

32. On the Massing of the Ladybird, *Hippodamia convergens* (Coleoptera), in the Yosemite Valley. By ONERA A. MERRITT HAWKES, M.Sc., F.E.S.*

[Received March 24, 1926: Read June 15, 1926.]

(Plate I.†)

CONTENTS.	
	Page
Introduction	693
Experiments at Night with Light and Heat	694
Observations on <i>Hippodamia convergens</i> during the Day ...	699
Reactions to Food.....	700
Altitude and Hibernation	701
Air-currents and their Relation to Ladybirds found on Mountain-tops	702
Summary	704
Bibliography	704

INTRODUCTION.

When I reached the Yosemite Valley on October 28, 1925, I immediately made enquiries from everyone I met whether they had seen any ladybirds (*Hippodamia convergens*) in large numbers. At the end of an hour I found a waggoner who directed me to a field in which a group of Azaleas were growing (see foreground of Pl. I. fig. 1), near which he had seen large numbers of ladybirds. He had been digging in a pit near by for the last four or five weeks and had seen the insects on the wing for a couple of hours in the middle of sunny days.

On reaching the group of leafless Azaleas, I found the spot sunless and cold, for the high cliffs had already, at 2.30 P.M., hidden the sun. The Azalea is indigenous in the Sierra Mountains at an elevation of 3500 feet. The air was destitute of ladybird-life, but among the dead leaves under the Azaleas I found eighteen masses of *Hippodamia convergens*. They were well hidden under the leaves and nearly always grouped around the base of a stem, but there was not time to find if there were more groups before twilight suddenly came.

Each group of insects was congregated into a ball-like mass the size of one-half to one fist in bulk. I shall follow the example of the woodmen, and call the spot in which each group lay a nest. There was a complete segregation of nests, not a continuity of ladybirds along the whole area. The social instinct that makes the ladybirds collect together is so strong that there were no stragglers between the masses, but the social instinct

* Communicated by Mr. E. ERNEST GREEN, F.Z.S.

† For explanation of the Plate, see p. 705.

was not, at that particular time, strong enough to make all the masses into one.

The condition in the Yosemite may be compared with that in a very narrow canyon on the side of Mount Tamalpais, near San Francisco, where Dr. Van Duzee very kindly took me to see a small massing of *Hippodamia convergens*. The several groups which had collected in some brush by the side of the road were disturbed in the late afternoon of October 25, 1925, by turning the brush over, in order to see how the ladybirds would re-assemble. A number began at once to climb up the main stem and collected at the very top, where some remained. Others also came up gradually, and pressed as near as possible to the first settlers, still more followed, and the latest comers crawled on top of those already assembled. Finally, the mass was so top-heavy that gravity became a greater force than the social instinct, and the top part of the mass toppled and fell. In the meantime, other centres of population had started in various parts of the bush, but the important point is that, when we left, there were more nests in this reassembling than there had been before we disturbed the insects. If we had returned the next morning or afternoon, would there have been a reduced number of nests because the social instinct would have had more time to act? It would be interesting to know what characteristic in some particular ladybird, at some special situation, served as the force which started each nest: was it the member of one sex rather than the other, a ladybird with a particularly strong odour or some other attribute?

In the Yosemite I marked the position of a number of the nests by pieces of yellow paper pinned on a branch above the nest, in order to find the ladybirds after dark.

The floor of the valley where the massing took place has an altitude of approximately 3960 feet, and an average width of only a mile. The Azalea bushes were near the base of a cliff which extends almost perpendicularly, 3254 feet high above the valley. The altitude of the top of the cliff is therefore 7214 feet. In Pl. I. fig. 1, groups of trees can be seen on the mountains above the valley, but so far, no ladybirds have been found hibernating there. In this case, the ladybirds have chosen for their winter-quarters the valley and not the highest possible point.

EXPERIMENTS AT NIGHT WITH LIGHT AND HEAT.

The night experiments planned had to be made on masses which had not been disturbed in the late afternoon. If the ladybirds were disturbed in the smallest degree they moved about in the immediate neighbourhood, and took one to two hours at least to settle quite quietly again. I wished to try the effect of light and heat, separately, upon the insects, about 9 P.M., when it was dark. The moon was bright and nearly full, eleven days old, but its light had no stimulating effect upon the movements

of the ladybirds. Under the Azalea bushes it was comparatively dark. The light of the moon is only a fraction of a candle-metre, but I understand it is sufficient to make bees restless at Rothamsted Experimental Station.

The pieces of paper could be seen a yard away in the moonlight, so the nests were soon located.

We lay upon the ground that the heat of our bodies might not affect the ladybirds. I held the torch, parallel to the ground, the axis of the light passing above the leaves under which the nest was hidden. The lens of the torch was four inches from the centre of the group of ladybirds, but shining only on the leaves that covered them. A companion counted the time, and in half a minute the ladybirds began to move; they did not move either straight towards or away from the light, but up the trunks of the Azalea bushes—they were neither positively nor negatively heliotropic. During the two evenings only one ladybird walked on the glass of the torch. The ladybirds collected on my hat, and several were found, three feet from the mass, on my coat. It was impossible to tell how far, if at all, they went beyond the bushes. At the end of twenty minutes no live ladybird was left under the leaves. All the ladybirds, so far as it was possible to see, were walking, none were flying.

It was impossible to tell how much light penetrated through the dead leaves or even to test the illuminating power of the torch in metre-candles, but I have since tested several torches which were supposed to be the same and found they varied from 2.3 to 5 metre-candles.

The heat produced by the torch is very small. In a laboratory, where the air is comparatively still, when the lens is placed at a distance of $\frac{1}{4}$ -inch from the bulb of a thermometer, the heat produced raises the temperature $0^{\circ}4$ C. at the end of five minutes and $0^{\circ}8$ C. at the end of ten minutes. At a distance of four inches, the distance of the lens from the nest in the original experiment, there is no effect on the thermometer even at the end of twenty minutes. In the open air the results would be even smaller. It is safe to state that the electric torch produced no heat effect upon the ladybirds.

It has to be remembered that, even by day, the sunlight falls on the leaves, but not directly on to the nest of ladybirds which are hidden away underneath.

The same experiments were repeated with other nests, but with the same results. On my way home I was aware that ladybirds were walking on me, and I caught about thirty in my clothes.

W. B. Herms and Martha S. Beaser (1) write, in an unpublished paper, that, in *Hippodamia convergens*, "The reactions to light are positive, but the light stimulation seems to cause an increased movement and a reaction causing dispersal rather than assembling." I made no observations on the reaction of light to assembling.

I then tried the effect of heat upon several nests. A frying-pan was heated over a tin of solid alcohol until the pan felt very hot to the finger, and the pan was then held upside down over a nest. At the end of two minutes I heard something knock the underside of the pan, and, on looking with a torch, a number of moving ladybirds were seen on the stem and adjacent leaves. Again, the ladybirds were walking up the stems. They did not move as a whole directly to the pan. At the end of ten minutes they were not as far up the stem as after ten minutes' stimulation with light. It was impossible to look often or for more than a second for fear of complicating the results by light stimulation.

The only thermometers available were one from an hotel and a clinical thermometer, and both were useless. Since my return to England I have repeated the experiment with a pan of the same size, raised to what I judge was the same temperature. By this means I found the temperature at the level of the covering leaves must have been approximately $23^{\circ}5$ C., a temperature which, judging by the observations carried on during the day, would be expected to cause some movement. It was impossible to keep a steady temperature, but the pan was periodically re-heated.

With heat alone the movements were not as great as during the day with the combination of heat plus light. This confirms my observations on ladybirds living in boxes, where I have found that sunlight plus a lower temperature caused greater movement than a higher temperature without direct sunlight.

Hermes and Beaser, in the paper quoted above, say, "Thermal reactions exert a powerful influence, as evidenced by the fact that the beetles assembled in the fields and the laboratory in small and increasingly larger groups as the temperature is lowered, and disperse again as the temperature is raised. The temperature at which *Hippodamia convergens* is caused to assemble is 28° C."

The following night the same experiments were repeated with similar results, but experiments were also made on ladybirds which were in the crevices of the bark of a yellow pine and also in a hollow at the base of its trunk.

The ladybirds were closely packed together, the head being directed towards the centre of the tree, so that, looking into a crevice, only the red elytra could be seen. This may be a device to hide from stimulus the sense-organs which would be affected by light and, perhaps, heat too. Dr. Essig allows me to publish a photograph of *Azion phagiatum* hibernating in empty acorn-cups, in which the ladybirds are in the same position. *Adalia bipunctata*, when hibernating in England, tends to take up the same position. Evidently this position is not an isolated phenomenon and probably has some biological importance.

The trunk of the tree was completely in shadow during the day. None of these ladybirds had been on the wing, and those in the crevices had not shown the slightest sign of movement. In a shallow hollow at the base of the tree there were a large

number of ladybirds. Those deep in the hollow were in the same position and as quiescent as those in the crevices higher up the tree, but those on the outer parts of the hollow were moving about slowly.

The torch used the second night gave a considerably brighter light than that used the first night. When the light was passed across the crevices there was no movement, and yet a much larger amount of light must have reached the ladybirds than through the leaves which covered the masses on the ground. Even at the end of twenty minutes there was no movement; evidently the response of the crevice ladybirds was different to that of the ladybirds under the Azalea bushes. The light was then directed full at the ladybirds, but there was only a slight movement even at the end of fifteen minutes.

The response of the ladybirds which were not quite in the hollow at the base of the tree was different. The application of both heat and light made them move, and at the end of fifteen minutes some were found crawling three feet up the tree-trunk but, again those deep in the crevices of the hollow were far less sensitive to light, and even after twenty minutes of direct light at a distance of only two inches none of them had moved.

The heated frying-pan was useless on the tree, so the ladybirds were warmed by breathing upon them very gently. After five minutes a few in the outer parts of the crevice moved. When warming by breathing, three other factors besides warmth are introduced—a current of air, moisture, and carbon-dioxide.

The ladybirds in the crevices of the tree were more responsive to warm breath than to light, but there is no evidence to show how much the other factors had to do with the response. It seems as if these ladybirds had sunk into a condition from which they were less easily roused than those under the Azalea bushes which, until that date, had had a few hours of flight on sunny days; here there is the appearance of a cycle of differing physiological conditions comparable with that of hibernating mammals. If the insect passes into such a condition that it no longer responds to the stimulus of the occasional warm day during the winter and to the brightness to which they would be exposed after an unexpected mid-winter thaw, they would surely be better able to survive the long hibernating period. The sundance must be a serious menace to survival, as it certainly uses up a considerable amount of the fat or whatever substance is stored up: So far I have been unable to get any information as to whether there is greater mortality when hibernation is interrupted by a number of sunny days than when winter comes and stays without intermission.

These simple and crude experiments make it quite clear that ladybirds react to pure heat and pure light stimuli. Under normal conditions there is light plus heat, and it remains to be found which plays the bigger part and what is the optimum condition for each. The experiments of the second night

suggest that the rapidity of response to both these stimuli varies considerably with the physiological condition of the ladybird. It depends upon the length of time the ladybird has been hibernating and the time it last responded to the stimuli of heat and light.

At 5.30 P.M. in the afternoon the whole of one mass, as far as I could see after careful examination of the site, was removed eighteen inches from the nest out into the open. At 8.15 P.M. there was a steady stream of ladybirds making their way back to the nest, but few had reached it. At 9 A.M. the next morning the mass was apparently complete again in its nest, and no ladybirds were on the road.

The individuals of this nest, during the hour that I watched them, showed no tendency to walk to several other nests which were within a radius of one foot from the disturbed group. If it had been possible to mark the ladybirds, one could have been sure of the results. It is certain that this procession homewards to the nest was not directed by either heat or light. I should have liked to try artificial solutions of the substance which produces the characteristic odour of the ladybird, for the obvious deduction is that they found their way back by the scent. Herms and Beaser remark, however, "They do not react either in the field or in the laboratory to their own odour or to artificial odours, so that odours seem to play no part other than that of protection and, without doubt, in sexual attraction." Ernest Crabbe has made solutions of ladybirds in the hope of thus collecting quantities of ladybirds, but the solution did not act as a special attraction.

Ladybirds had certainly hibernated under these Azaleas for a number of winters, for digging brought to light faded elytra three inches down in the decayed leaf-mould. These ladybird cemeteries were both under the modern nests and also at spots where, on those two particular days, there were no nests.

There are many instances of ladybirds, of various species, reassembling for a succession of years either continuously or interruptedly in the same situation: *Adalia bipunctata* in a top room in a house at Bournemouth, England; *A. bipunctata* in the same trees at Esher, England (observed by H. J. Burkill); in the same houses at Sutton, Surrey, and North Cray, Kent (observed by G. B. C. Leman); *Coccinella septempunctata* and *A. bipunctata*, the two species in segregated groups, under the bark of larch-poles at Ripley, Surrey (observed by G. Fox Wilson); *Hippodamia convergens*, among grass, at Horse-Tooth, near Fort Collins (observed by Miriam Palmer); *Semiadalia*, on a certain height above Nancy, France; *A. bipunctata*, *C. septempunctata*, and *Semiadalia*, on the summit of Puy-de-Gergovia, in Auvergne, France (observed by Professor Eusebio) (3).

This use of the same place by the same species is not confined to Coccinellids; Scott (2) states that certain *Chloripidæ* come to the same room, in England, time after time. This statement is

confirmed by a considerable amount of data collected by Dr. Gahan at the Natural History Museum at South Kensington, London. These flies do not hibernate in the rooms, but they do assemble in enormous quantities.

The Monarch Butterfly, *Danais plexippus*, assembles in large numbers in the autumn, and it is stated that it collects year after year in the same places in California.

The basal fact in all the cases, and only a few are enumerated, is the selective assembling, whether for migration or hibernation. The insects collect together in pure or nearly pure groups, just as birds do; they are not, to any appreciable extent, mixed with other insects of the same neighbourhood, and when there is a mixture it is usually with an allied insect. This also is the case with birds, where, in a flock of Chaffinches there may be a few Sparrows and a few Greenfinches. Such assemblings cannot be regarded as due to such a physical cause as an air-current, but must be the result of some biological force such as the reaction due to the presence of certain sense-organs. When the biological assembling has taken place, then an air-current may have important effects as a distributor.

OBSERVATIONS ON *HIPPODAMIA CONVERGENS* DURING THE DAY.

The Yosemite Valley, on the southern side where the ladybirds were found, is in deep shadow for a large part of the day in late October.

In the morning an ordinary thermometer was placed on top of a nest, supported on sticks so that there should be no mechanical disturbance of the insects. At a temperature of 63° F. in semi-shadow, the ladybirds were quiet; at the same temperature, but when there was a considerable increase in light but no direct sunlight, the ladybirds began to move, but when the sunlight was on the bushes and the temperature had risen to 70° F., some of them were flying in the air and there was general movement in the nest, but it is important to notice that while some individuals were flying, apparently with much excitement, others were merely crawling and a few were quite still, although not dead. There was, in fact, individual behaviour as well as an average tendency to certain average behaviour.

When, in direct sunlight, the temperature had reached 80° F. the nests were nearly deserted. The maximum temperature in the sun that day was 94° F. In every case the thermometer was placed on the ground, but the real temperature of the air, five feet above the ground, where the ladybirds were flying would be considerably less. It may perhaps be even as much as fifteen degrees less than the maximum temperature of 94° recorded by the thermometer, for on account of radiation the temperature indicated by the thermometer is not that of the air.

There appeared to be more excitement, as evidenced by rapidity and irregularity of flight, as the temperature rose towards 74° F.

than when, after a maximum of 94°, it sank again to 74°. This may have been due to muscular exhaustion or because the maximum stimulation had been received, and there was a physiological reaction of the same kind as that known in the higher animals. When the sun had gone and the temperature had sunk to 54° F. all the ladybirds had retreated under the leaves, except a few which will be mentioned later.

The Azaleas were on a narrow patch extending approximately east and west; the sun first fell on the eastern end, and there the insects deserted their nests and flew in the air when the necessary degree of temperature and light had been reached, and as its rays moved along the patch one mass after another arose. The sun seemed to pass along the Azalea town, knocking in succession at the doors of each house and awakening the inhabitants. At one time the temperature in the sun at the eastern end was 84° F. and in the shadow at the other end only 63° F.

The ladybirds did not fly in the air unlighted by the direct rays of the sun, and as the path of the sun's light moved along, the ladybirds kept in the lighted zone, like the prima donna who keeps always in the limited area of the spot light. The ladybirds were as much confined to certain limited aerial spaces as if they had been surrounded by stone walls. With such limited and definite response to the stimulation of light, there was no chance for them to migrate far. Ladybirds which hibernated on mountain-tops or in other well-lighted positions would not have their daily movements so confined. As the sun sank the ladybirds began to return to their nests, but I had no paint with which I could have marked the insects and so find out whether they returned, in the late afternoon, to the same place which they had left a couple of hours before. It seemed to me that there was an increase in the size of the groups nearer the place where the sun had last shone. Sixteen of the eighteen groups marked were re-formed, but two situated at the east end, which was first warmed and first cooled, had no ladybirds at night.

These observations show that very enlightening and interesting results concerning the tropisms of the ladybird might be obtained by a worker, with adequate apparatus, who could devote a considerable time to experimentation and observation in the field.

REACTIONS TO FOOD.

I knew by experience in England (4) that *Adalia bipunctata* would eat dates with avidity, so I tried *Hippodamia* with the only two likely foods I had—orange-juice and split raisins.

There was little or no interest in the orange-juice. A few ladybirds lapped at the juice when it had nearly dried on the twigs, but they did not stay long.

The split raisins were put near nests when the ladybirds showed signs of movement. At the end of an hour most of the raisins could not be seen, but their position could be recognised

by the crowd of red ladybirds which completely covered them. During the day there was a constant coming and going of diners, some remained only three minutes, but two, at least, stayed for five minutes. Even when dusk had come and the temperature had fallen to 54° F., two to four ladybirds remained on each raisin, although the majority of the ladybirds were sheltering under the leaves. On returning at 9.30 p.m., when the temperature was 42° F., there were still two ladybirds on one raisin, but by the next morning they had disappeared. The stimulus of the food was stronger than the tendency to retreat into shelter on the coming of darkness and cold.

There were certainly no aphids for the *Hippodamia* to eat, but they apparently had drinks from the fine film of moisture which covered the Azalea buds or from the minute drop of dew in the forks of the branches. I do not know if the fluid on the buds contained any dissolved albuminous matter or whether the ladybirds ate any of the fine hairs which outline each of the scale leaves.

Clearly some of the ladybirds were willing to eat if given the opportunity, but there was no wild starvation rush to the sugary raisin. The movements of the ladybirds towards the raisins did not appear purposeful, but, as I have observed so often before, the insect seems to find its food merely by wandering and not by any directive instinct. Perhaps the time will come when we shall be able to find the means by which the ladybird and its food are brought together. It seems biologically unsound that the ladybird should just happen on its food, and yet the spider lives successfully by merely sitting still until the fly, apparently, happens into her web.

ALTITUDE AND HIBERNATION.

Several other massings were reported in the Valley, but I did not have time to locate them.

As far as I could learn, the ladybirds hibernated in the Yosemite Valley and not on the surrounding mountains, but in such a great area very little is as yet known. A number of authorities now believe that canyons and valleys, rather than mountain-tops, are the usual position for hibernating in the Sierra Nevada Mountains of California. The mountain currents, either hot or cold, are very strong and well defined throughout the Sierras. They are indeed so limited that even the unscientific and unimaginative mind realizes them as definitely as if they were visible streams of water.

Over the Yosemite Valley the currents are so strong that aeroplanes are not allowed to land in the valley. How far these currents of air affect the movements and hibernation of ladybirds is an interesting and debatable question.

At some places in the Rocky Mountains the ladybirds are found on the highest points, but the only place of this kind that

I visited was Horse Tooth Mountain, 7160 feet, in northern Colorado, on the eastern side of the Rockies. The Horse Tooth is an isolated bare mass of rock, and has growing on it, here and there in its rough crevices, small tussocks of grass with from one to six inches of soil underneath. Miriam Palmer and George List, of the State Agricultural College of Fort Collins, reported that numbers of *Hippodamia convergens* had been repeatedly found hibernating on this height. We went there on November 21, 1925, and, although there were no living *Hippodamia*, there were elytra of dead ladybirds on or in the soil even when the tussocks of grass grew in the most exposed positions possible. A few elytra, the red considerably faded, were found two inches beneath the soil. Periodically the ladybirds had come and some dead were left behind.

Fig. 2 shows the eastern range of the Rocky Mountains with the Horse Tooth as the highest point. The foreground, 4994 feet, is the edge of the great plateau which stretches across the American continent.

The contrast between the conditions of the hibernating *Hippodamia* here and in the Yosemite Valley, as regards situation and altitude, is extreme. In both places the insects would pass some months under the snow. In the Yosemite the ladybirds are at an altitude of 3960 feet near the base of a mountain which has an altitude of 7214 feet, and in Colorado the ladybirds are at a height of 7160 feet at the top of a range that drops quickly, but not suddenly, to a flat plateau of 4994 feet; in both situations there is a difference of over 2000 feet between the level and the mountain-top.

AIR-CURRENTS AND THEIR RELATION TO LADYBIRDS FOUND ON MOUNTAIN-TOPS.

As the effect of air-currents upon the movements of ladybirds is fundamentally a physical and not a biological problem, I submitted certain queries to Dr. Shakespeare, Lecturer in Physics at Birmingham University, to whom I am indebted for much that follows.

The chief problems are, when biological forces have collected a large number of ladybirds together,

- (1) What may happen to them if they fly into a current of air?
- (2) How can a current of air deposit them on the top of a mountain?

We next need to know if and how much, ladybirds are helpless in a wind. It is certain that the ladybirds in the great gales that blow along the eastern side of the Rockies, and which are so strong that they can stop a high-powered car, would have no volition and would just go where they were carried.

At times winds have certainly blown ladybirds to destruction: for instance, there are a number of records of *C. septempunctata* being blown out to sea and drowned in enormous numbers, in

England, in late summer or early autumn, and Johnson (5) says, speaking of the conditions in the Western States, "These beetles (*Hippodamia*) are found in great numbers in the flotsam of the shore of large bodies of water when a certain sequence of winds occurs."

A flight of ladybirds might be caught by an air-current which was going up a mountain on its windward side. The air moves up the side of the mountain, curls over the top, twists down on the leeward side, and then, making a curl towards the earth, turns upwards towards the summit, so that the minimum speed would be on the leeward side, just below the top.

The minimum buoyancy will always be at the highest point.

If the wind up the side of the mountain is very gentle, there is no reason why the ladybird should not drop on to the ground whenever it so wished, but if the rate of the wind-movement was strong there must be a definite rate when the ladybird could not drop, its weight being so small in relation to the speed at which it was being carried along.

Any considerable change in altitude—say, from sea-level to 1000 feet, or from 3000 feet to 8000 feet—would cause the ladybird to drop owing to diminution of buoyancy. It is conceivable that a gale blowing ladybirds from the plateau at 5000 to the top of Horse Tooth at 7160 might so quickly reduce the buoyancy that they would be killed.

There are two principal factors involved—the rate of the wind and the rate of the reduction of the buoyancy.

The chance of the ladybird falling to the ground would be greatest when there is a combination of a minimum velocity and a minimum of buoyancy; this position will probably be just below the summit on the leeward side of the mountain. If they were deposited in this position by a wind, they would, owing to their undoubted tendency to go upwards, probably finally find their way to the top of the mountain.

The other factor to be considered is cold. Would the reduction of the temperature at the top of the mountain be sufficient to cause a sudden drop to the ground in that particular position? The reduction of temperature between the valley and the mountain-top is not sudden, but gradual, about ten degrees for every 3000 feet. If there is a minimum temperature at which ladybirds would automatically seek shelter, and that is, I think, sufficiently clear, even from my rough experiments in the Yosemite Valley, that temperature might be reached, and the ladybirds drop anywhere between the valley and the summit, and not necessarily at the top. The effect of cold alone would not, therefore, be expected to play a big part in making the ladybirds take up their position on the top of the mountains.

We do not yet know how far ladybirds can adapt themselves to rapidly changing altitudes, but we do know that man has considerable difficulty. As soon as material is available, experiments will be made to elucidate this point. It may be that

the ladybird that has grown to maturity at sea-level is quite incapable of living at an altitude of 8000 feet, and that, unless caught in a gale, it would automatically settle and hibernate at much lower altitudes.

SUMMARY.

1. Crude experiments in the Yosemite Valley show that *Hippodamia convergens* responds by movement to both light and heat stimuli, whether separate or combined. The optimum for each has yet to be determined.

2. The capacity to respond depends upon the length of time since hibernation began. A seasonal physiological insensitiveness to stimuli may be of considerable survival value.

3. *Hippodamia convergens* ate raisins, which they appeared to find by chance, and some continued to eat even when the low temperature had driven most to shelter.

4. *Hippodamia convergens* may be found hibernating in large masses at a variety of altitudes, but what determines that altitude is not yet known, or whether ladybirds which have grown in an altitude of, for example, 1000 feet would be physiologically capable of hibernating at an altitude of 7000 feet.

5. When biological forces have collected ladybirds in large numbers, then only, air-currents may have considerable effect upon their distribution and the positions where they ultimately hibernate.

6. Air-currents of great velocity might destroy ladybirds.

7. The effect of change of buoyancy upon ladybirds has yet to be determined.

My thanks are due to Professor Carlier for allowing me to do heat and light experiments in his laboratory at Birmingham University, and to Dr. Essig for the use of his photograph.

BIBLIOGRAPHY.

- (1) HERMS, W. B., and BEASER, MARTHA S.—An unpublished paper on the Tropisms of *Hippodamia convergens*.
- (2) SCOTT, H.—Ent. Month. Mag. vol. lii. 1916, pp. 18 and 43.
- (3) HAWKES, O. A. MERRITT.—“Hibernation of Coccinellidæ on Mountains.” Ent. Month. Mag. vol. lix. 1923, pp. 53-55.
- (4) HAWKES, O. A. MERRITT.—“Observations on the Life-history, Biology, and Genetics of the Ladybird Beetle, *Adalia bipunctata* (Mulsant).” Proc. Zool. Soc. London, 1920, pp. 475-490.
- (5) JOHNSON, H. ROSWELL.—“Determinate Evolution in the Colour-pattern of the Lady-Beetles.” Carnegie Institute Publication No. 122, 1910.

EXPLANATION OF THE PLATE.

- Fig. 1. The Eastern side of the Rocky Mountains in Colorado. The foreground has an approximate elevation of 5000 feet, and the highest summit, Horse Tooth, where the ladybirds hibernated, is 8000 feet.
2. The end of the Yosemite Valley. In the foreground is the patch of leafless Azaleas where the ladybirds were hibernating. The foreground of the picture is 3960 feet altitude, and the high mountain to the right is 8852 feet. Beyond the Azaleas is a small field, then an apple orchard, where large numbers of *Hippodamia* had been found at one period in the summer, and close to orchard there are pine-trees.
 3. A nearer view of Horse Tooth Mountain showing the bare rocks.
 4. *Axion phagiatum* (Oliver) hibernating in a corn-cup of *Quercus lobata*: this shows a definite orientation of the body.
(Photograph kindly lent by Dr. Essig of Berkeley University.)