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87th INAUGURAL LECTURE

THE MAGNUM OPUS OF REPRODUCTIVE ANATOMY: THE AFRICAN GIANT RAT AND THE GIANT OF AFRICA

by

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Great FUNAABITES!!!

PREAMBLE

Mr. Vice-Chancellor, Sir, it is with a deep sense of gratitude to God and utmost sense of humility that I stand before you this afternoon to present the 87th Inaugural Lecture of the Federal University of Agriculture, Abeokuta entitled; **"The Magnum Opus of Reproductive Anatomy: The African Giant Rat and The Giant of Africa".** This is the second Inaugural Lecture from the College of Veterinary Medicine and the first from my Department, the Department of Veterinary Anatomy. The first inaugural lecture from COLVET was presented by Professor Morenike Atinuke Dipeolu in 2010 titled; Healthy Meat for Wealth.

The Beginning

Mr. Vice-Chancellor, Sir, in a funny twist of fate, my love and passion for Anatomy began in my secondary school days at Ayedaade Grammar School, Ikire when our Biology teacher, Mrs. Pillar - an Indian lady, took us on "Introduction to Biology" in Form 3. She taught us the "Cell" as being the unit of life. Throughout the introductory class, I could not understand what a "cell" was. Was it an animal or a plant? "In fact, what is a cell in Yoruba language?" Among several other questions, I asked myself, what was a unit of life? At the end of the class, Mrs. Pillar asked if we all understood her lecture and to my utmost surprise, everybody answered in the affirmative - "Yes !!!". Seeing that everyone else understood the "Cell", I shamefully kept silent, pretending to have understood also. Thereafter, however, I decided to personally meet Mrs. Pillar to expose my ignorance and requested for full explanation of the "Cell". Long story cut short, I became one of the best Biology students in my set. Mr Vice-chancellor, Sir, that encounter laid a firm foundation for my understanding of biology and marked the beginning of my love and passion for Anatomy.

Thus, during the preclinical phase of my study at the University of Ibadan, Veterinary Anatomy came to me naturally. At that time, Professor Tom Aire and the then Dr. B. O. Oke, now Late Prof. B. O. Oke, renowned Reproductive and Endocrine Anatomists, caught my attention with their artistic flair and enthusiasm and the ease with which they taught complex concepts in Veterinary Anatomy. Throughout my undergraduate years, I was Prof. Oke's secret admirer until 1998 when I went to meet him for supervision of my M.Sc. project in Veterinary Anatomy. Prof. B. O. Oke painstakingly guided me into the field of reproductive and endocrine biology and by year 2000, I was done with my Masters within record time of three semesters and was ready for PhD.

At that time, the Department of Veterinary Anatomy, University of Ibadan was still busy characterizing the skin and the reproductive organs of African giant rat that was undergoing a primal domestication process. As at that time, almost all aspects of the male reproductive system had been characterized and Dr. Olusola Oke (M.Sc. student and a Lecturer in the Department) was just starting studies on exfoliative cytology of the vagina of the African giant rat. She in no time, however, left the Department for United Kingdom and three positions were defrosted in the Department thereby enabling Dr., now Professor James Olopade FAS, Dr. Matthew Akpan and I to be offered temporary appointments.

This appointment together with works of the two Okes left me with no option but to gravitate to the female reproductive system. Mr. Vice-Chancellor, Sir, Albert Eistein, the great philosopher once said; *"some men spend their lifetime in an attempt to comprehend the complexities of women while others pre-occupy themselves with somewhat simpler tasks such as understanding the theory of relativity"*. Mr. Vice-Chancellor, Sir, true to the saying, by choice and design of destiny, I fell on the side of comprehending these complexities by spearheading characterization of female reproductive system of one of the silent African giants within the shores of the Giant of Africa; the African Giant Rat.

My Journey to FUNAAB

My stint at the University of Ibadan was short. In 2001, as my appointment in the Department of Veterinary Anatomy was yet to be confirmed due to financial constraint in the University of Ibadan, Prof E. B. Otesile, who was just establishing COLVET in UNAAB, had extensive discussions with my supervisor, Late Prof Oke, and eventually, in 2002, Prof Otesile got me employed as a pioneer staff to establish the Department of Veterinary Anatomy in UNAAB.

Mr. Vice-Chancellor, Sir, my academic journey to FUNAAB has not only flamed the fire for a deeper understanding of the structural architecture of reproductive systems but has also given me a panoramic view of all the segments of the female reproductive system at gross, cytological, ultra-structural, histological, macroscopical and immunohistochemical levels. Unlike in humans, where oestrous cycle is divided into four stages (Proestrus, Oestrus, Metestrus and Dioestrus) seven stages of oestrous cycle exist in African giant rat; Mid Proestrus (MP), Late Proestrus/Early Oestrus (LP/EE), Mid Estrus (ME), Mid Metestrus (MM), Late Metestrus/Early Dioestrus (LM/ED), Mid Dioestrus (MD) and Late Dioestrus/Early Proestrus (LD/EP) (Oke and Oke, 1991). In each of these seven stages, hormonal patterns, as well as gross, histological, immunohistochemical and ultrastructural features of each segment of the reproductive tract (ovary, oviduct, uterus, cervix and vagina) differ significantly. At the end of the studies, beautiful cyclic features perfectly controlled by hormonal fluctuation that led to ovulation were discovered. This led to my conclusion that truly, the female reproductive system is a masterpiece; a **"Magnum Opus".** The high point also mirrors several societal factors that influence the multicultural and complex society called Nigeria - the Giant of Africa.

1.0 INTRODUCTION

1.1 Explanation of Concept

Mr. Vice-Chancellor, Sir, in a beautiful heterogeneous audience, as in an inaugural lecture like this where town and gown are seated, one may be wondering: What is *Magnum Opus*? What is Anatomy? Who is a Reproductive and Endocrine Anatomist? What is domestication? Why the African giant rat and how does it relate to Nigeria, the Giant of Africa? As this inaugural lecture will revolve round these, kindly permit me to briefly shed more light on these keywords for better understanding of the lecture.

1.1.1 Magnum Opus

Magnus Opus is a Latin language of Art that connotes the greatest piece of an artistic or musical work. The female reproductive system could be no less an analogy to describe the creative art of nature.

Mr. Vice-Chancellor, Sir, my lecture today captures the artistic design, finite make and fashion of the female reproductive system of the African giant rat through the anatomic focal lens as a Magnum Opus.

1.1.2 Anatomy

Anatomy is the oldest scientific discipline in medicine. Etymologically, very few words have longer history than the word "Anatomy". Since Aristotle introduced the word over 2500 years ago to describe the line of study that dealt with body structure, the word has come to be known in other senses as well. The term also means "any detailed analysis" of a subject matter (Singer, Charles, 1957).

"Anatomy", for the purpose of this lecture, will take its original meaning as articulated by Aristotle, that is, a study of body structures involving systemic method of studying the physical structure of living things. From its early days it has involved the detailed analysis both descriptive and quantitative physical structure of bodies of things living or dead. Traditionally, studies of Anatomy usually involved cutting up or dissecting organisms. Recently, however, imaging technology can show us much more about how the inside of a body works, reducing the need for dissection (McLachlan and Patten, 2006).

1.1.3 The Reproductive and Endocrine Anatomist

The Reproductive and Endocrine Anatomists are basic medical scientists that specialise in characterization of reproductive organs and their associated accessory sex glands in relation to hormonal regulation in animals. They usually conduct researches to establish biometric baseline data of different segments of the reproductive system.

1.2 Reproductive Anatomy: An Essential Tool for Wildlife Domestication and The Roles Of Veterinary Anatomist

The Veterinary Anatomist plays a critical role in decoding the structural and functional components, necessary for domestication and by extension production of animals. This holds great potentials beyond the science as the discoveries can aid artificial insemination and timing of mating which eventually result into profit for the farmer and increase the productivity of earning of a nation.

Nations such as the Netherlands, the United States and United Kingdom have garnered incredible gains through animal production. The Netherlands recorded earnings of over 8 billion euros on milk alone in 2022 with beef, poultry and pork grossing in tens of billions also (Friesland Campina, 2022). These advancements and profits come from better understanding of the reproductive components and reproducibility of traits that are favourable for profit.

At the earliest end of this spectrum is domestication. Domestication is the process of taming a plant or an animal and keeping it within or around human dwelling or on a farm, for human use. Domestic species are raised for food, work, clothing, medicine, and many other uses.

1.2.1 Animal Domestication

About the same time they domesticated plants, people in Mesopotamia began to tame animals for meat, milk, and hides. Hides, or the skins of animals, were used for clothing, storage, and building tent shelters. Goats were probably the first animals to be domesticated, followed closely by sheep (*Ovis aries*). In Southeast Asia, chickens *(Gallus domesticus)* also were domesticated about 10,000 years ago. Later, people began domesticating larger animals, such as oxen (*Bos taurus*) or horses (*Equus ferus caballus*), for ploughing and transportation. These are known as beasts of burden. (NGS, 2023)

Domesticating animals can be difficult work. The easiest animals to domesticate are herbivores that graze on vegetation, because they are easiest to feed: They do not need humans to kill other animals to feed them, or to grow special crops. Cattle, for instance, are easily domesticated. Herbivores that eat grains are more difficult to domesticate than herbivores that graze because grains are valuable as human food and their plants also need to be domesticated. Chickens are herbivores that eat seeds and grain. Some animals domesticated for one purpose no longer serve that purpose. Some dogs (*Canis lupus familiaris*) were domesticated to assist people in hunting, for instance. There are hundreds of domestic dog species today. Many of them are still excellent hunters, but most are pets (NGS, 2023).

Throughout history, people have bred domesticated animals to promote certain traits. Domestic animals are chosen for their ability to breed in captivity and for their calm temperament. Their ability to resist disease and survive in difficult climates is also valuable. Over time, these traits make domestic animals different from their wild ancestors. Dogs were probably domesticated from gray wolves

(*Canis lupus*). Domesticated animals can look very different from their wild ancestors. For example, early wild chickens weighed about 0.9 kilograms (two pounds). But over thousands of years of domestication, they have been bred to be larger. Larger chickens yield more meat. Today, domestic chickens weigh as much as 7.7 kilograms (17 pounds). Wild chickens only hatched a small number of eggs once a year, while domestic chickens commonly lay 200 or more eggs each year (NGS, 2023).

1.2.2 Wildlife Domestication in Nigeria

The idea of domesticating wild animal species for meat production and improved protein supply in Africa is not new. As far back as 1848, the domestication of the eland and buffalo was mooted in South Africa (Surujbally, 1975). However, despite these early intentions, the only African wild animal species which have been successfully domesticated completely are the ostrich and the camel. Several species, e.g., the crocodile, are farmed on large scale under semi-domesticated conditions. Domestication of wild species has been particularly popular in the West African sub-region where bushmeat is an important dietary item. Conservationists and advocates of wild animal domestication have argued for the farming of favourite species to increase bushmeat production and supply in the sub-region and also to reduce pressure on wild populations. Bushmeats advocated for include the grasscutter (Cane rat). the giant rat *Cricetomys gambianus*, a number of duiker species, the guinea fowl *Numida meleagris* and the giant African snail *Achatina* sp. and *Archachatina* sp. Pioneering work on domestication of the grasscutter was undertaken by the Game and Wildlife (now Wildlife Department) in Ghana in the 1970s, while the University of Ibadan, Nigeria concentrated on giant rats. Work on snails has been carried out in both Ghana and Nigeria for a long time e.g., a study on various aspects of biology and ecology of snails and captive rearing of snails has been going on in the Zoology Department of the

University of Ghana for over 20 years (Lawal, 2014).

While there is no doubt at all that domestication and farming of favourite wild animal species could provide viable complementary or alternative sources of animal protein the key to its acceptance on a wide scale depends on the development of technical know-how and inexpensive methods of production. It is obvious that rearing of wild species will only be widely embraced if production costs and efforts are lower than that of bushmeat obtained through hunting and the returns are comparable to what prevail in traditionally acceptable livestock ventures e.g. chicken, goats, sheep and cattle. (Yaa Ntiamoa-Baidu ,1997).

1.2.3 Roles of the Veterinary Anatomist

Anatomy is a complex discipline, especially in Veterinary Medicine where the variations between species makes its learning even more complicated. Anatomical knowledge is the basis for reasoning and developing surgical techniques, as well as for the analysis of medical imaging (radiography, Computed Tomography, Magnetic Resonance Imaging, etc.). A Veterinary Anatomist's time is spent in the laboratory and in the field, where he or she makes observation on relatively healthy animals, take notes of their behaviour, studies differences between genders and species, and draw conclusions on their observations. Conclusions drawn by Veterinary Anatomists usually serve as baseline data for further studies in physiology, pharmacology, pathology, microbiology and surgery, as well as other aspects of biomedical and clinical sciences. This is because it is essential for veterinarians to rely on normal values and features in order to build their clinical thought process.

In the process of domestication of an animal species, the Veterinary Anatomist conducts an in-depth study of the structure of a relatively healthy wild animal in order to describe all its organs at different stages of their development and obtain baseline data of all their anatomical features. As function and performance are dependent on structure, it is crystal clear that the Veterinary Anatomist plays critical roles in the success of domestication of any animal, as well as the continuous propagation of the animal. (Health and Lanyon,1996).

1.3 The African Giant Rat and Economic Potentials

The African giant rat (*Cricetomys gambianus,* Waterhouse) is known in Yoruba as *Okete*, in Ibo as *Ewi* and in Hausa as *Burugu*. It is also called the African pouch because they have a storage pouch inside of each cheek. When the pouches are full it gives the pouched rat an absolutely adorable, yet comical face (Fig. 1).

Fig.1: The African giant rat *(Cricetomys gambianus,* Waterhouse*)*

The Yorubas have quite a number of proverbs that show the relevance of African giant rat in the society. They include, among others:

- *i)* *Òkété gbàgbé ìbòsí, ó dé igbá alátẹ ó ká'wẹ́ lérí;* A stitch in time saves nine or to be forewarned is forearmed.
- *ii)* *Okete nbi nkan obe, o l'ohun bi'mo;* The African giant is giving birth to edible meat and thinks it is having offsprings
- *iii)* *Oro ti okete ba ba'ile so niigbo;* Whatever the African giant rat says, the earth must obey
- *iv)* *Enitobere to'ndesa okete, Olohun loke ndesa ohun naa;* He who is hunting for African giant rat, he also is being hunted

v) *Ti okete ba dagba tan, omun omo e lon mun;* When an African giant rat comes of age, it suckles the breast of its offsprings
vi) *Enikan kii ri ewu l'osan;* No one sees African giant rat during the day
vii) *Ninu keebu-keebu, oga ni okete;* Among the heap's maker, African giant rat is the master
viii) *Iyan wu okete je, isa re ko je;* The African giant rat wishes to eat pounded yam but its tunnel can't contain mortal
ix) *Bi okete ko ba tii ku, koni ye isa gbe;* As long as African giant rat is still alive, it will not stop digging tunnel
x) *Isu to ba ti b'okete wo'nu isa, o ti d'ajemonu okete;* Once African giant rat takes yam to its tunnel, it's irretrievable.

1.3.1 African Giant Rat Distribution

The pouch rats are huge among the largest of the murid rodents and are widely spread in sub-Saharan Africa (Kennerley, 2019). There are two main species of the Genus Cricetomys: *Cricetomys gambianus* Waterhouse and *Cricetomys emini*. The big size of this rat makes it one of the most striking of Africa's rodents. They have been found to be fairly tame and docile in captivity even though shortly after being captured, they tend to exhibit such escape reactions as violent struggles and hitting head and tail against the cage. The *Cricetomys gambianus* (Waterhouse) (Ajayi, 1977).

Homeland ranges from Senegal to Central Sudan and South Africa while the *Cricetomys emini* is found from Sierra Leone to Lake Tanganyika and Fernando Po (Novak and Paradiso, 1991). The African giant rats have a wide distribution occurring everywhere in sub-Saharan Africa and the species is adapted to a wide variation in climate and ecological zones (Fig.2).

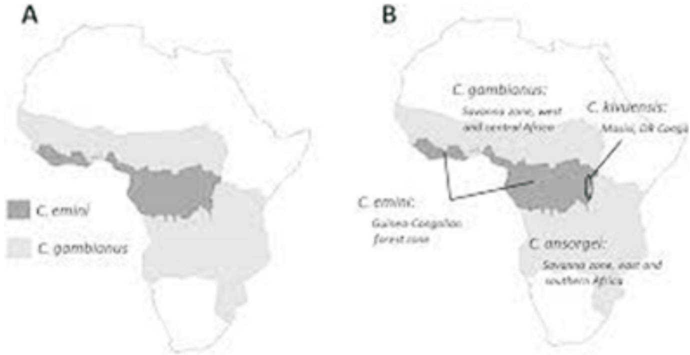


Fig. 2: Distributions of African giant rats in Africa
Source: Olayemi *et. al., 2012*

This kind of adaptations to various environmental conditions, social acceptance, their value as a delicacy among rural populations, and the need to meet the increasing demand for animal protein among other considerations, are attributes that were observed to be important criteria in selecting animals for domestication (Ajayi, 1977).

1.3.2 African Giant Rats as a Source of Protein

A programme to domesticate the giant rat was initiated at the Department of Forest Resources Management, University of Ibadan in the early 1970s (Ajayi, 1971; 1975; Ajayi et al. 1978) with the aim of maximizing meat production from the species. The reports from the studies indicate that giant rats adapt very quickly to captive conditions. Wild caught animal settle within two months of capture and start to breed; and by the fourth generation, all evidence of agonistic behavioral characteristic of wild rats had disappeared. Caged animals soon became habituated to their cages and readily adopted new diets (Fig. 3).

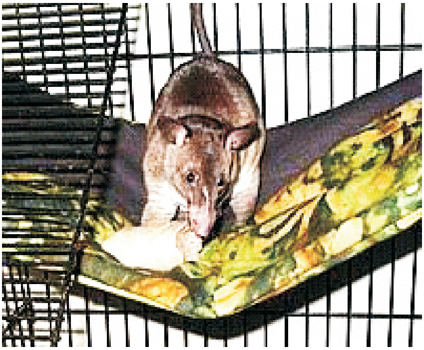


Fig. 3: The African giant rats adapted to cage and new diet

While the studies amply demonstrated that giant rats could be kept easily in captivity, large scale rearing of the animal never materialized. This is attributed to the wide-spread superstitions and cultural aversion towards rats which makes the meat unacceptable to many tribal groups within West Africa.

1.3.3 The African Giant Rats as Pets

However, far in Europe and in East Africa, the trend of African giant rat domestication has changed for better. In Britain, the African giant rat is increasingly becoming a popular exotic pet. A survey conducted on 41 licensed pet shops in the UK showed that the range of ages of giant rat presented for sale was between 4-12 weeks. The prices of single, and paired (buck and doe) rats inclusive of transport costs were £320 - £370 **(N639,152 - N739,019)** and £352.50 - £400.00 **(N703,067 - N798,940)** including VAT (£10 - £37.50) **(N19,973 – N37,900)** respectively (Cooper, 2008). On the average expect to pay $200 **(N315,612)** to $500 **(N789,030)** for an African giant rat in the US (Fig. 4).

Fig. 4: The African giant rats as exotic pets

1.3.4 The African Giant Rats for Detecting Landmines

As at 2005, two hundred and fifty (250) African giant rats were trained by scientists of Belgium's demining Anti-Personnel Landmines Detection Product Development (APOPO) organization and Tanzania's Sokoine University of Agriculture to use their olfactory sense to detect landmines. Unexploded ordinance and landmines are a menace in many African countries and the scientists' idea was to get an alternative method of detecting landmines that works well in Africa Fig. 5) (Isabelle, 2023). The trained pouched rats are called HeroRATS. The rats are far cheaper to train than mine-detecting dogs; a rat requires US$7,300 for nine months of training, whereas a dog costs about $25,000 for training, but lives about twice as long as the Hero Rat (Poling *et. al.*, 2011).

In 2020, a Hero Rat named Magawa (2013–2022) received a People's Dispensary for Sick Animals Gold Medal, the animal equivalent of the George becoming the first rat to receive the award since the charity began honouring animals in 2003. Before retiring in 2021, Magawa detected 71 landmines and 38 items of unexploded ordnance, clearing over 2,421,880 sq. ft (225,000 m^2) of land in Cambodia, preventing many injuries and deaths, in his 5-year career. Magawa died from natural causes at the age of 8 in 2022 (Kate, 2020).

Fig. 5: Trained African giant rat (*Cricetomys gambianus*) detecting landmines.
Source: Kate, 2020

1.3.5 The African Giant Rats for Detecting Tuberculosis (TB)

In the hope of developing a viable alternative to or adjunct for microscopy, APOPO is exploring the use of African giant pouched rats (*Cricetomys gambianus*) to detect the presence of TB. These large and long-lived rats, which are native to Africa, have an excellent sense of smell and can detect TB by sniffing sputum samples. They are trained to respond consistently in one way (pause) if the sample contains the TB bacillus (is positive) and respond in another way (not pause) if the sample does not contain the bacillus (i.e., is negative). Each rat can test hundreds of samples each day, allowing inexpensive testing (Fig. 6).

Fig. 6: Trained African giant rat (*Cricetomys gambianus*) detecting tuberculosis in samples.

In order to successfully domesticate any species, however, basic knowledge on their ecological adaptation, physiology, anatomy, habitat, breeding and feeding habits, diseases and pests etc., are essential if we are to successfully exploit their potential. Thus, it is necessary that its biology including the biology of reproduction be thoroughly investigated as a means of providing adequate information to aid the process of domestication. In this regard, a lot fell on me to carry out in-depth qualitative and quantitative studies of the gross morphology and microscopy of the female genitalia, as well as hormonal profiles and electron microscopy at different stages of oestrous cycle.

2.0 MY RESEARCH FOCUS AND CONTRIBUTIONS TO KNOWLEDGE

Mr. Vice-Chancellor, Sir, in Reproductive and Endocrine Biology, which is my area of specialization in Veterinary Anatomy, we aim at using gross morphometrical, histological and histomorphometrical, as well as ultrastructural, immunohistochemical and hormonal techniques to evaluate the reproductive organs of animals in order to produce baseline information on the reproductive performance. Results obtained from utilization of these anatomical techniques assist in the process of domestication and breeding of wildlife, as well as in improving production of livestock. They also serve as foundation for further studies in other fields of medicine.

Mr. Vice-Chancellor, Sir, in the last 26 years, I have been involved in five major research areas in Veterinary Anatomy: Reproductive Biology 65%, Osteology 10%, Phytotoxicology 10%, General Anatomy 10% and Diagnostic Imaging 5%. Out of my publications in Reproductive Biology, 78% are on the female while 22% are on the male. Therefore, for the purpose of this inaugural lecture, I will concentrate on my research works on female reproductive anatomy.

2.1 Anatomy of the Female African Giant Rat Reproductive Organs

Our studies on the female African giant rat reproductive system showed that it was made up of bilateral ovaries, two oviducts, duplex uterus and cervices, as well as vagina, vestibule, vulva and mammary glands (Akinloye, 2009; Akinloye and Oke, 2009a, 2009b) (Fig. 7). Physiologically, the organs of female reproductive system produce and sustain the female sex cells (egg cells or ova), transport these cells to a site where they may be fertilized by sperm, provide a favourable environment for the developing foetus, move the foetus to the outside at the end of the development period, and produce the female sex hormones (Eurell and Frappier, 2006).

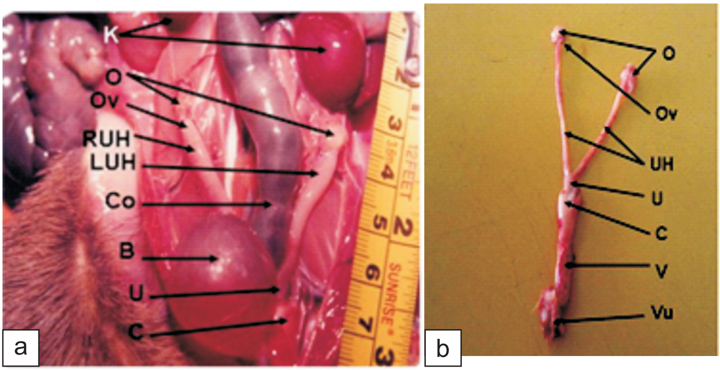


Fig 7: (a) A photograph of the reproductive organ of the adult female giant rat *in situ.* Observe the relationship of the ovaries (O) to the kidneys (K). Note that uterus (U) lies on the colon (Co) and both right uterine horn (RUH) and left uterine horn (LUH) run parallel to the colon then diverge laterally. The cervix (C) is short and the oviduct (Ov) is barely visible. The urinary bladder (B) is related to the cranial end of the vagina. (b) A photograph of the dorsal view of the female reproductive tract of the adult African giant rat showing various segments of the organ. Observe a pair of ovaries (O) stalked on the uterine horns (UH) by short Oviducts (Ov). Note the short body of uterus (U), distinct Cervix (C), Vagina (V) and Vulva (Vu).

2.2 Characterization of the African Giant Rat Ovaries at Different Stages of Oestrous Cycle

Grossly, in a sexually matured female African giant rat *(Cricetomys gambianus* Waterhouse*)* (AGR), Akinloye and Oke (2009a) showed that a single ovary had a reddish irregular nodular surface (Fig. 8), weighed between 80mg and 100mg and measured between 3.1mm and 3.3mm in length at different stages of oestrous cycle. Our findings also showed that although the right ovary appeared to be bigger and longer than the left ovary, both were relatively equal and did not differ significantly at different stages of oestrous cycle. In addition, Akinloye and Oke (2009a) revealed that both left and right ovaries recorded the highest weight at mid-proestrus while their weights dropped sharply at late proestrus/early oestrus and were relative maintained throughout the oestrous cycle till late dioestrus/early proestrus when their weights rose sharply again at mid proestrus. These findings suggested that perhaps the highest follicular growth was attained at mid proestrus and probably ovulation takes place at late proestrus/early oestrus in female AGR. (Tables 1-6). This is the first time that specific stage of oestrous cycle when ovulation took place in AGR was determined and could be employed in formulation of breeding strategies for African giant rats in captivity.

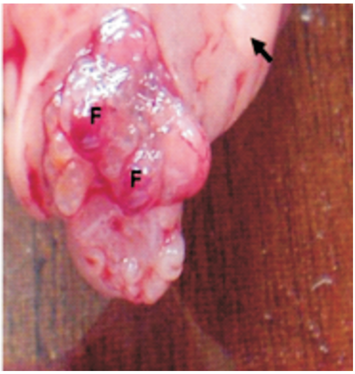


Fig. 8: A photograph showing follicles on the surface of ovary.
Clusters of follicles (F) were observed on the surface of the ovary when adipose tissue (arrowed) was removed.

Table 1: Mean absolute body and ovarian weights (g) of the female African giant rat at different stages of the oestrous cycle

Group	MP	LP/LE	ME	MM	LM/ED	MD	LD/EP
Body weight	[illegible]	812.00±22.45	788.00±61.19	800.00±85.09	692.00±37.20	828.00±40.30	956.00±44.47
Left ovary	0.11±0.04	0.06±0.01	0.09±0.02	0.09±0.03	0.08±0.01	0.08±0.02	0.082±0.02
Right ovary	0.28±0.21	0.07±0.010	0.09±0.02	0.07±0.01	0.06±0.01	0.08±0.02	0.08±0.02

Values are given as mean ± S.E. (n=5). Source: Akinloye and Oke (2009a)

Table 2: Means of relative ovarian weights (%) of the female African giant rat at different stages of the oestrous cycle

Group	MP	LP/LE	ME	MM	LM/ED	MD	LD/EP
Left ovary	0.02±0.01	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00
Right ovary	0.04±0.03	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00	0.01±0.00

Values are given as mean ± S.E. (n=5). Source: Akinloye and Oke (2009a)

Table 3: Means of groups ovarian weight (%) of the female African giant rats at different stages of the oestrous cycle

Group	MP	LP/LE	ME	MM	LM/ED	MD	LD/EP
Left ovary	0.0173[a]	0.0078[a]	0.0117[a]	0.0104[a]	0.0104[a]	0.0089[a]	0.0087[a]
Right ovary	0.0351[a]	0.0084[a]	0.0112[a]	0.0088[a]	0.0087[a]	0.0091[a]	0.0081[a]

Values with superscripts (a) in the same horizontal row are significantly different from one another at ($p<0.05$). (n=5) .
Source: Akinloye and Oke (2009a)

Table 4: Mean linear measurement (cm) of ovaries of the female African giant rat at different stages of the oestrous cycle

Group	MP	LP/LE	ME	MM	LM/ED	MD	LD/EP
Left ovary	0.27±0.04	0.345±0.04	0.28±0.04	0.24±0.04	0.30±0.04	0.38±0.04	0.36±0.08
Right ovary	0.30±0.05	0.38±0.04	0.25±0.04	0.26±0.02	0.35±0.06	0.42±0.17	0.38±0.08

Values are given as mean ± S.E. (n=5). Source: Akinloye and Oke (2009a)

Table 5: Means of relative linear measurements (%) of ovaries of the female African giant rat at different stages of the oestrous cycle

Group	MP	LP/LE	ME	MM	LM/ED	MD	LD/EP
Left ovary	0.04±0.01	0.04±0.01	0.04±0.01	0.03±0.00	0.05±0.01	0.05±0.01	0.04±0.01
Right ovary	0.04±0.01	0.05±0.01	0.03±0.01	0.03±0.00	0.05±0.02	0..5±0.02	0.04±0.01

Values are given as mean ± S.E. (n=5). Source: Akinloye and Oke (2009a)

Table 6: Means of groups for linear measurements (cm) of ovaries of the female African giant rats at different stages of the oestrous cycle

Group	MP	LP/LE	ME	MM	LM/ED	MD	LD/EP
Left ovary	0.2700[a]	0.3400[a]	0.2800[a]	0.2400[a]	0.3000[a]	0.3800[a]	0.3600[a]
Right ovary	0.3000[a]	0.3800[a]	0.2500[a]	0.2600[a]	0.3500[a]	0.4200[a]	0.3800[a]

Values with the same superscripts (a) in the same horizontal row are not significantly different from one another at ($p<0.05$). (n=5). Source: Akinloye and Oke (2009a)

Akinloye and Oke (2014) gave concise descriptions of the histology and ultrastructural features of the ovary at different stages of oestrous cycle. Generally, we found that in all stages of oestrous cycle, the ovaries in the sexually mature female African giant rat were enveloped in a germinal epithelium of a single layer of cuboidal cells (Fig. 9). Each ovary was observed to contain a central medulla and an outer cortex. The medulla consists of fibro-elastic connective tissue and numerous blood vessels while the cortex contains oocytes that are enveloped by one or more layer of follicular cells to form ovarian follicles. The ovarian follicles were observed to be in different stages of development and vary greatly in size (Fig. 10) (Madekurozwa *et al*., 2010; Akinloye and Oke, 2014a). At late proestrus/early oestrus, several large Graafian follicles with organized theca interna and theca externa as well as few small and secondary follicles were observed. The Graafian follicles contained large, fluid-filled cavities and eccentric oocytes. The oocytes are located in the thicken granulosa cell layer that projects into the antrum. The Graafian follicles occupied the full thickness of the ovarian cortex and bulged above the surface of the ovary (Fig. 9). At mid-metestrus, secondary and tertiary follicles as well as ovulatory follicles being transformed to corpus luteum were identified. The wall of the ovulatory follicles had collapsed and became infolded. The basement membrane that separated the granulosa cell layers from the theca became depolarized. At mid-dioestrus as well as in late dioestrus/early proestrus, matured follicles and corpus luteum were predominantly observed (Fig. 10). The cyclic histological features of the various segments of the reproductive tract observed at different stages of oestrous cycle in the present study correlate with observations earlier reported in other animal species (Weiss, 1983; Fawcett and Jensh, 2002; Eurell and Frappier, 2006).

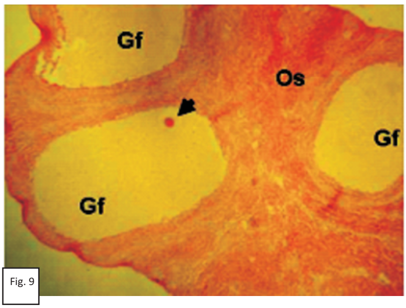


Fig. 9

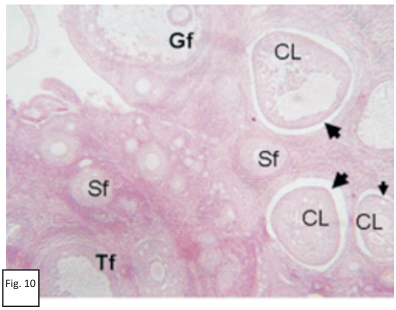


Fig. 10

Fig. 9: Photomicrograph of the ovary in the adult female African giant rat at late proestrus/early oestrus.
The large Graafian follicles (Gf) filled with follicular antrum and surrounded by theca interna and theca externa in the ovarian stroma (Os). Also note the separation of cumulus oophorous (arrowhead) from the stratum granulosum. H&E (x40)
Fig. 10: Photomicrograph of the ovary in the adult female African giant rat at mid-metestrus. The successive stages in the development of secondary follicles (Sf), tertiary follicles (Tf), Graafian follicle (Gf) and corpus luteum (CL). Observe that the ovulatory follicles are being transformed into corpora lutea (CL) by the depolarization of the basement membrane (arrow heads). H&E (x40).

Immunohistochemically, we observed that healthy secondary and tertiary follicles dominated the ovary during pro-oestrus and oestrus. The theca externa of the tertiary follicles was immunopositive for smooth muscle actin, but immunonegative for desmin (Fig. 11). Oestrus was also characterized by the presence of corpora haemorrhagica, which had an outer layer of smooth muscle actin immunopositive cells. Differentiating corpora lutea were observed during metestrus (Fig.12). A further notable feature of the ovary during metestrus was the presence of numerous atretic secondary and tertiary follicles. In the later stages of atresia, the follicles were in?ltrated by desmin and smooth muscle actin immunopositive cells (Fig. 13). Dioestrus was characterized by the presence of non-regressing and regressing corpora lutea. Immunostaining for smooth muscle actin was demonstrated in the enclosing layer of the corpora lutea, as well as in the tunica media of blood vessels within the corpora lutea. This study documents morphological and immunohisto-chemical changes occurring in the ovary of the African giant rat during the oestrous cycle. The results of the immunohistochemical study indicated that the perifollicular distribution of desmin and smooth muscle actin cells changes during follicular development and atresia (Madekurozwa, Akinloye and Oke, 2010). Based on the results of the study, it would appear that the morphology of healthy and atretic follicles in the giant rat is similar to that of laboratory rodents (Numazawa and Kawashima, 1982; Butcher and Kirkpatrick-Keller, 1984; Li and Davis, 2007).

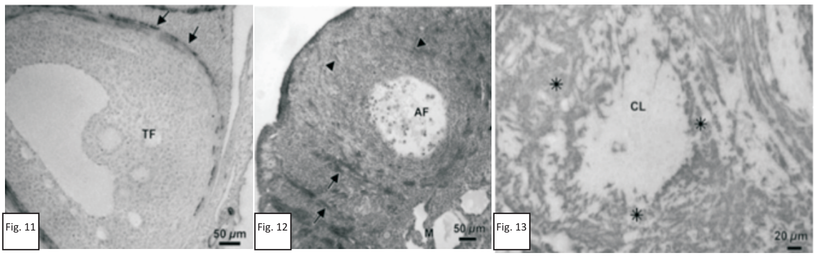
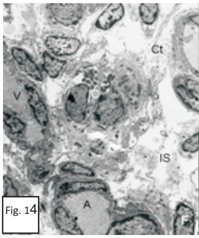
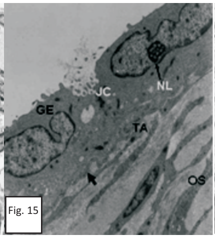


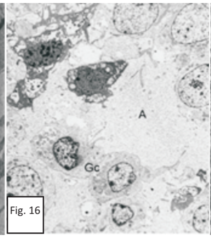
Fig. 11: Smooth muscle actin immunopositive theca externa (arrows) in a tertiary follicle (TF)

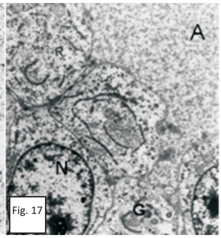
Fig. 12: Desmin immunoreactive smooth muscle cells (arrows) in the cortical stroma of the ovary.
The outer regions of the atretic folllicle (AF) shown radially arranged smooth mucle cells (arr0w-head). M:medulla
Fig. 13: Infiltration of a degenerating corpus luteum (CL) by desmin immunoreactive cells (astericks)

In our studies of the fine structures of the ovary during the oestrous cycle in African giant rats (*Cricetomys gambianus* Waterhouse), it was revealed that ultrastructural features of the germinal epithelium (Fig. 14) and the medullar of the ovary were similar at different stages of the oestrous cycle (Fig.15). During mid proestrus, there was disorganization of the inner layer of the granulosa cells of secondary follicles to form the antrum (Fig. 16). At late proestrus/early oestrus, antrum formation had advanced and there was evidence of reorganization of granulosa cells (Fig. 17). Fine structures of the ovary during mid oestrus included follicles with variably shaped mitochondria, profiles of Golgi complexes and dense concentration of ribosomes (Fig.18). The theca interna shared similar ultrastructure with the granulosa cells containing, in addition, lipid droplets and smooth endoplasmic reticulum (Fig.19). Cellular ultrastructure observed during mid metestrus showed commencement of differentiation of corpus luteum. At mid dioestrus, the general ultrastructural architecture of the ovarian follicles showed disorganized cellular contents and corpus luteum was recognized with conspicuous depolarization of the basement membrane originally separating granulosa cells from the theca (Fig. 20). At late dioestrus/early proestrus, granulosa cells displayed numerous mitochondria of variable sizes and shapes. Ribosomes were evenly distributed throughout the cytoplasm while electron lucid vesicles were sparsely distributed (Fig. 21) (Akinloye and Oke, 2014a). This ultrastructural study documented stages of corpus luteum formation for the first time in the ovary of African giant rat and further lent credence to previous observation that ovulation occurred at late proestrus/early oestrus (Redmer *et al*., 2001; Fraser & Wulff, 2001; Geva & Jaffe, 2000; Akinloye and Oke, 2009a).







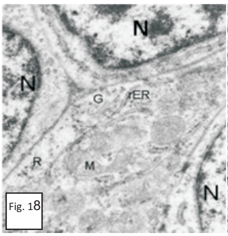


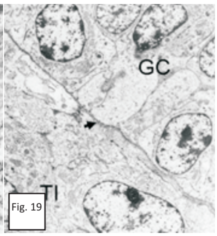
Fig, 14: Electron micrograph of medulla of ovary at Mid Proestrus. The numerous blood vessels: arterioles (A) and venules (V), spindle-shaped fibrocytes (F) and interstitial cells (IC) as well as large deposits of connective tissues (Ct) and coalesced interstitial spaces (IS) (x 2,600).

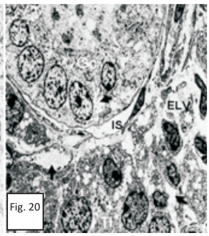
Fig. 15: Electron micrograph of superficial part of ovarian cortex at Mid Proestrus. The junctional complex (JC) that linked the germinal epithelium (GE) which laid on the basement membrane (arrow) and tunica albuginea (TA) that laid on ovarian stroma (OS). (x 5,800).

Fig. 16: Electron micrograph showing disintegration of granulosa cells to form antrum in Mid Proestrus.
The accumulation of follicular fluid from granulosa cells (Gc) enlarge and coalesce to form a fluid-filled cavity, the follicular antrum (A) (x 1,950).

Fig. 17: Electron micrograph of antral follicle in ovary at mid oestrus showing apical layer of granulosa cells and the antrum.
The cuboidal granulosa cells (G) containing numerous ribosomes (R), large nucleus (N) and overlaid by antrum (A). (x 4,600)







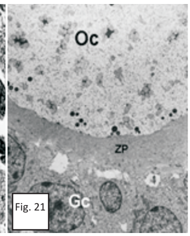


Fig. 18: Electron micrograph of granulosa cell in antral follicle at mid oestrus. Showing some cytoplasmic organelles. Mitochondria (M) of variable sizes and shapes, profiles of rough endoplasmic reticulum (rER), numerous free ribosomes (R), large nuclei (N) and Golgi apparatus (G) are sparse in number (x 13,500).

Fig. 19: The interface between the basal layer of granulosa cells and peripheral layer of theca interna mid oestrus.
The basal granulosa cell layer (GC) separated from the theca interna (TI) by a distinct basement membrane (arrowed) (x 3,900)

Fig. 20: Electron micrograph of corpus luteum at Mid-dioestrus. The intercellular space (IS) created when granulosa cells (Gc) detached from the basement membrane that separated them from the theca interna (TI). Observe the electron-lucid vesicles (ELV)

and abundant lipid droplets (arrowed) distributed throughout the forming corpus luteum (x 1,450)

Fig. 21: Electron micrograph of secondary follicle at Late Dioestrus/Early Proestrus. The oocyte (Oc) with abundant cytoplasmic organelles surrounded by a well-developed zona pellucida and granulosa cells (Gc) with large nuclei.

2.3 Characterization of the African Giant Rat Oviduct at Different Stages of Oestrous Cycle

Grossly, in our studies of oviduct of the African giant rat, we observed variable degrees of irregular coils and closely intertwined contact of oviduct with the ovary, as well as lack of distinct visible border zone of the ampulla and isthmus. This made the oviduct of the female African giant rat dissimilar from other laboratory animals (Fig. 22). (Akinloye *et al.*, 2018).

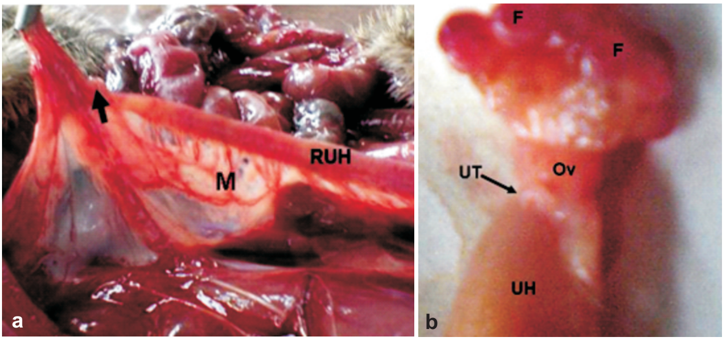
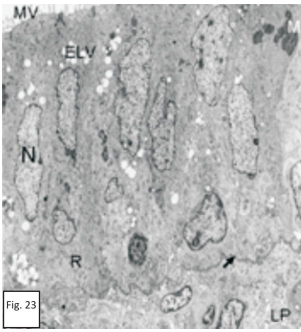
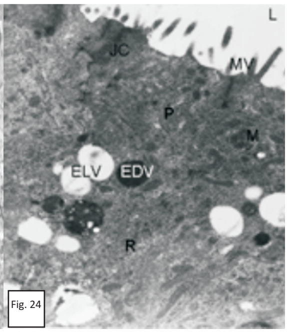


Fig. 22: (a) A photograph showing uterine horn and ligaments in the female African giant rat. The smooth musculature in the mesometrium (M) that is continuous with the longitudinal muscle layer of the right uterine horn (RUH). The broad ligament encloses the ovary (arrowed) and runs lateral to the kidney as far as the diaphragmatic crus of the same side.
(b) A photograph showing connections among some segments of the reproductive organ. Observe the constricted part of the oviduct (Ov) that connects abruptly to the uterine horn (UH) at the utero-tubal junction (UT). Note the several follicles (F) on the ovary.

Histologically, we found that tall simple columnar epithelium was displayed in the oviduct mucosa of the African giant rat. Its lamina muscularis showed concentric layers of inner circular and outer longitudinal smooth muscle. Ciliated and non-ciliated cells resting on a relatively straight or undulating basement membrane were observed. Our findings showed that at mid-oestrus, ciliated columnar epithelium resting on undulating basement membrane was displayed (Fig. 23). Epithelial ultrastructure revealed moderate number and even distribution of cytoplasmic organelles. The basal region of the epithelium resting on undulating basement membrane. Variably shaped mitochondria with prominent lamellar cristae, as well as numerous free ribosomes and polysomes were evenly distributed. The nuclei were ellipsoidal and had clumps of heterochromatin peripherally as well as finely dispersed chromatin centrally. Apical surface of the epithelium displayed numerous long microvilli. Lateral cell membrane of adjacent cells exhibited distinct junctional complexes apically and lateral infoldings along their course towards the basement membrane. Electron lucid and electron dense vesicles abound apically and were sparsely distributed throughout the cytoplasm (Fig. 24).

Our findings (Akinloye *et. al.,* 2018) showed that fine structure of the oviducts at mid metestrus, late metestrus/early dioestrus and mid diestrus as well as late dioestrus/early proestrus, mid proestrus and late proestrus/early oestrus were basically similar to the ultrastructural features described at mid oestrus though differences existed in spatial distribution and density of some cytoplasmic organelles (Fig. 25).





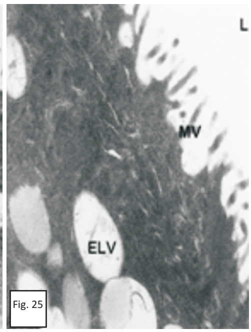


Fig. 23: Electron micrograph of surface epithelium of oviduct at Mid Oestrus. The undulating basement membrane (arrow), long microvilli (MV) on the luminal surface, widely distributed electron lucid vesicles (ELV) and free ribosomes (R) as well as elongated nuclei (N), mitochondria (M) and highly cellular lamina propria (LP). (x 2,200).

Fig. 24: Electron micrograph of apical part of the oviduct epithelium at Mid Oestrus. The long microvilli (MV) on the luminal surface, variable sizes of electron dense (EDV) and electron

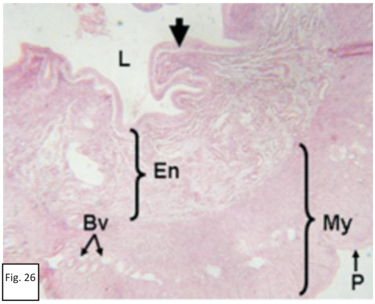
lucid vesicles (ELV), abundant free ribosomes (R) and polysomes (P), numerous mitochondria and apical junctional complexes (JC). (x 10,500)

Fig. 25: Electron micrograph of oviduct epithelium at Late Proestrus/ Early Oestrus. The microvilli (MV), electron lucid vesicles (ELV) (x 13,500).

2.4 Characterization of the African Giant Rat Uterus at Different Stages of Oestrous Cycle

We described gross morphometry of the uterus of AGR during oestrous cycle and classified the uterus as being duplex, having two separate uterine horns and two cervices. Akinloye and Oke (2009b; 2010b).

Akinloye and Oke (2015) gave detailed description of the histological and ultrastructural features of AGR uterus at different stages of oestrous cycle. Our findings showed that endometrial histology displayed glandular mucosa consisting of lamina epithelialis and lamina propria mucosae. Its epithelium varied between simple and pseudostratified columnar. The myometrium consisted of inner circular and outer longitudinal smooth muscles with medium-sized arteries and veins in-between. The perimetrium contained simple squamous epithelium (Figs. 26 and 27). Endometrial ultrastructures were variable during oestrous cycle. At mid oestrus, hemidesmosomes anchored undulating basement membrane of the mucosal epithelium. Preponderance spherical mitochondria, lipofuscin granules concentration, flocculent homogenous materials and indented nuclei were displayed (Figs. 28 and 29). At mid metestrus, late metestrus/early dioestrus and mid diestrus, the base of the mucosal columnar epithelium laid on relatively straight basement membrane and their cytoplasmic ultrastructure displayed variation to mid oestrus. Epithelial apex showed intermediate filament, microvilli and junctional complexes (Figs. 30 and 31). The uterine glands occurred in variable numbers and sizes during oestrous cycle and shared similar ultrastructure (Fig. 32 and 33). Mid dioestrus showed cell ultrastructure of uterine glands having apical accumulation of secretory vesicles. Some actively secreting uterine glands were lined by simple ciliated columnar epithelium intermingled with pseudostratified epithelium (Fig. 47). The findings of the study indicated that African giant rat endometrial ultrastructure varies during oestrous cycle and glandular secretion is merocrine (Akinloye and Oke, 2015).



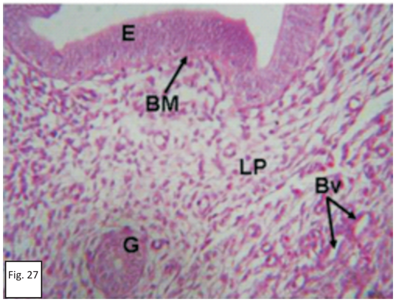
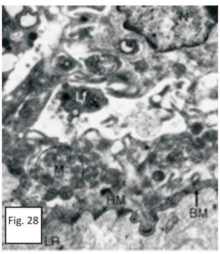
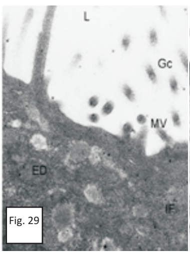


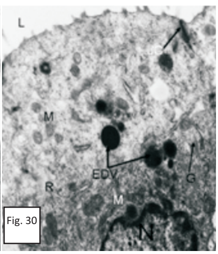
Fig. 26: Photomicrograph of the uterus in the adult female African giant rat at mid-metestrus.
The wide endometrium (En) with its mucosal surface facing the uterine lumen (L) and thrown into longitudinal folds (arrow). Also observe the relatively thick myometrium (My) interspersed with blood vessels (Bv) and surrounded by serosa, the perimetrium (P). H&E (x25).

Fig. 27: Photomicrograph of the endometrium in the adult female African giant rat uterus at mid-proestrus.

The pseudostratified/simple columnar epithelium (E) of the endometrial mucosa resting on relatively straight basement membrane (BM). The extensive lamina propria (LP) bears the glands (G) and numerous blood vessels (Bv). H&E (x140).







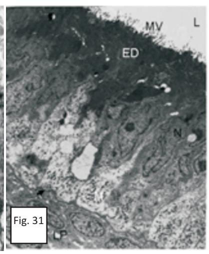


Fig. 28: Electron micrograph of basal part of uterine epithelium at mid oestrus. The nucleus (N), numerous mitochondria (M) and hemidesmosomes (HM) at the basement membrane (BM). The concentration of lipofuscin (Lf) granules. Below the epithelium is the lamina propria (LP) (x 11,500).

Fig..29: Electron micrograph of apical part of endometrium of uterus at mid oestrus. The junctional complex (JC) at the apical surface, lumen (L), numerous mitochondria (M), variably shaped electron dense vesicles (EDV) and profiles of golgi complex (G), as well as nucleus (N) and free ribosomes (R) (x 10,500).

Fig. 30: Electron micrograph of apical part of the endometrium of uterus at Mid Metestrus.
The microvilli (MV) and glycocalyx (Gc) on the luminal surface (L). Observe condensed intermediate filament (IF) and electron dense (ED) materials (x 28,500).

Fig. 31: Electron micrograph of uterine endometrium at Late Dioestrus/Early Proestrus. Note long microvilli (MV) projecting into the lumen (L), condensed electron dense (ED) materials at the apical part and accumulation of mitochondria (M) at the basal part close to the lamina propria (LP). Observe the undulating basement membrane (arrow) (x 2,200).

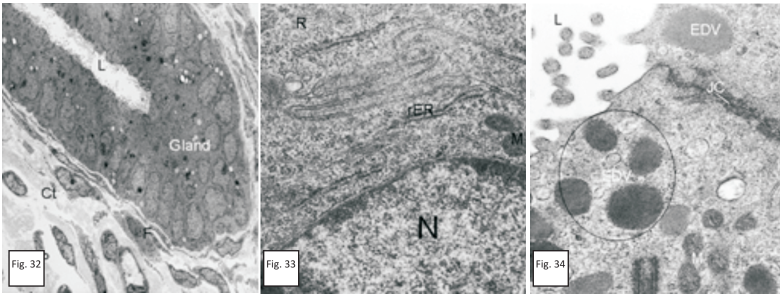


Fig. 32: Electron micrograph of uterine gland in the sub-mucosa of Uterus at Mid Dioestrus.
The columnar epithelium of the gland in the lamina propria (LP) surrounded by connective tissue (Ct) and fibrocytes (F). Observe scanty secretion in the glandular lumen (L) (x 12,100).

Fig. 33: Electron micrograph of cell of secretory gland in endometrial sub-mucosa at Mid Dioestrus.
The active nucleus (N), profiles of rough endoplasmic reticulum (rER), dense free ribosomes (R) and mitochondria (M) (x 28,500).

Fig. 34: Electron micrograph of the apex of cell of uterine gland in endometrial sub-mucosa at Mid Dioestrus.
The lumen (L), variably sized electron dense vesicles (EDV), mitochondria (M) and junctional complex (JC) (x 28.500)

2.5 Immunohistochemical Localization of the Progesterone and Oestrogen α Receptors in the Uterine Horns of the African Giant Rat (*Cricetomys Gambianus)*

In this study, we (Madekurozwa, Akinloye and Oke, 2009) investigated the immunolocalization of the progesterone and oestrogen α receptors in the uterine horns of the African giant rat during the oestrous cycle. Our findings showed that the progesterone and oestrogen α receptors were demonstrated in various cellular constituents of the endometrium, myometrium and perimetrium (Figs. 35 and 36). The intensity of progesterone and oestrogen α receptor immunostaining in the endometrial and myometrial layers of the uterine horns varied during the oestrous cycle. The intensity of oestrogen α receptor immunoreactivity in the luminal epithelium was high during pro-oestrus, oestrus and dioestrus. Progesterone and oestrogen a receptor immunoreactivity in the endometrial epithelia were absent during metestrus. Moderate to strong immunostaining for the progesterone and oestrogen α receptors were demonstrated in the myometrial smooth muscle cells during pro-oestrus, oestrus and dioestrus. The intensity of progesterone and oestrogen α receptor immunostaining in the myometrial smooth muscle cells was low during metestrus. Stromal cells in the perimetrium consistently expressed progesterone and oestrogen α receptor immunoreactivity throughout the oestrous cycle (Table 7). The ?ndings of our study indicated that in the African giant rat, the immunolocalization of the progesterone and oestrogen α receptors, in endometrial and myometrial regions of the uterine horns, vary during the oestrous cycle.

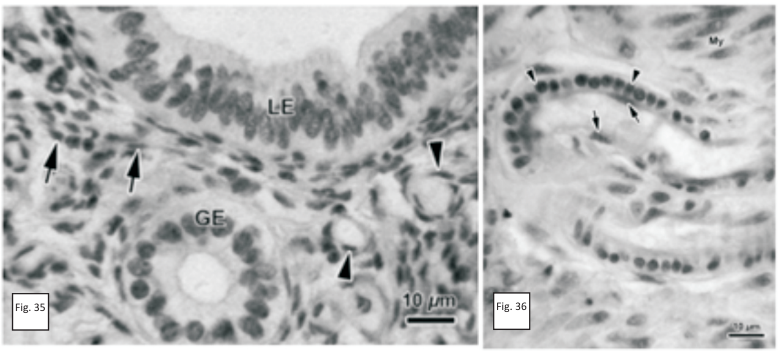


Fig. 35: Pro-oestrus. Progesterone receptor immunostaining.
It is demonstrated in the nuclei of cells in the luminal (LE) and glandular (GE) epithelia. Stromal cells (arr0ws) and the endothelial cells (arrow-heads) of ca[illaries are immunopositive for the progesterone receptor.

Fig. 36: Oestrus. Oestrogen α receptor immunostaining.
In the endothelial cells (arrows) and tunica media (arrow-heads) of a blood vessel in the vascular layer. Oestrogen α receptor immunostaining is also demonstrated in smooth muscle cells of the myometrium (My)

Table 7: Summary of the immunohistochemical localization of progesterone and oestrogen α receptors in the uterine horns of the African giant rat.

Stage of oestrous cycle	Progesterone receptor	Oestrogen α receptor
Pro-oestrus		
Endometrium		
Luminal epithelium	+ + +	+ + +
Glandular epithelium	+ + +	+ + +
Stromal cells	+ + +	+ + +
Myometrium	+ +	+ + / +
Perimetrium		
Stromal cells	+ +	+ + +
Mesothelial cells	+ + / −	+ + + / −
Oestrus		
Endometrium		
Luminal epithelium	+ + / +	+ + +
Glandular epithelium	+ + / + / −	+
Stromal cells	+ + +	+ + +
Myometrium	+ + +	+ + +
Perimetrium		
Stromal cells	+ +	+ +
Mesothelial cells	+ + / −	+ + / −
Metoestrus		
Endometrium		
Luminal epithelium	+ / −	+ / −
Glandular epithelium	−	−
Stromal cells	+ + / + / −	+ + / + / −
Myometrium	+ / −	+ / −
Perimetrium		
Stromal cells	+ +	+ +
Mesothelial cells	+ / −	+ + / −
Dioestrus		
Endometrium		
Luminal epithelium	+ + / +	+ + +
Glandular epithelium	+ + / +	+ + +
Stromal cells	+ + / +	+ + + / +
Myometrium	+ +	+ +
Perimetrium		
Stromal cells	+ +	+ +
Mesothelial cells	+ + / −	+ + / −

Intensities of immunostaining: −, absent; +, weak; + +, moderate; + + +, strong.

Source: Madekurozwa, Akinloye and Oke, 2009

2.6 Characterization of the African Giant Rat Cervices at Different Stages of Oestrous Cycle

We (Akinloye and Oke, 2010; 2014b) characterized the female AGR as having fused two cervices separated by a mid-sagittal septum. Their thick musculatures projected caudally into the vagina as the *portio vaginalis uteri.* The cervical canal was straight and had 4 – 5 interlocking longitudinal mucosal folds (Fig. 37).

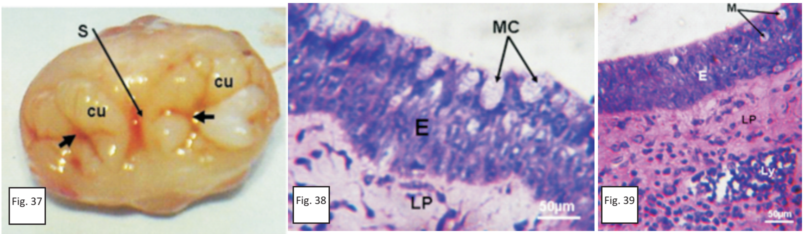


Fig. 37: A photograph of transverse section of the cervix of the African giant rat. The mid-sagittal septum (S) that separates the two cervix uteri (Cu). The interlocking longitudinal folds that form the cervical canal (arrowed) and the outer smooth muscle that fuses the two cervices.

Fig. 38: The cervix in the adult female African giant rat at mid-proestrus. The stratified columnar epithelium (E) with tall mucoid cells (MC). Also note the lamina propria (LP) H&E.

Fig. 39: The cervix in adult female African giant rat during mid-dioestrus. The stratified columnar epithelium (E) with about 4 – 5 layers and focal mucoid cells (M). Note the lamina propria (LP) having numerous lymphocytes (Ly) H&E.

Cervical histology showed mucosa-submucosa, muscularis and serosa layers with fused muscular layers between the two cervices forming mid-septum. Cervical epithelium, interspersed with tall mucoid cells, varied between stratified cuboidal and stratified columnar. Differential distribution of the mucous-secreting cells occurred during oestrous cycle. (Fig. 38). At mid-metestrus and mid-dioestrus, numerous lymphocytes were observed in the lamina propria and there was less mucous secretion (Fig. 39) (Akinloye and Oke, 2014b).

Our findings during oestrous cycle of the African giant rats showed slight variable cervical ultrastructures. At mid oestrus, the mucosa showed stratified squamous epithelium. The interface of basal layer and lamina propria was folded with cytoplasmic extension of the basal cells in the underlying connective tissue. Cell-to-cell contacts were tightened by desmosomes leading to lack of intercellular spaces. Minor intercellular spaces with projections of cell extensions were shown (Figs.40). The cervical mucosa at mid metestrus, late metestrus/early dioestrus and mid dioestrus shared similar ultrastructural features. Relatively straight basal lamina interfacing the basal layer and the underlying lamina propria showed hemidesmosomes with minor projections of cytoplasm. Cytoplasmic organelles were sparse. Indented nuclei containing condensed material were observed and intraepithelial lymphocytes commonly occurred in the basal cells. Above the basal layer, the cells became flattened, nuclei reduced in size and relatively smooth superficial surface were observed (Fig. 41). Cell ultrastructures of the cervical mucosa at late dioestrus/early proestrus, mid proestrus and late proestrus/early oestrus were basically similar to what was observed at mid oestrus. Hemidesmosomes, desmosomes and highly indented nuclei were observed. At mid proestrus, dorsoventrally flattened cells containing slightly indented, elongated nuclei with euchromatic and heterochromatic materials were observed (Figs 42 and 43) (Akinloye and Oke, 2014b).

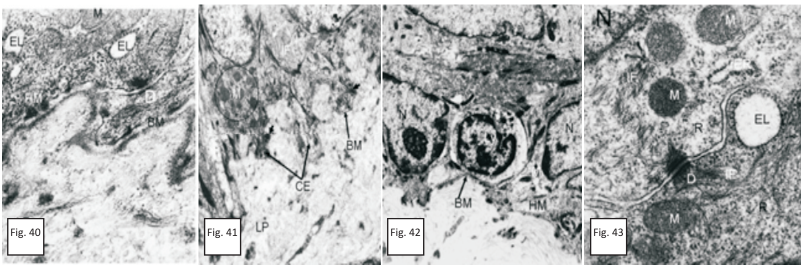


Fig. 40: Electron micrograph of stratum basale of Cervix at Mid Oestrus. The nucleus (N) with finely dispersed chromatin materials, accumulation of Mitochondria (M), condensation of intermediate filament (IF) and basement membrane (BM) followed projection of cytoplasmic extension (CE) into the lamina propria (LP) (x 7,900).

Fig. 41: Electron micrograph of stratum basale of cervix at Mid dioestrus. Observe lamina propria (LP), intraepithelial Lymphocyte (Ly), hemidesmosomes (HM), nucleus (N) and mitochondria (M) (x 5,800).

Fig. 42: Electron micrograph of stratum basale of cervix at Mid Proestrus. Note the lamina propria (LP), basement membrane (BM) that followed contour of cytoplasmic extension, hemidesmosomes (HM) and desmosomes (D) as well as electron lucid vesicle (EL), mitochondria (M), ribosomes (R) and filaments (F) (x 34,000).

Fig. 43: Electron micrograph of interface between strata spinosum and basale of cervix at Mid Proestrus.
Observe the nucleus (N), intermediate filaments (IF), rough endoplasmic reticulum (rER) and ribosomes (R) as well as electron-lucid (EL) vesicle, mitochondria (M) and desmosomes (D) (x 34.000).

2.7 Characterization of the African Giant Rat Vagina at Different Stages of Oestrous Cycle

We studied the histology and ultrastructures of the vagina at various stages of the oestrous cycle in female African giant rats (*Cricetomys gambianus* Waterhouse) (Akinloye, 2009; Akinloye and Oke, 2014b). Histologically, our findings showed that in all the stages of oestrous cycle, the vaginal wall was made up of a mucosa, a muscularis and a covering of connective tissue. The mucosal surface was generally lined by stratified squamous epithelium that displayed cyclic histological changes at different stages of oestrous cycle (Figs. 44). The lamina propria subjacent to the vaginal epithelium had a wide band of dense fibrous connective tissue with many blood vessels while the tunica muscularis was made up of layers of smooth muscle coat.

Ultrastructurally, we found that at mid-proestrus (MP), late proestrus (LP)/early oestrus (EE) and mid-oestrus (ME), as well as late metestrus (LM)/early dioestrus (ED) and mid-dioestrus (MD) there was complex interface of epithelium and lamina propria. Cells of the stratum basale formed finger-like extensions into the underlying lamina propria and tips of the extensions displayed hemidesmosome while basal lamina followed the contour of the extensions (Fig. 45). At mid-metestrus (MM) and late dioestrus/early proestrus, well developed, relatively straight basal lamina interfaced between the stratum basale and the lamina propria without finger-like projections. Polygonal cells with indented nuclei and, cytoplasm containing ribosomes, polysomes, intermediate filaments, and mitochondria were observed in stratum spinosum at all the phases of the oestrus cycle. At MM, LM/ED, and MD, the stratum spinosum had numerous desmosomes with tonofilaments, large microvilli that intermingled at the intercellular spaces and evidence of trapped/migrating neutrophils and lymphocytes (Fig. 46). The superficial layer displayed short microvilli at mid proestrus, cornification at LP/EE and desquamation at ME while it showed condensation of intermediate filaments; projections of large microvilli into the luminal surface at MM, and embedment of neutrophils at LM/ED, as well as MD (Fig. 47). The study produced the first comprehensive description of the vagina at the ultrastructural level during oestrous cycle (Akinloye and Oke, 2014c).

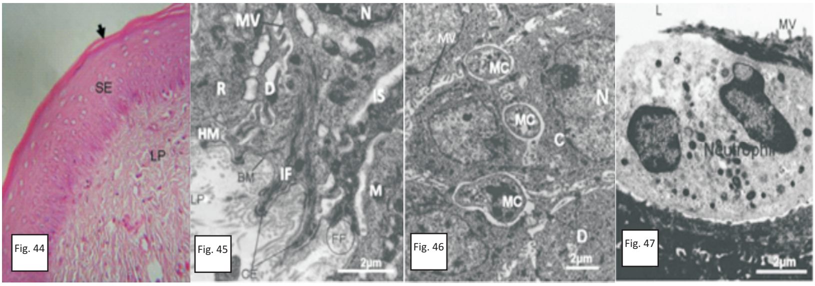


Fig. 44: Photomicrograph of the vagina in the adult female African giant rat at late proestrus/early oestrus.
The stratified epithelium (SE) of the vaginal mucosa with a lamina propria (LP). Observe that the mucosal surface bears the cornified layer (arrow) (x125).

Fig. 45: Showing complex interface at stratum basale at ME.
Observe the Basement Membrane (BM) that follows the smooth contours of Cytoplasmic extensions (CE) in the Lamina Propria (LP), Intermediate Filaments (IF). Note the Intercellular Space (IS), Microvilli (MV), Desmosomes (D), Hemidesmosomes (HM), Fine Filaments (FF), Mitochondria (M) and Ribosomes (R) (x 11,500).

Fig. 46: Electron micrograph of vaginal epithelium at Mid Metestrus. Showing trapped migrating cells (MC) in the intercellular spaces of stratum spinosum. The cytoplasm (C), nucleus (N), numerous desmosomes (D) and microvilli (MV) projecting into intercellular spaces (x 6,610).

Fig. 47: Neutrophil in the superficial layer at Late Metestrus/Early Diestrus. Showing the neutrophil containing granules and microvilli (MV) pointing into the lumen (L) (x 11,500).

2.8 Sex Hormonal Pattern of the African Giant Rat at Different Stages of Oestrous Cycle

We used Enzyme immunoassay (EIA) system to measure the serum concentrations of follicle stimulating hormone (FSH), luteinising hormone (LH), oestrogen, progesterone, and prolactin in a total of thirty-five sexually matured female African giant rats (*Cricetomys gambianus,* Waterhouse) at different stages of the oestrous cycle in order to determine the sex hormonal pattern (Akinloye and Oke, 2012). Exfoliative cytology of vaginal smears was used to classify the rats into different phases of the oestrous cycle. Our findings showed lack of LH surge at late proestrus/early estrus when the oestrogen concentration was highest 88.7 ± 0.14ng/ml while oestrogen and progesterone showed an inversely related cyclic pattern. Progesterone serum concentration, 96.8 ± 11.21ng/ml, was significantly high ($p > 0.05$) at late metestrus/early dioestrus but was at its basal level (10.8 ± 1.04ng/ml) at late dioestrus/early oestrus. Prolactin serum concentration, 20.7 ± 2.92ng/ml, decreased significantly ($p>0.05$) at late dioestrus/early proestrus and was at its peak during mid oestrus (72.8 ± 9.54ng/ml). Prolactin serum concentration displayed inverse relationship with the FSH whereas it exhibited synergism with oestrogen serum concentration (Tables 7 and 8). The hormonal pattern confirmed that ovulation occurred at late proestrus/early estrus, and that female African giant rat is a spontaneous ovulatory and its reproductive tract is not affected seasonaly (Akinloye and Oke, 2012).

Table 7: Mean serum concentrations (ng/ml) of the reproductive hormones in the female African giant rat at different stages of oestrous cycle.

Reproductive Hormones	MP	LP/EE	ME	MM	LM/ED	MD	LD/EP
LH	0.1 ± 0.01	0.1 ± 0.02	0.1 ± 0.01	0.1 ± 0.01	0.1 ± 0.01	0.1 ± 0.02	0.1 ± 0.01
FSH	0.2 ± 0.01	0.2 ± 0.03	0.2 ± 0.01	0.2 ± 0.02	0.1 ± 0.01	0.1 ± 0.01	0.2 ± 0.01
Oestrogen	86.8±0.14	88.7±0.09	87.2±0.36	66.1±0.17	17.8±0.34	78.3±0.18	56.5±0.22
Progesterone	17.6 ± 1.03	10.8 ± 1.04	21.7 ± 2.71	40.0 ± 3.95	96.8 ± 11.21	95.9 ± 10.08	17.3 ± 1.93
Prolactin	54.2 ± 8.21	65.2 ± 7.34	72.8 ± 9.54	49.2 ± 4.10	50.9 ± 7.16	59.7 ± 6.27	20.7 ± 2.92

Values are given as Mean ± S.E.
Source: Akinloye and Oke, 2012

Table 8: Means of groups for serum concentrations (ng/ml) of the reproductive hormones in female African giant rat at different stages of oestrous cycle.

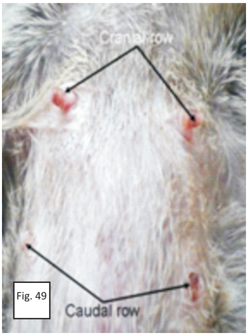
Reproductive Hormones	MP	LP/EE	ME	MM	LM/ED	MD	LD/EP
LH	0.0873[a]	0.0978[a]	0.0917[a]	0.0894[a]	0.0944[a]	0.0899[a]	0.0987[a]
FSH	0.1351[a]	0.1084[a]	0.1112[a]	0.1088[a]	0.0987[a]	0.0991[a]	0.1081[a]
Strogen	0.4472[a]	0.6194[a]	0.5437[a]	0.2189[a]	0.1188[b]	0.3188[a]	0.2339[a]
Progesterone	0.1353[a]	0.1206[a]	0.1411[a]	0.2329[a]	0.5197[b]	0.5193[b]	0.1323[a]
Prolactin	0.2474[a]	0.2879[a]	0.3175[a]	0.2114[a]	0.2995[a]	0.3238[a]	0.1120[b]

Values with different supers cripts in the same horizontal row are significantly different from one another at P<0.05 according to Duncan Multiple Range Test (1995). n=5

Source: Akinloye and Oke, 2012

2.9 Characterization of the Giant Rat Mammary Glands

Akinloye and Oke (2010b) characterized mammary glands of the female AGR for the first time as being thoraco-inguinal. Our findings showed that eight (8) mammary glands, distributed along the ventrolateral aspects of thoracic and inguinal regions are present (Fig. 48). The thoracic and the inguinal regions have four mammary glands each and are arranged in two pairs of cranial and caudal rows (Figs. 49 and 50). The number, distribution, and arrangement of mammary glands in the giant rat are at variance with all other species of laboratory animals (Akinloye and Oke, 2010b). In the rat (*Rattus rattus*), for example, there are twelve mammary glands arranged in two ventrolateral series along thoracic and inguinal regions while there are 10 mammary glands in the mouse arranged in six thoracic and four abdomino-inguinal. In guinea pig, there are two mammary glands located in the inguinal region while the eight mammary glands present in the rabbit are in two ventrolateral series along thoracic and abdomino-inguinal regions (Hafez, 1970).



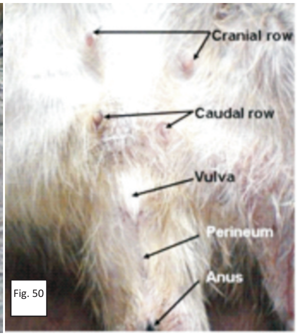


Fig. 48: A photograph of the mammary gland of the African giant rat. Showing location of the nipples and the arrangement of the mammary glands in the thoracic region (T), as well as the mammary glands in inguinal region (I).

Fig. 49: Mammary glands in the thoracic region
The four teats of the mammary glands that are arranged in pairs of cranial row and caudal row.

Fig. 50: A photograph of mammary glands in the inguinal region.
The four teats in two pairs of cranial and caudal rows. Also note the bulged vulva as it relates to the anus.

2.10 The African Giant Rat and the Giant of Africa

Mr. Vice-Chancellor, Sir, just as the African giant rat holds untold potentials of economic importance, Nigeria, the giant of Africa also holds numerous and advantageous potentials. As the most populous black nation in the world, Nigeria has Africa's largest economy, with a GDP of $477.38 billion in 2023. Nigeria is a big oil producer with a population of more than 225 million people. Its economy is mostly driven by oil exports, rendering it sensitive to global oil price changes and economic volatility. Despite this, Nigeria has a booming services industry, a young population, and diversification possibilities. However, this giant faces challenges that hinder its progress and development. The country can learn from nations that successfully diversified their economies, investing in sectors such as agriculture, technology, and manufacturing to ensure long-term stability and growth. Investing in infrastructure is crucial for Nigeria's growth. Addressing issues like inadequate power supply, road networks, and reliable public services can significantly impact the overall development of the country through a more conducive environment for business and daily life.

But of utmost interest, however, should be the agricultural development of Nigeria. The "Giant of Africa," possesses significant agricultural potential, particularly in the realm of animal production. Transforming this potential into a thriving sector requires strategic lessons learned from successful models globally. Her animal production sector should prioritize diversifying its livestock as relying on a single or certain types of animal production poses risks to the industry. For instance, Nigeria's overreliance on the cattle value chain is partly responsible for the premium placed on cattle rustling, banditry and ensuing security challenges.

For this to be possible however, Nigeria must deploy Technological Integration, value chain development, capacity building and training, research and innovation and most of all systematic research-based education. Fostering this culture of research and innovation is critical for staying competitive in the global market. Therefore, Nigeria can learn from nations that prioritize research in animal domestication, animal genetics, nutrition, and disease control. Properly funding research institutions (such as our great Federal University of Agriculture that was recently adjudged the best in Africa and among the world best schools of Agriculture) will go a long way in making this a reality.

Mr. Vice-Chancellor, Sir, a well-educated population is the backbone of any thriving nation. Nigeria must prioritize education and promote innovation to compete in the global arena. Investing in research and development, fostering a culture of entrepreneurship, and providing quality education at all levels will contribute to the country's intellectual and economic advancement.

Mr. Vice-Chancellor, Sir, my research on the female reproductive tract of the African giant rat is indeed a mirror of the state of the nation and is worth musing over. In summary, permit me to draw out the lessons this *magnum opus* of the African giant rat has with our nation - the Giant of Africa.

2.10.1 Signal Molecules of Quality Control

Mr. Vice-Chancellor, Sir, the timing of oestrus, fertilization, gestation, parturition and lactation are under the control of hormones. With these processes uniquely and intricately coordinated in the African giant rat, the various hormones as described in my research, ensure a critical quality control system that is necessary for success in any organization or nation. The giant of Africa must take a lesson from hormones as quality control system is a must for a smooth running of any organisation. Giant of Africa must learn to upregulate, for instance in salaries of citizens and in all areas where there are structural or socioeconomic deficiencies. The nation must also learn to peg down the issues of corruption and minimize the issues of the brain drain popularly called *"Japa"*.

2.10.2 The Cradle of Fertilization and Development

Fertilization occurs in the oviduct. This delicate process precedes implantation in the womb. Mr Vice-Chancellor, Sir, a nation's educational system is the cradle of fertilization and development. Whilst they must be regulated and sustained by control systems, they determine the success of the formation of the organism. For the giant of Africa to fulfil her potential like the giant rat, she must provide the enabling environment for cross fertilization of ideas and their development through the womb of qualitative research and innovation. This process must primarily be internal and may not be outsourced. Nigerian Universities in particular, need a boost through proper funding, better and increased emoluments of lecturers and staff and the provision of enabling environments. It is in this richly and tenderly prepared womb like that of the African Giant Rat that they can and must nurture the future giants of Africa and indeed the world.

2.10.3 Milk of Human Kindness

Further Mr. Vice-Chancellor, Sir, we have seen the reproductive anatomy of the African giant rat as one suited to carry several pups and birth them successfully also. The beauty of this is that the African giant rat also has the ability to nurse them successfully. With eight mammary glands positioned at lateral aspects of thoracic and inguinal regions, this rodent provides more than it typically gives birth to. This gives the African giant rat's pups enough chances to survive and grow, hence making this rodent a viable mini-livestock for production.

The giant of Africa must also position opportunities for the teeming population and circulate the milk of kindness through her abundant resources. When in a state of weakness, milk nurtures the pup to strength. Mr Vice-Chancellor, Sir, the youths and even the aged are presently in a state of moral, educational and financial weakness. What the nation needs is the proper circulation of resources and compassionate nationhood shall begin to rise again.

2.10.4 Economic Diversification: Giant of Africa and African Giant Rats

Economic diversification is the process of shifting an economy away from a single income source toward multiple sources from a growing range of sectors and markets. Traditionally, it has been applied as a strategy to encourage positive economic growth and development. During gestation (pregnancy), the cervix closes its gates to keep the developing embryo in place, but it is required to open during parturition (birthing). The African giant rat has a special double cervical opening to accommodate more fertilization and also aid easy birthing process. Diversification is therefore key to creating a robust and sustainable economy. Is it not high time the giant of Africa considered African giant rat for economic diversification?

3.0 CONCLUSIONS

Mr. Vice-Chancellor, distinguished audience, I have, in the last forty minutes, shown detailed anatomic structures of the female African giant rat and how useful opinions on the structures of the organs can be utilized to advantage. Through histomorphological, immunohistochemical, hormonal and ultrastructural techniques, I have been able to show that ovulation takes place at late proestrus/early estrus in female African giant rat and, therefore, suggested that late proestrus/early estrus stage be targeted for breeding of the giant rat in captivity. Unlike the previously held opinion that African giant rat is a seasonal breeder, our results showed that the female African giant rat can breed throughout the year. Therefore, season may not be a handicap to a successful breeding of the rat. In general, the gross organization of the reproductive organs is similar to those of the rat, mouse and hamster. However, nodular structures of the ovary, variable degrees of irregular coils of the oviduct with no distinct border between ampulla and isthmus, as well as duplex uterus with two cervices were among the significant gross structural features of the female giant rat. It was shown that African giant rat has economic potentials to meet economic diversification of the giant of Africa.

4.0 RECOMMENDATIONS

The Anatomy, Physiology and Ecology of the rats have been widely studied. Attempt has also been made to domesticate the wild rat in the past by Professor S.S. Ajayi, one of the foremost Wildlife Scientists at the University of Ibadan, but the attempt was not successful. African Giant rat has all indices and qualities of a domesticated animals with a very great potential for its production to become profitable to a farmer. Its sociology also satisfies the requirements of a domesticated animals and thus there will be no restrictions in marketing its products. Presently, efforts and studies are currently ongoing in Faculties and Department of Forestry and Wildlife Management and College of Veterinary Medicine including FUNAAB on Grasscutter Domestication in the country. But since the Giant Rat Project of Prof. S. S. Ajayi stopped, no other scientists have ventured into domestication of this Rat;

1. The African giant rat, as it has been explained in this lecture, is a treasure to behold and appreciated. Domestication and multiplication of this important animal resources is hereby advocated to complement the ongoing efforts in Grasscutter domestication.

2. The University needs to blaze the trail by encouraging scientists from Wildlife Management, Zoology, Animal Science and Veterinary Medicine to revive the work where it was stopped. This will go a long way to diversify the protein sources on the table, conserve the wild stocks and improve the revenue base of the micro-livestock farming communities.

3. The giant of Africa must begin to diversify from being an oil-based economy by opening more gates of possibilities for both fertilization of ideas and production of national profit. It is high time the giant of Africa tapped into the economic potentials of the African giant rats.

5.0 ACKNOWLEDGMENTS

All praises and adorations are due to Almighty Allah the most Beneficent, the most Merciful, the Eternal, the Most Sacred, the Embodiment of Peace, the Infuser of Faith, The Preserver of Safety, the Mighty, the Omnipotent, the Dominant, the Creator and the Self-Subsisting; to him belong all the beautiful names. I thank Almighty Allah for preserving my life and for making the presentation of this 87th Inaugural lecture feasible.

I am indeed grateful to my parents, Late Alhaji Abdul Kareem Akinloye and Alhaja Mariam Akinloye for giving all my siblings and I exceptionally good and sound Islamic upbringing. My father sent all his children to Modrasat and he actually wanted me to

become an Alfa but for my uncle, Mr. Johnson Folorunsho Akinloye who took me over from him. My father's belief, which I have also come to confirm, is that once you can recite and understand the Quran, there is no concept in western education that you would not be able to understand. May Almighty Allah grant him Aljanat Firdaus and continue to grant my mother long healthy life. I thank all my siblings and the entire members of Palata Family, Oke Oja, Ikire for your love and affection.

I owe my uncles, Late Mr. Johnson Folorunsho Akinloye, Late Mr. Zaccheus Akinloye and Alhaji Remi Oyefiade, as well as my elder brothers, Bro. Tunde Akinloye and Bro. Laitan Oyetoro, heartfelt gratitude for jointly seeing me through my education from modern school, secondary school and to the University. May Almighty God be meeting you at your points of needs.

Mr. Vice-Chancelor, Sir, distinguished audience, I dedicate this inaugural lecture to the loving memory of late Professor Bankole Olusiji OKE. He was my supervisor, my mentor and my confidant who eventually turned to be my big brother. Late Prof. Oke painstakingly initiated me into this field of reproductive and endocrine biology. His thoroughness, openness and active participation throughout my studies at the University of Ibadan paved way for me to reach the height of my academic career within record time. I owe Professor Bankole Olusiji Oke a profound and deep-seated gratitude for the pivotal roles he played in my life. How I wish he were here seated, he would have served as a source of additional encouragement for me, and I would have been the happiest man on earth. But all is not lost for me as I have his beautiful, humble and ever-caring wife, Professor Gbemisola Oke, here seated today. Madam is a Professor of Periodontology and Community Dentistry, a former Dean Faculty of Dentistry and a former DVC Academic at the University of Ibadan, Ibadan. Your presence here has really made my day. Thank you so much, Ma. May the soul of our loving father continue to rest in perfect peace.

My sincere and heartfelt gratitude goes to the founding father of COLVET, FUNAAB, Professor Ebenezer Babatunde Otesile who brought me to FUNAAB as one of the pioneer staff of COLVET to establish the Department of Veterinary Anatomy in 2002. Apart from being my excellent Ruminant Medicine teacher at the University of Ibadan, I also acquired all my administrative experience under his tutelage. Professor Otesile is an embodiment of knowledge, humility personified and a father indeed. I shall never forget how he paid part of my PhD school fees as a source of encouragement when he saw that I was not making desirable progress on my program. May Almighty God continue to spare your life for us and grant you sound health to enjoy the fruit of your labour.

My deep-seated appreciation also goes to “Mama COLVET” as she is fondly called, the beautiful and the “Whaoo” of COLVET, the former Dean COLVET and the former DVC Academic FUNAAB, Professor Morenike Atinuke Dipeolu. Madam worked assiduously to secure Senate approval for the establishment of COLVET when none of us in COLVET today was around. Professor Dipeolu was the foot soldier that sourced for personnel and space for the smooth take off of the College. Her *midas touch* has made COLVET to blossom. We truly owe her a lot of gratitude for providing a space for all of us in COLVET to develop. She ensured the birth of COLVET; Mama COLVET indeed. May your Midas touch never wane.

My thanks also go to my bossom friend, Professor Adekayode Olanrewaju Sonibare. We assumed duty the same day in FUNAAB; his SP number is 993 while mine is 994. Both of us left the services of the University of Ibadan for FUNAAB and we have been very intimate since then. While Professor (Mrs) Dipeolu was instrumental to the establishment of COLVET and Professor Otesile was the founder, Professor Sonibare, through his hard work and doggedness nurtured Veterinary Teaching Hospital (VTH) to maturity. His dedication and selfless service to uplift VTH is second to none and highly commendable. I wish you greater heights in all your future endeavours.

My sincere gratitude also goes to my Dean, Professor Olusola Lawrence Ajayi, all Heads of Departments and the entire COLVET family for providing an enabling environment to develop as a family. When I became the Dean COLVET in 2017, only five (5) of us were Professors; Profs Otesile, Dipeolu, Oyekunle, Talabi and myself. As at the time I finished my tenure as Dean on July 31, 2023, we had twenty (20) Professors in the College. We also secured full National Universities Commissions (NUC) and Veterinary Council of Nigeria (VCN) accreditations, and COLVET FUNAAB was ranked the Best College of Veterinary Medicine in Africa in 2022. The College has since been waxing stronger yearly. All these monumental progresses would not have been possible if not for the support and cooperation of both academic and non-teaching staff. At this juncture, I also want to specifically thank all the non-teaching staff who supported me in my various appointments in the University; former College Officers, former College Accountants, former College Librarians, especially our own current University Librarian, Dr. Owolabi, as well as my former Secretaries, former Executive Officers, former Administrative Officers and former Drivers. I also want to acknowledge former secretary to CODAD, Mr. Agbotoba and the current secretary CODAD, Dr. Abdsoboor Salam who was also one of former College Officers. May the bond of God's love that binds us together continue to wax stronger and stronger.

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