The effect of environmental temperature on the growth of vertebrae in the tail of the mouse

By JANET F. NOEL¹ AND E. A. WRIGHT²

From the Department of Pathology, St Mary's Hospital Medical School, London, W.2

SUMMARY

C₃H mice were bred at 30 °C and 22 °C. At 28 days of age the lengths of the sacral and caudal vertebrae were measured from radiographs and related to the local skin temperature. Growth of the sacral and proximal caudal vertebrae was slightly retarded in the hot environment, but the distal caudal vertebrae showed increased growth which could be quantitatively related to an increase in skin temperature. This suggests that in hot climates the increased growth of peripheral organs of some mammals is due to local increases in tissue temperature.

INTRODUCTION

In a survey of the mammals of North America, Allen (1905) noted that as he progressed from the colder regions of the north towards the warmer regions of the south, several species showed an increase in the size of the distal organs, e.g. tail and ears, while the general body weight became smaller. This phenomenon has been considered to be an adaptation of the species to increase the surface area available for heat loss in a hot environment.

More recently several workers have observed an increase in the length of the tail in laboratory animals reared under hot conditions (Przibram, 1923, 1931; Ashoub, 1958). Barnett (1965) studied the opposite effect of tail shortening under cold conditions. He allowed several strains of mice to interbreed at a low temperature, and found that over a few generations the tail length of these animals increased again towards the length found at normal temperatures. He therefore suggested that the variation in tail length of mammals with environmental temperature could be due to a direct local effect of temperature on the growth of tissues in the tail, rather than an adaptation to reduce surface area under cold conditions.

The experiment reported in this paper was designed to study the effect of increased environmental temperature on the growth-rate of individual vertebrae

¹ Author’s address: Department of Biological Sciences, Ahmadu Bello University, Zaria, Nigeria.
² Author’s address: Department of Morbid Anatomy, King's College Hospital Medical School, London, S.E.5.
in different regions of the body and tail to see whether the local growth rates could be related to local changes in tissue temperature.

**MATERIALS AND METHODS**

Six pairs of inbred C3H mice were used as parent animals. Three pairs were placed in a 'hot room' and three pairs in a 'control room'. For each of the three pairs placed in the 'hot room' a corresponding pair derived from the same litter was placed in the 'control room', to minimize parental variation. The 'hot room' consisted of a wooden box lined with aluminium foil (a 'tea chest'). A Phillips 150 W 'Infraglow' infrared bulb was placed in the roof of the tea chest. The mice were placed in plastic cages resting on the floor of the box. The average temperature near the floor of these cages was 30 °C as recorded with an Ellab TE 3 electric thermometer shielded from the direct beam of the infrared bulb.

The 'control room' consisted of a similar 'tea chest' with similar mouse cages, except that a 'Woolworth's' red 'fireglow' 40 W light bulb was used instead of the infrared lamp. This emitted very little heat and the mean temperature was 22 °C.

The six pairs of mice were left to breed continuously for five months (from mid-January to mid-June). The offspring were weaned at about 21 days. They were kept in the same temperature environment after weaning.

When each litter was 4 weeks of age, various observations were made.

(i) Each animal was weighed.
(ii) The tail length was measured from the anus to the tip.
(iii) A radiograph was taken. From the radiograph, measurements of the length of each sacral and caudal vertebra were made using a low-power microscope.
(iv) The skin temperature in the trunk, proximal tail, mid-tail and distal tail was measured in some of the animals, again using an Ellab TE 3 thermometer, but with a skin H 1 applicator.

The total number of animals studied was sixteen from the 'hot room' and twenty from the 'control room'.

**RESULTS**

1. *Total length of tail and body weight in hot and control environment*

   The mean tail lengths and body weights for all 'hot room' and 'control room' mice were first calculated (Table 1). Although the mean body weight was lower in the hot than control environment, the mean tail length was considerably greater than in the control environment.
2. Length of individual vertebrae

The mean lengths of the various sacral and caudal vertebrae in the hot and control environment are plotted in Fig. 1. The graph shows that from the 7th caudal vertebra to the tip of the tail the length of each vertebra in the hot environment was considerably longer than that of the corresponding vertebra in the control environment.

Fig. 2 shows mean vertebral length and local temperature in the ‘hot room’

Table 1. The mean tail length and body weight (plus or minus S.E. of the mean) at 28 days in mice reared at 30 °C and 22 °C

<table>
<thead>
<tr>
<th></th>
<th>Hot room (30 °C)</th>
<th>Control room (22 °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight (g)</td>
<td>9.23 ± 0.51</td>
<td>9.81 ± 0.73</td>
</tr>
<tr>
<td>Tail length (cm)</td>
<td>6.37 ± 0.14</td>
<td>4.87 ± 0.13</td>
</tr>
</tbody>
</table>

Fig. 1. The mean length at 28 days of each sacral and caudal vertebra in ‘hot room’ mice reared at 30 °C and ‘control room’ mice reared at 22 °C. •••••••• Mean length of vertebra in ‘hot room’ mice; ○○○○ Mean length of vertebra in ‘control room’ mice. ▲▲▲▲ Mean skin temperature in ‘hot room’ mice; △△△ Mean skin temperature in ‘control room’ mice. The standard errors of the means are shown for the 1st and 4th sacral and the 5th, 10th, 15th, 20th and 25th caudal vertebrae.
group expressed as a percentage of the controls. From this graph it becomes clear that in the 'hot room' mice, those vertebrae in the pelvic region of the body whose temperatures were unlikely to have been affected by the infrared treatment were on average shorter than the corresponding vertebrae in the 'control room' animals. Those at the beginning of the external part of the tail which were partially covered by fur (caudal vertebrae 4, 5 and 6) were on average 4% longer in the 'hot room' than the 'control' mice. Those in the middle and distal regions of the tail were on average 11% longer in the 'hot room' than the 'control room' mice. The skin temperature in these regions showed a fairly uniform rise in the 'hot room' to 117.5% of that in the 'control room'.

Fig. 2. The mean length at 28 days of each sacral and caudal vertebra in 'hot room' mice (reared at 30 °C) as a percentage of the corresponding vertebra in the 'control room' mice (reared at 22 °C).

- • length of bone in 'hot room', × 100
- • length of bone in 'control room', × 100
- • skin temperature in 'hot room'
- • skin temperature in 'control room', × 100
DISCUSSION

In mice, the temperature of the peripheral organs, such as the tail vertebrae, is probably not closely controlled by the homoiothermic mechanisms, and may be a few degrees lower than the general body temperature under normal conditions. The temperature of these organs can therefore be increased by raising the environmental temperature, while the temperature of the ‘internal’ organs is scarcely altered. The growth of the outlying vertebrae was significantly increased in the hot environment, while the ‘internal’ sacral vertebrae showed a small reduction in growth, which could be related to the general lowering of body weight in the hot environment. The vertebrae at the beginning of the external part of the tail, which showed a slight increase in temperature in the hot environment, showed a corresponding slight increase in growth. Thus the increase in tail length with temperature, in these genetically uniform animals, seems to be directly related to the local temperature.

The local temperature might affect the growth-rate of the vertebrae by altering the blood supply to the dividing cartilage cells or it may also have a direct effect on their metabolic rate and the length of the mitotic cycle. Since the growth-rate of vertebrae follows the local temperature so closely, variation in tail length is unlikely to be explained by any systemic adaptation designed to alter the surface area available for temperature regulation.

Thus the increase in tail length in individual animals reared in a hot environment seems to be due to a local effect. This type of local effect would also tend to increase the length of the distal organs of wild animals living in hot climates. However, since it has been shown (Harrison, 1958) that mice whose tails are amputated show a low tolerance of hot conditions, it is possible that increased tail length in a hot environment may be useful for thermo-regulation. Over long periods there could therefore be genetic selection for animals with longer tails. However, over short periods the increased length of the vertebrae in a hot environment seems to be due to the local rise in temperature of those vertebrae whose temperatures are not normally completely controlled by the homoiothermic mechanisms.

RÉSUMÉ

Action de la température ambiante sur la croissance des vertèbres de la queue chez la Souris

Des Souris de la souche C₃H ont été élevées à 30 °C et à 22 °C. A l'âge de 28 jours on a mesuré la longueur des vertèbres sacrées et caudales d’après des radiographies et on a étudié le rapport avec la température locale de la peau. La croissance des vertèbres sacrées et caudales proximales est légèrement retardée en milieu chaud, par contre les vertèbres caudales distales présentent une croissance accrue qui pourrait être quantitativement rapportée à une augmentation de la température de la peau. Ceci permet de suggérer que, sous les climats chauds, la croissance accrue d’organes périphériques chez quelques Mammifères est due à des élévations locales de la température du tissu.
We are grateful to Mr N. Hassan for technical assistance. This work was partly supported by the British Empire Campaign for Cancer Research and the Fitton Trust.

REFERENCES


(Manuscript received 14 November 1969)