DISCUSSION

MORPHOLOGY AND ANATOMY

Fishes exhibit a great deal of diversity in their food and feeding habits and the adaptations of the alimentary system of fish to its normal diet is demonstrated characteristically in the form of mouth, shape and structure of the bucco-pharynx, the dentication, shape of gill rakers, configuration of the gut, relative length of the gut besides other factors. "The gut also shows considerable reserve ability to respond to new food, new environment, and new opportunities. This versatility has been demonstrated in a number of cases in which a single genus has adapted to new niches and evolved whole new modes of feeding and digestion to utilise otherwise unutilised food resources and done so over a short evolutionary period of time" (Smith, 1978). Several workers have studied the morphology and anatomy of the alimentary canal in Indian freshwater fishes which are now known to indicate remarkable adaptive radiations influenced by the nature of the diet (Sarbahi, 1939; Islam, 1951; Kapoor, 1953, 1957, 1958; Das and Moitra, 1955, 1956a, b, c, 1958; Sarkar, 1959; Mohsin, 1962; Khanna, 1961, 1962, 1964; Das and Nath, 1965; Chitravy, 1964, 1965; Pasha, 1964a, b, c; Jaish, 1968; Mehrotra and Khanna, 1969; Khanna and Mehrotra, 1970, 1971; Moitra and Bhowmick, 1967; Moitra and Sinha, 1971; Sinha and Moitra, 1975a, b, 1976 and 1978; Moitra and Ray, 1977, 1979; Ray and Moitra,
1982). According to data derived from year round observations on the percentage of food ingested, Das and Noittra (1956a) classified the freshwater fishes of Uttar Pradesh, India, into three primary feeding categories viz., (a) herbivores, consuming unicellular and filamentous algae, soft higher plants and sand and mud; (b) omnivores, consuming almost equal quantities of plant and animal material and (c) carnivores, consuming animal food like crustaceans, insects, molluses and fish. The authors further observed a serial gradation from herbivorous to carnivorous condition of the alimentary canal – herbivorous fishes having a long, coiled, thin walled and more or less undifferentiated alimentary canal, carnivores having a short, much differentiated alimentary canal with well developed muscular stomach and the omnivores presenting an intermediate condition. They also (1955) proposed another system for dividing the fishes into three groups according to feeding affinities, i.e., their affinity to exploit food at different niches. Thus, they successfully evolved a scheme for categorising freshwater teleosts into surface-feeders, the mid-feeders and the bottom-feeders.

The Indian featherbacks are known to be carnivorous in habit. Mookerjee and Mazumdar (1946) considered *N. notopterus* as a carnivorous fish feeding mainly on small fish, insects and insect larvae with a little amount of plant material. Das and Noittra (1956) reported *N. chitala* to be a
predaceous species subsisting on larger crustaceans, insects, insect larvae, fish fry and small fishes. Menon et al., (1959) reported that N. notopterus was entomophagus during the young stages and carnivorous, feeding on small fishes and crustaceans, in the adult stages in Madras rural waters. Mohsin (1962) stated that food items of N. notopterus included small fishes and frogs. Parameswaran and Sinha (1966) observed parts of aquatic weeds, marginal grasses etc., in addition to shrimp and insect diet. Agrawal and Tyagi (1969) recorded insect, insect larvae, small crustaceans and parts of aquatic plants in the stomach contents of N. chitala. The present investigations are in conformity with most of the observations made by earlier workers. In the present studies N. notopterus was found to ingest small shrimps, larvae of fishes, and small insects. The gut also contained fish scales, broken bits of plant tissues and mud. In the present course of study N. chitala was observed to be a piscivorous species feeding mainly on small fishes, shrimps and fish fries. No plant material was recovered from the gut contents of N. chitala. This confirms earlier observations made by Das and Moitra (1956a) on the same species.

THE ALIMENTARY CANAL

The alimentary canal of fish can be divided into two main regions – the "Kopfdarm" comprising the buccal cavity and pharynx, and the "Rumpfdarm" comprising
the fore-gut (oesophagus and stomach), midgut (intestine) and hind-gut (rectum). The different regions present diverse morphological variations which are known to be influenced by the nature of diet.

The mouth: The structure and position of the mouth in fishes show adaptational features related to feeding habits. Nicolsky (1963) classified mouths of fishes as (i) grasping; (ii) sucking; (iii) imbibing; (iv) crushing; (v) planktophagic and (vi) periphyton-eating mouth on the basis of their position and structure. With regard to made of feeding he further described the position of mouth as dorsal, terminal and ventral. Norman (1976) stated that carnivorous and fish eaters have larger mouths. The mouth of *N. notopterus* is terminal, moderately large and non-protractile. The Chital has a larger mouth which is slightly upturned. Khanna (1962) also recorded a wide mouth in *N. notopterus* and three other carnivorous species. Das and Nath (1965) however, reported a narrow mouth in *N. notopterus*. Khanna and Pant (1964) reported a wide mouth in carnivorous *Nystus seenghala*. Jatish (1968) reported wide gape of mouth in carnivorous *Xenentodon cancila*. Singh (1973) observed a moderately large, slightly protusible mouth in *N. notopterus*. Nikolsky (1973) suggested that predators generally have a large mouth. Moitra and Ray (1979) however, reported the presence of small mouth in *Ambassis nama* and *A. ranga* although these species are known to
be carnivorous. It is, therefore, evident that moderately large mouth in _N. notopterus_ and a still larger mouth in _N. chitala_, bounded by strong jaws provided with large incurved specialised teeth, are typically predaceous in function. The terminal and slightly upwardly directed mouth in _N. notopterus_ and _N. chitala_ are suggestive of their surface-column feeding habit. Kapoor (1953) reported the presence of a superior mouth in the carnivorous surface-feeding fish _Vallago attu_. Das and Moitra (1956) also reported a superior protrusible mouth in surface feeding _Glossogobius giuris_. Moitra and Ray (1977) noted a slightly upturned mouth in _Colisa fasciata_, a mid-feeder and upturned and protractile mouth in surface feeding carnivores _Ambassis nama_ and _A. ranga_. According to Das and Moitra (1955) the surface feeders feed on surface and sub-surface organisms while the mid-feeders both on surface and bottom food organisms respectively. Observations made by Parameswaran and Sinha (1966) as well as those made during the present investigations indicate the presence of surface and sub-surface food elements in the alimentary canal of _N. notopterus_. Sand and mud have been recovered from the stomach of the species. Parameswaran and Sinha (1966) observed minute stones and pebbles in the stomach which constituted over 10% of the contents. The latter authors suggest that _N. notopterus_ has a browsing habit. Observations made by Das and Moitra (1956) as also those in the present investigations indicated the presence of mainly fish and shrimps in the stomach content of
N. chitala. Mud or sand were absent. This suggests that the fish subsists mainly on column food material. Singh (1973) suggested that *N. notopterus* should be considered as a surface-column feeder and not only a surface-feeder.

Bucco-pharynx: The bucco-pharynx of both the species, studied during the present course of investigations, have been found to be provided with a large number of teeth which indicate adaptational specialisations due to predatory habits. Suyehiro (1942) suggested that fishes which do not have efficient swimming abilities possess well developed teeth so as to have a strong hold on the prey once caught. Norman (1976) stated that in piscivorous fishes the teeth are generally strong and may be acutely pointed. They serve the purpose of not only holding the prey but also to tear and dismember the victim. Al-Hussaini (1947b) stated that pointed and conical teeth are generally present in the carnivorous predatory fishes. Das and Moitra (1956) observed that in carnivorous fishes the jaws are provided with highly specialised teeth meant for seizing, holding, tearing and trituration of the prey, while the anterior pharyngeal and horny-pad teeth are also enormously developed. Mahadevan (1950), Kapoor (1953, 1954), Khanna (1962), Das and Nath (1965), Jaish (1968), Subla (1970) etc., have also reported the presence of well-developed teeth in the buccopharyngeal region of several carnivorous fishes of India. Well developed dentition, however, have also been repor-
ted in case of omnivorous fishes. Das and Moitra (1956) have reported well developed dental armature in *Eutropiichthys vacha*, an omnivorous fish. Agrawal and Sharma (1966) reported the presence of well developed teeth in omnivorous *Hystus vittatus* which mainly consumes aquatic crustaceans constituting 55 to 85% of the total food ingested. Moitra and Ray (1977) also observed the presence of teeth on the roof and floor of the buccal cavity in the omnivorous *Colisa fasciata* and stated that the teeth were well adapted to the nature of the food ingested. On the other hand Das and Moitra (1956), Das and Nath (1965), Khanna and Mehrotra (1970) reported edentulous mouths in omnivorous *Puntius sophore*, *P. conchonius* and *Barbus hexastichus* and some other omnivorous species studied by them. Khanna and Mehrotra (1970) expressed the opinion that an exact relationship can not be established between the extent of dentition and feeding habits. They believe that this feature depends on the environment in which the fish lives. Mohsin (1962) stated that in herbivorous and omnivorous fishes the teeth are not so well developed since they subsist mostly on inert substances or very small animals, aquatic weeds and algae. He, however, reported well developed pointed teeth in the carnivorous species studied by him. In both the species of *Notopterus* well developed inwardly curved teeth on the maxilla and mandible, smaller but strong pointed teeth on different parts of the roof and floor of the buccal cavity and pointed incurved teeth on the tongue suggest predacious habit of the fishes. Al-Hussaini
(1947b) reported that in piscivorous *Pterois* and *Belone* the mouth and pharynx were found to be provided with villiform teeth some of which were observed to be developed into canine-like tusks. Norman (1976) stated that in Pike, *Esox* sp. the teeth on the premaxillaries were small while those on the sides and lower jaw were erect being used for seizing the victims. He also stated that in this species the teeth on the palate were found to be directed backwards towards the gullet for effectively preventing the escape of the prey. Sarkar (1959) reported well developed maxillary, mandibular, vomerine, supra and infrapharyngeal teeth in the carnivorous *Mystus senegalensis*. Kapoor (1953) and Chitrav (1964) held that the teeth in *Valloco attu* and *Eutropichthys vacha* are used for holding and biting the prey. Ray (1978) observed highly specialised maxillary and mandibular teeth in *Anabas testudineus* and stated that these teeth help in seizing the prey and subsequently tearing it. Mottra and Ray (1979) observed small, sharp and hooked jaw teeth in *Anabas maha* and *A. ranga* and suggested that these teeth were capable of securing small slender animals. The palatine, pharyngeal and horny pad teeth in these species help in triturating and mastication of the food ingested. During the present course of investigations the presence of whole fish, fish larvae, prawn etc., in the oesophagus and stomach of *Notopterus chitala* without any damage or sign of mastication suggest that the food is swallowed whole without mastication. In *N. notopterus* also entire fish larvae,
live worms etc. were recovered from the stomach suggest the similar phenomenon. Presence of fish scales, broken bits of prawns and vegetable matters (occasionally) however, suggest possible tearing or weak mastication also in this species. Barrington (1957) suggested that the food is often swallowed as a whole without any mastication. Similar view has also been expressed by Agrawal and Sharma (1966). Khanna and Mehrotra (1970) believe that backwardly directed teeth present in the jaws of carnivorous fishes do not serve to crush but help in preventing the escape of slippery prey. The present investigations are in agreement with the views expressed by the above mentioned authors. The teeth on the jaws in Notopterus serve the purpose of keeping a firm hold on the actively moving prey. Das and Moitra (1956), Moitra and Ray (1977) hold that pharyngeal and horny pad teeth in omnivorous R. vacha and C. fasciata serve the purpose of triturition. Das and Moitra (1956) also reported enormous development of teeth on the floor and roof of the bucco-pharynx including pharyngeal teeth in the carnivorous fishes studied by them. Norman (1976) reported backwardly directed palatine teeth in Esox and stated that they help to prevent escape of prey. Khanna and Mehrotra (1970) stated that these teeth serve for preventing the regurgitation of food from the gullet. It is assumed therefore, that bucco-pharyngeal teeth in Notopterus are used principally for seizing and holding the prey and preventing regurgitation. These teeth do not participate in mastication and if at all then to a
very negligible extent. The tongue of _Notopterus_ is well defined being provided with large incurved teeth in addition to small pointed teeth in two rows thus giving the tongue a horny appearance. Kapoor (1957d), Kapoor et al., (1975) believe that the tongue in fishes is not always sharply demarkated, rarely with a moveable tip and generally possesses a skeletal support. Khanna (1959) stated that the tongue in carnivorous species as a whole, and piscivorous ones in particular, are better developed. Tandon and Goswami (1968) suggested that the tongue in _Channa_ spp. supplement the function of teeth in retaining the prey. A tongue in the form of a mucosal thickening on the anterior part of the floor of the bucco-pharynx has also been observed by Ray (1978) in _Amabas testudineus_, a carnivorous species. A similar nature of tongue has been reported by Agrawal and Sharma (1966) in the omnivorous _Hystus vittatus_ with carnivorous tendency. It may be possible therefore, that the mobile tongue with a skeletal support and well developed dentition help in retaining and triturating prey in _Notopterus_. The presence of tongue confirms the carnivorous/piscivorous nature of _Notopterus_. Gill rakers have been reported to be variously modified according to the feeding habit of the fish. Das and Moitra (1956) observed that gill rakers are thin and long in herbivorous fishes and perform partly a sieving function, in the form of teeth like processes in omnivorous and prevent the
blocking of the gills and also to ensure firm gripping on the prey, and modified for grasping and preventing the escape of prey as also for rasping and crushing the food in carnivores. The structural modifications of gill-rakers in relation to feeding have been studied by several workers. Popova (1900) studied the gill-rakers in certain teleostean species and described briefly their structure and disposition. He concluded that gill-rakers are characteristic in all the species studied by him. Zander (1903) examined the gill-rakers of a large number of fish and observed that in the carnivorous types such as _Esoc_ and _Lutoperca_ the gill-rakers are in the form of teeth. Al-Hussaini (1947b) reported gill-rakers to be either absent or very short in carnivorous forms except in _Pterois_ in which they are spiny. He presumed a catching function of such gill-rakers. Kapoor (1953, 1958a, 1965) and Khanna (1962) suggested that in carnivores the gill-rakers have been modified to form pointed teeth-like structures in order to supplement the function of maceration and prevention of the escape of prey once caught. Mahadevan (1950) reported rudimentary gill-rakers in _Caranx_ and _Triturus_ both of which are carnivorous. Koshina (1958) reported that the gill-rakers of mature predatory fish were coarse, sparse, short and armed with small sharp denticles. Das and Nath (1965) believe that in carnivorous fishes the gill rakers are modified and fully adapted to prevent the escape of prey as well as for rasping and crushing food. Khanna and Mehrotra (1970) reported
the absence of gill-rakers in the piscivorous fish, *Muraenopsis telabon*. These authors expressed the opinion that gill-rakers aid in increasing the dental equipment in order to prevent the escape of slippery prey only and not for trituration or crushing the food. In both *M. chitala* and *M. notopterus* the gill-rakers are very well developed and finger-like bearing minute teeth on the outer row of the first gill-arch. The inner row on the first arch and those on the rest of the arches are stumpy and bear minute teeth. The modified fifth branchial arch forming the posterior inner-lining of the branchial cavity also bear 7-8 stumpy gill-rakers armed with small denticles. A crushing function however, cannot be associated with these gill-rakers because of the presence of entire fish, prawn or other organisms in the oesophagus and stomach. The present investigations therefore, agree with the views expressed by Khanna and Mehrotra (1970) and assume that these structures prevent the escape of prey only. Ray (1978) stated that plate-like gill-rakers studded with minute teeth in *Anabas testudineus* serve the purpose of holding and crushing the prey. Moitra and Ray (1977) suggested that the thin, long, hair-like gill-rakers in the omnivorous *Colisa fasciata* are used for straining planktonic food. *Ambassis nama* and *A. range*, which are carnivorous in feeding habits, were found to possess triangular gill-rakers provided with small pointed teeth (Moitra and Ray, 1979). These structures were also assumed to serve the purpose of grasping and preventing the escape of prey in
addition to rasping and crushing micro-crustaceans and insect larvae. Iwai (1963, 1964), Kapoor (1965), Kapoor et. al., (1975) opined that "the gill-rakers taste, filter or prevent the escape of food material in different fish ".

The number of gill rakers may not be uniform even within the same species. On the other hand the gill-raker equipment may show variation in fishes with identical modes of feeding (Khanna and Mehrotra, 1970). The number of gill-rakers in Mystus seenghala and Mystus vittatus have been mentioned by Sarker (1959) and Agrawal and Sharma (1966) respectively.

In the present investigations the number of gill-rakers observed on the outer row were 12, 11, 10 and 8 respectively, whereas, these were 12, 11, 9 and 7 for the inner row in N. notopterus. Das and Nath (1965) while describing the buccopharynx of several species of fish mentioned N. notopterus without any description of the gill-rakers. Singh (1977) observed 13/13, 12/12, 11/10 and 11/8 rakers on the gill arches of N. notopterus. The present observations however differ. Further Singh (1977) failed to notice gill-rakers on the 5th branchial arch bearing 7 stumpy gill-rakers provided with minute denticles. In N. chitala the number of rakers were observed to be 12, 12, 10 and 8 on the outer row of the 1st, 2nd, 3rd and 4th gill arches respectively. The corresponding number for the inner row were 12, 11, 9 and 8.
The reduced fifth branchial arch also bears a row of 8 extremely reduced stumpy gill rakers. No information appears to be available on the gill-rakers of *N. chitala*. It is, therefore, assumed that the number of gill-rakers in *Notopterus* may vary in different feeding environments and also with age. Kapoor et al., (1975) noticed a relationship between the number of gill-rakers and feeding habits in Salmoideae. A relationship between the number of gill-rakers and feeding habits were also recorded in the Characinoidea. The presence of small gill-rakers on one side of the pharyngeal bone (5th arch) have been reported by Agrawal and Sharma (1966). The presence of gill-rakers on the modified 5th branchial arch has also been reported by Kapoor et al., (1975).

Oesophagus: The oesophagus in *N. notopterus* and *N. chitala* are short, tubular, muscular and extensible structures with inner longitudinal mucosal folds. The oesophagus has been described as short and narrow tube in several herbivorous and omnivorous fishes (Curry, 1939 in Cyprinus carpio; Sarbahi, 1939 in Labeo rohita; Kapoor, 1957 and 1958b, in Barbus stigma and Catla catla; Al-Hussaini, 1947, 1949 in several fishes; Chaudhuri and Khan—delwal in Orienus plagiopterus, Khanna, 1961 in Barbus sarana and Tetradon fluviatilis; Mohsin, 1962 in Anabas testudineus; Khanna, 1964 in Clarias batrachus). Mohsin (1962) observed a large, broad and cylindrical oesophagus in carnivorous Channa marulius while short and tubular in other carnivorous species like *N. notopterus*, Sillago sinhama, Amphipnos
cuchia etc. Mehrotra and Khanna (1969) are of the opinion that carnivorous and piscivorous fishes possess a longer and distensible oesophagus. Such a type of oesophagus has been observed by them in Muraenoides telabon, Harpodon nehereus and Channa striatus - all carnivores, but a short and narrow oesophagus in omnivorous Tor tor. Pasha (1964) observed a dorsoventrally flattened oesophagus in the omnivorous Mystus gulio while a cylindrical short tube in the herbivore, Tilapia mossambica (1964b). Venkateswarlu (1966) observed that in gobid fishes there was no difference in the nature of the oesophagus in the herbivorous and carnivorous species. Khanna (1961) observed that the size of the oesophagus is considerably reduced in stomachless fishes. On the contrary Sarker (1959) reported a short narrow and thickwalled oesophagus in the carnivorous Mystus seenghala. Ray (1978), Moitra and Ray (1979) observed short and tubular oesophagus in Anabas testudineus, Ambassis nama and A. ranga although all these species possess a true stomach. Verighina (1978) reported that the oesophagus in Alepocephalus, a fish with stomach, consisted of a broadened anterior, narrowed middle and a broad posterior portions. Therefore, it may be inferred that the structure of the oesophagus may not have any bearing on the food habit of the fish although the carnivores in general have a highly muscular, tubular and broadened oesophagus which can accommodate larger food materials. The longitudinal mucosal folds in N. notopterus and N. chitala help in
conducting the food particles progressively backwards to the stomach by peristaltic action.

This was further evidenced by the presence of an entire specimen of Puntius sp. in the oesophagus of a Chital measuring 271 mm in total length where the oesophagus was found to be 12 mm.

Stomach: The structure of the stomach is influenced by the nature of the food ingested. Smith (1978) classified fish stomach into four general types: (a) a straight stomach with an enlarged lumen as in Esox; (b) a U-shaped stomach with enlarged lumen as in Salmo, Clupea etc.; (c) a stomach shaped like a 'Y' with the stem of the 'Y' forming a caudally directed caecum as in Anguilla; and (d) stomach less condition as in Cyprinids. Nicolinsky (1963) considers the size and form of the stomach to depend largely on the feeding behavior and nature and size of the prey. Barrington (1957), however, held a different opinion and stated that "it is doubtful whether the morphology of the stomach can always be so clearly related to the nature of the diet". Weisel (1962) observed toothless - stomach less condition in a piscivorous cyprinid, Ptychocheilus oregonese a predator on small salmon. Kapoor et. al., (1975) stated that the size of the stomach is related to the duration between the meals and the nature of the food and the disappearance or reduction of internal folds depends upon the bulk of the stomach contents. The
stomach is generally considered to be an organ for storage and for partial physical and chemical breakdown of the ingested food. Das and Moitra (1956) observed the absence of stomach in herbivorous L. rohita, C. mrigala, C. reba and Amblypharyngodon mola, muscular stomach in two omnivores, Gadusia chapra and Rohtee cotio and well developed stomach in carnivorous Mystus vittatus, M. cavasius, Wallago attu, Ophicephalus striatus, Glossogobius giuris, Ambassis nama, A. ranga etc. They postulated that well developed muscular stomach and short and muscular alimentary canal is obviously correlated with the carnivorous habit of these species. Nikolsky (1963) stated that the food bolus is not only broken down and partially digested in the stomach but sometimes the prey is also killed there. Al-Hussaini (1947b) held that the time interval between the meals and the nature of diet, influence the size of the stomach. Many authors have considered fish stomach to consist of a cardiac and a pyloric part. Mohain (1946, 1962) described the cardiac and pyloric regions in the stomach of Anabas testudineus and some other teleosts. Das and Moitra (1956) also reported the presence of cardiac and pyloric regions in the stomach of Wallago attu and Ophicephalus striatus. Other reports on the subject include those of Chandy and George, 1960; Khanna, 1961; Pasha, 1964b; Khanna and Pant, 1964; Agrawal and Sharma, 1966a; Tandon and Goswami, 1968; and Mehrotra and Khanna, 1969. Moitra and Ray (1977) observed an anterior cardiac and a posterior pyloric parts in the tubular
stomach of omnivorous *Colisa fasciata*. A very short pyloric portion was described by them (1979) in *Ambassis nama* and *A. ranoa*. Verigina (1978) reported cardiac and pyloric parts in the stomach of *Alepocephalus* spp. Clarke and Witcomb (1980) have reported a well developed "Y" shaped stomach divisible into cardiac and pyloric parts in *Anguilla anguilla*. They believe that the stomach serves the purpose of storage of food. Some workers recognise three regions in the stomach of fish viz., cardiac, pyloric and fundic regions (Kapoor, 1953; Sarkar, 1959; Saxena and Bakhshi, 1964). Pasha (1964a) described two regions - 'Corpus' and 'Pyloric' in the stomach of *Mystus gulio*, an omnivorous fish. Barrington (1957) however, stated that the nomenclature referred to as "Cardiac" and "Pyloric" derived from that of mammalian stomach is rather misleading in fish.

In the present investigations large, capacious and sac-like stomach have been observed in both *N. notopterus* and *N. chitala*. The stomach is thick-walled, highly muscular and elastic in both the species. Khanna (1961) also described a similar stomach in *N. notopterus*. The presence of a sac-like stomach have been observed by Kapoor, 1953 in *Wallago attu*; Das and Mottra (1956) in several carnivorous species; Chitravy (1965) in *Bagarius bagarius*; Tandon and Goswami (1968) in *Channa punctatus*; Mehrotra and Khanna (1969) in *Muraenesox telabon*, *Harpodon nehereus* and *Channa striatus*; and Ray (1978) in *Anabas testudineus*. Mehrotra and
Khanna (1969) believe that a sac-like muscular stomach is capable of distension and serves for storage and digestion of food. Heavy musculature of the stomach is helpful for mechanical breakdown of the food (Khanna, 1961). The sac-like muscular stomach in Genus *Notopterus* is so efficient that in the present studies only crushed food material in unidentifiable condition was recovered from the intestine. The strong and efficient musculature crush the food into small particles which is then conducted down to the anterior intestine. *N. chitala* swallow the whole prey (fish and prawn), and fish larvae, small shrimps etc., present in the stomach of *N. notopterus* justify the statement made by Nikol'sky (1963) that the stomach is usually large in fishes which swallow big prey. Notttra and Ray (1979) also described a muscular stomach in carnivorous *Ambastus* spp. In Notopteridae the stomach is not externally divisible into cardiac and pyloric parts and the pylorus is marked by an indistinct constriction.

Intestine: The ratio of the intestinal length to the total length of the fish is a significant feature about the digestive system. Jacobshagen (1913) reported that carnivorous teleosts e.g., *Clupea, Anguilla, Perca* etc., tended to have shorter intestine while plant and mud-feeders generally had an intestine two to several times longer than the body length. Klust (1939) showed that in Cyprinids studied by him, the ratio of the length of the intestine with the body increased with
age. Though such variations occur in carps — as also have been demonstrated by Kostomarov (1942) in *Cyprinus* and Sinha and Moitra (1975a, b) in the Indian major carps, *Cirrhinus mrigala* and *Labeo rohita*, in *Tinca* sp., which have relatively a shorter intestine, the ratio between the gut-length and body-length remained unaltered at all stages. Mookerjee and Das (1945) have shown that the total length of the alimentary canal in carnivorous fishes either equals or remains lesser than the body-length while in the herbivorous ones the length of the gut is much greater than the body-length. Al-Hussaini (1947b) reported that in carnivorous fishes, *e.g.* *Belone* and *Sphyraena* the intestine is a straight tube whereas, in herbivores it is a coiled and looped structure. Barrington (1957) comments that 'a generalisation is not possible from such data' as Al-Hussaini found a looped intestine in *Pterois* sp., a voracious carnivore. Islam (1951) observed that the relative length of gut in *Rita rita* and *Channa gachua*, the carnivorous forms, were 0.6 and 0.7 respectively whereas in herbivorous *Cirrhinus mrigala* the gut was 11.25 times longer than the body. Das and Moitra (1956, 1958) studied the relative gut length of several teleosts under different feeding categories and concluded that the gut-length — body-length ratio for a given species was fairly constant and that there was a gradual decline in the ratio from herbivorous to carnivorous species. The length of the gut has been reported to be longest in herbivores, shortest in carnivores and intermediate in values in omnivorous
ones (Kapoor, 1957c; Khanna, 1961; Kapoor et al., 1975; Das and Nath, 1965). Agrawal and Sharma (1966) observed in *Mystus vittatus*, a fish categorized as omnivorous by the authors, a low value of RLG to the tune of 0.76 (TL 13.7 cm; GL : 10.4 cm). Khanna and Mehrotra (1971) concluded that gut in carnivorous and piscivorous forms, studied by them, was shortest whereas, omnivorous and planktonphagus fishes had a gut of intermediate length. Moitra and Ray (1979) observed a short intestine in two carnivorous minor perchles, *Ambassis nama* and *A. ranga* and recorded RLG values of 0.35 to 0.39 in the former and 0.35 in the latter. Ray (1978) observed an RLG value of 0.42 in *Anabas testudineus*, a carnivorous fish. In *Colisa fasciata*, an omnivore, Moitra and Ray (1977) reported a long intestine, 4 to 5 times longer than the total length of the fish.

The present investigations indicate that both *N. notopterus* and *N. chitala* have very short intestine with an RLG value of 0.33 in both the species. As has been stated earlier these fishes are carnivorous/piscivorous in their feeding habits. Khanna (1961) and Sinha and Moitra (1975a) stated that the nature of food ingested by a fish influences its gut length. Thus the extremely short intestine in *Notopterus* strongly indicates its adaptation to carnivory. This also supports the observations made by Jacobshagen (1913) who stated that "carnivorous teleosts tended to have shorter intestines, about one third to three quarters of the body length". The
present observations however, indicate difference with the results obtained by Das and Nath (1965) where they observed an RLG value of 0.50 in *N. notopterus* from Kashmir waters. Even when the entire length of the gut (oesophagus to anus) was considered the RLG for both the species exhibited a value ranging from 0.42 to 0.45. Das and Srivastava (1979) reported that RLG in *N. notopterus* showed a fall from 0.47 in fingerlings to 0.42 in adults. Though the value obtained in case of adults come close to that of the present observation the present studies did not indicate any variation in the relative intestinal length from smaller to larger specimens. For example in a specimen of *N. notopterus* measuring 148 mm in total length the intestinal length was observed to be 49 mm giving a relative length of 0.33 whereas, in a fish with 315 mm total length the relative length of the intestine was observed to be 0.34. Similarly, in *N. chitala*, a fish measuring 658 mm in total length showed relative length of intestine was 0.33 whereas, in a 100 mm specimen the relative length observed was also 0.33, while, a 277 mm specimen demonstrated a value of 0.32. Thus the present observations showed that the intestinal length remained almost unaltered at different stages. The length of the gut, however, is a variable factor and reacts sensitively to changes in feeding condition (Kapoor et. al., 1975). The differences recorded in the observations of Das and Nath (1965), Das and Srivastava (1979) and the present investigations on the RLG of *N. notopterus* may be due to differences
in the ecological conditions of the places of study. In fish-stenophages such plasticity will be limited for their narrow specialisation (Spanovskaya, 1961; Verighina, 1963) and this is evident from the fact that RLG obtained by Das and Moitra (1956) in *N. chitala* (0.40) is very similar to those of the present investigations. Kapdör et al., (1975) believe that the length of the gut is specifically related to the feeding habits in Cyprinidae. The high value of RLG in herbivores is due to the food which contains a high percentage of indigestible ballast. The extensive length of the gut compensates for poor development of the mucosal folds which may be inadequate to regulate the passage of food through the intestine. On the other hand, the carnivorous predators are provided with short intestine accompanied with highly specialised complicated mucosal folds (Weisel, 1962; Verighina, 1965). In the genus *Potoperus*, the very short intestine is provided with highly complicated and specialised mucosal folds which regulates the passage of ingested food material through the gut. The longitudinal mucosal folds have high mounts in the oesophagus and stomach whereas, the intestine and pyloric caeca have parallel band like mucosal folds which effectively regulate the passage of food down towards the rectum. Ray (1978), Moitra and Ray (1979) however, observed longitudinal mucosal folds throughout the gut in *Anabas testudineus*, *Ambassis nama* and *A. ranga*. Moitra and Sinha (1971) observed parallel transverse folds
in omnivorous *Chaguntus chagunto* which have a relatively low RLG and concluded that such specialisations of muscosal folds have developed in order to retain food for longer periods so as to provide longer period of time for digestion and absorption. Verighina (1963, 1965) observed branched muscosal folds in the highly specialised predators *Elopichthys*, *Parasilurus* and *Silurus*.

Another aspect of the relative gut length is the surface area of the intestinal muscosa in relation to external dimensions of the intestine—a fact first emphasized by Al-Hussaini (1949a). Al-Hussaini (1949a) and Unnithan (1965) showed that shortness in the gut of a fish is compensated by the increase in the complexity of the muscosal folds and thus provide larger area for digestion. Another important aspect is the influence of dietary on the length of the intestine. Angelescu and Gneri (1949) reported a reduction in the intestinal length during starvation in *Prochilodus lineatus*. Suyehiro (1941) observed that omnivorous feeding habits of a vast majority of fish "must weaken the correlation between the length of the intestine and the nature of the diet". Smith (1978) believes that the fact that herbivores have longer intestines than carnivores is only partially true. He stated that "while this may be true in limited groups of fish it is not universal in teleosts as a whole". Thus "longest guts are found in herbivores but not all herbivores have long guts—
the gut lengths of some herbivores are shorter than those of some carnivores". He also holds that size of the food particles may influence gut configuration. The observations made by Das and Moitra (1956), Das and Nath (1965) and other works on Indian fishes however, do not fully agree with Smith's observations. The statement by Jacobshagen (1913), Das and Moitra (1956), Kapoor et al., (1975) and Moitra and Ray (1977, 1979) that carnivores have relatively shorter intestine holds good for the present investigations also. It is, however, apparent from the above discussion that the RLG is the product of a large number of interacting factors. Barrington (1957) stated that more than one factor is operative in determining the form and relative length of the intestine.

Pyloric caeca: The pyloric caeca, develop as blind outgrowths of the anterior intestine in teleostean fishes, are interesting structures the precise function of which are being still debated. Pyloric caeca are absent in cyclostomes, Dipnoi and practically in all elasmobranchs (Rahimullah, 1945). These structures have been studied by several workers all over the world (Rosenthal, 1824; Blanchard, 1882; Stirling, 1884; Macallum, 1886; Gulland, 1898; Greene, 1912; Dawes, 1929; Blake, 1930, 1936; Rahimullah, 1943, 1945; Mohsin, 1946; Al-Hussaini, 1946; Mahadevan, 1950; Islam, 1951; Pillay, 1953; Das and Moitra, 1956b, c; Kapoor, 1958; Swarup, 1959; Burnstock, 1959; Chandy and
George, 1960; Khanna, 1961; Pasha, 1964c; Das and Nath, 1965; Khanna and Mehrotra, 1971; Datta and Ghosh, 1975; Moitra and Ray, 1977; Smith, 1978; Verighina, 1978. The pyloric caeca present a good deal of morphological variations. Rahimullah (1945) classified the pyloric caeca in fishes into 10 morphological groups: (1) caeca are quite separate and open independently into duodenum, (2) caeca arranged in a linear series and each caecum opening independently at the beginning of the duodenum, (3) caeca bunched together and arranged in the form of brush or mop, (4) arbrescent type, (5) caeca arranged partly in whorls and partly in linear series, (6) caeca grouped together in the form of rosette, (7) caeca spiral, (8) numerous small caeca arranged in the form of bunches, clusters or tufts and studied thickly over the duodenum, (9) caeca with complicated secondarily branched tufts and (10) compact glandlike caecal mass. The caeca differ also in number and mode of communication with the intestine. The number of caeca may vary from one (Pistularia villosa) to several hundreds (Hilsa ilisha) [Rahimullah, 1945]. The number of caeca may vary even in the members of the one and the same family as reported by Mohsin (1962) who recorded a variation in number of the pyloric caeca from 3 to 4 in Anabas testudineus, while Moitra and Ray (1979) observed only two pyloric caeca in Colisa fasciata, a member of Anabantidae to which Anabas also belongs. Bernard (1949-50) and Svetovidov (1953) also expressed that the number of
pyloric caeca may not remain constant even in the same species. Rahimullah (1945) recorded 8 to 18 caeca in different species of the genus *Therapon*.

In the present studied the number of pyloric caeca noted in either species of *Notopterus* is two without any variation. Rahimullah (1945) also reported the presence of two conical pyloric caeca in *N. notopterus*. In the present investigations, however, the caeca were found to be fingerlike, tubular structures in both *Notopterus notopterus* and *N. chitala*. The caeca of *N. chitala* are longer than those of *N. notopterus*. In case of *N. chitala* the length of the two caeca when added together was found to exceed the intestinal length but in *N. notopterus* the intestinal length is greater than the total caecal length added together. The presence of pyloric caeca appears to bear no definite relationship with the diet of a fish since they are present in some carnivores, omnivores and herbivores but entirely absent in other fishes belonging to all the three categories. Mohsin (1962) stated that "the presence or absence of the pyloric caeca in both fishes with long alimentary canals and shorter canals cannot be satisfactorily explained". Barrington (1957) stated that "caeca are said to be absent from all stomachless teleosts although there are many teleosts with a stomach which also lack them". Several workers have reported the presence of pyloric caeca in carnivores with stomachs — *Ophicephalus* spp. (Rahimullah, 1945), *Ophicephalus gachua* (Islam,
1951; Gaur and Jaish, 1970; Datta and Ghosh, 1975); several such carnivores (Mohsin, 1962), Onanna striatus (Das and Moitra, 1956; Khanna and Mehrotra, 1971), Anabas testudineus (Mohsin, 1946, 1962 and Ray, 1978) and also in N. notopterus and N. chitala. as observed in the present investigations. On the other hand, Moitra and Ray (1978) reported the absence of pyloric caeca in the carnivorous Ambassiss nama and A. ranga although they possess true stomach. Similarly, the absence of pyloric caeca have also been reported by Agrawal and Sharma (1966) in Mystus vittatus having a true stomach. Thus it is evident that development of pyloric caeca are independent of the nature of the alimentary tract and influence of diet. The communication of pyloric caeca with the duodenum also varies in different species. They may communicate independently as in Ophicephalus spp., or a large number of caeca may unite together and open by means of two large ducts as in Hilsa (Rahimullah, 1945), or may fuse into a compact gland-like organ, as in Acipenser, and open through a common duct (Barrington, 1957). Burnstöck (1959) reported the presence of a sphincter at the base of pyloric caeca in Salmo trutta. In N. notopterus the caeca open independently at the anterior end of the small intestine a feature in agreement with the observations of Rahimullah (1945). In N. chitala the communication of the pyloric caeca into the intestine has been observed to be identical to N. notopterus. Roshetnikov (1961) stated that the number of pyloric caeca increases with the increase in length of the fish. Rahimullah (1945) concluded that in Ophicephalus
striatus and Therapon jarbua with the growth of the fishes in size the total length of the pyloric caeca increases proportionately along with that of the intestine. This feature, however, is not reflected in case of N. notopterus and N. chitala where the size of caeca increases with the increase in size of the fish but it does not indicate a corresponding relationship with increase in length of the intestine. For example in a 207 mm fish (N. notopterus) the length of the intestine was observed to be 68 m with two pyloric caeca of 19 and 16 mm giving a ratio of 3.6 : 4.2 compared to the intestinal length while in a 202 mm fish with 65 mm intestinal length the ratio of intestinal length to that of the two caeca were 3.6 and 5.0. The same relationship was noted in N. chitala.

Different functions have been attributed to the pyloric caeca by various workers. Dawes (1929) stated that these structures act as reservoirs of food besides being secretory and absorptive in function. Rahimullah (1945) thought that they possibly act as storage organs for semidigested food material. He further considered these outgrowths to increase the absorptive surface of the gut. Barrington (1957) suggested that pyloric caeca are merely an adaptation for increasing the surface area of the intestinal epithelium of fish in which the body cavity limits the length of the intestine itself due to carnivorous habit. Absorptive, secretory or physiological functions have been attributed to the pyloric caeca by various workers. These functions
have been discussed subsequently in this chapter. According to Rahimullah (1945) the pyloric caeca arise from the proximal region of the intestine and not from the pylorus, hence he considers the term 'pyloric caeca' as a misnomer. He proposed instead the term 'intestinal caeca' for these structures. Al-Hussaini and Kholy (1953) also considered the caeca as auxiliary intestinal appendages which serve the purpose of increasing the general intestinal surface. Khanna and Mehrotra (1971), Moitra and Ray (1977) have also expressed identical views. In the present studies, the intestinal caeca were invariably found to contain some food material thus indicating a storage function. Histological and physiological studies reveal additional functions of these structures in *Notopterus* which have been discussed subsequently. The intestine and pyloric caeca have similar transverse ringlike muscular folds and the latter structures communicate freely with the intestine thus indicating its origin from the intestine. Khanna and Mehrotra (1971), however, were unable to ascertain why the intestine become shorter in length initially in fishes like *Harpodon nehereus* and *Channa striatus* and later develop additional appendages for increasing the functional area. Smith (1976) suggested that pyloric caeca apparently represent a way to increase the surface area of the mid-gut and nothing more. According to him it is an interesting question of how food is moved into and out of the blind sacs which are often rather long and slim.
No taxonomic or phylogenetic significance can possibly be attached to the caeca because of extreme variation in number and disposition even amongst members of the same genus and "there is no gradual gradation of the caeca, as we pass from one lower family to the next higher one" (Rahimullah, 1945).

Rectum: There is no marked external differentiation between the terminal portion of the intestine proper and the rectum in *N. notopterus* and *N. chitala*. Internally the mucosal folds, however, present a different arrangement in the two regions. In the intestine the mucosal folds are transversely arranged whereas, in the rectum the mucosal folds are arranged longitudinally. Though the mucosal folds are shallower, the muscularis is highly developed in this region of the alimentary canal. Rogick (1931), McVay and Kam (1940), Girgis (1952), Kapoor (1957a, b), Sarkar (1959), Chitray (1965), Srivastava (1970), Khanna and Mehrotra (1971), Sinha and Moitra (1975a, b, 1976, 1978), Moitra and Ray (1977 and 1979) also observed no external differentiation of rectum from intestine proper in the fishes studied by them. Smith (1978) stated that the demarkation between midgut and hindgut is often minimal in terms of gross anatomy but more readily differentiated histologically. In certain teleosts, however, the presence of the so-called ilio-caecal valve, formed by the extension of muscles from both the regions, separates the rectum
from the intestine proper (Dawes, 1929, Al-Hussaini, 1946). A similar type of valve, termed ilio-rectal valve, has also been reported in *Nuragenesox telabon* by Khanna and Mehrotra (1971). An ilio-rectal valve observed by Mohsin (1946) in *Anabas testudineus* was confirmed by Ray (1978). A preanal ampulla provided with a spiral valve in the alimentary canal of *Alepocephalus* spp. was recorded by Verighina (1978). Ezeasor and Stoke (1981) reported the presence of a prominent funnel shaped ilio-rectal valve in rainbow trout *Salmo gairdneri*. Mohsin (1962), however, observed a sphincter instead of a valve at the junction of intestine and rectum of most of the fishes studied by him. Pasha (1964) distinguished rectum by thicker musculature in *Mystus guli* and by the thickness of the folds in *Tilapia mossambica*.

Thus the rectum of fishes with different food and feeding habits do not any extent reflect the nature of the diet. While the ilio-rectal valve is present in some carnivores like *Anabas testudineus* (Mohsin, 1946; Ray, 1978) and *Nuragenesox telabon* (Khanna and Mehrotra, 1971) they are known to be absent in many other carnivores like *Harpodon nehereus* and *Channa striatus* (Khanna and Mehrotra, 1971), in *Ambassie nama* and *A. ranga* (Moitra and Ray, 1979) and in *N. notopterus* and *N. chitala* as noted in the present studies. Barrington (1957) expressed the opinion that mid and hindgut in fishes is not sharply defined externally but the existence of ilio-caecal valve (designated as ilio-rectal or intestino-rectal valve by several other workers)
associated with certain histological peculiarities justify its recognition as a region concerned with final defection. In both the species the rectal musculature is thicker than the posterior part of the intestine and this helps in contraction and expansion of the rectal wall thus helping final expulsion of the faecal matter. The rectum is therefore, a region where the undigested food is lubricated for final egestion. Similar views have been expressed by Khanna and Mehrotra (1971), Moitra and Ray (1977, 1979). The histological nature further indicates other functions which are discussed in a later part of this chapter.

Rectal caecum: In both N. notopterus and N. chitala the rectum bears a tubular or fingerlike outgrowth - the rectal caecum. The later originates from the right side of the rectum. The rectal caecum is also provided with longitudinal muscular folds. Rahimullah (1945) stated that the caecal structures, found at the junction of large and small intestine in all the selachian fishes and probably absent in Teleostomi, are not homologous with the pyloric caeca of the teleostean fishes. Barrington (1957) also stated that the rectum of selachians bears a digitiform rectal (caecal) gland. The rectal glands of selachians are said to discharge a viscid secretion and as the opening of the gland directs towards the spiral valve they are believed to be involved in digestive functions (Barrington, 1957). In teleosts the presence of such structures is rare. Agrawal and Singh (1964) reported the
presence of rectal caecum in *N. notopterus* and attributed an absorptive function to it. They held that while the very short intestine was not sufficient to permit enough absorption it was compensated by the development of the rectal caecum. Singh (1966) reported the presence of a hallow outgrowth of the rectum in the carnivorous *Bagarius bagarius*.

In the present investigations the rectal caecum of *Notopterus chitala* was found to be longer than that of *N. notopterus*. The ratio of rectal caeca length : intestinal length was found to be 1 : 4.2 in *N. chitala* and 1 : 5.5 in *N. notopterus*. The increase in length of rectal caecum did not indicate any definite relationship with increase in size of the fish in both the species. The caeca was generally found to contain faecal matter or undigested food and their size noted to be variable depending on the presence or absence of food material. The caecum was found to communicate freely with the rectum. The presence of food material in the rectal caecum probably indicate either a digestive or absorptive or both the functions of the caecum. Development of well defined muscosal folds is also suggestive of absorptive function. It is, however, not clear why the intestine after being shortened subsequently develop pyloric caeca in order to compensate for the loss of absorptive surface once again develop rectal caecum for an identical purpose. On the other hand, information relating to rectal caeca of teleostean fishes indicate that this structure occurs only in three species of carnivorous
fishes in India. It may thus be assumed that such structures are present, if at all, only in the carnivorous species in which the intestine proper has become greatly reduced as a result of carnivorous and predaceous adaptations. Morgen (1916, cited by Barrington, 1957) believed that the secretion of rectal gland in selachians aided defecation by accelerating peristalsis. He demonstrated experimentally that extirpation of the gland prevented defecation which could be restored only by injecting the extracts of the gland into the region of the posterior intestine. Such a probability, however, cannot be assumed in Notopterus spp. as histological examination did not reveal a glandular nature of the mucosa of the rectal caecal villi.

DIGESTIVE GLANDS AND ASSOCIATED STRUCTURE

The liver and diffused pancreas in N. chitala and the hepatopancreas and diffused pancreas in N. notopterus are the principal digestive glands. A compact organised pancreas is absent in Notopterus. The right lobe of the liver is larger than the left lobe in both the species. The pancreatic tissue is distributed between the pyloric caeca and around the junction of pyloric caeca and anterior intestine. In addition, the pancreatic tissue in N. notopterus remaining attached to the under side of the liver with a few strands penetrating into the hepatic mass. Thus the pancreas in N. chitala can be considered to be a diffused type and that of N. notopterus as diffused with pancreatic tissue penetrating into liver
according to Boldyreff's (1935) classification. According to Slipper's classification (1946) the pancreatic tissue in *Notopterus* can be considered as pancreas diffusum with an additional pancreas hepaticum in *N. notopterus*. A diffused pancreas has been observed in large number of teleosts belonging to different feeding categories. Sarbahi (1939) found diffused pancreas throughout the body cavity besides being embedded into the substances of liver in *Labeo rohita*, an Indian major carp. Khanna (1963) noted the presence of diffused pancreas in the adipose tissue between the coils of the intestine with the exocrine cells entering into the liver to form hepatopancreas in another planktophagus Indian major carp *Catla catla*. Saxena (1966) observed that the exocrine portion of the pancreas is dispersed in the hepatic mass while the endocrine islets occur seperately over the intestine thus forming two seperate portions of pancreas in *C. catla*. Sinha and Moitra (1975) also reported the presence of hepatopancreas in *L. rohita*. On the other hand, the diffused pancreas has been reported in the carnivorous fishes also. Seshadri (1961) observed a diffused pancreas in *Channa striatus*. Khanna (1961) stated that the pancreas "is usually a diffused structure surrounding the blood capillaries either in the liver forming a hepatopancreas or outside the liver in the body cavity". He recorded the presence of a seperate liver and pancreas in *N. notopterus*, but the present studies reveal that the pancreatic strands invade into the hepatic tissue forming the
hepatopancreas, a condition not reported by Khanna. Later (1963) he noticed a diffused condition of pancreas in Channa punctatus also. Agrawal and Sharma (1966a, b) reported the presence of a diffused pancreas in the omnivore Mystus vittatus and carnivore Nanus nandus. Ray (1978) described the hepatopancreas in Anabas testudineus, a carnivore. Moitra and Ray (1979) reported the presence of a hepatopancreas in two carnivorous perches, Ambassis nama and A. ranga. A compact pancreas in some carnivorous fishes have also been reported. A compact pancreas in the freshwater shark Mallago attu has been described (Kapoor, 1953, Sinha, 1958). A compact type of gland has also been observed in Clarias batrachus, Heteropneustes fossilis and Mystus aer (Khanna, 1962) which predominantly consume food of animal origin. In Bita rita, Khanna (1962) observed an intermediate condition between the diffused and compact types. Clarke and Witcomb (1980) reported the presence of a compact pancreas in a typical carnivore, Anguilla anguilla. Khanna (1963) considers that the structural differences in the pancreas in various species are not related to the nature of food or the length of the alimentary canal. It may be concluded, therefore, that pancreas is in no way related to the nature of diet in fishes. Khanna (1963) also believed that the diffused condition of the pancreas in fish is a primitive feature. The structural organisation of the pancreas however, have been reported to be very different even in members of the same genus. For
example, Khanna (1963) reported a compact pancreas in *Mystus aur* whereas, Agrawal and Sharma (1966) and Jain and Jain (1980) reported the presence of diffused and hepatopancreas in *Mystus vittatus* and *M. cavasius*. Furthermore, fishes belonging to different families or even orders may possess pancreas of similar types. Thus catla (Khanna, 1961; Saxena, 1966) and *Ambassis* spp. (Moitra and Ray, 1979) possess both the diffused pancreas and hepatopancreas of similar type though the two groups are placed under two different taxonomic orders—cypriniformes and perciformes respectively. In *Notopteridae*, however, the general structural pattern and distribution of pancreas are the same in either of the constituent species. It appears therefore, that the pancreas in fish does not demonstrate any gradational relationship from lower to higher orders, classes of genera.

The shape and disposition of liver in both the species of *Notopterus* have been observed to be strikingly similar. In both the cases the liver is bilobed and lies on the right side of the stomach. The gall bladder containing yellowish green bile, remains hidden under the liver and is situated at the proximal part of the liver where the two arms fuse together. Bilobed liver has also been reported by several workers in freshwater Indian fishes with different feeding habits. Khanna (1964) noted a bilobed liver in *Clarias batrachus* an omnivore, Sinha and Moitra (1975) in *Labeo rohita*.
a herbivorous Indian major carp; Agrawal and Sharma (1966) in omnivorous Mystus vittatus; Chitray (1965) in herbivorous Puntius sarana etc. Thus the shape of liver may be similar in fishes with wide differences in feeding habits. Smith (1978) states that the basic functions of liver in processing the digested and absorbed food are entirely cellular and molecular in scope and there is no functional requirement of shape at any stage above the cellular level. He believes that livers may basically be of any shape as in the case of common carp in which the gland simply fills every available space between the loops of the intestine. Thus it may be concluded that the morphology of the liver is not influenced by the nature of the natural diet of fishes.
HISTOLOGY

Bucco-pharynx: The histological organisation of the buccopharyngeal region of either of the species of Notopterus studied, are similar in nature. It is made up of stratified epithelium overlying a basement membrane and provided with mucous cells and taste-buds. The number and size of taste-buds and mucous cells however, may vary.

Barrington (1957) considered the bucco-pharynx to be mainly concerned with selection, seizure, control and predigestive preparation of food for subsequent action by the digestive secretions. Kapoor et al., (1975b) postulate that mucous production and gustation are the main functions of this region. Schultze, (1867, cited by Agrawal and Rajbanshi, 1965), however, expressed doubts regarding the gustatory function of the terminal buds despite their presence in the mouth cavity of all vertebrates excepting mammals. Dawes (1929) was able to record only a few taste-buds and goblet cells in the pharynx of Pleuronectes. Rogic (1931) observed a larger number of taste-buds in the anterior region than in the posterior region of the bucco-pharynx in Campostoma. Al-Hussaini (1945, 1946, 1949a) described the presence of taste-buds in different regions of the bucco-pharynx in several teleosts and concluded that the region is concerned with gustation, the relative frequency of the taste-buds being dependent on the manner in
which the fish secures its food. Mahadevan (1950) and Islam (1951) recorded fewer taste-buds in carnivorous fishes compared to herbivores and omnivores. Kapoor (1953) recorded only a few taste-buds in the carnivorous *Wallago attu* but a large number of them in the carp, *Catla catla* (1958b) and the omnivorous cyprinid, *Barbus stigma* (1957c). Being unable to observe the presence of taste-buds in *Gadusia chapra*, he (1958a) concluded that planktophagous fishes do not need an acute sense of gustation. Swarup (1959) also noted the absence of taste-buds in the phytoplanktophagous *Hilsa ilisha*.

Taste-buds are known to be present in a large number in herbivorous and omnivorous fishes. Pasha (1964a, b) observed numerous taste-buds in the bucco-pharyngeal region of the omnivorous *Mystus gulio* and the herbivorous *Tilapia mossambica*. Agrawal and Sharma (1966) recorded taste-buds in the bottom-feeding omnivore *Mystus pittatus*. Moitra and Sinha (1971, 1972) recorded a large number of taste-buds in the omnivorous *Chagunius chagunio* and herbivorous *Cirrhinus mrigala*. Sinha and Moitra (1975b) recorded numerous taste-buds in the Indian major carp, *Labeo rohita*. They (1978) also observed the presence of a large number of taste-buds in the herbivore, *Labeo calbasu* and in moderate numbers in the omnivore *Catla catla*. Moitra and Ray (1977) found numerous taste-buds in the bucco-pharyngeal region of the omnivorous *Colisa fasciata*. The carnivorous fishes have been reported to possess fewer taste-buds in the bucco-pharynx. Islam (1951),
Kapoor (1953), Sarkar (1959), Pasha (1964c), Khanna (1964) and Sinha and Moitra (1978) observed only a few taste-buds in the carnivorous/predaceous Gharial, Wallago attu, Mystus seenghala, Megalops cyprinoides, Clarias batrachus and G. batrachus respectively. Khanna (1968) and Khanna and Mehrotra (1970) recorded few taste-buds in the carnivorous Muraenesox telabon and Channa striatus compared to the omnivorous and planktophagous fishes studied by them. They have observed complete absence of taste-buds in the bucco-pharyngeal region of the carnivorous Harpodon nehereus. Verighina (1979) observed that the taste-buds decrease in number towards the pharynx in the predatory cyprinid, Opsariichthys uncirostris amurensis. During the present course of investigations a few taste-buds were observed in the bucco-pharynx of Notopterus spp. The occurrence of taste-buds in N. chitala was found to be rare. This may be due to the carnivorous nature of the Indian feather-backs — a feature in conformity with the observations made by several workers in other carnivorous fishes. Mohsin (1962) and Singh (1973) mentioned the presence of taste-buds in the bucco-pharyngeal region of N. notopterus but made no observations on their numerical abundance. Khanna and Mehrotra (1970) believe that the presence or absence of taste-buds in the bucco-pharyngeal region of fishes does not have any bearing on the nature of the food but actually appears to depend on the mode of feeding. Khanna (1968) stated that taste-buds are numerically few in the bucco-pharyngeal region of those fishes which feed by sight and
taste while more numerous in fishes which feed by
gustation only. It may be assumed therefore, that
both N. notopterus and N. chitala feed by sight and
taste. The presence of large-eyes in both the
species further confirms the presence of this type
of feeding habit. Ray (1978) also holds
a similar view and states that Anabas testudineus,
a carnivorous perch, which is provided with a few
taste-buds in the buccopharyngeal region also pro-
cure food both by sight and taste. Moitra and Ray
(1979) recorded the presence of only a few taste-
buds in the buccopharynx of Ambassis nama, and A.
ranga and considered the fishes to be sight feeders.
The present studies are in agreement with the views
expressed by Khanna (1968), Ray (1978), and Moitra

Mucous cells were found to be abundant in
the buccopharyngeal region of either of the species
of Notopterus studied. The concentration of mucous
cells are greater towards the posterior region of
the buccopharynx. The presence of mucous cells in
the buccopharyngeal region of fishes has been re-
ported by several workers (Vanajakshi, 1938; Al-
Hussaini, 1946, 1949a; Islam, 1951; Kapoor, 1953,
1957, 1958; Sarkar, 1959; Pasha, 1964a, b, c;
Chitrav, 1965a; Moitra and Bhowmick, 1967; Khanna,
1968; Khanna and Mehrotra, 1970; Western, 1971;
Moitra and Sinha, 1971, 1972; Sinha, 1975, 1977a;
Sinha and Moitra, 1974, 1975; Moitra and Ray, 1977,
1979; Verighina, 1979; Sinha and Chakraborty,
1982 and Ray and Moitra, 1982). The number of mucous
cells were found to increase towards the posterior end in both \textit{N. notopterus} and \textit{N. chitala}. Kapoor (1957, 1958a, b), Chaudhuri and Khandelwal (1961), Khanna (1968), Khanna and Mehrotra (1970), Moitra and Ray (1977, 1979) and Verighina (1979) also recorded the increase in the number of mucous cells from the anterior to the posterior region of the bucco-pharynx. Kapoor (1953) observed a similarity in the disposition of mucous cells between the pharynx and the anterior region of the buccal cavity in a carnivorous fish, \textit{Wallago attu}. Sarkar (1959) and Moitra and Ray (1979) recorded a greater concentration of mucous cells in the posterior region of the bucco-pharynx in \textit{Mystus seenghala} and \textit{Ambassis} spp. Pasha (1964c) also recorded a similar condition in another carnivore \textit{Megalops cyprinoides}. Al-Hussaini (1969a) believed that the abundance of mucous cells in the bucco-pharyngeal region is associated with increased production of mucous required for lubrication of the food ingested. Moitra and Ray (1977, 1979) upheld the views expressed by Al-Hussaini. The presence of a large number of mucous cells in the bucco-pharyngeal region of \textit{Notopterus} probably also facilitates the propulsion of food besides providing protection to the buccal epithelium from mechanical injury. This confirms the observations made by Kapoor (1953), Sarkar (1959) and Moitra and Ray (1979) on other carnivorous species.

The mucous cells of the bucco-pharynx have
been found to be PAS positive. Khanna and Mehrotra (1970), Sinha (1977a) and Verighina (1979) also observed PAS positive mucous cells in the buccopharyngeal region of the fishes studied by them. Western (1971) believes that the fore-gut is the main site of PAS positive mucous production in Cottus gobio, Enophrys bubalis, Salmo trutta and Nemachilus barbatulus. The present observations on Notopterus spp. are therefore, in conformity with the above observations. Sinha and Chakraborty (1982), however, recorded a mosaic of PAS and AB positive mucins in the buccopharyngeal region of Catla catla, an Indian major carp. In N. notopterus however, the mucous cells of the buccopharyngeal region responded very weakly to AB (2.5).

The sub-mucosa of both the species studied was found to be fairly well developed in the buccopharynx. The muscular layer of the buccopharynx has been reduced due to the enormous development of adipose tissue. Reduction of muscular layer in the buccopharyngeal region due to development of adipose tissue has also been recorded by Mohsin (1962) in several teleosts. Islam (1951) observed the absence of a muscular coat as a distinct part of the buccal epithelium in Rota rita, a carnivorous species. A basement membrane has been observed in Notopterus which supports the superficial mucosal layer. The basement membrane has been described in the buccopharyngeal region of several carnivorous species e.g., Ophicephalus striatus (Islam, 1951),
Wallago attu (Kapoor, 1953), Clarias batrachus (Khanna, 1966), Anabas testudineus (Ray, 1978) and Ambassis nama (Moitra and Ray, 1979). Dawes (1929) and Sarbahi (1939) considered the basement membrane to be a supporting structure of the epithelial cells.

Tongue*: The histological nature of the tongue in Notopterus is almost similar to that of the bucco-pharyngeal region. The stratified epithelium provided with mucous cells and taste-buds form a coating round a central skeletal support. Taste-buds have been observed to be rare in occurrence in N. chitala. Islam (1951) recorded the presence of taste-buds in the tongue of the carnivorous Ophicephalus gachua. The tongue in fishes generally possess a skeletal support, striated muscles and connective tissue (Kapoor, 1957d). It is more developed in carnivores (Khanna, 1959). Tandon and Goswami (1968) recorded taste-buds in the tongue of Channa punctatus and C. striatus but could not recognise such structures in Channa gachua. They consider that the tongue in the members of the genus Channa serve to supplement the function of teeth in the retention of prey besides compensating the absence of barbels and other integumentary sense organs. The presence of taste-buds and goblet cells in the tongue of Glossogobius giuris has been reported by Mohsin (1962). Ray and Moitra (1982) also recorded the presence of taste-buds and mucous cells in the mucosal layer of tongue of Anabas testudineus. They believe that in addition
to the function of gustation the superficial mucosa of the tongue helps in lubrication of the food material within the buccal cavity so as to facilitate swallowing. It may be presumed therefore, that the presence of a well developed tongue armed with inwardly directed teeth strongly indicate the piscivorous/carnivorous habit of *Notopterus*. The presence of taste-buds in the mucosa of tongue in *Notopterus* also indicates a minor role of the tongue for sampling food, although in *N. chitala* the number of taste-buds is extremely reduced. The tongue may also help in lubricating the food as has been suggested by Tandon and Goswami (1968) and subsequently by Ray and Moitra (1982).

**Oesophagus**: The oesophagus comprises the mucosa, sub-mucosa, muscularis and serosa. The stratified mucosa of the anterior oesophagus is replaced gradually by the columnar epithelium towards the stomach in both the species of *Notopterus* studied. Kapoor (1953) described a gradual transformation of the stratified epithelium of the oesophagus into columnar towards the stomach in carnivorous *Wallago attu*. Pasha observed a replacement of the stratified epithelium of the anterior oesophagus into a single layered columnar epithelium in *Mystus gulio* (1964a) and *Megalops cyprinoides* (1964c). Sinha and Moitra (1975b) also recorded a stratified epithelium in the anterior and columnar in the posterior oesophagus respectively in *Labeo rohita*. Moitra and Ray (1977, 1979) recorded similar conditions in *Ambassie nama*, *A. ranga* and
Colisa fasciata. Clark and Witcomb (1980) observed a gradual replacement of stratified epithelium into columnar epithelium posteriorly in the oesophagus of the carnivorous Anguilla anguilla. Ray and Moitra (1982), however, observed a mixed type of epithelium, comprising both stratified and columnar, in Anabas testudineus, a carnivorous perch. Al-Hussaint (1946) observed a stratified epithelium in the anterior oesophagus of Mulloides auriflamma but a typical columnar epithelium in Atherina forskali (1947a). Kapoor (1957c) in Barbus stigma, Sehgal (1966), in Labeo calbasu, Moitra and Bhowmick (1967) in Catla catla, Moitra and Sinha (1971) in Chagunius chagunio and Mehrotra and Khanna (1969) in several Indian teleosts reported the presence of both stratified and columnar epithelium in the oesophageal mucosa. Barrington (1957) and Kapoor et. al., (1975b) stated that stratified epithelium is generally present in the oesophagus of fishes. On the other hand Sarkar (1959) in Mystus seenghala, Khanna (1964) in Clarias batrachus, Pasha (1964b) in Tilapia mossambica and Lal (1968) in Tor putitora observed only columnar cells in the oesophageal mucosa. It may, therefore, be said that the stratified or simple columnar epithelium of the oesophagus does not probably give any indication of the food habit of the fish as both the types of mucosa may be present in either of the feeding types. Venkateswaralu (1966) concluded that structurally there is no difference between the oesophagus of herbivores and carnivores. Moitra and Ray (1979) upheld the latter
Large number of mucous secreting cells were observed to be present in the oesophageal mucosa of either of the species of *Notopterus*. At certain places the mucous secreting cells virtually obliterate the columnar cells. Vanjakshi (1938) recorded a large number of mucous cells in the oesophageal mucosa of *Heteropneustes fossilis*. Islam (1951) recorded a large number of mucous cells in the oesophagus of *Rita rita* and *Ophicephalus gachua*. Sarkar (1959), Mohsin (1962), Khanna (1964), Sinha and Moitra (1976), Moitra and Ray (1977) and 1979) also recorded a large number of mucous cells in the oesophageal mucosa of * Mystus senghala*, in several teleosts, *Clarias batrachus, Cirrhinus reba, Colisa fasciata*, and *Ambassis nama* and *A. ranga*. Clarke and Witcomb (1980) and Ray and Moitra (1982) also recorded a large number of mucous cells in the oesophageal mucosa of *Anguilla anguilla* and *Anabas testudineus*. Moitra and Ray (1977, 1979) suggested that the preponderance of mucous cells in the oesophagus could be correlated with the need for lubrication of food in this region in order to facilitate its conduction into the stomach. Mehrotra and Khanna (1969) and Moitra and Sinha (1971, 1972) also suggested a similar function. The present observations on *Notopterus* also supports the view expressed by the latter authors. The oesophagus plays a significant role in lubricating the food in *Notopterus*. The entire oesophageal mucosa participates in lubrication of food as mucous cells are present throughout the mucosa in these species.
The mucous cells were found to be both PAS and AB positive in both the species of Notopterus. Sis et al. (1979) reported that the cranial half of oesophagus contained acid mucopolysaccharides, the caudal half contained neutral while at the mid-point some cells contained both blue and red staining granules indicating a mixture of products when stained with AB-PAS in the channel cat-fish Ictalurus punctatus. Sinha and Chakraborty (1982) observed that oesophageal mucous cells take up a bluish purple colour or purple bluish colour with PAS/AB or AB/PAS in Catla catla. They concluded that the mucous cells contained a mixture of neutral and acid mucins. Thus it may be assumed that the oesophageal mucous cells in Notopterus also contain a mixture of two types of mucins.

The presence of taste-buds was observed in the anterior oesophagus of N. notopterus. In N. chitala, however, no taste-bud could be observed. Mohsin (1962) failed to detect any taste-buds in the oesophagus of the fishes studied by him including N. notopterus. Presence of taste-buds in the oesophageal mucosa have been recorded by several workers. Sarbahi (1939) and Sinha and Moitra (1975) reported the presence of taste-buds in the oesophageal mucosa of Labeo rohita, an Indian major carp. Islam (1951), Moitra and Sinha (1972) also reported the presence of taste-buds in the oesophageal mucosa of Cirrhinus mrigala, another Indian major carp. Kapoor (1957c, 1958) noticed the presence of taste-buds in the oesophagus of Barbus stigma and
*Catla catla*. Al-Hussaini (1949a), Chit Ray (1965a), Sehgal (1966), Sinha (1976) and Sinha and Moitra (1976); Mehrotra and Khanna (1969) and Moitra and Sinha (1971) reported the presence of taste-buds in the oesophageal mucosa of *Cyprinus carpio*; *Puntius sarana*; *Labeo calbasu*; *Tor tor* and *Chaplinus chagunco* respectively. Pasha (1964a, c) observed the presence of taste-buds in the oesophagus of omnivorous *Mystus gulio* and carnivorous *Megalops cyprinoides*. Taste-buds have been reported to be present in the oesophageal mucosa of several carnivorous species also (Kapoor, 1953; Mehrotra and Khanna, 1969; Moitra and Roy, 1979; and Ray and Moitra, 1982). Many authors, however, were unable to detect the presence of taste-buds in the oesophageal mucosa of fishes (Mahadevan, 1950 in *Triturus* and *Garza*, Islam, 1951 in *Rita* rita and *Ophicephalus gachua*; Khanna (1964) in *Olarias batrachus*; Sarkar (1959) in *Mystus seen—ghala*; Pasha (1964b) in *Tilapia mossambica*; Agrawal and Sharma (1966) in *Mystus vitatus*; Tandon and Goswami (1968) in *Channa* spp.; Mehrotra and Khanna (1969) in *Harpodon nehereus*, *Ilisha filigera* and *Muraenesox telabon*). Smith (1978) postulated that taste-buds are usually present in the oesophageal mucosa of fishes. It is obvious therefore, that the presence of taste-buds in the oesophageal region does not reflect the nature of diet as the latter sense organs may also be present in herbivores, carnivores or omnivores. Mehrotra and Khanna (1969) also expressed similar opinions. The presence of taste-buds in the anterior oesophagus
of *N. notopterus* indicates that this region probably plays an important role in the selection or rejection of food. Moitra and Ray (1977, 1979) observed that the gustatory sense extends up to the anterior oesophagus in *Colisa fasciata, Ambassis nama* and *A. ranga* where final selection of food is effected. Barrington (1957) stated that the presence of taste-buds and striped muscles indicates the importance of oesophagus in the selection of food.

The occurrence of oesophageal glands is a characteristic feature in *Notopterus*. In both *N. notopterus* and *N. chitala*, oesophageal glands, bound by ramifying submucosa, are present. Sarbahi (1939) reported the presence of complex, racemose oesophageal glands in *Labeo rohita*. Chandy and George (1960) reported such structures in the transitional zone between oesophagus and stomach but did not indicate specifically their ability to produce mucous or enzymes in *Chanos chanos*. Mohsin (1961) observed simple mucous glands below the mucosal layer in the oesophagus of *Glossogobius giuris*. He (1962) described oesophageal glands in *N. notopterus* and presumed that they were deeply sunk in epithelial layer in the sub-mucosa. He was, however, unable to interpret the function of these structures. The oesophageal glands of *Notopterus* which are situated immediately below the mucosa were found to be full of AB and PAS positive mucopolysaccharides. This suggests that oesophageal glands probably participate in active mucous secretion necessary for the lubrication of animal prey. Verighina and Medani (1968) noticed oesophageal
glands in *Distichodus niloticus* and *D. rostratus* with their upper region containing large mucous cells loaded with PAS-positive contents and lower region with small cuboidal cells loaded with PAS-positive granules. The oesophageal glands in *Notopterus* respond to both haematoxylin and acid fuchsin dyes (Mallory’s triple stain). This probably indicate the nature of the secretions of the oesophageal glands although the exact nature of these secretions could not be confirmed. Sarbahi (1950) considered the oesophageal glands in *Labeo rohita* to have a secretory function. At the proximity of its connection with the stomach, the mucosa of the oesophagus in *Notopterus* presents a combination of the features of the oesophageal and gastric mucosa constituting a kind of oesogaster. Such a condition has also been reported by Kapoor (1958a) in the phytoplanktophagus *Gadusa chapra* and Clarke and Witcomb (1980) in the carnivorous *Anguilla anguilla*. Pasha (1964a) also recorded an oesogaster in *Mystus guilo*. The circular muscle layer is well developed in either of the species of *Notopterus*. In *N. chitala*, the longitudinal muscle layer which lies inner to circular layer can be seen scattered below the sub-mucosa in the anterior oesophagus. In *N. notopterus*, the muscularis longitudinalis, when present, is extremely reduced being restricted to a smaller area below the oesophageal glands. In the posterior part of the oesophagus the muscularis longitudinalis is poorly developed. Al-Hussaini (1946) observed a circular muscle layer only in the oesophagus of *Mulloides auriflamma*. 
Islam (1951) also noted a similar layer in the oesophagus of *C. mrigala*. He (1951), however, reported the presence of inner longitudinal and outer circular muscle layers in the oesophagus of *Ophicephalus gachua*. Kapoor (1953) described a similar arrangement in the carnivorous *Wallago attu*. A thick outer circular and a thinner inner longitudinal muscle layer has been reported by Agrawal and Sharma (1966) in *Mystus vitatus*. Such an arrangement of muscles have also been reported by Sarkar (1959) in *Mystus seenghala*, Pasha (1964) in *Mystus gulio*, Mohsin (1962) in *Anabas testudineus*, Mottra and Ray (1979) in *Ambassis nama* and *A. ranga* and Ray and Mottra (1982) in *Anabas testudineus*. Mottra and Ray (1979) observed a greater development of the longitudinal muscles than the circular muscles in the oesophagus of *Ambassis nama* and *A. ranga*. A similar condition was also described by the authors in *Anabas testudineus* (1982). They consider that the longitudinal muscles provide additional strength to the mucosal folds and help to increase the elasticity of the oesophagus for swallowing animal food. Khanna (1964) reported the presence of only circular muscle layer in the predatory omnivore *Clarias batrachus*. It is presumed that the highly developed circular muscle layer in the oesophagus of *Notopterus* advantageously employed for constricting the oesophagus and also to dilate it so as to accommodate larger prey like fish and shrimps.
Moitra and Ray (1977) described a reverse order of arrangement of muscles, i.e., external longitudinal and internal circular layers in Colisa fasciata. Islam (1951) also observed a similar arrangement of muscle layers in the oesophagus of Rota rita. Pasha (1964a) stated that there is actually no fixed order of succession of the muscular layers in the oesophagus of fishes. It may be concluded, therefore, that the muscular arrangement in the oesophagus of fishes is not influenced by the nature of diet in fishes.

Stomach: The stomach wall of either of the species of Notopterus studied, comprises the mucosa, consisting of columnar and glandular layers, sub-mucosa, muscularis and serosa. The gastric epithelial cells show a strong PAS and AB (2.5) positive reaction in their apical region. The mucoid nature of the gastric epithelium has been demonstrated in many teleosts - Islam (1951) in Rota rita, Kapoor (1958a) in Gadusia chapa, Khanna (1964) in Clarias batrachus, Pasha (1964a, b, c) in Mystus gulio, Tilapia mossambica and Megalops cyprinoides, Moitra and Ray (1977) in Colisa fasciata and later (1979) in Ambassis nama and A. ranga. Weinerb and Blistad (1955) found that the surface epithelium of the cardiac stomach in Salmo giardneri is composed of columnar cells, the apical borders of which are covered with a mucous coat. Jirge (1970) obtained a PAS positive reaction for the gastric epithelium of Tilapia mossambica and Otolithus ruber. He concluded that
the neutral mucins and glycogen are present in the
gastric epithelium and the submucosa of the carnivor-ous fishes. A non-globular PAS reaction in the
apical portion of the columnar cells of the stomach
was also obtained by Sis et. al., (1979) in Actalurus
punctatus. Pandey and Pandey (1980) demonstrated
a PAS positive reaction in the gastric epithelium of Channa punctatus. Clarke and Witcomb (1980)
observed AB/PAS, AB/AF and Alcian blue positive
reaction in gastric epithelium of carnivorous
Anguilla anguilla and concluded that these cells
contained acid and neutral mucopolysaccharides.
Barrington (1957) stated that this so called
'visible mucous' secreted by the columnar epithe-
lium cells protects the surface of the stomach
from mechanical injury. The present observations
on Notopterus also agree with the observations of
Clarke and Witcomb (1980) on Anguilla anguilla.
The densely packed mucous secreting cells present
in the stomach of Notopterus spp. presumably acts
as a protective barrier against mechanical or
chemical injury and autodigestion. This is confir-
med by the presence of entire specimens of animal
food or broken portions of organisms in the stomach
and high acidity prevailing in this region. The
mucous acts as a buffer helping in neutralising the
irritants, if any, besides, lubricating the food
for onward transmission. Ray (1978) observed in-
tensified mucous production in Anabas compared to
the other three species studied by him. He infer-
red that this phenomenon was due to ingestion of
larger prey by Anabas. The columnar epithelium
has been suggested to have an absorptive function (Dawes, 1929; Blake, 1936). Smith (1978) stated that absorption of soluble food could occur in the stomach as in mammals but this phenomenon has not been investigated in fish so far. Al-Husaini (1946), however, attributed a mucous secreting function to these columnar cells. Moitra and Ray (1979) suggested that the columnar cells in the stomach epithelium in Ambassis namu and A. ranga probably have a dual role, i.e., mucous secretion and absorption of digested food materials. These functions of the gastric epithelial cells were also noticed by Pasha (1964) in Megalops cuprinoides, Bishop and Odense (1966) in Gadus morhua, Nehrottra and Khanna (1969) in Channa striatus, Western (1969) in Cottus gobio and Shaft (1974) in Clarias batrachus.

A large number of gastric glands have been observed in the gastric glandular epithelium in either of the species of Notopterus studied. These glands are simple and rounded or tubular. Kapoor et. al. (1975), Ray (1978) stated that gastric mucosa varies in thickness in the different parts depending on the degree of development of the gastric glands. During the present investigations the gastric mucosa were found to indicate variation at different parts in the stomach of Notopterus. Mohsin (1962) expressed the opinion that the extent of development of glands from simple to elaborate complex gland types is an adaptation to the time taken for digestion in fishes with different feeding
habits. Konfal (1966) thought that the presence of gastric glands depends upon taxonomic position and not on the feeding habits. According to Kapoor et. al., (1975) the presence of gastric glands has no bearing on the feeding behaviour or food.

The gastric gland cells were found to be of only one type in either of the species of Notopterus. The gland cells, however, could not be differentiated into oxyntic and peptic types. Barrington (1957) regarded the glandular structure of the fish stomach to belong to a primitive level of organisation. Edinger (1877) also confirmed that gastric gland cells in fishes do not indicate any differentiation into two types of cells. Secretary cells of a single type described as chief or peptic cells have been recorded by Greene (1912) and Blake (1930) in the stomach of the fishes studied by them. Mahadevan (1950) in Carinajedaba and Tritiurus haumala, Islam (1953) in Rota rita and Ophicephalus gachua, Kapoor (1953) and 1958a) in Wallago attu, and Gadusia chapra, Nagar and Khan (1958) in Hastacembelus armatus, Sarkar (1959) in Mystus seenghala, Mohsin (1962) in several stomached fishes, Khanna (1964) in Clarias batrachus, Pasha (1964) in Mystus gilio, Tilapia mossambica and Megalops cuprinoides, Tandon and Goswami (1968) in Channa spp., Mehrotra and Khanna (1969) in Hardodon nehereus, Murgenesox telebon and Channa striatus, Sripastava (1970) in Rhyncobdella aculeata, Moitra and Ray (1977) in
Colisa fasciata and later (1979) in Ambassis nama and A. ranga, have also recorded the presence of only one type of cells in the gastric glands. Barrington (1957) stated that the body of the chief glands of the Actinopterygii contains only one type of glandular cell which is assumed to secrete both pepsin and hydrochloric acid. Kowal- ramani (1953) observed that as the cells of the gastric glands are identical they must have the dual function of secreting both acid and pepsin. Smith (1978) also stated that "there is agreement on the presence of only one type of secretory cell". It may be presumed, therefore, that both gastric enzymes and hydrochloric acid are secreted by the same cells in the gastric glands of Notopterus spp. also.

A distinction between neck cells, producing mucous and granular secretary cells, producing enzymes have been made by various workers e.g., Dawes (1929) and Mikolskaya and Verighina (1974) in Pleuronectes platessa; Islam (1951) in Ophicephalus gachua; Verighina (1967) in Tilapia mossambica and T. zilli. On the other hand Maha- devan (1950) in Caranx and Trichiurus; Islam (1951) in Rota rita, Kowalramani (1953) in Cottus scorpius and Zoarces viviparus; Kapoor (1953 and 1958a) in Wallago attu and Gadusia cypriaca; Sarkar (1959) in Mystus seenghala; Khanna (1964) in Clarias batrachus; Moitra and Ray (1977, 1979) in Colisa fasciata and Ambassis spp. could not differentiate mucoid neck cells in the gastric glands.
During the present investigations also, gastric gland cells were found to be PAS and AB negative. This indicates the absence of mucoid neck-cells in the gastric glands of *N. notopterus* and *N. chitala*. Many authors have emphasised that only one type of cell could be identified histologically in teleost stomach and no physiological division of secretory functions exist (Barrington, 1957; Western and Jennings, 1970; Kapoor et al., 1975 etc.)

In *N. notopterus* the glandular epithelium is found to contain a few deeply seeted mucous secreting glands. Each of these glands is made up of mucous cells and are PAS and AB (2.5) positive. These glands are probably formed by fusion of gastric mucosal folds. Chandy and George (1960) have also reported the presence of such type of glands at the oeso-gastric transitional zone in *Chanos chanos*. Ray and Nitra (1982) have also reported such type of glands in the anterior part of the cardiac stomach in *Anabas testudineus*. They found these glands to be PAS and muciarmine positive. Ray and Nitra (1982) suggested that these mucous glands are responsible for increased production of mucous and correlated this feature with the nature of diet in the carnivorous *Anabas testudineus*. The lamina propria is made up of connective tissue fibres and form a network between the spaces of the gastric glands and extend into the mucosal layer in both the species of *Notopterus*. Pasha (1964a) suggested that the lamina propria serves
to bind the glands, support the entire glandular tissue and carry the blood capillaries into the glandular tissue. These functions may also be attributed to the said structures in *Notopterus*. Such ramification of lamina propria has been recorded in most of the stomached teleosts by various workers (Kapoor, 1953; Sarkar, 1959; Khanna, 1964; Pasha, 1964a, b, c; Agrawal and Sharma, 1966; Moitra and Ray, 1977 and 1979; Verighina, 1978; Clarke and Witcomb, 1980 etc.). The stratum compactum of the sub-mucosa has been observed to be well developed in both the species of *Notopterus*. This layer has been regarded as a protective, supporting and strengthening layer which helps in distension of the wall within bounds, by Burnstock (1959a) and Bucke (1971). These authors regard this structure to be an adaptive feature characteristic of many carnivorous fishes. Ray (1978) also upheld the views of the above mentioned authors. The stratum compactum in *N. notopterus* and *N. chitala* also appears to serve the same purpose as both these species are carnivorous. The sub-mucosa following the stratum compactum is found to consist of connective tissue fibres traversed by some muscle fibres in either of the species of *Notopterus*. Mohsin (1962) considered such a structure present below the stratum compactum as the nearest approach or equivalent to the so called "mucosalis-mucosae" in *N. notopterus*. The stomach wall of *N. chitala* also showed these peculiarities. This histological layer however, is not the "mucosalis mucosae" which consists of both circular and longitudinal
muscles in mammals while in *N. chitala* and *N. notopterus* it comprises connective tissue fibres and longitudinal muscles only. Further, this muscle layer does not extend into the mucosal layer. Similar histological features were also observed by Verighina (1978) in the stomach wall of *Alepocephalus* spp. Moitra and Ray (1979) recorded an inner and an outer layer of longitudinal muscle fibres with a layer of circular muscles in between in minor perchs *Ambassie nama* and *A. ranga*. They suggested that such an arrangement helps in distension of the stomach wall within bounds. This may also be attributed to *Notopterus* spp. The food in *Notopterus* is passed down into the stomach in almost unaltered form and the stomach wall is so distensible that it can accommodate even entire small fishes and other organisms. Clarke and Witcomb (1980) observed 'muscularis mucosae', formed of irregular smooth muscle fibres supporting the deeper layer of glandular tissue, in the stomach of carnivorous *Anquilla anguilla*. It may therefore, be presumed that an inner longitudinal layer of musculature may sometimes be present in the stomach wall of carnivorous fishes so as to help in distension of the stomach wall and also probably in crushing food.

**Pylorus:** The wall of the pylorus comprises mucosa, sub-mucosa, muscularis and serosa. The mucosa is made up of columnar epithelial cells devoid of any gastric glands. The apical part of the mucosa demonstrated PAS* and AB positivity. At places the epithelial folds of the pylorus present a glandular
appearance. Bishop and Odense (1966) also observed similar situation in *Gadus morhua*. Verighina (1967) described primitive mucous secreting pyloric glands in *Tilapia mossambica* and *T. sili*.* Ray (1978) recorded mucous glands which were tubular and confined to the anterior region of the pyloric stomach, in *Anabas testudineus*. He suggested that these glands secrete mucous for lubricating the food and also for protection of the pyloric wall. Barrington (1957) however, did not consider these glands equivalent to pyloric glands as they are formed of cells resembling those of the surface layer.

The wall of the pylorus is thick. The circular muscle layer is highly developed forming a sort of sphincter at its junction with the anterior intestine. The circular muscle layer lies inner to the longitudinal muscle layer. Mohsin (1946) and Ray and Moitra (1982) also reported a similar feature in *Anabas testudineus*. Islam (1951) observed that in *Rita rita* the muscularis circularis increases so greatly that at the region of pyloric sphincter the longitudinal muscle layer becomes almost indistinguishable. Kapoor (1953) reported that the circular layer of muscles were very thick forming a pyloric sphincter in *Wallago attu*. Similar features were also encountered in *Mystus guilfo* and *Megalops cyprinoides* (Pasha, 1964a, c), *Mystus vittatus* (Agrawal and Sharma, 1966). Clarke and Mitcomb (1980) also recorded a three fold increase in thickness of circular muscle layer at the pyloric sphincter in *Anguilla anguilla*. Such enormous development of
circular muscles thus help in efficient contraction for regulating the passage of food from pylorus to anterior intestine.

Intestine: The intestinal mucosa is composed of absorptive columnar epithelial cells throughout its entire length. The free boarders of the columnar epithelial cells are lined with a thin top plate. In between the epithelial cells are distributed a large number of mucous cells. The presence of columnar cells provided with a top-plate indicate absorptive nature of the intestinal epithelium. Several authors have attributed similar function to the intestinal epithelium in different species of fishes (Curry, 1939; Sarbahi, 1939; Al-Hussain, 1946, 1947a, 1949a, b; Islam, 1951; Kapoor, 1953, 1957, 1958a; Chaudhuri and Khandelwal, 1961; Moitra and Sinha, 1971, 1972; Khanna and Behrotra, 1971; Sinha and Moitra, 1975a; Kapoor et. al., 1975b; Moitra and Ray, 1977, 1979; Esean and Stoke, 1981 etc.). Smith (1978) stated that the brush border (top-plate) on the surface of the epithelial cells which have been clarified as microvilli with electron microscopy, greatly increase the cells’ surface area and is probably involved in absorption. Clarke and Witcomb (1980) observed well developed microvilli in the intestinal epithelium of Anguilla anguilla.

At the anterior end of the intestine following the pylorus the intestinal villi show infolding and interdigitate in such a manner that the intestinal
lumen gets almost obliterated. This is observed in both the species of Notopterus. Khanna and Mehrotra (1971) observed a similar situation in the carnivorous Channa striatus. Moitra and Ray (1977), however, recorded such a condition in omnivorous Colisa fasciata. Later (1979) they reported on the high infoldings of the anterior intestine of carnivorous Ambassis nama and A. ranga. The above mentioned authors are of the opinion that infoldings greatly increase the absorptive surface so that compensatory adjustments can be made to ensure optimum absorption in view of the short intestine in the carnivorous fishes studied by them. As has been mentioned earlier the length of the intestine in both the species of Notopterus is very short. The highly infolded villi in the anterior intestine, therefore, increase the absorptive surface to a great extent in order to ensure maximum possible absorption. The middle and the posterior region of the intestine also demonstrated similar features excepting that the villi are shorter. The intestinal villi in these parts also form a complex structure as a result of fusion in both the species of Notopterus. Khanna and Mehrotra (1971) also observed such a complexity of intestinal villi in the carnivorous fishes studied by them.

A large number of mucous cells were found to be present throughout the length of the intestine with a greater concentration towards the anterior intestine, decreasing slightly towards the middle and posterior intestine. Khanna and Mehrotra (1971)
observed only a few mucous cells at the anterior intestine with their number decreasing in the middle but increasing considerably at the posterior region in most of the carnivorous species studied by them. Moitra and Ray (1977) also observed similar features in Colisa fasciata. Islam (1951) observed numerous mucous cells in the intestinal mucosa of carnivorous Rita rita, Ophicephalus gachua and herbivorous Cirrhinus mrigala. Kapoor (1953) recorded the presence of mucous cells in plenty in the intestinal mucosa of Mallago attu, a carnivorous fish. Pasha (1964) recorded only a few mucous cells in the intestine of Mystus gulio, an omnivore with carnivorous propensity. Moitra and Ray (1979) recorded mucous cells throughout the intestine in the carnivorous perches, Ambassis nama and A. range, with greater concentration in the posterior intestine. Clarke and Witcomb (1980) recorded the predominance of mucous cells throughout the intestine of Anguilla anguilla, a carnivore. Sis et al. (1979), Pandey and Pandey (1980) also recorded the presence of mucous cells in the intestinal epithelium of carnivorous Ictalurus punctatus and Channa punctatus respectively. Agrawal and Sharma (1966), however, recorded only a few goblet cells scattered with in the intestinal mucosa of Mystus vittatus. Al-Hussaini (1949b) observed that mucous cells stain more intensely in Gobio than in Butilus or Cyprinus and concluded that goblet cells secrete both mucous and mucusogen the concentration of latter being higher in carnivores. Khanna and Mehrotra (1971), however,
could not make such differentiation and concluded that the presence of mucous cells cannot be correlated with the feeding habit of the fish. Moitra and Ray (1979) stated that the number of mucous cells are minimised in the anterior intestine as the need for lubrication of food is also minimised since only semidigested food is passed down into intestine in *Ambassis nama* and *A. ranga*. This is, however, not tenable in case of *Notopterus* spp. as a large number of mucous cells were found to be present throughout the intestine with greater concentration in the anterior part and no undigested food was encountered in the intestine. Khanna and Mehrotra (1971) and Clarke and Witcomb (1980) also recorded a large number of mucous secreting cells throughout the intestine of *Channa striatus* and *Anguilla anguilla*, both the species being carnivorous.

The mucous cells of the intestine have been observed to be PAS, AB and PAS/AB positive in both the species of *Notopterus*. PAS positive reaction for mucous cells were also obtained by Khanna and Mehrotra (1971) in the intestinal mucosa of the fishes studied by them. Ray (1978) also recorded PAS and mucicarmine positive reaction for the mucous cells in the intestine of *Anabas testudineus, A. nama, A. range* and *Colisa fasciata*. Pandey and Pandey (1980) recorded PAS positive mucous cells in the intestine of *Channa punctatus*. Sinha and Chakraborty (1982) obtained PAS/AB and AB/PAS positive reaction for the mucous cells in the intestine of Indian
major carp *Catla catla*. It is therefore, evident that the mucous cells of the intestine probably contains a mixture of both acid and neutral mucins and is thus in conformity with the observations made by Sinha and Chakraborty (1982). Kaushik and Kapoor (1975) recorded strongly PAS positive mucous cells in the post oesophageal region of *Cirrhinus mrigala* and expressed the opinion that glycogen in the mucous cells provides a substrate for energy reaction in these cells. Sinha and Chakraborty (1982) are of the opinion that the coating of intestinal mucosa with mucous provides a favourable environment for ionic and molecular diffusion, an essential function of this region.

During the present investigations lymphocytes were found to be present at the basal region of the columnar epithelium throughout the length of the intestine in *Notopterus* spp. Various authors (Blake, 1936; Al-Hussaini, 1946, 1949b; Islam, 1951; Kapoor, 1953, 1957c, 1958ab; Pasha, 1964a; Khanna and Mehrotra, 1971; Sinha and Moitra, 1975a; Moitra and Ray, 1977, 1979) have also reported the presence of lymphocytes in the intestinal mucosa. It is generally believed that leucocytes (lymphocytes) enter the gut lumen, absorb lipid droplets and then return to the blood stream (Smith, 1978). Teleosts generally have a lymphatic system extending into the gut wall but its role in lipid uptake is uncertain and lacteals (lymph duct) have not been described in fishes (Smith, 1978). Lymphocytes are known to have neutralising action and their abundance beneath the epithelial lining of the digestive system may serve in neutralising
injurious materials in this area. It appears therefore, that the function of lymphocytes in the submu-
cosa of the intestine remains uncertain. Kapoor et. al. (1975b) expressed the opinion that the presence
of these cells in the intestinal sub-mucosa does not have any positive relation to the feeding habits of
the fishes.

A few granular cells were encountered in the
lamina propria and the submucosa in either of the
species studied. These are eosinophilic. Gulland
(1898) and Greene (1912) also described eosinophilic
granular cells in the alimentary canal of *Salmo.*
Khanna and Mehrotra (1971) recorded eosinophilic
granulocytes in the sub-mucosa of all the five species
studied by them. Pasha (1964) recorded only a few
granulocytes in *Mystus gulio.* Bolton (1933) described
both acidophilic and basophilic granules in these
cells. Al-Hussainti (1949b) stated that granular cells
may either be basophilic or acidophilic and while
present in some species of fish may be absent in
others. He found these cells to be absent in *Gobio.*
Bolton (1933) and Al-Hussainti (1946) considered these
cells to possess a secretory function of either exo-
crine or endocrine nature and also to be responsible
for lipase activity and elaboration of zymogen. Khanna
and Mehrotra (1971) observed that these granular cells
may perform different functions in different species
and relationship with the nature of diet could not be
speculated. Kapoor et. al., (1975) stated that in
fishes with stomach this is concerned with production
of zymogen granules.
The sub-mucosa is extremely reduced and muscularis is well developed in the intestine of *Notopterus*. The muscularis of the anterior intestine is more developed than the middle and posterior portions. Islam (1951) recorded a reduced sub-mucosa and well developed muscularis in *Rita rita*. Khanna and Mehrotra (1971) recorded reduced sub-mucosa in two other carnivorous fishes — *Harpodon nehereus* and *Channa striatus* in both of which the muscular layer is well developed. All these authors have described a well developed circular muscle layer as also observed in *Notopterus* ppp. Such a type of muscularis in the intestine probably helps in propelling the semi-digested food particles onwards into the rectum.

Rectum and rectal caecum: The rectum and its caecum have similar histological organisation as in the other parts of the intestine but with blunt villi and a larger number of mucous cells in addition to a greater development of the muscularis. Pasha (1964) stated that the rectum in *Mystus gulio* can be recognised by its thick musculature and shorter mucosal folds. An increase in the number of mucous cells have been observed in the rectum of *Mystus senegalus* (Sarkar, 1959), *Harpodon nehereus*, *Channa striatus*, *Ilisha filigera* (Khanna and Mehrotra, 1971), *Colisa fasciata* (Moitra and Ray, 1977), *Ambassis nama* and *A. ranga* (Moitra and Ray, 1979). On the other hand, Curry (1939), McVay and Kauw (1940) and Mahadevan (1950) recorded fewer goblet cells in the fishes studied by them. Several workers, e.g.,
Dawes (1929), Blake (1930), Al-Hussaini (1946, 1947a), Khanna (1961) etc. observed the presence of an ilio-
rectal valve clearly demarcating the rectum from the intestine. No such structure could be identified in
either N. notopterus or N. chitala. Khanna and Mehrotra
(1971) and Moitra and Roy (1977 and 1979) observed
that the rectal folds are broader and shorter than
those in the intestine in fishes studied by them. A
similar condition has been recorded in Notopterus.
The mucous cells in the rectal wall in Notopterus are
PAS and AB positive. Khanna and Mehrotra (1971) also
recorded PAS positive mucous cells in the rectum of
fishes studied by them. Sinha and Chakraborty (1982)
obtained a positive reaction for both neutral and acid
mucins in the rectal region of Catla catla and reported
that the quantity of acid mucins in the secretory
mucous cells becomes reduced since the intestine and
rectum do not play any major role in lubrication of
food. Khanna and Mehrotra (1971) and Moitra and Roy
(1977), however, expressed contradictory opinion and
stated that the large amount of mucous secreted by the
mucous cells is specifically meant for the lubrica-
tion of the rectal contents and help in easy defeca-
tion. The present observations are in conformity
with those of Mehrotra and Khanna (1971), Moitra and
Roy (1977, 1979), Liew (1967) who suggested that
variations in the number of goblet cells may be due
to different feeding conditions as has been observed
in well fed and starved Notopterus albus. Moitra and
Bhowmick (1967) recorded a greater number of goblet
cells in the rectal region of young Catla catla (car-
nivorous) than in the adult (omnivorous). The presence
of columnar cells in the rectal mucosa is also
suggestive of absorptive function (Khanna and Mehrotra, 1971). Barrington (1957) believes that the hind gut is not sharply differentiated externally from the mid gut in teleosts but histological peculiarities justify its recognition as a region concerned with final expulsion of faeces.

The rectal caecum in both *N. notopterus* and *N. chitala* presents similar histological features as that of the rectum except for the slightly thinner musculature. The villi in *N. notopterus* are blunt while in *N. chitala* some of the rectal caecal villi were found to be long and finger-like. The rectal caecal mucosa in both the species of *Notopterus* was found to bear columnar cells and abundant mucous cells which are both PAS and AB (2,5) positive as those of rectum. The lamina propria was found to be well defined and provided with blood capillaries. Agrawal and Singh (1964) studied the rectal caecum of *N. notopterus* and observed a few goblet cells in the mucosa. But in the present investigations a large number of goblet cells were noticed in both *N. notopterus* and *N. chitala*. Agrawal and Singh (1964) suggested that the mucosa of the rectal caecum in *N. notopterus* is absorptive in function and concluded that while the small intestine does not permit adequate absorption of food it is compensated by the development of the rectal caecum. The presence of columnar cells and well developed villi particularly in *N. chitala*, and at the same time digested food material which were often encountered in the rectal caecum of both the species of *Notopterus*
indicate its possible role in increasing the absorptive surface. The presence of mucous cells in abundance suggests that it has a lubricating function also which probably aid in the process of defecation. The rectal caecum was also observed in another Indian teleost, Bagarius bagarius (Singh, 1966) and was designated as rectal gland. Singh (1966) observed glandular structures in the rectal gland and complex mucosal folds which almost obliterate the lumen of the rectal gland. No such glandular structure could be observed in the rectal caecum of either of the species of Notopterus. Digitiform rectal glands however, have been reported in selachians and various functions of the gland as a lymph organ, as an organ involved in digestion etc., have been suggested by various workers (Barrington, 1957). The rectal caecum of Notopterus did not demonstrate the presence of any digestive enzymes. It can, therefore, be presumed that the rectal caecum helps in absorption of digested food in addition to lubrication of undigested faecal matter to facilitate expulsion, thus supplementing the function of rectum. The mucous cells were found to contain both PAS and Alcian blue positive mucins as in other regions of the intestinal tract - a feature not recorded by Agrawal and Singh (1964) and Singh (1966).

**Pyloric caeca (Intestinal caeca)**: The pyloric caeca of both N. notopterus and N. chitala present striking similarities in histological organisation with that of the anterior
intestine. Rahimullah (1945) expressed the view that histologically the pyloric caeca are very similar to the proximal part of the intestine from where they arise as outgrowths. He proposed that these structures be called intestinal caeca since they originate from the intestine and not from the pylorus. The villi of the pyloric caeca in Notopterus spp. show different arrangement in the different regions of the caecum - the proximal part has long fingerlike villi with frequently distributed mucous cells and blood vessels, the middle part demonstrating the fusion of caecal villi leading the formation of intercommunicating channels while distal part presents a syncytial structure almost obliterating the lumen. Al-Hussaini (1946) recorded the absence of villi in the pyloric caeca of Mulloides auriflamma. Rahimullah (1945) however, recorded the presence of villi in the pyloric caeca of all the 119 species of fish studied by him. He (1943) described the morpho-histology of the pyloric caeca of Ophicephalus spp., N. notopterus and various members of the family Mastocembelidae. The present studies however, revealed many more histological peculiarities in N. notopterus while the histology of the pyloric caeca of N. chitala is being reported for the first time.

The mucosa of the intestinal caeca in both the species of Notopterus is made up of columnar epithelial cells frequently interrupted by mucous secreting cells. Presence of columnar epithelium is probably indicative of an absorptive role of the caecal mucosa. Rahimullah (1945) attributed an absorptive function to the caecal villi and stated that the highly vascular nature is a
device for increasing the absorptive surface and thus supplement the function of intestinal digestion and subsequent absorption. Khanna and Mehrotra (1971) also expressed the same opinion. Ezeasor and Stoke (1981) observed extensive accumulation of low density lipoprotein particles with in the intestinal and caecal epithelium and concluded that these areas are primarily involved in fat absorption. Moitra and Ray (1977) also presumed an absorptive function of the caecal mucosa in Colisa fasciata.

The mucous secreting cells are abundant in the pyloric caeca but their frequency has been observed to be much less than in the anterior intestine of Notopterus and N. chitala. Pasha (1964c) recorded a large number of mucous cells in the pyloric caecal mucosa of Megalops cyprinoides. Numerous goblet cells in the caecal mucosa of Lutjanus was observed by Rahimullah (1945). He recorded variable number of goblet cells in the pyloric caeca of different fish species studied by him. Moitra and Ray (1977) observed only a few mucous secreting cells in the pyloric mucosa of Colisa fasciata.

The mucous secreting cells of the pyloric caeca have been observed to be AB and PAS positive during the present course of investigations on Notopterus spp. This indicates the presence of both the types of mucopolysaccharides in mixed form in the same cell as has also been observed in other parts of the intestine. Weinreb and Bilstad (1955)
observed neutral muco-polysaccharides in the striated border of the absorptive cells of intestine and pyloric caeca in *Salmo gairdneri iridatus*. The presence of mucous secreting cells in *Notopterus* spp. probably helps, to some extent, in the lubrication of the food. Ray (1978), however, observed only a few mucous cells in the pyloric caeca of *Anabas* and *Colisa* and concluded that this region had no significance in mucous production.

The presence of a few granular cells suggests a secretory function of pyloric caeca. Moitra and Ray (1977) also hold same opinion. It may therefore, be concluded that the pyloric caeca serves the purpose of secretion as well as absorption. The pyloric caeca in both the species of *Notopterus* have been observed to be provided with pancreatic acini sometimes penetrating even into the wall of the caeca. This is suggestive of pancreatic secretion into the pyloric caeca which helps in digestion also. Qualitative estimation of digestive enzymes indicated the presence of different digestive enzymes in pyloric caecal extract.

**DIGESTIVE GLANDS:**

The liver and the diffused pancreas are the main digestive glands in *Notopterus*. Histologically the hepatic tissue consists of polygonal hepatocytes arranged in whorls around a central venule or forming anastomosing cords. The hepatocytes have granular cytoplasm and contain centrally placed nuclei. A
similar histological nature of the hepatic tissue has been recorded by other workers in different fish species (Kapoor, 1953 in *Hilago attu*; Saxena, 1966 in *Catla catla*; Khanna, 1964 in *Clarias batrachus*; Chapman, 1981 in *Salmo gairdneri* etc.). The liver is an exocrine gland chiefly associated with the production of bile. The hepatocytes perform an important function of storing carbohydrate foods in the form of glycogen. The hepatic cells in both the species of *Notopterus* have been found to be PAS positive demonstrating thereby the presence of glycogen in them. Saxena (1966) also observed the hepatic cells of *Catla catla* to be strongly PAS positive. He however, observed differences in the intensity of PAS reaction depending upon the feeding state of fish. It is thus evident that the histological nature of liver does not appear to be related to the nature of diet in fishes as a similar histological organisation may be observed in fishes with different feeding habits.

In *N. notopterus*, however, a few pancreatic strands penetrate into the hepatic tissue forming hepatopancreas. Such condition has not been observed in *N. chitala*. The presence of hepatopancreatic condition in fishes has been recorded by several authors – Smallwood and Derrickson (1934) in *Cyprinus carpio*; Sarbahi (1939) in *Labeo rohit*a; Ganguli and Sarkar (1949) in several species of teleosts; Pasha (1964d) in *Tilapia mossambica*; Agrawal and Sharma (1966) in *Mystus vittatus*; Saxena (1966) in *Catla catla*;
Sinha and Moitra (1974, 1975) in *Catla catla* and *Labeo rohita*; Moitra and Ray (1979) in *Ambassis nama* and *A. ranga*. Jain and Jain (1980) recorded a compact pancreas in *Mystus cavasius* with strands of pancreatic tissues traversing the hepatic mass. Pancreas, as a compact gland has been reported by Kapoor (1953) and Sinha (1958) in *Wallago attu*. Khanna (1961, 1962) in several teleosts; Clarke and Mitcomb (1980) in *Anguilla anguilla* etc.

Many other workers, however, have reported diffused pancreas in several species of fish (Weinreb and Bilstad, 1955; Sarkar, 1959; Seshadri, 1961; Khanna, 1961, 1962, 1963a; Shafi, 1973 etc.).

Khanna (1961) recorded the presence of a separate liver and pancreas in *N. notopterus*. In the present course of studies however, penetration of pancreatic tissue into the hepatic mass has been noted in *N. notopterus*, forming hepatopancreas. In the case of *N. chitala*, however, the pancreatic tissue does not invade the liver. Islets of Langerhans could not be identified in the hepatopancreas during the present studies. The exocrine pancreas in both the species of Notopterus has been observed to be composed of a large number of pancreatic acini which remain distributed between the pyloric caeca and also around the anterior intestine. The acinar cells stain intensely red with Mallory's triple stain which indicates the granular nature of cytoplasm in these cells.
Shafti (1973) observed a similar situation in *Ophicephalus punctatus*. Seshadri (1961) recorded thickly packed acinar cell with densely loaded zymogen granules in *Mugil cephalus*, a herbivorous fish while few pancreatic acini with moderately loaded zymogen granules in carnivorous *Ophicephalus striatus*. Sinha and Moitra (1979) observed small quantities of zymogen granules in the exocrine pancreas of fry (carnivorous) while greater density of zymogen granules in the adult (herbivorous) *Labeo rohita*. Moitra and Ray (1979), however, recorded large zymogen granules deposited densely in the acinar cells of *Ambassis nama* and *A. ranga* despite their carnivorous habits and conforms the observations of Shafti (1973) who also noted acinar cells to be laden with zymogen granules in another predomently carnivorous fish *Ophicephalus punctatus*. The present observations on *Notopterus* spp. are therefore, in agreement with those of Shafti (1973) and Moitra and Ray (1979). The acinar cells of the exocrine pancreas have been observed to be PAS negative in both *N. notopterus* and *N. chitala*. Shafti (1973) also obtained a negative PAS reaction in the acinar cells of *O. punctatus* and concluded that these cells do not have the capacity of storing glycogen. The present observations also support Shafti’s view. Sinha and Moitra (1975), who reported the presence of stored food in the exocrine pancreatic acini of *Labeo rohita* did not actually subscribe to this view and regreted the inclusion of such a statement due to oversight in the course of publication. It is evident therefore, that the histological nature
of pancreas is in no way related to the nature of diet. Khanna (1963) and Moitra and Ray (1979) also expressed similar opinion. It may also be assumed that pancreatic acini do not store glycogen as is evident from the observations made by Shaft (1973) and also the present investigations. During the present course of investigations a channel pathway has been observed to be present which passes through the muscular layer from the pancreatic tissue adhering to the intestinal wall in a section of anterior intestine of *Notopterus*. Reports on such type of channel has not been encountered. It may be possible that exocrine pancreatic secretions pass through these pathways or ducts into the intestine. This, however, could not be ascertained finally and need further detailed investigations.

The endocrine islets of Langerhans were found to be embedded among the exocrine acini around the pyloric caecal and intestinal wall in both the species of *Notopterus*. Saxena (1966) recorded exocrine pancreas dispersed in hepatic mass while endocrine islets of Langerhans occur separately over the intestinal wall in *Catla catla*. Khanna (1963) however, recorded the presence of islets with in the mass of exocrine pancreas in *Ophicephalus punctatus* and *Hilsa ilisha*. It is, therefore, evident that diffused nature of the pancreas and distribution of endocrine islets of Langerhans have no bearing on the nature of diet in fish. Khanna (1963) considered the diffused condition of pancreas to be a primitive feature and the structural difference in various species are not related to the nature of diet.
PHYSIOLOGY

Investigations were conducted during the course of the present studies on the physiology of digestion in Indian feather-backs with a view to understand the extent to which the digestive enzyme equipment of these fishes are related to their food habits as also to obtain an idea on the physiology of digestion. Studies were mainly confined to the determination of the pH of the different regions of the alimentary canal and qualitative estimations of some digestive enzymes for reasons already discussed.

pH of the different regions of the alimentary canal:

The activity of a particular enzyme is largely determined by the pH of the system in which it operates. The pH of the alimentary canal is essentially the result of interaction between gut contents and the secretions of the different regions of the gastro-intestinal tract and the digestive glands. In both *N. notopterus* and *N. chitala* the pH of the stomach indicated high degrees of acidity. The pH ranged between 2.8 and 5.0 in the former and 3.0 to 5.8 in the latter species. Production of an acid gastric secretion has been demonstrated in teleosts by several workers. Bayliss (1935) recorded a pH range of 2.40 to 7.40 with a mean of 5.65 in the stomach of *Pleuronectes platessa*. Vonk (1929) found the pH of gastric content of *Esox* to range from 4.5 to 4.7. Kewalramani (1953) stated
that when food remains in the stomach for a longer period the gastric juice becomes more acidic. He obtained a gradual fall of pH from 7.35 to 4.5 in the stomach of *Cottus scorpius* starting from starved condition to 72 hours after introduction of food. The average pH values of the anterior stomach of *Zoarces viviparus* also showed a gradual fall from 6.9 to 4.85 under identical conditions. Fish (1960) obtained a gastric pH ranging between 2.5 and 3.5 in *Perca fluviatilis* after four hours of feeding. For *Tilapia mossambica* he obtained a value ranging from 2 to 3. The gastric protease – pepsin is known to act at an optimal pH in the vicinity of pH 2. Barrington (1957) however, observed that enzymes like other proteins may be expected to differ slightly from species to species and such differences have actually been demonstrated by Norris and Elam (1940). They showed that the crystalline material prepared from the gastric mucosa of *Oncorhynchus tschawytscha* differed from swine pepsin both from physical and chemical point of view. Norris and Mathes (1953) showed that tuna pepsin was more alkali stable than swine pepsin which Barrington considers to be of importance in relation to low acidity obtained under certain conditions in teleostean stomach. Kapoor et. al., (1975) opined that the occurrence of a second peak of peptic activity at pH values upto 4 in certain fishes is suggestive of a proteolytic digestion through a rather wide pH range possibly from 1 to 5. In both the species of *Hotopterus* the stomach pH clearly indicated a high degree of acidity at
which the peptic activity can proceed optimally. In some other Indian carnivorous teleosts still higher values of pH in the stomach have been reported. Agrawal and Tyagi (1963) obtained a pH value of 6.6 in the stomach of \textit{Mastacembelus pancalus}. Agrawal and Sharma (1966) recorded a pH value of 6.5 in another carnivorous species, \textit{Nandus nandus}. Gaur and Jaish (1970) obtained average pH of 6.18 in the stomach of carnivorous \textit{Channa gachua} the pH range being 5.8 to 6.3. Ghosh et. al., (1977) noted an average pH of 6.2 in specimens of \textit{Heteropneustes fossilis} starved for 48 hours. Agrawal and Chaturvedi (1974) are, however, the only Indian workers who have recorded a high acidity in the cardiac and pyloric stomach with a pH range of 2.0 to 2.4 and 2.5 to 2.8 respectively in the predominantly carnivorous \textit{Rita rita}. Page et. al., (1976) observed that in channel catfish the acid concentration (pH) in the stomach ranged from 2 to 4. The values obtained in the present investigations compare favourably with those of Agrawal and Chaturvedi (1974) and Page et. al., (1976).

The H-ion concentration in the different regions of the intestine in \textit{Notopterus} indicated values ranging from slightly acidic to slightly alkaline conditions. The pH of the intestine is necessarily the interaction of the acidic stomach contents passed down the pylorus into the intestine and also the secretions received from the pancreas, liver and obviously the secretions of the intestinal mucosa itself. Bayliss (1935) found that the intestinal pH in \textit{Pleuronectes platessa} was decidedly alkaline.
having a range of 7.43 to 8.65. Agrawal and Tyagi (1963) and Agrawal and Sharma (1966) obtained intestinal pH (average) of 6.5 and 6.6 in two carnivorous species i.e., Mastacembelus pancalus and Nandus nandus respectively. Similar values were also obtained by Agrawal and Dalela (1966) in carnivorous Rhycobdella aculeatum. In another species of carnivorous fish, Channa gachua, Gaur and Jatish (1970) recorded an average pH of 6.48 in the intestine. Page et. al., (1976) observed that the intestine immediately following the pylorus had a pH range of 7 to 9 in channel catfish. Ghosh et. al., (1977) recorded an average value of 6.8 in the intestine of Clarias batrachus. Ray (1978) recorded relatively high pH values ranging from 8.5 to 9.5 in the intestine of a carnivorous perch, Anabas testudineus. An intestinal protease acts maximally in an alkaline medium ranging from pH 7 to 11. Kapoor et. al., (1975) declined to designate this proteolytic enzyme as 'Trypsin' and suggested retention of the term reserved for fish intestinal protease. Thus it may be assumed that most carnivorous species possessing true stomach maintain a pH varying from slightly acidic to alkaline in the intestine which is ideally suited for the intestinal protease to act. This seems to be true in the case of both the species of Notopterus. The pH range maintained in the intestine is also conducive for other enzymes like amylase, invertase and lipase to act in such medium. In stomachless fishes however, where gastric epithelium and glands are entirely absent, e.g., in Rutilus sp. Al-Hussaini (1949a, b) observed complete absence of
HCl and pepsin. Sinha (1978) observed that pH in the intestinal bulb and intestine in the herbivorous Indian major carp, *Cirrhinus mrigala* was the same, ranging between 8.0 and 9.0. Smith (1978) conclusively stated that "one generalisation so far appears to have no exception. In fishes having no stomach, no acid phase of digestion occurs.

Thus it may be assumed that in stomached carnivorous fishes with specialised morpho-histologically different regions the pH in the different regions may vary while in stomachless herbivores the alimentary canal does not indicate marked morpho-histological variation with the result that the pH range from intestinal bulb through intestine also shows identical values.

**Digestive enzymes:**

**Digestion in the stomach:** *Notopterus notopterus* and *N. chitala* are both carnivorous in habit and possess well differentiated stomach hence digestion of protein food ingested by them is of primary importance. Pepsin and hydrochloric acid are known to be secreted by the gastric mucosa. The presence of gastric protease has been explicitly demonstrated in the stomach of *Pleuronectes platessa* (Bayliss, 1935), *Oncorhynchus tschawytscha* (Nortis and Elam, 1940), *Thunnus* spp. (Norris and Mathies, 1953), *Anguilla japonica* (Morishita, et al., 1964), *Tilapia mossambica* (Fish, 1960; Moitra and Das, 1967), *Perca fluviatilis* (Fish, 1960),
Ictalurus sp. (Smit, 1968), Rota rita (Arawal and Chaturvedi, 1974), Clarias batrachus (Ghosh, 1976), Heteropneustes fossilis (Ghosh, et. al., 1977), Anabas testudineus (Moitra and Ray, 1980). Albertini and Alliot (1979) reported proteolytic activity in the stomach of three species of mullets e.g., Mugil auratus, M. capito and M. saliens. Smith (1978) discussed critically peptic activity in several culturable commercial species. In stomachless fishes that lack gastric epithelium and gastric glands completely both gastric protease and HCl are absent. Smith (1978) stated that in fishes devoid of stomach the acid phase of digestion does not occur even when the mid-gut develops stomach-like pouches anteriorly. This is further confirmed by recent observations made by Sinha (1978) who observed alkaline pH throughout the digestive tract in the Indian major carp, Cirrhinus mrigala.

The identification of pepsin in the gastric mucosa of fish is to a large extent, dependent on the hydrolysis of protein substrates, such as fibrin (Vonk, 1927), gelatin (Bodansky and Rose, 1922), casein (Bayliss, 1935), edastin (Smit, 1968), haemoglobin (Norris and Elam, 1940, Alliot et. al., 1974) and also on optimum pH. Vonk (1929) recorded a peak in the peptic activity at about pH 2 in the gastric mucosal extract of pike. He (1929, 1937, 1941) also studied the pH optima of pepsins from some frog species and pig and obtained values which were very near to pH 2. From these observations he concluded the essential identity of the enzyme generally prevailing throughout the vertebrate
series. He (1937) stated that gastric protease, with an optimal proteolytic activity in the vicinity of pH 2, is found in all vertebrates except the stomachless fish. Barrington (1957), however, disagreed with the view and stated that the problem of precise identity of this enzyme throughout the vertebrate series can not be finally settled at the present state of knowledge. He considers enzymes like other proteins to be expected to differ, however, slightly, from species to species and "this difference might conceivably provide material upon which the natural selection could act to establish advantageous adaptations". Norris and Elam (1940) and Norris and Mathies (1953) obtained two pH optima for crystalline preparations of gastric mucosal extracts of salmon and tuna respectively using haemoglobin as the substrate. The activity curve of Ictalurus gastric juice acting on edastin showed a rather wide pH optima ranging between 3 and 4 (Smit, 1968). Two peaks in gastric proteolytic activity at pH values up to 4 suggests that the pH of chyme is not extremely critical, and gastric proteolytic activity may proceed at a considerable magnitude through a rather wide pH range, possibly from pH 1 to 5 (Kapoor, et al., 1975). Norris and Mathies (1953) further observed that tuna pepsin was more alkali stable than swine pepsin. This property may be considered important in explaining proteolytic activity in relation to low acidity which has been reported in the stomach of certain teleostean fishes. Taylor (1966) identified the existence of several pepsin fractions in mammals by electrophoretic studies. Kapoor, et al., 1975
believe that fish pepsin may also prove to be composed of a number of pepsins. Barrington (1957) considers that the old sub-divisions of proteases into proteinase (hydrolysing native protein) and peptidases should no longer be maintained and they should all be regarded as peptidases. From crystalline gastric mucosal preparation Norris and Elam (1940) concluded that Oncorhynchus gastric protease differed from swine pepsin in the shape of crystals and also in the percentage composition of different amino acids. The views expressed by different workers in the field of fish enzymology thus indicate profound difference between mammalian pepsin and fish gastric protease and at this stage no definite conclusion can be drawn. It is, therefore, more discreet to reserve the term 'Pepsin' for fish gastric protease and refer to it as gastric proteolytic enzyme. During the present course of investigations gastric proteolytic activity was observed to be fairly strong in both the species of Notopterus. This is in conformity with the carnivorous nature of the two species. Fish (1960) recorded high proteolytic activity at a low pH in Perca fluviatilis. Agrawal and Chaturvedi (1974) also recorded strong proteolytic activity in the stomach extracts of a predominantly carnivorous species, Rita rita. Ghosh (1976), Ghosh et. al., (1977) and Moitra and Ray (1980) recorded fairly high proteolytic activity in the stomach of Clarias batrachus, Heteropneustes fossilis and Anabas testudineus, all of which consume predominantly food of animal origin.

Alliot et. al., (1974) recorded strong protease
activity in the stomach extracts of *Dicentrarchus labrax* in acid medium and concluded that this protease was analogous to pepsin.

Tuna pepsin act optimally at 42°C (Barrington, 1957). Kitamikado and Tachino (1960b) recorded optimum activity of gastric protease in rainbow trout at a temperature ranging from 35 to 40°C employing casein as substrate. Norris and Mathies (1953) found tuna pepsin to be inactivated only by 50% at 56°C subsequent to heating for five minutes. A distinct effect of temperature on the secretory rate of both acid and pepsin in *Ictalurus nebulosus* has also been recorded by Smit (1967). Generally speaking, enzyme reaction rates continue to increase with increase in temperature although the temperature may exceed the lethal temperature for the species until the enzymes begin to denature around 50-60°C (Smith, 1978). Since body temperature of fish varies with environmental temperature substantial influence of temperature obviously will prevail on the activity of a particular enzyme and rate of digestion. Owen and Figgs (1971) noticed that the gastric mucosa extracts of brook trout, *Salvelinus fontinalis* acclimated to 5°C, peptic activity recorded 30% higher values than extracts obtained from fishes acclimated to 12°C. It may, therefore, be concluded that temperature optima for gastric protease activity in fish varies according to temperature of the environment in which the fish lives. According to Barrington "for the present in can be said that pepsins are characterised by differences of such properties as specificity and thermostability which might,
at least in theory, be a basis for adaptive evolution".

Amylase could not be detected in the stomach of either species of Notopterus. Weak amylolastic activity was recorded by Battle (1935) in the stomach of Clupea. Kenyon (1925) considered such weak activities to be insignificant in digestion. Bayliss (1935) obtained negative results in Pleuronectes. Moitra and Das (1967), Seshadri (1967), Satgal, Ghosh and Dutta (1974), Ghosh (1976) and Moitra and Ray (1980) recorded amylase in the stomach extracts of several fishes, e.g., Tilapia mossambica; Ophicephalus striatus, Mugil speigleri, M. dussumieri and M. cephalus; Heteropneustes fossilis; Clarias batrachus and Anabas testudineus respectively. Fish (1960) however, reported the absence of amylase in the stomach of Perca but detected amylase in the stomach of Tilapia. He considered the presence of amylase in the stomach to be 'Unusual' and concluded that this was 'possibly due to the result of absorption of intestinal secretion on the gastric muscosa'. He observed that amylase usually has a wide range of pH (5.0–8.0) for its activity and the pH values recorded was much lower in the stomach. Accordingly such values must inhibit any amylase activity in the stomach. During the present course of studies the stomach extracts of N. notopterus sometimes developed a reddish colour with picramic acid test. This was probably due to contamination of intestinal secretions. Agrawal and Sharma (1966) also observed the absence of any digestion of 2% starch solution upto 72 hours with stomach extracts of a carnivorous fish, Nandus nandus. During
the present course of investigations the absence of amylase activity in the stomach corroborates the observations of Bayliss (1935), Fish (1960) and Agrawal and Sharma (1966). Amylase, however, can not be expected to be active at the high acidity regime recorded in the stomach of *N. notopterus* and *N. chitala*. Presence of amylase activity in the stomach could be the result of regurgitation of duodenal contents (Kapoor et. al., 1975). Barrington (1957) expressed the opinion that the results obtained on the presence of other enzymes than pepsin in the stomach of fish are 'too fragmentary and uncertain' and they indicate no more than the presence in the crude extracts of tissue enzymes of 'no digestive significance' or may be the consequence of contamination from the intestine. Invertase activity could not be detected in the stomach of *N. notopterus* and *N. chitala* during the present course of investigations. Moitra and Das (1967) recorded weak invertase activity in the stomach of *Tilapia mossambica* while Agrawal and Sharma (1966) reported no digestion of 5% sucrose solution by the stomach extracts of *Nandus nandus*. Similarly, Ghosh (1976) recorded invertase activity in the stomach of *Clarias batrachus* while, Saigal, Ghosh and Dutta (1974) found it to be negative in the stomach of *Heteropneustes fossilis*. There appears to be almost no record on the pH optima of fish invertase activity except those of Agrawal and Gupta (1966) on liver invertase activity in *Amphipnous cuchia* and Dhaliwal (1975) on intestinal invertase in *Cyprinus carpio*. The former recorded pH to prevail in the vicinity of 5.6 while the later reported a value of 5.9. pH optima for mammalian sucrose (invertase)
is reported to be 6.2 (West and Todd, 1957). Vonk (1937) emphasized that in mammals, production of invertase occurs in the intestine. Thus it may be assumed that even if invertase is detected in the stomach it may be due to regurgitation or contamination of intestinal sucrase (invertase). The present observations are in agreement with those of Agrawal and Sharma (1966) and Saigal, Ghosh and Datta (1974).

A moderate lipase activity and a low activity (0.28 to 0.32 ml) has been detected in the stomach of N. notopterus and N. chitala respectively. Polimanti (1912) noticed lipoclastic activity in teleosts but Bayliss (1935) obtained negative results with stomach extracts of Pleuronectes. Lipase activity in stomach extracts have also been reported by Mackay (1929) in Zoarces, Nagase (1964) in Tilapia sp., Moitra and Das (1967) in Tilapia mossambica, Agrawal and Sharma (1966) a very little activity in Mnodus nandus, Ghosh et. al., (1977) in Heteronoeutes fossilis, Moitra and Ray (1981) in Anabas testudineus. Agrawal and Tyagi (1963), however, were unable to identify lipolytic activity in the stomach of Mastocembelus pancyclus. Since some form of fats is usually ingested along with the diet, the presence of a lipolytic activity in the stomach of carnivorous fishes cannot be totally ruled out. In fact, many of the stomached fishes are known to indicate lipolytic activity as discussed earlier. Mackay (1929) reported a strong lipase activity in the gastric mucosa of Zoarces but a weaker activity of the enzyme in the intestinal extracts. Babkin and Bowie (1928) and Ishida (1936)
also observed relatively weak activity of the enzyme in the intestinal mucosa compared to the gastric mucosa of Fundulus and in several teleosts e.g., Calotomus, Spheroides, Thallasoma and Salarias respectively. Smith (1978) recorded esterase (another lipase) activity in the stomach of rain-bow trout. Greene (1913) concluded that some absorption of fat occurred in the stomach of King Salmon. Dawes (1930) also found evidence of fat being absorbed in the stomach of Pleuronectes. Smith (1978) presumes the presence of lipase in the piscine stomach. It may therefore, be concluded that lipase is secreted by the gastric epithelium of at least some fishes, as has also been observed in Notopterus during the present course of investigations. Smith (1978) expressed the view that 'the site of secretion in teleosts stomachs appears to be a single kind of cell which produces both Hcl and enzyme (S)'.

Intestinal digestion: The pH at which intestinal digestion proceeds is essentially the result of interaction of stomach contents which pass down into the intestine, the secretions of the liver and pancreas and the intestinal wall itself. In N. notopterus and N. chitala the medium approximately indicated slightly acidic with a tendency to shift towards slight alkalinity.

Since the members of the genus Notopterus are all carnivorous, their intestinal protease assumes extreme importance. In the anterior intestine, the intestinal proteolytic activity was observed to be
fairly high in either of the species. An intestinal protease is known to act maximally in an alkaline medium. Most workers have recorded intestinal protease activity over a pH range of 7 to 11 using different substrates and have reported their results as tryp tic activity (Smith, 1978). Since the enzyme is yet to be isolated (Smith, 1978) it is not clear whether trypsins of different species are enzymologically comparable and therefore, it is better to reserve the term trypsin for the pancreatic proteolytic enzyme (Kapoor et. al., 1975). The diffused nature of the pancreas prevents the localisation of the enzyme in teleosts (Smith, 1978) a feature confirmed in the present studies with Notopterus spp. Smith (1978) stated that there are two sources of enzymes for the midgut - the pancreas and the secretory cells of the gut wall - with pancreas secreting the greater variety and quantities. Intestinal protease (or trypsin) has been reported in the intestine of several stomached teleosts. Bayliss (1935) recorded tryp tic activity in the intestine of Pleuronectes using casein as substrate. Proteolytic activity at pH 8 has been recorded in the pancreatic extracts of Perca and Tilapia (Fish, 1960). Intestinal proteolytic activity have been recorded in Tilapia by Nagase (1964) and Moitra and Das (1967). Kitamikado and Tachino (1960) noted alkaline protease activity in the intestine of rainbow trout. Agrawal and Tyagi (1963) detected intestinal protease activity in Mastacembelus panceulus but observed that the liver which is invaded by pancreatic tissue was the main site of enzyme secretion. Agrawal and Dalela (1966) observed liquidification of 10% gelatin with intestinal
extracts of carnivorous *Rhycobdella aculeata*. Agrawal and Sharma (1966), however, were unable to detect digestion of gelatin with the intestinal extracts of another carnivorous species, *Mandus nandus*. Sehgal (1969) observed proteolytic activity in the intestinal extracts of *Mystus senegalae* a typical carnivore with diffused pancreas (Sarker, 1959). Gaur and Jaish (1970) recorded intestinal proteolytic activity in *Channa gachua*. Strong intestinal protease activity has also been reported from the intestine of *Clarias batrachus* (Ghosh, 1976; Mukhopadhyay, Dehadrat and Banerjee, 1978) which is known to consume mainly food of animal origin. Chaturvedi and Gupta (1975) detected tryptic activity in *Bagarius bagarius*. Ghosh et al., (1977) recorded proteolytic activity in the intestine of *Heteropneustes fossilis*. Moitra and Ray (1980) reported pronounced proteolytic activity in *Anabas testudineus*. Digestion of protein in stomachless fishes assumes considerable physiological significance as the acid phase of digestion is reported to be absent in these fishes. Absence of gastric digestion in the latter has rendered protein digestion by pancreatic and/or intestinal protease more important than fishes with stomach. Al-Hussaini (1949) recorded proteolytic activity in the intestinal extracts of three cyprinids *Cyprinus, Rutilus* and *Gobio*. He supported the view expressed by Beaunalet (1933) that while in fishes with a stomach, the secretions of the intestine do not affect the proteins to any appreciable degree, the loss of stomach is compensated by the supplementation of the pancreatic trypsin with an intestinal enzyme of the same nature. Ishida (1936)
noted "trypsic" activity in some stomachless teleosts. Sarbahi (1951) reported "trypsic" activity in the hepatopancreas and intestinal extracts of Carassius and Niopterus. Proteolytic activity was recorded in the intestine of Labeo rohita, L. calbasu, Cirrhinus mrigala and C. reba by Moitra and Das (1971). Dhage (1968) also recorded intestinal protease activity in Catla catla, Labeo rohita and Cirrhinus mrigala, the Indian major carps. Stroganov and Buzinova (1969) observed that in grass carp, Ctenopharyngodon idella the intestinal protease activity was higher than that obtained from pancreatic extracts. Some authors have observed that the pancreatic protease activity is enhanced by the addition of intestinal extracts (Beauvalet, 1933b; Oya et. al., 1927; Oya and Yokota, 1933; Ishida, 1936). Bondi and Spandorf (1954) recorded that digestive action of pancreatic extract of carp was markedly enhanced by the addition of intestinal extract when casein was used as substrate at pH 7. This has been regarded as activation of trypsin by enterokinase (Kapoor et. al., 1975). Barrington (1957) stated that "trypsinogen is commony, and perhaps always, formed in the pancreas". He, however, doubted the secretion of this enzyme by the intestinal wall. Smith (1978) observed that in several cases when extracts of pancreas were mixed with extracts of intestine the trypsic activity increased ten times or more, suggesting therefore, the presence of enterokinase in the intestinal wall of the fishes. Barrington suggested that the old sub-divisions of proteases into proteinases (hydrolysing native proteins) and peptidases (hydrolysing oligopeptides) should no longer be
maintained and that they should all be regarded as peptidases—exopeptidases, acting on peptide bonds joining terminal amino-acid residues of the main chain and endopeptidases, acting in addition upon more central bonds. Baldwin (1967) described pepsin and trypsin as peptidases which act on larger protein molecules and break them into fragments. During the present studies the fairly high proteolytic activity observed in the anterior intestine of the members of Notopterus suggests that efficient digestion of protein occurs in this part of the gut and also that in these species protein is digested in acid medium (as in the stomach) and also in a slightly acidic to slightly alkaline medium (as in the intestine). This naturally provides an adaptive measure for maximum utilization of protein in species subsisting entirely on animal food. The presence of intestinal proteolytic activity in the intestine of stomached carnivorous species (Kitamikado and Tachino, 1960; Agrawal and Dalela, 1966; Sehgal, 1969; Gaur and Jaish, 1970; Ghosh, 1976; Ghosh et. al., 1977; Mukhopadhay, Dehadrai and Banerjee, 1978; Moitra and Ray, 1980) also suggests that intestinal protease activity in carnivorous fishes is in no way less important than the stomachless herbivores though the absence of gastric digestion provides an interesting field of studying protein digestion in the latter group. The precise site of secretion of the intestinal protease remains obscure (Kapoor et. al., 1975). Smith (1978) suggested two sources—the pancreas and the secretory cells of the gut wall, whereas, Kapoor et. al., (1975) consider pancreas as the chief source of "trypsin".
The latter authors also suggested that the tryptic activity sometimes found in the intestinal extracts may be caused by the pancreatic trypsin previously absorbed in the intestinal wall. The diffused nature of pancreas in fishes has made the problem more complicated.

A weak protease activity was also detected in the posterior region of the intestine in either species of *Notopterus*. Dhage (1969) also detected proteolysis in the posterior-most part of the intestine in *Epinephalus tawina*, a marine carnivorous species possessing stomach. Chaturvedi and Gupta (1975) recorded trypsin throughout the intestine.

The source of the protease in the posterior intestine, however, could not be ascertained. Barrington (1957) holds that if the pancreas is the sole source of the enzyme the intestinal caecal extracts with investing pancreatic tissue would show markedly higher activity than the posterior intestinal extracts. Bayliss (1935) conducted some experiments in this direction but the results obtained by him were confusing and he could not define the source of intestinal protease. The present observations, however, indicate a marked difference in the proteolytic activity in the anterior and posterior intestine (Table-1). Whatever be the source of secretions of the enzyme, the results obtained indicate a declining trend of the intestinal protease activity towards the posterior aspect. Similar views have also been expressed by Dhage (1969).

The existence of several carbohydrate splitting enzymes in the fish intestine have been explicitly
demonstrated by many workers. Investigations of the carbohydrates of fish have largely been confined to the identification of amylolytic activities (Barrington, 1957). Chesley (1934) demonstrated amylase activity in the extracts of diffused pancreas in *Brevoortia* as well as pancreatic and intestinal extracts of *Scomber* and *Spheroides*. Bayliss (1935) recorded a definite but not very strong amylase activity at pH 7.5 to 8.0 in the intestine of *Fleuronectes* and concluded that the enzyme was secreted probably by the intestine itself since the latter enzyme was not associated with caecal extracts. Ishida (1936) recorded amylase activity in the intestinal extracts of certain teleosts. Sarbahi (1951), McGeachin and Debnam (1960), Fish (1960) and Nagase (1964) detected amylase activity in the intestine of *Carassius*; large mouth bass as well as blue-gill sun-fish; *Tilapia* and *Tilapia* respectively. Moitra and Das (1967) recorded the strongest activity of both amylase and invertase in the intestine of *Tilapia mossambica*. In Indian major carps, *Catla catla*, *Labeo rohita* and *Cirrhinus mrigala* amylase has been reported to be secreted by the entire intestine including the intestinal bulb with mrigal showing more amylase concentration than rohu and catla (Dhage, 1968). Moitra and Das (1971) also recorded amylase activity in the intestinal bulb and intestine of four Indian carps e.g., *Labeo rohita*, *L. calbasu*, *Cirrhinus mrigala* and *C. reba*. Other records on the presence of amylolytic activity in the intestinal region include
those of Fundulus (Babkin and Bowie, 1928), Zparces (Mackay, 1929), Rutilus, Cyprinus and Gobio (Al-
Hussaini, 1949b), Mackerel and Plaice (Kandyak,
1967), in different species of Mugil (Seshadri, 1967),
Labeo calbasu (Sehgal, 1969a), Cirrhinus mrigala
(Sinha, 1978) etc.

The presence of amylase and other carbohy-
drases in the intestine of carnivorous and omnivorous
fishes with a tendency to carnivory, present an
interesting field of study. Amylase has been detec-
ted in the intestine of Salmo gairdnerii (Kitamikado
and Tachino, 1960), rainbow trout and Anguilla
japonica (Morishita, et. al., 1964), Cephalus
striatus (Seshadri, 1967), Bagarius bagarius
(Chaturvedi and Gupta, 1975) and Anabas testudineus
(Nyitra and Ray, 1980). The presence of both amylase
and invertase in the intestine of carnivorous species
have been recorded by Gaur and Jaish (1970) in Channa
gachua; Saigal, Ghosh and Datta (1974) in Heteropne-
ustes fossilis; Ghosh (1977) in Clarias batrachus.
Invertase activity has also been reported in herbivores
and omnivores as Salarias, Thalassoma and Calatomus
(Ishida, 1935), Cyprinus carpio (Dhaliwal, 1975 and
Smith, 1978), Tilapia mossambica (Moitra and Das,
1971) and others. On the other hand Agrawal and
Sharma (1966) expressed doubts on the presence of both
amylase and invertase in the intestine of Nandus nandus,
a carnivorous species. Agrawal and Tyagi (1963) and
Agrawal and Dalela (1966) obtained negative results
for both amylase and invertase in the intestine of
carnivorous Mastocembelus panascalus and Rhyncobdella
aculeata. During the present course of investigations both amylase and invertase have been found to be present in high concentration in the intestine of *N. notopterus* and *N. chitala*. The activity was found to be less in the latter species. The site of secretion of the carbohydrases could not be determined since the posterior intestinal extracts either indicated absence or doubtful existence of these enzymes but, the anterior intestine, receiving the secretions of intestinal caeca invaded by pancreatic tissue, demonstrated fairly high concentrations. Kapoor et. al., (1975) believe the pancreas to be the main site of secretion of carbohydrases with intestinal mucosa either producing less or perhaps none of the carbohydrases. Barrington (1957) while interpreting the results obtained by Vonk (1937) observed that the enzymes concerned are absorbed from the pancreatic secretions and not actually produced in the mucosa. Some authors have reported amylolastic activity in the bile of fish but Bayliss (1935) has demonstrated that no such activity was actually present if bile was not allowed to mix with extracts of the gall bladder wall. Al-Hussaini (1949b) found the bile of Cyprinids to be "practically devoid of enzymes". Barrington (1957), however, stated that secretion of intrahepatic pancreas may sometimes pass through the bile duct and gall bladder. Smith (1978) stated that fish with diffused pancreas, may not have a pancreatic duct hence amylase activity appears in the bile, while in fishes having compact pancreas the bile shows no amylase activity. In the present course of investigations pancreatic tissue was found to penetrate in-
to the pyloric caecal and anterior intestinal wall and the activity of carbohydrazes were high in the anterior part of the intestine indicating probably a pancreatic origin of the carbohydrazes. In fact, the hepatopancreatic, caecal and anterior intestinal extracts of *N. notopterus* demonstrated amylase activity of equal magnitudes, while the results obtained for invertase in both *N. notopterus* and *N. chitala* show almost equal activity in the hepatopancreas/liver and anterior intestine while pyloric caecal extracts demonstrated low activity leading to some confusion. Carbohydrazes as a whole, were found to be present in higher concentrations in *N. notopterus* than in *N. chitala*. Lipolytic activity was detected in the intestine of either species of *Notopterus*. The concentration of lipase was found to be higher in the anterior part of the intestine than in the posterior part. Lipase activity has also been reported in the intestinal mucosa of *Fundulus* (Babkin and Bouie, 1928), *Calotomus*, *Spheroideis*, *Thalassoma* and *Salarias* (Ishida, 1936), *Poacres* (Mackay, 1929), *Pleuronectes* (Bayliss, 1935). Bayliss (1935) considered lipase to be secreted by the intestine but Chesley (1934) demonstrated the presence of lipase in the pancreas of several teleosts. Ishida (1936) detected lipase activity in the pancreas of *Salarias*. Al-Hussaini (1949) recorded a higher concentration of lipase in the anterior intestine compared to the posterior in several Cyprinids. However, he noted the presence of lipase in both the pancreas and intestinal mucosa. It may, therefore, be assumed that the pancreas and/or the anterior intestine are
involved in lipase secretion in general. The anterior intestine in both the species of *Notopterus* demonstrated highest lipolytic activity followed by the hepatopancreas in *N. notopterus* and pyloric caeca invaded by pancreatic tissue in *N. chitala*. Thus it is presumed that both the anterior intestine and pancreatic tissue participate in lipase secretion in the intestine of *Notopterus*. Smith (1978) stated that "regardless of origin, some kind of lipase is essential to fish because fatty acids are essential dietary components" and "the occurrence of at least one lipase may be assumed in all fishes". The presence of a lipolytic activity with varying intensity in the intestine of different species of Indian fishes are on record. Agrawal and Dalela (1966) recorded a very little lipase activity in the intestine of carnivorous *Rhyncobdella aculeata* and so did Dhage (1969) in marine carnivorous species *Epinephalus tauvina*. Agrawal and Tyagi (1963), however, could not observe any lipase activity in the intestine of carnivorous *Nastrocembelus pancalus*. Sehgal (1969) recorded the presence of lipase throughout the greater part of the gut in *Mystus seenghala*, a predominantly carnivorous fish while Agrawal and Sharma (1966) failed to detect any lipolysis in the intestine of another carnivore *Hancus nandus*. The presence of lipolytic activity in the intestine of stomached fishes has also been reported by Noitra and Das (1967) in *Tilapia mossambica*. Ghosh (1976) and Mykhopadhyay (1977) in *Clarias batrachus*, Ghosh et. al., (1977) in *Heteropneustes fossilis*, Ray (1978) in *Oolisa fasciata*. 
Ambassis nama, A. ranga and Anabas testudineus, and Moitra and Ray (1961) in A. testudineus. Lipase has also been detected in the intestine of herbivorous or planktophagus fishes. Dhage (1968) and Moitra and Das (1971) reported the lipase activity in several Indian major and minor carps. Sinha (1978) recorded moderate lipase activity in the intestinal bulb and intestine of Cirrhinus mrigala. Obviously, therefore, lipase may be present in the intestine of teleosts irrespective of their feeding habits. According to Barrington (1957) lipases are enzymes of low specificity and the nature of the substrate does not afford any firm basis for a more precise characterisation of the enzyme. The present investigations on Notopterus indicate that the enzyme equipment of the two species studied are well adapted for digesting fatty foods ingested along with their diet.

Digestion in the Pyloric caeca (Intestinal caeca):

The role of the pyloric caeca (intestinal caeca) in digestion in fishes is very little known. Towards the end of nineteenth century these structures which show a good deal of diversity and occur in different groups of fishes, attracted the attention of scientists. Blanchard (1882) observed that the extracts of pyloric caeca in various fishes transformed boiled starch into grape sugar and when added to boiled egg white or fibrin produced peptone irrespective of acid, alkaline or neutral media. Macallum (1886) recorded lipase, pepsin and trypsin in the pyloric caeca of Acipenser. Chesley (1934) concluded
that in fishes with diffused pancreas the pyloric caeca partly supplanted it as a source of enzyme but Barrington (1957) expressed his doubts to this opinion and suggested the possibility of caecal extracts being contaminated by adhering pancreatic tissues. Rahimullah (1945) recorded the presence of lipase and trypsin in the intestinal caeca of Ophicephalus striatus and diastase and trypsin in the caeca of Osphronemus goramy. Sarbahi (1951) detected lipase in the intestinal caeca of large-mouth bass Micropterus. Mc Geachin and Debnam (1960) recorded amylase activity in the pyloric caeca of large-mouth bass. Kitamikado and Tachino (1960) found alkaline protease and lipase activity in the pyloric caeca of rainbow trout. Stern and Lockhart (1953) reported on the alkaline proteolytic activity in the pyloric caeca of the rose fish, Sebastes sp. Amylase activity has been detected in the pyloric caeca of Oncorhynchus (Ushiyama, et. al., 1965) and rainbow trout (Morishita et. al., 1964).

During the present course of investigations the pyloric caeca of Notopterus notopterus and N. chitala were found to indicate moderate proteolytic and amyloytic activity. The invertase activity was found to be low in N. chitala and low to moderate in N. notopterus. Lipase activity was moderate in N. notopterus but stronger in N. chitala. The site of secretions of these enzymes could not, however, be fixed specifically as the histological preparations indicated adhering and penetrating pancreatic acini around the caeca and associated with the muscular
layer. Histologically the pyloric caeca presents striking similarity with the anterior intestine. Therefore, it is possible that enzymes, if any, secreted by the intestinal mucosa are also secreted by the mucosa of the pyloric caeca although their relative activity may vary depending on the conditions prevailing in the particular region, since different enzymes have been found to occur in varying concentrations in the pyloric caeca and anterior intestine in Notopterus. Similar views have also been expressed by Smith (1978) who stated that histologically the pyloric caeca had the same structure and enzyme content as that of the upper intestine.

The presence of digestive enzymes in the pyloric caeca have been demonstrated in other Indian fishes also. Rahimullah (1945) obtained similar enzymes (trypsin and lipase) in Ophicephalus punctatus as in another species of the same genus O. stristus. The intestinal caeca in Channa gachua, indicated insignificant amounts of invertase but 10% gelatin solution was dissolved in four hours with caecal extracts (Gaur and Jatish, 1970). Agrawal and Tyagi (1963) observed that gelatin was slightly dissolved with intestinal caecal extracts in Mastocembelus pancerlus, but 1% starch and 5% sucrose remained unaffected. Dhage (1969) found the pyloric caeca to be the main site of proteolysis in Epinephelus tauvina. A slight lipase concentration was also recorded with caecal extracts. Agrawal and Dálela (1966), however, could not record any enzyme in the pyloric caeca of Rhyncobdella aculeata. Ray (1978)
recorded a moderate proteolytic and amylolytic activity as well as a weak lipolytic activity in the pyloric caeca of carnivorous *Anabas testudineus*, but was unable to detect these enzymes in the pyloric caeca of *Colisa fasciata*. It may be concluded therefore, that the pyloric caeca is involved in digestion of food, confirmed during the present course of investigations on *Notopterus*. Rahimullah (1945) expressed a similar view, and stated further that at least some enzymes are secreted by the pyloric caeca themselves. Smith (1976) also expressed a similar opinion.

**FOOD ENZYME RELATIONSHIP:**

Data derived from the present investigations reveal that the digestive enzyme equipment in *N. notopterus* and *N. chitala* are well adapted to their natural diet. It is generally belived that the enzyme equipment in a fish is related to its diet e.g., proteases would be more abundant in carnivorous while herbivores would have larger quantities of carbohydrases. Al-Hussaini (1949b) found that the concentration of carbohydrases was highest in the predominantly herbivorous *Cyprinus* and lowest in the carnivorous *Gobio* while for protease the situation was exactly the reverse. Kitamikado and Tachino (1960) recorded a lower level of amylase in rainbow trout than in the carp. Amylase activity in the digestive tract of the omnivorous *Tilapia* was found to be much higher than that of perch, *Perca fluviatilis* (Fish, 1960). Pasha (1964) also recorded that in *Nystus guilio* and *Megalops cyprinoides* the proteolytic
enzymes were more abundant which was reverse in case of *Tilapia mossambica*, known to have an effective enzyme equipment for digesting various types of carbohydrates. Dhage (1969) stated that in *Epinephalus* a marine carnivorous species, amylase was practically absent in both the liver and intestinal tract. However, he recorded high amylase activity in the digestive tract of the planktophagous Indian major carps (1968).

Sehgal (1969a) reported the absence of peptic digestion in Indian major carp *Labeo calbasu* where carbohydrases were found to be present in high concentrations. She (1969b) further observed practically no carbohydrase activity in the predominantly carnivorous *Mystus senegalus* in which species protease was found to occur in high concentrations.

Strong proteolysis was also observed in the digestive tract of several other carnivorous species, e.g., *Rhycobdella aculeata* (Agrawal and Dalela, 1966), *Bagarius bagarius* (Chaturvedi and Gupta, 1975), *Clarias batrachus* (Ghosh, 1976; Mukhopadhyay, Dehadrai and Banerjee, 1978), *Heteropneustes fossilis* (Ghosh et al., 1977) and *Anabas testudineus* (Moitra and Ray, 1981). It may, therefore, be concluded that the high protease concentrations observed in the digestive tract of *Notopterus* spp. is due to their dependence largely on animal food. Smith (1978) also expressed similar views and stated that predatory species have higher proteolytic and lipolytic activity compared to the planktivores. Sinha (1978)
also demonstrated a low protease activity in the digestive tract of adult *Cirrhinus mrigala*, which is known to be herbivorous. Their fry and fingerlings, however, showed moderate to strong activity which is probably due to their carnivorous (zooplanktonic diet) feeding habits.

Vonk (1941) concluded that the differences between omnivores and carnivores was much greater for carbohydrases than for proteases. He observed much higher amylase concentration in carp than in pike. Although many authors (Agrawal and Mahajan, 1966; Dhage, 1969) have shown that concentration of carbohydrases are higher in herbivores and carbohydrases, mainly amylase give an indication of food and feeding habits of fishes while proteases may or may not show significant differences. Kapoor et. al., (1975) expressed the view that it is by no means clearly established. Chesely (1934) found that amylase level in the alimentary canal was correlated with the general activity rather than with diet. As far as the digestive protease activity is concerned adaptation to natural diet was less prominent. Schlotkke (1939 cited by Barrington, 1957) in a study of carp, found that proportions of amylolastic and proteolytic activity were not clearly correlated with the nature of the diet although artificial diet stimulated the production of a larger amounts of secretion than did natural food. Smith (1978) considered the hypothesis of 'carnivores being deficient in one or the other carbohydrases', is largely nulified by the widespread presence of amylase in salmonids and other predators,
and by the presence of maltase in sea bream and ayu. During the present investigations amylase and invertase could be detected in the digestive tract of both the species of *Notopterus* and in the hepatopancreas of *N. notopterus*. This conforms the observations of Kapoor et al., (1975) and Smith (1978). Carbohydrases have been reported in the alimentary tract of many Indian carnivorous species — Mastacembelus pancalus (Agrawal and Tyagi, 1963), Haplochilus mandarinus (Agrawal and Sharma, 1966), Channa gachua (Gaur and Jaish, 1970), Heteropneustes fossilis (Satgal, Ghosh and Datta, 1974), Channa punctatus (Nayita and Bhattacharya, 1975), Olarias batrachus (Ghosh, 1976), Bagarius bagarius (Chaturvedi and Gupta, 1975), Anabas testudineus (Moitra and Ray, 1980) etc. Thus it may be said that carnivorous species may also possess carbohydrate splitting enzymes and that the digestive enzyme equipment of *Notopterus* in general and *N. notopterus* in particular, is well adapted for digesting carbohydrate food.

Lipolytic activity in the fish digestive system does not appear to bear any definite relationship to the diet. Chesly (1934) found a concentration of lipase in the food consumer, Brevoortia sp. which was not greater than that of other fish which consumed less fat. Wya (1966) concluded that proteolytic and lipolytic activities were high in predatory *Trachurus* and *Scomber*. Lipase has been detected from the alimentary canal of many Indian carnivorous species also. Agrawal and Sharma (1966), Sehgal (1969), Dhage (1969), Gaur and Jaish (1970), Chaturvedi and Gupta (1975),
Ghosh (1976), Ghosh et. al., (1977) and Noitra and Ray (1980) recorded lipase in the digestive system of carnivorous species studied by them. During the present investigations lipase was detected at varying concentrations throughout the gastro-intestinal tract of *N. notopterus* and *N. chitala*. Hepatonpancreas of *N. notopterus* demonstrated fairly high concentration of lipase while liver extract of *N. chitala* showed moderate concentration. Kapoor (1975) expressed the opinion that the occurrence of lipase may be assumed for all fishes. Similarly, Smith (1978) stated that at least one lipase is present in fish digestive tract and regardless of origin some kind of lipase was essential to fish for digesting fatty components of food.

The results obtained in the present investigations reveal that protease are present in high concentrations in the stomach and anterior intestine and this concentrations gradually decrease towards the posterior end, lipase concentration increases progressively from stomach to the anterior intestine and thereafter declines. Amylase and invertase are active only in the anterior intestine and intestinal caeca. Results obtained from the present studies also indicate the positive role of intestinal caeca in digestion. Digestion is initiated in the stomach, continues in the intestine and possibly up to the posterior intestine. Smith and Lovel (1973) observed the protein digestion to continue during passage through each part of gut, in channel cat fish. The site of secretion of different enzymes could not be ascertained and the problem regarding the localisation of
the exact source of enzyme secretion remains unsolved. Barrington (1957) stated that there seems good evidence that the production of pepsin is associated with the granular secretory cells of the gastric glands and the common assumption is that pepsin and HCl are produced in the same cells. Kewalramani (1953) also expressed a similar view and stated that as the cells of the gastric glands are identical they must have the dual function of secreting both acid and pepsin. During the present course of investigations the gastric glands in *N. notopterus* and *N. chitala* were found to consist of only one kind of rounded or rhomboidal cells with centrally placed nuclei. Therefore, it may be assumed that both gastric protease and acid are produced by the same cells of the gastric glands. A weak to moderate lipase concentration was also noticed in the stomach extracts of both the species. This lipase is also assumed to have been secreted by the gastric mucosa. Smith (1978) states that the site of secretion in teleost stomachs appears to be a single kind of cells which produces both HCl and enzyme(s). The present work also confirms the latter view.

Regarding the enzymes of the mid-gut or intestine most authors are of the opinion that the precise site of their synthesis and secretion remain undetermined. Kapoor et. al., (1975) considered the pancreas as the main source of "trypsin" (intestinal protease) and carbohydrases. They believe that the presence of trypsin and carbohydrases in the intestine may be explained by assuming that intestinal mucosa absorbs
pancreatic enzymes but this can not be inferred with certainty. Barrington (1957) states that "trypsino-
gen" is commonly and perhaps always formed in the pancreas but the extent of its secretion by the intestine still remains doubtful. He quoted Al-
Hussaini (1949b) who recorded highest proteolytic activity in the posterior one third part of the intestine in three teleosts and concluded that in stomachless cyprinids the loss of stomach is compen-
sated by supplementation of pancreatic trypsin with a similar intestinal enzyme. Smith (1978) has suggested two sites of production of "mid gut" enzymes - the pancreas and the intestinal wall. The diffused nature of the pancreas in both the species of Notopterus with presence of hepatopancreatic condition in N. notopterus has made the problem complicated. As both the pyloric caeca and anterior most-part of the intestine are invaded by exocrine pancreas in the wall, and anterior intestine is the main site of carbohydrases and intestinal protease activity, it may be assumed that the pancreas is the main source of enzyme production. It was further observed during the present studies that the hepatopancreas in N. notopterus, pyloric caecal extracts of both the species and liver extracts of N. chitala demonstrated lesser enzyme concentration that that of the anterior intestine. This is indicative of a possible secretion of these enzymes by the anterior intestinal wall also and thus is in conformity with the view expressed by Smith (1978). Barrington (1957) states that the source of production of lipase in fish is not yet clearly established. Bayliss
(1935) believed that lipase of *Pleuronectes* like the amylase was secreted by the intestine as lipase activity was not specially associated with pyloric caeca invaded by diffused pancreas. Al-Hussaini (1949) obtained positive histo-chemical response for the enzyme in the pancreas as well as intestine. Barrington (1957) observed the absence of precise evidence for pancreas producing lipase and assumed that such an activity might be a property of hepatic tissues. Sarbahi (1951) reported trypsin and lipase in the liver of *Micropterus salmoides* in which species pancreas exists as a separate compact organ. Lipase and a little protease activity was also demonstrated in the liver of *Notopterus chitala* during the present investigations. The hepatopancreas in *N. notopterus* indicated fairly high concentration of lipase.

Anterior intestine as also pyloric caeca in both the species showed the presence of lipase. These evidences obviously indicate that the digestive enzyme equipment in both species of *Notopterus* is well adapted for digesting fatty food, although the precise source of secretion could not be determined. It may be assumed, however, that this enzyme is secreted by the pancreas, hepatic tissue and intestinal mucosa as well. Baldwin (1967) considered the lipolytic activity of liver as liver lipase.

Obviously therefore, much remains to be known about piscine digestive enzymes and no conclusive opinion can be expressed at the present state of knowledge. Kapoor et. al., (1975) concluded that comparison
between fish species regarding secretory levels of digestive enzymes are not fully justified as experimental conditions adapted by various workers are bound to vary as also the physiological condition of fish. Smith (1978) believes that the gut of fishes retains considerable reserve ability to respond to new food, environment and opportunities. Moitra and Das (1967) expressed the opinion that the nature and relative activity of the digestive enzymes of a fish may be correlated with its dietary and is subject to adaptation as a result of change in its food habits, it may also be possible that fish may have the potentiality to secrete a particular enzyme the relative activity of which depends upon the availability of the specific food in the environment.