TEMPERATURE CHANGES IN HIBERNATING HEDGEHOGS

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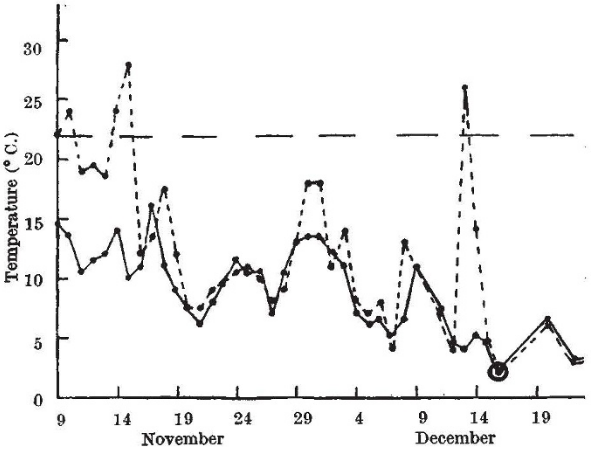
THESE records of the varying temperatures of hedgehogs during their period of hibernation, and of the relationship between these and relevant air temperatures, were made during three winters before and just after the Second World War. In pre-war days the feeding of these animals was less difficult (we used milk and eggs). Our aims were to discover: (1) whether an adequate supply of fresh food would delay hibernation; and (2) to what degree temperature changes were related to or independent of relevant air temperatures.

We have long lists of statistics covering three or four years of observation; but the integration of our results gives some fairly definite information, and a frequent recurrence and constancy of certain temperatures which seem even more significant now, in view of the fact that we are receiving some of the same recurring constants with other hibernating mammals—in particular with *Glis glis*, one of Dr. Vever's squirrel-tailed dormice.

The hedgehog, when not hibernating, is a normally homoiothermic animal with a constant summer temperature a little higher than our own (37·0° C. or 98·6° F.). During its hibernation it passes through a poikilothermic phase, that is, it becomes virtually a 'cold-blooded' animal, with a temperature which varies with that of the surrounding atmosphere. The length of this poikilothermic phase may be lengthened, as in the case of our H.3, which had not achieved its normal summer temperature by midsummer (in captivity).

Outlined below are some of our more important discoveries concerning hedgehogs 1, 2 and 3, with a graph of the temperature behaviour of H.3—which showed a remarkable recovery from the abnormally low temperature of 2·0° C.

Hedgehog 1 (*Female*). H.1 was received into a hutch in an old outside aviary on January 18, 1937. It was already in hibernation, and its temperature was 11·0° C.—that of the air in the aviary was 15·0° C. Between January 18 and March 12, 1937, we kept daily records (at 1 p.m.) of the temperatures of hedgehog and of air.



Full line, air temperature; broken line, hedgehog's temperature. ———, line of W.T.22, waking temperature. ○, occasion upon which H.3 sustained a temperature of 2·0° C.

Four times during this period the hedgehog woke from hibernation, with no external stimulus except that of varying air temperature. The 'waking temperature' was found each time to be 22·0° C. (71·6° F.), and this temperature was obtained on all but one occasion only after the air temperature had risen to 12·0° C. (53·6° F.). It was observed that whenever the air temperature was recorded at 12·0° C. the animal stirred and that when its own temperature touched 22·0° C. it sought food (which was always accessible). The hedgehog is by no means a continuously 'deep sleeper' in hibernation. Even at its lowest ebb (except on the classic occasion when H.3 touched 2·0° C.) it showed slight movements of the spines in response to touch. This aggressive stiffening of the spines was our most reliable indication of life even when heart beats and breathing were imperceptible.

The blood temperature of H.1 never rose to the normal summer temperature of 37·0° C. while in captivity. At the end of March we took it back to the woods. Whether its temperature ever became normal in a wild environment we do not know, although another hedgehog (H.4) captured in July 1941 and brought in for two days observation gave us the normal summer temperature of 37·0° C., or 98·6° F. We formed the impression that hedgehogs retained in captivity during their hibernating period and afterwards do not achieve a normal summer temperature. This hypothesis was borne out by H.3, which on June 11 still remained at 32·0° C. (89·6° F.).

Hedgehog 2 (*Male*). (The winter of 1938.) The brief record of temperature readings from our second hedgehog was important from one aspect only, that the animal died and we were able to record a 'death temperature'. This was a smaller animal than H.1 and not so well nourished. We found it in deep hibernation in February and knew that it was alive from slow but perceptible heart-beats and the sensitivity to touch of the spines. On February 26 all spine reaction ceased, and at 4·0° C. the hedgehog died, and in death relaxed from a 'rolled' to a straight position. We waited for putrefaction to set in before disposing of the body. This case was amply justified when H.3 (1939–40) sank below this death temperature and revived again.

In order to facilitate references to our records we now established a series of abbreviations for the more outstanding or constant of our temperature results, as follows:

W.T.22 = waking temperature of hedgehog (constant); that is, 22·0° C. (71·6° F.).

C.T.37 = normal summer temperature (constant); that is, 37·0° C. (98·6° F.).

S.N.T.32 = subnormal summer temperature in captivity (constant); that is, 32·0° C. (89·6° F.).

D.T.4 = death temperature of H.2; that is, 4·0° C. (39·2° F.).

Hedgehog 3 (*Female*) (1939–40). Hedgehog 3, from which we obtained our most significant range of temperature variations, was a well-nourished female. We found her in a local ditch on November 9, awake but not very active. It is interesting to note at this point that the female hedgehogs (probably because of extra subcutaneous fat) appear to be better nourished and to survive winter better than do the males.

Between November 9, 1939, and the final emergence from hibernation on April 21, 1940, H.3's blood temperature rose above W.T.22 four times; but with these exceptions a state of hibernation was maintained for five months.

We retained H.3 in captivity until June 11, in an effort to record the constant summer temperature, but C.T.37 was never achieved by H.3. After April 21 until we let her go on June 11 she remained healthy, and nocturnally active, with a constant temperature of 32·0° C. (S.N.T.32).

The most startling performance of H.3 was her amazing recovery after having sustained the low temperature of 2·0° C.—two degrees lower than the death temperature of H.2. The winter of 1939 was severe, a particularly bitter December. Apart from one rise of air temperature between December 1 and 16, which dragged up the blood temperature of H.3 with it, the atmosphere became progressively colder until we recorded 2·0° C. as the temperature of both air and hedgehog on December 16.

The revival of H.3. No readings were taken between December 23 and March 1, because H.3 was presumed dead. Even spine reaction had ceased although the animal remained curled up. A student examining the hutches on March 1 stated that she believed the hedgehog to be alive, although there seemed nothing to justify this belief at the time. However, we began temperature records again, only to find that air and blood temperatures were practically similar. Since this was fairly common during deep hibernation we persisted, and at the beginning of April a slight reaction of spines was observed, and we knew H.3 to be alive. The blood temperature remained 'chained' to the air temperature until a general rise took place on April 19, 20 and 21, during which time the blood temperature of H.3 gained independence and eventually rose to 32·0° C. (S.N.T.32), where it remained constant until the release of the animal on June 11. As stated before, it never achieved a normal summer temperature in captivity.

Two other hedgehogs, H.4 (which has already been mentioned) and H.5, were studied in subsequent years. Their records helped to verify our previous discoveries.

D.D.T. AND 'GAMMEXANE' AS RESIDUAL INSECTICIDES AGAINST *ANOPHELES GAMBIÆ* IN AFRICAN HOUSES

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DESPITE the great developments in residual insecticides in the last few years, there is still difficulty in assessing and comparing their value in controlling anopheles—under African conditions at least.

The dramatic fall in the day-catch of mosquitoes in houses treated with D.D.T. is now known to be of doubtful significance by itself, and may give an entirely misleading impression that a high kill of mosquitoes has been obtained[1].

To estimate the effect on the incidence of malaria, or rather on the incidence of new infections, of large-scale treatment of African houses, is also a difficult matter, although in theory this should constitute the ultimate criterion of success. Large-scale experiments of this kind have to be planned on a long-term basis, during which time the African may be exposed several times to infection outside the controlled area. This may introduce a considerable source of error and uncertainty into the experiment, a point which has recently been emphasized by Walton[2].

It seems to me that before embarking on such large-scale experiments, the first thing is to try to find out exactly what happens inside an African house after treatment with a residual insecticide. For this purpose the technique worked out in West Africa offers the most simple and accurate solution so far[1,3].

In a study of the normal habits of anopheles in African native houses, it was found that mosquitoes leaving the shelter of the house at dusk or dawn were strongly attracted to light coming in through window and door openings. To the restless mosquito the attraction to light was equally strong during the hours of darkness, mosquitoes being attracted to the faint light coming in from the night sky. This principle was used to design a simple mud and thatch African-type hut in which two to four paid Africans slept every night. The hut was so constructed that while hungry anopheles could gain entrance through innumerable small cracks and crevices, the only light coming in from outside was through a 1-ft. square window opening, over which a mosquito netting trap-cage was fixed. Mosquitoes attracted to the light were directed into a narrowing funnel which led through a small opening into the cage. This one-way valve idea is essential, as mosquitoes trapped in the cage are attracted once more towards the darkness of the hut when bright daylight appears.

D.D.T.

D.D.T. in kerosene. As already reported[1], huts of this type were used in Lagos, West Africa, to test the effect of house treatment with D.D.T. in kerosene. Treatment of inside walls and roof at the rate of approximately 100 and 250 mgm. D.D.T. per sq. ft. afforded almost complete protection from biting for about one week. After that time, a steadily increasing number of blood-fed *A. gambiæ* and *A. melas* were taken every day in the window-traps. Among these anopheles there was no appreciable mortality in the following 48 hours. Within a few weeks of treatment, large numbers of anopheles were feeding regularly in the treated huts, were irritated by brief contact with the treated walls and roof, and were trapped in the window-cage as they attempted to leave the hut. The day-time catch of resting anopheles inside the treated hut remained practically zero for at least two months after treatment. The initial few days of complete freedom from biting was later shown to be due to the repellent effect of the heavy dose of kerosene which accompanied the D.D.T.

Possibly the first suggestion that mosquito control by treatment of houses with D.D.T. might not be as simple as it first appeared was due to Kennedy[4], who showed in laboratory experiments with *Anopheles maculipennis* that mosquitoes are excited by contact with D.D.T.-treated surfaces. In this state they were attracted to light, and could escape without having absorbed a lethal dose of the insecticide.

The field experiments in Lagos show that this irritant effect of D.D.T.-treated surfaces is a factor