CHAPTER 2

CHARACTERIZATION OF THE PECTORALIS MUSCLES OF BIRDS

In the previous chapter the red and white fibres have been characterized as the two fundamentally different cellular entities which in the course of evolution emerged as distinct morphological as well as physiological units of muscle metabolism, the red fibres being adapted for an aerobic metabolism using fat as the chief fuel and the white ones for an anaerobic metabolism using glycogen as their main fuel. If structure is the complement of function, the presence and relative distribution of these fibre types or their intermediate forms, or the absence of one of them or both in a muscle should indicate a functional significance. It was therefore thought rewarding to conduct a survey of the cellular organization of the pectoralis muscles in various representative birds and the results of such an investigation is reported in this chapter.

In characterizing the nature of the component fibres in the muscle, the distribution pattern of succinic dehydrogenase (SDH) activity in them was found to be the most satisfactory criterion. Metabolites like fat and glycogen are liable to vary in amount according to the physiological state of the animal at the time of death.

MATERIALS AND METHODS

The pectoralis muscles of a variety of birds (listed in Table 1) was studied. A piece of the muscle was excised from

a freshly killed bird and frozen sections of about 20μ thickness were cut on a freezing microtome. The sections were quickly transferred to phosphate buffer, pH 7.6 for five minutes in order to destroy the endogenous substrates. The modified method by George and Talesara (1961) for the demonstration of succinic dehydrogenase (SDH) activity was employed.

The diameter of the fibres was measured by means of an occular eyepiece and a micrometer scale.

RESULTS AND DISCUSSION

Unlike in the pigeon pectoralis muscle which consists of two types of fibres, the red and white, the pectoralis of the domestic fowl was found to have three types, the third being intermediate between the two. The three types of fibres have been noted in the appendicular muscles of reptiles and mammals (Stein and Padykula, 1962; Ogata and Mori, 1964). The fibre types are designated as R (red), W (white) and I (intermediate).

The diameter of the component fibres and the relative distribution of the fibre types in the pectoralis muscle of the birds studied are presented in Table 1. On the basis of the fibre diameter and the distribution pattern of SDH activity, the pectoralis muscles of the various birds studied could be classed into the following six groups:

1. Fowl type (W, I and R fibres)
2. Duck type (R, W and I fibres)
3. Pigeon type (R and W fibres)
4. Kite type (I fibres)

5. Starling type (R and I fibres)

6. Sparrow type (R fibres)

The fibre composition of the muscle for each type is given in parenthesis in the order of predominance of the fibre types. For example, the fowl pectoralis consists predominantly of white fibres, the intermediate fibres being less neumerous and the red ones least.

Group 1.

The pectoralis of the domestic fowl, guinea fowl (Figs. 1 & 2) and perhaps also of other galliform bird consists of very few red fibres. Therefore the domestic fowl and guinea fowl are poor fliers and incapable of sustained flight.

Group 2.

The fibre composition of the domestic duck is similar to that of the domestic fowl but differs from it in that the red fibres are much more numerous than the other two types (Fig.3). It is of considerable interest to note that the nature of the fibres in the pectoralis of migratory ducks and teals which are capable of sustained flight show only two types of fibres red, and white, the red ones being predominate. Hence these birds are grouped in Group 3, the pigeon type.

Group 3.

In this group the pectoralis muscle consists of only two types of fibres, the red and white, the former predominating. This seems to be a characteristic feature of the pectoralis of columbiformes since the same fibre composition is seen in the

pectoralis of the Spotted Dove. Further, it is interesting to note here that the Group 3 type of pectoralis is also encountered in the birds belonging to other orders viz. the Quail, Coturnix c. coturnix (Galliformes), (Boisiger, 1950), the Cattle Egret, Bubulcus ibis (Ciconiiformes), the Purple Moorhen, Porphyrio porphyrio (Gruiformes), the Koel, Eudynamys scolopacea (Cuculiformes), the Hoopoe, Upupa epops (Coraciiformes), the Redwattled Lapwing, Vanellus indicus (Charadriiformes), the Brahminy Duck, Tadorna ferruginea (Anseriformes), the Large Whistling Teal, Dendrocygna bicolor (Anseriformes) and Cotton Teal, Nettapus coromandelianus (Anseriformes) (Figs. 4 to 11).

It appears from the fibre composition of the pectoralis muscle that these orders of birds may be phylogenetically related since atleast with regard to Galliformes, Anseriformes and Columbiformes phylogenetic relationship has been proposed by systematists.

Group 4.

In this group may be included the pectoralis muscles of birds which consists of only the I type of fibres, viz. the Pariah Kite, Milvus migrans (Fig. 12) and the Indian Whitebacked Vulture, Gyps bengalensis (Fig. 14). The fibres are circular in cross section and loosely packed. They are considerably larger than the red fibres of the pigeon pectoralis and slightly larger as compared to the I fibres of the fowl pectoralis but possess more fat and succinic dehydrogenase activity than the I fibres of the fowl pectoralis. Certain regional differences in the pectoralis muscle of the Pariah Kite have been noted. George and Naik (1959) observed that the superficial part of the muscle is larger having darker and narrower fibres than the deeper part. It was observed that in the lateral part of the

same muscle both W and I types (53% and 47% respectively) of fibres are present (Table 1. Fig. 13).

In the case of the Shikra, another member of the Order Falconiformes, and two others of the Order Strigiformes, the Great Horned Owl (Bubo bubo) and the Spotted Owlet (Athene brama) however, certain variations occur. In the first bird all the three types of fibres (W.I.R) are present (Fig. 15). In the case of the second and the third, two types (I and R) of fibres exist(Figs. 16 & 17). The relative distribution and diameter of these fibres is given in Table 1. These variations from the typical condition seen in the Kite pectoralis may be attributed to the ability of these birds for some versatility in flight in addition to their characteristic soaring or gliding modes of light.

There seems to be no doubt that the circular loosely packed I type of fibres are a characteristic of the pectoralis of soarers and gliders and not a phylogenetic feature, since a parallel organization of the fibres is seen in certain other distant orders of birds which indulge in soaring and gliding viz. The Lesser Goldenbacked Woodpecker, Dinopium benghalense (Piciformes), and the Crow-Pheasant, Centropus sinensis (Cuculiformes). This is also suggestive of the close relationship of structure with function (Figs. 18 & 19).

Group 5.

The following passerine birds with pectoralis muscle having

the R and I types of fibres are included in this group (Figs. 20 to 38).

Roseringed Parakeet, Psittacula krameri (Psittacidae)

House Swift, Apus affinis (Apodidae)

Whitebreasted Kingfisher, Halcyon smyrnensis (Alcedinidae)

Green Bee-eater, Merops orientalis (Meropidae)

Swallow, Hirundo rustica (Hirundinidae)

Striated Swallow, Hirundo daurica (Hirundinidae)

Whitebellied Drongo, Dicrurus caverulescens (Dicruridae)

Rosy Pastor, Sturnus roseus (Sturnidae)

Brahminy Myna, Sturnus pagodarum (Sturnidae)

Common Myna, Acridotheres tristis (Sturnidae)

Bank Myna, Acridotheres ginginianus (Sturnidae)

House Crow, Corvus splendens (Corvidae)

Jungle Crow, Corvus macrorhynchos (Corvidae)

Blackheaded Cuckoo-shrike, Coracina melanoptera (Campephagidae)

Small Minivet, Pericrocotus cinnamomeus (Campephagidae)

Common Iora, Aegithina tiphia (Irenidae)

Redvented Bulbul, Pycnonotus cafer (Pycnonotidae)

Jungle Babbler, Turdoides striatus (Muscicapidae)

Whitespotted Fantail Flycatcher, Rhipidura albogularis (Muscicapidae)

Pied Bush Chat, Saxicola caprata (Muscicapidae)

Indian Robin, Saxicoloides fulicata (Muscicapidae)

Yellowheaded Wagtail, Motacilla citreola (Motacillidae)

Group 6.

This group consists of pectoralis containing only the

R fibres (Figs 39 to 47) and include the following birds.

Crimsonbreasted Barbet, Megalaima haemacephala (Capitonidae)

Yellowfronted Pied or Mahratta Woodpecker, Dendrocopos mahrattensis (Picidae)

Dusky Crag Martin, Hirundo concolor (Hirundinidae)

Black Drongo, Dicrurus adsimilis (Dicruridae)

Large Grey Babbler, Turdoides malcolmi (Muscicapidae)

Tailor Bird, Orthotomus sutorius (Muscicapidae)

Purple Sunbird, Nectaninia asiatica (Nectarinidae)

White-eye, Zosterops palpebrosa (Zosteropidae)

House Sparrow, Passer domesticus (Ploceidae)

Whitethroated Munia, Lonchura malabarica (Ploceidae)

The pectoralis of Rubythroated Hummingbird, Archilochus colubris (Trochilidae) also consists of only the R fibres is included in this group. This muscle among all the pectoralis muscles hitherto studied was found to possess the most copious blood supply (Figs. 48 & 49). It may also be mentioned here that Salt (1963) demonstrated the presence of two types of fibres in the pectoralis muscle of certain passerine birds after staining the muscle sections for fat.

It has been stated earlier that there exists relationship between the structure and function of the pectoralis muscle and that an identical organization of fibres may be met with in the pectoralis muscle of birds belonging to different orders. Such differences could now be extended even to the species level. The fibre architecture of domestic duck falls in group 2, whereas the migratory ducks like the Brahminy Duck, the Large-Whistling Teal and Cotton Teal in group 3. The pectoralis of one

species of Wood pecker (Mahratta Woodpecker) falls in group 6, whereas another (Goldenbacked Woodpecker) in group 4. Similarly, one species of babbler (Jungle Babbler) and a species of drongo (Whitebellied Drongo) are included in group 5, whereas another babbler (Large Grey Babbler) and the drongo (Black Drongo) are placed in group 6. Such variations are to be expected if we realize that in the evolution of the avian body the most conspicuous changes had taken place in such of those parts that are directly concerned with flight.

It should be stated here that we have no information on the fibre composition of the pectoralis muscles of several important group of birds such as the ratites, the penguins etc. Studies on the pectoralis of these flightless birds would be of considerable interest.

TABLE 1

DIAMETER OF THE FIBRES IN MICRONS AND THE PROPORTIONS OF THE FIBRE TYPES IN PERCENTAGE IN THE PECTORALIS MUSCLES OF BIRDS

Names of birds	Fibre diameter and fibre distribution		
Group 1.	(W)	(I)	(R)
Domestic Fowl (Phasianidae)	75.5(67.3)*	75.0(21.7)	62.5(11.0)
Guinea Fowl (Numididae)	85.5(65.0)	85.5(20.3)	70.5(14.7)
Group 2.	(R)	(W)	(I)
Domestic Duck (Anatidae)	32.0(60.0)	79.0(23.1)	37.5(16.9)
Group 3.	(R)	(W)	
Cattle Egret, Bubulcus ibis (Ardeidae)	37.5(77.5)	55.0(22.5)	
Blue Rock Pigeon, Columba livia (Columbidae)	30.0(85.9)	70.0(14.1)	
Purple Moorhen, Porphyrio porphyrio (Rallidae)	50.0(80.6)	75.0(19.4)	
Koel, Eudynamys scolopacea (Cuculidae)	40.0(69.7)	75.0(30.3)	

Names of birds	Fibre diameter and fibre distribution		
Hoopoe, Upupa epops (Upupidae)	40.0(74.0)	70.0(26.0)	
Redwattled Lapwing, Vanellus indicus (Charadridae)	37.5(86.6)	60.0(13.4)	
Brahminy Duck, Tadorna ferruginea (Anatidae)	35.5(80.3)	60.0(19.7)	
Large Whistling Teal, Dendrocygna bicolor (Anatidae)	35.7(86.7)	62.5(13.3)	
Cotton Teal, Nettapus coramandelianus (Anatidae)	37.5(83.1)	55.0(16.9)	
Group 4.	(I)		
Pariah Kite, Milvus migrans (Accipitridae)			
Centre	42.5(100)		
	(W)	(I)	
Lateral	90.3(53.2)	60.0(46.8)	
Indian Whitebacked Vulture, Gyps bengalensis (Accipitridae)	(I)		
Centre	60.0(100)		
Lateral	62.0(100)		
Shikra, Accipiter badius (Accipitridae)	(I)	(R)	(W)
	50.0(50.5)	35.0(29.5)	70.0(20.0)
Great Horned Owl, Bubo bubo (Strigidae)	53.0(64.3)	48.0(35.7)	

Names of birds	Fibre diameter and fibre distribution	
Spotted Owlet, *Athene brama* (Strigidae)	58.2(85.4)	42.0(14.6)
Goldenbacked Woodpecker, *Dinopium benghalense* (Picidae)	42.5(72.2)	25.0(27.8)
Crow-Pheasant, *Centropus sinensis* (Cuculidae)	46.2(79.2)	28.0(20.8)
Group 5.	(R)	(I)
Roseringed Parakeet, *Psittacula krameri* (Psittacidae)	32.0(71.4)	40.0(28.6)
House Swift, *Apus affinis* (Apodidae)	37.5(63.4)	38.0(36.6)
Whitebreasted Kingfisher, *Halcyon smyrnensis* (Alcedinidae)	32.5(67.7)	57.5(32.3)
Green Bee-eater, *Merops orientalis* (Meropidae)	50.0(52.1)	55.0(47.9)
Swallow, *Hirundo rustica* (Hirundinidae)	32.5(74.0)	35.5(26.0)
Striated Swallow, *Hirundo daurica* (Hirundinidae)	32.5(61.9)	40.0(38.1)
Whitebellied Drongo, *Dicrurus caerulescens* (Dicruridae)	42.5(62.3)	45.0(37.7)
Rosy Pastor, *Sturnus roseus* (Sturnidae)	35.5(69.3)	45.0(30.7)
Brahminy Myna, *Sturnus pagodarum* (Sturnidae)	42.5(57.6)	50.0(42.4)
Common Myna, *Acridotheres tristis* (Sturnidae)	42.5(66.2)	62.5(33.8)

Names of birds	Fibre diameter and fibre distribution	
Bank Myna, *Acridotheres ginginianus* (Sturnidae)	37.5(66.7)	50.0(33.3)
House Crow, *Corvus splendens* (Corvidae)	37.5(64.9)	45.0(35.1)
Jungle Crow, *Corvus macrorhynchos* (Corvidae)	52.5(78.0)	65.0(22.0)
Blackheaded Cuckoo-Shrike, *Coracina melanoptera* (Campephagidae)	32.5(68.4)	40.0(31.6)
Small Minivet, *Pericrocotus cinnamomeus* (Campephagidae)	40.0(55.9)	49.0(44.1)
Common Iora, *Aegithina tiphia* (Irenidae)	37.5(59.6)	55.0(40.4)
Redvented Bulbul, *Pycnonotus cafer* (Pycnonotidae)	32.5(61.2)	50.0(38.8)
Jungle Babbler, *Turdoides striatus* (Muscicapidae)	52.5(54.8)	65.0(45.2)
Whitespotted Fantail Flycatcher, *Rhipidura albogularis* (Muscicapidae)	35.0(60.5)	45.0(39.5)
Pied Bush Chat, *Saxicola caprata* (Muscicapidae)	40.0(61.4)	52.5(38.6)
Indian Robin, *Saxicoloides fulicata* (Muscicapidae)	32.5(70.0)	52.5(30.0)
Yellowheaded Wagtail, *Motacilla citreola* (Motacillidae)	50.0(57.3)	67.5(42.7)

Names of birds	Fibre diameter and fibre distribution
Group 6	(R)
Rubythroated Hummingbird, *Archilochus colubris* (Trochilidae)	25.0(100)
Crimsonbreasted Barbet, *Megalaima haemacephala* (Capitonidae)	40.0(100)
Yellowfronted Pied Woodpecker, *Dendrocopos mahrattensis* (Picidae)	38.5(100)
Dusky Crag Martin, *Hirundo concolor* (Hirundinidae)	32.5(100)
Black Drongo, *Dicrurus adsimilis* (Dicruridae)	45.0(100)
Large Grey Babbler, *Turdoides malcolmi* (Muscicapidae)	45.0(100)
Tailor Bird, *Orthotomus sutorius* (Muscicapidae)	44.0(100)
Purple Sunbird, *Nectarinia asiatica* (Nectariniidae)	32.5(100)
White-eye, *Zosterops palpebrosa* (Zosteropidae)	33.0(100)
House Sparrow, *Passer domesticus* (Ploceidae)	35.0(100)
Whitethroated Munia, *Lonchura malabarica* (Ploceidae)	45.0(100)

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

Figures 1 to 38 and 40 to 47.

Photomicrographs of the T. S. of the pectoralis muscles of various birds showing the localization of succinic dehydrogenase activity.

Figure 39.

Photomicrograph of the T. S. of the pectoralis muscle of the Rubythroated Hummingbird (Archilochus colubris) stained for fat.

W ... White fibre type

I ... Intermediate fibre type

R ... Red fibre type

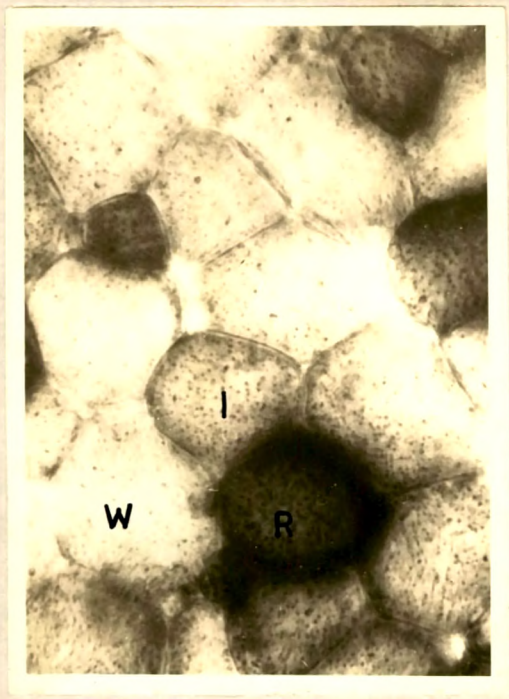


Fig. 1.
Domestic Fowl X 288.

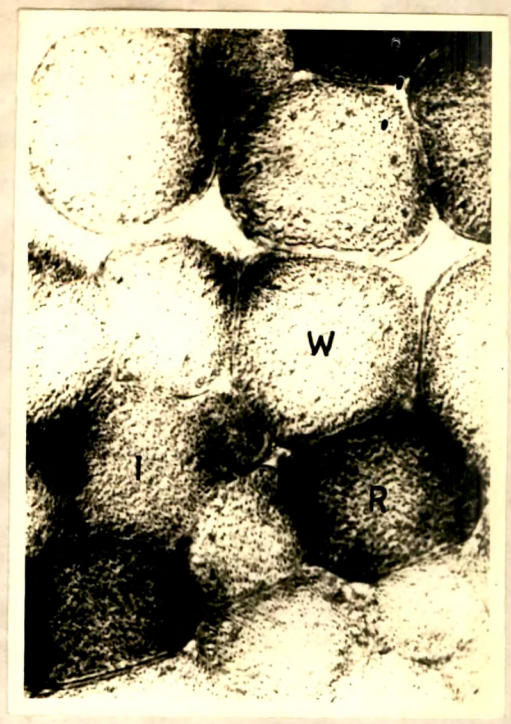


Fig. 2.
Guinea Fowl X 288.

Fig. 3.
Domestic Duck X 376.

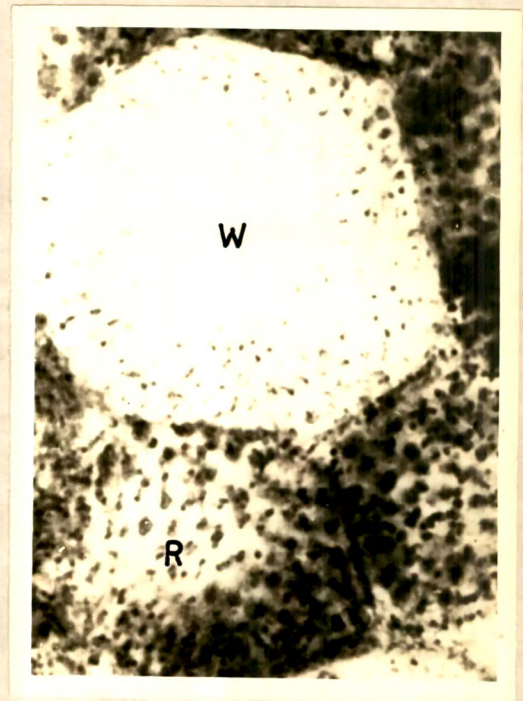


Fig. 4.
Cattle Egret
(Bubulcus ibis) X 1040.

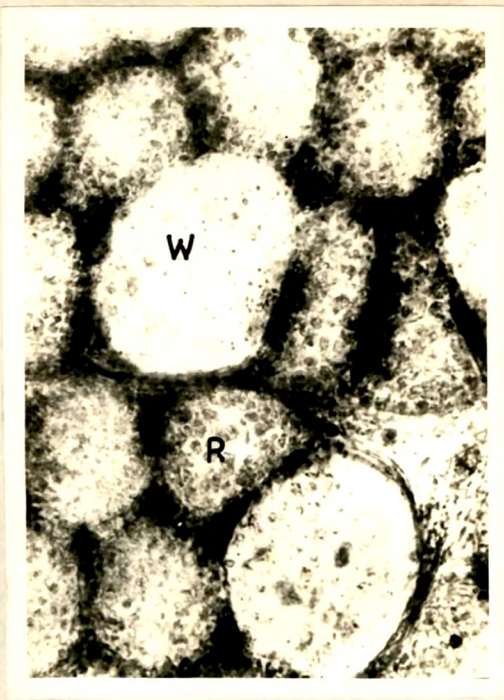


Fig. 5.
Purple Moorhen
(Porphyrio porphyrio) X 432.

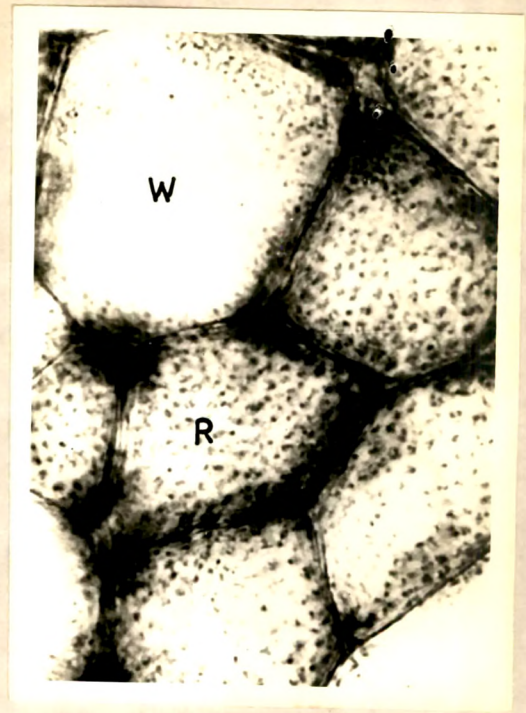


Fig. 6.
Koel
(Eudynamys scolopacea) X 752.

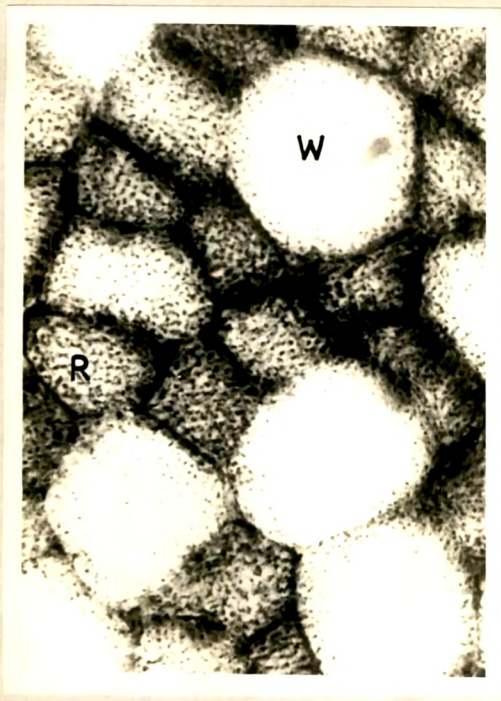


Fig. 7.
Hoopoe
(Upupa epops) X 752.

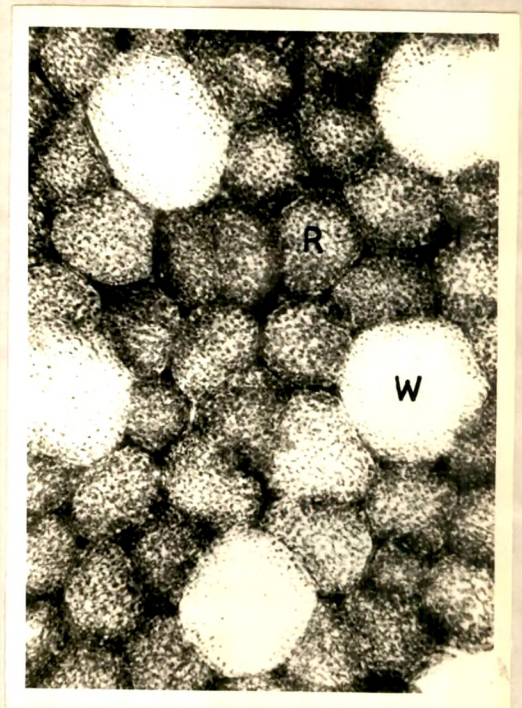
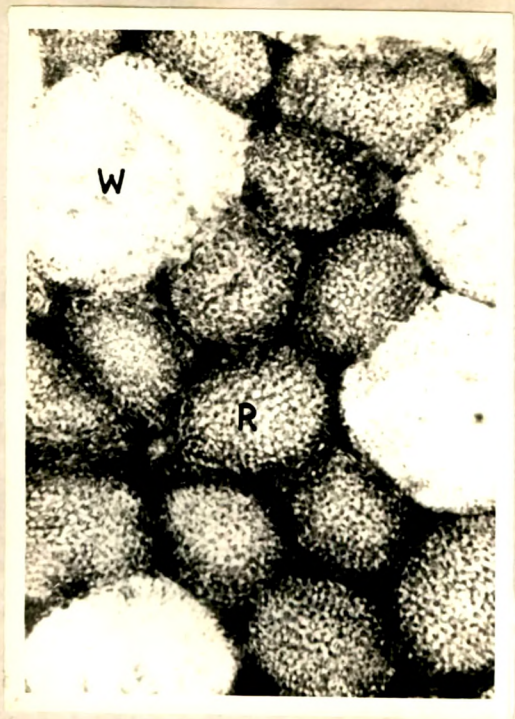


Fig. 8.
Redwattled Lapwing
(Vanellus indicus) X 216.



Big. 9.
Brahminy Duck
(Tadorna ferruginea) X 432.

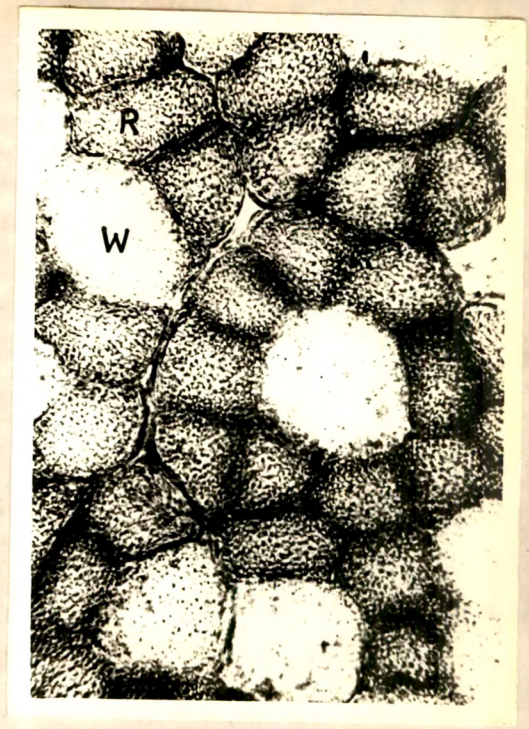


Fig. 10.
Large Whistling Teal
(Dendrocygna bicolor) X 216.

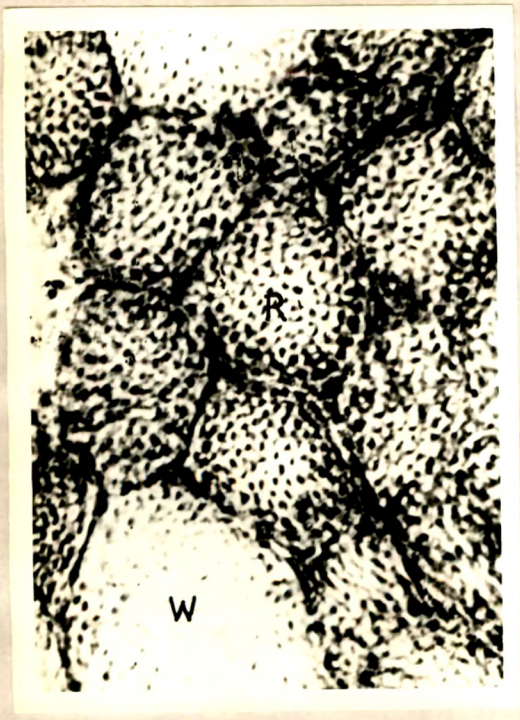


Fig. 11.
Cotton Teal
(Nettapus coramandelianus) X 672.

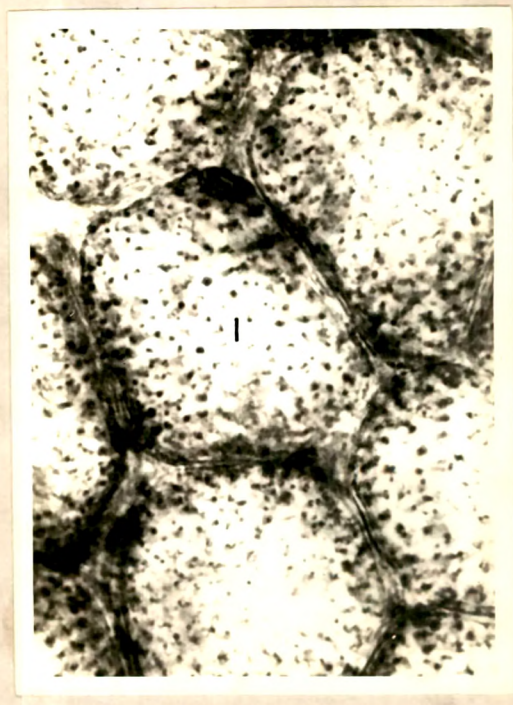


Fig. 12.
Pariah Kite
(Milvus migrans) X 752.

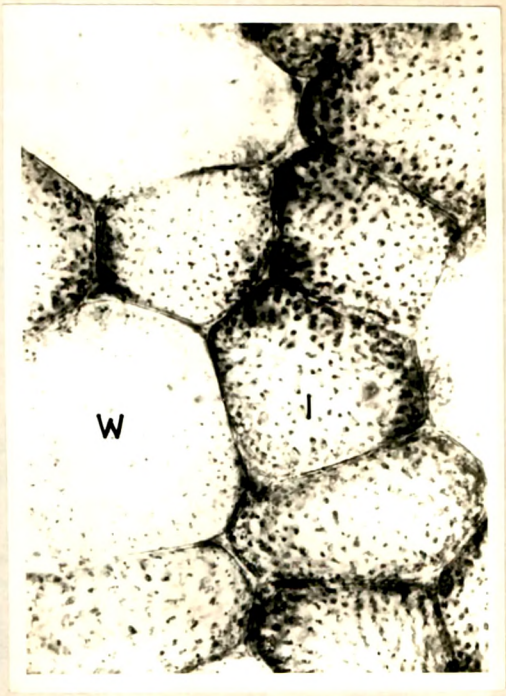


Fig. 13.
Pariah Kite (lateral region)
(Milvus migrans) X 376.

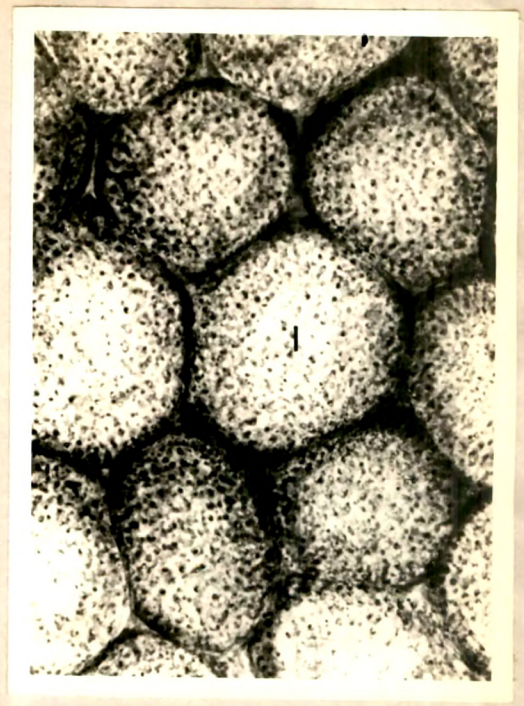


Fig. 14.
Indian Whitebacked Vulture
(Gyps bengalensis) X 376.

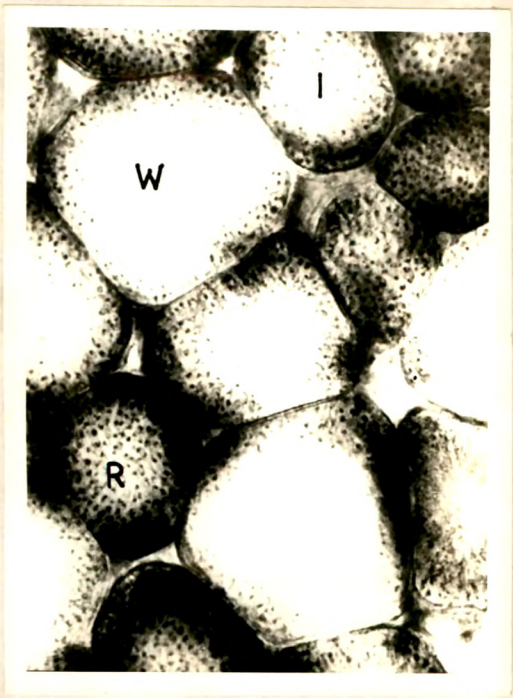


Fig. 15.
Shikra
(Accipiter badius) X 376.

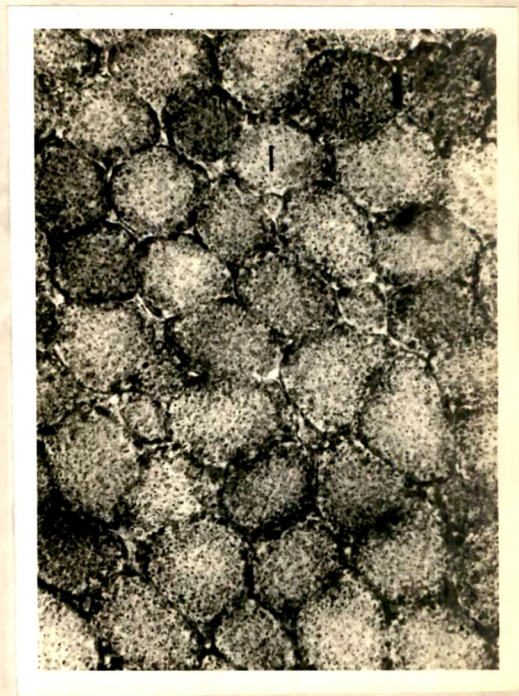


Fig. 16.
Great Horned Owl
(Bubo bubo) X 216.

Fig. 17.
Spotted Owlet
(Athene brama) X 520.

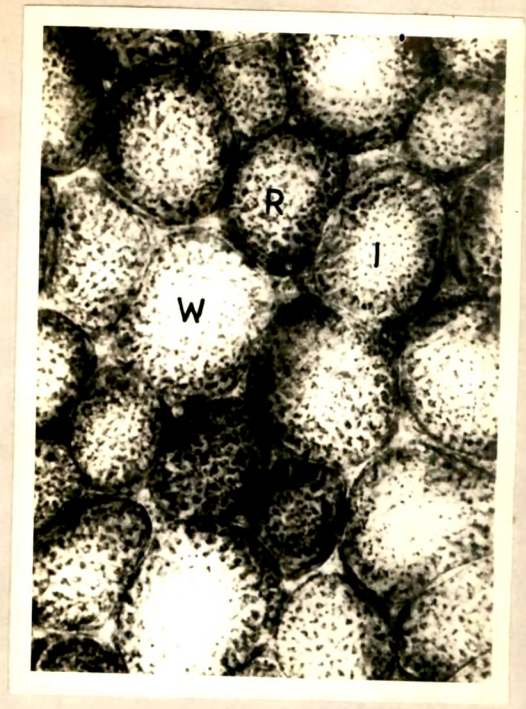


Fig. 18.
Goldenbacked Woodpecker
(Dinopium benghalense) X 376.

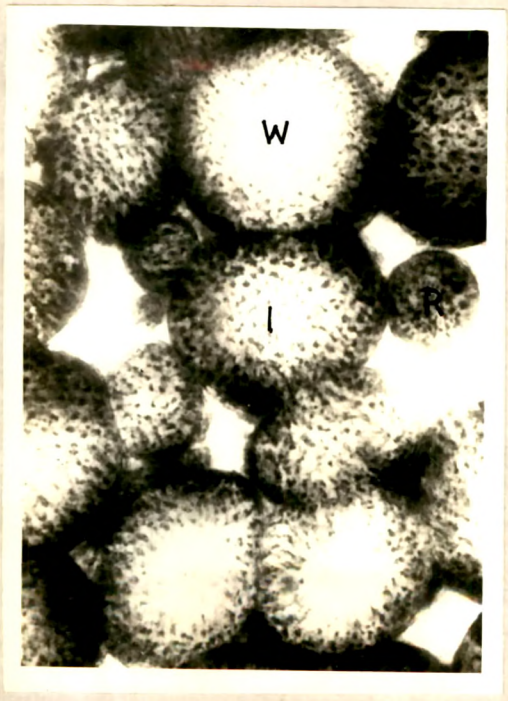


Fig. 19.
Crow-Pheasant
(Centropus sinensis) X 376.

Fig. 20.
Roseringed Parakeet
(Psittacula krameri) X 520.

Fig. 21.
House Swift
(Apus affinis) X 520.

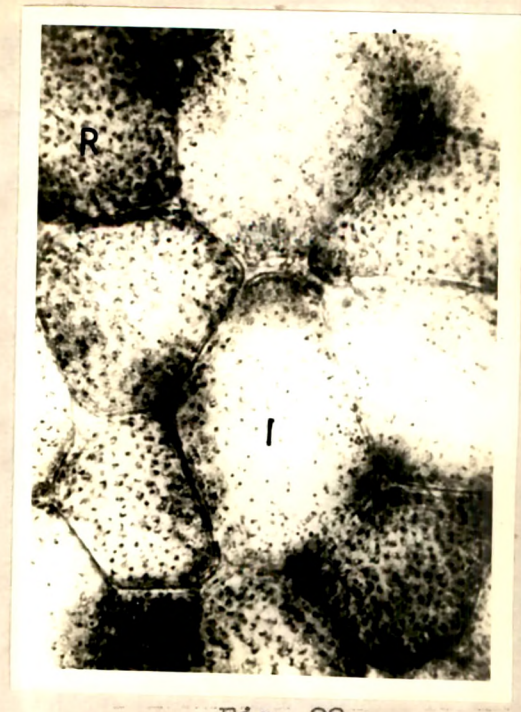


Fig. 22.
Whitebreasted Kingfisher
(Halcyon smyrnensis) X 520.

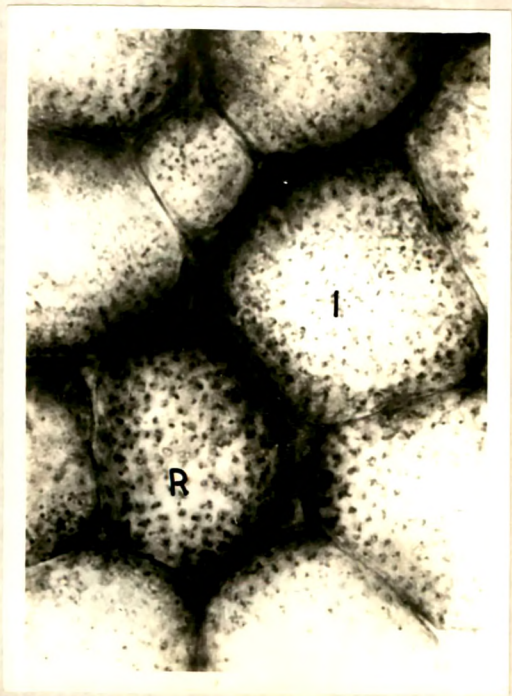


Fig. 23.
Green Bee-eater
(Merops orientalis) X 520.

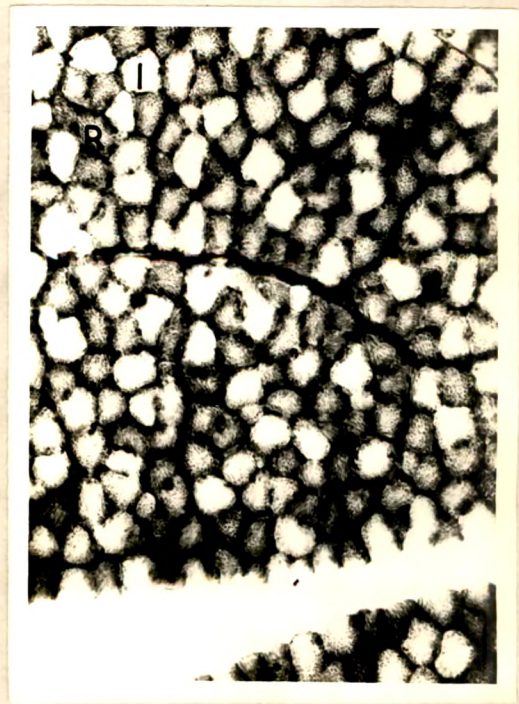


Fig. 24.
Striated Swallow
(Hirundo daurica) X 144.

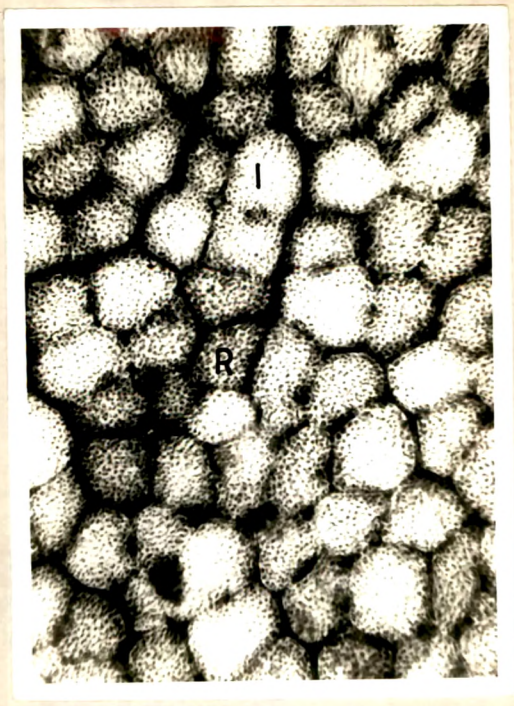


Fig. 25.
Whitebellied Drongo
(Dicrurus caerulescens) X 144.

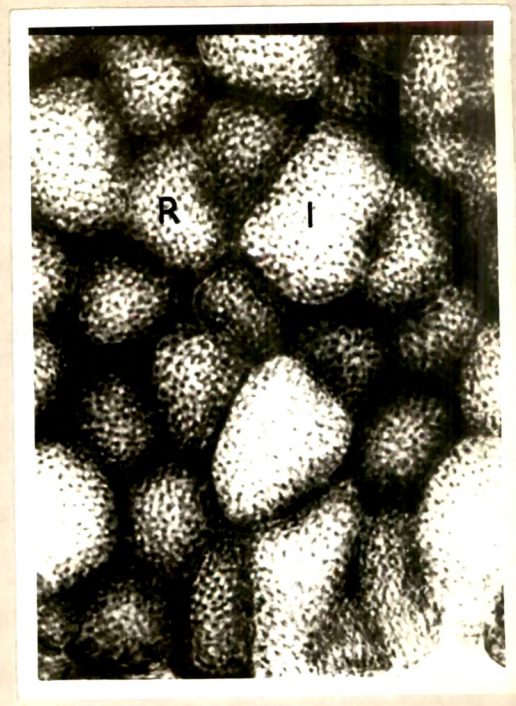


Fig. 26.
Rosy Pastor
(Sturnus roseus) X 336.

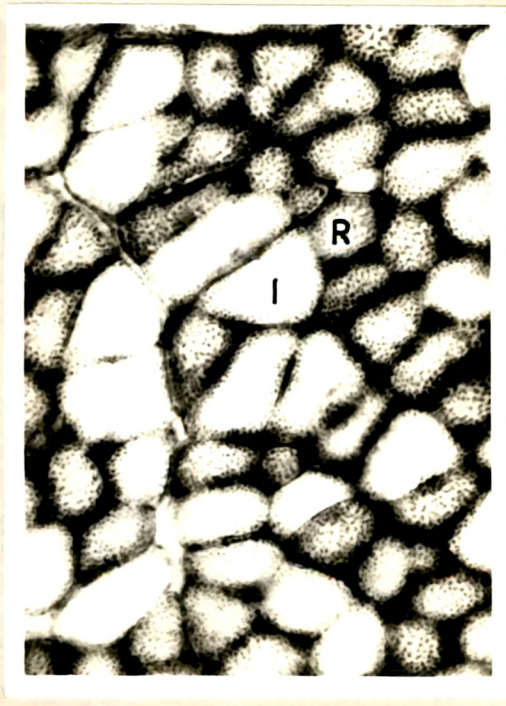


Fig. 27.
Common Myna
(Acridotheres tristis) X 288.

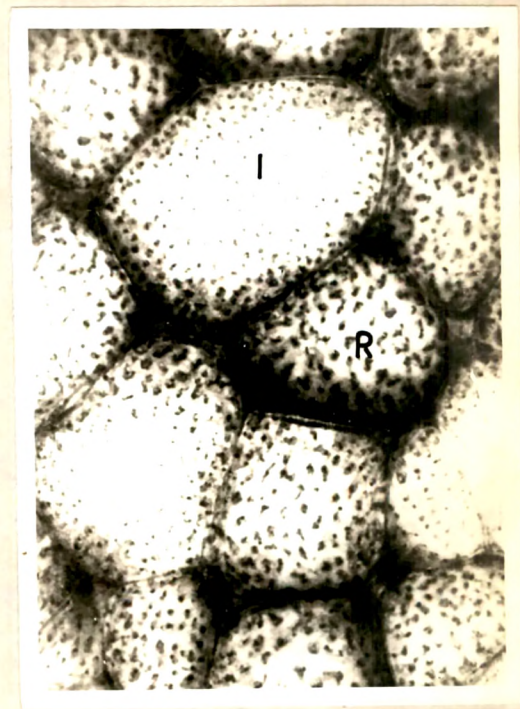


Fig. 28.
House Crow
(Corvus splendens) X 520.

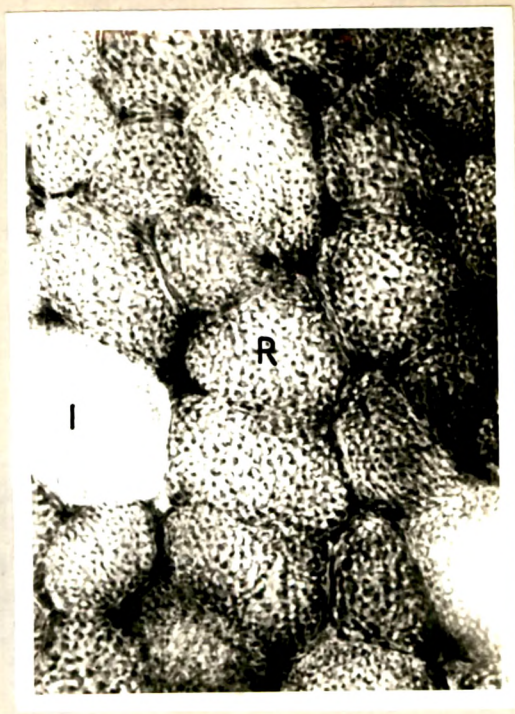


Fig. 29.
Jungle Crow
(Corvus macrorhynchos) X 376.

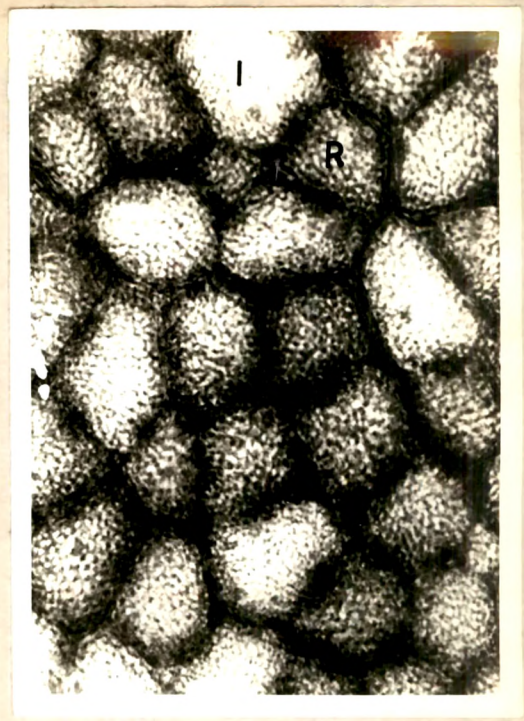


Fig. 30.
Blackheaded Cuckoo-shrike
(Coracina melanoptera) X 336.

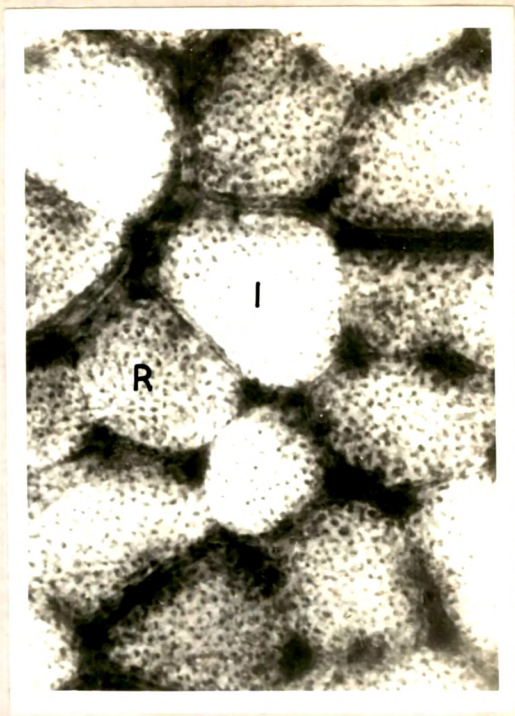


Fig. 31.
Small Minivet
(Pericrocotus cinnamomeus) X 520.

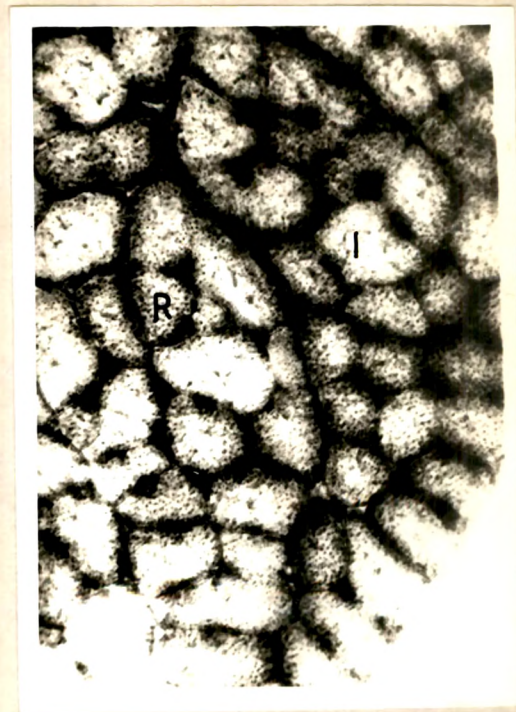


Fig. 32.
Common Iora.
(Aegithina tiphia) X 144.

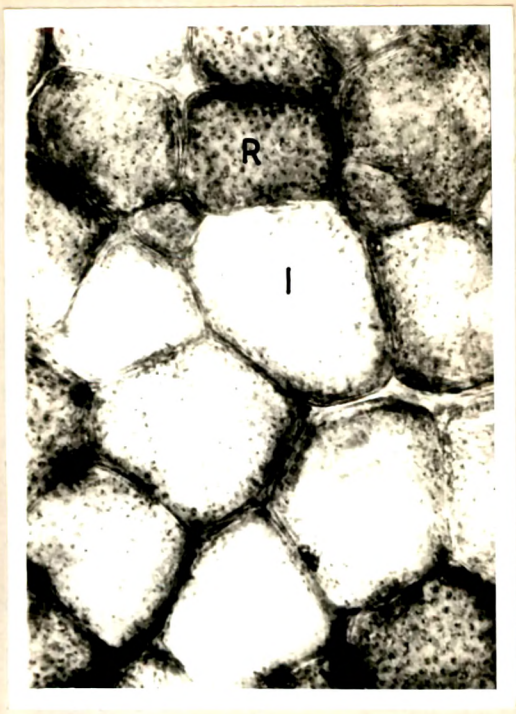


Fig. 33.
Redvented Bulbul
(Pycnonotus cafer) X 376.

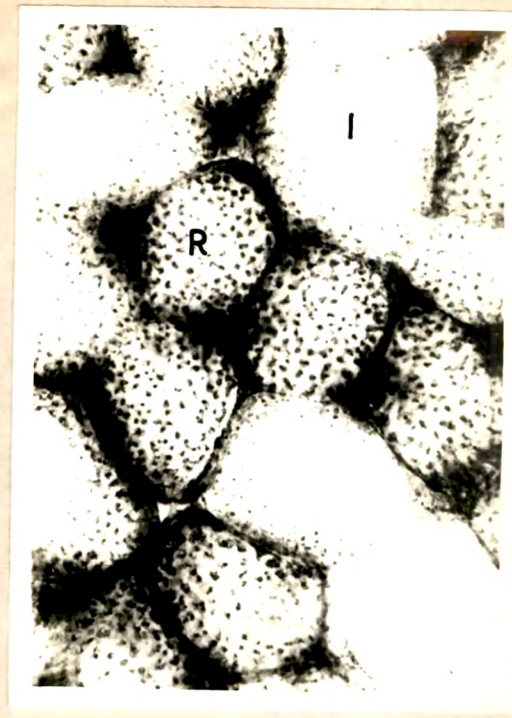


Fig. 34.
Jungle Babbler
(Turdoides striatus) X 376.

Fig. 35.
Whitespotted Fantail Flycatcher
(Rhipidura albogularis) X 520.

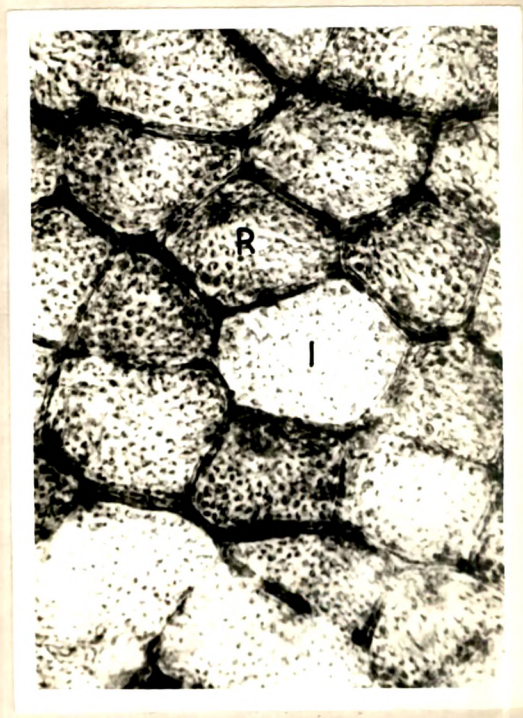


Fig. 36.
Pied Bush Chat
(Saxicola caprata) X 376.

Fig. 37.
Indian Robin
(Saxicoloides fulicata) X 120

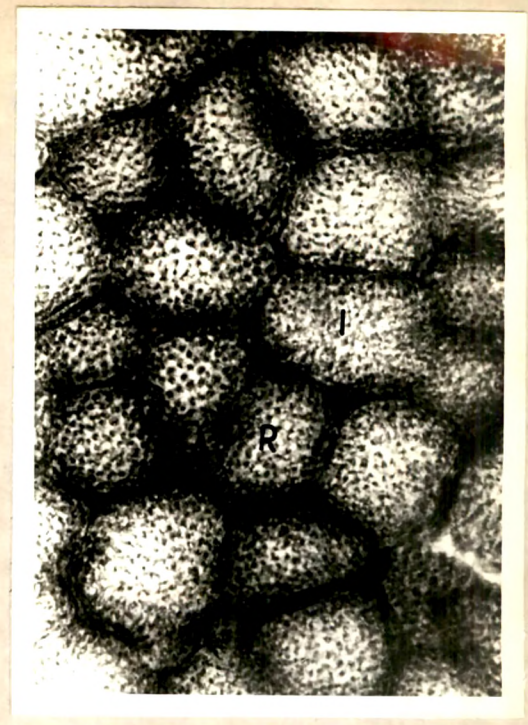


Fig. 38.
Yellowheaded Wagtail
(Motacilla citreola) X 336.

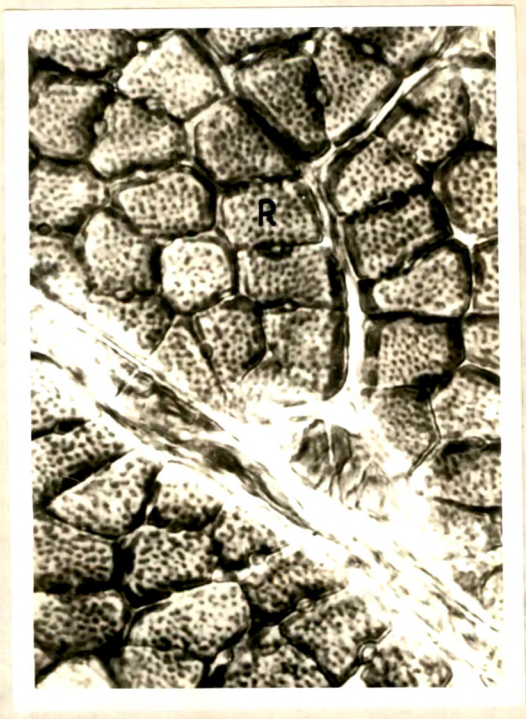


Fig. 39.
Rubythroated Hummingbird
(Archilochus colubris) X 504.

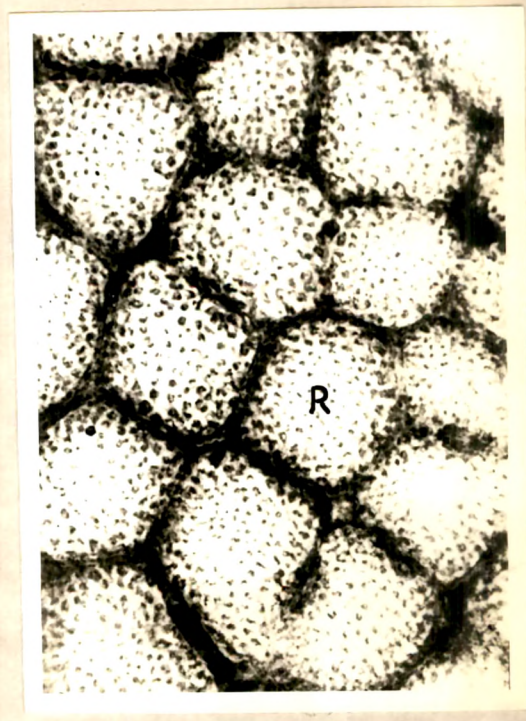


Fig. 40.
Crimsonbreasted Barbet
(Megalaima haemacephala) X 360.

Fig. 41.
Yellowfronted Pied Woodpecker
(Dendrocopos mahrattensis) X 360.

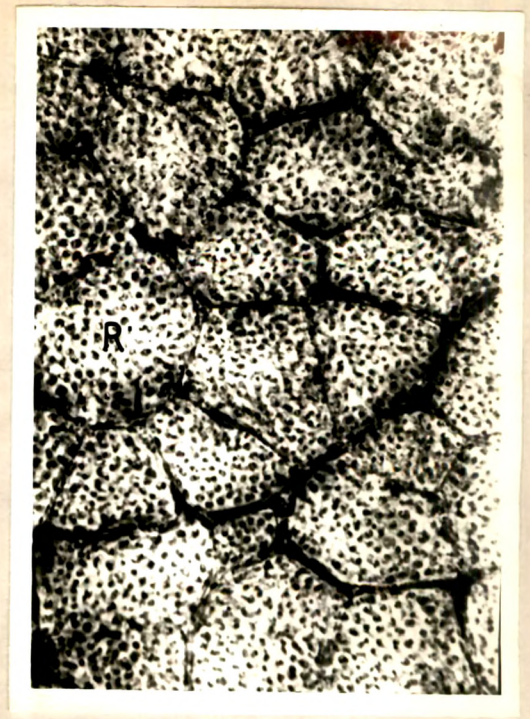


Fig. 42.
Black Drongo
(Dicrurus adsimilis) X 360.

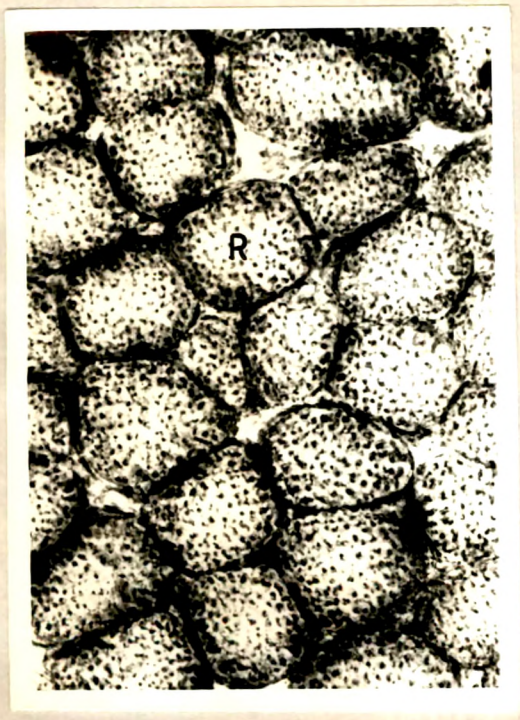


Fig. 43.
Large Grey Babbler
(Turdoides malcolmi) X 360.

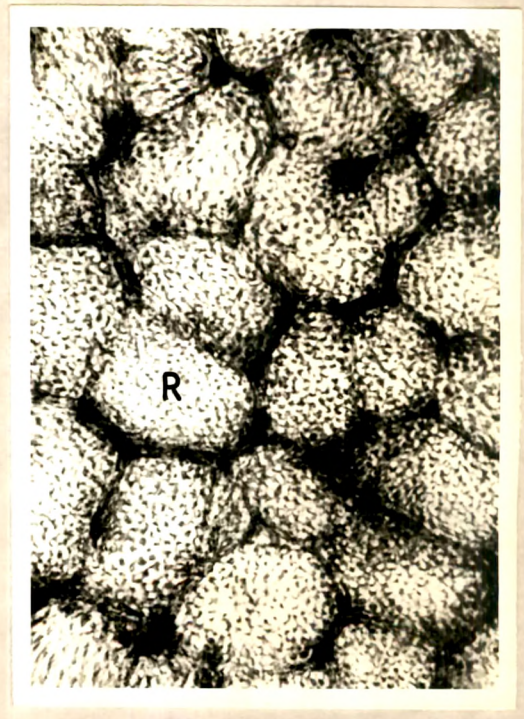


Fig. 44.
Tailor Bird.
(Orthotomus sutorius) X 360.

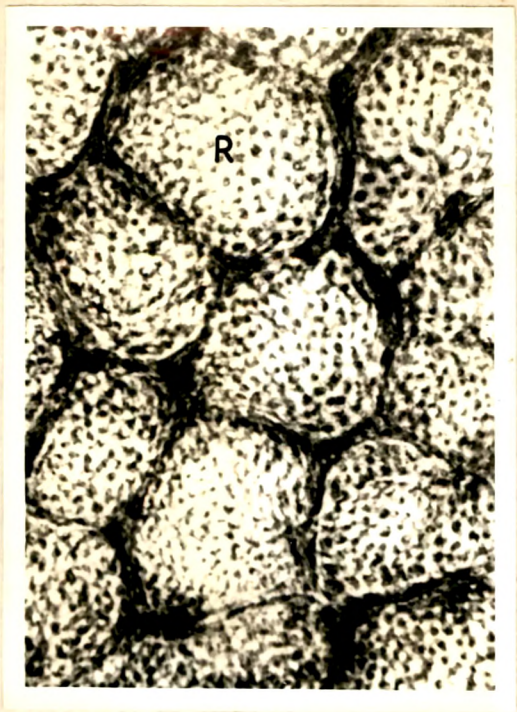


Fig. 45.
Purple Sunbird
(Nectarinia asiatica) X 504.

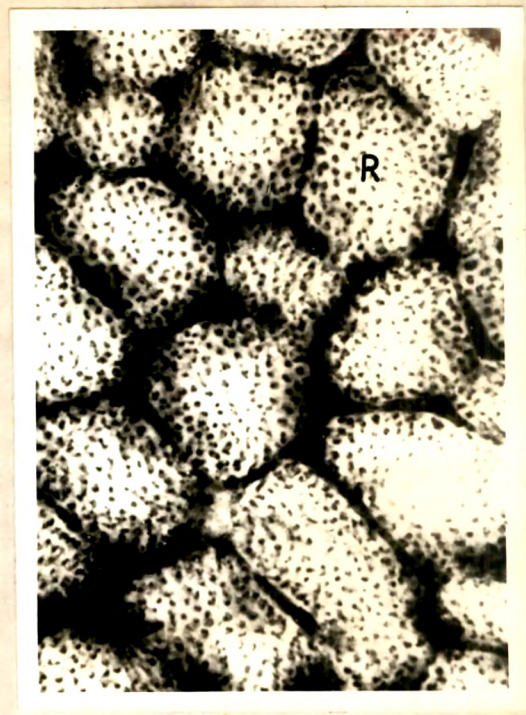


Fig. 46.
White Eye
(Zosterops palpebrosa) X 504.

Fig. 47.
House Sparrow
(Passer domesticus) X 504.

Fig. 48.
Photomicrograph of the T. S. of the pectoralis muscle of the Rubythroated Hummingbird (Archilochus colubris) showing the copious blood supply X 128.

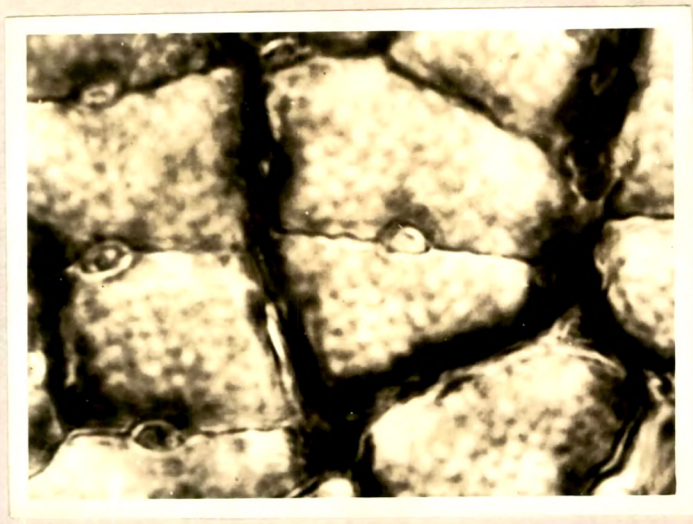


Fig. 49.
Photomicrograph of the T. S. of the pectoralis muscle of the Rubythroated Hummingbird (Archilochus colubris) treated with Nile blue sulphate showing the distribution of fat, mitochondria and blood capillaries. The sarcoplasmic reticulum is also stained. ×1632.