The thesis entitled "Studies on the functional morphology, anatomy and histo-physiology of the digestive system in relation to food and feeding habits in some Indian freshwater perches" presents the results obtained from the investigations carried out in the Fisheries Laboratory, Department of Zoology, Burdwan University, during the period April, 1974 to September, 1977. The thesis covers 391 pages including 16 tables with 74 text figures.

The thesis records observations on the functional morphology, anatomy, histology and physiology of the digestive system of four Indian freshwater perches, viz., *Anabas testudineus*, *Colisa fasciata*, *Ambassis nama* and *Ambassis ranga*. The following are some of the important results:

A. **Morphology and anatomy**:

1) *Anabas testudineus* is a carnivorous mid-feeder, *Colisa fasciata* an omnivorous, mid-feeder while *Ambassis nama* and *Ambassis ranga* are both carnivorous, surface-feeders.
2) The mouth of *Anabas testudineus* is wide, slightly upturned, non-protractile and the lips are provided with highly specialized maxillary and mandibular teeth adapted for the carnivorous feeding habit. In *Colisa fasciata*, the mouth is upturned and protractile. The jaw teeth are small and feeble and are employed for nibbling aquatic vegetation and catching small prey. The mouth in *Ambassis nama* and *Ambassis ranga* is upturned and protractile and adapted to a surface-feeding habit. The jaw teeth are small, strong, sharp and hooked and employed for procuring small slender animals.

3) In *A. testudineus*, the bucco-pharyngeal region comprises vomerine teeth in addition to palatine, pharyngeal and horny pad teeth. They are large in size and strong. In *Ambassis nama* and *A. ranga*, the palatine, pharyngeal and horny pad teeth are small and pointed. All these teeth work against each other for trituration and mastication of the ingested food. In *Colisa fasciata*, the pharyngeal and horny pad teeth are minute and weak but adequate for dealing with the minute animal food organisms ingested.

4) The gill-rakers in *Anabas testudineus* are plate-like structures provided with minute pointed teeth, and
Anabas testudineus, gizzard-like in Colisa fasciata and tubular in Ambassis nama and A. ranga. The pyloric stomach is more muscular in all the four species and is a region associated with crushing food materials.

8) Pyloric caeca are present only in Anabas testudineus (four) and Colisa fasciata (two). The caeca are situated at the junction of the pyloric stomach and the intestine. The mucosal folds of the caeca are similar in nature to those of the intestine and may help increase the total absorptive area.

9) The length of the intestine reflects the nature of the food and feeding habits of the fishes studied. In the carnivorous Anabas testudineus, Ambassis nama and Ambassis ranga, the relative length of the gut (R.L.G.) is low. In the former species it is 0.42 and the latter two species, it varies from 0.35 to 0.39. The R.L.G. in the omnivorous Colisa fasciata is high (4 to 5). In the latter species, the intestine is extremely long and coiled in the manner of a cork-screw. In Anabas testudineus, the intestine is slightly looped.

The intestine of all the four species studied is divisible into anterior, middle and posterior regions on the basis of the differences in the mucosal folds.
These folds are generally longitudinal in nature except in the posterior intestine of *Colisa fasciata* where it is transverse. The mucosal folds of the intestine are less raised in the latter species.

10) The rectum of *Anabas testudineus* is demarcated from the rest of the intestine by the ileo-rectal valve. In the other three species, the rectum can be identified by the typically shorter, shallower and longitudinal mucosal folds.

11) The hepatopancreas is the principal digestive gland in all the four species studied. A compact and discrete pancreas could not be identified. The pancreatic acini are present in a primitive diffused condition and are dispersed within the lobes of the hepatic tissue and mesenteries, along the sides of the alimentary canal, gall bladder, pyloric caeca etc.

The gall bladder is a thin-walled, greenish sac-like structure lying below the right lobe of the hepatopancreas. It communicates with the intestine by means of the bile duct.
B. **Histology:**

1) The mucosa of the lip, bucco-pharynx and the anterior oesophagus in all the four species studied, is made up of stratified epithelium. The stratum compactum of the buccal cavity, tongue and pharynx in *Anabas testudineus* is thick and participates in the formation of lamina propria of the taste-buds.

2) The presence of taste-buds and mucous cells in the alimentary tract reflects the feeding habits of the fishes studied. Taste-buds are present from the lip to the anterior oesophagus in all the four species. They are more abundant and well developed in the lips of *Anabas testudineus* and *Colisa fasciata* which have primarily taste-feeding habits. Both *Ambassis nama* and *Ambassis ranga* are sight-feeders, as a result of which taste-buds are very few and poorly developed in their lips. In the latter species and in *C. fasciata*, taste-buds are more developed and numerous in the anterior pharynx. In *Anabas testudineus*, they are almost constant in number in the bucco-pharyngeal region.

The abundance of mucous cells in the bucco-pharyngeal region facilitates swallowing of the food particles by copious mucous production. The buccal region
of *Ambassis ranga* contains few mucous cells. The tongue-like structure in *Anabas testudineus* also bear a few taste-buds and numerous mucous cells.

3) The anterior and middle regions of the oesophagus in all the four species is provided with stratified epithelium. The posterior oesophagus contains columnar epithelium except in *Anabas testudineus* where it is provided with both stratified and columnar epithelial cells. The villi are branched in the anterior oesophagus. The presence of functional taste-buds in the anterior oesophagus in all the four species suggests that the sense of gustation extends upto the anterior oesophagus. The abundance of mucous cells in the oesophageal mucosa helps facilitate the movement of food particles. The muscularis of the oesophagus is thick and comprises an inner longitudinal and an outer circular layer in *Anabas testudineus, Ambassis nama* and *Ambassis ranga*. In *Colisa fasciata*, it shows a reverse arrangement. The longitudinal layer is most developed along the dorsal and ventral aspects of the oesophageal tube in *Ambassis nama* and *Ambassis ranga*.

4) The superficial epithelium of the cardiac stomach in all the four species studied is made up of simple
columnar cells. This epithelium in *Anabas testudineus* contains specific mucous cells - a rare feature met with in teleosts. In the other three species, the apical border of the columnar epithelium has a mucoid nature. The superficial epithelium has a dual function - secretion of mucous and food absorption. The glandular epithelium contains a large number of simple, tubular gastric glands which open into the lumen through the gastric crypts. These glands contain only one type of secretory cell. In *Anabas testudineus*, mucous producing tubular mucous glands are present in the glandular epithelium of the anterior region of the cardiac stomach. The muscularis in this region is thick in all the four species studied. In *Ambassis nama* and *A. ranga*, however, the muscularis is constituted of two longitudinal muscle layers - an inner and an outer, with a circular muscle layer in between - a unique feature being reported here for the first time.

5) The mucosa of the pyloric stomach is made up of columnar epithelial cells. The villi are longer than those in the cardiac region. The apical border of the columnar cells are mucoid in nature in *Anabas testudineus*. Besides, the pyloric stomach indicates a more primitive
nature, due to the presence of tubular mucous glands or pyloric glands. The muscularis is thicker than that in the cardiac stomach in all the four species.

6) The mucosa of the intestine, pyloric caeca and rectum is made up of columnar epithelial cells. The villi of the anterior intestine show secondary infoldings. In the posterior intestine the villi are short and mucous cells are more numerous. Pyloric caeca contain very few mucous cells. Deeply staining lymphocytes are also present in the basal region of the columnar cells of the mucosa of the intestine, pyloric caeca and rectum. Eosinophilic granular cells are present in the submucosa of the intestine, pyloric caeca and rectum. They are probably secretory in nature. The muscularis is most developed towards the posterior region of the intestine. The intestinal wall is thicker in the carnivorous species. A supplementary layer of circular muscle is present in the submucosa of the intestine in *Ambassis ranga* - a feature being reported here for the first time. This layer also, enters the lamina propria. Muscularis of the pyloric caeca is very thin. Numerous mucous cells are present in the rectal mucosa. The muscularis of the rectum is extremely thick and helps contraction.
of the rectal wall for easy defecation. The villi of
the rectum are short and broad.

7) The hepatopancreas in all the four species studied,
is made up of hexagonal hepatic cells and pyramidal or
cuboidal pancreatic acini. The latter are also present
in the walls along the sides of the alimentary canal and
mesenteries. The acini are arranged in one to many rows
around the blood capillaries. Acini lying in close
proximity of blood capillaries are columnar in shape.
Each exocrine cell is provided with a basal homogeneous
portion containing a large spherical nucleus and an
apical portion containing zymogen granules. Pancreatic
acini are larger in size in the omnivore *Colisa fasciata*
and the zymogen granules are larger in size. In *Ambassia
namu* and *Ambassia ranga* also, zymogen granules are
heavily deposited. In *Anabas testudineus*, however, they
are small in size and few in numbers.

8) Histologically, the gall bladder shows almost
similar features in all the four species studied except
in the nature of the folds of the columnar epithelium.
In *Ambassia ranga*, the folds are more complex than in
the other three species. A few mucous cells are present
in the mucosal layer in *Colisa fasciata*. These cells
secrete mucous which probably increase the viscosity
of the bile.
C. **Physiology**:

1) A low pH (4.0 to 6.2) has been recorded in the stomach of all the four species studied. In *Anabas testudineus*, however, a very low pH has been recorded in the pyloric stomach (4.0 to 5.5) and high pH in the hepatopancreas (8.0 to 9.0), gall bladder (7.0 to 8.0) and intestine (8.5 to 9.5). The pyloric caeca in *A. testudineus* showed a weak to moderate alkaline pH (7.9 to 9.0), whereas in *Colisa fasciata*, the caeca recorded a weakly acidic to weakly alkaline nature (6.8 to 7.5).

2) Qualitative estimations of the enzymes in the digestive tract of the four species of fishes reveal that most of the protein, fat and carbohydrate splitting enzymes, viz., protease, lipase and amylase are secreted by the hepatopancreas and intestine. The cardiac stomach, pyloric stomach, pyloric caeca and the gall bladder also secrete the digestive enzymes. The relative activity of the digestive enzymes have been correlated with the dietary of the fishes. A weak to moderate amylase activity has been recorded from the alimentary canal of the carnivorous *Ambassia nama* and *Ambassia ranga*. But a moderate to strong activity of amylase has been recorded in the alimentary tract of *Anabas testudineus* inspite of its being carnivorous. This feature indicates that it can also consume carbohydrate food. Protease activity is more pronounced in the carnivorous species.