THE ANATOMY AND HISTOLOGY OF
THE ALIMENTARY CANAL OF
AN OMNIVOROUS FISH MYSTUS
(=MACRONES) GULIO (HAM.)*

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INTRODUCTION

Study of the alimentary canal of fishes is of special interest since it exhibits a higher degree of variation than that of any other group of vertebrates. The teleosts particularly show a good deal of diversity in their food and feeding habits and the correlation of food and feeding habits is of great interest because of this diversity.

Several studies have been made to correlate the structure of the alimentary tract with the feeding habit. A recent review of the literature has been given by Barrington (1957). The present work deals with the anatomy and histology of the alimentary canal of Mystus gulio (an omnivorous fish), Tilapia mossambica (a herbivorous fish) and Megalops cyprinoides (a carnivorous fish). This paper presents a concise account of the alimentary canal of Mystus gulio and will be followed by other papers.

MATERIAL AND METHODS

The investigation was confined to freshwater (occasionally brackish) forms because of the greater ease with which they could be obtained. They were kept in the laboratory for about three months, when they were observed with regard to their feeding habits. Only freshly preserved material was used for histological purposes. Standard fixatives and staining techniques were used throughout the investigation.

Food, Feeding Habits and Gross Anatomy

The stomach contents of about forty fish were examined and found to be mainly composed of crustaceans. A few algae and decaying leaves were

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also noticed. In the laboratory they were fed on rice and earth-worms. These facts go to show that the fish is omnivorous though animal food predominates.

A few specimens of the fish were kept in the laboratory under observation. These were not supplied with any food for about two months. During this period they were found to feed on algae that had made their appearance on small stones kept in the water.

The animal is a bottom feeder; when food materials are supplied, the fish does not try to get hold of them as they descend from the surface of the water, unless they are starved. The fish takes the food only after the food material has settled down at the bottom, except on rare occasions. According to Sarkar (1959) *Mystus seenghala* is a column feeder and piscivorous. But this species *Mystus gulio* should be considered as an omnivorous bottom feeder.

The several parts of the alimentary canal of the fish are the mouth, the buccal cavity, the pharynx, the oesophagus, the stomach, the intestine and the rectum (Text-Fig. 1). The pyloric caeca are absent. The mouth is inferior. It is a crescentic slit. Each jaw has a crescentic patch of teeth medially within the lip margin. The teeth are villiform and homodont. There is also another crescentic patch, the vomerine patch, a little posterior to the maxillary crescent. The maxillary valve is between the two patches. There is also a U-shaped mandibular valve.

The gill arches are of variable length. The first arch has an anterior row of well developed gill rakers, the posterior row being absent. The same condition obtains in the second arch also except that the gill rakers are slightly shorter. The gill rakers of the other two arches are reduced to small knobs. The function of the gill rakers in this fish may be to protect the gill filaments from silt material and to some extent for filter feeding. Such
gill rakers have been described by Al-Hussaini (1946) in *Mulloides auri-flamma*.

Dorsally the pharynx has a pair of oval patches of teeth. Each one of these patches is carried on a rectangular whitish muscular region and can be moved for mincing the food. Between these oval patches there is a longitudinal depression. The median portion of the floor is raised into a ridge which fits into this depression. The posterior portion of this ridge includes the inferior pharyngeal bones of the last gill arches. The anterior parts of these inferior pharyngeal bones have narrow, elongated patches of teeth. The dorsal patches work against the ventral patches.

The function of the pharyngeal patches was observed in the laboratory. The mouth of the fish was kept open and with the help of a pair of pointed forceps, a small bit of a worm was placed near the oval patches. Immediately the patches began to move, obliterating the longitudinal depression between them and simultaneously the ventral pharyngeal patches were raised up and the food material was found to get pressed and swallowed.

Al-Hussaini (1949) mentions that the degree of development of the pharyngeal masticatory apparatus (horny pad, pharyngeal teeth) bears a direct relationship to the amount of plant food in the diet. But in this fish the buccal teeth probably prevent the prey from escaping and the pharyngeal patches crush it before it is swallowed. The fact that the prey is not masticated is shown by the stomach contents, as the prey is only injured but not masticated. The bulk of the food material in the stomach was found to have had no effects of mastication.

The oesophagus is a little dorsoventrally flattened tube overlapped ventrally by liver lobes. The pneumatic duct opens into the posterior region of the oesophagus. It leads on to the U-shaped stomach that is differentiated into a 'corpus' portion and a pyloric portion, the latter being found ventral to the oesophagus. There is a well-developed constriction separating the pyloric region from the duodenum.

The intestine is not very long. It measures only 6.5 cm. in a fish 10 cm. in length. The duodenum is its widest part. There is no intestino-rectal valve or external constriction to demarcate. The rectum opens out through the anus situated in front of the anal fin.

**Histology**

The lip consists of mucosa and submucosa (Plate IX, Fig. 1). The mucosa is made of stratified epithelium and basement membrane. The epithelium
has many layers of cells which are of different shapes in different places. Taste-buds are present, which are flask-shaped. Each measures about 45µ in length and 30µ in thickness. The taste-bud has its basal side concave and the other sides convex and encloses a few elongated cells. The presence of taste-buds indicates that the fish is able to sense the nature of the food before swallowing. The well-developed gustatory faculty can be correlated with the bottom-feeding habit. According to Al-Hussaini (1949), “the abundance of taste-buds is rather to be correlated with the way in which the fish secures its food than with its nature”.

The buccal cavity has the mucosa (consisting of mucous epithelium, the basement membrane and stratum compactum) the submucosa and muscularis (Plate IX, Figs. 2 and 3). The mucous epithelium is stratified consisting of 6 to 10 layers of cells, of which only the peripheral two or three layers and basal two or three layers are continuous. The middle region has cells which have been described as conspicuous cells or club cells or giant cells. They are seen arranged in a row in section. They are fairly numerous, particularly on the sides. The club cells in *Macrones vittatus* are few and in *Saccobranchus fossilis* scattered (Vanajakshi, 1938). While in *Rita rita* they are arranged in rows (Islam, 1951). The club cells are generally polygonal or oval. Each cell has a large nucleus with conspicuous chromatin network. The cells occupy three-fourths of the space between the surface of the epithelium and the basement membrane. The epithelium has a few mucous cells which are spherical or oval. Their nuclei are situated basally on the concave surface. There are numerous taste-buds. They are rare in *Macrones vittatus* (Vanajakshi, 1938) and few in *Mystus seenghala* (Sarkar, 1959). They are found over the papillary out pushings of the submucosa into the epithelium. The stratum compactum is found just below the epithelium. In the middle region, it is thicker, being as broad as the stratified epithelium. The submucosa is made up of connective tissue fibres and is areolar. In the posterior region of the buccal cavity where musculature is noticed the submucosa is a thin layer. The roof of the posterior buccal cavity has musculature. The floor shows no musculature. Even in the roof the musculature is confined to two areas on each side of the midfloor of the cranium.

As already stated there are two oral valves. They are composed of dorsal and ventral mucosae with a submucosa between (Plate IX, Fig. 4). They have a number of taste-buds.

The pharynx can be distinguished into an anterior, a middle and a posterior region. Vanajakshi (1938) has divided the pharynx of *M. vittatus* into anterior and posterior regions. Histologically the anterior region
Alimentary Canal of an Omnivorous Fish Mystus gulio (Ham.) 215

resembles more the buccal region (Plate IX, Fig. 5). The roof of the anterior pharynx has two projections on the sides which are prominent and turned towards the interior. They are mostly made of stratified epithelium and have a number of taste-buds. Their significance is not clear (Plate IX, Fig. 6).

The middle pharynx has low folds (Plate IX, Fig. 7). It consists of more layers of cells. There are numerous mucous cells (Plate IX, Fig. 8). Club cells are few in number, except on the sides. There appears to be a negative relation between the number of club cells and that of mucous cells. In the middle region where mucous cells are numerous, the club cells are few and on the sides where the club cells are numerous, the mucous cells are few. Further, the positions of mucous cells in the regions where they are numerous correspond to those of club cells in other regions where they are numerous. It is also noticed that a few club cells are in the process of getting converted into mucous cells. Taste-buds are abundant. Their presence in this region must be concerned with the more active role of the region in feeding. The stratum compactum is found only on the sides. A layer of circular muscle fibres, a layer of longitudinal muscle fibres and a few oblique muscle fibres are also noticed. They are all striated.

The posterior pharynx has a striking resemblance to the anterior oesophagus and differs considerably from the anterior and middle regions of the pharynx. At the summit of each mucosal fold there are a few goblet cells in the stratified epithelium. The mucous secreting cells are larger and attain the maximum development in this region (Plate IX, Fig. 9). Such an abundance of mucous cells has been noticed by Dawes (1929) in Pleuronectes and by Al-Hussaini (1947) in Atherina and also by a number of other workers. The taste-buds are fewer in number. The submucosa is very broad and is not distinguishable from the lamina propria. The muscularis consists of an outer layer of circular muscle fibres and inner groups of longitudinal fibres found in the meshes of the submucosa (Plate IX, Fig. 10). A few oblique muscle fibres are also present. All the muscle fibres are striated.

The oesophagus lies partly outside and partly inside the body cavity. The former portion consists of four layers, mucosa, lamina propria, submucosa and muscularis, the hinder portion consisting of an additional serous layer. The longitudinal folds of the pharynx become strikingly deeper. There are 12 to 16 primary folds. Some of the folds are thrown into secondary folds, increasing the surface of the mucosa (Plate IX, Fig. 12).

The edges of the mucosal folds of the anterior oesophagus have stratified epithelium, the sides having one or two layers of columnar epithelial cells
which are mostly mucous producing. There are a few goblet cells occurring at the tips of the folds (Plate IX, Figs. 11 and 13). A few taste-buds are noticed in the anterior oesophagus but none in the posterior oesophagus (Plate IX, Fig. 13). They are absent in *Mystus seenghala* (Sarkar, 1959). Currey has found them in the anterior region of the oesophagus, while many others have noted their complete absence. The mucosa of the posterior oesophagus has a single layer of columnar cells (Plate IX, Fig. 13). The cells measure about 53μ by 11μ. Goblet cells are found at the crests of the mucosal folds. Currey (1939) found a top-plate covering the columnar cells. It has not been seen here. Club cells are also noticed in this region (Plate IX, Fig. 13). Nothing is mentioned about club cells in *Macrones vittatus*. There is a basement membrane. The lamina propria consists of loose connective tissue fibres. It is highly vascular. The submucosa lies next to the lamina propria. The muscularis consists of an outer circular and an inner longitudinal layer, both of them formed of striated muscle fibres. The longitudinal muscle fibres are present in the meshes of submucosa. The serosa is thick and the cells are not clearly seen.

The passing of the oesophagus into the stomach can be recognized distinctly by histological features. There is an oblique line of demarcation between the two made of connective tissue (Plate IX, Fig. 14). The deep arborizing folds of the oesophagus pass into low ones, having columnar epithelium with fan-shaped apical cells. Along with this change the gastric glands appear and soon become numerous. Striated fibres of circular muscles and longitudinal bundles are also noticed. Therefore, the term "oesogaster" can be used to refer to this transitional region.

The stomach has 8 to 10 gastric folds (Plate IX, Fig. 15). The thickness of the gastric epithelium (mucous epithelium) varies in different regions of stomach, depending on the degree of development of the gastric glands. Usually in the case of U-shaped stomach it is common to divide it into two, the 'corpus' and pyloric regions. Generally, the gastric glands are present in the former and absent in the latter.

The 'corpus' or body of stomach consists of mucosa (superficial epithelium and glandular epithelium), lamina propria, submucosa, muscularis and serosa. The superficial epithelium of the mucosa is made up of columnar cells and has numerous crypts. The cells are closely arranged. They are columnar and trumpet-shaped being slender at the base and broader at the free surface, measuring about 7μ at the free end and about 30μ in length. Many of the cells are gracefully curved. The cells at the bottom of the crypts
are shorter and assume cylindrical form. The nucleus is situated at the basal third of the cell.

With Mallory's stain the reaction of the cells is striking. The peripheral part of the cells stains slightly blue, while the narrow basal region stains slightly red, the nucleus staining deep. Besides, the peripheral part of the cell exhibits a reticular appearance and shows a faintly purple reaction with thionin, indicating the presence of mucus.

The glandular epithelium consists of numerous elongated tubular glands opening into the gastric crypts. The glands are compactly arranged with thin extensions of lamina propria between them. This serves to bind the glands together. The gastric glands which are packed in bundles are similar in details except in length. They are simple and tubular with one end blind and the other open, the latter opening into the crypt (Plate IX, Fig. 18).

Each gland consists of a number of cells arranged round a tubular lumen. In a cross-section the cells appear polygonal and have central nuclei which are spherical. There are granular bodies in all the cells. All the cells are alike, not differenced into oxyntic and peptic as in mammals. This condition has been reported in all the fishes. Probably the granular cells found here are zymin-producing ones, the granules being zymogen granules. No differentiation of neck-cells was observed.

The lamina propria is a connective tissue consisting of fibres in the form of a network. These fibres extend into the spaces between gastric glands. Blood vessels also enter along with this connective tissue. Thus the lamina propria serves a threefold purpose, binding the glands, supporting the entire glandular tissue and carrying the blood capillaries into the glandular tissue. The submucosa is built of an areolar connective tissue. The muscularis consists of an inner circular layer and an outer longitudinal layer. Both consist of unstriated muscle fibres. The serosa is much thicker than that of the oesophageal wall.

The pyloric stomach differs in certain respects. The gastric glands are absent and the muscularis is much thicker. The circular muscle layer is considerably thicker measuring about 275 μ (Plate IX, Fig. 17). The region just anterior to the pyloric valve has very thick circular muscles which form the pyloric sphincter. The pyloric valve is present at the place where the pylorus ends and the duodenum begins (Plate IX, Fig. 16). The valve is in the form of a few flaps (Plate IX, Fig. 16) and out pushings into the lumen of the duodenum. The lamina propria is thick and forms the major part of the flap. The circular muscles take part in the formation of the flap.
A transverse section passing through this region shows the presence of a narrow layer of circular muscles which are helpful in the closure of the pylorus.

The intestine has the same structure throughout, varying in minor details like the number and shape of the cells in the epithelium and the thickness of the musculature. The intestine consists histologically, of mucosa, lamina propria, submucosa, muscularis and scrosa (Plate IX, Fig. 19). The mucosa is thrown into a number of folds, longitudinal and transverse, giving a complicated reticulate appearance. The mucosa is simple. Only two type of cells are found, the columnar and the goblet cells (Plate IX, Fig. 20). The columnar cells form the major part of the epithelium. They are long and slender, tapering towards the base. The nucleus is large. Its presence always causes a bulging of the cell outline. The swollen portions of the neighbouring cells interlock serving to strengthen the epithelium. There is a top-plate. The goblet cells are found scattered. There are a number of leucocytes and a few granular cells in the epithelium.

The rectum can be recognized due to its thicker musculature (Plate IX, Fig. 21). There is no intestine-rectal valve. The folds of the rectum are not as tall as those of the intestine. The circular muscles are a characteristic feature of the rectum, being about thrice as thick as the longitudinal layer.

DISCUSSION

The present investigation based on stomach contents shows that Mystus gulio, though it takes in more animal food, is omnivorous. According to Al-Hussaini (1947) there are certain features which are well adapted to the modes of feeding and the kinds of diet. In M. gulio the mouth is inferior and not protrusible and it is mostly a bottom feeder. There are jaw-teeth and pharyngeal teeth patches, as the fish takes in a mixed diet. The gill rakers are well developed on the first two gill arches. Probably there is filter-feeding to some extent. The alimentary canal is short as the bulk of the food consists of animals.

According to Al-Hussaini (1949), "the histology of the teleostean" intestine is one of the simplest among vertebrates. The present investigation confirms this view. The taste-buds are common structures. They are present in the lips, buccal cavity, the pharynx and the anterior oesophagus. The pharynx has the largest number of taste-buds. The abundance of taste-buds has been correlated with the way in which the fish secures its food rather than to its nature. Accordingly there is a well-developed gastatory faculty in this fish. It is expected to be so, as the fish has to select its food from the bottom. The presence of numerous mucous cells is a common feature;
they are saccular or spherical. As mentioned by Barrington (1957), the buccal cavity and pharynx with mucous cells and taste-buds are concerned in the seizure, control and probably selection of food. The stratified epithelium of the buccal cavity is supported by a stratum compactum. It is as thick as the stratified epithelium except anteriorly, where it is absent. The musculature consists of circular and longitudinal fibers, the latter being in bundles in the sub-epithelial connective tissue. They are not continuous and therefore not in a definite layer as circular.

The mucosal folds of the oesophagus are much more branched than in the pharynx. The anterior part shows stratified epithelium which is gradually replaced towards the posterior by columnar epithelium. Taste-buds occur in the anterior part. The muscularis consists of an outer circular and an inner longitudinal layer. However, the longitudinal muscles do not form a continuous thick layer throughout. Currey (1939) found longitudinal bundles outside the circular in the carp. Dawes (1929) also found the same arrangement. Hence there appears to be no fixed order of succession of these muscle layers in oesophagus.

Some fish are mentioned as stomachless (Barrington, 1957). This condition appears to be unrelated to the nature of the diet of fishes. Since a stomach is present in most fishes, the absence of the structure may be secondary. In *M. gulio* the stomach is U-shaped. The gastric glands are present only in the 'corpus' region. The gastric glands are not differentiated into two types, oxyntic and peptic. The pyloric part has thicker musculature and no gastric glands.

The intestine is short, as pointed out already. There are tall mucosal folds which have mostly columnar cells and some goblet cells. There is no agreement among the authors in respect of the definition of the rectum or its histological character. In *M. gulio* the rectum has thicker musculature and a large number of goblet cells.

**Summary**

The anatomy and histology of the alimentary canal has been described. The mouth is inferior and the fish is mostly a bottom feeder. Jaw-teeth and pharyngeal teeth patches are well developed. Taste-buds are present in the lips, buccal cavity, pharynx and anterior oesophagus. The pharynx is divisible into three regions. A transitional region termed the 'oesogaster' is present. The stomach is U-shaped and the gastric glands are present only in the 'corpus' part. There is no differentiation of glandular cells into oxyntic and peptic cells. The pyloric stomach has thicker musculature. A
pyloric valve is present. The intestine is short; the mucosa has only
two kinds of cells, columnar and goblet cells. The rectum has thicker muscu-
lature and a large number of goblet cells.

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EXPLANATION OF PLATE IX

FIG. 1. T.S. of lip.
FIG. 4. T.S. of maxillary oral valve.
FIG. 5. T.S. of Anterior pharynx.
FIG. 6. L.S. of pharyngeal projection.
FIG. 7. T.S. of Middle pharynx.
Alimentary Canal of an Omnivorous Fish Mystus gulio (Ham.)

Fig. 8. T.S. of Middle pharynx (part enlarged).

Figs. 9 and 10. T.S. of Posterior pharynx.

Fig. 11. T.S. of Anterior oesophagus (part enlarged).

Fig. 12. T.S. of Oesophagus.

Fig. 13. T.S. of posterior oesophagus (part enlarged).

Fig. 14. L.S. of Oesogaster.

Fig. 15. T.S. of 'Corpus'.

Fig. 16. L.S. of Pylorus.

Fig. 17. T.S. of Pyloric stomach.

Fig. 18. T.S. of 'Corpus' (part enlarged).

Fig. 19. T.S. of Intestine.

Fig. 20. T.S. of Intestine (part enlarged).

Fig. 21. T.S. of Rectum.

Abbreviations

a.n., anus; a.t., areolar tissue; b.m., basement membrane; c.c., conspicuous cell; c.st., 'corpus' (stomach); d.u., duodenum; g.c., gustatory cell; g.g., gastric gland; g.g.c., gastric gland cell; g.cr., gastric crypt; g.o.c., goblet cell; g.r.c., granular cell; i.n., intestine; l., leucocytes; l.m., longitudinal muscle; l.p., lamina propria; m.c., mucous cell; m.f., mucosal fold; o.l., oblique line; o.e., oesophagus; p.p., papillary projection; p.r., projection; p.s.t., pyloric stomach; p.v., pyloric valve; rec., rectum; s.m., submucosa; s.t.c., stratum compactum; s.t.e., stratified epithelium; s.t.ml., striated muscle layer; t., teeth; t.b., taste-bud; v.m., ventral mucosa.
FIGS. 1-21