ANATOMICAL AND HISTOCHEMICAL STUDIES OF THE DIGESTIVE SYSTEM OF THE AFRICAN GIANT RAT (*Cricetomys gambianus* – Waterhouse).

BY

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AHMADU BELLO UNIVERSITY,ZARIA.

DECEMBER, 2010

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Ph.D/Vet. Med./41731/2004-2005.

A DISSERTATION SUBMITTED TO THE POSTGRADUATE SCHOOL,
AHMADU BELLO UNIVERSITY.
IN PARTIAL FULFILMENT OF THEREQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY VETERINARY ANATOMY.

DEPARTMENT OF VETERINARY ANATOMY
FACULTY OF VETERINARY MEDICINE,
AHMADU BELLO UNIVERSITY,ZARIA.

DECEMBER, 2010

DECLARATION

I declare that the work in the dissertation entitled "Anatomical and Histochemical Studies of the Digestive System of the African giant rat (*Cricetomys gambianus* – Waterhouse)" has been performed by me in the department of Veterinary Anatomy under the supervision of Dr. B. I. Onyeanusi, Prof. S. A. Ojo and Prof. A. A. Voh. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of the dissertation was previously presented for another degree or diploma at any university

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Name of Student	Signature	Date

CERTIFICATION

This Dissertation entitled "ANATOMCAL AND HISTOCHEMICAL STUDIES OF THE DIGESTIVE SYSTEM OF THE AFRICAN GIANT RAT (*Cricetomys gambianus* – Waterhouse)" by OLIVER JAMES NZALAK meets the regulations governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentations.

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DEDICATION

This work is dedicated to my late junior brother (Sunny, James Nzalak) who passed onto glory in February, 2010, and to all members of the Nzalak family.

ACKNOWLEDGEMENT

My most profound gratitude goes to Dr. B. I. Onyeanusi who as the chairman supervisory committee shared the difficult moments of this work with me. I am also very grateful to Prof. S. A. Ojo who as a member of my supervisory committee was always there for me. I thank him for his encouragement, assistance and advice. I wish to acknowledge with gratitude the assistance of Prof. A. A. Voh, who as a member of my supervisory committee was always there for me despite his tight schedule. Special thanks also go to my Head of Department, Dr. S. O. Salami and the Assistant Dean Postgraduate for their encouragement during the period of this work.

I sincerely appreciate the encouragement and advice from Prof. Ben Ahmed and Dr. Gambo of the Department of Agricultural Economics. I am also indebted to all members of staff of my Department for ensuring that I complete this work. To Dr. Abidoye of the Department of Veterinary Surgery and Medicine, Mr. Yaro of Pathology Department, ABUTH, Dr. Oliver Hamman, Mr. Iliya and Mr. Bamidele of the Department of Human Anatomy, Mr. Tobias of the Faculty of Education, Drs. Ibe, Ghali, Isa, Shawulu and Godfrey of the Faculty of Veterinary Medicine, ABU, Dr. Martins of the Faculty of Arts and Mr. Mainasara manto of NITT, I say thank you for the assistance you people rendered. I would also like to thank the Ahmadu Bello University, Zaria for the assistance towards the completion of the work and my family for their understanding and above all, I give thanks to the Almighty.

ABSTRACT.

Forty African giant rats (AGRs*), (Cricetomys gambianus*) were used for morphometric, morphologic, histologic and histochemical studies. The various segments of the gastrointestinal tract (GIT) were weighted, measured and photographs taken. Transverse sections of different segments of the GIT were stained with Haematoxylin and Eosin for normal histological studies. For histochemical studies, transverse sections were stained with Alcian Blue, Periodic Acid Schiff and Alcian Blue-Periodic Acid Schiff to determine their nature of secretions. The large intestine was found to have the highest mean weight (19.98 ± 0.39 g) followed by the stomach (19.47 ± 0.26 g) and then the small intestine (17.19 ± 0.30 g), respectively. Of all the digestive glands, the liver was found to have the highest weight (21.29 ± 0.43 g). The small intestine was observed to be the longest (109.17 ± 28.68 cm) followed by the large intestine (75.57 ± 1.78 cm).Out of all the intestinal segments (small and large), the jejunum was observed to be the longest (72.26 ± 2.39 cm) followed by the colon (57.30 ± 1.58 cm).Grossly, the AGR had two upper and two lower incisor teeth and three upper and three lower molar teeth. The parotid and mandibular salivary glands were found to be non-lobulated and lobulated, respectively. The esophagus was found to lie dorsal to the trachea throughout its length. The stomach was made up of glandular and non-glandular parts with a constriction separating the two parts. Esophageal epithelium was non-keratinized and devoid of lamina muscularis and glands. The stomach was observed to be divided into two parts (non-glandular and glandular) with an isthmus separating them. The non-glandular part had papillae which were covered with stratified squamous epithelium and resembled the rumen of ruminants. The isthmus was made up of keratinized stratified squamous epithelium with no glands. The glandular stomach had mucous secreting epithelium with gastric pits and glands at the mucosa. The small intestine was made up of the

duodenum, jejunum and ileum. The duodenum had villi that were covered by simple columnar epithelial cells. The duodenal (Brunner's) glands were seen on the upper part of the submucosa. The jejunum had intestinal glands (*crypts of Lieberkuhn)*, while the ileum had villi, aggregate of lymphatic nodules (Payer's patches) and intestinal glands (*crypts of Lieberkuhn*).The large intestine was observed to be made up of the caecum, colon and rectum. They all had similar basic structures and none had villi. The mucosal surfaces were smooth with goblet cells. Histochemical studies of the GIT showed a positive response to AB, PAS, and AB-PAS with the exception of the esophagus that was negative to all the reactions. The jejunum and ileum were AB positive and PAS negative. The parotid salivary glands consisted entirely of serous acini as they were PAS positive while the mandibular salivary glands consisted of both serous and mucous acini as they were AB and PAS positive. The gall bladder had the shape of a balloon and was found on the visceral surface of the liver. The liver was observed to be divided into four lobes. The gross and histological features of the stomach of the AGR which resembled the abomasum and rumen of ruminants may be responsible for its feeding habit (omnivorous).The thickening of the tunica muscularis of the colon and rectum has been correlated with the temporary storage and expulsion of fecal materials. Although the esophagus had no mucous secreting glands, the mucous produced by the salivary glands and the enzymes of surface origin may protect the mucosal surface and also provides digestive functions for the esophagus. The production of acidic and neutral mucins in the stomach and duodenum is to maintain the p.H of the chyme. The presence of large number of mucous secreting cells provides a mucous layer around the fecal pellets facilitating its release and protecting the epithelium.

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CHAPTER ONE INTRODUCTION

1.1 Historical Background

There is a great need to enhance food production in the developing countries. According to Paarlberg (2000), the UN's Food and Agriculture Organization (FAO) recently reported that one out of every five citizen from the Developing countries; totaling approximately 828 million people is still suffering from chronic malnutrition. The situation may even be more disastrous for the whole of the African continent, with an estimated population of about 776 million inhabitants (FAO, 2002a). Most of these people live under deplorable conditions, with little or no hope of significant future development in sight. The shortage of protein rich food in some areas has reached serious levels.

Protein, an essential constituent of our daily diet, like fat and carbohydrates, can also serve as a source of energy for the body. Protein is also the only source of amino acids especially essential amino acids. A regular daily intake is absolutely necessary to replace nitrogenous materials in the tissues (FAO, 2002a). An alternative source of protein is being provided by the African Giant rat (*Cricetomys gambianus*- waterhouse). Its meat is habitually consumed in most areas of Africa where the rodents are still occurring naturally. A study carried out in Nigeria showed that 71.4% of the people find it acceptable to use the animal as food (Ajayi and Olawoye, 1974). Despite taboos and prohibitions that exist in some areas of Democratic Republic of Congo (DRC), the meat of this rodent is generally well appreciated. The African giant rat (*Cricetomys gambianus*-Waterhouse) is a member of the order, *Rodentia,* subfamily, *Cricetomyinae,* and genus, *Cricetomys* (Delany and Happold, 1979). This rat weighs up to 1200gm at adult life and grows up to 38cm long with a 45cm tail which has a characteristic white tip (Delany and

Happold, 1979). They are omnivorous animals feeding on vegetables, insects, crabs, snails and other items but apparently preferring palm fruits and palm kernels. They can support themselves in sewages and rubbish dumps of large towns, where they do little damage and on farms where their status as pest is in little doubt (Booth, 1991). The rats are distributed in all parts of Nigeria. In the rain forest zone, they are restricted to farmlands, grasslands and human habitations. They are frequently seen at night crossing roads, running along drains and in house compounds. They are social animals and as such several individuals live together in a burrow. They walk and run on their four legs, usually with their tails raised and are good climbers and jumpers. In Nigeria, these rodents are often incorrectly called "rabbits" or "Nigerian rabbits" (Delany and Happold, 1979).

In view of their abundance and size, the rodents are often eaten by the people and considered a delicacy. Their smoked carcasses are often seen in village markets. Attempts have been made to breed and rear the animal in captivity for food (Ajayi, 1975). The rodent has a good potential for use as a laboratory animal (Dipeolu *et al*., 1981) and has been shown to be a good host for the laboratory passage of *Schistosoma mansoni* and *Trypanosoma evansi* (Lariviere and Buttner, 1961). Recently, the rodent has been used to detect tuberculosis patients and to sniff out landmines in Mozambique (Lindow, 2001).The excessive and uncontrolled consumption of this animal poses a threat to the ultimate survival of this species and Ajayi (1975) had attempted to study its biology and domestication. As a contribution towards this pioneering effort, several attempts at characterization of the reproductive organs have been made by Oke (1988), Oke and Aire (1989, 1990, and 1995) and Ali (2009). Other works on the AGR include those on the brain by Nzalak (2002), Nzalak *et al*. (2005, 2008) and Ibe (2010).

The dietary requirement and feeding habit of the African giant rat cannot be properly understood without a detailed knowledge of the digestive system. It is also a well known fact that the subfamily, *Cricetomyinae,* exhibits food storing behavior (Ewer, 1967) and it comprises pouched rats that obtain their common name from large storage pouches inside their cheeks. As mentioned earlier, this animal collects seeds, fruits, roots and other foods on the ground pack them into the pouches and carry them to special food stores in their burrows, but all these behavioral acts appear to have been based on feeding habit in the wild. An understanding of the digestive system will aid in maintenance, domestication and preservation of wild and endangered species (Ewer, 1967).The morphology of the gastrointestinal tract (GIT) has been reported in a number of other animals such as the cattle, sheep, pig, horse, dogs (Getty, 1975), man (Haroldy, 1992), laboratory rats (Olds and Olds, 1991) and birds (Devyn *et al*., 2000). Despite the features of this rat that have been studied, the digestive system is yet to be fully investigated. The only work done on the digestive system of this rodent in this part of the country is on the morphometry of some aspect of the digestive system (Ali *et al*., 2008; Dauda, 2009).

However, basic information on the morphometry, morphology, histology and the histochemical features of the digestive system of the African Giant Rat is not fully available. In addition there were no reports on the histochemical studies on its mucous secretion which is a common feature of the digestive tract of the AGR. Mucous is a term applied to a variety of secretions also known as mucosubstance and glycoprotein cells from different parts of the body secrete slightly different mucous that may look similar macroscopically and microscopically but differ histochemically and is usually classified as either acidic or neutral mucous. Acidic mucous is found in connective tissues and in most mucin secreting epithelial cells, whereas neutral mucous is abundant in Brunner’s glands and in the alveolar epithelial cells. Neutral mucous is also

present to some degree in goblet cells of the gastrointestinal and respiratory tract and in the prostatic glands. Although mucous can be demonstrated by a variety of techniques the most frequently used are Mayer mucicarmine, Alcian blue and Periodic acid-schiff. The mucous secreted differ from species to species along the alimentary tract. The presence of mucous is correlated with different functions such as lubrication, protection against proteolytic degradation and the inhibition of microorganisms (Reid *et al.*, 1988). This work seeks to describe the morphometry, morphology, histology and histochemistry of the digestive system of the African giant rat

1.2 Statement of Research Problems.

The paucity of scientific information on the biology, especially the digestive system which could facilitate their maintenance in captivity and expand their production from small scale to large scale farming. The high demand of this rat has led to trap setting and bush burning, which is a threat to the environment and other resources therein. The African giant rats can be used as laboratory animals, however for the effectiveness of using them in the laboratory; one needs more information on their dietary requirements and feeding habit, which include a thorough understanding of their digestive tract and its accessory organs.

1.3 Justification

As part of resources to provide food security, job opportunities and income generation for both the rural and urban farmers. To harness the production of bush meat as a solution to animal protein shortage. The domestication of the African giant pouched rat can only be made easy if there is information on their dietary requirement, feeding habit and the digestive system. The study of healthy individuals, may add to the understanding of the normal morphological and

histological patterns of the GIT which if well understood will contribute to the knowledge of pathological conditions and/or physiological alterations.

1.3 Aims and Objectives

(a) To study the gross anatomy and the histology of the digestive system of the AGR.

(b) To study the histochemistry of the digestive system using Alcian Blue(AB),Periodic acid Schiff (PAS) and a combination of Alcian Blue and Periodic acid Schiff(AB-PAS) to ascertain the nature of their secretions.

CHAPTER TWO LITERATURE REVIEW

The digestive system is made up of series of tubular organs and associated glands whose main function, is to break down the ingested food materials into smaller units that can be absorbed into the tissues and utilized for the maintenance of the organism. All epithelial components of the digestive system except those of the oral cavity are derived from endoderm (Dellmann and Brown, 1987).The major subdivisions of the digestive system are the oral cavity, the pharynx, the esophagus, stomach, and the intestine; the intestine being divided into small and large portions in tetrapods. Associated with these structures are the accessory organs, principally the mouth, the tongue, the teeth, oral glands, the pancreas, the liver and the gallbladder (George, 1973). The digestive organs of fishes, amphibians and most reptiles occupy the pleuro-peritoneal cavity, a major compartment of their coelom, along with lungs in tetrapods. In few reptiles, birds and mammals, the lungs occupy their own pleural cavities and the digestive organs beyond the esophagus occupy the peritoneal (abdominal) cavity. The heart always occupies its own pericardiac cavity (George, 1973). In any given specie, the overall morphology is chiefly related to the nature of food, feeding habits, body size, shape and sex (Smith, 1989). There is a general structural pattern for all tubular organs of the digestive system and familiarity with this general pattern is helpful in understanding the specific characteristics of each organ (Dellmann and Brown, 1987).

Histologically, the structure of the wall is essentially the same throughout its length consisting of four layers: mucosa, submucosa, muscularis externa and serosa (Milton, 1974).

The inner surface of the digestive tube is lined with a mucous membrane or mucosa which consists of a superficial layer of epithelium, regionally specialized for different digestive

functions and a supporting layer of loose connective tissues, the lamina propria. The peripheral layers of the wall of the digestive tube are made up of smooth muscles making up the serosa (Fawcett, 1986). The mucous membrane lines all organs that communicate with the outside of the body and is protected by layer of mucous, a viscous secretory material produced by specialized glands. In some organs, the lamina propria contains glands and because they are confined to the mucosa, they are referred to as mucosal glands. The tela submucosa is a layer of connective tissue which may contain glandular units (submucosal glands). In organs without a lamina muscularis, the lamina propria and the submucosa blend together without a clear line of demarcation. The tunica muscularis is the layer of muscle responsible for the movement of the ingesta through the tract (Dellmann and Brown, 1987).

Usually two layers of muscles are found in the digestive system. The muscle fibers of the inner layer are oriented circularly or in a tightly coiled pattern whereas, the outer layer is composed of longitudinally or loosely coiled muscle fibers. The outermost layer is the serosa or serous membrane and it is composed of connective tissue, with mesothelium covering organs enclosed within the thoracic, pericardiac and abdominal cavities. Whereas, those located outside the cavities, such as the cervical portion of the esophagus do not have mesothelium, a connective tissue called tunica adventitia blends with the surrounding fascia (Dellmann and Brown, 1987). Although the large accessory digestive organs such as the pancreas, salivary glands and liver are located outside the tubular portion of the digestive system, they originate as epithelial evaginations from the digestive tube and their main ducts penetrate the walls of the tubular organs and empty their secretory products into the lumen (Dellmann and Brown, 1987).

2.1 The Lips

In laboratory rats, the upper lip is divided midsagittally by a deep, hairless philtrum and the groove is continued as a deep pocket around the neck of the upper incisors and caudally as a groove directed towards the roof of the oral cavity (Rudolf and Stromberg, 1976). In rabbits, the lips form the rostral border of the mouth, and are made up of three layers; from outside inwards are the skin, which is hairy; the muscular layer and the mucous membrane layer internally. The mucous membrane is non pigmented but pinkish in color and the cheeks form the lateral wall of the oral cavity (Timothy, 1990).

2.2 The Cheeks

2.2.1. Gross features

The cheeks of the rabbit form the junction between the integument and the digestive system and are covered on the outside by the skin and on the inside by the mucous membrane. The cheeks like the lip are composed of an external covering of skin, a middle muscular layer and a mucous membrane lining. The cheek forms the lateral border of the oral cavity. It continues rostrally with the lips and has same layers as the lip. Its mucosa is pink and non-pigmented. It also forms the cranial border of the oral cavity proper (Timothy, 1990).

2.2.2. Histological features.

The buccal mucosa is lined with stratified squamous epithelium that may or may not be keratinized, depending on the particular area. In ruminants, the mucosa is studded with conically shaped macroscopic papillae which facilitate prehension and mastication of food (Dellmann and Brown, 1987).

Near the junction, the skin is devoid of hair follicles and the epidermis is thicker with a more elaborate interdigitation with the underlying connective tissue (Dellmann and Brown, 1987). The inner side of the lip is covered by stratified squamous epithelium which is keratinized in

ruminants and horse. If the food is rough and fibrous, the epithelium is more keratinized and the lamina propria and the submucosa blend together without a clear junction. The aggregations of the labial glands, usually serous or seromucous in type are distributed in the propria and the submucosa. The tunica muscularis consists of striated muscle fibers of the orbicularis oris muscles (Dellmann and Brown, 1987).

2.3 The Palate

2.3.1 Gross features

The palate forms the roof of the oral cavity and is divided into hard palate and soft palate. The hard palate has a short bony portion in the laboratory rat (Stanbury, 1972). The soft palate is long in rabbit and divides the pharynx into oral and nasal portions with the later receiving the opening of the Eustachian tube .The hard palate is bordered rostrally by the caudal border of the upper incisor teeth to the last molar tooth and laterally by the gum(Kozma, 1974). The hard palate has a median longitudinal groove which is more distinct towards the caudal end in rabbits with sixteen transverse ridges (Timothy, 1990), with the same type of mucosa as the soft palate which is devoid of transverse ridges. The median longitudinal groove is more prominent in the soft palate than the hard palate and ends in a pendulous flap, the uvula (Timothy, 1990).

2.3.2 Histological features

The mucosa of the hard palate has stratified squamous epithelium in the rat and rabbit (Rudolf and Stromberg, 1976; Timothy, 1990).It is keratinized and thick in ruminants. The stratum corneum of the rostral portion of the hard palate is especially thick in ruminants and forms the dental pad and the lower incisor teeth press down on the dental pad forming a tight grip on the forage during grazing (Dellmann and Brown, 1987).The lamina propria has a well developed papillary layer which blends with the submucosa without an intervening lamina muscularis

(Dellmann and Brown 1987). The submucosa is composed of a dense network of collagens and reticular fibers and blends with adjacent periosteum (Fawcett, 1986). The soft palate is formed by a fold of mucous membrane of the oral and nasal cavities, the oral surface being covered by a stratified squamous epithelium whereas the nasal mucous membrane has ciliated, pseudostratified columnar epithelium and a zone of transition between the two types of epithelium occurs on the nasal surface. The propria and submucosa contain branched tubuloacinar mucous and seromucous glands (Fawcett, 1986).

2.4 The Esophagus

2.4.1 Gross features

The esophagus is the first part of the alimentary canal connecting the laryngeal part of the pharynx and the stomach. It is divided into cervical, thoracic and abdominal portions. The cervical portion being the most cranial part extends from the pharynx to the thoracic inlet and measures about 7cm long in the rabbit. It lies dorsal to the trachea and ventral to the ventral cervical muscles, and at the thoracic inlet, it still maintains its position dorsal to the trachea to enter the thoracic cavity and continues as the thoracic esophagus till it reaches the trachea bifurcation (Timothy, 1990). Craigie (1951) observed that in the guinea pig, the thoracic esophagus maintains its median position and through the hiatus esophagus, it passes into the abdominal cavity to become the abdominal esophagus and enters the stomach in the region known as the cardia. In the laboratory rat, the esophagus deviates slightly to the left only in the cervical region. It runs midsagittally along the dorsal aspect of the trachea, its length being 7.5cm (Rudolf and Stromberg, 1976). The esophagus of the rabbit was observed to be a pale red narrow muscular tube located between the pharynx and the cardia of the stomach. Its cervical part was the most cranial and extends from the pharynx to the thoracic inlet, measuring about

7cm long. It lies dorsal to the trachea and ventral to the ventral cervical muscles. At the thoracic inlet it still maintains its position dorsal to the trachea and continues as thoracic esophagus, until it reaches the trachea bifurcation where it lies in between the lung lobes. The thoracic esophagus maintains its medial position and passes into the abdominal cavity through the hiatus esophagus in the diaphragm. The thoracic esophagus was observed to be 5cm long, while the abdominal esophagus was observed to be 2cm long (Timothy, 1990).

In a medium-sized dog, the esophagus is about 30cm in length with a diameter of about 2cm when collapsed (Miller, 1965), while in the bovine, it ranges from 90 to 105cm long from its junction with the pharynx. Measurement of its diameter is unreliable because of its dilatability in living state. After formalin fixation, the smallest diameter of the bovine esophagus is about 3cm and this is in the caudal third of the neck. It gradually increases to 4cm wide and 7cm on the caudal part of the throat (Getty, 1975). Getty (1975) further observed that the esophagus in sheep is 45cm long, increasing in diameter from 1.8cm at the pharynx to 2.5cm at the cardia. He observed that in the horse the esophagus is a muscular membranous tube of about 125 to 150 cm in length and extends from the pharynx to the stomach, while that of the pig is short and nearly straight and has a potential caliber of nearly 7cm in the adult at either end and about 4.2cm in the middle part.

2.4.2 Histological features

The esophagus consists of tunica mucosa, tunica submucosa, tunica muscularis and tunica adventitia/serosa (Dellmann and Brown, 1987). The mucosa is composed of three layers, the stratified squamous epithelium, a lamina propria and a lamina muscularis. The degree of keratinization varies with the species. It is usually non-keratinized in carnivores, slightly keratinized in pig, more so in the horse and highly keratinized in ruminants (Dellmann and

Brown, 1987). The lamina propria is made up of a network of fine collagen fibers with evenly distributed elastic fibers while the lamina muscularis contains only longitudinally oriented smooth muscle bundles which are absent on the cranial end of the esophagus of the pig and dog but present in the cat, horse and ruminants, near the pharynx and increase in number (Dellmann and Brown, 1987). The tunica submucosa is a loose connective tissue layer containing large, longitudinally oriented arteries, veins and lymphatic vessels. Seromucous glands containing mucous acini with serous demilunes characterize this layer in the pig and dog with the glands being abundant in the cranial half and not extending into the caudal half in the pig. In the dog, they are present throughout extending into the cardiac region of the stomach (Dellmann and Brown, 1987). The tunica muscularis of the esophagus of ruminants and dog are entirely striated .In the horse, striated muscles make up the rostral two third of the tunica muscularis but they gradually change to smooth muscles in the caudal third. The tunica muscularis of the pig is similar to that of the horse except that the middle third has a mixed smooth and striated muscles. In the cat, the striated muscles may extend four fifths of the length of the esophagus before changing to smooth muscles (Dellmann and Brown, 1987). The tunica adventitia surrounds the tunica muscularis in the cervical region and it is made up of loose connective tissues containing blood vessels, lymph vessels and nerves (Fawcett, 1986).

Diaz *et al.* (2003) observed that the esophagus of *Engraulis anchoita* was short with wide lumen and the tunica mucosa showed deep longitudinal folds.Two zones with distinguishable morphological characteristics in the epithelium were present, cranial and caudal. They further observed that the cranial zone was lined by few layers of squamous stratified epithelium with numerous superficial mucous cells. In the caudal zone this epithelium was replaced by a columnar epithelium involved in secretion processes. Ahmed *et al.* (2009) observed that the

epithelium of the esophagus of *Varanus niloticus* was lined by ciliated columnar epithelium and mucous secreting goblet cells.

2.4.3 Histochemical features

The esophagus is a highly specialized organ designed for the propulsion of food from the mouth to the stomach. As a result of its position in the gastrointestinal tract it may be exposed to a variety of noxious stimuli. The mucous barrier is an important factor in the protection of the esophagus from damage (Dixon *et al.*, 1999). The presence of mucous barrier in the normal esophagus is disputed with reports of its presence (Dixon *et al.*, 1999) and complete absence under normal condition (Saroseik and McCallum 2000). The need to protect the mucosal surface is accepted and the presence of mucin from the saliva or esophageal glands and ducts is not disputed (Dixon *et al.*, 1999). Arellano *et al.* (1999) observed that at the cranial zone of the esophagus of the *Engraulis anchoita,* the mucous cells of the epithelium contain sialosulphoglycoproteins, because they were weakly stained with Periodic Acid Schiff (PAS) and strongly stained with Alcian Blue (AB). They further observed that this secretion increased at the cranial zone of the esophagus and may serve together with the stratified squamous epithelium to protect the first part of the esophagus tract. Ahmed *et al.* (2009) observed that the esophagus of *Varanus niloticus* contained mucous secreting cells which stained positive with PAS and AB, suggesting that they secreted both neutral and acidic mucosubstance. They further observed that this mucous especially the acidic one, which increased the viscosity of the mucous content, may be important for lubrication of the mucosa for the passage of large food particles, in addition to immobilization of food such as arthropods. The mucous is also important in protecting the mucosa from sharp objects such as spiny fish. The presence of both neutral and acidic mucin is

not unique for the *Varanus niloticus* but is, seen in other reptiles (Elliot, 2007), fish species (Parillo *et al.*, 2005) and in birds (Selvan *et al.*, 2008).

2.5 The Esophago-cardiac Junction

The morphologic characteristic of this junction varies considerably because the junctions of the several layers do not take place at the same level. The skeletal muscles of the tunica muscularis change gradually to smooth muscles (Fawcett, 1986). The glands of the esophagus may extend a short distance within the submucosa of the stomach, whereas the stratified squamous-simple columnar epithelial junction is very abrupt. In the cat, the junction is 3 to 5cm rostal to the cardia; in the dog, it is 1 to 2cm rostral to the cardia and only the pig has a well developed internal sphincter muscles (Dellmann and Brown 1987). Fawcett (1986) observed that in the ruminants, the stratified squamous epithelium is continuous caudally to line the fore stomach, but in horse and pig, it extends throughout the non- glandular region of the stomach.

2.6 The Stomach

2.6.1 Gross features

The stomach of the rabbit is a sac-like organ which is wider at the cardia region than the opposite pyloric region and occupies the epigastric and partly the mid-gastric region of the abdominal cavity. It is mostly enclosed by a cavity formed by the lobes of the liver. Its greater curvature is ventrally located while the lesser curvature is dorsal. The greater curvature is relatively longer in circumference than the lesser curvature, making the stomach have an outline of an air-filled car tube (Timothy, 1990). Cranially, it is related to the lobes of the liver, caudally to the caecum and to the right, the duodenum and part of the pancreas. It also has an omentum which attaches it at the greater curvature and curves to follow the caudal surface to be attached to the periosteum (Timothy, 1990).The stomach of the grasscutter was observed to be small in relation to the size

of the animal and forms a curved sac similar to an inverted letter-J (Byanet *et al*., (2008). Ali *et al*. (2008) stated that the stomach of the AGR accounted for about 3% of the total body weight. Gastrointestinal endocrine cells are dispersed in the epithelia and gastric glands of the digestive tract and have been found to synthesize various kinds of gastrointestinal hormones, and these play an important role in the physiological functions of the alimentary tract (Bell, 1979). The stomach of ruminant, adapted for processing cellulose, is divided into four chambers: rumen, reticulum, omasum and abomasum. The relative proportions of these parts in adult are 64% for reticulum/rumen, 25% for omasum and 11% for abomasum (Olusanya and Olowo, 1988). In typical ruminant, the first three compartments (rumen, reticulum and omasum) are non-glandular whereas, the fourth compartment (the abomasum) is glandular and contains cardiac, fundic and pyloric glands (Banks, 1993; Eurrell and Dellmann, 1998). Camels are similar to ruminants in several aspects, which include: the regurgitation of ingesta and active microbial fermentation in the stomach (Frandson, 1981). However, in contrast to the compound stomach of a typical ruminant that comprises of four compartments, the stomach of camel has only three compartments (the rumen, the reticulum and the abomasum). Camels are thus considered pseudo-ruminants (Vallenas *et al.,* 1971 and Singh *et al.,* 1996). The second compartment of the stomach of the dromedary camel is the reticulum, and the third is the abomasum-a tubular portion with cardiac and fundic glands. The first compartment (the rumen) is divided into cranial and caudal sacs by a transverse pillar (Vallenas *et al.,* 1971 and Singh *et al.,* 1996). However, Eerdunchaolu *et al.* (1999) regard the stomach of Bactrian camel as a single cavity stomach formed by multiple differentiations of cardiac glands.

The stomach capacity varies with species: in cattle, it is 115-150 litres; in sheep and goat, 15-18 litres; in horse, 8-15 litres and in pig, 5.7-8 litres (Getty, 1975). The stomach of dog is C-shaped,

rotated 90 degrees in a clockwise direction and more to the left of the median plane. The division is similar to those of monogastric animals, divided into cardiac, fundus and pyloric portions. The greater curvature is approximately 30cm long in a moderately filled stomach (Miller, 1965). Typical ruminant and monogastric herbivores stomachs comprise of four types of mucosae; non-glandular (esophageal), cardiac, fundic, and pyloric mucosae. In ruminants, the gastric groove (*Reticular sulcus*), which directs ingested fluids from the esophagus to the abomasum is continuous with the cardiac region (Eurell and Dellmann, 1998). But in camel, Abdel-Maigied and Taha (2002) demonstrated five different types of mucosa in the compound stomach of one-humped camel; they are the esophageal, pseudo cardiac, cardiac, fundic and pyloric mucosae.

2.6.2 Histological features

Byanet *et al.* (2008) observed three regions in the grasscutter (cardia, fundus, and pylorus). They further observed that the stomach wall has the same structural layers within the three regions and these are similar to those of the gastrointestinal segments. These layers include the following (from the innermost to the outside): the tunica mucosa, tunica submucosa, tunica muscularis and the tunica serosa. They further observed that the cardia region contains mucosa glands extending deep into the mucosa with the gastric pits lined by simple columnar epithelium. Byanet *et al.* (2008) also observed that the fundic region has numerous gastric glands with shallow gastric pits and long branched tubular glands that contain cell types namely, the parietal and chief cells. The pyloric region was similar to those of the gastric gland and had deep, wide gastric pit and short coiled pyloric glands. The stomach is an enlarged part of the digestive tube specialized for the enzymatic and hydrolytic breakdown of food into digestible nutrients. The muscular wall helps in mixing the ingesta. The stomach is lined exclusively by glandular mucosa in carnivores

whereas herbivores have, in addition to a glandular regions, a non-glandular region lined by stratified squamous epithelium (Dellmann and Brown, 1987). The wall of the stomach has all the layers of a typical tubular organ. The tunica mucosa is composed of epithelium, a lamina propria (of collagen, elastic and reticular fibers) and a lamina muscularis. The submucosa layer contains collagen fibers, fat and the sub-mucosal nerve plexuses. The tunica muscularis has three layers of smooth muscles: an inner oblique, middle circular and outer longitudinal. The myenteric plexuses are located between the middle and outer muscle layers. The outermost layer, tunica serosa or adventitia is composed of mesothelium overlying a layer of loose connective tissue (Dellmann and Brown, 1987). The mucosa and submucosa of the undistended stomach are thrown into longitudinal folds called “rugae” (Dellmann and Brown, 1987) and flattened when the stomach is filled. The fundic region has glands which are typical gastric glands. They are elongated simple tubular glands, many with tubules that open into a single terminal duct. There are several types of cells in their epithelium, among them are zymogenic cells (chief cells), that synthesize and release the pre-enzyme pepsinogen; the parietal cells, which secrete hydrochloric acid; and goblet cells, found mostly in the neck of the tubule. Mucous cells lubricate the lining and provide a vehicle for accumulating products of digestion (David, 1975). The cardiac and pyloric regions of the human stomach according to George (1973) can be distinguished from other regions on the basis of the histology of their glands. The mucosa in the cardiac region resembles that of the lower end of esophagus, the gland being compound tubular with many goblet cells. A few parietal cells are also present. Pyloric glands are simple branched tubular glands, and they extend deeper into the mucosa than other types. They have many goblet cells and relatively few parietal cells. The pattern of distribution of these different varieties of gastric mucosa is not necessarily the same in all mammals. In the rat, within

the glandular mucosa, cardiac glands are found only in narrow strip along the line of epithelial transition. The glands are said to be branched and coiled (Rudolf and Stromberg, 1976). Histological and histochemical studies of the camel stomach revealed that the fundic cells were similar to those of other mammals (Abdel-Maigied and Taha, 2002).

2.6.3 Histochemical features

Diaz *et al.* (2003) observed that in the stomach of *Engraulis anchiota* the cells of the epithelial lining were stained by PAS reaction which was more intense than in the cells of the gastric glands. In the different gastric zones, at the apex of the columnar cells which make up the superficial epithelium, large quantities of both acidic and neutral mucosubstance are synthesized. The acidic mucosubstance are shown to be chiefly of the sialylated type so that the mucosal secretion is probably rather fluid (Diaz *et al.*, 2003). Domeneghini *et al.* (1999) observed that similar secretions which are related to the movement of fluid carried out by the cilia are present in the epithelium of the gastric mucosa. In fishes, neutral mucosubstance secreted by the stomach epithelium have also been shown to be related to the absorption of easily digested substrates such as disaccharides and short chain fatty acids (Grau *et al.*, 1994). Ahmed *et al.* (2009) observed that in the *Varanus niloticus*, the gastric surface epithelium showed histological features in both fundic and pyloric regions and exhibited strong staining with PAS but did not react with AB. In the fundic region the epithelium forms deep glands, fundic glands. They further observed that the fundic glands are branched tubular and are formed primarily by dark oxynticopeptic cells with some clear mucous cells located between the gastric pit and the fundic glands. They further observed that the oxynticopeptic cells showed different gradient of staining. Some were deeply stained while others appeared granulated or nearly empty. The

oxynticopeptic cells were cuboidal or pyramidal in shape. Oxynticopeptic cells stain negatively to both PAS and AB.

2.7 The Intestine

The intestine occupies less than half of the abdominal cavity and lies in the right side of the cavity. The subdivisions of the intestine are the duodenum, the jejunum and ileum which constitute the small intestine while, the caecum, colon and rectum makes up the large intestine (Ojo *et al*., 1987). The soluble foodstuffs resulting from digestion are absorbed into the blood stream in the small intestine, while the materials which are not absorbed are passed into the large intestine. Here most of the water contained in the undigested food is absorbed into blood and the semi-solid feces are then ejected through the anus (Ojo *et al*., 1987).The morphology of the intestine of mammals is highly variable and correlates with diet and is systematic only in a general way. The small intestines extend from the pyloric end of the stomach to the ileo-cecal junction (Dellmann and Brown, 1987).

2.7.1 The Small intestine

*Gross Features***:** Duodenum is the first and most fixed part of the small intestine. It has two loops: ascending and descending loops; it measures about 25cm long in the dog (Miller, 1965), 40cm long with a diameter of 0.5cm in rabbits and 9.5-10cm long with a diameter of 0.25-0.3cm in laboratory rat (Rudolf and Stromberg, 1976). Byanet *et al.* (2008) showed that the small intestine of the grasscutter was divided into the duodenum which was 21.25cm long, jejunum 109.5cm long and ileum 12.8cm long. The duodenum appeared smooth and was measured from the pylorus to the origin of the jejunum and occupied the abdominal floor between the stomach

cranially and the urinary bladder caudally. It was observed to be long and coiled, but gradually stopped forming coils near its end. They also observed the ileum to be smooth and curved only where it joined the large intestine. Timothy (1990) observed that the duodenum of the rabbit is long compared to the total length of the intestine. He further observed that the jejunum is the longest portion of the small intestine measuring 3.5 times the length of the duodenum and is thrown into folds. The ileum, being the shortest portion of the small intestine, measures only about one fifth the length of the jejunum. In man, the distal three-fifth of the jejuno-ileal segment is regarded as ileum, the proximal two-fifth as jejunum. The ileum is smooth and not sacculated like the jejunum (George, 1973).

In the dog, the small intestine has an average length of 3.5 times the body length in the living animal. After death and cessation of peristaltic contractions, the intestine increases in length owing to the loss of muscular tone (Miller, 1965). The length of the intestine in the formalin-embalmed dog is longer than it is in the live state. Unlike man, the ileum in the dog contains fewer aggregated lymphoid follicles. The small intestines of laboratory rat (Brown and Black rats) measure 1020 – 1480mm long (Rudolf and Stromberg, 1976), while in the horse; it has an average length of about 22m. When distended, its diameter varies from 7.5 to 10.0cm. In the pig, the small intestine is about 15 – 20 m long (Getty, 1975). The total length of the small intestine and large intestine in cattle is about 20 times the length of the body and 25 times in the sheep and goat. The small intestine has an average length of 40m in the Ox and 25m in the sheep and goat. The average diameter is 5cm in the Ox and 2 – 3cm in the small ruminants (Getty, 1975). The small intestine of dog, cat and rat, unlike those of the other mammalian species, has similar arrangement found in man (Dellmann and Brown 1987).Small intestine of the dog are relatively long, approximately 5m, and this permits prolonged contact between food

and digestive enzymes, as well as between the digested products and the absorptive cells of the epithelial lining (John, 1986).

Histological Features: The small intestine is modified to aid in absorption in three ways: the upper two thirds have circularly disposed mucosal folds (*Plica circularis*) in ruminant but in other domestic animals they are seen only as relaxed mucous membrane and disappear when the organ is distended. Secondly, the surface of the mucosa is lined with finger-like projections, the intestinal villi, with a length of 0.5 – 1.0μ depending on the region and species. And thirdly, the absorptive surface is further increased by the microvilli on the free surface of the simple columnar epithelial cells of the folds (Dellmann and Brown, 1987). The small intestine has all the typical tunics or layers. These include:

a. The tunica mucosa - which includes the lining epithelium, lamina propria with glands and lamina muscularis.
b. Tunica submucosa – this is a connective tissue layer of collagen and elastic fiber bundles located between the lamina muscularis and tunica muscularis. The type of glands present in this layer is mucous in dog and ruminants, serous in pig and horse, but seromucous in the cat. The submucosal nerve plexuses are scattered throughout the submucosa.
c. Tunica muscularis consists of the inner circular and outer longitudinal smooth muscle layers in all species. The mesenteric plexus is present between the two muscle layers.
d. Tunica serosa is the outermost layer of the tunics. It is similar to that of the stomach, with loose connective tissue which is continuous with the mesentery. Both are covered by the mesothelium of the peritoneum (Dellmann and Brown, 1987).

There are histological variations in the small intestinal regions. The duodenum has Brunner's glands in the submucosa; and has the longest villi of the entire three regions. It has the highest

numbers of goblet cells, but *Plica circularis* is absent. The jejunum is next to duodenum and has glands or lymphoid nodules in the mucosa. The ileum is the last region of the small intestine; it has permanent aggregates of lymphoid nodules in the submucosa and has the shortest villi, with the least number of goblet cells (Charlotte, 2004). Between the villi are small openings of simple tubular glands called intestinal glands (*crypts of Lieberkuhn*). Formation of crypts and villi enlarges the surface of the mucous membranes in the small intestine. In human for example, the villi lead to 5 – 6 fold enlargement of the absorptive surface of the small intestine (Leonhardt, 1990). The intestinal villi in growing pig have been identified to be tongue-shaped or leaf-like, sometimes blunt, branched or ridged (Kenworthy, 1976). In growing pigs of 2-3 weeks post weaning histological measurement of the villous height ranges from 300 to 600μ, while the crypt depth is 150 – 400 μ (Cera *et al.,* 1988). Crypts are said to be deeper than the width of the lamina propria- mucosa. In the *crypts of Lieberkuhn*, one finds undifferentiated cells, sometimes absorptive cells and goblet cells, paneth cells, and entero-endocrine cells (John, 1986). Vertical rows of small, round structures occurring occasionally among microvilli of jejunum and colonic epithelial cells called "*microvillar microblebs*" have been reported in rat and man (Ceurremans, 1971; Toner *et al*., 1971), and in ground squirrels (*Citellus tridecemlineatus*) (Williams, 1975) as arising from the lateral surfaces of the tips of microvilli of intestinal epithelial cells.

Gastro-intestinal tract endocrine cells have been studied in eight portions of mice GIT (fundus, pylorus, duodenum, jejunum, ileum, caecum, colon, and rectum) (Lee *et al.*, 1991). The endocrine cells are generally divided into two types, one is round to spherical closed-type cells which were located in the stomach regions and the other is spherical to spindle-shaped open-type cells which were situated in the intestinal regions. These cells synthesize many gastro-intestinal hormones (Bell, 1979). The distribution of the endocrine cells in the intestinal tract has also been

studied in the Korean tree squirrel (Lee *et al.,* 1991).Most of the lymphoid follicles are located in the jejunum and ileum; they form lymphoid aggregates, known as Payer's patches. In several species such as sheep (Reynolds and Morris, 1983, 1984), bovine (Landsverk, 1984; Landsverk *et al*., 1991; Yasuda *et al.,* 2002) and pig (Bianchi *et al*., 1992), there are two types of Payers patches in the small intestine which differ in developmental location, structure and function. The ileum Payers patch is considered to be the equivalence of the bursa of fabricus of birds in ruminants (Torres-Medina, 1981; Reynolds and Morris, 1983). In routine haematoxylin and eosin sections, four layers of the intestinal wall can be distinguished according to Copenhaver and Pehaneer (1971); Reith and Ross (1977); Leeson and Leeson (1976) and Lee and Toner (1980). The mucosa, which appears dark due to large number of epithelial cells and other cells in the lamina propria, contains both villi and intestinal glands. The glands are called *crypts of Lieberkuhn*. The villi project above the surface into the lumen and the glands dip into the supporting connective tissue (Reith and Ross, 1977; Dellmann and Brown, 1987).

Three kinds of cells are present on the surface of the villi and are named columnar absorptive cells, goblet cells and argentaffin cells (Copenhaver and Pehaneer, 1971). Leeson and Leeson (1976) have also included Paneth cells, caveolated cells and migrating cells as present. The nuclei of the absorptive cells of the small intestine possess a striated border and can easily be identified while the argentaffin cells are in contact with the basement membrane and require special stain for their demonstration (Copenhaver and Pehaneer, 1971; Leblond and Stevens, 1948; Palay and Karlin, 1957).The tunica muscularis is external to the submucosa. It occurs as two distinct muscular layers namely, an inner circular layer and an outer longitudinal layer.The serosa is the light staining region external to the tunica muscularis. Where the intestine has no serosa as in the visceral peritoneum, the layer external to the tunica muscularis would be referred

to as the adventitia (Leeson and Leeson, 1976). For example, the duodenum is adherent to the posterior abdominal wall and therefore has much of its wall as an adventitia rather than a serosa. Whereas the *Plica circularis* have submucosa as their central core, the villi are mucosal projections and have lamina propria as their central core (Leeson and Leeson, 1976; Copenhaver and Pehaneer, 1971). In addition to the lacteal vessels present, the lamina propria contains small blood vessels and smooth muscle cells (Copenhaver and Pehaneer, 1971; Reith and Ross, 1977). The lacteal are lined by extremely flat endothelial cells with elongated dark staining nuclei (Copenhaver and Pehaneer, 1971; and Reith and Ross, 1977; Palay and Ravel, 1964).

Histochemical Features: Ahmed *et al.* (2009) noticed that it was difficult to distinguish between the different parts of the small intestine of *Varanus niloticus*. They observed that two basic types of cells were present in the intestinal lining epithelium; columnar absorptive cells and goblet cells that secrete both types of mucinous substances as indicated by positive reaction to both PAS and AB. The epithelium covering the villi was simple columnar with goblet cells and no paneth cells were seen. The lamina propria was rich in lymphocytic infiltrations and many eosinophils (Ahmed *et al.,* 2009). Oliveira and Fanta (2000) observed that in fresh water fish the intestine has two loops and is formed by four types of tissues: mucosa, submucosa muscularis and serosa. They were numerous goblet cells. Histochemical reaction showed neutral and carboxylated acid mucous and a weak reaction for sulphated acid mucous. They further observed that some cells have acid mucous secretion at the basal region and neutral secretion at the loop one region and others are only acid or only neutral mucous secreting cells. Some granular cells or macrophages (Sire and Vernier, 1992) were identified in the epithelium, presenting large granules in the cytoplasm and were group mainly close to the epithelial base, but occur also at the apical region. Daniel and Helen (2005) applied Alcian Blue and Periodic Acid

Schiff to sections of the gastrointestinal tract of eleven mammalian species to study the pattern of distribution of the gastrointestinal epithelium mucous and revealed that there were different distributions of epithelial mucous substance throughout the gastrointestinal tract. They further observed that differences were obvious in the stomach and the duodenum. Neutral mucosubstances were most evident in the stomach and acidic mucosubstances in the intestine with sulfomucin prominent in the large intestine. Acidic mucosubstance was noted in the paneth cell granules of rodents only (Daniel and Helen, 20005).

2.7.2 The Large intestine

Gross Features: Large intestine starts from the ileo-cecal junction and ends in the anal canal. It is divided into caecum, colon, rectum and the anal canal. Kotze *et al.* (2010) observed that the caecum in the mole rat was arranged in a flat spiral form with the presence of spiralling or taniae. The commonly recognized but unspecified immune related function of the associated lymphoid tissues was proposed to be the preservation of commensal bacteria, which can recolonize the colon in the event of original bacteria being lost during diseases which is being carried out by immune molecules such as immunoglobin A and mucin that support growth of bacterial biofilms on the epithelium of the proximal large bowel particularly the human appendix. They further observed that the heavy reliance of the mole rat on gut flora and fermentation in the cecocolon is highly possible that the presence of appendix may play a smaller role. Taeniae, haustra and cecal semilunar folds are postulated to regulate flow of ingesta in small herbivores (Langer, 2002).The presence of spirally arranged caecum in the mole rat is a morphological adaptation to regulate flow of ingesta enhancing uptake of nutrients (Kotze *et al.,* 2010). They further observed that looping may be a way of streamlining and packaging a relatively long colon into the abdominal cavity.Byanet *et al.* (2008) observed the caecum of the grasscutter to be the largest segment of

the entire GIT. It was a very large, coma-shaped blind ended sac situated at the ileo-caecal junction with intervening sacculations or haustra. The colon was observed to be the longest of the GIT segment (121cm) with wide lumen and fecal balls, seen particularly in the transverse and descending parts. Its colon has three portions namely the large ascending, the small transverse and the descending colon. The ascending colon is related to the small intestine ventrally. The transverse colon is close cranially to the stomach and descending colon is close medially to the left kidney (Byanet *et al.* (2008).The rectum is short and straight and terminates at the slightly enlarged region of the anal orifice. The large intestine is rarely coiled but circa is common and generally there are several flexures. In mammals, some reptiles and birds, the large intestine is divisible into the caecum, the colon, which commences at the ileo-colic sphincter and rectum, a straight terminal portion in the pelvic cavity. The colon of some mammals has ascending, transverse and descending portions with pronounced flexures between them (George, 1973). The rectum is the caudal continuation of the colon and it differs from colon by the absence of wrinkles and the presence of pellated feces. It is about 55 cm long with a 0.5cm diameter in small ruminants. In man, the large intestine is subdivided for descriptive purposes into: Caecum with its appendix vermiform, ascending colon (12-20cm), transverse colon (45cm), descending colon (22-30cm), sigmoid colon (37cm), rectum (12cm) and anal canal averaging 4 cm (Haroldy, 1992).

The large intestine dimensions have been documented for many animals. In rabbit, it measures about 123cm in length; the caecum is 38cm long with a diameter of 3.5cm at ceco-colic junction. The laboratory rats (Brown and Black rats) have about 220 to 260mm as the entire length of the large intestine. The caecum lies in the left caudal part of the abdominal cavity and measures about 50 – 70mm in length and 10mm in diameter. The rectum runs as a straight midline tube

through the pelvic cavity and ends in the anus just below the roof of the tail. It measures 80mm in length and 3-10mm in diameter (Rudolf and Stromberg, 1976). The large intestine in ruminants is, for most of its length not greater in diameter than the small intestine. It has no longitudinal band and no sacculations, the caecum has an average length of 875cm and a diameter of 12cm in Ox, a length of 30cm with 8cm diameter in the sheep and goat (Getty, 1975). Ruminant colon differs from the dog and horse colons by having a spiral ascending colon with three separate parts; proximal loop sigmoid, spiral loop (two centrifugal and two centripetal turns) and distal loop (Getty, 1975). The large intestine of horse is well developed and is about 7.8 – 8.0m in length. The horse is a simple stomached animal; fermentation of regurgitation is achieved in the caecum and ascending colon. The large intestine has sacculated appearance. Sacculation, otherwise known as "haustra", is the result of contraction of longitudinal muscle bands, otherwise known as "taenia". The caecum is particularly large and comma shaped. In the pigs, the large intestine is about 60-75 cm in length; the colon has conical spiral shape. The caecum diverticulum is about 5cm long; the colon is like a question mark with a diameter of 2-3cm (Getty, 1975).The rectum runs as a straight midline tube through the pelvis, and ends in the anus just below the roof of the tail in rat and is about 80mm in length (Rudolf and Stromberg, 1976). They further observed that the fecal material is normally condensed into compact balls, and the wall is similar to that of the terminal part of the colon in this species. In man, rectum is reported to be 12cm in length (Haroldy, 1992). Haroldy observed that the rectum is straight in lower mammals (hence its name) but is curved in man to fit the sacral hollow. He described the gross anatomy of this organ in man to consist of valves of Houston, projecting left, right and from above downwards. The anal canal is 4cm long and is directed downwards and backwards from rectum to end at the anal orifice. Forming the walls of the anal canal is a complicated

muscular arrangement which constitutes a powerful sphincter mechanism; the internal sphincter and the external sphincter (Haroldy, 1992).

Histological Features: The large intestine consists of mucous membrane with no fold except in its distal (rectal) portion. The villi are absent. The epithelial lining is made up of columnar cells and the cells have short, irregular microvillus, suggesting an absorptive function for these cells (John, 1986).The intestinal glands of *Lieberkuhn* (crypts) are long and characterized by abundance of goblet cells and a small number of endocrine cells. Dellmann and Brown (1987) described the characteristics of large intestine to include: the absence of villi; the longer, straighter, more compact intestinal glands with large goblet cells. *Plica circularis* are absent. Histologically, it is difficult to distinguish the various portions of the large intestine. The large intestine has the same layers like the small intestine. The tunica mucosa is lined by simple columnar epithelium and contained in the sub-layer are the glands, goblet cells, stem cells and lymphocytes. The lamina propria is composed of loose connective tissues with numerous lymphatic vessels, collagen, lymphocytes and plasma cells and lastly, lamina muscularis mucosa. Tunica submucosa is similar to that of the small intestine. And tunica muscularis has inner circular and outer longitudinal layers. The outer is organized into three separate bands known as taenia coli (John, 1986). It has been documented that the epithelium of colon contains at least five types of cells: vacuolated, columnar, entero-endocrine, caveolated and goblet, all of which are believed to originate from the same stem cells. It is probable, however, that the cells called "*vacuolated*" cells may be of more than one type and may vary in morphology with species. Histologically, at the recto-anal junction the epithelium changes abruptly from columnar to stratified squamous. In this region, the lamina propria contains a plexus of large veins (John, 1986). John (1986) further explained that the mucous membrane forms a series of longitudinal

folds termed, the rectal column of *Morgagni*. Haroldy (1992) described the columns of *Morgagni* in man to be present in the upper half of the anal canal that is lined by columnar epithelium. He observed that this structure is connected at the distal extremities by valve-like folds (the valve of Ball).

Histochemical Features: Pakowadee *et al.*, (2008) studied the colon of the goat using AB, PAS and AB-PAS and observed that the mucosal surface of the goat descending colon was lined with simple columnar epithelium and goblet cells and when the epithelium was reacted with PAS, mucous granules of goblet cells and striated border of columnar cells stained moderately to deep blue. However, they further observed that when the colonic epithelium was reacted with AB-PAS both structures at lower crypts were blue or red while those in the mucosa at the mucosal surface were deep purple. In the rectum, Oliveira and Fanta *(*2000) observed an increased number of goblet cells in the rectum and they stated that this is so because of the need to increased mucosal protection and lubrication for fecal expulsion. The presence of large mucous secreting cells provides a mucous layer around the fecal pellet, facilitating its release and protecting the epithelium. According to Grau *et al.* (1994) the thickening of the muscularis had been correlated with the temporary storage and expulsion of fecal material from this area.

2.8 Accessory Digestive Glands

2.8.1 The oral cavity

The oral cavity is the first part of the alimentary canal. The lips form the rostral border of the oral cavity while the oral cavity is continued caudally and laterally by the cheeks; dorsally by the mylohyoid muscles in the rabbit (Timothy, 1990).A transition from the hairy outer surface to the oral mucosa takes place along the edge from the corner of the mouth as far as to the caudal side of the incisor tooth. The oral cavity proper in the rabbit is formed by the gum rostrally, palate

dorsally, the tongue ventrally and the cheeks laterally (Timothy, 1990). The size and form of the oral cavity vary greatly in different breeds of dogs, the cavity being in some, long and narrow and others short and wide. The rima oris is very extensive, so that the labial commissure is opposite the third or fourth cheek tooth. The cheeks are loose and capacious, and their mucous lining smooth and more or less pigmented (Miller, 1965).

The oral cavity of the ox is shorter and wider than that of the horse and the vestibule is immobile, while the middle part of the upper lip and the surface between the nostrils are bare and is termed muzzle (Getty, 1975). The oral cavity of the horse is a long, cylindrical cavity, and when closed, it is almost entirely filled up with the contained structures, a small space remains between the roof of the tongue, the soft palate and the epiglottis. While the mouth of the pig was found to be relatively long, the length was found to be influenced by breed; the rima oris is extensive and the angle of the mouth being situated far caudal (Getty, 1975).

2.8.2 The tongue

Gross Features: The tongue is situated on the floor of the mouth between the rami of the mandible and is supported mainly in a sort of sling formed by the mylohyoid muscles (Getty, 1975). In the laboratory rat, the length of the tongue from its bilaterally compressed tip to the base of the epiglottis is about 30mm. Gustatory buds are abundant on the dorsal surface of the tongue. Well developed filiform papillae cover the rostral part of the tongue. The paired foliate papillae lie at the level of the third molar on the lateral aspect of the tongue (Rudolf and Stromberg, 1976). In rabbit, the tongue presents paired pin-head sized foliate papillae on the craniolateral aspect of the tongue. They are parallel folds of lingual mucosa located on the lateral border just rostral to the palatoglossal arch. They are covered with stratified squamous epithelium and have taste buds located in the epithelium on the side of the fold. The papillae are

separated by gustatory furrows into which the taste buds open (Fawcett, 1986). The vallate and the fungiform papillae are found on the rostrodorsal aspect. They are covered by a non-pigmented pale mucous membrane dorsally and ventrally and each measures about 140mm in length and 100mm in width. When the mouth is closed, the tongue is related to the hard and soft palates, laterally to the mandibles and ventrally it lies on the floor of the mandibular space (Timothy, 1990). In dogs, the tongue is wide and thin in front; thicker posteriorly and very mobile. It is not pigmented but has a bright red color. The dorsum is marked by a median groove which is thick and has short pointed filiform papillae with the free ends directed backwards. On the root, there are conical papillae .There are usually two or three vallate papillae on the caudal part of the dorsum where the conical papillae begin. Small foliate papillae are also present just in front of the cranial pillars of the soft palate (Miller, 1965). The tongue of the ox is often variably pigmented. The root and body are wider than that of the horse but the tip is pointed and has a rather narrow edge. It has fungiform and vallate papillae. The tongue of the sheep resembles that of the ox in form but its tip is comparatively smooth, the papillae are very numerous, but short and blunt (Getty, 1975). In the horse, the mucous membrane of the tongue presents numerous papillae. The filiform are fine, thread-like projections which stud the dorsum and the sides of the tip. The fungiform papillae are larger and easily seen. They are rounded at the free end and are supported by the neck. They occur principally on the lateral part of the tongue. The vallate papillae are normally two or three in number (Getty, 1975). In the pig, the tongue is long and narrow and the apex is thin. Two or three vallate papillae are present. The fungiform papillae are small and most numerous laterally, while the filiform papillae are soft and small (Getty, 1975).

Histological Features: The epithelium of the pig is stratified squamous type with varying degree of keratinization. It is thickest on the dorsal surface where it has thick stratum corneum and thinnest on the ventral surface where it may be non-keratinized. The filiform, conical and lenticular papillae facilitate the movement of ingesta within the oral cavity, while the fungiform, vallate and foliate papillae contain taste buds which are responsible for mediation of sense of taste, and differ in shape and are named according to their morphologic characteristics (Dellmann and Brown, 1987). The filiform papillae are slender with sharp pointed structures that have a mechanical function in the movement of food into and within the oral cavity. They project above the surface of the tongue and are covered by keratinized stratified squamous epithelium with a thick stratum corneum and they are supported by a highly vascularised connective tissue core (Dellmann and Brown, 1987). The lenticular papillae are flattened lentil-shaped projections on the tongue surface and occur mainly in ruminants. They are covered by stratified squamous epithelium and have core of dense irregular connective tissue (Fawcett, 1986). The fungiform are scattered among the filiform papillae and have dome-shaped upper surface in the horse and pig. The shape is suggestive of a mushroom thus the name fungiform. The papillae are covered by non-keratinized stratified squamous epithelium containing one or more taste buds on the upper surface.

The taste buds are sparse in the papillae of the horse and cattle and numerous in those of sheep and swine and abundant in those of carnivores and goat (Dellmann and Brown, 1987). The vallate papillae are located on the dorsum and rostral to the root of the tongue. They are large flattened structures completely surrounded by an epithelium lined by cleft or moat. They extend straight, if at all, above the lingual surface and are covered by a stratified squamous epithelium. The epithelium on the papillary side of the moat contains many taste buds. Mucous glands may

also be found beneath the papillae, but their secretary products are emptied onto the lingual surface (Kozma, 1974).

2.8.3 Salivary glands

Gross Features: The term is usually restricted to the three pairs of large glands situated on the side of the face and the adjacent part of the neck in all domestic species. Their ducts open into the mouth (Getty, 1975). Salivary glands are extremely complex organs that are known to secrete a wide range of substances (Young and Van Lennep, 1978). Although numerous histological, histochemical and ultrastructural interspecific differences have been documented (Nagato *et al.,* 1984; Philips *et al., 1977*; Tandler *et al.,* 1983, Tandler,1986; Young and Van Lennep, 1978), the basic histology of the gland appears to be conservative among mammals. For example the mandibular gland, which in bat sometimes is divided into separate principal and accessory glands (Pinkstaff *et al*., 1982) consists of secretory endpieces with a mixed population of cells, which are attached by intercalated ducts to intralobular striated duct of increasing caliber (Tandler, 1978). Timothy (1990) observed four types of salivary glands in the rabbits which are the sublingual, parotid; mandibular and the infraorbital salivary glands. The sublingual salivary gland is located at the ventrocaudal aspect of the tongue close to the root and is non-lobulated and elongated. The parotid glands are paired, lobulated and are located ventral to the ear. He also observed that the mandibular salivary gland is also paired, lobulated and located ventral to the parotid salivary glands. The infraorbital glands are paired, non-lobulated and are located below the median canthus of the eyes. However, Rudolf and Stromberg (1976) observed that the parotid salivary glands of the laboratory rat are flat with four to five distinct lobes; and the oval

compressed mandibular glands lie in the cervical region. Codon *et al.* (2003) observed two pairs of tubuloacinar exocrine salivary glands in the armadillos (*Dasypus hybridus);* the parotid and the mandibular. They further stated that these were surrounded by a capsule of dense connective tissue which penetrated towards the interior of the glands. The septum of this connective tissue, containing blood vessels and excretory conduits, divided the glands into lobes and lobules. The presence of sublingual glands was not observed.

In the dog, the parotid gland is small and is irregularly triangular in outline. The mandibular gland is usually larger than the parotid and rounded in outline, pale yellow in color and is enclosed in a fibrous capsule. The sublingual gland is pink in color and divided into two parts (Miller, 1965). In the pig, the parotid gland is large and distinctly triangular while the mandibular gland is small, reddish in color and oval in outline and is covered by the parotid gland. The sublingual gland has an arrangement similar to that of the ox (Getty, 1975). In the ox, the parotid gland is smaller and denser in texture than that of the horse and is red-brown in color; the mandibular gland is larger than the parotid and is pale-yellow in color. Meanwhile the sublingual gland consists of two parts, the dorsal and ventral parts, which are long and thin. The dorsal part is pale-yellow in color, while the ventral part is salmon pink. The parotid gland of the sheep resembles that of the ox in general but that of the sheep is darker in color and more compact in texture (Getty, 1975).

Histological Features: Codon *et al.* (2003) observed that the parotid glands are located cranial to the mandibular glands, having their posterior portion in close contact with the anterior part of the latter. They are composed exclusively of small serous acini with pyramidal cells having basal basophilic cytoplasm. The intralobular ducts are very numerous. There were intercalated ducts with columnar epithelium connecting the acini with the striated ducts. The mandibular salivary

glands are of greater size and are located caudal to the parotid glands and each has two lobes. The serous components of the lobe are formed by serous demilunes having occasional serous acini with remarkable well-developed interlobular duct.The posterior lobes are more in size and are mucous. Histologically, the parotid salivary gland is predominantly serous although occasionally, isolated mucous secretory units may occur in dogs and cat, and is made up of numerous lobular units and separated by thin connective tissue septa (Dellmann and Brown, 1987). Fawcett (1986) observed that the lobules of the parotid salivary gland consist of acinar secretory units formed by pyramid-shaped cells with basal nuclei and surrounded by well developed basophilic granular endoplasmic reticulum. The apex of each cell is filled with secretory granules, the zymogens, which initiate carbohydrate digestion. Myoepithelial cells (Basket Cells) located between the secretory cells and the basement membrane can be demonstrated by special stain (Dellmann and Brown, 1987). The narrow lumen of the acini opens into a short intercalated duct lined by narrow cuboidal epithelium. The intercalated duct joins a large striated or salivary duct lined by cuboidal or columnar epithelium (Fawcett, 1986). The interlobular ducts are recognized as the largest structures within the lobules and participate in secretory process by transport of ions and water and possibly excretion of salt (Fawcett, 1986). These ducts are lined by simple columnar epithelium which changes to stratified columnar epithelium as the duct becomes larger and fuses with similar ducts draining other lobules. The interlobular ducts converge to form the main parotid duct which opens into the oral cavity and the epithelium changes to stratified squamous epithelium (Dellmann and Brown, 1987). The mandibular salivary gland is a compound branched tubulo-acinar gland composed of both mucous and serous acini and its morphology varies from specie to specie, but generally consists of a tubular unit with an enlarged endpiece (Fawcett, 1986). The serous secretion reaches the

lumen through small canaliculi located between the mucous acinar cells. Variation of this basic pattern may include separate serous and mucous units or mucous tubular units with enlarged serous acinar endpiece (Dellmann and Brown, 1987). Asoje and Aire (1986) stated that the mandibular salivary glands of the AGR and guinea pig had only serous acinar.

In dog and cat, the mucous elements predominate and even demilune cells react in some degree to histochemical test for mucus (Fawcett, 1986). Myoepithelial cells occur between the base of the epithelium cells and the basal lamina. The tubulo-acinar secretory units are connected to short intercalated duct that gives rise to striated ducts which have characteristics similar to those of parotid gland (Dellmann and Brown, 1987). The columnar epithelium of the interlobular duct gradually changes to two layered cuboidal epithelium and finally becomes stratified squamous epithelium before entering the oral cavity. Goblets cells may occur in the epithelium of the main duct (Kozma, 1974). The sublingual salivary gland is a compound branched tubulo-acinar gland. The number of mucous acini, serous demilunes and seromucous nature of their secretory products vary among species. Sublingual glands of the cow, sheep and pig are almost entirely mucous with few demilunes. In addition to the typical mucous acini and demilunes in the dog and cat, these glands contain clusters of serous acini with developed intercellular canaliculi (Dellmann and Brown, 1987).

Histochemical Features: Kimura *et al.* (1998) observed that all the major salivary glands are found in Haory Bamboo rats (*Rhizomys Purinosus*). The secretory endpieces of the parotid salivary gland are composed of a single type of cells and are not stained with alcian blue (AB) or periodic acid Schiff (PAS). Their ductal portions are weakly reactive with some lecithins but, acinar cells are not reactive with any lecithin. Kimura, *et al.* (1998) further observed that the sublingual glands existed rostral and adjacent to the mandibular gland and shared the same outer

membrane or capsules. These glands were composed of central cells but had some demilune secretory cells. Central cells reacted with alcian blue and periodic acid schiff. The mandibular gland secretory endpieces were composed of two types of secretory cells. One type which occupied most end pieces and did not react with Alcian blue. However, the other type stained with aniline blue, periodic acid schiff, and some lecithins. The granular duct which exists uniquely in submandibular glands in most rodents was not observed (Kimura *et al.*, 1998).Sozmen and Brown (1999) observed that in the acinar epithelial cells of the cotton-top tamarins are many fine granules of alcian blue positive staining and some large periodic acid schiff positive granules in the parotid salivary glands. Some duct epithelial cells contained a few small periodic acid schiff positive granules as well as more diffuse cytoplasmic staining. They further observed that the mandibular salivary gland acini consist of a mixture of mucous and serous cells. The mucous acini cells are cuboidal and pyramidal with basal nuclei and cells were pyramidal cells present at the periphery of mucous acini; they had basal nuclei which were large and rounded with finely granular chromatin and abundant pale cytoplasm.

2.8.4 The teeth

Gross Features: They are hard white or yellowish structures implanted in the alveoli of the bones of the jaws. Domesticated animals have two sets of teeth. The teeth of the first set appear during early life and are referred to as deciduous teeth. These are replaced during the period of growth by the permanent teeth (Getty, 1975). The dental formula for the rabbit was found to be 2(1 2/1 C0/0 P 3/2 M3/3) =28 (where I = incisor, C = canine, P= premolar and M= molar) and were lodged in the socket or alveoli in the premaxilla, maxilla and mandibles, (Okerman, 1988; Stanbury, 1972; Timothy, 1990). Olds and Olds (1991) observed that laboratory rats have one incisor and three molars with no premolar and canine teeth in each half of the jaw 2

(1/1C0/0P0/0M3/3) =16; with the incisor growing continually and is honed by wear into sharp chisel specialized for gnawing. Timothy (1990) and Stanbury (1972) further observed that the two incisors are situated not beside each other but one behind the other, though the second incisor is however, smaller. The upper incisor is chisel-like and sharp and is referred to as "pig tooth" (Okerman, 1988). The lower incisor corresponds in shape with the upper except for its size (Timothy, 1990). He further observed that the premolars were three in the upper jaw and two in the lower jaw while the molars were three in both the upper and lower jaws. The molar resembles the premolar. Rabbits have, in their dentition, the usual gap characteristics of herbivores i.e. the absence of canine tooth, the diastema which allows room to maneuver the bulky food and provide space for the cheek pouch (Stanbury, 1972).

All the teeth in the dog have short crown and are placed almost vertical and close together in the jaw bones. They do not correspond to the opposing teeth, but rather to parts of other teeth of the jaw. The canine tooth is large, conical and curved (Miller, 1965). The sheep incisor tooth forms a narrow and strongly curved arch. The crown is long and narrow; the labial surface is strongly convex and ends up at a sharp edge which is used in cropping grass. The cheek tooth resembles that of the ox but has a thinner layer of cement (Getty, 1975).The pig has a full number of teeth possessed by the primitive placental mammals. The incisor teeth, the canine teeth (Tusks) and the cheek teeth are present (Getty, 1975).The incisor tooth of the horse has a peculiarity of presenting, instead of a simple cap of enamel on the crown, a deep invagination, the infundibulum, which becomes partly filled with the cement. In the mare, the canines are usually very small and do not erupt, reducing the number of teeth (Getty, 1975).In the Ox, the incisors are absent from the upper jaw. The incisors in the lower jaw are arranged in a somewhat fan-like

manner and are simpler teeth without infundibulum. The cheek teeth resemble those of the horse in number and general arrangement (Getty, 1975).

2.8.5 The liver

Gross Features: The liver is a large gland located in the upper right portion of the abdomen and under the diaphragm (Sylvia, 2002). It is the largest accessory organ in the body. It is a solid, reddish-brown organ situated mainly on the right side of the body and in contact with the undersurface of the dome of the diaphragm, most of the organ thus enjoying the protection of the lower ribs (Basmajian, 1964). The liver has two main lobes, which cross the midline and lie above the stomach (Sylvia, 2002). The fresh liver is deep red in color, firm in consistency but friable. The size and weight of the liver vary greatly because it stores fat and glycogen, and the liver usually decreases with age (Ojo *et al.,* 1987). The color of the liver varies with such factors as the amount of blood it contains, the species, the age of the animal, but primarily with the nutritional status of the animal and type of food eaten prior to death. In suckling, pregnant and animals on fattening diet, the liver has a yellowish brown color while emaciated or starving animals have a dark reddish brown color (Ojo *et al.,* 1987). In situ, the liver molds itself readily to the neighboring structures but flattens out when removed from the carcass in the fresh state (Ojo *et al.,* 1987). The serosal covering gives the liver a smooth and glossy appearance (Ojo *et al.,* 1987). The lobes of the liver are left, caudate, quadrate and right lobes (McMinn, 1994).The liver is held in place by a system of mesenteries posteriorly and it is also attached to the diaphragm by the falciform ligament. Additionally, most of the liver is covered by visceral peritoneum (McMinn, 1994).

The liver of the cat is relatively large, weighing usually about 3 percent of the body weight. It is divided into six chief lobes by fissures which converge at the portal fissure. These include the

left lateral lobe (the largest), the left medial lobe, and the right medial lobe which is somewhat tongue-shaped, the quadrate lobe, the right lateral lobe, and the caudate lobe which further consists of two parts: the caudate process on the right and the papillary process (on the left) both of them being subdivided by secondary fissures (Getty, 1975). In birds, the liver is dark brown and the weight of the liver increases 33.9 folds between hatching and maturity. The liver has left and right lobes which join cranially in the midline. The liver is slightly more caudally situated in the male than in the female (Getty, 1975).The fundamental structures of rat and human livers are similar, and the findings of Kogure *et al*. (1999) have demonstrated a new interpretation of the anatomy of the human liver. The liver of rat is mahogany-brown in color with four lobes -left, middle, right, and caudate (Kogure *et al*., 1999; Olds and Olds, 1991). The left and middle lobes form a single lobe but the middle lobe has a deep notch to which the round ligament is attached (Kogure, *et al*., 1999). Rudolf and Stromberg, (1976) observed that most of the liver of the laboratory rat is situated in close contact with the diaphragm within the rib cage and ventrally, it extends along the abdominal wall beyond the ribs. The diaphragmatic surface is strongly convex. The visceral surface is in contact with the stomach, descending duodenum, transverse colon, jejunum and spleen. Dorsally, the esophagus runs across the strongly indented obtuse margin giving rise to the esophageal impression (impression esophagica). A deep fissure divides the liver into left, middle and right lobes. The left consists of a great left lateral lobe joined to the other lobes only by means of interstitial tissue and vessels, and a smaller left medial lobe, situated cranial to the first. It is separated from the middle lobe by a deep fissure which receives the insertion of the falciform ligament. The liver of rat makes up 4.15% of the body weight (Caster *et al*., 1956; Webster *et al*., 1974). The liver of the rabbit was found to be made up of five lobes while that of the chicken was made up of two lobes (Timothy, 1990).

The liver of the dog is divided into four lobes and four sub lobes, as well as two processes, by deeply running fissures. They are the left hepatic lobe which is divided into two sub lobes –left lateral hepatic lobe and left medial hepatic lobe; the quadrate lobe; the right hepatic lobe - divided into medial and lateral sub lobes; the caudate lobe divided into papillary process and caudate process. The average weight of liver in adult mongrel dogs of both sexes was 450gm.The average weight of these dogs was 13.3kg. Thus the weight of the liver averaged 3.38 percent of the body weight. The liver is relatively much heavier in puppy than the aged dog (McMinn, 1994).In equine; it is situated obliquely on the abdominal surface of the diaphragm. Its highest point is at the level of the right kidney. The greater part of it lies to the right of the median plane and its average weight is about 5kg but in large draft horse, it weighs about 10kg. It presents, for description, two surfaces: diaphragmatic (parietal) surface and visceral surface with the following features, the portal fissure, gastric impression, duodenal impression, colic impression, caecal impression and four borders. The dorsal border is thick and has the renal impression, a notch and a deep esophageal impression. The vertical border is thin and marked by three deep interlobar fissures which partially divide the organ into four lobes- right, caudate, quadrate and left lobes and several small fissures, right border, left border. The lobulation of the horse liver is not usually distinct and also quite friable (Getty, 1975). In the horse, the left lobe is undivided. The caudate lobe presents several notches on its border and is separated from the right lobe by a deep interlobar notch. The caudate lobe has a caudate process but no papillary process (Ojo *et al.,* 1987). In ruminants, the liver lies almost entirely to the right of the median plane, being rotated 90 degrees from its position in the embryo and in most mammals, so that the right lobe is dorsal and the left lobe is ventral. The average weight of bovine liver is 4.5- 5.5kg, while those of the sheep and goat are 550-700gm. The gall bladder fossa and the fissure for the round

ligament are more distinct in the sheep and goat than in the ox. The lobation of the ruminant liver is more distinct in the sheep and goat than in the ox. There are four lobes in the ruminant liver- the right, left, caudate and quadrate lobes. The caudate lobe has two processes, the smaller and variable papillary process, and the large, elongated caudate process. The liver is in contact with the right abdominal wall from the ventral end of the seventh rib to the last rib with much of it covered by the lung. In the sheep and goat, the area of the liver exposed caudoventral to the basal border of the lung is larger. It occupies 7-9 intercostals spaces between the lung and the costochondral junctions (Getty, 1975).The liver of porcine is relatively large, its average weight in the adult being about 1.5-2.0kg. It is thick centrally but the circumference is thin. It is divided by three deep interlobar fissures into four principal lobes- right lateral, right medial, left medial and left lateral (the largest) lobes. There is the caudate lobe on the dorsal part of the right lateral lobe and the caudate process which projects to the right dorsally (Getty, 1975). There is no papillary process but there is the quadrate lobe (Getty, 1975; Ojo *et al.,* 1987).

Histological Features: The liver is bounded by a connective tissue capsule which extends into its substance as highly branched septae. The basic functional unit of the liver is the liver lobule. A single lobule is about the size of a sesame seed and is roughly hexagonal in shape. The liver contains approximately 10,000 lobules that serve as the functional units of the liver (Sylvia, 2002).The classic liver lobule is the basic structural unit of the mammalian liver. It is best illustrated in the liver of the pig which has interlobular connective tissue. The classic liver lobule is a five to seven sided polygon. The hepatic cells are arranged in a series of plates or sheets of cells of one cell thick which extend from the periphery of the classic lobule to the central vein. The bile canaliculi have no walls of their own; they are simply spaces between adjacent hepatic cells. The sinusoids, however, are lined by reticuloendothelium. Lobules are almost impossible

to miss in porcine liver, but one should also be able to recognize them in other species (Sylvia, 2002).

Although the precise boundaries of lobules are sometimes difficult to discern, orienting of central veins and portal tracts allow "easy" identification. The connective tissue from the capsule extends into the interlobular spaces and support the vascular system and bile ducts. A fine network of reticular fibers surrounds the cells and sinusoids. Smooth muscle cells may be present in the capsule and interlobular tissue. The capsule also contains nerve trunks, bundles, individual fibers and receptors. Interlobular tissue and trabeculae are scanty and difficult to see, except in the pig, which has distinct fibrous connective tissue septa surrounding each liver lobule. This accounts for the tougher nature of pork liver as food, as opposed to beef liver. The connective tissue supporting the branches of the hepatic artery, portal vein, bile ductile and a lymph vessel appears throughout any section of liver (Dellmann and Brown, 1987).The hepatic lobule is especially well delineated in pig because it is surrounded completely by connective tissue septa. In other species, the septa are less conspicuous and the parenchyma of one lobule appears to blend into adjacent lobules without a clear line of demarcation (Dellmann and Brown, 1987).The polyhedron-shaped liver cells or hepatocytes have a centrally located spherical nucleus with one or more prominent nucleoli and scattered clumps of chromatin. The cytoplasm contains mitochondria, the Golgi complex located near the nucleus, liposomes, glycogen, fat and pigment granules (Dellmann and Brown, 1987). Although the general liver morphology is similar in all mammals, there are some differences in structural features in apparently healthy laboratory rodents. These peculiarities are known to be influenced by a great variety of endogenous and exogenous factors. Incidence, intensity, development and disappearance of such elements as extramedullary haemopoiesis, polyploidy, intranuclear and intracytoplasmic inclusions depend

markedly upon genetics, age, hygienic condition, hormonal regulation and nutrition of the animals. It is concluded from this short review that the term "normal histology" should only be understood as being relative and that it may only be applied to a given, well defined animal population held under well defined conditions (Allen, 2002).

Allen (2002) stated that the liver has essentially four functions which include:

a) Gate keeping between the digestive and circulatory system,
b) Processing of toxic substances before they enter general circulation,
c) Storing and converting of nutrients for future use, and
d) The synthesis of most plasma proteins and secreting of bile into small intestine to break down fats.

2.8.6 The gall bladder

Gross Features: In chicken, the fusiform gall bladder lies on the visceral surface of the right lobe (Getty, 1975).The gallbladder of the dog is a pear-shaped, muscular sac attached to the surface of the liver. Bile is produced by the liver and any excess is stored in the gallbladder (Sylvia, 2002). The gallbladder of the dog and cat lie in between the two parts of the right medial lobe and, usually they do not reach the ventral border of the liver (Getty, 1975).Its rounded extremity or fundus projects beyond the liver and is in contact with the anterior abdominal wall at the point where the border of the right *rectus abdominis* crosses the ninth costal cartilage. It is a reservoir for bile with a capacity of about 50ml (Basmajian, 1964; McMinn, 1994) but it is not vital for life. Some animals possess gall bladders, while others do not (Basmajian, 1964). The Horse, the deer and the rat do not have gall bladder (Gardner *et al.*, 1963). The gall bladder lies in a fossa on the visceral surface of the liver (Ojo *et al.*, 1987; McMinn, 1994; Gardner *et al.*, 1963). Its capacity in beagle-sized dog is 15ml (Mann *et al.*, 1920).The gall bladder is a vesicular

organ that stores and concentrates the bile produced by the liver (Dellmann and Brown, 1987; McMinn, 1994). It is attached in the fossa between the quadrate and right medial lobes of the liver (Getty, 1975).The gall bladder is 10-15cm long in the ox, and lies partly in contact with the visceral surface of the liver, to which it is attached, but largely against the abdominal wall at the ventral part of the tenth or eleventh rib (Getty, 1975).

Histological Features: Its mucosa is characterized by high primary folds especially in the dog and cat but in other species, the folds are lower or almost absent. The gall bladder is lined by tall columnar epithelium (Dellmann and Brown, 1987; *Ojo et al.*, 1987).The hepatic and common bile ducts are similar in structure to that of gall bladder. Both circular and longitudinal muscle layers are present. The muscle is thickest in the bovine species and thinnest in carnivores. In the other domestic animals, the muscle layer is discontinuous (Dellmann and Brown, 1987).

2.8.7 The pancreas

Gross Features: The pancreas, an elongated gland, is located behind the stomach. The pancreas consists of a head, a body and a tail (Gardner *et al.*, 1963). It is both an exocrine and an endocrine gland. The exocrine portion consists of secretory units, the pancreatic acini. The endocrine portion of the gland consists of small clumps of cells, the pancreatic islets, which are scattered throughout the pancreas (Gardner *et al.*, 1963). The pancreas lies deep in the abdominal cavity, resting on the posterior abdominal wall. It is an elongated and somewhat flattened organ (Sylvia, 2002). It is a soft, pliable, solid and fragile organ lying entirely behind the posterior parietal peritoneum (Basmajian, 1964). In outline, it has the shape of a chemist's retort (McMinn, 1994; Basmajian, 1964) or resembles the upper end of a thick walking stick or hook (McMinn, 1994) but it is flattened from front to back and is about six inches long. Its head occupies and overflows the concavity of the duodenum and lies in front of the bodies of the first

and second lumbar vertebrae. Its elongated body about one inch wide and six inches long is continuous with the upper part of its head and crosses almost horizontally to the left in front of the middle of the left kidney to reach the spleen; this terminal part of the organ is called its tail (Basmajian. 1964). The pancreas is pale red when fresh but after death it rapidly decomposes because of autolysis from the intestine (Ojo *et al.,* 1987). The pale yellow or reddish pancreas of chicken has dorsal, ventral and pelvic main lobes (Getty, 1975). Malenitz and Calhoun (1958) observed no difference between the pancreas of the turkey and that of the chicken.The bird's pancreas is made up of dorsal, ventral and splenic lobes, which are positioned between the ascending and descending lobes of the duodenum (Rawdon, 1998). Moreover, quail pancreas contains a third lobe positioned between the dorsal and ventral lobes but neighbors' with descending loop of the duodenum (Simsek and Alabay, 2008). The pancreas is composed of exocrine and endocrine compartments; the exocrine tissue which secretes the pancreatic digestive juice and the endocrine tissue which secretes the hormone insulin, glycogens, somastin and pancreatic polypeptides for the control of the carbohydrate metabolism (Ku *et al.,* 2000; Motta *et al.*, 1997). The exocrine pancreas is formed by acinar cells and excretory ducts with small and large diameters. The cytoplasms of the acinar cells are richer in rough endoplasmic reticulum (ER), mitochondria of the crista type, free ribosomes and zymogen granules (Motta *et al.,* 1997). Centro-acinar lumina of acini produce fluid rich in sodium and bicarbonates. The pancreatic juice empties from highly branched duct system into the duodenum via the ampulla of vater (Egerbacher and Bock, 1997).The endocrine pancreas of mammals is made up of islets of langerhans which are distributed throughout the exocrine pancreas, and are more numerous in the tail lobe than other lobes. These islets are formed by alpha, beta, delta and pancreatic polypeptide cells. The insulin and glycogen hormones are produced in their greatest amounts by

the beta and alpha cells which decrease and increase blood glucose levels, respectively. Delta cells release somotostain which inhibits the release of glycogen and insulin hormones, but pancreatic polypeptide hormones inhibit the exocrine pancreas secretion (Gulmez *et al.*, 2004; Ku *et al.*, 2002; Lucini *et al.*, 1996; Mikam and Mutoh, 1977; Rawdon, 1998). The pancreas in rat is diffuse and part lies within the U-shaped bend of the duodenum and from here it ramifies through the gastro-splenic omentum. The characteristic U-shape of the duodenum encloses one part, the 'head' of the pancreas (Olds and Olds, 1991).One part is embedded in the mesoduodenum and the beginning of the mesojejunum (body and right lobe); a branched, flattened part (left lobe) runs along the dorsal aspect of the stomach and is embedded in the dorsal part of the greater omentum (Rudolf and Stromberg, 1976). The weight of the gland varies from 550mg (at 100g body weight) to 1g (at 300g body weight) (Richards *et al*., 1964). In dogs, the pancreas is located within the upper abdominal cavity in close proximity to the stomach, liver and small intestines. The pancreas is composed of two lobes. The right lobe is located near the descending part of the duodenum, which is the first segment of the small intestines. The left lobe of the pancreas lies next to the stomach with a small central portion that joins the lobes (Spiefman, 1999). The pancreas is located in the dorsal part of both the epigastric and the mesogastric abdominal segments, caudal to the liver. The pancreas of the carnivores (dog and cat) is V-shaped, consisting of two long narrow lobes, the right lobe and the left robe, which meet at an acute angle caudal to the pylorus (Spiefman, 1999).Sheep and goat have only one pancreatic duct and it opens into the common bile duct. The entire pancreas of the cow is drained by the accessory pancreatic duct (of dorsal pancreatic primordium). In the horse, both ducts are functional, but in the pig, the accessory duct may be absent. The pancreas is very similar to the parotid salivary gland in histologic structure. However, it can be distinguished by the presence of

pancreatic islets and centroacinar cells and the absence of striated interlobular ducts (Dellmann and Brown, 1987). In equine, the pancreas is situated transversely on the dorsal wall of the abdomen, the greater part being to the right of the median plane. Its central part lies under the seventeenth thoracic vertebra. When fresh, it has a reddish cream color. It resembles the salivary glands in appearance but it is softer and its lobules are more loosely united. Its average weight is about 350g. It is triangular in outline and presents for description two surfaces: - dorsal and ventral surfaces; three borders: right, left and caudal borders, and three angles (Getty, 1975).

In ruminants, the pancreas is located almost entirely to the right of the median plane. It weighs 350-500gm in the ox; 50 - 70gm in the sheep and goat. It consists of a large right lobe and a smaller left lobe (Getty, 1975).In porcine, the pancreas extends across the dorsal wall of the abdominal cavity caudal to the stomach. It is tri-radiate or triangular. It has the right lobe, left lobe and the middle portion. The interlobular tissue usually contains a good deal of fat. (Getty, 1975).

Histological Features: The overall appearance of the pancreas is that of a serous gland. At a first glance, it may be possible to confuse the pancreas with other serous glands, such as the parotid gland. At low magnification, the pancreas is subdivided into numerous lobes and lobules with connective tissue between the lobes and lobules (Slomianka, 2006). It is designated as a tubulo-alveolar gland, which is divided into lobes and lobules by extensions from the thin connective tissue capsule. It consists of three main structural components: the acini, the system of ducts and the islet of Langerhans. The acini consist of a single row of pyramidal epithelial cells resting on a basement membrane and converging toward a central lumen in which the centro-acinar may be seen.The stroma of the pancreas consists of the thin capsule which gives rise to delicate connective tissue septa separating the parenchyma into distinct lobules. The lobule is composed of secretory units and

intralobular ducts. The secretory units are tubuloacinar, with the tubular portion more prominent in ruminants (Dellmann and Brown, 1987). The ductular system of the pancreas which may be included in the centroacinar cells comprises the main excretory duct, the interlobular and the intralobular or intercalated ducts (Bertelli and Bendayan, 1997).The microscopic structure of the pancreas of the laboratory rat is that of a sero-tubular gland with sparse interstitial tissue within the excretory lobules and scattered spherical endocrine cell clusters (islet of langerhans) (Rudolf and Stromberg 1976). Spiefmann (1999) stated that the pancreas has two main functions; first, it produces and stores digestive enzymes and fluids. Pancreatic juice is secreted (released) into the intestinal tract in response to eating of food. The pancreatic juice contains enzymes needed to digest proteins, carbohydrates and fats. Secondly, the pancreas produces and secretes hormones vital to the regulation of blood sugar. When the beta cells detect an increase in the blood sugar concentration, insulin is released directly into the blood where it acts to carry glucose into the body cells. The higher the blood sugar, the more insulin is secreted. Thus, insulin lowers the blood glucose concentration. The hormone, glucagon, acts to increase the blood sugar and is released when the blood sugar is low.

CHAPTER THREE MATERIALS AND METHODS

3.1 Animal Source

Forty adult African giant rats, (AGR) *Cricetomys gambianus,* of both sexes were captured alive in the wild around Samaru and Bomo villages in Zaria, Kaduna State, Nigeria from January to April 2009 using metal cage traps. They were transferred into standard laboratory rat cages in the Department of Veterinary Anatomy, Ahmadu Bello University, Zaria and fed with commercial feed for a while before sacrifice. Water was given *ad libitum* during the period.

3.2 Experimental Design

The captured African giant rats were used for morphometric, morphologic, histologic and histochemical studies.

3.2.1 Morphometric studies

Forty of these rats were used for the morphometric study and each was weighed alive using a mettler balance (Model P1421) with a sensitivity of 0.1gm and the weight recorded in grams. Sex difference was not taken into consideration. Each rat was later sacrificed according to Adeyemo and Oke (1990) and placed on a lateral recumbency. The skin and fascia at the base of the ear and the caudal border of the mandibles were excised, and the parotid and mandibular salivary glands dissected out. The weights and lengths were recorded in grams and centimeters, respectively. The mouth of each of the rats was opened and a cut made through the masseter muscles. The articulating surfaces of the mandibles were dislocated using a handsaw to show the complete tongue. Each tongue was dissected out and its weight and length recorded. Another incision was made from the first cervical region up to the level of the pelvic region with the rat lying on a dorsal recumbency to show the esophagus and the content of the GIT. The entire GIT was exteriorized and the contents removed starting from the esophagus and the various segments

of the stomach (non-glandular and glandular), the small intestine (duodenum, jejunum and ileum), the large intestine (caecum, colon and rectum), the pancreas, gall bladder and the liver were weighed and their lengths measured and recorded. All these measurement were done using a Fatzun balance (model P141 with a sensitivity of 0.01 gm), a ruler and thread (in cm), respectively.

3.2.2 Morphologic studies

Photographs of the live AGR were taken before sacrificing, according to Adeyemo and Oke (1990). The buccal cavity of each rat was opened after sacrificing the rat and the tongue pulled to the side to show the tongue and teeth. The same rats were placed on a lateral recumbency while the skin and fascia at the base of the ear and the caudal border of the mandible were removed. The parotid and mandibular salivary glands were dissected out. Incisions were later made from the first cervical vertebrate up to the level of the pelvic region to show the various portions of the GIT in situ. These portions, in relation to other organs, were noted. Each entire GIT was exteriorized and stretched out to full length. The positions of the pancreas, gall bladder and the lobes of the liver were noted. Photographs of all the relevant structures were taken at appropriate times.

3.2.3 Histological studies

After sacrificing the rats according to Adeyemo and Oke, (1990) they were opened up and tissues were collected from the parotid and mandibular salivary glands, the esophagus, the stomach (non- glandular and glandular), the segments of the intestinal segments (small and large). These tissues were immediately fixed by complete immersion in 10% normal formalin and labeled and kept for two days. They were dehydrated through a series of graded alcohol (70%, 80%, 90%, 95% and 100%). They were later cleared in xylene and infiltrated with molten paraffin wax. Transverse sections of 5μ thick were cut from the embedded tissues using

disposable microtome knives. These sections were mounted on grease free clean glass slides and stained at room temperature using Haematoxylin and Eosin (H and E) method for routine histological studies.

3.2.4 Histochemical studies

For histochemical studies transverse sections from the embedded tissues were cut and stained with Alcian blue (AB), for acidic mucin identification, Periodic Acid-Schiff (PAS), for identification of neutral mucin and Alcian blue together with Periodic Acid-Schiff (AB-PAS) for the identification of both the neutral and acidic mucins.

Alcian blue (AB) staining procedure: Paraffin sections were deparaffinised, rinsed in water and immersed in 1% alcian blue (pH 2.5) solution for 5 minutes at room temperature. The sections were rinsed in water and counterstained with 0.5% aqueous neutral solution for 5 minutes and dehydrated, rinsed in absolute alcohol, cleared in xylene and mounted. Blue color is indicative of acidic mucin production.

Periodic Acid-Schiff (PAS) staining procedure: Dewaxed sections were washed in water and treated with periodic acid for 5 minutes, washed and covered with Schiff reagent for 15 minutes. The sections were washed with water again and stained with Harris Haematoxylin. The sections were finally dehydrated, rinsed in absolute alcohol, cleared in xylene and mounted. Pink color is indicative of neutral mucin production.

Alcian blue-Periodic Acid Schiff staining procedure: Dewaxed sections were immersed in 1% alcian blue (pH 2.5)solution for 5 minutes at room temperature; rinsed and treated with 1% periodic acid for 5 minutes; rinsed and exposed to schiff reagent for 15 minutes; rinsed and stained with Meyer haematoxylin for 3 minutes; dehydrated, cleared in xylene and mounted. The

presence of blue and pink color or magenta color is indicative of the production of both the acidic and neutral mucin.

The slides were studied using light microscope (Olympus binocular microscope) at x40 x100, x250 and x1000 magnifications. Photographs of the prepared slides mounted on the binocular microscope were taken using a digital camera. These pictures taken were transferred to a computer and detailed studies were carried on them. Relevant areas and structures were labeled and printed.

3.3 Statistical Analysis

Recorded weights and lengths studied were express as mean $\pm$ standard error of mean (M$\pm$SEM) using statistical package for social sciences (SPSS) version 17.

CHAPTER FOUR RESULTS

4.1 Gross Anatomical Features.

4.1.1 Weights and dimensions

The mean weight of the AGR was observed to be 1045.0 ± 28.06 g. The mean weight of the gastrointestinal tract was 58.18± 0.89 g which accounted for 5.56 % of the total weight of the animal. The mean weight of the esophagus was 1.39± 0.08 g accounting for 0.13 % of the total weight of the animal. The mean weight and the percentage of the stomach: Glandular and non-glandular stomachs were 19.47±0.26 g, 4.67± 0.08 g and 14.79± 0.21 g representing, 1.86 %, 0.45 % and 1.41 % of the total weight of the animal, respectively. The mean weight of the small intestine and its segments: duodenum, jejunum and ileum were 17.19 ± 0.30 g, 5.06± 0.11 g, 9.46 ± 0.20 g and 2.65± 0.07 g, representing 1.64 %, 0.48 %, 0.90 % and0.26 % of the total weight of the animal, respectively. Those of the large intestine and its segments: caecum, colon and rectum were 19.98± 0.39 g, 9.51 ± 0.21 g, 8.83± 0.21 g and 1.84± 0.07 g, accounting for 1.91 %, 0.85 %, 0.88 % and 0.18 % of the total weight of the animal, respectively.

The mean weight of the accessory digestive glands: parotid, mandibular, liver, pancreas gall bladder and tongue were 0.81 ± 0.03 g, 0.78 ± 0.02 g, 21.29± 0.43 g, 0.99 ± 0.03 g, 0.35± 0.16 g and 2.76± 0.61 g, respectively. The accessory digestive glands: parotid, mandibular, pancreas, gall bladder and tongue accounted for 0.08 %, 0.07 %, 0.01 %, 0.03 % and 0.27 % with the liver accounting for 2.03 %, respectively.

The large intestine was found to have the highest mean weight (19.98 ± 0.39 g) followed by the stomach (19.47 ± 0.26 g) and then the small intestine (17.19 ± 0.30 g), respectively. Of all the

digestive glands, the liver was found to have the highest weight (21.29 ± 0.43 g) and accounted for about 2.03% of the total body weight (Table 4.1).

Table 4.1: Morphometric Features of the Digestive System of the African giant rat (AGR) (g).

Parameters	Minimum Value (g)	Maximum Value (g)	Mean±SEM	% body wt
Body weight	800	1400	1045.0±28.06	100
Weight of GIT	47.70	69.20	58.18±0.89	5.56
Weight of esophagus	0.60	2.40	1.39±0.08	0.13
Weight of stomach	15.40	23.0	19.47±0.26	1.86
Weight of glandular stomach	3.90	5.80	4.67±0.08	0.45
Weight of non glandular stomach	11.10	18.00	14.79±0.21	1.41
Weight of small intestine	14.00	21.00	17.19±0.30	1.64
Weight of duodenum	4.00	7.00	5.00±0.11	0.48
Weight of jejunum	6.10	12.00	9.46±0.20	0.90
Weight of ileum	2.00	3.90	2.65±0.07	0.26
Weight of large intestine	15.40	25.70	19.98±0.39	1.91
Weight of caecum	5.90	11.40	9.51±0.21	0.85
Weight of colon	5.00	10.47	8.83±0.21	0.88
Weight of rectum	1.20	2.70	1.84±0.07	0.18
Weight of the tongue	2.00	3.70	2.76±0.61	0.27
Weight of the parotid gland	0.50	1.20	0.81±0.03	0.08
Weight of mandibular gland	0.50	1.00	0.78±0.02	0.07
Weight of liver	18.00	28.00	21.29±0.43	2.03
Weight of pancreas	0.60	1.40	0.99±0.03	0.01
Weight of gall bladder	0.20	0.60	0.35±0.16	0.03

n = 40, SEM = Standard Error of Mean.

The mean length of the gastrointestinal tract was found to be 213.32 ± 3.88 cm. The mean length of the esophagus was observed to be 11.78 ± 0.53 cm, accounting for 5.50 % of the total length of the gastrointestinal tract (GIT).The mean length and the percentage of the stomach and its segments: glandular and non-glandular stomachs were 15.80 ± 0.47 cm, 6.85 ± 0.231 cm and 9.06 ± 0.32 cm, accounting for 7.40 %, 3.20 % and4.30 % of the total length of the GIT, respectively. The mean length of the small intestine and its segments: duodenum, jejunum and ileum were 109.17 ± 28.68 cm, 20.15 ± 0.93 cm, 72.26 ± 2.39 cm and 16.25 ± 0.37 cm, respectively. The mean length of the large intestine and its segments: caecum, colon and rectum were found to be 75.78 ± 1.78 cm, 12.70 ± 0.37 cm, 57.30 ± 1.58 cm and 5.68 ± 0.26 cm, respectively. The length of the small intestine and its segments: duodenum, jejunum and ileum accounted for 51.20 %, 9.50 %, and 33.90 % and7.80 %, while the length of the large intestine and its segments: caecum, colon and rectum accounted for, 35.50 %, 6.0 %, 26.90 % and 2.60 % of the total length of the GIT, respectively.

The small intestine was observed to be the longest (109.17 ± 28.68 cm) followed by the large intestine (75.57 ± 1.78 cm).Out of all the intestinal segments (small and large), the jejunum was observed to be the longest (72.26 ± 2.39 cm) followed by the colon (57.30 ± 1.58 cm). The mean lengths of the tongue, the parotid and mandibular salivary glands were 4.62 ± 0.14 cm, 1.47 ± 0.04 cm and 1.68 ± 0.049 cm, respectively (Table 4.2).

Table4.2: Morphometric Features of the Digestive System of the African giant rat (cm).

Parameter	**Minimum Value (cm)**	**Maximum Value (cm)**	**Mean±SEM**	**% body wt**
Length of GIT	169.0	264.50	213.32±3.88	100.00
Length of esophagus	5.40	18.40	11.78±0.53	5.50
Length of stomach	9.50	23.00	15.80±0.47	7.40
Length of glandular stomach	3.50	10.40	6.85±0.23	3.20
Length of non glandular stomach	6.00	13.10	9.06±0.32	4.30
Length of small intestine	81.00	141.00	109.17±28.68	51.20
Length of duodenum	12.00	33.00	20.15±0.93	9.50
Length of jejunum	55.00	95.00	72.26±2.39	33.90
Length of the ileum	11.00	20.00	16.25±0.37	7.80
Length of large intestine	54.00	95.00	75.78±1.78	35.50
Length of caecum	9.00	17.00	12.70±0.37	6.00
Length of colon	39.00	74.00	57.30±1.58	26.90
Length of rectum	3.00	9.00	5.65±0.26	2.60
Length of tongue	3.80	8.80	4.62±0.14	
Length of parotid gland	1.00	1.90	1.47±0.04	
Length of mandibular gland	1.00	2.40	1.68±0.049	

n = 40, SEM = Standard Error of Mean.

4.1.2 Morphologic features.

*The oral cavity :*The upper lip(labium maxillae) was cleaved midsagittally by a deep hairless philthrum.The lip has three layers; the skin on the outside, the muscular layer in the middle and the mucous membrane that is pinkish and non pigmented on the inside. The lip forms the rostral border of the mouth and is continued with the gum caudally and the cheeks laterally. The caudal continuations of the cheeks form a pouch with great elasticity and are covered by the same layer as that of the lips. The caudal border of the buccal cavity is formed by the gum and is also pink, non- pigmented and forms the cranial border of the oral cavity. The oral cavity proper is formed by the gum rostrally, palate dorsally, the tongue ventrally and the cheeks laterally. The AGR has a dental formula of (I 2/2, C 0/0, P 0/0 M 3/3) =20, where: I, C, P, and M are the incisor, canine, premolar and molar teeth, respectively. Both upper and lower incisors, and the upper and lower molar teeth were found to be lodged in the maxillary bone and the mandibular bones, respectively. The upper incisor was found to be long, curved and covered with the enamel on the outer surface, giving it a chisel-like edge with their labial and buccal surfaces being convex and concave, respectively (Plate I).

The Esophagus: This was observed to be a direct continuation of the pharynx, extending from the pharynx to the cardia of the stomach. It was observed to lie dorsal to the trachea (Plate II), throughout its length until it enters the stomach at the non-glandular part (Plates V and VI).

The Stomach: The stomach of the AGR was found to be covered by the visceral surface of the liver cranially. Caudally, it made contact with the colon, jejunum, and ileum and dorsally with the left kidney, the abdominal wall and the spleen. The stomach was observed to be divided into glandular and non-glandular parts with the isthmus separating the two parts (Plate V). The

glandular part constituted of the following regions: cardia, fundus and pylorus parts, respectively. The non-glandular and glandular parts looked like a coma or C-shaped with blind sac-like ends (Plates IV, V). The opened stomach revealed thick glandular mucosa which was observed to be soft and velvety, while that of the non-glandular part was observed to be brownish in color with numerous soft towel-like papillae (Plate VI).

The Intestines: The intestines were observed to be divided into small and large. The small intestine was made up of the duodenum, the jejunum and the ileum. The duodenum was observed to be the first part of the small intestine and occupied the right dorso-lateral part of the abdominal cavity and had the largest diameter (Plates III, IV and VII). The jejunum was the distal continuation of the duodenum and was observed to be the longest part. It was differentiated from the duodenum by its folding nature and was made up of many folds held together by mesentery. The jejunum was related craniomedially to the caecum (Plates III, VII). The ileum was observed to be the distal continuation of the jejunum with the same diameter as the jejunum and only differed from the jejunum by the absence of folds seen on the jejunum (Plate VII).

The large intestine was made up of the caecum, colon, and rectum. The caecum was the largest segment of the intestine. It was large, a cone-shaped, blind-ended sac situated at the ileo-cecal junction (Plate VII). The colon was wrinkled in appearance with a wide lumen which contained fecal balls and had sacculations with a thick wall compared to the caecum (Plate VII). The rectum was observed to be the caudal continuation of the colon and was observed not to be wrinkled but had some fecal pellets therein. (Plate VII). The anal opening formed the caudal end of the gastrointestinal tract (Plate VII).

The Tongue: The tongue was observed to be a muscular organ that formed the ventrum of the oral cavity with its rostral portion bearing a longitudinal grove (median sulcus), which is about

one third the length of the tongue. Immediately after the median sulcus were numerous irregular folds (Dorsal lingual prominence) which extended to the lower quarter of the tongue. This muscular organ which formed the ventrum of the oral cavity was covered by numerous conical projections on its dorsal surface. From its tip were the filiform papillae and the fungiform papillae which were spread on the transverse groove and appeared as pale dot-like projections (Plate VIII).

The Salivary Glands: In this study, two salivary glands were seen (parotid and mandibular). The sublingual salivary gland was absent. The parotid salivary gland was observed to be paired, non-lobulated, elongated, canoe-like (Plate IX) and was located ventral to the ear. It was also located dorsal to the mandibular salivary gland and related cranial to the masseter muscles. The mandibular salivary gland was observed to be lobulated, paired, roughly square shaped (Plate X) and was located ventral to the parotid salivary gland.

The Liver and Pancreas: The liver was the most cranial organ in the abdominal cavity and occupied the cranial part of the epigastric region. It had two surfaces; the diaphragmatic and the visceral surfaces. The diaphragmatic surface was convex and the visceral surface, concave and had the impression of the stomach (Plate III). The liver was found to be divided into four lobes namely, the right, the left, the intermediate and accessory lobes (Plate XI). The left, the intermediate and the accessory lobes were subdivided into sub lobes (Plate XI). The liver was also observed to be dark red in color and had the stomach impression on its visceral surface (Plate II). The liver had gall bladder embedded on its visceral surface (Plate X). The pancreas was observed to be a thin layered diffused organ located in between the two folds of the duodenum held by duodenal mesentery and had a single duct, that opened at the ascending loop of the duodenum (Plate IV).



Plate I: Oral cavity of the AGR showing the incisors teeth (A) and the molar (B).

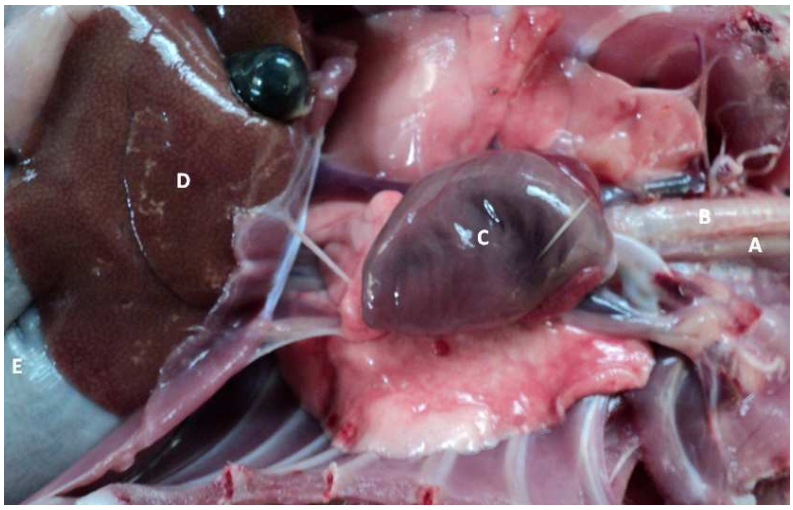


Plate II: Thoracic and abdominal viscera showing the esophagus (A) the trachea (B), the heart (C), the liver (D) and the stomach(E).

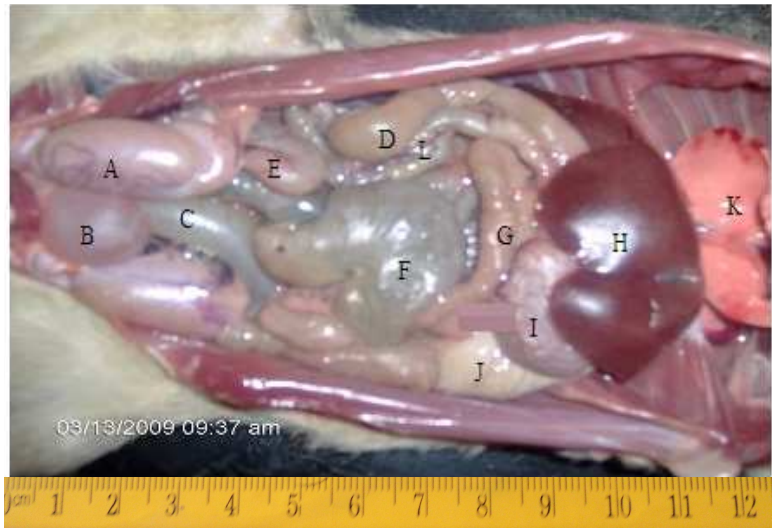


Plate III: Abdominal viscera of the AGR showing the testes (A), the urinary bladder (B), the rectum (C), the duodenum (D), the jejunum (E), the caecum (F), the transverse colon (G), the liver (H), the glandular stomach (I), the non glandular stomach (J), the lungs (K) and descending colon (L).



Plate IV: The reflected part of the GIT of the AGR showing the pancreas (A), the caecum (B), the duodenum (C), the glandular stomach (D), the non glandular stomach (E) and the kidney (F).

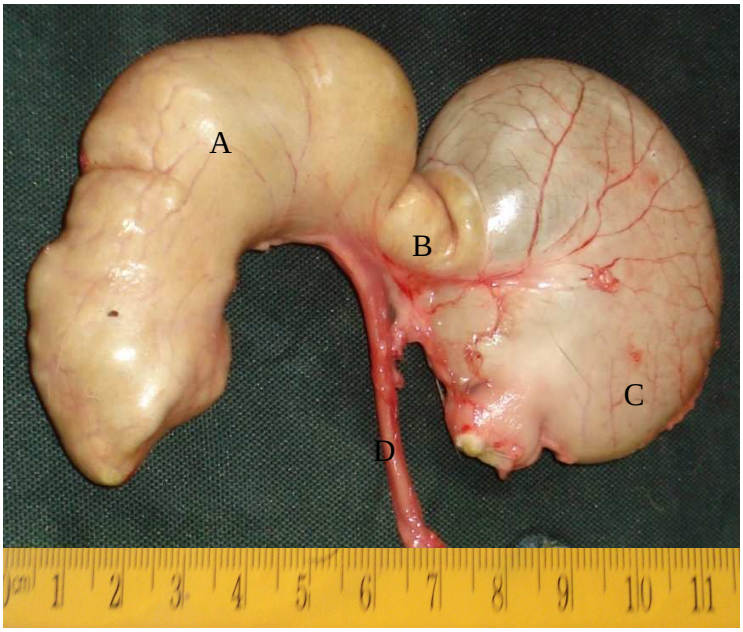


Plate V: The stomach of the AGR showing the non-glandular stomach (A), junction between the glandular and non glandular stomach (isthmus) (B), the glandular stomach (C) and the stump of the esophagus (D).

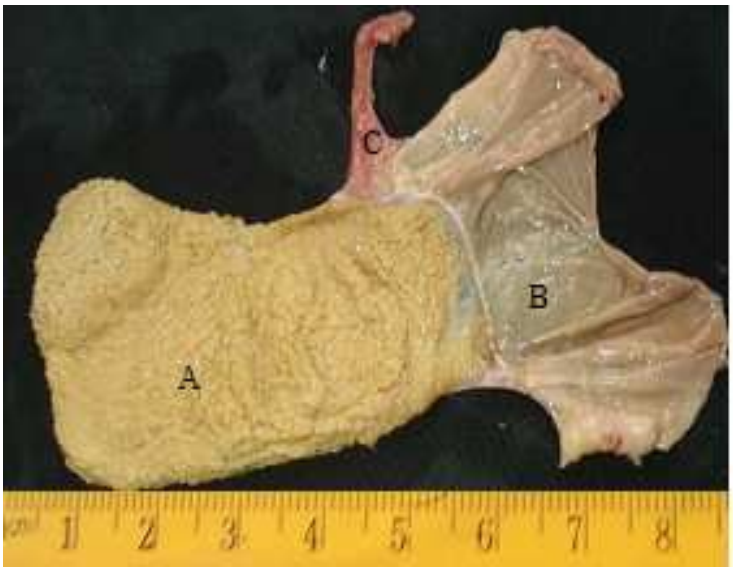


Plate VI: Internal surface of the AGR stomach showing the non-glandular Part (A), the glandular part (B) and the stump of the esophagus (C).

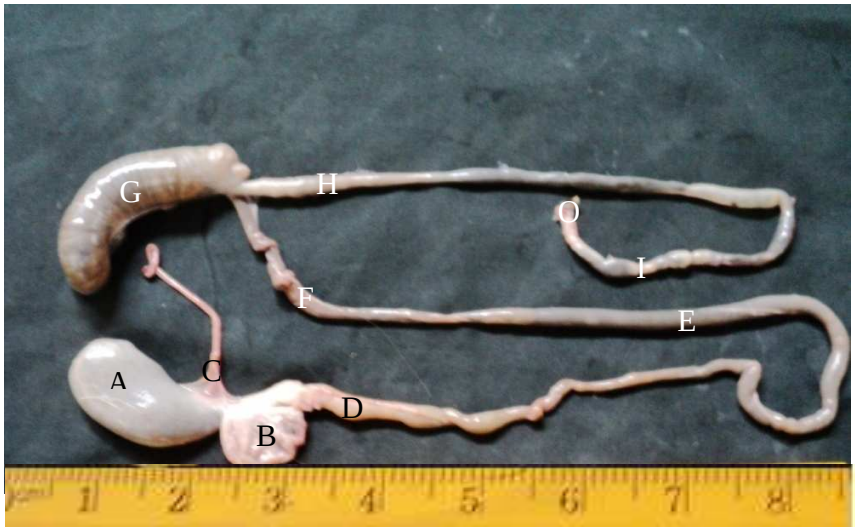


Plate VII: The GIT of the AGR showing the non glandular stomach, the glandular stomach (B), the esophagus (C), the duodenum (D), the jejunum (E), the ileum (F), the caecum (G), the colon (H), the rectum (I) and the anal opening (O).



Plate VIII: Dorsal surface of the tongue showing the radix of the tongue (A), dorsal prominence (B) and median sulcus (C) x5 magnification.

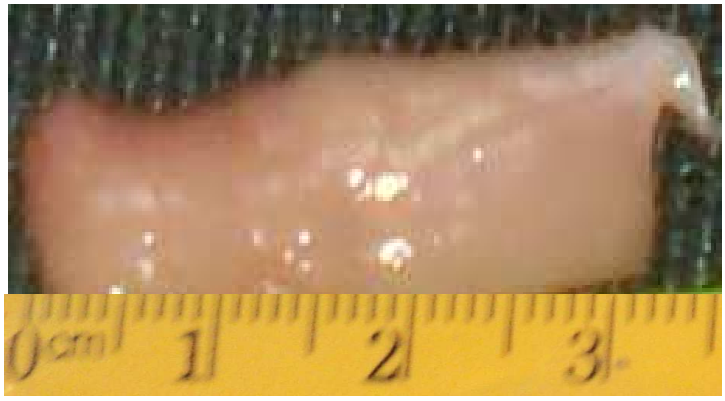


Plate IX: Non-lobulated parotid salivary gland x 10 magnification.



Plate X: Lobulated mandibular salivary gland. x10 magnification.

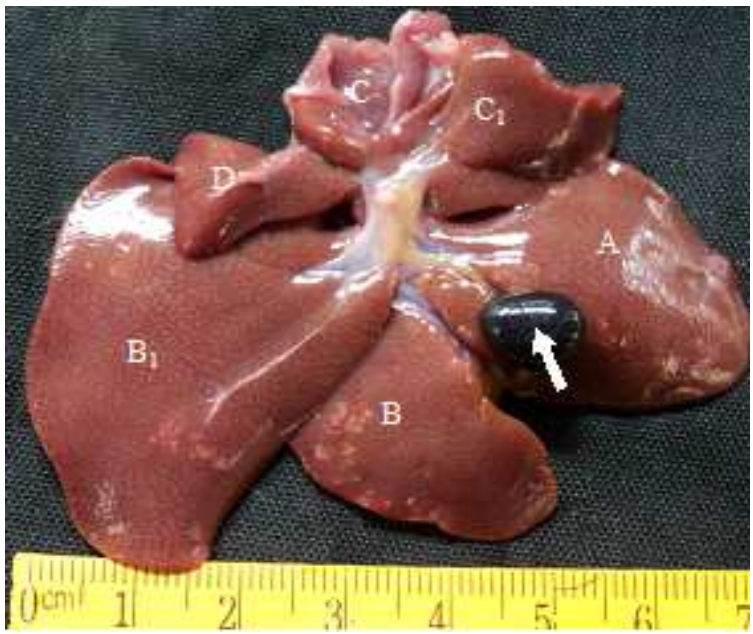


Plate XI: Visceral surface of the liver showing the right lobe (A), the left lobes (B & B_1), the intermediate lobes (C & C_1), the accessory lobe (D) and gall bladder (arrow).

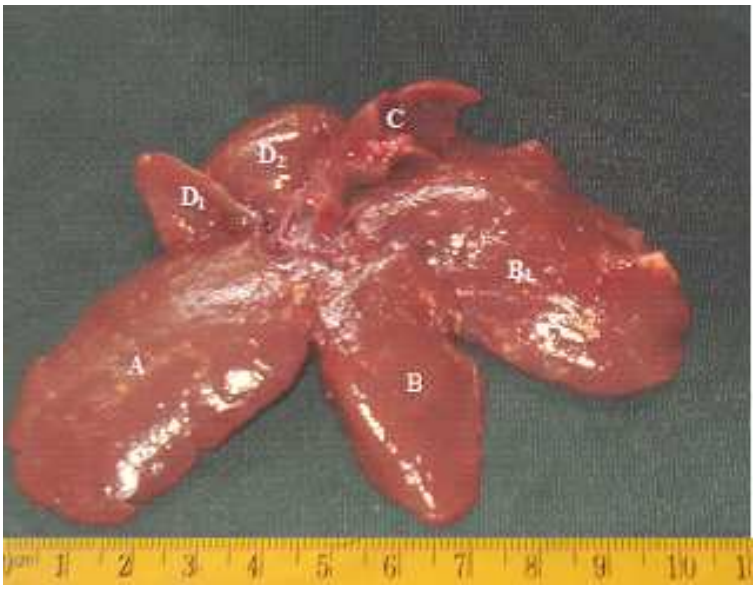


Plate XII: The Diaphragmatic surface of the liver of the AGR showing the right lobe (A), the left lobe (B & B_1), the intermediate lobe (C) and the accessory lobes (D_1 & D_2).

4.2 Histological Features

4.2.1 The Esophagus

The esophagus of the AGR was observed to be a short tube extending from the distal end of pharynx to the stomach (Plates II and V). Its epithelial layer consisted of stratified non-keratinized squamous epithelium lining the entire esophagus and had no lamina muscularis. There was no gland in the submucosa. The submucosa was made up of loose connective tissue (Plate XIII).

4.2.2 The Stomach

The stomach of the AGR was observed to be divided into non-glandular and glandular parts with an isthmus separating them (Plates III, IV, V and VII).The non glandular stomach was observed to have papillae which resembled those of the rumen of ruminants and were made up of keratinized stratified squamous epithelium (Plates XIV and XXIX). The lamina propria was found beneath the epithelium and consisted of collagens and reticular fibers. Glands and lamina muscularis were absent (Plate XIV). The submucosa was observed to contain connective tissues, while tunica muscularis was observed to contain longitudinal muscles; the tunica serosa was made up of collagens and elastic connective tissues (Plate XIV).The glandular stomach was observed to have same structural layers within the three regions and similar to those of other GIT sections. These layers include the following (from inside to the outside), the mucosa, submucosa, tunica muscularis and the tunica serosa, with the mucosa having numerous glands. Gastric pits were also found around the mucosa (Plate XVI). The muscularis mucosa was observed to be thin and had smooth muscles. The submucosa contained blood vessels and loose connective tissues (Plate XVI).

4.2.3 The Small Intestine

The small intestine had three segments (duodenum, jejunum and ileum). These three segments had many common histological features like the villi and some minor structural differences (Plates XVII, XVIII, and XIX).The duodenum had intestinal villi which were seen in the mucosa. Intestinal glands (Brunner's) were seen in the submucosa and were the major distinguishing features observed in the duodenum (Plate XVII).The jejunum was observed to have long leaf-like villi, which were mucosa projections with numerous intestinal glands (*crypts of Lieberkuhn*) that opened into pits between the bases of the villi and penetrated the mucosa as far as the muscularis (Plate XVIII). The ileum was observed to have villi and the intestinal glands around the mucosa. There were Payers patches in the submucosa, while the tunica muscularis had longitudinal muscles (Plate XIX).

4.2.4 The Large intestine

The large intestine was found to be subdivided into three segments: the caecum, colon and rectum. The four tunics or layers of the intestinal walls were the same with that of the small intestine. The intestinal glands were seen to be larger than those of the small intestine and the goblet cells were more numerous compared to those of the small intestine (Plates XX, XXI, and XXII). The caecum was observed to have numerous goblet cells and intestinal glands. Adipose tissues were found in submucosa and the tunica muscularis was made up of longitudinal muscle (Plate XX).The colon was observed to have a wider lumen than the small intestine. Simple columnar cells with abundant goblet cells were seen. The muscularis externa presented thick band of longitudinal muscles (Plate XXI). Like the colon and caecum, the rectum was observed to be made up of the goblet cells and intestinal glands which, were found to be more

numerous compared to those of the caecum and colon (plate XXII). All other features were found to be similar to those of the colon and caecum.

4.2.5 The Salivary glands

Two salivary glands were observed in the African giant rat (parotid and mandibular).The parotid salivary gland had only the serous acini (Plate XXIII and XXIV) while the mandibular salivary gland had both serous and mucous acini (Plate XXV).

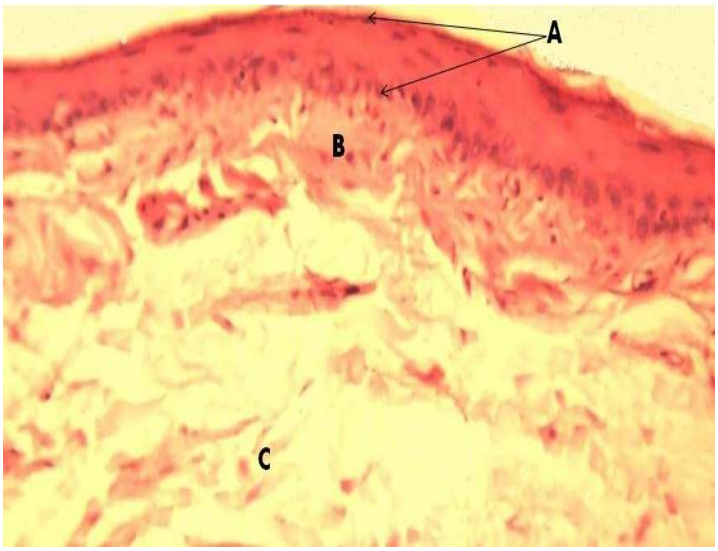


Plate XIII: Transverse section of the esophagus showing the non-keratinized stratified squamous epithelium (A), lamina propria (B) and the tunica submucosa(C).H&E x100.

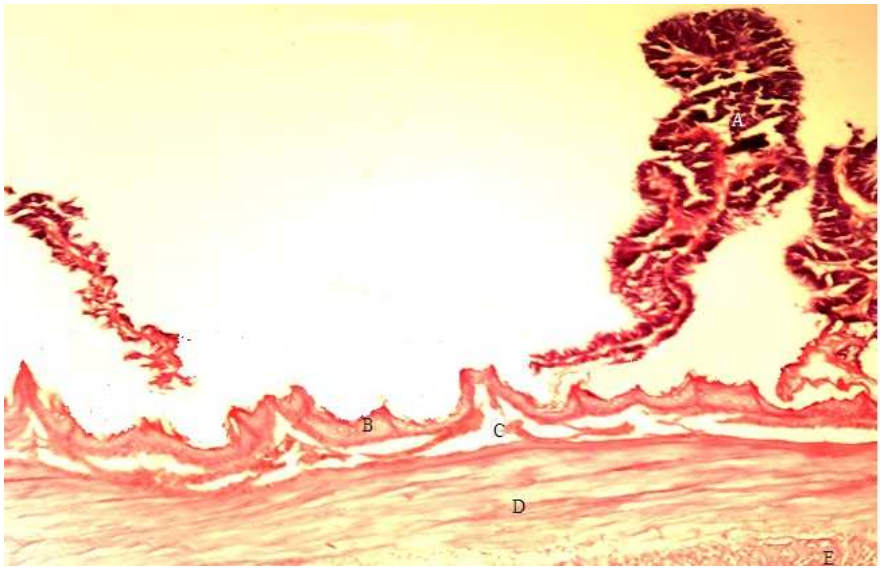


Plate XIV: Transverse Section of the non- glandular stomach showing papillae (A), keratinised stratified squamous epithelium (B), lamina propria (C),tunica muscularis (D) and tunica serosa (E). H&E x 40.

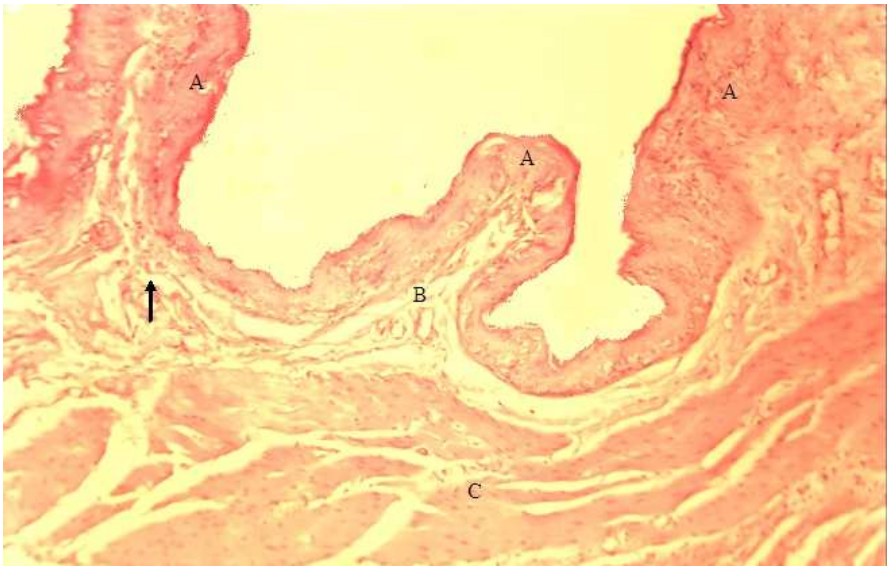
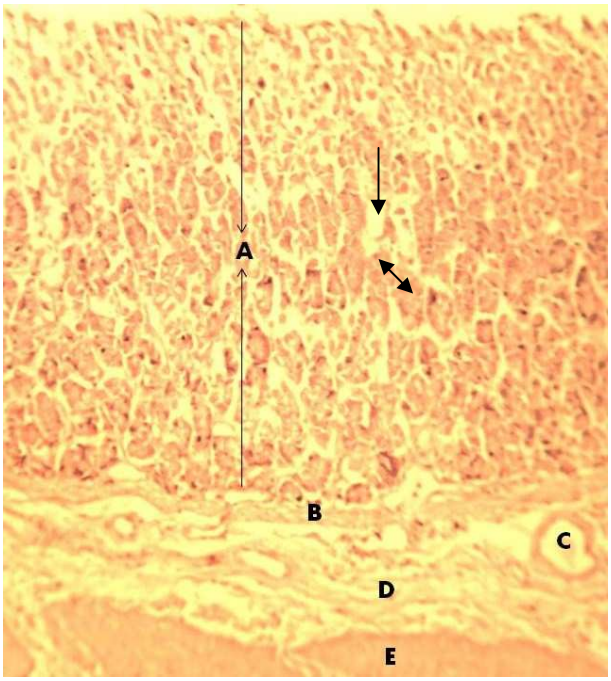


Plate XV: Tranverse section of the junction between the glandular and non- glandular stomach showing stratified squamous epithelium(A), lamina propria (B), tunica muscularis (C) and the arrow showing blood vessel. H&E x 100.



Pate XVI: Transverse section of the glandular stomach showing the mucosa (A), gastric pit (arrow), glands (double arrows), muscularis mucosa ((B), blood vessel(C), circular muscles (D) and longitudinal muscles (E). H&E x100



Plate XVII: Transverse section of the duodenum showing the epithelium (A), villus (B) and the Brunner's glands(C).H&E x100.



Plate XVIII: Transverse section of the jejunum showing the mucosa fold (A), mucosa(B), intestinal glands (C),lymphatic nodule(D) , submucosa(E), blood vessel(F)and tunica muscularis showing longitudinal muscles(G).H&E x40.

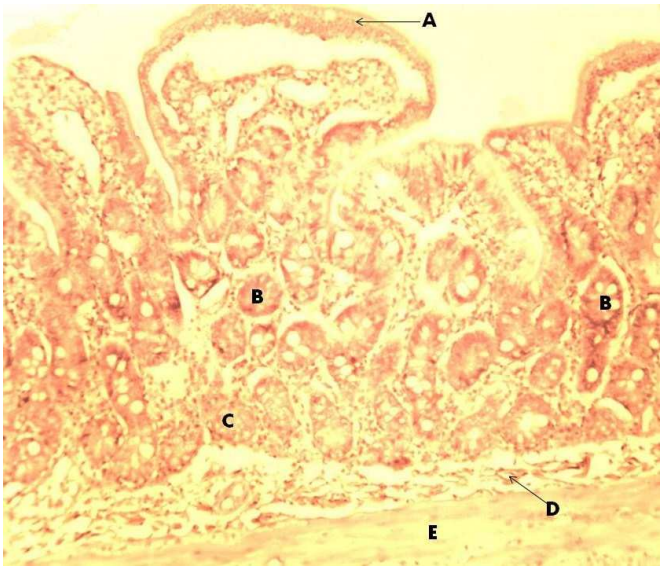


Plate XIX: Transverse section of the ileum showing the villi (A), intestinal glands (B), Payer's patches (C), blood vessel (D) and longitudinal muscle (E). H&E x100.

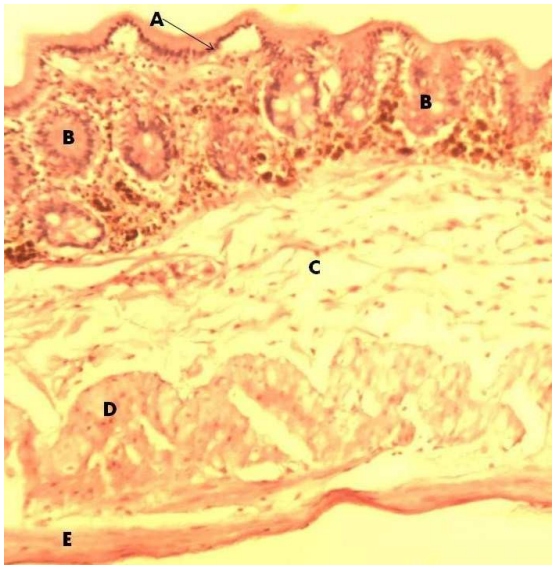


Plate XX: Transverse section of the caecum showing simple columnar epithelium (A), intestinal gland and goblet cell (B), submucosa(C) adipose tissue (D) and the tunica muscularis (E). H&E x100.

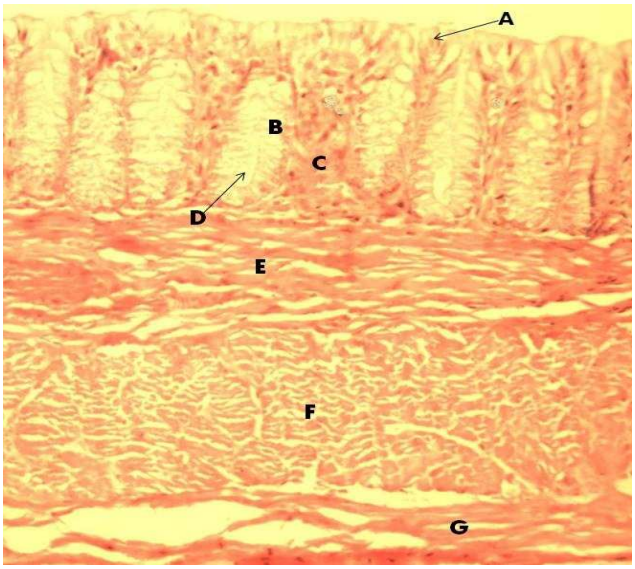


Plate XXI: Transverse section of the colon showing the epithelial lining (A), goblet cells (B), muscularis mucosa (C), intestinal glands (D), submucosa (E), tunica muscularis (F) and tunica serosa (G). H&E x 40.

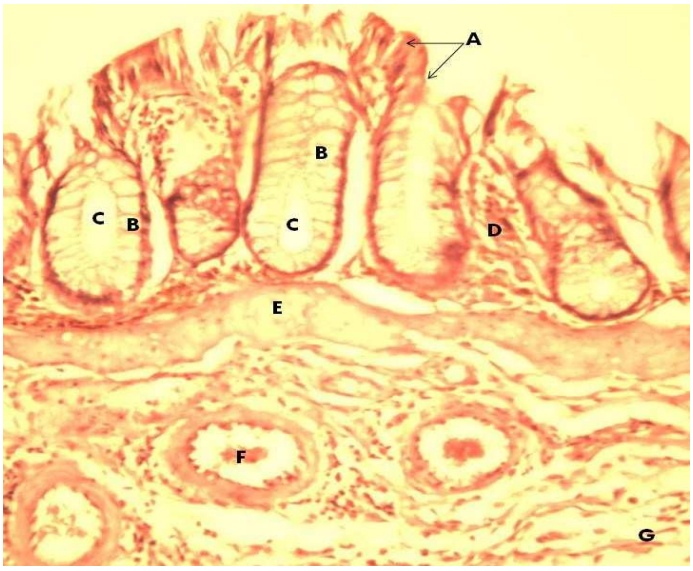


Plate XXII: Transverse section of the rectum showing the absorptive columnar cells (A), goblet cells (B), intestinal glands (C), laminar Propria (D), muscularis mucosa (E), blood vessels (F), submucosa (G). H&E x 100.

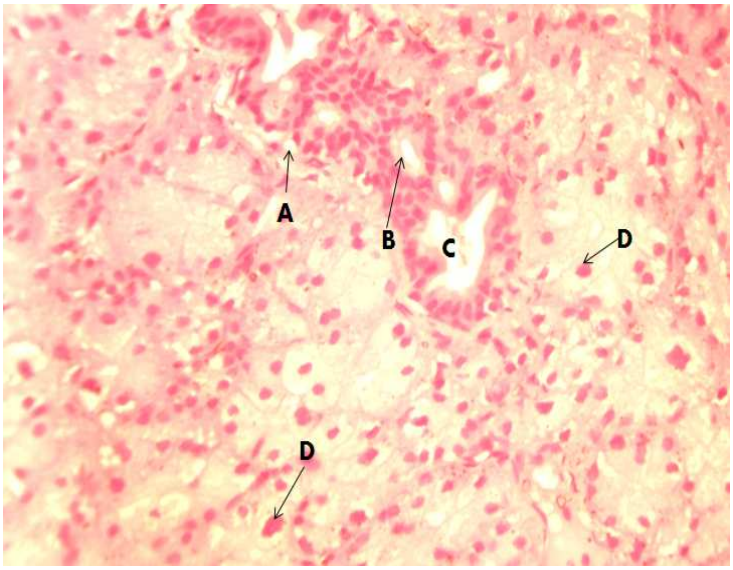


Plate XXIII: Parotid salivary glands showing the interlobular septum (A), venule (B), interlobular excretory duct (C) and serous acini (D). H & E x250.

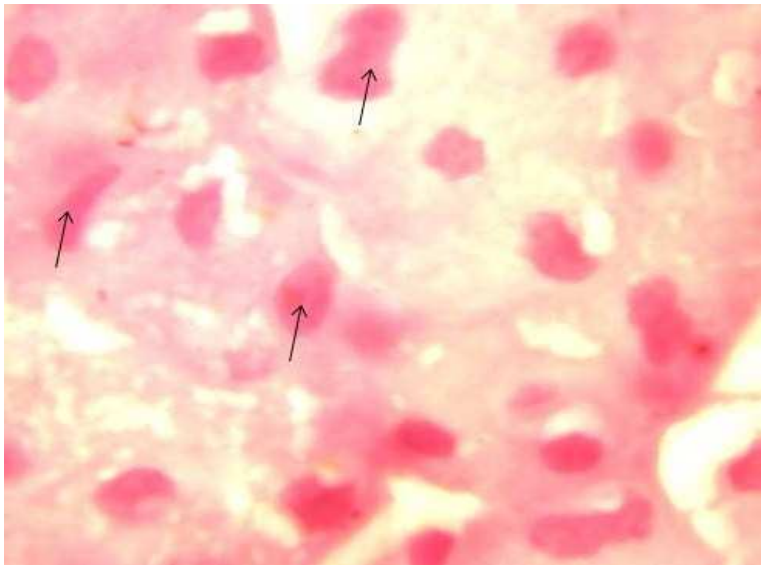


Plate XXIV: Higher magnification of the Parotid salivary gland showing serous acinar cells (arrows) H& E x 1000.

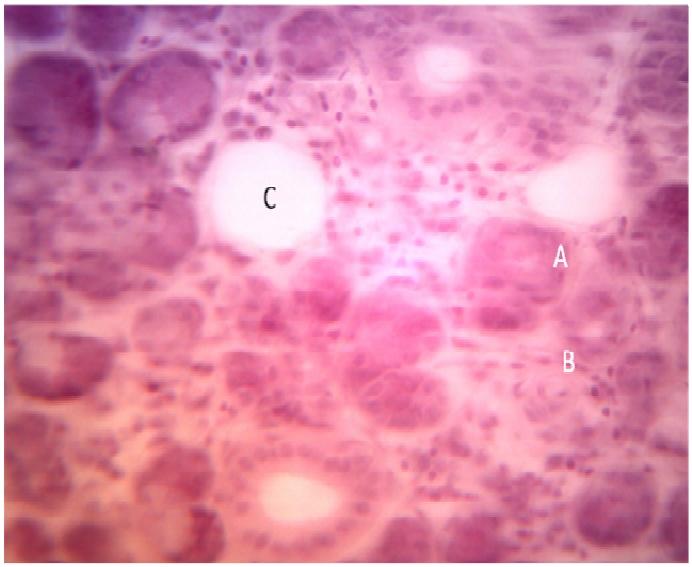


Plate XXV: Mandibular gland showing the serous acini (A), mucous acini (B), interlobular duct (C),) H&E x 250.

Table4.3: Histochemical Reaction of the gastrointestinal tract and the Salivary Glands of the African giant rat (*Cricetomys gambianus* – Waterhouse).
Histochemical Test.

Organs	AB	PAS	AB-PAS
Esophagus	-	-	--
Non-glandular stomach	+	+	+ +
Glandular Stomach	+	+	++
Duodenum	+	+	+ +
Jejunum	+	-	+-
Ileum	+	-	+-
Caecum	+	+	++
Colon	+	+	++
Rectum	+	+	++
Parotid gland	-	+	++
Mandibular gland	+	+	++

+ = Positive.

- = negative.

4.3 Histochemical Features

Table 4.3 shows the histochemical reactions of the gastrointestinal tract and the salivary glands of the AGR, using Alcian Blue (AB), Periodic Acid Schiff (PAS) and Alcian blue combined with periodic Acid Schiff (AB-PAS). Positive reactions are seen when there is a color change to blue and pink for Alcian Blue and Periodic Acid Schiff and Magenta or blue and pink for Alcian Blue combined with Periodic Acid Schiff. Plates XXVI to XLVIII show the result of the histochemical reaction of gastrointestinal tract and the salivary glands of the AGR.The esophagus was observed to be AB, PAS and AB-PAS negative (Plates, XXVI, XXVII and XXVIII), respectively. The entire non-glandular part of the stomach was observed to be AB positive (Plate XXIX), its mucosa was observed to be fairly PAS positive (Plate XXX). The entire glandular part of the stomach was observed to be AB, PAS and AB-PAS positive (Plates XXXII, XXXIII and XXXIV). The entire duodenum was observed to be positive for AB (Plate XXXV). The Brunner's glands and the submucosa were observed to be PAS positive (plate XXXVI).The entire Brunner's glands and the area surrounding it and the tunica muscularis were AB-PAS positive respectively, (Plate XXXVII). The intestinal glands of the jejunum and ileum were observed to be AB positive and PAS negative (Plates XXXVIII, XXXIX, XL, XLI, XLII and XLIII). The goblet cells and the intestinal glands of the large intestine were all observed to be AB and PAS positive, respectively (Plates XLIV, XLV and XLVI).The mandibular salivary glands were observed to be AB and PAS positive (Plate XLVII and Table 4.III) and AB-PAS positive (Plate XLVIII), while the parotid was observed to be AB negative and PAS positive (Table 4. 3).

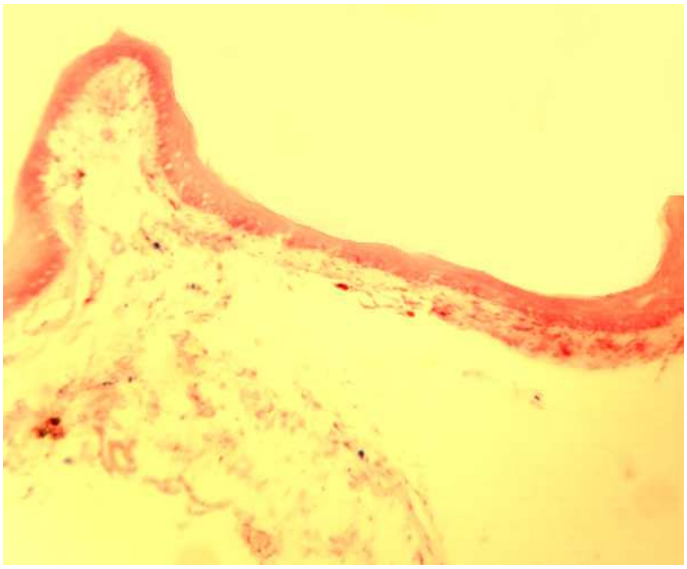


Plate XXVI: Transverse section of the esophagus showing negative response to AB x40.

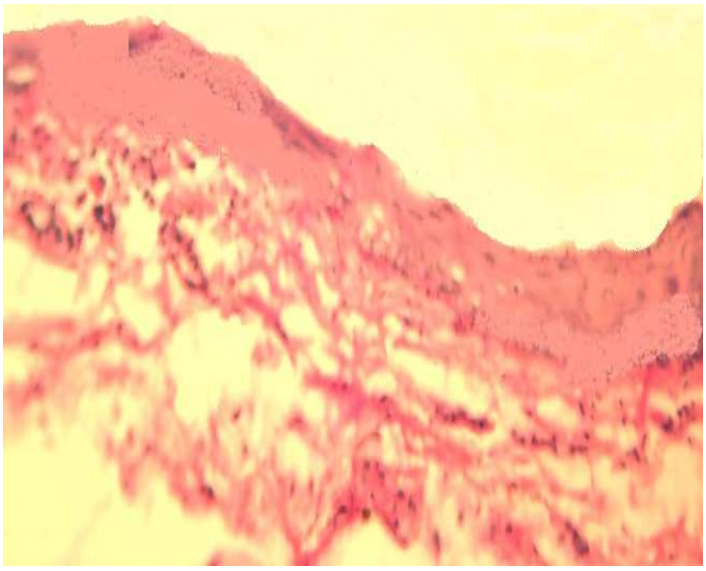


Plate XXVII: Transverse section of the esophagus showing PAS negative x 40.

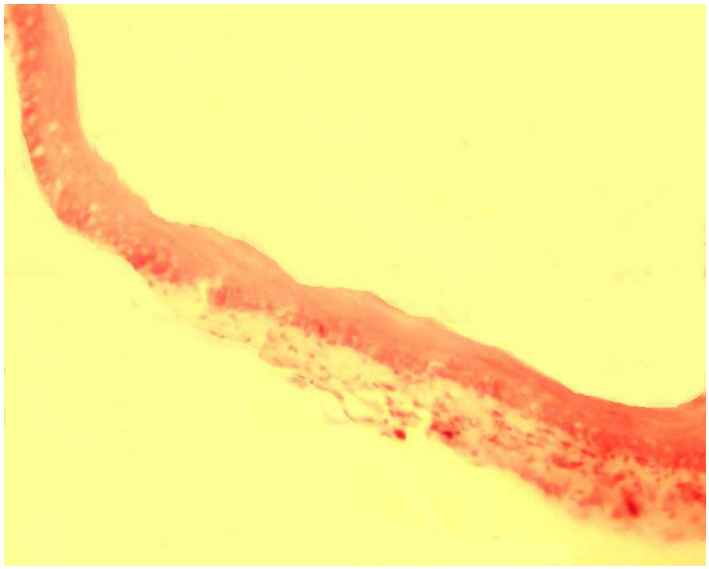


Plate XXVIII: Transverse section of the esophagus showing AB-PAS negative x 40.

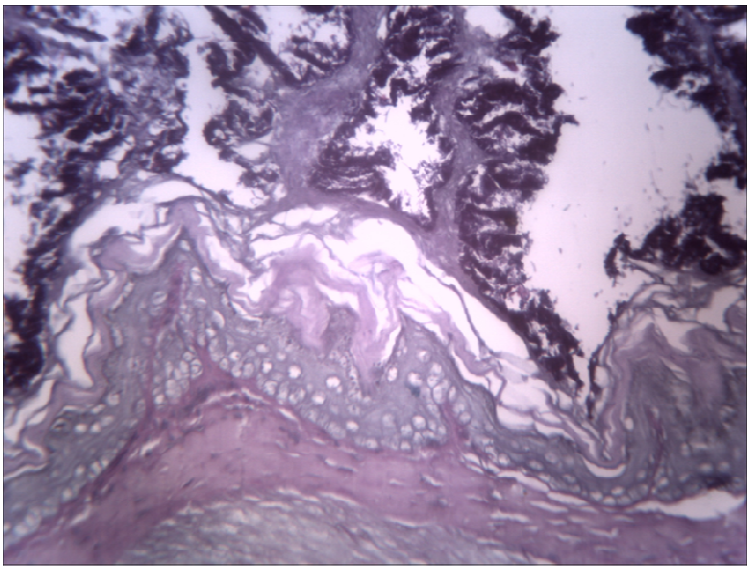


Plate XXIX: Transverse section of the non-glandular stomach showing AB positive reaction x100.

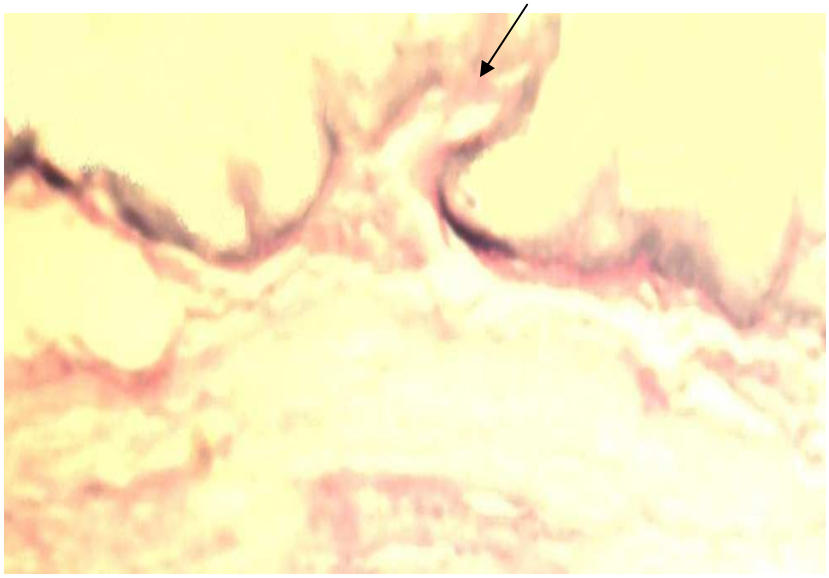


Plate XXX: Transverse section epithelial layer of the non glandular stomach showing PAS positive, arrow x100.

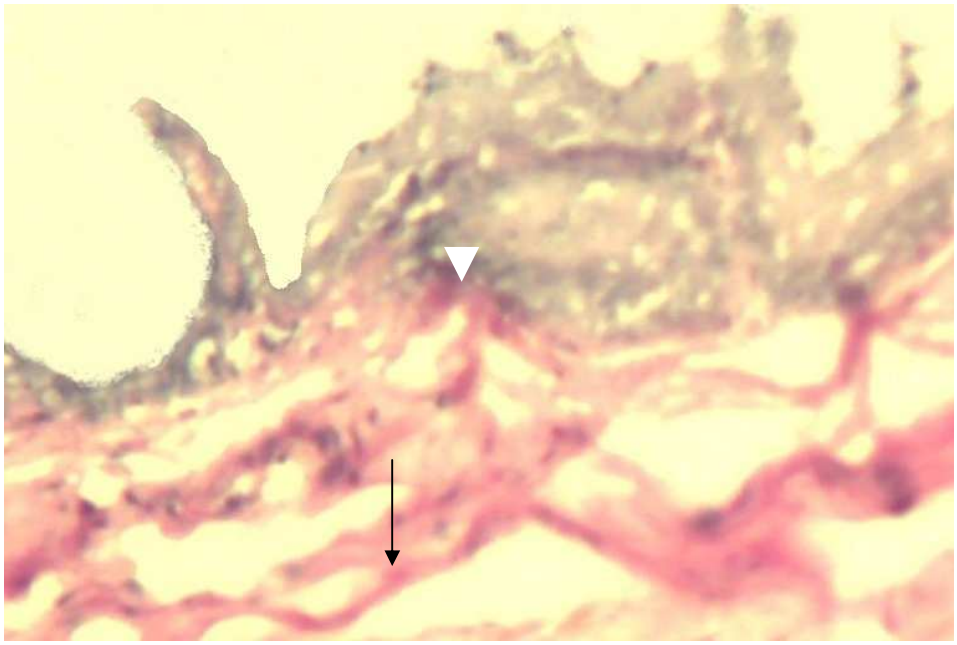


Plate XXXI: Part of the mucosa of the non- glandular stomach showing AB positive (arrow) and the tunica muscularis showing PAS positive (arrow head) x100.

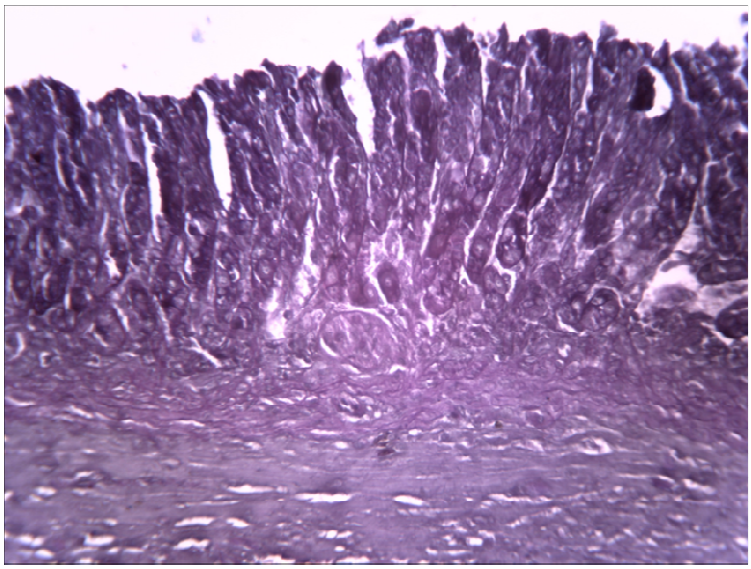


Plate XXXII: Transverse section of the glandular stomach showing AB positive x100.

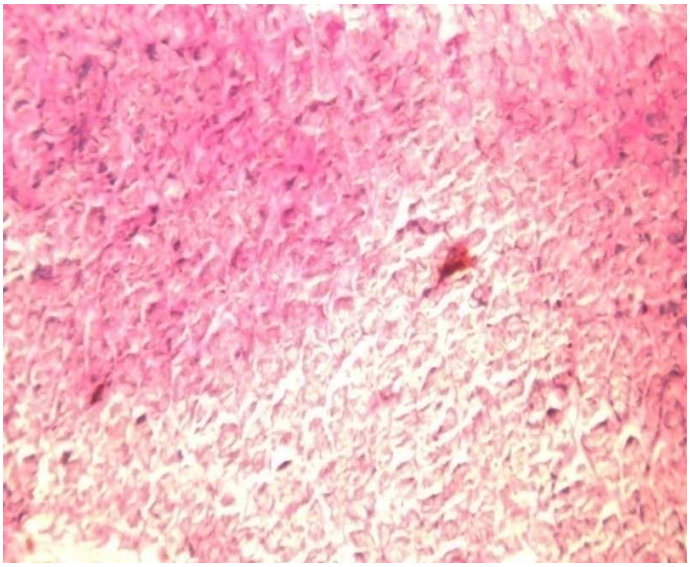


Plate XXXIII: Transverse section of the glandular stomach showing PAS positive x 100.

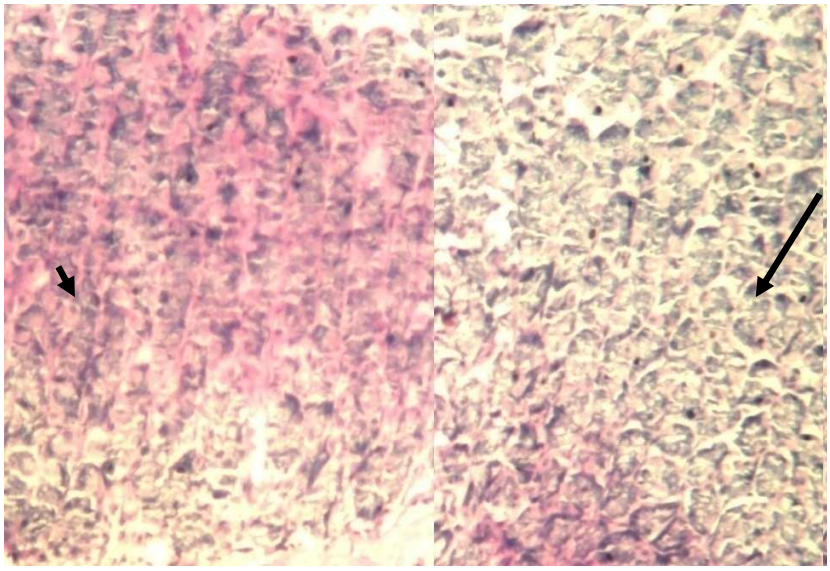


Plate XXXIV: Transverse section of the glandular stomach showing AB positive (arrow) and PAS positive (short arrow) x 100.

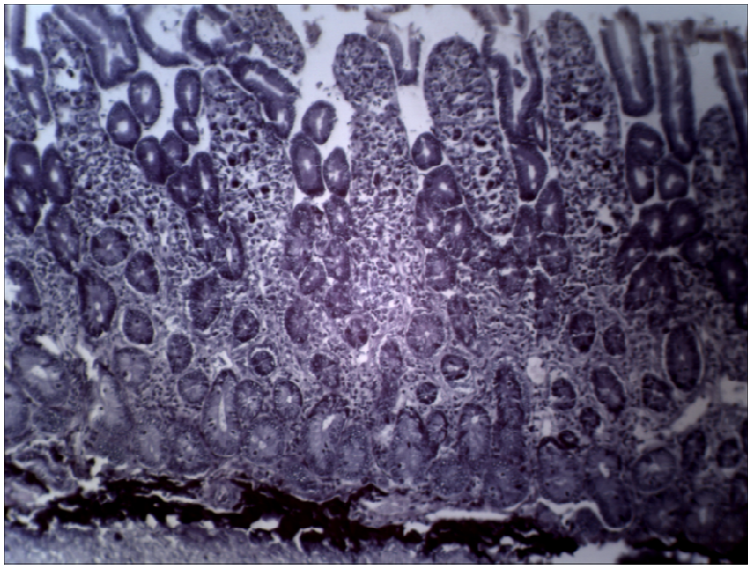


Plate XXXV: Transverse section of the duodenum showing AB positive x 100.

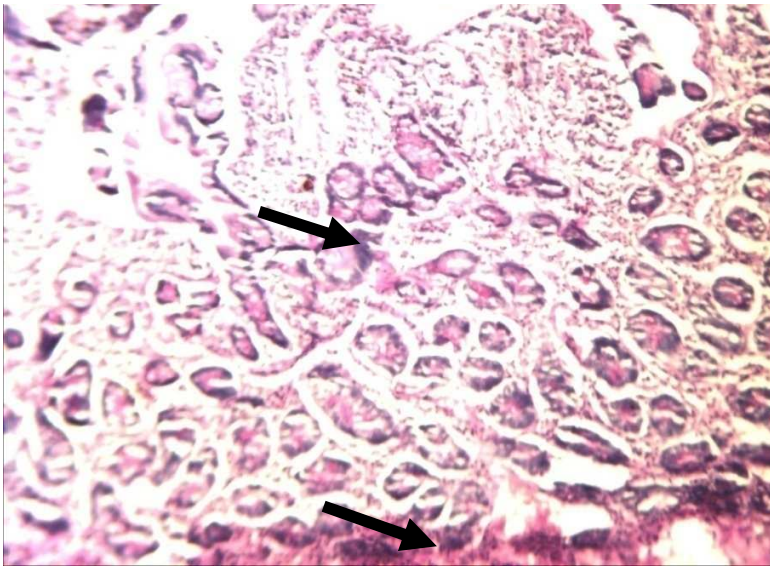


Plate XXXVI: Transverse section of the Brunner's gland of the duodenum and the tunica mucosa showing PAS positive (arrows) x 100.

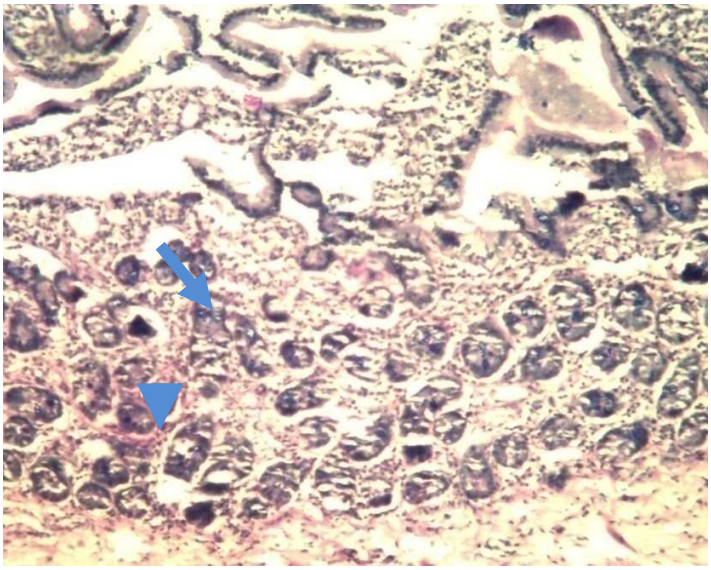


Plate XXXVII: Transverse section of the Brunner's glands of the duodenum showing AB positive (arrow) and the area surrounding the Brunner's glands and the tunica muscularis showing PAS positive (arrow head) x100.

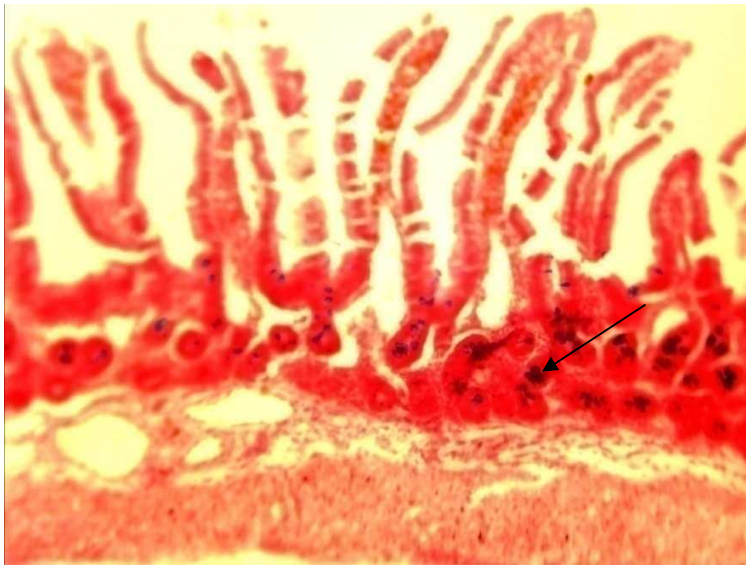


Plate XXXVIII: Transverse section of the intestinal glands of the jejunum showing AB positive (arrow) x 100.

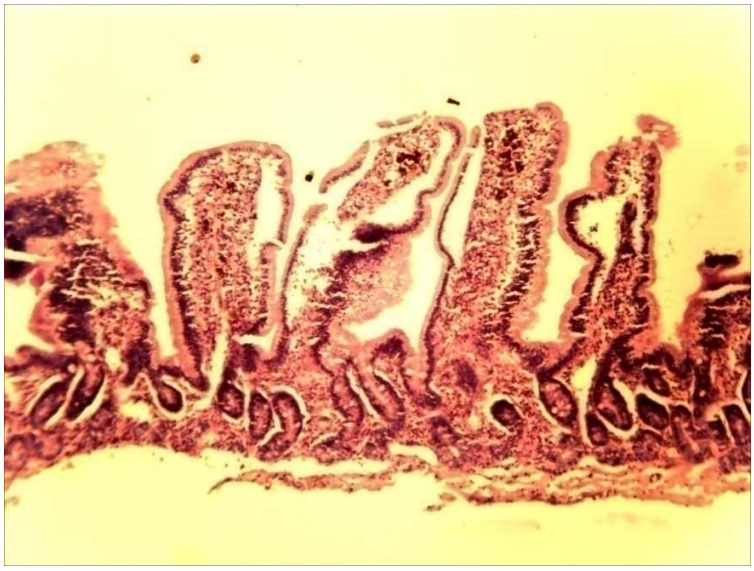


Plate XXXIX: Transverse section of the jejunum showing PAS negative x 100.

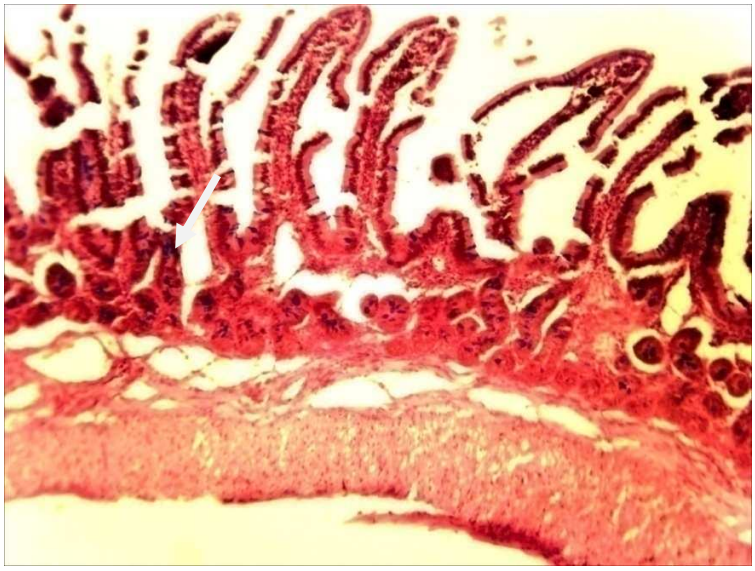


Plate XL: Transverse section of the intestinal glands of the jejunum showing AB positive (arrow) and the rest of the jejunum showing PAS negative x 100.

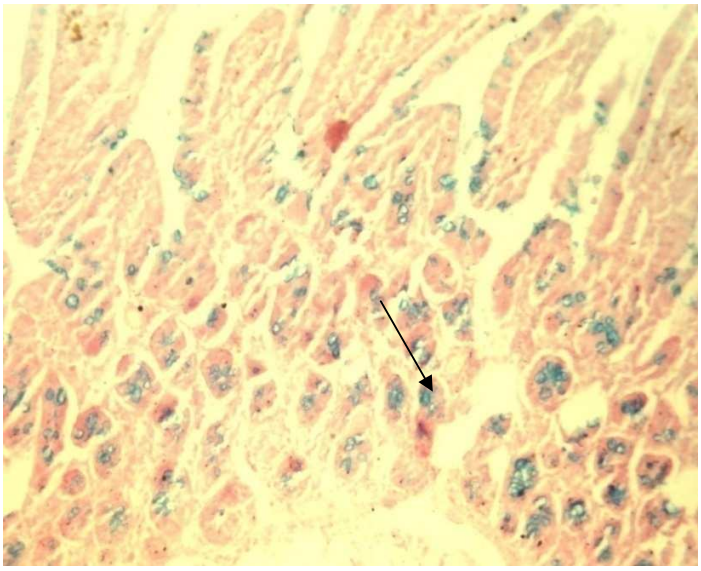


Plate XLI: Transverse section of the epithelium and the intestinal glands of the ileum showing AB positive (arrow) x 100.

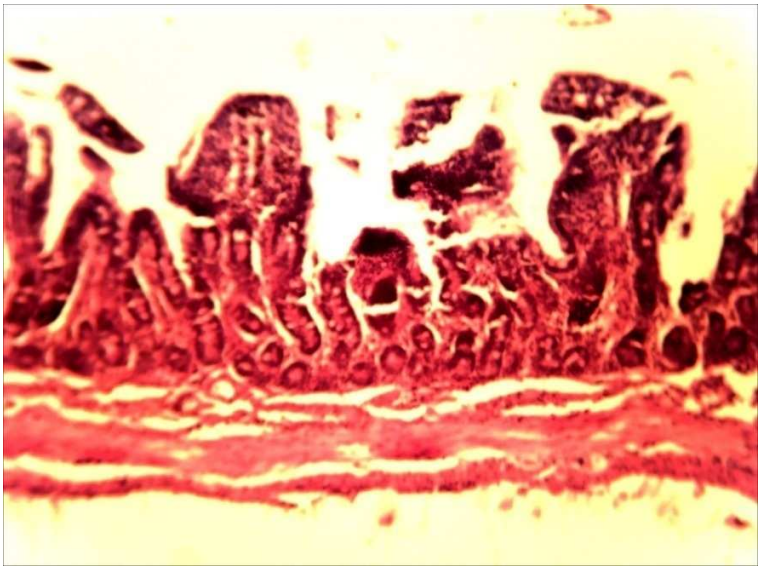


Plate XLII: Transverse section of the ileum showing PAS negative x 100.

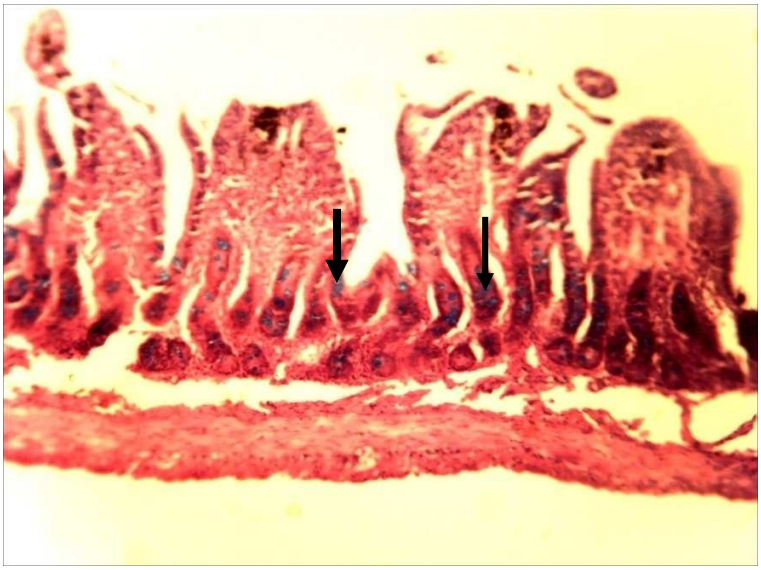


Plate XLIII: Transverse section of the epithelium of the ileum showing AB positive (arrows) and the rest of the ileum showing PAS negative x 100.

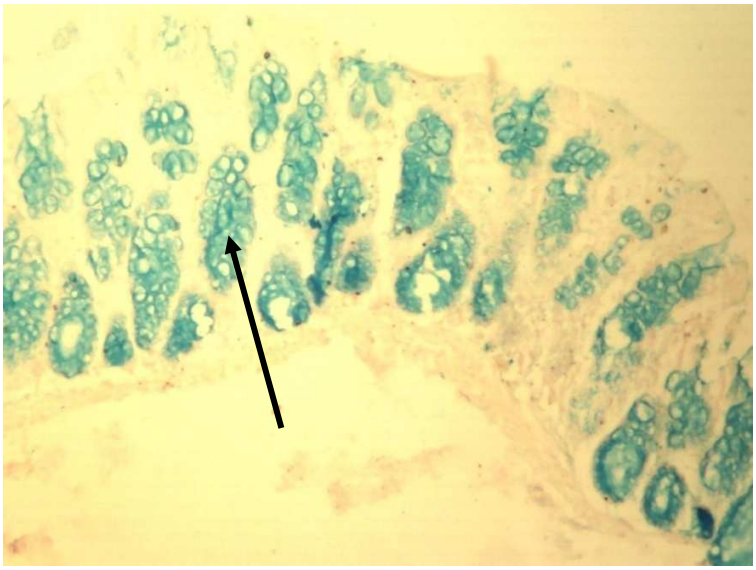


Plate XLIV: Transverse section of the intestinal glands and the goblet cells of the colon showing AB positive (arrow) x100.

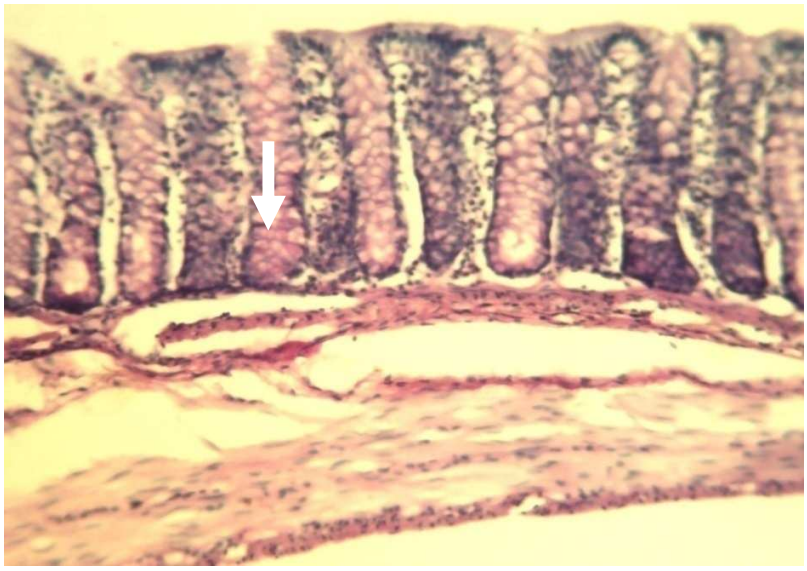


Plate XLV: Transverse section of the intestinal glands and the goblet cells of the colon showing PAS positive (arrow) x100.

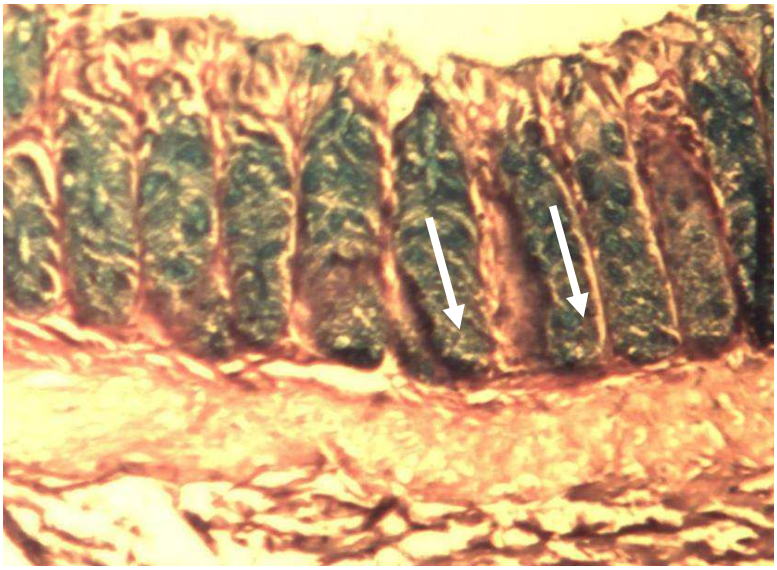


Plate XLVI: Transverse section of the intestinal glands and the goblet cells of the colon showing AB-PAS positive (arrows) x100.

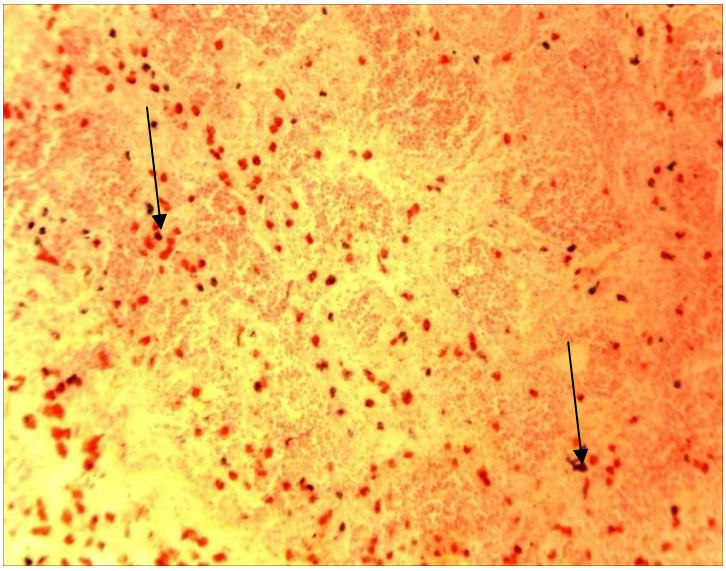


Plate XLVII: Transverse section of the mandibular salivary gland showing AB positive (arrows) x 100.

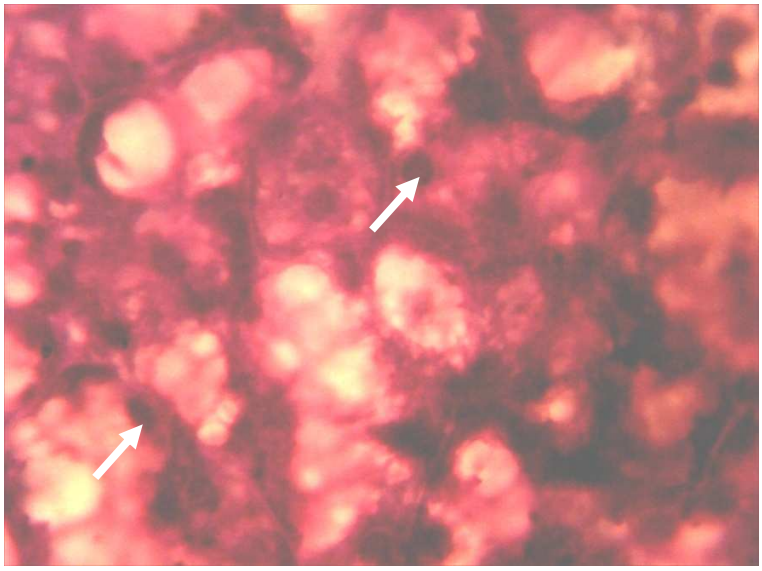


Plate XLVIII: Transverse section of the mandibular salivary gland AB-PAS positive (arrows) x 100.

CHAPTER FIVE DISCUSSION

In the present study the mean weight of the AGR was found to be lower than that of male grasscutter and higher than that of the female grasscutter. This agrees with the findings of Byanet *et al*. (2008). However, the mean weight was the same with what was reported by Ali *et al*. (2008) for the same animal. The weight of the GIT was observed to be 58.18±0.19g which accounted for about 5.6% of the weight of the animal .Ali *et al.* (2008) observed the mean length of the GIT of the AGR to be 232.3±11.9cm which was higher than 213±0.88cm that was obtained in the present study. Byanet *et al*. (2008) reported a higher value for the grasscutter and Rudolf and Stromberg (1976) reported lower value for the laboratory rat.

The esophagus was observed to be longer than those of the laboratory rat (Rudolf and Stromberg, 1976) and shorter than those of the rabbit (Timothy, 1990).The esophagus was observed to be the first part of the alimentary canal connecting the laryngeal part of the pharynx with the stomach and was divided into the cervical, thoracic and abdominal portions. It was pale red in color and lied dorsal to the trachea throughout its length. Similar result was observed for the rabbit (Timothy, 1990).However, Rudolf and Stromberg (1976) observed that the esophagus of the laboratory rat deviated slightly to the left around the cervical region. The lining of the esophagus of the AGR was observed to be non-keratinized stratified squamous epithelium without lamina muscularis and esophageal gland, throughout its entire length. The degree of keratinization depends on the feeding habit with herbivores having keratinized stratified squamous epithelium. This observation agrees with that of Dellmann and Brown (1987) but contrary to Diaz *et al.* (2003).They observed the cranial zone to be lined by few layers of stratified squamous epithelium with numerous superficial mucous cells while in the caudal zone,

the epithelium was replaced by columnar epithelium which is involved in secretion process. Just as in the AGR, the lamina muscularis was absent in the *Engraulis anchoita* (Diaz *et al*., 2003).

Saroseik *et al*. (2000) stated that the esophagus is a highly specialized organ designed for the propulsion of food from the mouth to the stomach. As a result of its position in the gastrointestinal tract, it may be exposed to a variety of noxious stimuli. The AGR being omnivorous needs this mucous to increase the viscosity of the esophagus which may be important for protecting the esophagus from damage and lubricating the mucosa for easy passage of food particles such as arthropods and grasshopper. Although the esophagus had no mucous secreting cells as it was AB, PAS and AB-PAS negative, it may therefore be postulated that the mucous produced by the salivary glands helps in protecting the mucosal surface of the esophagus from sharp objects that may reach the esophagus and provide a suitable chemical environment for possible digestive function. It may also be postulated that enzyme of surface origin may combine with the mucous from the salivary glands to provide digestive functions for the esophagus. The present postulation agrees with that of Arellano *et al.* (1999).

In the present study, the weight of the stomach accounted for 1.86% contrary to what was observed by Ali *et al*. (2008). In their study, they observed that the weight of the stomach accounted for 3% of the total weight of the animal. However, it was noticed that they did not remove the content of the stomach before weighing the stomach and this was responsible for that increase in weight. Grossly, the stomach of the AGR was found to be made up of two parts; the glandular and non-glandular parts with an isthmus separating the two main stomach regions. With the exception of a pouch-like diverticulum which is not found in the dog, the glandular part of the stomach resembles the simple stomach of the rabbit (Byanet *et al.*, 2008) and the abomasum of the ruminants (Olusanya and Olowo, 1988). The non-glandular part was presented

with numerous, short, soft, towel-like papillae similar to those described in the rumen of the ruminants. However, in the ruminants, the ventral part is thrown into long, finger-like ruminal papillae (Olusanya and Olowo, 1988) which were longer than the ones observed in this study.The stomach in this study was larger than the simple monogastric stomach of the rabbit described by Byanet *et al.* (2008). The observation of the stomach is in conformity with Wikipedia (2008), who stated that the AGR are omnivorous animals feeding on vegetable, insects, crabs, snails and other items by preferring fruits and palm kernels and are likely to have larger stomach. Histologically, the non-glandular stomach was observed to be made up of papillae that covered the stratified squamous epithelial lining. The non glandular stomach plays an important role in breaking down the coarse fibrous ingesta ingested by the AGR into absorbable nutrients by both mechanical and chemical actions. The tunica muscularis was observed to be thick and played an important role in this mechanical process. In addition to its mechanical and chemical actions, the non-glandular stomach acted as fermentation vat. This observation agreed with the observation of Dellmann and Brown (1987).The glandular stomach resembles the stomach of the dog (Ojo, *et al.,* 1987). Its mucosa was observed to have shallow gastric pits which were continuous with the gastric glands and received secretory products that served as protective coat to prevent autolysis of the mucosa. This observation agrees with that of Byanet *et al.* (2008).The non-glandular stomach was observed to be AB and PAS positive indicating acidic and neutral mucosubstance secretions. Murray *et al.* (1996) observed that the mucous played an important role in the regulation of the pH of the gastric fluid. The present observation agrees with that of Murray *et al*. (1996). The glandular stomach was positively stained with both AB and PAS, and it is likely that the cells are responsible for the secretion of the acidic and neutral mucosubstance, unlike what is obtained in the *Varanus niloticus* and some

rodents where Ahmed *et al*.(2009) and Daniel and Helen (2005) observed only the neutral mucosubstances.The neutral mucosubstance which is basic in nature protects the gastric mucosa from the effects of hydrochloric acid and pepsin in the diet of the AGR, while the acidic mucosubstance role primarily is to serve as lubricant.

The small intestine was made up of the duodenum, jejunum and ileum. The small intestinal segments were observed to be longer than those of the large intestine. The jejunum was the longest segment of the GIT. The histology of the small intestine of the AGR reveals similar structural pattern and indicates three segments, the duodenum, jejunum and ileum. These segments were modified and differentiated into the mucosal and submucosal folds. The shape of the villi was leaf-like in the duodenum and ridge-like in the jejunum. The Brunner's glands were found in the submucosa of the duodenum. The lamina propria of the jejunum had abundant intestinal glands (*crypts of Lieberkuhn*). Charlotte (2004) observed the location of the Brunner's glands to be in the first two-third part of the duodenum in the dog, cat and man. However, in the present study, the location of the Brunner's glands was not determined. Research on glands, villi and goblets cells have been widely documented (Millar, 1965; Dellmann and Brown, 1987; Haroldy, 1992 and Timothy, 1990). The absorption capacity of the small intestine is an important feature for the growth and survival of the AGR. In the present study the jejunum villi surface was observed to be more extensive compared to that of the duodenum and ileum, indicating that the absorptive capacity is highest in the jejunum compared to any other part of the small intestine and this confirms the report of Byanet, *et al.* (2008).

Histochemical study showed that Brunner's glands of the duodenum reacted positive to AB and the Brunner's gland together with the lamina muscularis reacted positive to PAS. AB-PAS reaction showed that the Brunner's gland was AB positive and the lamina muscularis PAS

positive. The main function of the Brunner's gland is to produce a neutral mucosubstance that will protect the duodenal mucosa from the highly corrosive action of the gastric chyme that enters the duodenum from the stomach. However, in the AGR, it was observed that the stomach (both the non-glandular and glandular) secretes acidic and neutral mucosubstance, and the content of the chyme from the stomach will have been neutralized from the stomach. However, to maintain this neutrality, the duodenum from the present study was observed to be positive for AB and PAS suggesting that, the duodenum secretes both the acidic and neutral mucosubstance. This present study is at variance with Ojo *et al.* (1987) who observed neutral mucosubstance in the duodenum and Daniel and Helen (2005) who observed acidic mucosubstance in the duodenum while the jejunum and ileum were observed to secrete acidic mucosubstance only.

The large intestine of the AGR was observed to be made up of caecum, colon and rectum. The caecum was the largest segment in the abdominal cavity and serves as a principal site for microbial fermentation. Vitamins and fatty acids are absorbed in the colon, water is also said to be absorbed resulting in fecal ball formation. These fecal balls which are the undigested and mostly indigestible portion of what was fed will then pass through the rectum to the anus. The histology of the large intestine of the AGR was characterized by the absence of villi and a gradual increase in the number of goblet cells from the caecum to the rectum. The intestinal glands were numerous in the caecum compared to the colon and rectum, while the goblet cells were more abundant in the colon and rectum than the caecum. The epithelium lining this region was observed to be simple columnar with long irregular microvilli, suggesting an absorptive function, particularly in the colon. The gross and histological studies of the large intestine in this study showed that its major functions are water absorption and formation of fecal mass in addition to the production of mucous to lubricate the intestinal surface. The observations of the

large intestine in this study agreed with the findings of Byanet *et al.* (2008). They reported that the caecum in the grasscutter is the largest internal organ, within the abdomen cavity. In the caecum, fermentation of the intestinal contents occurs and periodically the caecum contracts and the fermented ingesta are propelled into the colon and then out of the anus. The thickening of the muscularis has been correlated with the temporary storage and expulsion of fecal materials from this area. These fecal materials are coated with mucus which acts as a barrier to the acidic pH of the jejunum and the ileum. In the present study, the pattern of staining for acidic and neutral mucosubstance with PAS at the mucosal surface and AB throughout the colon and rectum suggested the presence of acidic mucins in all these segments. The presence of neutral mucosubstance may indicate absorptive functions. An increase in number of goblet cells in the rectum implies of the need for increase mucosa protection and lubrication for fecal expulsion. The presence of large number of mucous secreting cells provides a mucous layer around the fecal pellets, facilitating its release and protecting the epithelium as was described by Ahmed *et al.* (2009).

Two salivary glands were observed, namely the parotid and mandibular salivary glands. The parotid salivary gland was located at the base of the ear and ventral to it was the mandibular gland. The parotid salivary glands were observed to be non-lobulated while the mandibular salivary gland was lobulated. This finding was at variance with the observations of Timothy (1990) and Rudolf and Stromberg (1976) who documented four salivary glands in the rabbit and the laboratory rat. The histology of these salivary glands showed that the parotid salivary glands had serous acinar while the mandibular salivary gland had serious and mucous acini. In the present study, the classification of the salivary glands was done according to the contents of their mucous (neutral and acidic) as were determined by Alcian Blue (AB) and Periodic Acid Schiff

(PAS) method. According to this classification the endpieces of secretory unit of the parotid gland were observed to be serous because they were PAS positive, while the mandibular salivary gland was observed to be serous and mucous. This observation was at variance with those of Asojo and Aire, (1986) who observed serous acini only in the mandibular gland of the AGR and Guinea pig.

The AGR was observed to have two incisor teeth and three molar teeth each in the upper and lower jaw with no canine and no premolar teeth. However, this was not the same with that of the rabbit (Timothy, 1990) and rat (Stanberry 1972). The absence of the canine teeth gives rise to a diastema or stretch of jaw which was devoid of teeth. The presence of the diastema may be suggestive of its dietary nature which allows room to maneuver the bulky food and to provide space for the cheek pouch. This observation is in line with the observation of Timothy (1990) and Stanbury (1972).

The liver of the AGR in this study was observed to be made up of four lobes and three sublobes while that of the rabbit was observed by Timothy (1990) to be made up of five lobes. The gall bladder was found on the visceral surface of the liver. In the present study the bile duct was not grossly seen on the visceral surface of the liver. The pancreas was observed to be diffused and part lied in the U-shaped bend of the duodenum.

CHAPTER SIX SUMMARY, CONCLUSION AND RECOMENDATION

6.1 Summary

From the present study, it was observed that the esophagus of the AGR had no esophageal gland and lamina muscularis and because of the absence of these glands, histochemical reactions showed AB, PAS and AB-PAS negative.

The stomach was observed to be divided into the glandular and non-glandular parts. The non-glandular part was brownish with numerous soft towel-like papillae that resembled the rumen of ruminants. Histological studies showed that the non-glandular stomach resembled the rumen of ruminants while histochemical studies showed that the non-glandular stomach was AB, PAS and AB-PAS positive. The glandular stomach was soft and velvety resembling the stomach of the dog and the abomasum of ruminants. Histological studies revealed numerous gastric glands which were observed to be AB, PAS and AB-PAS positive.

The small intestine was made up of the duodenum, jejunum and ileum. The duodenum had the largest diameter and was the distal continuation of the stomach and had villi and the Brunner's glands. The jejunum was the distal continuation of the duodenum and had leaf-like villi and intestinal glands (*crypts of Lieberkuhn*) and was the longest segment. The ileum was found immediately after the jejunum and was the shortest. Payer's patches or lymphatic nodules were found here. Histochemical reactions showed that the duodenum reacted positively to AB and PAS while the jejunum and ileum were AB positive and PAS negative.

The large intestine of the AGR was made up of the caecum, colon and rectum. The caecum was the largest organ found within the abdominal cavity and was a blind sac. Histological and

histochemical study of the caecum, colon and rectum reveal numerous goblet cells and intestinal glands which were AB, PAS and AB-PAS positive.

The AGR had a diastema which is a feature that is not common among all rodents. The liver was divided into four lobes, with three of the lobes being divided into sub-lobes.

6.2 Conclusion

Because of the absence of the mucous secreting cells in the esophagus, it can be postulated that the enzymes of surface origin may combine with the mucous from the salivary glands to protect and provide digestive functions for the esophagus.

The gross and histological features of the stomach of the AGR showed that it had two parts, (non-glandular and glandular).The non-glandular part resembled the rumen of ruminants while the glandular part was similar to the simple stomach of the rabbit. These two stomach compartments in the AGR may be responsible for its feeding habits (omnivorous). Histochemical studies revealed the production of acidic and neutral mucins in the stomach of the AGR which may aid regulate the pH of the gastric fluid.

The duodenum was observed to produce acidic and neutral mucins, which may help maintain the pH of the chyme from the stomach. However, the jejunum and ileum were observed to produce only the acidic mucin which may assist in food absorption. The large intestine was characterized by the absence of villi and increase in number of goblet cells which were AB and PAS positive. The presence of large number of mucous secreting cells provides a mucous layer around the fecal pellets facilitating its release and the protection of the epithelium.

Two salivary glands were observed (parotid and mandibular).The parotid salivary glands were non-lobulated while the mandibular salivary glands were lobulated. The parotid salivary glands secretory endpiece was observed to be serous because it was PAS positive while that of the mandibular salivary gland was serous and mucous.

6.3 Recommendations

There is the need to look at the physiology of the GIT so as to have a complete anatomical and physiological knowledge of the digestive system which will aid nutritionists use such knowledge to formulate feeds for the domesticated species.

There is also the need to look at the histochemistry of the gastrointestinal tract of different species of omnivorous rodents and compare their secretions with that of the AGR.

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