# BLOOD: DIFFERENT STROKES FOR DIFFERENT ANIMALS

*An Inaugural Lecture delivered at the University of Ibadan*

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*By*

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*The Vice-Chancellor, Deputy Vice-Chancellor (Administration), Deputy Vice-Chancellor (Academic), Registrar, Librarian, Provost of the College of Medicine, Dean of the Faculty of Veterinary Medicine, Dean of the Postgraduate School, Deans of other Faculties, and of Students, Distinguished Ladies and Gentlemen.*

This inaugural lecture is the 29th to be given from the Faculty of Veterinary Medicine since 1976 when the first lecture was delivered by Professor Desmond Hill, the founding Dean of the Faculty. It is also the eighth in the 2010/2011 series of inaugural lectures and the third lecture from the Department of Veterinary Physiology, Biochemistry and Pharmacology (formerly known as the Department of Veterinary Physiology and Pharmacology). This however, is the second lecture from the Physiology section of the Department. The first inaugural lecture from our Department came from the Physiology section about 26 years ago and was delivered by Professor Michael O. Olowookorun in May, 1985. It was titled "The Digestive System: A Perfect Example of United We stand, Divided We Fall". In April, 1996, Professor Reuben O. A. Arowolo from our Pharmacology section delivered the second lecture with the title "Protecting Our Livestock Resources".

Today, I feel highly honoured to present the third inaugural lecture from our Department titled "Blood: Different Strokes for Different Animals". I have chosen this title because of the significance of blood to the lives of man and animals. It is also because it encapsulates much of the thrust of my research activities, having worked on the blood profiles of several species of normal healthy animals and birds under various environmental conditions for about three decades. Although the proverbial saying 'different strokes for different folks', from where the title of this lecture was derived, refers to 'different people living or doing things in different ways', blood can be viewed as containing basically similar constituents in different animals with each of these

constituents differing qualitatively and quantitatively to match the physiology of each species.

**What is Blood?**

According to the Oxford English Dictionary, the word "blood" originated before the 12th century and is derived from the Old English word "blôd", which is akin to the German word "blut", meaning blood.

Blood is the fluid that circulates through the heart, arteries, veins and capillaries of multicellular animals (including human and non-human vertebrates). It carries oxygen ($O_2$) and nutrients to the cells of the body and removes waste products and carbon dioxide ($CO_2$) from same. It consists of a fluid part called **plasma** (mainly water, but with a mixture of hormones, nutrients, enzymes, electrolytes, gases, antibodies and waste products), which is in equilibrium with the tissue fluid of the body, and **cells** including red blood cells (which carry oxygen), white blood cells (which help combat infections), and platelets (which help the blood to clot). The cells are derived from extravascular sites (i.e. outside the blood vessels) namely the red bone marrow and lymphoid tissues and then re-enter the extravascular spaces where some of them become transformed into connective tissue cells.

**Historical Perspective**

Blood has always been universally acknowledged as a living tissue, the very essence of life. "*Le sand c'est la vie*" (Blood is life) and similar philosophical expressions of other languages attest to this. The doctrine of the **humors**, which dominated Western medical thinking until the Renaissance, held that disease is the consequence of imbalance of the four components of which the human body is composed: blood, phlegm, black bile and yellow bile.

The English physician, William Harvey (1578-1657) wrote: "Blood acts above all the powers of the element and is endowed with notable values and is also the instrument of the omnipotent creator." He believed that, "blood is the fountain of life and the seat of the soul."

An understanding of the structure of blood (that it consists of cells suspended in a protein-rich fluid known as plasma) slowly accumulated from the 17th century onwards. The first person to describe red blood cells (or red corpuscles as they were known then) was the young Dutch biologist, Jan Swammerdam, who, in 1658, used an early microscope to study the blood of a frog. Another microscopic description of red blood cells was provided 20 years later, in 1678, by Anton van Leeuwenhoek (1632-1723) who unaware of Swammerdam's work, provided a more precise description of red blood cells, even approximating the cell size as "25,000 times smaller than a fine grain of sand". The white blood cells (called white corpuscles) were first described by the British physician, William Hewson (1739-1774), who also discovered the essential features of how blood coagulates, showing that it is due to the clotting of plasma and not as a result of changes in the cellular components of blood. It was in the latter half of the 19th century that blood cells were found to be the progeny of more primitive cells in the bone marrow.

The modern science of haematology stemmed from the work of the Greek pharmacologist, Paul Ehrlich (1854-1915), who developed a stain that led to a clear distinction between the different types of blood cells. The knowledge of the functions (physiology) of blood also evolved over many centuries. William Harvey described blood circulation in 1628, and some few years later, the English physician, Richard Lower (1631-1691) reported the change from dark blue color of venous blood to the bright red color of arterial blood after its passage through the lungs. In 1790, the French chemist, Antoine Lavoisier (1743-1794) discovered oxygen and found it was the constituent of air that is responsible for the change in the color of blood. In the mid-nineteenth century, it was found that oxygen combines with a substance in the red cells which was identified as a protein, haemoglobin (Hb) by the German biochemist, Felix Hoppe-Seyler (1825-1895). By 1900, it was appreciated that white blood cells play crucial roles in defense against infection.

This idea was first proposed by the Russian zoologist, Ilya Metchnikoff (1845-1916).

Karl Landsteiner, in 1901, published his discovery of three main blood groups–A, B and C (C, he later renamed O). Landsteiner described the regular patterns in which reactions occurred when serum was mixed with red blood cells, identifying compatible and conflicting combinations between the blood groups. A year later, in 1902, Alfred von Decastello and Adriano Sturli, who were two of Landsteiner's colleagues, identified the fourth blood group, AB. In 1959, Dr. Max Perutz, using x-ray crystallography, was able to unravel the structure of Hb, the red blood cell protein that carries $O_2$. This work resulted in his sharing with John Kendrew the 1962 Nobel Prize in Chemistry.

**Significance of Blood**

Since ancient times, blood has been identified with life and, through the ages, people have produced endless speculations about that connection. People assigned various sacred and magical properties to blood and used it in a variety of rituals. This, ladies and gentlemen, I am sure is well understood by us in Africa. Some drank it, rubbed it on their bodies and manipulated it in ceremonies. Some people believed that by drinking the blood of a victim, the conqueror absorbed the additional strength of the conquered. By drinking the blood of an animal, one took on its qualities. As late as the 17th century, the women of Yorkshire in England were reported to believe that by drinking the blood of their enemies they could increase their fecundity.

The aura created around blood probably derives from its eye-catching distinctive ***red colour***, and the fact that its exit (loss) from the body in large amounts, say in battle, led to loss of life. As a result, redness came to be seen as an essential characteristic of blood and the vehicle of its power. Thus, red objects were often endowed with the same potency as blood. In particular, red wine was identified with blood. For instance, in ancient Greece, red wine was drunk by the devotees of the god Dionysus in a symbolic ritual drinking of his blood.

Blood was, is, and continues to be seen as somehow related to the qualities possessed by an individual. Several beliefs make references to admirable people as having "good blood" or evil persons as possessing "bad blood". Thus, blood, in a somewhat literal sense, carries the essential characteristics of the larger families, clans, national/ethnic groups, even whole races. Due to its importance to life, blood is associated with a large number of beliefs. One of these is the use of blood as a symbol for family relationships through birth/parentage. For instance, to be "related by blood" is to be related by ancestry rather than marriage. This is closely related to sayings such as "blood is thicker than water" which literally replaces a biological brother with a "blood brother".

***In Islam***

The consumption of food containing blood is forbidden by Islamic dietary laws. This is derived from the statement in the Qur'an, sura Al-Ma'ida (5:3): "Forbidden to you (for food) are: dead meat, blood, the flesh of swine, and that on which has been invoked the name of no other than Allah."

***In Christianity***

In the book of Genesis Chapter 9 verses 4 - 6, God told Noah: "But you must not eat the flesh with the life, which is the blood in it. And further, for your life-blood, I will demand satisfaction; for every animal will I require it...."

In the New Testament, the thought of the early Christians on the significance of Christ's death was clearly presented in the Book of Revelation, in which John spoke of Jesus as the one who "freed us from our sins with his life's blood" (Revelation 1:5).

It is out of obedience to the commands of the bible such as "Keep abstaining from anything offered to idols and from blood" (Acts 15:28, 29), that Jehovah Witnesses refuse to partake in the consumption of blood or accept transfusions of blood.

## Composition of Blood

Blood consists of the cellular part, which is made up of red blood cells, white blood cells and platelets (or thrombocytes), and the fluid part called plasma.

## Cellular Components

### Red Blood Cells (Erythrocytes)

Red blood cells (RBCs) are also known as red blood corpuscles (an archaic term), haematids or erythrocytes (from Greek "erythros" for "red" and "kytos" for "hollow", with "cyte" translated as "cell" in modern usage).

#### *Vertebrate Erythrocytes*

While in invertebrates various respiratory pigments may be found in the blood plasma and infrequently in simple cells, the vertebrates have developed a specialized cell containing haemoglobin (Hb) called the **erythrocyte.** The erythrocyte consists mainly of Hb, a metalloprotein containing haeme groups whose iron atoms temporarily link to $O_2$ molecules in the lungs and release them to body tissues. $O_2$ can easily diffuse through the cell membrane of RBCs. Hb in the erythrocyte also carries some of the waste product, $CO_2$, back from the tissues. Most of the $CO_2$ is however transported as bicarbonate dissolved in the blood plasma. **The only known vertebrates without erythrocytes are the crocodile icefishes (family *Channichthyidae*)**, that live in very $O_2$ rich cold water and transport $O_2$ freely dissolved in their blood. Although they don't use Hb, remnants of Hb genes can be found in their genome (Carroll 2006).

#### *Mammalian Erythrocytes*

Among vertebrates, mammalian erythrocytes are unique as they are non-nucleated in their mature form. The sizes of individual erythrocytes and their number per unit volume of blood (RBC count) vary between mammalian species. The goat has the smallest erythrocyte size and the greatest erythrocyte number among domestic animals and man, followed by the sheep as a close second (Schalm et al. 1975). The ancestors of sheep and goats lived on mountain tops

where $O_2$ tension is low and efficient respiration is required. This may partly explain why domestic sheep and goats have an arrangement for a more efficient respiration than is required for life during domestication.

***Non-Mammalian Erythrocytes***

In non-mammalian vertebrates, such as birds, fish, reptiles and amphibians, the nucleus is not removed during red cell production (erythropoiesis) and is retained throughout the life of the red cell in the peripheral blood. The erythrocytes of these non-mammalian vertebrates are therefore nucleated. **The known exceptions are salamanders of the genus *Batrachoseps* and fish of the genus *Maurolicus* and closely related species, which are non-mammalian vertebrates that have non-nucleated erythrocytes** (Cohen 1982).

**Shapes of Erythrocytes**

The observation of the shapes and sizes of erythrocytes of various vertebrates creates two major impressions: First, that there is a marked species variation in red cell morphology among the submammalian forms. Second, mammalian erythrocytes are relatively similar in size and quite similar in shape. They appear as biconcave disks in most domestic animals (dog, cat, cow, horse, sheep and goat) and man (fig. 1a – g), with the exception of the camel family, *Camelidae*, in which the normal erythrocyte is of a biconvex, ellipsoid or oval shape (fig. 1h).

***Biconcave Disk-shaped Erythrocytes***

The biconcave shape of most mammalian erythrocytes (which are flattened and depressed in the center, with a dumbbell-shaped cross-section) offers maximum surface area for exchange of $O_2$ and $CO_2$ with the surroundings. However, the proportion of such biconcave erythrocytes and the degree of concavity vary between species. Typical biconcave erythrocytes are present in the dog (fig. 1a), cow (fig. 1b), sheep (fig. 1c) and man (fig. 1d), while horse (fig. 1e) and cat erythrocytes (fig. 1f) have shallow concavity and most goat erythrocytes are flat disk-shaped (fig. 1g).

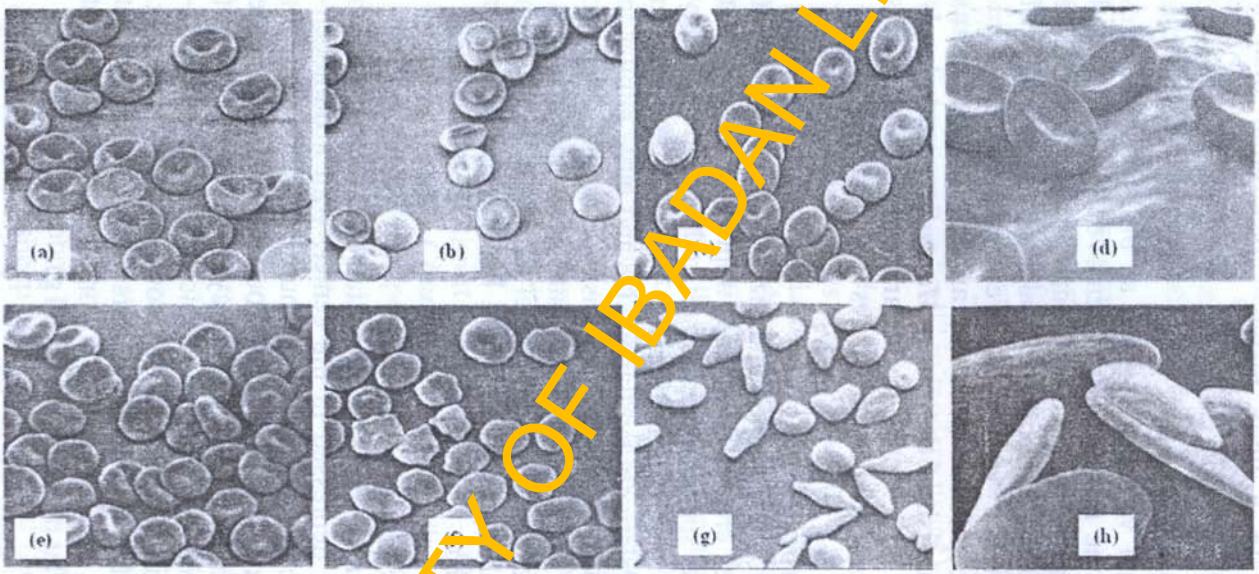



**Fig. 1a-h.** Scanning electron micrographs of erythrocytes from normal **(a)** dog, **(b)** cow, **(c)** sheep, **(d)** human, **(e)** horse, **(f)** cat, **(g)** goat and **(h)** camel. *Source:* (Dog, cow, sheep, horse, cat, goat and camel – *Schalm et al., 1975).* Human erythrocytes –*www.fi.edu/learn/heart/blood/red.html;* retrieved 10 June, 2010).

The peculiar shapes of normal erythrocytes of the camel, Ilama and deer have been compared to the aberrant shapes associated with some human diseases. For instance, hereditary elliptocytosis is an abnormality of the normally biconcave human red cells in which an abnormally large number of erythrocytes are elliptical (fig. 2a) rather than the typical biconcave disk shape. In the Ilama (family *Camelidae*), the normal erythrocyte is an elliptical disk (fig. 2b).

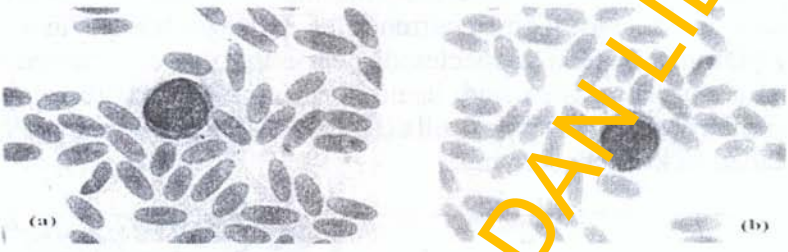



**Fig. 2.(a)** Hereditary elliptocytosis (**abnormal erythrocytes** from humans). Lymphocyte at the center.
*Source*: (*en.wikipedia.org/wiki/Hereditary_elliptocytosis;* retrieved 15 July, 2010).
**(b) Normal** elliptical anucleate **erythrocytes** from Ilama (family *Camelidae*). Lymphocyte present at the center.
*(Source (www.felipedia.org/~felipedia/wiki/indrex.php/Elliptocytosis; retrieved 20 July, 2010))*

## Sickle-shaped Erythrocytes

A sickle cell is an abnormal red blood cell that has a crescent shape and an abnormal form of haemoglobin. The deer erythrocytes circulate as round cells and are similar in size to cattle erythrocytes. The normal deer erythrocyte is not sickle-shaped *in-vivo* and when first removed from the body, but sickling takes place as the sample stands at either room or refrigerator temperatures (fig. 3c). Sickle cell anaemia or disease is a genetic life-long disorder characterized by red blood cells that assume an abnormal, rigid, sickle shape. The disease occurs in a person who has inherited two abnormal (mutant) haemoglobin genes from both parents. It has been estimated that over 200,000 infants are born each year in Africa with sickle-cell disease and 150,000 of these are born

in Nigeria (WHO, 2006). The sickle-cell gene is caused by a point mutation in the *haemoglobin beta gene* that leads to replacement of glutamic acid by valine at position 6 of the beta chain of haemoglobin. This results in a haemoglobin of reduced solubility and, especially in the deoxygenated state, haemoglobin molecules align themselves and distort the erythrocyte membranes, taking up the distinctive sickle-cell shape (fig. 3a, b). However, the sickling phenomenon of the normal erythrocytes of deer (which was first described by Gulliver in 1840) is different from that of sickle-cell disease seen in humans. The occurrence of *in-vitro* sickling in the erythrocytes of most species of deer might have remained a laboratory curiosity had it not been for the existence of similarly shaped (sickle) cells (figs. 3a, b) in a human disease called sickle cell anaemia.

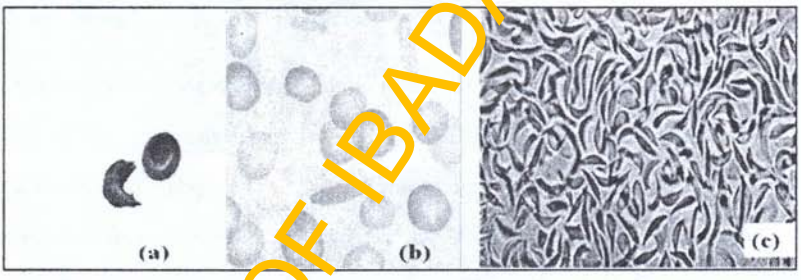



**Fig. 3.** Scanning electron micrograph of **(a)** a sickle erythrocyte and a normal human erythrocyte; and blood smears showing sickle erythrocytes from **(b)** human and **(c)** deer blood.

In contrast to the limited racial and geographical distribution of sickle cell anaemia in man (the sickle-shaped human erythrocytes being found most frequently among people whose ancestors come from Sub-Saharan Africa, South America, Cuba, Central America, Saudi Arabia, India and Mediterranean countries such as Turkey, Greece and Italy), the sickling phenomenon occurs in most species of deer representing a wide variety of ecological and geographical areas of the world. In the deer, sickling is an *in-vitro* phenomenon which occurs under high $O_2$ tension and elevated pH and has no apparent pathologic consequences.

**White Blood Cells or Leukocytes**

The name 'white blood cell' derives from the fact that after centrifugation of a blood sample, the white cells settle in the buffy coat, a thin typically white layer of nucleated cells between the sedimented red cells and the blood plasma. The scientific term, *leukocyte* is derived from the Greek words *leukos* (white) and *kytos* (cell).

***Types of White Blood Cells***

Five different and diverse types of white blood cells are known. They include neutrophils, eosinophils, monocytes, lymphocytes and basophils. The various types of leukocytes in the blood of different animal species (dog, cat, cattle, horse, and elephant) and man are as shown in figure 4 (a – p).

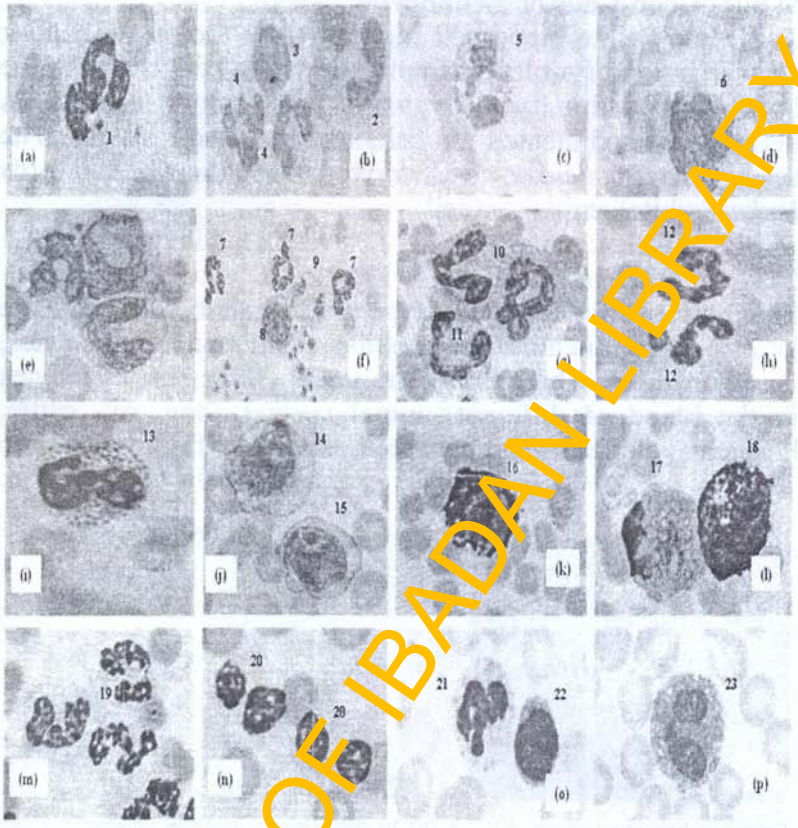


**Fig. 4. Normal leukocyte types in animal and human blood. a - Dog** (1) Nuclear sex-bud or drumstick of segmented neutrophil from a female dog. **b -** Dog. (2) Band neutrophil. (3) Lymphocyte. (4) Two segmented (mature) neutrophils. **c -** Dog. (5) Eosinophil. **d - Dog** (6) Basophil. **e - Dog**. Three typical monocytes. **f - Cat**. (7) Three neutrophils. (8) Small lymphocyte. (9) Eosinophil. **g - Cat**. (10) Two basophils. (11) Eosinophil. **h - Cattle**. (12) Two neutrophils. **i - Cattle**. (13) Eosinophil. **j - Cattle**. (14) Monocyte. (15) Lymphocyte. **k - Cattle**. (16) Basophil. **l - Horse**. (17) Eosinophil. (18) Basophil. **m – Horse**. (19) Three mature neutrophils. **n - Elephant**. (20) Two monocytes. **o – Human**. (21) Neutrophil. (22) Lymphocyte. **p – Human**. (23) Eosinophil

They are all produced and derived from a multipotent cell in the bone marrow called haemopoietic stem cells. Their production and maturation is controlled by a family of

proteins called haemopoietic growth factors. Following their release from the bone marrow into the blood, many of the white blood cells remain in a so-called storage pool, attached to the wall of blood vessels. The numbers circulating freely in the blood therefore represent just a fraction of the total white blood cell count in the body. Species differences occur not only with regard to the total white blood cell count, but also in the proportion of different leukocytes in the blood. For instance, the average total white blood cell count (per microlitre of blood) in man is 8,000. In the dog, cat, cattle, and domestic fowl the average values for normal total white blood cell counts (per microlitre of blood) are 11,500, 12,500, 8,000, and 33,370, respectively (Schalm et al. 1975; Oyewale 1987a). Neutrophils predominate in the human, dog and cat blood, but in the horse, they slightly exceed lymphocytes and in ruminants (cattle, sheep and goats) and laboratory animals (such as rats and mice), neutrophils are outnumbered by lymphocytes.

**Plasma**

Plasma is the fluid of blood left after removal of the cellular elements. Serum is the fluid which is obtained after blood has been allowed to clot and the clot removed. Serum and plasma differ only in their content of fibrinogen and several minor components which are in part removed in the clotting process. It might appear that plasma is less important than the blood cells it contains. But this would be like saying that the stream is less important than the fish that swims in it. You cannot have one without the other.

Although plasma is composed of over 90% water, it also contains a mixture of proteins which include albumin, globulins and fibrinogen. Albumin forms the main bulk of the plasma proteins, and is of considerable importance in maintaining osmotic homeostasis, as it prevents the accumulation of excess fluid in body tissues. Globulins are subdivided into $\alpha_1$, $\alpha_2$, $\beta$ and $\delta$-globulin fractions. The $\delta$-globulin fraction contains the antibodies. Many substances

circulating in the blood (e.g. hormones, vitamins, electrolytes, metabolites etc.) are partially or wholly bound to albumin or globulin fractions, while fibrinogen participates in the blood clotting mechanism.

There are many other classes of compounds circulating in blood plasma. Most of these are smaller molecules which diffuse freely through cell membranes and are therefore more similarly distributed throughout all the fluids of the body. In terms of their concentration and function, the electrolytes are the most important. They primarily regulate the osmotic pressure of plasma and contribute also to the control of pH. The major cations are sodium, potassium, calcium and magnesium, while anions are chloride, bicarbonate, phosphate, sulfate and organic acids. Plasma also contains many small compounds which are transported to the site of synthesis of larger molecules in which they are incorporated, or which are shifted as products of metabolic breakdown to the sites of their excretion from the body.

**Platelets (Thrombocytes)**

The blood contains platelets and at least 12 other factors active in blood clotting. Platelets are small, spindle-shaped or rod-like structures occurring in large numbers in the circulating blood. They change their shapes rapidly on contact with injured blood vessels or foreign surfaces and take part in clot formation. Platelets are cytoplasmic fragments broken off from their precursor cells of origin in the bone marrow, the megakaryocytes, and are therefore not nucleated in mammals. However, platelets of birds are nucleated.

**Blood in Invertebrates**

In insects, the blood, known as haemolymph, is not involved in oxygen transport. There are openings called tracheae which allow oxygen from the air to diffuse directly to the tissues. Haemolymph in insects moves nutrients to the tissues and removes waste products in an open circulatory system.

Other invertebrates use respiratory pigments, like the copper-containing haemocyanin in crustaceans and mollusks which are freely soluble in the blood, to transport oxygen.

**Color of Blood**

In man and animals, arterial blood and capillary blood are bright red as $O_2$ imparts a strong red color to the haeme group of Hb in the erythrocyte. Deoxygenated blood shows a darker shade of red as seen in veins or when venous blood samples are obtained.

The skink, *Prasinohaema virens* (fig. 5), which is a scincid lizard species native to New Guinea, is a green-blooded land vertebrate. The green blood pigmentation results from accumulation of the waste product, biliverdin in levels that would be toxic to other vertebrates. Biliverdin is a compound formed from the breakdown of Hb, and is normally converted to bilirubin. It is believed, however, that mutation in various genes regulating bilirubin formation leads to formation and accumulation of biliverdin in this species (Austin and Perkins 2006).

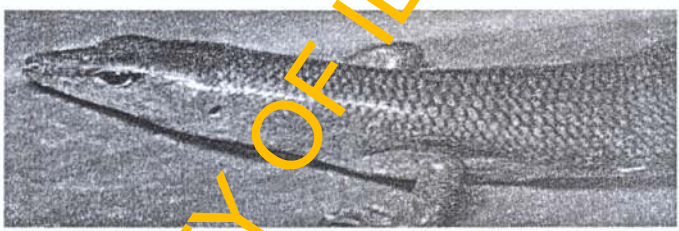


**Fig. 5.** Green–blooded skink (*Prasinohaema virens*) (*Source:* en.wikipedia.org/wiki/*Prasinohaema_virens;* retrieved 26 November, 2010)

The blood of most mollusks (including cephalopods and gastropods) and some arthropods (such as horseshoe crabs) is blue as it contains the copper-containing protein, haemocyanin.

## My Own Contributions

I started my research career in 1980, a year after graduating from the University of Ibadan. Two weeks after completing the National Youth Service Corps in Owerri, Imo State, I travelled to Ibadan to discuss my interest in academics with my former teacher, Professor M. O. Olowookorun, the then Head of Department of Veterinary Physiology and Pharmacology, with whom I had earlier had series of discussions on the same subject matter. Meanwhile, I had been offered a job, each by the Civil Service Commission of Lagos and Kano States and by the Police Service Commission. I preferred a university appointment and refused to take up any of these earlier offers. In September 1980, I got employed as a temporary Lecturer II in the Physiology Unit of the Department. In the remaining part of that year and for the next two years that followed, my research work was on gastrointestinal physiology under the supervision of Professor Olowookorun. I soon gave up on that field of study because as a young researcher, I discovered that Professor Olowookorun had covered so much ground in that field and breaking a new one within a short time would be a difficult task for me. I also observed that the available equipment for gastrointestinal studies in the Department were becoming obsolete and non-functional and there was no immediate hope of upgrading them. In addition, I had just a few publications to show for the 2 years spent on gastrointestinal studies. It was obvious that the only way forward for me was to make a new choice of research interest. To start with, I recalled the field experience during my Youth Service year, when with a colleague and classmate, Dr. Eric Omogbai (currently Professor of Pharmacology, University of Benin) and a Sri Lankan Veterinarian, Dr. S. Tangarajah who was in the employment of the private farm where I worked, we relied on the blood data of animal breeds in Europe and America to assess the health status or treat sick animals in our Nigerian environment. This is because reference data on blood parameters of our animals were not available. In an attempt to fill this gap, I switched over to studying the blood

characteristics of normal animals and birds in the tropical environment. This has been my main thrust ever since, and so far, I have investigated and established data on:

(i) Normal blood parameters of domesticated and non-domesticated animals in the hot humid tropics;
(ii) Osmotic behavior of mammalian and non-mammalian erythrocytes and factors influencing such behavior;
(iii) Haematological changes after blood loss in animals.

**Normal Blood Data of Animals in the Hot Humid Tropics**

***Blood Values of the Large Ruminant***

Mr. Vice-Chancellor Sir, cattle commands a prominent position in our meat supply and livestock industry. Beef accounts for over 50% of the total meat consumed in Nigeria. Although developing countries have about two-thirds of the World Cattle population, about two-thirds of total beef production is accounted for by developed countries. Cattle production in developing countries including Nigeria provides millions of families with good nutrition, family income and employment opportunities, draft power and a more balanced agriculture. Our studies on the blood values of cattle examined two popular breeds: White Fulani and N'dama (fig. 6a, b). The White Fulani is a white, black-eared and medium-horned breed with well developed hump and dewlap and is the most numerous and widespread of all Nigerian cattle breeds. They are found from Lagos to Sokoto, Katsina and Kano States and spread across the Nigerian Middle Belt. The N'dama was brought into Nigeria from Guinea in 1959 on an experimental basis, because it is trypanotolerant. The N'dama has a medium-sized compact body with lyre-shaped black-tipped horns and no hump.

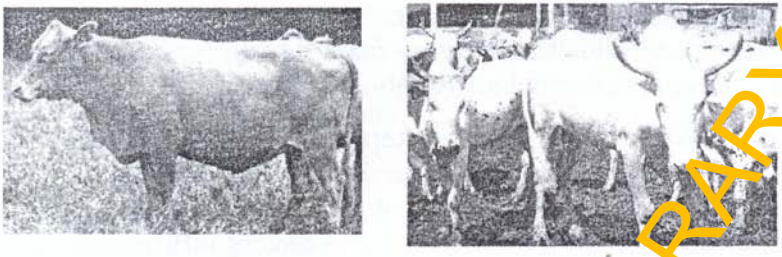


**Fig. 6.** Nigerian cattle breeds: (a) Adult N'dama Cattle (b) Adult White Fulani Cattle

Oduye and Okunaiya (1971), and Oduye and Fasanmi (1971) compared some haematological and serum biochemical parameters, respectively, in White Fulani and N'dama breeds of cattle in Nigeria. However, few parameters were investigated. For instance, the haematological parameters were limited to packed cell volume (PCV), haemoglobin (Hb) concentration and white blood cell count. My former postgraduate student, Dr. Funsho Olayemi (currently Senior Lecturer and Acting Head of my Department) and I compared the various haematological and plasma biochemical parameters of the adult (2 - 5 year- old) White Fulani cattle and adult (2 - 6 year-old) N'dama cattle reared under similar intensive management system at the International Livestock Research Institute, Ibadan, Nigeria (Olayemi and Oyewale, 2002a). We found that the Hb, MCH and MCHC values were significantly higher in White Fulani than in N'dama cattle (table 1).

This is attributed to genetic differences, as both breeds of animals were reared under identical systems of management. The neutrophil count was however lower in White Fulani cattle (table 2). These observations seem to suggest that haematological values obtained for one breed of cattle in Nigeria cannot be accepted as representing the values that may be found in another breed.

Table 1: Erythrocyte values (mean ± SD) of the White Fulani and N'dama breeds of cattle

| Parameter | White Fulani ($n$ = 28) | N'dama ($n$ = 15) |
|---|---|---|
| RBC ( $\times 10^6$ /µl) | 5.47±0.92 | 5.46±1.15 |
| PCV (%) | 39.00±4.62 | 37.13±4.26 |
| Hb (g/dl) | 12.28±1.48 | 9.88±1.33*** |
| MCV (fl) | 72.92±13.21 | 69.90±10.99 |
| MCH (pg) | 23.11±5.29 | 19.00±5.01* |
| MCHC (g/dl) | 31.75±5.37 | 26.94±4.4[illegible]** |

N'dama values significantly different from those for White Fulani cattle at *$p<0.05$, **$p<0.01$, ***$p<0.001$

*Source*: Olayemi and Oyewale (2002a)

Table 2: Leukocyte values (mean ± SD) of the White Fulani and N'dama breeds of cattle

| Parameter | White Fulani ($n$ = 28) | N'dama ($n$ = 15) |
|---|---|---|
| Total WBC ( $\times 10^3$/µl) | 9.11±3.65 | 9.19±4.66 |
| Lymphocytes ( $\times 10^3$/µl) | 6.00±[illegible] (66.00%±3.64%) | 5.86±0.54 (63.73%±4.76%) |
| Neutrophils ( $\times 10^3$/µl) | 2.23±0.[illegible] (24.54%±4.35%) | 2.53±0.26 (27.53%±3.35%)** |
| Eosinophils ( $\times 10^3$/µl) | 0.[illegible]6±0.1[illegible] (6.14%±1.08%) | 0.53±0.14 (5.80%±1.61%) |
| Monocytes ( $\times 10^3$/µl) | 0.3[illegible]±0.1[illegible] (3.30%±1.13%) | 0.25±0.12 (2.73%±1.39%) |

Percentage data in parentheses

**N'dama values significantly different from that for White Fulani cattle at $p<0.01$

*Source*: Olayemi and Oyewale (2002a)

Furthermore, we reported that although the levels of plasma electrolytes and metabolites were identical in both breeds, the plasma sodium, total proteins and albumin were significantly higher in the zebu (White Fulani) than in the N'dama breed (Olayemi and Oyewale, 2002a; table 3). This may be due to the fact that zebu cattle have greater ability to

digest dietary protein and re-utilize nitrogen more efficiently than other breeds of cattle including the N'dama.

**Table 3: Comparison of the plasma electrolyte, protein and metabolite values (mean ± SD) of the White Fulani and N'dama breeds of cattle**

| Parameters | White Fulani ($n$ = 19) | N'dama ($n$ = 15) |
|---|---|---|
| Sodium (mmol/L) | 142.26 ± 9.07 | 126.15 ± 9.1[illegible]** |
| Potassium (mmol/L) | 4.81 ± 0.94 (18) | 5.13 ± 1.[illegible] (14) |
| Bicarbonate (mmol/L) | 9.05 ± 2.91 | 7.5[illegible] ± 2.70 |
| Calcium (mmol/L) | 2.15 ± 0.02 | 2.[illegible]6 ± [illegible].0 |
| Inorganic phosphate (mmol/L) | 1.62 ± 0.76 | 1.57 ± 0.7[illegible] |
| Total protein (g/L) | 90.00 ± 8.10 | 74.[illegible]0 ± [illegible].20 (14)** |
| Albumin (g/L) | 28.90 ± 4.30 | 23.40 ± [illegible].70 (14)** |
| Globulin (g/L) | 62.00 ± 8.80 | 51.40 ± 15.40 (14)* |
| Albumin/globulin ratio | 0.48 ± 0.10 | [illegible].47 ± 0.13 |
| Urea (mmol/L) | 2.89 ± 2.14 | 1.84 ± 1.25 |
| Creatinine (μmol/L) | 162.66 ± 47.74 | 135.25 ± 53.04 |

Numbers of animals are shown in parentheses
N'dama values significantly different from those for White Fulani [illegible] $p < 0.02$, ** $p < 0.01$

*Source:* Olayemi and Oyewale (2002a)

The White Fulani cattle in Nigeria are mainly owned by the nomadic Fulani, who keep them under a variety of traditional management systems from nomadic pastoralism to intensive backyard management. We investigated the blood parameters of White Fulani cattle under intensive and extensive management systems and observed that the RBC and PCV values were significantly higher in the intensively managed animals (Olayemi and Oyewale, 2002b; table 4). This finding, which is consistent with observations in pigs (Sarror and Santiago, 1981) and sheep (Olayemi et al. 2000), may have resulted from the higher plane of nutrition and adequate veterinary care given to the intensively managed animals. In addition, we found significantly higher total WBC count due to higher lymphocyte, neutrophil, eosinophil and monocyte counts in the intensively managed cattle (table 5).

Table 4: Erythrocyte values (mean ± SD) of White Fulani cattle under intensive and extensive managements

| Parameter | Intensive (28) | Extensive (29) |
|---|---|---|
| RBC ($X10^6$/ ul) | 5.47 ± 0.92 | 4.50 ± 1.63* |
| PCV (%) | 39.00 ± 4.62 | 32.41 ± 5.65** |
| Hb(g/dl) | 12.23 ± 1.48 | 11.65 ± 1.29 |
| MCV (fl) | 72.92 ± 13.21 | 79.84 ± 25.98 |
| MCH (pg) | 23.11 ± 5.29 | 29.78 ± 11.92* |
| MCHC (g/dl) | 31.75 ± 5.37 | 36.94 ± 6.53* |

Number of animals in parentheses
*Values significantly different from intensive management at *P<0.01 and **P<0.001

*Source*: Olayemi and Oyewale (2002b)

Table 5: Leukocyte values (mean ± SD) of White Fulani cattle under intensive and extensive managements

| Parameters | Intensive (28) | Extensive (29) |
|---|---|---|
| Total WBC ($X10^3$/ul) | 9.11 ± 3.65 | 6.26 ± 3.20* |
| Lymphocyte ($x10^3$/ul) | 6.00 ± 0.49 | 4.14 ± 1.01** |
| | [66.00 ± 3.69][a] | [80.83 ± 4.79][a] ** |
| Neutrophil ($x10^3$/ul) | 2.23 ± 0.36 | 0.83 ± 0.33** |
| | [24.54 ± 4.35][a] | [16.10 ± 5.10][a] ** |
| Eosinophil ($x10^3$/ul) | 0.56 ± 0.11 | 0.12 ± 0.07** |
| | [6.14 ± 1.08][a] | [2.41 ±1.48][a] |
| Monocyte ($x10^3$/ul) | 0.31 ± 0.11 | 0.03 ± 0.03** |
| | [3.30 ±1.13][a] | [0.69 ± 0.66][a] |

Number of animals in parentheses
[a]Value expressed as a percentage of total WBC count
Values significantly different from intensive management at *P<0.01 and **P<0.001

*Source*: Olayemi and Oyewale (2002b)

Olayemi, Oyewale and Fajimi (2001) had earlier investigated the plasma electrolyte levels of the White Fulani cattle reared under intensive and extensive management systems. We observed that the plasma electrolyte levels were similar in both systems of management (table 6). However, we also found the total plasma protein and albumin levels to be higher in the intensively reared cattle (table 7). This could

be because they were on a better diet, being fed on improved pasture supplemented with maize, citrus pulp and brewer's grains. The extensively reared cattle, on the other hand, did not receive any feed supplementation.

**Table 6: Plasma electrolyte concentrations (mean ± SD) of White Fulani cattle under intensive or extensive management**

| Parameters | Intensive (*n*) | Extensive (*n*) |
|---|---|---|
| Sodium (mmol/L) | 142.26±9.07 (19) | 141.83±8.84 (27) |
| Potassium (mmol/L) | 4.81±0.94 (18) | 5.22±1.09 (26) |
| Bicarbonate (mmol/L) | 9.05±2.91 (19) | 7.85±2.35 (27) |
| Calcium (mmol/L) | 2.15±0.02 (19) | 2.15±0.03 (28) |
| Inorganic phosphate (mmol/L) | 1.62±0.76 (19) | 1.62±0.78 (28) |

*Source:* Olayemi, Oyewale and Fajimi (2001)

**Table 7: Plasma protein and metabolite concentrations (mean ± SD) of White Fulani cattle under intensive or extensive management**

| Parameters | Intensive (*n*=19) | Extensive (*n*=28) |
|---|---|---|
| Total protein (g/L)[a] | 90.00±8.10 | 79.80±16.70 |
| Albumin (g/L)[b] | 28.90±4.38 | 25.00±6.80 |
| Globulin (g/L) | 62.00±8.80 | 55.30±24.30 |
| Albumin/globulin ratio | 0.48±0.10 | 0.47±0.17 |
| Urea (mmol/L) | 2.89±2.14 | 1.93±1.30 |
| Creatinine (mmol/L) | 162.66±47.74 | 161.77±58.34 |

Values differ significantly at [a]$p<0.02$ and [b]$p<0.05$

*Source:* Olayemi, Oyewale and Fajimi (2001)

### *Blood Volume Changes in Small Ruminants and Birds*

In Nigeria, there are over 55 million goats and 34 million sheep (National Bureau of Statistics, NBS, 2010). Small

ruminants (i.e. sheep and goats) contribute an estimated 35% of the total meat consumed, with goats contributing about 20% and the rest (15%) from sheep. The predominant goat breed in the country is the West African Dwarf (WAD) (fig. 7a) and the predominant sheep breed is the *Yankasa*. However, the WAD sheep (fig. 7b) is the predominant breed of the humid tropics from southern West Africa through Central Africa.

Although increases in plasma and blood volumes in WAD sheep and goats during experimental *Trypanosoma vivax* infections have been reported (Anosa and Isoun 1976), no reports are available on these parameters during the physiological states of pregnancy and lactation in these animals. We investigated the total blood volume and plasma volume in WAD goats (Makinde, Durotoye and Oyewale 1983) and WAD sheep (Durotoye and Oyewale 2000) during pregnancy and lactation. Our results showed that the plasma and blood volumes in WAD sheep and goats are higher than in sheep and goats in temperate climate. Both volumes are greater in lactating than in pregnant animals (tables 8 and 9). This is similar to the report of Schalm et al. (1975) in reproducing cows. It suggests that the blood and plasma volumes which were increased during pregnancy were probably maintained during lactation, such that the volumes per unit body weight appeared greater in lactating than in pregnant animals. Contrary to the common situation in women, in which pregnancy is accompanied by anaemia, we did not observe anaemia in our pregnant sheep and goats. This agrees with a similar finding in pregnant cows (Schalm et al. 1975).

Fig. 7a. Pregnant West African Dwarf (WAD) goat

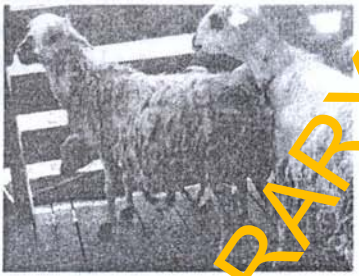


Fig. 7b. Pregnant West African Dwarf (WAD) sheep

**Table 8: Mean values (±SD) for live body weight, packed cell volume (PCV), haemoglobin (Hb) concentration, plasma and blood volumes in West African Dwarf goats**

| Goat | Body weight (kg) | PCV (%) | Hb (g/dl) | Plasma volume (ml/kg) | Blood volume (ml/kg) |
|---|---|---|---|---|---|
| Pregnant | 35.00 ±12.72 (9) | 31.00 ±5.12 (9) | 10.30 ±2.28 (9) | 67.60 ±21.50 (7) | 105.20 ±15.00 (7) |
| Lactating | 22.00 ±8.70 (8) | 27.00 ±3.20 (8) | 8.60 ±1.70 (8) | 89.30 ±18.90 (8) | 115.60 ±19.40 (8) |
| Non-pregnant, non-lactating | 27.40 ±3.20 (8) | 30.40 ±4.60 (8) | 9.96 ±110 (8) | 81.00 ±31.10 (8) | 106.99 ±2.50 (7) |

*Number of animals in parenthesis*

**Table 9: Mean values (±SD) for live body weight, packed cell volume (PCV), haemoglobin (Hb) concentration, plasma volume and blood volume in West African Dwarf sheep**

| Parameters | Rams | Dry Ewes | Pregnant Ewes | Lactating Ewes |
|---|---|---|---|---|
| Body Weight (Kg) | 21.89 ± 2.71(9) | 20.50 ± 0.59(8) | 28.17 ± 1.56(12)* | 22.57 ± 1.70(7) |
| PCV (%) | 30.00 ± 1.09(9) | 29.63 ± 1.67(8) | 38.15 ± 1.40(10)* | 32.2[illegible] ± 1.9[illegible] |
| Hb (g%) | 9.41 ± 1.17 (9) | 9.43 ± 0.97(6) | 12.07 ± 0.50(12) | 10.[illegible]7 ± 0.71(7) |
| Plasma Volume (ml/kg body weight) | 45.70 ± 5.37(6) | 40.16 ± 7.03(6) | 43.10 ± 3.12(9) | 96.16 ± 6.55(6)** |
| Blood volume (ml/kg body weight) | 64.08 ± 6.11(6) | 55.74 ± 9.31(6) | 7[illegible].16 ± 6.[illegible]6(8) | 147.12 ± 12.97(6)** |

*Numbers in parenthesis represent number of animals used; * = P<0.05 compared to data on the same row; ** = P<0.001 compared to data on the same row*

Our blood volume studies were extended to domesticated and non-domesticated birds in Nigeria including domestic fowls, ducks and guinea-fowls. We compared the plasma and blood volumes of the Nigerian fowl (local strain) and White Leghorn fowl (exotic strain) reared under identical environmental conditions in order to determine whether or not these parameters differed between the two strains of domestic fowls (Makinde, Fatunmbi and Oyewale 1986). The White Leghorns are among the most popular commercial strains of laying chickens in the world. The results showed larger plasma and blood volumes in the local Nigerian fowl (which though more excitable and more active, is capable of laying fewer eggs) than the White leghorn fowl.

In a study involving the local Nigerian ducks (*Anas platyrhynchos*), Olayemi, Oyewale et al. (2003) found that although the plasma and blood volumes did not differ significantly between the young (8 - 10 weeks old) and the adult bird (52 - 80 weeks old), the values in the adult Nigerian duck are lower than those of the plasma and blood

volumes reported in the temperate environment in wild and domesticated ducks. Apart from the work done on domestic birds, I investigated the effect of egg-laying on plasma and blood volumes in the semi-domesticated guinea fowl (*Numida meleagris galeata*, Pallas), which is a seasonal breeder. The results showed that the plasma and blood volumes were lowered in the guinea-hen by egg-laying during the breeding season (Oyewale 1990). Earlier reports have indicated that the PCV is decreased (Oyewale and Fajimi 1988) and the blood oestrogen level is increased (Ogwuegbu 1987) during egg-laying in the guinea-hen. It seems therefore, that the decrease in PCV associated with the decrease in blood volume is seasonally dependent on increase in blood oestrogen level during egg-laying.

***Blood Values of Domestic Fowls, Guinea-Fowls, Ducks and Turkeys in Nigeria***

The haematological and plasma (serum) biochemical data of several avian species have been studied in the temperate climate, but reports on birds in our tropical environment are scanty. Blood values may provide, when properly interpreted, a precise picture of the health condition of an animal at the moment of sampling (i.e., nutritional status, disease condition, or stress due to capture and handling in wild animals) and may also reflect the quality of the habitat or environment where the animal is kept. Several studies have been conducted in our laboratory on haematological and plasma (serum) biochemical parameters of domestic birds in the Nigerian environment and the way they are affected by breed, sex, species, egg laying and age.

My research on the haematology of the adult Nigerian domestic fowl showed that although the PCV and Hb values are similar to the values found in temperate breeds, the RBC and WBC counts are lower in the Nigerian fowl (Oyewale 1985b). These observations are attributed to genetic and environmental differences. In another study, Oyewale and Durotoye (1988) compared the haematological values of the

adult male and female Nigerian domestic fowls and adult male and female Hubbard fowls (exotic domestic fowls) reared under identical environmental conditions. The results revealed that the values of PCV and Hb were significantly higher in Nigerian domestic fowls (which are more resistant to prevalent Nigerian poultry diseases) than Hubbard fowls (table 10).

**Table 10: Comparison of Haematological Values of the Adult Nigerian Domestic Fowl and Adult Hubbard Fowl**

| *Parameters* | *Sex* | *Nigerian domestic fowls* | *Hubbard fowls* |
|---|---|---|---|
| PCV (%) | Male | 35·77±2·97 (13) | 33·25±3·31 (8) |
| | Female | 33·39±1·70 (13) | 28·29±2·16 (12) |
| | Male and female | 34·08±2·95 (26) | 30·28±3·61 (20) |
| RBC ($10^6$/mm$^3$) | Male | 2·55±0·42 (13) | 2·33±0·17 (8) |
| | Female | 2·42±0·38 (13) | 2·14±0·25 (12) |
| | Male and female | 2·48±0·40 (26) | 2·22±0·24 (20) |
| Hb (g/dl) | Male | 11·31±1·06 (13) | 10·06±0·95 (8) |
| | Female | 9·84±1·01 (13) | 9·19±0·65 (12) |
| | Male and female | 10·58±1·27 (26) | 9·54±0·89 (20) |

Note: Number of birds shown in parentheses. *Source:* Oyewale and Durotoye (1988)

If PCV reflects the total red cell volume in the body, and if the latter is an indication of the oxygen ($O_2$) carrying capacity of blood, then it can be concluded that the Nigerian domestic fowl with a higher PCV is better suited than the Hubbard fowl to survive in the hot humid tropics, where metabolic activities and $O_2$ requirements would be greater than in the temperate or subtropical climate. In both breeds of domestic fowl, the values of PCV and Hb were significantly higher in males than in females. The role of androgens in increasing RBC, PCV and Hb values in birds has been well documented (Panda and Juhn 1961; Freid et al. 1964; Nirmalan and Robinson 1971). In humans, testosterone has been shown to increase PCV and Hb values in males (Coviello et al. 2008).

The above findings of breed and sex differences in the haematological data of domestic fowls in our tropical environment challenged us to assess the blood picture of the

semi-domesticated guinea-fowl (*Numida meleagris galeata*, Pallas). The comparison was made of the content of electrolytes (table 11) and proteins (table 12) in the serum of adult guinea-fowl and adult Nigerian fowl (Oyewale et al. 1988). Our results showed that the guinea-fowl had significantly higher values for sodium, potassium and albumin. The Nigerian fowl, on the other hand, exhibited higher values for calcium, chloride, bicarbonate, inorganic phosphate, total proteins and globulins, which were also significant. What this implies is that, although most of the values in both types of birds are within the range reported for other breeds of domestic fowls, there is need for caution in applying the normal blood biochemical values of Nigerian fowl to assess the health and nutritional status of guinea-fowl in the same environment.

**Table 11: Mean Serum Electrolyte Values (± SD) in Nigerian Fowl and Guinea-fowl**

| Parameter | Nigerian fowl | | | Guinea fowl | | |
|---|---|---|---|---|---|---|
| | Male | Female | Both sexes | Male | Female | Both sexes |
| Sodium (mmol/l) | 145.73 ± 13.84 (11) | 129.17 ± 10.25 (30) | 133.61 ± 13.39 (41) | 204.10 ± 11.59 (10) | 199.06 ± 23.71 (33) | 200.23 ± 25.85 (43 ) |
| Potassium (mmol/l) | 4.94 ± 2.40 (10) | 3.54 ± 1.50 (31) | [illegible] (41) | 5.18 ± 0.70 (10) | 5.64 ± 0.62 (33) | 5.54 ± 0.67 (43) |
| Chloride (mmol/l) | 105.00 ± 7.35 (13) | 107.00 ± 3.80 (31) | [illegible] (44) | 98.18 ± 8.99 (11) | 102.69 ± 6.60 (36) | 101.64 ± 7.73 (47) |
| Bicarbonate (mmol/l) | 21.55 ± 1.57 (11) | [illegible] (30) | 20.59 ± 1.83 (41) | 12.46 ± 3.73 (11) | 15.49 ± 3.55 (37) | 14.79 ± 3.81 (48) |
| Calcium (mg/dl) | 9.64 ± 0.71 (11) | [illegible] (1) | 9.89 ± 0.72 (22) | 7.24 ± 1.22 (11) | 7.27 ± 1.35 (36) | 7.26 ± 1.32 (47) |
| Inorganic phosphate (mg/dl) | [illegible] ± 0.[illegible]9 (11) | 4.22 ± 1.03 (31) | 4.04 ± 0.96 (42) | 3.07 ± 1.34 (11) | 3.12 ± 0.64 (37) | 3.11 ± 0.85 (48) |

Note: Number of birds in parentheses

*Source:* Oyewale, et al. (1983)

Table 12: Mean Serum Protein Values (± SD) in Nigerian Fowl and Guinea-fowl

| Parameter | Nigerian fowl | | | Guinea fowl | | |
|---|---|---|---|---|---|---|
| | Male | Female | Both sexes | Male | Female | Both sexes |
| Total protein (g/dl) | 4.72 ± 0.50 (13) | 5.06 ± 0.50 (30) | 4.95 ± 0.52 (43) | 3.33 ± 0.56 (11) | 3.68 ± 1.26 (37) | 3.60 ± 1.15 (48) |
| Albumin (g/dl) | 1.46 ± 0.30 (13) | 1.57 ± 0.23 (30) | [illegible] ± 0.26 [illegible] | 1.56 ± 0.25 (11) | 1.78 ± 0.37 (37) | 1.73 ± 0.36 (48) |
| Globulin (g/dl) | 3.25 ± 0.29 (13) | 3.50 ± 0.49 (30) | 3.43 ± 0.45 (43) | 1.76 ± 0.46 (11) | 1.91 ± 1.05 (37) | 1.88 ± 0.95 (48) |

Note: Number of birds in parentheses

*Source*: Oyewale, et al. (1988)

Although we had earlier shown that the plasma and total blood volumes were lowered by egg-laying in the guinea-hen, we desired to know whether the haematological parameters and plasma electrolytes and proteins were also affected. The results of our investigation (Oyewale and Fajimi 1988) revealed that egg-laying in the guinea-hen was accompanied by decreased PCV and increased plasma Ca level, which are both attributable to the activity of oestrogen. There was no significant effect of egg-laying on the Hb concentration. This agrees with a similar finding in domestic fowl (Jaffe 1960), but conflicts with reports on turkeys (Paulsen et al. 1950) and geese (Hunsaker et al. 1964), in which Hb levels are raised during egg-laying. An observation that was of particular interest was the significant increases in total plasma proteins, albumin and globulins in the laying guinea-hen. This again may be associated with the endogenous activity of oestrogen in laying birds.

Given that data on the effect of age on blood parameters of the semi-domesticated guinea fowl were sparse, Oyewale (1991a) using male guinea-fowls compared the haematological parameters of the 15-week-old and 21-week-old birds. The results showed that the RBC, PCV and Hb values were not significantly different between the two age-groups. We also compared the haematological values of the guinea-fowl with those of the turkey, domestic fowl and duck in our tropical environment and found that all the erythrocyte values studied in the guinea-fowl were similar to those of the turkey and domestic fowl, but the values in the duck (except the MCV) were higher than in the guinea-fowl (table 13).

**Table 13: Comparison of haematological values (mean ± SD) of guinea-fowl, turkey, domestic fowl and duck in the same tropical environment**

| | Guinea fowl[a] | Turkey[b] | Domestic fowl[c] | Duck[d] |
|---|---|---|---|---|
| Number of birds | 20 | 14 | 10 | 1 |
| RBC x $10^6/\mu L$ | 2.44 ± 0.26 | 2.59 ± 0.35 | 2.45 ± 0.22 | 2.8[illegible] ± 0.30 |
| PCV % | 38.13 ± 3.14 | 38.68 ± 2.27 | 36.65 ± 2.50 | 4[illegible].60 ± 2.10 |
| Hb g/dl | 12.10 ± 2.21 | 12.26 ± 0.92 | 11.33 ± 0.28 | 1[illegible].10 ± 1.14 |
| MCV fl | 154.99 ± 9.31 | 150.48 ± 19.45 | 148.99 ± 16.[illegible]5 | 1[illegible]54.46 ± 14.04 |
| MCH pg | 49.58 ± 3.30 | 47.69 ± 5.41 | 46.29 ± 4.7[illegible] | [illegible]3.59 ± 5.34 |
| MCHC g/dl | 32.01 ± 1.39 | 31.71 ±1.61 | 31.79 ± 3.88 | 34.70 ± 2.56 |

*Sources*: [a](Oyewale, 1991a); [b](Oyewale and Ajibade, 1990a); [c](Oyewale, 1988); [d](Oyewale and Ajibade, 1990b)

### *Blood Values of Zoo and Non-domesticated Animals*

Part of our research efforts over the years had been the documentation of the baseline haematological and plasma biochemical data of zoo and non-domesticated animals in our environment, which should be useful in diagnosis and treatment of diseases, metabolic disorders or nutritional deficiencies in these animals.

The peafowl is one of the most ostentatiously adorned creatures on earth, with the male (peacock) using its brilliant plumage to entice the females (peahens). Peacocks (*eye okin* in Yoruba) are large colorful pheasants (typically blue and green) known and admired by humans for their iridescent tail. Like the late American superstar, Michael Jackson (August 29, 1958 – June 25, 2009) who, with his exceptional singing and dancing talents, was popularly known to the world as the 'king of pop music', the peacock in the local parlance is described as the 'king of birds' (*eye okin l'oba eye* in Yoruba). The tail feathers spread out in a distinctive train that is over 60% of the bird's total body length. The large train is used in mating rituals and courtship displays. It can be arched in a magnificent fan that reaches across the back of the bird and touches the ground on the other side. Females select their mates according to the size, color and quality of this outrageous feather train. It is the same way women select

their prospective husbands, using such criteria as physical appearance, intelligence, race, tribe, skin color, religion and economic, social or political considerations. I compared the blood values of the adult peafowl (*Pavo cristatus*) (fig. 8), which is a staple resident of many of the world's zoos, with those of the adult domestic pigeon (*Columba livia*) (fig. 9), which is used as food or game bird in many cities of the world. I observed that no significant sex differences were apparent in the haematological values of either species, but the mean RBC, PCV and Hb values were significantly higher in the pigeon than the peafowl (Oyewale 1994; table 14). This may be because the pigeon is a smaller-sized and a more active flying bird than the peafowl.

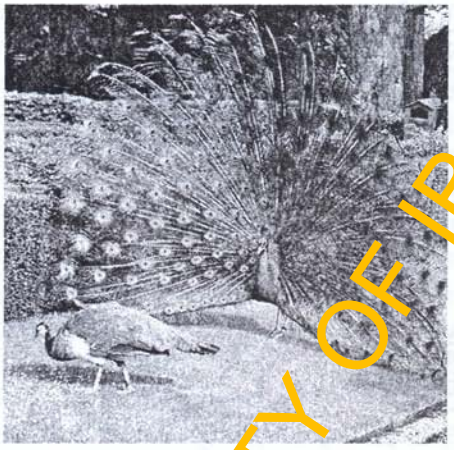


**Fig. 8.** A peacock (rear) wooing a peahen (front)

**Fig. 9.** Adult domestic pigeon

Table 14: Haematological Values (mean ± SD) of the Pigeon and Peafowl

| | Sex | Pigeons | Peafowls |
|---|---|---|---|
| RBC × $10^{12}$/l | Male | 2.91 ± [illegible]17( 8) | 2.09 ± 0.10(5) |
| | Female | 2.6[illegible] ± 0.20( 6) | 2.07 ± 0.17(4) |
| | Male and Female | 2.7[illegible] ± 0.13(14) | 2.08 ± 0.09(9) |
| PCV % | Male | 44.00 ± 1.76( 8) | 34.40 ± 1.04(5) |
| | Female | 41[illegible] ± 1.70( 6) | 34.00 ± 0.71(4) |
| | Male and Female | 42.[illegible] ± 1.20(14) | 34.25 ± 0.68(9) |
| Hb g/dl | Male | 1[illegible] ± 0.62( 8) | 11.70 ± 0.01(5) |
| | Female | 1[illegible] ± 0.47( 6) | 11.68 ± 0.01(4) |
| | Male and Female | 1[illegible] ± 0.38(14) | 11.69 ± 0.01(9) |
| MCV fl | Male | 1[illegible].45 ± 11.16( 8) | 165.98 ± 6.82(5) |
| | Female | 160.16 ± 11.96( 6) | 167.61 ± 10.67(4) |
| | Male and Female | 156.90 ± 7.53(14) | 166.59 ± 5.93(9) |
| MCH pg | Male | 52.34 ± 2.02( 8) | 56.71 ± 3.06(5) |
| | Female | 61.15 ± 4.12( 6) | 57.98 ± 4.94(4) |
| | Male and Female | 56.12 ± 2.28(14) | 57.19 ± 2.71(9) |
| MCHC g/dl | Male | 35.17 ± 1.52( 8) | 34.16 ± 1.03(5) |
| | Female | 38.28 ± 0.46( 6) | 34.41 ± 0.73(4) |
| | Male and Female | 36.34 ± 0.98(14) | 34.26 ± 0.68(9) |

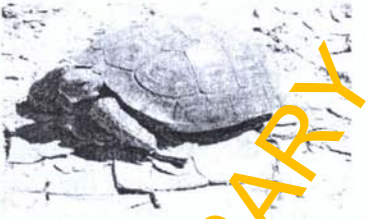
Note: Number of birds in parentheses

*Source*: Oyewale (1994)

Tortoises are land-dwelling reptiles with life-spans longer than those of human beings. There are authenticated cases of some individual tortoises living for over 150 years. In humans, the 2010 estimates of the life expectancy at birth which is the average number of years to be lived by a group of people born in the same year, for **Nigeria**, Ghana, Singapore, Canada, United Kingdom and United States are **47.24**, 60.55, 82.06, 84, 79.92 and 78.24 years, respectively (CIA - The World Factbook, 2010). These figures compare poorly to the life-span of the tortoise.

In the late 1990s, with one of my post-graduate students, Mr. Paul Ebute, I determined the blood profile in the adult wild West African hinge-backed tortoise, *Kinixys erosa* (fig.10a) and the adult wild desert tortoise, *Gopherus agassizii* (fig. 10b) kept under identical environmental conditions. A comparison between sexes showed the male *K. erosa* had significantly higher PCV and Hb concentration and lower plasma alkaline phosphatase (ALP) values than the female, while no significant sex differences appeared in these parameters in *G. agassizii* (tables 15 and 16) (Oyewale, et al. 1988). The haematological parameters and plasma levels of electrolytes, enzymes, proteins and metabolites did not differ significantly between the two species (tables 15 and 16), suggesting that the blood values of *K. erosa* resembled those of *G. agassizii* under identical environmental conditions. However, in tortoises and turtles, factors such as season, nutrition and temperature have been shown to have significant effects on blood values.

(a)



(b)

**Fig. 10.** Adult tortoises (a) West African hinge-backed tortoise *Kinixys erosa*, (b) Desert tortoise, *Gopherus agassizii*

In the light of these considerations, the blood values of *K. erosa* and *G. agassizii* are likely to be different if the two species were studied in their normal habitats, in which diet, temperature, rainfall, moisture and vegetation differ. *G. agassizii* lives in the desert zone of Nigeria, where it rarely has access to free drinking water and depends on water from its entirely herbivorous diet. On the other hand, *K. erosa* stays on the shore of the river in the rain-forest zone of our country, where it has unrestricted access to drinking water. It feeds mostly on plants, which it supplements with insects and their larvae.

**Table 15: Haematological Values (mean ± SEM) in *Kinixys erosa* and *Gopherus agassizii***

| | *Kinixys erosa* | | | *Gopherus agassizii* | | |
|---|---|---|---|---|---|---|
| | Male (n = 6) | Female (n = 6) | Both sexes (n = 12) | Male (n = 6) | Female (n = 7) | Both sexes (n = 13) |
| PCV (%) | 34.17 ± 2.68 | 26.50 ± 1.93 | 30.33 ± 1.95 | 28.17 ± 1.56 | 29.86 ± 1.40 | 29.08 ± 1.03 |
| RBC ($\times 10^6/\mu l$) | 0.712 ± 0.148 | 0.568 ± 0.112 | 0.640 ± 0.091 | 0.422 ± 0.049 | 0.529 ± 0.048 | 0.479 ± 0.036 |
| Hb (g/dl) | 11.37 ± 0.89 | 8.83 ± 0.66 | 10.10 ± 0.65 | 9.40 ± 0.54 | 9.96 ± 0.47 | 9.70 ± 0.35 |
| MCV (fl) | 612.32 ± 137.94 | 563.22 ± 120.37 | 587.77 ± 87.71 | 753.48 ± 159.56 | 587.11 ± 49.19 | 661.82 ± 78.22 |
| MCH (pg) | 203.90 ± 46.03 | 201.38 ± 47.31 | 202.64 ± 31.52 | 253.17 ± 52.92 | 195.86 ± 16.55 | 222.31 ± 26.88 |
| MCHC (g/dl) | 33.27 ± 0.05 | 33.32 ± 0.08 | 33.29 ± 0.05 | 33.46 ± 0.14 | 33.35 ± 0.04 | 33.40 ± 0.06 |

n = number of animals.

*Source:* Oyewale, et al. (1998)

**Table 16: Mean (± SEM) Plasma Electrolyte, Enzyme, Protein and Metabolite Levels in *Kinixys erosa* and *Gopherus agassizii***

| | *Kinixys erosa* | | | *Gopherus agassizii* | | |
|---|---|---|---|---|---|---|
| | Male (n = 6) | Female (n = 6) | Both sexes (n = 12) | Male (n = 6) | Female (n = 7) | Both sexes (n = 13) |
| Na (mmol/l) | 122.67 ± 1.09 | 122.00 ± 1.00 | 122.33 ± 0.71 | 122.83 ± 1.08 | 123.86 ± 1.74 | 123.38 ± 1.03 |
| K (mmol/l) | 4.77 ± 0.04 | 4.97 ± 0.09 | 4.87 ± 0.06 | 4.98 ± 0.14 | 5.00 ± 0.16 | 4.99 ± 0.10 |
| Cl (mmol/l) | 98.33 ± 0.21 | 98.67 ± 0.34 | 98.50 ± 0.19 | 98.83 ± 0.17 | 99.29 ± 0.36 | 99.10 ± 0.21 |
| $HCO_3$ (mmol/l) | 20.17 ± 0.40 | 20.50 ± 0.34 | 20.33 ± 0.26 | 20.00 ± 0.01 | 19.86 ± 0.34 | 19.92 ± 0.08 |
| Inorganic phosphate (mmol/l) | 1.49 ± 0.02 | 1.46 ± 0.02 | 1.48 ± 0.01 | 1.50 ± 0.02 | 1.47 ± 0.01 | 1.49 ± 0.01 |
| Ca (mmol/l) | 2.09 ± 0.01 | 2.10 ± 0.02 | 2.10 ± 0.04 | 2.09 ± 0.02 | 2.10 ± 0.02 | 2.10 ± 0.02 |
| ALP (i.u/l) | 152.17 ± 3.26 | 162.00 ± 2.58 | 157.08 ± 2.74 | 159.00 ± 8.28 | 163.71 ± 5.38 | 161.54 ± 4.63 |
| GOT (i.u/l) | 29.67 ± 0.99 | 31.67 ± 1.52 | 30.67 ± 0.92 | 28.83 ± 2.09 | 29.86 ± 3.53 | 29.38 ± 2.05 |
| GPT (i.u/l) | 11.83 ± 0.60 | 13.50 ± 0.76 | 12.67 ± 0.53 | 12.00 ± 0.68 | 14.29 ± 1.68 | 13.23 ± 0.98 |
| GGT (i.u/l) | 2.67 ± 0.42 | 2.50 ± 0.23 | 2.58 ± 0.23 | 2.83 ± 0.40 | 3.00 ± 0.43 | 2.92 ± 0.33 |
| Total protein (g/l) | 61.15 ± 0.74 | 61.04 ± 0.67 | 61.10 ± 0.44 | 61.47 ± 0.50 | 61.28 ± 0.43 | 61.35 ± 0.33 |
| Albumin (g/l) | 29.28 ± 0.34 | 28.03 ± 0.53 | 28.65 ± 0.44 | 29.27 ± 0.44 | 29.36 ± 0.53 | 29.38 ± 0.32 |
| Globulin (g/l) | 32.02 ± 0.51 | 33.01 ± 0.64 | 32.46 ± 0.44 | 32.49 ± 0.63 | 31.89 ± 0.44 | 32.20 ± 0.34 |
| Albumin/Globulin Ratio | 7.30 ± 1.33 | 7.23 ± 0.94 | 7.26 ± 0.72 | 6.73 ± 1.34 | 8.88 ± 0.24 | 7.76 ± 0.63 |
| Urea (mmol/l) | 9.63 ± 0.43 | 9.66 ± 0.20 | 9.64 ± 0.23 | 10.13 ± 0.55 | 9.41 ± 0.31 | 9.74 ± 0.31 |
| Creatinine (μmol/l) | 141.44 ± 4.42 | 139.67 ± 2.65 | 140.56 ± 2.65 | 147.63 ± 7.07 | 144.09 ± 4.42 | 145.86 ± 3.54 |
| Cholesterol (mmol/l) | 1.91 ± 0.05 | 1.81 ± 0.05 | 1.86 ± 0.04 | 1.93 ± 0.07 | 1.86 ± 0.08 | 1.90 ± 0.05 |
| Triglyceride (mmol/l) | 0.64 ± 0.01 | 0.61 ± 0.03 | 0.62 ± 0.02 | 0.66 ± 0.02 | 0.68 ± 0.04 | 0.67 ± 0.02 |

n = number of animals.

Na=Sodium; K=Potassium; Cl= Chloride; $HCO_3$=Bicarbonate; Ca=Calcium; ALP=Alkaline phosphatase; GOT=Glutamate oxaloacetate transaminase; GPT=Glutamate pyruvate transaminase; GGT=Gama-glutamate transferase

*Source:* Oyewale, et al. (1998)

The pangolin (*aka,* in Yoruba) is a non-domesticated ant-eating mammal. Perhaps not many of us are familiar with this animal, but I suspect that the Vice-Chancellor, coming from Ilesha, is familiar with the pangolin, which is often on display as *bush-meat* along Ibadan–Ife expressway. Their entire body is covered with protective horny overlapping scales, except for the belly, snout, eyes, ears and undersides of the limbs. They are largely semi-arboreal with small heads and long broad tails and are widely distributed in sub-Saharan Africa. They are toothless and have no external ears. They have well-developed sense of smell, but as nocturnal mammals, they have poor eyesight. The tree pangolin (*Manis tricuspid*) also called white-bellied pangolin or three-cusped pangolin, is one of the extant species of pangolin and the most common of the African forest pangolins. They are subject to widespread and often intensive exploitation for *bush-meat* and traditional medicine. We studied the blood parameters of the adult African white–bellied pangolin (*Manis tricuspid*) (fig. 11) captured in Ibadan, and compared our findings with those of the adult African giant rat (*Cricetomys gambianus,* Waterhouse) (*okete*, in Yoruba) (fig. 12), which like the pangolin, is also a largely non-domesticated nocturnal mammal found in sub-Saharan Africa, where it serves as a ready source of supplementary dietary protein for the rural population. Although it has many of the same mannerisms as our domesticated laboratory rats (*Rattus norvegicus*), the giant rat is bigger in size and displays many of its wild natural behaviour, even in captivity.

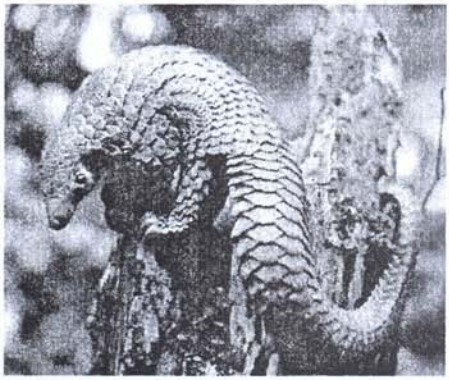


**Fig. 11.** Adult white-bellied (tree) pangolin (*Manis tricuspid*)

**Fig. 12.** Adult African giant rat (*Cricetomys gambianus, Water-house*)

In the first series of experiments, we investigated the haematological parameters of the pangolin and African giant rat (Oyewale, Ogunsanmi and Ozegbe 1997; Oyewale, Olayemi and Oke 1998). The results showed that the erythrocyte values in both species did not differ significantly between sexes, but the RBC, PCV and Hb values in giant rats were significantly higher than in pangolins (table 18). The MCV in giant rats, similar to pangolins, was significantly higher than the values in laboratory rats, sheep and goats (table 18). We reasoned that this could be as a result of the small number of circulating erythrocytes in giant rats and pangolins. **Our observation that RBC, PCV and Hb values in giant rats are similar to those of humans is unexpected in view of the inactivity of giant rats at daytime and at the time of blood sampling. I recall the expression of a technologist at the Ahmadu Bello University Teaching Hospital, Zaria in 2007 who upon analyzing the samples of blood we obtained at night (10.00pm) from giant rats remarked that "this sample cannot be from a normal human being" because the RBC, PCV and Hb values were too high. Yes, he was right. It was obtained from a normal giant rat at night when the animal was active.**

**Table 18: Comparison of Erythrocyte Values (mean ± SD) in African Giant Rats, Pangolins, Humans, Cattle, Goats, Sheep and Laboratory rats in the same Tropical Environment.**

| | African giant rat[a] (n=15) | Pangolin[b] (n=10) | Human[c] (n=500) | White Fulani cattle[d] (n=150) | Nigerian goat[e] (n=85) | West African Dwarf sheep[e] (n=295) | Laboratory rat[f] (n=36) |
|---|---|---|---|---|---|---|---|
| RBC (x $10^{12}$/l) | 5.90±1.56 | 4.19±0.68 | 5.37±0.41 | ND | 12.30±2.40 | 7.50±2.10 | 6.86±0.79 |
| PCV (%) | 48.43±3.93 | 40.40±4.95 | 46.50±4.36 | 30.10±4.40 | 26.10±4.10 | 27.40±4.50 | 31.16±4.47 |
| Hb (g/dl) | 14.36±2.45 | 10.01±1.44 | 15.06±1.27 | 9.04±1.50 | 8.59±1.31 | 8.42±1.50 | 12.98±2.38 |
| MCV (fl) | 86.85±22.02 | 97.75±14.35 | 87.70±5.70 | ND | 21.80±4.40 | 38.30± 10.50 | 45.72±6.55 |
| MCH (pg) | 25.77±6.67 | 24.13±3.43 | 27.69±2.16 | ND | ND | ND | 19.49±1.90 |
| MCHC (g/dl) | 29.84±5.44 | 24.84±2.46 | 32.39±0.76 | ND | 33.10±3.40 | 30.80±5.40 | 43.07±4.52 |

n=No. of animals ND = No data

*Sources:* Oyewale, Ogunsanmi and Ozegbe (1997)
[a](OYEWALE et al., 1998)
[b](OYEWALE et al., 1997)
[c](EZEILO and OBI, 1983)
[d](ODUYE and OKUNAIYA 1971
[e](ODUYE, 1976)
[f](OYEWALE 1987c)

The mean total WBC count in pangolins was lower than in giant rats, laboratory rats, cattle, sheep, goats and humans (table 19). This could be due to the low eosinophil count in pangolins. In giant rats, like in humans, donkeys, sheep, cattle and pigs, lymphocyte counts are much higher than neutrophils, but the reverse is the case in horses, dogs and cats. However, in pangolins, our results showed that lymphocytes and neutrophils are present in the blood in the same proportion. We decided to investigate further whether the plasma biochemical parameters in pangolins are different from those of giant rats in the same environment. Our results (table 20) revealed that, in both species, the levels of plasma electrolytes (Na, K, Cl, $HCO_3$, Ca, and inorganic $PO_4$) and enzymes (ALP, GOT, GPT and GGT) did not differ significantly between sexes (Oyewale, Ogunsanmi and Ozegbe, 1998; Oyewale, et al. 1998). When compared with the values in pangolins, we found that the plasma Na, Cl and Ca levels were significantly lower in giant rats. However, both species have similar K, total protein, albumin and globulin values. The Cl value in the giant rat was significantly lower than in pangolin, goat, cattle and humans (table 20).

We observed that plasma Ca value in giant rat or pangolin was significantly lower than in goats, pigs and cattle. We reasoned that this could have resulted from the supplementary feeds, in form of concentrates or salt lick, given to the ruminants and pigs, whereas these were unavailable to giant rats and pangolins in the wild.

**Table 19: Comparison of Leukocyte Values (mean ± SD) in African Giant Rats, Pangolins, Humans, Cattle, Sheep and Goats in the same Tropical Environment.**

| Parameter | African giant rat[a] (n=15) | Pangolin[a] (n=10) | Human[b] (n=500) | White Fulani cattle[c] (n=150) | West African Dwarf sheep[d] (n=295) | Nigerian Goat[d] (n=85) |
|---|---|---|---|---|---|---|
| Total WBC x $10^9$/l | 7.56 ± 2.55 | 4.80 ± 2.09 | 6.22 ± 1.43 | 9.98 ± 2.66 | 15.25 ± 4.69 | 16.10 ± 4.55 |
| Neutrophil x$10^9$/l | 1.49 ±1.38 (18.71±12.91) | 2.44 ± 1.29 (49.30±11.71) | 2.35 ± 0.8[illegible] (37.80) | ND (19.90±9.30) | ND (35.80±13.60) | ND (46.80 ± 10.80) |
| Lymphocyte x$10^9$/l | 5.15±1.88 (67.07±14.58) | 2.22 ± 1.01 (46.90 ± 9.61) | 3.15 ± [illegible] (50.[illegible] | ND (66.40±9.70) | ND (54.20±14.00) | ND (47.00 ± 1.60) |
| Monocyte x$10^9$/l | 0.43 ± 0.28 (5.57 ± 3.50) | 0.10 ± 0.11 (2.70 ± 2.79) | [illegible] ± [illegible].16 ([illegible]) | ND (4.35 ± 3.10) | ND (1.50 ± 1.60) | ND (0.90 ± 0.90) |
| Eosinophil x$10^9$/l | 0.21 ± 0.17 (2.71 ± 1.77) | 0.04 ± 0.04 (0.90 ± 0.99) | 0.60 ± 0.64 (9.60) | ND (8.73 ± 6.80) | ND (4.60 ± 4.50) | ND (4.70 ± 4.50) |
| Basophil x$10^9$/l | 0.31 ± 0.27 (3.93 ± 2.92) | 0.01 ± 0.0[illegible] (0.20 ± 0.6[illegible]) | ND (1.0) | ND (0 ± 0) | ND (ND) | ND (ND) |

n = No. of animals;
Values in brackets expressed as percentage of total WBC count;
ND = No data.

*Sources:* Oyewale, Olayemi and Oke (1998) [a](OYEWALE et al., 1998) [a](OYEWALE *et al.*, 1997) [b](EZEILO and OBI, 1983) [c](ODUYE and OKUNAIYA, 1971) [d](ODUYE, 1976) [d](ODUYE, 1976)

**Table 20: Comparison of Plasma Electrolyte and Enzyme Values (mean ± SD) in African Giant Rats, Pangolins, Goats, Pigs, Cattle and Humans in the same Tropical Environment**

| | Africa giant rat[a] | Pangolin[a] | Nigerian goat[b] | Nigerian pig[c] | White Fulani cattle[d] | Human[e] |
|---|---|---|---|---|---|---|
| Na (mmol/l) | 96.85±10.29 (13) | 142.60±6.45 (10) | 138.76±9.71 (70) | 85.75±1.84 (270) | 134.80±19.00 (147) | 130.00±5.20 (948) |
| K (mmol/l) | 5.47±0.52 (14) | 5.60±0.95 (10) | 4.44±0.49 (70) | 33.70±3.11 (270) | 4.47±0.80 (147) | 3.50±0.80 (963) |
| Cl (mmol/l) | 81.14±4.91 (14) | 105.10±3.38 (10) | 104.72±6.70 (70) | ND | 102.37±13.70 (147) | 92.00±7.80 (951) |
| $HCO_3$ (mmol/l) | 10.43±0.76 (14) | 21.10±2.13 (10) | ND | ND | ND | 21.00±3.70 (922) |
| Ca (mg/dl) | 2.72±0.61 (14) | 8.18±0.13 (10) | 9.57±1.51 (70) | 25.93±0.98 (270) | 9.81±1.52 (147) | ND |
| ALP (i.u/l) | 107.79±18.38 (14) | 51.30±5.4 (10) | 34.51±42.29 (70) | 59.94±2.45 (270) | ND | ND |
| GOT (i.u/l) | 26.36±8.74 (14) | 48.10±18.56 (10) | 52.84±19.84 (70) | ND | ND | ND |
| GPT (i.u/l) | 15.57±7.64 (14) | 21.80±14.52 (10) | 11.02±4.78 (70) | ND | ND | ND |

Note: Number of animals in parentheses ND=No data

*Sources:* Oyewale, et al. (1998) [a](OYEWALE *et al.*, 1998) [a](OYEWALE *et al.*, 1998) [b](ODUYE and ADADEVOH, 1976) [c](ENDELEY, 1979) [d](ODUYE and FASANMI, 1971) [e](McFARLANE *et al.*, 1970)

We also observed significantly lower total plasma protein and urea levels in giant rats or pangolins than those in goats, cattle, buffaloes and humans (table 21). This low urea level could probably be due to low protein intake, as reflected in the low total plasma protein levels of these non-domesticated mammals, at least during the dry season (January) when the study was conducted. It is postulated that some changes in the selective action of the renal tubules in the control of urea excretion might arise during periods of protein malnutrition, or alternately that, when dietary protein intake is low, urea may be utilized as a source of nitrogen in protein synthesis. Our finding of low urea level in giant rats in the dry season (November – March) was confirmed in another study (Olayemi, Oyewale et al. 2001) in which we found a higher urea level in the wet season (April – October). We also found that giant rats have higher Hb, MCH, MCHC and total WBC values, but lower MCV, Na, Cl, Ca, creatinine and albumin values in the wet season than in the dry season. However, the RBC, PCV and K values did not exhibit seasonal variations.

**Table 21: Comparison of Plasma Protein and Metabolite Values (mean ± SD) in African Giant Rats, Pangolins, Goats, Cattle, Humans and Buffaloes in the same Tropical Environment.**

| | Africa giant rat[a] | Pangolin[b] | Nigerian goat[c] | White Fulani cattle[d] | Human[e] | Buffalo (*Bos bubalis*)[f] |
|---|---|---|---|---|---|---|
| Total protein (g/dl) | 5.84±0.31 (14) | 5.96±0.53 (10) | 6.36±0.80 (70) | 7.55±2.50 (151) | ND | 8.80±0.66 (12) |
| Albumin (g/dl) | 2.70±0.31 (14) | 2.80±0.26 (10) | 2.58±0.41 (70) | 2.56±1.04 (151) | ND | 2.95±0.26 (12) |
| Globulin (g/dl) | 3.14±0.24 (14) | 3.16±0.32 (10) | 3.78 (70) | 4.96±2.68 (151) | ND | 5.85±0.57 (12) |
| Albumin/ Globulin ratio | 0.87±0.12 (14) | 0.90±0.08 (10) | 0.68 (70) | 0.51 (151) | ND | ND |
| Urea (mg/dl) | 11.71±2.30 (14) | 16.40±7.89 (10) | 44.07±10.8 1 (70) | ND | 20.00±5.10 (1010) | ND |
| Creatinine (mg/dl) | 0.59±0.10 (14) | 0.75±0.11 (10) | ND | ND | ND | ND |

Note: Number of animals in parentheses **ND=No data**

*Sources:* Oyewale, et al. (1998)

[a](OYEWALE et al., 1998)
[b](OYEWALE et al., 1997)
[c](ODUYE and ADADEVOH, 1976)
[d](ODUYE and FASANMI, 1971)
[e](McFARLANE et al., 1978)
[f](OLUSANYA et al., 1976)

## Osmotic Behavior of Mammalian and Non-Mammalian Erythrocytes

The osmotic fragility of erythrocytes refers to their quantifiable resistance to haemolysis or rupture when exposed to osmotic stress. Erythrocytes that are immersed in a hypotonic salt (NaCl) solution take up water from the medium, swell and ultimately lyse when the suspending fluid is of sufficient hypotonicity to cause an inflow in excess of what can be accommodated by the red cells. This feature is one of the defining characteristics of the erythrocyte and is well documented in the human red cell. The osmotic fragility of an individual's erythrocytes is often determined in the clinical diagnostic identification of certain populations of abnormal disease-related red cells, which manifest diminished capacity to withstand hypotonic challenges. In humans, a classic example is the recognition of microcytic, spherocytic red cells in the blood of patients with hereditary spherocytosis (familial haemolytic anaemia). Increased erythrocyte fragility has also been found in dogs with immune-mediated haemolytic anaemia, dyserythropoiesis and polyarthritis of possible autoimmune origin as well as in cats with haemobartonellosis, and in cattle with anasplasmosis (Schalm et al. 1975). In contrast, there is increased resistance to osmotic lysis of erythrocytes from porphyric cows attributable to presence of young erythrocytes with mitochondria.

Apart from human erythrocytes, the osmotic characteristics of other mammalian and sub-mammalian erythrocytes are imperfectly understood and, as would be anticipated, demonstrate variation among different species. Among the factors that have been cited as potentially influencing osmotic fragility of mammalian and non-mammalian erythrocytes are cell size, volume and form, age of erythrocytes, structure of Hb molecule, viscoelastic properties of erythrocyte membrane, presence or absence of a nucleus and temperature and pH of the surrounding hypotonic medium (Perk et al. 1964; Oyewale 1994). Although the osmotic fragility of erythrocytes of a given subject is correctly viewed as one of

its quantifiable properties, evaluation as to which physiologic function it reflects or has an impact upon is usually incomplete. A significant, though detail-limited exception to this observation, are **camel's erythrocytes, whose osmotic capacity permits the animal to ingest huge volumes (about 100 liters) of water at a single standing without initiating haemolysis in its resultant hypoosmotic plasma, which would occur in equivalent circumstances in other animals and man**. We will examine the osmotic behavior of camel erythrocytes later.

I have shown earlier in this lecture that the RBC, PCV and Hb values in the domestic fowl differed between sexes and breeds. In attempting to determine the effect of sex and breed on the erythrocyte fragility, Oyewale and Durotoye (1988) investigated the osmotic behavior of erythrocytes in both sexes of the adult Nigerian fowl and adult Hubbard fowl. A cumulative fragility curve was obtained by plotting the percentage haemolysis against the NaCl concentration, while the derivative fragility curve was obtained from the values of percentage haemolysis by using the principle of 'haemolytic increment' (Oyewale and Durotoye 1988). Our results revealed that although differences existed between the two breeds of domestic fowl (with erythrocytes of the Hubbard fowl showing a greater osmotic challenge than those of Nigerian fowl), erythrocytes from male fowls in both breeds were more susceptible to osmotic lysis than those from females (figs. 13a, b and 14; Oyewale and Durotoye 1988).

We also observed in another study that domestic fowl erythrocytes were more osmotically stable (or less fragile) than those of guinea-fowl (Durotoye and Oyewale 1988). The duck offered erythrocytes with osmotic characteristics almost identical with those of the guinea-fowl, but more sensitive to osmotic challenge than the domestic fowl (Oyewale and Ajibade 1990b; fig. 15a). Analysis of the derivative haemolysis curves (fig. 15b) revealed two or more haemolytic peaks in the duck and guinea-fowl, indicating the presence of more than one erythrocyte population in the blood (i.e. young

and old erythrocyte populations), while in the domestic fowl, a single major haemolytic peak was observed which indicated a homogenous (or one) erythrocyte population, possibly comprising of predominantly young erythrocytes. We reasoned that the differences in osmotic fragility of erythrocytes between these avian species could be associated with differences in the metabolic rates of the birds, since fragility varies with the age of erythrocyte, the old erythrocytes being more fragile than the young erythrocytes (Perk et al. 1964), and the proportion of erythrocytes of different ages in the blood varies with the level of metabolic activity in the body (March et al., 1966).

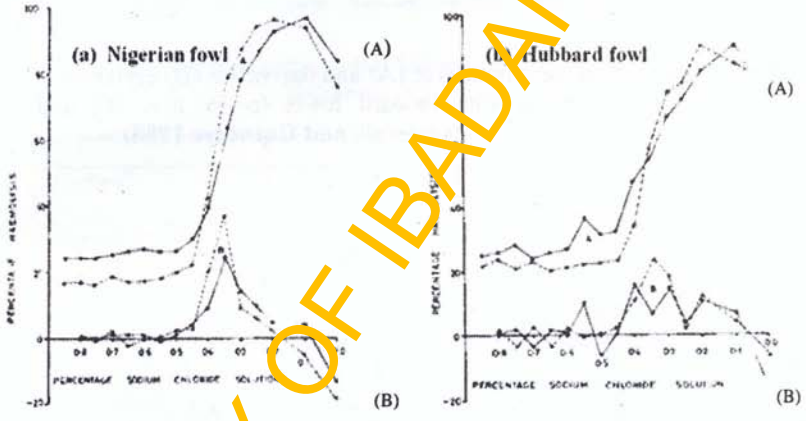



**Fig. 13.** Cumulative (A) and derivative (B) erythrocyte osmotic fragility curves for (**a**) male (o---o, n = 13) and female (•—•, n = 13) **Nigerian fowls** and (**b**) male (o---o, n = 8) and female (•—•, n = 12) **Hubbard fowls. (Oyewale and Durotoye 1988)**

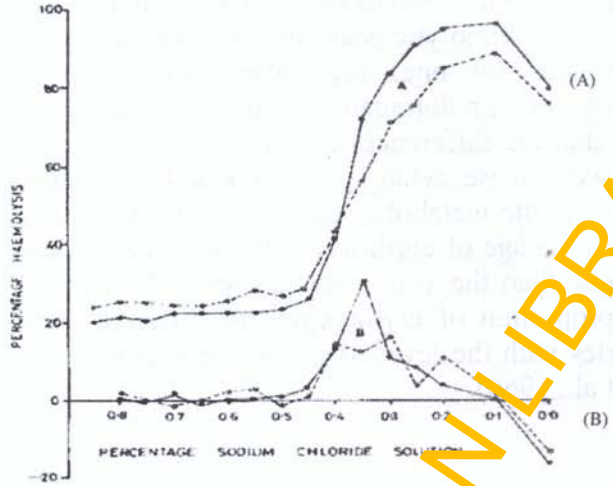



**Fig. 14.** Comparison of the cumulative (A) and derivative (B) erythrocyte osmotic fragility curves for Hubbard fowls (o---o, n = 20) and Nigerian fowls (•—•, n = 26). **(Oyewale and Durotoye 1988)**

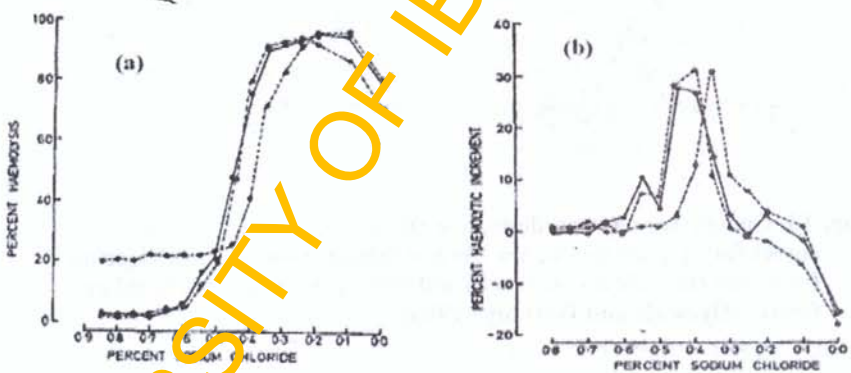



**Fig. 15.** Cumulative (**a**) and derivative (**b**) erythrocyte fragility curves for ducks (•—•, n = 18) (**Oyewale and Ajibade 1990b**), domestic fowls (•—•, n = 26) (**Oyewale and Durotoye 1988**) and guinea-fowls (o---o, n = 35) (**Oyewale 1988**).

Apart from the age of erythrocyte, we also investigated the effect of age of bird on osmotic fragility of erythrocytes. Our observations seemed to differ in different species of birds. We found a higher fragility of erythrocytes in older birds than in younger birds in domestic fowl (Azeez, Oyewale and Okunola 2009) and guinea-fowl (Oyewale 1991a), but a lower fragility in older birds than in younger birds in turkeys (Oyewale and Ajibade 1990a). What is of particular interest in these findings is the similarity of erythrocyte sizes (i.e. MCV) in birds of different age groups in each of the avian species we studied (table 22). An initial obvious conclusion that could be reached, in regard to at least these subjects, is that the osmotic capacity is not determined by the size of the erythrocytes. The issue of erythrocyte size and osmotic fragility will be revisited later in this lecture.

**Table 22: Mean Corpuscular Volume, MCV (± SD) in Birds of Different Age Groups**

| | Age (n) | MCV (fl) |
|---|---|---|
| Turkey[a] | 6 – 8 weeks (14) | 147.54 ± 12.71 |
| | 20 – 22 weeks (28) | 155.72 ± 33.15 |
| Guinea-fowl[b] | 21 weeks (11) | 152.31 ± 5.98 |
| | 156 weeks (9) | 160.46 ± 10.96 |
| Domestic fowl[c] | 7 – 9 weeks (20) | 145.74 ± 39.80 |
| | 49 weeks (19) | 127.00 ± 35.50 |

n = Number of birds

*Sources*: [a] Oyewale and Ajibade (1990a); [b] Oyewale (1991a); [c] Azeez, Oyewale and Okunola (2009)

Poultry birds are good converters of feed into useable protein in meat and eggs. The guinea-hen, unlike the domestic hen, does not lay eggs throughout the year in our tropical environment. I investigated the effect of egg laying on the fragility of erythrocytes in the guinea-hen. My finding showed that erythrocytes of the laying guinea-hen exhibited higher osmotic fragility than those of the non-laying guinea-hen (Oyewale 1990). This may be associated with the increased blood level of oestrogen during the laying period, which probably affects the lipid composition of erythrocyte

membrane through the levels of individual free fatty acids in the blood.

Mr. Vice-Chancellor Sir, I have shown earlier in this lecture that goats have the smallest erythrocyte size among domestic animals and man, followed closely by sheep. I found that goat erythrocytes exhibited greater osmotic fragility (i.e. would lyse more easily) than sheep erythrocytes (Oyewale 1991b, 1993). This is because an erythrocyte absorbs water from the surrounding hypotonic solution and swells until it reaches a maximum size, the 'critical haemolytic volume', after which it will rupture. As expected, the smaller the erythrocyte volume, as it is with the goat erythrocyte, the earlier the critical volume is reached and the greater the osmotic fragility. However, I did not find any significant relationship between osmotic fragility and erythrocyte size. This suggests that the fragility of sheep and goat erythrocytes may be related to some other feature, rather than the cell size. For instance, goat erythrocytes are flat disc-shaped instead of the biconcave shape of sheep erythrocytes. I extended this study to a number of mammalian species and found the order of decreasing erythrocyte osmotic fragility to be: goat, sheep, pig, cattle, mouse, rabbit and rat (Oyewale 1993) (fig. 16). The species differences in the osmotic fragility of these mammalian erythrocytes are attributable to factors that vary between species such as the nature of the erythro-cyte membrane or the physical and chemical constitution of the cell.

We also found that even within the same animal species, the erythrocyte fragility differs between breeds. For instance, we observed that in cattle, erythrocytes of the N'dama breed were more susceptible to osmotic lysis than those of the White Fulani (Olayemi and Oyewale 2002) (fig. 17).

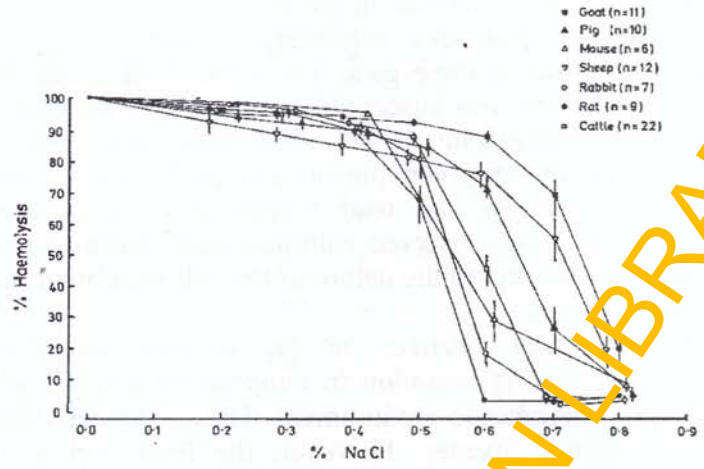



**Fig. 16.** Osmotic fragility of mammalian erythrocytes. Each point is the mean ± SEM. Where vertical bars are absent, the SEM is less than the size of the symbol.

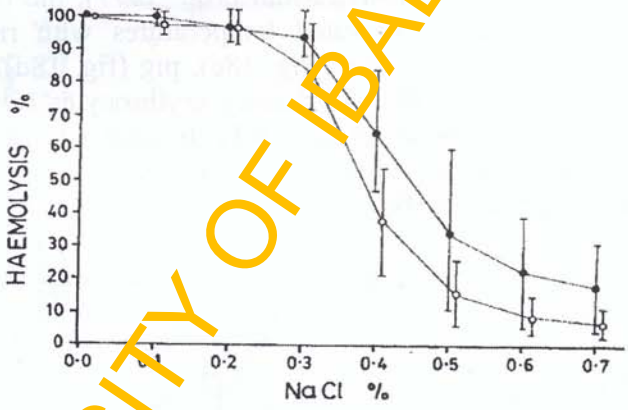
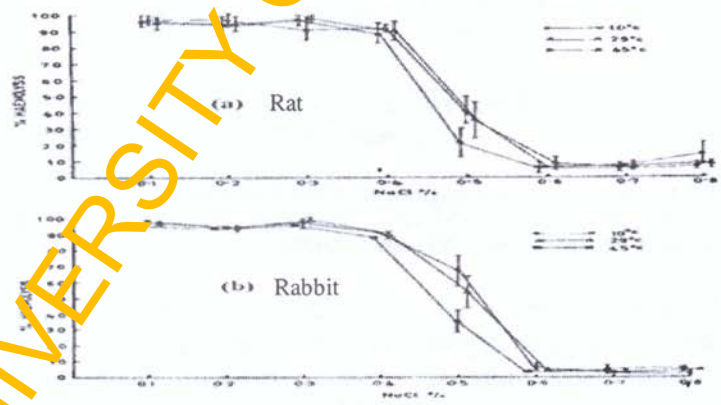



**Fig. 17.** Erythrocyte osmotic fragility of White Fulani (open circles, n=28) and N'dama (solid circles, n=24) cattle. Values are means ± SD. n=Number of animals (After **Olayemi and Oyewale 2002).**

In a comparative evaluation of the osmotic fragility of peafowl and pigeon erythrocytes, I found that erythrocytes of the former were more sensitive to osmotic challenge than those of the latter (Oyewale 1994). I also found that there was

a significant sex difference in the erythrocyte fragility of the peafowl (with peacocks exhibiting greater fragility than peahens), but not in the pigeon. I observed further that lizard erythrocytes were less susceptible to osmotic lysis than toad erythrocytes (Oyewale 1994). The differences found in osmotic fragility between pigeon and peafowl erythrocytes and between lizard and toad erythrocytes, which are all nucleated could, as observed with non-nucleated mammalian erythrocytes, be due to the nature of the cell membrane of the different species.

We observed changes in the osmotic fragility of erythrocytes during variation in temperature and pH of the surrounding hypotonic environment. These changes differed between animal species. However, the limitation of time would only allow me to review a very small fraction of our findings on osmotic behaviour of erythrocytes that are related to temperature variation. We observed that, similar to human erythrocytes (Murphy 1967; Aloni et al. 1977), the osmotic fragility decreased at elevated temperatures with rat (fig. 18a), rabbit (fig. 18b), cattle (fig. 18c), pig (fig. 18d), sheep (fig. 18e) goat (fig. 18f) and donkey erythrocytes (Oyewale 1991b; 1992a; Oyewale, et al. 2011). In contrast, we found that camel erythrocytes exhibited increased fragility at elevated temperatures (fig. 19) (Oyewale et al. 2011).



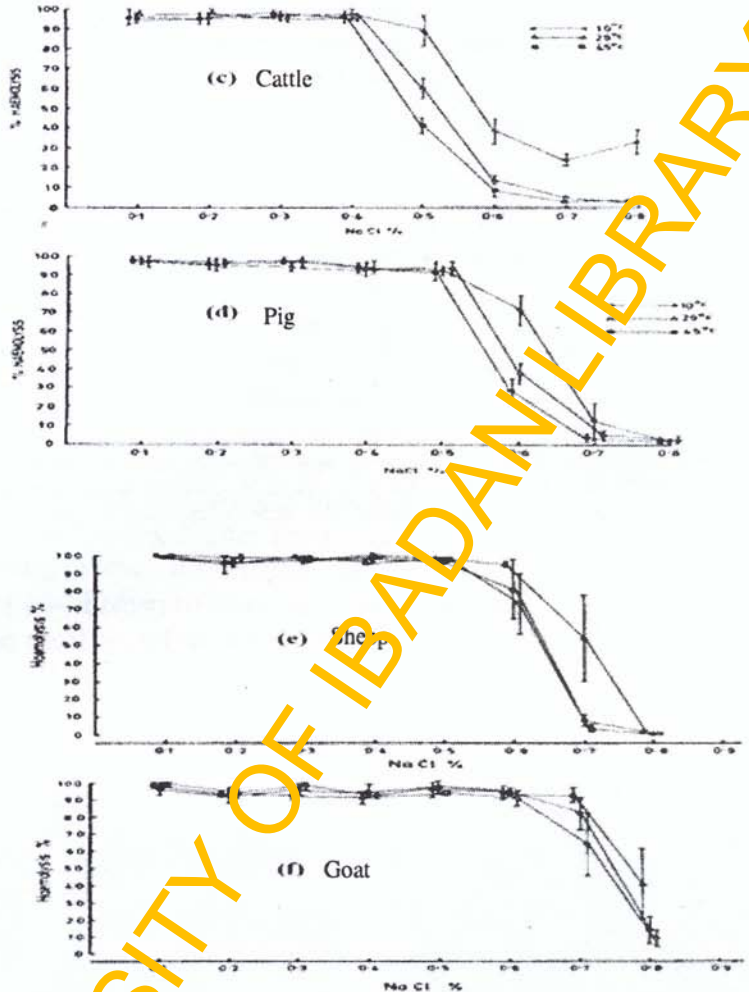



**Fig. 18.** Osmotic fragility of erythrocytes of **(a) rats;** and **(b) rabbits; (c) cattle (n = 8); (d) pigs (n = 10); (e) sheep (n = 10);** and **(f) goats (n = 8)** at pH 7.7 and 10 $^0$C, 29 $^0$C and 45 $^0$C. Each point is the mean ± SD for 6 animals.

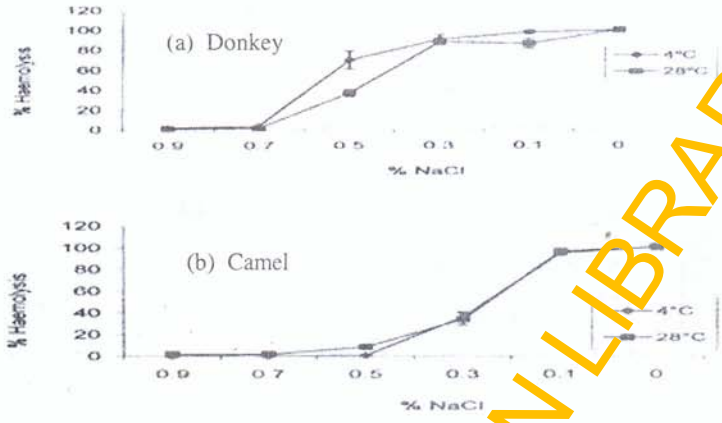



**Fig. 19.** Changes in osmotic fragility of erythrocytes in **(a) donkeys (n = 8)** and **(b) camels (n = 10)** at pH 7.4 and 4 $^{0}$C and 28 $^{0}$C. Each point is the mean ± SEM. Where vertical bars are absent, the SEM is less than the size of the symbol (After **Oyewale, et al. 2011**).

The above findings with mammalian erythrocytes, which are non-nucleated (see fig. 20a), are not too different from our observations with some avian, reptilian and amphibian erythrocytes, which are nucleated (see fig. 20b).

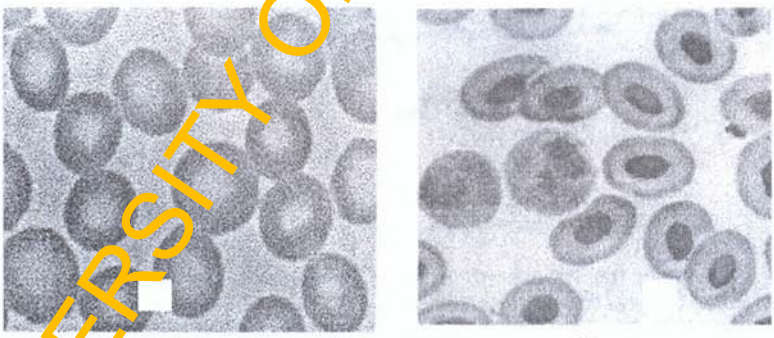



**Fig. 20.** Blood smears showing (a) non-nucleated mammalian erythrocytes from sheep and (b) nucleated non-mammalian erythrocytes from domestic fowl.

For instance, we observed that at elevated temperatures, the osmotic fragility of domestic fowl, guinea-fowl, pigeon,

lizard, and toad erythrocytes decreased (Oyewale, 1992b, 1994) (fig. 21), while that of the peafowl and duck increased (Oyewale 1994; Oyewale, Sanni and Ajibade 1991) (fig. 22). Since duck and peafowl erythrocytes, like erythrocytes of domestic fowls, guinea-fowls, pigeons, lizards and toads, are nucleated, and camel erythrocytes, like those of cattle, pigs, rats, rabbits and donkeys, are not nucleated, it may be concluded that the differences in osmotic behaviour during temperature changes are not related to the presence or absence of a nucleus. Aloni et al. (1977) have shown that lipids and proteins of the erythrocyte membrane are the sites for the effect of temperature on osmotic fragility. The differences between species in osmotic behaviour with respect to temperature changes, therefore, may be related to the structural features of the erythrocyte membrane. For instance, camel erythrocyte membrane differs from that of humans in having higher protein to lipid ratios and also in exhibiting some differences in amino acid composition (Livine and Kuiper 1973).

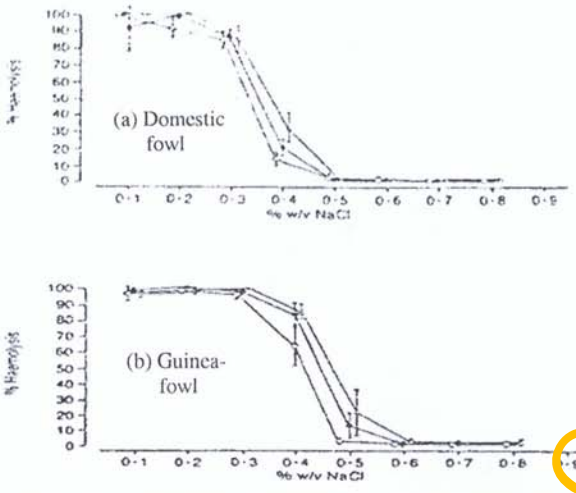
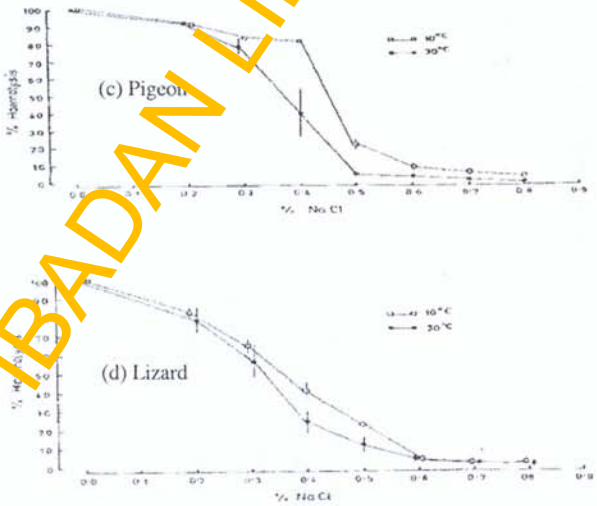



**Fig. 21.** Osmotic fragility of erythrocytes of **(a) domestic fowls** and **(b) guinea-fowls** at pH 7.7 and 10 $^{0}$C (Δ), 29 $^{0}$C (●) and 45 $^{0}$C (O). Each point is the mean ± SD for 8 birds. Where vertical bars are absent, the SD is less than the size of the symbol.




Osmotic fragility of erythrocytes of **(c) pigeons (n = 8)** and **(d) lizards (n = 8)** at pH 7.6 and 10 $^{0}$C and 30 $^{0}$C. Each point is the mean ± SEM. Where vertical bars are absent, the SEM is less than the size of the symbol.

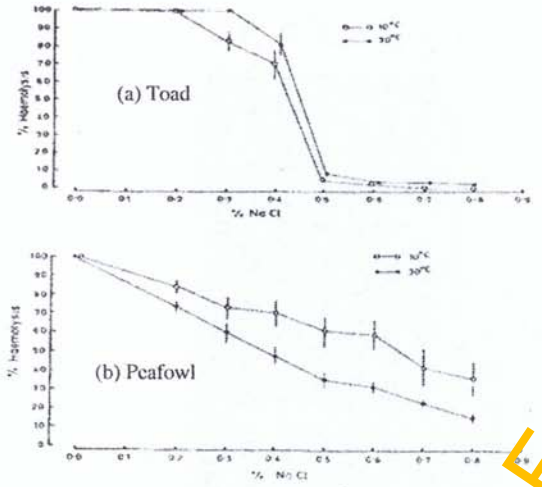
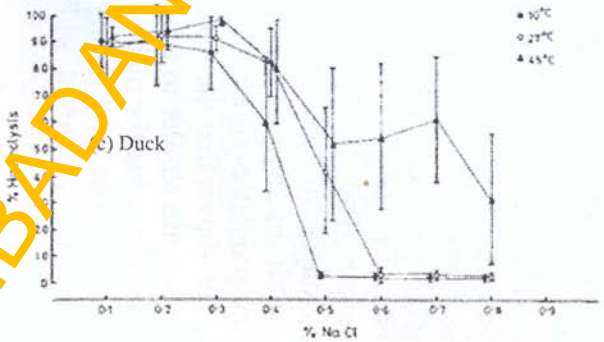



**Fig. 22.** Osmotic fragility of erythrocytes of **(a) toads** (n = 6) and **(b) peafowls** (n = 8) at pH 7.6 and 10 $^{0}$C and 30 $^{0}$C. Each point is the mean ± SEM. Where vertical bars are absent, the SEM is less than the size of the symbol.




**(c)** Effect of temperature on osmotic fragility of duck erythrocytes at pH 7.7. Each point is the mean ± SD for 8 birds (After **Oyewale, 1991**).

What do all these findings signify? Where temperature of blood is elevated, for instance, by activities of blood parasites or other infections, cattle, sheep, goat, donkey, pig, domestic fowl or pigeon erythrocytes are less susceptible to osmotic lysis (or rupturing) than those of the camel, duck or peafowl. Whereas, this observation may be true for erythrocytes of the duck, peafowl, cattle, donkey and other animals, it is doubtful whether this can be so with the camel erythrocyte which is capable of swelling to twice its original volume without rupturing in hypotonic solutions (Perk 1966). This and other characteristics such as resistance to lytic effect of snake venom and resistance to sonic haemolysis (Condrea et al. 1964) indicate some unusual properties of camel erythrocyte membrane. Ralston (1975) has shown that the major proteins of camel erythrocyte membrane are similar to those of cattle and man with the major difference being the major membrane protein 'spectrin', which appears to be very tightly bound to the camel erythrocyte membrane. Concurrent with the total release of spectrin, camel erythrocytes undergo a change in shape from ellipsoid to spherical, suggesting an important shape-maintaining role of spectrin in the erythrocytes of the camel. It is therefore not surprising that, in collaboration with Prof. Joseph Ayo of the Department of Veterinary Physiology and Pharmacology, Ahmadu Bello University, Zaria, we observed that erythrocytes of the camel (fig. 23) demonstrated considerable resistance to osmotic lysis than those of the donkey (fig. 24) as shown in figure 25 (Oyewale et al. 2011). Camel erythrocytes have also been shown elsewhere to be more resistant to osmotic lysis (or less fragile) than those of man, cattle, rat, rabbit, sheep, goat, pig, horse and domestic fowl (Perk et al. 1964; Livine and Kuiper 1973; Al-Qarawi and Mousa 2004).

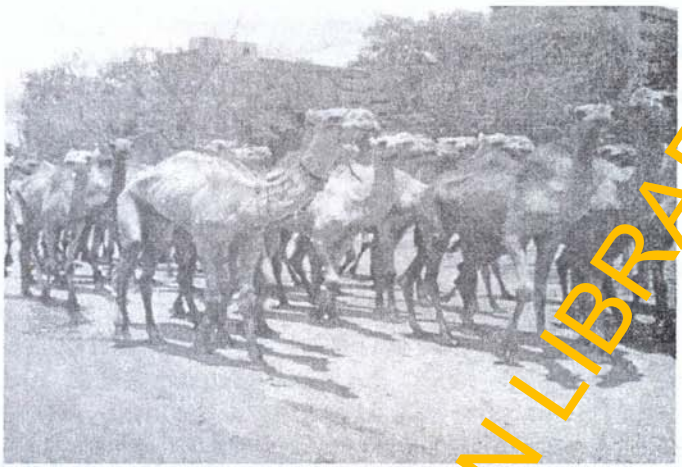


Fig. 23. Adult one-humped camels (*Camelus dromedaries*) along Kano-Zaria road.

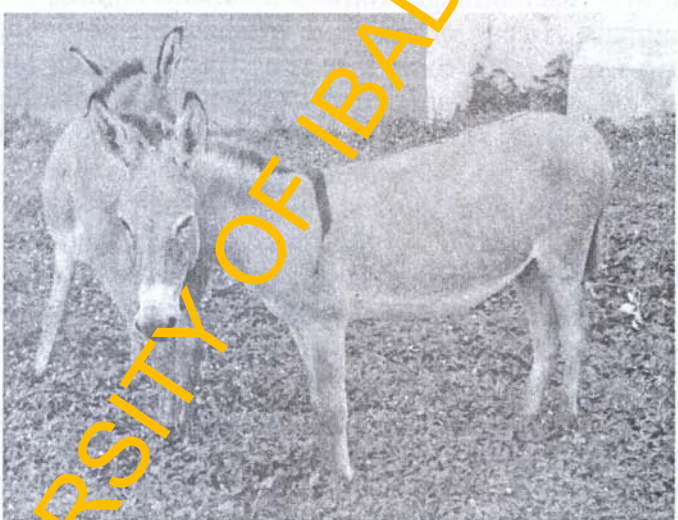


Fig. 24. Adult Nubian donkeys (*Equus asinus*).

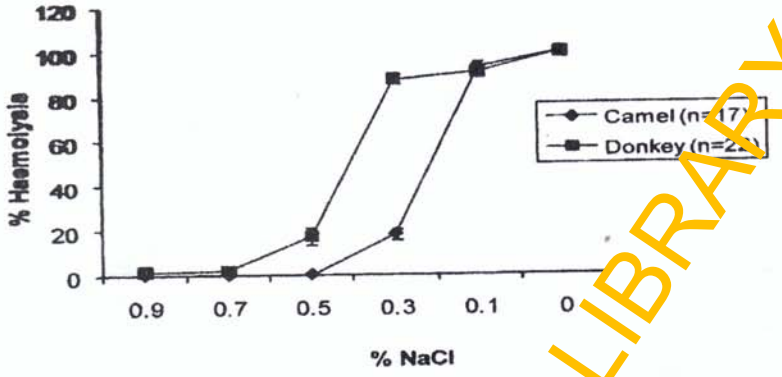



**Fig. 25.** Comparison of osmotic fragility of camel and donkey erythrocytes. Each point is the mean ± SEM. n=Number of animals (After **Oyewale et al. 2011).**

## Haematological Changes after Blood Loss

Blood loss (haemorrhage) follows traumatic injuries in man and animals. As part of efforts to evaluate the physiological responses of animals to various stress factors in our laboratory, Oyewale, Okewunmi and Olayemi(1997) investigated the haematological changes in the healthy adult female WAD goats during the first 24 hrs following acute blood loss. Thirty percent of the calculated blood volume of the goat (Makinde, Durotoye and Oyewale 1983) was removed through the jugular vein. We found a significant decrease in Hb concentration at the end of blood withdrawal in our WAD goats. We also observed significant decreases in RBC, PCV and Hb values 4 or 24hrs after haemorrhage in the goat (table 23), which are in agreement with similar findings in the horse (Torten and Schalm 1964). The observations are due to movement of intestinal fluid into the vascular system to replace fluid volume lost through haemorrhage (Torten and Schalm 1964; Schalm et al. 1975). The decrease in Hb value of the goat after 24 hrs causes the decrease seen in the MCHC value (see table 24). However, we found increases in the total WBC counts 4 and 24 hrs after haemorrhage in the goat due to increases in the number of circulating neutrophils and

eosinophils. The lymphocyte, monocyte and basophil counts were not altered by blood loss (see fig. 26a-d). Our observation suggests that following an acute blood loss in goats, an increase in total white blood cells in peripheral circulation (i.e. leucocytosis) should be anticipated. This should not be interpreted as evidence of an infectious process. We also found significant increases in neutrophil and eosinophil counts 1 hr after bleeding in our goats (fig. 26b and c) which are probably due to mobilization of marginated white blood cells that adhere to the walls of blood vessels.

From these results, it appears the WAD goats can withstand an abrupt loss of one-third of the circulating blood volume without exhibiting serious signs of distress.

**Table 24: Changes in Haematological Values (mean ± SD) of West African Dwarf Goats after Haemorrhage.**

| Parameters | Pre-haemorrhage | Post haemorrhage | | | |
|---|---|---|---|---|---|
| | | Zero hr | 1 hr | 4 hr | 24 hr |
| | (8) | (8) | (8) | (8) | (8) |
| PCV (%) | 24.63 ± 4.24 | 21.69 ± 4.20 | 20.13 ± 4.36 | 17.56 ± 3.58* | 18.63 ± 3.42* |
| Hb (g/dl) | 8.44 ± 1.54 | 6.68 ± 1.57** | 6.40 ± 1.72** | 6.15 ± 1.95** | 4.99 ± 1.23*** |
| RBC (x $10^{12}$/L) | 9.88 ± 2.32 | 8.64 ± 1.22 | 8.06 ± 2.90 | 9.42 ± 4.26** | 7.47 ± 1.73** |
| MCV (fl) | 25.47 ± 6.05 | 25.09 ± 2.81 | 27.24 ± 8.45 | 21.11 ± 7.09 | 24.93 ± 5.31 |
| MCH (pg) | 8.79 ± 1.98 | 7.50 ± 0.87 | 8.52 ± 2.81 | 6.87 ± 2.53 | 6.08 ± 1.38* |
| MCHC (g/dl) | 34.28 ± 2.63 | 29.84 ± 3.73 | 31.67 ± 3.64 | 34.42 ± 5.25 | 26.67 ± 2.17*** |

Number of animals in parentheses.
Asterisks denote significant difference from pre-haemorrhage value: *:P<0.01; **: P<0.05; ***: P<0.001.
*Source*: **Oyewale, Okewumi and Olayemi (1997)**

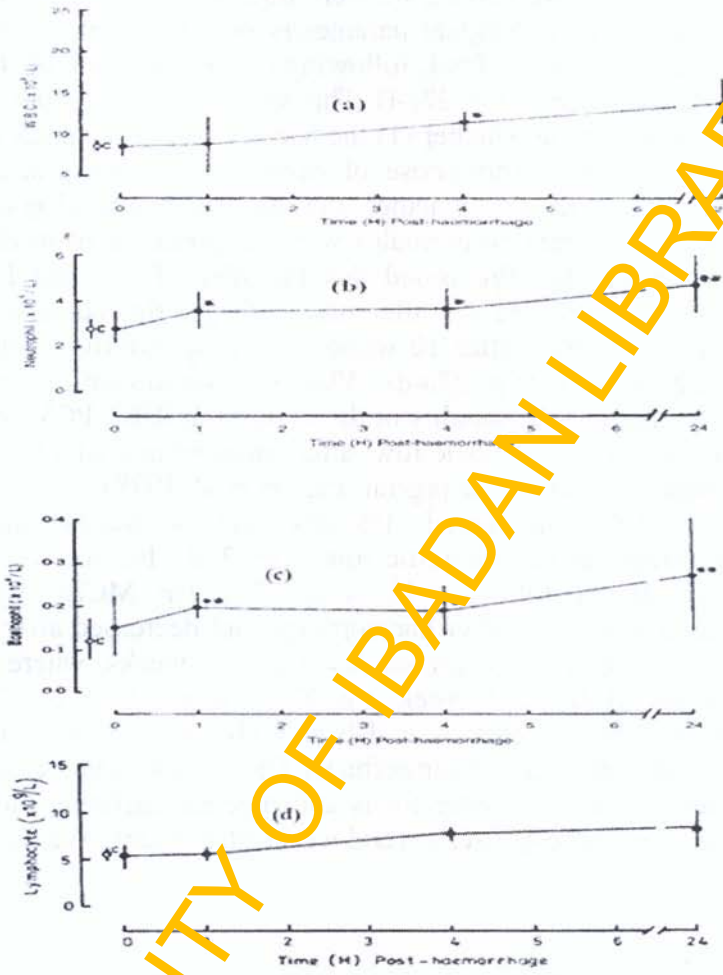



**Fig. 26.** Changes in (a) total WBC; **(b)** neutrophil counts; **(c)** eosinophil counts; and **(d)** lymphocyte counts of the goat after haemorrhage. Each point is the mean ± SD for 8 animals. Asterisk denotes significant difference from pre-haemorrhage value (C): *: $p < 0.05$; **: $p < 0.001$ (After **Oyewale, Okewumi and Olayemi 1997).**

With the above results, we went further to investigate the changes in haematological parameters of a non-mammalian species, the domestic fowl, following removal of 30% of the total blood volume (fig. 27a-f). This study was carried out in order to determine whether (1) the haematological changes in the bird differed from those of mammals following acute blood loss, and (2) whether the altered haematological parameters returned to normalcy within a period of 10 weeks post-haemorrhage. We found that the RBC, PCV and Hb values decreased 1½ hrs after haemorrhage, fluctuated and returned to normal after 10 weeks (Oyewale, Olofintila and Famakinde 1997) (fig. 27a-d). What is of significant interest in this finding is the rapidity of the changes in RBC, PCV and Hb values in the domestic fowl after haemorrhage which has also been reported in the pigeon (Palmer et al. 1979).

The MCH increased 1½ hrs and 4 weeks after haemorrhage in our domestic fowl (fig. 27d), but the MCV was not altered by blood loss (fig. 27e). The MCHC was normal immediately after haemorrhage, but decreased after 2 weeks and returned to normal level after 4 weeks, where it remained till the tenth week (fig. 27f). Palmer et al. (1979) however, found increases in Hb and MCHC values in the pigeon 10 weeks after haemorrhage. This indicates that avian species, at least domestic fowls and pigeons, differ in their haematological responses several weeks after haemorrhage.

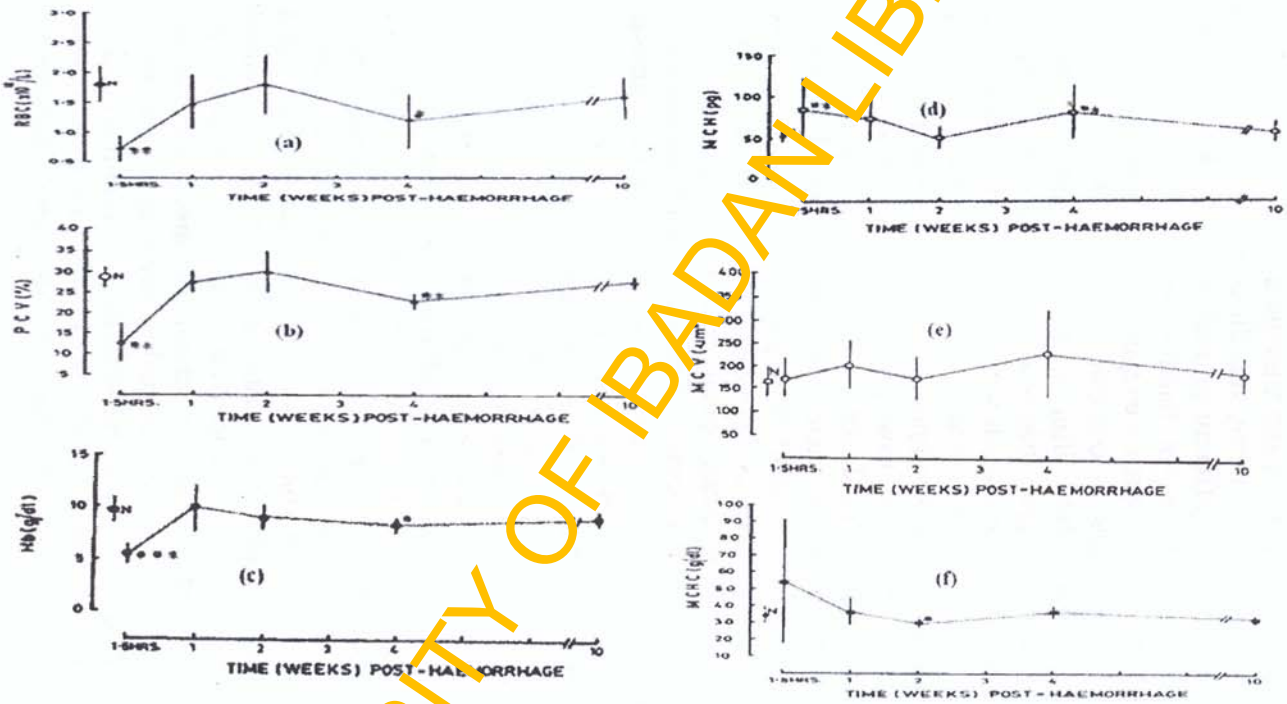



**Fig. 27.** Changes in **(a)** red blood cell (RBC) count; **(b)** packed cell volume (PCV); **(c)** haemoglobin (Hb) concentration; **(d)** mean corpuscular haemoglobin (MCH); **(e)** mean corpuscular volume (MCV) and **(f)** mean corpuscular haemoglobin concentration (MCHC) of domestic fowl after haemorrhage. Each point is the mean ± SD for 9 birds. Asterisk denotes significant difference from pre-haemorrhage (N) value: *=P<0.05 (After **Oyewale, Olofintila and Famakinde 1997).**

## Conclusions and Recommendations

Ladies and gentlemen, I have attempted to explain to you in the last 50 minutes or more, the differences in the normal blood parameters of different animal species. I have shown that the normal values for haematological parameters and plasma/serum electrolytes, enzymes and proteins differ between cattle breeds in our environment and that in each breed the values also differ with the system of animal management. I have described to you the role of egg-laying in domestic fowls and guinea-fowls and that of pregnancy and lactation in sheep and goats causing changes in plasma volume and total blood volume. I have shown that the blood parameters of domestic fowls, ducks, turkeys and guinea-fowls are altered by breed, sex, species, egg-laying and age. I have also shown the differences between the blood values of wild and domestic animals and birds. In addition, I have described the differences between species in the osmotic behaviour of mammalian, avian, reptilian and amphibian erythrocytes and the influence of temperature of the surrounding hypotonic solution in causing alterations in the osmotic fragility of erythrocytes. Furthermore, I have described the haematological responses of the goat and the domestic fowl following sudden blood loss. Above all, I have informed you of my modest contribution to knowledge in all of these, which have been targeted at highlighting the differences that exist in the blood parameters of different animal species.

In the evaluation of the health and nutritional status of animals, blood examination is an issue that has always been given top priority. One of the measures that can be taken to ensure proper interpretation of haematological and plasma/serum biochemical data from animals includes applying appropriate reference values for each animal breed or species to minimize the effect of breed or species differences. These I have provided in my extensive research on blood values of various mammalian and non-mammalian species. Other measures which should be taken into account include the physiological variation in blood parameters

(caused by age- and sex- related differences, pregnancy, lactation and egg-laying) and the quality of the habitat or environment where the animals are kept (i.e. feed availability, rainfall, temperature and humidity variations).

I wish to stress at this point that basic science research by its nature is driven by a sense of curiosity and looking for fundamental and innate beauty in natural phenomena. Its main motivation is to expand man's knowledge. In today's world, basic science research is carried out in most top universities at biotechnological and molecular biology levels. However, Nigerian universities are left behind as a result of lack of appropriate research equipment and facilities in laboratories, dearth of research grants, low level of funding by proprietors of universities (Federal and State Governments and Private Institutions), limited access to Information Communication Technology (ICT) infrastructure and equipment, decaying and ageing facilities, incessant power (electricity) outage, and lack of regular water supply. In order to be listed among the top universities in the world, to which our University aspires, institutions are ranked by a combination of indicators of academic and research performance including visible presence on the web, presence of international staff and students, student-faculty ratio and research citations. In the 2010 QS World University Rankings, Harvard University was demoted to second place by University of Cambridge, having topped the ranking every year since 2004. In Africa, the only university among the top 200 is the University of Cape Town in South Africa which ranked 161st. The University of The Witwatersrand, Johannesburg, South Africa ranked 360th, while Cairo University, Egypt ranked in the top 500. Sadly, no Nigerian university ranked in the top 600 in the world. However, several developmental and advancement programmes have taken place in the last one decade in the University of Ibadan to suggest that it will eventually emerge as one of Africa's top universities. These include the visible transformation of our teaching, research and learning environment and the

remarkable achievements recorded through the MacArthur Foundation Grants which have assisted in the areas of ICT, staff training abroad and provision of a Central Multi disciplinary Research Laboratory. However, a lot more needs to be done. Staff and student exchange programmes resulting from local and international linkages with acclaimed institutions should be further strengthened. The government should increase the level of funding to universities. Adequate provision for staff development programmes, such as short- and medium-term training in international laboratories and attendance at local and international conferences and workshops for academic staff and technologists, should be made and enforced.

In the past, our University Teaching and Research Farm used to provide research materials for scientific investigations in agriculture, veterinary medicine, medicine and other disciplines. It also used to supply livestock products such as milk, beef, pork, poultry and eggs to this community. Mr. Vice-Chancellor Sir, the University should reactivate and reorganize the farm which has been in a state of coma for the past three decades. There is no doubt that your tenure will forever be remembered and your name written in gold if the farm can come alive again.

**Acknowledgements**

I give praise, honour and glory to Almighty God for making it possible for me to be where I am today and to be able to stand before you to give this inaugural lecture. I thank my late parents, Pa Julius Oyewale and Madam Sefania Obi Oyewale for their wonderful support and upbringing. I appreciate my lovely sisters and brothers and their spouses.

I thank Professor M. O. Olowookorun for being my M.Sc and Ph.D supervisor and for his positive contribution during the preparation of this inaugural lecture. I am grateful to members of the Committee for my Inaugural Lecture; Professors S. O. Akpavie, B. O. Oke, A. O. Adeyefa, M. O. Abatan and my former teachers, Professors V.O. Anosa and R. O. A. Arowolo. I thank you all for making my problems

your problems. I will like to show my appreciation to my very good friend, who is more than a ''blood brother'' to me, Dr. Adesoji A. Fasanmade, for numerous years of our interactions and discussions which have been very rewarding. I am greatly indebted to all teaching and non-teaching staff in my Department. I have enjoyed your company. God bless you.

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Mr. Vice-Chancellor, ladies and gentlemen, I thank you all for listening. God bless you.

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# BIODATA OF
# PROFESSOR JOHNSON OLUWAYEMISI OYEWALE

Professor Johnson Oluwayemisi Oyewale was born in Abeokuta on 23rd July, 1954. He attended Saint Peter's College, Abeokuta for his secondary education between January, 1969 and June, 1973. In October, 1973, he was admitted to read Veterinary Medicine at the Jos Campus of the University of Ibadan. He was transferred to the Ibadan Campus of the University in October, 1974 and graduated with a DVM degree in 1979. He obtained a Master of Science (M.Sc) degree in 1983 and a Ph.D in Veterinary Physiology in 1988 from the University of Ibadan.

Professor Oyewale started his teaching career in September, 1980 as Lecturer II in the Department of Veterinary Physiology and Pharmacology (now Department of Veterinary Physiology, Biochemistry and Pharmacology). He rose through the ranks to become Lecturer I in 1984, Senior Lecturer in 1988, Reader in 1994 and Professor in October, 1998. He was a Visiting Senior Lecturer to University of Maiduguri, from April to June, 1992 and a Visiting Professor to Ahmadu Bello University, Zaria, from November, 2006 to October, 2007. He was also a Visiting Professor to University of Agriculture, Abeokuta, from June, 2008 to May, 2009.

He has supervised the research work of many post-graduate and undergraduate students in the field of Veterinary Haematology. He has over 50 journal articles published in highly reputable peer-reviewed international journals based in Great Britain, Germany, Croatia, the Netherlands, Nigeria, Kenya, Russia, Pakistan and Israel, and has attended many national and international conferences, seminars and symposia where he presented a number of papers.

Professor Oyewale has held many administrative positions at the University level. He has served as Acting Head (1990 - 1992) and as the substantive Head of Department of Veterinary Physiology and Pharmacology,

University of Ibadan (2001 - 2004). He was Head of Department of Veterinary Physiology and Pharmacology, University of Agriculture, Abeokuta (2008 - 2009). He has been a member of Senate of University of Ibadan since 1999; Member, Central Appointments and Promotions Committee, representing the Faculty of Veterinary Medicine, University of Ibadan (2002 - 2004). He was a member of Senate, Ahmadu Bello University, Zaria (2006 - 2007) and University of Agriculture, Abeokuta (2008 - 2009). He has been a Consultant to the Veterinary Teaching Hospital, University of Ibadan since 2001. He was a Consultant, at different times, to the Veterinary Teaching Hospitals of Ahmadu Bello University, Zaria (2006 - 2007) and University of Agriculture, Abeokuta (2008 - 2009).

He has served as External Examiner and External Assessor to University of Nigeria, Nsukka, University of Maiduguri, Ahmadu Bello University, Zaria and University of Ghana, Legon; Member, National Accreditation Board of Ghana Panel of Assessors for the Accreditation of Bachelor Programme in Veterinary Medicine and Surgery at University of Ghana, Legon and Kwame Nkrumah University of Science and Technology, Kumasi, Ghana (2009).

His membership of learned professional bodies include the Nigerian Veterinary Medical Association, Physiological Society of Nigeria, and African Association of Physiological Sciences. He is a registered Veterinarian and a Fellow of College of Veterinary Surgeons of Nigeria (FCVSN).

Professor Oyewale is happily married with children.