FURTHER STUDIES ON THE ALIMENTARY TRACT OF THE MILK-FISH *CHANOS* IN RELATION TO ITS FOOD AND FEEDING HABITS

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ABSTRACT

In the alimentary tract of the fish *Chanos*, a pair of complicated pharyngeal pockets, the spiral mucosal folds in the oesophagus, a spacious corpus with giant mucous cells and massive gastric glands and a highly muscular triturating pylorus are peculiar features. They are special adaptations to a diet consisting of algae and molluscs mixed with mud and sand particles. Analysis of the gut contents of different age groups of the genus *Chanos*, points out that feeding habits change from fry, through juvenile to adult, and that the adult fish is not exclusively a plankton feeder.

INTRODUCTION

The morphology and histology of the alimentary canal of teleostean fishes have attracted the attention of many workers. Reviews of the various investigations on the subject have appeared from time to time and therefore, it may be necessary here to confine to the observations published on the genus *Chanos*.

Chacko (1945) made a brief note on the food and alimentary canal of *Chanos chanos* (Forskal), which he (1949 and 1956) followed up by a detailed list of the food items present in the gut. Kapoor (1954) has given an account of the suprapharyngeal organs of this fish and has pointed out that it is more related to the digestive than to the respiratory system. Chandy (1956) described in detail the spiral mucosal folds of the oesophagus. Tampy (1958), has critically analysed the food of *Chanos* in three arbitrary age groups, *viz.*, (1) frys and fingerlings, (2) juveniles and (3) adults. His analysis points out, as earlier suggested by Hiatt (1944), that there are possible changes in the food habits of these fishes, accompanying age and growth.

While studying the oesophagus of *Chanos* the senior author observed that the stomach presented certain peculiarities which needed investigation. Further as the accounts of the various organs are scattered in the literature, it is necessary to make a consolidated account of the whole alimentary canal and review the existing knowledge in relation to the feeding habits of this commercially important food fish.

MATERIAL AND METHODS

Specimens of adult *Chanos* fixed in Bouin's fluid were obtained from Kottayam Biological Supplies. With a view to tracing the course of the food-particles, frys specially fed on Carmine, were obtained from Mr. P. I. Chacko, Director, Madras Fisheries. For histological studies, sections were cut at 6–8μ and were stained with Delafield's Haematoxylin and counter-stained with alcoholic Eosin. Mallory's Triple stain and Hiedenhains Haematoxylin were also used as alternative stains. Meyer's Mucicarmine was used for the detection of mucous cells.

Ecological Considerations

Chanos chanos is a large Clupeoid fish of the family Chanidae having a wide distribution in the Indo-Pacific Ocean, from Red Sea to Hawaii. It is thus an essentially marine form; but it invades the inshore waters for breeding. Incidentally it may be mentioned that *Chanos* gets acclimatized to fresh water and can be cultured in ponds. Chidambaram and Unnie (1946) have shown that the maximum growth of *Chanos* is in freshwater, which clearly indicates that there is a change in its feeding habits. The larvae, frys and fingerlings enter tidal mudflats, canals and estuaries. There is nothing on record to show when they go back to sea. The genus *Chanos* is thus an interesting one, which follows certain cyclic pattern in its life-history in different ecological conditions.

Like the majority of Clupeid fishes it has been customary to classify the Milkfish as a plankton feeder. This is to some extent supported by the edentulous nature of the buccal cavity and the presence of long gill rakers which serve as filtering apparatus.

Studies on the gut contents of adult *Chanos* point out that it feeds on a variety of organisms, both plant and animal. It would be worthwhile to analyse these in detail here. Tampy (1958) critically examined the food items in different age groups of *Chanos* and came to the following conclusions. In the food of the fry and the fingerlings diatoms constitute the major portion and in the juveniles, there is a dominant occurrence of blue green algae but a relatively smaller proportion of diatoms. Nematode worms, spironid larvae (polychaetes), crustacean eggs and larvae, copepods, small gastropods and spats of Lamellibranchs constitute the chief food items in the adult fish. In brief, diatoms constitute only a relatively small proportion, compared to other algae in the adult gut (Tampy, 1958), It has also been observed that there is always an admixture of sand and mud particles. The above analysis points out that the food and feeding habits of *Chanos* differ in pattern from fry to adult, By the present study it has been possible to correlate the morphology and histology of the various parts of the alimentary tract to the feeding habits of the fish.

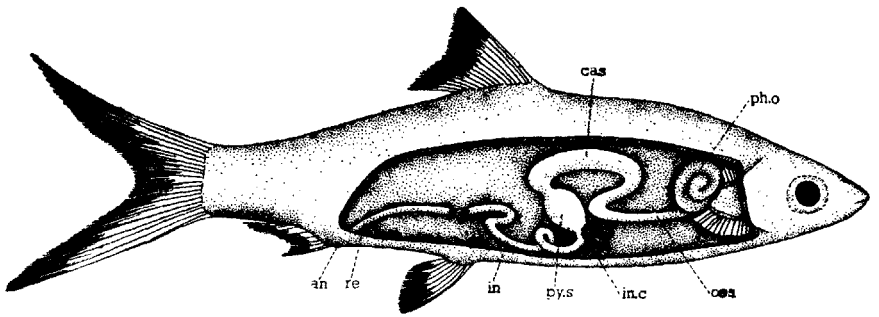
Gross Anatomy

The alimentary tract of *Chanos* consists of the buccal cavity, pharynx with pharyngeal organs, oesophagus, stomach, intestine with its numerous caeca and rectum (Fig. 1). The buccal cavity and pharynx constitute the organs of ingestion or the 'Kopfdarm' while the rest of the organs are the 'Rumfdarm' of Banki (1936) (op. cit. Brown 1957). The oesophagus and the stomach together form the foregut, the intestine, the midgut, and the rectum, the hindgut. Each of the major regions of the digestive system of this fish is distinctly demarcated externally and is therefore seen easily in gross anatomy.

The mouth is small, transverse and terminal. It is bounded by jaws which are without teeth. None of the bones of the cranium or branchial arches bears teeth. The buccal cavity is small and immediately leads to the more spacious pharynx. The gill arches are four in number and each one bears on its inner border rows of gill-rakers which are united at their ends by a common connective tissue. The gill-rakers are numerous, close-set, long and slender. Those of the successive arches intersect the gill slits so as to form an effective sieve.

A distinctive feature of the pharynx of *Chanos* is the presence of a pair of pharyngeal pockets, formerly known as 'gill-helix' or "suprabranchial organs"—a feature also shared by other Clupeid genera, like *Gadusia*, *Hilsa* and *Dorosoma*. The pharyngeal organ consists of a highly muscular sac and a canal passage, internally lined by rakers. Anatomical and histological studies point out that these organs are diverticula of the pharynx. (For a full description, see Kapoor, 1954*a*).

Microscopical study of the contents of the pharyngeal organ shows the presence of food particles along the canal passage as well as in the sac. Carmine-fed fingerlings corroborated these findings, pointing out that the organ is concerned in collection and direction of food from the pharynx to the oesophagus.



TEXT-FIG. 1.

Diagram showing alimentary canal of *Chanos chanos* (Forskal). *an.*, anus *ca.s.* cardiac stomach; *in.*, intestine; *in.c.*, intestinal caeca; *oes.*, oesophagus; *ph.o.*, pharyngeal organ; *re.*, rectum.

After giving off the pharyngeal organs, the alimentary tract narrows considerably and opens into the oesophagus. The oesophagus pierces the septum transversum and emerges into the peritoneal cavity. The oesophagus is a straight, narrow, somewhat flattened tube, of more or less uniform calibre, with a fairly thick wall. On opening the oesophagus by a median longitudinal incision, it is seen that the mucosa is raised into a series of closely arranged folds, about 20–22 in number, making a spiral coil, like the threads of a screw along the whole length of the oesophagus. (For full details, see Chandy, 1956).

Following the connotation of the comparative anatomists, the stomach or ventriculus in a vertebrate animal is defined as that part between the terminus of the oesophagus and the beginning of the intestine. Accordingly, the stomach in *Chanos* occupies an extensive portion of the alimentary canal, between the oesophagus anteriorly and the cluster of intestinal caeca, posteriorly. On uncoiling the alimentary canal, the stomach is seen to consist of two distinct parts, the corpus or proventriculus and the pylorus or gizzard. The corpus is the descending loop and the pylorus the ascending loop, which run parallel to the oesophagus and at the anterior level of the latter, continues into the intestine.

The corpus portion of the stomach presents differential thickening, which is discernible externally and the presence of three distinct zones in it has been corroborated by histological study. The pyloric division, demarcated by the pyloric constriction, is modified into a pyriform gizzard with glistening wall. The gizzard is a highly muscular organ with a narrow lumen which communicates with the intestine.

The intestine is a long narrow tube which falls into many convolutions. It does not show differentiation into duodenum and ileum. The anterior region, following the gizzard, receives internally a series of openings about 18 in all, which are arranged in three piles. These openings communicated with the intestinal caeca, numbering about 120 to 150. Intestinal caeca are simple or branched finger-shaped organs of different lengths. They form a compact cluster and lie in the space between the pyloric stomach and the loops of the intestine. It is more or less of uniform diameter and passes imperceptibly into rectum, which is not morphologically different from the intestine.

The liver is a bilobed organ, extending over the entire length of the oesophagus which it conceals. The gall bladder is situated in between the two liver lobes. The bile duct takes a straight course posteriorly and opens into the first part of the intestine amidst the cluster of intestinal caeca. In vertebrates, the location of the opening of the bile duct lends a clue to the exact boundary between the stomach proper and intestine.

The pancreas is diffused and the different patches are scattered in the mesenterial folds surrounding the intestine and the intestinal caeca, which are also interspersed by adipose tissue. The lobes of pancreas are seen in transverse sections adhering to the intestine.

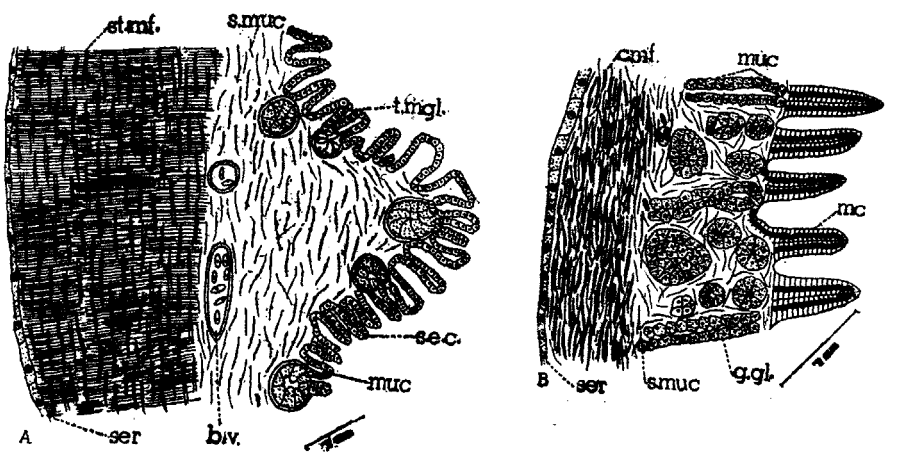
HISTOLOGY

The histology of the buccal cavity, pharynx and pharyngeal organ has already been dealt by Kapoor (1954*a*) and that of the oesophagus by Chandy (1956). The present account, therefore, deals with the histology of the rest of the alimentary tract, posterior to oesophagus.

The Stomach :

The wall of the stomach is constituted by the usual four layers, *viz.*, serosa, muscularis, submucosa and mucosa. These layers are by no means uniform throughout the extensive stomach. Their variations bring about some arbitrary differentiations, that one notices three distinct zones in the corpus as already described. The first is the anterior, transitional zone immediately following the oesophagus; the second or the middle zone lies in the descending loop and lastly the third zone which adjoins the gizzard.

The serosa is a narrow, but distinct layer of membraneous tissue, with a large number of nuclei, arranged in two to three piles. Blood vessels course between serosa and the layer of muscles beneath. The muscular layer is differentiated into an outer longitudinal and an inner but broader circular bands. Submucosa is a loose network of connective tissue and is highly variable in the different zones. Mucosa, the most characteristic tissue of the stomach, is made of columnar epithelial cells which have undergone modifications to form mucous and gastric glands.



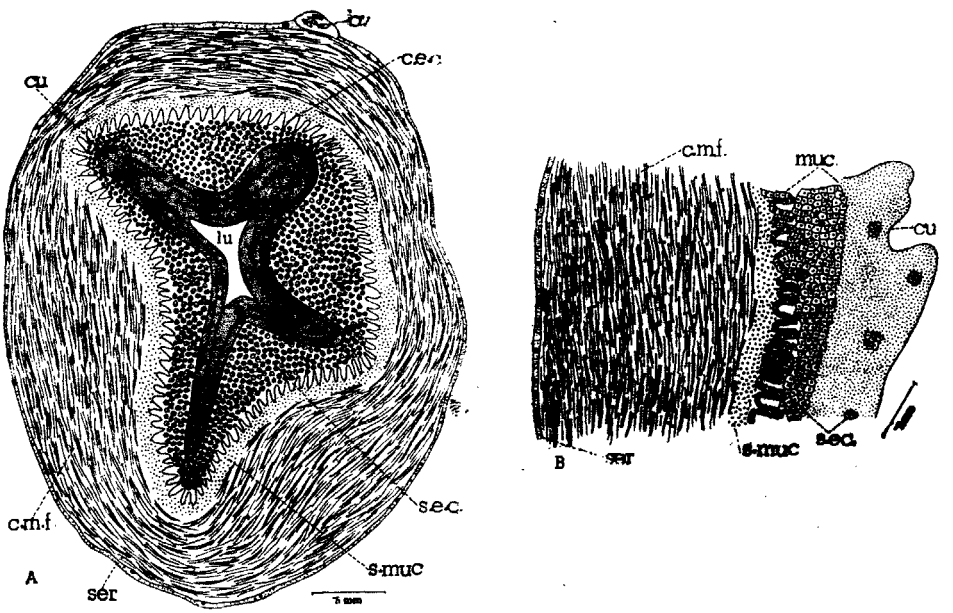
TEXT-FIG. 2.

Transverse sections—A. Transitional zone. B. Cardiac stomach of *Chanos*. *b.v.*, blood vessel; *c.m.f.*, circular muscle fibres; *g.gl.*, gastric gland; *muc.*, mucosa; *m.c.*, mucous cell; *s.e.c.*, stratified epithelial cells; *st.m.f.*, striated muscle fibres, *s.muc.*, sub mucosa; *t.m.gl.*, tubular mucous gland.

While the general histology of the stomach is as described above, slight variations in the three zones are noteworthy. In the transitional zone which is between oesophagus and stomach proper, the musculature is thick and the muscle fibres are distinctly of the striated nature. The submucosa is a broad layer with numerous large capillary vessels. In the submucosa there are present tubular glands with giant cells. Each gland is made up of cluster of cells, which are filled with a clear, hyaline fluid. The nucleus is basal and it takes a light stain with haematoxylin. They differ in size and their staining reaction from the mucous cells of the oesophagus and the gastric glands to be described later. Whether these giant glands of the first zone produce only mucous—they do give a positive test with mucicarmine—or whether they produce any enzyme, it is difficult to comment from mere histology. The mucosal epithelium resolves into numerous villi-like structures. The cells at the distal free end of the villi show complete stratification (Fig. 2A).

The middle zone presents a very characteristic and interesting feature. The columnar epithelium is modified to form the gastric glands which sink deep below the inner border. The glands are tubular and branched. The glands are numerous and form a very compact mass, occupying a major belt in the thickness of the wall (Fig. 2B). A comparatively thick zone of muscles, resolved into an outer longitudinal and an inner circular layers, surrounded the glandular belt. The muscles are of the striated nature as in the first region of the stomach. But as the corpus passes into its last zone, a change from striated to smooth muscles is clearly visible. This is an interesting feature of the histology of the stomach and points out that a major portion of the corpus is under voluntary control of the fish.

The third or the last zone is characterised by an extremely thin peritoneum and a thin smooth muscle layer, where circular layer of muscles is distinctly seen,



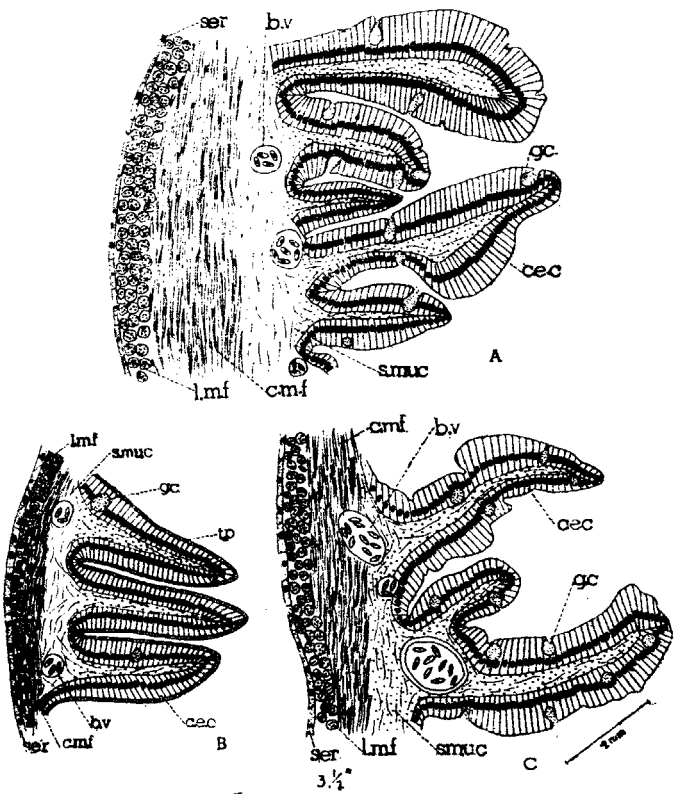
TEXT-FIG. 3.

Transverse sections—A. Pyloric stomach of *Chanos*. B. Same much enlarged *b.v.*, blood vessel; *c.o.s.* columnar epithelial cell; *cu.*, cuticle; *c.m.f.*, circular muscle fibres, *lu.*, lumen; *muc.*, mucosa; *ser.*, derosa; *s.e.c.*, stratified epithelial cells; *s.muc.*, submucosa.

while the longitudinal muscle fibres are seen with difficulty. The mucosa is an insignificantly thin layer with little or no glands.

The wall of the pylorus or gizzard is composed of the same series of coats as those of the corpus, *viz.*, serosa, muscularis, submucosa, and mucosa (Fig. 3A). But each tunic in it has undergone great modifications. The serosa is very much reduced and consists of few layers of cells. Blood capillaries are seen to course along it. The muscular layer reaches the maximum degree of specialisation. This layer is composed solely of circular bundles of smooth muscle, the longitudinal muscle bundles being totally absent. The hypertrophied circular layer of muscles thus constitutes the bulk of the wall.

The submucosa is quite distinct and subtends the villi of the mucosa. The mucosa is a characteristic feature of this region. It is disposed into a large number of villi-like folds which are composed of epithelial cells with prominent nuclei. No glands are present. Inner to the mucosal layer are discernible a stratified epithelial layer and a layer of non-cellular cuticle or keratinised tissue. Scattered in the matrix of the cuticle are groups of isolated cells broken off from the epithelium below. The cuticle shows a tendency to become more and more dense towards the lumen (Fig. 3B). It may be mentioned here that in fingerlings of 3½–4″ length the cuticular layer is absent in the gizzard.



TEXT-FIG. 4.

Transverse sections—A. Intestine. B. Intestinal caeca C. Rectum of *Chanos b.v.*, blood vessel; *c.m.f.*, circular muscle fibres; *c.e.c.*, columnar epithelial cells; *g.c.*, goblet cell; *l.m.f.*, longitudinal muscle fibres; *muc.*, mucosa; *s.muc.*, submucosa; *t.p.*, top plate.

The Intestine :

The spacious lumen of the intestine is surrounded by the four layers, serosa, muscularis, submucosa and mucosa (Fig. 4A).

The serosa is a delicate membrane enveloping the muscularis. The muscularis is composed of an outer longitudinal and an inner circular layer, both of non-striated nature. The submucosa is a thin layer ramifying into the mucosa. Blood corpuscles, evidently of the leucocytes series, are scattered in the submucosa. The mucosa is a prominent layer of columnar epithelium and is characterised by simple or branched long villi. The epithelial cells are narrow and long with basal nuclei and are arranged compactly. Large mucous cells, in various stages of activity, is a regular feature throughout the coils of the intestine. No glands have been observed. Blood capillaries laiden with corpuscles are abundant.

The Intestinal caeca :

Microscopical study of the intestinal caeca points out to the fact that they are extensions of the intestine. The histology of both the organs is very much alike. However, a noteworthy difference is the comparatively thinner musculature in the caeca. The mucosal villi are unbranched, more slender and pointed. Free border has been detected in various preparations. Mucous glands are present in large numbers in the caeca. (Fig. 4B).

The Rectum :

That the last portion of the intestine is modified into a distinct rectum is amply proved by its histology. The usual four layers are present.

The serosal layer is thin but distinct. The muscularis is much thicker than that of the intestine and the circular layer of muscles is more conspicuous than the longitudinal layer. The submucosa is a loose network made of an anastomosing strands of connective tissue, with a large number of vacuolated spaces and rich in vascular supply. The mucosa made up of columnar cells, falls into broad, blunt villi, simple or branched. Large unicellular goblet cells are present all along the mucosa (Fig. 4C).

Discussion

In reviewing the knowledge of the digestive system in relation to food and feeding habits of *Chanos*, it is necessary to compare it with other members of its order. Like the majority of the Clupeids, the mouth is edentulous. The gill rakers form a sieve to strain the food particles from the incurrent water. Like *Hilsa*, *Gadusia* and *Dorosoma*, *Chanos* also possesses pharyngeal pockets which according to the authors are food procuring device.

The presence of a spiral mucosal fold in the oesophagus, with its rich supply of mucous glands is a unique feature in *Chanos*. The transition zone, between the oesophagus and the cardiac stomach, has in its submucosa many giant tubular mucous glands. The copious production of mucus may be correlated to the composite food items of diatoms, other algae, gastropods, lamellibranchs and concomitant admixture of sand and mud.

The stomach is concerned with the storage of food and gastric digestion. The size for storage is influenced by two factors : the nature of the food, and the duration of intervals between the meals. Tampy (1958), reports that he noticed in the stomach of some of the adult fishes, only mucoid matter in the form of a white paste, and came to the conclusion that the fishes were starving. From this it may be surmised that *Chanos* may be an irregular feeder. The stomach of *Chanos* is considerably large and complex in comparison to the rest of the alimentary canal.

The size of the stomach and the capacity of the cardiac zone for dilatation point out that it serves a very important function of food storage. The abrupt changes in the direction of loops of the stomach obviously check the quick passage of food from the stomach to the intestine.

The extension of the striated muscles of the oesophagus over part of the stomach has been observed in a few fishes. The presence of such muscle fibres in *Chanos* gives the anterior region of the stomach voluntary control, whereby the food could be regurgitated whenever necessary.

Histological studies reveal that there is a large area occupied by the gastric glands. This enables the fish to secrete large amounts of gastric juice making the gastric digestion efficient, before the food is passed on to the gizzard.

A highly muscular gizzard (grinding mill) is present in *Chanos*. The most striking feature in the histology of the gizzard is the presence of two supplementary layers, the stratified and the cuticular layers, apparently developed from the epithelium itself. That the cuticle arises by the modification of the epithelium is amply supported by the presence of detached and scattered cells in the cuticle. In the gizzard, following the mucosal epithelium, there is a region of stratified epithelium, an adaptation to withstand its wear and tear. It may be mentioned here that since the stratified epithelium is inefficient as an absorptive membrane, the gizzard only performs the function of trituration. A cuticular region is present and it affords protection from the gritty and hard food materials the fish takes. The first layers of the cuticle, by fusion of contiguous areas, form the innermost dense cuticle of the gizzard. All the previous authors, who have worked on the gizzard of fishes, are of opinion that the cuticular layer is formed by the secretion of mucous glands. But in *Chanos* such glands are totally absent in the gizzard. The present study points to a different mode of cuticle formation in gizzard. The cuticle in *Chanos* gizzard arises by stratification and cornification of the epithelium, as is the method of origin of cuticle in the epidermis of skin.

Differences in the nature of the food of young and adult *Chanos* have been observed by Tampy (1958). He points out that the adult fish takes more of coarser food particles, whereas the young of *Chanos* is exclusively a plankton feeder. The histology of the gizzard of the fingerlings shows that all the layers of the adult fish, except the cuticular layer, are present. The acquisition of the cuticle in the gizzard by the adult fish is a subsequent adaptation when the change-over takes place to a harder type of food.

Blood corpuscles in large numbers scattered in the submucosa are present in the intestine. It may be inferred that as in other Teleosts, the wall of the intestine is a haemopoietic organ.

The free border which is an additional layer of absorption is absent in the intestine and rectum. But its presence in the intestinal caeca supports the view that it is primarily an absorption region.

Several fishes, belonging to the different orders, are known the possess gizzard. One of the well known orders with gizzard is the Mugilidae. Gazzawi (1935), Ishida (1935), Pillay (1953), and Mahadevan (1950) have worked out in detail the digestive system of a few species of *Mugil*. Among the Clupeids the gizzard of *Dorosoma cepedianum* and *Gadusia chapra* have been described by Weir and Churchill (1945), and Kapoor (1958) respectively. The authors (unpublished) have observed the presence of a gizzard in *Colisia fasciata* of the order Anabantidae. All these genera, though unrelated phylogenetically, show similar modifications The similarity is explained on the basis of their feeding habits. *Mugil* sp., *Gadusia chapra* and *Colisia fasciata* are mudfeeding forms, grovelling in mud for organic debris, algae and plant tissues. *Chanos* also takes in a good amount of mud and sand along with diatoms, other algae and molluscs. This appears an interesting case of convergence in evolution.

Chanos is thus a mixed feeder, a habit, probably it has acquired because of its migratory habits. Its digestive system recalls that of a grain-eating bird, with its crop, large cardiac portion and well developed gizzard. The structure of the stomach is elaborate in *Chanos*. The zonal differentiation is marked and the gastric glands are highly developed. The giant mucous cells, the massive complicated gastric glands, and the powerful gizzard with cuticular lining are indications of an advanced state of physiological activity.

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