ORIGINAL

# The Effects of Long Term Exposure to Adverse Environmental Temperatures on the Organ Weight and Histology of the Body

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**Using the albino mouse as a mammalian model the long term effects of changes in the environmental temperature on the weight and histological appearance of body organs was studied. Except for the lungs, the fresh weights of the liver, spleen, kidneys, heart and thymus were lighter in the mice maintained at 33°C than those kept at 21°C and 8°C. The organ weights of the latter groups were similar. The cellularity of the bone marrow in the tail bones in the 3 groups was also studied .**

THE EFFECTS of environmental variables, particularly temperature, on body organs and a number of metabolic indices have been studied by many authors (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12). Most body organs and tissues were found to be heavier in cold-reared animals compared with higher temperatures. However, the long term effects of environmental temperature on the weight and histological appearances of these organs have received little attention.

## MATERIALS AND METHODS

A total of 33 inbred colony of strain A, albino mice of both sexes aged 6 months maintained at 33°C (hot group), 21°C (control group) and 8°C (cold group) (9, 14 and 10 animals respectively) from the age of 25 days were used. The details of these experimental conditions were described previously (13). The mice were killed by deep ether anaesthesia and the liver, spleen, kidneys, heart, thymus and lungs were carefully dissected and weighed to the nearest 0.05 mg. These organs were then sliced and all the sections taken were fixed in 10 formol saline, processed for histological examination (5 um thickness) and stained (haematoxylin & Eosin) as one batch so as to standardize and uniform the physical factors exposed to each section.

To study the cellularity of the bone marrow the 14th tail bone of the three experimental groups were examined .

## RESULTS

### *Organ Weights*

Figure 1 shows the mean weights of the 3 groups and figure 2 shows the mean organ weights of the cold and hot groups expressed as a percentage of the mean organ weights of the control group. Except for the lungs, the organ weights (liver, spleen, kidneys, heart and thymus) of the hot group were lighter than those of the cold and control groups. The organ weights of the latter groups were similar or fell within the same range.

### *Organ Histology*

#### *1. Liver*

The lobular pattern of the liver was similar in the 3 experimental groups but those of the cold group were more vascular than the others. The liver cells however, showed striking differences. The cold group cells were larger than the other groups, had large nuclei and abundant darkly-stained slightly vacuolar eosinophilic cytoplasm. The chromatin condensations of the nuclei were also more prominent than the other groups. Binucleated parenchymal cells were frequent. The liver cells near the periphery of the hepatic lobules were more deeply stained than those around the central veins.

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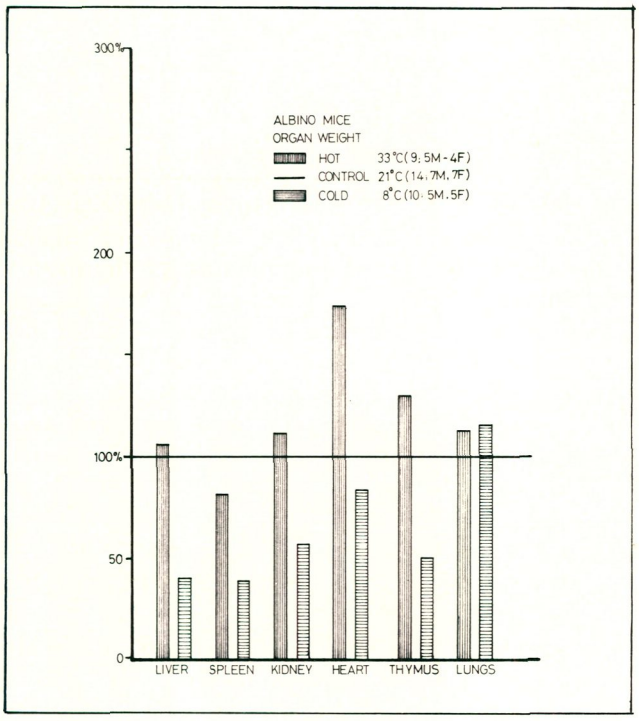


Fig. 1. A histogram of the mean organ weight of 3 experimental group of mice maintained at 33°C, 21°C, and 8°C.

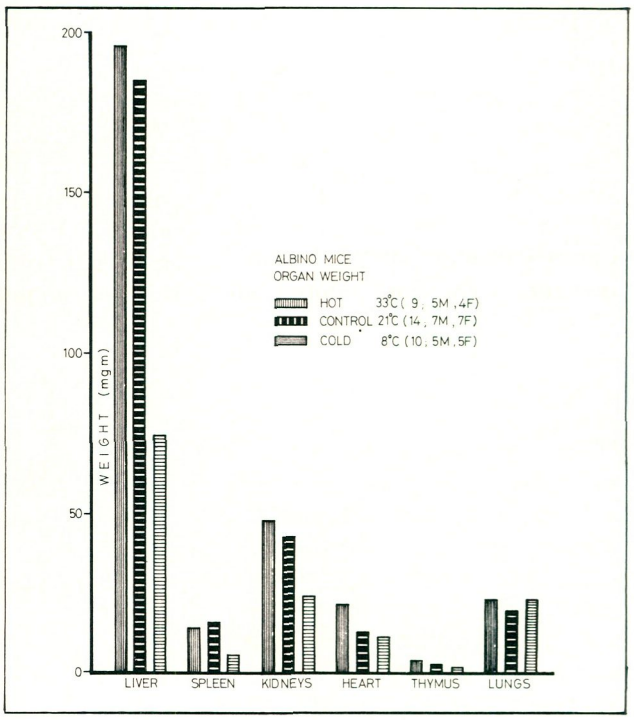


Fig. 2. The mean weights of body organs of the cold (8°C) and hot (33°C) groups expressed as percentage of the mean weights of the control group (21°C)

In the hot group, the liver cells were small with small rounded nuclei and scanty light stained basophilic and finely granular cytoplasm. Binucleated cells were infrequent .

The appearance of the liver cells of the control group lay midway between the cold and hot groups.

In the hot and control groups the liver sinusoids were dilated and empty while in the cold group they were filled with blood.

2. *Spleen*

Again the general histological appearance of the spleen was similar in the 3 groups, but more vascularity was observed in the cold than the other groups. The amount of blood pigments was also greater. Haematopoiesis was more evident in the cold group.

In the spleen, several multinucleated giant macrophages and megakaryocytes were seen especially near the splenic capsule. The number of these cells was greater in the cold, less in the control and in frequent in the hot group. In the cold group, the macrophages were larger than the other groups and were made of abundant, faintly stained, basophilic cytoplasm and between 4 to 8 rounded nuclei which were also lightly stained. The number of nuclei was less in the other groups.

In the cold, the megakaryocytes appeared typically as giant — although smaller than the multinucleated macrophages — irregular shaped cell with single, darkly stained nucleus and eosinophilic cytoplasm.

3. *Kidneys*

In most sections of the kidneys including those of the control group, diffuse areas of hyaline degeneration and angiomatous stroma were seen at the corticomedullary junction. Occasional mild lymphocytic infiltrate was also evident, but in none of the groups was there sufficient histological damage to indicate serious functional impairment.

However, the glomeruli of the cold group were smaller than the controls but larger than those of the hot group. In the cold group, the cells of the renal tubules were large, lightly stained and contain uniform vesicular nuclei. In contrast, the cells of the renal tubules of the hot and control groups were small, darkly stained and contain darkly stained nuclei. Albuminous degeneration and dilatation of the convoluted tubules were found to be more frequent in the hot an cold groups then in the controls.

4. *Heart*

The general histological pattern of the heart was similar in the 3

groups, but the vascularity was greater in the cold group than in the other groups. In addition, the width of the myocardial muscle fibres was greater in the cold and less in the hot than the control group. In the cold and control groups these fibres were darkly stained and contained large nuclei. In contrast, the muscle fibres of the hot group were lightly stained and the nuclei were small.

5. *Thymus*

The histological appearance of the thymus was similar in the 3 groups with the cold more cellular and vascular than the other groups. There were also more reticulum cells in the cold than the other groups. These cells typically had pale spherical nuclei and fine chromatin granules and ill-defined cell outlines.

The distinction between the medullae and cortex in the thymus gland of the hot group was inconspicuous. However, occasional multinucleated giant macrophages, similar to those found in the spleen were also seen.

Hassall's corpuscles were seen in the sections of all the groups but were more frequent in the cold and control groups than in the hot group.

6. *Bone Marrow*

In the tail of the control and cold groups, the bone marrow was almost completely yellow and fatty with few clusters of haemopoietic cells which were seen mainly near the growth plates on the metaphyseal side. The picture was entirly different in the hot group in which the narrow cavity was filled with highly cellular red marrow. The predominent cells were granular leucocytes. A typical field showed stem cells, many eosinophils, myelocytes, reticular and endothelial cells. Erythrocyte precursors were rather scanty but megakaryocytes were frequent.

7. *Lungs*

The histological appearance of the lung tissue was similar in the 3 groups. Aggregates of lymphocytic infiltrate were also seen in the 3 groups.

## DISCUSSION

The relationship between organ weights and environmental condition is only one aspect of the process by which an animal adapts to its environment. These processes are the end products of many feedback mechanisms which regulate the rates of body metabolism. For example, on exposure to cold, food consumption may be diverted from growth to heat production (9, 13, 14) and the growth of certain body organs may be favoured at the expense of others. Moreover, the morphological changes seen in any organ only imperfectly reflects its activity. The weight of body organs may vary greatly according to the tissue structure, differences in blood content and the amount of extracellular or intracellular water and fat. It has been shown that mice inbred at - 3°C (7, 8, 9) and 2 4°C (12) were lighter than control mice maintained at 21°C. They also had less fat, collagen, nitrogen, calcium and phosphorus but contained more water. It would appear that the increased body metabolism which the cold environment demand is so high that despite the increased food consumption (13, 15) the mice of the cold group were unable to meet their fat requirements. It could also be assumed that the cause for the heavier body organs in the cold than the other groups may possibly be due to their high contents of water.

The liver weights in the cold and control groups fell within the same range. In contrast, the livers of the hot group were significantly reduced in weight. This may again be possibly due to the reduced water content. A further possible cause for the reduced liver weight in the hot group may be that the body metabolism was directed from growth and storage to heat loss. Consequently, the heavier kidney weights of the cold and control groups than those of the hot groups may indicate kidneys actively secreting the waste products of increased body metabolism.

It is often said that a small body tends to have smaller organs with smaller cells compared with animals with a large body. This is supported by the finding that mice maintained in a hot environment of 33°C have a smaller body compared with those kept at 8°C (13). In this study it was found that all the organs weights (except for the lungs) were smaller in the hot group than in the other groups. In addition, some histological evidences may confirm this assertion. In the cold group, the parenchymal liver cells, cells of the renal tubules and even the glomeruli were found to be large with large vesicular nuclei, while in the hot group the cells were smaller and had nuclei of variable size. These findings agree with those of Hale et al (3).

The metabolic pathways which may be responsible for the differences in weight (and cell size) of the liver and kidneys are not clear. However, the blood flow and oxygen uptake of these organs have been found to increase in cold and to decrease in hot conditions (7, 11, 16, 17). Certain liver enzymes were also reported to be equally involved (18).

The adaptive capability of the heart in response to functional and physiological demands is well known. The heavier hearts in the cold group reflects higher

metabolic activity and possibly the increased peripheral vascular resistance associated with cold exposure. As a result, the cardiac output and respiratory rate are reportedly increased (7).

The enlargement in the cold group was shown by the increased width of the myocardial muscle fibres in the cold group compared with the other groups. These findings are also consistent with those of Hale et al (3).

In the normal rat (and probably the mouse as well) the vertebrae of the trunk which lie inside the body contain red marrow and yellow bone marrow appears only in the tail vertebrae outside the body and extends to the tip of the tail (19). This sharp transition suggests that a physical factor may be responsible. One of the main differences between the trunk and tail vertebrae is the higher temperature of the former (20). In this study when the tail temperature was raised nearly to the level of the body temperature the yellow fatty marrow (of the cold and control groups) changed to red marrrow (in the hot group). This may also suggest that the haemopoietic tissue is very sensitive to changes of temperature and found only where the temperature is raised such as the internal bones of mammals (19) and birds (21) in addition to the haemopoietic organs notably the spleen and thymus.

The different environmental temperatures may possibly affect the spleen and thymus in the same way as the bone marrow. Thus the lighter weights of these organs in the hot group compared with the other groups indicate that haemopoiesis is taken over by the tail bones and possibly by the bones of feet and hands (19).

The distribution and formation of haemopoietic tissue in man and most mammals is related to temperature (19). Thus in normal mice (and possibly the cold reared mice as well) it is found in the peripheral bones (such as the sternum, ribs, pelvic bones, vertebral column and proximal end of femur) where the temperature is few degrees lower than the internal temperature (20). In the hot room, the temperature of the tail was raised to that of the proximal bones and this was accompanied by the appearance of red marrow in these bones.

Of particular interest are the multinucleated macrophages and megakaryocytes, which are normally seen in the internal organs of the mouse (22, 23) and were more frequently seen when the temperature was raised. Similarly, they were found to be more common in the spleen and thymus of the cold and control groups than in the same organs of the hot group. Was this because in the latter group they appeared to be more localised in the bone marrow of the tail bones ?

In the rat and mouse the thymus gland is retained throughout life (22, 24) and continues to produce the hormones thymosin (which stimulated the growth of the lymphoid tissue) and promine (which stimulates general body growth). The greater thymus weight and the increased cellularity of the thymic and splenic tissues in the cold group may reflect the action of thymosin, whereas the increased organ weights in the control and cold groups than that of the hot group may reflect the action of promine. On the other hand, the inconspicuous distinction between the medulla and cortex in the thymus gland of the hot group may possibly means that heat has enhanced the involution of this organ.

Another point of interest is the case of the lungs. The gross (eg. fresh weight) and histological features were found to be similar in the 3 experimental groups, despite the low relative humidity level in the hot environment and the high level in the cold environment (13). Similar findings were also reported by Heroux and Grideman (4) from rats maintained at 30°C and 6°C. It seems therefore that changes in the environment temperature has no effect on the structural morphology of the lung tissues.

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