CHAPTER 7

THE SUCCINIC DEHYDROGENASE LEVELS OF THE PECTORAL MUSCLES OF A FEW REPRESENTATIVE TYPES OF BIRDS AND A BAT IN RELATION TO THE FIBRE DIAMETER, MUSCLE WEIGHT AND BODY WEIGHT

Muscular tissue in general exhibits a wide range of morphological and biochemical variations. That the homologous muscles of animals belonging to the same group may show great variations in microscopical structure as well as function, has been shown in the flight muscles of insects (Tiegs, 1955; George and Bhakthan, 1960a and 1960b) and in the breast muscles of birds (George and Jyoti, 1955a; George and Naik, 1957a, 1959a, and 1959b). While studying histochemically the distribution pattern of certain oxidizing enzymes in the pectoralis major muscle of 3 birds (Chapter 6) it was suggested that a correlation between structure and function could be derived in terms of the body weight, muscle weight, fibre architecture, fibre diameter, metabolite load and certain cell inclusions against the nature and mode of flight. In order to put this suggestion to further test it was thought desirable to study the concentration of SDH in the pectoral muscles of a few representative types of birds exhibiting different modes of flight and a bat for comparison. SDH was chosen for the present investigation since this enzyme is one of the prime movers of oxidation in the metabolic mill. It may be mentioned here that though considerable amount of data have accumulated in the recent years on the respiratory enzyme levels in the homologous tissues of mammals of different sizes (Adolf, 1949;

Krebs, 1950; Bertalanffy and Prozynski, 1951; Kunkel and Campbell, 1952; Fried and Tipton, 1953 and Kunkel *et al*, 1956), comparatively little is known about this aspect in the case of birds and hence the justification for the present investigation.

Material and Methods

The SDH activities in the *pectoralis major* and *minor* muscles of the following birds and a bat were quantitatively assessed.

Rosy Pastor (*Pastor roseus*)
House Sparrow (*Passer domesticus*)
Green Parakeet (*Psittacula krameri*)
Pigeon (*Columba livia*)
Common Myna (*Aeridotheres tristis*)
Cattle Egret (*Bubulcus ibis*)
Common Babbler (*Argya caudata*)
Crow Pheasant (*Centropus sinensis*)
Fowl (*Gallus domesticus*)
Bat (*Hipposideros speoris*)

All the animals studied except the fowl and the pigeon were either trapped or shot with an air rifle. The weight of each of the animals was recorded prior to decapitation. The *pectoralis major* muscle of one side was removed completely and weighed. Since the ratio of the distribution of the different types of fibres in a mixed muscle vary from region to region (Chapters, 1, 3 and 4), for the estimation of SDH activity, a strip of muscle (with its entire depth) cut along the direction

of the fibres was removed quickly from the middle of the pectoralis in each case. The muscle strips removed from the pectoralis major and minor muscles were homogenized separately in cold distilled water in mortars chilled previously. 1 ml. of approximately 5 % homogenate prepared in each case was used for the estimation of SDH activity. The enzyme activity was estimated according to the procedure of Kun and Abood (1949) using TTC as the hydrogen acceptor as described earlier (Chapter 1). The only change in the incubation medium was that a concentration of 0.5 M sodium succinate was used instead of 0.2 M. The enzyme activity is expressed in μg of formazan formed per mg. dry weight of the muscle per 30 minutes at 37° C. under aerobic conditions. The dry weight of the homogenate used was determined on 1.0 ml. duplicate samples dried to constant weight at approximately 100° C.

Simultaneously a small piece of muscle was cut from the pectoralis major muscle and used for determining the diameter of the fibres. Fresh frozen sections of this muscle piece were mounted in 50 % glycerol solution on microslides and the diameter of the fibres for each preparation were recorded using an occular scale and a micrometer slide.

Results

The body weight, the weight and fibre diameter of the pectoralis major muscle and the SDH activity of the pectoralis major and minor muscles of the different birds and a bat studied, are given in Table 1. In each individual bird and the bat, the pectoralis major muscle showed considerably higher concentrations

of SDH than that of the pectoralis minor muscle except in the case of the fowl, where the difference in the enzyme activity was not much marked. The mean diameter of the fibres in the pectoralis major muscles was found to vary with the size of the muscle. The variations in the weight of the pectoralis major muscle also showed some variations in relation to the variations in the body weight in most of the cases. The pectoral muscles of rosy pastor, sparrow, bat, parakeet and pigeon showed higher concentration of SDH than that of myna, egret, babbler and crow pheasant, whereas the pectoral muscles of fowl showed the least concentration. The results obtained indicate a reciprocal relationship between enzyme activity and body weight, fibre diameter and weight of the pectoralis major muscle within the limits of the animals studied. Statistical evaluation after converting all the values for body weight, weight of the pectoralis major muscle, fibre diameter and SDH activity to their logarithms, results in a regression equation

$$\log X = 6.8117 - 3.6395 \log D - 0.1021 \log B - 0.1208 \log P \quad (1)$$

where log X is the logarithm of the SDH activity of the pectoralis major muscle, log D the logarithm of the diameter in μ, log B the logarithm of body weight in gm. and log P the logarithm of the weight of the pectoralis major muscle in gm.

From the regression equation (1) it appears that the regression coefficients of log B and Log P are nearly same and also the correlation coefficient between log B and log P is 0.97. Taking this fact into consideration any one variable

can be omitted, say log P, then the regression equation obtained will be

$$\log X = 6.5607 - 3.4171 \log D - 0.2051 \log B . \quad (2)$$

The expected values by the equations 1 and 2 also tally with the experimental values. Hence the SDH activity of the pectoralis major muscles of the birds and the bat, studied can be correlated in terms of the body weight, fibre diameter and weight of the pectoralis major muscle as shown in the regression equations 1 and 2. Apart from this, the SDH level was found to be sufficiently increased in the pectoralis major muscle of rosy pastor just prior to migration (Table 2).

Table 2

Seasonal variations in the body weight and levels of SDH activity of the pectoralis major muscle of rosy pastor

Month	SDH activity in µg. formazan/mg. dry muscle/30 min.	Body weight in gm.
November	7.7	58
January	9.0	63
February	11.3	68
March	12.7	73
April	16.8	90
Average	11.5	70

Discussion

George and Jyoti (1955a) and George and Naik (1957a, 1959a) recorded some histological and cytochemical observations on the breast muscle of a few birds and a bat and suggested the possibility of some relationship between the structure of the muscle and its function. The reduction in the amount of SDH with increase in fibre diameter have been noted in the mixed muscle of the rat (Nachmias and Padykula, 1958), the bat (George, Susheela and Scaria,1958a) and certain muscles of reptiles (Shah, Unpublished). Similar observations have been made by George and Bhakthan (1960a, 1960b) on the concentration of lipase in the flight muscles of certain butterflies and moths as revealed by histochemical as well as biochemical studies. Same holds true in the case of the pectoralis major muscle of different birds when the SDH content is compared in terms of the fibre diameter of the individual muscle.

George and Naik (1959b) recorded the fibre diameter of a few representative types of birds and suggested that in birds with similar flying habits, the mean diameter of the fibres in the pectoralis major muscle varies with the size of the muscle and also that the rate of increase in the diameter of the fibres per gm. weight of the muscle differs in birds with different flying habits. Nair (1952) studied the chemical composition of the pectoral muscles of some Indian birds and showed a higher concentration of iron in the good fliers among the birds he studied whereas the lowest iron content was reported in the case of the domestic fowl thereby suggesting a

high concentration of myoglobin in the pectoral muscles and consequently higher respiratory metabolism in the good fliers than that of the poor or non-fliers. This is also indicated by the SDH levels in the braest muscles of different birds.

A considerably higher concentration of SDH in the pectoralis major muscle than that in the pectoralis minor of the different birds suggest that the former muscle is metabolically much more active and highly evolved. The pectoralis major muscle of the fowl which is practically a non-flier, does not show a considerable increase in the concentration of SDH over that of its minor muscle. This may be expected in such a case in which the activity of two muscles is more or less equally restricted.

The various structural and functional features of an organism are known to vary with body size (Adolf, 1949; Fried, Samuel and Tipton, 1953). The decrease in the respiratory metabolic intensity with increase in body size is reflected in a decrease of the respiratory intensity of several homologous tissues (Krebs, 1950). There is then an inverse correlation of both the whole body and the tissue metabolic intensity and body size among different species, although intraspecific comparisons do not always demonstrate this relationship (Bertalanffy and Prozynski, 1951; Kunkel et al, 1956).

As is obvious from the results and the regression equations obtained in the present study such a relationship holds good in the case of the birds as well but it should be mentioned that though a reciprocal relationship between the

enzyme activity and the other factors studied exists there can be no definite generalization since there could be exceptions to such relationships which may be produced by the interplay of other factors and are difficult to explain. For example as mentioned in the case of the goose (Chapter 6) which is a poor flier and is as big as that of a fowl if not bigger but the pectoralis major muscle is composed predominantly of the narrow red fibres. Apart from this, the SDH activity of the breast muscles of birds also depends on the mode of flight.

It is of interest to note that in the case of the rosy pastor which is a migratory form, the pectoralis major muscle shows a marked increase in the SDH activity under standard conditions of the experiments, even with considerable increase in body weight just prior to migration (Table 2). This elevation in SDH level might be due to the higher activity of the thyroid just prior to migration since it is known that cytochrome oxidase activity is elevated in thyrotoxicosis (Kunkel and Campbell, 1952). Kunkel et al (1956) suggested that the cytochrome oxidase activity could be altered by hormonal, dietary or physiological treatment and that a decline in the cytochrome oxidase level with increasing body weight might represent the results of the similar adaptive phenomenon. This is again a generalization that cannot be accepted without reservations. At best the suggestion of Fried, Samuel, and Tipton (1953) that "the constant enzymic activity within a single species indicates indirect genetic factors regulating

metabolic enzymes rather than hormonal or other direct somatic factors" appears more tenable. It is likely that the hormonal, dietary and physiological treatment may be secondary factors responsible for regulating the various metabolic processes of the different tissues and ultimately of the organism as a whole but the basic organization being directed by the pre-determined genetic factors.

In conclusion it may be said that the results obtained in this study show a relationship more or less similar to what has been observed in the homologous tissues of mammals of different sizes. Though no exact mathematical correlation can be derived between the SDH activity of the pectoralis major muscle and the body weight, and fibre diameter and weight of the pectoralis major muscle, among the different birds studied, a reciprocal relationship, to a certain extent, does seem to exist between the SDH activity and the other factors. This suggestion, however, does not rule out the possibility of this enzyme activity being correlated with other factors which might be concerned with the SDH level of this muscle in birds.