CHAPTER 5

CELLULAR ORGANIZATION AND DISTRIBUTION OF FAT AND SUCCINIC DEHYDROGENASE ACTIVITY IN THE PECTORALIS MAJOR AND PECTORALIS MINOR OF CERTAIN REPRESENTATIVE BATS

The occurrence in the flight muscles of birds of two distinct types of fibres and their intermediate forms has already been discussed in the previous chapters. Since the morphological heterogeneity has an important bearing on the physiology of muscle function, it was interesting to study the cellular organization of the flight muscles of bats, another group of animals which has successfully taken to air. Birds exhibit different modes of flight, whereas bats as a group appear to be more uniform in their mode of flight. Comparative study of the fibre composition of the flight muscles of birds and bats would therefore be helpful in elucidating the cause-effect relationship between the mode of flight and fibre composition.

The presence of only one type of fibre was reported by Bullard (1912) in the flight muscles of bats. George and Jyoti (1955) who studied the flight muscles of microchiroptera also noted the presence of only one type of fibres. However, George and Naik (1957) showed the presence of two distinct types of fibres as in the pigeon pectoralis in the breast muscles of another species of bats, Hipposideros speoris. An intermediate type of fibre has been noted in the pectoralis of some of the birds (Chapter 2 and 3) and in certain skeletal muscles of mammals

(George and Susheela, 1961; Stein and Padykula, 1962; and Chinoy and George, 1964). In the present study a characterization of the fibre types in the pectoralis major and pectoralis minor muscles of certain representative bats, is attempted.

MATERIALS AND METHODS

The following species of bats were used for the investigation:

Hipposideros speoris

Pteropus giganteus

Sctophilus heathi

Pipistrellus ceylonicus

Pipistrellus mimus

The bats were collected in the field, brought alive to the laboratory and were decapitated. A piece of the pectoralis major muscle was removed from the central region of the muscle as was done in the study of the pigeon pectoralis muscle by George and Naik (1959). A piece was also excised from the pectoralis minor muscle. Each muscle piece was quickly frozen on the stage of a freezing microtome and sections about 15 to 20μ thick were cut.

For the demonstration of fat, fresh frozen sections were stained with Sudan Black-B in 70% alcohol. Some sections were stained in Fettrot-7B in 70% alcohol for the demonstration of neutral lipids. The sections were mounted in glycerine jelly and observations were made.

For the localization of succinic dehydrogenase (SDH) activity, the sections were quickly transferred to phosphate buffer,

pH 7.6 for five minutes to remove the endogenous substrates and then to the incubation medium. The incubation medium used, as well as the procedure followed, was the same as that of George and Talesara (1961).

The diameter of the fibres was measured by means of an ocular micrometer scale. Over hundred fibres were measured in each case and the average values are presented. The numbers of different types of fibres, in various unit regions of a section were counted by means of a fibroscope and their percentages were calculated.

RESULTS

The results obtained are presented in Table 1. and Table 2.

Table 1. presents data obtained on the pectoralis major muscle of the different species of bats studied. Based on the fibre diameter, the SDH activity and the fat content, the different species of bats studied could be classified into three groups: Group 1. (R. W.) having red and white fibres; Group 2. (R. I.) having red and intermediate fibres and Group 3. (R) having only the red type of fibres. The fibre composition of the muscles in the different groups (given in parenthesis) are in the order of predominance of the fibre types.

A similar characterization of the muscle types was made with regard to the pectoralis minor muscles of the bats mentioned in Table 1. and Table 2. The pectoralis minor muscles of various bats could be classed into three groups: Group 1. (R. W. I.)

having red, white and intermediate types; Group 2. (R. I. W.) having red, intermediate and white types and Group 3. (R. I.) having red and intermediate types of fibres. It may be noted that though group 1 and 2 contain all the three types of fibres, the order of predominance of these types is different.

DISCUSSION

The present study shows that all the three types of fibres the red, white and intermediate which exist in the flight muscles of birds are also represented in the flight muscles of bats.

The specialization of the two characteristic types eg. red (R) and white (W) of the fibres in birds is met with in the pectoralis of the "pigeon type" as represented by the Blue Rock Pigeon (Columba livia), Cattle Egret (Bubulcus ibis), Purple Moorhen (Porphyrio porphyrio), Hoopoe (Upupa epops) etc., which are good fliers. A similar type of fibre organization is found in the pectoralis major of Hipposideros speoris among the bats, which have been studied (Fig. 1). Here the muscle consists predominantly of narrow red, fat-loaded fibres which are adapted for an aerobic metabolism and a considerably fewer number of broad, white and glycogen-loaded fibres adapted for an anaerobic metabolism. In the pectoralis major of Hipposideros speoris as in the pigeon pectoralis a higher fat content (Fig. 2) and SDH activity was noted (+++) in the red fibres, where as the white fibres showed the minimum fat content and SDH activity (+). By this, is revealed a biochemical diversity side by side with a morphological diversity between the two types of fibres (the difference between the diameters

of the red and white fibres being quite conspicuous, about 15μ). It may be noted that among the bats studied Hipposideros speoris was the only species which showed such a striking difference in diameter between the two types of fibres.

Group 2. as represented by Pteropus giganteus, Sctophilus heathi also possess two types of fibres in their pectoralis major muscles (Figs. 3 to 6). However, in the present group unlike in group 1 the fibres other than the red ones contain considerably more fat and SDH (++). These fibres are therefore considered to be intermediate in nature. Such a distribution of fibres (red and intermediate) is met with in the "Starling type" among birds such as Rosy Pastor (Sturnus roseus), Common Myna Acridotheres tristis), House Crow (Corvus splendens) etc. (Chapter 2). Though a biochemical difference was thus evident between the red and intermediate fibres, no morphological distinction could however be made with respect to the diameter of the fibres.

In Group 3. as represented by Pipistrellus ceylonicus and Pipistrellus mimus, only one type, the red, narrow fibres are present throughout the pectoralis major muscle (Figs. 7 to 10). The fibre diameter was also the least recorded among the red fibres of the bats studied. Both the fat content and SDH activity were high (+++). This fibre architecture compares with that noticed in the "Sparrow type" among birds, such as Hummingbird (Archilochus colubris), Sparrow (Passer domesticus), Crimsonbreasted Barbet (Megalaima haemacephala) etc., which are capable of swift flight.

The bats represented in this group belong to Microchiroptera and are the smallest in body size among all the bats examined in the present study. They are also swift fliers as the birds mentioned above.

While comparing the pectoralis major muscle of the bats with the avian pectoralis two points stand out clearly. Firstly, none of the bats possess a pectoralis major muscle composed of all the three types of fibres, the red, white and intermediate as seen in the "Fowl type" (W. I. R.) and "Duck type" (R. I. W.) of birds (Chapter 2). It may be pointed out that these birds which possess all the three types of fibres are generally poor or non-fliers. The absence of such a muscle type among the bats is obviously because all bats are good fliers. Secondly, a muscle type composed exclusively of the intermediate fibres as seen in the "Kite type" (I) of birds was also not encountered among the bats studied. This muscle type is characteristic of birds indulging in soaring and gliding mode of flight (Chapter 2). If this type of muscle is correlated with the soaring and gliding mode of flight, its absence in the bats is understandable since they do not exhibit this mode of flight.

In contrast to the pectoralis major muscle, the pectoralis minor muscle of the bats showed the presence of all the three fibre types occurring together in some of the species. In the pectoralis minor three groups could be distinguished: Group 1. (R. W. I.) as represented by Hipposideros speoris (Figs. 11 & 12)

and Pteropus giganteus (Fig. 13), composed of red, white and intermediate types of fibres in descending order of predominance. Group 2. (R. I. W.) as represented by Sctophilus heathi (Figs. 14 & 15) though have the same three types of fibres are distinct from the former in that the intermediate fibres predominate over the white. Group 3. (R. I.) represented by Pipistrella species (Figs. 16 to 19) have only two types of fibres, the red and intermediate.

Considering the flight muscle of bats as a whole the following points may also be noted: 1. The pectoralis major and minor muscles of the same species did not show the same type of fibre composition. 2. In all the species of bats studied, the red type of fibres predominated in both the pectoralis major and minor; Such a predominance of red fibres was noted also in the pectoralis of birds which are good fliers, thereby indicating that both the pectoralis major and pectoralis minor muscles of bats are well adapted for the sustained activity of the muscle. 3. Among the bats studied, Pipistrellus species showed the minimum number of fibre types in both the pectoralis major (R) and pectoralis minor (R. I.) muscles.

The present study has shown that the pectoralis major and pectoralis minor muscles of bats have certain resemblences to the flight muscles of the active fliers among birds. The red fibres both in the pectoralis major and minor of the bats possess high concentrations of mitochondria, SDH activity and fat which are evenly distributed throughout the fibre unlike in some of the poor fliers among birds such as the Jungle Babbler (Turdoides

striatus) and Crow-Pheasant (Centropus sinensis), where these were distributed more towards the periphery of the fibres only. It is evident that there has been a considerable degree of parallelism in the evolution of the flight muscles in these two diverse group of animals.

TABLE 1

FIBRE DIAMETER AND DISTRIBUTION PATTERN OF FAT AND SUCCINIC DEHYDROGENASE (SDH) ACTIVITY IN THE PECTORALIS MAJOR MUSCLES OF SOME DIFFERENT SPECIES OF BATS

Group	Name of the bat	Diameter of muscle fibres in μ		Diameter difference in μ	Concentration of SDH		Concentration of FAT	
Group 1 (R.W.)	Hipposideros speoris	(R) 37.5 (70.9)	(W) 52.5 (29.1)	15	(R) +++	(W) +	(R) +++	(W) +
Group 2 (R.I.)	Pteropus giganteus	(R) 50.0 (77.8)	(I) 55.0 (22.2)	5	(R) +++	(I) ++	(R) +++	(I) ++
	Sctophilus heathi	40.0 (59.9)	40.0 (40.1)	Nil	+++	++	+++	++
Group 3 (R)	Pipistrellus ceylonicus	(R) 32.5 (100)		Nil	(R) +++		(R) +++	
	Pipistrellus mimus	32.0 (100)		Nil	+++		+++	

Figures in parentheses denote the percentage of the respective fibres in the muscle

+++ Denotes maximum activity

++ Denotes medium activity

+ Denotes minimum activity

TABLE 2

FIBRE DIAMETER AND THE DISTRIBUTION PATTERN OF FAT AND SUCCINIC DEHYDROGENASE (SDH) ACTIVITY IN THE PECTORALIS MINOR MUSCLES OF SOME BATS

Group	Name of bat	Diameter of muscle fibres in μ			Concentration of SDH			Concentration of FAT		
		(R)	(W)	(I)	(R)	(W)	(I)	(R)	(W)	(I)
Group 1 (R.W.I.)	Hipposideros speoris	35.0 (61.2)	50.0 (20.0)	45.0 (18.8)	+++	+	++	+++	+	++
	Pteropus giganteus	40.0 (45.3)	50.0 (42.6)	40.0 (22.1)	+++	+	++	+++	+	++
		(R)	(I)	(W)	(R)	(I)	(W)	(R)	(I)	(W)
Group 2 (R. I.W)	Sctophilus heathi	40.0 (52.3)	40.0 (34.2)	45.0 (13.5)	+++	++	+	+++	++	+
		(R)	(I)		(R)	(I)		(R)	(I)	
Group 3 (R.I.)	Pipistrellus ceylonicus	37.5 (65.2)	37.5 (34.8)		+++	++		+++	++	
	Pipistrellus mimus	37.0 (60.0)	37.0 (40.0)		+++	++		+++	++	

Figures in parentheses denote the percentage of the representative fibres in the muscle

+++ Denotes maximum activity

++ Denotes medium activity

+ Denotes minimum activity

Figures 1 to 10.

Photomicrographs of the T. S. of the pectoralis major muscles of some bats showing the localization of succinic dehydrogenase activity (SDH) and of fat.

Figures 11 to 19.

Photomicrographs of the T. S. of the pectoralis minor muscles of some bats showing the localization of succinic dehydrogenase activity (SDH) and of fat.

W ... White fibre type

I ... Intermediate fibre type

R ... Red fibre type

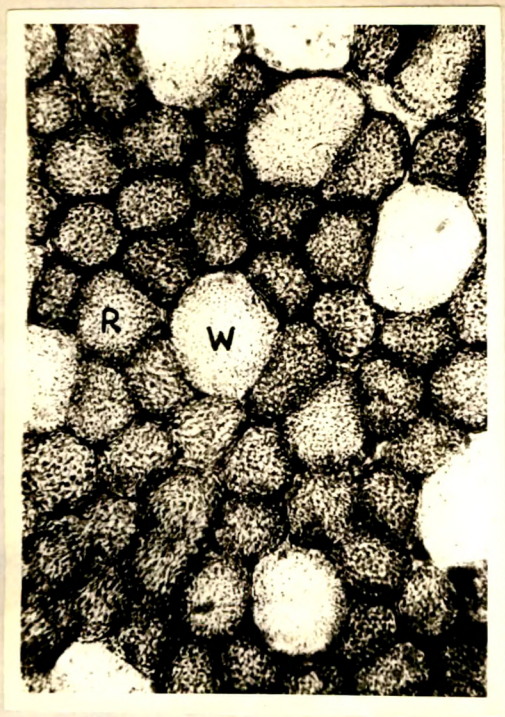

Fig. 1.
Hipposideros speoris (SDH) X 216.
(Pectoralis major)

Fig. 2.
Hipposideros speoris (Fat) X 432.
(Pectoralis major)

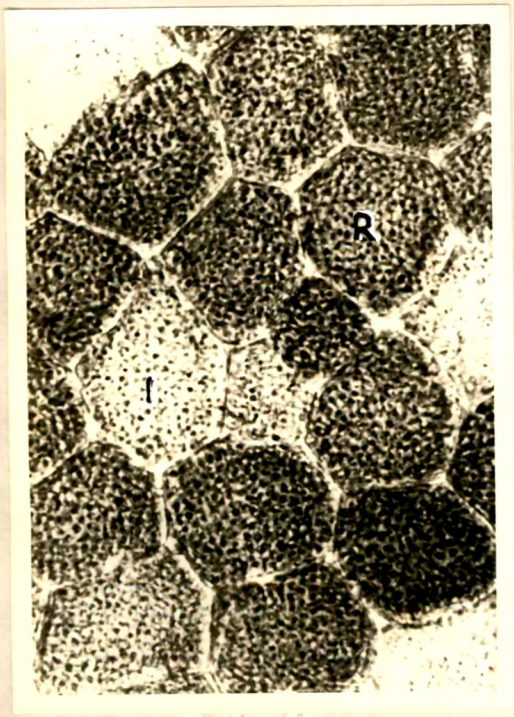

Fig. 3.
Pteropus giganteus (SDH) X 432.
(Pectoralis major)

Fig. 4.
Pteropus giganteus (Fat) X 432
(Pectoralis major)

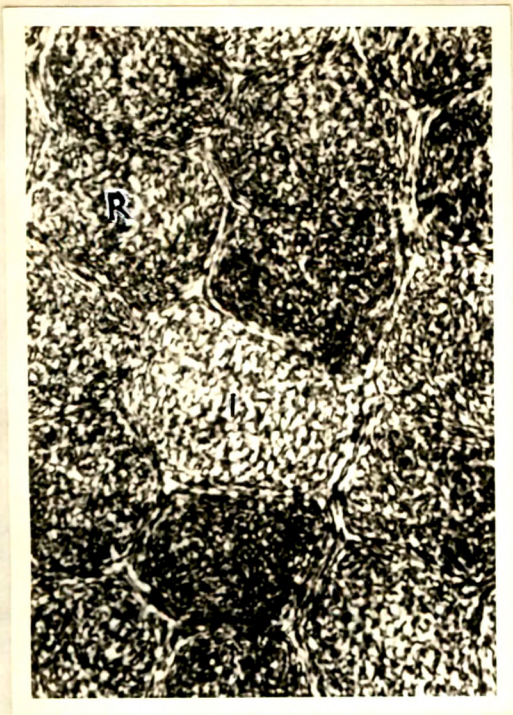

Fig. 5.
Sctophilus heathi (SDH) X 672.
(Pectoralis major)

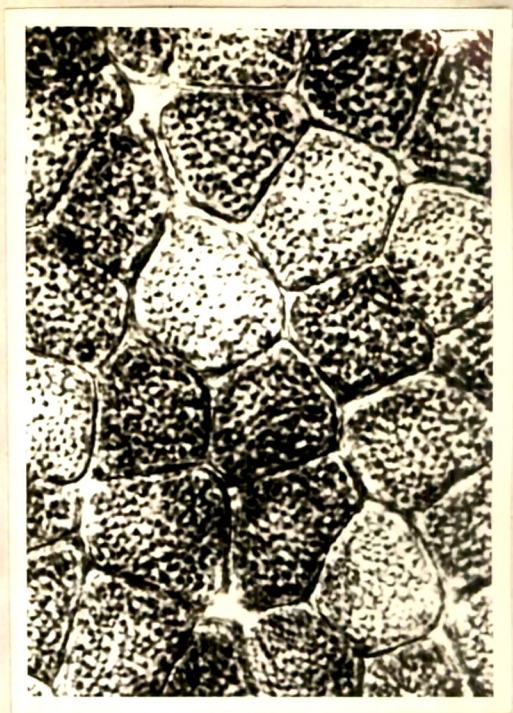

Fig. 6.
Sctophilus heathi (Fat) X 672.
(Pectoralis major)

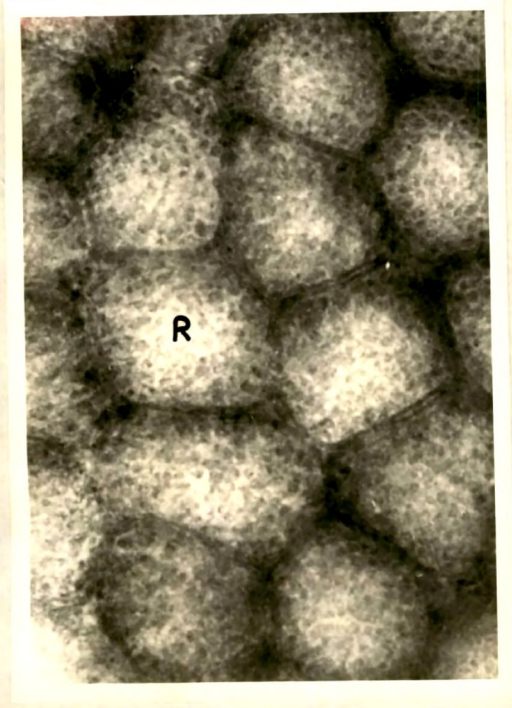

Fig. 7.
Pipistrellus ceylonicus (SDH) X 672.
(Pectoralis major)

Fig. 8.
Pipistrellus ceylonicus (Fat) X 672.
(Pectoralis major)

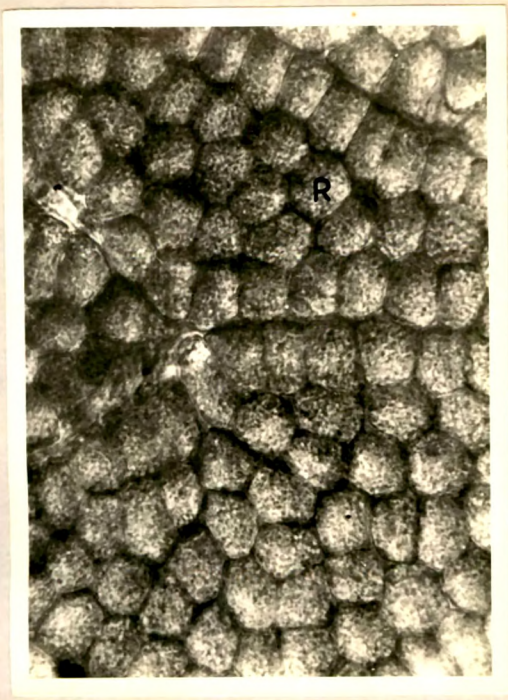

Fig. 9.
Pipistrellus mimus (SDH) X 288.
(Pectoralis major)

Fig. 10.
Pipistrellus mimus (Fat) X 672.
(Pectoralis major)

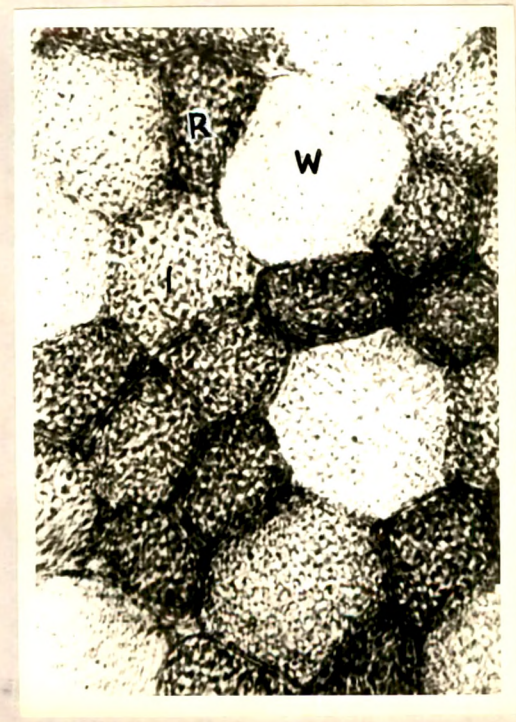

Fig. 11.
Hipposideros speoris (SDH) X 432.
(Pectoralis minor)

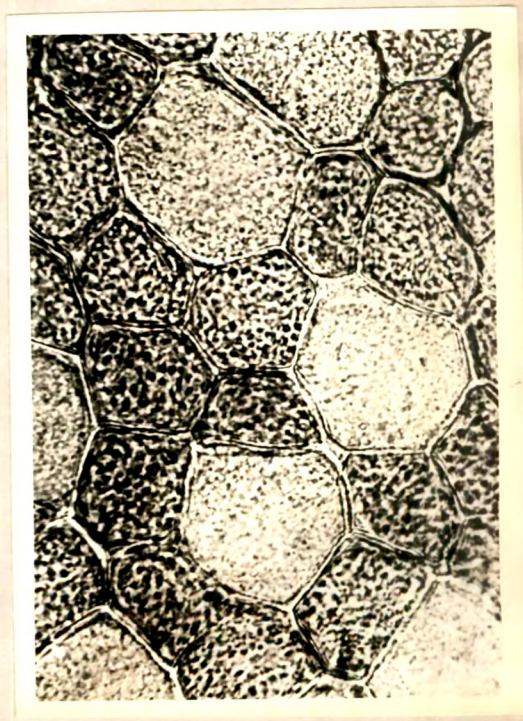

Fig. 12.
Hipposideros speoris (Fat) X 432.
(Pectoralis minor)

Fig. 13.
Pteropus giganteus (Fat) X 432.
(Pectoralis minor)

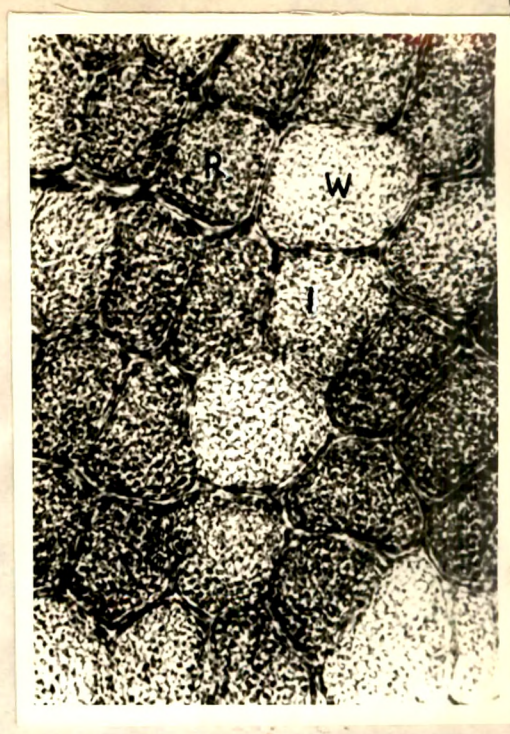

Fig. 14.
Sctophilus heathi (SDH) X 432.
(Pectoralis minor)

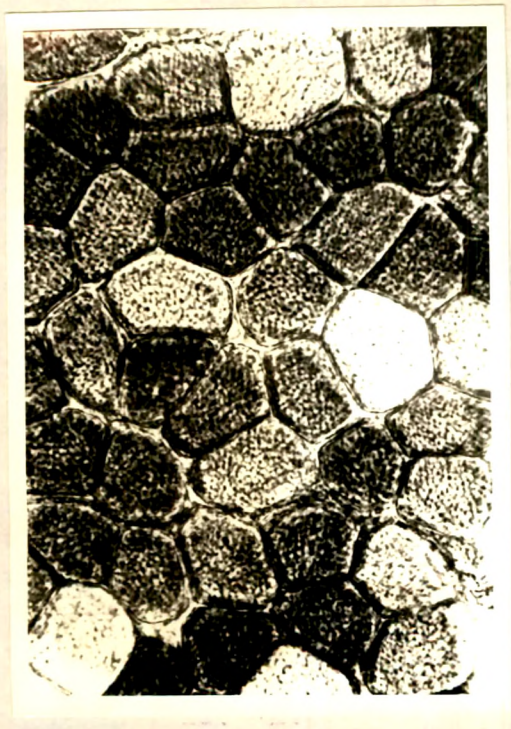

Fig. 15.
Sctophilus heathi (Fat) X 432.
(Pectoralis minor)

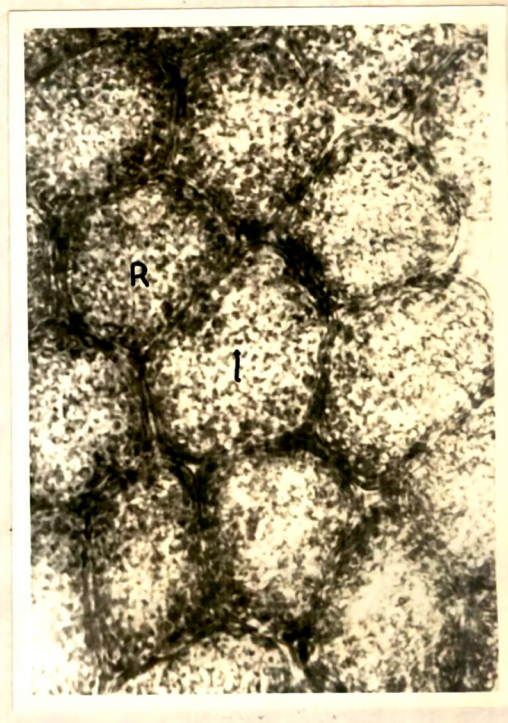

Fig. 16.
Pipistrellus ceylonicus (SDH) X 672.
(Pectoralis minor)

Fig. 17.
Pipistrellus ceylonicus (Fat) X 672.
(Pectoralis minor)

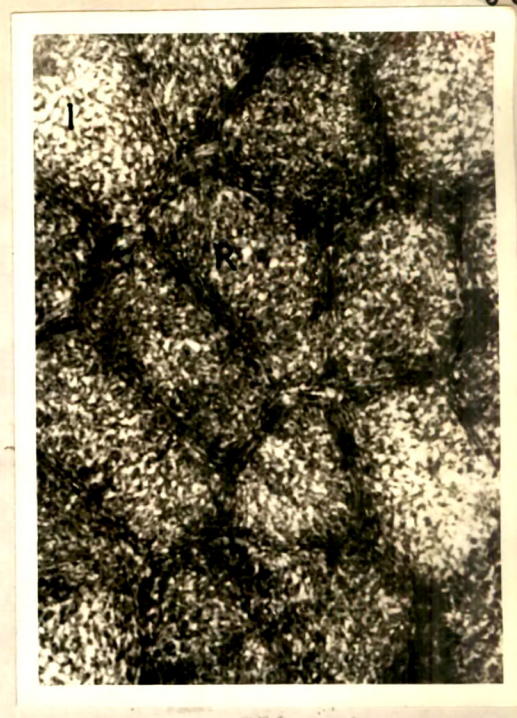

Fig. 18.
Pipistrellus mimus (SDH) X 672.
(Pectoralis minor)

Fig. 19.
Pipistrellus mimus (Fat) X 672.
(Pectoralis minor)