Discussion

CHAPTER FOUR

D I S C U S S I O N

DISCUSSION ON HISTOLOGY AND HISTOCHEMISTRY

OF MUCOSUBSTANCES IN -

A. ESOPHAGUS
B. PROVENTRICULUS
C. GIZZARD
D. DUODENUM
E. SMALL INTESTINE (ILEUM)
F. LARGE INTESTINE

OF THE POND HERON, A.grayii.

The present chapter deals with the discussion on the results obtained in the present investigation (and existing) literature on mucosubstances in the vertebrate alimentary tract. The present dissertation deals with the mucosubstances present in various layers from mucosa to serosa in esophagus, proventriculus, gizzard, duodenum, small intestine (ileum) and large intestine in male and female pond heron, A.grayii. As it is brought to notice the paucity of literature particularly on the avian alimentary tract, it was hoped that such a study will provide the knowledge of alimentary tract of the particular bird investigated, species differences and sexual dimorphism, if any, in the alimentary tract mucosubstances and simillarities and/or dissimilarities in alimentary tract mucosubstances when compared to the mammalian and submammalian vertebrate alimentary tract mucosubstances. The purpose of the present discussion is to view critically the results obtained in the present investigation and the information available through the existing literature.

A. ESOPHAGUS

The esophagus is a muscular thin walled extensible elongated tube that conduct food material from pharynx to the stomach.

A-1 : Histology

The histological observations revealed the presence of mucosa, submucosa, muscularis and serosa in the esophagus of A.grayii. The mucosa consisted of stratified epithelial cells without keratinized layer. The glands were observed in esophageal mucosa of this bird. Warner et al. (1967) also described the presence of alveolar mucous glands in esophagus of Japanese quill. Structure of epithe-

lium and glands in various birds were studied by using light and electron microscope (Feder, 1972). Magon and Mohan (1976) found greatest cornification in the esophagus of two Indian birds, Passer and Corvus. Hanke (1957) reported three muscular layers in the esophagus of O. crucis and T. major unlike two layers in other birds.

A-2 : Histochemical reactivities of mucosubstances.

The histochemical reactivities indicated the presence of neutral mucosubstances, glycogen, sulfomucins and sialomucins singly or in some combinations in the different histological sites in the esophagus of this bird. Atypical mucosubstances were absent in avian esophagus.

A-3 : Distribution of the mucosubstances

The present histochemical observations on esophagus revealed the presence of glycogen in the stratified epithelium. Earlier Bradfield (1951) reported the presence of glycogen in poorly keratinized embryonic chick. The glands observed in esophagus of this bird elaborated a mixture of neutral mucosubstances, sulfomucins and sialomucins. Grossi and Millo (1967) reported the presence of acid mucopolysaccharides (predominantly carboxylated) in the esophageal glands of some birds. Allenspeck and Berlin (1971) also reported same results for other birds. Only sulfomucins were reported in esophageal glands of birds during histogenesis (Van Alten and Fennel, 1957). Rangel et al. (1970) showed the presence of neutral polysaccharides, sulfated and non-sulfated polysaccharides in the esophageal glands of the fowl as in the

present observations on glands. In the submucosal connective tissue of the esophagus of this bird only neutral mucosubstances were identified. The presence of hyaluronic acid in connective tissue is well established (Meyer, 1947; Wislocki et al., 1947; Duran-Reynals, 1958; Jackson, 1964; Nalavade, 1975; Gaikwad, 1981). In the present investigation the variation noted in submucosal mucosubstances was the absence of hyaluronic acid.

The presence of glycogen in the muscles is also well established (Nalavade and Varute, 1973; Nalavade, 1975; Gaikwad, 1981). The present studies revealed the presence of glycogen in the esophageal muscularis of this bird. The importance of glycogen as energy source for muscle contraction has been known for many years (Parnas and Wagner, 1914; Meier and Meyerhof, 1924). This is true for muscles in the other organs of the alimentary tract.

The serosa of the esophagus of the bird investigated contained only diastase resistant PAS reactive neutral mucosubstances.

A-4 : Sex dimorphism

Sexual dimorphism was not observed in the esophagus of the pond heron in histological as well as histochemical observations. This is of particular interest because sex dimorphism is reported in the duodenum of some mammals.

A-5 : Mucosubstances in the vertebrate esophagus

The next point of discussion concerns with the comparision of the results obtained in the present investigation and the

existing literature on mucosubstances in the vertebrates other than birds. This discussion will give the similarities and dissimilarities of avian esophageal mucosubstances and those present in the esophagus of the other vertebrates from fishes to the mammals.

Pope et al. (1975) commented that the esophagus is much neglected part of the gastrointestinal tract. But there are many reports on the anatomy, morphology and in some cases on histology of esophagus in several fishes (Pasha, 1964; Bullock, 1967; Bucke, 1971; Singh, 1974; Sinha, 1977; Sis et al., 1979). Among the fishes, teleostean esophageal mucous cells have been reported to react with PAS and AB (Bullock, 1967; Bucke, 1971). Recently, in a detailed investigation the esophagi of ten species of fishes, Reifel and Travill (1977) have identified six types of mucous cells, but in a given fish only two types of mucous cells were present. They reported a heterogenous distribution of sialidase resistant sialomucins, sialidase labile sialomucins, sulfomucins and neutral mucins in mucous cells. Chakrabarty et al. (1983) studied with the fluorescence microscopy the localization of sulfo- and sialomucins in esophageal mucus cells of L. rohita.

Norris (1959) reported on PAS reactive goblet cells and glands in the esophagus of R. papiens. Loo and Wong (1975) identified mainly sialomucins, small amount of sulfated mucins and some neutral mucins in the esophageal goblet cells of the toad, Bufo melanostictus. Mutkekar (1981) investigated histochemically the presence of neutral mucosubstances in the columner epithelial

cells, a mixture of neutral -, sulfo - and sialomucins in type-I goblet cells and type I cells in glands and neutral - and sialomucins in type II goblet cells and type II cells in glands in esophagus of Euperodon systoma. Patil (1983) analysed neutral mucosubstances in the cilliated epithelial cells, type II goblet cells and mucous cells in the glands and the presence of neutral-, sulfo- and sialomucins in the type I goblet cells in the esophagus of Rana cyanophlyctis. Mangalware (1981) reported on the presence of only neutral mucosubstances in the columner epithelial cells and predominant sulfomucins with traces of sialomucins in the goblet cells and glands in the distal portion of esophagus of B. melanostictus. Suganuma et al. (1981) studied mucosubstances in alimentary tract of several vertebrates including five amphibians viz. tree frog, common frog, African clawed frog, axolotle and newt. Their histochemical studies revealed the presence of neutral mucosubstances in columner epithelial cells in frogs and sialomucins in the corresponding cells in axolotle; small amount of sialomucins in goblet cells of the frogs.

Varute and Nalavade (1973) demonstrated mucosubstances in epithelium and glands in esophagi of three species of lizards. The epithelium in esophagi of C. versicolor and M. carinata consisted only of goblet cells which elaborated neutral mucosubstances, sulfomucins and sialomucins. The mucosa in the H. flaviviridis exhibited the presence of goblet cells and columner epithelial cells, the former cells elaborated neutral, sulfo- and sialomucins and the latter type only neutral mucosubstances and protein masked sialomucins. The esophageal glands in all the species of lizards

were peptic glands (protein elaborating) and mucous glands (elaborating only neutral mucosubstances). Loo and Swan (1978) demonstrated acidic sulfated mucins in esophageal epithelium of the Australian lizard, Egernia cunninghami. Ferri et al. (1977) identified sialic, neutral and acidic polysaccharides in the goblet cells of the esophagus of the snake, Xenodon merremii. Mandlik (1983) showed the presence of neutral mucosubstances in the ciliated epithelial cells, sulfomucins in type I goblet cells and sulfomucins and neutral mucosubstances in the type II goblet cells in the proximal part and only neutral mucosubstances in the goblet cells and mucous cells in the glands of distal esophagus in Indian skink, Mabuya carinata.

There are sporadic reports in the literature mostly concerned with glycogen in normal esophagus of man and monkey (Wislocki et al., 1951; Rywlin and Ortega, 1970; Theman et al., 1971; Hopwood et al., 1977a). Rambourg (1969) demonstrated the presence of a mucosubstance, probably a glycoprotein containing sialic acid, between the esophageal cells of rat. Hopwood et al. (1977 b) reported on the neutral mucosubstances in normal human esophageal epithelium. These mucosubstances were observed in the cell coat and membrane coating the granules. The presence of neutral mucosubstances and sialomucins in esophageal keratinized epithelium in some bats but neutral mucosubstances and sulfomucins in some bats was demonstrated by Deshmukh (1984).

Carvalho et al. (1968) identified glycogen, sialic acid and neutral polysaccharides in the mucins of esophageal glands of armaddillo, D. novemcinctus. Masuda et al. (1977) showed the

presence of PAS and AB positive cells in the esophagus of man and rabbit. The presence of sulfomucins has been reported in the middle layer of esophageal epithelium (Bescol-Liversac and Guillam, 1972) and esophageal glands (Lambert, 1971). Al Yassian and Torner (1977) considered that the glands in the human esophagus can be compared with mucous secreting minor salivary glands.

A-6 : Functional significance

Now it is proposed to discuss some functional significance of the esophageal mucosubstances based on some circumstantial evidences as experimental work has not been carried out in the present investigation. Varute and Nalavade (1973) suggested that esophageal mucosubstances may be acting as lubricants during the transport of the prey or food through esophagus. Lison (1960) and Goudsmit (1972) described sulfomucins as biological lubricants. Such mucosubstances may also help in protection of the lower part of the esophageal mucosa being digested by the gastric juice (Guyton, 1964). Kathleen et al. (1977) and Logan et al. (1977) suggested protective role to acidic mucopolysaccharides in the epithelial cell coat of human esophagus. From the existing literature it seems that esophageal mucosubstances have the protective role and these also act as lubricants, which may be true in the animal under present investigation. This is only suggestion which could further be studied and confirmed by some experimental investigations.

STOMACH

Of all the parts of the digestive system, the most highly

variable is the stomach. The avian stomach is a dual structure. The thin walled and glandular anterior portion of stomach is known as proventriculus and posterior highly muscular region is gizzard or ventriculus (Patt and Patt, 1969). Magon and Mohan (1976) also distinguished two distinct chambers - anterior proventriculus and posterior gizzard-in Passer and Corvus. In the present investigation also the stomach of pond heron was distinguished into proximal proventriculus and distal gizzard or ventriculus. A small pyloric bulb was located behind gizzard.

B. PROVENTRICULUS

B-1 : Histology

The proventriculus of pond heron consisted of mucosa, submucosa, muscularis and serosa. The muscularis is thin in this bird and the submucosa is scanty. The mucosa is thrown into numerous folds and the lining epithelium consists of only goblet cells. Many compound tubulo-alveolar glands are present extending upto the submucosa and opened by collecting ducts at the region of gastric pits. Patt and Patt (1969) and Jain (1976) also described similar histology for avian proventriculus. The cells lining the duct are considered as neck cells and remaining cells in the glands are comparable to the oxyntic cells which secrete pepsin and HCl .

B-2 : Histochemical reactivities of mucosubstances

The tinctorial affinities of the various mucosubstances in different histological sites of proventriculus elaborated the presence of neutral mucosubstances, sulfo- and sialomucins and glycogen, either singly or in some cases in different combinations.

Atypical mucosubstances are absent in the proventriculus of this bird.

B-3 : Distribution of the mucosubstances

The mucosubstances distributed in the various histological sites of proventriculus of the pond heron show similarities among avian proventriculur mucosubstances. Luppa (1959) showed the presence of hyaluronidase resistant acid polysaccharide-protein complex in the lining epithelium of the glandular stomach of embryonic chick. Mogil'naya et al. (1978) observed the presence of neutral carbohydrates, sulfosaccharides and sialosaccharides in the gastric epitheliocytes of birds. Recently, Moqil'naya and Bogatyr (1983) reported the presence of neutral glycoproteins, sialo- and sulfoglycoproteins in epithelial lining of avian glandular stomach. Identical results are reported in the present investigation which indicated the presence of neutral mucosubstances, sulfo- and sialomucins in the surface goblet cells in the proventriculus of pond heron. Migicovsky (1961) indicated the presence of sulfomucins in the superficial glands and duct portion of deep glands of chick proventriculus. In the present studies also predominant sulfomucins were identified in the ducts of glands but together with poor quantities of neutral mucosubstances.

B-4 : Sex dimorphism

Sexual dimorphism was not observed in the proventriculus of the pond heron in histological and histochemical studies. The existing literature also shows the absence of sexual dimorphism in the cardiac stomach of the vertebrates.

B-5 : Mucosubstances in cardiac stomach of vertebrates

Mucosubstances contained in gastric epithelial cells have been reported in many teleosts (Kapoor et al., 1975). The epithelial cells in the stomach of E. lucius have been shown to react with PAS and AB (Bucke, 1971). Jirage (1970) described sialomucins and sulfomucins in the striated border of gastric epithelial cells and basophilia with AB and presence of neutral mucins in gastric glands of T. mossambica. Shafi (1974) demonstrated acidic sulfated mucopolysaccharides in the gastric surface epithelial cells of C. batrachus. A heterogenous distribution of neutral-, sialo- and weakly acidic sulfomucins was found in the surface epithelial cells and cells lining pit regions in the stomach of eight different species of teleosts (Reifel and Travill, 1978).

Norris (1959) demonstrated PAS reactive surface epithelial cells and foveolar cells in the stomach of R. pipiens. The presence of neutral mucins in columner cells and neutral mucins and traces of acidic mucins in the mucous neck cells in stomach was observed in B. melanostictus (Loo and Wong, 1975; Mangalware, 1981). The columner epithelial cells showed neutral mucosubstances in E. systoma (Mutkekar, 1981) and R. cyanophlyctis (Patil, 1983). On the other hand Suganuma et al. (1981) demonstrated traces of sialomucins in these cells of five different amphibians. Goblet cells were identified in the gastric epithelial layer which contained higher concentration of mucosubstances in B. melanostictus (Mangalware, 1981) and a mixture of neutral, sulfo- and sialomucins in the E. systoma (Mutkekar, 1981) and R. cyanophlyctis (Patil, 1983).

Mogil'naya et al. (1978) studied gastric pavement epitheliocytes in amphibians and reported that protection of stomach is connected with neutral carbohydrate components. Norris (1959) reported on PAS reactive mucous neck cells in the gastric glands of R. pipiens. The mucous neck cells have been reported to elaborate only neutral mucosubstances in frogs (Mutkekar, 1981; Patil, 1983), toad (Loo and Wong, 1975; Mangalware, 1981) and five different amphibians viz. frogs, newts and axolotle (Suganuma et al., 1981).

Mogil'naya et al. (1978) studied gastric pavement epitheliocytes in reptiles and reported the presence of neutral carbohydrates and sialosaccharides in them. Loo and Swan (1978) demonstrated the presence of neutral mucins in the neck cells and both neutral and acidic mucins in the lining epithelial cells in stomach of the Australian lizard, E. cunninghami. Giraud et al. (1979) found PAS reactive mucous cells in the stomach of lizard Tiliqua scincodes. Mandlik (1983) identified only neutral mucosubstances in gastric epithelial cells in M. carinata. The mucous neck cells in the gastric glands contained only neutral mucosubstances in the Australian lizard (Loo and Swan, 1978), Indian skink (Mandlik, 1983) and a snake, X. merrimii (Ferri et al., 1975).

The mammalian stomach is much studied organ as far as mucosubstances are concerned. Lambert et al. (1968) demonstrated PAS and AB reactive mucosubstances in the surface coating of gastric mucous cells in several animals including man. The gastric mucosal epithelial cells have been reported to contain glycogen in dog, man, cat but absence of glycogen in rat, rabbit, mouse, monkey,

guinea pig (Fruschelli, 1967), acidic mucosubstances in rat (Wattel et al., 1977), sulfomucins in armadillo (Carvalho et al., 1975), human and dog (Tyrrko et al., 1968), sulfo and sialomucins in dog (Spicer and Sun, 1966), glycoprotein and sialidase susceptible mucin in canine (Gerard et al., 1967), neutral and acidic mucosubstances in pig (Roy, 1974), and neutral and sulfomucins in man (Sinitsina, 1968). Deshmukh (1984) demonstrated a heterogenous distribution of neutral-, sulfo- and sialomucins in these cells of bats.

The mucous neck cells have been reported to contain glycogen in dog (Tsujimura, 1976). These cells exhibit PAS reactivity in gastric glands in dog (Roy, 1974) and armadillo (Carvolho et al., 1975). More (1969) reported that mucus secreted by stomach of rabbit contained neutral mucins. Cuevas-Chavez (1966) by employing a new method as Hale succinic unhydride, found identical distribution of mucins in gastric glands of diverse animal species. Spicer and Sun (1966) observed much sulfated mucoubstances in zymogen cells in the deep glands of cardiac stomach of dog.

The gland cells other than the ducts cells are considered as analogous to the pepsin and HCl secreting cells (Patt and Patt, 1969). These cells in the pond heron investigated showed the presence of weak to poor quantities of neutral mucosubstances. Jain (1976) studied histomorphology, proteolytic activity of HCl and pepsin producing oxyntico-peptic cells in the proventriculus of three species of birds. These oxyntic or oxyntico-peptic cells in birds indicate pepsin as the chief cells in mammalian stomach. The chief cells in the stomach of bat, R. leschenalti have been

reported to contain neutral mucosubstances (Deshmukh, 1984).

B-6 : Functional significance

Moneaux (1935) reported that mucin absorbs the acidity beyond the physiological pH. Kent (1971) opined that secreted mucus carries out lubricant function and possibally plays a role in prevention of dehydration. There are few reports which indicate that gastric mucosa is protected against peptic activity and HCl (Komarov, 1936; Levey and Sheinfeld, 1954; Lambert et al., 1968; Martin et al., 1968; Mikuni and Hotta, 1979). Mogil'naya et al. (1978) opined barrier function to mucins in gastric pavement epitheocytes. In the pond heron the mucosubstances secreted in the proventriculus may be acting as a buffer against acidic pH created by the HCl and may protect the gastric mucosa against proteolytic enzymes secreted by gastric glands. They may also act as lubricants. This is only a suggestion and it should be confirmed by experimental studies.

C. GIZZARD

The highly muscular posterior region of the avian stomach is known as gizzard or ventriculus. In addition to its food grinding function, the gizzard has a role in storage and in protein digestion (Patt and Patt, 1969). Magon and Mohan (1976) also described posterior stomach of the Passer and Corvus as gizzard, with stones or grit which help in mechanical mastication of the food.

C-1 : Histology

The histological studies on the gizzard of pond heron

indicated highly folded mucosa with crypts. The surface epithelium consisted of only goblet cells. Many tubular glands are present in this bird. The mucosa was followed by submucosa, muscularis and serosa. The important pecularity of the gizzard in avian stomach is the presence of non-cellular inner lining known as koilin-lining. In Corvus the koilin lining is of deep amber colour with a few but prominent grooves and ridges while in Passer it is of dark greenish yellow colour with prominant grooves and ridges (Magon and Mohan, 1976). In the present investigation the gizzard was of medium size and koilin layer was with prominent grooves and ridges.

Another speciability of this organ is thicker muscularis than in any region of the alimentary tract (Patt and Patt, 1969). Magon and Mohan (1976) observed same results in Corvus and Passer.

The mucosa consisted of only goblet cells. The crypts and glands were well developed in the present bird under study.

C-2 : Histological reactivities of mucosubstances

The mucosubstances in different histological sites from the mucosa to serosa of the gizzard of pond heron resembled in their tinctorial affinities to neutral mucosubstances, glycogen, sulfomucins and sialomucins containing other tissues or organ-systems. In the gizzard of A.grayii also there is no indication of the presence of any atypical mucosubstances.

C-3 : Distribution of the mucosubstances

The histochemical results obtained in the present investigation, indicated the presence of sulfomucins (predominant) and

sialomucins (poor quantities) in the surface goblet cells and cells in the crypts, neutral mucosubstances in the glands, submucosa and serosa and glycogen in muscularis. There is very little information on the ventricular mucosubstances in birds. Mogil'naya and Bogatyr (1977, 1983) demonstrated the presence of neutral carbohydrates, sulfosaccharides and sialosaccharides in the secretion of avian gizzard. Belanger and Migicovsky (1961) indicated sulfomucins in the superficial portion of gastric glands and cuticle in chick. Thus, the available limited data is in good agreement with the results obtained in present studies.

C-4 : Sex dimorphism

Sexual dimorphism was not observed in the gizzard of the pond heron in histological and histochemical studies.

C-5 : Mucosubstances in pyloric stomach of vertebrates

Reifel and Travill (1978) studied carbohydrates in pyloric epithelial cells in pyloric stomach of eight species of teleosts and reported a heterogenous distribution of sialidase resistant sialomucins, sialidase labile sialomucins, weakly acidic sulfomucins and neutral mucosubstances.

Norris (1959) demonstrated PAS reactive cells in the pyloric epithelium and glands in R. pipiens. Suganuma et al. (1981 a) also demonstrated traces of sialomucins in the epithelial cells in pyloric stomach of amphibians, near the junction of stomach and intestine. On the other hand, Mutkekar (1981) in frog and Mangalware (1981) in toad demonstrated only neutral mucosubstances in the goblet cells and pyloric glands. Patil (1983) identified

neutral mucosubstances and sialomucins in the foveolar epithelial cells in pyloric stomach of the frog, R. cyanophlyctis.

Neutral polysaccharides in the pyloric cells were demonstrated in the snake, X. merremii (Ferri et al., 1975). Mandlik (1983) also analysed presence of only neutral mucosubstances in the surface goblet cells and pyloric glands in M. carinata.

Among the mammals, the surface epithelial cells in the pyloric stomach contain neutral mucosubstances in cow (Birgele, 1969), sialidase labile and resistant sialomucins in ferret (Poddar and Jacob, 1979) and sulfate and carboxyl containing mucopolysaccharides in armadillo (Carvalho et al., 1973). Deshmukh (1984) analysed type-I cells in surface epithelium of pyloric stomach containing only neutral mucosubstances but the type-II cells contained neutral substances and sialomucins in the bat. The elaboration of mucosubstance in the pyloric glands of mammals differed slightly. Mucosubstances have been identified in the pyloric glands as neutral mucosubstances in dog (Tsujimura, 1976), ferret (Poddar and Jacob, 1979) and bats (Deshmukh, 1984) and neutral and acidic mucopolysaccharides in cow (Birgele, 1969) and armadillo (Carvalho et al., 1973). The presence of neutral mucosubstances and sialomucins was in the pyloric glands of bats (Deshmukh, 1984).

Thus the comparative account reveals that more neutral mucosubstances are secreted in the pyloric stomach by epithelial goblet cells and/or glands. In some animals, the pyloric epithelial goblet cells and glands also elaborate acidic mucosubstances either

sialomucins or sulfomucins or their mixture. This may be due to the species diversity and whether these mucosubstances have any phylogenetic relationships remains to be established.

C-6 : Functional significance

At a gross level it appears that neutral mucosubstances are produced more in this organ. These neutral mucosubstances may act as buffer against the cardiac or proventricular cardiac chyme. Mogil'naya et al. (1978) suggested that in amphibians, the protection of mucosa is connected with the presence of neutral mucosubstances. This may be true in pond heron also. This should be confirmed by experimental studies.

INTESTINE

The narrow, tubular and elongated part of digestive tract from stomach onwards is called as intestine. The proximal part immediately behind pyloric bulb which was 'U' shaped region is called as duodenum. The duodenum receives ducts from liver and pancreas. The remaining part is called as small intestine or ileum and the distal part of slightly wider diameter is called as large intestine. A short rudimentary caeum is present at the junction of small and large intestine in this bird.

D. DUODENUM

D-1 : Histology

The duodenum in this bird consisted of mucosa, submucosa, muscularis and serosa. The mucosal epithelium consisted of columner/absorptive cells and goblet cells. The duodenal mucosa

is thrown into numerous elongated finger-like villi. The glands are absent but well developed crypts were observed between the villi. The submucosa consisted of connective tissue and it was comparatively thin. The muscularis was surrounded on outer side by typical serosa. Similar histological structure was also observed by Magon and Mohan (1976) in the duodenum of Corvus and Passer. The fine structure of chief cells in duodenal crypts of white leghorn cockrel is described by Hodges and Michael (1975).

D-2 : Histochemical reactivities of mucosubstances

The histochemical reactivities of the mucosubstances present in various histological sites of duodenum of the pond heron such as columner epithelial cells, goblet cells, crypts, connective tissue, muscularis and serosa were identical to the neutral mucosubstances, sulfomucins and glycogen containing other tissues or organ-systems. There is not indication of any atypical mucosubstance in duodenum of this bird.

D-3 : Distribution of the mucosubstances

The histochemical results of the duodenum indicates the presence of some typical mucosubstances such as neutral mucosubstances (poor quantities) in columner cells and serosa, slightly more in submucosa, glycogen in muscularis and a mixture of neutral mucosubstances (poor quantities) and sulfomucins (predominant) in duodenal goblet cells and crypt cells.

D-4 : Sex dimorphism

Sexual dimorphism was not evident in the duodenum of the pondheron in histological and histochemical observations. The

existing literature also shows the absence of sexual dimorphism in the duodenum of the submammalian vertebrates. In this regard it is interesting to note that Shackleford and Wilborn (1978) described sex dimorphism in the duodenal glands of hamsters. They reported that the glands in males contained the double amount of acidic mucosubstances than the female duodenal glands and PAS reactivity was found to be stronger in the duodenal glands of females than in the males. In other animals no such sexual dimorphism is known.

D-5 : Mucosubstances in duodenum of the vertebrates

A critical analysis of the existing literature by Krause (1973) and that reviewed in the introductory chapter (Chapter One) shows that duodenal mucosubstances have mainly been studied in the mammals. In the present investigation the Brunner's glands were found to be absent in the pond heron, A. grayii. Therefore it was decided to restrict the present discussion to epithelial mucosubstances.

In the columner epithelial cells the neutral mucosubstances were observed in frogs (Mutkekar, 1981; Patil, 1983) and toad (Mangalware, 1981). The duodenal goblet cells contained sulfomucins in the toad (Mangalware, 1981), sulfomucins and sialomucins in balloon frog (Mutkekar, 1981) and mixture of neutral-, sulfo- and sialomucins in the skipper frog (Patil, 1983).

Gabe and Saint-Girous (1972) studied mucous secreting goblet cells in the duodenum of 33 species of saurians and observed that mucins were stronger in acidity in goblet cells of some lizards and weaker in other. Presence of neutral mucosubstances was

demonstrated in the duodenal columner epithelial cells and neutral mucosubstances and sulfomucins in the duodenal goblet cells of M. carinata (Mandlik, 1983).

The available literature shows a species diversity in the type of mucosubstances in the mammalian duodenal goblet cells. The duodenal goblet cells have been observed to contain neutral mucosubstances in cat (Silva et al., 1973), sialomucins in goat (Carvalho et al., 1972), sulfomucins in man (Hoskiss and Zamcheck, 1963) and neutral mucosubstances, carboxymucins, sialomucins and sulfated mucopolysaccharides in man (Sinitsina, 1966). Podder and Jacob (1979) reported sialidase resistant and labile sialomucins in the duodenal cells of ferret. Deshmukh (1984) investigated the presence of neutral-, sulfo- and sialomucins in type-I goblet cells, neutral- and sulfomucins in type-II goblet cells and neutral- and sialomucins in type-III goblet cells in bats. Thus, the comparative account on duodenal mucosubstances points out that the duodenum contains greater concentration of acidic mucosusbtances.

D-6 : Functional significance

The duodenal mucosubstances may be involved in the protection of the duodenal mucosa. More and Bayle (1972) reported that duodenal mucins act as buffer against the gastric acidic chyme. Uspenskii (1972) noted that in subjects with chronic increase of gastric acidity, the morphological changes in the duodenal mucosa are accompanied by increase of more active sialomucins and sulfomucins in the goblet cells. Thus, atleast from the existing literature it appears that the goblet cell mucins in the duodenum protect the mucosa from the gastric acidic chyme. This may be true

in birds also which should be further confirmed by experimental studies.

E. SMALL INTESTINE (ILEUM)

E-1 : Histology

The small intestine is most important region of the alimentary tract because most of the digestive activities are carried to conclusion here. The histological observations revealed the presence of mucosa, submucosa, muscularis and serosa in the small intestine of A.grayii. The villi were more in number and contained numerous goblet cells than in the duodenum. Crypts were well developed. Similar histology is described for avian small intestine by Patt and Patt (1969). Magon and Mohan (1976) found similar histological structure in the small intestine in Passer and Corvus. Bayer et al. (1975) studied the ultrastructure of intestinal goblet cells of chick by scanning and transmission electron microscopes.

E-2 : Histochemical reactivities of mucosubstances

The histochemical results reported the presence of typical mucosubstances such as neutral mucosubstances, glycogen, sulfomucins and sialomucins; some of these are in combinations in the given histological site in small intestine of pond heron. Atypical mucosubstances were not seen in this region of the bird investigated.

E-3 : Distribution of the mucosubstances

The present investigation revealed the presence of poor quantities of neutral mucosubstances in the columner epithelial cells and serosa, slightly enhanced quantity in submucosa, glycogen

in muscularis and sialomucins (poor quantities) and sulfomucins (predominant) in goblet cells and crypt cells, in small intestine of A. grayii. Neutral and acidic sulfated mucosubstances were reported earlier in the goblet cells of small intestine of eight species of birds (Kim, 1972).

E-4 : Sex dimorphism

Both histological and histochemical observations revealed the absence of sexual dimorphism in the small intestine of this bird. In the existing literature also there are no reports about sex dimorohism in the small intestine of other vertebrates.

E-5 : Mucosubstances in small intestine of the vertebrates.

PAS and AB reactive cells were observed in the intestinal epithelium of fish, E. lucis (Bucke, 1971). Shafi (1974) demonstrated acid mucosubstances and sulfated acid mucosubstances in the intestinal goblet cells of C. batrachus. Reifel and Travill (1979) studied mucous cells in intestine of ten species of teleosts. Their histochemical results revealed the presence of sialidase resistant sialomucins, some weakly acidic sulfomucins, only sialomucins and mixture of sialomucins and neutral mucosubstances in these fishes showing species variations.

The brush border of the columner cells reacted with only PAS in R. nigromaculata (Suganuma et al., 1981 a). Neutral mucosubstances have been identified in the columner cells in E. systoma (Mutkekar, 1981), B. melanostictus (Mangalware, 1981), and R. cyanophlyctis (Patil, 1983). The duodenal goblet cells exhibited some species variations. The goblet cells contained sulfomucins

in toad (Mangalware, 1981), tree frog (Suganuma et al., 1981), sulfomucins and sialomucins in the balloon frog (Mutkekar, 1981) and a mixture of neutral-, sulfo- and sialomucins in the skipper frog (Patil, 1983).

Anwar and Mohmoud (1975) reported the presence of goblet cells in the ileum of two Egyptian lizards which elaborated acidic mucoproteins. On the other hand these cells contain sulfomucins in the Australian lizard (Loo and Swan, 1978) and neutral mucosubstances and sulfomucins in Indian skink (Mandlik, 1983). Mandlik (1983) demonstrated traces of neutral mucosubstances in columner epithelial cells in small intestine of Indian skink, M. carinata.

The mucosubstances have been studied mainly from the goblet cells of small intestine of various mammals. These mucins showed species diversity. These cells contain only neutral mucosubstances in sheep, cattle (Skorodinskii et al., 1970) and sulfomucins, sialidase resistant sialomucins and sialidase labile sialomucins in ferret (Poddar and Jacob, 1979). Many workers have reported different reports for these cells in the same animal. For example, human small intestinal goblet cells have been reported to contain neutral mucosubstances (Subbuswamy, 1971), neutral mucosubstances and sialomucins (Fillipe and Fenger, 1979) and PAS reactive, sialic acid containing and sulfated mucins (Lev and Spicer, 1965). Kim (1972) studied small intestine and large intestine of 7-mammals, 8-birds, 6-reptiles, 5-amphibians and 7-fishes. The mucins in goblet cells in them contained neutral and acidic sulfated mucosubstances. They varied according to species and regions they inhabited.

Thus the aforementioned brief review shows that mucosubstances from the small intestine of vertebrates exhibit a species diversity but the present investigation revealed the presence of neutral mucosubstances and sulfomucins in the intestinal goblet cells and crypt cells, and only neutral mucosubstances in the columner epithelial cells in pond heron.

E-6 : Functional significance

Shafi (1974) considered that in fish intestine, the mucus provides lubrication to the ingested food, saves cells from mechanical injuries and prevents autodigestion. Bucke (1971) suggested that neutral and acidic mucins in the alimentary tract are involved in digestion, absorption, protection and lubrication. Gillies-Ballien (1981) described the role of intestinal mucus in absorption. Mitjavila et al. (1968) suggested that mucins in rat protected the mucosa from toxic effects of tannin. Fox (1979) considered that gastrointestinal mucins prevent the attachment of microorganisms to the membrane receptors. These circumstantial evidences indicate that mucins in small intestine have important role in the protection of mucosa. The functional significance of mucosubstances in pond heron intestine should further be studied by involving similar such experiments.

F. LARGE INTESTINE

The distal part of the intestine is known as large intestine. It can be differentiated from small intestine by abruptly increase in the diameter. At the junction of small intestine and large intestine a rudimentary caecum is observed in this bird.

F.1 : Histology

The histological observations revealed the presence of normal mucosa to serosa in the cross section of large intestine of pond heron. Mucosal folds were few and broad. Mucosa consisted of columner epithelial cells and increased number of goblet cells. Crypts are well developed but glands are absent. The submucosa, muscularis and serosa layers are typical. Similar histology is reported by Patt and Patt (1969) and Magon and Mohan (1976) for avian large intestine.

F.2 : Histochemical reactivities of mucosubstances

The tinctorial affinities of mucosubstances present in various histological sites of the large intestine of the pond heron are similar to those exhibited by identical mucosubstances in the other tissues and organ-systems. These histochemical results indicated that other atypical mucosubstances are absent in the large intestine of this bird.

F.3 : Distribution of the mucosubstances

The histochemical results elaborated the presence of neutral mucosubstances (poor quantities) in the columner epithelial cells, serosa and submucosa (slightly more than these two sites) and predominant sulfomucins and poor neutral mucosubstances in the surface and crypt goblet cells in the large intestine of pond heron. Kim (1972) observed in the similar biochemical studies, the presence of neutral mucosubstances and sulfomucins in the large intestine of eight different species of birds.

F.4 : Sex dimorphism

Histological and histochemical results on the large intestine

of the pond heron revealed the absence of sex dimorphism. This is in good agreement with the existing literature on the large intestine of other vertebrates.

F.5 : Mucosubstances in large intestine of the vertebrates

The existing literature on the mucosubstances in large intestine of the vertebrates is scanty but it shows some similarities in vertebrates. Reifel and Travill (1979) studied mucous cells in rectal intestine of ten teleosts and observed the presence of sialidase resistant sialomucins and weakly acidic sulfomucins in these cells of eight fishes, only neutral mucosubstances in one fish and only sulfomucins in other fish.

The columner epithelium in the large intestine contain only traces of neutral mucosubstances in frogs (Mutkekar, 1981; Patil, 1983) and toad (Mangalware, 1981). The goblet cells contain neutral- and sulfomucins in E. systoma (Mutkekar, 1981) and B. melanostictus (Mangalware, 1981). On the other hand Patil (1983) showed type-I goblet cells containing only sulfomucins and type-II goblet cells with neutral mucosubstances in large intestine of R. cyanophlyctis.

Anwar and Mohmoud (1975) reported on the presence of acidic mucoproteins in the rectal goblet cells of Egyptian lizards. The trace quantities of neutral mucosubstances in columner cells and sulfomucins (in less quantities) in elongated type-I goblet cells and sulfomucins (predominant) in oval type-II goblet cells were reported in large intestine of Indian skink (Mandlik, 1983).

Among the mammals, Subbuswamy (1971) reported the presence

of acidic mucosubstances in human large intestinal goblet cells. Masuda et al. (1977) recorded PAS and AB reactivities in goblet cells of large intestine of rabbit. Kim (1972) identified neutral and acidic mucosubstances in the goblet cells of large intestine of 7-mammals, 8-birds, 6-reptiles, 5-amphibians and 7-fishes. The goblet cells in all these vertebrates contained neutral mucosubstances and sulfated mucosubstances. Similar results are also observed in the goblet cells in the large intestine of the pond heron investigated here.

F.6 : Functional significance

The large intestine participates no principal digestive function (Reeder, 1964), although it is possible here the breakdown of some inaccessible compounds. The products of this hydrolysis may be absorbed here. Mainly water and salts are absorbed in the large intestine. The function of lubrication and protection of mucosa against potentially injurious chemicals, enzymes, bacteria and diatary constituents are assigned to the intestinal mucus (Forstner, 1978). The mucus secreted here may have lubricating function and may possibally prevent the dehydration. This is only a suggestion based on some circumstantial evidences. Further studies are required to confirm these suggested roles in the large intestine of the birds.