CHAPTER 10

CELLULAR ORGANIZATION AND DISTRIBUTION OF FAT AND SUCCINIC DEHYDROGENASE IN THE GASTROCNEMIUS MUSCLES OF A FEW BIRDS

The central theme in the preceeding chapters was an elucidation of the cellular organization of the flight muscles of birds and bats and their functional implication. That the distribution pattern of the various fibre types is related to the nature and extent of activity of the flight muscles has been established unequivocally. Apart from the wings, the legs of birds are also called upon to perform certain functional activity. Legs may be used to swim in water, to walk on marshy land, to run on open land, or to perch on trees etc. Thus in certain birds the leg muscles have to perform sustained activity whereas in certain others their activity is limited to less strenuous movements. It was therefore thought to be of interest to study the fibre composition of the leg muscles of birds exhibiting diverse adaptations of the leg. Of the various muscles of the leg, the gastrocnemius muscle is one of the largest and most powerful in the movements of the leg. Hence this muscle was chosen for the present study. The localization and distribution pattern of succinic dehydrogenase (SDH) activity and fat were found to be satisfactory criteria for the elucidation of the fibre types which constitute a muscle and was used in the characterization of the gastrocnemius muscle as was done in the case of the pectoral muscles (Chapters 2, 3 and 4).

MATERIALS AND METHODS

The gastrocnemius muscles of the following twelve species of birds which show different modifications of their legs depending on their particular mode of life, were selected for observations (Figs. 1 to 20).

Common Myna (Acridotheres tristis)

Rosy Pastor (Sturnus roseus)

Spotted Dove (Streptopelia chinensis)

Redvented Bulbul (Pycnonotus cafer)

Jungle Babbler (Turdoides striatus)

Crow-Pheasant (Centropus sinensis)

Guinea Fowl

Redwattled Lapwing (Vanellus indicus)

Pariah Kite (Milvus migrans)

Brahminy Duck (Tadorna ferruginea)

Large Whistling Teal (Dendrocygna bicolor)

Cotton Teal (Nettapus coromandelianus)

Among all these birds, the Common Myna, Rosy Pastor, Spotted Dove, Redvented Bulbul, Jungle Babbler and Crow-Pheasant use their legs mainly for walking or hopping on the ground or for perching on trees. The other six birds put their legs to varied actions. The Guinea Fowl (like the Domestic Fowl) is mostly on land and its legs are used not only for walking and running as the other gallinaceous birds but also to dig the soil and debris to obtain insects, worms etc. on which they feed. The Redwattled Lapwing has long and thin legs which are mainly used for wading

in shallow waters and walking or running on land. In the Pariah Kite, the legs are provided with powerful talons and are used for grasping and holding the prey while in flight. The Brahminy Duck, Large Whistling Teal and Cotton Teal are aquatic birds with webbed feet and their legs are used for paddling through water.

All the birds, except the Guinea Fowl which was killed in the laboratory by decapitation, were shot by an air rifle in the field and were brought to the laboratory within half an hour. The gastrocnemius muscle was quickly dissected out and frozen in the deep freeze of a refrigerator. Hand sections about 15 to 20μ thick were cut from the middle region of the muscle. The methods used for the demonstration of fat and SDH were as described for the pectoral muscles (Chapters 2 and 4). The diameter of the different fibres and number of each fibre type in a given unit region were also measured as described in chapter 5. The concentrations of SDH and fat in the different fibres were assessed by visual observation under the microscope and denoted as + for the minimum to ++++ for the maximum.

RESULTS AND DISCUSSION

The gastrocnemius muscle of all the twelve birds studied showed the presence of all the three types (R, W and I) of fibres described in the pectoral muscles of birds, and as A B C cells by Stein and Padykula (1962) in the gastrocnemius muscle of the rat. Based on the relative abundance of the three types of fibres the gastrocnemius of the different birds could be classed into two groups (Table 1).

Group 1. (W.I.R.)

In the gastrocnemius muscle of birds belonging to this group the fibre types were in the following order of predominance - white, intermediate and red (Figs 1 to 8). Within the group, the percentage of the fibre types were, white:47 to 59%, intermediate: 22 to 35% and red: 17 to 23% (Table 1). This type of fibre distribution is comparable to the pectoralis muscle of the 'Fowl type' birds (Chapter 2). The birds belonging to the present group have their legs adapted either for landing on the ground, for hopping or for perching on trees. Hence the gastrocnemius muscle in these birds is not put to sustained activity as is the case with the pectoralis muscles of the 'Fowl type' birds. The nature of the fibre distribution in the gastrocnemius of these birds is also in accordance with the activity of the muscle, since the red fat utilizing fibres are the least in number. On the other hand this muscle should be capable of quick and fast contractions as seen in a sudden take off from the ground.

Group 2. (I.W.R.)

Though the gastrocnemius muscle in this group of birds consists of all the three types of fibres (Table 1) represented in group 1., their order of predominance differ in the fact that the intermediate fibres are more in number than the white (Figs. 9 to 20) (intermediate : 40 to 44%, white: 32 to 38% and red: 20 to 26%). The birds in group 2 make greater use of their legs than those in group 1 and it is significant that the fibre

compositions of the gastrocnemius muscle in the two groups also show two different patterns. Among the red fibres of group 2 those in the gastrocnemius of the swimming birds, Brahminy Duck, Large Whistling Teal, and Cotton Teal show the highest concentrations of fat and SDH (++++, Table 1), and are studded with numerous mitochondria. Hence the gastrocnemius of these birds are evidently the most adapted, among the gastrocnemius muscles of all the birds studied, for sustained muscular activity. This is in keeping with a greater amount of sustained work they have to put in while paddling.

It may be seen that the gastrocnemius muscle has evolved along two lines: 1. Gastrocnemius muscle such as those of birds in Group 1 in which three types of fibres exist in the order (W), (I) and (R) with white fibres predominating and 2. Those as in Group 1 in which the three types of fibres are arranged in the order (I), (W) and (R) with the intermediate fibres predominating.

The fibre composition of the gastrocnemius muscle of the various birds reported here offers some comparision with the fibre composition with the flight muscles of birds. The gastrocnemius of Group 1 (W.I.R.) is similar in its fibre distribution to the pectoralis of the non-flying birds (Fowl type) while that of Group 2 (I.W.R.) the birds have their gastrocnemius better adapted for sustained activity in keeping with their functional demand. It is interesting to note that though all the fibre types encountered in the pectoralis of birds are also represented

in the gastrocnemius of the birds studied, the wide variety of fibre distribution patterns encountered in the pectoralis muscles of birds is not found in the gastrocnemius. For example none of the gastrocnemius muscles studied were found to be exclusively composed of either two types of fibres or one type of fibre only as in the pectoralis of some birds. Further a muscle type in which the R fibre predominates as in some of the flying birds is not represented in the gastrocnemius muscle of any of the birds investigated.

With regard to the diameter of each of the three types of fibres in the gastrocnemius studied in the twelve birds, it may be noted that the Guinea Fowl has the maximum diameter in all the three types (90.0μ in W, 80.0μ in I and 70.0μ in R). In the Redvented Bulbul the diameters of the fibre types are 52.5μ in W, 47.5μ in I and 40.0μ in R. The smallest red fibre (35.0μ) was obtained in the Cotton Teal, the smallest white fibre (52.5μ) in the Redvented Bulbul and the smallest intermediate fibre (45.0μ) in the Spotted Dove and the Cotton Teal. It is interesting to note that the largest of the red fibres (70.0μ in the Guinea Fowl) is larger than the smallest of the white fibres 52.5μ in the Bulbul. In the biological world, various systems fall into defenite and overlapping size ranges. It is a matter of common knowledge that the largest cell is larger than the smallest mammal, the largest virus larger than the smallest cell.

TABLE 1

THE FIBRE DIAMETER AND DISTRIBUTION PATTERN OF FAT AND SUCCINIC DEHYDROGENASE ACTIVITY IN THE GASTROCNEMIUS MUSCLES OF SOME BIRDS

Names of birds	Diameters of the muscle fibres and their respective percentages			Concentration of SDH			Concentration of FAT		
Group 1. (W) I. R)	(W)	(I)	(R)	(W)	(I)	(R)	(W)	(I)	(R)
Common Myna (*Acridotheres tristis*)	60.0(47.0)	50.0(34.9)	52.5(18.1)	+	++	+++	+	++	+++
Rosy Pastor (*Sturnus roseus*)	65.0(48.0)	52.5(32.0)	45.0(20.0)	+	++	+++	+	++	+++
Spotted Dove (*Streptopelia chinensis*)	60.0(59.9)	45.0(22.8)	40.0(17.3)	+	++	+++	+	++	+++
Redvented Bulbul (*Pycnonotus cafer*)	52.5(46.0)	47.5(31.2)	40.0(22.8)	+	++	+++	+	++	+++
Jungle Babbler (*Turdoides striatus*)	65.0(48.5)	50.0(34.3)	42.5(17.2)	+	++	+++	+	++	+++
Crow-Pheasant (*Centropus sinensis*)	67.5(47.4)	52.5(31.6)	42.5(21.0)	+	++	+++	+	++	+++

(Contd.)

Group 2. (I. W. R)	(I)	(W)	(R)	(I)	(W)	(R)	(I)	(W)	(R)
Guinea Fowl	80.0(41.4)	90.0(36.2)	70.0(22.4)	++	+	+++	++	+	+++
Redwattled Lapwing (*Vanellus indicus*)	55.0(40.0)	65.0(33.8)	47.5(26.2)	++	+	+++	++	+	+++
Pariah Kite (*Milvus migrans*)	50.0(42.9)	60.0(37.5)	42.5(19.6)	++	+	+++	++	+	+++
Brahminy Duck (*Tadorna ferruginea*)	55.0(42.0)	70.0(35.4)	45.0(22.6)	++	+	++++	++	+	++++
Large Whistling Teal (*Dendrocygna bicolor*)	57.5(43.7)	70.0(32.3)	47.5(24.0)	++	+	++++	++	+	++++
Cotton Teal (*Nettapus coromandelianus*)	45.0(44.4)	57.5(33.4)	35.0(22.6)	++	+	++++	++	+	++++

Figures in the parentheses denote the respective percentage of the fibre types.

The intensity of SDH activity and fat content is denoted by the number of + signs.

Figures 1 to 20.

Photomicrographs of the T. S. of the gastrocnemius muscles of some birds 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.
Rosy Pastor (SDH)
(Sturnus roseus) X 432.

Fig. 2.
Rosy Pastor (Fat)
(Sturnus roseus) X 432.

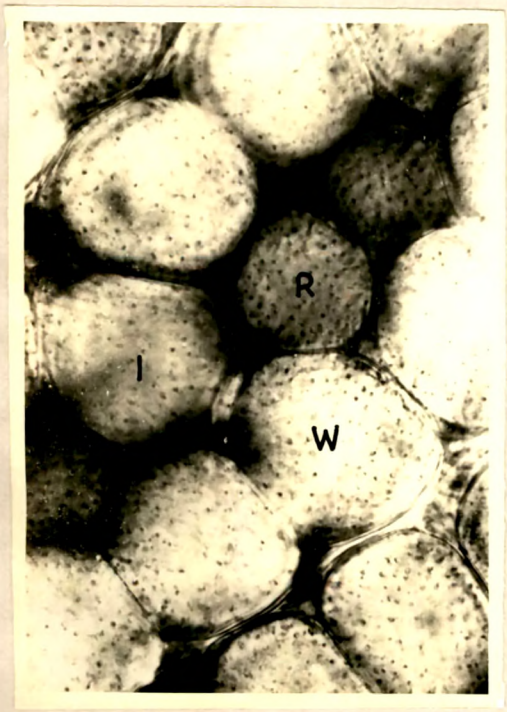

Fig. 3.
Redvented Bulbul (SDH)
(Pycnonotus cafer) X 432.

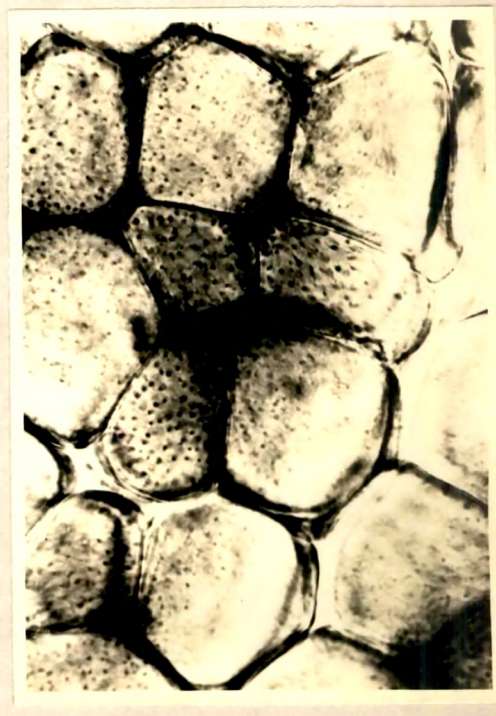

Fig. 4.
Redvented Bulbul (Fat)
(Pycnonotus cafer) X 432.

Fig. 5.
Jungle Babbler (SDH)
(Turdoides striatus) X 432.

Fig. 6.
Jungle Babbler (Fat)
(Turdoides striatus) X 432.

Fig. 7.
Crow-Pheasant (SDH)
(Centropus sinensis) X 432.

Fig. 8.
Crow-Pheasant (Fat)
(Centropus sinensis) X 432.

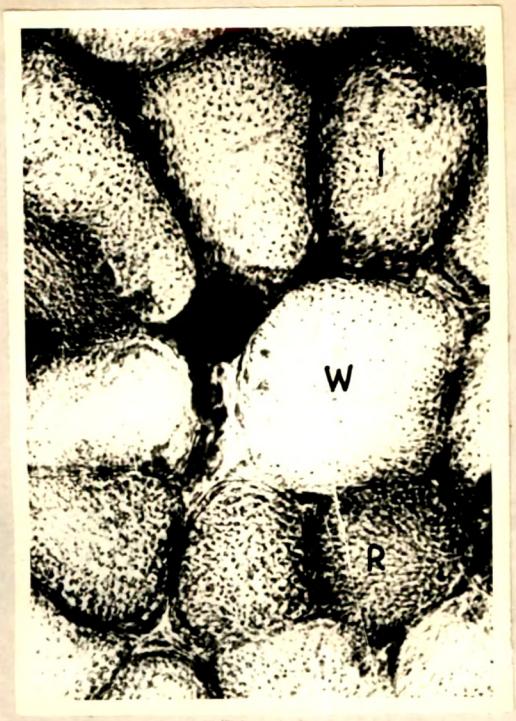

Fig. 9.
Guinea Fowl (SDH)
X 288.

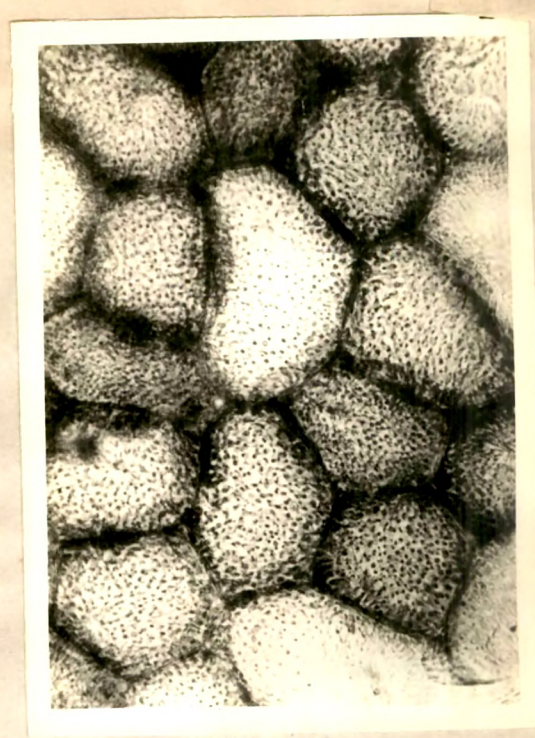

Fig. 10.
Guinea Fowl (Fat)
X 288.

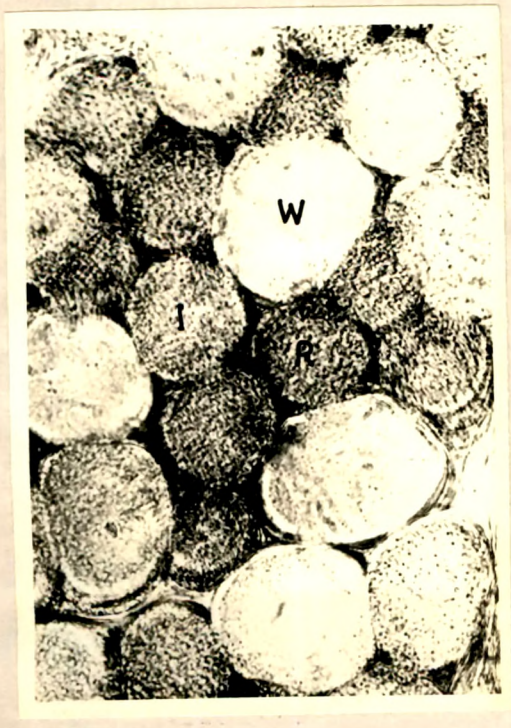

Fig. 11.
Redwattled Lapwing (SDH)
(Vanellus indicus) X 288.

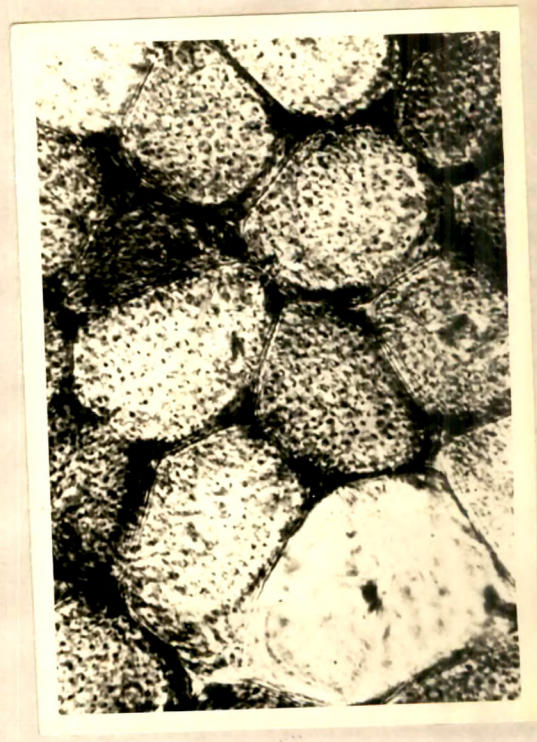

Fig. 12.
Redwattled Lapwing (Fat)
(Vanellus indicus) X 432.

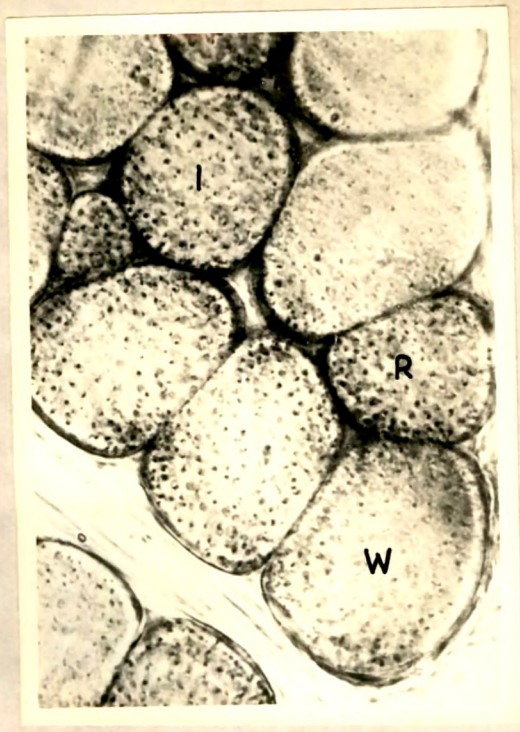

Fig. 13.
Pariah Kite (SDH)
(Milvus migrans) X 432.

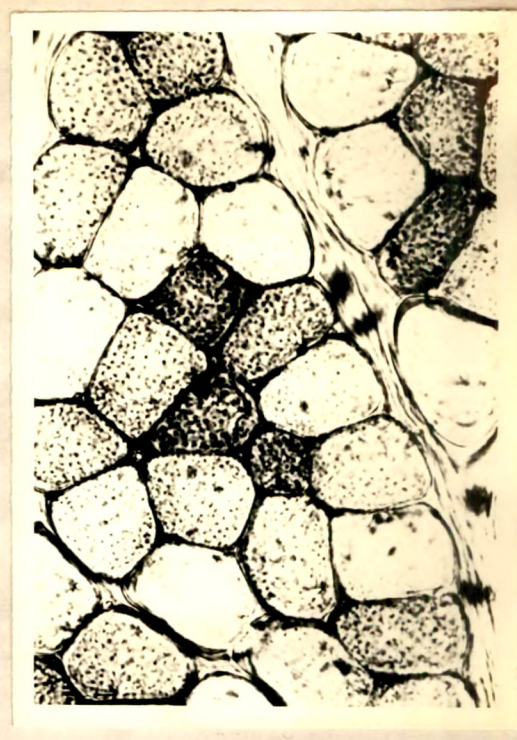

Fig. 14.
Pariah Kite (Fat)
(Milvus migrans) X 288.

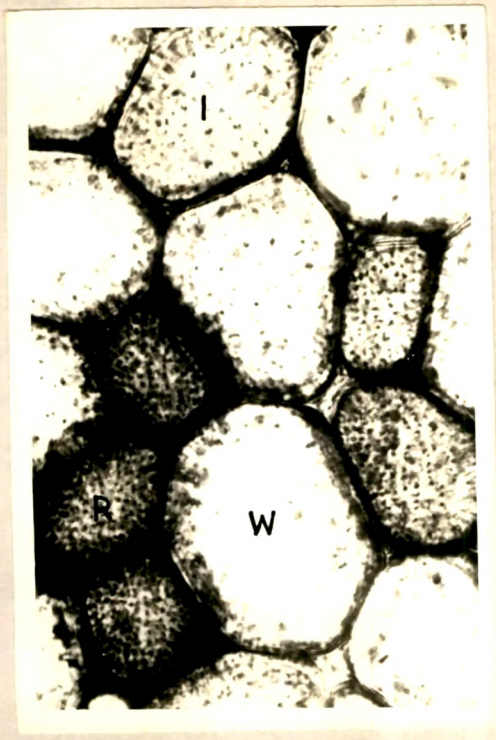

Fig. 15.
Brahminy Duck (SDH)
(Tadorna ferruginea) X 432.

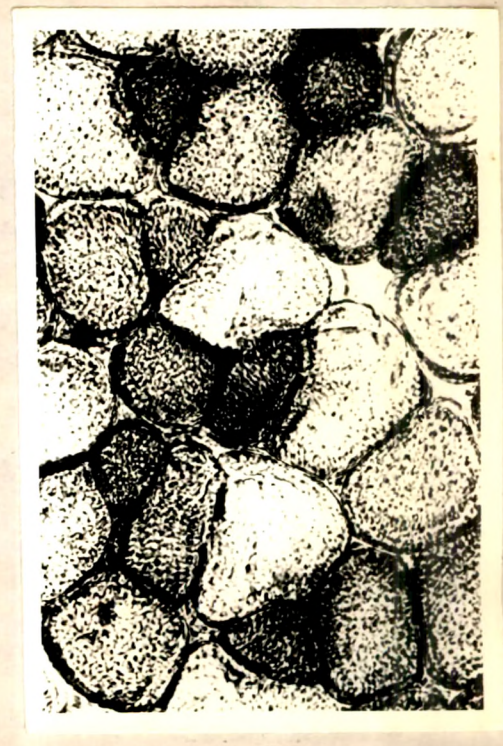

Fig. 16.
Brahminy Duck (Fat)
(Tadorna ferruginea) X 288.

Fig. 17.
Large Whistling Teal (SDH)
(Dendrocygna bicolor) X 288.

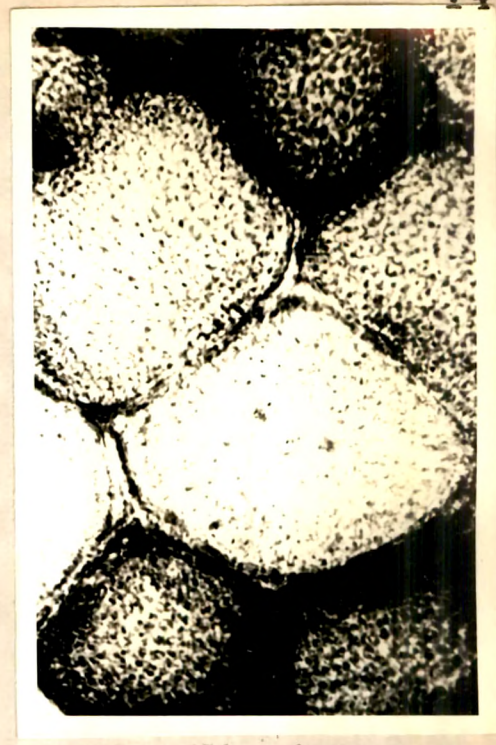

Fig. 18.
Large Whistling Teal (Fat)
(Dendrocygna bicolor) X 752.

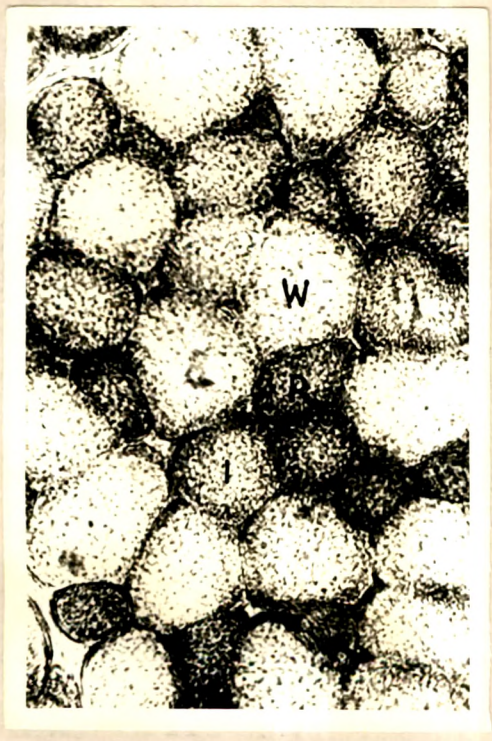

Fig. 19.
Cotton Teal (SDH)
Nettapus coramandelianus) X 288.

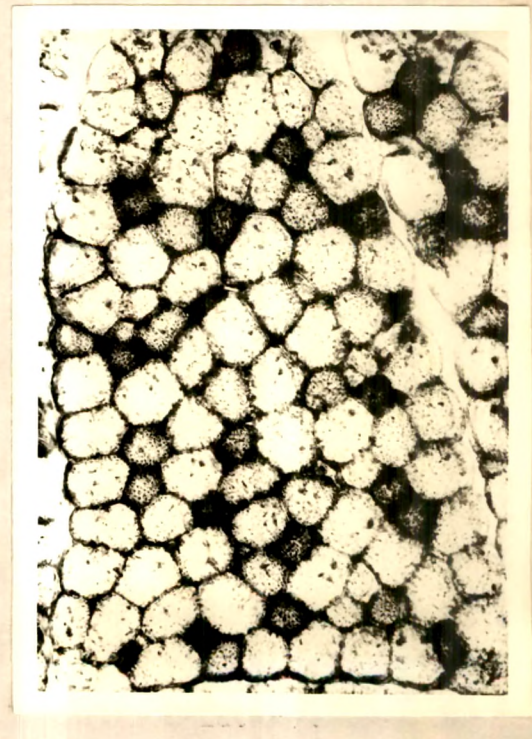

Fig. 20.
Cotton Teal (Fat)
(Nettapus coramandelianus) X 133.