Experiments on the regulation of the body temperature of certain tenebrionid beetles.

by

NIELS BOLWIG

Zoology Department, University of the Witwatersrand, Johannesburg.

On two visits to the Kalahari Gemsbok Reserve in 1956 and 1957, arranged by the National Parks Board, as well as on other journeys to arid areas, I noticed that some very black tenebrionid beetles were active even in the hottest part of the day when the sand was so hot that it was most uncomfortable for me to walk about barefooted. In a comparatively cool period in February 1957, the surface soil temperature was 57°C., while the air temperature at 12 cm. above the ground was 46°C. These observations drew my attention to the question of how these insects are able to tolerate such high temperatures.

Various workers have investigated the temperature preferences of insects, the extremes of temperatures that they are able to tolerate and the extent to which they can regulate their body temperatures. Strel'nikov (1932), Uvarov (1948), and Parry (1951), found that heat absorption is affected by the colour of the animal. The radiation load depends on the shape of the body and may be affected by the insect's orientation with respect to the source of heat. (Bodenheimer, 1929, and Parry, 1951). Fraenkel and Gunn (1940), and Gunn (1942), have shown that desert locusts, *Schistocerea gregaria* Forsk., orientate themselves in the early mornings so that the long axis of the body is kept perpendicular to the rays of the sun, thereby exposing themselves to the maximum heat radiation. When the air is dry, insects, particularly large ones, can maintain a body temperature below that of their surroundings. This is done by transpiration. (Buxton, 1924, and Mellanby, 1932). Gunn (1942), however, is of opinion that the cooling mechanism cannot be an active one. Although he admits that a lowering of the body temperature by transpiration can be useful over a short period, he maintains that it is harmful over a longer period.

On my journeys to arid areas in 1956 and 1957, I collected various black tenebrionid beetles and brought them home alive. More live beetles were presented to me by Dr. C. Koch, of the Transvaal Museum. In am grateful for the help he has given me and I am particularly thankful for the specimens of *Onymacris bicolor marshalli* Koch, which are remarkable in having white elytra. This beetle, he informs me, is found in the hottest parts of the Kalahari.

Since the beetles are not only exposed to very hot air but also to an intense heat radiation, I was wondering whether they were able to reflect the heat rays in spite of their dark coloration. A number of beetles was therefore

C. Koch

With compliments
Niels Bohr

140

(1) beetles - onymacris - their [illegible] d
(2) " - tenebrionids - "
(3) S.A. fauna

examined in an infra-red converter in the Department of Physics of the University of the Witwatersrand. I am very grateful indeed for the help I received from the staff there. The results were that no heat waves were reflected by any black part of the beetles.

To determine the effect of heat absorption on the body temperature of the beetles, I attempted in the laboratory to copy the climatic conditions in the Kalahari, to the best of my ability. This was done by exposing the live beetles to the radiation from an electric heater. I employed three different species of diurnal beetles, namely *Onymacris bicolor marshalli*, which is black with white elytra, *Onymacris multistriata* Haag, which is jet black with only a narrow yellow edging of its prothorax and *Adesmia sp.* which also is black. All these beetles are diurnal and can be seen running about in the sun. For comparison the nocturnal *Gonopus sp.* was also tested. *Adesmia sp.* and *Gonopus sp.* were both from the north-western Transvaal while the two species of *Onymacris* were from the Kalahari.

During the experiment the insects were suspended, dorsal side facing the heater, about 25 cm. above the table on which the experiments were carried out, with a thermo-couple in their body. During the first experiments the thermo-couple was inserted from the dorsal aspect into the prothorax of the beetle. It was, however, found difficult to protect the wires well enough so as to avoid heat conduction to the couples. In later experiments the couples were therefore inserted from the ventral side of the abdomen, thus facilitating a better screening of the wires. An effective protection of the wires was also provided by a rubber tube which surrounded them. Next to the beetle was a test tube blackened with soot. In the bottom of the test tube was a little water into which was inserted a thermometer and the other thermo-couple. The water, together with the inserted bulb of the thermometer, was kept at a volume approximately the same as that of the beetle. Behind the beetle and the test tube was a linoleum screen. The difference in temperature between the water in the test tube and the body of the beetle was read on a low-resistance galvanometer and the actual temperatures of the beetles could thereafter easily be calculated by adding it to that read on the thermometer in the test tube. In most experiments the temperature of the beetle was determined for each rise of 1°C. in temperature of the water. The results were plotted on sheets of graph paper.

The graph in Fig. 1 is a typical example of the body temperatures of *Onymacris bicolor marshalli*, and *Onymacris multistriata.* It will be seen that the increase in body temperature of *O.bicolor marshalli* follows practically a straight line. Below 40°C. it is lower than that of *O.multistriata.* The latter, however, has a mechanism which sets in at 40°C. and keeps the body temperature at this level for some time until exhaustion makes their temperature go up again. The lower temperature of *O.bicolor marshalli* during the beginning of the experiment in undoubtedly due to reflexion from its white elytra.

The temperatures of *Adesmia sp.*, see Fig. 2, followed a curve similar to that of *Onymacris multistriata* while the nocturnal *Gonopus sp.* (Fig. 3) had no

Fig. 1. Body temperatures of

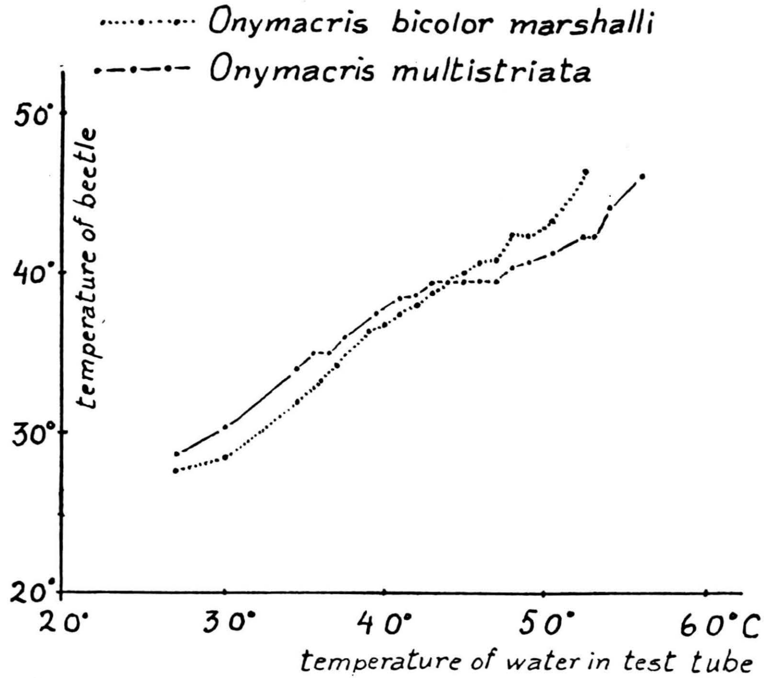


Fig. 2. Body temperatures of Adesmia sp.

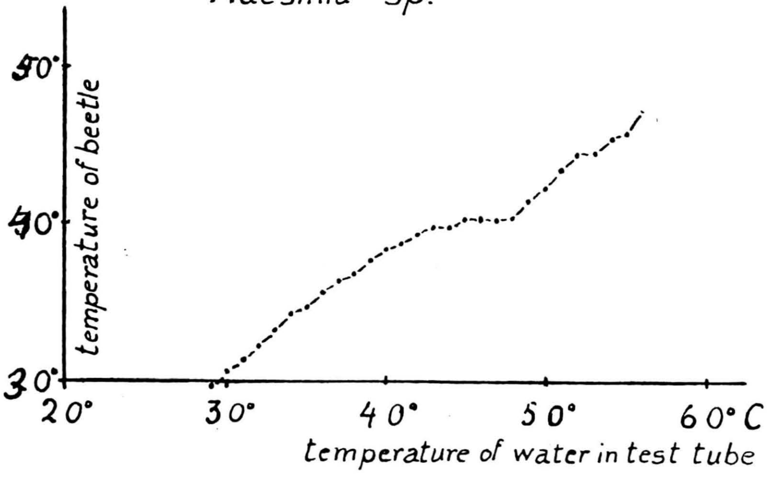


Fig. 3. Body temperatures of Gonopus sp.

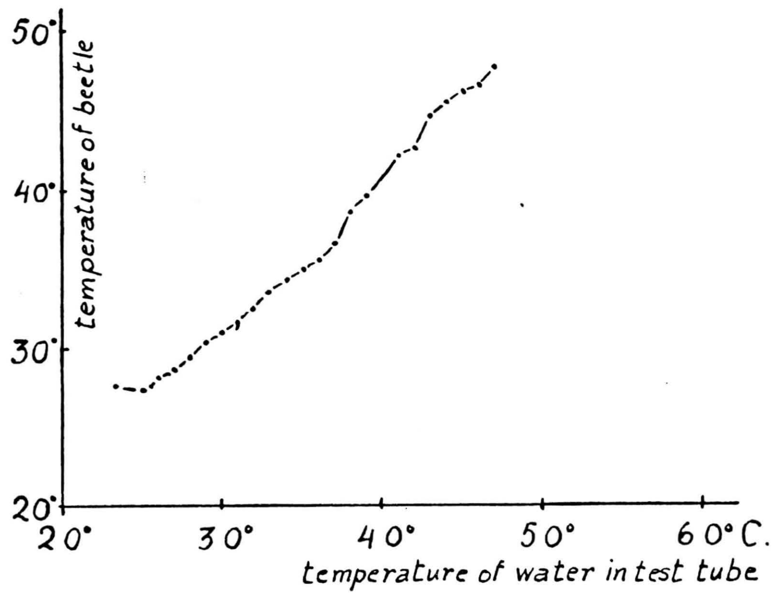
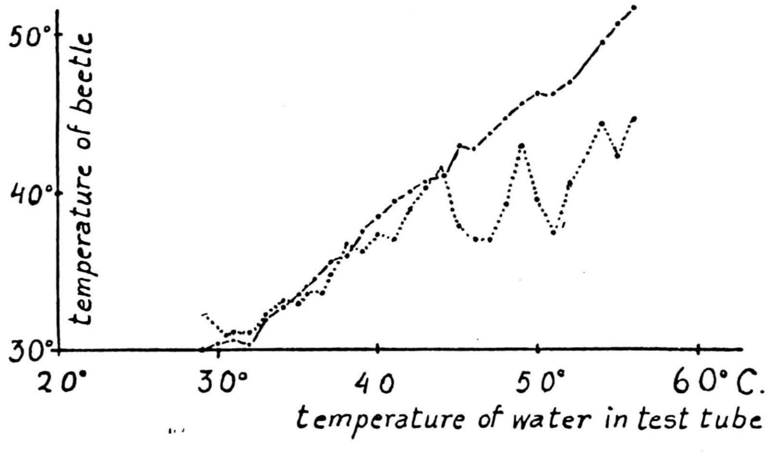


Fig. 4. Temperatures of Onymacris bicolcolor marshalli
·–·–·– in body, ·········· under elytra.



effective mechanism for keeping its body temperature down. It showed signs of being severely troubled when its body temperature rose above 37°C. by having sudden outbursts of activity, bending its legs under its body, trembling and finally becoming motionless. At the same time the body temperature rose faster than before. Death occurred much sooner in this beetle than in the others, the fatal temperature depending on the speed with which the body temperature rose.

The temperature preferences of the beetles were tested in a "temperature orgen" and was found to be 38°—39°C. in the diurnal beetles. In *Gonopus* it was much lower. Its actual preference could not be accurately determined because the beetles always tried to press themselves into the corners of the "temperature orgen".

Recordings of the temperature of the air under the elytra of the two species of *Onymacris* gave only little evidence that it was much lower under the white elytra of *O.bicolor marshalli* than under the black elytra of *O.multistriata.* When the body temperature approaches 40°C. the air temperature under the elytra of *O.bicolor marshalli* shows great fluctuations (Fig. 4). This is due to a strong ventilattion of the sub-elytral cavity. *O.multistriata* does not ventilate its sub-elytral cavity to the same extent, with the result that the temperature of the air in the cavity closely follows that of the body. Besides ventilating the sub-elytral cavity both beetles were also seen to ventilate their tracheal systems by rythmical protractions and retractions of the head. Another device employed when the body temperature rose fairly rapidly was to expose the genital apparatus. There seemed to be no rules for the temperature at which the last two mechanisms were employed and there seemed to be individual variations.

The above experiments show that the diurnal tenebrionid beetles are adapted to tolerate high temperatures for short periods, and that the black beetles studied have an active mechanism which makes it possible for them to maintain a body temperature at 40°C. long enough to make it possible for them to run over the exposed sand from one sheltering place to another. This applies even to the hottest part of the day. They can, however, not survive exposure to the heat over a prolonged period of time.

REFERENCES

BUXTON, P. A. (1924a) Heat, moisture and animal life in deserts. *Proc. Roy. Soc. B,* **96**, 123-31.

FRAENKEL, G. S. & GUNN, D. L. (1940) The orientation of animals. Clarendon Press, Oxford.

GUNN, D. L. (1942) Body temperature in poikilothermal animals. *Biol. Rev.* **17**, 293-314.

MELLANBY, K. (1932) The effect of atmospheric humidity on the metabolism of the fasting meal-worm (*Tenebrio molitor* L., Coleoptera) - *Proc. Roy Soc. B,* **111**, 376-90.

PARRY, D. A. (1951) Factors determining the temperature of terrestrial arthropods in sunlight. - *J. exp. Biol.* **28**, 445-62.

UVAROV, B. P. (1948) Recent advances in acridology: Anatomy and physiology of Acrididae. - *Trans. R. ent. Soc. Lond.* Vol. **99**, pp. 1-75.