Detailed studies of the food and feeding habits of the three species, namely *Mystus* (Osteobagrus) *seenghala* (Sykes), *Labeo calbasu* (Hamilton) and *Tor tor* (Hamilton) revealed that *Mystus* (Osteobagrus) *seenghala* is a purely carnivorous fish feeding mostly on teleosts, insects and crustaceans form only a small portion of its diet. *Labeo calbasu* and *Tor tor* on the other hand feed mostly on algae, plant matter and diatoms, though the latter is also found to feed on quantities of gastropods and crustaceans. Since the items of diet in these two cases are almost identical in their gross components, it is likely that there must exist some similarity in the structures of the alimentary canal as regards anatomy, histology and physiology. The following discussion tends to bring out the structural modifications of the alimentary canal in each species in relation to the food and feeding habits of the fish.

The results of the present investigations on the food and feeding habits of *Mystus seenghala*, *Labeo calbasu* and *Tor tor* as indicated in the chapter "Food and Feeding habits" clearly reveal that the adult *M. seenghala* is a purely carnivorous fish, subsisting predominantly on teleosts. The fingerlings up to 131 mm feed on insects, mostly larvae of dragon fly, may fly, stone fly, beetle larvae and dipterous
larvae and quantities of plant matter. The juveniles ranging from 131 mm-300 mm stage feed both on teleosts and insects though \textit{Puntius} sp. formed the dominant item of their diet. The adult \textit{M. seenghala} is a predominantly piscivorous fish and feeds on a variety of teleosts. The seasonal fluctuations in the intensity of feed is closely correlated with the breeding season of the fish. The fish shows poor feeding intensity during the months April to June, this period coincides with the breeding season when fish with mature gonads were encountered. However, the juveniles are found to show active feeding activity throughout the whole year, this is because the growing specimens need more food for their development.

Earlier workers who worked on the food habits of young stages of \textit{M. seenghala} are Chacko and Job (1948), who observed that algae formed the most dominant item of diet contributing as much as 50\% of the total bulk. Alikhuni and Rao (1948) reported the presence of quantities of gastropods in the stomach, though the fish is decidedly piscivorous. Khan (1948), Alikhuni and Rao (1948) reported the presence of eggs and fry of other fishes in the stomach of \textit{M. seenghala}. However, my observations based on the examination of over hundred juvenile specimens confirmed that juveniles like the adults are also piscivorous, which is quite contrary to the observations of Job (1948).
_Labeo calbasu_ on the other hand, represents the other extreme in being purely herbivorous fish subsisting mainly on algae, diatoms and aquatic plants. Though the present investigations show no marked differential feeding habits in the different development stages of _L. calbasu_; the juveniles up to 145 mm were found to feed mostly on green algae and also quantities of plant matter. The guts show poor feeding intensity during the months March to August. The juveniles during this period however, do not show any decline in their feeding intensity. Earlier observations by Mookerjee and Ganguly (1948), and Das and Moitra (1955) on the food habits of _L. calbasu_ support these findings.

_Tor tor_ feeds mostly on algae, diatoms, crustaceans and plant matter. Occasionally it feeds on gastropods. No apparent difference in the feeding habits of various development stages were observed. At no stage of my investigations did I come across a single specimen of _Tor tor_ having fish in its gut, as has been reported by Khandelwala (1960).

The nature and length of the alimentary canal of a fish is closely correlated with the type of diet on which it subsists. The alimentary canal of _M. seenghala_ is well defined, short and muscular; the ratio of the length of the gut to the length of the fish varies between 0.69-0.88. Statistically it has been shown (Plate 19, Fig. 45) that the length of the intestine increases
rapidly during the I (1-300 mm) and II (301-600 mm) groups and not so much during the III (600 mm onwards) group. The fact that *M. seenghala* in the first group up to 131 mm stages consumes a considerable percentage of plant matter along with its food, which is subsequently replaced by larger amounts of insects and teleosts matter makes it necessary for the juvenile *seenghala* to have a longer intestine as the plant food containing cellulose require a longer intestine for its digestion. It may also be stated that the development of the intestine is more rapid during the early developmental stages. In the case of *Tor tor* the alimentary canal is not so well defined. It is long and coiled, and a true stomach is absent. The length of the gut is longer than that of *M. seenghala* and much smaller than that of *L. calbasu*, the ratio varies between 1.20-4.04. *L. calbasu* on the other hand represents the other extreme. The alimentary canal is long and coiled, a true stomach is absent and the ratio of the length of the gut to the length of the fish varies between 5.75-10.33.

In the case of *L. calbasu* and *Tor tor* I & II groups (size range 1-200 mm, 201-400 mm in *calbasu* and 1-300 mm, 301-600 mm in *tor*), (Figs. 46 and 47) show maximum rate of growth of the intestine. The food at this stage being mostly green algae, plant matter and diatoms; the cellulose of the plant matter and the hard shells of diatoms require a much longer surface of reaction for their complete digestion. Thus it is
evident that as a general rule the rate of growth of the intestine is more rapid in the first two groups than in the third group.

Earlier investigators who worked on the ratio of the length of the gut to the length of the fish are Hora (1935), Al-Hussaini (1949), Pillay (1953), Sarojini (1954) and Das and Moitra (1955, 56). All these workers except Hora correlated the length of the gut to the type of diet on which the fish subsists.

**HISTOLOGY**

In the histological features we find that abundance of taste buds is closely correlated with the manner in which the fish secures its food rather than the nature of the food. The importance of taste buds in relation to the feeding habits of the fish was first pointed out by Herrick (1903) who observed that it may be regarded as established that fishes which possess terminal buds in the outer skin possess taste by means of these organs and habitually find their food by their means.

Taste buds are completely absent from the lips and buccal cavity of *Mystus seenghala* while their number is enormous in the lips and oral cavity of *Labeo calbasu* and *Tor tor*. *Labeo calbasu* being a bottom feeder is greatly assisted by these tactile
organs to detect the presence of food. Taste buds likewise help Tor tor to locate its food from the rocks and stones, showing thereby how closely they are related with the feeding habits of the fish. The presence of taste buds in the buccal cavity of various teleost fishes have also been recorded by earlier workers like Rogick (1931) in Cempostoma auriflamma, Sarbahi (1940) in Labeo rohita, Vanajakshi (1938) in Saccobranchus fossilis and Macrones vittatus, Curry (1939) in Carpio communis, Mohsin (1944-46) in Anabas testudineus, Mahadevan (1950) in Catnax djanaba, Kapoor (1953) in Wallago attu and Nagar and Khan (1956) in Mastacembelus armatus. On the other hand, taste buds are absent in the lips and buccal cavity of Mystus seenghala which is probably due to the fact that the fish being a surface and column feeder obtains its food by sight rather than by taste. The complete absence of taste buds in the buccal cavity have also been recorded by Dawes (1929) in Pleuronectes platessa and Pillay (1953) in Mugil taze.

A number of mucus cells have been observed in the buccal cavity of M. seenghala and the lips and buccal cavity of Labeo calbasu and Tor tor. They show a great variety of form and size. The secretion of the mucus cells in the buccal cavity of each species helps in forming a coating of mucus round the particles of food and thus prevent any accidental injury to the
internal lining of the organs by friction and also to soften and lubricate the food for its easy passage down the pharynx and oesophagus. In *Tor tor* and *Labeo calbasu*, mucus performs a double function of capturing small organisms and plankton which get stuck in the mucus and hence their escape is made impossible. Giant cells are few in the buccal cavity of *M. senghala*, none in *L. calbasu* and few but big ones in *Tor tor*. The true function of the giant cells is not yet known, probably they are secretory in their function. Similar observations regarding the presence of mucus and giant cells in the buccal mucosa of teleosts have been recorded by Vanajakshi (1938), who found that giant cells are dividing cells and from the similarity of shape between these (giant) cells and that of mucus cells, it may be inferred that they are in the process of being converted into the mucus cells. Islam (1951) termed them as club cells. Oxner (1905) and Bhatti (1938) pointed out that the presence of club cells is indicative of the genetic relationship rather than adaptation of the feeding habits.

The pharynx shows the same histological details as the buccal cavity with slight variations. Taste buds in the case of *M. senghala* make their first appearance in this region. In other words the fish tastes its food for the first time in the pharyngeal region. As the fish feeds by sight the presence of
taste buds in the pharynx only helps in the final testing of the food and throwing out anything undesirable that has been taken accidentally; the number of mucus cells is reduced in this case. The pharyngeal mucosa of *Labeo calbasu* and *Tor tor* records a considerable increase in the number of mucus cells and decrease in the number of taste buds. Dawes (1939) differentiated pharynx by three main features (i) the absence of longitudinal muscles, (ii) the presence of stratified epithelium and goblet cells, (iii) the presence of taste buds. Macallum (1886) described the presence of taste buds in the oesophageal mucosa of *Acipenser*, remarking on the rare occurrence of these in similar situations in higher vertebrates. Later on many workers recorded the presence of taste buds and goblet cells in the pharynx of various teleost fishes, the more important ones are Vanajakshi (1938), Rogick (1931), Al-Hussaini (1946, 53), Mohsin (1944-46), Mahadevan (1950), Kapoor (1953) and Sehgal (1960).

The oesophageal region of *M. seenghala* shows enormous branching of the folds to form an arborising system. Mucus cells are few and giant cells are absent. The oesophageal mucosa of *L. calbasu* and *Tor tor* are flooded with mucus cells, they are so numerous that they obliterate all other cells. The function of the oesophagus is purely mucus production and aiding in easy gulping of the prey. Other workers who observed similar conditions in teleosts
are Bogick (1931) in minnow, Curry (1939) in carp, Al-Hussaini (1949) in the roach, mirror carp and the gudgeon and Islam (1951) in Cirrhina mrigala. A fall in the number of mucus cells in the oesophagus as in the case of Mystus seenghala have also been recorded by Berndt (1938) in Anguilla fluviatilis; Ghazzawi (1935) found no goblet cells in the oesophageal mucosa of Mugil cephalus, but the oesophagus of Mugil capito on the contrary showed goblet cells; these variations may probably be due to the diverse feeding habits of the two species.

The oesophageal region of Mystus seenghala is found to be highly organised structure as is reflected in the basic similarities in the histological structures of the oesophagus and the stomach. The presence of gastric glands in the oesophagus is noteworthy and digestion is initiated at this region by the pouring out of the digestive juices. Thus the presence of digestive glands in the oesophageal region helps a great deal in the digestion of hard food which is mainly animal matter. Similar phenomenon has also been observed by Purser (1928-29) in Calamoichthys calabaricus, Ghazzawi (1935) in Mugil capito and Pillay (1953) in Mugil tade.

Heidenhain, as early as 1870 discovered two types
of gastric glands in mammals and referred to them as central and parietal or oxyntic cells. Edinger (1877) studied the histology of the alimentary canal of fishes in detail and concluded that the only one type of cells are neither central nor parietal. Gulland (1898) in his researches on the gland tubule of salmon also came to the same conclusion that the parietal cells are non-existent. He, however, observed two types of cells the intermediate and the zymain producing, the former being found in the neck and the latter forms the base of the tubule. Dawes (1929) reported that cells in the neck of the tubules are undoubtedly responsible for the production of the mucus, being possibly derived from the goblet type of cells. The superficial cells, which are not typical mucus producing cells, are probably in some way connected with the production of the acid found in the stomach during digestion. Among the recent investigators Blake (1930,36), Vanajakshi (1938), Mohsin (1944, 46), Islam (1951), Kapoor (1953) and Nagar and Khan (1958) point towards the presence of only one type of gastric glands in the fishes studied. The results of my investigations in the case of *Mystus seenghala* are incomplete harmony with those of the above workers in so far as the histological structure of the stomach of *M. seenghala* is concerned.

Both, *Laboe calbasu* and *Tor tor* are devoid of a true stomach. The long mucosal folds of the
intestinal bulb with its striated top plate, helps to increase the digestive surface considerably, which is needed for the plant matter and containing a lot of cellulose. Similar observations on the intestinal bulb in cyprinids have been recorded previously by authors like Rogick (1931), Curry (1939) and Sarbahi (1940).

It is of interest to note that the distribution of various digestive enzymes in the alimentary canal of the fish are greatly influenced by its food and feeding habits. For instance, pepsin which acts only in an acid medium is present in the oesophagus and stomach of *M. seenghala*, is completely absent from the alimentary tract of the other two fishes, namely *Labeo calbasu* and *Tor tor*. The presence of gastric glands in the oesophagus would imply the presence of acid in that region and hence the presence of pepsin. On the other hand, the complete absence of gastric glands in the oesophagus and the intestinal bulb in *L. calbasu* and *Tor tor* results in the complete absence of peptic digestion. This whole phenomenon is closely correlated with the food habits of the fish. The diet of *M. seenghala* being mostly of animal origin is rich in proteins and requires strong enzymes for its breaking up and digestion while the green plant matter being much simple in its composition does not require an elaborate enzymes for its digestion. The nature of the alimentary canal in this case also plays a very
important role. The thick muscular stomach with its numerous gastric glands form an efficient arrangement for the digestion of the animal food. On the other hand, the absence of a true stomach implies the absence of gastric glands and hence the absence of peptic digestion. The digestion of proteins in *L. calbasu* and *Tor tor* on the other hand is affected by trypsin, which is also a proteolytic enzyme, but acts in an alkaline medium. Since these stomachless fishes take large quantities of food at a time they have a much longer intestine and trypsin is liberally secreted. It is present in the intestinal bulb, intestine and hepatopancreas in the case of *L. calbasu*, and intestinal bulb, intestine and rectum in *Tor tor*. Earlier investigators who studied the digestive enzymes in stomachless fishes and arrived at similar conclusions are Babkin and Bowie (1928), Beauvalet (1933-4), Barrington (1942), Al-Hussaini (1949), Sarbahi (1951) and Bernard (1952).

The intestine is a simple structure in all the three species. In *M. seenghala* it shows long mucosal folds with narrow crypts between them and few goblet cells. The intestine of *L. calbasu* and *Tor tor* shows a prominent top plate, besides a few goblet cells. Cole and Johnstone (1901) found that in plaice there is no essential difference between the intestine and the rectum, but it is convenient to distinguish the
terminal portion of the alimentary canal from that immediately preceding it. Goblet cells are few in the intestine of *M. seenghala*, *L. calbasu* and *Tor tor*; smaller number of goblet cells from the intestinal region has attracted the attention of other workers on cyprinids, including Rogick (1931), Curry (1939) and Sarabhi (1940). Rectum in all the three species studied is distinguished by the presence of a comparatively larger number of goblet cells and thick musculature. Dawes (1929) distinguished rectum in plaice by the abundance of goblet cells and a thick musculature. A rectum is not mentioned either in *Campostoma anomolium* (Rogick 1931) or in *Mugil capito* (Ghazzawi, 1935). Curry (1939) described a homogeneous appearance of the alimentary canal from the oesophagus to the anus and made no mention of the anus. Al-Hussaini (1945, 46 and 47) on the other hand distinguished rectum by abundant goblet cells. Nusbaum-Hilarowicz (1928) distinguished rectum by a strong musculature.

The results of the present investigations regarding the histological details of the rectum are in agreement with the above mentioned workers for the rectal region in all the three species studied shows an increase in the number of goblet cells and thick musculature, especially the circular muscle fibres. The abundant goblet cells probably help in rolling the faecal material in balls and the circular muscles facilitate defecation.
The study of the digestive enzymes reveals that carbohydrates like amylase, maltase and invertase were completely absent from the digestive tract of *M. seenghala*, showing clearly that the food of *seenghala* does not contain appreciable amount of carbohydrates. On the other hand, the food of *L. calbasu* is mainly of plant origin while that of *Tor tor* contains a fair amount of vegetable matter requiring a higher percentage of carbohydrates for its complete digestion and utilisation, hence their abundant secretion along the length of the alimentary tract.

Lipase, which is a fat hydrolyzing enzyme is secreted by the intestine, rectum and hepatopancreas in the case of *Mystus seenghala*. In *L. calbasu* the intestinal bulb, intestine and the hepatopancreas secrete this enzyme and in *Tor tor* almost the entire length of the alimentary canal secretes lipase. The observations of Al-Hussaini (1949), Sarbahi (1951) and Bernard (1952) also agree with the above findings.

From the above discussion it is evident that the presence of well developed dentition, strong muscular stomach and a small thick walled intestine in *Mystus seenghala* is closely correlated with its piscivorous feeding habits. The effect of the varied feeding habits is also manifested in the histology and physiology of the alimentary tract. The absence of taste buds in the buccal cavity, the presence of numerous mucus cells and giant cells in the buccal cavity and pharynx,
the presence of gastric glands in the oesophagus and stomach, the occurrence of many goblet cells and thick musculature, the presence of pepsin and the absence of carbohydrases are all manifestations of the adaptive modifications of the alimentary canal of the fish to its food and feeding habits.

Similarly in the case of *L. calbasu*, the absence of a true stomach and the presence of an intestinal bulb and an extremely long intestine and a well developed gustatory apparatus are fine modifications of the alimentary canal to its herbivorous mode of existence. The presence of numerous taste buds in the lips and buccal cavity along with numerous mucus cells helps the fish to find its food in sand and mud at great depths as the fish is a bottom feeder. The long folds of the intestinal bulb and the intestine, and the presence of a well defined top plate, are adaptations to increase the surface of the digestive tract for the complete digestion and assimilation of food which is mainly plant matter rich in cellulose and carbohydrases. The distribution of the digestive enzymes in various regions of the alimentary tract are also the result of the adaptive modifications to suit a particular type of diet. The complete absence of pepsin and the secretion of trypsin in major portions of the digestive tract, the abundant secretion of carbohydrases like amylase, maltase and lactase are all manifestations of adaptive modifications of the
alimentary canal in relation to its food and feeding habits. Lastly, *Tor tor* being an omnivorous fish comes between *M. seenghala* and *L. calbasu* in its feeding habits and also its adaptive modifications of the alimentary structures. The presence of thick, firm lips, efficient gustatory apparatus, the absence of a true stomach and the presence of a thin and fairly long intestine are some of the adaptations in the anatomy of the alimentary canal towards its omnivorous diet. The histology and physiology of the alimentary canal also show various adaptations to suit the type of diet on which the fish subsists. Thus the varied feeding habits in all the three species is clearly manifested in the anatomy, histology and physiology of the alimentary canal of each of these species.