Some Observations on the Thermo-regulation

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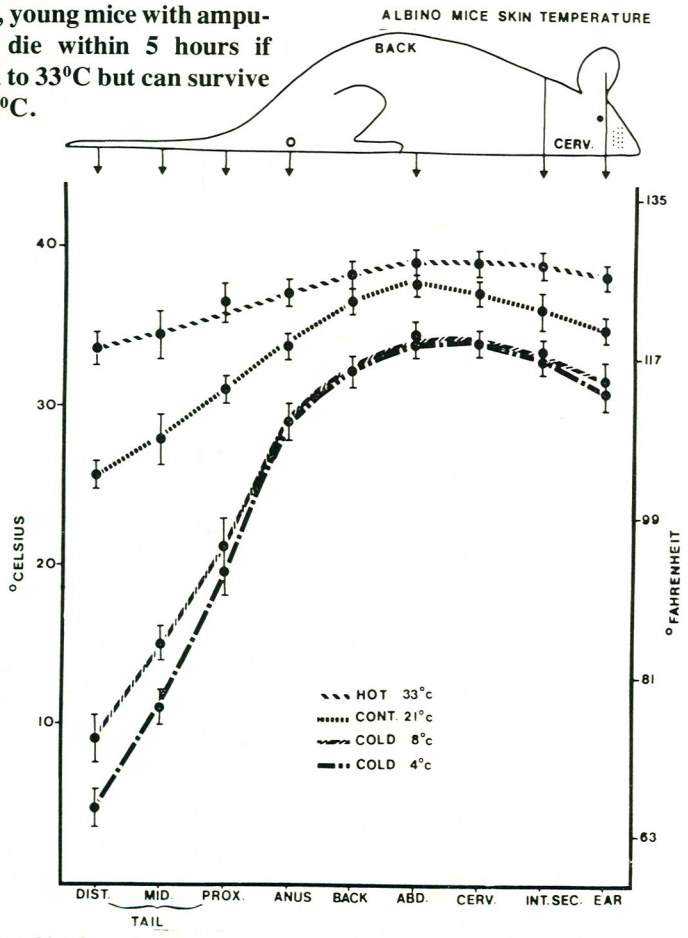
THE external temperature of the bodies and tails of 4 groups of mice maintained at 33°C, 21°C, 8°C and 4°C for the first 6 months of their lives was found to be different depending on the surrounding environmental temperature. But the internal temperature has not changed. The ear pinnae however of mice kept at 33°C were found not only to be larger but also thinner than those reared at 21°C and 8°C. In addition, young mice with amputated tails die within 5 hours if transferred to 33°C but can survive if kept at 8°C.



The external body and tail temperatures of group of mice maintained at 4° C, 8° C, 21° C, and 33° C. The temperatures over the tails were below that of the body.

IN most homeothermic mammals, the body appendages play a significant part in the heat loss and its regulation (1, 2, 3, 4). The particular appendage concerned may vary from one species to another. For example, the ears may be the primary thermoregulatory organ in the elephant and rabbit. The neck and limbs may have the same role in the camel, llama, giraffe and possibly the fingers and toes in man (5). In the mouse and rat (and possibly other species) the tail seems to be the primary thermoregulatory organ (2, 6, 7, 8, 9). Other auxillary thermoregulatory organs in the mouse are ears, paws and possibly the scrotal sacs. It is the aim of this work to study the effect of changes in the environmental temperature on the morphological aspects of the thermoregulatory organs in the mouse.

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MATERIALS AND METHODS

Strain A inbred albino mice of both sexes aged 6 months maintained at 33°C, 21°C, 8°C, and 4°C from the age of 25 days were used. The details of these experimental environmental conditions were described previously (10).

Temperature : The external skin temperature of the bodies and tails of groups of mice maintained at 33°C, 21°C, 8°C, 4°C (22, 15, 12 and 14 animals respectively) were measured using an electric thermometer with a 1 mm exposed indicator (E11ab, Copenhagen. Supplied by Sirex Ltd., 15 — 18 Clipston Street, London W 1). The thermocouple was applied directly under the fur.

Using the same thermometer but a different thermocouple, the internal (rectal) temperature of another group of mice of the same age group maintained at 33°C, 21°C, 8°C, and 4°C (14, 19, 10 and 19 animals respectively) was also measured. In this case 1 cm of the thermocouple lead was inserted into the rectum.

The temperature of any part of the mouse was repeated several times and the readings of the indicator was left to stabilize before the final measurement was made.

Ears : A group of mice of the same above age group kept at 33°C (hot

group), 21°C (control group) and 8°C (cold group) (12, 7 and 10 animals respectively) were killed and their ears were dissected from the bodies and fixed in 10% formal saline. The ears were then laid flat and the ear pinnae were cut along and close to the tragus from as low as the lower border of the incisura intertragica (a point homologous to that of the human ear) to the upper border of the ear pinna. The ears were then weighed to the nearest 0.01 mg by two methods. : (1) *Wet Weight Method* : The ears were dried and then weighed. (2) *Area Weight Method* : The ears were dried and laid as flat as possible between two thin layers of glass and their images enlarged on photographic paper. The images were then cut out and weighed and the estimated weights were divided by the magnification factor to calculate the original area of each ear.

Tails : Four 25 days old mice were used. The tails of these animals were amputated close to the body and the bleeding stumps were cauterised. The animals were then taken to the hot (33°C) and two the cold (8°C) rooms.

RESULTS

Generally, the external (skin) temperature of the female mice was 0.4 — 1.7°C lower than in the male mice. The general pattern (see figure) between the 4 groups was similar with the temperature over the tails always below that of the body. The temperature of the tails, particularly the distal parts, were only a few degrees higher than the surrounding environmental temperature. The maximum difference in the external temperature of the body between the 4 groups was seen over the interscapular, cervical and abdominal regions. A small difference of 0.9°C was observed over the ears of the cold groups (8°C and 4°C).

Table 1 shows the internal (rectal) temperature of the 4 groups. The difference in the means between the 4°C and 33°C groups was 1.1 C. This was influenced by the predominent male group in the 4°C group which had 0.8°C higher rectal temperature than the females.

TABLE 1

	COLD (°C)		CONTROL (21°C)	HOT (33°C)
	4°C	8°C		
No.of mice	19 (12M,7F)	10 (5M,5F)	19 (9M,10F)	14 (7M,7F)
Range (°C)	33.9 - 36.8	33.4 - 37.3	34.0 - 37.8	34.5 - 37.2
Mean	35.14°C	35.24°C	36.20°C	36.24°C
S.D.	0.75	1.12	1.10	0.91
$P_{(1)}$	0.00109	0.02382		0.95424
$P_{(2)}$	0.00262	0.04652		

Internal (rectal) temperature. P(1) indicates the significance of differences between 21° C group and 4° C, 8° C and 33° C groups and P(2) indicates the significance of differences between 33° C group and 4° C and 8° C groups. The significance between the 4° C groups was 0.77796 (see footnote to Table 2, 3)

Ears : Table 2 shows the ear weights as measured by both methods. In the area-weight method, the ears of the hot group were heavier than those of the cold and control groups. In the wet-area method however, the ears of the hot group were lighter than the other groups.

TABLE 2

METHOD	WET WEIGHT (mg)			"AREA WEIGHT" (mg)		
Temp.(°C)	8	21	33	8	21	33
No.of cases	10	7	12	10	7	12
Range	0.022 - 0.033	0.026 - 0.034	0.015 - 0.022	0.180 - 0.208	0.195 - 0.224	0.227 - 0.268
Mean	0.027	0.030	0.019	0.196	0.211	0.241
S.D.	0.003	0.003	0.002	0.009	0.010	0.013
$P_{(1)}$	0.07629	<0.00001		0.00426	0.00015	
$P_{(2)}$	0.00001			<0.00001		

The size of the ears of the 3 experimental groups as estimated by the wet weight and area weight methods. P(1) is the significance of the differences between the control and the cold and hot groups. P(2) is the significance of the difference between the cold and hot groups. (see footnote to Table 2, 3)

Tails : The two mice which were transferred to the hot room (33°C) at the age of 25 days were found dead after 5 hours but those housed in the cold room (8°C) were alive until on the following day they were transferred to the hot room, they were then found dead after 3½ hours.

It was also noticed in the male mice kept in the hot room (33°C) since the age of 25 days until hey were 6 months old that the testes were found to fill the scrotal sac which hung below the animals. In the cold groups (8°C and 4°C), the testes were found to be drawn up into the passage which connect the scrotal sac to the abdominal cavity as long as the mice were in the cold rooms, but if transferred to the hot room, the scrota hung down again.

DISCUSSION

Although the internal temperature of the mouse is more labile than that of larger mammals (11) the difference in the internal (rectal) temperature in the mice maintained at the different environmental temperatures was small. It was about 1°C lower in the 4°C and 8°C

than in the 21°C and 33°C groups. This was however, mainly due to the temperature of the male mice in the cold groups (4°C and 8°C) which was 0.8°C higher than the females. These findings agree with those of most workers (12, 13, 14) and confirm Brody's statement (11) that among the eutherian mammals, the mouse has one of the lowest temperatures.

Sumner (12) found no difference in the internal temperature of mice kept at 22.3°C and 5.8°C once the animals were acclimatised to the environmental temperature. Likewise, it was found (14) that the rectal temperature of mice kept at 32°C was similar to those maintained at 22°C. However, the works of Harrison et al (7, 15) indicated that mice reared at 90°F (32.5°C) tended to be 1 — 2°C higher than their control group maintained at 70°F (21.5°C). In addition, thermoregulatory studies on a wide variety of species (2), indicated that arctic mammals and birds have a rectal temperature similar to that of animals in temperate climates.

The external body temperature reflects both the internal temperature of the part and the surrounding environmental temperature. This was especially seen over the cervical and interscapular regions of the cold and control groups. In these regions, the underlying brown adipose tissue serves as a heat generator (16). In the hot group, this form of fat had transferred into ordinary white adipose tissue (17) and this had no thermal function as a heat generator. The relatively higher local temperature over the abdomen in the cold group have been due to the thicker fur coat which provided better insulation (17), but mainly reflected the internal (abdominal) temperature.

The main difference however, in the external temperature was seen over the tails, particularly the distal parts which were few degrees higher than the surrounding environments. This also reflects the internal temperature of the tails (tail bones) as well as surrounding temperature. The temperature of the tail was found to be below that of the external and internal body temperature. In this sense, the mouse appears to be unable to control the temperature of its tail (15).

The tail is a richly vascular structure containing many arteriovenous anastomoses (18). By controlling the blood flow to and from the tail, the heat loss may be regulated (9). The occlusion of the blood flow of the tail, in the muskrat caused the internal body temperature to rise in the hot environment (19). In the rat, sudden vasodilation was seen in the tail when the external temperature rose to between 27 — 30°C with the blood flow rising from 5 to 40 ml/100 ml tissue/minute (9). In the monkey, however, more than 10% of the cardiac output was estimated to flow to the tail when the environmental temperature exceeded 40°C (20). One may therefore conclude that in the hot room, heat loss was increased by opening up the arteriovenous anastomoses to increase blood flow while in the cold room heat loss was reduced by closing these anastomoses.

The absence of hair on the tail and its large surface area in the relation to its volume makes it a suitable heat radiator. It seems therefore that the long spindly tails of the hot reared mice which were held straight behind the animals (15) is to increase heat loss from the body to the air which is a bad conductor to heat. The behaviour of the cold reared mice is different for they sit on their tails so as to reduce heat loss by warming their tails.

Mice and rats have long tails with no sweat glands (21, 22). Thus the possession of a tail increases the fitness of these animals to survive a hot environment. Indeed, the evolutionary progress and the wide geographical and climatic ranges of these species (1) may in part be due to the possession of tails. In this work, mice with amputated tails could tolerate the cold environment of 8°C and adjust their thermoregulatory mechanisms. But in the hot environment, they die within a few hours. These observations are consistent with those of Harrison (7) that the removal of tails decreases the adaptability of these animals to a hot environment.

According to Allen (1) certain peripheral parts of various animals tended to enlarge in the higher temperature as one moves towards the tropics. In mammals, such as the mouse, this is manifested by the size of tail, ears and feet. Sumner (23, 24) reported smaller ears and shorter tails in mice reared at a low temperature and this has been confirmed by other investigators (2, 6). But in most reports, the size of the ear in relation to that of the body was not accurately measured. This is because of the peculiar complex shape of the ear. In this work, weighing method, although crude, were devised as a method of measuring the size of the ear and thus the effect of environmental temperature on the size of the ear. The weight of the projected images on photographic paper gave a measure of the surface area of the pinna, while the weight of the ear pinna itself gave an indication of the thickness of the ear. Thus the ears of the heat reared mice were not only larger than the other groups, but also thinner. This was because the larger surface area/volume ratio was needed in these animals, so that the ears could act as auxillary cooling

organs in the hot environment. It is not clear however, whether these changes in the size and thickness of the ears represented a generally adaptive mechanism or merely a local effect of temperature on the hyaline cartilage of the ears. The small difference in the external temperature of the ears of the animals kept at 4°C and 8°C may point to the possibility of a local effect similar to that on the epiphyseal cartilage plate of the tail bones (17, 25).

The scrotal sacs have also been reported to be influenced by changes in environmental temperature (6, 26). The male mice observed in this work formed no exception to this rule. The hanging scrotal sacs which have scanty hair may also have acted as auxillary cooling organs in the hot reared mice. It seems probable that the testes are very sensitive to changes in the environmental temperature and that a cooler temperature than the internal body temperature is necessary for the production of sperms. Thus the testes of the hot group mice hang down below their bodies where the temperature is below that of the internal temperature. In the cold group, the testes were drawn into the passage which connects the scrotal sac to the abdominal cavity (the mice have no distinct inguinal canal). The temperature of this passage is probably few degrees lower than that of the body.

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