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SECTION II

STUDIES ON CERTAIN METABOLIC ASPECTS OF GIZZARDS OF ADULT REPRESENTATIVE BIRDS

CHAPTER 6

QUANTITATIVE LEVELS OF GLYCOGEN AND HISTOCHEMICAL DEMONSTRATIONS OF ALDOLASE; LACTATE, SUCCINATE AND MALATE DEHYDROGENASES IN THE GIZZARDS OF CERTAIN ADULT REPRESENTATIVE BIRDS

The form and relative size of the avian gizzard are known to be variable, with a fairly high degree of correlation with the type of food. It is generally known that the musculature and keratinized lining of the epithelial tubules in gizzard show their greatest development amongst granivores in contrast to the carnivorous species where the gizzards tend to be relatively thin walled and bag like, with those of omnivores and insectivores displaying a large variety of intermediate conditions. Frugivorous species, especially those which feed on fleshy fruits or nectar have distinctly reduced gizzards, sometimes so reduced as to be seen only as an insignificant swelling between the proventriculus and duodenum. Since the gizzards of birds vary structurally and functionally according to food and feeding habits, there might also be differences in their biochemical and physiological adaptations. It would be worthwhile in this connection to study the metabolic pattern and/or adaptations of the representative types of avian gizzards which would not only provide a comparative data but also might help in the elucidation and understanding of the smooth muscle physiology in general, as gizzard is chiefly constituted of smooth muscles.

MATERIALS AND METHODS

All the birds studied herein were shot from the University campus in the early morning hours by means of an air rifle. They were grouped as under according to Salim Ali (1968).

GRANIVORE:	
Blue rock pigeon	(*Columba livia*)
CARNIVORES:	
Rofousbacked shrike	(*Lanius schach*)
Pariah kite	(*Milvus migrans*)
OMNIVORES:	
Brahminy myna	(*Sturnus pagodarum*)
House crow	(*Corvus splendens*)
Jungle crow	(*Corvus macrorhynchus*)
Fowl	(*Gallus domesticus*)
INSECTIVORES:	
Indian robin	(*Saxicoloides fulicata*)
Green bee-eater	(*Merops orientalis*)
Drongo	(*Dicrurus adsimilis*)
Crow pheasant	(*Centropus sinensis*)
Jungle babbler	(*Turdoides striatus*)
Redvented bulbul	(*Pycnonotus cafer*)
Koel	(*Eudynamus scolopacea*)
Common myna	(*Acridotheres tristis*)
House sparrow	(*Passer domesticus*)

FRUGIVORE:

Rose-ringed parakeet (*Psittacula krameri*)

NECTAR FEEDER:

Purple sunbird (*Necterinia asiatica*)

For histochemical demonstrations of aldolase; lactate, succinate and malate dehydrogenases, the gizzards from the representative birds were separated, blotted well to remove their contents, blood and other tissue fluids and fixed on a chuck of a cryostat microtome maintained at -20°C. Sections of 12 μ thickness were cut and processed in the respective incubation media as described in chapter 2.

For the quantitative estimation of glycogen, a known quantity of gizzard was digested in 30% Potassium hydroxide and processed according to the method of Seifter *et al*. (1950).

OBSERVATIONS

Aldolase and Lactate dehydrogenase: (1 - 24; 1a - 24a).

The present study on different groups of birds tend to classify them into three well defined entities as per the activities of these enzymes. Whereas the carnivores and insectivores depicted the highest intensity of these two enzymes, the frugivore registered the lowest, nevertheless perceptible, concentration with the granivores recording an intermediate level of the enzyme concentration. Interestingly enough, the omnivores resolved themselves into two divergent groups with one (house crow and jungle crow) demonstrating aldolase and lactate dehydrogenase (LDH) responses identical to those of carnivores and insectivores and the other (brahminy myna and fowl), a low response characteristic of the frugivore. The nectar feeder (sun bird) also depicted concentrations of these enzymes identical to that of frugivore. It is also to be noted that in all the groups of birds investigated herein, not only were the activities of both these enzymes equal and identical but also the response of the two anatomical components of the gizzard towards these enzymes.

Succinate and Malate dehydrogenases: (Figs. 25-48; 26a-48a).

Frugivores, carnivores, insectivores and granivores all depicted a higher concentration of succinate dehydrogenase (SDH) in comparison to malate dehydrogenase (MDH). And amongst the omnivores, whereas crow projected a similar concentration which was identical to the nectar feeder (sun bird), brahminy myna and fowl displayed a slightly different pattern wherein the activities of both SDH and MDH were identical and equal but slightly lesser

EXPLANATIONS FOR FIGURES

(Figures 1 - 12 aldolase activity in the mucosal tubules of gizzards of various birds)

(Figures 1a- 12a aldolase activity in the smooth muscle fasciculi of gizzards of various birds)

Figs. 1 & 1a - Shrike

Figs. 2 & 2a - Kite

Figs. 3 & 3a - Crow

Figs. 4 & 4a - Fowl

Figs. 5 & 5a - Bee-eater

Figs. 6 & 6a - Drongo

Figs. 7 & 7a - Crow Pheasant

Figs. 8 & 8a - Bulbul

Figs. 9 & 9a - Babbler

Figs. 10 & 10a --Koel

Figs. 11 & 11a - Parakeet

Figs. 12 & 12a - Sunbird

EXPLANATIONS FOR FIGURES

(Figures 13 - 24 Lactate dehydrogenase activity in the mucosal tubules of gizzards of various birds) and

(Figures 13a - 24a Lactate dehydrogenase activity in the smooth muscle fasciculi of gizzards of various birds).

Figs. 13 & 13a - Shrike
Figs. 14 & 14a - Kite
Figs. 15 & 15a - Crow
Figs. 16 & 16a - Fowl
Figs. 17 & 17a - Bee-eater
Figs. 18 & 18a - Drongo
Figs. 19 & 19a - Crow Pheasant
Figs. 20 & 20a - Bulbul
Figs. 21 & 21a - Babbler
Figs. 22 & 22a - Koel
Figs. 23 & 23a - Parakeet
Figs. 24 & 24a - Sunbird

EXPLANATIONS FOR FIGURES

(Figures 25 - 36 Succinate dehydrogenase activity in the mucosal tubules of gizzards of various birds) and

(Figures 25a - 36 a Succinate dehydrogenase activity in the smooth muscle fasciculi of gizzards of various birds)

Fig. 25 & 25a - Shrike

Figs. 26 & 26a - Kite

Figs. 27 & 27a - Crow

Figs. 28 & 28a - Fowl

Figs. 29 & 29a - Bee-eater

Figs. 30 & 30a - Drongo

Figs. 31 & 31a - Crow Pheasant

Figs. 32 & 32a - Bulbul

Figs. 33 & 33a - Babbler

Figs. 34 & 34a - Koel

Figs. 35 & 35a - Parakeet

Figs. 36 & 36a - Sunbird

EXPLANATIONS FOR FIGURES

(Figures 37 - 48 Malate dehydrogenase activity in the mucosal tubules of gizzards of various birds) and

(Figures 37a - 48a Malate dehydrogenase activity in the smooth muscle fasciculi of gizzards of various birds)

Fig. 37 & 37a - Shrike

Fig. 38 & 38a - Kite

Fig. 39 & 39a - Crow

Fig. 40 & 40a - Fowl

Figs. 41 & 41a - Bee-eater

Figs. 42 & 42a - Drongo

Figs. 43 & 43a - Crow Pheasant

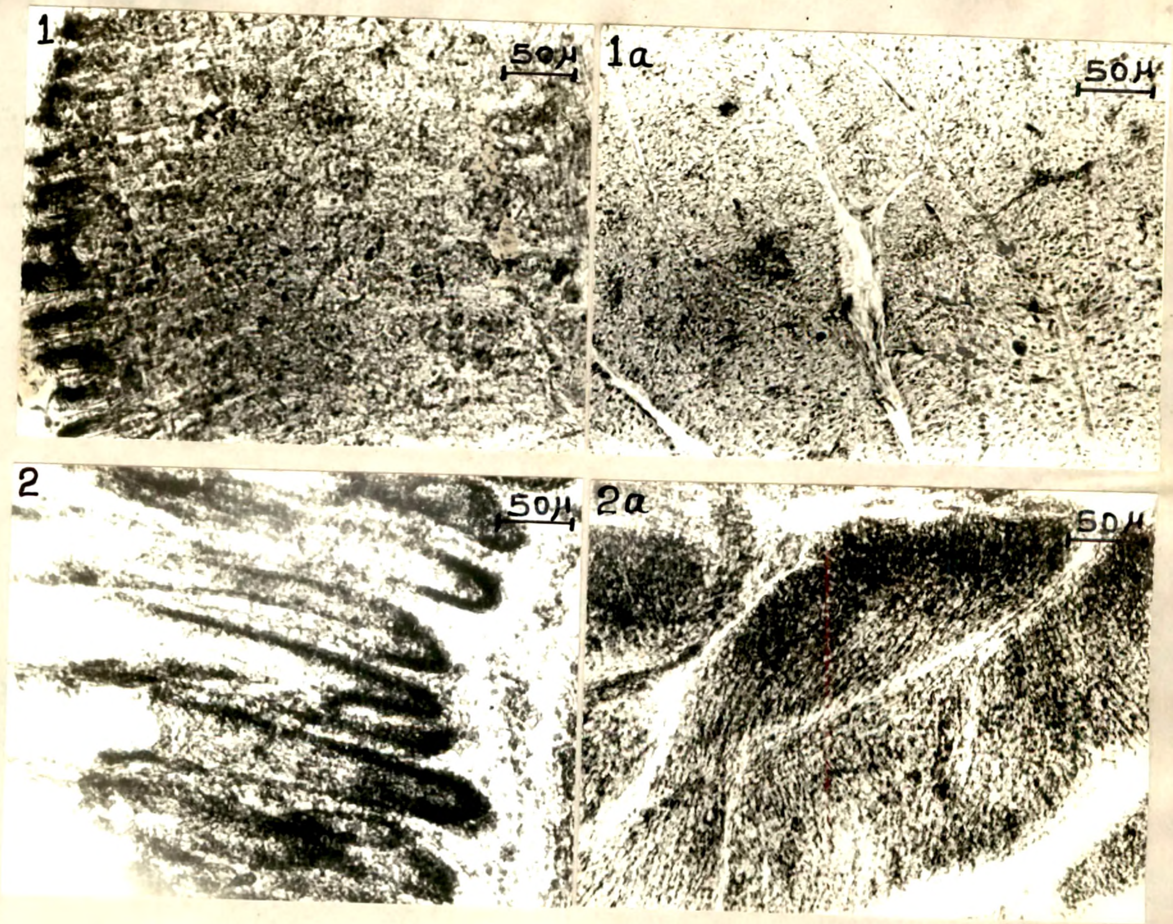
Figs. 44 & 44a - Bulbul

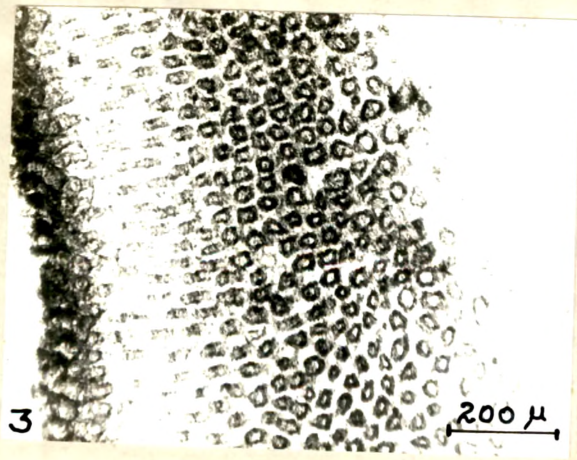
Figs. 45 & 45a - Babbler

Figs. 46 & 46a - Koel

Figs. 47 & 47a - Parakeet

Figs. 48 & 48a - Sunbird


1
50μ
1a
50μ
2
50μ
2a
50μ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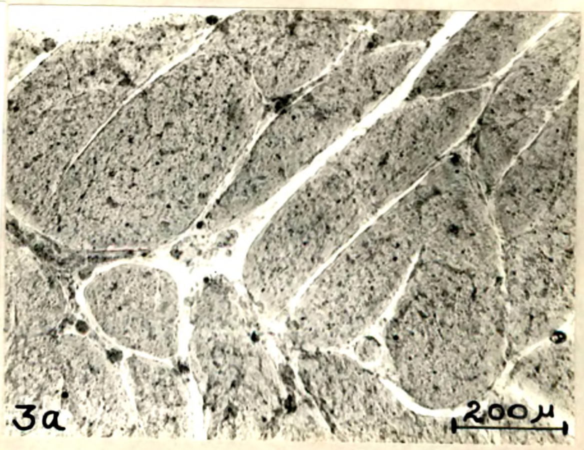
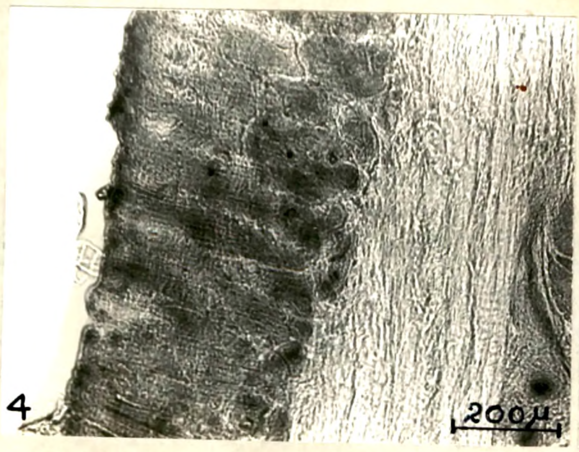

3a
200 µ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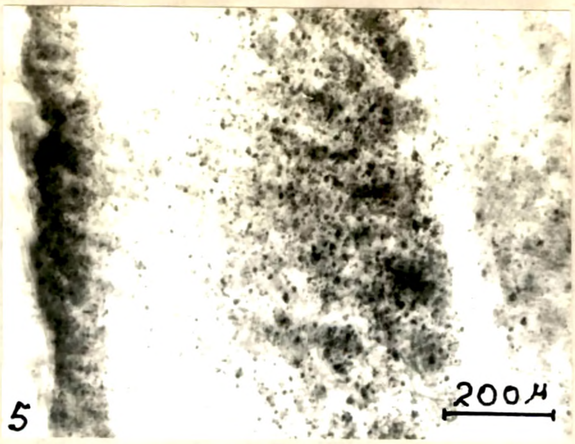
4a
200 µ



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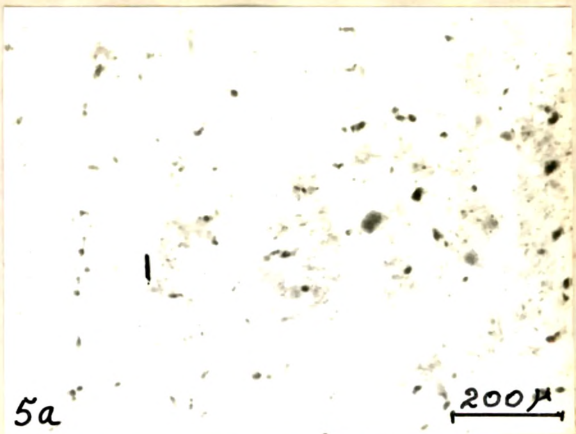
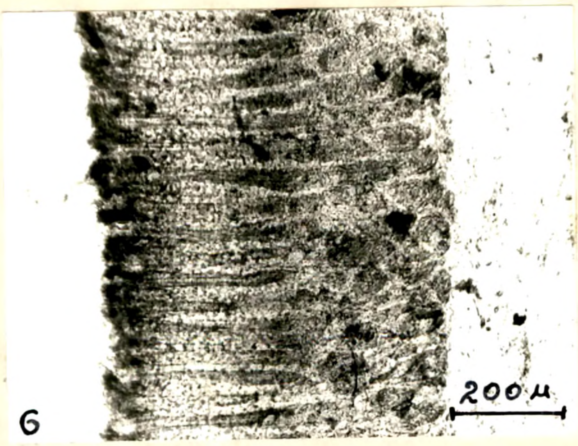


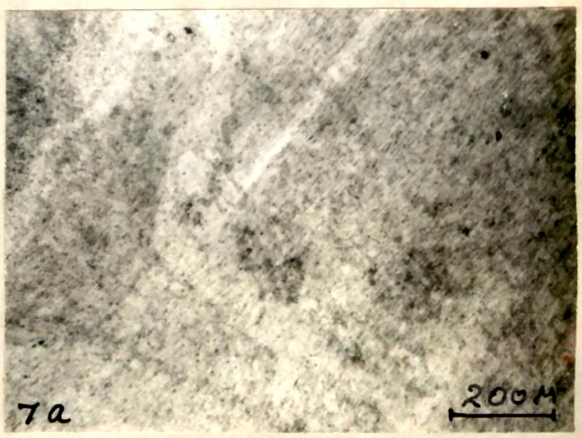
5a



6

6a

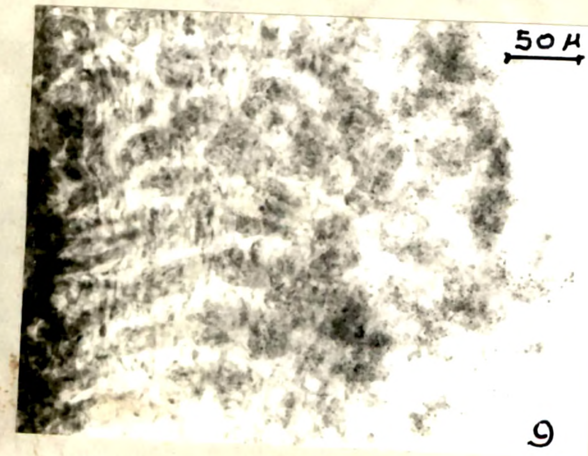
7



7a


200μ
8


200μ
8a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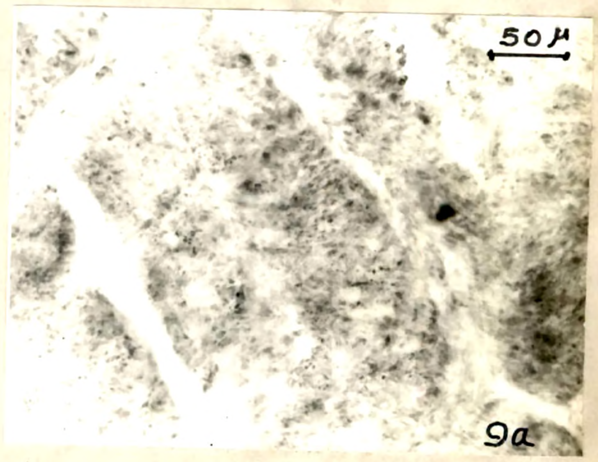
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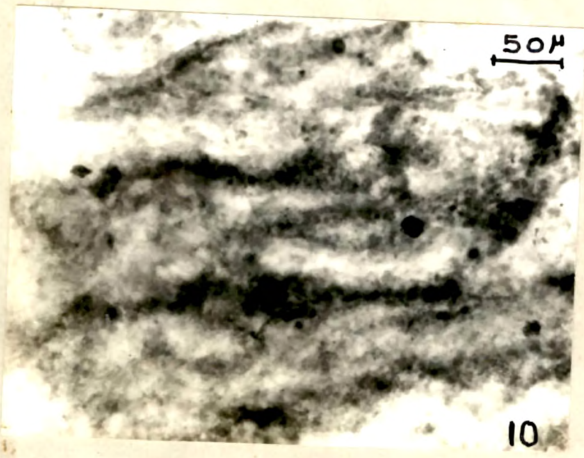
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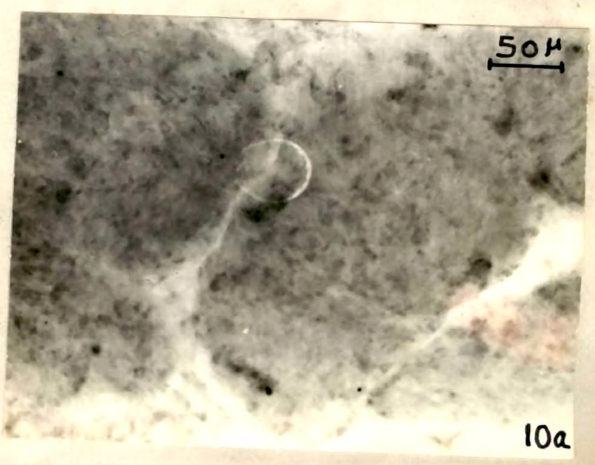
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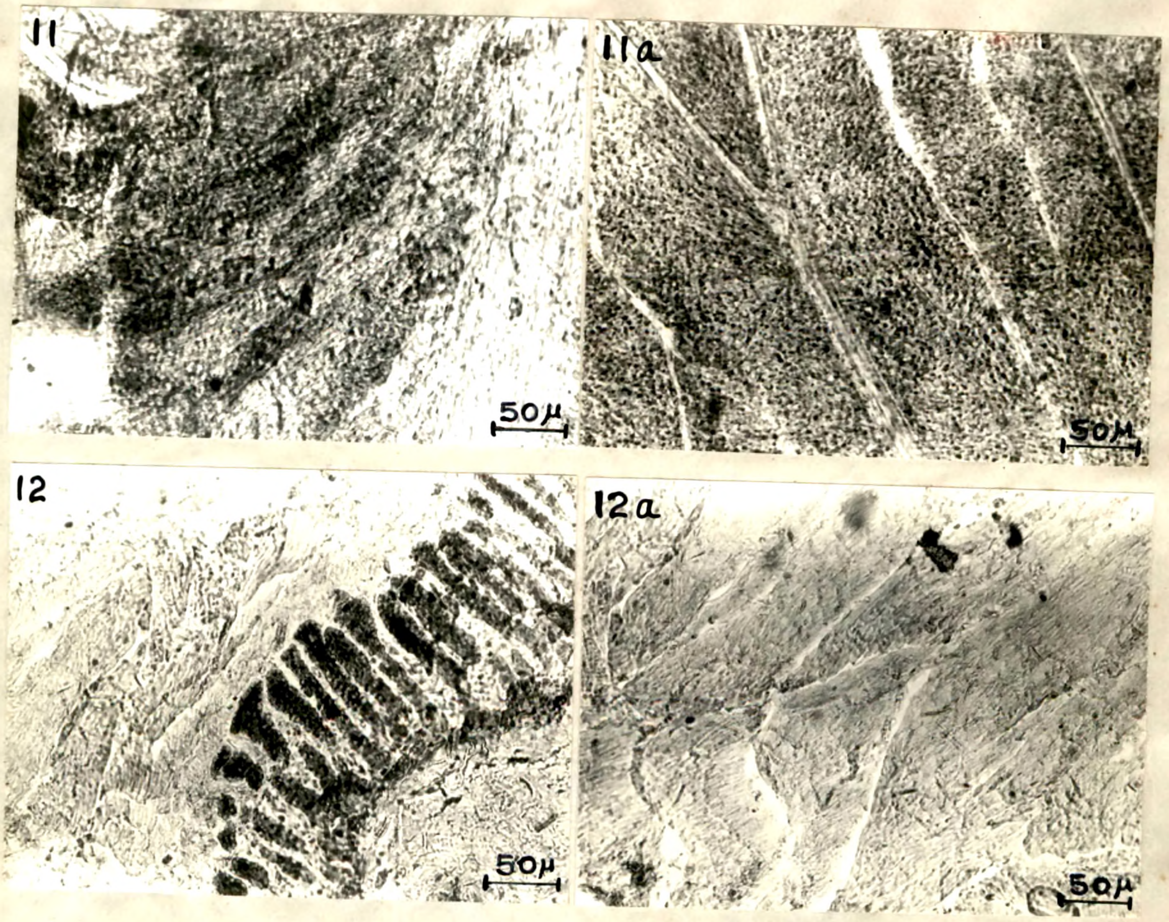
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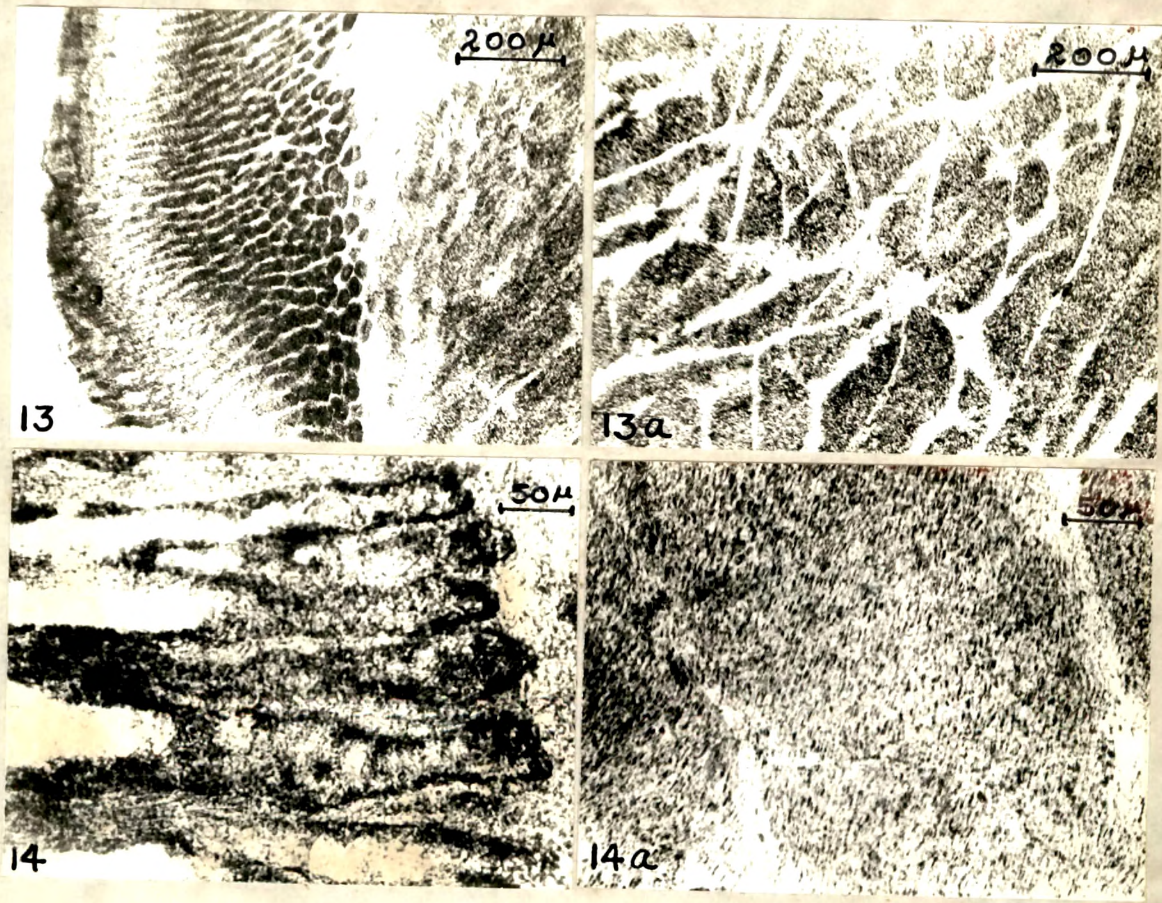
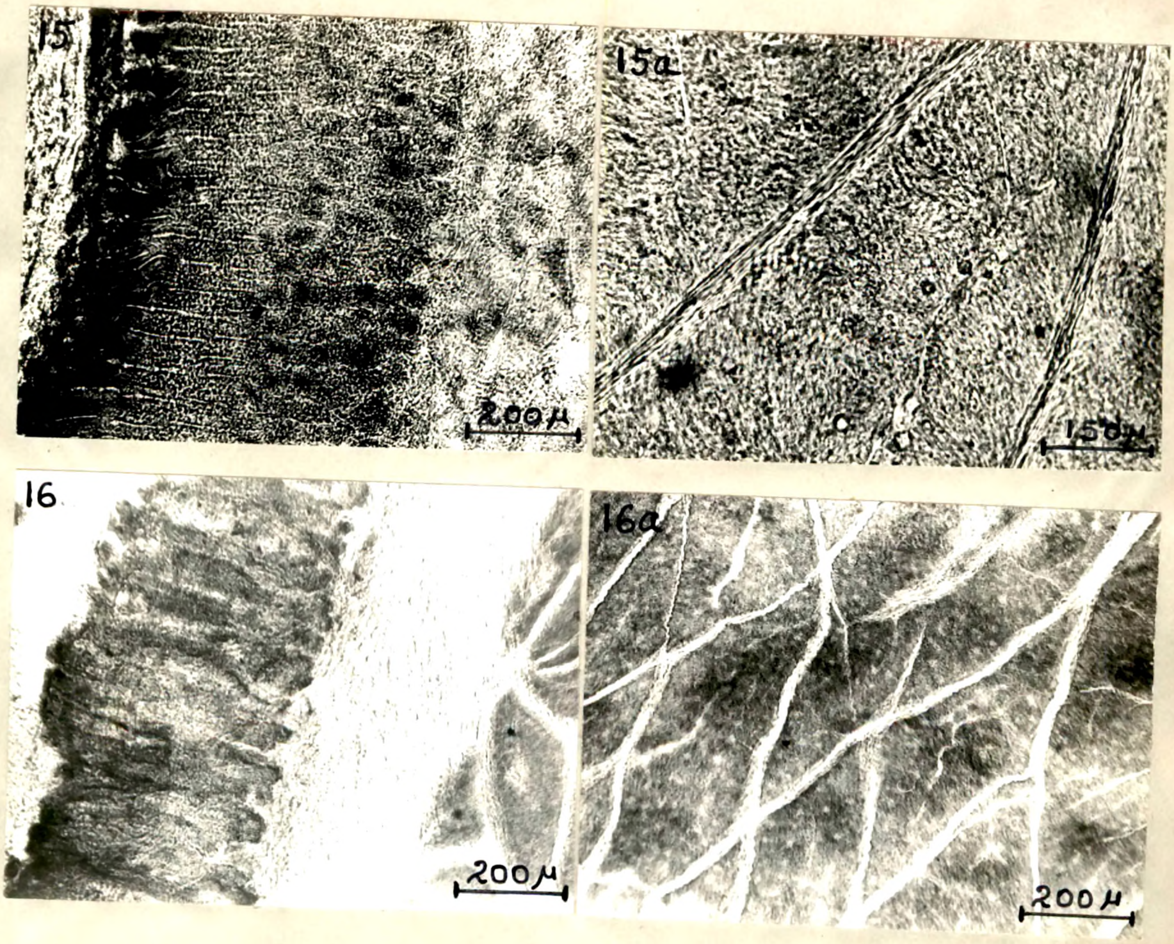
50μ
11a
50μ
12
50μ
12a
50μ


200µ
13
200µ
13a
50µ
14
50µ
14a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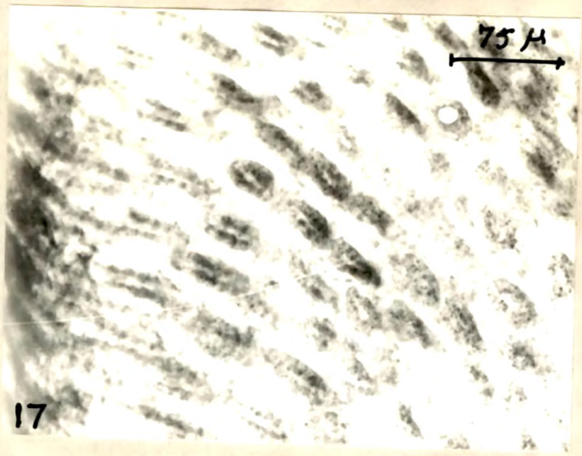
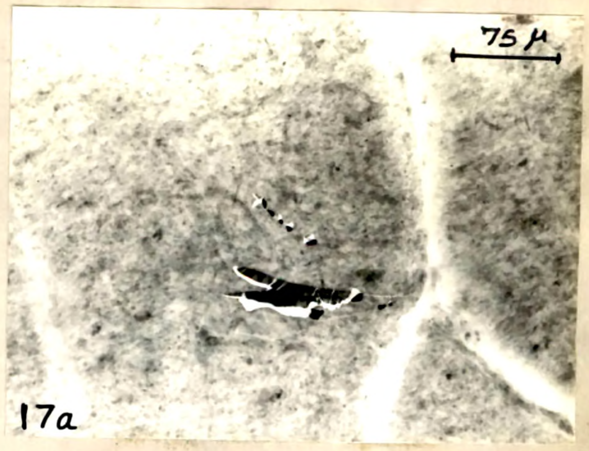
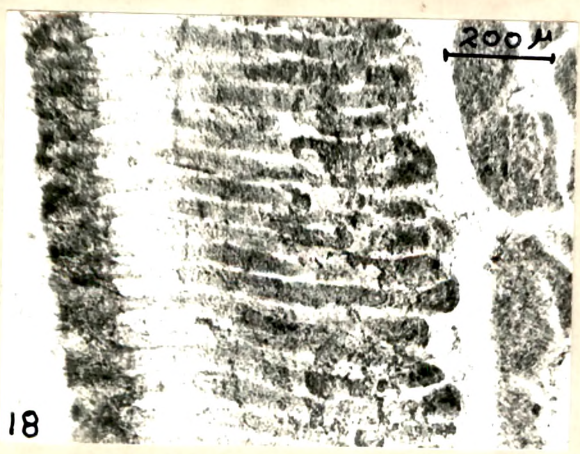
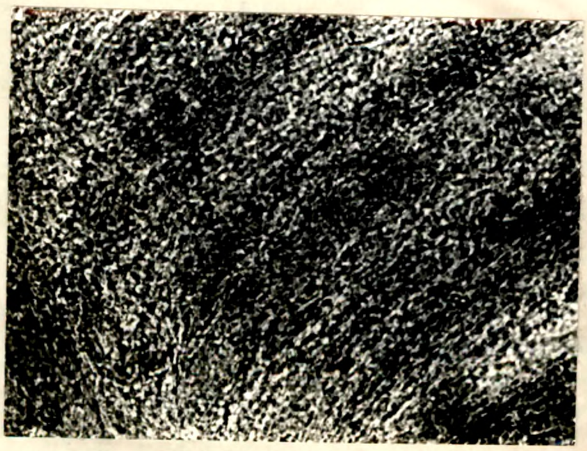
200μ
15a
150μ
16
200μ
16a
200μ









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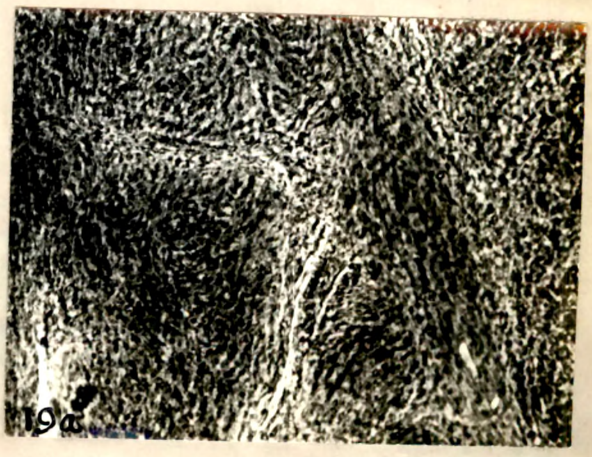
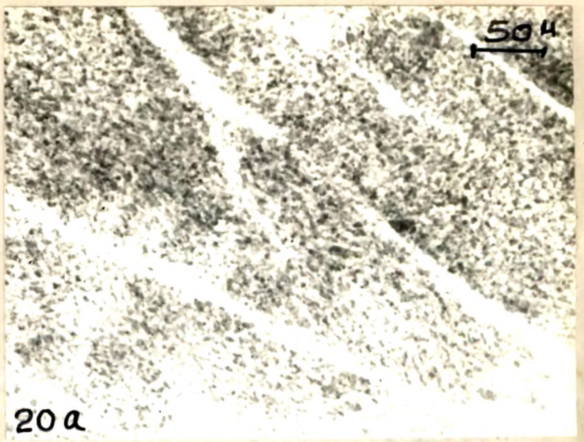


50 μ


50μ
20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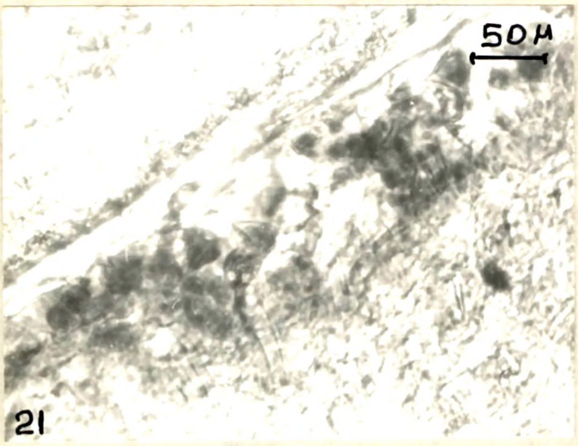
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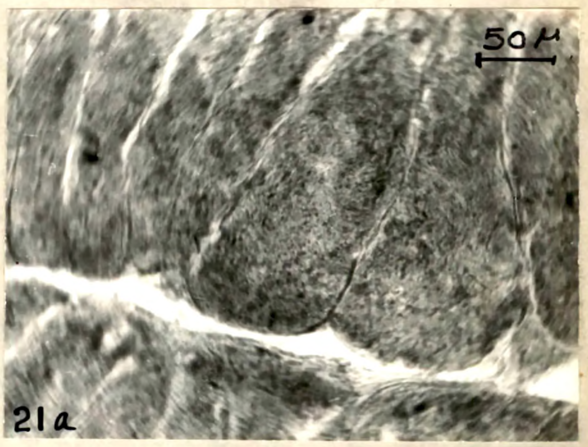
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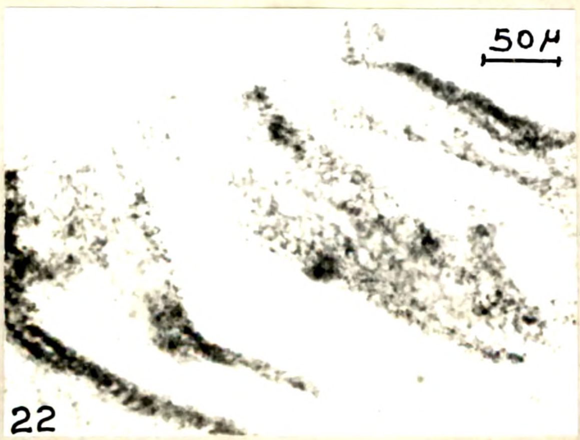
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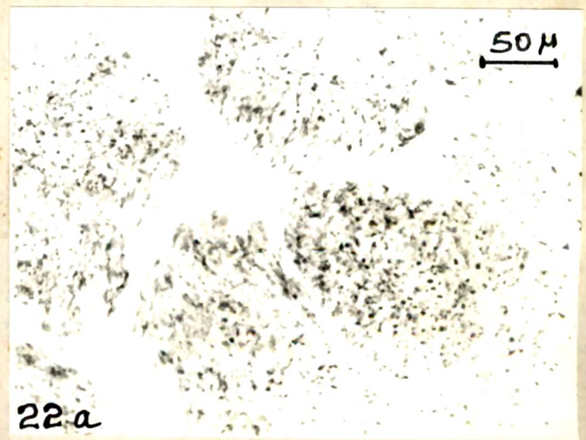
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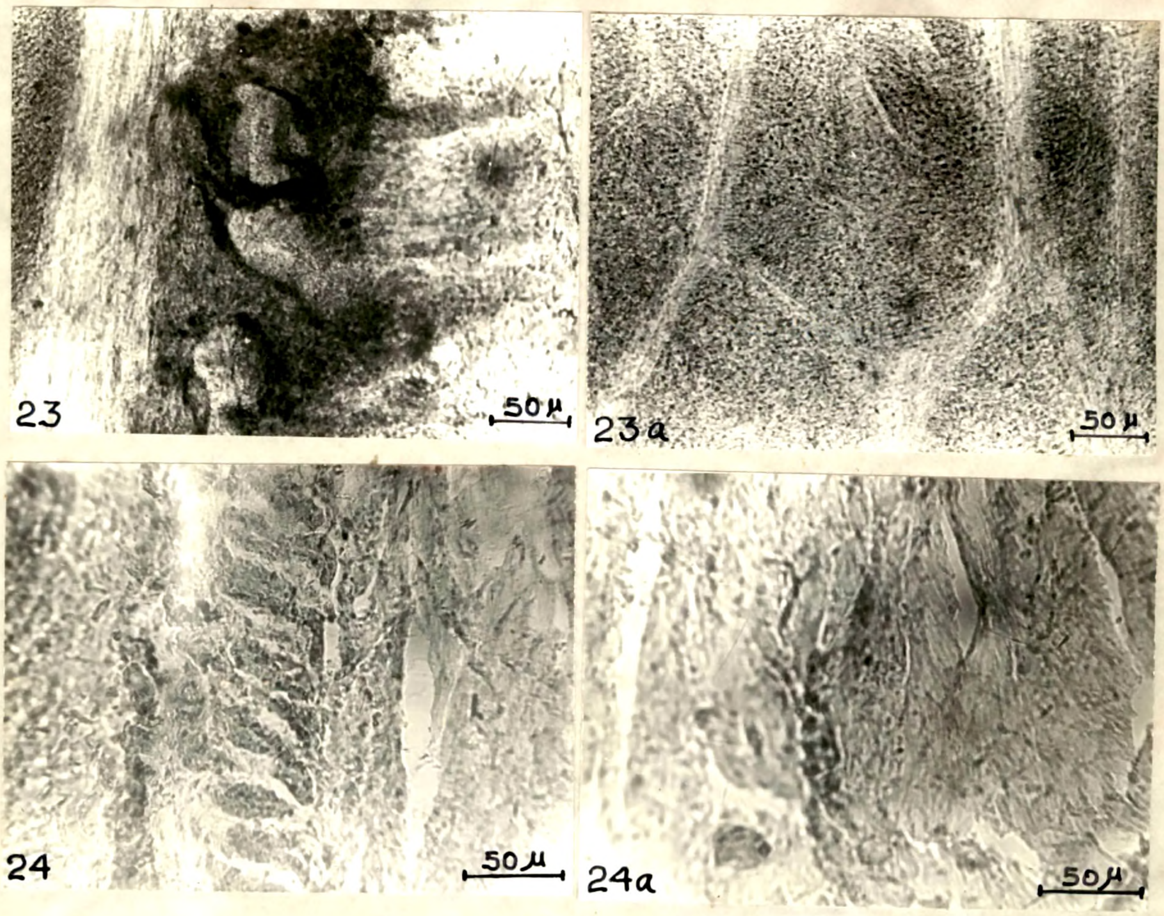
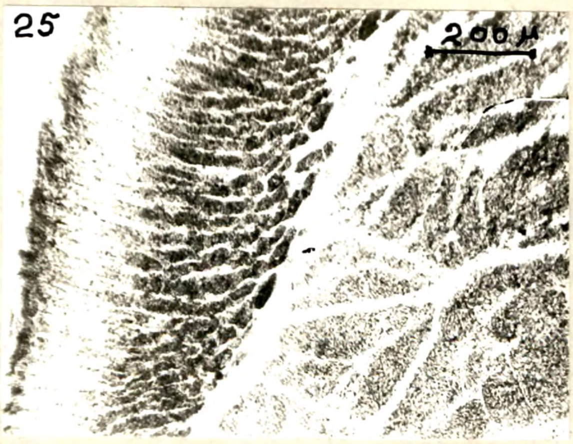
22a


23
50 μ
23a
50 μ
24
50 μ
24a
50 μ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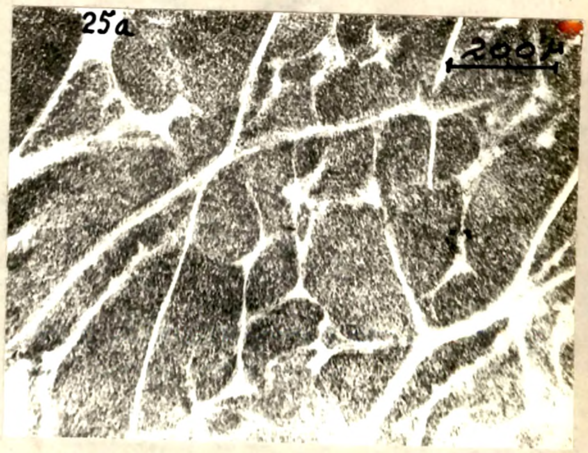
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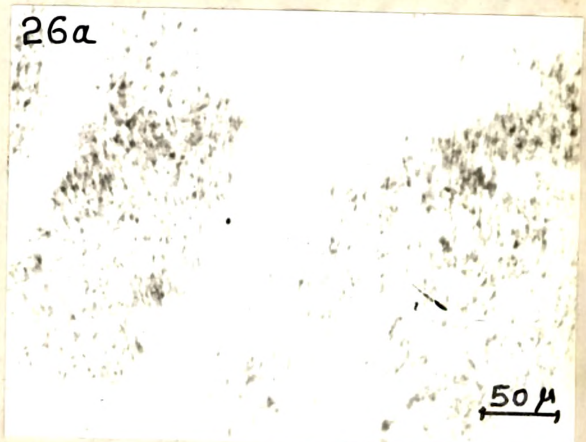
200 μ


26
50 μ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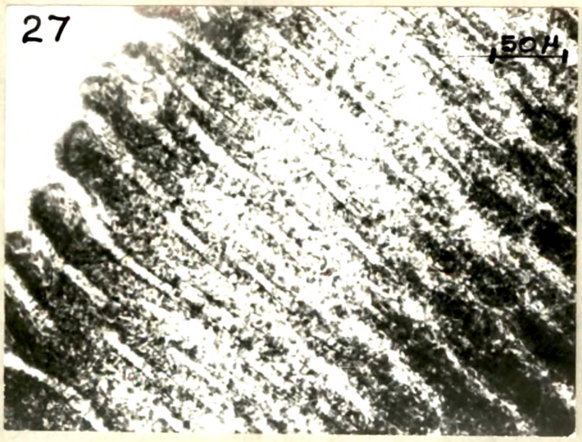
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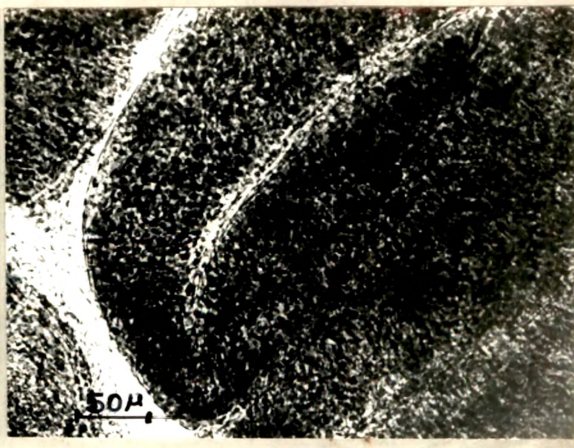
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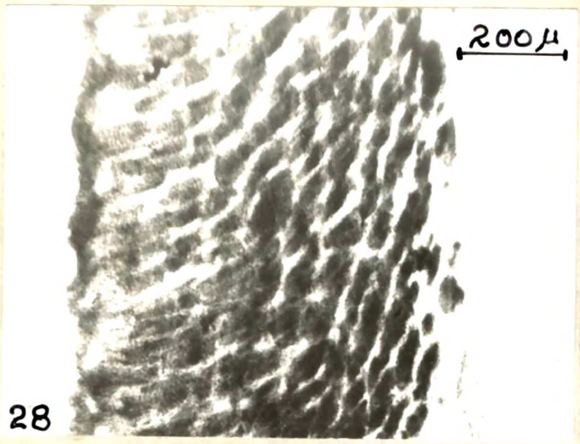
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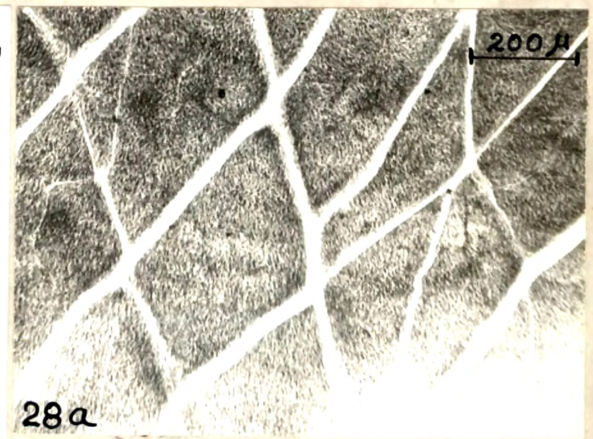
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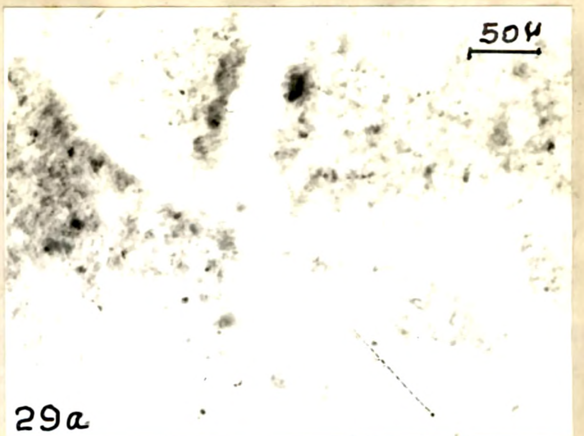
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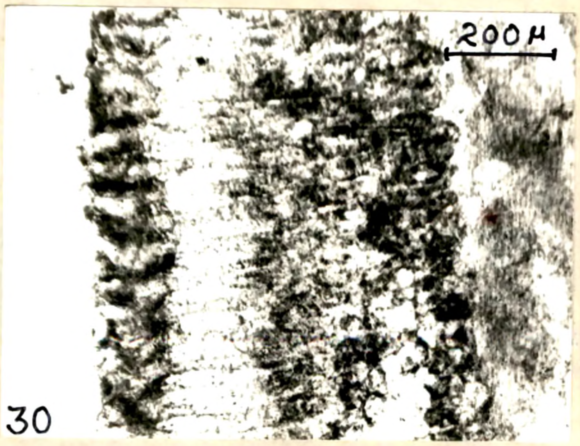
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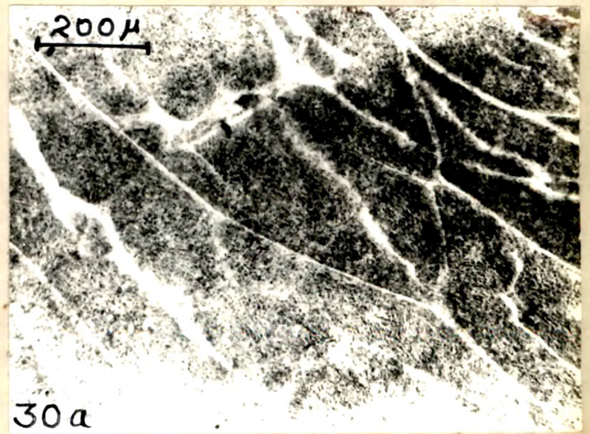
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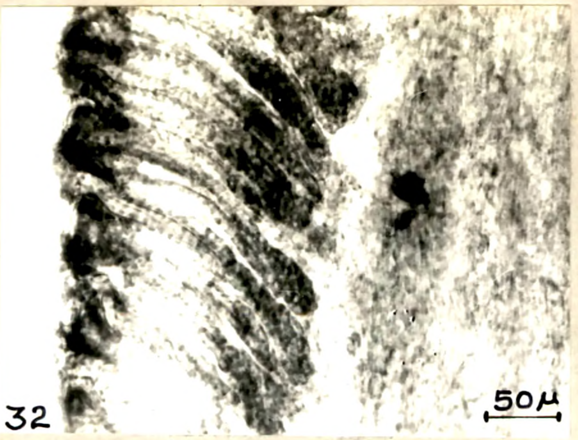
30a


50μ
31


50μ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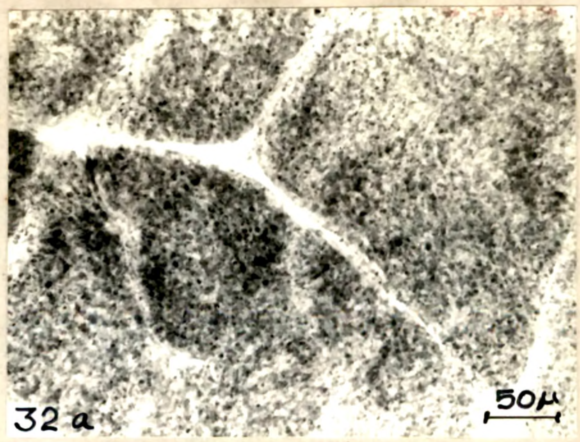
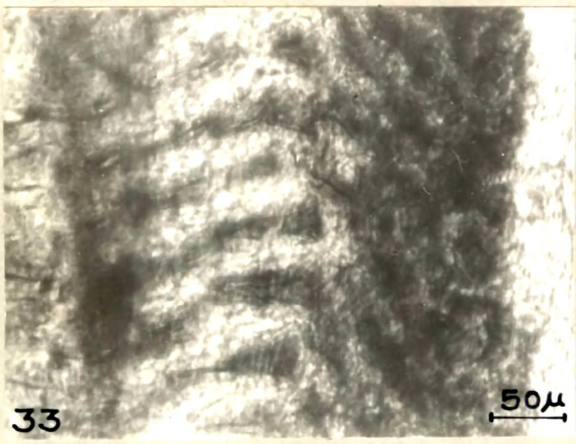

32 a
50μ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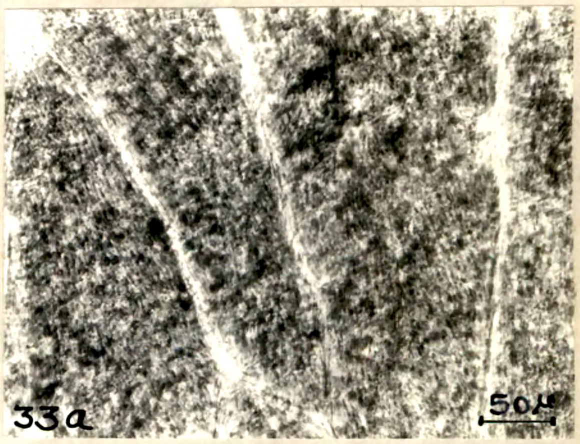
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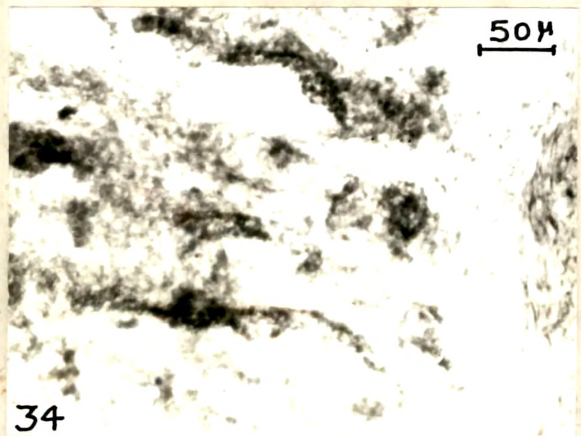
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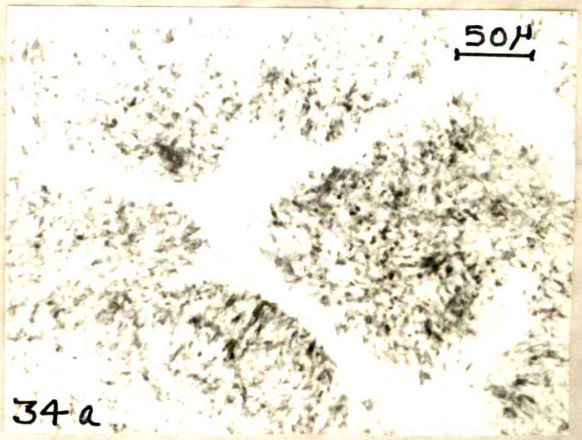
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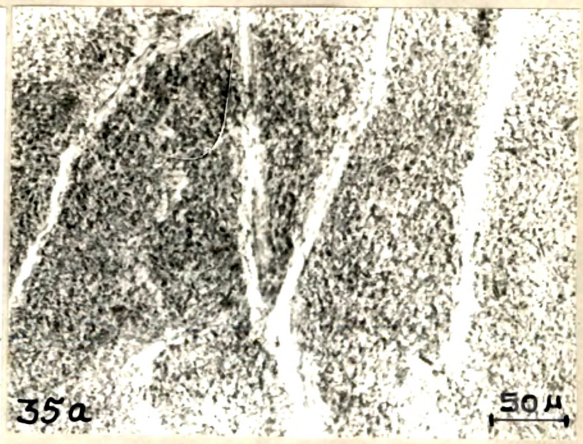
50μ

35



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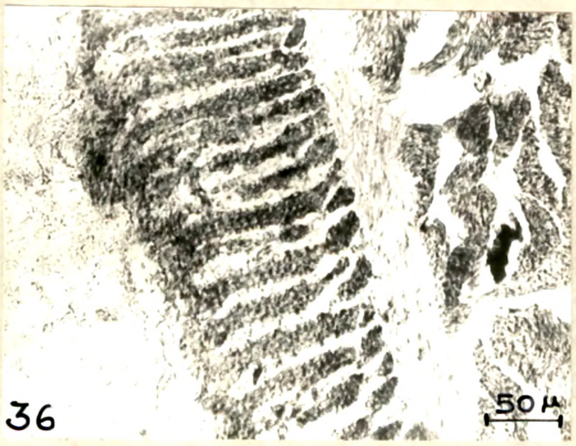
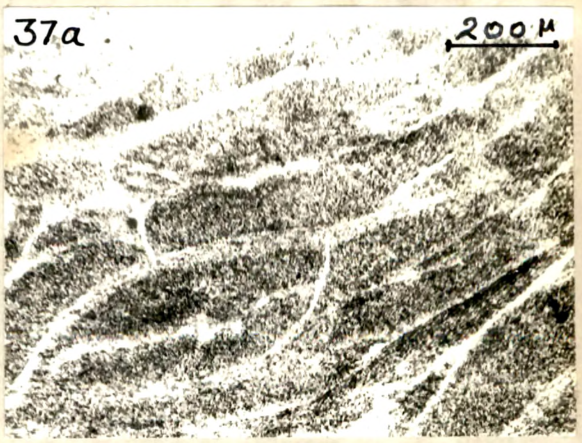


36

36a


37
200 µ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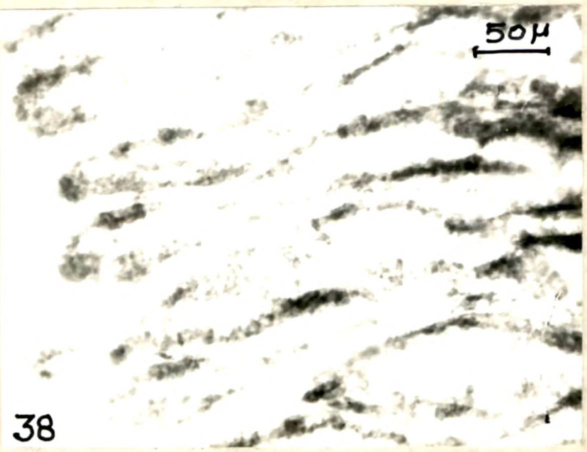
200 µ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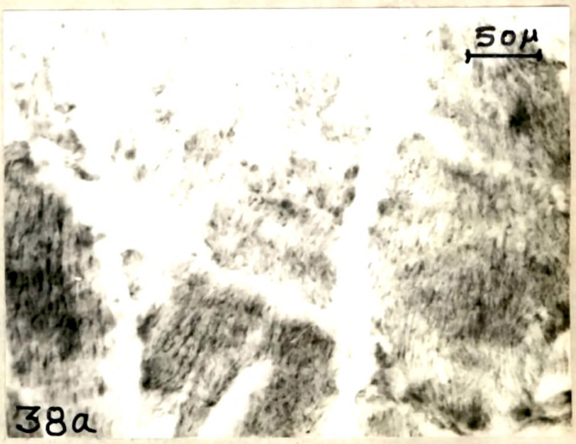
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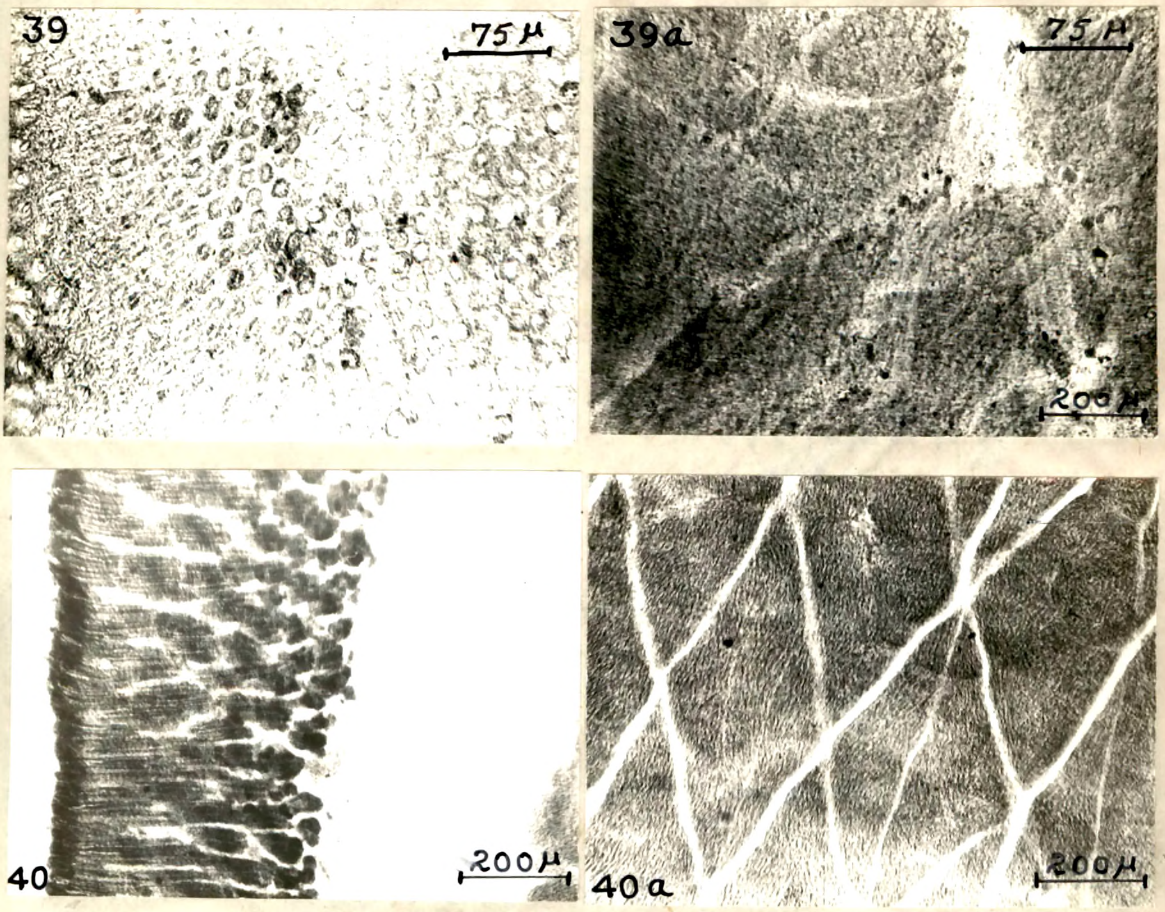
38a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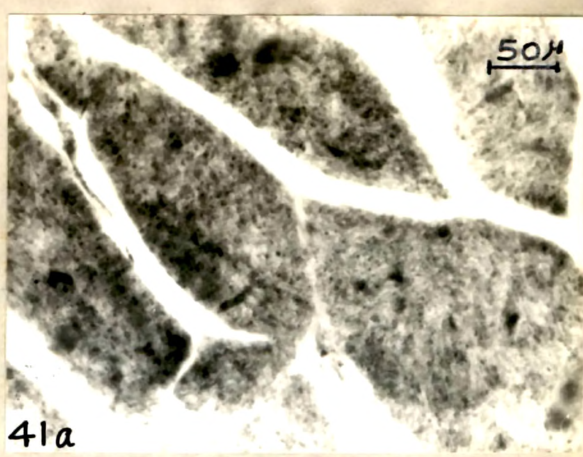
75 μ
39a
75 μ
200 μ
40
200 μ
40 a
200 μ

41



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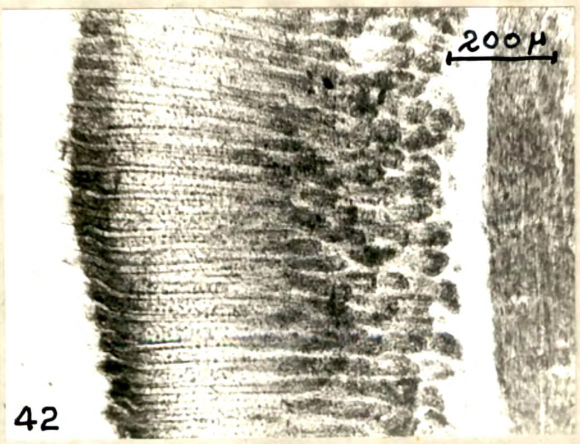

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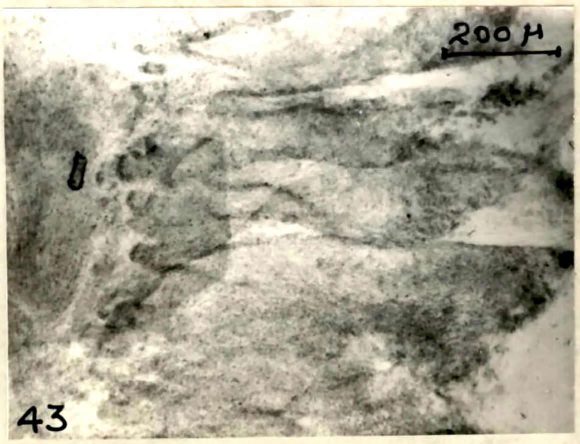
42a



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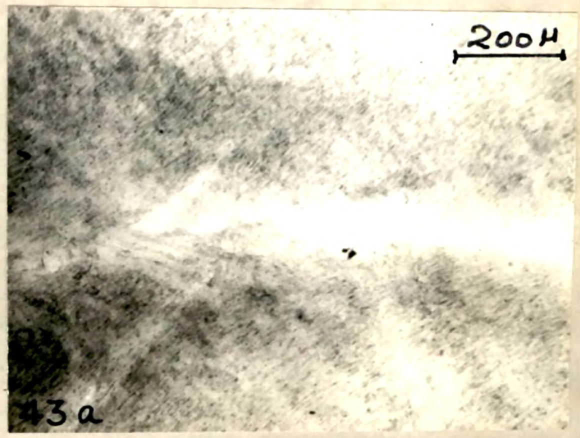

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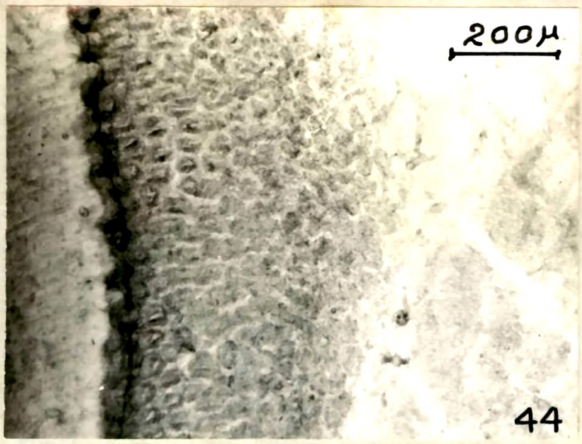

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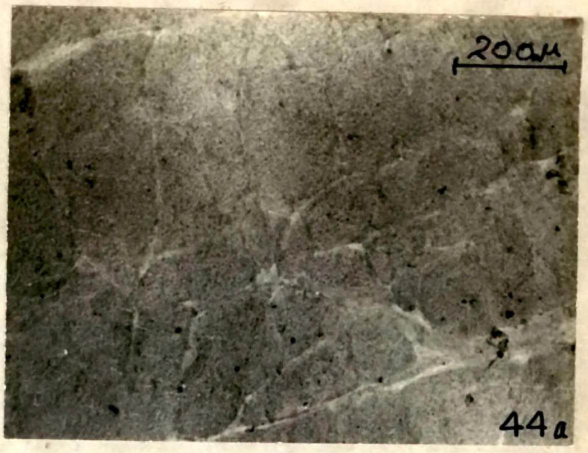

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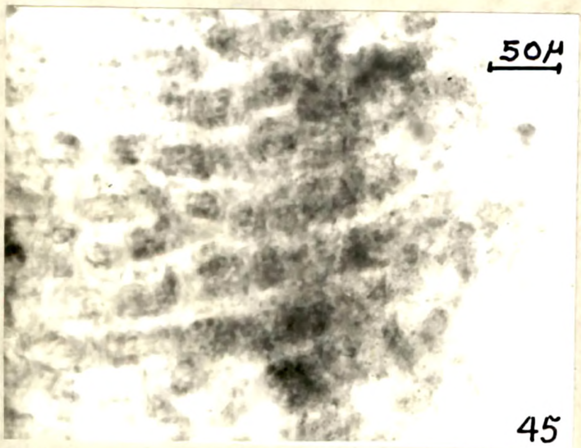

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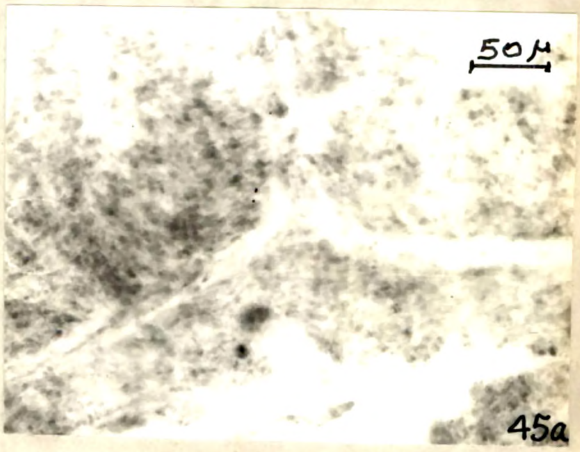

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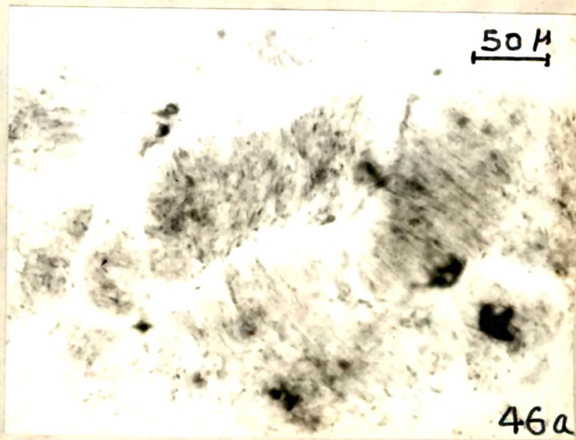

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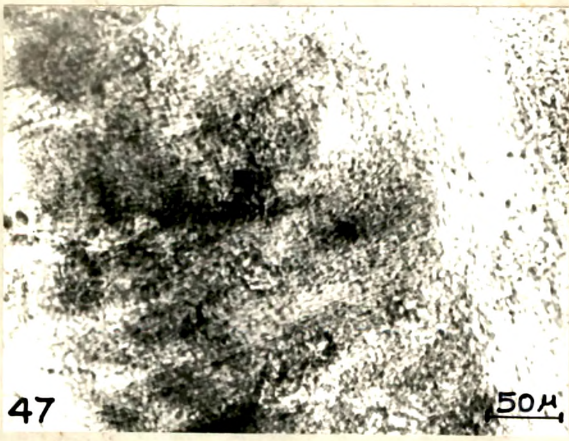

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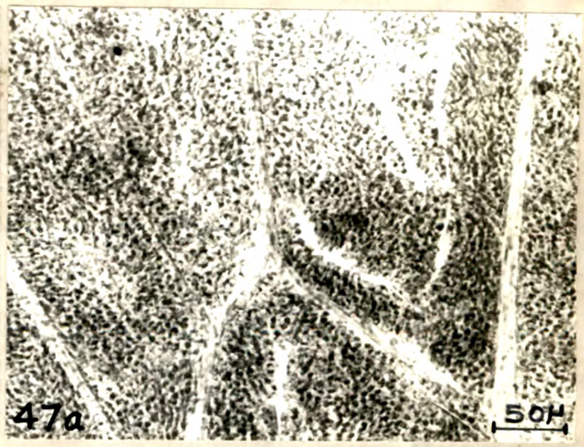

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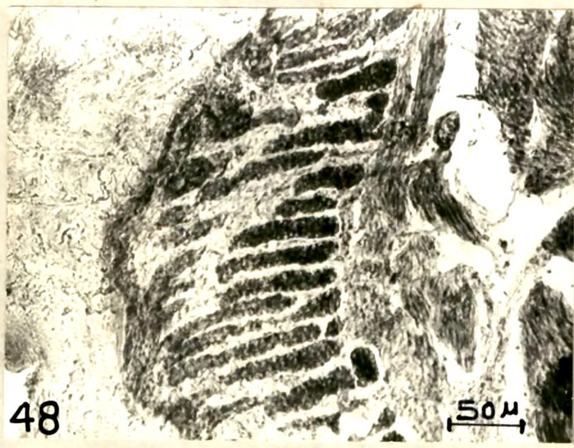

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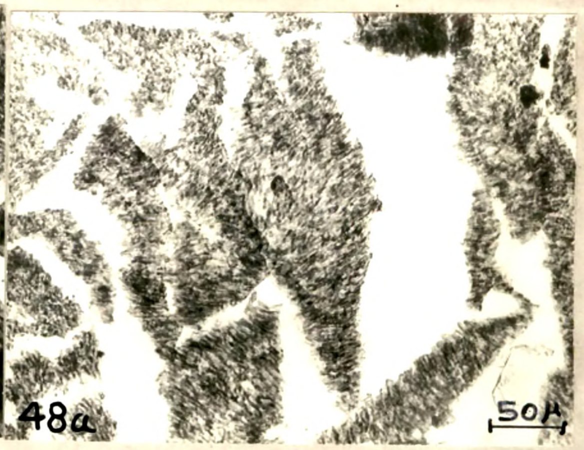

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TABLE I SHOWING THE LEVELS OF GLYCOGEN EXPRESSED IN RELATION WITH BODY AND GIZZARD WEIGHT OF ADULT REPRESENTATIVE BIRDS*

Birds	Body weight	Gizzard weight	Amount of glycogen (gm/100 gm wet tissue)
Blue rock pigeon	310	5.581	0.0430
Shrike	40	1.163	0.1305
Pariah kite	980	4.90	0.0430
Brahminy myna	31	0.9717	0.1149
House crow	268	4.576	0.0157
Jungle crow	407	5.225	0.0513
Domestic fowl	1105	11.78	0.0513
Indian robin	18	0.60	0.0039
Green bee-eater	16	0.382	0.0121
Drongo	45	1.483	0.1239
Crow pheasent	215	3.873	0.0213
Jungle babbler	48	1.1527	0.1123
Redvented bulbul	40	1.273	0.1027
Koel	220	3.991	0.2458
Common myna	100	1.3669	0.1329
House sparrow	16	0.264	0.0953
Parakeet	118	2.3872	0.0013
Purple sunbird	07	0.193	0.0260

*Average of 5 birds

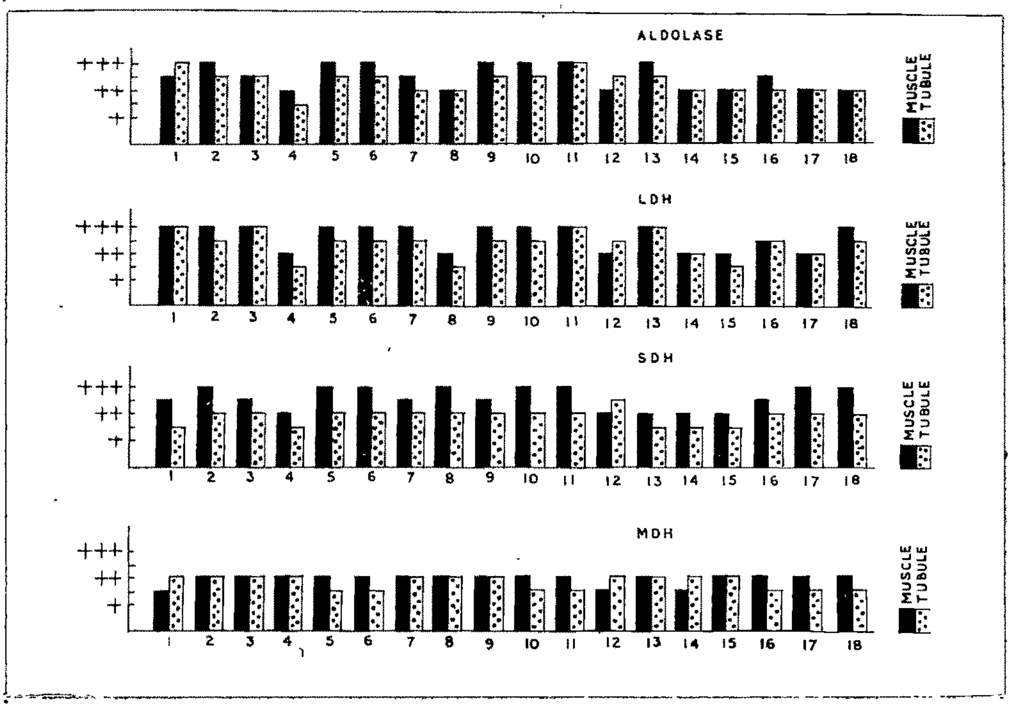

FIGURE 49.

Graphical representation of the changes in aldolase, LDH, SDH and MDH distribution pattern in the gizzards of adult representative birds than those observable for crow. A point of interest is that the level of SDH was never lower than that of MDH in any of the group of birds under investigation.

Glycogen:

The quantitative data on the concentration of glycogen in the gizzards of various birds studied is represented as grams per 100 grams of wet tissue (Table I).

Histochemically observed concentrations of the above mentioned four enzymes *viz.*, aldolase, LDH, SDH and MDH are represented diagrammatically in figure 49.

DISCUSSION

The present study on glycogen and enzymes like aldolase, LDH, SDH and MDH in the gizzards of adult birds, showing structural and functional variations according to the type of food, have shown very minor variations in their concentration and pattern of distribution. From the observations made herein, it becomes quite evident that the muscles of the gizzards of carnivorous and granivorous species of birds are well equipped with an efficient machinery to utilize carbohydrate. A high concentration of SDH and an appreciable concentration of MDH with a pronounced response towards BDH and G6PDH (chapter 7) and a very low level of glycogen when taken together might be indicative of a slightly higher level of lipid catabolism in comparison to that of carbohydrate in the gizzards of frugivores and nectar feeder as is also referred to in chapter 7. Both omnivores and insectivores, however, appear to have an almost equal and identical capacity to metabolize carbohydrates and when taken together with their degree of lipid metabolism (chapter 7) tend to occupy a position intermediate to that between granivores and carnivores on one hand and frugivores and nectar feeder on the other.

An important and significant aspect that has been brought out by the studies on the metabolic features of the voluntary muscles of vertebrates, specially those of avian and mammalian species, is that whereas the slow, sustained contractile fibres (red) are chiefly dependent on lipid catabolism, the quick, tetanic contractile fibres (white) are better adapted for carbohydrate catabolism

(George & Jyoti, 1955; George & Naik, 1958; Nene & George, 1965; Denny-Brown, 1929; Stein & Padykula, 1962; Aleksakhina, 1953; Gasper, 1957; Ogata & Mori, 1964). Based on this scheme of biochemical characterization of muscles, the expectance of a moderate and uniform incidence of lipid catabolism in the gizzard smooth muscles of all types of birds appears to be [illegible] reasonable and tenable as gizzard is an organ which could be functionally associated with the process of slow and sustained contractility. In fact such a conclusion has been reached in the present study with reference to lipid metabolism (chapter 7). The present observations on the activities of aldolase and LDH tend to indicate the operation of carbohydrate catabolism, even at a low minimum level, in the gizzards of all the herein mentioned groups of birds. The utilization of carbohydrate sources, even to a low level, however, seems to gain justification not only from the fact that there is always a minimal level of carbohydrate catabolism in all the animal tissues but also from the possibility that the gizzard, at times (immediately after digestion of food in the gizzard) might have to engage itself in quick, tetanic mode of contractions to evacuate the contents into the duodenum. However, the higher grade of carbohydrate metabolism indicated in the case of granivores and carnivores also tends to highlight the possibility that the gizzards of these birds have a greater exigency to engage in quick, tetanic type of contractions keeping in agreement with the hard and tough nature of the food ingested by these birds and the resultant mechanical action gizzards might have to put in thereby. In contrast, the comparatively lower level of oxidation of carbohydrates by the gizzards of frugivores and nectar feeder and of an intermediary level of oxidation of the same by the gizzards of omnivores and insectivores also seems to gain credulence and validity in this light, when reflected on the type and nature of the food consumed by these groups of birds. It, thus, appears that the different levels of carbohydrate metabolism, though not of a wider nature, observed in the gizzards of various groups of birds presently under investigation could, proportionately, be related to the type of organic food matter they are associated with; being of a low level where the food is of a soft and fluid consistency (frugivore and nectar feeder), of high order where the food is of hard and tough nature (granivores and carnivores) and of an intermediary grade where the food is of a mixed or intermediary nature (omnivores and insectivores).

Finally, two interesting aspects that have come to light in the course of the present study are the possibilities of a poor capacity of smooth muscles (at least of gizzard) to store glycogen and the thereby inherent property of gizzard smooth muscles to utilize more of circulating blood glucose. The latter aspect~~s~~ receives adequate support in this connection not only from the presently observed activities of glycolytic enzymes and a poor concentration of glycogen but also from the clinical observations of a high vascularity of the alimentary canal (Schofield, 1968).