KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF SCIENCE

DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY

MORPHOLOGICAL ANALYSIS OF HUMAN HAIR AMONG ASHANTI AND DAGOMBA ETHNIC GROUPS OF GHANA

BY

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CERTIFICATION

I hereby declare that this submission is my own work toward the award of degree MSc and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational Institution, except where due acknowledgment is made in the thesis.

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ABSTRACT

Hair is an important piece of evidence in forensic investigations. Analysis of the morphological features (medulla) of hair has been reported since the early 1800's. However, many questions still remain unanswered especially as to, how local populations could be analysed and separated from each other based on the morphology (medulla) of their hair?This investigation examined the medulla types of hair among Ashanti and Dagomba ethnic groups of Ghana by using the Comparison and Compound microscopy together with Computer imaging.Statistical analysis was performed on the data to determine the variability and relationships between the populations. Generally, 51.5% of the Ashanti population examined had no medulla while of the Dagomba 33 % have no medulla and 48.5% and 33% have at least one of the three type medulla respectively . There was no significant difference between the two ethnic groups examined with respect to hair medulla index, medulla diameter or hair shaft diameter. The closerelationship and overlap between these two populations is a limiting factor in attempting to discriminate between these two populations using their medulla morphology and should be taken into account in future investigations.

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DEDICATION

I dedicate this book to my parentsand my children Edudzi, Edem, Eyram and Elorm, you were a gift to us.

CHAPTER ONE

BACKGROUND OF THE STUDY

1.1. INTRODUCTION

Forensic hair analysis is a scientific technique or method of analysing trace evidence from a crime scene. It involves examining the hair shaft, including its medulla (inner core), cortex (intermediate layer) and cuticle (outer covering) using comparison microscopes. Hair evidence ought to be collected properly and analyzed according to protocols (Chatterjee, 2012).

The French scientist Edmond Locard revealed that people constantly pick up and transfer bits of dust, hair, fibers and other "trace" material without being conscious of it. Locard realized that these material exchanges were key to analyzing a crime scene, and the "Locard Exchange Principle" became the foundation of forensic science in the early 1900s which states that “any time there is contact between two surfaces, an exchange of materials will occur such as dust, hair and fibers” (Chattha *et al*, 2011).

Hair can easily be transferred from one person to another. It clings to furniture, carpets and clothing, and it can last for a number of years without decomposing or degrading. This uniqueness makes the hair left at a crime scene a key aspect of trace evidence. Even if a suspect tried to clean up the crime scene, he or she would most likely leave hair behind (Collier, 2004).

Hair is easily analyzed using comparison microscopes, which bring out the colour and details of a hair specimen and comparison microscope allows the forensic scientist to analyse two pieces of hair evidence side-by-side (Benner Jr, and Levin, 2005).

Hair analysis helps investigators identify individuals involved in a crime scene. Forensic scientists first determine whether the hair came from the victim, a suspect or an animal. If the hair is human and matches the hair of the victim, it may help to identify the victim. If the hair does not belong to the victim, it may belong to the suspect. In that case, it may provide information about the link between the perpetrator and the crime scene or between the perpetrator and the victim. Hair evidence may also eliminate a particular suspect, thereby exonerating him (Weitzel, 1998).

The forensic analyst compares the trace hair sample taken from the crime scene with another sample from a known source, either the victim or a suspect. The samples have to come from the same area of the body, generally either from the head or the pubic area. Forensic scientists will look at the two samples through a comparison microscope to determine if there are any matches in their morphology (Chen and Bhushan, 2005).

Forensic hair analysis has a limitation; that is human hair shares some characteristics such as colour and texture, so hair alone cannot positively identify someone as a perpetrator. However, hair analysis can point to a suspect, but without DNA evidence, hair analysis alone cannot state positively that a specific hair sample came from one particular individual and not another (Araújo *et al,*2010). Even if the hair evidence matches the known hair sample from a suspect, it can also match samples from many other individuals. But even with this limitation, forensic hair analysis is considered one of the most important tools available to crime investigators (Araújo *et al,*2010).

During the normal hair-growth cycle, hairs are lost from people, and these hairs may be transferred during criminal activity (Beary and Leelyman, 2014).

1.2. PROBLEM STATEMENT.

Forensic analysis of hair has been used as a tool for making determination at crime scenes (Areida *et al*, 2006).

However, there are many challenges ranging from collection of hair evidence, analysis of hair collected from crime scene and how to link the hair evidence to a person during forensic investigations in Ghana (Vaughn *et al*, 2009).

Some Countries in USA, Europe, and Asia as well as some in Africa like Egypt have database for morphological features of hair and also have adequate knowledge about hair morphology (Lavker *et al*, 2003) but in Ghana there is lack of such database and adequate knowledge in hair morphology. Due to lack of such database and adequate knowledge about hair morphology in Ghana, investigators have difficulties in using hair evidence to charge a suspect or exonerate a suspect in court of law in Ghana.

1.3. OBJECTIVE OF THE STUDY

To analyse the medulla structure of a set of human hair data among the Ashanti and Dagomba ethnic groups in Ghana.

1.4. SPECIFIC OBJECTIVES.

1. To characterize morphological difference(s) in the medulla of hair among Ashanti and Dagomba ethnic groups in Ghana.
2. To use the medulla structural differencesof human hair to include or exclude the two ethnic groups when there are suspected crimes.
3. To generate or develop a partial hair database for the two ethnic groups in Ghana.

1.5. JUSTIFICATION.

Human hair is the most important piece of evidence met in forensic investigations (Taupin, 2004). Observation of morphological features of hair can reveal a lot of information about the person from which it came, such as race or population they represent (Ogle, 1998).

Forensic scientists have become interested in hair because hair has constantly been released or deposited through the process of natural shedding (De Veragh, and Meuli, 1995).

Hair, once recovered can offer a lot of information, thus aiding in understanding of a crime scene if there is an organized method used for isolating ethnic groups of people based on specific morphological features of their hair. This can constitute to establishment of a database for comparison.

Due to this lack of hair database and the inadequate use of hair evidence from crime scenes, there is the need to help generate or develop a partial database of hair that can be used in forensic investigations in Ghana.

Use of morphological features, especially the medulla, can help investigators to resolve crimes in Ghana such as rapes and defilement when the suspect(s) cannot be identified by the victim, but sample(s) of hair has been found at the scene.

The Ashanti and Dagomba ethnic groups of Ghana were therefore used to help generate or develop an initial database for the country.

CHAPTER TWO

LITERATURE REVIEW

2.1 Hair Morphology

2.1.1 Skin

Hair, itself, is an organ. However, to fully understand the growth structure of hair it is important to have some facts about the body's largest organ: the skin. The skin is a complex system that has great depth.

The body's skin is roughly divided into three layers, the dermis or cutis, the epidermis or cuticle and subcutaneous layer (Fig.2.1). The dermis is a connective tissue layer consisting of blood vessels which provide nourishment to the skin cells, nerves and sensory receptors called the tactile corpuscle (Deedrick and Koch, 2004).

The base of the dermis is attached to a layer of fatty tissue or muscle. The dermis is a tough, flexible layer that protects the underlying organs. Its thickness varies depending on the body region: for example, while the dermis is very thick on the palms of the hands and feet, it is thin on the eyelids. Thickness of the dermis may also vary with age and sex of an individual. Males tend to have denser dermis layer than females, as do adults when compared to children (Deedrick and Koch,2004).

Above the dermis lies the epidermis (Fig.2.1) which also varies in thickness at differing body regions, often the same way as the dermis, such as being thicker at the palms of the hands and feet.

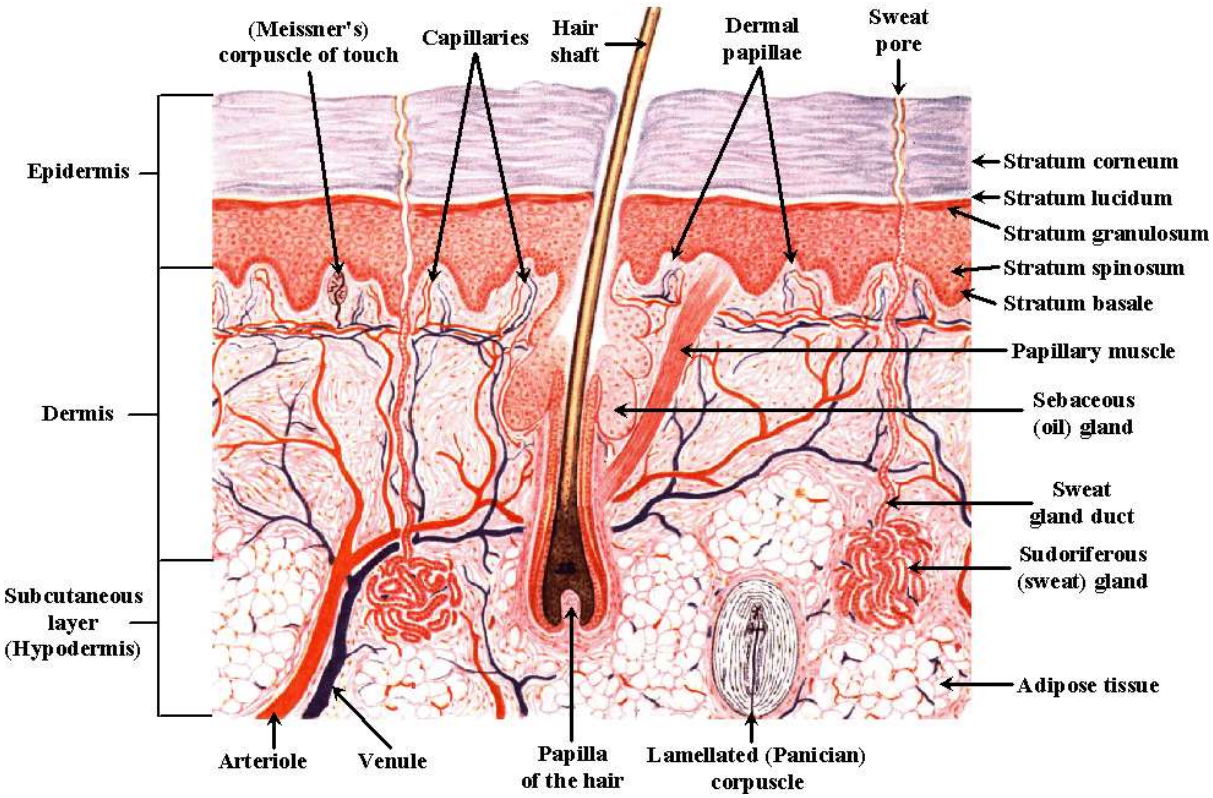

Fig.2.1. Structure of the skin (Benner, 2005)

The epidermis is a non-vascular layer composed of both dead and living skin cells. The dead cells reside in the two outer layers of the epidermis: the stratum lucidem and stratum corneum. The stratum lucidem consists of a clear layer of indistinct cells with traces of nuclei. The stratum corneum is a layer of scale-like cells that have become flattened. These cells lack a discernible nucleus and are composed of soft 'keratin, as opposed to the 'hard' keratin which makes up most of the hair itself (Beary, 2014). These dead cells are continually sloughed away and replaced from the underlying layers so that the developing skin always has protective function. The living layers of the epidermis lie below the dead and include a transitional layer of flattened, polygonal cells with central nuclei called the stratum granulosum. This is the layer which produces the protein keratin. Below this is a basal layer where cells divided and maintained the epidermis. The cells in this layer form a bulge or nodule which grows

and penetrates down into the dermis. These cells become the hair follicle(Paus and Cotsarelis, 1999).

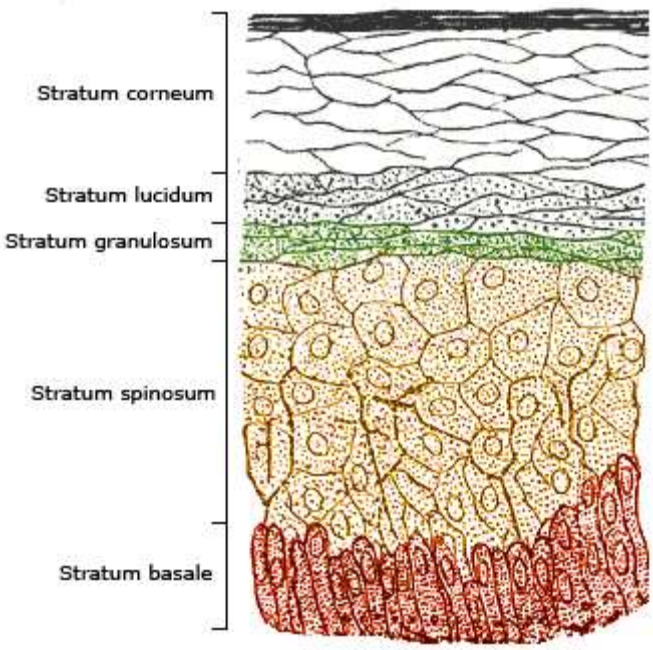

Fig. 2.2: Structure of the epidermis (Benner, 2005).

2.1.2. Follicle and root

Dermis contains the majority of the hair follicle. The follicle is an epidermal structure with associated cellular composition to the epidermis, but developing mainly in the dermis (Efremenko *et al,* 2007). An initial signal from the dermis instructs the epidermis to form a bulge. The cells or a dermis become concentrated around the resulting bulge and form a dermal papilla or a small conical intrusion with vascular characteristics in response to the second signal from the epidermis.

The dermal papilla provides the stimuli for growth cycle of a new hair (DiZinno *et al*, 1999). As the hair nodule continues to grow, the cells arrange themselves parallel to each other and at right angles to the longitudinal axis of the nodule (Robbins, 2005), in response to a final dermal message.

The product, the epidermal hair follicle (Fig.2. 3), has a wide base with a concavity (the dermal papilla). Together they make up the hair bulb. Self-propagating cells of the dermis begin to form an outer connective- tissue sheath at the lower region of the bulb, migrating upwards toward the surface of the skin approximately halfway up the follicle. This external root sheath separates the internal migrating cells from the external dermis. Swellings often develop out of this sheath; muscle (arrectorspili). The sebaceous gland is an organ composed of a single duct with a variable number of sacs inside the duct. The sacs contain cells and fatty oils. The arrector muscle is a small bundle of muscle fiber below the sebaceous muscle gland. Both glands exist on the side towards which the hair slopes (Gillen *et al,* 1999). When the arrector muscle contracts, it causes the hair to 'stand on end' resulting in goose bumps on the skin, thus increasing the amount of insulating air trapped by the hair.

As the nodule continues to grow and differentiate, an inner root sheath forms from the base of the bulb at the matrix. The internal root sheath can be separated into the following layers; a weak cuticle layer with scales pointing downward, the Huxley layer with nucleated cells, and the Henley layer with oblong cells and no distinguishable nucleus (Katz andChatt, 1988). The entire inner root sheath grows between the outer root sheath and the cells of the hair shaft and moves distally by sliding against the outer root sheath.

When its cells reach the opening of the sebaceous canal, they are destroyed by proteolytic enzymes, thus freeing the hair shaft from the inner sheath (Deedrick *et al*, 2004a).

However, prior to reaching the sebaceous gland, the hair shaft and both root sheaths are still connected. It is this part of the follicle that sometimes is seen as the root of a plucked hair. The hair shaft is formed from the matrix cells at the bottom of the hair

follicle, but only about 10% of the cells that leave the matrix form the mature hair, the other 90% building up the root sheaths (Brown and Davenport, 2011). The intact hair filament can be divided into three regions along its longitudinal axis (Fig.2. 3). The lower region and round the bulb of the hair is known as the site of biological synthesis and organization. This is a transient region of hair growth where cell differentiation occurs. The middle region is the site of keratinisation where the hair shaft undergoes hardening or stability through cysteine cross-linking. Finally, the region of the permanent hair is that which emerges from the surface of the skin. The permanent hair region does not change positions like the region of biological synthesis. The permanent hair consists of three types of cells: dehydrated cornified cuticle, cortical and medullary cells connected by intercellular cement (Fig.2. 4) (Jackson and Jackson, 2004).

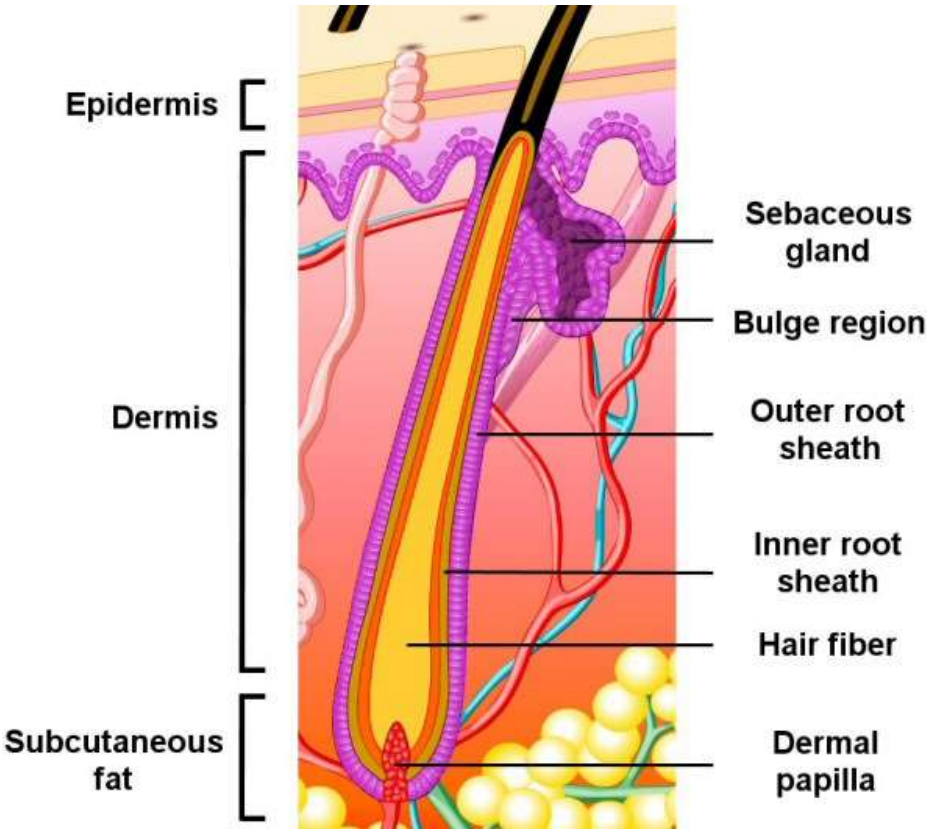

Fig.2.3: Structure of the hair follicle (Taupin, 2004).

2.1.3. Cuticle.

The cuticle layer of the hair shaft is the most outer layer of cells; that is resulting from the matrix cells at the peak of the dermal papilla. The cuticle cells move distally from the matrix in a single row, but as the hair grows the cells form approximately five layers at approximately 100 millimetres above the human scalp (Chenand Bhushan, 2005).The number of these cell layers varies between species of animals (Kempton *et al,* 2010).

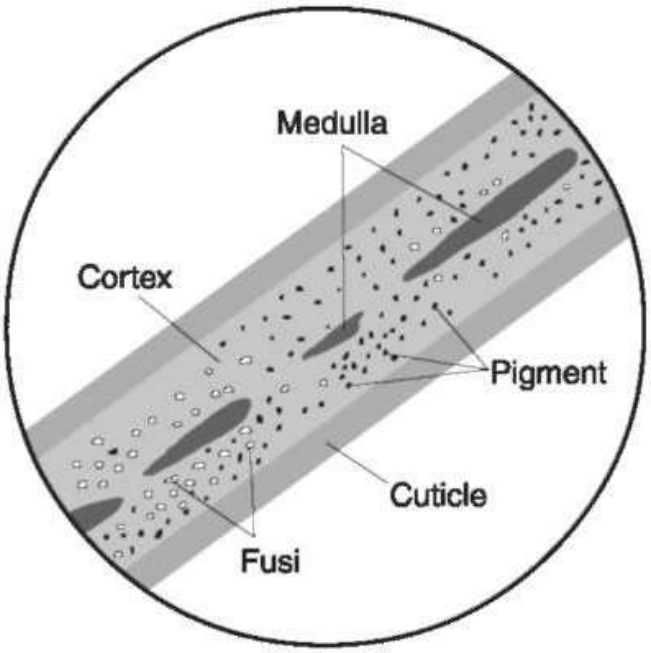

Fig.2.4: Structure of the hair fiber (from Tridico*et al,* 2014).

Resulting from this layer formation is a well detailed terminology describing the differing cuticle cells from one layer to the next (Fig.2.5). At the most outer surface of the fiber is a thin membrane called the epicuticle. Robbins, (2012a) estimated that the most common thickness of the epicuticle is 25Angstrom. Beneath the epicuticle lies the A- layer, a region of resistant cysteine greater than 30% also present in other layers but to a lesser degree. Below this is the exocuticle layer, sometimes called the

B-layer, also relatively rich in cysteine, approximately 15% beneath the exocuticle, the endocuticle is mechanically the weakest layer of the cuticle (Chatthae*t al,*2011) and low in cysteine content and approximately 3%. Finally, there is an inner layer of intercellular cement with an underlying epicuticle layer. The cuticle does not exhibit any micro fibril/ matrix features that are present within the cortex. All together, these scales surround and provide a protective layer to the interior part of the hair. They also serve to anchor the hair to the skin. The cells are generally flat and overlapping much like the scales of a fish. The size of a cell can be anywhere from 0.5µm to 1 µm thick and 45 µ long (Kolowski *et al* 2012). Each cell is attached at the proximal end from which it grows and is free at the opposite end that points distally. As a result, the hair is less resistant when felt from proximal to distal end rather than vice versa. The scales are usually non-pigmented and appear translucent (Robertson, 2017).

Scales vary in individual shape as well as their overall pattern. This pattern is very important as a diagnostic feature of the hair and important in investigations into the identification of hair, particularly in determining species of mammals (Robbins, 2012b).

The cuticle is subject to change due to factors such as time and activities like washing brushing or environmental factors. It is common, therefore, for the scale pattern to be smooth and distinct near the root end, but broken and damaged to the tip (Fig.2. 6).

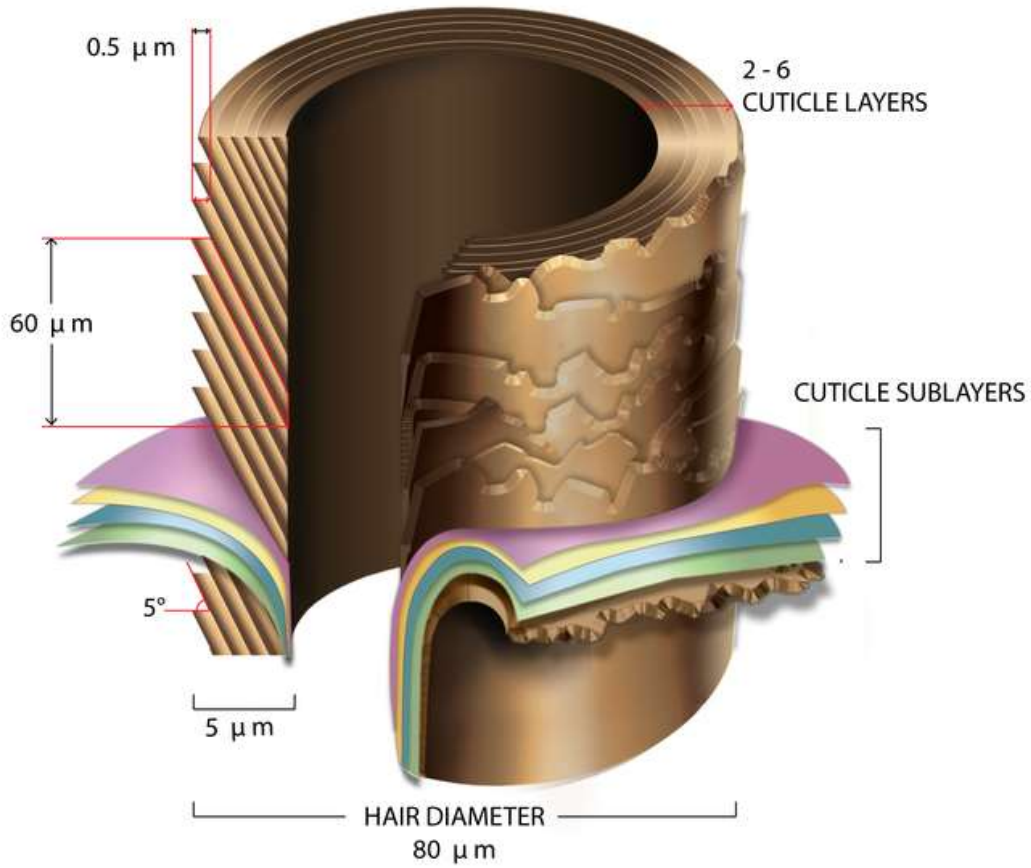

Fig.2. 5: Structure of the cuticle layer of the hair (Robbins, 2012b).

2.1.4 Cortex

The Cortex lies intermediate between the cuticle and the medulla and make up the majority of the hair shaft. It is made up of cells that may vary considerably in their size and shape yet appear identical under the light microscope. Cells are spherical at the proximal end of the hair, but become spindle-shaped as the hair moves distally as a result of the keratinisation process (Taupin., 2004).

After a hair is fully formed, cortical cells may be 20 times as long as they are wide (Tridico, 2014). The cells are arranged with their longitudinal axis parallel to the longitudinal axis of the hair shaft (Thibaut *et al.*, 2010). Cortical cells vary in thickness from 1µm to 6µm and the length is approximately 100µm. Throughout the cells are fibrous microfilaments ranging in diameter from 0.1µm to 0.4µm (Bhushan.,

2010). Between the cells are variable small air spaces called fusi. In the living portion of the hair root, the fusi are filled with water, but as the hair grows and dries out air replaces the water (Lavker*et al*, 2003). Human cells of the cortex generally have an equal amount of fibrillar to nonfibrillar material. Many nonhuman hairs, however, typically have two different types of cells: orthocortical and paracortical.

The cortex of the hair also contains the majority of pigment granules, which develop in the cells by a phagocytosis mechanism in the zone of differentiation and biological synthesis (Sato *et al*, 2006).

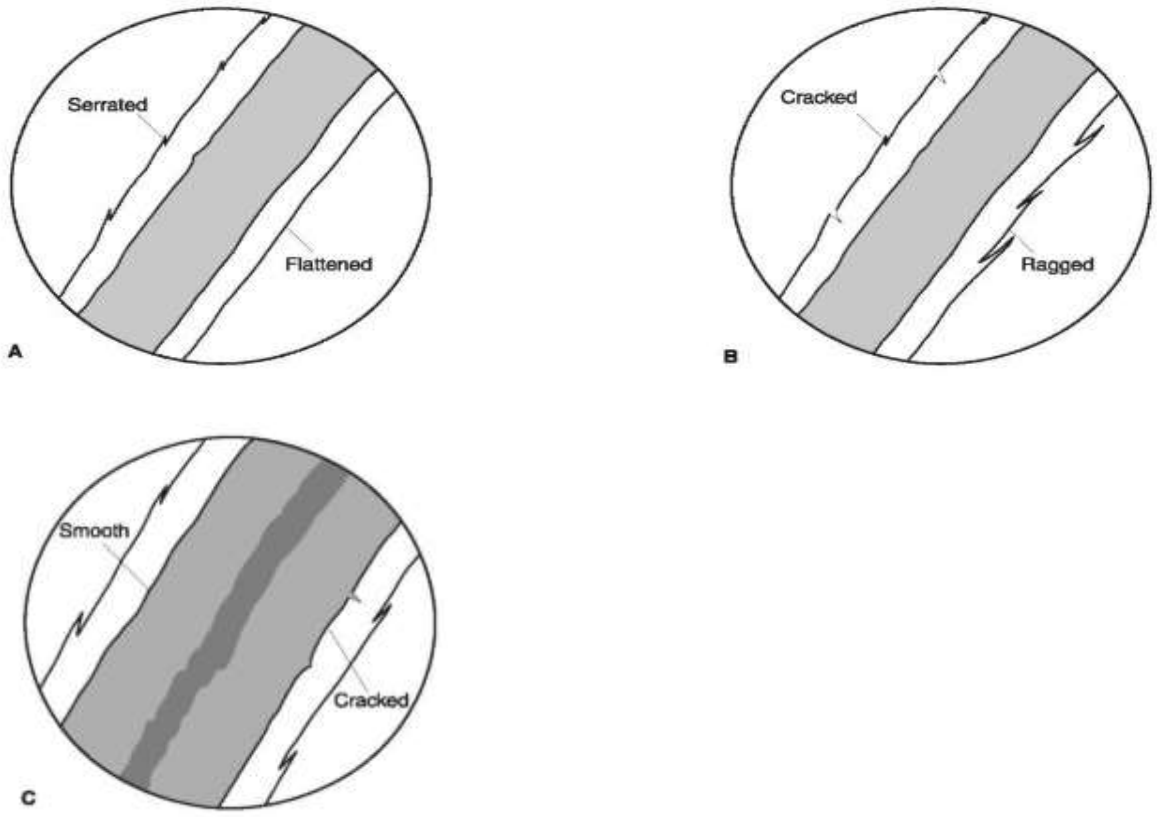

Fig.2.6: Structures of the cuticle layer (Robbins 2012b)

2.1.5 Medulla

At the core of the hair shaft, the cells take on yet another form differing from both the cuticle and the cortex regions (Fig.2.4). This central region is the medulla and though it may not always be seen, it is present in every hair. Thornton stated that, “the

medulla does, in fact, exist in hairs which are casually referred to as being of the 'absent medulla' type, but the medulla cannot be visualized as easily in the absence of air vacuoles.'' Air vacuoles appear as a result of the medullary cells shrinking during growth and keratinisation, the space between these cells subsequently filling with air bubbles. The medulla exists, as a combination of variable and loosely shaped cells connected by a filamentous network and pockets of air. As a result, the medulla's function has been regarded as maintaining hair diameter without increasing the weight of the hair. Medulla has provided evidence for the mystery behind why a hair grows back coarse after it has been shaved off, for it is this region of the hair which is stimulated to enlarge (Jackson and Jackson, 2004). In addition the medulla plays a very important role in providing thermal insulation (Beary, 2014).

According to Robbins (2012b) the medulla provides little to the chemical and mechanical properties of the hair.

Many animal/human hairs lack a medulla within the fine under fur or vellum hairs. According to MAg*et al,* (2014) the percentage of medullated hairs increases rapidly during the first seven month. From the seventh month to second year, the percentage of medulla hairs decreases; a period of great irregularity follows and then the percentage tends to rise slightly at five years (Robertson, 2017).

Occasionally, the medulla may make up the majority of the entire hair. The medulla, like the cuticular scales, forms a unique pattern differing between species and this pattern too can be used for identification purposes. In humans, the medulla is a relatively small fraction of the hair and the pattern appears altogether absent or fragmented along the shaft. However, the medulla pattern can differ in form along a single shaft of hair (Marschner *et al*, 2003). The male shows lesser frequency of the discontinuous and the continuous types of human hair medulla among Japanese as

compared with female. The frequency of the absent of medulla of hair among Japanese is quite different from the India Indian (Chattopadyay*et al,* 1994).

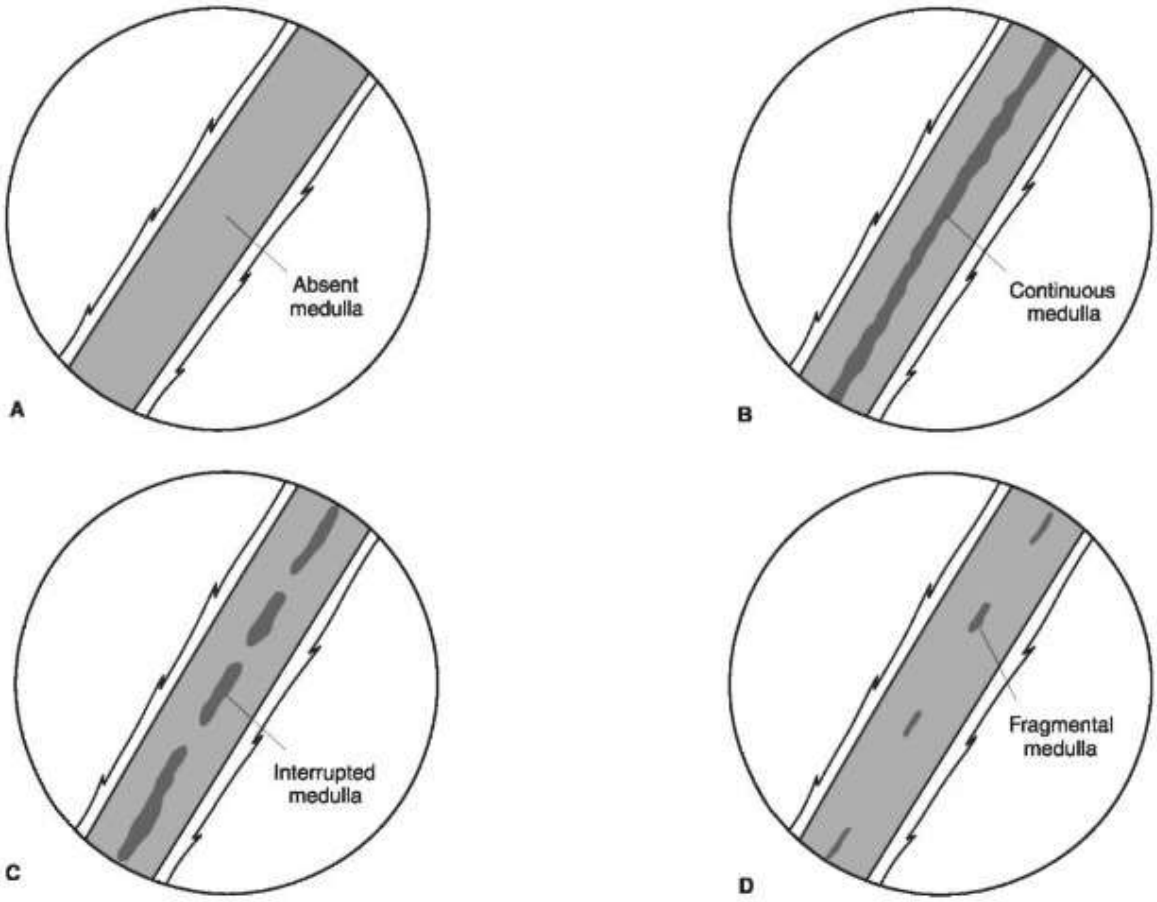

Fig.2.7: Medulla types in human hair (Robbins, 2012b)**.**

2.2 Chemical Components of Hair

2.2.1. Keratin

Keratin, from the Greek word ‘’keras’’ meaning horn, is a generic name referring to the group of highly resistant proteins present in structures such as the hair, horn, nail, feather and skin of mammals (Meyer*et al,*2000). Areida*et al.* (2006) describes a typical keratin molecule as a two-to three stranded cable of highly oriented polypeptide chains wound into a helix with secondary folds or distortions combined with a relatively unorganized matrix.

Keratin can be divided into groups of ‘’hard and soft’’ depending on chemical properties and their content. Hard keratin contains greater than 3% sulfur and is present in the horn and hoof as well as the cortex and cuticle regions of the hair. Soft Keratin contains less than 3%, sulfur and is present in the skin and inner root sheath and medulla. Keratin provides hairs with its durability (Robertson, 2017).

2.2.2 Pigment.

Hair colour is in part, a result of pigment granules existing in either one or all three regions of the hair, but mostly in the cortex. These pigment granules are called melanin: the brown to genetically and chemically different forms: eumelanin also called tyrosine melanin, the brown to black form and phaemelanin the yellow to red form. Eumelanin pigment granules are ellipsoidal in shape and range from 0.8 to1.0µ in length and 0.3 to 0.4 µ in diameter ((Nogueira*et al.*,2006). The darker a hair, the more eumelanin it is likely to contain.

Hair receives pigment only as it is growing. Melanin granules are formed from cells called melanocytes present in the hair bulb. As the cells move distally, melanocytes of the hair matrix donate organelles called melanosomes to the follicular keratinocytes during the growth phase. The melanosomes are then dispersed within the cells of the cortex, resulting in a melanised hair. Hair colour is a function of absorption, reflection and scattering of incident light and these are influenced by the size, number and distribution of melanosomes (Robins, 2005).

Though hair pigmentation appears to be under genetic control, little is known about how this control works in humans (Nakamura *et al.*, 2001). Factors such as hormones, nutrition and metabolic disorders can also play a role in altering hair pigmentation. A common occurrence that can often be anticipated is darkening of the

hair as a child gets older, and greying of the scalp hair as an adult reaches approximately age 40 to 50, though this is highly variable (Wilson *et al*, 2007). Darkening of the hair is brought on by an increase in melanogenic activity, greying by a decrease (Wilson*et al*, 2010).

In most mammals, hair is not of uniform colour. Often hair is banded with multiple colours. In such cases the melanocytes present in the hair bulb have the capability to switch from eumelanogenesis. This switch is related to the cysteine content and is genetically determined (Wilson *et al*.2010).

2.3 Hair Growth

Hair growth occurs in a cycle of three distinct stages. These stages are anagen, catagen and telogen; each one is controlled by androgens, or the hormones that stimulate the activity of male sex glands. (Robbins.2012a). The dynamics of the hair growth cycle are influenced by differences in species, differing body regions and follicle types within the same body region (Wilson *et al*, 2010).

2.3.1. Anagen

The anagen stage is the period of active growth in which there is an increase in metabolic activity in the hair bulb. Macko *et al* (1999) divided the anagen phase into six sub-phases: four initial sub-phases (proanagen), a fifth sub-phase i.e. mutagen. Robbins (2012a) have grouped the processes involved with the preceding sub-phases into one stage; anagen. Because anagen succeeds a resting stage (telogen), cells of the hair bulb undergo a restoration at the onset of anagen. The hair bulb begins to grow into dermis, again around the redeveloping dermal papilla.

The hair itself then begins to form as the follicle is restructured. The hair reaches the sebaceous gland and then with the matrix starts to experience an increased rate of growth, a phase that can last as long as three years in humans. The entire anagen phase lasts from approximately two to six years in human scalp hair (Robbins, 2012a).

2.3.2 Catagen

Catagen is a transition stage between anagen and telogen. During this stage mitotic activity in the matrix of the bulb is strictly slowed and finally discontinued. Though new cells are no longer being produced, existing cells are moving distally into keratinisation region. The cells are contracted, forming a club shape or bulge. Researchers (de Viragh and Meuli, 1995) have argued that the bulge is the actual site of origin for stem cells of the follicle. Regardless, when movement of the cells is completed, the telogen stage begins. Catagen lasts one to two weeks (Wilson *et al*, 2007).

2.3.3. Telogen.

Telogen phase is a complete end of growth. Both cell division and differentiation have stopped. The hair bulb below the sebaceous gland has experienced a harsh reduction in size and there is significant atrophy. The dermal papilla has been diminished to a ball of cells and the dead hair lies in the follicle fastened by its bulge. Eventually the dead hair gets away or forced out by new ones during the next anagen stage, (Weitzel.,1998).

According to Robbins (2012a) telogen lasts only a few weeks. Weitzel (1998) however, describes telogen as lasting three to four months. If a hair is plucked during

telogen, anagen will almost immediately resume; if plucked during anagen, however, more time is needed for regeneration of the follicle before hair growth can begin (Velasco *et al.,* 2009). Roughly, once a human hair is plucked it can take from 61-147 days to regenerate depending on the anatomical region from which it came (Walter, 2001).

2.4. Dynamics of Hair Growth

The growth cycle and the overall rate of growth vary with each hair follicle. In humans, each follicle follows its own cycle, a mosaic pattern of growth independent of surrounding follicles (Macko*et al*., 1999). Human hair is capable of growing 0.35mm per day (Ogle, 1998), approximately 1cm per month, 12 cm per year. Scalp hair normally grows to length of approximately one meter (m) at maturity, yet lengths of 3m or more have been reported (Robbins, 2012b). There is no evidence that cutting or shaving hair affects rates of growth (Robbins, 2012b). The commencement of hair growth in humans starts at the second to fourth month of foetal development. These prenatal hairs, called lanugo, are very fine and short and lightly pigmented (Macko *et al*, 1999). Usually these hairs are located on the upper lip, then chin and eyebrows, and are lost prior to birth or shortly thereafter. Primary hairs replace prenatal hair and are thicker and longer. At this stage the hair makes a marked change in both size and location on the body (Ogle, 1998). The terminal hair once again becomes thicker and longer and spreads to new regions of the body; to the axillary, pubis and beard regions (Ogle, 1998). Head hair can grow to a maximum length of 100 cm at this time. At age 25 to 30, however, there is a shortening of head hair as well as a decrease in thickness (Ogle, 1998). Terminal hairs often become what are called vellus. Vellus hairs will often grow in regions not usually characterized by having hair, for example the nose,

forehead, otherwise bald scalp and eyelids. There are approximately 175 to 300 terminal hairs per cm on the scalp, 50 to 100 hairs are naturally shed each day (Robbins 2012b). In animals, hairs provide insulation (Vanghn*et al.*, 2009).

2.4.1 Stability of Hair over Time

Keratin-rich hair is a strong, stable fiber throughout its lifetime. As yet, no definitive statements have been made regarding the long-term post-mortem stability of the hair fiber (Van der Veen*et al.,* 1999). Hair fiber has been proven to exist for several thousands of years, but just how many thousands it may exist cannot be accurately stated (Tridico *et al.*, 2014).

2.4.2 Variability of Human Hair Morphology

Hair development has been discussed from changes taking place in the skin, to the evolution of the follicle, and finally, change into a mature hair. The different features that make up the hair fiber and the variability that exists within and between these featuresand difficulty related to analysing hair for any purpose lies in the profound differences in morphology existing between local populations of people, but within species or populations, between hairs of differing anatomical regions and finally, along the shaft of a single hair(Tridico, 2015).

2.4.3 Variability along a Single Hair Shaft

Morphological variation along a single shaft of human hair does not outweigh the variation existing between body regions, individuals and local populations (Houck *et al,* 2002). This investigation will proceed on the assumption that the variation existing within a medulla of single hair is relatively minimal compared to the larger differences existing between hair of differing individuals and local populations.

Ogle, (1998) was one of the first to recognize that a single hair shows various types of features. He correlated the patterns of medulla and scales to the overall shaft diameter and concluded that since scales and medullas vary with diameter of the hair shaft, any hair may show different types of these structures in different regions of the shaft.Taupin,(2004) further substantiated Housman's claims with a new set of sample. Weizel, (1998) demonstrated an increase of shaft diameter in cross-sections progressing from the scalp to the tip of the hair contrary to Robertson (2017), claims. "The hair shaft varies little in area and shape of cross-section from place to place except at the tip where the hair is frayed.'' Siegel (2015), noted that the diameter of the hair is usually smaller towards the outer end, but in some cases may also be larger, probably due to the kind and amount of hair dressing used.

The Federal Bureau of Investigation (FBI) also pointed out the potential for single hair shaft variation (Sato *et al*, 2006). It was found that the scales near the root are often smooth edged while those near the tip show rippled edge. This is attributed to the physical and chemical distress experienced by daily brushing, combing, etc (Sato *et al.,* 2006).

Medulla variation is very common in hair of humans. This change in medulla may be accompanied by a change in medulla diameter and cross-section of the medulla shape. The distribution and density of pigment of hair also show variation from the proximal to distal end of the hair according to Weitzel (1998). The FBI pointed out, however, that while the pigment may show variation, butit is concentrated in, the overall colour of human hair is consistent; it is the hair of the animals that show radical colour changes.

2.4.4. Variability of Hairs of Differing Anatomical Regions

The task matching an unidentified hair to the particular body region from which it originated can be extremely difficult. FBI studies stated, "body area determinations may be made with considerable accuracy; but variations may occur which make this determination difficult or impossible" (Ogle*et al.*, 1998). The following traits are useful when identifying body region: shaft diameter, medulla diameter, medulla pattern, tip, texture and number of scales (Robertson, 2017).

Tobin(2007), stated that scalp hair falls into the moderate category. Robertson, (2017) gave a range of scalp hair diameters of 45µm to 190µm.

The medulla ranges from appearing absent to continuous. It is narrow when compared to medulla diameters of hair from other body regions (Houck *et al,* 2002).

Eyebrow and eyelash hairs are fairly short when compared to other hairs with a maximum length of one centimeter, according to Van der Veen*et al*, (1999).

Beard and mustache hairs range in length from two to four millimeter or three cm less. They have a "coarse'' diameter than head hair at .004µm to .121µm or 10µm to 13µm, (Robbins, 2012a). In a cross-section the hair is often irregular or triangular in shape. The medulla is larger in diameter than scalp hair and usually continuous. The medulla is also more developed in beard and mustache hair than in hair from the pubic region (Pausand Cotsarelis., 1999). Hairs from the arm or leg have a length of less than three (3) cm and a ''fine'' shaft diameter displaying little variation. Overall, these hairs have an arc-like shape. The medulla is broad, like that of the beard and mustache and discontinuous. The texture of these hairs is ''soft'' and cross-sectional shape is round(Ogle, 1998). The diameter range, according to Ogle and Fox, (1998) is 15µ, for soft body hair and 70µ for coarser body hair. Auxiliary or underarm and

chest hairs have a moderate shaft diameter with some variation (Nogueira *et al.,* 2006).

Hair from the pubic region is distinguished by the wide variation in shaft diameter causing a ‘’buckling’’ effect. The medulla is relatively broad and usually continuous if present (Deedrickand Koch 2004a).

Morphological features may also vary in hairs from the same anatomical region within a single individual. Lavker.*et al,* (2003) found that the variances within populations are quite comparable to the variances of different hairs from a single individual.

2.4.5. Intrapopulation Variability.

Variability exists within a single shaft and between hairs of differing anatomical regions; there are morphological differences between hairs from different individuals, even individuals of the same local population (Weitzel, 1998).

Weitzel (1998) stated when looking at pigmentation; “as identifying individuals from hair samples under the microscope, it is believed, is impossible unless the hair is marked by some abnormality in its structure or pigmentation.’’

In forensics, hair is a form of evidence considered circumstantial and identification of whether it came from a given subject is based on probability theory. “at best, a hair may provide evidence indicating either that it probably came from a given individual or that it could not possibly have come from this individual,’’ (DiZinno*et al,* 1999). Others state similarly that when comparing an unknown hair specimen with one from a known subject side-by-side, the examiner may conclude: 1) that the hairs are consistent or similar and could have come from the same source; 2) that the hairs are dissimilar and did not come from the same source; or 3) that the hairs possess

characteristics which are not sufficiently defined to arrive at a meaningful conclusion (Velasco *et al*., 2009). Randall. (1994) stated that "The chance of individualizing hair by light microscopy alone is very difficult and in most cases impossible.''

Most investigators have used a combination of the following; colour (hue, value and intensity) and colour throughout the shaft (i.e. radical colour changes), length, tip whether cut, broken, split or finely pointed), root (plucked prior to maturation or naturally shed from the body), diameter of shaft, cuticle thickness and colour, scales, pigment (size, distribution and density), medulla pattern and cell structure, medulla diameter in relation to shaft diameter, cortex appearance and artificial treatment(Robbins,2012b).

Weitzel, (1999) suggested the following as valuable characteristics: colour, diameter, scale count, scale picture; pigment distribution and medullation. He added physical factors such as refractive index, bifringence and chemical factors. Kirk stated that these factors point to the possibility that human head hair may be positively individualized and used in personal identification. Combination of morphological, chemical and molecular analysis appears as the best method for determining intra population variability and personal identification.

2.4.6. Classification and Personal Identification.

Hair morphology has been used in classifying people into groups; stemming as far back as the time of Herodotus(1846) who used the appearance of one's hair as a basis of dividing Xerses army into groups of straight-and woolly- haired people (Weitzel, 1998).

These early studies were fervent activities and certainly made some advances in the field, even if they were fraught with racial biases at the time. One of the ambiguities is that some studies observed differences between continentally-defined populations (traditional geographic races) while others examined and compared local populations and still others used regional types or ethnic or tribal populations (Weitzel, 1998).

Later investigators tend to use a more quantitative approach when observing hair morphology with regard to population differences, though many still added to the uncertainty of hair form.

After the 1960s, studies in hair morphology remain few. Those that do exist lend themselves mainly to the more applied task of identification for forensic purposes (Taupin, 2004). Furthermore; the introduction of new and better technologies has allowed those same hair attributes that were used in early studies to be looked at in a closer and more effective way (Thibaut*et al*., 2010).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study site

Samples was collected from Kwame Nkrumah University Science Technology campus

3.2. Sample.

.Analysing human hair required the use of a routine set of detailed procedures to be followed constantly from one sample to the next. Thus the methodology began with the acquisition of the hair samples followed by a set of laboratory procedures which included cleaning the hair and the examination procedures using the Comparison and Compound microscopes.

3.2.1. Methods

3.2.2 Hair Acquisitionand Examination

Ethical consideration was sought from KNUST medical school. Hair sample was acquired from individuals with the consent between the ages of 15-25 years; this is because study has shows that they are the age groups that usually commit crime in Ghana.

For every individual hair donor, hair sample was collected from five different parts of the scalp using scissors with the consent. Samples were examined with compound and comparison microscopes which brought out details of a hair specimen and comparison microscopes also allowed the researcher to analyse two pieces of hair evidence side-by-side.

The following factors were included in analysing the data: place of birth (Towns and Regions), place of residence for the majority of their life, age, whether or not their hair had been chemically altered.

3.2.3. Questionnaire

Questionnaire or forms were given to the sample population in order to get the age group and to verify whether their parents and grandmother are from the same ethnic group.

The hair sample collected was analysedusing comparison microscopes for identification, comparison and calculation of various frequencies of the medulla types among the study population.

The result was then used to generate or develop a partial database of hair for the country.

As hair was acquired from each of the sampled populations, it was placed into a Ziploc bag and labeled with the population name and an accession number assigned to each individual i.e. 'DA01' to 'DA200' for Dagomba and 'A01' to 'A200' for Ashanti and hairs from each individual were stored in one Ziploc bag. While conducting analysis, the researcher was only aware of the accession number and therefore randomly selected to the two hundred (200) sample origin in order to avoid any biases.

3.2.4. DAGOMBA

The hair samples were collected from two hundred (200) individual students of Dagomba ethnic group after signing questionnaire. The individuals were students of KNUST from the Northern part of Ghana and ranged in age from 15 to 25 and above

which includes both sexes. The hair was collected with support from other colleagues from lecture room to lecture room.

3.2.5. ASHANTI.

The hair samples were collected from two hundred (200) individual students of Ashanti ethnic group after signing questionnaire. The individuals were students of KNUST from the Ashanti Region part of Ghana and ranged in age from 15 to 25 above which included both sexes. The hair was collected with support from other colleagues from lecture room to lecture room. The population is somehow one of the biggest ethnic groups in Ghana today and plays an important role in Ghana's development and are found in the middle part of Ghana.

3.3. EXAMINATION PROCEDURES

Each hair specimen was examined individually under a Leica Compound microscope. The microscope was connected to a Sony Trinitron colour video monitor by a Javelin Smartcam Video camera. The monitor allows a full-screen view microscope image. In addition, the monitor was connected to a Gateway 2000 P-90 computer. Computer imaging allows a good view of the medulla of hair shaft. As data was gathered from each hair, it was input into a database.

Wet-mounting was used to prepare specimens for microscopic examination. Using a mounting fluid with a refractive index close to that of the hair reveals the medulla and other internal structures of the hair. Glycerol (glycerin) was used to make a temporary wet mount of the samples.

Following steps were followed to wet-mount specimens:

Amicroscope slide was labeled with a description of the specimen.

Adrop or two of mounting fluid was smeared in the center of the microscope slide.

Using forceps, the specimen was placed in the center of mounting fluid and the ends were looped back until they adhered to the mounting fluid.

A coverslip was carefully placedover the specimen and pressed into place, making sure no air bubbles are trapped beneath it.

Excess mounting fluids on the cover slip were removed using disposable pipettes or paper towels. The steps were repeated for each of the remaining specimens till all samples were examined.

3.3.1. IMAGING

Analysis of hair attributes utilizes a combination of both microscopic viewing and computer imagings; however, computer images were mainly used for evaluating attributes simply because it allowed for more detail to be seen. The image was captured in Optimas 6.0 and saved in a file on an optical hard drive.Optimas 6.0 allowed various calibrated measurements to be applied to hair images at each magnification of the microscope (100X, 250X and 400X).

The Stored images were then transported to Adobe Photoshop, which allows enhancement of the image. Each image followed a routine enhancement procedure, which usually includes rotating the image in a consistent orientation. This placed the hair so that it lies horizontal or vertical on the screen. This was followed by the adjustment of the brightness and contrast of the image. Also the image can be sharpened entirely or only along the edges if necessary. When the image was of an acceptable quality, the background was erased and converted to white to avoid interference with the image of the medulla.

There was a fine line between enhancing image for better viewing and enhancing an image to the extent that the information is manipulated to the point where it is no longer revealing perfect information about the hair. Some amount of bias was unavoidable. In this methodology, images were improved only to bring the already existing attributes into better view of hair (medulla) and caution was taken to avoid altering the integrity of the attributes.

After the improvement or enhancement was completed, the image was transported back to Optimas 6.0 where it was eventually stored. At this point measurements were takenof the hair shaft and medulla for the calculation of medullar index.

3.3.2 Medulla Examination.

Absence or presence of the medulla was noted. If present whether the medulla was continuous, broken, or fragmentary/ discontinuous was noted. The Ocular micrometer was usedto measure the width or diameter of the medulla and this was used to calculate the medullar index (MI) using the formula stated below. Groups of data sharing at least one common characteristic were divided into smaller groups based on differences and similarities of at least one additional characteristic.

3.3.3. Medullar Index

The medullar index (MI) is simply the ratio of the diameters of the medulla and the shaft of the hair. For example, if medulla diameter is 15µm and shaft 100µm, the MI as 0.15. MI is one easy way to discriminate human hair. Human hair has MI of 0.35 or lower (usually much lower) while animal hair has a high MI value (Weitzel 1998).

$$\mathrm{MI} = \frac{medulladiameter}{hairshaftdiameter}$$

CHAPTER FOUR

4.0. RESULTS.

Hair is an appendage of the skin that grows out of an organ called the hair follicle. It is composed primarily of the protein keratin. Hair is a common feature in all mammals and therefore its relevance is not limited to human even in forensic investigations.

Each species of animal possesses hair with characteristic length, colour, shape, root appearance, and internal microscopic features that distinguish one animal from another(Araujo 2010). Variability also exists in types of hairs found on different parts of the body; head, pubic region, arms, legs and other body areas.

Human hair is one of the most frequently found pieces of evidence at the scene of a violent crime (Brown and Davenport, 2011). It can provide a link between the criminal and the crime due to its varying characteristics within and between populations. Analyses of hair can be carried out by studying the characteristics of the shaft by microscopy or by DNA analysis of the follicular tag (Katz, 2005). Morphological analysis of the shaft by microscopy is usually focused on either the cuticle (usually for specie identification) or on the medulla.

From hair one can determine; if the source is human or animal, the race (sometimes), origin of the location on the source's body, whether the hair was forcibly removed, if the hair has been treated with chemicals, if drugs have been ingested etc.

Figures 4.1-4.7 below are microscopic images of some of the hair samples analyzed. They show the variations in medulla type and medulla diameter.

Variability between Medulla Types among the Ashantis and Dagombas

Figure 4.1 is a sample obtained from the Ashanti population. It is also an example of hair strand with absent medulla. In the Ashanti population, this hair medulla type is the most common.The sample's shaft diameter is 159.5µm

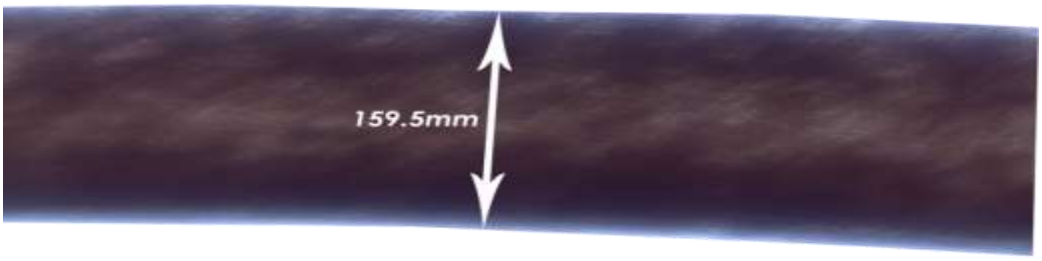

Fig. 4.1**:** Hair sample from Ashanti showing absent medulla type.

Fig. 4.2 is a sample obtained from the Dagomba population. Its microscopic image shows the sample lacked any form of medulla (absent medulla). The sample has a hair shaft diameter of 133.6µm. The Dagomba population, like the Ashanti population has this hair medulla type being the most common.

Fig. 4.2: Hair sample from Dagomba showing absent medulla type.

Figure 4.3: is a sample from the Dagomba population. It shows the continuous medulla type. Among the Dagombas about 33.5% of the population possesses the continuous type of medulla.It has medulla diameter of 28.8µm and a hair shaft diameter of 171.2µm. This happens to be the most dominant medulla pattern type.

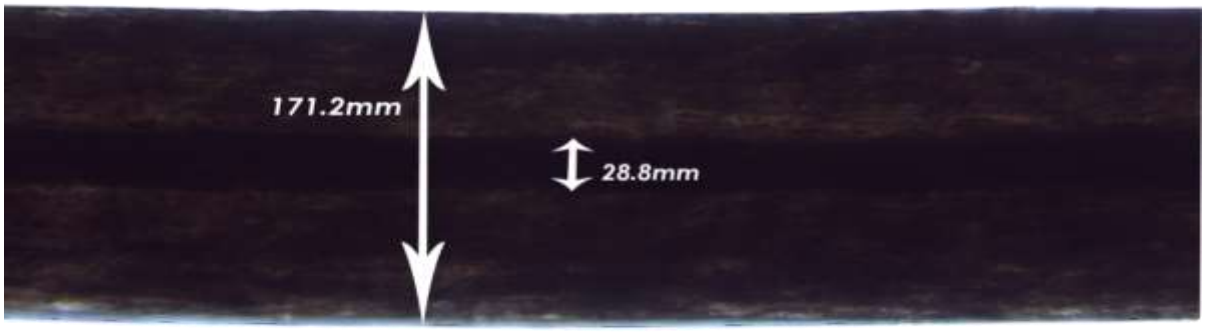

Fig. 4.3:Hair sample from a Dagomba showing continuous medulla

The Fig. 4.4 is the microscopic image of a hair sample of a Dagomba showing fragmented medulla type. The hair shaft diameter (161.1µm) is far larger than the medulla diameter (20.6µm).

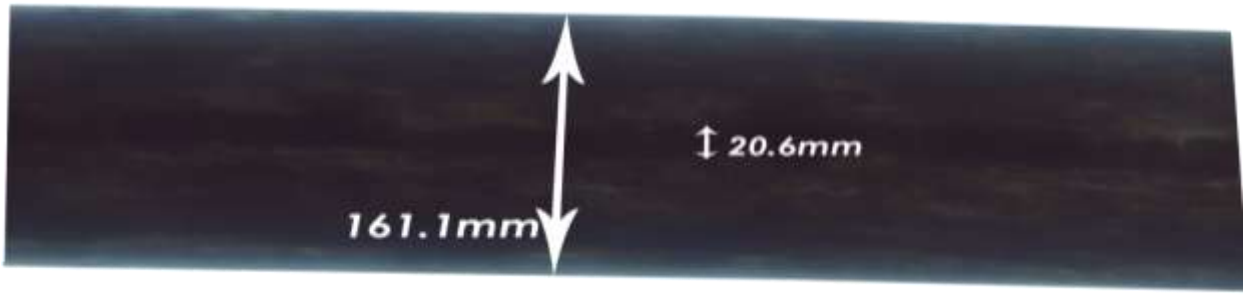

Fig. 4.4: Hair sample from a Dagomba showing fragmented medulla type.

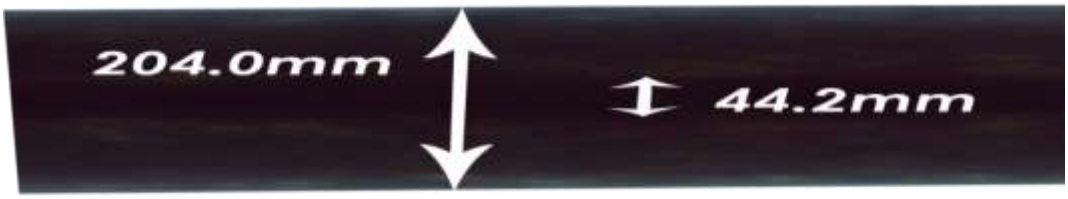

Fig. 4.5: Hair sample from an Ashanti showing continuous medulla.

Fig. 4.5 is a sample from the Ashanti population. It shows continuous medulla type. In the Ashanti population, only about 17% possesses this medulla type. The shaft and medulla diameters are 204.0µm and 44.5 µm respectively.

The Fig. 4.6 is the microscopic image of a hair sample of an Ashanti showing fragmented medulla type. The hair shaft diameter (171.7µm) is far larger than the medulla diameter (23.8µm).

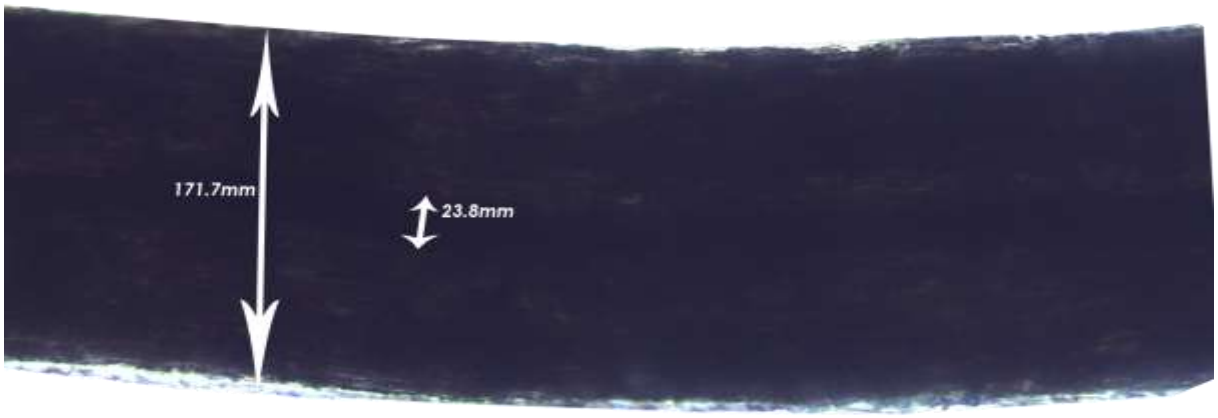

Fig. 4.6: Hair sample from an Ashanti showing fragmented medulla

Fig. 4.7 is a microscopic image of a hair sample obtained from an Ashanti showing discontinuous medulla. The hair shaft diameter is 156.4 µm for the sample illustrated.

Fig. 4.7:Hair sample from an Ashanti showing discontinuous medulla type.

Hair evidence is class evidence and can be used to back up other circumstantial evidence. It is evident from the above figures (Fig 4.0 - 4.7) that the medulla diameter is always equal or less than one-third of the hair shaft diameter, a feature that distinguishes human hair from animal hair (other mammals). Forensic analysis of hair has been used as a tool for making determinations at crime scene for several years (MAgr *et al*, 2014).

The characteristics of hair medulla that prove to be useful in forensic analysis include the medulla diameter and medulla/ shaft diameter ratio (all are based on measurements).

Table 4.1 shows the averages of the medulla diameter, hair shaft diameter and the medulla index for the Ashanti population. The mean hair shaft diameter (HSD) for the Ashanti population was 148.235µm. The hair shaftdiameter was well expected to be higher than the medulla diameter (25.08µm) since the medulla diameter is a component of hair diameter. The medulla index of the hair is the maximum breadthof the Medulla Diameter per Hair Shaft Diameter of a population. The average medulla index for the Ashanti population is 0.082. The medulla index provides a unique characteristic of a population and it has been used by several researchers in describing different populations in recent times (Benner and Levin, 2005).

Table 4.1: Averages of medulla types among Ashanti population studied.

Attributes of hair	Total	Average (Mean)µm
Hair shaft diameter (HSD)µm	29647	$\frac{29647}{200} = 148.235$
Medulla diameter (MD)µm	2433.2	$\frac{2433.2}{97} = 25.08$
MD/HSD(µm)	0.082	

The frequency of medulla types in the Ashanti population has been summarized in table 4.2 and Fig. 4.1 below. Over 103 sample units representing 51.5% of the total sample size of the Ashanti population had no medulla (medulla absent), 15.5% had fragmented medulla and 16% had discontinuous medulla. The continuous type of medulla represents about 17% of all medulla types in the Ashanti population.

Table 4.2: Frequency of medulla types among the Ashanti population

Medulla Type	Continuous	Discontinuous	Fragmentary	Absent
Percentage(%)	17	16	15.5	51.5

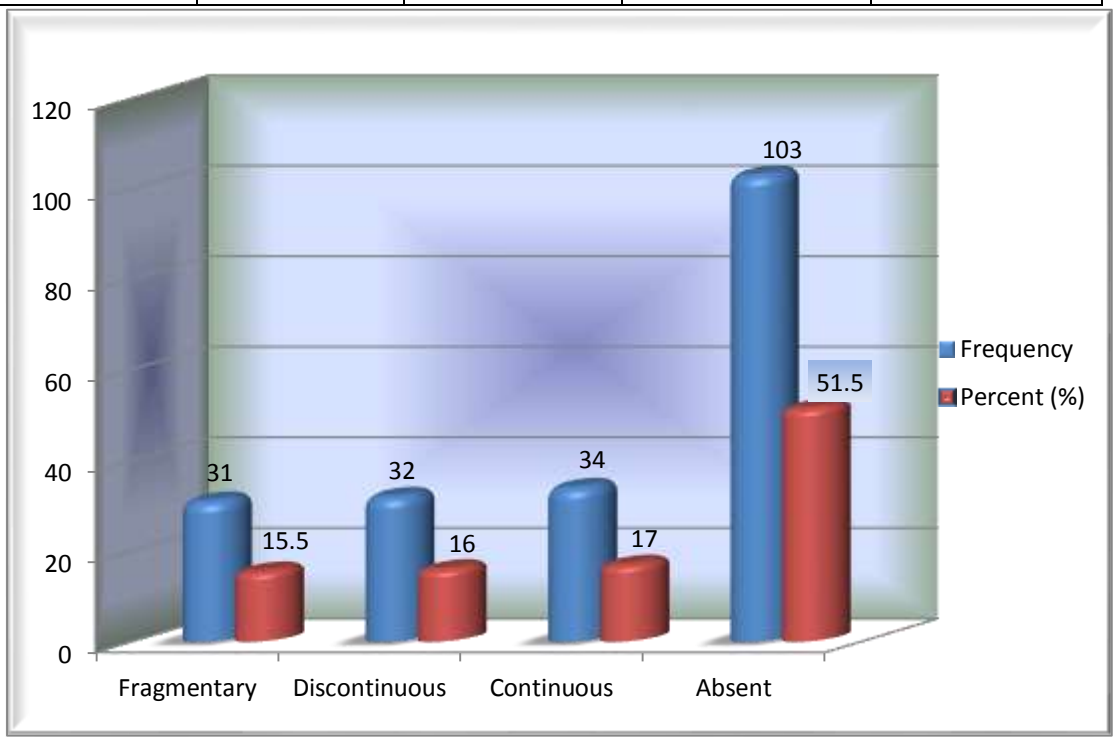

Fig.4.8:Histogram ofMedulla Types among the Ashanti population.

The greater percentage of the Ashanti population having no medulla therefore makes it very difficult to rely on the use of the medulla types to trace suspects at crime scenes among this ethnic group.

The results clearly indicate that the number of individuals without medulla is approximately equal to those with medulla variables (48.5%). This implies that using medulla type to trace suspects present at crime scene is a fifty-fifty chance among the Ashanti's.

Table 4.3 below summarizes the averages of medulla diameter (MD), hair shaft diameter (HSD) and the medulla index for the Dagomba population. The average

medulla diameter and the average hair shaft diameter are 27.81 and 156.25 respectively. The medulla index for the population is 0.12 which is very similar to the results obtained in the Ashanti population as shown in Table 4.1 above.

Table 4.3: Averages of Medulla Types among Dagomba population studied.

Attributes of hair	Total	Average (Mean)
Hair shaft diameter (HSD)µm	31250.66	$\frac{31250.66}{200} = 156.25$
Medulla diameter (MD)µm	3726.60	$\frac{3726.6}{134} = 27.81$
MD/HSD	0.12	

Comparing the medulla types of the Ashanti's (Table 4.1) with those of the Dagombas (Table 4.3), there is no statistical difference (p-value = 0.522) between the two ethnic groups. This therefore confirms the overall relationship between these two ethnic groups (Taupin, 2004). Since the medulla index provides a unique characteristic of a population and used to describe same, the closeness of the values for the two groups is a furtherconfirmation of their relationship. The mean medulla diameter and hair shaft diameterof the Dagomba were higher than those of the Ashanti population as shown in table 4.3 and 4.1 respectively.

The frequency of medulla types obtained in the Dagomba population is shown in table 4.4. It can be seen that 67 (33.5%) of the sample units have Continuous type of medulla while 38 (19%) of the population show Discontinuous medulla type. A smaller proportion of 29representing 14.51% have Fragmented medulla type.

Table 4.4:Frequency of medulla types among the Dagomba.

Medulla Types	Continuous	Discontinuous	Fragmentary	Absent
Percentage(%)	33.5	19.0	14.5	33.0

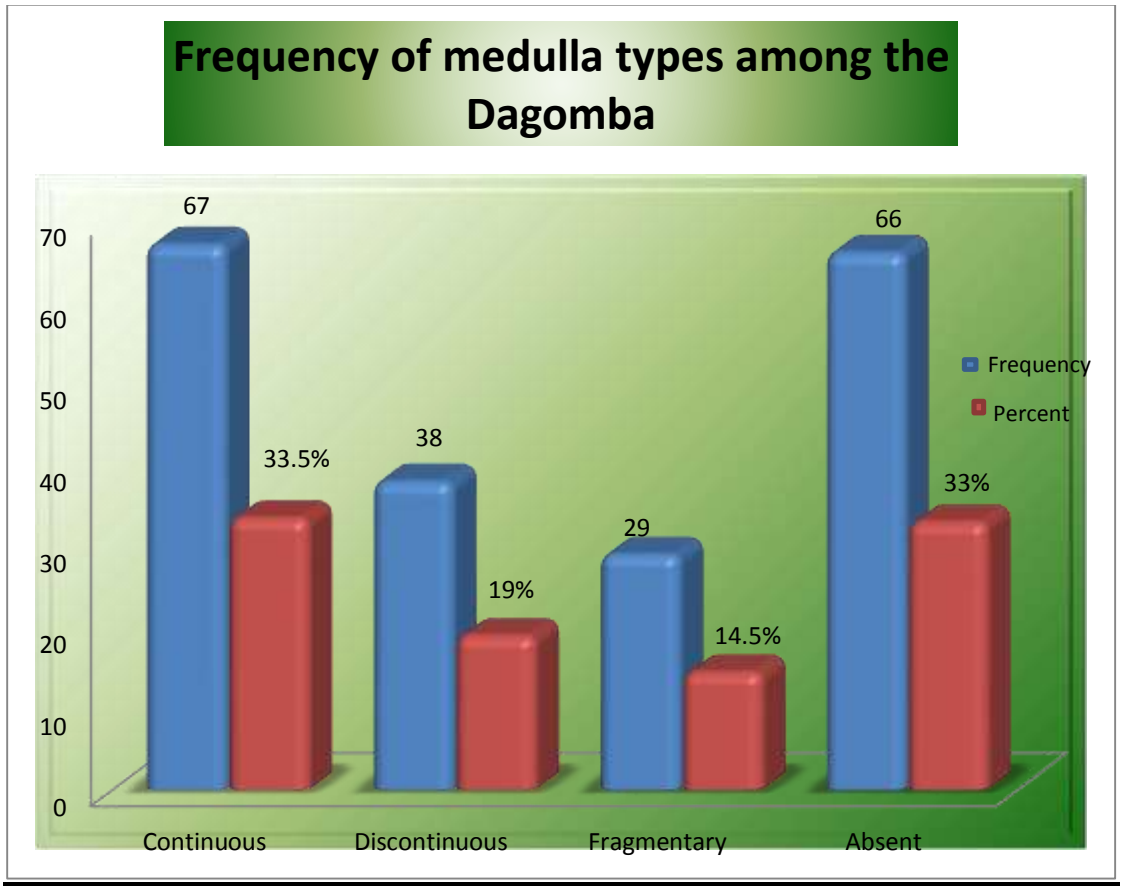

Fig.4.9: Histogram of Medulla Types among the Dagomba population studied.

Table 4.5 Frequency of medulla types among the two ethnic group.

Medulla types	**Continuous**	**Discontinuous**	**Fragmentary**	**Absent**
Ashanti(µm)	34	32	31	103
Dagomba(µm)	67	38	29	66

Figure 4.9 is a graphical presentation of the medulla type distribution within the Dagomba population. Unlike the Ashanti population, the Dagomba population is characterized by a higher percentage of medulla presence (14.5% +19% +33.5%). The percentage of individuals without medulla (33%) is almost equal to those with continuous medulla type alone (33.5%) as also shown in Table 4.4. According to Macko *et al*, (1999) forensic hair analysis has limitations. Humans share hair characteristics, like colour and texture, so hair alone cannot positively identify someone as perpetrator. Comparing the two histograms it can be deduced that the two ethnic groups have almost the same chart and look the same. Hair analysis can point to a suspect, but, without DNA evidence, forensic hair analysis alone cannot state positively that a specific hair samples came from one particular individual and not another. Even if the trace hair matches the known hair sample from a suspect, it would probably also match samples from many other individuals. But even with this limitation, forensic hair analysis is considered one of the most valuable tools available to crime investigators (Ogle, 1998).

Table 4.6 is the summary of the test for significance of the variation between the Ashanti and Dagomba populations. From the paired sample T test analysis, it can be seen that the variation between the two populations in terms of hair shaft diameter (HSD) was insignificant. At 95% confidence level, the p-value was 0.745 which is greater than the α-0.05. The variation between the populations for medulla diameter (MD) was also not significant at α-0.05 (p-value 0.522). On the bases of these results, one may conclude that the Asanti and Dagomba populations of Ghana do not vary significantly. However, Africa has been described as the most genetically diverse continent in the world (Tridico *et al*, 2014), therefore this result was least expected for

populations that are geographically, culturally and historically diverse like the Ashanti and Dagomba populations of Ghana. This may be due to the close relationship between the ethnicgroups. According toliterature migration and age can affect the medulla of human hairs. As an individual is aging the structure of the medulla also changes, as an individual migrate environmental factors like weather affect the medulla structure of the hair shaft. Medulla types hence its utility for forensic hair examination is limited (Chattopadhyay, *et. al*. 1994).

Table 4.6: Test for significance of variation for hair shaft diameter and medulla diameter between the two populations.

Paired Samples Test

		Paired Differences					T	df	Sig (2 tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
HSD	Ashanti – Dagomba	-2.00202	86.40484	6.14052	-14.11162	10.10758	-.326	197	.745
MD	Ashanti – Dagomba	-.00968	.11834	.01503	-.03973	.02037	-.644	61	.522

4.1.1.DISCUSSION

From observation of the microscopic image of this work, it is evident that some level of differences exists between the Ashanti and Dagomba populations of Ghana (Tables 4.1 and 4.3). However, it is difficult or almost impossible to rely on the results for any kind of identification at this level since the differences are all insignificant (Table 4.5). Weitzel, (1998) stated that variability exists within a single shaft and between hairs of differing anatomical regions. He also stated that there are morphological differences between hairs from different individuals, even individuals of the same local population (Weitzel, 1998). The results of this work confirmWeitzel's opinion that morphological differences exist within hairs from different individuals within a population and that these differences may be strong enough to shadow inter-population variations in hair. The results can best be explained by the fact that the intra-population variation may be higher thus suppressing the variation between the two populations.

In the Ashanti population 93 exhibited a fragmentary/continuous/discontinuous medulla pattern and in 103 cases; the medulla was absent altogether, whilst in the Dagombapopulation134 samples exhibited a fragmentary/continuous/discontinuous medulla pattern except in the **66** cases where the medulla was absent. In each population, at least one sample showed an absent medulla. Robertson (2017) suggested that whether or not a medulla is present or absent is probably not a result of the local population variability, but rather dependent on each hair and location of the hair. The statistical analysis of the medulla types also indicates that there is no significant difference between the two populations. This observation also confirms the suggestion made by Robertson(2017) when he stated that the presence or absence of

the medulla is not a result of the population variation, but dependent on each hair and the location of the hair. There were varying medulla type characteristics within most of the sample units and these variations were in no definite order. This makes it very difficult to rely on medulla type characteristics alone for forensic individualization.

In forensics, hair is a form of evidence considered circumstantial and identification of whether or not it came from a given subject is based on probability theory. "At best, a hair may provide evidence indicating either that it probably came from a given individual or that it could not possibly have come from this individual,'' (DiZinno*et al,* 1999). Others stated similarly that when comparing an unknown hair specimen with one from a known subject side-by-side, the examiner may conclude: 1) that the hairs are consistent or similar and could have come from the same source; 2) that the hairs are dissimilar and did not come from the same source; or 3) that the hairs possess characteristics which are not sufficiently defined to arrive at a meaningful conclusion (Ogle, 1998). However, Randall (1994) stated that "The chance of individualizing hair by light microscopy alone is very difficult and in most cases impossible.'' The current research confirms Randall's statement since the findings of this work are inconclusive on individualization. According to the American Association of Physical Anthropologists, (Weitzel, 1998) and Lavker *et al* (2003) the distribution of physical traits resembles the distribution of genetic variation within and between human populations. This may be due to the fact that this investigation focused on only one parameter of hair (medulla).

Some investigators have used a combination of morphological features of hair to achieve stronger conclusions. The frequently used parameters include colour (value and intensity) and colour throughout the shaft (i.e. radical colour changes), length, diameter of shaft, cuticle thickness and colour, scales, pigment (size, distribution and

density), medulla pattern and cell structure, medulla diameter in relation to shaft diameter, cortex appearance and artificial treatment (Robbins, 2012a). Weitzel (1998) added that physical factors such as refractive index, bifringence and chemical factors could also be added to enhance the results of hair analysis. Tridico *et al.,* (2014) however reported that these factors point to the possibility that human head hair may be positively individualized and used in personal identification. Combination of morphological, chemical and molecular analysis appears as the best method for determining intra-population variability and personal identification. The findings of this research can therefore serve as an important part of a database of morphological characteristics of hair for the Ashanti and Dagomba populations of Ghana. According to Taupin (2004) "When you are dealing with hair morphology and issues of race you're dealing with range", in which case the results for this work is expected since it is almost impossible to have exclusively significant differences by using only medulla characteristics. The results however will be good and very important in the resolution of crime when combined with other parameters.

Regarding the contribution to forensics in Ghana, even though the study does not provide a method for determining the exact local population associated with an unknown hair of the above named ethnic groups, DNA from their hair would help to support conclusions made from morphological analysis of hair in Ghana.

CHAPTER FIVE

CONCLUSIONAND RECOMMENDATION

5.1. Conclusion

The study showed that medulla morphologicalcharacteristics (ie. medulla index, medulla diameter and hair shaft diameter) of human hair cannot be used to differentiate Ashantifrom Dagomba ethnic. Thus medulla morphology alone is not adequate information for answering some forensic questions. However, thiscan be useful when combined with others such as DNA, finger prints and footprint.

5.2. Recommendations

The following suggestions are made towards future researches.

1. A similar study using samples collected from remote areas of the study population would be very useful to determine statistical significance because migration can affect phenotypic variability of an individual.
2. Utilizing a broader geographic scope would also help to further test variability between populations as well as theories regarding the movement ofpeople.

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APPENDICES

MD	-	Medulla Diameter
HSD	-	Hair Shaft Diameter
S/NO	-	Serial Number
µM	-	macrometer

Questionnaire

Ethical approval

The Main Frequency Table 1 And 2

Table 1

ASHANTI.

S/No	Hair Shaft Diameter/mm	Medulla Diameter (mm)	MD/HSD
1	99.0	-	-
2	99.5	49.7 discontinuous	0.5
3	104.2	17.9 fragmentary	0.2
4	151.3	-	
5	171.7	-	
6	114.6	23.8 continuous	0.2
7	165.6	-	
8	114.3	34.7discontinuous	0.3
9	171.2	-	
10	88.4	28.8 continuous	0.3
11	88.9	-	
12	133.6	-	
13	183.4	-	
14	173.8	-	
15	196.9	46.6 continuous	0.2
16	174.5	41.5 continuous	0.2
17	156.4	32.0 fragmentary	0.2
18	148.8	16.9 discontinuous	0.1
19	159.8	-	
20	139.2	-	
21	143.2	23.0 discontinuous	0.2
22	143.7	35.5fragmentary	0.3
23	140.5	-	
24	141.5	-	
25	133.3	40.5 discontinuous	0.3
26	122.2	-	

27	137.6	-	
28	134.1	10.6 continuous	0.1
29	130.9	22.0 discontinuous	0.2
30	142.6	-	
31	134.1	16.9 continuous	0.2
32	140.5	-	
33	141.5	21.0 fragmentary	0.2
34	124.6	32.0 discontinuous	0.3
35	131.0	-	
36	134.6	-	
37	119.4	19.8 continuous	0.2
38	113.9	-	
39	116.2	-	
40	121.4	-	
41	123.0	32.8 discontinues	0.3
42	135.7	20.8 continuous	0.2
43	108.8	18.9 fragmentary	0.2
44	135.7	20.5 continuous	0.2
45	108.6	-	
46	109.5	19.2 continuous	0.2
47	174.2	-	
48	168.3	10.9 continuous	0.1
49	136.6	15.9 fragmentary	0.1
50	189.2	-	
51	129.2	15.3 discontinuous	0.1
52	130.1		
53	117.3	-	
54	119.9	21.0 continuous	0.2
55	168.2	18.9 fragmentary	0.1
56	160.9	-	
57	120.0	-	
58	192.0	30.5 continuous	0.2
59	138.3	-	

60	145.5	19.7 fragmentary	0.1
61	152.3	-	
62	172.9	35.2 discontinuous	0.2
63	180.3	-	
64	171.5	19.9 continuous	0.1
65	122.1	-	
66	115.4	25.0discontinuous	0.2
67	113.9	-	
68	118.3	25.3 continuous	0.2
69	178.0	-32.1 discontinuous	0.2
70	112.3	-	
71	129.0	-	
72	139.0	-	
73	135.3	15.3 continuous	0.1
74	120.0	42.0 fragmentary	0.4
75	159.3	23.5fragmentary	0.2
76	180.5	-	
77	139.5	-	
78	143.7	18.9 continuous	0.1
79	171.8	-	
80	171.9	20.6 discontinuous	0.1
81	155.3	-	
82	135.9	10.0fragmentary	0.1
83	179.3	-	
84	185.0	39.8 fragmentary	0.2
85	193.0	-	
86	153.9	19.9 discontinuous	0.1
87	115.8	-	
89	138.9	-	
90	138.9	-	
91	153.0	27.8 discontinuous	0.2
92	167.0	-	
93	189.0	-	

94	193.0	29.0 fragmentary	0.2
95	197.0	-	
96	188.3	32.0 continuous	0.2
97	123.0	-	
98	138.4	-	
99	163.8	18.9 continuous	0.1
100	179.8	-	
101	188.3	-	
102	182.3	19.0fragmentary	0.1
103	120.9	-	
104	1147.8	-	
105	121.1	14.0 fragmentary	0.1
106	125.0	-	
107	132.3	18.9 discontinuous	0.1
108	144.6	-	
109	156.0	-	
110	172.3	23.1 continuous	0.1
111	157.0	19.3 fragmentary	0.1
112	181.2	21.3 continuous	0.1
123	110.0	29.3 discontinuous	0.3
114	180.3	32.0 continuous	0.2
115	127.3	41.0fragmentary	0.3
116	130.1	25.0 discontinuous	0.2
117	170.3	27.9 discontinuous	0.2
118	180.0	23.9 fragmentary	0.1
119	172.0	26.3 continuous	0.2
120	150.0	-	
121	160.0	-	
122	192.0	29.0 continuous	0.2
123	153.0	-	
124	179	42.6fragmentary	0.2
125	124.0	-	
126	122.0	-	

127	130.0	23.0 discontinuous	0.2
128	138.0	-	
129	114.0	-	
130	107.0	-	
131	132.0	19.9 discontinuous	0.2
132	135.0	-	
133	118.0	21.0fragmentary	0.2
134	110.0	-	
135	113.0	20.9 discontinuous	0.2
136	120.9	-	
137	173.0	29.4 fragmentary	0.2
138	123.0	-	
139	121.0	15.9 discontinuous	0.1
140	251. 9	-	
141	188.2	19.9 fragmentary	0.1
142	172.9	-	
143	182.7	22.9 fragmentary	0.1
144	133.5	-	
145	149.0	-	
146	153.8	20.9 continuous	0.1
147	181.0	16.2 discontinuous	0.1
148	153.3	-	
149	121.0	-	
150	110.8	14.0 fragmentary	0.1
151	135.0	-	
152	159.0	-	
153	173.9	18.5 continuous	0.1
154	145.9	-	
155	124.8	23.8 discontinuous	0.1
156	126.0	-	
157	181.9	42.3 continuous	0.2
158	146.7	-	
159	132.0	-	

160	124.9	38.0fragmentary	0.3
161	125.2	-	
162	134.1	-	
163	145.0	43.3 fragmentary	0.3
164	143.9	-	
165	156.9	27.8fragmentary	0.2
166	138.2	-	
167	191.2	32.8 continuous	0.2
168	109.3	-	
169	112.0	44.2 discontinuous	0.4
170	165.8	45.3 continuous	0.3
171	179.1	-	
172	173.8	18.0 fragmentary	0.1
173	111.8	-	
174	123.0	17.9 continuous	0.2
175	209.0	-	
176	179.0	-	
177	235.4	13.9 fragmentary	0.1
178	159.3	-	
179	156.5	17.7discontinuous	0.1
180	147.0	-	
181	203.0	43.3fragmentary	0.2
182	185.0	-	
183	125.0	18.9 continuous	0.2
184	132.0	-	
185	255.9	22.9 discontinuous	0.1
186	145.0	-	
187	149.1	18.9 discontinuous	0.1
188	152.6	-	
189	157.8	15.7continuous	0.1
190	163.0	-	
191	145.9	18.6 discontinuous	0.1
192	181.1	-	

193	185.2	15.5 fragmentary	0.1
194	112.9	-	
195	119.8	24.5 continuous	0.2
196	179.0	-	
197	138.0	23.8 discontinuous	0.2
198	173.1	-	
199	188.0	19.3 discontinuous	0.1
200	190.0	18.9 continuous	0.1

Table 2

DAGOMBA

S/NO	HSD (MM)	MD (MM)	MD/HSD
1.	159.5	19.0 fragmentary	0.1
2.	129.5	28.6 continuous	0.2
3.	161.1	20.6 discontinuous	0.1
4.	128.6m	-	
5.	204.0	44.2 continuous	0.2
6.	152.3	40.5 continuous	0.3
7.	142.3	29.4 continuous	0.2
8.	132.5	19.7 continuous	0.2
9.	153	-	
10.	152.7	11.9 continuous	0.1
11.	205.0	-	
12.	193.0	19.3 fragmentary	0.1
13.	185.0	-	
14.	175.0	20. 9 continuous	0.1
15.	133.0	35.0 discontinuous	0.3
16.	129.0	43.0 continuous	0.3
17.	130.1	15.0 continuous	0.1
18.	153.0	-	

19.	183.1	20.3 fragmentary	0.1
20.	179.0	-	
21.	177.2	-	
22.	181.9	17.0 continuous	0.1
23.	183.5	18.5 continuous	0.1
24.	183.5	19.2 continuous	0.1
25.	179.9	25.0 discontinuous	0.1
26.	219.0	26.0 discontinuous	0.1
27.	143.0	-	
28.	145.0	-	
29.	187.9	24.0 fragmentary	0.1
30.	185.1	-	
31.	192.1	28.2 fragmentary	0.2
32.	195.9	-	
33.	207.3	30.0 continuous	0.2
34.	133.2	-	
35.		-	
36.	152.3	20.0 continuous	0.1
37.	157.8	25.0 continuous	0.2
38.	181.3	-	
39.	122.0	32.0 discontinuous	0.3
40.	123.8	-	
41.	132.0	-	
42.	115.0	26.0 continuous	0.2
43.	145.0	28.0 discontinuous	0.2
44.	189.3	29.0 continuous	0.2
45.	174.8	20.0 fragmentary	0.1
46.	153.9	30.3discontinuous	0.2
47.	144.3	42.0 continuous	0.3
48.	120.9	-	
49.	209.0	-	
50.	151.0	43.3 fragmentary	0.3
51.	152.8	-	

52.	153.1	45.0 continuous	0.3
53.	161.1	25.3 continuous	0.2
54.	176.0	32.0 continuous	0.2
55.	189.0	43.0 continuous	0.2
56.	163.0	17.0 continuous	0.1
57.	165.1	-	
58.	171.1	32.9 discontinuous	0.2
59.	153.9	-	
60.	190.1	19.3 continuous	0.1
61.	193.0	-	
62.	132.9	-	
63.	133.1	20.9 discontinuous	0.2
64.	149.1	25.0 discontinuous	0.2
65.	177.9	-	
66.	179.0	40.3 fragmentary	0.2
67.	101.3	-	
68.	105.2	17.0 continuous	0.2
69.	110. 3	18.0 discontinuous	0.2
70.	198.0	21.0 continuous	0.1
71.	126.3	14.3. continuous	0.1
72.	251.0	45.6 fragmentary	0.2
73.	124.9	-	
74.	159.0	18.3 continuous	0.1
75.	181.1	21.0 discontinuous	0.1
76.	138.1	34.3 fragmentary	0.3
77.	191.3	-	
78.	178.0	-	
79.	109.3	22.3 fragmentary	0.2
80.	149.0	32.0 discontinuous	0.2
81.	150.3	42.0 fragmentary	0.3
82.	160.7	45.3 continuous	0.3
83.	170.3	-	
84.	180.3	36.6fragmentary	0.2

85.	133.9	-	
86.	151.0	37.3 continuous	0.3
87.	155.9	46.0 continuous	0.3
88.	165.0	-	
89.	179.0	32.4fragmentary	0.2
90.	180.3	-	
91.	190.1	28.0 discontinuous	0.2
92.	193.0	-	
93.	122.3	23.5fragmentary	0.2
94.	113.0	-	
95.	111.0	21.4 fragmentary	0.2
96.	109.3	-	
97.	105.3	32.0 continuous	0.3
98.	103. 7	31.0 continuous	0.3
99.	101.4	-	
100.	106.3	31.3 discontinuous	0.3
101.	108.9	-	
102.	161.1	15.3 continuous	0.1
103.	157.3	-	
104.	189.0	42.5 fragmentary	0.2
105.	197.3	-	
106.	125.1	20.4 continuous	0.2
107.	175.1	17.0 continuous	0.1
108.	121.1	18.9 discontinuous	0.2
109.	123.0	-	
110.	152.0	25.6 fragmentary	0.2
111.	162.3	37.5 continuous	0.2
112.	173.0	-	
113.	182.0	18.9 discontinuous	0.1
114.	192.0	35.1 fragmentary	0.2
115.	106.3	-	
116.	189.1	26.2 discontinuous	0.1
117.	199.2	-	

118.	200.0	-	
119.	209.0	-	
120.	203.0	20.0 discontinuous	0.1
121.	209.0	25.3 continuous	0.1
122.	157.1	-	
123.	158.0	15.0 continuous	0.1
124.	130.0	-	
125.	140.2	28.9 continuous	0.2
126.	153.0	30.0 continuous	0.2
127.	129.0	35.2 discontinuous	0.3
128.	128.0	32.0 continuous	0.3
129.	181. 9	35.0 continuous	0.2
130.	141.0	40.0 continuous	0.3
131.	143.0	42.0 discontinuous	0.3
132.	145.0	39.0 continuous	0.3
133.	147.8	21.0 continuous	0.1
134.	159.1	40.1 fragmentary	0.3
135.	170.0	18.0 continuous	0.1
136.	171.1	-	
137.	183.9	16.0 continuous	0.1
138.	186.0	15.9 continuous	0.1
139.	187.9	17.8 fragmentary	0.1
140.	198.8	-	
141.	123.1	16.0 discontinuous	0.1
142.	128.1	18.0 continuous	0.1
143.	132.0	19.0 discontinuous	0.1
144.	138.0	-	
145.	172.3	18.3 continuous	0.1
146.	180.1	21.0 continuous	0.1
147.	182.0	22.2 discontinuous	0.1
149.	193.0	-	
150.	113.0	35.0 discontinuous	0.3
151.	117.0	19.0 discontinuous	0.2

152.	118.3	16.3 fragmentary	0.1
153.	101.3	-	
154.	139.3	32.0 continuous	0.3
155.	149.0	-	
156.	152.0	-	
157.	150.2	43.3 discontinuous	0.3
158.	155.9	35.3 continuous	0.2
159.	182.3	-	-
160.	193.0	34.5 fragmentary	0.2
161.	106.3	-	
162.	181.0	28.9 discontinuous	0.3
163.	185.3	39.3 continuous	0.2
164.	101.3	17.8 discontinuous	0.1
165.	109.0	42.3 fragmentary	0.4
166.	121.0	44.5 discontinuous	0.4
167.	122.3	41.0 fragmentary	0.3
168.	129 .0	33.3 discontinuous	0.3
169.	123.0	30.9 continuous	0.2
170.	143.1	45.0 continuous	0.4
171.	143.9	38.3 continuous	0.3
172.	159.0	40.9 discontinuous	0.3
173.	160.0	21.9 continuous	0.2
174.	170.1	21.7 fragmentary	0.1
175.	180.0	23.3 fragmentary	0.1
176.	205.0	37.3 discontinuous	0.2
177.	183.0	22.5 continuous	0.1
178.	150.0	18.9 continuous	0.1
179.	170.0	17.3 continuous	0.1
180.	172.0	16.9 continuous	0.1
181.	183.0	-	
182.	133.9	-	
183.	145.0	-	
184.	156.0	15.9 continuous	0.1

185.	179.1	14.3 discontinuous	0.1
186.	184.0	17.0 discontinuous	0.1
187.	188.3	31.3 discontinuous	0.2
188.	189.3	-	
189.	205.0	32.4 fragmentary	0.2
190.	209.0	23.1 discontinuous	0.1
191.	189.0	-	
192.	179.0	42.9 continuous	0.2
193.	123.0	-	
194.	132.0	18.3 continuous	0.1
195.	109.0	-	
196.	103.0	19.5 fragmentary	0.2
197.	190.0	-	
198.	170.0	28.9 discontinuous	0.2
199.	120.0	-	
200.	133.9	40.3 continuous	0.3

QUESTIONNAIRES

This questionnaire seeks to collect data of hair regarding Forensic Science discipline at Kwame Nkrumah University of Science and Technology. The data collected will be used for academic purpose only and confidentiality is assured. Please answer the question by ticking the appropriate boxes or providing your answers where necessary. Thank you

TO BE COMPLETED BY PARTICIPANTS.

Demography of Respondent

1. **Gender:** Male [ ] Female [ ]
2. **Age**

   Under 15 years [ ] 15-20 years [ ] 21-25 above [ ]
3. **Which tribe are you?** Ashanti [ ] Dagomba [ ]
4. **Place of residence:**.....:
5. **Place of birth:** .....:
6. **Home town:**.....:
7. **Mother's home town**.....:
8. **Father's home town**.....:
9. **Which tribe does your grandmother belong to?**

   (i) **Ashanti [ ]**

   (i) **Dagomba [ ]**

Committee on Human Research Publications and Ethics
School of Medical Sciences, Kwame Nkrumah University of Science and Technology
Kumasi, Ghana. Tel: 233 3220 63248 or 233 20 5453785. Email: chrpe.knust.kath@gmail.com

Tel: 03220 63248 or 020 5453785

CONSENT FORM

Statement of person obtaining informed consent:
I have fully explained this research to _____ and have given sufficient information about the study, including that on procedures, risks and benefits, to enable the prospective participant make an informed decision to or not to participate.

DATE: _____ NAME: E. D. Buame Buffa

Statement of person giving consent:
I have read the information on this study/research or have had it translated into a language I understand. I have also talked it over with the interviewer to my satisfaction.

I understand that my participation is voluntary (not compulsory).

I know enough about the purpose, methods, risks and benefits of the research study to decide that I want to take part in it.

I understand that I may freely stop being part of this study at any time without having to explain myself.

I have received a copy of this information leaflet and consent form to keep for myself.

NAME:_____

DATE: _____ SIGNATURE/THUMB PRINT: _____

Statement of person witnessing consent (Process for Non-Literate Participants):

I _____ (Name of Witness) certify that information given to

_____ (Name of Participant), in the local language, is a true reflection of what I have read from the study Participant Information Leaflet, attached.

WITNESS' SIGNATURE (maintain if participant is non-literate): _____

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF HEALTH SCIENCES
SCHOOL OF MEDICAL SCIENCES / KOMFO ANOKYE TEACHING HOSPITAL
COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/AP/080/16

3rd March, 2016.

Mr. Erasmus Dodzi Buame
Department of Biochemistry
and Biotechnology
College of Science
KNUST-KUMASI.

Dear Sir,

LETTER OF APPROVAL

Protocol Title: *"Morphological Analysis of Human Hair among Asante and Dagomba Ethnic Groups in Ghana."*

Proposed Site: *Department of Biochemistry and Biotechnology, KNUST.*

Sponsor: *Principal Investigator.*

Your submission to the Committee on Human Research, Publications and Ethics on the above named protocol refers.

The Committee reviewed the following documents:

- A notification letter of 21st January, 2016 from the Department of Biochemistry and Biotechnology Seeking permission from The Dean of Students, KNUST (study site) and was approved.
- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Protocol.
- Questionnaire.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, renewable annually thereafter. The Committee may however, suspend or withdraw ethical approval at anytime if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Yours faithfully,

Rev. Prof. John Appiah-Poku
Honorary Secretary
FOR: CHAIRMAN

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