Metabolism of the Gerbil, Meriones unguiculatus

Abstract. The critical temperature for the Mongolian gerbil, *Meriones unguiculatus,* is determined to be 30°C. The zone of thermal neutrality extends to 40°C. This species possesses a high degree of tolerance for heat and has a greater capacity for temperature regulation than is reported for many of the desert rodents.

The small desert rodents of the genus *Meriones* are widely distributed throughout North Africa, southeast Russia, Asia Minor and southwest Asia. The species used in this study was *Meriones unguiculatus,* first described by Milne-Edwards in 1867 (*1*). Milne-Edwards' nomenclature was verified by Chatworth-Musters and Ellerman in 1947 in their revision of the genus (*2*). The locality where Milne-Edwards collected his type specimens of this species is given as an area north of Peking and west of a line drawn between Mukden and Harbin, corresponding on a modern map to northwest Manchuria near the Mongolian plateau. Members of this genus dig elaborate underground retreats, often at two levels, including numerous chambers for both storage and nesting. The chambers are interconnected, with a labyrinth of runways (*3*). Very little is known of the physiology of this genus. A small number of gerbils were available, and it was thought worth while to ascertain the oxygen consumption of these under controlled conditions.

The oxygen consumption was measured by the closed-circuit method. Nine animals were used, three males and six females, ranging in weight from 61 to 80 g. They were housed individually during the course of the experiments in glass cylinders large enough to allow them to move back and forth and to turn around. A wire screen separated the animals from the bottom of the tube, which was covered with soda-lime for CO_2 absorption. The cylinder was immersed in a thermostatically controlled water bath and connected to a manometer and to an oxygen supply. The animals, after being introduced into the chamber, were allowed about 1 hour in which to become quiet. During this time a flow of air was maintained through the cylinder. When the animal appeared to be in a resting state, the air flow was interrupted and the experimental period was begun. The oxygen used was fed from an oiled graduated syringe. The pressure within the test chamber was maintained at the pressure of the external atmosphere.

The experimental periods were usually limited to a length of time necessary for the animal to consume 50 ml of oxygen. Before a given measurement was accepted as valid, it was required that at least two consecutive runs agree closely. Metabolic measurements were conducted at ambient temperatures ranging from 15° to 40°C, as measured in the water bath. All gas volumes were corrected to standard conditions of temperature and pressure. The metabolic rate was expressed as oxygen consumption in milliliters per gram of body weight per hour. Since the animals were awake and quiet, but not fasting, this quantity should be regarded as the resting, not the basal, metabolism.

From the results presented in Fig. 1, it is estimated that the critical temperature for *Meriones unguiculatus* is approximately 30°C and that the regression equation for the points below 30°C is

$$\text{ml of } O_2/\text{g hr} = 5.660 - 0.141\,^\circ\text{C}$$

It must be concluded that the zone of thermal neutrality extends to 39°C, since no significant regression could be demonstrated between 30° and 40°C. The term *critical temperature* is used here in its original sense: the lowest ambient temperature at which the animal remains in a basal or resting metabolic condition. At temperatures above 35°C these animals appeared to be severely affected, showing increased respiratory rate, panting, matted fur, and general demeanor indicative of impending collapse. One animal died after about 1 hour's exposure to a temperature of 40°C. It was for this reason that few measurements were made at temperatures above 35°C.

The comparatively wide zone of thermal neutrality observed in this series of experiments is in contrast to the narrow zones described by Herrington (*4*) for the laboratory rat, mouse, and guinea pig. Herrington found the neutral zone for the rat to be 28.0° to 28.9°; for the guinea pig, 30.0° to 30.9°; and for the mouse, 31.0° to 31.9°C. Similarly, Dawson (*5*) found a fairly restricted range of neutrality in the two species of kangaroo rat and in the antelope ground squirrel he examined. The latter animal exhibited no sign of distress when its body temperature was elevated to 42.4°C. If, as Scholander (*6*) points out, a distinguishing physiological characteristic of most tropical animals is a limited and transitory zone of thermal neutrality, one is justified in doubting that *Meriones unguiculatus* is a true desert rodent. The individuals used in our study came from an area which, as far as can be ascertained, is temperate, with well-defined seasons, a moderate cover of vegetation, and cold winters. Other members of the same species from a hotter, dryer area such as North Africa may exhibit different physiological responses to the same thermal load.

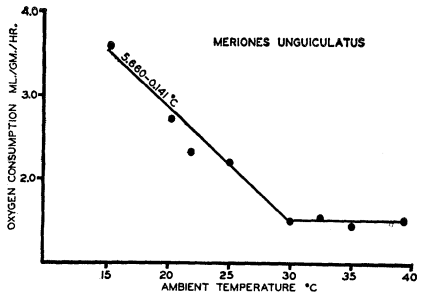

Fig. 1. Effect of ambient temperature on oxygen consumption.

Since these animals would not accept a rectal thermocouple for any length of time, it was not feasible to obtain their body temperatures and make metabolic measurements simultaneously. Therefore, after the metabolic measurements had been completed, some of the animals were reexposed to these ambient tempertures in a hot room, and their body temperatures were recorded over 5-hour periods.

In the hot room, the gerbils were individually housed in large plastic cages and supplied with water; however, they were not seen drinking during any of the exposures, and it is believed that they did not drink. Rectal temperatures were taken hourly with a thermocouple probe, care being taken that the tip was inserted deeply enough to obtain a true reading of the core temperature. Exposures at each of the three ambient temperatures chosen, 30°, 35°, and 40°C, were carried out, on different days. Table 1 summarizes the results of these exposures. The 2-hour value is included to show the thermal state of the animal at the end of a metabolic experiment which usually took 2 hours.

It is apparent that an ambient temperature of 40°C for a period of 5 hours is well tolerated by the gerbil. Although the animals were observed to lie quietly in an extended position for the duration of their exposure to this temperature,

Table 1. Summary of the results of exposure of gerbils to different degrees of heat.

Ambient temperature (°C)	Relative humidity	Body temperature (°C)				
		Mean control at 23°C ambient	After exposure to heat		Change	
			2 hr	5 hr	2 hr	5 hr
30	50	38.2	38.1	38.4	−0.1	0.2
35	40	38.6	38.7	39.3	0.1	0.7
40	30	38.4	39.3	39.9	0.9	1.5

they exhibited no other overt signs of discomfort.

The salivation and fur-licking behavior described by Herrington (*4*) for the mouse, rat, and guinea pig, and by Schmidt-Nielsen (*7*) for the cat and rabbit, was at no time apparent in the gerbil upon exposure to heat. The distress and near-prostration that was seen when the gerbils were in the metabolic chamber at 40°C was doubtless due to the saturated atmosphere within the tube, as evinced by the film of moisture that appeared on the sides. Adolph (*8*) pointed out some time ago that evaporative cooling is one of the principal factors in determining an animal's tolerance of heat.

It is of interest that the gerbil, *Meriones unguiculatus,* has a greater capacity for temperature regulation under heat conditions than either of the two species of kangaroo rats or the antelope ground squirrel observed by Dawson (*5*). Unfortunately, there are published in the available literature no observations on the habits of *Meriones unguiculatus* in a natural state; with the degree of heat tolerance this species apparently possesses, it is likely that these animals would be able to spend a good part of their time in activity outside of the burrow during daylight hours.

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Incorporation of Tritiated Thymidine into Meiotic Chromosomes

Abstract. In pachytene nuclei of *Melanoplus* the heterochromatin of the sex chromosome was found to synthesize DNA at a different time than the autosomal euchromatin.

Grasshoppers of the species *Melanoplus differentialis differentialis* Thomas were injected with tritiated thymidine (500 μc/ml). Each animal received 0.02 to 0.04 ml. After 2 to 7 days testes were fixed, squashed, and stained by the Feulgen method. Stripping film was applied in the usual way for autoradiographic work. During the squashing procedure, care was taken to obtain well flattened nuclei, in order to insure their intimate contact with the emulsion. The 5- and 7-day animals showed a distinct incorporation of the radioisotope into early pachytene nuclei. Thymine occurs solely in deoxyribonucleic acid (DNA), and thymidine is incorporated efficiently into DNA (*1*).

At pachytene, in the spermatocytes of *Melanoplus,* the sex chromosome forms a large block of heterochromatin which is quite distinct from the euchromatin of the autosomes. The incorporation of labeled thymidine is different for eu- and heterochromatin. In the examination of over 500 cells from five animals, four categories of nuclei were found (Fig. 1): (i) unlabeled nuclei, (ii) nuclei with only the autosomal euchromatin labeled, (iii) nuclei with grains over both eu- and heterochromatin, and (iv) nuclei with only labeling in the heterochromatic block. Due to the 1-μ resolution afforded by the tritium β-particles (*2*) and the large size of the darkly stained heterochromatic block (2.5 to 3.0 μ in diameter), the differential uptake of the isotope is clear-cut. The heterochromatin synthesizes DNA at a different time than the euchromatin, and there is an intermediate period during which the hetero- and euchromatin are synthesized either simultaneously or at close intervals.

To check accurately which of the nuclear types represents a more advanced stage, sections of the same material were made by the same procedure. The testes of *Melanoplus* animals consist of a series of follicles in which the spermatocytes are grouped in cysts. These cysts are known to be synchronized in their meiotic stages, especially during prophase. Furthermore, there is a regular anteroposterior sequence of the stages along the follicle; the younger cysts are at the

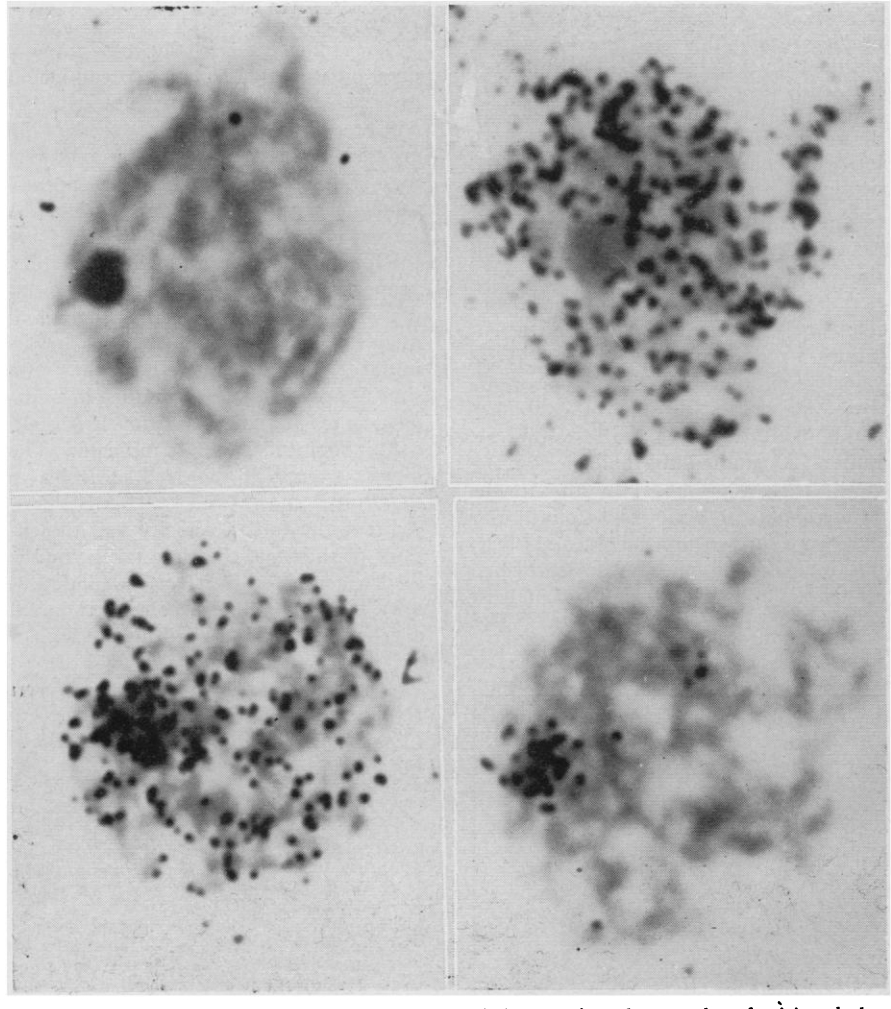

Fig. 1. Photographs of four categories of nuclei, illustrating the uptake of tritiated thymidine into early pachytene nuclei of *Melanoplus.* The sex chromosome forms a deeply stained block of heterochromatin (at the 9 o'clock position in each of the four nuclei shown). The autosomes constitute the remaining euchromatic portion of the nucleus. (Top left) Unlabeled; (top right) labeled in euchromatin only; (bottom left) labeled in both eu- and heterochromatin; (bottom right) labeling only in heterochromatin. The photograph at the top left was taken at the level of the nucleus, the others were taken at a focal level intermediate between that of the nucleus and that of grains in the emulsion (×3200).