CHAPTER 4

CELLULAR ORGANIZATION AND DISTRIBUTION OF THE FUEL STORE (FAT) IN THE PECTORALIS AND SUPRACORACOIDEUS MUSCLES OF REPRESENTATIVE BIRDS

The greater amount of fat inclusions in the narrow fibres compared to the broad ones in pigeon pectoralis muscles were observed by Knoll (1891); Denny-Brown (1929) and George and Jyoti (1955). That fat is utilized by the pigeon pectoralis as a fuel for sustained activity has also been well established (George and Berger, 1966). The lipid content of the flight muscles of birds varies considerably depending on the flight ability of the birds. High concentration of intracellular lipid is found in muscles of birds indulging in sustained flight. George and Naik (1960) and Hartman and Brownell (1961) reported the fat content of the pectoralis of several species of birds. The fat content of the muscle could well be regarded as an index of the capacity of the muscle for sustained activity. In the present investigation, the localization and distribution of fat in the pectoralis and supracoracoideus muscles of various flying and non-flying birds were studied histochemically so as to assess the intracellular fat load of the different fibre types which constitute a particular muscle.

MATERIALS AND METHODS

The pectoralis and supracoracoideus muscles of 48 different species of birds were studied. All the birds were shot by

air rifle except the domestic birds which were brought to the laboratory alive and were sacrificed. (The Hummingbirds used were obtained from Canada fixed in 4% formalin). Muscle pieces from the pectoralis and supracoracoideus were excised and were frozen immediately on the stage of a freezing microtome and sections were cut at 15 μ. The sections were stained with Sudan Black B and Fettrot 7B in 70% alcohol. The stained sections were mounted in glycerine jelly and photographs were taken.

The amount of fat present in the component fibres was assessed by visual evaluation of the intensity of staining under the microscope and expressed as +++ for maximum, ++ for medium and + for minimum amount of fat.

RESULTS AND DISCUSSION

Based on the Succinic dehydrogenase (SDH) activity and the diameter, the fibres of the pectoralis and supracoracoideus muscles were characterized into three types R, W and I. On the basis of the relative distribution of these fibre types in the pectoralis and supracoracoideus muscles were classed into 6 and 9 groups respectively (Chapters 2 and 3). In the results on the distribution of fat, the same classification of fibres is followed. The grouping of the birds followed in the present chapter is also the same as in Chapter 2 for pectoralis and Chapter 3 for supracoracoideus.

PECTORALIS:

Group 1. Fowl type (W, I and R fibres)

This group consists of non-flying birds such as Domestic

Fowl and Guinea Fowl. All the fibres are uniformly stained showing the minimum amount of fat (+) (Figs. 1 & 2). However, in the lateral region of the muscle some fibres were found to be stained deeper (++) (Figs. 3 & 4). It may be recalled here that from the distribution of fat only two types of fibres could be distinguished instead of three as with SDH activity.

Group 2. Duck type (R, W and I fibres)

In this group represented by the Domestic Duck the distribution of fat was found to be similar to the distribution of SDH activity; highest (+++) in the red fibres, minimum (+) in the white fibres and medium (++) in the intermediate fibres (Fig.5).

Group 3. Pigeon type (R and W fibres)

The distribution of fat and the intensity of staining for fat in the fibres of the birds belonging to this group are indicated below:

	(R)	(W)
Blue Rock Pigeon (*Columba livia*)	+++	+
Cattle Egret (*Bubulcus ibis*)	+++	+
Purple Moorhen (*Porphyrio porphyrio*)	+++	+
Hoopoe (*Upupa epops*)	+++	+
Redwattled Lapwing (*Vanellus indicus*)	+++	+
Brahminy Duck (*Tadorna ferruginea*)	+++	+
Large Whistling Teal (*Dendrocygna bicolor*)	+++	+
Cotton Teal (*Nettapus coromandelianus*)	+++	+
Koel (*Eudynamys scolopacea*)	+++	++

As in the case of SDH activity the R type of fibres in all these birds showed the maximum concentration of fat (+++) and the W type of fibres showed the minimum of (+) (Figs. 6 to 8) with the only exception of the Koel which showed a higher amount of fat (++) in their W fibres than the white fibres of the other birds . Koel being a local migratory bird the higher concentration of fat in W fibres may be of use for longer muscular activity during their long flights.

Group 4. Kite type (I fibres)

In the kite type are included pectoralis of birds which possess only I type of fibres or those predominantly of the I type of fibres. The data on the distribution and the intensity of staining for fat are presented below:

	(I)	(R)	(W)
Pariah Kite (*Milvus migrans*)	++		
Indian Whitebacked Vulture (*Gyps bengalensis*)	++		
Goldenbacked Woodpecker (*Dinopium benghalense*)	++	+++	
Crow-Pheasant (*Centropus sinensis*)	++	+++	
Great Horned Owl (*Bubo bubo*)	+	++	
Spotted Owlet (*Athene brama*)	+	++	
Shikra (*Accipiter badius*)	++	+++	+

With regard to the Pariah Kite and Indian Whitebacked Vulture it may be noted that the R fibres are absent in their pectoralis and the I fibres possess only moderate amount of fat (Figs. 9 & 11) These birds exhibit a soaring mode of flight in which the amount of fat utilized will be less than for flapping mode of flight.

In the Kite the pectoralis towards its insertion near the humerus, in some fibres only the minimum amount of fat is present. These fibres are like the W fibres of other birds (Fig. 10). The Spotted Owlet and Great Horned Owl possess in their pectoralis I and R types of fibres, having only the minimum amount of fat in the I fibres and medium in the R fibres. These two birds are nocturnal in their habit and are always vigilant to catch their prey. Capture of the prey involves quick movements and so the nature of the fibres in the muscles should be fast contracting ones with more glycogen and less fat in them. Hence the minimum amount of fat in the I fibres may be considered an advantage. The Shikra is a predator of the small garden birds. Its pectoralis possess all the three types of fibres with the fat content being medium in the I fibres, highest in the R fibres and least in the W fibres (Fig. 12). The fastest flying bird known is also a member of the Hawk family, The Falcon Duck-Hawk is recorded to reach a speed of 180 miles per hour (Clarance J. Hylander, 1959) and it would be of interest to know the pattern of fat distribution and the fibre composition of the pectoralis in this Hawk. The Golden backed Woodpecker has in its pectoralis moderate amount of fat in I fibres and highest in R fibres. This bird is a good flier exhibiting flapping mode of flight. They quickly flap the wings for some time to reach a momentum then close the wings and shoot forward. This is followed immediately by another series of flappings. The Crow-Pheasant is not capable of long flight but flies by vigorously flapping its wings for some

distance and then glides with wings spread out. It has moderate fat content in the I type fibres and highest in R type.

Group 5. Starling type (R and I fibres)

The pattern of distribution and the concentration of fat in the fibre types of the birds coming under this group are presented below:

	(R)	(I)
Roseringed Parakeet (Psittacula krameri)	+++	++
Green Bee-eater (Merops orientalis)	+++	++
Whitebellied Drongo (Dicrurus caerulescens)	+++	++
Rosy Pastor (Sturnus roseus)	+++	++
Indian Robin (Saxicoloides fulicata)	+++	++
Yellowheaded Wagtail (Motacilla citreola)	+++	++
House Swift (Apus affinis)	+++	+
Jungle Babbler (Turdoides striatus)	+++	+
Swallow (Hirundo rustica)	+++	+
House Crow (Corvus splendens)	+++	+
Jungle Crow (Corvus macrorhynchos)	+++	+
Redvented Bulbul (Pycnonotus cafer)	+++	+
Small Minivet (Pericrocotus cinnamomeus)	++	+
Whitespotted Fantail Flycatcher (Rhipidura albogularis)	++	+

	(R)	(I)	
Whitebreasted Kingfisher (Halcyon smyrnensis)	+++	++	+
Common Myna (Acridotheres tristis)	+++	++	+
Brahminy Myna (Sturnus pagodarum)	+++	++	+
Bank Myna (Acridotheres giginianus)	+++	++	+

Though there are variations in the amount of fat present in the I type fibres high amount of fat (+++) is present in all the R type fibres except in Small Minivet and Whitespotted Fantail Flycatcher which possess slightly less (++) amount of fat in them. In the Whitebreasted Kingfisher (Fig. 13) and the three different species of mynas the I type fibres have among them, some fibres having only the minimum amount of fat (+). The Kingfisher is well known for its hovering flight over water and its sudden dive down to capture fish. For such quick actions the possession of faster fibres is an advantage. In the three different species of mynas are also a few fibres containing less fat. Such fibres may be considered faster in action than the others of the same fibre type.

Group 6. Sparrow type (R fibres)

In this group the pectoralis consists exclusively of R type fibres. The intensity of staining for fat is shown below:

	(R)
Rubythroated Hummingbird (Archilochus colubris)	+++
Crimsonbreasted Barbet (Megalaima haemacephala)	+++
Yellowfronted Pied Woodpecker (Dendrocopos mahrattensis)	+++
Large Grey Babbler (Turdoides malcolmi)	+++

	(R)		
Tailor Bird (Orthotomus sutorius)	++		
Purple Sunbird (Nectarinia asiatica)	++		
White Eye (Zosterops palpebrosa)	++		
House Sparrow (Passer domesticus)	++		
Whitethroated Munia (Lonchura malabarica)	++		
Dusky Crag Martin (Hirundo concolor)	+++	++	+
Black Drongo (Dicrurus adsimilis)	+++	++	+

The amount of fat present in the fibres in the present group varies from high (+++) to moderate (++) (Figs. 14 to 16) except in the Dusky Crag Martin and the Black Drongo in which there are also a few fibres showing minimum fat (+) (Fig. 14). The presence of faster fibres (in the sense they contain less fat) may be attributed to their varied flight in their habit of feeding while in flight. The smallest bird in the world, the Hummingbird has high (+++) amount of fat in the fibres. In addition to the high fat load, the efficiency of the muscle for rapid and sustained activity is increased by the profuse blood supply to the flight muscles.

SUPRACORACOIDEUS:

Group 1. Fowl type (W, I and R fibres)

	(W)	(I)	(R)
Domestic Fowl	+	+	++
Guinea Fowl	+	+	++

Like the pectoralis, the supracoracoideus also contains a minimum amount of fat in the majority of the fibres (Fig. 17). From the type of distribution of fat in both the muscles it is evident that these birds are not fliers. Hence these birds flap their wings for acquiring speed in running or may fly low a few yards while running.

Group 2. Kite type (W and I fibres)

	(W)	(I)
Pariah Kite (Milvus migrans)	+	++
Indian Whitebacked Vulture (Gyps bengalensis)	+	++

The distribution of fat in the two types of fibres that constitute the muscle in these birds, show that this muscle is not capable of continuous flapping flight (Fig. 18).

Group 3. Hawk type (W, R and I fibres)

	(W)	(R)	(I)
Shikra (Accipiter badius)	+	+++	++
Whitebreasted Kingfisher (Halcyon smyrnensis)	+	+++	++

The supracoracoideus in these birds like their pectoralis consists of all the three types of fibres, but the W type fibres predominate instead of I type.

Group 4. Owl type (R, W and I fibres)

	(R)	(W)	(I)
Great Horned Owl (Bubo bubo)	++	+	++
Spotted Owlet (Athene brama)	++	+	++

	(R)	(W)	(I)
Crow-Pheasant (Centropus sinensis)	+++	+	++
Domestic Duck	+++	+	++

The first two, the Great Horned Owl and the Spotted Owlet contain equal amounts of fat in the R and I types of fibres. In the W type the fat content was minimum. In the Domestic Duck and Crow-Pheasant the fat content was found to be high in the R type, medium in the I type and minimum in the W type (Fig. 19)

Group 5. Pigeon type (R, I and W fibres)

	(R)	(I)	(W)
Blue Rock Pigeon (Columba livia)	+++	++	+
Redwattled Lapwing (Vanellus indicus)	+++	++	+
Brahminy Duck (Tadorna ferruginea)	+++	++	+
Redvented Bulbul (Pycnonotus cafer)	+++	+++	+
Jungle Babbler (Turdoides striatus)	+++	+++	+
Indian Robin (Saxicoloides fulicata)	++	++	+
Hoopoe (Upupa epops)	++	++	+

In this group the supracoracoideus of the pigeon, Redwattled Lapwing and Brahminy Duck showed the typical distribution of fat high in R, medium in I and minimum in W fibres (Figs. 20 to 23). In the Hoopoe and the Indian Robin the R and I types of fibres there was no perceptible difference in the fat load, both having moderate amount of fat. The Redvented Bulbul and the Jungle Babbler

also showed the same concentration of fat in their R and I types of fibres but for the fact that the fat content in both was high. The white fibres in all the birds contained the normal minimal amount of fat.

Group 6. Egret type (R and W fibres)

	(R)		(W)
Cattle Egret (Bubulcus ibis)	+++		+
Purple Moorhen (Porphyrio porphyrio)	+++		+
Koel (Eudynamys scolopacea)	+++	++	+

The maximal amount of fat was seen in their R type fibres and the minimal in the W type fibres (Fig. 23). In the Koel however, a few of the R type fibres contained only moderate amount of fat.

Group 7. Swift type (I, and R fibres)

	(I)	(R)
Whitebellied Drongo (Dicrurus caerulescens)	+	+++
House Swift (Apus affinis)	+	++
Green Bee-eater (Merops orientalis)	+	++
Crimsonbreasted Barbet (Megalaima haemacephala)	+	++

The I type which constitute the majority of the fibres contained only the minimal amount of fat. The R type of fibres also showed only moderate amount of fat except in the Whitebellied

Drongo in which they contained the usual maximal amount.

Group 8. Sparrow type (R and I fibres)

	(R)	(I)
Roseringed Parakeet (Psittacula krameri)	+++	++
Whitethroated Munia (Lonchura malabarica)	+++	++
Purple Sunbird (Nectarinia asiatica)	+++	++
Rosy Pastor (Sturnus roseus)	+++	+
House Crow (Corvus splendens)	+++	+
Jungle Crow (Corvus macrorhynchos)	+++	+
Brahminy Myna (Sturnus pagodorum)	++	+
Common Myna (Acridotheres tristis)	++	+
Bank Myna (Acridotheres ginginianus)	++	+
Tailor Bird (Orthotomus sutorius)	++	+
House Sparrow (Passer domesticus)	++	+

In this group the R type of fibres form the major bulk of the muscle and the amount of fat varied from high to moderate in the different birds. The rest of the fibres are of the I type with minimal amount of fat. The Roseringed Parakeet, the Whitethroated Munia and the Purple Sunbird (Fig. 24) were the only birds which showed the usual moderate amount of fat in the I type

of fibres.

Group 9. Hummingbird type (R fibres)

	(R)
Rubythroated Hummingbird (*Archilochus colubris*)	+++

The only bird so far observed having exclusively R type of fibres in the supracoracoideus also is the Hummingbird. The amount of fat present in all the fibres was also found to be maximum (Fig. 25). Like its pectoralis, this muscle is also provided with a profuse blood supply. The ability of this bird to hover for a considerably long time may be attributed to its exceptionally developed and metabolically adapted pectoralis and supracoracoideus muscles.

Figures 1 to 16.

Photomicrographs of the T. S. of the pectoralis muscles of some birds showing the localization of fat.

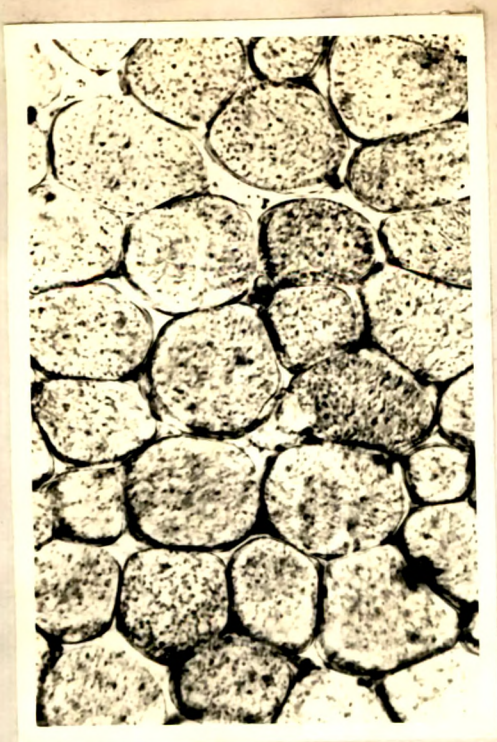

Fig. 1.
Domestic Fowl Central region X 288.

Fig. 2.
Guinea Fowl Central region X 288.

Fig. 3.
Domestic Fowl Lateral region X 288.

Fig. 4.
Guinea Fowl Lateral region X 288.

Fig. 5.
Domestic Duck X 432.

Fig. 6.
Redwattled Lapwing
(*Vanellus indicus*) X 376.

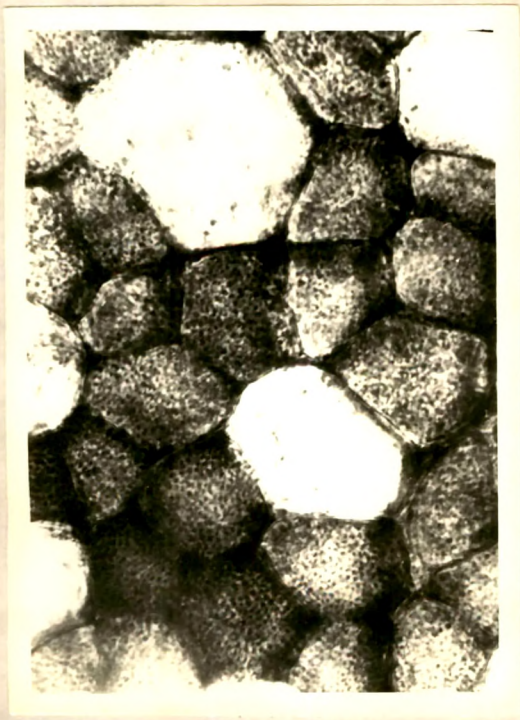

Fig. 7.
Brahminy Duck
(*Tadorna ferruginea*) X 432.

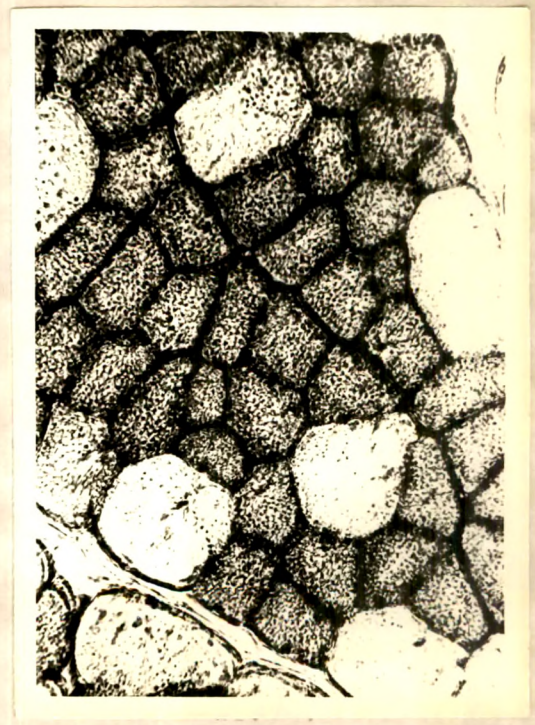

Fig. 8.
Large Whistling Teal
(*Dendrocygna bicolor*) X 216.

Fig. 9.
Pariah Kite Central region
(Milvus migrans) X 520.

Fig. 10.
Pariah Kite Lateral region
(Milvus migrans) X 752.

Fig. 11.
Indian Whitebacked Vulture
(Gyps bengalensis) X 376.

Fig. 12.
Shikra
(Accipiter badius) X 216.

Fig. 13.
Whitebreasted Kingfisher
(Halcyon smyrnensis) X 432.

Fig. 14.
Dusky Crag Martin
(Hirundo concolor) X 520.

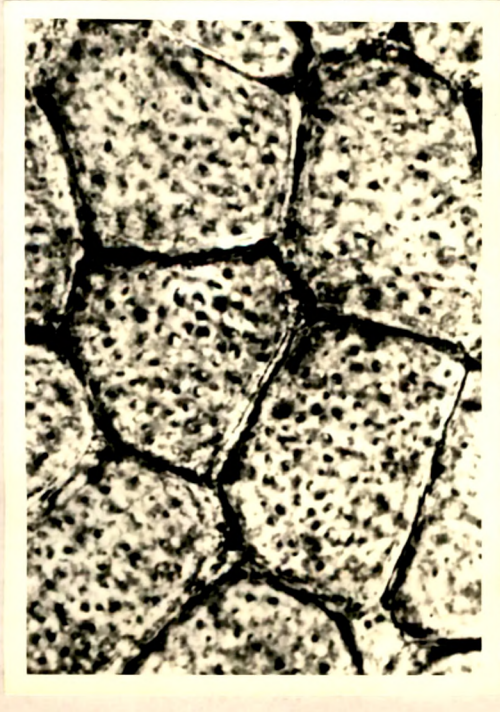

Fig. 15.
Crimsonbreasted Barbet
(Megalaima haemacephala) X 752.

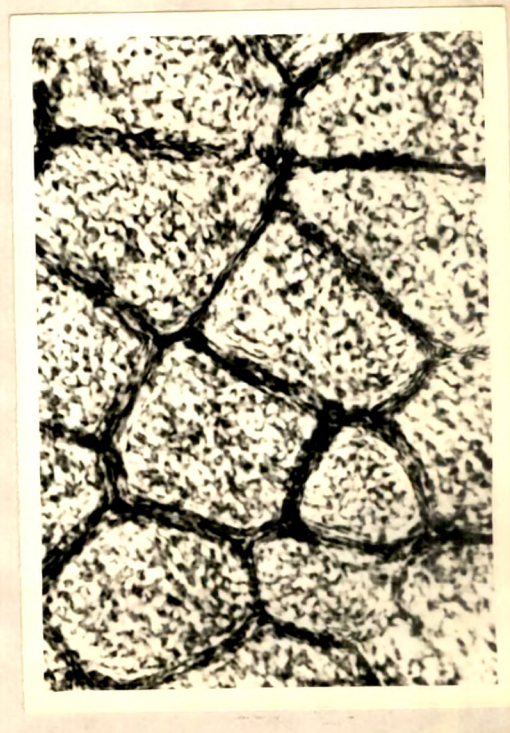

Fig. 16.
Purple Sunbird
(Nectarinia asiatica) X 752.

Figures 17 to 25.

Photomicrographs of the T. S. of the supracoracoideus muscles of some birds showing the localization of fat.

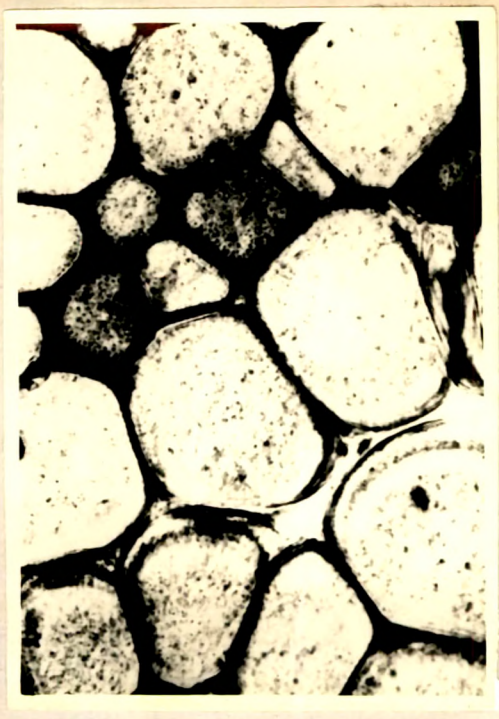

Fig. 17.
Guinea Fowl X 288.

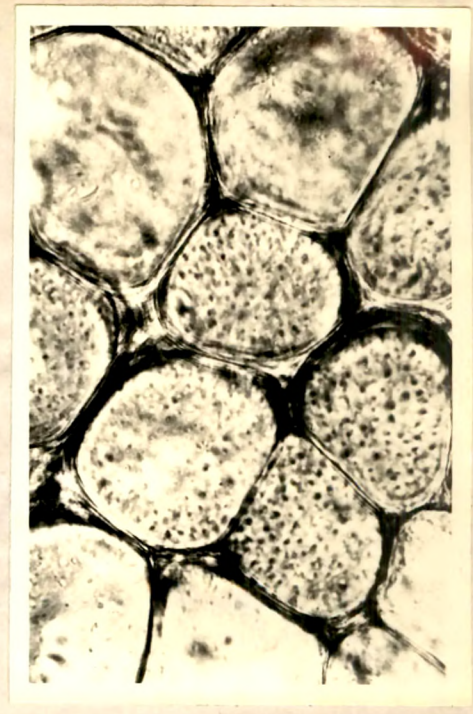

Fig. 18.
Indian Whitebacked Vulture
(Gyps bengalensis) X 376.

Fig. 19.
Domestic Duck X 376.

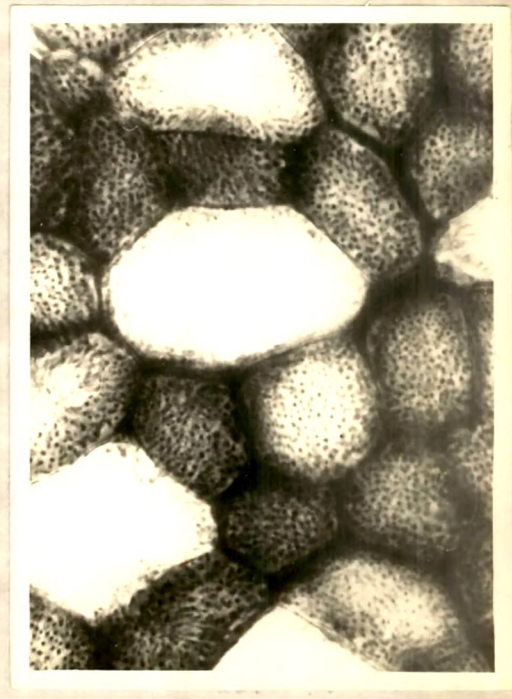

Fig. 20.
Blue Rock Pigeon
(Columba livis) X 432.

Fig. 21.
Redwattled Lapwing
(Vanellus indicus) X 376.

Fig. 22.
B Brahminy Duck
(Tadorna ferruginea) X 216.

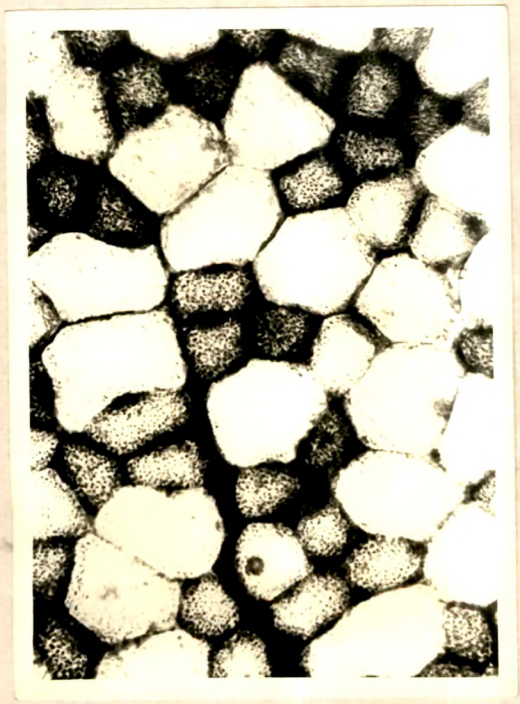

Fig. 23.
Purple Moorhen
(Porphyrio porphyrio) X 144.

Fig. 24.
Purple Sunbird
(Nectarinia asiatica) X 752.

Fig. 25.
Rubythroated Hummingbird
(Archilochus colobris) X1040.