Anatomy and Histology of the digestive system of the carnivorous fish, the brown-spotted grouper, *Epinephelus chlorostigma*(Pisces; Serranidae) from the Red Sea

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Abstract: The present investigation aims to give a detailed anatomical and histological studies on the digestive system of a carnivorous serranid fish, *Epinephelus chlorostigma*, in correlation with its feeding habits. The anatomical studies revealed that the mouth opening is large leading to a large bucco-pharyngeal cavity containing teeth on dentary, premaxillary, vomer, palatine and superior and inferior pharyngeal bones. The pharynx opens into a short muscular oesophagus which ends with the stomach. The stomach is divided into three regions: cardiac, pyloric and caecal portions. The pyloric portion terminates as a narrow, highly muscular valve, the pyloric sphincter. The anterior intestine originates just posterior to the pyloric sphincter, giving rise to thirty six blind tubes, the pyloric caeca. The intestine narrows posteriorly at the ileo-rectal valve that demarcates it from the rectum. The rectum is terminated at the anus. The liver is a brownish compact gland, which is not completely divided into lobes. The bile is stored within a greenish gall bladder and then dispersed to the duodenum through a long and stout bile duct. The juxtahepatic pancreas is scattered throughout the mesenteries and viscera of the peritoneal cavity. The exocrine pancreas surrounds the hepatic portal veins. The endocrine pancreas is formed of a large principle and several smaller islets of Langerhans. The histological examination of the digestive system revealed that the mucosa of the buccal cavity, pharynx, tongue and anterior oesophagus is composed of stratified epithelium with numerous large oval and circular goblet cells and taste buds. Posteriorly, the stratified epithelium of the oesophageal mucosa gradually changes to a columnar type, which will proceed throughout the rest of the alimentary canal.The submucosa has two layers, a stratum compactum of dense connective tissue and an underlying areolar connective tissue. The oesophageal muscularis is formed of a striated circular muscle layer, which become two layers in the rest of the alimentary canal: an inner circular and an outer longitudinal unstriated muscle layers. The serosa is formed of a connective tissue band covered by simple squamous epithelium. The hepatic parenchyma is formed of hepatocytes in a diffuse or radial patterns. The exocrine pancreas is located within mesenteric fat and surrounds the portal veins. The islets of Langerhans of the endocrine pancreas contain several hundreds of endocrine cells surrounded by a fibrous connective tissue layer.

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1. Introduction

The study of the digestive system of the teleost fishes is of special interest where it shows a great diversity in form and structure. There is usually a direct correlation between the structure of the digestive system and the feeding habits of the fish. Although extensive studies had been carried out on the digestive system of teleost fishes in general, yet a very little work had been done on that of the serranid fishes.

From the pioneer rare workers who dealt with the gross and microscopic anatomy of the digestive system of some serranids are Dawes (1929) on the plaice, Blake (1930) on the black sea bass and Groman (1982) on the stripped bass.

The digestive system is one of the most studied aspects of fish anatomy and histology. Worthmentioning are the studies of Green (1912) on king salmon; Blake (1936) on sea robin;Rogick (1931) on minnow; Curry (1939) on common carp; Al-Husaini (1946, 1947 and 1949) on bottom and plankton feeders; Islam (1951) on freshwater teleosts; Kapoor (1953) on a siluroid fish; Weinreb and Bilstad (1955) on rainbow trout; Hale (1965) on guppy and threespine stickleback; Bucke (1971) on northern pike; Chao (1973) on oncunner; Wassersung and Johnson (1976) on a lepisauroid fishes; Thurmond (1979) on American eel; Sis *et al*. (1979) on channel catfish; Walker *et al*. (1981) on fathead minnow; Martin and Balber (1984) on Ambassidae; Cataldi*et al*. (1987) on sea bream; Grau*et al*. (1992) on amberjack; Gargiulo*et al*. (1998) on on a hybrid teleost; Albrecht *et al*. (2001) on two neotropical omnivorous fishes; Park and Kim (2001) on mud loach; Petrinec*et al*. (2005) on northern pike;Suicmez and Ulus (2005) on *Orthorias*;Carason*et al*. (2006) on a sparid; Amer*et al*. (2008) on two Nile fishes;Khojasteh*et al*. (2009) on rainbow trout; Ikpegbu*et al*. (2012) on African catfish; and Khojasteh(2012) on teleost fishes.

2. Material and Methods

Specimens of the brown-spotted grouper, *Epinephelus chlorostigma*, were collected alive from the coral reefs in the neighbourhood of the Marine Biological Station, Ghardaqa, Red Sea. These specimens were carefully dissected to expose the digestive system and study its anatomical features.

For histological purposes, small pieces of the different regions of the digestive system were fixed in aqueous Bouin's fluid for 24 hours. After fixation and washing for several times in 70% ethyl alcohol, dehydration was carried out in ascending grades of ethyl alcohol. These materials were then cleared in terpineol and embedded in molten paraplast. Sections of 5-7 µm thick were cut, mounted on glass slides and stained with Harris' haematoxylin and counterstained with eosin. Some sections were stained with Mallory's triple stain. The sections were examined by a light microscope and measurements were carried out using the eyepiece micrometer, calibrated by the stage micrometer. Photomicrographs were made as required.

3. Results and Discussion

The brown-spotted grouper is a carnivorous fish feeding on fishes and different invertebrates. Its alimentary canal reflects this carnivory: large mouth, buccal cavity and pharynx; short expandable oesophagus; large distensible stomach; and relatively short intestine. These results agree with those of Grau *et al*. (1992), Petrinec *et al*. (2005) and Garasson *et al*. (2006). The digestive system has two functional units: an alimentary canal and digestive glands.

Anatomy of the Alimentary Canal

a- The mouth and the bucco-pharyngeal cavity:

The mouth opening of the brown-spotted grouper is large in size, terminal in position and slightly oblique. It is protractile and bounded by upper and lower jaws. The lower jaw is slightly projecting in front of the upper jaw. The maxillae are broad and exposed posteriorly. They lie posterior to the premaxillae. The upper and the lower jaws are provided with lips (Fig. 1). These results agree with those of Kapoor (1953). The jaws are provided with small villiform teeth. On the upper jaw, several rows of maxillary teeth are arranged on the inner sides of the premaxillae (Fig. 2a); The teeth of the outer row are slightly longer than the others. The teeth are curved posteriorly. A pair of large canines occurs at the anterior end of each premaxilla. The maxillae are toothless. On the lower jaw, several rows of mandibular teeth are arranged on the sides of the dentaries (Fig. 2b); the outer row is slightly longer and strongly curved posteriorly. There is also a pair of large canines at the anterior end of each dentary. These results agree with those of Kapoor (1953), Woolcott (1957) and Groman (1982).

The mouth opening leads into a spacious buccal cavity. The mucous membrane lining the roof of the buccal cavity is thrown into longitudinal folds which are not represented on the floor of the buccal cavity (Fig. 2a). The maxillary and the mandibular oral valves are narrow, thin semilunar membranes (Figs 2a,b). These result agrees with that of Kapoor (1953). On the roof of the buccal cavity, there are three patches of small villiform teeth: a crescentic patch of vomerine teeth on the vomers and two large oval patches of palatine teeth on the palatines(Fig. 2a). The floor of the buccal cavity is flat with shallow transverse folds which are deeper at the posterior end (Fig. 2b). The tongue is small, elongate, free anteriorly and attached posteriorly to the floor of the buccal cavity (Fig. 2b). It lacks teeth, a result which contradicts with that of Groman (1982).

The buccal cavity leads into a narrower pharyngeal cavity (Figs 2a,b). Four pairs of gills are arranged on the sides of the pharynx. Each gill consists of a long curved gill arch, two rows of gill filaments as well as two rows of toothed gill rakers (Fig. 3). The outer row of gill rakers of the first anterior gill arch is longer than the inner row of the same arch and those on the other arches (Fig. 3). These gill rakers form a screen that directs food particles toward the esophagus and protects the gill filaments. These results agree with those of Groman (1982). There is usually a well developed pseudobranch in the roof of each branchial chamber (Fig. 4). Five small patches of villiform teeth, the superior pharyngeal teeth, are arranged on each side of the roof of the pharynx (Fig. 2a). Two large triangular patches of inferior pharyngeal teeth also occur on the sides of the floor of the pharynx (Fig. 2b). They lie against those occurring on the roof of the pharynx.

The teeth of the buccal cavity and those of the pharynx are homodont villiform teeth. They are pointed at the apex and broad at the base, being embedded in depressions and bent downwards and backwards. These results agree with those of Kapoor (1953). Since the present species is a carnivorous fish, therefore, its teeth are not used for mastication of food, but they are specialized for preventing the escape of the preys out of the buccal cavity. This conclusion was verified by the occurrence of complete preys inside the stomach.

b- The oesophagus:

Posteriorly, the pharynx of the brown-spotted grouper narrows gradually to attain a cylindrical form, merging into a short, stout and muscular oesophagus (Fig. 3). This extends posteriorly over the lobes of the liver and below the air bladder. The oesophagus opens directly into the stomach without any external demarcation.

Although the air bladder has no digestive function, but it is always associated with the digestive system. The air bladder is a large, cylindrical and single-chambered sac of the physoclistous type. This result agrees with that of Harder (1975) and Groman (1982). This hydrostatic organ fills most of the dorsal peritoneal cavity extending the length of the trunk kidney. This result agrees with that of Dobbin (1941) and Groman (1982).

c- The stomach:

The oesophagus leads into a large sac-like cylindrical stomach (Fig. 3). The stomach of the brown-spotted grouper is of the caecal type. It extends on the ventral side of the gas bladder. It can be divided into three definite portions: The proximal cardiac portion, the distal blind fundus or caecal portion and the mesial pyloric portion (Fig. 3). This result agrees with that of Harder (1975). In addition to digestion, the stomach seems to serve in this case for the storage of food. It is highly distensible so that the stomach of a small fish can accommodate a large prey.

d- The intestine:

It follows the pyloric portion of stomach, being separated from it by a pyloric sphincter (Figs. 3,5). The intestine of the brown-spotted grouper extends forward for a short distance where it curves strongly backward towards the cardiac portion of stomach (Fig. 5). On reaching a short distance behind the middle region of the body cavity, the intestine curves forward again ventral to the caecal portion of stomach making a U-shaped loop. Opposite to the pyloric portion of stomach, the intestine curves strongly backward again. This free limb slightly dilates just posterior to the bottom of the U-shaped loop and continues backward. At the point of dilation there is a slight constriction marking the presence of an internal ileo-rectal valve. These results agree with those of Groman (1982). The part of the intestine lying posterior to this valve represents the rectum. The rectum opens to the exterior by the anus which is one of three external openings on the postero-ventral surface of the body, just anterior to the anal fin (fig. 3). From anterior to posterior, these openings are the anus, the genital and the urinary openings. This result agrees with that of Groman (1982).

In the mean time , it is very difficult to differentiate externally between the other two regions of the intestine, namely the duodenum and the ileum, due to the lack of any external clear demarcation. However, the first part of the of the intestine following the pyloric sphincter (the duodenum) is slightly wider than that of the other portions of the intestine (Fig. 5).

At the anterior end of the duodenum where it turns backward, Just posterior to the pyloric sphincter, there are about thirty to thirty six blind tubes, the pyloric caeca (Figs 3,5). These are arranged in two groups of a circular pattern. The function of these pyloric caeca is poorly understood, but they may secrete some intestinal enzymes. It is also considered likely that they are important in neutralizing the acidity of the chyme before it reaches the intestine, where the environment is alkaline.

Anatomy of the Digestive Glands

a- The liver:

The liver of the brown-spotted grouper is a brownish compact gland situated centrally within the peritoneal cavity, ventral to the esophagus as well as to the cardiac and pyloric portions of stomach (Figs 3,5). It is not completely divided into lobes. A shallow depression is present on the antero-mesial part of the ventral aspect of the liver giving the impression of a bilobed structure (Fig. 5). The gall bladder is a greenish oval structure situated in the right side of the liver (Fig. 3). This result agrees with that of Harder (1975). Bile produced in the liver can be stored within the gall bladder and then dispersed to the duodenum through a bile duct. This duct is long and stout and extends over the first part of intestine, the duodenum (Fig. 3). These results agree with those of Fange and Grove (1979).

b- The pancreas:

The pancreas of the brown-spotted grouper is represented by whitish areas scattered throughout the mesenteries and viscera of the peritoneal cavity, being more concentrated in the gastero- and duodeno-hepatic omenta (Fig. 5). This result agrees with that of Khalilov (1966). Small exocrine pancreatic patches almost always surround the hepatic portal veins as well as their branches which extend through the intestinal mesenteries. This result agrees with that of Groman (1982). The pancreatic tissue is usually concealed in large areas of adipose tissue found in the body cavity.

The endocrine pancreas occurs as a large principle and several smaller islets of Langerhans scattered in the mesenteries adjacent to the neck of the gall bladder (Fig. 5). This endocrine pancreas is surrounded by exocrine pancreatic tissue. These results agree with those of Brinn (1973) and Groman (1982). The islets of Langerhans are generally whitish in colour and are usually encapsulated since they possess definite shape within the pancreatic tissue. There are no external signs to indicate that the pancreatic tissue invades the liver, a case referred to as the juxtahepatic pancreas.

Histology of the Alimentary Canal

a- The bucco-pharyngeal cavity:

The mucosa of the roof of the buccal cavity and pharynx of the brown-spotted grouper is composed of a layer of stratified squamous epithelium,wich is thicker in the pharynx (Fig. 7)

than that in the buccal cavity (Fig. 6). Numerous large goblet cells of circular and oval shapes are present in the distal epithelium (Figs. 6,7). These goblet cells secrete mucus to assist in swallowing food. These results agree with those of Kapoor (1953). Taste buds are sparsely present at the distal end of the epithelial folds. This result agrees with those of Walker *et al*. (1981).

A thick lamina propria underlies the buccal and pharyngeal stratified squamous epithelium, which is composed of dense fibrous connective tissue lacking vascularization and cell diversity (Figs. 6,7). This result agrees with that of Groman (1982).

The tongue mucosa is formed also of stratified squamous epithelium, containing goblet cells and taste buds (Figs. 8,9). The goblet cells are large circular and ovoid in shape. Superficially, the taste buds are numerous and bulb-shaped papillae (Fig. 9). This result agrees with that of Walker *et al*. (1981). The tongue mucosa is supported by a dense lamina propria that encircles a central core of loose areolar connective tissue and a hyalinizedcentral lingual cartilage (Fig. 8). These results come in agreement with those of Groman (1982).

b- The oesophagus:

The oesophagus of the brown-spotted grouper comes after the pharynx, which is a muscular tube that leads to the stomach. Its wall consists of four layers;the mucosa, the submucosa, the muscularis and the serosa.

The anterior oesophageal mucosa is formed of stratified squamous epithelium that rests on a thick basement membrane (Fig.10). No lamina propria is present as it is replaced by the stratum compactum of the submucosa. Taste buds occur in the distal portion of the primary folds of the anterior esophagus, whereas the large circular and oval goblet cells are situated centrally, on the sides and at the bases of the folds (Fig. 10). The goblet cells secrete mucus that keeps the food lubricated and helps it to move along the tube. These results agree with those of Groman (1982).

Posteriorly, in the transitional area between the oesophagus and the stomach, the posterior oesophagus, the mucosal folds lenghthen and gradually the stratified epithelium changes into columnar epithelium with numerous circular goblet cells in between (Fig. 12). These results agree with those of Flood *et al*. (1975) and Groman (1982). At the posterior end of the oesophagus the mucosa extends posteriorly to form an oesophageal-stomach junction (Fig. 13).No muscularis mucosa exists in the oesophagus.

The oesophageal submucosa has two layers, a stratum compactum of dense connective tissue that supports the mucosa and an underlying zone of loose areolar connective tissue (Fig. 11). Interfasicular connective tissue of the submucosa surrounds bundles of longitudinal striated submucosal muscles which occur in triangular-shaped cords that terminates in the anterior part of the cardiac stomach. This result agrees with that of Groman (1982).

The oesophageal external muscularis is formed of a single thick circular striated muscle layer (Fig. 11).

The serosa is present only where the oesophagus extends into the peritoneal cavity. It consists of an underlying fibrous connective tissue layer covered by simple squamous epithelium (Fig. 11).

c- The stomach:

The stomach of the brown-spotted grouper has two histologically distinct areas: the cardio-caecal stomach region and the pyloric stomach region (Fig. 13). The gastric mucosa shows primary and secondary longitudinal folding of their mucous membranes (Fig. 14). The mucosal surface of the stomach is made up of simple columnar epithelium with basal nuclei forming a secretory sheath which has no goblet cells (Fig. 15). This sheath secretes mucus to protect the stomach against self digestion. The secretory sheath is followed by branched tubular gastric glands which secrete the gastric juice into the lumen of the stomach through gastric pits (Fig. 15). The mucosal epithelium of the cardiac portion of stomach stomach is continuous with that of the caecal and pyloric portions (Fig. 13). The complexity of the mucosal folds diminishes posteriorly toward the pyloric stomach, which contains no gastric glands and has a thin lamina propria (Fig. 16). This result agrees with that of Kapoor (1953). There is a prominent constriction, called the pyloric sphincter, between the pyloric portion of stomach and the intestine which may serve to control the food passage into the duodenum (Figs 16,17). This result agrees with that of Weinreb and Bilstad(1955), Martin and Balber (1984), Albrecht *et al*. (2001), Mai *et al*. (2005) and Amer *et al*. (2008). There is no muscularis mucosa.

The submucosa of the stomach has two zones, an inner stratum compactum of dense collagenous connective tissue and an outer loose connective tissue (Fig. 14).

The muscularis of the stomach begins in the cardiac portion where the striated muscles of the esophagus changes into smooth muscles. It consists of two layers, a thick inner circular and a thin outer longitudinal smooth muscle layers (Fig. 14). This bi-layer arrangement of the muscularis is retained throughout the remainder of the of the alimentary canal.

The serosa of the stomach is a continuation of that covering the oesophagus with a thin fibrous connective tissue layer covered by simple squamous epithelium.

d- **The intestine:**

The intestine of the brown-spotted grouper can be distinguished histologically into three regions: the duodenum, the ileum and the rectum which are more or less similar in structure. Generally, the intestinal wall is constructed of the main four layers: the mucosa, submucosa, muscularis and serosa. The lymphocytes are numerous and scattered in the mucosal epithelium and the lamina propria of the whole intestine, which may play a role in protecting the fish from pathogenic organisms. This result comes in agreement with that of Osman and Caceci (1991)and Park and Kim (2001).

The anterior intestine and its appendages, the pyloric caeca, originate immediately posterior to the pyloric sphincter (Fig. 17). They differ histologically from the stomach by having decreased amounts of submucosal and muscular tissues and longer mucosal folds (Fig 18). This result agrees with that of Groman (1982). The pyloric caeecal mucosa is built up of columnar epithelium with goblet cells. The lamina propria of the pyloric caeca extend throughout the complex folds of the mucosa (Fig. 18). The submucosa is very thin vascularized loose connective tissue (Fig. 18). The muscularis of the pyloric caeca is formed of an inner thick circular and an outer thin longitudinal smooth muscle layers (Fig. 18). The serosa is formed of simple squamous epithelium. This is absent in areas of connection with pyloric stomach, where it is replaced by loose connective tissue.

The mucosa of the three regions of the intestine is built up of two types of cells: the enterocytes and the goblet cells, and contain a thin vascular lamina propria (Figs 19,20and 21). This result agrees with that of Cataldi *et al*. (1987) and Gargiulo *et al*. (1998). The enterocytes of the mucosa has the typical structure of the absorptive cells. They are tall columnar cells with prominent brush borders and numerous goblet cells in between (Fig. 22). These results agree with that of Olsen *et al*. (1999). There are variations in the morphology of the mucosal folds in the different parts of the intestine. The mucosa of the duodenum is thrown up into long and highly branched villi (Fig. 19), while that of the ileum is simple un-branched villi (Fig. 20). This result agrees with that of Amer *et al.* (2008). Posteriorly, the mucosal folds of the ileum become shorter toward the ileo-rectal valve (Fig. 23). The rectum has shorter primary and few secondary villi with numerous goblet cells between the enterocytes (Fig. 21). These goblet cells secrete mucus which may serve as a lubrication aid to defecation. This result agrees with that of Martin and Balber (1984) and Amer *et al*. (2008).

The ileo-rectal valve (or the intestinal valve) is the morphologic separation between the ileum and the rectum. It consists of a circular tissue flap with a central opening that is directed posteriorly within the rectal lumen(Fig. 24). The mucosal and submucosal layers of the valve are continuous with those of the ileum; however, only the circular layer of the muscularis is present in the valve (Fig. 25). These results agree with those of Groman (1982).

The intestinal submucosa is formed of thin dense connective tissue (Figs 19, 20 and 21). There is no muscularis mucosa.

The intestinal muscularis is built up of two layers: a thick inner circular and a thin outer longitudinal smooth muscle layers. These two layers remain intact throughout the intestine, but their relative proportions change between the anterior intestine and the rectal sections. In the rectum, the circular muscle layer increases in thickness (Fig. 21). This result agrees with that of Grau *et al*. (1998), but contradicts with that of Gargiulo *et al*. (1998).

The serosa of the anterior intestine and rectum is composed of a layer of a simple squamous epithelium.

Histology of the Digestive Glands

a- The liver:

The hepatic parenchyma of the brown-spotted grouper contained hepatocytes. The hepatocytes are polyhedral in shape and each contained a basophilic central nucleus (Figs 26,27). The hepatocytes are arranged in a diffuse or radial patterns (Fig 26). These results agree with those of Raskovie *et al.* (2011), Rocca *et al*. (1994) and Iqpegbu *et al.* (2012). Some hepatocytes surround the central veins in a radial pattern, while others surround the hepatic portal venules and the hepatic arterioles in a diffuse pattern (Figs 26,27). The bile is connected in the bile canaliculi found between the adjacent hepatocytes (Fig.26). These canaliculi are lined with a low simple cuboidal epithelium and surrounded by a thin layer of of fibrous connective tissue (Fig. 27). The canaliculi are connected to larger hepatic ductules (Figs 26,27), which join together to form the hepatic duct that emerges out of the liver. Each ductule is lined with simple cuboidal to short columnar epithelium which is surrounded by a supporting fibrous connective tissue sheath (Fig. 27). These results agree with those of Kapoor (1953).

b- The pancreas:

The pancreas consists mainly of two components: an exocrine and an endocrine pancreas. The brown-spotted grouper has a diffuse pancreas that can be found scattered within the mesenteries and viscera in the peritoneal cavity (Fig.28). The exocrine pancreas is located within the mesenteric adipose tissue and surrounds the branches of the hepatic portal veins (Figs. 29,30). This result agrees with that of Groman(1982). It is made up of large polyhedral cells attached by their basal ends to the portal veins (Figs 29,30). Each

cell has a rounded nucleus, situated centrally to basally on one side (eccenteric nucleus), surrounded by a cytoplasm which is granular in nature (Fig. 30). Zymogen granules are located in the apical ends of these cells. This result agrees with that of Leeson and Leeson (1970). The pancreatic juice is collected in the interlobular excretory ducts, which are lined with columnar epithelium surrounded by connective tissue (Fig. 28). This result agree with that of Fiore *et al*. (1973). These interlobular ducts empty their contents into the main pancreatic duct.

The endocrine pancreas occurs as a principle and several smaller islets of Langerhans scatterred in the intestinal mesenteries (Fig. 28). This result agrees with that of Groman(1982). The islets of Langerhans usually contain several hundreds of endocrine cells surrounded by a fibrous connective tissue layer containing blood capillaries (Fig. 31).

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List of Abbreviations

a.bl.	Air bladder
ad. t.	Adipose tissue
an.	Anus
an. f.	Anal fin
ant. Int.	Anterior intestine
a.oe.	Anterior oesophagus
ba. mb.	Basement membrane
bi. Ca.	Bile canalicule
bi. d.	Bile duct
bi. du.	Bile ductule
bl. ca.	Blood capillaries
br. bo.	Brush border
b. w.	Body wall
cae. st.	Caecal stomach
ca. st.	Cardiac stomach
cau. f.	Caudal fin
ce. v.	Central vein
c. m. l.	Circular muscle layer
cn.	Canine
co. ep.	Columnar epithelium
com. mes. d.	Common mesonephric duct
den. c. t.	Dense connective tissue
do. F.	Dorsal fin
du.	Duodenum

ec.nu. Eccenteric nucleus
en. pa. c. Endocrine pancreatic cells
ex. pa. t. Exoxrine pancreatic tissue
fi. C. t. Fibrous connective tissue
f. ph. Floor of pharynx
ga. bl. Gall bladder
ga. gl. Gastric glands
g. ar. Gill arch
ga. p. Gastric pits
g. fl. Gill filament
go. c. Goblet cells
g. ra. Gill rakers
h. Heart
hp. ar. Hepatic arteriole
hpc. Hepatocytes
hp. po. v. Hepatic portal vein
hp. po. ven. Hepatic portal venule
il. Ileum
ilr. v. Ileo-rectal valve
int. du. Interlobular duct
i.ph. t. Inferior pharyngeal teeth
is. Lan. Islets of Langerhans
k. Kidney
la. pr. Lamina propria
li. Liver
lf. p. li. Left part of liver
li. car. Lingual cartilage
l. m. l. Longitudinal muscle layer
lo. c. t. Loose connective tissue
lo. c. t. co. Loose connective tissue core
l. subm. m. Longitudinal submucosal muscles
lu. il. Lumen of ileum
lu. r. Lumen of rectum
ly. Lymphocytes
m. Muscularis
max. t. Maxillary teeth
max. v. Maxillary valve
mes. Mesenteries
m. gen. op. Male genital opening
mnd. T. Mandibular teeth
mnd. v. Mandibular valve
m. op. Mouth opening
mu. Mucosa
muc. Mucus
mu. vi. Mucosal villi
no. nostril
oe. Oesophagus
op. b. Opercular bones
pa. t. Palatine teeth
p. br. Pseudobranch
pec. f. Pectoral fin
pel. f. Pelvic fin
pr. is. Principle islet
py. cae. Pyloric caeca
py. sph. Pyloric sphincter
py. st. Pyloric stomach
r. Rectum
r. buc. Roof of buccal cavity
r. ph. Roof of pharynx
rt. p. li. Right part of liver
se. Serosa
sec. sh. Secretory sheath
sh. co. ep. Short columnar epithelium
sof. r. Soft rays
sp. Spines
s. ph. t. Superior pharyngeal teeth
st. com. Stratum compactum
st. sq. ep. Stratified squamous epithelium
subm. m. submucosal muscles
su. Mu. Submucosa
t. Testis
ta. bu. Taste buds
ub. Urinary bladder
u. op. Urinary opening
v. d. Vas deferens
vo. t. Vomerine teeth
zy. gr. Zymogen granules

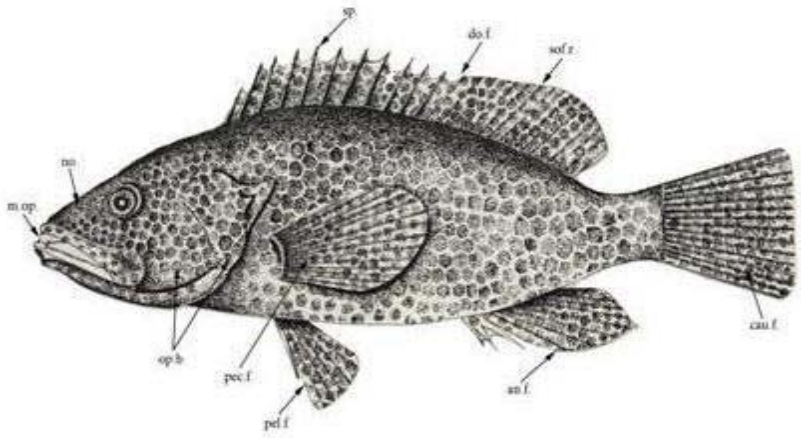


Fig.(1) : An illustrated drawing showing the general features of *Epinephelus chlorostigma*.

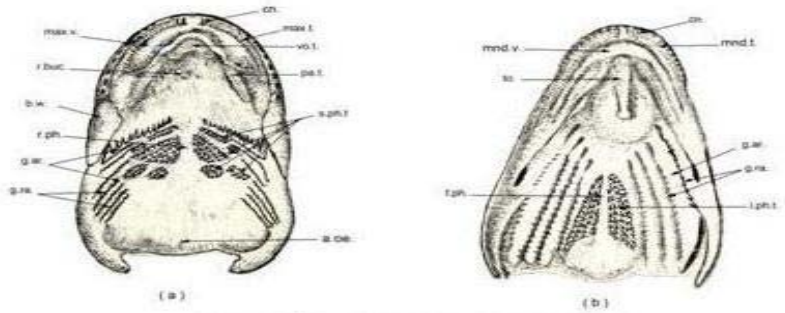


Fig. (2) : Illustrated drawings showing the structure of the roof (a) and the floor (b) of the bucco-pharyngeal cavity of *Ep. hlorostigma*

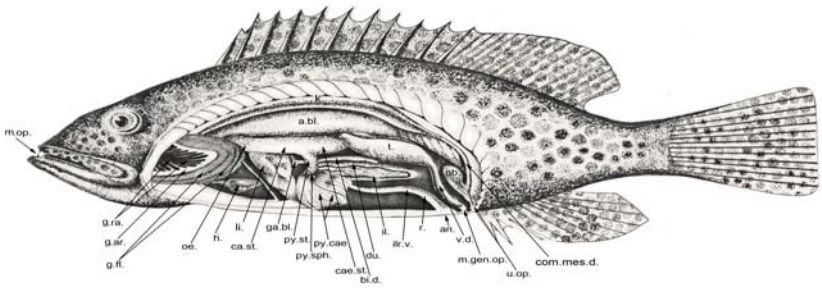


Fig.(3): An illustrated drawing of a dissected specimen of a male of *Ep. chlorostigma* showing the structure of the digestive system(Lateral view)

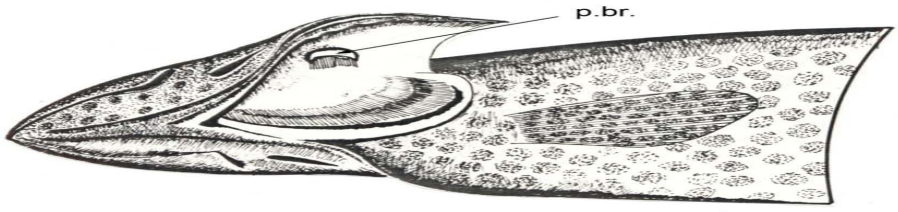


Fig.(4) : An illustrated drawing showing the position of the pseudobranch of *Ep. chlorostigma*

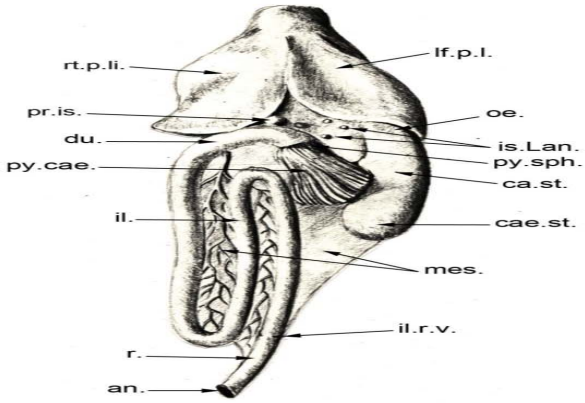


Fig.(5) : An illustrated drawing showing the structure of the digestive system of *Ep. chlorostigma* (Ventral view).

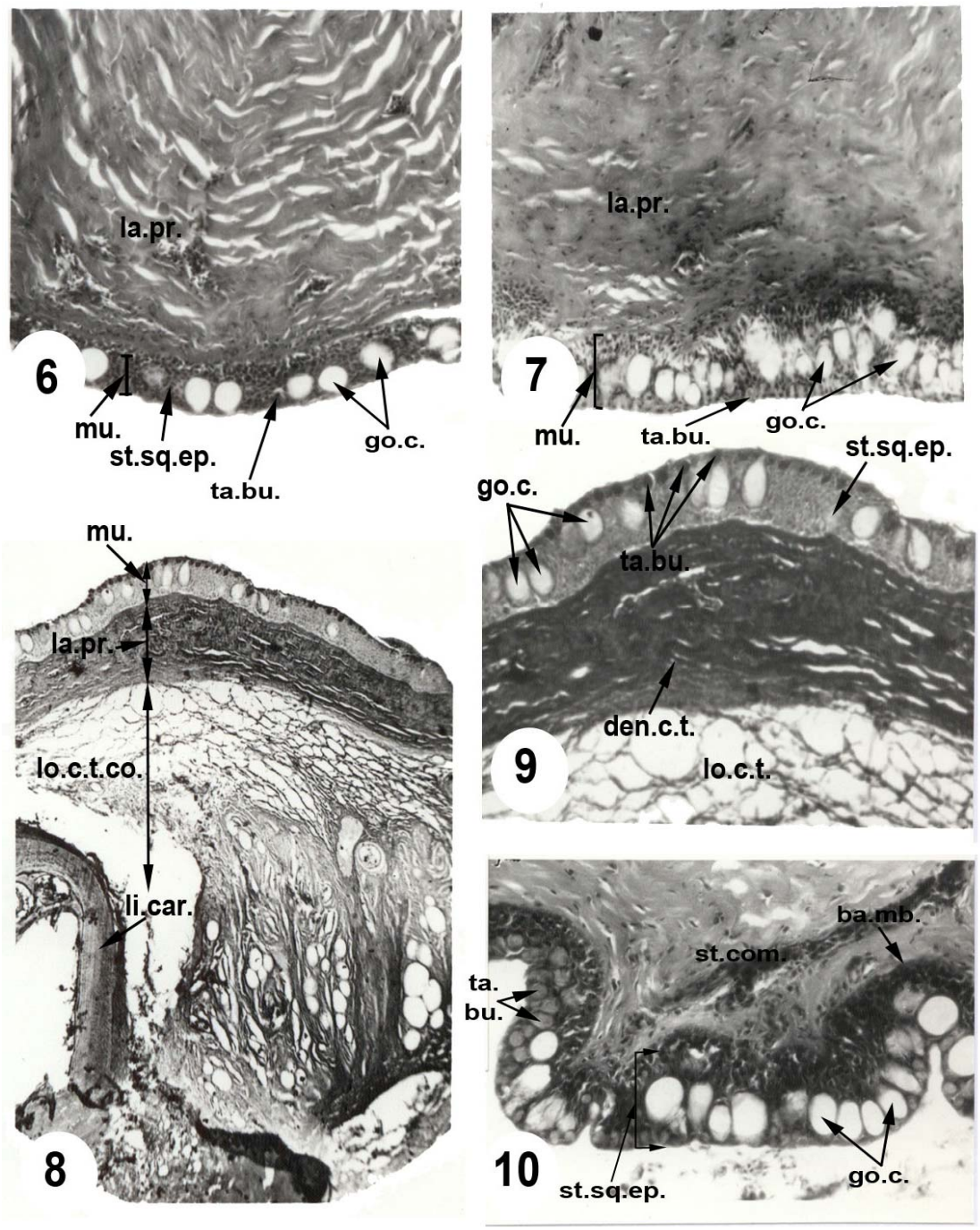


Fig. (6): T.S. of the roof of the buccal cavity showing the mucosal epithelial cells, goblet cells, sparse taste buds and lamina propria. H & E stain, X 180.

Fig. (7): T.S. of the roof of the pharynx showing the mucosal epithelial cells, goblet cells, sparse taste buds and lamina propria. H & E stain, X 200.

Fig. (8): T.S. of the anterior region of the tongue showing the mucosa, lamina propria, loose connective tissue core and lingual cartilage. H & E stain, X 65.

Fig. (9): Enlarged portion of Fig. (8) showing the mucosal epithelial cells with goblet cells and numerous taste buds, lamina propria and loose connective tissue. H & E stain, X 190.

Fig. (10): T.S. of the anterior region of the oesophagus showing the mucosal epithelial cells with goblet cells and taste buds, basement membrane and stratum compactum of the submucosa. H & E stain, X 230.

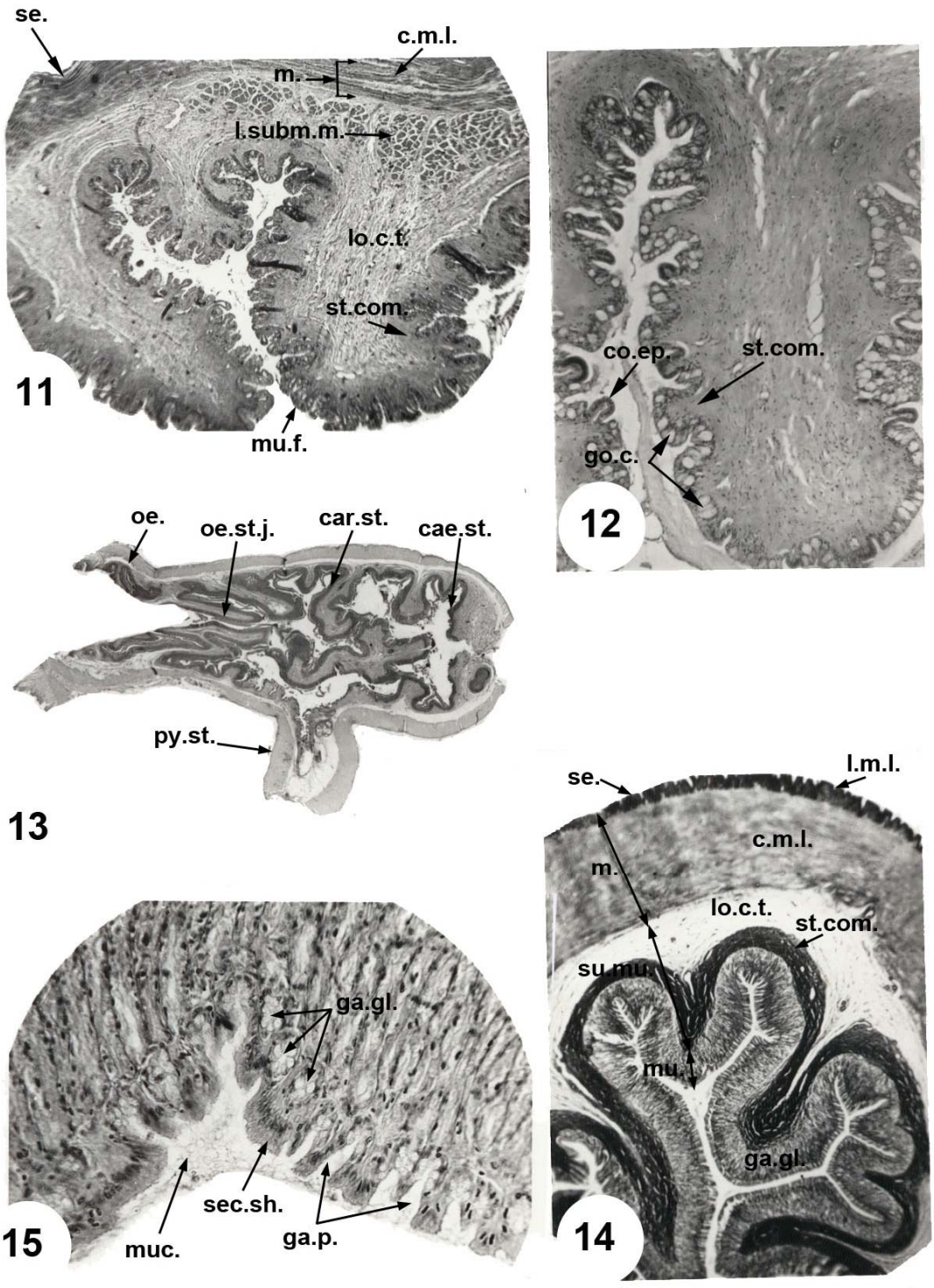


Fig. (11): T.S. of the posterior region of the oesophagus showing the mucosa, submucosawith submucosal muscles, muscularis and serosa. H & E stain, X 45.

Fig. (12): Enlarged portion of Fig. (11) showing the mucosal columnar epithelium with numerous goblet cells and the stratum compactum. H & E stain, X 195.

Fig. (13): L.S. of the oesophageal-stomach regions showing the structure of the oesophageal-stomach junction and different portions of stomach. H & E stain, X 25.

Fig. (14): T.S. of the cardio-caecal stomach showing the mucosa, submucosa, musularis and serosa. Malory Tri. Stain, X 45.

Fig. (15): Enlarged portion of Fig. (14)showing the secretory sheath and tubular gastric glands opening with gastric pits. Malory Tri. Stain, X 420.

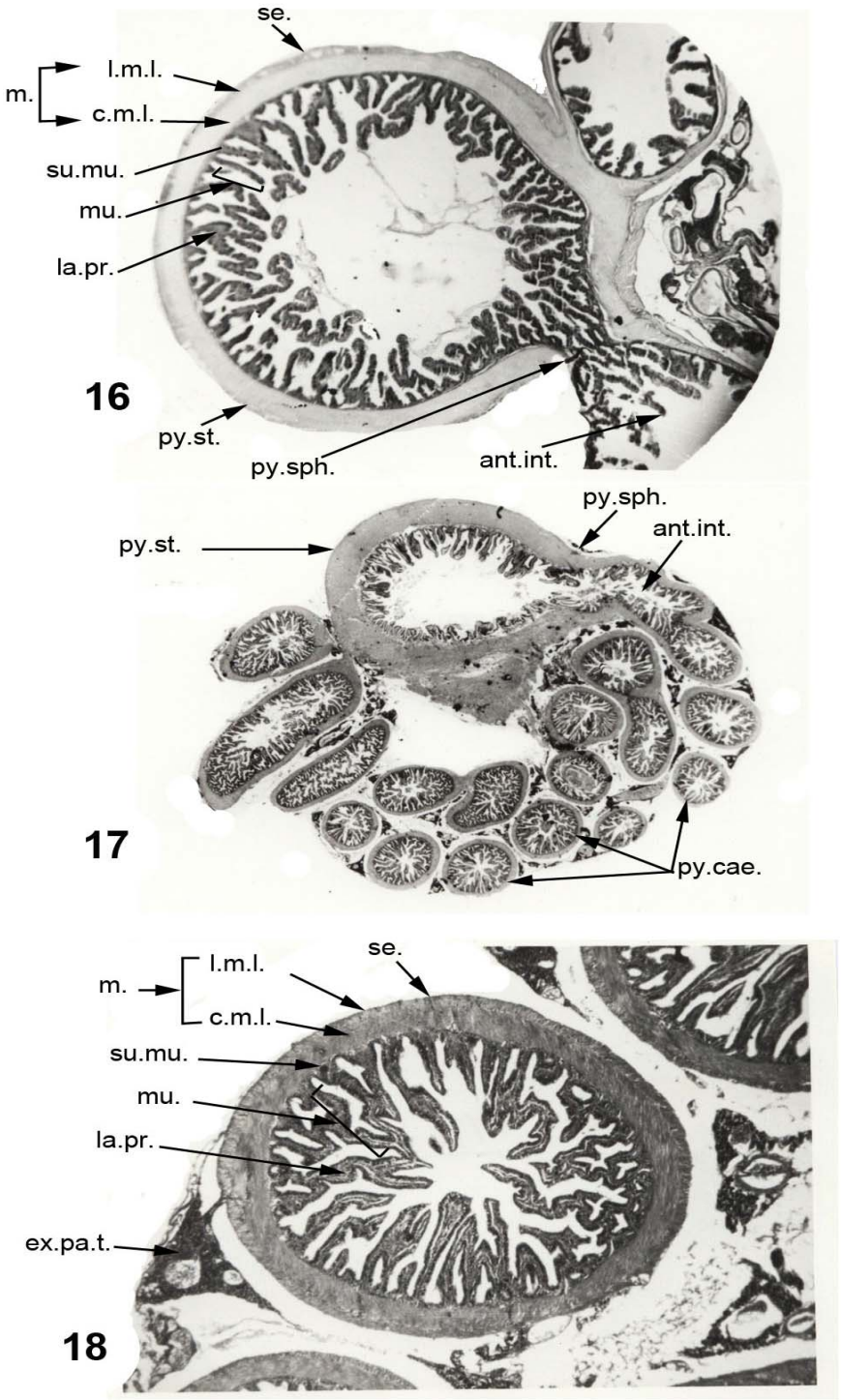


Fig. (16): T.S. of the pyloric stomach showing the absence of the gastric glands and the presence of a pyloric sphincter. H & E stain, X 75.

Fig. (17): T.S. of the pyloric stomach showing the pyloric sphincter and sections of pyloric caeca. H & E stain, X 45.

Fig. (18): T.S. of the pyloric caecum showing the mucosa, submucosa, muscularis and serosa. H & E stain, X 85.

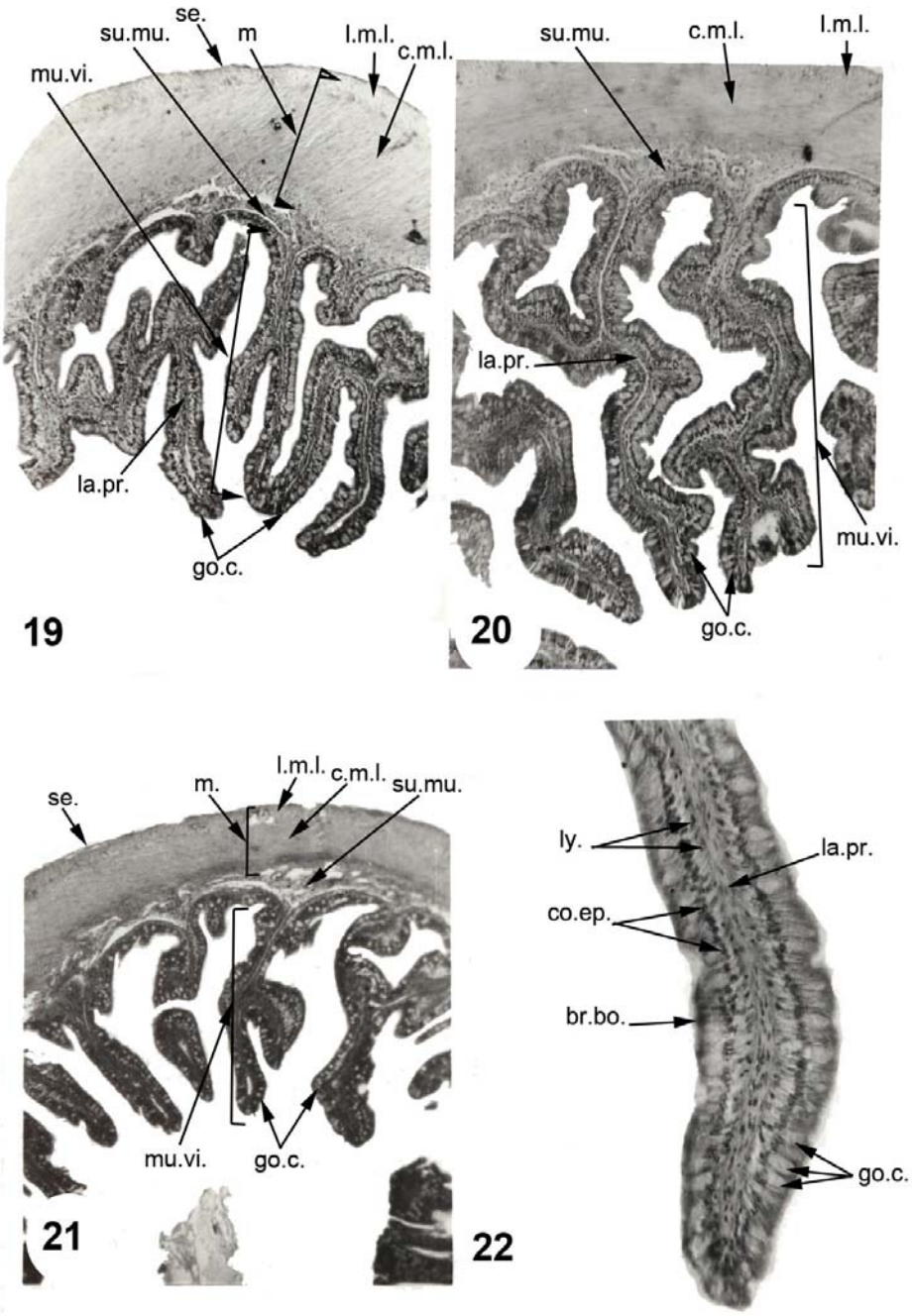
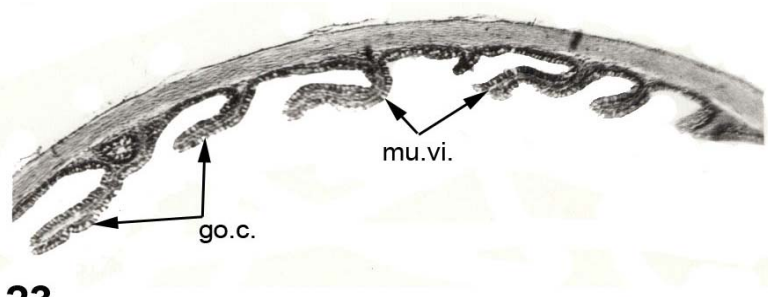


Fig. (19): T.S. of the duodenum showing the mucosa, submucosa, muscularis, serosa and highly branched mucosal villi. H & E stain, X 115.

Fig. (20): T.S. of the ileum showing the simple un-branched mucosal villi. H & E stain, X 130.

Fig. (21): T.S. of the rectum showing the mucosa, submucosa, muscularis, serosa and short mucosal villi. H & E stain, X 110.

Fig. (22): Enlarged portion of Fig. (20) showing the mucosal epithelial cells, goblet cells, lymphocytes, brush border and lamina propria. H & E stain, X 425.



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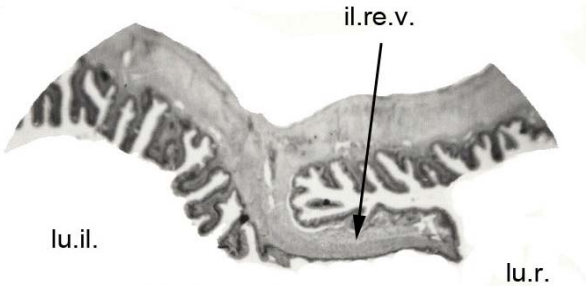

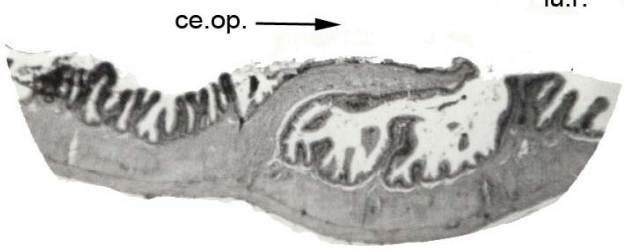

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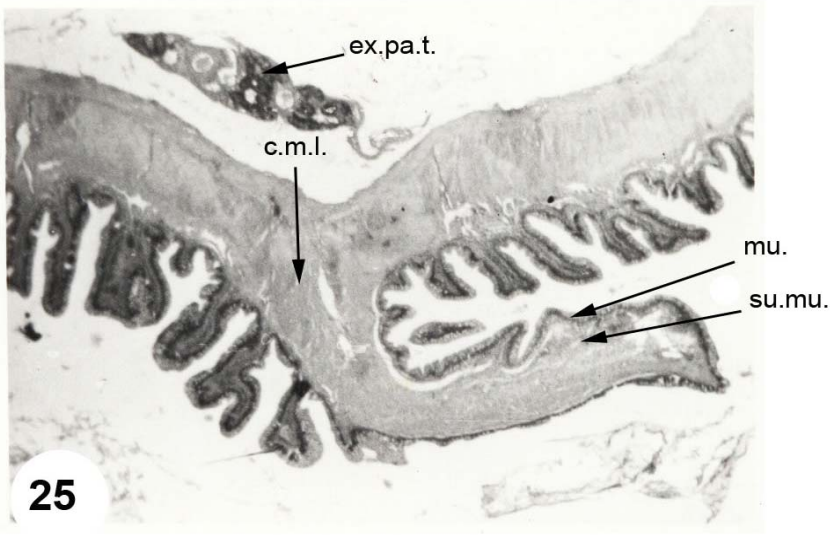

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Fig. (23): T.S. of the posterior region of the ileum showing short mucosal villi toward the ileo-rectal valve. H & E stain, X 105.

Fig. (24): L.S. of the region between the ileum and rectum showing the structure of the ileo-rectal valve. H & E stain, X 78.

Fig. (25): Enlarged portion of Fig. (24) showing that the mucosal, submucosal and only circular muscle layers of the ileum extend into the ileo-rectal valve. H & E stain, X 120.

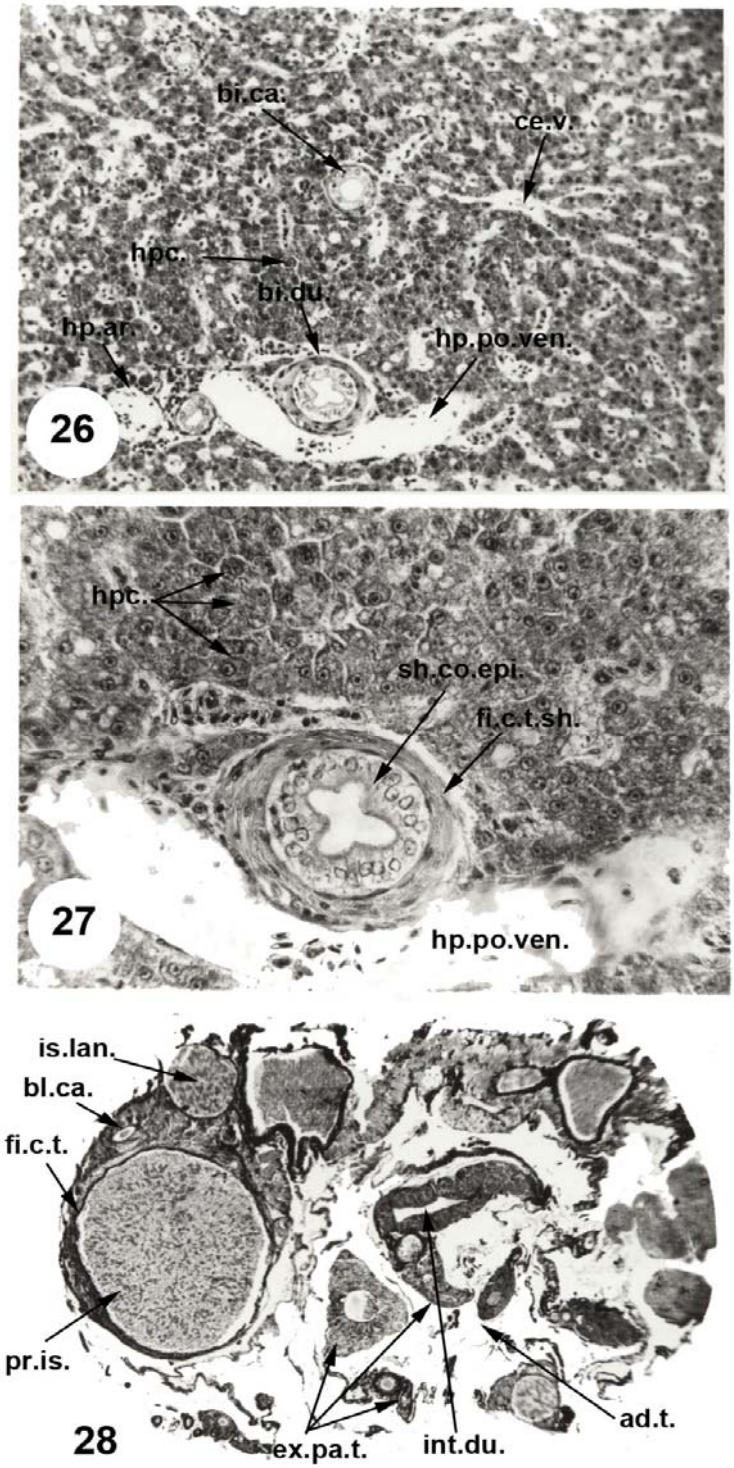
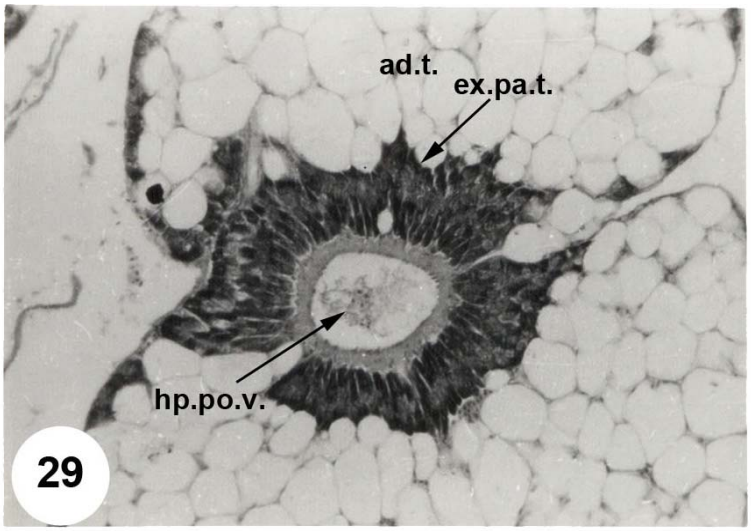
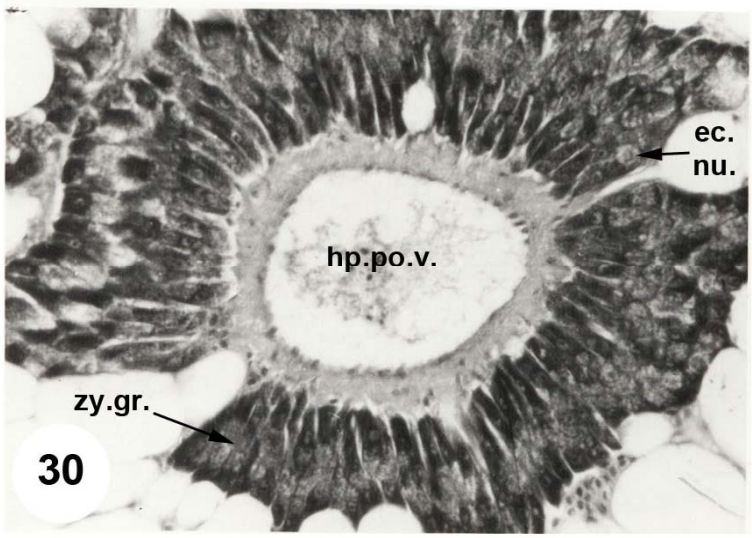


Fig. (26): S. of the liver showing the diffuse and radial patterns of arrangement of hepatocytes, bile canalicule and hepatic ductule. H & E stain, X 210.

Fig. (27): Enlarged portion of Fig. (26) showingthe structure of the hepatocytes, bile canalicule and hepatic ductule. H & E stain, X 485.

Fig. (28): S. of the mesenteries of the peritoneal cavity showing the exocrine pancreas, interlobular duct, principle and small islets of Langerhans. H & E stain, X 55.





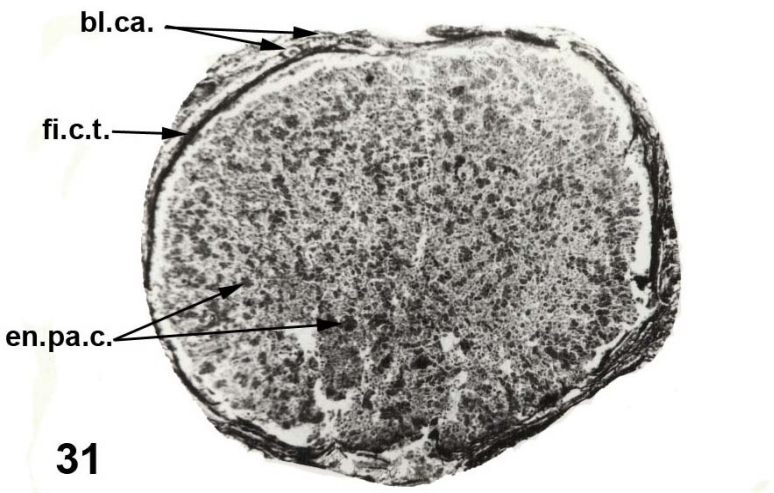


Fig. (29): S. of the exocrine pancreatic tissue surrounded by adipose tissue and surrounds a portal vein. H & E stain, X 150.

Fig. (30): Enlarged portion of Fig. (29) showing the polyhedral exocrine pancreatic cells with eccentric nuclei and apical zymogen granules. H & E stain, X 410.

Fig. (31): S. of the principle islet of Langerhans showing the surrounding fibrous connective tissue layer and the numerous endocrine pancreatic cells. H & E stain, X 355.