THE COMPARATIVE HISTOLOGY OF THE ALIMENTARY CANAL OF CERTAIN FRESH WATER TELEOST FISHES

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The work done on the histology of the alimentary canal of fishes of Europe and America has been summarised by Dawes (1929). Recently some valuable work has been done by Al-Hussaini (1946, 1947, 1949 a, 1949 b) on the histology, cytology and physiology of the gut of Teleost fishes from the Red Sea. Very little work has, however, been done on the histology of the alimentary canal of fishes of this subcontinent, the only noticeable contributions to the subject being those of Rahimullah (1935, 1936, 1939, 1941, 1943 and 1945), Dharmarajan (1936), Vanajakshi (1938), Sarbahi (1940) and Mohsin (1942, 1944-46).

The object of the present study is to find any possible correlation between the histological structure of the gut and the food and feeding habits of fishes. No work has so far been done with this object on the indigenous fishes. A study of the skin of the fishes has also been made as such a study greatly helps in the correct interpretation of the various structures in the lining of the buccal cavity and the pharynx. This factor has been completely neglected by previous workers on the histology of the alimentary canal and no use has been made of the extensive literature on the integument of fishes.

MATERIAL AND METHOD

Living specimens of Rita rita Hamilton, Cirrhina mrigala Hamilton and Ophicephalus gachua Hamilton were obtained from fishermen. Small pieces of the various regions of the alimentary canal were fixed in Bouin's fluid or in Zenker-Formol for 16 to 18 hours. Pieces of skin from the head region were either fixed in Jenkin's decalcifying and dehydrating fixative or in Bouin's fluid for 16 to 20 hours. Satisfactory results were obtained with all these fixatives, though Bouin's fluid was preferred on account of its being easy to make, store, use and wash out.

The portions of the alimentary canal studied were from the buccal cavity, pharynx, oesophagus, stomach and intestine along with the rectum.
Tongue and pyloric caeca present in *Ophicephalus gachua* were also studied. Contents of the guts of all the available specimens of each fish were examined to verify the previous reports on the food of these fishes.

**Food**

Study of the contents of the stomach and intestine of *Rita rita* showed that two fishes had taken shrimp-like crustacea of fairly big size measuring over 1½ inches in length, one had taken some insect larva, while the stomachs and intestines of two fishes were quite empty. *Rita rita* is carnivorous and as stated by Hamid Khan (1934) "it feeds mostly on insects, their larvae and young fishes".

*Ophicephalus gachua* too is carnivorous and "destroys eggs, and fry of other fishes" (Hamid Khan, 1934). Mookerjee, Ganguly and Islam (1946) find that in the case of *Ophicephalus punctatus*, the fish when very young takes only unicellular and multicellular algae. Later, they take to carnivorous diet consisting of Protozoa, Insecta, Copepoda, etc. As growth proceeds, the inclination towards fish-diet becomes evident, till in the adult, the percentage of fish in the diet of this fish may be upto 100%. *Ophicephalus gachua* is said to have a food similar to that of *O. punctatus*.

*Cirrhina mrigala* is a vegetarian fish but "has no objection to taking a bait of worms" (Hamid Khan, 1934). Mookerjee and Das (1945) describe *Cirrhina mrigala* as a bottom feeder taking lots of mud and sand. Mookerjee and Ghosh (1945) find that although adult *Cirrhina mrigala* "takes a mixed diet but the animal diet is almost negligible in comparison with vegetable...... The major portion of the diet is the higher plant bodies in semi rotten condition".

**Skin**

The skin consists of epidermis and corium. A basement membrane usually separates the two regions.

*Epidermis.*—The epidermis of *Rita rita* is stratified and as described by Bhatti (1938) consists of ordinary epidermal cells, club-cells, mucus-cells, sensory cells and fibroblasts. The ordinary epidermal or epithelial cells (Fig. 1, *epc.*) are oval in shape with a large vesicular nucleus. In the superficial layers they tend to get flattened and lie parallel to the surface. The basal layer (*epb.*) rests on the basement membrane (*b.m.*) and consists of columnar squarish or rectangular cells. *Club-cells* (*c.c.*) are large oval or round cells having a central nucleus and cytoplasm which stains pink with eosin. In young cells the cytoplasm is homogeneous, but in older cells
small vacuoles may appear inside the cells or near the periphery. The club-cells vary considerably in size, form and arrangement in the skin from different regions of the body. Generally they are arranged in two or three rows. Some of the club-cells may be produced into a neck-like structure, but this neck never opens to the exterior. Mucus-cells or goblet cells (m.c.) are large round cells with basophilic reticular contents staining deeply with haematoxylin. Each mucus-cell has a crescentic nucleus lying at the bottom of the goblet-shaped body. The mucus-cells are scattered all over the epidermis, but are more common in the upper layers, where they may be seen opening to the exterior by a very short neck. Sensory cells generally occur in the form of end-buds, which are identical with the taste-buds found in the buccal cavity and pharynx. The taste-bud is an aggregation of sensory cells into a flask-shaped body situated on a finger-like projection of the corium. Fibroblasts are spindle-shaped cells with big granular nuclei lying in the basal layer of the epidermis.

In Ophicephalus gachua, the epidermis is thin and stratified. It consists of squarish or polygonal epithelial cells and numerous sac-cells (Fig. 2, s.c.). Club-cells are absent. The sac-cells are generally big cells, traversing more than three-fourth the thickness of the epidermal layer. Occasionally small sac-cells may be found in two or more layers. Very often the bigger cells can be seen to open to the outside by a short neck. These cells possess a very deeply-staining crescentic nucleus lying at the bottom of the sac. These cells differ from the typical mucus-cells in their staining reaction: the latter stain blue with haematoxylin, but the sac-cells fail to do so and pick up cytoplasmic stains. These sac-cells resemble closely the “Sackformige serose Drüsen” or “sac-cells” described by Bhatti (1938) in the integument of some Siluroidea. No sensory elements in the form of end buds seem to be present in the portion of the skin of Ophicephalus gachua studied. A distinct basement membrane is not present.

In Cirrhipna mrigala the epidermis contains, in addition to the ordinary epidermal cells (Fig. 3, epc), numerous club-cells (c.c.) which have the typical structure exactly like those on the skin of Rita rita. At places the club-cells are seen protruding out of the general surface of the epidermis and may sometimes be seen completely ejected out. A similar condition has been described by Bhatti (1938) in some Silurooids and has been interpreted as indicating an excretory function. Mucus-cells, sensory elements and fibroblasts are not distinguishable in the region of the skin studied.

Corium.—In Rita rita the upper region of the corium (Fig. 1 co.) is frequently raised into papillae projecting into the epidermis. The number,
height and diameter of these papillae varies in the skin from different regions of the body. Lower down the fibres in the corium run parallel to the surface of the skin. In the lower region the lamellate character is better exhibited. A few bundles of vertical fibres may also be present in this region. Pigment cells and blood-vessels are often present below the basement membrane.

In *Ophicephalus gachua* the corium consists of highly vascular connective tissue and in it lie numerous scales which are also covered over by the epidermis (Fig. 2, *co.*).

The corium in *Cirrhina mrigala* consists of two well defined regions, an upper layer, just below the epidermis, consisting of very thick and closely packed connective tissue fibres that run parallel to the surface of the epidermis; and a lower layer of very loose and thin connective tissue fibres that run in all directions and enclose numerous fat cells. Blood vessels are present all over in this layer (Fig. 3, *co.*).

**Buccal Cavity**

The histological structure of the buccal cavity is essentially the same as that of the skin. The epidermis of the skin is represented here by the stratified *mucous epithelium* or *mucosa* and the corium by the *submucous connective tissue*.

*Mucosa.*—In *Rita rita* the bulk of the *mucosa* is formed of the ordinary epidermal cells (Fig. 4, *epc.*). Interspersed among these cells are the club-cells (*c.c.*), the mucus-cells (*m.c.*) and the sensory elements (*t.b.*). The *ordinary epithelial cells* are large and cubical on the surface, while in the region between the layers of the mucus cells and the club cells they are oval and lie parallel to the surface. The basal layer consists of squarish or rectangular cells with large spherical nuclei and rests on a thin basement membrane. The *club-cells* are closely packed in two or three rows, but are relatively fewer in number than in the epidermis of the skin. The *mucus-cells* are much commoner and form a more or less regular layer just below the surface. Some of the mucus-cells can be seen to open to the outside. Their contents stain light blue with haematoxylin. The *sensory cells* are in the form of globular or flask-shaped *end-buds* or *taste-buds*, situated on projections of submucosa. They consist of a bundle of elongated cells with their outer ends more deeply stained with eosin, and with an oval nucleus in each cell, and are similar in structure to *taste buds* described by Dawes (1929) and Rogick (1931) in fishes studied by them.

In *Ophicephalus gachua* the *mucosa* has numerous *sac-cells* (Fig. 5, *s.c.*) in addition to the oval ordinary epithelial cells (*epc.*). The basal layer rests
on a structureless basement membrane. The sensory elements take the form of flask-shaped taste-buds containing only a few sensory cells, and are very few in number.

In *Cirrhina mrigala* the mucus-cells are present in very large number in the superficial region of the *mucosa*. They may be arranged in two or more rows, but large areas may be completely devoid of them. The *taste-buds* and *club-cells*, though typical in structure are extremely rare. In size the club-cells do not reach the size of those found in *Rita rita*. *Fibroblasts* are numerous, and are found in the basal layer which rests on the basement membrane.

**Submucosa.**—In *Rita rita* the submucosa of the buccal cavity is a very thick coat, the upper region of which consists of compactly arranged connective tissue fibres running parallel to the surface immediately below the basement membrane and forming *stratum compactum* (Fig. 4, *str. comp.*), and with frequent vertical bundles. Lower down the submucosa becomes loose. Blood vessels are frequently seen all over the layer. A muscular coat, as a distinct part of the buccal lining, is absent.

In *Ophicephalus gachua* two layers can be distinguished in the *submucosa*: an upper consisting of loosely arranged thin connective tissue fibres and a lower consisting of thick fibres. A stratum compactum is not present. Some of the fibres may run down to separate muscle fibres from each other. The muscles of the buccal cavity are striated.

In *Cirrhina mrigala* immediately below the basement membrane is the *stratum compactum* (Fig. 6, *str. comp.*), consisting of a compact layer of thick connective tissue fibres. In the lower strata the fibres of the submucosa enclose fat cells. Blood vessels and nerves are also present.

**Tongue.**—Tongue is present in *Ophicephalus gachua*. It is an oval structure consisting of *mucosa* (Fig. 7) and *submucosa* forming almost complete coats round the central cartilaginous support. The histological structure of these coats is the same as that of the buccal cavity, with the difference that a basement membrane (*b.m.*) and a stratum compactum (*str. comp.*) are very clear and a few typical *taste-buds* are present. The *taste-buds* consist of flask-shaped structures formed by a few elongated cells and situated on slight elevations of stratum compactum. They open to the outside. The *submucosa* is richly supplied with blood vessels. Its middle region is full of fat cells.

**Pharynx**

In general the histological structure of the pharynx is the same as that of the skin and the buccal cavity, except that a well developed *muscularis* is present in addition to the *mucosa* and *submucosa*,

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Figs. 1–10.—Fig. 1. *Rita rita*: V.S. Skin (×257). Fig. 2. *Ophicephalus gachua*: V.S. Skin (×575). Fig. 3. *Cirrhina mrigala*: V.S. Skin (×575). Fig. 4. *Rita rita*: V.S. Buccal cavity (×55). Fig. 5. *Ophicephalus gachua*: V.S. Buccal cavity (×265). Fig. 6. *Cirrhina mrigala*: V.S. Buccal cavity (×257). Fig. 7. *Ophicephalus gachua*: T.S. Tongue (×575). Fig. 8. *Rita rita*: T.S. Pharynx (×257). Fig. 9. *Cirrhina mrigala*: V.S. Pharynx (×257). Fig. 10. *Rita rita*: T.S. Oesophagus (×17).

**Mucosa.**—In *Rita rita* the mucosa of the pharynx contains, in addition to ordinary epithelial cells, a single layer of club-cells, which are generally elongated with a smooth outline. The mucus-cells are present in large numbers, giving in some regions the appearance of stratification. The mucus-cells are chiefly concentrated in the superficial layers, and some of them can be seen to open to the exterior. Their secretion is often present in the lumen of the pharynx. The taste-buds (Fig. 8, t.b.) are more frequent than in the buccal cavity.

In *Ophicephalus gachua* the mucosa of the pharynx has the same structure as that of the buccal cavity with the difference that the sac-cells are more numerous. The taste-buds, though not very common, are however frequent than in the buccal cavity. A distinct basement membrane is absent.

In *Cirrhina mrigala*, the mucosa of the pharynx (Fig. 9, m.ep.) consists, as usual, of ordinary epithelial cells; mucus-cells, which are very numerous; taste-buds, having typical structure; and numerous fibroblasts scattered all over the epidermis.

**Submucosa.**—In *Rita rita* the submucosa of the pharynx is well developed, compact and muscular. Scattered all over the submucosa are numerous muscle bundles, fewer in upper layers but more in deeper layers. The submucosa thus passes insensibly into the muscle layer or muscularis, which consists of bundles of circular and longitudinal, generally striated muscles, lying without any regular arrangement. The fact that the circular and the longitudinal muscles do not form regular tunics, has been mentioned by Curry (1939) for the pharynx of *Cyprinus carpio communis*.

In *Ophicephalus gachua* a distinct stratum compactum is absent. The submucosa contains numerous fat-cells, nerves, blood vessels and stray bundles of apparently smooth muscle fibres.

In *Cirrhina mrigala* stratum compactum is narrow, and immediately below the submucosa consists of loose connective tissue in which numerous striped muscle fibres lie in criss-cross fashion. In the lower region of the submucosa the muscle fibres lie in bundles, and in this region there are numerous fat cells. Nerves and blood vessels are present in both the layers. A regular muscle coat is absent.
Oesophagus

The oesophagus, stomach and intestine have their wall composed of 4 coats, known respectively from without inwards as: Serosa, Muscularis, Submucosa and Mucosa or mucous membrane. The first three coats are of very similar structure in all parts of the gut while the mucosa has a characteristic structure in the different regions.

Serosa.—In Rita rita the serosa or the serous coat of the oesophagus (Fig. 10) is very thin and is almost indistinguishable at places. The great bulk of the serous coat is formed of the subserous connective tissue, the bundles of which even pass into the muscularis. The serous epithelium which usually consists of a single layer of cells (Dawes, 1929; Rogick, 1931, Curry, 1939), is not distinguishable in Rita rita. The serous coat gives the appearance of stratification, probably due to a resemblance between the nuclei of the serous epithelium and those of the subserous connective tissue. Many blood vessels supply the serosa.

In Ophicephalus gachua (Fig. 11) the serous coat is quite conspicuous and encloses nerves and blood vessels. In Cirrhina mrigala the serous coat is extremely thin. At places, the subserous connective tissue is well developed and encloses nerves and blood vessels.

Muscularis.—In Rita rita both the muscle coats, an outer muscularis longitudinalis and inner muscularis circularis, are fairly well developed and seem to be composed of unstriped muscle fibres (Fig. 10, mus.). Purser (1929) who describes a similar condition in Calamoichthys calabaricus, says that the extent of the striated muscle fibres is used by many authors for determining the boundary between the pharynx and the oesophagus. Blood vessels are sometimes present between the two layers or in the muscularis longitudinalis.

In the oesophagus Ophicephalus gachua, contrary to the condition in other parts of the alimentary canal, the muscularis circularis lies outside the muscularis longitudinalis. The fibres of the longitudinal muscles often wander into the outer region of the submucosa. Both striped and unstriped muscles are met with. The muscularis passes insensibly into the submucosa.

In Cirrhina mrigala the muscularis consists of circular muscle coat only (Fig. 12, mus. c). The muscularis longitudinalis is absent as a distinct outer coat. Numerous longitudinal muscle fibres, however, lie in the meshes of the submucosa, a condition also reported by Curry (1939) in Cyprinus carpio communis, Mohsin (L 944-46) in Anabas testudineus and by Rogick (1931) in Campostoma anomalum. The muscularis circularis is well developed and consists of very fine striated muscle fibres lying in quite a loose
manner. Fibres of connective tissue are often present in this layer and enclose minute blood vessels.

Submucosa.—The submucosa in \textit{Rita rita} (Fig. 10, \textit{s.m.}) is extensive and vascular, and enters the various folds of the mucous membrane. Its outer portion is loose, but the portion adjacent to the mucosa is somewhat denser and more deeply stained. No muscle fibres are present in this coat. In \textit{Ophicephalus gachua} the muscularis passes insensibly into the submucosa. The region of the submucosa adjacent to the mucosa is free of muscles and contains numerous blood vessels. In \textit{Cirrhina mrigala} the submucosa (Fig. 12, \textit{s.m.}) is poorly developed and consists of very loosely arranged connective tissue fibres, scattered among which lie numerous longitudinal muscle fibres (\textit{mus.\,f.}).

Mucosa.—In \textit{Rita rita} the mucosa or the mucous membrane (Fig. 10, \textit{m.}) is deeply folded, the folds often simulating tubular glands. A muscularis mucosæ and a tunica propria are not present. A basement membrane is also not distinguishable. The mucous epithelium consists of long columnar cells with oval nuclei. Mucus-cells are round or sac-like and are present in large numbers and can sometimes be seen opening to the exterior.

In \textit{Ophicephalus gachua}, too, the mucosa is thrown into very high folds, which exhibit a tendency to branch. Muscularis mucosæ is absent. The mucous epithelium (Fig. 11, \textit{m.ep.}), though definitely simple at places especially at the top of the folds, appears to be stratified at most places. Almost the whole of the mucous membrane is formed of very closely packed sac-cells, (\textit{s.c.}), which lie in one or more layers. At places unmodified epithelial cells lie as supporting cells below the sac-cells. The older sac-cells appear to be empty, but some typically goblet-shaped deeply-staining oxyphilic cells, probably younger sac-cells are also present.

In \textit{Cirrhina mrigala} the mucosa is simple, and is composed of a single, but greatly folded layer of ordinary epithelial cells (Fig. 12, \textit{epc.}), with goblet—or mucus-cells (\textit{m.c.}) and occasional taste-buds (\textit{t.b.}). Some of the folds may be simple, others are branched. The ordinary epithelial cells are restricted to the tops and sides of certain folds. At other places they have either been replaced or squeezed in between the mucus-cells, which form the commonest element in the \textit{oesophageal} mucosa of \textit{Cirrhina mrigala}. Typical taste-buds are found here and there, especially near the top of the folds, and their presence in the \textit{oesophageal} mucosa of this fish is a remarkable phenomenon and is presumably correlated with the feeding habits of the fish.
Stomach

Essentially the structure of the stomach is quite similar to that of the oesophagus except for the modification of the lining epithelium of the stomach to form the characteristic gastric epithelium and the gastric glands. Of the three fishes studied, Cirrhina mrigala does not possess a true stomach. In the other two fishes, the wall of the stomach consists of serosa, muscularis, submucosa and mucosa.

Serosa.—In Rita rita the serous coat of the stomach is similar to that of the oesophagus, and often encloses blood vessels and nerves. In Ophicephalus gachua, the serosa or the serous coat is extremely thin (Fig. 15, se.) and at most places consists of serous epithelium only.

Muscularis.—Serosa is followed by Muscularis, which is composed of complete coats of longitudinal and circular muscles. The two coats are separated by an ill-defined layer of connective tissue enclosing blood vessels and a nerve-plexus called Auerbach’s Plexus. The longitudinal coat of muscles is broken up into bundles separated by connective tissue. Fibres of connective tissue can also be seen running into the muscle layer. Muscularis longitudinalis is thin and in the region of the pyloric sphinctre it becomes so much reduced as to be almost indistinguishable, while the muscularis circularis increases greatly to form the sphincter.

In Ophicephalus gachua, the muscularis consists of almost equally thick muscularis longitudinalis (Fig. 15, mus. l.) and muscularis circularis (mus.c.) composed entirely of unstriated muscle-fibres. The two coats are separated by a layer of connective tissue, whose fibres penetrate both the coats and also enclose nerves.

Submucosa.—In Rita rita numerous bundles of longitudinal muscle fibres lie scattered in the submucosa, especially in the region adjacent to the mucosa. But these muscles do not form a muscularis mucosae. The submucosa is rich in blood vessels. The submucosa in Ophicephalus gachua is very well developed (Fig. 15, s.m.) richly vascular and invaded by numerous muscle fibres. These muscle fibres, mostly longitudinal, however, do not form a definite layer. The connective tissue fibres just below the submucous layer are said to comprise the tunica propria because they often penetrate into the mucous layer.

Mucosa.—The mucous membrane in Rita rita, consists of the lining epithelium (Fig. 13, epc.), the gastric glands and the tunica propria. Stratum compactum is not present. The tunica propria is a vascular and well-defined layer of connective tissue, similar in structure to the submucosa. It
penetrates into the mucous layer, separating the gastric glands from each other, and supporting the lining epithelium. The epithelium consists of typical columnar cells frequently turning inwards to form the crypts of gastric glands. The epithelial lining consists of very long and narrow cells. As the epithelium turns inwards to form the crypt, the cells become short and broad, till at the bottom of the crypt they assume a cubical or cuboid form. The outer extremity of the epithelial cells stains deep blue with Mallory’s stain. With mucicarmine, which is a specific mucous, stain, this zone stains red. The cytoplasm of these cells appears more or less non-granular when stained with eosin or picro-indigo-carmine, but Mallory’s stain brings out fine granulations. This granulation does not increase in any perceptible degree in the crypt cells, but the secretory cells are heavily granulated. In the region of pyloric sphinctre, where the gastric glands are absent, the free ends of the epithelial cells stain deep red with mucicarmine, thus exhibiting a mucoid nature. The folds of the epithelium in this region may be taken to represent the crypts of the glands, with the secretory portions missing.

The gastric glands are of the simple tubular type, each gland (Fig. 14) consisting of one or more secretory portions or tubules (s.t.), opening into the bottom of the crypt (cr.). The lumen of the secretory tubule is very narrow and may even appear to be obliterated. Secretory cells of only one type are present, and have been described as the chief or the peptic cells by Greene (1912) and Blake (1930 and 1936) in the fishes studied by them. The absence of any differentiation into peptic (chief) and oxyntic (parietal) cells in fishes, was made a generalization by Edinger in 1877, (Blake, 1936). The secretory cells are large, round, oval or pear shaped with a very big and round nucleus. The cytoplasm is choked with granules, called zymogen granules, which are particularly well stained by Mallory’s stain.

The Mucous membrane or mucosa in Ophicephalus gachua consists of gastric epithelial cells (Fig. 15, epc.), lining the lumen of the stomach, and gastric glands (g.g.), several of which lie in the region between the tunica propria and the gastric epithelium. The gastric epithelium consists of elongated columnar cells, narrow proximally, broad distally, and having most of the stainable protoplasm accumulated at the free, distal end. The protoplasm is faintly granular. The gastric glands consist of secretory portions or funduses and ducts of crypts. Many secretory tubules open to the exterior by one crypt. At the base of some crypts the cells remain unstained with Mallory’s stain and pick up a very light stain with eosin.
Similar cells in Pleuronectes platessa have been called "undoubtedly mucus producing cells, which can be compared to the mucoid cells scattered among the so-called peptic cells of the mammalian fundic glands" (Dawes, 1929). The cytoplasm of the secretory cells is full of zymogen granules, which stain red with Mallory's stain.

**Intestine**

The histological structure of the intestine is simple and resembles that of the oesophagus. The wall of the intestine consists of serosa, muscularis submucosa, and mucosa.

**Serosa.**—In *Rita rita* the serous coat of the intestine is vascular, (Fig. 16, *se*.). In *Ophicephalus gachua*, the *serosa* is very thin, being distinguishable only at places where it gets separated from muscularis to enclose blood vessels (Fig. 17, *se*.). In *Cirrhina mrigala*, the serous coat is extremely thin, without any subserous connective tissue and probably incomplete, (Fig. 19 and 20, *se*.).

**Muscularis.**—In *Rita rita*, both the muscle coats are present. The muscularis circularis (Fig. 16 *mus.c.*) is only slightly thicker than the muscularis longitudinalis (*mus. l*.). All the muscles are unstriped. The thin layer of loose connective tissue separating the two muscle coats encloses blood vessels and the nerve plexus of Auerbach. In *Ophicephalus gachua*, both the coats of muscularis are well developed, though the muscularis circularis (Fig. 17, *mus.c.*) is about four times as thick as muscularis longitudinalis (*mus. l*.). Numerous blood vessels and nerves lie between the two coats, though there is no definite layer of connective tissue between them. In *Cirrhina mrigala*, muscularis circularis is generally four to five times thicker than the muscularis longitudinalis (Figs. 19 and 20, *mus.c.* and *mus. l*.). All the muscles are unstriped. The two coats are separated from each other by a zone which is traversed by protoplasmic threads and contains numerous blood vessels and nerves. These threads do not stain blue with Mallory's connective tissue stain.

**Submucosa.**—In *Rita rita* the submucosa (Fig. 16, *s.m.*) is not very well developed and consists of loose connective tissue containing numerous blood vessels. It is produced into finger-like processes covered over by the
lining epithelium to form the so-called "villi" True "villi" do not exist in any fish as is shown by the absence of the lacteals and the granular cells such as those of Paneth" (Rahimullah, 1945). The submucosa has also been designated as the "tunica propria", "combined parts of a true tunica propria and a submucosa" or merely as "areolar tissue" by various authors in the fishes described by them. In Ophicephalus gachua, the submucosa is loose, fairly well developed and richly supplied with blood vessels. In Cirrhina mrigala, too, submucosa is well developed and highly vascular (Figs. 19 and 20, s.m.).

Mucosa.—In Rita rita, the mucous membrane or mucosa consists only of a single layer of columnar epithelial cells (Fig. 16, epc.), interspersed amongst which are the mucus-cells (m.c.). A muscularis mucosae, a tunica propria, a stratum granulosum and a stratum compactum are not distinguishable. The cells of the intestinal epithelium are of the simple columnar type, many times longer than broad, with slightly granular cytoplasm, and each with a well-defined top-plate. The nucleus lies towards the basal or attached end of the cell. The mucus-cells are present throughout the epithelium but their distribution is not uniform. They are round, oval or pear shaped with a filamentous basal portion which stains deeply with eosin and contains the nucleus. This indicates the evolution of the mucus-cells from the ordinary epithelial cells. The mucus-cell itself stains blue with hæmatoxylin or Mallory's stain.

In Ophicephalus gachua the mucosa is simple, consisting of a single layer of columnar epithelial cells (Fig. 17, epc.), resting on a well defined tunica propria (t.p.). No muscularis mucosae, stratum compactum or stratum granulosum are present. The mucous membrane is greatly folded to form "villi", the core of which is formed by the submucosa as in Rita rita. The columnar epithelial cells are very narrow, have a deeply staining cytoplasm, and are provided with top-plates. Interspersed among the columnar epithelial cells are numerous mucus-cells.

In Cirrhina mrigala, the mucosa is thrown into folds, and the mucosal folds in the proximal region of the intestine proper differ from those in the greater length of the intestine by being transverse rather than longitudinal. The epithelium of the mucosa is simple consisting of ordinary epithelial cells (Fig. 21, epc.), in addition to the mucus-cells (m.c.). The ordinary epithelial cells are many times longer than broad, more markedly so in the distal parts of the intestine proper. Their nuclei are, consequently, compressed and oval. Top plates are present, though they are not so prominent in the distal part of the intestine proper. The mucus-cells are fairly
numerous and may be goblet-shaped, sac-shaped or tube-like, sometimes extending through the whole thickness of the epithelium. The cells of the latter type indicate that the mucus-cells are formed by the transformation of the ordinary columnar epithelial cells. Numerous leucocytes are also strewn across the epithelium.

**Pyloric Cæcum**

Two pyloric cæca are present in *Ophicephalus gachua* and their histological structure is very similar to that of the intestine (duodenum) of which they are the outgrowths (Fig. 18). Their mucosa consists of a layer of epithelial cells (m.ep.), resting on well-defined tunica propria (t.p.). The tunica propria consists of a compact layer of connective tissue. Rahimullah (1945) regards this layer as differentiated part of the submucosa, but Greene (1912) and others consider it a part of the mucous membrane and treat it accordingly. The mucosa is raised into finger-like folds, the core of which is formed by the submucosa. These folds have been termed as the "cæcal villi" by Rahimullah (1943) in contrast with the true villi. The cæcal villi are simple, unbranched and very long. The cæcal epithelium is simple and exactly like the intestinal epithelium. The stratified condition of the cæcal epithelium described by Rahimullah (1943) for *Ophicephalus striatus* and other species of this genus was, however, not observed.

**Intestinal Bulb**

In *Cirrhina mrigala*, the oesophagus passes into a long tube, slightly wider than the oesophagus and termed "the intestinal bulb" by Rogick (1931), or "the large arm of the intestine" by Curry (1939). The intestinal bulb gradually narrows down to the intestine proper, which forms by far the greater length of the gut.

Essentially, the histological structure of the intestinal bulb is similar to that of the rest of the intestine, the chief difference being in the degree of folding of mucosa. The serosa of the intestinal bulb (Figs. 22 and 23, se.) is very thin. In the muscularis, the circular (mus.c.) and the longitudinal (musc. l.) coats, though well developed, form only an insignificant part of the wall. The two coats, formed chiefly of unstriped muscle fibres, are separated by a thick pad of connective tissue containing nerves and blood vessels and a few striped muscles. A similar observation has been made by Curry (1939) in *Cyprinus carpio communis*.

The submucosa (s.m.) of the intestinal bulb is a very thin layer of coarse fibrous connective tissue, the processes of which pass into the mucosal folds
and carry numerous blood vessels. The mucosa shows an extensive degree of folding, the folds or villi being more than ten times as high as the three outer coats taken together. Posteriorly, however, the folds gradually decrease in size. Only ordinary columnar epithelial cells (epc.) and mucus-cells are present. The ordinary epithelial cells are extremely narrow and have most of their granular protoplasm aggregated near the free end of the cell. Top plates are present. Mucus-cells, though quite common, are not profuse.

**RECTUM**

The histological structure of the rectum resembles that of the intestine so closely that many authors do not describe rectum as a region distinct from the rest of the intestine.

**Muscularis.**—In all the three fishes studied, both the coats in the muscularis of the rectum are better developed than the corresponding coats in the intestine. The muscularis circularis (Figs. 24 and 26, mus.c.) is about three times as thick as the muscularis longitudinalis (musc. l.). Blood vessels and small nerves are present between the two coats. A definite layer of connective tissue does not exist between the two coats in the rectum.

**Submucosa.**—Submucosa in the rectum in all the fishes studied is well developed, but as in the case of the intestine, this layer may be regarded as representing the tunica propria or tunica propria and submucosa combined.

**Mucosa.**—The epithelial cells are exactly like the corresponding cells in the intestine. The mucus-cells are much more numerous than in the intestine. In Ophicephalus gachua, the mucous membrane of the rectum differs from that of the intestine in the fact that the "rectal villi" show a slight tendency towards branching. In Cirrhina mrigala, just below the mucosa, the connective tissue is compact and stains more deeply and may be regarded as tunica propria. The mucus-cells in the mucosa (Fig. 27, m.c.) are narrow, long and finger like with a narrow neck, but sometimes their middle or basal region may be swollen. They stain dark blue with hæmatoxylin, but fail to stain with Mallory’s stain.

**DISCUSSION**

**Skin.**—Different types of gland-cells are met with in the skin of the three species studied. In Rita rita there are mucus-cells and club-cells; in
Ophicephalus gachua there are the sac-cells and in Cirrhina mrigala there are the club-cells. So far as the club-cells are concerned, it was pointed out by Oxner (1905) and later by Bhatti (1938) that the presence of club-cells is indicative of genetic relationship because these cells are absent in all Physoclisti and are present in all Physostomi, except the Salmonidae and Loricariidae. The present study corroborates this generalization in a striking manner. Thus Rita rita and Cirrhina mrigala both belonging to the group physostomi possess club-cells and Ophicephalus gachua belonging to the group Physoclisti is devoid of them, though Rita rita and Ophicephalus gachua are both carnivorous whereas Cirrhina mrigala is herbivorous. This shows that the club-cells in the skin, and hence in the buccal cavity and pharynx, indicate genetic relationship rather than an adaptation to feeding habits.

In Cirrhina mrigala some club-cells can be seen protruding out of the epidermis or even bodily ejected out, indicating the possibility of an excretory function of these cells. Wright (1884) attributed this condition to "defects in superficial layers of epidermis and due to the action of hardening reagents". Later observers (Oxner, 1905; Bhatti, 1938, and others) have, however, established the excretory function of these cells. Support or protection for the soft epidermis, is also advanced as a possible function of these cells.

Mucus-cells do not appear to be present in the portion of the skin of Ophicephalus gachua studied, and the sac-cells are the only type of gland-cells present. These sac-cells are exactly like the mucus-cells except for the staining reaction of the contents. Bhatti (1938) in the course of his studies on the integument of Siluroidea found that the sac-cells formed a definite generic character as they were present or absent in all the species of a genus. Presumably these cells also indicate a genetic relationship and are not concerned with feeding habits.

Terminal buds (taste-buds) have been observed in the skin of Rita rita, whose skin is naked, and are apparently absent in Cirrhina mrigala and Ophicephalus gachua, which have an exoskeleton of scales. Importance of taste-buds in feeding was first pointed out Herrick (1902) who wrote that "it may be regarded as established that fishes which possess terminal buds in the outer skin taste by means of these organs and habitually find their food by their means". This was amply confirmed by Hamid Khan (1934) who described a totally blind but robust and healthy specimen of Rita rita from the Ravi, proving that in this fish taste, and not sight, played the major role in feeding. Ophicephalus gachua is piscivorous in the adult condition and obviously sight is much more important than the sense of taste in hunting. Cirrhina mrigala has been described by Mookerjee and
Das (1945) as a Bottom-feeder taking lot of sand and mud. This mode of feeding does not require the presence of taste-buds in the skin of this fish.

**Alimentary Canal.**—The buccal cavity being a part of the embryonic stomodæum, has essentially the same structure as the skin. In *Cirrhina mrigala* mucus-cells appear in the buccal lining in large numbers, but the club-cells record a decrease in number in this fish as also in *Rita rita*. Taste-buds are present in the buccal cavity of all the three fishes, but there are comparatively very few in *Ophicephalus gachua*. This may easily be correlated with the nature of the food and the feeding habits.

A tongue is present in *Ophicephalus gachua*. As pointed out by Owen (1866) and Wiedersheim (1907), the tongue in fishes serves only as a tactile organ. The presence of a tactile organ in the buccal cavity of *Ophicephalus gachua* may be interpreted as a compensation for the absence of barbels and other integumentary sense-organs.

The pharynx, being a continuation of the buccal cavity, has the same structure as the latter. However, the mucus-cells in *Rita rita* and *Cirrhina mrigala*, and the sac-cells in *Ophicephalus gachua*, as well as the taste-buds in all the three fishes, show a marked increase in number in this region. The mucous membrane is thrown into low broad folds, probably in order to lodge a great number of gland-cells and taste-buds. An increase in gland-cells has been reported in many fishes, e.g., *Cyprinus carpio* (Curry, 1939), *Campostoma anomalum* (Rogick, 1931). Probably the secretion of these gland-cells serves to wash the food down the oesophagus.

The oesophagus has the same four coats as characterise the rest of the alimentary canal. In the oesophagus there is a transition from the stratified to simple epithelium. Moreover, the folding of the mucosa becomes very well marked, "the complexity of folding is characteristic of this coat" (Blake, 1930). The oesophagus is richly supplied with gland-cell so much so that at places the gland-cells completely replace the ordinary, epithelial cells. No taste-buds are present in the oesophagus except in *Cirrhina mrigala*. Probably this backward extension of the taste-buds can be correlated with the mode of feeding and the nature of food of this fish.

In *Rita rita* and *Ophicephalus gachua* there is a typical cæcal stomach provided with gastric glands. A true stomach, however, is absent in *Cirrhina mrigala*. The absence of a true stomach in *Cirrhina mrigala* has been correlated with its food. Absence of a true stomach in the Cyprinidæ has also been recorded by Wiedersheim (1907). Jacobshagen (1937) pointed out that a true stomach is absent, among others, in "pure carnivorous fishes
of which the intestine is shorter than the total length of the animal”, and in “herbivorous fishes with an intestinal length of 5–6 times the length of the fish”. In *Rita rita*, *Ophicephalus gachua* and *Cirrhina mrigala* the length of the gut is, respectively, 0·6, 0·7 and 11·25 times the length of the body. According to Jacobshagen’s generalisation, all the three fishes should be stomach-less, but only *Cirrhina mrigala* comes up to expectations. Something more than the mere ratio between the lengths of the gut and the whole body should be sought for to explain the absence of a true stomach in some fishes.

In *Cirrhina mrigala* the function of storage, performed in other fishes by the stomach, has been taken over by the intestinal bulb which lies immediately behind the oesophagus and simulates a stomach. The intestinal bulb has been mistaken for a stomach by many authors (Mookerjee and Ghosh, 1945). However, its histological structure which is exactly like that of intestine, the opening of the bile duct immediately behind the oesophagus, and the absence of gastric glands, prove definitely that this organ is a part of the intestine.

The gastric glands of *Rita rita* and *Ophicephalus gachua* have the structure usual in the fishes, *i.e.*, they consist of (a) a crypt formed by an inturning of the gastric epithelium, and (b) a fundus or the secretory portion. The cells of the gastric epithelium have their outer ends stained red with mucicarminine, thus confirming the view of Stirling (1884), Jordan (1937) and others that these cells are mucoid in nature. The secretory cells are all of on the type, confirming the statement of Edinger (1877) that in fishes in general there is no differentiation into peptic and oxyntic cells. The only type of secretory cells present is comparable, according to Edinger (1877), neither to the central nor to the parietal cells of Mammalia. Recent authors (Greene, 1912; Blake, 1930 and 1936; and others) compare these cells with the chief or peptic (Central) cells in mammalian gastric glands. The question of the source of acid is still unsettled. According to Stirling (1884) the superficial cells, in addition to producing mucus, also produce acid. This problem, however, needs further investigation.

The correlation between the nature of food and the length of the intestine is clearly shown by the fishes studied. The intestine of the two carnivorous fishes studied is shorter than the total length of the body. *Cirrhina mrigala*, which lives on organic particles in mud and sand, has an intestine about 11 times as long as the length of the body, probably because such food requires a very large surface for its absorption. Similar conclusions have been arrived at Al-Hussaini (1947) for other herbivorous fishes.
In *Rita rita* and *Ophicephalus gachua*, the intestine has, throughout, the structure typical of piscine intestine. In *Cirrhina mrigala* however, the intestine is differentiated into various regions. The first part has a wide diameter. It is called the intestinal bulb and its mucosa is thrown into very long folds. A short portion immediately behind the intestinal bulb has transverse folds, whereas in the rest of the intestine and the rectum the mucosal folds are longitudinal as is the usual condition.

Since the structure of the epithelium in all the three fishes is the same in all the regions of the intestine, no adaptive value can be attached to the intestinal mucosa. Goblet-cells or mucus-cells are present in the intestine of all the three fishes. In *Ophicephalus gachua* the mucus-cells are not met with in any other region of the alimentary canal except in the intestine.

In the fishes studied, pyloric caeca are found only in *Ophicephalus gachua*. As pointed out by Rahimullah (1945) "histologically, in general, the pyloric caeca are very similar to the intestine (= duodenum) of which they are outgrowths". As regards their function, Rahimullah (1945) says, "it is not yet certain what exact correlation exists between diet and the significance of these caeca in fishes. I think pyloric caeca have arisen in those fishes where the abdominal space has to be economised owing to the influence of some environmental factors". What factors have lead *Ophicephalus gachua* to have a short straight intestine and then to have two pyloric caeca as compensation, it is difficult to guess.

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**SUMMARY**

1. The comparative histology of the alimentary canal of *Rita rita* Ham., *Ophicephalus gachua* Ham., and *Cirrhina mrigala* Ham., has been studied to correlate the histological structure with the nature of food.

2. In addition to the ordinary epithelial cells, the epidermis of the skin contains mucus-cells and club-cells in *Rita rita*; sac-cells in *Ophicephalus*
gachua; and only club-cells in Cirrhina mrigala. Taste-buds are present only in the skin of Rita rita. In Cirrhina mrigala the club-cells have been seen being extruded bodily from the epidermis, thus providing a strong evidence for the view that the club-cells have an excretory function.

3. The histological structure of the buccal cavity and the pharynx is the same as that of the integument. Taste-buds and mucus-cells are present in the buccal cavity and pharynx of Cirrhina mrigala. In Ophicephalus gachua a few taste-buds are present on the tongue but none in the buccal and pharyngeal epithelia.

4. In the oesophagus the epithelium is simple. No club-cells are present in Rita rita and Cirrhina mrigala, but in Ophicephalus gachua sac-cells are profusely abundant. In Cirrhina mrigala a few taste-buds extend even upto the oesophagus. This has been correlated with the food of this fish.

5. A true stomach is present in the two carnivorous fishes Rita rita and Ophicephalus gachua, but in the herbivorous fish Cirrhina mrigala it is absent as shown by (i) the absence of gastric glands, (ii) opening of bile-duct just behind the oesophagus, and (iii) the part following the oesophagus having the typical structure of intestine. The absence of a stomach in Cirrhina mrigala has been correlated with its food. The cells forming the gastric epithelium in Rita rita and Ophicephalus gachua are mucoid in nature. Oxyntic cells are absent.

6. In Cirrhina mrigala the intestine is exceedingly long and coiled but in the other two fishes it is short and straight. This difference has been correlated with the difference in food in these fishes. In Cirrhina mrigala the first part of the intestine is dilated and is called the 'intestinal bulb'. In the region just behind the intestinal bulb the mucous membrane is transversely folded. In the rest of the intestine, as also in the intestinal bulb, the mucosa is longitudinally folded. No multicellular glands are present in the epithelium of the intestine. The mucus-cells (goblet-cells) are present in the intestine of all the three fishes studied. The mucus-cells make their appearance for the first time in the intestine in Ophicephalus gachua.

7. Pyloric ceca, present only in Ophicephalus gachua amongst the fishes studied, have the same histological structure as the intestine.

8. The rectum differs from the intestine only in having thicker muscular coats and more numerous mucus-cells,
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LITERATURE CITED


——— . . . . “Studies on the Comparative Histology of the Digestive Tube of certain Teleost Fishes, II. A bottom-feeding Fish, the Sea robin (Prionotus carolinus),” Ibid., 1936, 60.


Ahsan-ul-Islam


Mookerjee, H. K. and Das, B. K. "Gut of carnivorous and herbivorous fishes in relation to their food at different stages of their life," ibid., 1945, 32.


Mookerjee, H. K., Ganguly, D. N. and Islam, M. "On the composition of food and their correlation with weight and length of the body in the development of Opicephalus punctatus Bloch.," Ibid., 1946, 33.


....... "The structure of the Pyloric Caeca in the family Mastacembelidae," Ibid., 1936, 23.

....... "On the structure and functions of the so-called Pyloric Caeca in two genera of Fishes, Lactarius and Osphromenus" Ibid., Calcutta, 1938, 25.

....... "On the disposition of the so-called Pyloric Caeca in a Brotulid fish, Sirembo imberbis (Tem. and Sch.)," Ibid., 1941, 28.

....... "Contributions to our knowledge of the Pyloric Caeca of three families of Fresh-water Indian Fishes (Opicephalidae, Notopteridae and Mastacembelidae) together with some remarks on their probable functions," Proc. Ind. Acad. Sci., 1943, 18 B.

....... "A comparative study of the Morphology, Histology and probable Functions of the Pyloric Caeca in Indian Fishes, together with a Discussion on their Homology," Ibid., 1945, 21 B.

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**Key to Lettering**

- b.m., Basement membrane; c.c., Club-cell; co., Corium; cr., Crypt; eph., Basal layer of epithelium; epc., Ordinary epithelial cell; g.g., Gastric gland; m., Mucous membrane; m.c., Mucus-cell (goblet cell); m.ep., Mucous epithelium; mus., Muscularis; mus.c., Muscularis circularis; mus.f., Muscle-fibre; mus.l., Muscularis longitudinalis; s.c., Sac-cell; se., Serosa; s.m., Submucosa; s.t., Secretory Tubule; str.comp., Stratum compactum; t.b., Taste-bud; t.p., Tunica propria.