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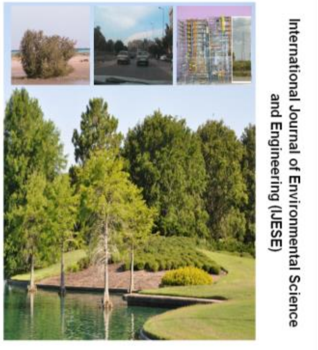

Comparative study on the histological structures of the intestine in some coral reef fishes in Hurghada, Red Sea, Egypt

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ABSTRACT

The present work focuses on the variation of the histological structure of the intestine in some coral reef fishes (*Siganus rivulatus*, *Mulloidichthys flavolineatus* and *Tylosurus choram*) in relation to food and feeding strategy. Fish specimens were collected from Abu Galawa Lagoon in Hurghada, Red Sea, during the period from December 2014 to November 2015.

The intestine of the herbivorous fish (*S. rivulatus*) is exceedingly long and variously convoluted. A character related to cellulose digestion, which requires a longer time in the intestine. While, the intestine of the carnivorous (*M. flavolineatus*) and the piscivorous fish (*T. choram*) are short tubes.

The ileo-rectal valve marked the beginning of the rectum and prevents the passage of food particles into the posterior part before intestinal digestion and absorption is completed. This valve is absent in the posterior intestine of herbivorous (*S. rivulatus*) and piscivorous fish, (*T. choram*). But, the posterior intestine of carnivorous fish (*M. flavolineatus*) was recognized by the presence of ileo-rectal valve.

The duodenal mucosa of all studied species is thrown into primary, secondary and tertiary folds. Such structures are short and few in number towards the ileum and are much thicker in the rectum. The epithelial lining of the intestine is consists of columnar and numerous large goblet cells. This may provide viscosity for both food and fecal materials.

In conclusion, the intestine of studied species is subjected to diverse and significant variations and much modification in accordance to the food and feeding strategy.

1. INTRODUCTION

From the economic importance of view, the Red Sea coasts constitute a very important sector in the Egyptian fisheries, both for significant total catch and a large number of economically important species. Research on reef fisheries and fish biology has a short history. Concurrently, reef fish biology flourished with numerous academic studies of small elements of reef fish communities. Coral reefs of the Red Sea support approximately 400 fish species which utilize corals for shelter, food and/or breeding ground. However, a little is known about the biology of the large variety of fish living in and around the coral reefs in the Red Sea (ERSR, 1998; Mohamed, 1999).

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The adaptations of the digestive organs of the fish to their normal diet are particularly evident in the form, size, structure, abundance and limitation of the microscopically elements such as dentition, mucous cells, taste buds, digestive glands and muscular coat in the esophagus, stomach, intestine and pyloric caeca in the fish.

All of these features are subject to diverse and significant variations and much modification in accordance with the feeding habits (Dasgupta, 2000; Khalaf Allah, 2009).

Several studies are available on the adaptations of the alimentary canal of fish to their food and feeding habits notably by Kamel *et al.* (1995) on the Nile cat fish (*Bagrus docmac*), Shehata (1999) on the grass carp (*Ctenopharyngodon idella*), Shehata *et al.* (1999) on the characinid fish (*Alestes dentex*), Khalaf-Allah (2001 and 2009) on the cichlid fish (*Tilapia zillii*), the mullet fish (*Liza aurata*), the sole fish (*Solea solea*), the spiny checked grunter (*Terapon puta*) and the striped sea bream (*Lithognathus mormyrus*), Yashpal *et al.* (2006 and 2009) on the carnivorous fish (*Rita rita*) and the carp (*Cirrhinus mrigala*), Delashoub *et al.* (2010) on the bighead carp (*Hypophthalmichthys nobilis*), Gamal, *et al.* (2012) on the cat fish (*Clarias gariepinus*) and Deshmukh *et al.* (2015) on the cat fish (*Heteropneustes fossilis*).

However, information on the morphological and histological adaptations of digestive tube according to food and feeding habits of coral reef fish in the Egyptian Red Sea are rare (Al-Hussini, 1947; Gohar and Latif, 1959; Khalf-Allah, 2013).

Therefore, the present study aimed to provide comparative description on the histological adaptations of the intestine in some coral reef fish such as the rabbit fish (*Siganus rivulatus*) (Forsskål, 1775), the yellow striped goat fish (*Mulloidichthys flavolineatus*) (Lacepède, 1801) and the needle fish (*Tylosurus choram*) (Rüppell, 1837) in Hurghada, Red Sea, Egypt in relation to its food and feeding habits to understand the functional mechanisms of fish digestive physiology and feeding strategy.

2. MATERIAL AND METHODS

2.1. Specimens collection:

A total of 26 specimens; 10 of rabbit fish (*Siganus rivulatus*), 10 of yellow striped goat fish (*Mulloidichthys flavolineatus*) and 6 of needle fish (*Tylosurus choram*) formed the material for the present study. Fish specimens were collected from Abu Galawa lagoon in Hurghada, Red Sea, during the period from December 2014 to November 2015. Long lines nets were the main fishing method used to collect the fish. Wherever possible fish were examined fresh or preserved in 10% formalin solution for latter examination. In the laboratory, fish were taxonomically identified, as far as possible up to genera according to Randall (1983) and Lieske and Myers (2004). They were identified, total length were measured to the nearest millimeters and recorded.

2.2. Histological studies of the intestine:

For histological studies, small pieces (5 mm) of intestine were removed from the dissected specimens and immediately fixed in alcoholic Bouin`s fluid for at least 48 hours, dehydrated in ascending concentrations of ethyl alcohol, cleared in xylene and embedded in paraplast wax (M.P.: 58°C). Transverse sections were cut at the thickness of 4-6 µm, stained with Harris`s haematoxylin and eosin and the histological procedures were completed for general structure (Humason, 1979). Sections were microscopically examined then photographed and described.

3. RESULTS

3.1. *Siganus rivulatus*:

At the macroscopic observations level, the intestine of *S. rivulatus* is exceedingly long and variously convoluted. It can be divided into three portions: anterior, mid and posterior intestine. The wall of each portion is made up of the ordinary four layers: mucosa, submucosa, muscularis and serosa.

The microscopic observations revealed that the mucosal lining of the anterior intestine is greatly folded. The villi are relatively short and closely set with tapering, round and blunt tips. Small folds are present at the bases of the crypts in between the comparatively large folds. The epithelial mucosa is made up of two kinds of cells: columnar and mucus secreting cells. Mucus secreting cells are few in number and have a typical goblet outline. They are concentrated at the sides of the folds, rarely on the crests. While, in extensive areas along the bases, they are entirely absent (Plate I A&B). The submucosa is comparatively thinner and composed of areolar connective tissue, richly supplied with fibrocytes, lymphocytes and blood vessels. The muscularis consists of two layers: an inner circular and an outer longitudinal muscle layers. Both of which are formed of unstriated muscle fibers. They are held together by areolar connective tissue. The inner layer of muscle fibers is relatively thicker than the outer one. The serosa consists of simple squamous epithelium (Plate I A&B).

The histological structure of the mid intestine of *S. rivulatus* is almost similar to that of the anterior one, except the villi, which are enormously short with round or tapering tips. The epithelial lining is provided with broad and long columnar cells. Goblet cells are comparatively large. The muscularis is well developed. The serosa consists of simple squamous epithelium and covering a thin layer of connective tissue (Plate II A& B).

The histological structure of the posterior intestine of *S. rivulatus* is similar as far as the anterior one. But, some differences can be easily observed. Generally, the villi are thicker and tend to be more slender towards the posterior end with round or tapering tips. The mucosa is well developed and mucus cells are abundant (Plate III A&B). The submucosa is well developed and lymph spaces, lymphocytes and large blood vessels are highly abundant. The muscularis is well developed and the inner layer is much thicker than the outer one. The serosa consists of simple squamous epithelium (Plate III A&B).

3.2. *Mulloidichthys flavolineatus*:

At macroscopic observation level, the intestine of *M. flavolineatus* is differentiated into three regions (duodenum, ileum and rectum).

The microscopic observations showed that the duodenal mucosa is greatly folded to form villi, which are enormously short and closely associated with shallow crypts. The epithelial mucosa is made up of columnar cells and numerous mucus-secreting cells, which concentrated at the sides and bases of the folds (Plate I C&D). The submucosa is comparatively thinner and composed of areolar connective tissue, penetrated by blood vessels and lymphocytes. Muscularis mucosa is completely absent. The muscularis consists of two layers: a thick inner circular layer and a thin outer longitudinal one of unstriated type. The serous layer is made up of simple squamous epithelium (Plate I C&D).

The ilial mucosa is provided with broad and long columnar cells. Mucous cells are comparatively large. The submucosa consists of fibrous connective tissue, richly supplied with blood vessels. The muscularis is well developed. The serosa consists of simple squamous epithelium (Plate II C&D).

The rectal folds are irregular in shape, being short and numerous. Mucus cells are highly abundant. Lamina propria is comparatively compact and contains small lymph spaces. The muscularis is poorly developed. The serous connective tissue covered by a thin layer of simple squamous epithelium (Plate III C&D).

3.3. *Tylosurus choram*:

The intestine proper of *T. choram* is a short straight tube. It is divided into three portions (the anterior, middle and posterior). The wall of each portion is made up of the ordinary four layers: mucosa, submucosa, muscularis and serosa.

The mucosal folds in the anterior portion of intestine are very long, numerous, more or less parallel to each other with rounded tips. Small folds or buds are also present at the bases of the crypts. The epithelial cells are of two kinds: absorptive and less frequently mucus secreting cells. The latters are saccular or spherical in shape (Plate I E&F). The submucosa is comparatively wider and consists of areolar connective tissue supplemented by fibrous connective tissue. The muscularis is relatively thick and consists of two layers: an inner circular and an outer longitudinal muscle layers formed of unstriated type. The serosa consists of simple squamous epithelium (Plate I E&F).

There is no line of demarcation between the anterior and middle portions of intestine in *T. choram*. However, some histological peculiarities can be easily demonstrated. The mucosa is thrown into primary mucosal folds. The epithelial mucosa is made up of a compact simple columnar epithelium involved with large number of goblet cells (Plate II E&F). The submucosa is wide and composed of fibrous connective tissue contains lymph spaces and numerous blood vessels. Muscularis and serosa are similar in structure to those found in the anterior portion of intestine (Plate II E&F).

The histological structure of the posterior portion of intestine is similar as far as the middle one, but some differences can be easily found. The mucosa is thrown into deep primary mucosal folds. The folds are high, more tapering ends and branched into secondary folds. Mucus secreting cells are comparatively numerous, being saccular or global in shape and distributed among the columnar epithelium (Plate III E&F). The submucosa is well developed and made up of areolar connective tissue supplemented by fibrous connective tissue. Lymphocytes, lymph spaces and large blood vessels are highly abundant. The muscularis is relatively thicker. The serosa consists of simple squamous epithelium (Plate III E&F).

4. DISCUSSION

All parts of the alimentary canal from oesophagus to anus are known as gut. The gut is distinguished into oesophagus, stomach or intestinal bulb, duodenum, ileum, rectum and anus. These parts may or may not be distinguished from each other in some fish, while in others there is clear morphological distinction between these chambers (Kumar and Tembhre, 1996).

In this study, the intestine of the herbivorous fish (*S. rivulatus*) is exceedingly long and variously convoluted. This is necessary for the amount of cellulose materials, which requires a longer passage and remain for considerable time in the intestine. Therefore, the function of this part is connected with the completion of the digestion and absorption of the digested food. Externally, the intestine is not differentiated into different distinguished regions due to the lack of any clear demarcation between them. Internally, however, the intestine can be divided into three portions: anterior, mid and posterior intestine. These results are consistent with previous studies by Almeida *et al.* (1993); Shehata (1997) and Khalaf-Allah (2001).

In the present study, the intestine in the carnivorous fish (*M. flavolineatus*) and the piscivorous fish (*Tylosurus choram*) are short tubes. These findings of the present work are very similar to those described in other carnivorous fishes by Dasgupta (2002 and 2004), Al-Abdulhadi (2005), El-Bakary (2007), Khalaf-Allah (2009 and 2013) and Hassan (2013).

From the above mentioned results, it is clear that, the intestinal length is considered as a significant feature considered in assessing the nature of diet and is varied from species to another. The variations in the gut length of studied species may be due to the fact that, the carnivorous (*M. flavolineatus*) and piscivorous (*T. choram*) fish have no need of storage food so a long gut is unnecessary. These findings of the present study are agree with the studies previously described by Al-Abdulhadi (2005), El-Bakary (2007), Khalaf-Allah (2009 and 2013) and Hassan (2013) on carnivorous fishes. On the other hand, the food of herbivorous fish (*S. rivulatus*) contains more cellulose which requires longer remains for digestion and large absorptive surface for the proper assimilation. Similar observations were reported by Almeida *et al.* (1993), Shehata (1997) and Khalaf-Allah (2001).

On the other hand, the ileo-rectal valves were absent in the posterior intestine of herbivorous (*S. rivulatus*) and piscivorous (*Tylosurus choram*) fish. But, the posterior intestine of carnivorous fish (*M. flavolineatus*) is recognized by the presence of ileo-rectal valve as well as by increase in its diameter. The ileo-rectal valve, which is more or less constant feature of teleost intestine, marked the beginning of the terminal segment (the rectum). This valve presumably prevents the passage of food particles into the posterior part before the intestinal digestion and absorption is completed. Similar observations were detected in many carnivorous fishes including *Gambusia affinis holbrookei* (Shehata, 1982), *Morone Labrax* (Shehata, 1997), *Solea solea* (Khalaf-Allah, 2001), *Lates niloticus* (Albattal, 2002), *Mylio cuvieri* (Al-Abdulhadi, 2005), *Anguilla anguilla* (El-Bakary, 2007) and *Cheilinus lunulatus* (Khalaf-Allah, 2013).

The histological picture of the intestinal epithelium of various teleostean species is relatively very similar across developmental stages and different species (Shehata, 1997; Al-Abdulhadi, 2005). The duodenal mucosa of all studied species is thrown into primary, secondary and tertiary folds. Such structures are shorter and fewer in number towards the ileum and much thicker in the rectum. Goblet cells are large in size and great in number. This may provide viscosity for both food and fecal materials (Agamy *et al*., 1992; Khalaf-Allah, 2009 and 2012; Khalil *et al*., 2011; Hashem *et al*., 2012; Mabrouk, 2015).

In all species of the present study, the epithelial lining in the middle portion of the intestine is provided with large columnar cells, covered by a thin top Plate. The latter is discontinuous at the places where mucous cells are present, confirming the absorptive nature of this organ. In the posterior portion of the intestine, however, the villi are comparatively shorter, blunt and tend to be more slender. Muscularis is well developed. Goblet cells are larger in size and higher in number. The presence of goblet cells in the posterior intestine has been considered essential for fecal lubrication. Similar observations were detected in most fish described by Shehata (1997 and 1999), Alne-na-ei (1994), El-Bakary, (2007), Khalaf-Allah (2009 and 2012) and Hassan (2013).

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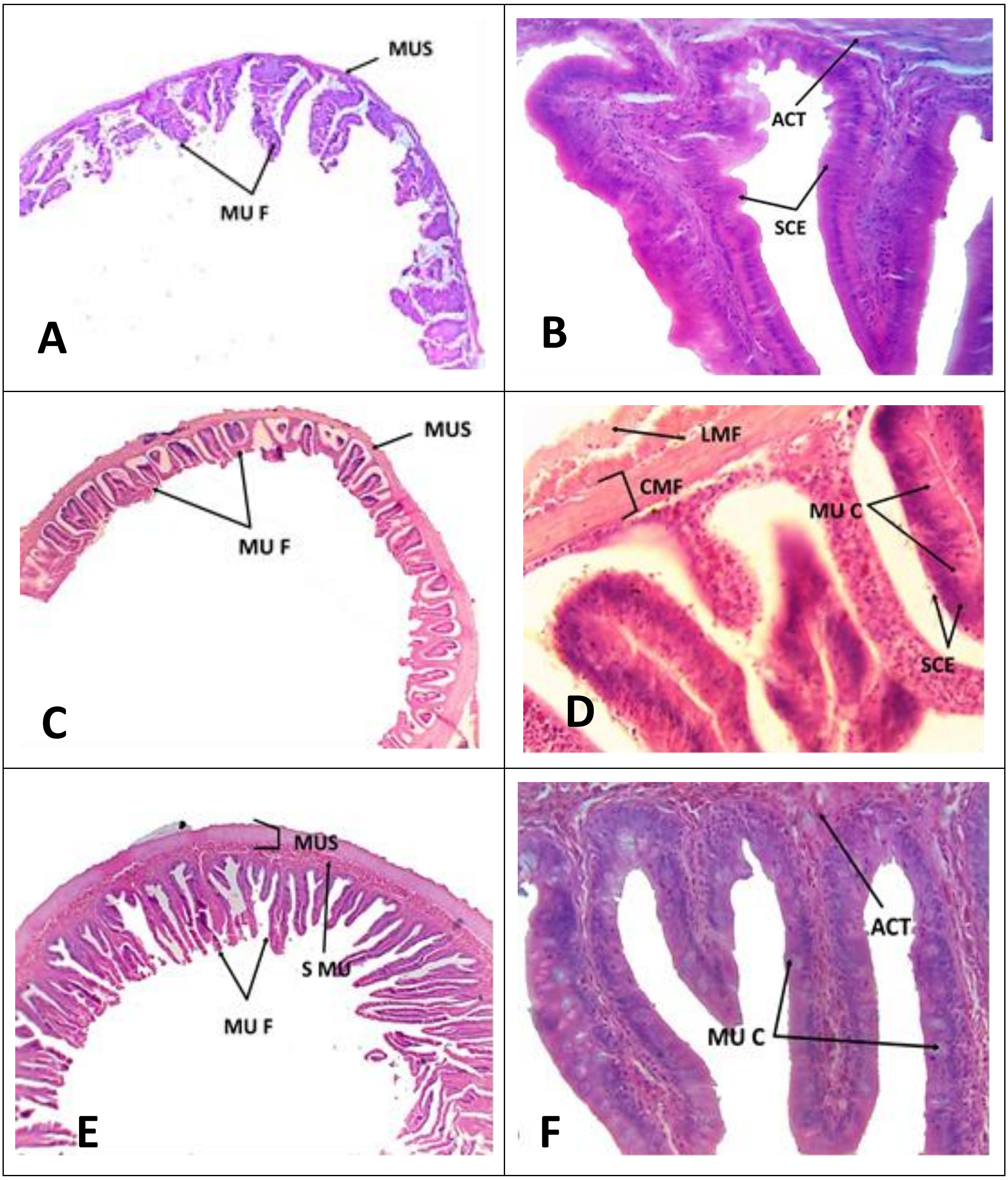

Plate I: Photomicrographs of T.S. in (A&B) the anterior intestine of *S. rivulatus*, (C&D) duodenum of *M. flavolineatus* and (E&F) anterior intestine of *T. choram* showing muscularis (MUS), submucosa (SMU), mucosal fold (MU F), circular muscle fibers (CMF), longitudinal muscle fibers (LMF), areolar connective tissue (ACT), simple columnar epithelium (SCE) and mucous secreting cells (MU C). (H & E; A, C & E X40 and B, D & F X400).

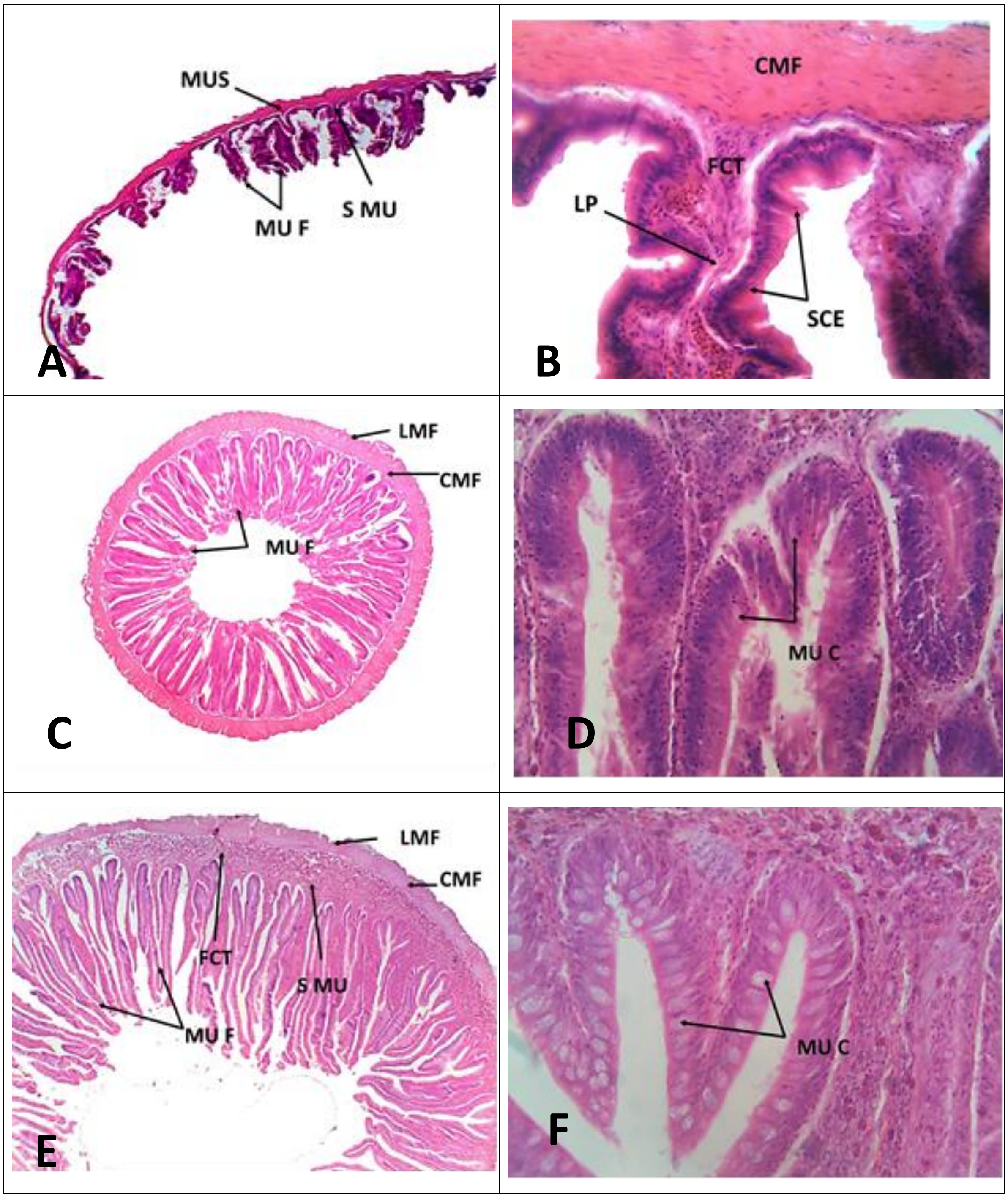

Plate II: Photomicrographs of T.S. in (A&B) the Mid intestine of *S. rivulatus*, (C&D) ileum of *M. flavolineatus* and (E&F) mid intestine of *T. choram* showing muscularis (MUS), submucosa (SMU), mucosal fold (MU F), circular muscle fibers (CMF), longitudinal muscle fibers (LMF), fibrous connective tissue (FCT), lamina properia (LP), simple columnar epithelium (SCE) and mucous secreting cells (MU C). (H & E; A, C & E X40 and B, D & F X400).

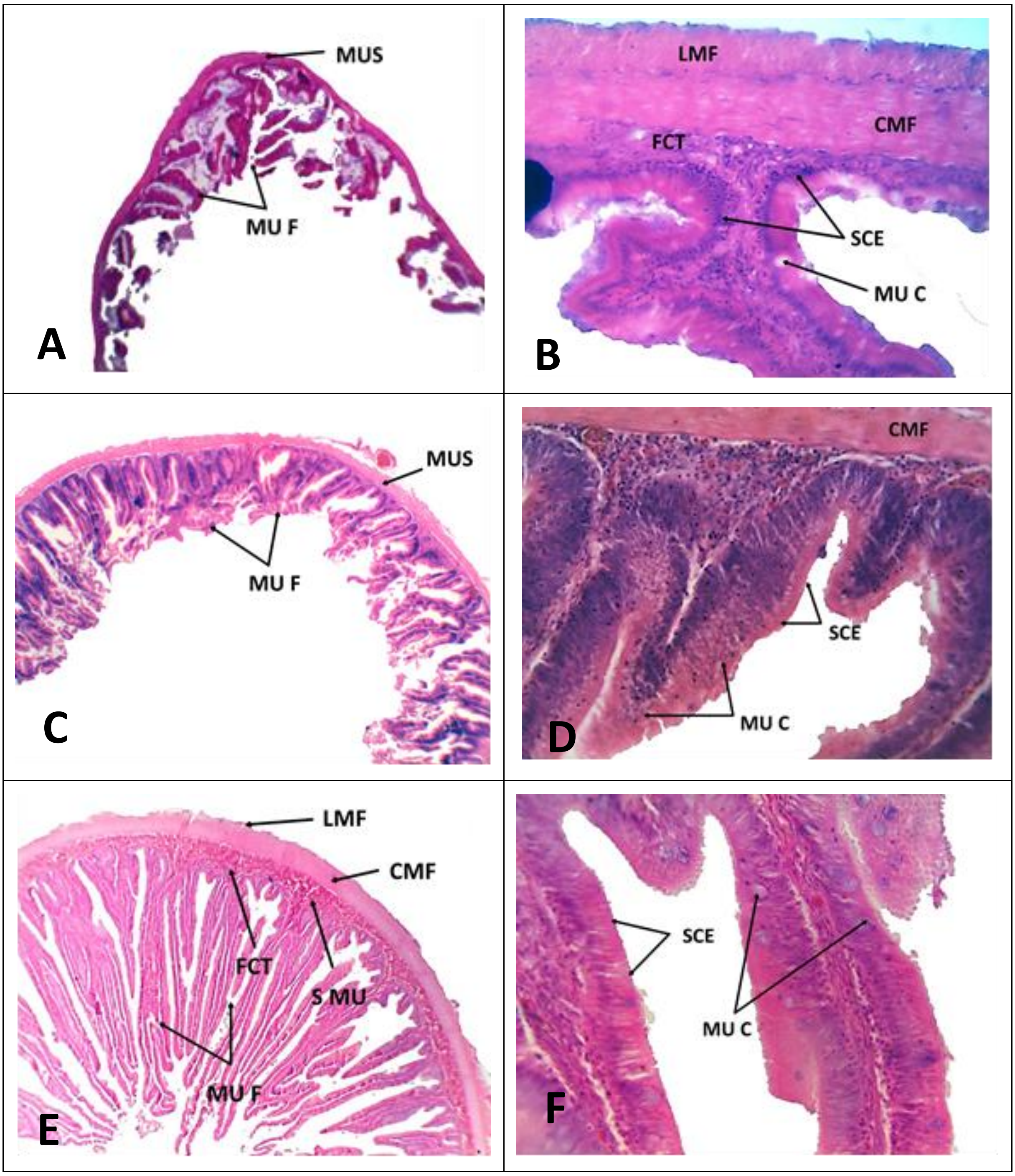

Plate III: Photomicrographs of T.S. in (A&B) the posterior intestine of *S. rivulatus*, (C&D) rectum of *M. flavolineatus* and (E&F) posterior intestine of *T. choram* showing muscularis (MUS), submucosa (SMU), mucosal fold (MU F), circular muscle fibers (CMF), longitudinal muscle fibers (LMF), fibrous connective tissue (FCT), simple columnar epithelium (SCE) and mucous secreting cells (MU C). (H & E; A, C & E X40 and B, D & X400).