THE EFFECTS OF LETHAL TEMPERATURES ON ORIBATID MITES

BY

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1. LETHAL EFFECTS OF HIGH TEMPERATURES.

INTRODUCTION.

The thermal death point (TDP) is the highest possible temperature for life in arthropods. This temperature varies depending on the length of exposure, the relative humidity and the physiological condition of the animals, such as starvation (MELLANBY, 1934) or acclimatization (MELLANBY, 1954). Arthropods have been usually exposed for 1 hour or 24 hours. Alternatively, the time required for exactly 50 % mortality (T_{50}) has been found, but there is little advantage in using this method (MELLANBY, 1960).

It is not clear which mechanism is responsible for heat death. For short exposures in dry air, large arthropods cool themselves by evaporation or convection and hence depress their body-temperature : their TDP will therefore be higher in dry air than in saturated air (GUNN and NOTLEY, 1936 ; EDNEY, 1951). During long exposures this effect is reversed. Moreover, death in dry air is mainly caused by desiccation and in saturated air by lethal heat ; hence results in saturated air are probably more accurate because there is no water-loss. This factor is especially important in small arthropods, where the ratio of volume to surface area is small. Therefore, they must loose water to a much greater extent to depress their body-temperature, resulting in acute water shortage.

This is the fourth of several papers on the sensory physiology and behaviour of oribatid mites (for other work see MADGE, 1964 *a*, *b*, and *c*).

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Materials and methods.

The TDP of oribatid mites living in differing microclimates has been found. The mites used and the different habitats from which they were collected (Madge, *in preparation*) are given below :

Humerobates rostrolamellatus Grandjean (bark of apple trees)
Carabodes labyrinthicus (Mich.) (heathland)
Belba geniculosa Oudms. (syn. *Damaeus onustus* Koch) (oak litter)
Euzetes globulus (Nic.) (oak litter, woodland moss and sphagnum)
Steganacarus magnus (Nic.) (oak litter, woodland moss and sphagnum)
Platynothrus peltifer (Koch) (oak litter and sphagnum)
Fuscozetes fuscipes (Koch) (sphagnum)
Nanhermannia nana (Nic.) (sphagnum)
Hypochthonius rufulus (Koch) (sphagnum)

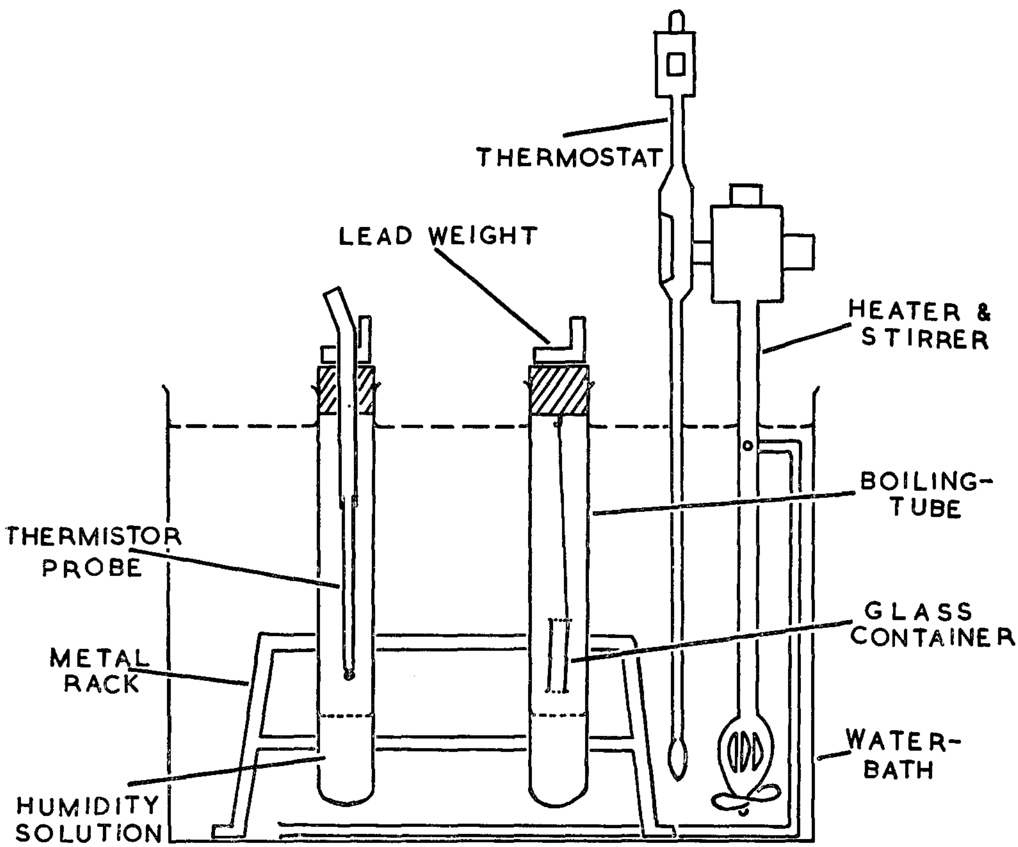

Fig. 1. — Apparatus for investigating the thermal death point of oribatid mites (not to scale).

The apparatus is illustrated in Fig. 1. The mites were taken from culture at 15°C (± 1.7°C), put into short hollow lengths of glass tubing (2 cm × 0.5 cm) covered at both ends by fine nylon mesh and suspended in boiling-tubes (17 cm × 2 cm) 1 cm above aqueous solutions of sodium hydroxide (MADGE, 1961), in 0 % (P_2O_5), 30 %, 60 %, 90 % and 100 % (H_2O) relative humidity. The boiling-tubes were immersed up to the neck in a thermostatically controlled water-bath, accurate to within 0.1°C. The air temperature inside the boiling-tubes was frequently checked with a thermistor unit (PENMAN and LONG, 1949). The apparatus was kept at the required temperature for 15 minutes before starting the experiment. When the TDP was found, the experiment at this temperature was repeated with another group of mites. After each experiment, the mites were removed to small petri dishes with moist filter paper floor and observed ; this was necessary for some of them eventually recovered and then behaved normally.

The weight-loss with *B. geniculosa* in different relative humidities at various high temperatures was found by weighing groups of mites on a 5 mg torsion balance (sensitive to 0.02 mg) immediately before and after each experiment. There was no defaecation, so loss in weight was only due to evaporation.

RESULTS AND DISCUSSION.

a) *Experiments with Belba geniculosa Oudms.*

Fig. 2 shows the TDP and weight-loss by evaporation at the TDP and Table 1 gives the weight-loss in different relative humidities at high temperatures. The TDP after 15 minutes was 41.5°C at all humidities, the mites losing about 1 % of their original body-weight ; evaporation in dry air was slightly higher than in saturated air (ratio 1.3 : 1). After 1 hour the TDP was 39.5°C in 0 % R.H. and 40.0°C in all other humidities. The mites lost about 11 % of their weight in 0 % to 60 % R.H., 6 % in 90 % R.H. and 1 % in 100 % R.H. The TDP after 12 hours was 32°C-33°C in 0 % to 60 % R.H. and 36°C in 90 % to 100 % R. H. The mites lost about 15 % of their weight in 0 % to 60 % R.H., 13.5 % in 90 % R.H. and 2 % in 100 % R.H.

Thus, evaporation is negligable in all humidities for short exposures (15 minutes), death being caused by lethal heat and not by desiccation. After 1 hour exposure, evaporation in dry air was 10 times higher than that in moist air, but the difference in the TDP at all humidities was only 0.5°C or less. Hence, at low humidities death was again mainly caused by high temperature and not by excessive evaporation. During 12 hours, evaporation in low humidities was 14-16 times higher than that in saturated air and the TDP in dry air was 4°C lower than that in moist air. Therefore, death at low humidities was caused by the accumulative effects of evaporation and high temperature ; at high humidities it was caused mainly by excessive heat.

Thus, the true TDP of *B. geniculosa* was found after 15 minutes or 1 hour in different humidities, because death was mainly caused by lethal heat. During

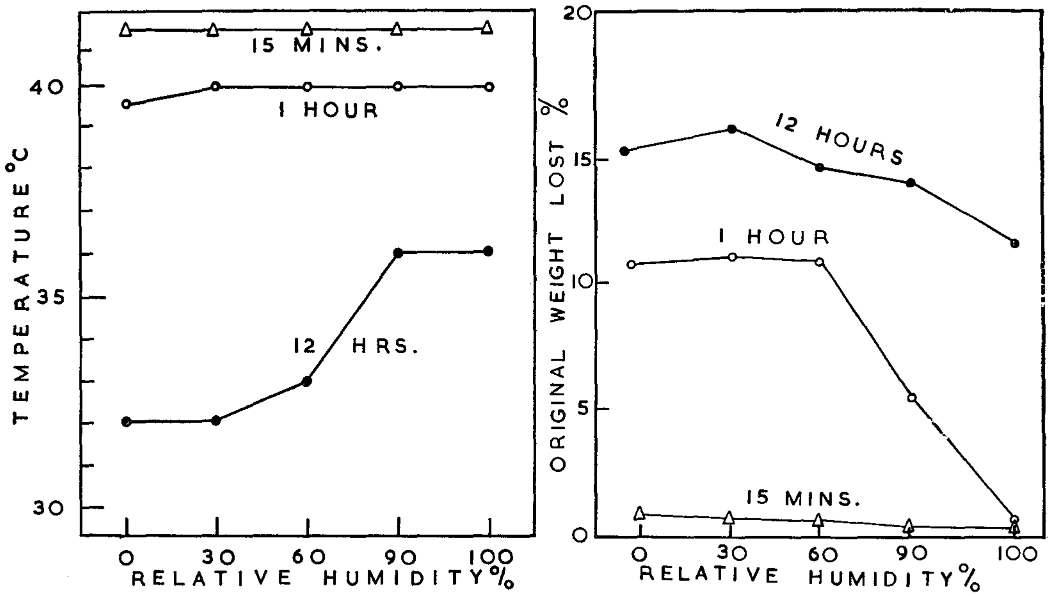

Fig. 2. — The relationship between thermal death point (left) and weight-loss by evaporation (right) with adult *Belba geniculosa* Oudms. at different relative humidities for 15 minutes, 1 hour and 12 hours (5 mites at each temperature and R. H.).

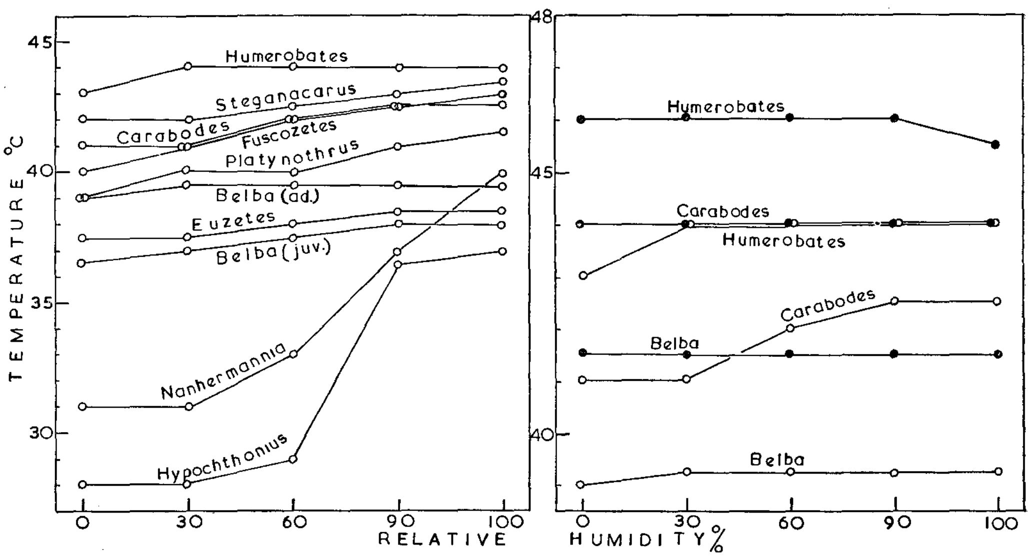

Fig. 3. — The thermal death point of adult oribatid mites at different relative humidities for 1 hour (left) and 15 minutes (right) exposures. 10-15 mites (5 with *B. geniculosa*) at each temperature and R. H. (*N. B.* Solid symbols on right denote 15 minute exposures, clear symbols denote 1 hour exposures.)

TABLE 1.

Evaporation, expressed as percent original weight-loss, of adult *Belba geniculosa* Oudms. in different temperatures and relative humidities after 15 minutes, 1 hour and 12 hours. Numbers in italics represent the thermal death point of the mites (5 mites for each test).

THERMAL DEATH POINT : 15 MINUTES.

Temperature °C	*Relative humidity %*				
	0	*30*	*60*	*90*	*100*
42	1.4	1.4	1.3	0.9	0.8
41.5	*1.4*	*1.3*	*1.3*	*0.8*	*0.8*
41	1.3	1.3	1.2	0.9	0.8
40	1.4	1.3	1.3	1.0	0.7
39	1.3	1.4	1.1	0.8	0.6

THERMAL DEATH POINT : 1 HOUR.

Temperature °C	*Relative humidity %*				
	0	*30*	*60*	*90*	*100*
40	11.4	*11.3*	*11.2*	*5.9*	*1.4*
39.5	*11.3*	11.1	10.9	5.7	1.1
39	10.8	10.9	10.6	0.9	0.1
38	10.7	11.0	10.4	1.1	0.1
37	10.8	11.0	10.5	1.0	0.4

THERMAL DEATH POINT : 12 HOURS.

Temperature °C	*Relative humidity %*				
	0	*30*	*60*	*90*	*100*
37	20.1	17.9	19.4	13.7	1.9
36	18.9	17.0	18.1	*13.5*	*1.9*
35	18.0	16.9	17.2	13.4	1.8
34	17.2	17.0	16.5	12.0	1.7
33	17.0	16.9	*14.0*	11.2	1.4
32	*15.2*	*16.4*	12.9	12.1	1.4
31	13.0	11.9	12.5	12.8	1.5
30	12.8	12.0	12.2	13.0	1.1

12 hours the mites were unable to conserve water and hence death was due to the combined effects of dessication and high temperature.

b) *Experiments with other species of oribatid mites.*

Fig. 3 gives the results obtained for 1 hour exposures in different humidities, showing that the TDP varied with (a) the species of mites and (b) the relative humidity. In all experiments the mites survived longer in moist air, since in dry air they were unable to keep their bodies cool by evaporation because of their small size. *H. rufulus* and *N. nana* were very susceptable to differences in humidity during 1 hour. For instance, the TDP of *H. rufulus* was 28°C in dry air and nearly 37°C in moist air ; that of *N. nana* was 31°C and 40°C respectively. With the other species of mites, the TDP in dry humidities was 1°C-2°C lower than in high humidities.

Some experiments lasting 15 minutes are also given for comparison (Fig. 3), showing that the TDP was higher and fell within narrower temperature limits at different humidities compared with experiments lasting 1 hour. The TDP of *H. rostrolamellatus* was slightly lower (45.5°C) in saturated air than in non-saturated air (46°C) for 15 minute exposures (this experiment was repeated five times with 5 batches of 15 mites, with consistent results). Thus, for short exposures this species cools itself to a limited extent by evaporation in 0 % to 90 % R.H., unlike the other species of mites.

There is an ill-defined relationship between the TDP of the mites and their different habitats : the moister the habitat, the lower the TDP. Thus, *H. rostrolamellatus* and *C. labyrinthicus*, collected from the bark of trees and heathland soil respectively (xerophyls), had a TDP of 43°C-44°C and 41°C-42.5°C respectively. That of *H. rufulus* and *N. nana* was 28°C-36-5°C and 31°C-40°C respectively, these mites being usually found in sphagnum (hygrophyls). The TDP of woodland litter and woodland moss mites, *B. geniculosa*, *E. globulus* and *P. peltifer* (mesophyls or meso-hygrophyls), varied from 39°C-41.5°C in 0 % R. H. and 100 % R.H. respectively. But that of *F. fuscipes*, a hygrophyl, was 40°C-43°C and that of *S. magnus*, a meso-hygrophyl, was 42°C-43.5°C, which are higher than the TDP of other " typical " mites. Most other arthropods show little relationship between their TDP and the kind of habitat in which they live (WIGGLESWORTH, 1953).

A correlation is also apparant between the TDP of the mites and their integumental covering. Many arthropods restrict evaporation through their integument by an impermeable waxy epicuticle. MADGE (1964 *a*) showed that, with the exception of *H. rufulus* and *N. nana*, other species of oribatid mites studied had a waxy epicuticle. Thus, these two species died at a much lower temperature in dry air than in saturated air, owing to excessive evaporation. The shrunken abdomen of *H. rufulus* in 0 % R.H. to 60 % R.H. suggested that death was mainly caused by desiccation and the normal turgid appearance in 100 % R.H. suggested that lethal heat was the main cause of death. The results with *B. geniculosa* lasting for 12 hours would thus correspond with those with *H. rufulus* lasting for 1 hour.

Acclimatization and the thermal death point.

The TDP of some arthropods may be altered by acclimatization at different temperatures but their subsequent life-history may become become permanantly affected if they are allowed to recover (MELLANBY, 1954). Acclimatization may take a day or longer or it may take less than one minute.

Experiments with *B. geniculosa*, *S. magnus* and *N. nana* were done by putting them in stoppered tubes (2.5 cm × 2.5 cm) with moist filter paper floor and detritus as food and keeping them at 0.7°C, 5°C, 20°C and 25°C. Groups of mites were removed 2-3 days later and their TDP found. Their TDP was similar to those already given (Fig. 3), showing that they were not acclimatized to previous temperatures, but they may have been rapidly acclimatized to laboratory temperature (14°C-17°C) during transfer to the experimental apparatus.

2. LETHAL EFFECTS OF LOW TEMPERATURES.

Experiments were also done on the cold death temperature of the mites, i.e. the temperature below which exposure is lethal. Their chill coma temperature (i.e. the temperature at which cold stupor occured) was also found, but as the results were variable they are not given.

METHOD.

The experimental chamber (Fig. 4) was left at the required temperature for half an hour before starting the experiments. Mites were taken from culture at about 15°C and put on to the bulb of a mercury thermometer, keeping them dry to prevent frozen water inocculating their body-fluids (SALT, 1958). One hour later they were removed to culture cells at 15°C and periodically re-examined. The temperature was noted before and after each experiment, and varied about ± 1°C.

RESULTS.

The results, given in Table 2, showed that all the mites survived at —3°C and all died at —12°C. Unlike the TDP for 1 hour, when they died within narrow temperature limits (mean difference : 2.5°C), the cold death temperature was more variable (mean difference : 8°C-9°C). There was no obvious relationship between the habitat and the cold death point of the mites.

Acclimatization and cold death temperature.

B. geniculosa was left for 16-18 hours at 0.7°C-25°C and their cold death point then found (Table 3). The mites were not acclimatized to these temperatures.

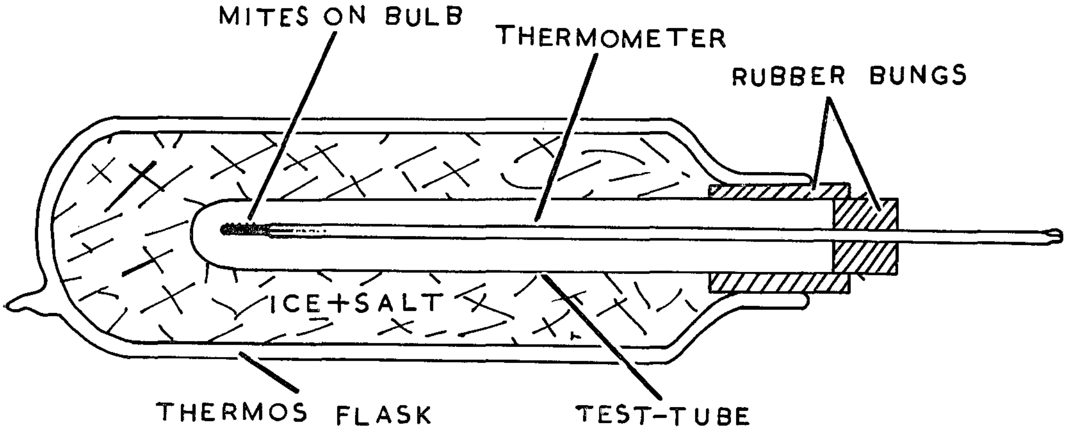

FIG. 4. — Apparatus for investigating the cold death temperature of oribatid mites.

TABLE 2.

The survival of oribatid mites for one hour exposures at various sub-zero temperatures. Results accurate to ± 1°C (10 adults mites per experiment)

Temperature °C	—3	—4	—5	—6	—7	—8	—9	—10	—11	—12
H. rostrolamellatus	10	10	10	10	10	8	6	4	1	0
C. labyrinthicus	10	9	7	7	7	7	6	2	0	0
B. geniculosa	10	10	9	7	2	0	0	—	—	—
E. globulus	10	9	7	2	0	0	—	—	—	—
S. magnus	10	10	10	10	10	10	8	3	2	0
P. peltifer	10	10	10	10	10	9	7	2	0	0
F. fuscipes	10	10	10	10	10	9	8	4	3	0
N. nana	10	10	10	10	10	7	4	2	0	0
H. rufulus	10	10	10	10	10	10	9	6	3	0

TABLE 3.

The effect of different acclimatization temperatures on the cold death temperature of adult *Belba geniculosa* Oudms. Ten mites for each test ; number of live mites after 1 hour given.

Survival temperature °C / *Acclamatization temperature °C*	—4	—5	—6	—7	—8
0.7	10	9	7	3	0
5	10	8	8	2	0
15	9	10	7	2	0
25	10	9	8	3	0

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SUMMARY.

1. The lethal effects of temperature extremes with different species of oribatid mites were studied.
2. Each species has a characteristic thermal death point.
3. The TDP also depends on the relative humidity and on the length of exposure.
4. With *B. geniculosa*, death after 15 minutes or after 1 hour exposures is caused mainly by lethal heat at all relative humidities. After 12 hours it is caused mainly by excessive water-loss at low humidities and mainly by lethal heat at high humidities.
5. There is a broad relationship between the TDP of the mites and their different habitats.
6. The TDP of *B. geniculosa* remains unchanged when previously kept at 0.7°C-25°C; they are thus not acclimatized to these temperatures.
7. The cold death temperature of various species of mites after 1 hour varies from —3°C to —12°C.
8. The cold death temperature of *B. geniculosa* was not changed when previously kept at 0.7°C to 25°C.
9. There is no correlation between the cold death temperature and the natural habitat of the mites.

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