperature but with a patchy temperature field and the responses of the locusts to this situation. This was further investigated in a series of more natural experiments.

Apparatus

These experiments were carried out in a large cage 1.8 × 1.2 × 1.8 m. high. The walls were largely of zinc gauze with cellulose acetate observation windows and strips to prevent the hoppers climbing out, since the cage was open above. A source of radiant heat was present in the form of an electric heater with a parabolic reflector suspended about 1 ft. above the top of the cage. This apparatus will be described more fully elsewhere (Chapman, in press).

In support of the suggestions made above concerning the 'choice' of warm situations, tests showed that basking groups could be produced in any desired spot by placing a small piece of plywood on the hard-board floor of the cage, such pieces of wood being comparable, in their relative warmth, with the stones mentioned by field workers. Hopper temperature within such groups was about 35° C., which showed a good agreement with the temperature-preference experiments. Groups were formed only in places where a surface temperature exceeded the general floor temperature.

Some experiments were carried out to see if surface texture was of any importance in basking-group formation. Two similar pieces of hardboard 7.5×12.0 sq. cm. in area were grooved to take a thermometer, one on the rough side, the other on the smooth. The rough side was a little paler in colour than the smooth. These two plates were placed side by side in appropriate parts of the cage, each with a thermometer in position with the bulb in the groove so as to be just below the surface of the hardboard and obtain an approximation to the surface temperature. The column of mercury exposed was the same in both cases, and the thermometers were exchanged after each experiment to avoid instrumental error.

Results

In the absence of radiant heat, a series of counts of hoppers on the two plates of hardboard was made at half-hourly intervals throughout 3 hr. tests. In thirty-four such counts, the numbers on the two plates were equal on eight occasions, and in the remaining twenty-six tests the greater number of hoppers occurred on the rough plate on eighteen occasions. This difference was not significant ($p > 0.05$), showing that there was no marked preference for either of the surfaces. However, when the plates were subject to radiant heat, the greater number of hoppers was found on the hotter plate, irrespective of its surface. This was true in twenty out of twenty-one cases ($p < 0.01$). When the temperatures of the plates differed by 1° C. or more, the difference in numbers was most marked, groups being formed only on the hotter plate (Table 3, *a* and *b*). If the difference was less than 1° C. (*c* and *d*) groups formed on both plates but with more hoppers on the hotter one, except in one case where the converse was true. When the temperatures were equal (*e*), groups were formed on both plates and the larger number of hoppers might be found on either plate. These experiments showed that basking-group formation was dependent on a patchy temperature field, the hoppers being sensitive to difference of temperature of about 1° C.

Basking groups in the big cage were not static aggregations of hoppers but were in a very dynamic state. Their formation, persistence and break-up at a given site depended on the numbers of hoppers arriving and departing. Counts of hoppers arriving and departing from a group on one of the plates were made for 5 min. periods, at intervals over a number of 3 hr. tests with two bars of the heater on, so that ground temperature rose to a steady level of about 35° C. by the end of the first hour. Out of ten such counts in the first hour of the experiments, the number of hoppers arriving exceeded the number leaving in eight cases, but in the second hour the number arriving was greater in only three out of eleven cases (Table 4). In seven of the remainder the converse was true. Thus, over the first hour, basking groups were generally forming, while over the second hour they were breaking up. Counts obtained in the third hour were neglected because the hoppers were usually actively marching and counts became meaningless.

Alternating with the 5 min. counts described above, the time spent by individual hoppers in basking groups was also recorded. The average of twenty-four such readings was 6 min. 46 sec., varying from 2 sec. to 50 min. 56 sec.

Table 3. *Hoppers on the basking plates*

(a) Rough plate hotter than smooth

Rough (35.0° C.)	Smooth (34.0° C.)
10	4
18	3
25	5
34	6
26	1
36	2

(b) Smooth plate hotter than rough

Smooth (35.5° C.)	Rough (34.0° C.)
4	1
5	2
11	1
17	0
16	1
20	7

(c) Rough little hotter than smooth

Rough (36.0° C.)	Smooth (35.5° C.)
14	6
17	14
22	16
15	10
24	17
21	16

(d) Smooth little hotter than rough

Smooth (36.0° C.)	Rough (35.5° C.)
12	13
22	17
24	15

(e) Temperatures of two plates equal (37.0° C.)

Smooth	Rough
8	7
19	7
22	13
10	18
18	12
13	7

Discussion

Under the conditions described, groups were formed only on surfaces hotter than the general floor surface. There was thus no doubt that true basking groups did not differ from the groups formed in the 12 l. cages; environmental temperature differences due to radiant heat had the same effect as differences due to other causes. Hopper temperature in these cases was in the region of 35° C., but hoppers still

collected on the warmest available surfaces and did not aggregate elsewhere. This was in keeping with the observations of field workers outlined above, and further indicated that patchy surface temperatures must be of importance initially in the formation of basking groups.

Table 4. *The dynamic state of basking groups*

		(a) First hour									
		No. hoppers/5 min. period									
Arriving	4	3	7	9	11	17	6	11	7	9	
Departing	1	3	5	5	9	16	4	12	3	5	
		(b) Second hour									
		No. hoppers/5 min. period									
Arriving	7	2	8	4	3	6	8	8	11	14	9
Departing	8	6	12	5	2	6	11	9	5	17	7

The changes recorded in the groups in the preceding paragraphs were not associated with any changes in temperature, for by the end of an hour ground temperature was fairly steady at 35° C. They may be correlated with the physiological state of the hoppers. The observation that on some days hoppers at the end of a 3 hr. period of radiant heat were marching, while on other days, under identical external conditions, all would be basking, can also be explained on the basis of their physiological state. It is known that the amount of marching increases with the degree of starvation (Ellis, 1951), and Rubtzov (1935), having worked on a number of grasshoppers, stressed the importance of the 'previous physiological state' of the insects with regard to feeding, degree of desiccation and so on. Strel'nikov (1936) also observed that marching depended not only on the temperature of the hoppers but also on their 'general state of excitability'. These observations show that it is misleading to state that hoppers bask up to a certain temperature, above which they march and at which they resume basking later. A deciding factor is the physiological state of the hoppers. In so far as this is dependent on temperature, so will the temperature at which basking begins and ends vary.

SUMMARY

1. The results of experiments in a temperature gradient showed a definite temperature 'preference' on the part of hoppers (nymphs) of all stages. This 'preference' was constant from instar to instar but varied with the preconditioning temperature.
2. The rate of movement of first-instar hoppers was shown to increase in a linear manner with temperature up to 25° C., above which the rate fell off. It is suggested that these are quantitative data supporting Kennedy's (1939) remarks on negative thermokinesis.
3. Experiments in 12 l. cages showed that group formation depends on a patchy temperature field rather than on any particular temperature, and that environmental conditions are more important than mutual responses of the hoppers. Hoppers less than 3 days old, as well as older ones, formed groups under the conditions of patchy temperature.

4. The experiments suggested that surface temperatures are more important than air or body temperatures in the initial formation of groups.
5. Basking groups induced by local radiant heat in a large cage did not differ in form from the groups in the 12 l. cages formed in the absence of radiant heat.
6. Surface texture was shown to be unimportant in group formation, hoppers always collecting on the hotter surface even when temperature differences were of the order of only 1° C.
7. The groups were shown to be in a very dynamic state, with hoppers continually coming and going. The average time spent in a group by any one hopper was 6 min. 46 sec.
8. Formation of basking groups in the field depends on the physiological state of the hoppers, rather than on any definite temperature.

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