THE ANATOMY AND HISTOLOGY OF THE ALIMENTARY CANAL OF A HERBIVOROUS FISH TILAPIA MOSSAMBICA (PETERS)*

BY S. M. KAMAL PASHA

(Department of Zoology, Presidency College, Madras)

Received February 14, 1964

(Communicated by Dr. S. Krishnaswamy, F.A.S.C.)

This work represents a part of a series of studies on the structure of the alimentary canal in relation to feeding habit of fishes. Tilapia mossambica is an exotic cichlid fish which was imported to Madras from Ceylon in 1952. It has bred prolifically and is present in fresh and brackish waters in large numbers. It thrives well in sea-water also. This paper gives an account of its alimentary canal in relation to its herbivorous feeding habit. A similar account of an omnivorous fish Mystus gulio was previously given (Pasha, 1964).

The material was supplied by the fisheries station at Adyar. Standard fixatives and staining techniques were used throughout the investigation.

FOOD, FEEDING HABITS AND GROSS ANATOMY

The stomach contents of about 25 fish were examined. The contents consisted chiefly of algae. There were a few higher aquatic plants. In the laboratory they fed on algae that were present on the stones and on the sides of the glass. Under starvation, they took rice and even bits of earthworm. According to Peter Devadas and Chacko (1953), Tilapia mossambica has a number of favourable qualities which make this fish ideally suited for culture in South India. One of the features they have reported on is that it is non-cannibalistic.

The alimentary canal of Tilapia mossambica consists of the mouth, buccal cavity, pharynx, oesophagus, stomach, intestine and rectum. Pyloric caeca are absent (Text-Fig. 1). The mouth is terminal. The gape of the mouth is about 1.7 cm. in a fish measuring 12 cm. The lips are thick. The lower jaw is a little longer, consequently the mouth opens rather upwards. The upper jaw is protrusible; when it is protruded the mouth becomes actually

* Formed part of the thesis approved by the University of Madras for the M.Sc. degree.
terminal. Both the jaws bear teeth. Each tooth has its projecting end slightly flattened and divided into two or three teeth, like those of a saw. In the upper jaw the teeth of the outermost row are longer and their position is such that when the upper jaw is protruded, the teeth are so thrust forward as to be used to scrape off the surface of stones, water plants etc.

There is a rudimentary tongue which has its anterior end free and the posterior part attached to the floor of the buccal cavity. The floor of the cavity is flat and the roof is arched. The buccal cavity is broad anteriorly and narrows down posteriorly. The oral valves are present just behind the lips. The maxillary valve is broader. The mucous membrane lining the buccal cavity is thrown into folds, both longitudinally and transversely forming a network. It is always slimy due to copious secretion of mucus.

The pharynx, where the gills are attached, opens out through the gill slits. The gill rakers are reduced to small knob-like projections. Consequently, the fish cannot collect finer particles of food as a plankton feeder does. The mucous membrane covering the pharynx is a continuation of the buccal cavity but there are no folds visible to the naked eye. The pharynx bears dorsal and ventral teeth patches or apparatus which are bulged and cushion-like. The teeth of the pharyngeal patches are all alike. They are long with slightly curved pointed tips. The dorsal and ventral patches of teeth can be moved, the dorsal patches working against the ventral patches.

Das and Moritra (1955) are of opinion that gill rakers, pharyngeal and other teeth patches crush and masticate food in omnivorous and carnivorous fishes. According to Al-Hussani (1949) the relative development of the pharyngeal masticatory apparatus (horny pad, pharyngeal teeth) bears a
direct relationship to the amount of plant food in the diet. In *Tilapia mossambica*, probably the oral teeth are used for scraping the plant materials and the pharyngeal dentition which is well developed is used for grinding.

The pharynx leads into the oesophagus which is cylindrical and short, measuring only 0.8 cm. in a fish 13 cm. in length. The oesophagus has complex longitudinal folds which are continuous with those of the stomach. Posteriorly it leads into a bag-like structure, which is the corpus or body of the stomach. This serves as a reservoir for the ingested food. The shape of the stomach largely depends on the amount of food contained. The pyloric stomach starts as a small tube from the right side of the stomach very near the junction between the oesophagus and the body of the stomach. A pyloric construction is present. The proximal part of the intestine is in the form of a U-shaped loop, the space between the two limbs of the loop being occupied by a projecting lobe of the liver. The rest of the intestine is coiled in the form of a cork-screw. The intestine is very long measuring 103 cm. in a fish 13 cm. long (Table I). It is about eight times as long as the fish. Great length of the intestine is usually a characteristic feature of herbivorous forms. An intestine-rectal value is not present. Therefore, the posterior part of the intestine which has shallow mucosal folds may be considered as the rectum.

**HISTOLOGY**

The lip is made up of mucosa and submucosa (Pl. XV, Fig. 1). The mucosa consists of stratified epithelium, basement membrane and a thin stratum compactum. The epithelium is thrown into very shallow folds and has many layers of cells. The cells have different shapes. They are polyhedral at the surface, columnar in the centre and of irregular shapes at the bottom. Many of the cells of the topmost layers have no distinct nuclei and some of these cells do not show a compact arrangement. Probably these are worn-out cells. There are numerous taste-buds which are elongated and flask-shaped. They are found on the papillary projections of the submucosa. Each taste-bud encloses a few elongated cells which stain deeply and have elongated processes forming a compact bundle. Presence of a large number of taste-buds indicates that the fish has a well-developed gustatory faculty. Mucous cells are completely absent. The submucosa is made up of loose connective tissue which is areolar in nature.

The buccal wall is made up of mucosa, submucosa and muscularis. The mucosa consists of stratified epithelium, basement membrane and stratum
compactum. The mucosa of the roof of the buccal cavity is not uniform throughout. Anteriorly, it is more or less like that of the lips, though the folds are slightly deeper (Pl. XV, Fig. 2). It has a typical stratified epithelium like that of the lips. Mucous cells are absent though they are present in the floor. However, a little posteriorly the mucous membrane not only has more pronounced folds which are both transverse and longitudinal forming a network, but also changes from a typical stratified epithelium to one that is mostly composed of mucous cells (Pl. XV, Fig. 3). The mucous cells occurring posteriorly are mostly cylindrical and are arranged in rows. They rest on the basement membrane and extend up to the free surface of the epithelium. They stain characteristically with thionin. Taste-buds are present only in the anterior part of the buccal cavity. They resemble those of the lips. The basement membrane is thin, so also is the stratum compactum. The submucosa is in the form of a network as it is areolar in nature. The muscularis is found only in the floor of the buccal cavity and consists of inner circular and outer longitudinal fibres. All the fibres are striated.

There are two oral valves. The maxillary oral valve consists of mucosa dorsally and ventrally, made of stratified epithelium with submucosa between (Pl. XV, Fig. 4). The mucosa of the ventral side shows 6–8 layers of cells. There are mucous cells of spherical shape with basal nuclei. In addition to these mucous cells a few large spherical or elongated mucous cells with central nuclei are also present. Taste-buds are not numerous. The dorsal mucosa has the same structure as that of the ventral mucosa except that the taste-buds are very rare. The submucosa is made up of wavy fibres and shows large meshes. It is highly vascular. The mandibular valve resembles the maxillary valve, except that the dorsal mucosa shows numerous taste-buds which are borne by the papillary projections of the submucosa and that the mucous cells are also larger in number. A transverse mucosal fold just below the mandibular valve is rather broad and looks like another mandibular valve (Pl. XV, Fig. 5).

The pharynx is made up of mucosa, submucosa and muscularis (Pl. 1, Fig. 6). Currey (1939) deals with the pharyngeal region of the Carp, Cyprinus capio communis, elaborately dividing it into anterior and posterior regions on histological differences. In Tilapia mossambica the tunics are more uniform, there being only minor differences.

The mucosa is made up of stratified epithelium, basement membrane and stratum compactum which is thin. It is thrown into folds which are shallow in the anterior part of the pharynx and deep posteriorly. The stratified epithelium is not uniformly thick, and consists of from 10 to 20 layers
of cells. Superficial layers have polyhedral cells and in the base the cells are either oval or cylindrical. A large number of mucous cells occur in the epithelium. They are of two kinds. Those occurring superficially are spherical with darkly stained basal nuclei. The other kind occurs in the deeper layers, of which some are cylindrical, some spherical and some oval (Pl. XV, Fig. 6). Usually, the spherical nucleus occurs in the centre and the contents appear in the form of a network. However, in some of them the nuclei are found shifted towards their bases and the cells appear empty, probably due to the mucus having been discharged. Further study of these cells may be of significance due to the fact that the fish is a mouth-breeder. Numerous taste-buds occur, particularly in the posterior part of the pharynx. They resemble those of the lips, except that they are larger. The exposed extremity is sunk in a pit which is probably similar to the gustatory pore seen in the mammals. The epithelium is supported below by a basement membrane. The stratum compactum found next to the basement membrane is very thick and wavy in outline. It consists of fibres arranged very closely. The submucosa is extensive and consists of areolar connective tissue having very large meshes. The muscularis is in two layers, an inner longitudinal and an outer circular. Both have striated fibres.

The proximal part of the oesophagus which lies outside the body cavity consists of four layers, mucosa, lamina propria, submucosa and muscularis. The distal part lying inside the body cavity has in addition a serous layer. There are 7–8 deep folds in the anterior and middle regions (Pl. XV, Fig. 7). Posteriorly, there are more folds which are mostly shallow.

The mucosa is made up of columnar cells, goblet cells and undifferentiated cells (Pl. XV, Fig. 8). There are also a few simple mucus-secreting cells. The columnar cells occur in one or two layers throughout the oesophagus. They are present in the edges of the folds, where they are slender, broad towards the lumen and narrow towards the base. They are also present on the sides and in the crypts where they are larger. The goblet cells are numerous occurring intermingled with simple mucus-secreting cells and columnar cells (Pl. XV, Fig. 8). The undifferentiated cells of the epithelium are present in the edges of the folds and at the base of the columnar and mucous cells. Many leucocytes which may have migrated are also found scattered in the epithelium. Taste-buds are absent in the entire oesophagus. This feature has been noticed by Al-Hussaini (1945, 1946, 1947), Rogick (1931) and Sarbahi (1940) in the fishes studied by them.

The lamina propria is composed of dense areolar tissue which continues into the mucosal folds to the very tips. It is highly vascular. The sub-
mucosa resembles the lamina propria and it is difficult to distinguish them from each other but for the fact that in the meshes of the submucosa there are numerous scattered bundles of longitudinal muscle fibres. The circular and longitudinal layers form the muscularis. Both are of striated fibres. The serosa is very thin and is made up of flattened cells.

The stomach is of the caecal type. Corpus and pyloric parts are well differentiated with regard to histological details also. There are about 10–12 primary longitudinal folds. They are very thick and quite conspicuous. The mucosa is made up of two types of epithelium, superficial epithelium and glandular epithelium.

The superficial epithelium is composed of compactly arranged columnar cells (Pl. XV, Fig. 9). The cells lining the crypts are shorter and almost cylindrical. The nuclei are large and oval. They are situated in the basal half of the cells, all the nuclei occurring at the same level in the epithelium. About one-fourth of the cell nearer the lumen stains pale blue while the rest stains red and appears granular. With thionin the above-mentioned one-fourth of the cell stains red showing the presence of mucus. This is in agreement with Al-Hussaini's (1946) observation that the columnar cells have the function of mucus secretion.

The glandular epithelium consists of the gastric glands. These are all simple and tubular, made up of cells which are rhomboidal in shape with a spherical nucleus in each at the centre. They have a very narrow lumen. The zymogen granules present in these cells are distributed uniformly. There is no differentiation of the cells into oxyntic and peptic cells as all of them are similar. Each gland is surrounded by a thin layer of lamina propria which helps to keep the glands in position. The glands open in groups of two or three into the gastric crypts. There are no neck cells.

The pyloric stomach has 6–8 longitudinal folds which are branched (Pl. XV, Fig. 10). The epithelium of the mucosal folds resembles that of the corpus. There are no gastric glands.

The lamina propria consists of very loose connective tissue and it is similar throughout the stomach. The muscularis of the corpus has an inner circular and an outer longitudinal layer, both of which consist of unstriated fibres. In the pyloric stomach, the circular layer is mostly made of unstriated fibres. However, here and there a few striated fibres also occur probably extending from the oesophagus (Pl. XV, Fig. 11). There is plenty of connective tissue among the fibres. There are two longitudinal layers, one outer to the circular and another inner to it. Both of them are in
bundles. The inner layer has a large number of bundles which are found in the meshes of the submucosa. The serosa is thicker than that of the oesophagus. The cells are not seen clearly.

There is no special valve between the pyloric stomach and the intestine. However, mucosal folds in the region of the pyloric constriction are very thick and deep. They are directed towards the lumen of the pyloric stomach (Pl. XV, Fig. 12). Probably, they are responsible for regulating the passage of food from the stomach to the intestine.

The intestine can be divided into an anterior part, a middle part and a posterior part or the rectum. All these parts are fundamentally similar in structure and are made up of the same layers throughout, the differences being few and minor. The folds of the duodenum are thin with pointed crests and broader bases. They are mostly longitudinal in arrangement. This condition is noticed in the middle intestine also (Pl. XV, Fig. 13). In the posterior region the folds are thick, shallow and fewer.

The epithelium is made up of two principal types of cells, the columnar and the goblet cells. The columnar cells are so numerous that the epithelium is mostly composed of these cells. The goblet cells are few and scattered. The columnar cells are typically cylindrical and high. The nucleus is oval and shows a distinct chromatin network. A thin sheet, which is striated, forms a top plate. It is continuous over the columnar cells except in those regions where the goblet cells open. The goblet cells have a swollen portion and a narrow tail portion. The latter contains the nucleus (Pl. XV, Fig. 14).

The lamina propria is composed of richly vascular areolar connective tissue which merges with the submucosa. The submucosa is also areolar in nature. The muscularis consists of an outer longitudinal layer and an inner circular layer. It is of uniform thickness. Both the layers are made of unstriated fibres. The serosa is made up of one or two layers of flattened cells. There is a little subserous connective tissue between the serosa and muscularis.

In the rectum the thickness of the musculature is almost the same as in the anterior and middle parts. However, the rectal region can be easily distinguished by the shallowness and the greater thickness of the mucosal folds. Further, the lamina propria occupies a wider area (Pl. XV, Fig. 15). The columnar cells and the goblet cells resemble those of the intestine.
Anatomy and Histology of Alimentary Canal of a Herbivorous Fish

**Table I**

Length measurements of various regions of the alimentary canal of *Tilapia mossambica*

<table>
<thead>
<tr>
<th>No.</th>
<th>Length of fish in cm.</th>
<th>Buccopharynx in cm.</th>
<th>Oesophagus in cm.</th>
<th>Stomach in cm.</th>
<th>Intestine in cm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13.0</td>
<td>2.5</td>
<td>0.8</td>
<td>2.6</td>
<td>2.1</td>
</tr>
<tr>
<td>2</td>
<td>12.6</td>
<td>2.4</td>
<td>0.8</td>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>3</td>
<td>12.0</td>
<td>2.2</td>
<td>0.7</td>
<td>2.3</td>
<td>1.8</td>
</tr>
<tr>
<td>4</td>
<td>11.7</td>
<td>2.0</td>
<td>0.7</td>
<td>2.2</td>
<td>1.8</td>
</tr>
<tr>
<td>5</td>
<td>11.2</td>
<td>1.9</td>
<td>0.6</td>
<td>2.1</td>
<td>1.7</td>
</tr>
</tbody>
</table>

**Summary**

The anatomy and histology of the alimentary canal of a herbivorous fish has been described.

The mouth is terminal. The jaw teeth and pharyngeal teeth patches are well developed. The gill rakers are reduced into small knob-like projections.

Taste-buds are present in the lips, buccal cavity and pharynx. The pharynx has the largest number of taste-buds. The stomach is of 'caecal' type and the gastric glands are present only in the body of the stomach. There is no differentiation of glandular cells into oxyntic and peptic cells. The pyloric stomach has thicker musculature.

The intestine is very long. It is about eight times the length of the fish. The intestinal mucosa has only two kinds of cells, columnar and goblet cells.

An ileo-rectal valve is not present. The rectal musculature is not thicker than that of the intestine.

**Acknowledgements**

I am grateful to Prof. P. K. Menon, former Professor and Head of the Department of Zoology, Presidency College, Madras, for suggesting the problem and guidance.
REFERENCES


Currey, E. ........................................... "The histology of the digestive tube of the Carp *Cyprinus carpio communis,*" *J. Morph.,* 1939, 65, 53-78.


EXPLANATION OF PLATE

Fig. 1. T.S. of lip.
Fig. 2. T.S. of anterior buccal membrane.
Fig. 3. T.S. of posterior buccal membrane.
Fig. 4. T.S. of maxillary oral valve.
Fig. 5. T.S. of mandibular valve.
Fig. 6. T.S. of pharynx.
Fig. 7. T.S. of Oesophagus.
Fig. 8. T.S. of Oesophagus (part enlarged).
Fig. 9. T.S. of stomach showing gastric glands.
Fig. 10. T.S. of pyloric stomach.
Fig. 11. T.S. of pyloric stomach (part enlarged).
Fig. 12. L.S. of pylorus.
Fig. 13. T.S. of intestine.
Fig. 14. T.S. of intestine part enlarged.
Fig. 15. T.S. of rectum.
ABBREVIATIONS

a.t., areolar tissue; b.m., basement membrane; c.c., columnar cell; c.m., circular muscle layer; c.st., corpus of stomach; d., duodenum; d.m., dorsal mucosa; g.c., goblet cell; g.cr., gastric crypt; g.g., gastric gland; g.g.c., gastric gland cell; i.l.m., inner longitudinal muscle layer; int., intestine; l., leucocytes; l.m., longitudinal muscle layer; l.p., lamina propria; m.c., mucous cell; m.f., mucosal fold; o.e., oesophagus; o.v., oral valve; p.p., papillary projection; rec., rectum; p.st., pyloric stomach; s., serosa; s.m., submucosa; st., stomach; st.c., stratum compactum; st.e., stratified epithelium; t.b., taste-bud; t.p., top plate; u.c., undifferentiated cell; v.m., ventral mucosa.