PART V

STUDIES ON OXYGEN CONSUMPTION AS A METABOLIC ADAPTATION
IN THERMOREGULATION
adaptation may be described as a change in the nature of an animal's logical system in response to a change in the external environment and the maintenance of efficiency of an animal. Environmental temperature may be considered to be a problem in body temperature regulation. Concerning the ability of animals to withstand temperature extremes and their metabolic acclimatization to extreme heat and cold, there is as yet only scattered information. The responses of oxygen consumption to temperature changes have been recognized (Barnes, Lüdtke, 1915; Krogh, 1916). In the poikilothermic animals oxygen consumption increases with rising temperatures and in the homoiothermic animals oxygen consumption increases as the temperature decreases. It has been stated that the difference is mainly due to the presence in the latter of a temperature-regulating mechanism by which external temperature changes are offset to a large extent by metabolic and physiologic reactions. It has been shown that body temperature falls with decreasing atmospheric pressure (Baleague et al., 1927; Chevillard and Mayer, 1935; Cordier and Mayer, 1935). Gellhorn and Janus (1936) proved that oxygen tension in the inhaled air is the determining factor. Chevillard and Mayer and Cordier and Mayer have further shown that the decrease in body temperature resulting from oxygen deficiency is associated with a decrease in oxygen consumption. Oxygen consumption is an index of metabolic activity. Increase in oxygen consumption in cold and decrease in heat is an important adjustment reaction in the warm-blooded animal in temperature regulation (Gellhorn, 1937). Hence an attempt has been made in this part to study the changes in oxygen consumption in baby rabbit and pigeon at higher ambient temperature to
city of these animals in having a metabolic adaptation temperature.

Thirty healthy adult pigeons weighing to 280 g. and thirty baby albino rabbits weighing to 300 g. were kept as control in a room with an average ambient temperature of 32°C. After recording their oxygen consumption at post-absorptive state the baby rabbits and pigeons were assigned treatment which consisted of exposure to 45°C and 48°C respectively in constant temperature chambers for a period of 2½ hours. The standard error fluctuation in the chambers was never greater than 0.1°C and the walls of the chambers were within 0.5°C of the air temperature. The animals were handled as gently as possible at the time of exposure and recording the oxygen consumption so as to prevent any sort of muscular activity which might result in some increase in oxygen consumption. Oxygen consumption has been measured by the technique described by Richards and Collison (1928). The principle of this method is to place the animal in a closed chamber and the carbon dioxide and water which it produces are absorbed by soda lime. Oxygen bubbles in through paraffin oil to keep the pressure constant in the chamber and the entrance of each bubble is recorded on a drum. The oxygen consumption is determined from the rate of formation of the bubbles. The detailed method is as follows:

The Chamber

The chamber is a rectangular museum jar 6½ inches long, 4 inches wide and 8½ inches high. It rests on a brass plate ½ inch thick into which are screwed 6 upright brass rods (10 x 5/16 in.) threaded at the upper ends to receive the wing nuts by which the brass cover is fixed to the chamber. A rubber gasket between cover and jar makes the joint airtight. The whole
in a thermostat below the surface of water.

**Apparatus**

Ventilating apparatus is attached to the cover. It consists of a cylindrical soda lime container rotated in the upper part of the container so that the chamber air circulates through it continuously. The fan shaft bears a collar which rotates in a mercury filled cup within the neck of the soda lime cylinder, thus making an air tight mercury seal. The mercury is covered with a layer of liquid paraffin. This lubricates the mercury and prevents the leakage of air between the mercury and the brass.

**Oxygen Recorder**

The inflow of oxygen necessary to maintain a constant pressure within the chamber is recorded by means of a valve. The valve consists of a glass bottle connected to a brass collar, which is threaded on the inside for attachment to its stopper. The latter is made of solid brass and is threaded at the bottom to receive the bottle, and at the top so that it may be screwed either into the cover of the chamber or into a solid brass bracket fixed below the water surface to the side of the thermostat bath. Two \( \frac{3}{4} \) in. holes are drilled vertically through the stopper, one in the centre, and the other midway between the centre and the circumference. A horizontal hole is drilled from the circumference into the central hole at a point midway between the two threaded ends. A short piece of thickwalled brass tubing is soldered into the upper end of the central hole for the connection of this with a tambour. When the valve is fixed to the thermostat bath instead of to the cover of the chamber, a piece of wider brass tubing is soldered into the horizontal hole and this
Fig. 1. Oxygen consumption of pigeons exposed to higher ambient temperature of 48°C for 2½ hours. Oxygen consumption measured continuously, is plotted in the form of a 5-minute histogram. The break in the hatching indicates a two-minute interruption of the recording.
Fig. 2. Oxygen consumption of rabbits exposed to 45°C for 2½ hours. Oxygen consumption is plotted in the form of a 5-minute histogram. The break in the hatching indicates a two-minute interruption of the recording.
of this are allowed to flow into a volumetric flask, while the oxygen bubbles which enter to replace the air thus displaced are taken at the time of temperature of the aspirator is taken at the time of and an appropriate correction applied to the volume of air withdrawn.

Calibration has been performed both on days when the barometer has been high, and on days when it has been low and the volume of the bubble appears to be independent of the barometric pressure. However, when the barometric pressure is rising, air passes into the chamber even when no air is being withdrawn by the aspirator, when the barometer is falling, the process occurs. A suitable correction is applied as follows:

Accurate barometric readings are taken at frequent intervals, and the change occurring during the calibration is calculated from the smooth curve drawn through the observed points. If \( V \) is the volume of the chamber, \( P \) the barometric pressure and \( \Delta P \) the increase of \( P \) occurring during the experiment, then a quantity \( V \Delta P/P \) is added to the volume of the mercury withdrawn. Calibrations performed at intervals have usually given quite concordant results.

The measurement of oxygen consumption: When an animal is placed in the chamber, its respiration is recorded by the tambour. This is presumably due to the rise and fall of the pressure of the air in the chest. Other movements are shown by sudden large distortions of the record, and also by irregularities in the rate of inhaling. These may be due to exaggerated respiratory movements with the glottis partially closed; this may also be due to sudden fluctuations of temperature.

When the animal is accustomed to the apparatus, it usually makes only slight and infrequent movements during the greater part of the experiment.
Table 1

Oxygen consumption in ml./kg./hour of baby rabbits and pigeons exposed to warm environment.

<table>
<thead>
<tr>
<th>Animals with No. in parentheses</th>
<th>Ambient temperature (°C)</th>
<th>Oxygen consumption (ml./kg./hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baby rabbit (30)</td>
<td>32</td>
<td>855.1 ± 20.9</td>
</tr>
<tr>
<td>Baby rabbit (30)</td>
<td>45</td>
<td>1040.5 ± 13.5</td>
</tr>
<tr>
<td>Pigeon (30)</td>
<td>32</td>
<td>693.4 ± 25.3</td>
</tr>
<tr>
<td>Pigeon (30)</td>
<td>48</td>
<td>904.4 ± 21.2</td>
</tr>
</tbody>
</table>
The barometric pressure should be recorded during the experiment, if it is changing rapidly, a correction should be applied as in the case of calibration. The volume thus obtained should be reduced to a standard pressure.

Results

Oxygen consumption of baby rabbit and pigeons has been studied as an index of their metabolism in higher ambient temperature. On heat exposure there is increase in oxygen consumption in both groups of animals. Exposure to higher ambient temperature of 48°C for 2½ hours, the pigeons showed an increase in oxygen consumption of 30%. The results are shown in Table 1 and in Fig. 1. The baby rabbits on exposure to 45°C for 2½ hours showed an increase in oxygen consumption of 21%. The results are shown in Table 1 and in Fig. 2.

Discussion

It is clear from the results presented in this part that baby rabbits and pigeons on short exposure to higher ambient temperature show a significant increase in oxygen consumption. Calorogenic effect of catechol hormones has been reported. Nor-adrenaline has been found to produce a powerful and prolonged stimulation of heat production, while after adrenaline administration only a 20% or less increase in oxygen consumption has been observed (Moore and Underwood, 1959, 1960a). It has also been reported that a rise in oxidative heat production, which is indicated by the rise in the oxygen consumption and skin temperature,
must precede the rise in body temperature. (Moore and Underwood, 1959).
Moore and Underwood (1980b) further demonstrated that increase in oxygen consumption by nor-adrenaline varies with age, maximal effects being in the first few weeks of life. It has been shown in Parts I and II that the baby rabbits and pigeons show an increase in rectal temperature on heat exposure. Increased activity of the adrenergic system and release of adrenaline and nor-adrenaline under such condition has also been demonstrated in Section 3 of Part III. Increase in oxygen consumption along with rectal temperature, in these animals, show increased heat production and is indicative of the increased activity of the adrenergic system and the direct heat on the activity of body cell. It can be interpreted that the baby rabbits and pigeons suffer from a defective thermoregulation and are in the stenothermic phase of thermoregulatory evolution.

Summary

Oxygen consumption of baby rabbits and pigeons has been measured as in index of their metabolism in higher ambient temperature. It has been shown that in pigeons, on exposure to 48°C for 2 1/2 hours, there is an increase in oxygen consumption of 30%, while in the baby rabbits, on exposure to higher ambient temperature of 45°C, only 21% increase in oxygen consumption is noticed. Increase in oxygen consumption along with increase in rectal temperature indicates increased heat production and is interpreted to be due to increased activity of the adrenergic system. It has been concluded that the baby rabbits and pigeons suffer from a defective thermoregulation and are in the stenothermic phase of thermoregulatory evolution.