4.1. Histochemistry

Tables 4.1 to 4.15 shows the distribution pattern and the levels of staining intensity of the various constituents/components/enzymes studied.

4.1.1. Organic constituents

4.1.1.1. Proteins (Table 4.1)

**Buccopharynx**

Intensely positive reaction for total proteins is discernible in the stratified epithelial cells of the buccopharyngeal mucosa and the muscularis (Fig. 1 and 2). The submucosal connective tissue depicts moderate reaction. Whereas, the mucous cells are negative to mercury bromophenol blue test.

**Oesophagus**

The stratified epithelial cells of the oesophageal mucosa, the submucosa especially towards the basal portions and the muscularis stain intensely (Fig. 3). The mucous secreting goblet cells and the serosa on the other hand do not show any reaction.

**Intestinal bulb**

In the intestinal bulb, the stain intensity is intense in the submucosal connective tissue and blood capillaries particularly along the basal portions of the villi, the muscularis and the serosa (Fig. 4). The submucosa along the apical portions of the villi and the mucosal epithelial cells show moderate reaction. The mucous cells are however, devoid of any reaction.
Results

Intestine

The entire length of the intestine shows positive results for general proteins. However, the reaction is intense along the free border of the absorptive cells, the cytoplasm of the columnar epithelial cells of mucosa and the submucosal blood capillaries and the connective tissue towards the basal portions of the intestinal villi, the muscularis and the serosal layer (Fig. 5). However, the submucosa along the apices of the villi show a steady decrease. The mucous secreting goblet cells are totally devoid of any reaction.

Rectum

The sites of localization of proteins in the rectum are almost similar to that of the intestine of the fish studied except that there is a gradual decrease in the stain intensity (Fig. 6).

Hepatopancreas

The hepatocytes react moderately for total proteins, whereas intense reaction is noticeable in the intrahepatic pancreatic acini confirming the occurrence of large amount of protein contents (Fig. 7).
Results
4.1.1.2. Tyrosine (Table 4.2)

**Buccopharynx**

The cytoplasm of the stratified epithelial cells of the buccopharyngeal mucosa shows intensely positive reaction for tyrosine (Fig. 8). On the other hand, the submucosal blood capillaries, connective tissue and the muscularis are weakly positive.

**Oesophagus**

Intense reaction is noted in the stratified epithelial cells throughout the oesophageal mucosal fold and in the submucosal blood capillaries and the connective tissue along the basal portions (Fig. 9). The mucous cells react negatively, whereas, the muscularis depicts moderate reaction.

**Intestinal bulb**

In the intestinal bulb, the mucosal border and the basal portions of the columnar epithelial cells of mucosa react intensely positive for tyrosine (Fig. 10). Tyrosine is also intensely localized in between the muscularis and the serosa. The submucosa however, depicts moderate reaction, while the muscularis is weakly positive. The serosal layer reacts negatively for tyrosine.

**Intestine**

Uniformly intense stain intensity is discernible in the mucosal epithelial cells throughout the length of the villi and the entire submucosal region (Fig. 11). The muscularis shows weak reaction whereas, the serosa is tyrosine negative.
Rectum

The columnar epithelial cells of mucosa along the basal portion of the villi depict intense stain intensity (Fig. 12). The epithelial cells along the basis of the villi show pronounced reaction whereas there is a steady decrease in the stain intensity towards the apices of the villi. The submucosal blood capillaries and the connective tissue react moderately. The muscularis is weakly positive, while the serosa is devoid of any reaction.

Hepatopancreas

Weak reaction is noticeable in the hepatocytes. The sinusoids do not show any reaction. The intrahepatic pancreatic acini are however, intensely positive for tyrosine (Fig. 13).
4.1.1.3. Tryptophan (Table 4.3)

Intestinal bulb

The free border of mucosa, the basal portions of the columnar epithelial cells, the muscularis and the serosal layer stain intensely for tryptophan (Fig. 14). The submucosal blood capillaries particularly towards the bases of the villi exhibit moderate reaction. Weak reaction is noticeable in the connective tissue.

Intestine

The entire length of the intestine reacts positively for tryptophan. The brush border, the basal portions of the epithelial cells especially along the apices of the villi, the muscularis and serosa are the sites of intense localization (Fig. 15). The submucosal blood capillaries, on the other hand react moderately for tryptophan, whereas the connective tissue is weakly positive.

Rectum

The sites of localization for tryptophan in the rectum are almost similar to that of the intestine except that there is a steady decrease in the stain intensity (Fig. 16).

Hepatopancreas

Weak reaction is noticeable in the hepatic cells. The sinusoids, blood capillaries and the connective tissue stain moderately. However, the pancreatic acini stain intensely for tryptophan (Fig. 17).

The buccopharynx and oesophagus are observed to be tryptophan negative.
4.1.1.4. Elastic Fibres (Table 4.4)

**Buccopharynx**

Intense reaction for elastic fibres is discernible in the walls of blood vessels present in the submucosa (Fig. 18). No reaction however, is observed in the mucosa and the muscularis.

**Oesophagus**

In the oesophageal region, intensely positive reaction for elastic fibres is observed in the walls of the blood vessels in the muscularis only (Fig. 19).

**Intestinal bulb**

The blood vessels present along the basal portions of the villi in the submucosa and the serosal layer exhibit moderate reaction for elastic fibres (Fig. 20 and 21). The mucosa and the muscularis however, react negatively.

**Intestine**

The stain intensity is moderate in the walls of the blood vessels present in the submucosa along the basal portions of the intestinal villi (Fig. 22). The mucosa, muscularis and serosa do not exhibit any reaction for elastic fibres.

**Rectum**

The stain intensity and the sites of localization of elastic fibres in the rectum is almost similar to that of the intestine of the fish studied (Fig. 23).

**Liver**

The stain intensity is well pronounced in the walls of the blood vessels in the liver (Fig. 24).

No reaction for elastic fibres is observed in the intrahepatic pancreatic tissue.
4.1.1.5. DNA (Table 4.5)

**Buccopharynx**

The nuclei of the stratified epithelial cells and the mucous cells of the buccopharyngeal mucosa are intensely positive (Fig. 25). On the other hand, the stain intensity is moderate in the nuclei of the submucosal connective tissue.

**Oesophagus**

Intense reaction is discernible in the nuclei of the stratified epithelial cells of the oesophageal mucosa (Fig. 26). The scattered oval nuclei of the submucosal connective tissue and the nuclei of the blood vessels however, react moderately. The muscularis is weakly positive, where as the serosa is devoid of any reaction.

**Intestinal bulb and intestine**

The basal nuclei of the columnar epithelial cells of the mucosa along the entire length of the villi of both the intestinal bulb and intestine exhibit intensely positive reaction for DNA (Fig. 27 and 28). The reaction is also well pronounced throughout the entire submucosal region in the scattered oval nuclei of the connective tissue and the nuclei of the blood vessels. The muscularis however, reacts moderately. No reaction is observed in the serosa.

**Rectum**

The distribution and the intensity of localization of DNA in the rectum is almost similar to that of the intestinal bulb and intestine of the fish studied (Fig. 29).

**Hepatopancreas**

Intense reaction is discernible in the centrally placed nuclei of hepatocytes. The distribution is almost uniform along the perilobular and centrolobular zones of the liver. However, in comparison to the hepatic cells, the reaction is more pronounced in the intrahepatic pancreatic acini (Fig. 30).
4.1.1.6. Glycogen (Table 4.6)

Liver

The reaction is observed to be well pronounced in the cytoplasm of hepatocytes throughout the perilobular and centrolobular zones of the liver (Fig. 31). The hepatic sinusoids, blood vessels and the connective tissue however, are negative to Best’s Carmine reaction.

Rest of the tissues of the digestive system studied during the present investigation are observed to be devoid of glycogen.

Table 4.6: Distribution and localization of the glycogen in the digestive system of *Schizothorax esocinus*

<table>
<thead>
<tr>
<th>Digestive organ/ Tissue</th>
<th>Distribution and localization of glycogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buccopharynx</td>
<td>-</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>-</td>
</tr>
<tr>
<td>Intestinal bulb</td>
<td>-</td>
</tr>
<tr>
<td>Intestine</td>
<td>-</td>
</tr>
<tr>
<td>Rectum</td>
<td>-</td>
</tr>
<tr>
<td>Liver:</td>
<td></td>
</tr>
<tr>
<td>Hepatocytes</td>
<td>+++</td>
</tr>
<tr>
<td>Hepatic sinusoids, Blood vessels and connective tissue</td>
<td>-</td>
</tr>
</tbody>
</table>

Levels of the staining intensity:
+++ (Pronounced), - (Absent).
4.1.1.7. Neutral Mucin (Table 4.7)

**Buccopharynx**

In the buccopharynx, the peripheral secretory and deeper non-secretory mucous cells exhibit intensely positive reaction for neutral mucin (Fig. 32). The stratified epithelial cells however, react negatively. The wavy subepithelial connective tissue of the submucosa stains weakly.

**Oesophagus**

The mucous cells react intensely for neutral mucin (Fig. 33). The reaction is also well pronounced in the mucosal border and the stratified epithelial cells. Moderate reaction is however, discernible in the submucosal connective tissue. The muscularis and serosa depict negative reaction.

**Intestinal bulb**

The scattered mucous cells depict strong reaction for neutral mucin (Fig. 34). The entire submucosa reacts moderately. The free border of mucosa shows weak reaction. However, the columnar epithelial cells of mucosa, muscularis and serosa are devoid of any reaction.

**Intestine**

Different types of mucous cells along the entire length of the intestine are intensely positive (Fig. 35). The brush border of the mucosa and columnar epithelial cells however, react negatively. The submucosa depicts moderate reaction where as, the muscularis and serosa react negatively.

**Rectum**

Uniformly intense reaction is observed in the mucous cells of the rectal mucosa (Fig. 36). On the other hand, the free border of the mucosa and the columnar epithelial cells react negatively. Moderate reaction is noticeable in the submucosa. The muscularis and serosa reveal negative results.

The hepatopancreas exhibits negative results for neutral mucin.
4.1.1.8. Acid mucin (Table 4.8)

**Oesophagus**

The mucous cells stain strongly with alcian blue (Fig. 37). The submucosa, basement membrane, stratified epithelial cells and the muscularis exhibit negative reaction.

**Intestinal bulb**

The stain intensity is uniformly well pronounced in the mucous cells of the intestinal bulb (Fig. 38). The free border of the mucosa, columnar epithelial cells, entire submucosal region, muscularis and the serosa stain negatively with alcian blue.

**Intestine**

The mucous secreting goblet cells along the entire length of the intestine react strongly with alcian blue (Fig. 39). The brush border, the columnar epithelial cells of the mucosa and the submucosal connective tissue however, do not show any reaction.

**Rectum**

The mucous cells of the rectal mucosa stain intensely with alcian blue (Fig. 40). The secreted luminal mucin and brush border also display strongly positive reaction with alcian blue (AB). The submucosal connective tissue, epithelial cells, muscularis and serosa are, however, negative to the test.

The buccopharynx and hepatopancreas are observed to be devoid of acid mucin.
4.1.1.9. Neutral lipids (Table 4.9)

Oesophagus

The stratified epithelial cells of oesophageal mucosa exhibit pronounced reaction for neutral lipids (Fig. 41). Moderate reaction is noticeable in the entire submucosal region and the muscularis.

Intestinal bulb

The brush border and the mucosal epithelial cells throughout the length of the villi are strongly positive to Sudan black B test (Fig. 42). Moderate to week reaction is observed in the submucosal lymph spaces and blood capillaries along the basal portions of the villi. The muscularis is weakly positive whereas, the goblet cells do not show any reaction for neutral lipids.

Intestine

The stain intensity is intense in the brush border and the columnar epithelial cells of mucosa as evidenced by intense black coloration throughout the length of epithelium of the intestine (Fig. 43). The submucosa particularly along the basal portions of the villi depict moderate reaction in the lymph spaces, blood vessels and blood capillaries. The muscularis stains negatively, whereas, the serosa stains intensely.

Rectum

The distribution of lipid in the rectum is almost similar to that of the intestine except for a slight decrease in the stain intensity (Fig. 44).

Liver

Intense reaction is discernible in the cytoplasm of hepatocytes (Fig. 45). The distribution of stained lipids is almost uniform in the perilobular and centrolobular regions of the liver. The sinusoids and the connective tissue do not show any reaction.

The buccopharynx and the intrahepatic pancreatic tissue are negative to Sudan black B test.
4.1.2. Inorganic constituents

4.1.2.1. Iron (Table 4.10)

Liver

The distribution of iron is more or less uniform throughout the cytoplasm of the hepatic cells. However, the stain intensity is pronounced in the hepatocytes along the perilobular region than the centrolobular region (Fig. 46). The hepatic sinusoids and the connective tissue on the other hand, react negatively for iron.

Rest of the tissues studied during the present investigation are devoid of any iron reaction.

4.1.2.2. Calcium (Table 4.11)

Intestinal bulb

The stain intensity is intense in the submucosal lymph spaces, blood vessels, blood capillaries and the connective tissue, particularly along the basal portions of the villi (Fig. 47). The columnar epithelial cells of the mucosa show weak reaction. The muscularis and serosa on the other hand, react negatively for calcium.

Intestine

The intensity and the sites of localization of calcium in the intestine are more or less similar to that of the intestinal bulb (Fig. 48).

The buccopharynx, oesophagus, rectum and hepatopancreas are noted to be devoid of calcium.
4.1.3. Enzymes

4.1.3.1. Alkaline phosphatase (Table 4.12)

**Buccopharynx**

Alkaline phosphatase is intensely localized in the stratified epithelial cells of the mucosa, the nuclei of the club cells, blood capillaries and the connective tissue while weak activity is noticeable in the muscularis (Fig. 49). The mucous cells are devoid of any activity.

**Oesophagus**

In the oesophagus, the stratified epithelial cells of mucosa are the sites of intense localization (Fig 50). Moderate enzyme activity is observed in the entire submucosa and lamina propria. The mucous cells, muscularis and the serosa do not show any activity.

**Intestinal Bulb**

The brush border and columnar epithelial cells of the mucosa depict intense enzyme activity (Fig. 51). In the submucosa, moderate activity is detected in the blood capillaries and the connective tissue, while the muscularis and serosa react negatively for the enzyme.

**Intestine**

Uniformly intense activity for alkaline phosphatase is demonstrated along the entire length of the villi, in the brush borders and in the mucosal epithelial cells (Fig. 52). Moderate to weak activity is noted in the entire submucosal core of the villi. No activity is observed in the muscularis and serosa.
Rectum

In comparison to the intestine, a progressive decrease in the intensity of enzyme activity is discernible in the rectum (Fig. 53). The sites of localization are almost similar to that of the intestine.

Hepatopancreas

Intense enzyme activity is noticeable in the nuclei of the hepatocytes, whereas, the activity is noted to be feeble in the cytoplasm of the hepatic cells. However, the activity is more pronounced in the pancreatic acini (Fig. 54).
4.1.3.2. Acid phosphatase (Table 4.13)

**Buccopharynx**

The activity of acid phosphatase is observed to be intense in the stratified epithelial cells, club cells, basement membrane and the submucosal layer (Fig. 55). The muscularis shows negative activity.

**Oesophagus**

Intense activity for acid phosphatase is noted in the stratified epithelial cells all along the oesophageal mucosal fold, lamina propria and in the submucosal blood vessels, blood capillaries and connective tissue (Fig. 56). The mucous cells, the muscularis and the serosa react negatively for the enzyme.

**Intestinal Bulb**

In the intestinal bulb, the brush border and the columnar epithelial cells of the mucosa throughout the villi reveal intense activity for acid phosphatase (Fig. 57). The submucosal lymph spaces, blood vessels, blood capillaries and the connective tissue are also intensely localized sites. The mucous cells, muscularis and the serosa do not show any enzyme activity.

**Intestine**

The pattern of distribution and the intensity of enzyme activity throughout the intestine is similar to that of the intestinal bulb (Fig. 58).

**Rectum**

In the rectum, intense activity is discernible particularly along the bases of the villi in the mucosal epithelial cells and the submucosal layer from where the enzyme activity gradually decreases towards the apices of the villi.
(Fig. 59). The brush borders, mucous secreting goblet cells, muscularis and the serosa are phosphatase negative.

**Hepatopancreas**

Weak activity for acid phosphatase is noticeable in the cytoplasm of hepatocytes, while the nuclei of the hepatocytes and the pancreatic acini exhibit intense acid phosphatase activity (Fig. 60).
4.1.3.3. Lipase (Table 4.14)

Intestinal bulb

In the intestinal bulb, intense lipase activity is found along the basal portions of the villi in the mucosal border and in the epithelial cells (Fig. 61). The submucosal lymph spaces, blood vessels and blood capillaries towards the bases of the villi are intensely localized sites. A steady decrease in the enzyme activity is observed towards the apices of the villi in both the mucosal and submucosal layers. The mucous secreting goblet cells, muscularis and the serosa are devoid of any activity.

Intestine

In the intestine, the enzyme is distributed throughout the columnar epithelial cells of the mucosa although the brush border is observed to be intensely localized site (Fig. 62). The inter-villar portions or crypts also exhibit pronounced activity. Moderate lipase activity is however, noticeable throughout the submucosa. On the other hand, the goblet shaped mucous cells, muscularis and the serosa are observed to be lipase negative.

Hepatopancreas

Lipase activity is observed to be intense in the hepatocytes. The enzyme is uniformly distributed throughout the perilobular and centrolobular regions of the liver (Fig. 63). The intrahepatic pancreatic acini are conspicuous by their intense enzyme activities appearing as dark patches (Fig. 64).

The buccopharynx, oesophagus and the rectum on the contrary are observed to be devoid of any lipase activity.
4.1.3.4. Adenosine triphosphatase: ATPase (Table 4.15)

Buccopharynx

The stratified epithelial cells of the buccopharyngeal mucosa depict intense ATPase activity (Fig. 65). Well pronounced activity is also noticeable in the submucosa and muscularis.

Oesophagus

Moderate to weak enzyme activity is discernible in the stratified epithelial cells of the mucosa, whereas, uniformly intense activity is discernible throughout the lamina propria, and in the submucosal blood vessels, blood capillaries and connective tissue (Fig. 66). The muscularis however, exhibits moderate activity.

Intestinal bulb

ATPase is distributed in the brush border and the mucosal epithelial cells along the entire length of the villi (Fig. 67). The activity is observed to be intense. On the other hand, weak activity is noted along the entire submucosa. The muscularis and serosa however, do not show any activity.

Intestine

In the intestine, the brush borders and the columnar epithelial cells of the mucosa are intensely localized sites (Fig. 68). The enzyme is uniformly distributed throughout the length of the villi. The submucosa particularly towards the basal portions of the villi show moderate enzyme activity, whereas, along the apices, a significant decrease is noticed in the submucosa. The muscularis and serosa are observed to be ATPase negative.
Rectum

The sites of intense localization include the brush border of the mucosa particularly towards the apices of the villi and the entire submucosal region (Fig. 69). Mild activity is noted in the columnar epithelial cells. The muscularis and the serosa on the other hand, do not show any enzyme activity.

Hepatopancreas

The enzyme activity is observed to be moderate in the cytoplasm and nuclei of the hepatic cells. However, the intrahepatic pancreatic tissue exhibits intense activity in the acini (Fig. 70).
4.2. Biochemistry

The biochemical studies with respect to the estimation of total proteins, lipids, carbohydrates and enzymes namely, alkaline phosphatase, acid phosphatase and lipase have been carried out in the digestive organs viz., hepatopancreas, intestinal bulb and intestine of \textit{Schizothorax esocinus}. Table 4.16 shows the mean (± S.E.) values of proteins, lipids and carbohydrate content in the said organs.

Proteins are found to be the major biochemical constituents of the digestive organs studied in the fish investigated, as compared to the lipids and carbohydrates. The mean percentage of protein content in the hepatopancreas is found to be higher i.e. 37.33 ± 2.74 than that of the intestine (20.87 ± 2.02) and intestinal bulb (19.05 ± 1.01) of the said fish.

The lipid concentration in the organs studied range between 22.65±3.16\% to 14.21±3.23\%. Hepatopancreas shows a higher lipid content (22.65 ± 3.16) when compared to that of the intestinal bulb (16.67 ± 3.50) and intestine (14.21 ± 3.23). The order of the lipid variation in the tissues studied is hepatopancreas > intestinal bulb > intestine.

The carbohydrates forms a minor percentage of total composition and the lowest component observed in the tissues studied. The carbohydrate content however, ranges from 0.80 ± 0.29 to 4.72 ± 1.78. The hepatopancreas shows the higher quantity (4.72\% ± 1.78) of carbohydrate content than the intestinal bulb and the intestine. However, little variation has been observed in the total carbohydrate content of intestinal bulb (0.92 ± 0.26) and intestine (0.80 ± 0.29).

Fig. 71 shows the protein, lipid and carbohydrate contents in the different digestive organs of \textit{Schizothorax esocinus}.
The results of the specific activity of the digestive enzymes studied in the hepatopancreas, intestinal bulb and intestine of the naturally feeding fish, *Schizothorax esocinus* are given in table 4.17.

The activity of alkaline phosphatase observed in the said tissues of the fish investigated is noted to be higher in the intestinal bulb (2.46 ± 0.36 U/mg), followed by intestine (2.28 ± 0.23 U/mg) and hepatopancreas (1.93 ± 0.49 U/mg).

The acid phosphate activity on the other hand shows higher mean value in the hepatopancreas (3.30 ± 0.25 U/mg) than the intestinal bulb (2.94 ± 0.21 U/mg) and intestine (2.76 ± 0.43 U/mg).

Fig. 72 shows the specific activities of alkaline phosphatase and acid phosphatase in the said digestive organs.

Similarly, lipase assay shows higher mean values in the hepatopancreas (301.1 ± 38.66 U/g) followed by the intestinal bulb (271.9 ± 35.94 U/g) and intestine (253.56 ± 32.20 U/g).

Fig. 73 shows the specific activity of lipase in the digestive organs of *Schizothorax esocinus*.

**Table 4.16**: Protein, lipid and carbohydrate content in the digestive organs of *Schizothorax esocinus*.

<table>
<thead>
<tr>
<th>Digestive organs</th>
<th>Protein (%) Mean ± S.E</th>
<th>Lipid (%) Mean ± S.E</th>
<th>Carbohydrate (%) Mean ± S.E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatopancreas</td>
<td>37.33 ± 2.74</td>
<td>22.65 ± 3.16</td>
<td>4.72 ± 1.78</td>
</tr>
<tr>
<td>Intestinal bulb</td>
<td>19.05 ± 1.01</td>
<td>16.67 ± 3.50</td>
<td>0.92 ± 0.26</td>
</tr>
<tr>
<td>Intestine</td>
<td>20.87 ± 2.02</td>
<td>14.21 ± 3.23</td>
<td>0.8 ± 0.29</td>
</tr>
</tbody>
</table>

S.E. = Standard Error  
*Mean values of 10 replicates*
**Fig. 71:** Mean (± SE) protein, lipid and carbohydrate contents of hepatopancreas, intestinal bulb and intestine.
Table 4.17: Digestive enzymatic activities in digestive organs of *Schizothorax esocinus*.

<table>
<thead>
<tr>
<th>Digestive organs</th>
<th>Alkaline Phosphatase</th>
<th>Acid Phosphatase</th>
<th>Lipase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± S.E</td>
<td>Mean ± S.E</td>
<td>Mean ± S.E</td>
</tr>
<tr>
<td>Hepatopancreas</td>
<td>1.93 ± 0.49</td>
<td>3.30 ± 0.25</td>
<td>301.1 ± 38.66</td>
</tr>
<tr>
<td>Intestinal bulb</td>
<td>2.46 ± 0.36</td>
<td>2.94 ± 0.21</td>
<td>271.9 ± 35.94</td>
</tr>
<tr>
<td>Intestine</td>
<td>2.28 ± 0.23</td>
<td>2.76 ± 0.43</td>
<td>253.56 ± 32.20</td>
</tr>
</tbody>
</table>

S.E. = Standard Error

*Mean value of 10 replicates.*
Results

**Fig. 72:** Mean (± SE) alkaline phosphatase and acid phosphatase activities in hepatopancreas, intestinal bulb and intestine.

**Fig. 73:** Mean (± SE) lipase activity in hepatopancreas, intestinal bulb and intestine.
4.3. SEM

Buccopharynx

The mucosal surface of buccopharynx reveals prominent longitudinal mucosal folds (major or primary folds) which are further subdivided into the series of irregular and well circumscribed folds called minor or secondary folds (Fig. 74). The fine structure of the surface epithelium further reveals that the apical surfaces of the stratified epithelial cells are sculpted with a network of prominent microridges (Figs. 75 and 76). The microridges are observed to be regularly spaced bearing shallow concavities between them to hold mucous. The mucous secreting goblet cells are also recognized in between the stratified epithelial cells.

Oesophagus

The mucosal surface of the oesophagus is seen to be provided with primary longitudinal folds (major mucosal folds). Smaller infoldings of the mucosa are noted to be present on the sides of the main primary folds (Fig. 77). The stratified epithelial cells of the outer layer of the oesophagus are beset with numerous microridges arranged in various patterns. In addition to a goblet cell observed, scattered mucous coatings between the cellular surfaces and microridges appear distinctly (Fig. 78).

Intestinal bulb

High mucosal folds are discernible in the intestinal bulb of the fish studied. The mucosal folds also known as primary folds consist of zigzag or chevron-like structures which course along the long axis of the intestinal bulb (Fig. 79). The angles of the zigzag patterns are noted to be quite distinct. The space between the primary longitudinal folds is observed to be fairly large. However, the folds are noted to be generally round topped. Numerous pores are
observed on the surface of the primary fold which represents openings for mucous release. The mucosal folds of the intestinal bulb are further subdivided into the series of circumscribed elevations causing the formation of minor mucosal folds or secondary folds. Microridges of the columnar epithelial cells are observed to be quite prominent (Fig. 80).

**Intestine**

The entire length of the intestine is noticed to consist of primary longitudinal mucosal folds. However, the folds are not as high as observed in the intestinal bulb (Fig. 81). The longitudinal folds exhibit zigzag type invaginations of the internal mucosa and are provided with many minor or secondary mucosal folds (Fig. 82). The separation between the adjacent folds is however, less distinct than that of the intestinal bulb of the fish studied. It has been observed that a continuous cavity runs parallel throughout the entire length of the intestine in between these two major longitudinal folds (Fig. 81).

**Rectum**

The rectum exhibits irregular mucosal folds. The mucosal folds are covered by thick mucous and are beset with distinct pores (Fig. 83). However, in comparison to the intestinal bulb and intestine, the minor mucosal folds are not observed. Besides, very little separation between the adjacent folds is noticeable.