COMPARATIVE MORPHOLOGIC AND HISTOLOGICAL STUDIES ON GUINEA PIG AND WISTAR RATS LIVER

BY

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P16MDHA7004

A PROJECT REPORT SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY IN PARTIAL FUFILLMENT FOR THE AWARD OF THE POSTGRADUATE DIPLOMA ANATOMICAL SCIENCES IN THE DEPARTMENT OF HUMAN ANATOMY AHMADU BELLO UNIVERSITY ZARIA

APRIL, 2018

DECLARATION

I declare that the work in this project report entitled Comparative Morphologic and Histologic Studies on Guinea Pig and Wistar Rat Liver has been performed by me in the Department of Human Anatomy. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this project report was previously presented for another degree or diploma at this or any other Institution.

Danjuma Idris Kamat   Date

CERTIFICATION

This project report entitled Comparative MORPHOLOGIC AND HISTOLOGICAL STUDIES ON GUINEA PIG AND WISTAR RAT LIVER by DANJUMA IDRIS KAMAT meets the regulations governing the award of the degree of post graduate diploma anatomical science of the Ahmadu Bello University and is approved for its' contribution to knowledge and literary presentation.

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ACKNOWLEDGEMENT

My unreserved gratitude goes to my supervisor Prof S.S Adebisi for allowing me draw from his fountain of wisdom, it was indeed a great privilege to be your supervisee.

Dr S.A Musa words will fail me to thank you enough, you are indeed far too kind, God bless you sir.

All my lectures that didn't only teach us but imparted us immensely, we are grateful.

Mr Peter Ankpulu & Mr Akinyemi thank you for sharing your technical knowledge with me on this study.

To my wife (Yorbin) and (David) my son, thank you for your unwavering love and support, it was that love and support that keep me afloat the challenges on my way to earning this diploma, I love you so much. And to my extended family also

My oga Saddiq Yusuf and the pioneer PGDAS class thank you for making this past year memorable.

ABSTRACT

Comparative anatomy is the study of similarities and differences in the anatomy of different organisms. It is closely related to evolutionary biology and phylogeny.

This research work is aimed at making comparisms between two animals constantly in use in research primarily as models for various human medical conditions and even for production of antibodies for vaccines. The study is aimed at finding the differences and similarities of the guinea pig and wistar rat liver.

Guinea pigs and wistar rats are currently in use in laboratory research as models for various human medical conditions, for virology and toxicological studies just to mention a few. In this study a total number of 5 Guinea pigs and 5 Wistar rats all adult males were used. The mean body weights of the Guinea pigs were 481.4g and 90.80g for the wistar rat. The mean weight for the liver was 17.80g for the Guinea pig and 6.80g for the wistar rat. The mean length of the liver was 5.22cm for the Guinea pig and 1.88 cm for the wistar rat. A gross physical examination of the liver was carried out, the colour, texture, and number of lobes were observed and recorded. Histological study was done using routine (H and E staining) histological techniques. Findings are: Basic histology of the guinea pig and wistar rat liver are similar. Comparatively, the liver of the Guinea pig and Wistar rat studied showed that they are phylogenetically related. Histologically, liver of the experimental animals studied showed basic similar histo-architecture.

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1.0 CHAPTER ONE

1.1 INTRODUCTION

Comparative anatomy is the study of similarities and differences in the anatomy of different organisms. It is closely related to evolutionary biology and phylogeny. Comparative anatomy has long served as evidence of evolution. It indicates that various organisms share a common ancestor. Also, it assists scientists in classifying organisms based on similar characteristics or diversity of their anatomical structures. A common example of comparative anatomy is the similar bone structures in the fore limbs of cats, whales, bats and human beings. Even though all these appendages consist of the same basic parts; yet they serve completely different functions (Campbell *et al.,* 2002). The Guinea pig (Cavia porcellus) also called cavy, is specie of rodent belonging to the family caviidae and genus cavia. These animals which do not belong to the pig family originated from the Andes and earlier studies based on biochemistry and hybridization suggested they are domesticated descendants of a closely related specie of cavy such as cavia asperea, cavia tschundii and therefore do not exist naturally in the wild (Weir 1974, Nowak, 1999). Their domestication began around 5000 B.C and because of their popularity as pets and meat source they are now globally distributed. They are indigenous to South America, with fossil records extending as far back as 9000 B.C European colonization of South America lead to their introduction as pets in European and ultimately the world over (Morales, 1994; Vanderlip, 2003).

Biological experimentation on guinea pigs has been carried out since the 17th century. During the 19th and early 20th centuries, the Guinea pig was a popular experimental animal for studying prevalent bacterial diseases such as tuberculosis and diphtheria, (Padilla-carlin *et al.*, 2008) resulting in the epithet ‘guinea pig’ being used to describe a test subject. Guinea pigs are currently in use in research primarily as models for various human medical conditions, for virology and toxicological studies just to mention

Albino Wistar rat is the most common type of Laboratory rat, belonging to the species Rattus norvegicus. This strain was developed at the Wistar Institute in 1906 for use in biological and medical research, and is notably the first rat strain developed to serve as a model organism at a time when laboratories primarily used Musmusculus, or the common House mouse. It is a perfect reserve of all the qualities attributable to domestic rats which includes: tolerant of crowd, calmness, breed earlier, less likely to bite and produce more off-springs (Sharon *et al.*, 1999). The Wistar rat is currently one of the most popular rats strains used for laboratory research. It is characterized by its wide head, long ears, and having a tail length that is always less than its body length. The rat can be feed with regular poultry feed and normal water. The cage does not require a complex construction. All that is needed is a feeding bottle-like source of drinking water, a feeding trough and an aerated environment.

1.2 THE AIM AND OBJECTIVES OF THE STUDY

1.21 THE AIM OF THE STUDY

The aim was to study the comparative anatomy of the liver of Wistar rat and Guinea pig.

1.22 THE OBJECTIVES OF THE STUDY

i. To comparatively study the morphology and morphometric parameters of the liver, in male guinea pigs and wistar rats.
ii. To comparatively study the histology of the liver, in male guinea pigs and wistar rats.

1.3 JUSTIFICATION OF THE STUDY

i. The economic importance of guinea pig and wistar rat cannot be over emphasized as it serves a laboratory animal, pet and as meat source.

ii. Guinea pig and wistar rat are invaluable resources in biomedical research where they are used as laboratory subjects.

CHAPTER TWO

2.0 LITREATURE REVIEW

2.1 COMPARATIVE ANATOMY

Comparative anatomy is the study of similarities and differences in the anatomy of different organisms. It is closely related to evolutionary biology and phylogeny (the evolution of specie). Comparative anatomy has long served as evidence for evolution; it indicates that various organisms share a common ancestor. Also, it assists scientists in classifying organisms based on similar characteristics of their anatomical structures. Comparative anatomy supports Darwins theory of descent with modification, also known as evolution. A common example of comparative anatomy is the similar bone structures in forelimbs of cats, whales, bats, and humans. All of these appendages consist of the same basic parts; yet, they serve completely different functions. The skeletal parts which form a structure used for swimming, such as a fin, would not be ideal to form a wing, which is better-suited for flight. One explanation for the forelimbs' similar composition is descent with modification. Through random mutations and natural selection anatomical structures gradually became better-adapted to the every organism's respective habitat (Campbell *et al.,* 2002).

The Two major concepts of comparative anatomy are:

A. **Homologous structures** - structures (body parts/anatomy) which are similar in different species because the species have common descent. They may or may not

Perform the same function. An example is the forelimb structure shared by cats and whales.

— B. **Analogous structures** - structures similar in different organisms because they evolved in a *similar environment*, rather than were inherited from a recent common ancestor. They usually serve the same or similar purposes. An example is the streamlined torpedo body shape of porpoises and sharks. So even though they evolved from different ancestors, porpoises and sharks developed analogous structures as a result of their evolution in the same aquatic environment (Campbell *et al.*, 2002). The rules for development of special characteristics which differ significantly from general homology were listed by Karl Ernst von Baer (the Baa- laws) (Caldwell,2006).

2.2 GUINEA PIGS

Physical Description of Guinea Pig

Guinea pigs are tailless rodents that weigh between 700g and 1200g, with males being larger than females. They have small, compact, cylindrically shaped bodies, ranging from 20.3cm to 25.4cm in length. They have small petal-shaped ears that are laterally positioned at the apex of the head. Their eyes are laterally positioned mid-way down the snout, between the ears and nose. They have small triangular-shaped mouth, which contain 20 teeth in 2 (I=1/1, C=0/0, PM=1/1, M=3/3) dental arrangement. Like many other rodents, guinea pigs have continuously growing teeth, and tooth length is maintained by grinding them together during feeding (Terril *et al.,* 1998).

2.2.1 Behaviour of Guinea Pig

Guinea pigs are gregarious and prefer close contact with other conspecifics. They are active during dusk and dawn (crepuscular). They are also exceedingly good swimmers.

Like many rodents, guinea pigs sometimes participate in social grooming, and they regularly self-groom. A milky substance is secreted from their eyes and rubbed into the hair during the grooming process (Richardson, 2000). Male guinea pigs establish social hierarchies in which a single alpha male dominates subordinates males. Males are known to be extremely aggressive when competing for territory or potential mates. As a result, males are often separated when females are present (Ballard *et al.,* 2003). Guinea pig sight is not as good as that of human, but they have a wider angle of vision (about 340^0) and see in particular color (dichromacy). They have well developed senses of hearing, smell, and touch. Vocalization is the primary means of communication between members of the species (Richardson, 2000).

The most common sounds made by the guinea pig are:

- A "wheek" is a loud noise, the name of which is onomatopoeic, also known as a whistle. An expression of general excitement, it is sometimes used to find other guinea pigs if they are running. If a guinea pig is lost, it may wheek for assistance.
- Squealing or shrieking is a high-pitched sound of discontent, in response to pain or danger.
- A chattering sound is made by rapidly gnashing of the teeth, and is generally a sign of warning. Guinea pigs tend to raise their heads when making this sound.

- Chutting and whining are sounds made in pursuit situations, by the pursuer and pursue, respectively.
- A bubbling or purring sound is made when the guinea pig is enjoying itself, such as when being petted or held. It may also make this sound when grooming, crawling around to investigate a new place, or when given food (Terril *et al.,* 1998).

2.2.2 Feeding in Guinea Pig

Guinea pigs are strict herbivores and depend on human for food. Grass is the guinea pig's natural diet. They are often fed lettuce, cabbage, and various types of fruit. In some cases, barley and "Timothy hay" a wide-spread perennial grass, are grown especially for consumption by domesticated mammalian herbivores such as guinea pigs. Their molars are particularly suited for grinding plant matter, and grow continuously throughout the animal's life (Wagner *et al.,* 1976). Most grass-easting mammals are quite large and have a long digestive tract; while guinea pigs have much longer colons than most rodents, they must also supplement their diet by Coprophagy, the eating of their own feces. However, they do not consume all their feces indiscriminately, but produce special soft pellets, called Cecotropes, which recycle vitamins B, fiber, and bacteria required for proper digestion (Terril *et al.,* 1998; Wagner *et al.*, 1976). The cecotropes (or caecal pellets) are eaten directly from the anus, unless when the guinea pig is pregnant or obese. They share this behavior with rabbits.

Like humans, but unlike most other mammals, guinea pigs cannot synthesize their own vitamin C and most obtain this vital nutrient from food. Guinea pigs require about 10mg of vitamin C daily (about 20mg if pregnant), which can be obtained through fresh, raw fruits and vegetables (such as broccoli, apple, cabbage, carrot and spinach) or through dietary supplements (Richardson, 2000). Healthy diets for guinea pigs require a complex balance of calcium, magnesium, phosphorus, potassium, and hydrogen ions; adequate amounts of vitamins E, A and D are also necessary.

2.2.3 Habitat of Guinea Pig

Guinea pigs are extremely adaptable and could survive in a variety of environments, for example, they can live in a broad range of elevation, from sea level of 400m. Although studies have shown that they cannot survive in extreme hot cold, guinea pigs can tolerate a large range of temperatures from 22^0c in the daytime to -7^0c at night (Morales, 1994, Sandweiss *et al.,* 1997).

Wild cavies are found on grassy plains and occupy an ecological niche similar to that of cattle. They are social, living in the wild in small groups which consist of several females (sows), a male (boar), and the young (pup). They move together in groups (herbs) eating grass or other vegetation, and do not store food. While they do not burrow or build nests, they frequently seek shelter in the burrows of other animals, as well as crevices and tunnels formed by vegetation (Wagner *et al,* 1976). Domestic guinea pigs generally live in cages, although some owners of large numbers of guinea pigs dedicate entire rooms to their pets. Cages are often lined with wood shavings or a similar material, safer beddings made from hardwoods (such as aspen), paper products, and corn cob materials are commonly use.

2.3.4 Breeding in Guinea Pig

Sows need to be bred before 7 months of age to prevent dystocia from a fused pelvis, and are usually bred at around two or three months. They are continuously polyestrous (every 15 to 17 days), nonseasonal and have spontaneous ovulation, estrous lasts six to twelve hours (Gurling, 2003). Any present male will “purr” then fuss over the sow, mounting and licking the anogenital areas.

A couple of hours after mating, a copulatory plug can be found in the cage, the plug is formed in the vagina and made up of the boar’s semen, and is thought to prevent semen leaking out and prevent fertilization by other boars (Quesenberry *et al.,* 2004). Pregnancy can be identified two to three weeks post-mating by palpitation or ultrasonography. When nearing the end of the gestation period, sows can achieve double their pre-gestation weight when the hormone relaxin initiates parturition, the pubic ligaments start to spread, widening the pelvis in preparation for passing the relatively large pups. Immediately following parturition, the sow usually eats the placenta. Unlike the offspring of most other rodents, which are altricial at birth, newborn pups are well developed with hair, teeth, claws and partial eyesight. They are immediately mobile, and begin eating solid food immediately, though they continue to suckle. Domesticated guinea pigs occur in many breeds, which have been developed since their introduction to Europe and North American. These varieties vary in hair and colour composition. The most common varieties are the English shorthair (also known as American), which have a short, smooth coat and the Abyssinian, whose coat is ruffled with cowlicks, or rosettes. Also popular among the breeders are the Peruvian and the Sheltie (or Silkie), both straight, long hair, and the Texel, a curly longhair (Harkness *et al.,* 1995).

The use of guinea pigs in scientific experimentation dates back at least to the 17th century, when the Italian biologists Marcello Malpighi and Carlo Fracassati conducted vivisections of guinea pigs in their examination of anatomic structure (Guerrini, 2003). In 1780, Antoine Lavoisier used a guinea pig in his experiments with the calorimeter, a device used to measure heat production. The heat from the guinea pig's respiration melted snow surrounding the calorimeter, showing that respiratory gas exchange is combustion, similar to a candle burning (Buchholz *et al.,* 2004). Guinea pigs played a major role in the germ theory in the late 19th century, through the experiments of Louis Pasteur, Emile Roux, and Robert Koch (Guerrini, 2003). Guinea pigs have been launched into orbital space flight several times, first by USSR on the sputnik 9 biosatellite of March 9, 1991, with a successful recovery. China also launched and recovered a biosatellite in 1990 which included guinea pigs as passengers. Guinea pigs were popular laboratory animals until the later 20th century; about 2.5 million guinea pigs were used annually in the U.S for research in the 1960s (Gad, 2007). But that total decreased to about 375,000 by the mid1990s (Harkness and Wagner, 1995). As of 2007, they constitute about 2% of the current t otal of laboratory animals. Since the middle 20th century, they have been replaced in laboratory contexts primarily by mice and rats. This is in part because research into genetics of guinea pigs has lagged behind that of other rodents, although geneticists W.E. Castle and Sewall Wright made a number of contributions to this area of study, especially regarding coat color (Robinson, 1974;Wagner and Manning, 1976).

In 2004, the U.S's National Human Genome Research Institute announced plans to sequence the genome of the domestic guinea pig. The guinea pig was most extensively implemented in research and diagnosis of infectious diseases (Reid, 1958). Common uses included identification of brucellosis, chagas disease, cholera, diphtheria, foot-and-mouth disease, and various strains of typhus. They still frequently used to diagnose tuberculosis, since they are easily infected by human tuberculosis bacteria (Gad, 2007).

Complement, an important component for serology was first isolated from the blood of the guinea pig (Gad, 2007). Guinea pigs have an unusual insulin mutation. And are a suitable species for the generation of anti-insulin antibodies (Bowsher *et al.*, 1999) present at a level ten (10) times that found in other mammals, the insulin in guinea pigs may be important in growth regulation, a role usually played by growth hormone (Adkins *et al*, 2001). Additionally, guinea pigs have been identified as model organisms for the study of juvenile diabetes and, because of the frequency of pregnancy toxemia, of pre-eclampsia in human females (Percy *et al.,*, 2001).

Guinea pig are also used extensively in reproductive studies because of their placental structure is similar to that of humans and their gestation period can be divided into trimesters that resemble the stages of fetal development in humans. In 2009, over 222,000 rabbits were used in research, more than any other species covered under the Animal Welfare Act (AWA), followed next by guinea pigs and hamsters, which are both used a great deal in toxicity testing and as models for infectious, cardiovascular, and neurological diseases and drug abuse research (National Research Council, 2009).

2.2.5 Scientific Classification of Guinea Pig

Kingdom - Animalia

Phylum - Chordata

Subphylum	-	Vertebrata
Class	-	Mammalia
Order	-	Rodentia
Suborder	-	Hystricomorpha
Infraorder	-	Hystricognathi
Family	-	*caviidae*
Subfamily	-	*caviinae*
Genus	-	*cavia*
Species	-	*cavia porcellus*

The local names include:

Hausa	-	Beran masar
Igbo	-	Oke Bekee
Yoruba	-	Emo-Ile

2.2.6 Economical Importance of Guinea Pig to Humans

Positive: Globally, guinea pigs are sold as pets and in South America, as a food. Also, they are often used as subjects in biomedical research investigating scurvy, tuberculosos (Basombrio *et al.,* 1997; Bloom, 1994; Olsson *et al.,* 1998).

2.3 Wistar Rat

The Wistar rat is an outbred albino rat. This breed was developed at the Wistar Institute in 1906 for use in biological and medical research, and is notably the first rat developed to serve as a model organism at a time when laboratories primarily used the common house mouse (Mus musculus). More than half of all laboratory rat strains are descended from the original colony established by physiologist Henry Donaldson, scientific administrator Milton J. Greenman, and genetic researcher/embryologist Helen Dean King

(The wistar institute, 2007)

neuroanatomist Henry H. Donaldson wrote a beautifully succinct testament to the "rightness" of the rat as a laboratory animal: As we have progressed with our studies on this animal, it has become increasingly evident that the choice was a fortunate one, as the albino rat is easy to keep, breeds freely, bears young that are both numerous and immature, and is also responsive to changes in its environment as well as being easily trained. It would be hard to find another animal that combined so many virtues in so compact and pleasing a form.1 Nearly fifty years later, referring to the descendants of Donaldson's rats as the "famous colony of albino rats at The Wistar Institute in Philadelphia," Curt Richter echoed Donaldson's tribute. Claiming half a century of behavioral and neurological research using "many different animals such as cats, dogs, monkeys, sloths, rabbits, beavers, porcupines, honey bears, alligators, and others

TYPE: Outbred rat

COLOUR AND RELATED GENOTYPE : Albino rat - Tyrc/Tyrc

ORIGIN: Zentralinstitut für Versuchstierzucht (Hannover) 1982 (from Allington Farm - UK - 1964)

BREEDING: Good breeder

2.3.1 Scientific Classification of Wistar rat

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Rodentia
Super-family	Muroidea
Family	Muridae
Sub-family	Murinae
Genus	Rattus
Specie	Norvegicus

2.4 ANIMALS IN RESEARCH

Along with mice and other rodents, wistar rats make up more than 90 percent of animals used for medical research .Because humans and rats are both mammals, they share many similarities in structure and function. In addition, their small sizes, low cost, ease in handling, and ability to breed in captivity make rats ideal for laboratory experiments (Anderson 2007).

Table 2.1Comparative Taxonomic Classifications of Humans and animals used in this Study

	HUMAN	**GUINEA PIG**	**WISTAR** RAT
Kingdom	Animalia	Animalia	Animalia
Phylum	Chordata	Chordata	Chordata
Class	Mammalia	Mammalia	Mammalia
Order	Primates	Rodentia	Rodentia
Super-family	-	-	Muroidea
Family	Hominidae	caviidae	Muridae
Sub-family	-	caviinae	Murinae
Genus	Homo	cavia	Rattus
Specie	Homo sapiens	Cavia porcellus	Norvegicus

(Nowak, 1999).

Rats are the main subject in product safety tests. One is the repeated-dose chronic toxicity test, which is used to test a substance for effects of long-term exposure. Another is the developmental and reproductive toxicity test, which measures the likelihood of infertility or the effect on pregnancy of using a product. Toxicological studies, which test whether certain products are harmful or poisonous, have relied on rats as their primary subjects for testing compounds for safety (Anderson, 1999). •

- **Neurology**

Scientists believe research on rats may lead someday to development of a drug that can reduce or prevent permanent paralysis following a spinal cord injury. Researchers have discovered the protein that stimulates the regeneration of damaged nerves. Using rats with damaged spinal cord nerves, they have stimulated growth of new nerve cells. This may help in the treatment of trauma patients and gives hope to those suffering from paraplegia, strokes, Lou Gehrig's disease and other diseases involving nerve damage. (Schnell,et *al.,* 1990) Researchers have duplicated the effect of human Alzheimer's disease by injecting rats with a protein called beta amyloid, which is found in the brains of people with the disease.

- **Product Safety**

Scientist will us rats to explore ways of blocking beta amyloid's toxic effects, possibly slowing or halting the effects of Alzheimer's (Kowall, *et al.,* 1991).

- **Behavioural Science**

Since the late 19th century, researchers have used rats in behavioural studies and applied the data to humans. Experiments with mazes have provided a major research tool for the - study of learning. Researcher have used rats to study the effects of psychological factors in susceptibility to disease. Scientists are studying how genetics affects learning and reasoning functions (Adler, 1971)

- **Hypertension/Diabetes**

Certain strains of rats develop elevated blood pressure. These rats allow researchers to study the disease processes and possible treatments for obesity, diabetes and hypertension (Bishop,*et al* 2001)

- **Infectious disease**

The study of natural infection of rats has allowed for the control of diseases, improving the health of laboratory colonies, thus providing more accurate research data. Rats have been used as animal models for human infections like streptococcus and salmonella (Spring, 2006).

- **Reproductive Biology**

Researchers have used rats to understand aspects of the reproductive cycle, including the effects that immunization of pregnant females could have on their offspring (Bernard, 1979).

- **Nutrition**

Rats are being used to study the relationship between nutrition and aging, in particular, exploring the possibility that restricted diets may increase life spans. (Spring, 2006).

Transplants

Work with rats as led to advances in understanding tissue rejection and transplant immunology. Scientists study rejection and genetics in transplants done with the pancreas, skin, heart, kidney, and hone marrow. Rats have also been used in the development of microsurgery techniques (Givne, 2003).

- **Cancer**

Rats have been used in various cancer studies because certain strains can develop cancer spontaneously, as well as by viral and chemical induction. Rats are used to study dietary components and environmental chemicals that may either prevent or cause cancers (Pour, *et al* 1991).

2.5 THE LIVER

The liver has multiple functions. It is greatest metabolic organ, initially receiving all absorbed foodstuffs except fats. It is also our largest gland, functioning as an extrinsic intestinal gland in producing bile. The liver occupies essentially the entire right dome of the diaphragm and extends to the apex of the left dome (Moore and Dailey, 2006).

2.5.1 EMBRYOLOGY OF THE LIVER

The liver arises as a ventral outgrowth-hepatic diverticulum-from the caudal or distal part of the foregut early in the. fourth week (Tremblay and Zaret, 2005: Moore and Persuad, 2011).

The hepatic diverticulum develops from two cell populations in the embryonic endoderm. The diverticulum extends into the *septum transversum*, a mass of splanchnic mesoderm between the developing heart and midgut. The septum transversum forms the ventral msentery in this region. The hepatic diverticulum enlarges rapidly and divides into two parts as it grows between the layers of the *ventral mesogastrium* .The larger cranial part of the hepatic diverticulum is the primordium of the liver. The proliferating endodermal cells give rise to interlacing cords of hepatocytes and to the epithelial lining of the - intrahepatic part of the biliary apparatus. The *hepatic cords* anastomose around the primordia of the *hepatic sinusoids*. The fibrous and hematopoietic tissue and *Kupffer* cells of the liver are derived from mesenchyme in the septum transversum. The liver grows rapidly and, from the 5th to 10th weeks, fills a large part of the upper abdominal cavity .The quantity of oxygenated blood flowing from the umbilical vein into the liver determines the development and functional segmentation of the liver. Initially, the right and left lobes are approximately the same size, but the right lobe soon becomes larger. Eematopoiesis begins during the sixth week, giving the liver a bright reddish appearance. By the ninth week, the liver accounts for approximately 10% of the total weight of the fetus. Bile formation by hepatic cells begins during the 12th week. (Moore and Persuad, 2010).

2.5.2 GROSS ANATOMY OF THE LIVER

The liver is the largest internal organ and the largest gland of the human body, weighing about *1.3-1.5* kg *(3.5—4.0* ibs) in an adult. It is positioned immediately beneath the diaphragm in the epigastric and right hypochondriac regions of the abdomen and it overlies the gall bladder. Its reddish brown color is due to its great vascularity (Standring, 2008).

2.5.3 HEPATIC ATTACHEMENTS

The liver is attached to the anterior abdominal wall, diaphragm and other viscera by several ligaments, which are formed from condensations of the peritoneum. A brief description of the ligaments is as follows: *Falciform ligament:* Anteriorly, the liver is attached to the anterior abdominal wall by the falciform ligament.
Coronary ligament: The coronary ligament is formed by the reflection of the peritoneum from the diaphragm onto the posterior surfaces of the right lobe of the liver.
Triangular ligaments: The triangular ligament is divided into two; the right and the left triangular

ligament. The left triangular ligament is a double layer of peritoneum which extends to a variable length over the superior border of the left lobe of the liver. Medially the anterior leaf is continuous with the left layer of the falciform ligament. The posterior layer is continuous with the left layer of the lesser omentum.The left triangular ligament lies in front of the abdominal part of the esophagus, the upper end of the lesser omentum and part of the fundus of the stomach. *Lsser omentum:* The lesser omentum is a fold of peritoneum which extends from the lesser curvature of the stomach and proximal duodenum to the inferior surface of the liver (Moore and Dalley, 2006).

2.5.4 HEPATIC SURFACES AND BORDERS

The liver has five surfaces. These are superior, anterior, right, posterior and inferior surfaces, and have a distinct inferior border. However, *superior, anterior and right .Surfaces* are continuous and no definable borders separate them so they are grouped as .diaphragmatic surface, which is separated from the inferior or visceral surface, by inferior border. The inferior border follows the right costal margin lateral to the fundus of the gallbladder, which is *4-5* cm to the right of the midline (Moore and Dalley, 2006).

Superior surface: The superior surface is the largest surface and lies immediately below the diaphragm, separated from it by peritoneum except for a small triangular area where the two layers of the falciform ligament diverge.

Anterior surface: The anterior surface, which is approximately triangular and convex, is covered by peritoneum except at the attachment of the falciform ligament. *Right surface:* The right surface is covered by peritoneum and lies adjacent to the right dome of the diaphragm which separates it from the right lung and pleura and the seventh to eleventh ribs.

Posterior surface: The posterior surface is convex, wide on the right, but narrow on the lefL It is triangular. Its middle part shows a deep concavity for vertebral column. Much of thó posterior surface is attached to the diaphragm by loose connective tissue, which forms the so-called bare area (Moore and Dalley, 2006).

2.6 HISTOLOGY OF THE LIVER

The liver, like the pancreas, develops embryologically as an epithelial-mesenchymal — glandular outgrowth of the fore gut (Young *et a!.*, 2007). The liver which is a solid organ composed of tightly packed plates of epithelial cells termed hepatocytes. Hepatocyte is the basic structural component of the liver. These hepatocytes are large polyhedral cells with round nuclei with peripherally dispersed chromatin and prominent nucleoli. The outer surface of the liver is covered by a capsule composed of collagenous tissue called *Glisson 's capsule* over which is a layer of mesothelial cells from the peritoneum. This thin connective tissue capsule *(Glisson's capsule)* becomes thicker at the hilum, where the portal vein and the hepatic artery enter the organ and where the right and left hepatic — ducts and lymphatics exit. These vessels and ducts are surrounded by connective tissue all the way to their termination (or origin) in the portal spaces between the liver lobules. At this point, a delicate reticular fiber network that supports the hepatocytes and sinusoidal — endothelial cells of the liver lobules is formed (Junqueira and Cameiro, 2005: Young *et al.*, 2007).

Liver lobule is the structural units of the liver. The liver lobule is formed of a polygonal mass of tissue about 0.7 x 2 mm in size, with portal spaces at the periphery and a central vein, in the center. Portal spaces, regions located in the corners of the lobules, each containing connective tissue, bile ducts, a venule (a branch of the portal vein), an arteriole (a branch of the hepatic artery), a duct (part of the bile duct system), and lymphatic vessels. The venule contains blood coming from the superior and inferior mesenteric and splenic veins. The arteriole contains oxygen-rich blood coming from the celiac trunk of the abdominal aorta. The duct, lined by cuboidal epithelium, carries bile synthesized by the hepatocytes and eventually empties into the hepatic duct. One or more lymphatics carry lymph, which eventually enters the blood circulation (Young *et al., 2007).*

The hepatocytes in the liver lobule are radially disposed and are arranged like the bricks of a wall. These cellular plates are directed from the periphery of the lobule to its center and anastomose freely, forming a labyrinthine and sponge like structure. The space between these plates is the liver sinusoids (Junqueira and Carneiro, 2005: Young *et al.,* 2007).

Sinusoid is a space between the plates of liver cells. The sinusoids are lined by flat, discontinuous, fenestrated endothelial lining cells which are readily distinguishable from hepatocytes by their flattened condensed nuclei and attenuated poorly stained cytoplasm these endothelium is separated from the hepatocyte by a narrow space (space of Disse).It allows blood to come into contact with the hepatocytes. The very close association of the sinusoidal vasculature of the liver with the hepatocytes is essential for normal function. Certain diseases of the liver cause obliteration of the normal sinusoidal arrangement which then causes impairment of liver function the sinusoids also contain macrophages known as *Kupffer cells* which are a large phagocytic cell with ovoid nuclei that are scattered among the endothelial cells lining the sinusoid Its main functions are to metabolize aged erythrocytes, digest hemoglobin, secrete proteins related to immunological processes, and destroy bacteria that eventually enter the portal blood through the large intestine (Junqueira and Cameiro, 2005: Young, *et al.*, 2007). The structural integrity of the liver is maintained by a fine meshwork of *reticulin fibres* (collagen type III). The reticulin meshwork supports both the hepatocytes and the sinusoidal lining cells (endothelial cells). The sinusoids are also bounded by the same reticulin framework. The reticulin merges with the sparse collagenous supporting tissue of the portal tract and terminal hepatic venule. At the periphery of the liver, the reticulin becomes continuous with Glisson's capsule (Junqueira and Carneiro, 2005: Young, *et al.*, 2007).

2.7 FUNCTIONS OF THE LIVER

The major functions of the liver may be summarised as follows:

Fat metabolism

•Oxidising triglycerides to produce energy.

•Synthesis of plasma lipoproteins.

•Synthesis of cholesterol and phospholipid.

• Carbohydrate metabolism

• Converting carbohydrates and proteins into *fatty* acids and triglyceride.

• Regulation of blood glucose concentration by glycogenesis, glycogenolysis and gluconeogenesis.

Protein metabolism

• Synthesis of the plasma proteins, including albumin and clotting factors.

• Synthesis of the non-essential amino acids.

• Detoxification of metabolic waste products, e.g. deamination of amino acids and production of urea.

Storage

• Storage of glycogen, vitamins, iron.

Intermediary metabolism

• Detoxification of' various drugs and toxins, such as alcohol.

Secretion

• Synthesis and secretion of bile; bile contains many of the products of the above processes (Young *et al.*, 2007).

The main functional cell in the liver is a form of epithelial cell called the hepatocyte. These cells are arranged as thin plates separated by fine vascular sinusoids through which - blood flows. The close association of liver cells and the circulation allows absorption of nutrients from digestion as well as secretion of products into the blood. Blood flow into - the liver sinusoids comes from terminal branches of both the hepatic portal vein and hepatic artery. The liver is therefore unusual in having both arterial and venous blood supplies as well as separate venous drainage. With the exception of most lipids, absorbed food products pass directly from the gut to the liver via the hepatic portal vein. This brings blood that is rich in amino acids, simple sugars and other products of digestion but is relatively poor in oxygen. Oxygen required to support liver metabolism is supplied via the hepatic artery. After passing through the sinusoids, venous drainage of blood from the liver occurs via the hepatic vein into the vena cava. (Young *et al.*2007).

The main blood vessels and ducts run through the liver within a branched collagenous framework termed the portal tracts. These tracts also contain the bile ducts that transport - bile away from the liver to be secreted into the small bowel (Young *et al.*2007).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 STUDY ANIMALS

A total number of 5 adult male Wistar rats were obtained from Faculty of Veterinary Medicine, Ahmadu Bello University Zaria, while 5 adult male Guinea pigs were obtained from Samaru market. They were transported using animal cages to the Department of Human Anatomy Laboratory, Ahmadu Bello University Zaria. The animals were kept for acclimatization for a period of one week before the commencement of the study.

3.1.2 OTHER MATERIALS

The following materials were also used during the study, Dissecting kits, Cotton wool, Chloroform, Specimen bottles, Chloroform, Normal saline, Formalin, Containers with cover, Weighing balance, Dissecting tray, Vernier caliper, Thread and meter rule, Light and meter rule, Antiseptic soap, Disinfectant, etc.

3.2 METHODS

Three studies were conducted in this study and they are, morphologic study, morphometric and histologic studies all varying in their methods and procedures. Before all that the animal was sacrificed and laid on a dissection board after it was anaesthetized lightly using chloroform. The livers, were removed by gentle traction with scalpel blade

3.2.1 MORPHOLOGIC STUDIES

The structural characteristics of the animals were examined; the weights of the animals were taken before the sacrifice and also after they were sacrificed a gross observation of the liver, conducted with naked eye. This includes the shape, sizes and weight of the liver, and also the number of lobes of each liver was evaluated in each of the specimen. The liver was weighed using a digital micro scale and recorded in grams

3.2.2 MORPHOMETRIC STUDY

The body weights of the experimental animals (Guinea Pig and Wistar rat) were recorded, the livers, were removed by gentle traction with scalpel blade was then fixed in formalin (10% formol saline). Dimensions of the organs were determined by measurements of the length, diameter and width using a meter rule.

3.2.3 HISTOLOGIC STUDY

Using routine (H and E staining) histological techniques, histological examination of the Liver was conducted. Tissues processing and Histological staining procedures are indicated in **Appendix I and II.**

3.3 STATISTICAL ANALYSIS

Data obtained (recorded weights, length and widths) were analyzed using statistical package for social science software (SPSS version 23) and result were expressed as mean ± Standard error of mean (SEM) and presence of significant differences among means of the groups were determined using one way ANOVA. Independent t-test was also employed for the comparism of mean as appropriate values were considered significant when P< O.O5.

CHAPTER FOUR

4.0 PRESENTATION OF RESULTS

4.1 PHYSICAL OBSERVATION

Physical observation of the experimental animals showed differences in the weight, size (length) and physical appearance. The Wistar rat was smaller, in size and weight than the Guinea pig

4.2 BODY WEIGHT OF STUDY ANIMALS

Table 4.1 shows the descriptive statistic of the body weights of the experimental animals used in the study, with mean and standard error of mean values and descriptive statistic of the organ - body weights ratio of the experimental animals used in the study

Table 4.1: Descriptive statistics of body weight/organ weight and relative organ weight of study animals used.

Variables	Guinea pig (N=5)			Wistar Rat (N=5)		
	Mean ± SEM (g)	Min – Max (g)	Relative Organ WT (%)	Mean ± SEM (g)	Min – Max (g)	Relative Organ WT (%)
Body Weight	481.4.0±46.80*	370 -615	100	90.80±5.67	80-110	100
Liver Weight	17.80±3.07	14 -30	3.70	6.80±1.15	4-10	7.5

*p≤0.05 = statistically significant; SEM: standard error of mean, WT: weight; Min: Minimum; Max: Maximum; N: Number of animals

4.3 GROSS ANATOMICAL FEATURES OF ORGANS STUDIED

Plate 4.1 Shows the gross anatomical features of the Liver of the experimental animals studied; respectively

Plate 4.1: Gross features of liver of Wistar rat and guinea pig.

Plate 4.1: Gross features Wistar rat liver

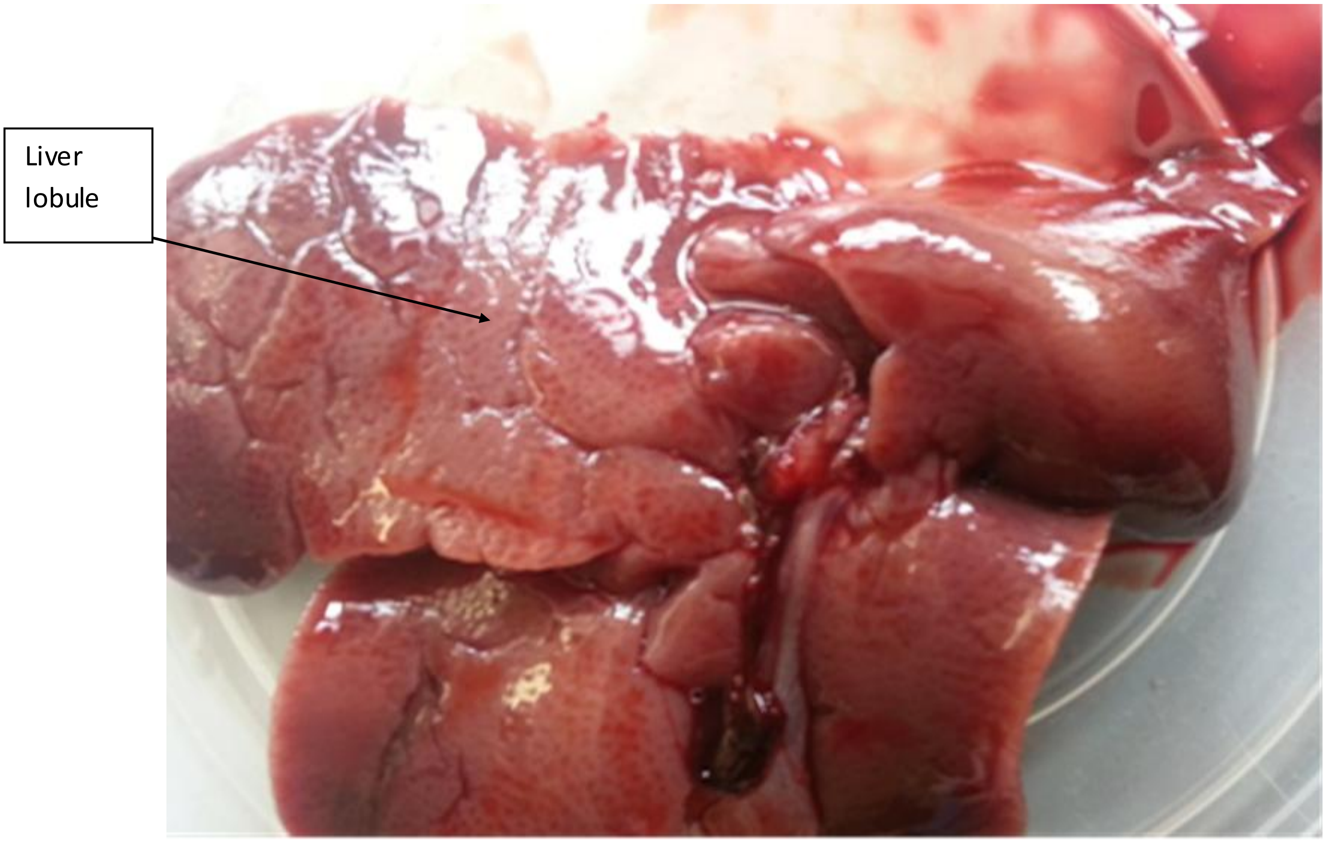

Plate 4.1: Gross features of Guinea Pig Liver

4.4 MORPHOMETRY OF ORGANS STUDIED

Table 4.2: Shows Comparative morphometric parameters of the liver (length and width)

Table 4.2: Comparative morphometric parameters of the liver (length and width)

Variables	Guinea pig (N=5)		Wistar Rat (N=5)			
	Mean ± SEM (cm)	Min – Max (cm)	Mean ± SEM (cm)	Min – Max (cm)	*t*	p value
Liver length	5.22±0.19	4.7-5.8	1.88±0.07	1.7-2.1	16.336	0.00
Liver Width	2.66±0.19	2.1 -3.2	1.02±0.86	0.8-1.3	7.818	0.00

4.5 HISTOARCHITECTURE OF THE LIVER STUDIED

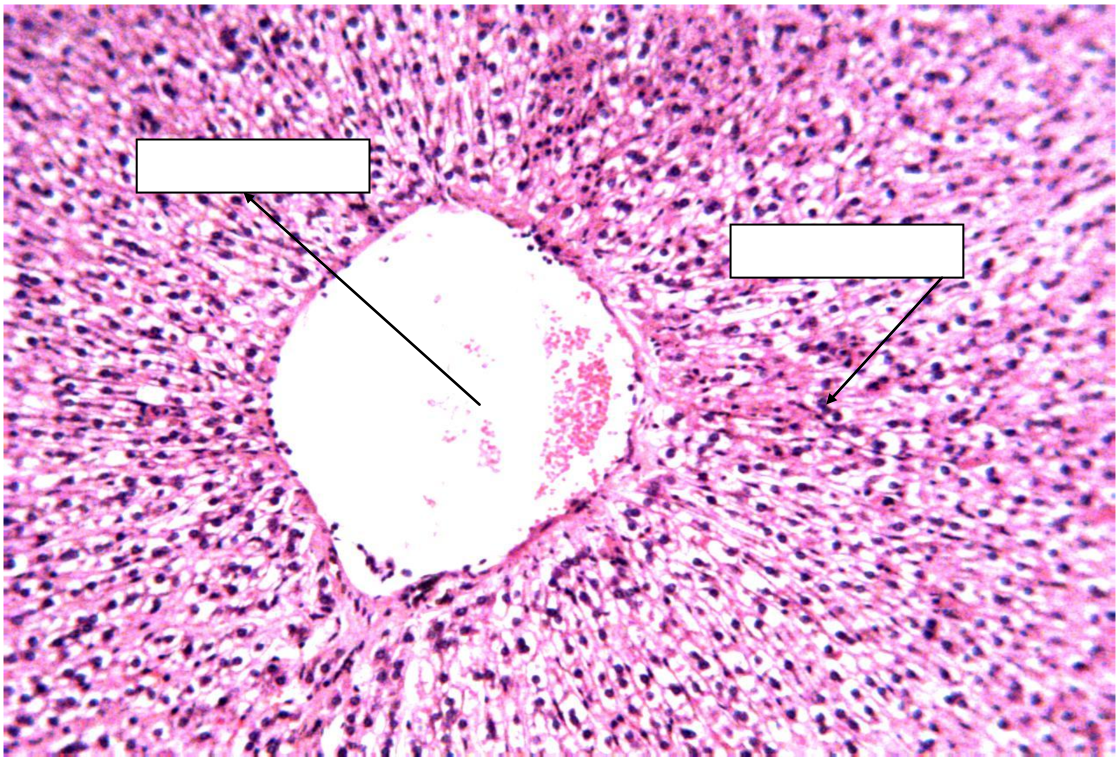

Plate 4.3: Micrograph of Guinea pig liver H&E X 100

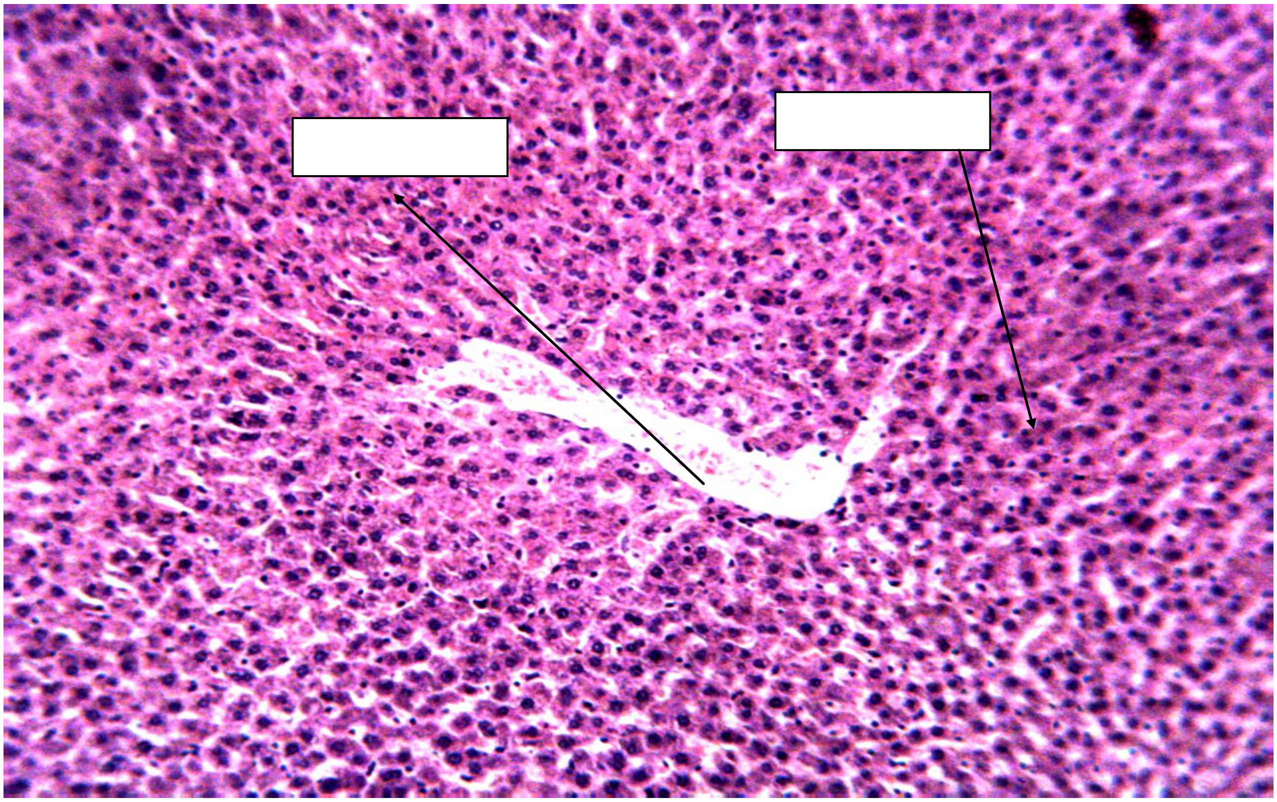

Plate 4.3: Micrograph of Wistar rat liver H&E X 100

CHAPTER FIVE

5.0 DISCUSSION

5.1 PHYSICAL OBSERVATION

Physical observation of the physical appearance of the experimental animals revealed differences in length and size. The wistar rat was smaller in size and length than the Guinea pig. The weights of the organs harvested from the experimental animals were also found to be related to the sizes of animals, which was expected.

Comparatively the weight, length, and width of the liver studied were relative to the absolute body weight of the experimental animals. This observation may be related to the varying sizes and weights of the experimental animals as reported by David and Hiadic (2001) and Ozegbe *et al.,* (2000).

5.2 GROSS ANATOMY

Gross feature of the liver revealed a larger organ with the Guinea pig and a smaller organ with the wistar rat. This was also expected as the larger the animal the larger its organ size. Both the experimental animals had the same number of liver lobes six in number while vestigial lobes were found on the Guinea pig Liver.

Comparatively, the liver of Wistar rat and guinea pig are phylogenetically related. This is in accordance with Ozegbe *et. al* (2000). The sizes of all the organs were related to the sizes of the animals as expected.

The liver produces bile continuously which accumulates between meals and is stored in the gallbladder, which also concentrates the bile by absorbing water and salts. The gall bladder is closely related to the liver (Moore and Dailey, 2006). In this study, absence of gall bladder was observed in Wistar rat but present in the Guinea pig. This finding is in accordance to report of previous researchers (Dimitrov, 2011; Ajayi et al., 2009).

5.3 HISTOLOGICAL FEATURES

Histologically, the liver of all the experimental animals studied have similar histo-architecture. Similar histological features have been reported in selected rodents, by (Dimitrov, *et al 2005).*

Histological features of the organs of rodents are useful in gaining better understanding of microscopic anatomy and the slides can be used for teaching purpose in addition to human abdominal organs (Steiniger, 2011).

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 SUMARRY

A thorough comparative study was carried out on the guinea pig and wistar rat where the morphologic, morphometric parameters and histology of the liver was conducted, the data obtained were recorded and analyzed. The data was also discussed and the findings and recommendations were highlighted.

6.2 CONCLUSION

Based on the results obtained from the morphometric, morphologic and histologic studies conducted on the Guinea pig and wistar rat Liver, comparatively the liver of these animals are phylogenetically related. The organs are similar from a physical observation and histologically, the Liver of the experimental animal studied have similar histo-architecture as seen on the micrograph plates.

6.3 RECOMMENDATION

Further studies should be conducted using other rodent species and gender to check for sexual dimorphism

Comparative Histochemical and ultrastructural studies should be conducted on these and other organs of the rodent specie.

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APPENDIX I

CALCULATION OF ORGAN BODY WEIGHT RATIO IN PERCENTAGE

To determine the organ: body weight ratio in percentage, the following formula was applied.

$$\frac{\textbf{ORGAN WEIGHT}}{\textbf{BODY WEIGHT}} \textbf{ X 100\%}$$

So, the organ weight is divided by the body weight of the animal multiplied by 100% gives the organ body weight ratio in percentage (as seen above).

APPENDIX II

TISSUE PROCESSING

Fixation in 10% formolsaline lasted for 48 hours.

Washing in running water for two hours

Dehydration in grades of alcohol

30% alcohol for 4 hours

50% alcohol for 4 hours

70% alcohol for 16 hours

First change 95% alcohol for 4 hours

Second change 95% alcohol for 4 hours

First change absolute (100%) alcohol for 4 hours

• Second change absolute (100%) alcohol for 4 hours Xylene + absolute alcohol equal parts for 2-4 hours.

Clearing

Put in pure xylene first change for ‘4 hours

Put in pure xylene for second change for 4 hours

Infiltration

Xylene + paraffin 2 -4 hours

Pure paraffin 16 hours

Embed in paraffin

PREPARATION OF STAINING SOLUTION

HAEMATOXYLIN

Haematoxylin -1g

Absolute alcohol -lOml

Ammonium or potassium alum - 20g

Distilled water -200m1

Mercuric oxide - *O.5g*

Heamatoxylin was dissolvded in alcohol and alum which was dissolved in water was added. The mixture was then boiled and mercuric acid added when solution turn dark purple.it was then cooled rapidly.

EOSIN

Distilled water

Crystal of thymol

5% eosin solution was made ‘by dissolving 5g of eosin in lOOml of distilled water.. To prevent growth of mould, in the stock solution, a crystal of thymol was added to obtain 1% staining solution, 20m1 of the stock solution was diluted by making it up to lOOml.

STAINING

Removal of wax with xylene

Dewaxing I, -3 minutes

Dewaxing II, - 3 minutes

Hydration with graded alcohol

Absolute alcohol, 1 minute

95% alcohol, 1 minute

70% alcohol, 2 minutes

50% alcohol, 2 minutes

30% alcohol, 1 minute

Staining

Haematoxylin, 10 - 20 minutes

Distilled water (washing)

35% alcohol, 1 minute

Acid- alcohol, 30 seconds (for differentiation between nucleus and cytoplasm)

Distilled water, 1 minute

Alkaline- alcohol, 2 minutes (for bluing of the nucleus)

Distilled water, 1 minute

Staining in 1% eosin, 2 minutes

Dehydration in alcohol