BANC-113

Forensic Anthropology

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Content

INTRODUCTION

Forensic Anthropology is a complex and rapidly evolving discipline of science. These applications are mainly diverse, that include the recovery of evidence, estimating the biological portfolio, examining time since death, reporting the evidence for a foul play, and resulting in positive identification. Each of its sub-disciplines has its own system, methodologies, and supporting scientific literature. Such type of diversity can be challenging to those who are entering the field and to those who are established practitioners defending their interpretations in the legal arena.

Forensic anthropology is the branch of physical anthropology that deals for forensic purposes with skeletonised remains known to be or suspected of being human and tries to answer the questions related to the sex, origin, stature, ethnicity, and age of the concerned individual. At the time of examination, a forensic anthropologist applies his human osteology knowledge to bring out all the facts related to the number and origin of individuals who were involved besides determining age from the dentition, ossification of long bones epiphyses with diaphysis, closure of cranial sutures using the superimposition of the skull or videographic methods to condense face to the skull for a complete identification.

Block 1 Introduction to Forensic Anthropology of the course highlights the use of forensic anthropology and the role of anthropologists in forensic science. It also talks about basic human skeletal biology through long and short bones. The discovery and different techniques for recovering skeletonised human remains have also been discussed.

Block 2 Human Identification: Establishing Identity I deals with the identification of an individual whether complete or partial identity. Personal identification can be performed by analysing the skeletal remains. Sex, age, race, and stature can be determined from the skeletal remains and, bodily fluids such as blood, semen, saliva, and urine found at the crime scene. The presumptive and confirmatory tests are discussed in the module for the personal identification of the questioned sample.

Block 3 Human Identification: Establishing Identity II, discusses the identification of an individual from teeth and the difference between human and non-human dentition. The unit has also discussed the recent trends in forensic anthropology such as DNA typing, etc. These branches of forensic anthropology are such that their use in different disciplines is in much demand. This surely helps in the betterment of human society in different aspects which has been explored in the three blocks.

The Practical Manual will facililate you in understanding about human long bones and their application in the estimation of age, sex and stature, an integral part of forensic anthropology, apart from somatometric and somatoscopic observations on living persons. Identification of bloodstain, urine, semen and saliva and examination of fingerprints and handwriting are of immense significance in identification.

BLOCK 1
INTRODUCTION TO FORENSIC ANTHROPOLOGY

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UNIT 1 INTRODUCING FORENSIC ANTHROPOLOGY*

Contents

Learning Objectives

After going through this unit you will be able to:

- understand the concept of forensic anthropology;
- learn about the development of forensic anthropology;
- discuss the scope of forensic anthropology; and
- know the uniqueness of forensic anthropology.

1.0 INTRODUCTION

Forensic anthropology is generally defined as the application of physical anthropology for the legal process in the identification of skeletonised, badly decomposed or otherwise unidentified human remains. It is in such a situation that forensic anthropologists hold significance and aid in investigation with their expert observations and conclusions. The advancement of the discipline has increased the horizon of anthropology involving its varied applications to medico legal problems and identification and aging of living individuals. In fact, the discipline has an interdisciplinary approach when it comes to dealing with issues like learning about aging juvenile perpetrators, identifying individuals taped on video surveillance systems, etc. Here it is imperative to understand what does identification of an individual imply? It is the determination of a unique personality on the basis of an array of characteristics that distinguish an individual from other persons. Identification holds significance for legal and humanitarian issues, in solving criminal cases, resolving inheritance concerns, marital status, etc.

* ***Contributor:*** *Prof. Rashmi Sinha, Discipline of Anthropology, School of Social Sciences, Indira Gandhi National Open University, New Delhi.*

In 1971, Charles Snow defined forensic anthropology as the application of physical anthropology, the specific knowledge of humans, race, age, sex, and person's unusual variation to the medico-legal prudence problem.

Thomas Stewart (1979) defined forensic anthropology as the branch of physical anthropology that deals with the identification of skeletonised remains which are suspected to be that of a human.

A very important question in any death investigation is the identification of the deceased. However, identification becomes challenging in forensic cases where the next of kin may not be accessible to identify the body or that unsure identifying features may make visual identification untrustworthy. Positive identification necessitates scientifically ascertaining identity by the presence of recognised unique characteristics.

> *The domain of forensic anthropology is quite vast and focuses on the assessment of every facet of human remains in a medico-legal context in establishing identity and where possible, the cause of death and conditions surrounding this event. Forensic anthropologists frequently work together with forensic pathologists and forensic odontologists. They provide invaluable inputs to explore and validate historic and even prehistoric remains and relics.*

Forensic anthropologist aids in a court of law with the:

- Identification of whether the skeletal remains are of a human or not,
- Identification of Race,
- Personal identification,
- Minimum number of persons involved,
- Determination of age,
- Determination of sex.

Did you note the areas where forensic anthropologists play a significant role?

1.1 HISTORY OF FORENSIC ANTHROPOLOGY

The diversification and development of the discipline of forensic science is associated with the development of techniques and principles in comparison and identification of physical evidence. Individuals who have recognised the necessity of combining all these principles into a science also promote the forensic science development (Saferstein, 2011). There are number of scientists who have contributed specifically to the development of forensics. Following information gives an idea of contributions based on their profiles to the development of scientific methods that together led to the growth and development of forensic science.

The history of forensic anthropology dates back to the nineteenth century when physical anthropologists and anatomists were occasionally asked to provide their support in the human identification process. In 1813, Mathiew Orfina, who is known as the Father of modern toxicology, a native of Spain, published his first scientific work that aimed at poison detection and its impact on animals. The first paper was published on the nature of fingerprints in 1823 by John E. Purkinji and recommended a fingerprint classification system that is based on nine types of principle (Verma, 2015). M. Orfilla, a French expert in forensic medicine, published a textbook in 1835, containing data about the measurements of arm bones and their differences in sex.

Ludwig Teichmann in 1853, proposed the first microscopic crystal test using hemin crystals for heamoglobin. Then, Francis Galton in 1892 published a book named *Fingerprints* where he had identified the uniqueness and individuality of fingerprints. A public prosecutor, Hans Gross, wrote his first treatise in which he described the application of his scientific methods in criminal investigation (Verma, 2015; Saferstein, 2011).

In 1878, Thomas Dwight wrote an essay on 'The Identification of Human Skeleton: A Medico-Legal Study'. One of the first cases of osteological expertise was published in the mid of nineteenth century. E. Rollet in 1889 illustrated tables for females' and males' stature reconstructing from lengths of bone. All this raw information was used subsequently for the determination of new stature methods by K. Pearson and L. Manouvier.

Bertillon System of Identification

In 1879, Alphonse Bertillon, a French Criminologist developed the first anthropometric system of physical body parts measurements, especially face, and head components, to produce a detailed individual description. This system is called Bertillonage or Bertillon system which is widely used as a scientific and reliable method of criminal identification.

Following data and physical measurements were involved in this system:

Data: Colour of hair, eyes, shape of ear, chin, and nose, complexion.

Measurements of body parts: Height, length of head, breadth of head, arm span, height while sitting, length of a left middle finger, length of left little finger, length of left foot, length of the right ear.

Marks on Body: Scars, moles, and tattoo marks.

Photographs: Head's right profile and front view.

These body measurements along with photographs were recorded on forms of cardboards which were kept in an ordered cabinet. Then, by dividing each of the body measurements into medium, large and small groupings, Bertillon could place the magnitudes of any single individual into one of 243 distinct classifications. This entire process required the use of special tools and equipment and a large number of individuals so that there is a chance of error reporting into the actual measurements record.

However, this anthropometric system has critical disadvantages. It was only limited to adults, and sometimes there was a marked difference in an individual's measurement who had been measured in different departments of police or for a second time in the same organisation.

Early Genetic Testing for Human Identification

In 1901, Karl Landsteiner discovered the human blood groups. Antigens present on RBCs (Red Blood Cells) can be used for individual identification. Antigens are not alleles but are the outcome of what allele is encoded by an individual's DNA. The 6 different blood group systems that have been used for identifying humans are Rh, ABO, MNS, Duffy, Kell, and Kidd. The ABO system and each blood group is derived from a genetic locus for the genetic testing for identifying humans.

Table 1: ABO Blood Group System

Type of Blood	Blood Antigens	Anti-A	Anti-B
A	A	+	-
B	B	-	+
AB	A and B	+	+
O	Neither A nor B	-	-

***Source*:** https://epgp.inflibnet.ac.in/

Reconstruction of facial characteristics from cranial remains was first performed by Welcker in 1883 and His in 1895. His was a renowned scientist in advancing this technique and recorded the first data on facial tissue thickness. Facial reconstruction originated from two major sub-fields of anthropology i.e., archaeology and physical/biological anthropology. Earlier, it was used to reconstruct the appearance of early forms of hominid in biological anthropology whereas validation of remains of the historic skeleton was performed in archaeology. The appearance of ancient individuals was constructed using paleo-anthropological facial reconstruction which was first used in 1964 by M. Gerasimov. One of the first microscopic studies on age-associated changes in human bones was published in 1911 by V. Balthazard. Krogman (1962) presented his technique in his publication, on facial reconstruction, *The Human Skeleton in Forensic Medicine*. The very first facial reconstruction of the around 2200-year-old Egyptian mummy was performed by Christian Corbet using laser scan and CT scan (noted by Dr Nelson of University of Western Ontario, in 2004, known as the Sulman Mummy Project).

A book named *Classification and Uses of Fingerprint* was published by Sir Edward Richard Henry in 1896 which described the first comprehensive system of classifying fingerprints. Thordore Roosevelt (1905), established FBI i.e., Federal Bureau of Investigation. A book titled *Questioned Documents* (1974) written by Albert S. Osborn explained the fundamental

principles of document analysis. He has also made his contribution to forensic document examination.

In 1912, Masaeo Takayama propounded the microscopic crystal test for haemoglobin by using hemochromogen crystals. A simple process to detect the blood group of a dried blood stain was developed by Leone Lattes in 1915. This test helped in solving marital disputes. Police Deparment of Lyon in 1910 provided Edmond Locard the option to open the first police laboratory, where evidence collected from crime scenes could be analysed scientifically. He also formulated the principle of Locard Exchange which states that when two articles come into contact with each other, a cross-transfer of evidence takes place i.e., each object will take something from the other or leave something behind.

In 1925, Calvin Goddard wrote an article named *Forensic Ballistics* in which he described the use of comparison microscope in relation to firearms investigation (https://en.wikipedia.org/wiki/Calvin_Goddard_(ballistics). He was also known as the pioneer in forensic ballistics. FBI started a national laboratory under the leadership of J. Edgar Hoover that provided forensic science services to all the law enforcement companies in the US. In 1937, Walter Speecht propounded luninol as a preliminary test for blood which helped investigators to detect and prove whether or not the blood was present at the crime scene. The study of Rh blood group in 1940 was first described by the Landsteiner and AS Wiener. In 1945, Frank Lundquist devised the acid phosphatase test for the presence of semen while working at the Legal unit of Medicone at Copenhagen University (http://perriweinstein. blogspot. in/2013/04/forensic-science-in-1930s-and-1940s.html).

Douglas in 1960 wrote an article named 'The identification of petroleum products on forensic science by Gas Chromatography' in *Forensic Science Journal* and also discussed the gas chromatography principles for the identification of petroleum products in the laboratory and in differentiating different brands of a kind of petroleum product (Stauffer, Dolan, & Newman, 2008).

In 1983 Wessel et al. developed a technique for detecting gun-shot residues by Scanning Electron Microscope with Electron Dispersive X-rays (SEM-EDX). Then, in 1977, Masato Soba developed a scientific method for lifting latent prints by Super glue fuming (Verma, 2015).

Kary Mullis, proposed the PCR i.e., Polymerase Chain Reaction which created the fundamental base for all types of DNA Typing used nowadays. Sir Allec Jeffery started the DNA fingerprinting system which includes the detection of a multi-locus RFLP (Restriction Fragment Length Polymorophism) pattern. And, in 1986, he was the only one to use DNA profiling systems for criminal investigation to solve a double murder case in England. DNA evidence was first time used to acquit an innocent suspect.

Walsh Automation Inc. in 1991 introduced the development of an automated imaging system known as Integrated Ballistics Identification System (IBIS) with an aim of comparing of the impressions left on the shell castings, cartridge cases and fired bullets and this system was subsequently developed for the US industry in association with the Bureau of Alcohol and Firearm (ATF).

In 1998, the National DNA Index System (NDIS) was started by Federal Bureau of Investigation to implement interstate cooperation, in associating crimes and in 1999, Drugfire and IBIS were integrated by the ATF and FBI, forming the NIBIN (National Integrated Ballistics Identification Network (Houck, 2007).

A number of research works have been going on in the last few years aiming at institutionalising, standardising, and professionalising various components of forensic investigations including expertise in anthropology. The role of applied forensic anthropology is increasing and developing while simultaneously drawing upon its traditional roots and the process of embracing other problems including osteology, human rights, international law, gender discrimination, remote sensing techniques, taphonomy, exhumation techniques, and so on.

Check Your Progress 1

1. What is forensic anthropology?

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2. What is Bertillon System of Identification?

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1.2 SCOPE OF FORENSIC ANTHROPOLOGY

Nowadays, forensic anthropology is a well recognised and popular discipline within the field of forensic science. Anthropologists are required to investigate skeletal remains to help identify the persons from the bone when other physical features might be missing to identify a body that no longer exists. Forensic anthropologists work in equal coordination with forensic pathologists to establish the identity of remains on the basis of their skeletal

features. If in case the victim is not found for a long time period or has been eaten by animals, then in those cases flesh markers used for the identification can destroy the investigation and make a normal process of identification difficult. Forensic anthropologists can also provide physical features of an individual to be entered into the databases of missing individuals such as the National Crime Information Centre.

The scope of anthropology is quite extensive and is increasing day by day. It involves the collection, preservation, and analysis of human skeletal remains for the purpose of identifying and reconstructing the events surrounding the individual's demise. Various killers dump the dead body of a victim in remote locations which simply means that sometimes police needs help in their investigation to find the skeletal remains. It is then that the forensic anthropologist is called for to use the scientific methods and aid with his forensic expertise.

Forensic anthropologists help in the crime or crime scene investigation because of their expertise and training in the discipline of archaeology, taphonomy, and cultural and biological anthropology. The training in cultural anthropology helps them to identify cultural markers that explain about the origin, nationality, or religion. Training in these disciplines helps them in excavating graves and crime scenes where any incident might have happened.

The forensic anthropologist is mainly responsible for answering the following questions:

- Is the material found at the scene, bone?
- Is the bone found human or non-human?
- How do we preserve the skeletal remains?
- Are the skeletal remains of forensic importance?
- How many persons were present at the scene?
- What is the individual's ancestry?
- What is the individual's sex?
- What is the individual's age?
- What is the individual's stature?
- Are there any individual characteristics?
- The evidence found at the scene is of pathology and/or trauma?

Check Your Progress 2

3. What is the scope of forensic anthropology?

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1.3 WHAT CAN BE IDENTIFIED FROM THE SKELETAL REMAINS IN FORENSIC SCIENCE?

With the help of skeletal remains, the forensic anthropologist will be able to answer the questions given below and all these questions will describe particular biological features of deceased remains which finally lead to the deceased person's identification. The forensic investigation of skeletal remains identification determines whether the remains are bone, whether they are of human or non-human, whom the remains belong to, age, ethnicity, the stature of an individual, cause, and time of death.

Are the remains bone?

Forensic anthropologists, at first, try to assess whether the material excavated is bone or not. In some cases, bones have been confused with other materials such as tree root parts, plastics, foam insulation, rocks, turtle shell, or any other materials which look similar to bones. Moreover, bones are consumed rarely by fire though exposure due to fire changes the color and the bone's texture, and make the bone more deformed and brittle which may make visual detection difficult.

Whether the bones are of humans or animals?

Forensic anthropologists then try to assess whether the recovered bones are of human or animal. This simple knowledge of human skeletons and non-human skeletons can help in determining the forensic importance of the recovered skeletal remains.

Bones of big mammals like bears, deer, pigs, and big dogs are sometimes confused with adult human bones and small animals may often be confused with fetal or juvenile bones. With intense examination, a number of features of bones are checked that can help differentiate between non-humans and humans using morphology and maturity.

Whether the bones belong to one or more persons?

Forensic anthropologist examines the excavated remains and assesses whether the bone material found at the scene belongs to one person or the bones belong to different people. This helps the anthropologist to determine the number of present persons at the scene.

Humans have a fixed number of bones having one skull, two arm bones (in pairs), two leg bones, twelve pair of ribs, one sacrum, twenty four vertebrae, one pelvis, and one coccyx. If the forensic anthropologists have an extra set of any of the bones, it means that the bones belong to more than one person. However, it becomes quite difficult in cases if the skeletal bone material is fragmented.

What is the sex, age, race, and stature of an individual?

Forensic anthropologists also help in personal identification by establishing the sex, ethnicity, and age of an individual. Sex determination from unknown skeletal remains depends upon the comparative completeness of the skeleton. An individual's sex can be determined by skull, pelvis, long bones, and other skeletal remains such as the mandible, clavicle, and scapula. The approximate age can be estimated from the recovered skeletal remains. It can be determined from cranial sutures, dentition, and epiphyseal union of long bones.

1.4 IMPORTANCE OF FORENSIC ANTHROPOLOGISTS

Following are some of the important tasks performed by forensic anthropologists.

- Species determination: The bones are determined if they are of a human or non-human.
- Determination of age: The presence and union of centers of bone, the growth, and various other changes in the teeth and bones helps the forensic anthropologist in determining the individual's age at the death time
- Determination of sex: The skeleton of an adult has various morphological differences between the different sexes which are used to establish the individual's sex.
- Race determination: Bones have some morphological features which are limited to the particular race in an individual.
- Assessment of Height: The individual's height can be computed with accuracy by using formulae to the individual bone length, especially the limb's long bones.

Check Your Progress 3

4. What is the importance of forensic anthropologists?

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1.5 RELATIONSHIP OF FORENSIC ANTHROPOLOGY WITH OTHER DISCIPLINES

Forensic science refers to the methodological application of a large number of scientific methods to aid in the law enforcement process. It includes the

use of a comprehensive range of sciences that help in the collection, preservation and examination of evidence. These sciences involve biology, chemistry, medicine, physics and other more specialised anatomy, anthropology, ballistics, etc. Over the time criminal activities have become more complicated and so the evidence demands of guilt or innocence is developed by forensic scientists using systematic methodology and objective (Holt et al., 2011). With the advancement of criminal activities, the applied practices and background of forensic science have become more refined and technologically more accurate leading to the development of an interdisciplinary approach. As an outcome, more disciplines are getting involved in forensic science eg. computer science, engineering, and psychology.

This interdisciplinary approach helps in searching crime scenes and collecting evidence to be used in the offender's prosecution in the court of law. For a forensic investigator learning to work and manage across various disciplines is an important factor. This can be established easily if the forensic investigation is perceived as an interdisciplinary research procedure where most of the intellectual breakthroughs were performed by crossing boundaries of discipline (Wilson et al, 2007). Forensic experts examine objects such as blood or samples of drug, chemicals like toxins, explosives and paints, traces of tissues like skin and hair or impressions like bitemarks or fingerprints that are left behind at the scene of crime. These days, forensic science has advanced involving area of DNA evidence collection and analysis and the crime scene reconstruction. However, it is a very important skill based discipline that demands professionals and experts trained with understanding the potential of science in family, civil and criminal legal matters.

Forensic science is defined as the methodological application of a broad range of scientific disciplines to the service of law.

The forensic goal, regardless of body condition or phase of investigatory activity, is to identify the remains and to determine the circumstances, of the unexplained death. Ascertaining major biological characteristics, such as age, sex, ethnicity and stature are often the first pieces of data that help focus the investigation on specific group characteristics. Individual biological characteristics, such as pattern of dental restoration, evidence of previous trauma and medical conditions, or unusual biological characteristics, focus the search within a specific age/sex/race-ethnicity group. The discipline of forensic anthropology focuses on the identification and determination of these characteristics. Examining small structures on the skeleton and determining what they mean is the anthropologist's key contribution to forensic investigation (Pickering and Bachman, 2009).

The field of forensic anthropology is relatively new. The American Academy of Forensic Sciences (AAFS), which is the premiere forensic organisation in the United States, traces its beginnings to 1948. The AAFS is composed of

forensic scientists from numerous specialties (e.g., pathology/biology, criminalistics, odontology, and toxicology) and has been publishing leading scientific research papers in its journal, the *Journal of Forensic Sciences*, since 1956. In 1972, physical anthropology became a recognised section within the AAFS, and in 1978, the American Board of Forensic Anthropology was created to certify forensic anthropologists. Many organisations such as Forensic Anthropology Society of Europe, the British Association for Forensic Anthropology, and the American Society of Forensic Anthropologists are continuously providing guidelines for the up gradation and the development of standards within the discipline of forensic anthropology (Adams, 2009).

Forensic Medicine

The scientific knowledge and application including medical information to legal questions to determine particulars in criminal or civil legal cases as to the time and cause of a suspicious death are called forensic medicine. It was first recognised as a distinguished discipline in the early nineteenth century, although the utilisation of medical evidence in law-related cases is cited way back in 1598 by Fortunatus Fidelis. Forensic medicine helps in the identification of victims in cases of mass disasters such as plane crashes or landslides. Forensic pathologists' services are used in determining the death cause and also in case of inheritance and insurance. In case of death caused because of a weapon, for instance, the forensic pathologist has expertise in providing extensive information about the weapon type used and also the important related details, e.g., in case of death by gunshot, the angle and range of fire can be determined with accuracy.

Autopsy has been one of the most significant instruments of forensic medicine that is used frequently for the identification of death and to determine the cause of death. It is of utmost significance in the forensic investigation in which issues concerned with death are raised. As mentioned earlier, forensic anthropologists work in equal coordination with forensic pathologists to establish the identity of remains on the basis of their skeletal features. Forensic anthropologists along with forensic pathologists play an important role in the following situations:

- Collecting trace evidence or finding the deceased's identity;
- Studying and recording injuries and wounds important for results;
- Gather and study samples of tissue under the microscope to categorise the absence or presence of natural diseases and other related microscopic findings such as gunpowder particles present around a gunshot wound;
- Collect and construct toxicological examination on body tissues and fluids to determine the chemical cause of accidental overdoses or poisonings;
- They play an important role along with medico-legal authority at the time of exploring unforeseen and unexpected deaths; and

- Appearing in a court of law as an expert witness in criminal or civil cases.

Forensic Science

As we know forensic anthropologists help in recovering and analysing skeletonised or decomposed skeletal remains, their specialised training helps them to recover skeletons in a quick manner. Along with the quick recovery, their training also helps them to collect information from the location that may be important after analysis.

Anthropologists also help in reconstructing earlier events that are associated with the deceased individual as well as intentional and natural changes to the body and its surroundings at the site of discovery. After discovering, the forensic anthropologist can establish various biological features of a skeleton that are required to identify the deceased individual. Ultimately, the forensic expert will search for important evidence on teeth and bones that may be associated with the cause of death. The first question asked by the medico-legal expert is, 'How do forensic anthropologists help in this case?' The answer is mainly defined as per the training and expertise of the forensic expert. In order to make a gross analysis, there are four cases in which human skeletal remains need investigation:

- Full skeletal remains with minimal or no decomposition
- Decomposition of skeletal remains
- Skeletonised remains
- Skeletal remains are changed by unexpected conditions like dismemberment, fire, high-affected trauma, or any artificial methods.

In these scenarios, the objective is to establish the individual's identity and to reconstruct the incidents surrounding his/her death. Hence, the task of recovering and examining the more disfigured and less complete skeletal remains is entrusted to the forensic anthropologist.

These types of scenarios can be classified into activity phases. Earlier, the forensic anthropologist was involved in the examination phase. However, now it is possible that the anthropologists can help in starting phases also like the discovery and recovery stages. Discovery includes all of the work previously done to the point at which the actual skeletal remains are found. And, the recovery stage involves the work of removing the skeletal remains to the lab. The formal examination or last stage begins in the laboratory.

The objective in terms of forensics, irrespective of body condition or stage of investigation, is the identification of remains and to assess the circumstances of the unexplained demise.

Check Your Progress 4

5. What do forensic anthropologists do?

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1.6 SUMMARY

Anthropology is most commonly categorized into four disciplines, involving archaeology, linguistics, cultural, and biological (physical) anthropology. Alphonse Bertillon 1885 proposed a system of anthropometry of adult persons for personal identification. This method relied on taking body parts measurements, involving human ear measurements that were further uncontrolled in favor of fingerprinting. Forensic anthropologists also help in reconstructing past incidents that are associated with the deceased and intentional and natural changes to the body and its environments at the discovery site. The scope and aim of forensic anthropologists are comprehensive and increasing day by day. It involves the collection, preservation, and examination of human skeletal remains for reconstruction and identification of the incidents surrounding the individual's death.

1.7 REFERENCES

Adams, B.J. (2007). *Forensic anthropology*. Chelsea House Publishers.

Bami, H.L. (1968). *Forensic science in crime investigation*. Personal communication.

Baryah et al. (n.d.). *The development and status of forensic anthropology in India: A review of the literature and Future Directions*. Medicine, science, and the law. Retrieved May 1, 2022, from https://pubmed.ncbi.nlm.nih. gov 30661453/#:~:text=The%20primary%20role%20of%20a,well%20as%20law %20enforcement%20agencies.

Bell, S. (2019). *Forensic science: An introduction to scientific and investigative techniques*. CRC Press, Taylor & Francis Group.

Chow, K.P., Chong, C.F., Lai, K.Y., Hui, L.C.K., Pun, K. H., Tsang, W.W., & Chan, H.W. (2005). Digital evidence search kit. In *First International Workshop on Systematic Approaches to Digital Forensic Engineering (SADFE'05)* (pp. 187-194). IEEE.

Grover, N. & Tyagi, I. (1910). Development of forensic science and criminal

prosecution-India. *Nature*, *23*(578), 76.

Houck, M. (2007). *Forensic science: Modern methods of solving crime.* Greenwood Publishing Group.

http://cbi.nic.in/aboutus/manuals/Chapter_27.pdf

http://cbi.nic.in/cfsl/cfsldivision.htm

http://mha.nic.in/hindi/sites/upload_files/mhahindi/files/pdf/bprd.pdf

http://perriweinstein.blogspot.in/2013/04/forensic-science-in-1930s-and-1940s.html

http://www.apfsl.gov.in/forensicindia.html

http://www.bprd.nic.in/content/2_1_About.aspx

http://www.encyclopedia.com/doc/1G2-3448300603.html

https://en.wikipedia.org/wiki/Calvin_Goddard_(ballistics)

https://en.wikipedia.org/wiki/Law_enforcement_in_India

https://www.academia.edu/871065/An_Overview_On_Forensic_Sciences_And_Criminology

https://www.fbi.gov/about-us/lab/scientific-analysis/fire_tool

Klepinger, L.L. (2006). *Fundamentals of forensic anthropology*. Wiley-Liss.

Misra, G.J., & Damodaran, C. (2010). *Perspective plan for Indian forensics: Final report presented to the Ministry of Home Affairs, Government of India***.** G.o.I. Ministry of Home Affairs, New Delhi; Accessed from: http://www.mha.nic.in/hindi/sites/upload_files/mhahindi/files/pdf/IFS (2010)-FinalRpt.pdf).

Nanda, B.B., & Tewari, R.K. (2001). *Forensic science in India: A vision for the twenty-first century*. Select Publishers.

PGPathshala. e. (n.d.). Retrieved May 1, 2022, from https://epgp.inflibnet.ac.in/

Pickering, R., & Bachman, D. (2009). *The use of forensic anthropology*. CRC Press.

Prahlow, J.A. (2010). *Forensic pathology for police, death investigators, attorneys, and forensic scientists*. Springer Science & Business Media.

Saferstein, R. (2011). *Criminalistics: An introduction to forensic science*. Upper Saddle River, NJ: Prentice Hall.

Siegel, J.A., & Mirakovits, K. (2007). *Forensic science: The basics*. Boca Raton, FL: CRC Press, Taylor & Francis Group.

Siegel, J.A., & Mirakovits, K. (2021). *Forensic science: The basics*. CRC Press.

State., B.E.J. (dept. O.A.C.) (2014). *Forensic anthropology- Current methods and practice*. Elsevier Science Publishing Co.

Stauffer, E., Dolan, J.A., & Newman, R. (2008). *Fire debris analysis*. Boston, MA, USA: Academic Press.

Tiwari, R.K., & Ravikumar, K.V. (2000). History and development of forensic science in India. *Journal of Postgraduate Medicine*; 46:303-8.

Verma, S. (2015). *Emerging technologies and their applications in the Indian criminal justice system with special reference to DNA profiling narco analysis and polygraph test an appraisal*. Ph.D. thesis; Aligarh Muslim University, Uttar Pradesh, India (unpublished report); accessed from : http://shodhganga.inflibnet.ac.in/bitstream/10603/70232/6/chapter2.pdf

1.8 ANSWERS TO CHECK YOUR PROGRESS

1. Forensic anthropology is a sub-discipline of physical anthropology i.e., the study of human remains which involves the application of skeletal examination and techniques in solving criminal cases.

2. French Anthropologist called Alphonse Bertillon developed a technique in 1879 for describing persons based on a catalog of body physical measurements. The measurements include sitting height, standing height, and distance between the fingertips with outstretched arms.

3. The scope of forensic anthropology involves the collection, preservation, and analysis of human skeletal remains for the purpose of identifying and reconstructing the events surrounding the individual's demise. Forensic anthropologists help in the crime or crime scene investigation because of their expertise and training in the discipline of archaeology, taphonomy, and cultural and biological anthropology. For more details refer to section 1.2.

4. Forensic anthropologists can help determine the species, sex, age, race, and height of an individual. For details, refer to section 1.4.

5. Forensic anthropologists help in recovering and analysing human skeletal remains, mainly those which are skeletonised or decomposed rapidly. They also help in reconstructing earlier events that are associated with the deceased individual as well as intentional and natural changes to the body and its surroundings at the site of discovery. They also work to suggest whether the remains found are bone, whether it is human or non-human bone, how to preserve it, the age, sex, ancestry, stature, and unique features of a decedent from the skeleton.

UNIT 2 BASIC HUMAN SKELETAL BIOLOGY*

Contents

LEARNING OBJECTIVES

After going through this unit, you will be able to:

- understand the concept of forensic anthropology;
- know how anthropologists determine identity from skeletal remains;
- distiunguish between human and non-human skeletal remains; and
- proceed with personal identification process from skeletal remains.

2.0 INTRODUCTION

Forensic Anthropology is a discipline within physical anthropology that involves applications of osteology and identification of skeletons to matters involving the public and law. Now, what is osteology? It is the study of bones. Forensic anthropologists mainly work with the skeletal remains to assess the deceased's identity. They sometimes also work with forensic odontologists and forensic pathologists to help determine the cause and the manner of death and also the post mortem interval i.e., PMI or length of time

*Contributor: *Kaneeka Joshi, Research Scholar, Discipline of Anthropology, School of Social Sciences, Indira Gandhi National Open University, New Delhi*

since death. The fundamental principle of skeletal identification is that the human skeleton is quite unique in every way. Most of the bones have exclusive characteristics that arise mainly from growth, genetics, injury, or trauma.

Human beings are the inimitable among the primates where they exercise bipedalism and distinctive adaptations as shown by their skeleton for this sort of movement. Another unique character of humans is the ability to regulate their body heat for longer periods of heavy amount of activity. All these abilities support humans to go through over water, into the depths and into the air. Moreover, humans live almost in all the terrestrial sections of the planet and inhabit even the unreceptive surroundings.

Differentiating between non-human and human bone is a task taken care by forensic anthropologists or distinct experts in osteology. All these aspects involve determining whether the suspected material found is a bone or not, or if it's a bone, is it of a human or non-human? The number of non-osseous materials like pottery, plastics, wood, or sometimes even stone can be mistaken for the fragmented bones of a human. So, before determining whether a bone is of a human or not, at the start of the investigation that involves suspected skeletal remains, the first and foremost thing the forensic anthropologist must confirm is whether the material found is a bone or not. Then, after the confirmation that the material is a bone, experts must ascertain whether the material came from a human or non-human. A trained and experienced anthropologist can effortlessly distinguish non-osseous component from bone. This means that the general knowledge about the human skeleton can help save a lot of time while determining the forensic significance of fragmentary or complete skeletal remains. When analysing the shape, structure, and size of the bone, a forensic anthropologist can assess if the bone material is of human or not. While determining the identity, it is of utmost significance to differentiate between the bone area for the articulation of bone, the muscle attachment area, and the region of relatively smooth bone that is neither an articulation area nor the muscle attachment region.

What Can an Anthropologist Identify from the Skeletal Remains?

Figure 1: Skeletal Remains

Source: https://nypost.com/2018/11/01/li-man-believes-he-found-missing-fathers-bones-in-his-basement/

As mentioned in the previous unit, the forensic anthropologist will be able to answer the following questions by identifying skeletal remains which finally lead to the deceased person's identification:

- Whether the skeletal remains constitute a bone?
- Whether the bones are of a non-human or a human?
- Whether the bone belongs to one or more individuals?
- What is the individual's sex?
- What is the individual's estimated age?
- What is the individual's ethnicity?
- What is the stature of an individual?
- What is the cause of death?
- What is the time of death?
- Are there any kind of skeletal injuries?
- Any other differentiating characteristics that lead to personal identification?

Are the remains bone?

The first and foremost responsibility of a forensic anthropologist is to determine whether the discovered skeletal remains are bone or not. Sometimes, bony material might be confused with tree roots pieces, foam insulation, plastic, rocks, turtle shell, or any other material which looks the same as human bones. Moreover, bones are mainly destroyed by fire which changes the colour and the bone texture and makes the bone more deformed and brittle which may make visual detection problematic. It is to be noted that bones are lighter in comparison to rocks because some irregular bones like carpals, patella, and tarsals, have more concentration of cancellous or trabecular bones, making them lighter than the rocks.

As already mentioned, it is very important to determine at an early phase of an investigation whether the material found is bone or not. After the confirmation, that the discovered material is bone, a forensic anthropologist should proceed to determine the bone's identity Siegel & Mirakovits, 2021; ePG Pathshala; State, 2014)

Figure 2: Partial Skeleton Remains Excavated from a Burial Site
***Source*:** https://www.ucl.ac.uk/news/2021/may/remains-oldest-known-human-burial-africa-discovered

Check Your Progress 1

1) What is forensic anthropology?

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2.1 DISTINGUISHING HUMAN SKELETAL REMAINS FROM NON-HUMANS

Forensic anthropologists try to assess whether the recovered bones are of a human or non-human. From an anatomical view, non-humans and humans are kind of similar in their skeletal components. Humans are mammals so they have many similar skeletal attributes. There are two important bone characteristics that can help make a distinction between non-human and human skeletal bone convenient:

Maturity

Maturity helps in distinguishing small non-human animals which have bones similar in shape and size compared to juvenile humans, even after reaching adult stages. One of the most common bones of humans to be mistaken for animal bones are the infant's bones. They are definitely different from adults and even from older children, which causes confusion. Various animals have adapted themselves to the living environments that are very different from the kinds of environments in which we humans live, so they sometimes possess different skeletal components that human beings don't have. The bird bones are suitable for flying purposes because they are very light in size. In addition to this, birds also have unique bones that are not commonly found in human skeleton such as an extended sacrum i.e., synsacrum, and the wishbone i.e., furculum. These bones in a skeleton is an indication that the material found is not of a human.

Some components of bone, though distinguishable can be confused with the bones of humans when fragmented. For example, turtle shell pieces look like the top of a human skull. The main point to distinguish turtle shells from human skeletal remains is to examine the cross-sections of those pieces. The interior part of the bones of a human skull consists of spongy type cancellous bone, but turtle shells don't have this distinction.

Morphology

Another characteristic that helps in distinguishing human and non-human mammals is the shape of a bone or its morphology. Human being bipedal, have different morphological characteristics associated with walking upright.

This property odds them out from all the quadrupeds that have four-legged locomotion. On the other hand, humans (bipeds) have a singular positioning at central vertical axis. The person's weight is distributed by this position using wide ranging bony mechanisms which have been specifically crafted to soften the bipedal locomotion or movement effect. And, crania of humans are placed at the centre position on the vertical axis. The pelvis is short and broad, the spinal component has four curves which are opposing, the tibiae having thicker proximal surface that helps in bearing more weight, the angled femora, more range of motion, feet having double arch structures and the upper limbs do not have that pronounced musculature.

Generally, there are three stages of identification that can be helpful in differentiating between human and non-human bones. Let's take a look:

- Macrostructure of Bone
- Gross Skeletal Anatomy, and
- Microstructure of Bone i.e., called Histology

2.1.1 Bone Macrostructure

Animal or non-human bones

- have a large density as compared to their size,
- are thicker in cross-section, and
- are less porous than human bones.

In the case of human beings, cortical thickness of femoral and humeral is roughly one-fourth of the over-all diameter as compared to about half of the full diameter in proximal limb bones of animal (epgp.inflibnet.ac/).

Table 1: Basic Differences Between Non-Human and Human Bone Macrostructure

Human	Non-Human
Cortical bones are more porous	Cortical bones are less porous
One-fourth thickness of the diameter of long bone	The half-thickness of the diameter of long bone

Source: *https://epgp.inflibnet.ac/*

Check Your Progress 2

2) How to distinguish between human and non-human skeletal remains?

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2.1.2 Gross Skeletal Anatomy

2.1.2.1 Cranium

Morphology of the cranium differs majorly between humans and non-humans because of the large brain. It is different because they have a flat and large rounded brain or orthognathic. But animals, even the large animals have very small brains and their crania bones are usually more curved and smaller individually.

Mandibles of animals are often V-shaped in inferior/superior position. They are separated from the mid-line as opposite to the U-shaped mandible of humans having singular construction. At vertical axis, crania of human are positioned, and the orbits are placed above and from the nasal aperture. At horizontal axis, crania of animals are placed. The orbits are laterally positioned and placed behind the nasal aperture.

Moreover, all these kinds of positioning causes foramen magnum to be positioned in an inferior side mostly in humans and posteriorly in case of animals.

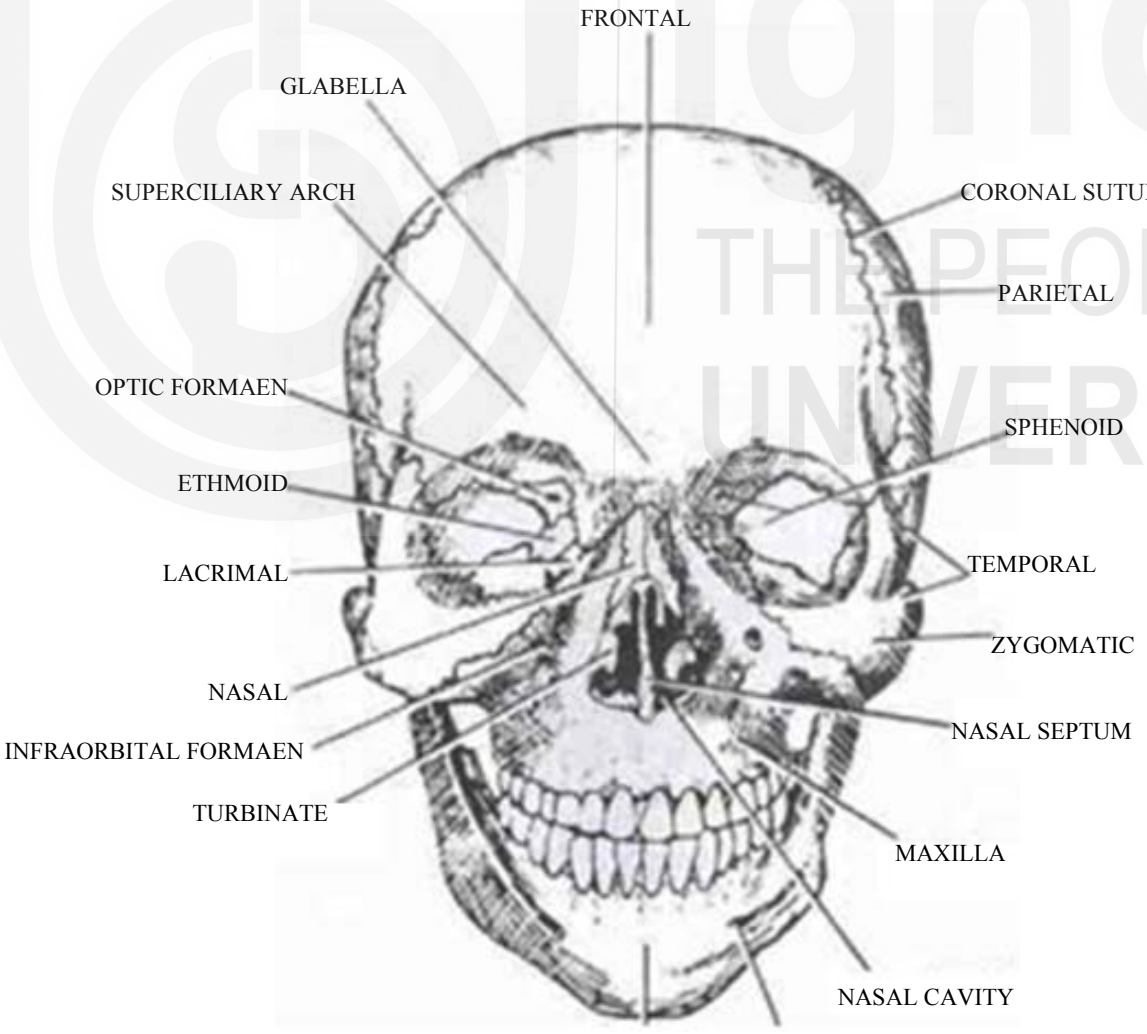

Figure 3: Illustration of Anterior Skull

Source: https://www.sciencephoto.com/media/1134969/view/illustration-of-anterior-skull

Table 2: Differences between Human and Animal Cranium

Human	Animal
Small face and large bulbous vault	Large face and a small vault
Smooth vault	Muscle markings are pronounced and the sagittal crest inferior
Mandible of U-shaped (no separation of the midline)	Mandible of V-shaped (midline separation)
Orbits present above and in front of the nasal aperture	Orbits present at sides and posterior to nasal aperture
Presence of chin	Absence of chin
Inferior foramen magnum	Posterior foramen magnum

Source: *https://epgp.inblibnet.ac.in*

2.1.2.2 Dentition

Dentition differs majorly between animals and humans. Teeth of human shows a generalised type of design like incisors (mix of slicing), canines (puncturing), and molars (grinding) teeth. Human teeth are usually more rounded than those of non-human. On the other hand, most animal teeth show some special dietary habits or adaptations. Carnivores have more cutting teeth with sharp ridges and grazing animals have more kinds of grinding teeth with specific ridges. Additionally, the dental formula for various animals is different from that of humans. Humans (Adults) generally have 32 teeth i.e., 8 in each quadrant including 2 incisors, 1 canine, 2 premolars, and 3 molars. The ratio is 2:1:2:3. Although more variable, various placental mammals possess a basic dental formula that involves 3 incisors, 1 canine, 4 premolars, and 3 molars. The ratio is 3:1:4:3. (Bell, 2019; Siegel & Mirakovits; 2021)

Table 3: Differences between Human and Animal Dentition

Human	Animal
They are mainly Omnivorous	They can be herbivorous, carnivorous, and omnivorous
The dental formula for humans is 2:1:2:3	The dental formal for animals is 3:1:4:3
Canines are small	Large conical canines are there in carnivores, and herbivores have missing or small canines
Incisors present in maxilla are much larger than in other mammals	Incisor in the maxilla of the horse is larger than the incisor of human
Cusps of molars and premolars teeth are rounded and they are divided by different grooves	Herbivores have flat and broad teeth with parallel ridges and furrows. Carnivores have pointed and sharp teeth

Source: *https://affiliateddentists.com/info/animal-teeth/*

2.1.2.3 Scapula

When comparing humans and non-humans, the variation in the scapula shape can be very different and in human and animal skeletal remains positive identification can be made quickly. Majorly in non-humans, the scapula is more lengthened with the glenoid fossa i.e., articulation points along with humerus bone, at the last of the elongated axis. The scapula shape is triangular in case of humans, along with the glenoid fossa which is present at the extreme side surface.

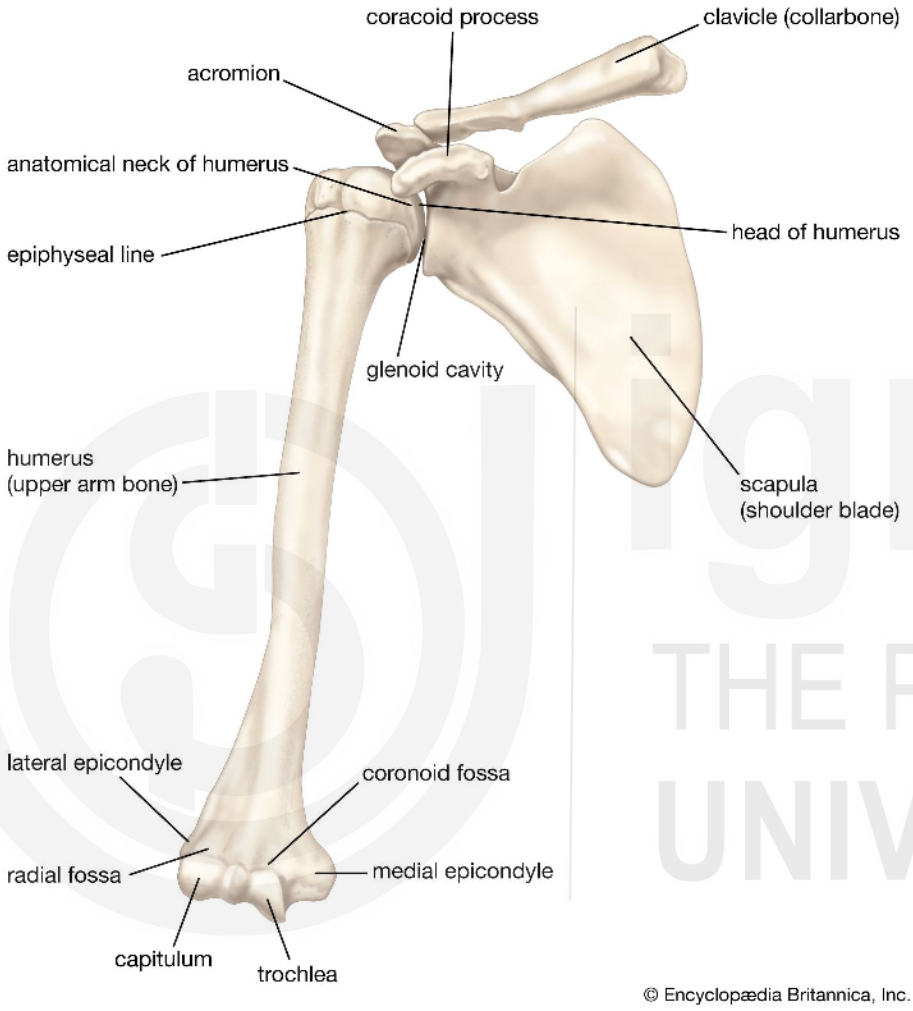

Figure 4: Human Scapula with Clavicle and Humerus

***Source*:** *https://www.britannica.com/science/scapula*

2.1.2.4 Clavicle

The clavicle maintains the distance between the scapula and the sternum. It gives support to the shoulder girdle in humans. On the other hand, in some of the other mammals where the forelimbs are mainly used vestigially for manipulation, sometimes may get shrunken or absent in several mammals. So, this part is of limited use in the identification of species.

2.1.2.5 Thorax and Vertical Column

Humans and animals have similar vertebrae. Like in some animals there are seven neck or cervical vertebrae as in case of girrafes and also separated

bodies of vertebrae are dissimilar. There are certain characteristics of the thorax and vertical column that differentiate humans from animals:

In quadrupeds, the vertebral column has one gradual curve commencing from the neck to the pelvic girdle whereas human beings have an S-shaped column. The distinction in the shape of the vertebral column is mainly reflected in the vertebrae morphology as well.

Generally, quadrapeds have extended and cylindrical bodies of verterbrae in comparison to humans. The verterbrae are almost same in length from neck to pelvis region. The chest cavity that also includes ribs called the thorax is thin, deep and narrow in case of quadrupeds, and in humans it is broad and shallow. In quadrupeds, the ribs are straighter and in humans' ribs are curved.

2.1.2.6 Long Bone/Femur

In long bones, locomotion is the main difference between humans and non-humans. Based on the developmental level, long bones of juvenile humans may have individual epiphyses which are unfused. On the other hand, small adult animals will have fused epiphysis. This means animals can easily be differentiated from humans by examining the bone maturity level.

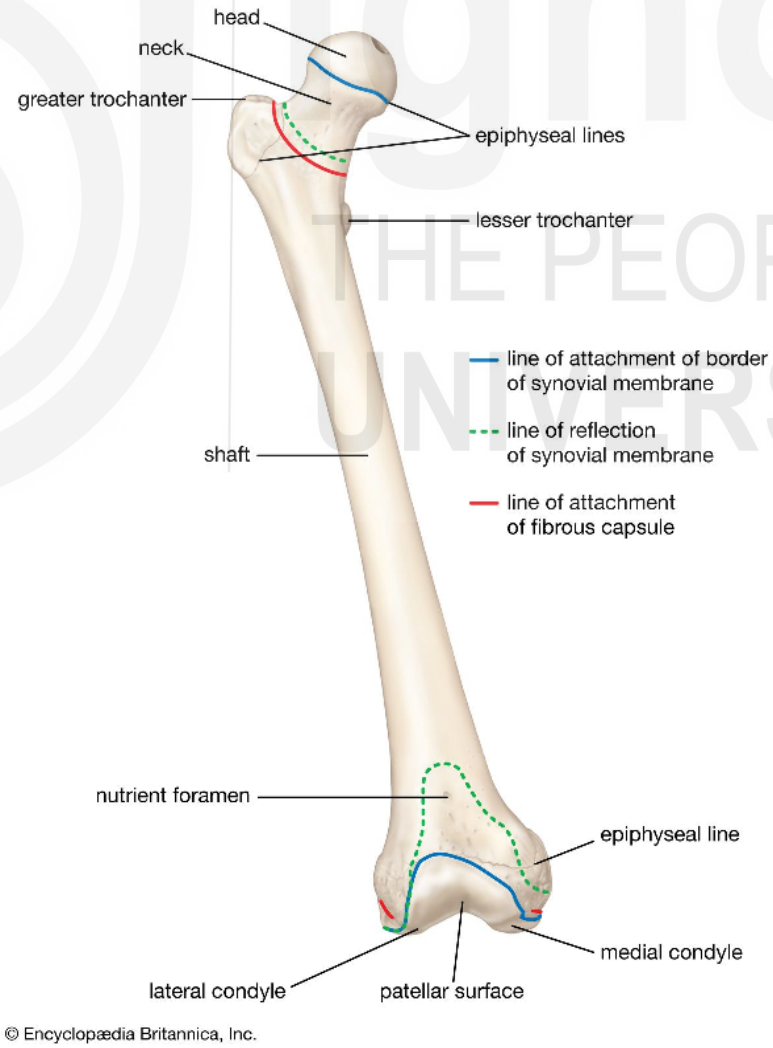

Figure 5: Long Bone/Femur

***Source*:** *https://www.britannica.com/science/human-skeleton/Long-bones-of-arms-and-legs*

2.1.2.7 Radius and Ulna

Many larger mammals have fused and curved ulna and radius. In humans, the straight diaphysis is observed in radius and ulna and it remains unfused throughout one's life.

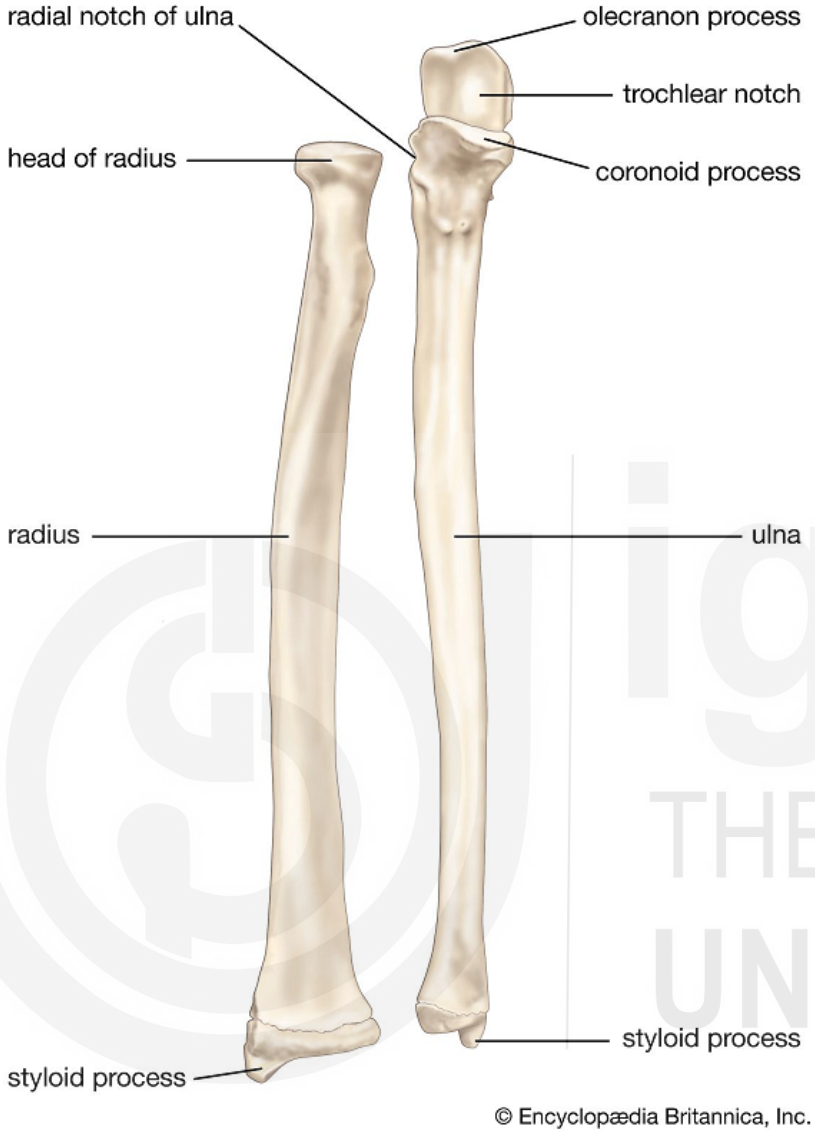

Figure 6: Radius and Ulna

Source*: *https://www.britannica.com/science/radius-bone

2.1.2.8 Tibia and Fibula

In the case of small sized animals such as mammals, the size of fibula is decreased in size and tibia's shaft is fused. But in the case of humans, the fibula doesn't commonly fuse to the tibia unless the presence of pathology like ossification of pathogens helps keep both bones articulated. Additionally, other morphological attributes which might help in differentiating small animals from human's long bones are non-human features of skeleton like a fusion of tibia and fibula, and the diaphysis i.e., the curvature of the shaft of a long bone. In case of small sized animals, the shaft of long bone is curved and in case of humans, it is straight.

2.1.2.9 Pelvis

If the pelvis gets fused to only one unit then it is of an animal because a human pelvis is present in numerous pieces and the two adult bones of human pelvis don't fuse unless a pathological condition arises.

Figure 7: Pelvic Girdle

***Source*:** *https://www.britannica.com/science/pelvis*

2.1.2.10 Foot

Mammals are from a family of artiodactyls i.e., mammals having an even number of toes on each foot, which is either two or four, and can easily be differentiated from humans by the metapodials presence. In animals such as sheep, goats, and deer, the third and fourth metatarsals and metacarpals are fused together in a single structure during early development.

You will study more about the Human Skeletal System and related estimations in the next Unit.

Below table illustrates the differenence between the post cranial skeletal anatomy of animals and humans. (Katzenberg & Saunder, 2008; ePG Pathshala; State, 2014)

Table 4: Differences Between Post Cranial Skeletal Anatomy of Animals and Humans

Humans	Animals
Less robust upper limbs	Robust upper limbs
Large, flat, broad, vertebral bodies having short spinous	Vertebral bodies are small with concave/convex surfaces and long spinous
Individual bones of Radius and Ulna	Sometimes, fused Radius and Ulna
Short, broad and bowl-shaped	Long, narrow, blade-shaped pelvis

pelvis	
Broad and short sacrum with five fused vertebrae	Long and narrow sacrum with three-fourth fused vertebrae
Tibia and fibula are separated	Tibia and fibula are fused sometimes
Narrow and long foot, weight is on toes and heels	Broad foot, weight is borne on toes
Longest bone in body is femur, linea aspera is a singular characteristic	Femur is of same length to other bones of limb, linea aspera plateau or double

Source: *https://statemuseum.arizona.edu/*

Check Your Progress 3

3) How can we identify an individual using cranium and scapula?

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4) Can we determine one's identity from teeth?

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2.1.3 Bone Microstructure

The microscopic study of cells and tissues used in knowing the pathogenesis and diagnosis of several ailments is called Histology. If a small fragment of bone is recovered with no morphological features, then the only method to identify i.e., whether it is of a human or non-human, is DNA analysis or microscopic analysis i.e., called histological examination. You will study about it in detail in the upcoming units. Additionally, in terms of the general gross shape of the skeletal component, the internal and external bone textures are important for examining the species and the bone.

The bone colour is not as crucial as other characteristics while diagnosing species. The study called Taphonomy which deals with something that occurs to any human body after its demise which involves modifications by natural agents such as water, climate, insects, decomposition environment, and the laboratory temperature in which the skeletal remains are kept, the history of post-mortem i.e., after demise. One of the important differentiation between animals and humans is the microscopic structure. In the cortical bone of humans, osteons are dispersed and positioned evenly, whereas, in some animals, osteons are aligned in rows called Osteons banding or creating rectangle type of structures i.e., plexiform bone.

There are a number of methods using which a forensic anthropologist can exactly determine the distinction between human and animal bones. (ePG Pathshala)

Table 5: Distinction between Human and Animal Bones

Humans and non-humans	Transparency	Relative weight	Cortical Bone	Bone Surface morphology	Epiphysis	Medullar cavity
Humans	Not transparent	Heavy	Thick	Well developed	Distinguished	Small
Birds	Not transparent	Light	Thin	Well developed	Some species	Large
Mammals	Not transparent	Heavy	Thick	Well developed	Distinguished	Small
Reptiles	Not transparent	Moderately heavy	Moderately thick	Almost absent	Vary	Decreased or absent
Fish	Transparent or semi-transparent	Light	Non-cancellous	Moderately developed	Absent	Absent
Amphibians	Not transparent	Light	Vary	Poorly developed	Absent	Vary

Source: *https://epgp.inflibnet.ac.in/ , https://affiliateddentists.com/info/animal-teeth/*

Check Your Progress 4

5) What are the differences between human and animal bone?

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2.2 SUMMARY

Humans and non-humans have anatomical distinctions in the skeletal constitution which differentiate bones all over the body parts. Human and animal skeletal remains are majorly distinguished by gross skeletal examination, bone macro, and microstructure. Some of the bones of animals and humans are so similar, that it becomes difficult to recognise fragmentary and isolated bones in the laboratory.

The morphology of crania varies between humans and non-humans due to the large size of the brain that humans have. Humans usually have smaller faces in comparison to cranial vaults and vice versa for animals, with the exception of primates.

The teeth layouts of humans and animals are different. This difference in the layout called dentition, indicates the changes in a human and non-human

dental formula, shape, and tooth size. For instance: human dentition has low molars and canines whereas animals have non-existent or small canine teeth. These are pointed and sharp in carnivores and flat or rounded in case of herbivores.

All mammals share a basic skeleton, which means that they have all the same bones approximately in the same positions such as ribs, skulls, four sets of limb bones, and a spine.

2.3 REFERENCES

Bell, S. (2019). *Forensic science: An introduction to scientific and investigative techniques*. CRC Press, Taylor & Francis Group.

Katzenberg, M.A., & Saunders, S.R. (2008). *Biological anthropology of the human skeleton.* John Wiley & Sons.

PGPathshala. e. (n.d.). Retrieved on May 1, 2022, from https://epgp. inflibnet.ac.in/

Siegel, J.A., & Mirakovits, K. (2021). *Forensic science: The basics*. CRC Press.

State, B.E.J. (dept. O.A.C.). (2014). *Forensic anthropology - Current methods and practice*. Elsevier Science Publishing Co.

2.4 ANSWERS/ HINTS TO CHECK YOUR PROGRESS

1) Forensic anthropology is a sub-discipline of physical anthropology i.e., the study of human remains, that involves the application of skeletal examination and techniques in solving criminal cases.
2) There are usually three steps of identification that can help distinguish between human and non-human skeletal remains: Gross Skeletal anatomy, Bone microstructure, and Histology i.e., bone microstructure.
3) The shape of the scapula is different when comparing human and animal skeletal remains. In humans, the scapula is flat, and triangular-shaped that is located in the upper thoracic area.

   In the cranium, the morphology differs between humans and non-humans. The human cranium is flat and large rounded whereas the animals brain is very small and their skull bones are generally smaller and more curved.
4) Yes, we can determine one's identity from teeth. The dental anomalies and characteristics help in reestablishing the identity and uniqueness of the deceased individual in forensic analysis. Human teeth are usually more rounded than non-humans, and, humans generally have 32 teeth with a ratio of 2:1:2:3 and in animals the ratio is 3:1:4:3.
5) The main difference between human and animal skeletal bone structures is their density. The density of non-human bones is greater compared to their size and they are thicker in cross-section and are less porous than the human bones. Refer to section 2.1 for details.

UNIT 3 DISCOVERY AND TECHNIQUES FOR RECOVERING SKELETONISED HUMAN REMAINS*

Contents

LEARNING OBJECTIVES

In this unit you will be learning about:

- fundamentals of human skeleton;
- human versus animal bone;
- numbers of individuals represented;
- sex determination from skeletal remains;
- age estimation from the skeletal remains;
- ascertaining of ancestry from skeletal remain; and
- stature estimation from skeletal remains.

3.0 INTRODUCTION

Forensic anthropologists obtain vigorous training in studying the human skeleton. Their main aim is to aid in personal identification and reconstructing the events before death by analysing osteological and non-osteological evidence of the human body. This calls for knowledge of the field of physical anthropology and its sub-fields such as osteology,

* ***Contributor:*** *Dr. Priyanka Khurana, Assistant Professor, Department of Anthropology, Utkal University, Bhubaneswar*

anthropometry, growth and development, physiology, anthropological genetics and others to properly interpret the evidence. This knowledge and training of forensic anthropologists helps them in inferring sex, age, ethnicity, living stature, time since death, cause of death, disease conditions and other information to solve medical-jurisprudence problems.

In this unit we will learn about the various methods employed by forensic anthropologists to identify human skeletal and ascertain the number of individuals represented, their sex, age, ethnicity and living stature from the bone remains

But before we proceed to understand how the above mentioned parameters are ascertained using skeletal remains, we should have an elementary understanding of the human skeletal system and its terminology.

3.1 FUNDAMENTALS OF HUMAN SKELETAL SYSTEM

Let's look in to the fundamentals of human skeleton system which help forensic anthropologists to differentiate the human bones from animal bones as well to discern the sex, age, stature and ethnicity of the person from the partial or debilitated remains.

> Initially the human skeleton was made up of cartilages and fibrous membrane which was soon replaced by bones. Few cartilages that are retained in adult can also be helpful in estimation of age and sex. For example, the changes in their mineralisation and ossification patterns in the costal cartilages in the thoracic region are highly predictive of sex and age (Zasshi, 1997; Rejtarová et al., 2004). However, being soft tissue they are not frequently available for analysis.

Bones are the hardest tissue after enamel that covers the tooth. At the time of birth about 300 bones exist which eventually fuse together to form the 206 bones in adults. These bones can be classified into two groups: axial and appendicular bones. Axial bones constitute bones such as the skull, vertebral column and rib cage that form the long axis of the body. Appendicular skeletal on the other hand includes bones of upper and lower limbs and pelvic and pectoral girdles that attach the limbs to the axial skeletal. Bones are also classified as long, short, flat or irregular on the basis of shapes and as compact and spongy bones on the basis of their texture.

Long bones as their name suggests are longer than wider. They are classified as long because they are elongated and not due to their size. Even the bones of the hands (carpels) are also long bones; other long bones are the limbs bones except, wrist, ankle and patella (knee cap).

Short bones are cube shaped. Typical examples are wrist, ankle bones. Patella is a special type of short bone known as sesamoid bone. It is embedded in tendons.

Flat bones are flat in shape with slight curvature. The sternum, scapulae, ribs and most skull bones are flat bones.

Irregular bones are bones that cannot be classified in above categories. The best example is human vertebrae and pelvic bones.

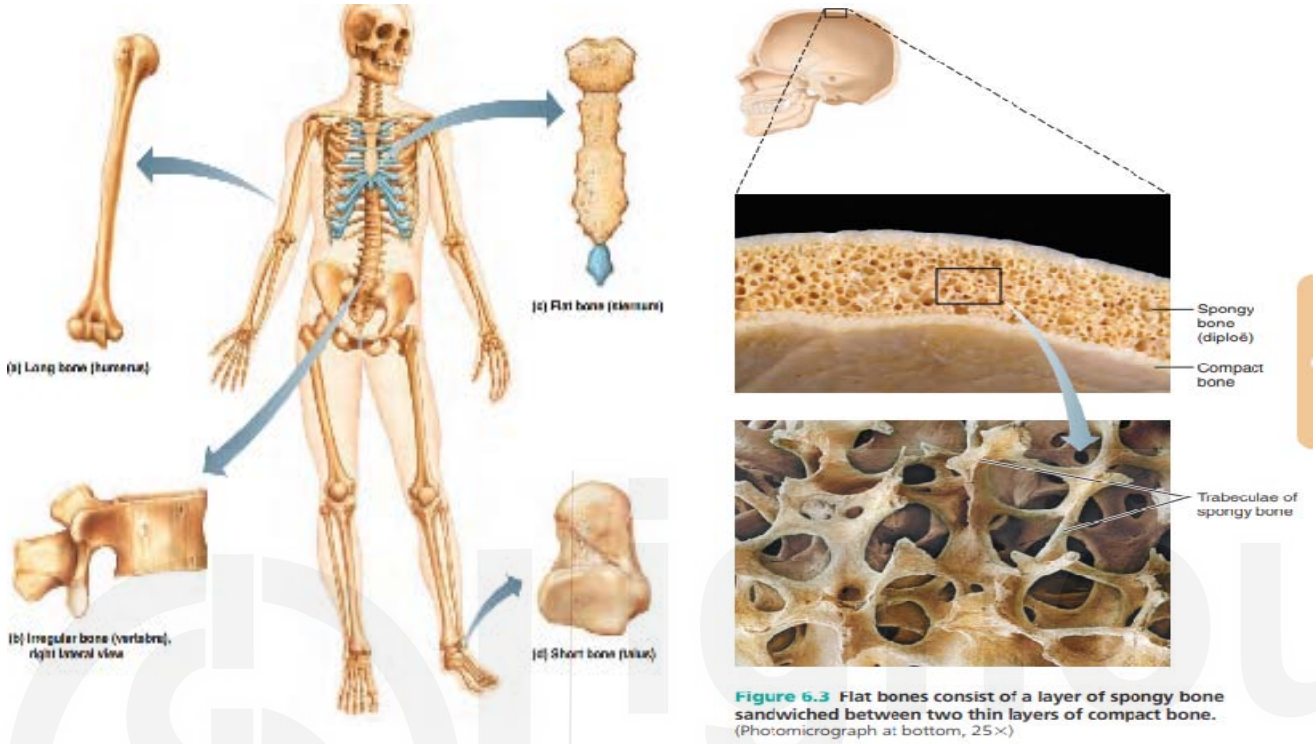

Figure1: Classification of bone on the basis of shape and texture

Source: Human Anatomy & Physiology by Elaine N. Marieb and Katja Hoehn, 9th ed. 2013

3.2 STRUCTURE OF BONES

It is also important to know the structural composition of the bone. It can be studied at three levels: chemical, microscopic and gross anatomy.

3.2.1 Gross Anatomy

Every bone has two parts, the outer smooth layer is called a compact bone and the inner layer is called a spongy bone. The spongy bone internally looks like a honeycomb of small needle-like structure known as trabeculae. The space between the trabeculae is filled with yellow or red bone marrow in living bones.

Structural Features of Typical Long Bone

The main features of long bones are Diaphysis (also known as shaft) and Epiphysis (the two ends of the bone) and membranes. The diaphysis is generally tubular and forms the long axis of the bone; it is composed of compact bone and encloses the red and yellow bone marrow cavity. Epiphyses structurally are more expanded than the diaphysis and contain spongy bone. The joining point diaphysis and epiphysis is called metaphysis. At metaphysis epiphysial line exists which is remnant of epiphysial plate, a

hyaline disc that grows during childhood leading to bone development. The bone is covered by two membranes, the outer white colour, double membrane is called as periosteum and the inner bone surface is covered by endosteum. Both the layers are composed of osteoblasts (bone forming cells) and osteoclasts (bone destroying cells). Unlike the periosteum that covers the outer surface of the entire bone except the joint areas, endosteum covers the internal bone surface i.e trabeculae of spongy bone and canals that connect with compact bones.

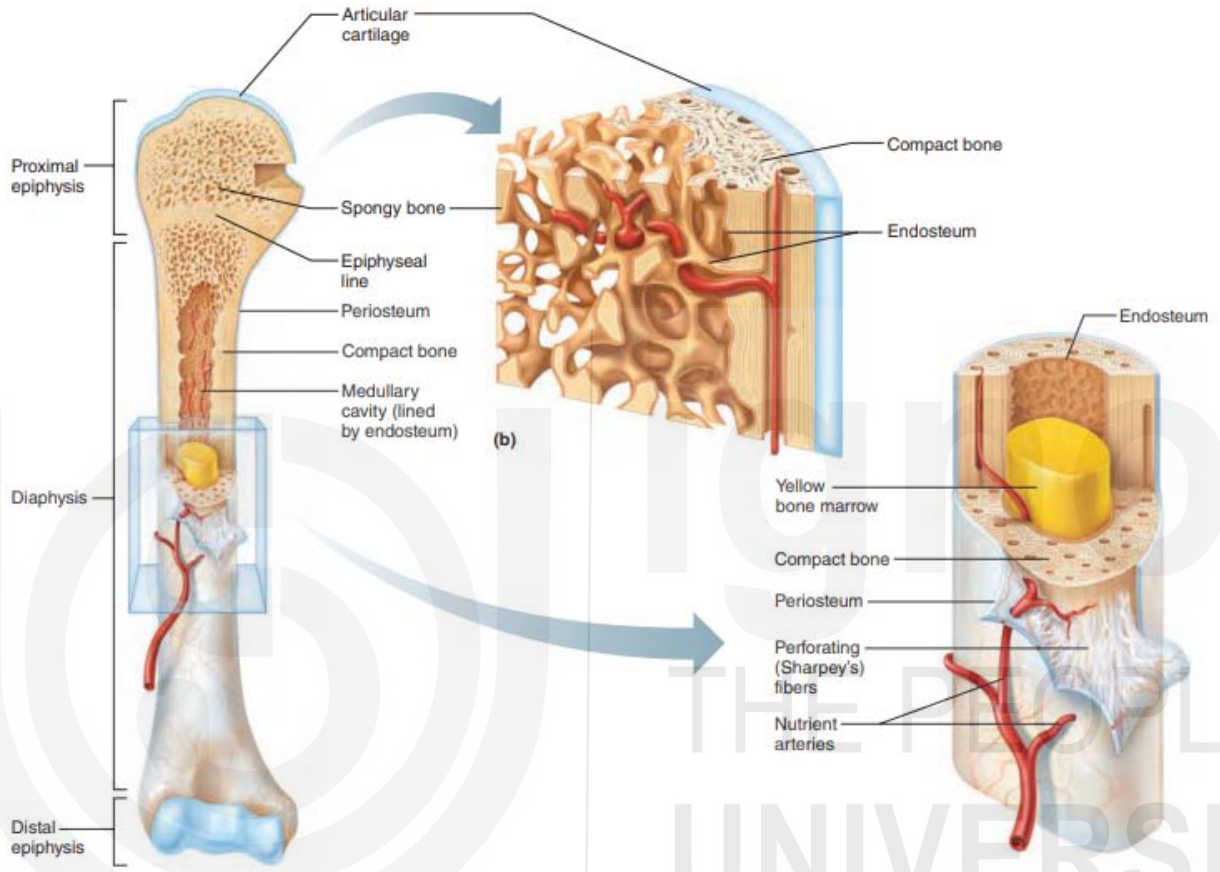

Figure 2: Structure of a long bone (Humerus bone)

Source: Human Anatomy & Physiology by Elaine N. Marieb and Katja Hoehn, 9th edition, 2013

3.2.2 Microscopic Structure of Bones

It is also important to remember the microscopic anatomy and chemical composition of bones so as to differentiate from non-human bones. Bones are made up of bone tissues composed of cells embedded in the matrix. The outer layer of most bones is made up of compact bone tissues enclosing spongy bone tissue.

Although the compact bone looks very dense and solid from the outside but microscopic view reveals it to be perforated making passages for nerves, blood vessels and lymphatic vessels.

The basic structural unit of bone tissue is called osteon or haversian systems which are parallely arranged along the long axis of the bone. Each osteon is

cylindrical in appearance and contains concentric layers called lamellae. The central part of the osteon is known as the central or harversian canal containing small blood vessels and nerve fibers and provides nourishment to osteon cells. The other kind of canal that lies at the right angle to the central canal and joins the blood and nerve supply of the periosteum to those in the central canals is called as perforating or volkmann's canal. The space in between the adjacent lamellae is called lacunae and contains specialised cells of osteocytes having hair-like branches called canaliculi. The calaniculi connects the lacunae to each other and to the central canal creating canals for the movement of nutrients and waste.

In contrast to the compact bones, spongy bones are less organised. They are composed of irregularly arranged lamellae and osteocytes. No osteon are present. This structure is called as trabeculae i.e tiny spikes of bone tissues surrounded by calcified bone matrix.

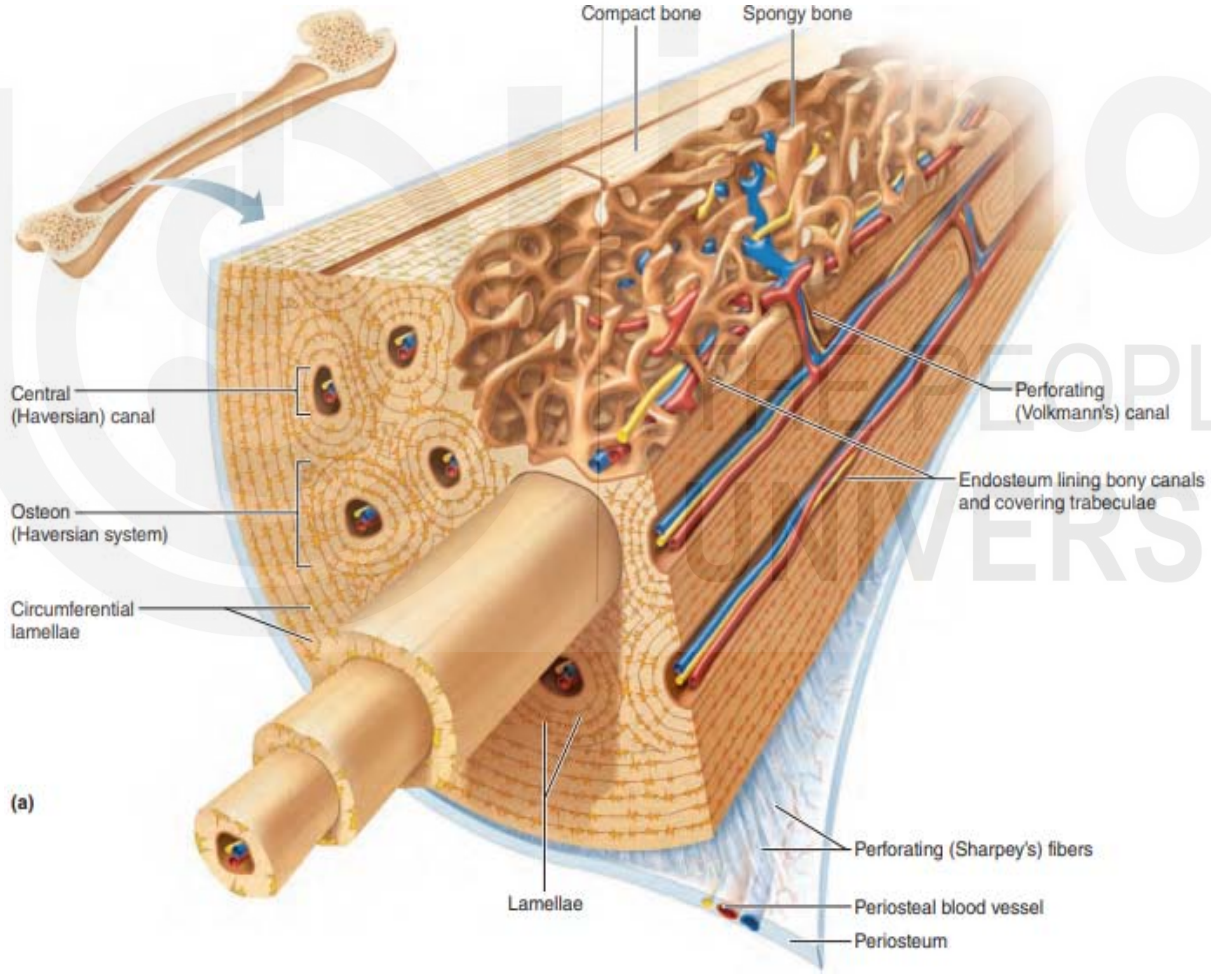

Figure 3: Microscopic structure of bone (Compact bone)

Source: Human Anatomy & Physiology by Elaine N. Marieb and Katja Hoehn, 9th edition, 2013

3.2.3 Chemical Composition of Human Bone

Bone is composed of bone cells such as osteoblasts, osteocytes, and osteoclasts and matrix. The osteoblasts secrete organic substance-osteoid in matrix. Osteoid includes glycoproteins, proteoglycans and collagen fibers

which give flexibility and tensile strength to the bone to withstand stretching and twisting. The inorganic part of the matrix that constitutes 65 per cent of bone mass is composed of hydroxyapatite and mineral salts mainly calcium phosphate. Their tightly packaging in the form of tiny crystals imparts hardness to the bone to withstand compression and helps in preservation of the bones after death. The combination of organic and inorganic components of the bone is species specific and hence can be used in distinguishing human and non-human bones.

3.3 METHODS OF PERSONAL IDENTIFICATION THROUGH SKELETAL REMAINS

3.3.1 Animal versus Human Bones

Distinction between human samples and samples of any other origin comes as a primary precondition for any anthropological expertise but even before that it is important to establish whether the material is bone or not. Many non-osseous materials such as wood, pot sheds, plastics, or even stones can sometimes be confused with parts of human bone. However with detailed morphological, molecular and histological analysis, this distinction between bone and other material can be judged. These methods also help in taxonomic identifications of the bone.

Figure 4: Human cranial bone (up) (fragment with the petrous portion of temporal bone) and the internal part of a turtle carapace (down).

Source: Corrieri and Marquez-Grant, 2015

In Figure 4, as the sutures look very similar, if found fragmented, a turtle carapace might be misidentified as human bone, or vice versa.

3.3.1.1 Gross Morphology

Due to differences in locomotion, weight bearing capacity and evolutionary trends, human bones differ greatly from other animals. The first thing to be observed in the bone is the epiphyseal line, this indicator of bone maturity can help in ruling out the possibility of smaller animal bones as they are comparable to children bone with an unfused epiphyseal plate. Next, larger

animal bone density, size and robustness of the bone should be checked. Human bones in comparison to other large mammals tend to have gracile muscle attachments and cortical bone thickness due to their bipedal locomotion strategy (Christensen et al., 2014; Croker et al., 2016).

In addition the presence, absence or fusion of some skeletal elements also helps in identification. For example the bird's bone which can be confused with infant bone can be differentiated on the basis of being light (pneumatic) and having furculum (Wishbone function) and synsacrum which are missing in the human skeleton. The prey animals (e.g. deer, sheep, and horses) tend to have a fused radius and ulna with an accentuated diaphysis curvature to aid in weight displacement of the forelimb during their extended times spent running. In humans, the radius and ulna are unfused, with long, narrow diaphyses, and a wider range of movement since they play no role in weight-bearing (Gilbert, 1990; Dupras et al., 2012).

Just like bone, tooth morphology can also aid in human identification. Animal dentition reflects specialised dietary adaptation in response to carnivorous or herbivorous diets. Herbivorous animals can be distinguished by the presence of grinding and pasting teeth features such as large incisors, small or no canine, broad and flat molars and premolars etc. Similarly carnivorous animals can be distinguished on the basis of shearing and cutting tooth apparatus such as conical canines and pointed and sharp molars and premolars and diastema. Human dentition in contrast reflects generalised design due to omnivorous dietary habits. Human canines are small and not pointed whereas premolars and molars have rounded cusps separated by grooves.

Figure 5A: Radiographs of human hand (left) and bear forepaw (right)
***Source*:** Fundamental of forensic science by Linda L. Klepinger, 2006

Figure B: Human (left) and deer (right) teeth which can be misidentified
Source: Distinguishing Human from Non-Human Animal Bone by T. Watson, and John McClelland, 2018

3.3.1.2 Histological Analysis

Another important but destructive method of identifying the human bone is the microscopic analysis of the bone. Various parameters such as cortical bone thickness ratios, osteon shape/ consistency, directionality/ type of vascularisation, and many other can be studied from thin bone cross sections to effectively determine human versus non-human bone (Urbanová and Novotný, 2005; Cuijpers, 2009; Dominguez and Crowder, 2012; Nor et al., 2015; Croker et al., 2016).

The features such as uneven distribution, elliptical shape of the osteon, less cortical thickness and more porosity in the human bone helps in differentiating it from other animal's bones. The animal bones in general are more compact, dense with humeral and femoral cortical thickness of about half of the total diameter in animal proximal limb bones. Animal osteon also tends to have a more circular shape, orderly arranged and has a folded over pattern known as plexiform arrangement imparting a different appearance from human haversian system (Owsley et al., 1985). Many animals such as pigs, have combination of plexiform and haversian systems, in those situations metric analysis of haversian canals is undertaken typically, haversian canal with reference to non-human origin. In addition to this histometric parameters such as diameters of haversian canal less than 50 mm, number of osteons in 1 mm^2, maximum osteon diameter, maximum area of Haversian canal aid in discriminating human and non human bone (Lackey 2000; Urbanova and Novotny, 2004).

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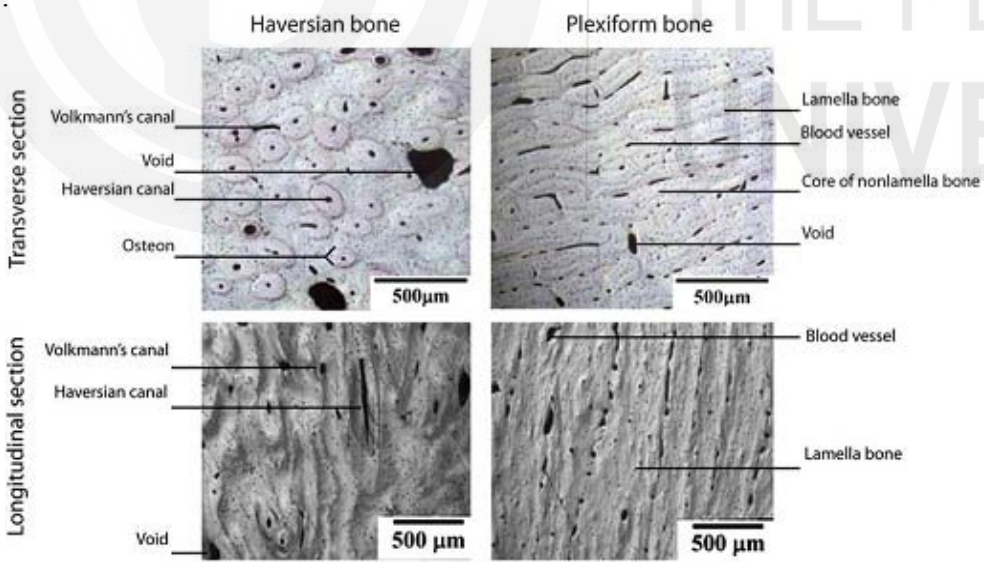

Figure 6: Thin section comparison of Haversian and Plexiform bone showing diagnostic structures.

Source: Justin Bradfield, 2013

3.3.1.3 Molecular Analysis

With the advent of high through put molecular techniques, DNA analysis can also be undertaken to discern the taxonomic profiling of the bone. However,

it is not commonly used in forensic contexts due to cost, time constraints, and the destructive nature of the method. The method involves purification, isolation and amplification of DNA using standardised protocols, followed by sequencing where a nucleotide base sequence is generated and specific regions can be targeted for taxonomic analysis and interpretation (Schanfield, 2007; DiGangi and Moore, 2013).

Check Your Progress 1

1) Illustrate the difference between human and non human bones.

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3.4 NUMBER OF INDIVIDUALS

Discerning the minimum number of individuals from commingled human remains is a major challenge. Commingled skeletal remains refer to the mixing of whole or fragmented skeletal elements of two or more individuals in a single context (Ubelaker, 2002). These are commonly observed in cases of mass fatality incidents. Generally duplications of the bones such as two or more long bones of one side such as two right femurs or humerus bones indicate the presence of more than one individual. Another method is in compatibility in articulation between joints which indicates configurationally, age, sex differences. However, the real problem arises when bones are fragmented or bones of vertebrae or only teeth are recovered.

A variety of methods to estimate the number of individuals is practiced to deal with this problem. These methods have been largely borrowed from zooarchaeology. Ubelaker (2002) in his book, "*Approaches to the study of commingling in human skeletal biology*" has discussed many of these methods in detail.

3.5 SEX DETERMINATION

Sexual dimorphism is not well marked in human population as compared to many other species. Yet these limited sexual differences are well reflected in skeletal remains. In general male bones are longer and heavier than female bones. But due to the existence of more variation within the population, only visual identification may not give accurate results. Therefore, both metric and non metric techniques on different sites such as skull, pelvis, long bones, etc., are recommended for evaluation of sex.

3.5.1 Non-Metric Visual Analysis

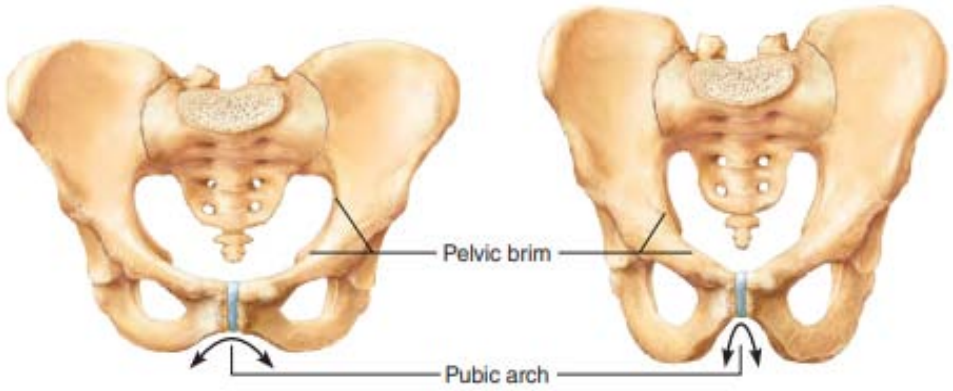
i) Discrimination from Pelvis

Pelvic region is considered as "Gold standard" for sexual discrimination. The fact that females give birth to large brained human babies imparts certain distinct features to the female pelvic bone. Given below is the comparison between male and female pelvis.

Table 1: Sex Determination from Pelvis

S.No.	Feature	Male	Female
1.	Size and Texture	Massive and rough with more muscular impression	Light and smoother, less marked muscular impressions
2.	Illium and Iliac fossa & Crest	Vertical directed, deeper and rough	Laterally expended, shallow and less rugged.
3.	Ischial tuberositites	More averted	Less averted
4.	Sub pubic angle	V shaped, sharp edges and small	U shaped , round , and large
5.	Depth of pubic symphysis	More	Less
6.	Pubic arch	Pointed and less than right angle	Rounded, wide and at right angle.
7.	Sacrum (os sacrum)	Long and narrow	Short and broad
8.	Obturator Foramen and Acetabulum	Large, Obturator foramen is oval	Small, Obturator foramen is approximately triangular.
9.	Pelvic Cavity	Deep and narrow,	Shallow and broad
10.	Coccyx	Less movable	More movable
11.	Sciatic Notch	Narrow and deep	Broad and shallow

Source: Singh and Bhasin, 1989 and Nath 1996



(a) Posterior view

(b) Left lateral view

(c) Anterior view

Figure 7: Comparison of Female (left) and Male (right) pelvis. Posterior (a) Left lateral, (b) and Anterior (c) view.

Source: Human Anatomy & Physiology by Elaine N. Marieb and Katja Hoehn, 9th edition, 2013

ii) Skull

Together with pelvis skull provides 98 per cent accurate estimation of sex. Table 2 demonstrates the traits of male and female skulls. These are most frequently analysed traits but not all equally reliable as there is a wide range variation within the population. Therefore, the experts make a final conclusion on the basis of the majority of the traits in the given skull. Studies also show that as the age progresses, the morphology of the cranium appears progressively more masculine (Meindl et al., 1985a; Walker, 1995). The trend toward accentuation of male characteristics holds for both males and females, so a preliminary evaluation for age is advisable first.

Table 2 Sex Determination from Skull

S.No.	Features	Male	Female
1.	Size and texture	Large and rough	Small and gracile
2.	Forehead	Steeper and sloping	More vertical and rounded
3.	Supra-orbital ridges and shape of orbit	Medium to large, orbits square in shape with round margins	Small to medium, orbits round in shape with sharp margins
4.	Zygomatic arch	Heavy and flaring	Lighter and compressed
5.	Parietal eminence	Less developed	Prominent

6.	Occipital area	Developed nuchal lines	Less developed nuchal lines
7.	Mastoid process	Medium to massive	Small to medium in size
8.	Foramen magnum and occipital condlyes	Large	Small
9.	Mandible	Large and heavy	Small and light
10.	Palate	U shaped	Parabolic in shape
11.	Teeth	Large in size with 5 cusps in lower molar	Small in size oftenly with 4 cusps

Source: *S*ingh and Bhasin, 1968 and Nath 1996

iii) Long Bones

The pelvis and cranium provide high degree of reliability for sex determination using non metric, macroscopic data. However the best metric analysis falls for Metric analysis of long bones. Out of many long bones in the human body, femur bones by far display the maximum sexual dimorphism. The diameter of the head of the femur is one of the most critical discriminator of sex followed by length of femur, angle of the neck to the shaft and mid-shaft circumferences. After the femur, the humerus is the most studied bone. Since male humerus is more robust than female, perforation of olecranon-coronoid septum at the distal end of humerus is observed more often among females than males (Benfer and McKern, 1966). In terms of metric analysis the head of the humerus is reported to be more reliably dimorphic even that of the head of the femur (Dwight, 1905, Stewart, 1979a). Other features that are scrutinized in assigning sex from humerus include analysis of trochlear constriction, trochlear symmetry, olecranon fossa shape and depth, and angle of the medial epicondyle gives (Rogers, 1999). Tibia bones also give approximate estimation of sex, however it is found to be subjected to inter population variations (Bass 1995).

Other bones apart from long bones, stermun bone has been studied extensively. As rule of thumb the manubrium part of a male is usually less than half the length of the body, while the manubrium of a female is usually more than half the length of the body. However this observation has not passed any sort of rigorous testing (Stewart, 1979a). Likewise the glenoid surface of the scapula may be sufficiently dimorphic to be of use, but has not been sufficiently tested.

3.5.2 Microscopic and Molecular Analysis

Microscopic and Molecular analysis of sexing is the most accurate and definitive method yielding the most valuable information for personal

identification especially when samples are less or heavily fragmented. However it is an expensive method and involves further destruction of samples for extraction of DNA. Therefore, it is always used in the cases where morphological analysis is not possible at all.

Sex determination using polymerase chain reaction PCR is a method of amplifying small quantities of relatively short target sequences of DNA using sequence-specific oligonucleotide primers and thermostable Taq DNA polymerase enzyme. The most common genes used in methodologies for sex estimation are sex determining region Y (SRY) and amelogenin (AMEL) genes. SRY gene is present on Y chromosomes of male and is involved in male-typical sex development. Therefore samples showing bands for the SRY gene indicate male samples.

Amelogenin gene which contributes to the tooth enamel formation is present on both X and Y chromosomes but exhibits variation in base pair size. The AMELX gene, which is located on the X chromosome, makes almost all of the body's amelogenin. Since female possess two copies of X chromosome therefore two identical bands in gel electrophoresis are found in female samples. The copy of the amelogenin gene on the Y chromosome, AMELY, makes very little amelogenin and is not needed for enamel formation. Correspondingly in male samples bands of two different lengths are observed.

Apart from these commonly used methods/ markers many alternative markers/techniques such as STS, SRY, TSPY, DXYS156, SNPs, DYZ1 and Next generation sequencing have also been developed for accurately sexing the bone remains.

Figure 8: Gel electrophoresis of the duplex PCR showing AMGX/Y loci (upper bands) and the SRY locus (lower band): lanes 1, 5 male controls; lanes 2, 3 the AMG -deleted individuals; lane 4 female control; lane 6 blank control

Source: Wanda Lattanzi et al., 2005

Check Your Progress 2

2) Differentiate between male and female using non metric visual analysis of human skeleton.

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3) Explain the molecular method of determining sex of an individual from skeletal remains

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3.6 AGE ESTIMATION

Forensic anthropologists employ various methods ranging from microscopic examination, morphological examination, chemical and molecular to radiological and radiocarbon methods to estimate age at the time of death. It is important to use more than one method as estimation of age at the time of death of an individual is unique in its both internal and external set up. It is affected by the body's internal conditions such as disease, growth pattern and genetics as well as by the external factors such as environmental, socio-cultural and nutritional situation of a person.

3.6.1 Morphological Indicators of Age

Bones and teeth constitute great resources for estimation of age at the time of death as they follow a predictable pattern of growth and maturation. Once they are matured and fully developed then their degenerative changes are taken into account for assessment.

Teeth: Tooth starts developing before birth and progresses through appearance and loss of deciduous teeth (milk teeth=20) followed by eruption of permanent teeth (32). By the age of 18 years, with the development of the last molar the process of eruption of permanent teeth is complete. The timeline for eruption of teeth is the most popular method for age assessment from adolescent skull remains. Apart from this radiological method of age estimation from teeth is also employed by experts. The original Demirjian (1973) dental method employs appraisal of calcification stages of seven left permanent mandibular teeth to estimate dental age up to 16 years. It was later modified by Chaillet and Demirjian to include mandibular third molar and increase estimation age to 18 years (Chaillet and Demirjian, 2004). After the complete eruption of teeth retrogressive changes in the teeth are studied for age estimation. Gustafson (1950) suggested the use of six retrogressive dental changes such as degree of attrition, transparency of root, secondary dentin deposition, cementum apposition and root resorption and periodontal ligament retractions that are seen with increasing age.

Skull: Paul Broca in 1975 first devised a method of age assessment from the pattern of fusion of suture lines of skulls. This method is based on the correlation between ossifications of sutures with progression of age.

However suture line fusion occurs simultaneously and gives a wide age range but this method is extensively used.

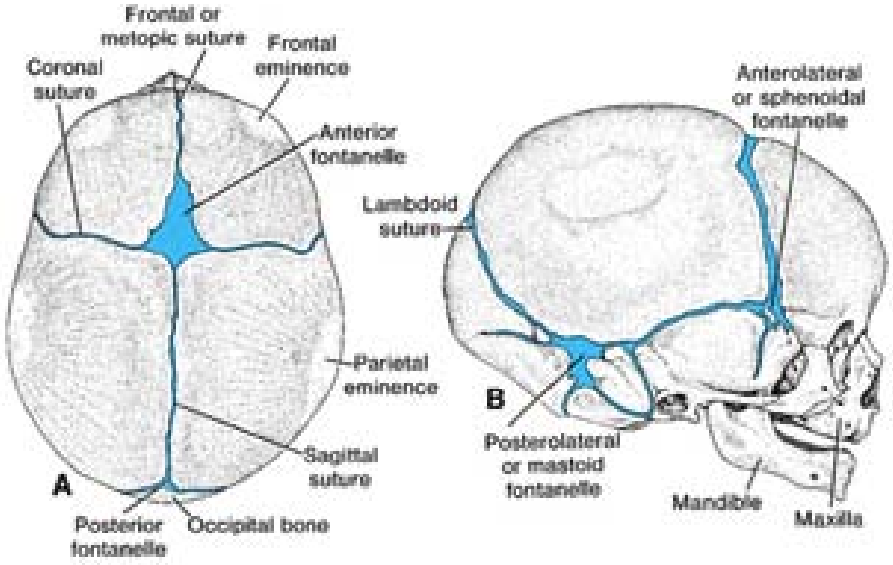

Figure 9: Major Sutures in the Human Skull
Source https://web.duke.edu/anatomy/embryology/craniofacial/craniofacial.html

Post Cranial Bones: While studying long bones one of the obvious indicators of adult bones is bone length, followed by analysis of closure of bone opening also known as closure of epiphysis (growth plates). However this method is useful especially for ascertaining ages of people younger than 25 years as ossification of epiphysis is completed by then.

Pelvis: The analysis of pubic symphysis, a cartilaginous joint that fuses together the front part of the two pelvic bones near the midline of the body, is the standard examination for age estimation. This method was first described by Todd (1920) and based on the principle of phase wise change in the morphology of pubic symphysis consistent with age intervals. Roughly, it has a zigzag shape in the beginning, but it straightens with progression of age. Similarly, sacro-iliac joints also show age wise changes.

Ribs: The morphological analysis of cartilage joint between the sternum bone and the ribs known as costo-chondral junction especially that between right 4^{th} rib and sternum bone is also utilized. The joint surface is smooth and rounded at the younger age which over time becomes pitted and sharp with changes in the walls and surrounding rim and overall texture of the bone. These changes are tabulated and related to broad age categories.

Table 3 provide key features in terms of fusion of sutures, eruption of teeth and changes in other bones with respect to age intervals.

Sl. No.	Estimated Age in years	Fusion of Suture	Eruption of teeth	Other bones
1.	0-1	Fusion of posterior, posterior-lateral and	Eruption of medial lower and upper incisor teethes	Presence of centre of ossification in lower end of femur, upper end

		antero-lateral frontanelle sutures in cranium.		of tibia & head of humerus
2.	1-2	Fusion of anterio-fontanelle, mandibular halves	Eruption of lateral upper and lower incisors, first upper and lower molar and canines	-
3.	2-4	Fusion of metopic suture	Eruption of second molar.	-
4.	4-6	Fusion of condylar part of occipital bone with squama occipital, and base of occipital bone.	Eruption of permanent teethes begins	Ossification centre appears on the medial epicondyle of humerus,
6.	6-7	-	Fist molar(both upper and lower emerge)	-
7.	7-8	-	Permanent medial incisors of both upper and lower side erupt.	Sacral vertebra of the vertebral column separates by cartilage, in pelvic girdle rami of ischium and pubis joins.
8.	8-9	-	Permanent lateral incisors of both upper and lower side erupt.	Centre of ossification appears in Olecranon fossa in humerus.
9.	10-12	-	First pre molar appears first followed by eruption of upper and lower canine.	Pissiform bone in the wrist ossifies.
10.	12-14	-	Second premolar erupts	Lateral epicondyle of humerus unites fuses with trochlea and cpaitulum portion.

11.	15-16	-	-	Triradiate cartilage of acetabulum fuses, caracoid process in humerus fuses with acetabulum. Olecranon gets fused with ulna.
12.	16-18	-	Third molar begin to erupt which may take 8-10 years for complete eruption.	All the epiphysis of elbow barring medial epicondyle, head of femur and lower end of tibiajoin their respective shafts.
13.	18-20	-	-	Epiphysis of wrist, knee, lateral end of clavicle joins. acromianprocess fuses with scapula in the pectoral girdle, articular facets of ribs gets united.
14.	20-21	Fusion of basilar suture in cranium takes place	-	-
15.	21-25	sagittal suture in the cranium begin to fuse which gets completed by 35 years of age.	-	Ischial tuberosity in the pelvis fuses, inner epiphysis of clavicle fuses, sacral vertebra fuses with one another by 25 all the epiphysis have united
16.	28-29	Coronol suture starts fusing and the fusion is complete by 35-40 years of age.	-	-
17.	30-31	Lambdoid suture begin to fuse. The fusion is complete by	-	-

		50-55 years of age		
18.	50-55	Fusion of spieno-temporal begins which gets completed by 70 years of age	-	-
19	60-65	Occipito-mastoid and parieto-mastoid, spheno-parietal suture begins to fuse and the fusion is complete by 80-82-85 years respectively.	-	-

Source: Singh and Bhasin, 1968 and Nath 1996

Bone Density: With age, bones tend to lose calcium and other minerals and become less dense. Many 2d-3d visualisation examinations such as X-ray, CT scans can reveal the bone density and other age related changes that help with determining age. However, the major drawback with this method is the effect of malnutrition and diseases such as osteoporosis or arthritis on bones which may interfere in accurate age assessment if not known prior.

3.6.2 Microscopic Method

Histological examination of bone especially that of long bones for quantitative assessment of osteons size, type and density, non-haversian canals, and the percentage of lamellar bone from the mid-shaft of the bone and accordingly age estimation was first described by Kerley (1965). Since then the indicators to be considered have been expanded and modified (Ahlqvist and Damsten, 1969; Bouvier and Ubelaker, 1977, Ericksen, 1991). The major limitation with the method is being destructive in nature.

3.6.3 Molecular Method

The end parts of the chromosomes are known as telomeres. These are repetitive non coding regions, late replicating which provides structural integrity to the chromosome. It has been found that the length of telomeres decreases with age, presumably due to cell divisions – the more cell divisions, the shorter the telomere length – and, since the number of cell divisions increases with age, telomere length could be a proxy for age (Zapico and Ubelaker, 2013). However, this is a relative method and may not

give accurate estimation as telomeres length is individual specific and affected by the environment and genetic makeup of an individual.

3.6.4 Chemical Method

Among the list of chemical methods, amino acid racemization, Millard reaction and ^{14}C radiocarbon estimation methods are most common.

Amino Acid Racemisation: The building blocks of protein molecules are amino acids, which exist in two alternative mirror image forms L and D for all the amino acids except glycine. In living bodies proteins are synthesized from L form which gets converted to D form until equilibrium is attained. This *in situ* chemical reaction of conversion of one form to another is called racemisation and the progress of conversion for a protein molecule provides information on time elapsed since the synthesis of the protein and indirectly informs about the age at the time of death. Age dependent amino acid racemisation has been observed for proteins found in vertebral discs and the eye lens (Masters et al., 1977; Ritz and Schütz, 1993; Mörnstad et al., 1994).

Millard Reaction: This is also known as browning reaction as it is based on yellowing or browning of the tissues and bones due to reaction between free amino acids and reducing sugars (Zapico and Ubelaker, 2013). This list is mainly observatory and gives only indication of time lapse after death and should be further corroborated with other tests.

Radiocarbon Method: estimation of ^{14}C in the skeletal remains is an indirect way of estimation of age at the time of death. It is based on the principle of having the same concentration of ^{14}C in living tissues as the atmospheric ^{14}C which starts depleting from the time of death. Radiocarbon dating for estimating the time of birth has also been applied to many tissues such as neurons of the brain, crystallines (a protein in eye lens fibres), and different bones (Bhardwaj et al., 2006; Hedges et al., 2007; Lynnerup et al., 2008).

Check Your Progress

4) List three most common chemical methods of age determination from skeletal remains and describe the principle behind them.

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3.7 ASCERTAINING OF ANCESTRY

Ascertainment of ancestral background constitutes a valuable piece of information for personal identification from human remains. It helps in narrowing down the list of possible candidates from the list of victims or criminals. In biological anthropology the scheme for describing ancestral populations has evolved from being static and fixed racial categories to more fluid, dynamic categories accommodating vast human population diversities. However, the same terminology continues but it is used with the consideration of the role of geographic, cultural, demographic and evolutionary forces in shaping the existing human population variation.

Overall the ancestry attribution is a daunting task because:

- Human population has more intra population variation than inter-population and it is difficult to classify samples in true exclusive categories.
- Sex and age of the individual influence the bone development and may influence the results therefore it is advised to determine to carry out sex and age determination of the skeletal remains determination before ancestry ascertainment.
- The skeletal remains from people of mixed ancestry do not fit into any category and therefore a number of features should be considered indicating predominant ancestral population contribution.

Despite these limitations, forensic experts have devised methods and ways which allow ascertainment of ancestry, albeit in a limited way.

Morphological Method:

Population specific skeletal markers for ancestry determination are rare. Skull provides the most information on ancestral background followed by femur bone. Descriptions of these features are given below as per the three predominant racial groups.

Table 4 Traits for Ancestry Assignment

S.No.	Features	Caucasians	African	Asians/Amerindian
Cranial Features				
1	Cranial Vault	Inion hook often pronounced	Long, low narrow cranial Vault	Rounded vaults
2	Frontal profile	Receding	Rounded, vascular markings on formal bone frequent	Vertical , Depressed glabella frequent

3	Orbits	Circular with sloping downward laterally	Low and wide more squarish with broad inter-orbital distance	Rounded
4	Nasal root	Depressed	Little depressed	Tented nasals, Nasal aperture rounded and medium wide
5	Nasal bridge	Elevated and sharply angled	Broad and low	Narrow nasal bridge with nasal crest frequent
6	Nasal spine and sill	Projecting, pronounced and sharp	Small nasal spine , sill rare	Inferior nasal spine moderate and nasal sill indistinct
7	Zygomatics	Retreating	Somewhat retreating	Prominent flared zygomatics with inferior projection, Posterior process (tubercle) on zygomatics
8	Lower facial prognathism	Little or no	Alveolar prognathisim	Moderate to no alveolar prognathism
9	Dental acrade and teeth	Parabolic, small teeth set closely together	Hyperbolic , Large teeth with wider spacing	Elliptic (horseshoe-shaped) dental arcade Shovel-shaped' upper incisors
10	Carabelli's cusps and shoveling of incisors	Carrabelli's cusp on maxillary first molar frequent	Carrabelli's cusp rare	Shoveling of lingual incisors
Post cranial features				
1	Anterior curvature of the diaphysis of femur	Caucasians fall in between African and asian	Femora of African tend to be flat; that is has less anterior curvature	Tend toward the greatest anterior bowing
2	Degree of torsion of the proximal femur	Moderate	Least	Tend to have the greatest anteversion of the femoral head and angulation of the femoral neck
3	Ratio of distal limb bone length to	Moderate	significantly greater	Least

	proximal limb bone length			
4	Intercondylar notch height (viewed from the distal end)	Moderate	Greater intercondylar notch height	Moderate

Source: Fundamental of forensic science by Linda L. Klepinger, 2006

Metric Analysis

The metric approach is more objective than the non-metric method of ancestry assignments. It is based on the number of cranial and post cranial measurements between the landmarks. Although it appears simple, it is not always reliable as the craniometric or post craniometric measurements from unknown samples are compared with the database on living individuals with known ancestry. Thus, if the geographic region of the individual under analysis is not represented in the database, the ancestral group cannot be determined. Number of software such as 3D ID, OSSA, 3 SKULL , FORDISC, CRANID, Ancestree are available having geography specific population data for ancestry estimation.

Molecular Analysis

The way DNA fingerprinting is used in forensic science for individual identification similarly, wide variety of DNA based Ancestry Informative markers such as Single nucleotide polymorphism (SNP), Short tandem repeats STR , Variable number tandem repeats VNTRS, Insertion deletions In-Del, Transposons such as Alu SINE are used in forensic and biological anthropology for ancestry assignment from a given bone or tooth remains. The markers from autosomal chromosomes are called as autosomal markers or bi-parental markers and provides information of ancestral background of both the sexes whereas those from mitochondrial DNA (mtDNA)and Y chromosomal markers(SNP and STR) indicates maternal and paternal population background.

Check Your Progress 4

5) Why is ancestry attribution considered as a challenging task for forensic anthropologists?

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3.8 STATURE ESTIMATION

Forensic scientists rarely get complete skeletons and mostly rely on fragmented or few bones for estimation of stature of the person. Many mathematical and anatomical methods such as Pan 1924, Trotter and Gleser 1952, Fully 1966, Kate and Majumdar 1976, have been devised by the experts to estimate stature at the time of death from long bones. Mysorekar, 1984 and Nath and Badkur 1990 are few studies which show estimation of stature from broken or burnt bones. All these methods do not provide the exact stature but provide a range for expected height of the person at the time of death. Along with stature, long bones also give information about overall build and the handedness of the person by observing the thickness of the bones.

As mentioned by Nath, (1996) , the most accurate anatomical method is that of Fully (1956) which takes into account the sum of basion to bregma height on the cranium, total vertebral column height, first sacral segment height, oblique length of femur, tibial length and tarsal height to obtain the complete stature using the formula :-

Stature=0.98 (total skeletal height obtained from the sum of above measurements)+14.63±2.05cm .

However, in case of absence of any of the one above mentioned bones Fully's methods cannot be applied.

Most of the mathematical methods on the other hand relying on individual or fragmented bones involve osteometry and regression analysis. Regression analysis in simple terms means equations for calculating the second unknown variable based on the values of the first variable. However, it should be noted that stature is sex, population and age specific and accordingly these regression formulas are also sex, age and population dependent. Therefore it is recommended that age , sex and ancestry profiling should precede stature estimates.

Let us understand the procedures for stature estimation using regression formulas from upper arm humerus bone .

Roughly, the height of the skeleton is five times the length of the humerus bone. However scientifically humerus is analysed by measuring its complete length in case the complete bone is recovered or sum of the measurements of the following segments of the bones in case of fragmented bones.

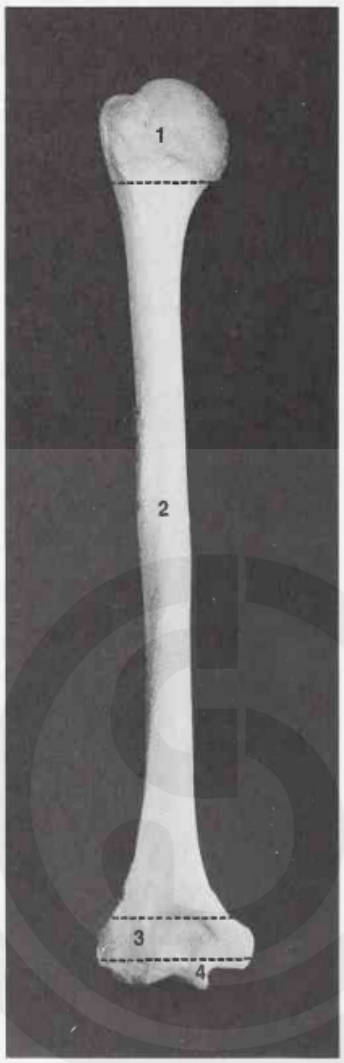
Segment 1: Measurement from the most proximal point of the head to the most distal point of the circumference of the head.

Segment 2: Distances between the most distal point of the circumference of the head and the most proximal margin of the olecranon fossa.

Segment 3: Measurement of olecranon fossa from its most proximal to distal part.

Segment 4: Distance between the most distal margin of the olecranon fossa, and the most distal point of the trochlea.

The following regression table is used for calculation of the complete length of the humerus from different segments of the bone



Segments 1–4 Used in Estimating Complete Long Bone Length from Humerus

Regression Formulae for Estimating the Maximum Length of the Complete Humerus from Incomplete Segments Based upon a Prehistoric American Indian Population of Mississippian Cultural Affinities (measurements taken in cm)

Segments	Regression Formulae with s.e.
	Males
1	2.0(segment 1) + 25.22 = humerus length ± 1.18 cm
2	1.1(segment 2) + 5.23 = humerus length ± 1.17 cm
3	1.8(segment 3) + 27.4 = humerus length ± 1.23 cm
4	2.4(segment 4) + 28.66 = humerus length ± 1.23 cm
1–2	1.4(segment 1) + 1.0(segment 2) + 1.74 = humerus length ± 0.28 cm
2–3	1.0(segment 2) + 1.4(segment 3) + 2.37 = humerus length ± 0.34 cm
3–4	1.7(segment 3) + 2.3(segment 4) + 24.28 = humerus length ± 1.16 cm
1–3	1.1(segment 1) + 1.0(segment 2) + 1.0(segment 3) + 0.38 = humerus length ± 0.17 cm
2–4	1.0(segment 2) + 1.4(segment 3) + 1.2(segment 4) + 1.55 = humerus length ± 0.26 cm
	Females
1	1.4(segment 1) + 25.89 = humerus length ± 0.13 cm
2	0.9(segment 2) + 9.16 = humerus length ± 0.84 cm
3	2.0(segment 3) + 25.03 = humerus length ± 1.18 cm
4	1.2(segment 4) + 28.35 = humerus length ± 1.26 cm
1–2	1.5(segment 1) + 1.0(segment 2) + 1.95 = humerus length ± 0.32 cm
2–3	1.0(segment 2) + 1.2(segment 3) + 3.86 = humerus length ± 0.37 cm
3–4	1.9(segment 3) + 1.0(segment 4) + 24.02 = humerus length ± 1.14 cm
1–3	1.2(segment 1) + 1.0(segment 2) + 0.8(segment 3) + 1.01 = humerus length ± 0.26 cm
2–4	1.0(segment 2) + 1.4(segment 3) + 1.1(segment 4) + 1.89 = humerus length ± 0.22 cm

SOURCE: Modified from Steele and McKern 1969.

Figure 10: Regression formulae for calculating complete humerus length from incomplete segments

Source: *The Anatomy and Biology of the Human Skeleton by D. Gentry Steele and Claud A. Bramblett, 2003*

After determining the length of the humerus, the following formulae are used for calculation of living stature.

Regression Formulae for Estimating Maximum Living Stature (with Standard Errors) from Maximum Long Bone Length of the Humerus, Radius, and Ulna (measurements taken in cm)

White males

3.08(humerus) + 70.45 = stature ± 4.05 cm
3.78(radius) + 79.01 = stature ± 4.32 cm
3.70(ulna) + 74.05 = stature ± 4.32 cm

Black males

3.26(humerus) + 62.10 = stature ± 4.43 cm
3.42(radius) + 81.56 = stature ± 4.30 cm
3.26(ulna) + 79.29 = stature ± 4.42 cm

White females

3.36(humerus) + 57.97 = stature ± 4.45 cm
4.74(radius) + 54.93 = stature ± 4.24 cm
4.27(ulna) + 57.76 = stature ± 4.30 cm

Black females

3.08(humerus) + 64.67 = stature ± 4.25 cm
2.75(radius) + 94.51 = stature ± 5.05 cm
3.31(ulna) + 75.38 = stature ± 4.83 cm

Mongoloid males

2.68(humerus) + 83.19 = stature ± 4.25 cm
3.54(radius) + 82.00 = stature ± 4.60 cm
3.48(ulna) + 77.45 = stature ± 4.66 cm

Mexican males

2.92(humerus) + 73.94 = stature ± 4.24 cm
3.55(radius) + 80.71 = stature ± 4.04 cm
3.56(ulna) + 74.56 = stature ± 4.05 cm

SOURCE: After Trotter 1970.

Figure 11: Regression formulae for estimating living stature
Source: The Anatomy and Biology of the Human Skeleton (D. Gentry Steele, Claud A. Bramblett, 2003

Check Your Progress 5

6) Describe the procedure of estimating stature using regression formulae for the upper arm humerus bone.

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3.9 SUMMARY

Human Skeletal remains constitute one of the mainline evidence in medico-legal cases. In this unit we have learnt about various methods of analysing human skeletal remains which helps in generating valuable information for personal identification. Forensic experts employ multiple combinations of techniques and methods for accurate estimation of the above mentioned parameters. For this forensic anthropologists obtain in depth knowledge and training in the field of human osteology, histology, molecular biology and biochemistry. The basic knowledge and understanding of these fields in other animals also helps the experts in making inferences about human remains. The general process of evaluation for identification proceeds from differentiating human bone from animal remains followed by ascertaining the number of individuals represented in the remains. Once this is established sex determinationt, age estimation and ancestral background is assigned. Living stature at the time of death is evaluated in the end as it is affected by sex, age and ancestry of the person. Forensic experts usually relay on non-metric visual examination of the remains followed by the metric analysis by using number of landmarks on the bones for accurate estimation of origin of bone or number of individuals represented in samples, their sex, age, ancestral background and living stature at the time of death. However in case of debilitating, fragmented remains other methods such as microscopic, molecular methods and chemical methods are used. Although these analysis provides robust inferences but have a limitation of being expensive methods (as instruments and reagents are required for analysis) and involves further destruction of skeletal remains for analysis. Finally, it should also be noted that forensic anthropology is an interdisciplinary field that applies the knowledge from diverse fields for devising techniques and methodologies to decipher the relevant information from human skeletal remains.

3.10 REFERENCE

Ahlqvist, J., & Damsten, O.A. (1969). Modification of Kerleys method for the microscopic determination of age in human bone. *Journal of Forensic Sciences 14*, 205-212

Badkur, P., & Nath, S. (1990). Use of regression analysis in reconstruction of maximum bone length and living stature from fragmentary measures of the ulna. *Forensic Science International Vol.45,* No. 1, 2, 3, pp15-25

Bass, W.M. (1995). *Human osteology: A laboratory and field manual* (4th ed.). Columbia, MO: Missouri Archaeological Society.

Benfer, R.A., & McKer, T.W. (1966). The correlation of bone robusticity with the perforation of the coronoid-olecranon septum in the humerus of man. *Am J Phys I Anthropol. 24*(2):247-52.

Bhardwaj, et al. (2006). Neocortical neurogenesis in humans is restricted to

development. *Proc. Natl. Acad. Sci. U.S.A. 103,* 12564–12568

Bradfield, J. (2013). Investigating the potential of microfocus computed tomography in the study of ancient bone tool function: results from actualistic experiments. *Journal of Archaeological Science 40*: 2606-2613

Bouvier, M., & Ubelaker, D.H. (1977). A comparison of two methods for the microscopic determination of age at death. *Am. J. Phys. Anthropol. 46,* 391–394

Chailet, N., & Demeirjian, A. (2004). Dental maturity in South France: A comparision between Demeirjian's method and polynomial functions. *Journal of Forensic Sciences 49*, 1059-1066

Christensen, A.M., Passalacqua, N.V., Bartelink, E.J. (2014). Forensic anthropology: Current methods and practice. Elsevier. Retrieved from https://linkinghub.elsevier.com/retrieve/pii/C20130097605

Corrieri, B., & Marquez-Grant, N. (2015). What do bones tell us? The study of human skeletons from the perspective of forensic anthropology. *Science Progress 98*(4), 391-402

Croker, S.L., Reed, W., & Donlon, D. (2016). Comparative cortical bone thickness between the long bones of humans and five common non-human mammal taxa. *Forensic Science International, 260,* 104.e1-104.e17

Cuijpers, S. (2009). Distinguishing between the bone fragments of medium-sized mammals and children. A histological identification method for archaeology. *Anthropol Anzeiger 67*:181– 203.

Demirjian, A., Goldstein, C. & Tanner, J.M. (1973). A new system of dental age assessment. *Human Biology 45*(2), 211-227

DiGangi, E.A., Moore, M.K. (2013). *Research methods in human skeletal Biology.* Elsevier. Available from: https://linkinghub.elsevier.com/ retrieve/pii/C20100658500.

Dominguez, V.M., & Crowder, C.M. (2012). The utility of osteon shape and circularity for differentiating human and non-human Haversian bone. *Am J Phys Anthropol 149*:84–91

Dupras, T.L., Schultz, J.J., Wheeler, S.M., & Williams, L.J. (2012). *Forensic recovery of human remains: Archaeological approaches.* 2nd ed. Boca Raton, FL: CRC Press.

Dwight, T. (1905). The size of the articular surfaces of the long bones as characteristics of sex: an anthropological study. *American Journal of Anatomy 4*: 19 –32.

Ericksen, M.F. (1991). Histologic estimation of age at death using the anterior cortex of the femur. *Am. J. Phys. Anthropol. 84*, 171–179

Fully, G. (1966). "Une nouvelle me´thode de de´termination de la taille. Annales De MedecineLegale, Criminologie. *Police Scientifique Et Toxicologie Journal.Vol.35* p

Gilbert, B.M. (1990). *Mammalian osteology*. Columbia: Missouri Archaeological Society.

Gustafson, G. (1950). Age determination on teeth. *J. Am. Dent. Assoc*. 41, 45–54

Hedges RE, Clement, J.G., & Thomas, CD, O.T. (1950). Collagen turnover in the adult femoral mid-shaft: modeled from anthropogenic radiocarbon tracer measurements. *Am. J. Phys. Anthropol. 133*, 8 08–816 (2007).

Kate, B.R., & Majumdar, R.D. (1976). Stature estimation from femur and humerus by regression and autometry. *Acta Anatomica Vol.94* pp311-320.

Kerley, E.R. (1965). The microscopic determination of age in human bone. *Am. J. Phys. Anthropol.23,* 149–163

Klepinger, L.L. (2006). Fundamental of forensic science. Hoboken, NJ: Jhon Wiley-sons

Lynnerup, N., Kjeldsen, H., Heegaard, S., Jacobsen, C. & Heinemeier, J. (2008). Radiocarbon dating of the human eye lens crystallines reveal proteins without carbon turnover throughout life. *PLoS One 3*, 1–3

Marieb E.N., & Hoehn K. (2013). *Human anatomy & physiology* (9th ed.). mount Royal University: Pearson.

Masters P.M., Bada J.L., Zigler, J.S. (1977). Aspartic acid racemization in the human lens during ageing and in cataract formation. *Nature 268,* 71–73

Meindl, R.S., Lovejoy, C.O., Mensforth, R.P., & Walker, R.A. (1985). A revised method of age determination using the 0s pubis, with a review and tests of accuracy of other current methods of pubic symphyseal aging. *Am. J. Phys. Anthropol. 68*

Mörnstad, H., Pfeiffer, H. & Teivens, A. (1994). Estimation of dental age using HPLC-technique to determine the degree of aspartic acid racemization. *Journal of Forensic Sciences 39,* 142-1431

Mysorekar, V.R., Nandedkar, A.N., & Sarma, T.C. (1984). Estimation of stature from parts of ulna and tibia. *Medical Science and the Law, Vol.24* pp113-116

Nath, S. (1996). Forensic anthropology. Ashtam Prakashan.

Nor, F.M., Pastor, R.F., & Schutkowski, H. (2015). Histological study to differentiate between human and non-human long bone. *Int Med J 22*:413–417

Owsley, D.W., Mires, A.M., & Keith, M.S. (1984). Case involving differentiation of deer and human bone fragments. *J Forensic Sci 30*(2): 572–8.

Pan, N. (1924). Length of long bones and their proportion to body height in Hindus. *Journal of Anatomy.Vol. 58.* Pp 374-378.

RejtarováO, SlížováD, ŠmorancP, RejtarP, Bukač (2004). *J Biomedical Papers 148(2)*, 241-243

Ritz, S., & Schütz, W. (1994). Aspartic acid racemization in intervertebral discs as an aid to postmortem estimation of age at death. *Journal of Forensic Sciences 38*, 633-640

Rogers, T.L. (1999). A visual method of determining the sex of skeletal remains using the distal humerus. *Journal of Forensic Sciences 44*: 57– 60

Sauer N.J., & Lackey W.L. (2002). Anthropology: skeletal analysis. In: J.A. Siegel, P.J. Saukko, G.C. Knupfer (Eds.). *Encyclopaedia of forensic sciences.* Academic Press. A Hartcourt Science and Technology Company, online version, www.academicpress.com/forensic/forline.htm, 7. 3. Pp. 261–270.

Schanfield, M. (2007). Applications of molecular genetics to forensic sciences. In: M., Crawford (Ed.). *Anthropological genetics: Theory, methods, and applications.* Cambridge University Press.p 235–276 2007

Singh, I.P, & Bhasin, M.K. (1989) (reprint). *Anthropometry.* K-Raj enterprises.

Steele, D.G., & Bramblett, C.A. (2003). The anatomy and biology of the human skeleton. Texas A & M University Press.

Stewart, T.D. (1979). Essentials of forensic anthropology. Springfield, IL: Charles C. Thomas.

Todd, T.W. (1920). Age changes in the pubic bone. I. The male white pubis. *Am. J. Phys. Anthropol.*3, 285–334

Trotter, M., & Gleser, G.C. (1952). Estimation of stature from long bones of American Whites and Negroes. *American Journal Physical Anthropology Vol.10* pp463–514.

Ubelaker, D.H. (2002). Approaches to the study of commingling in human skeletal biology. W.D. Haglund, M.H. Sorg (Eds.). *Advances in forensic taphonomy: Method, theory, and archaeological perspectives.* CRC Press, Boca Raton, pp. 355-378

Urbanova, P., & Novotny, V. (2004). Distinguishing between human and non-human bones: Histometric method for forensic anthropology. *Anthropologie XLII*/2 pp. 175–174

Urbanová, P., & Novotný, V. (2005). Distinguishing between human and non-human bones: Histometric method for forensic anthropology. *Anthropologie 43*:77–85.

Walker, P.L. (1995). Problems of preservation and sexism in sexing: Some lessons from historical collections for paleodemographers. In: S. Saunders, & A. Herring (Ed). *Grave reflections: Portraying the past through skeletal studies*. Toronto: Canadian Scholars' Press. p 31–47

Wanda, L. Di Giacomo, M.C., Lenato, G.M., Voglino, G.C.G., Gabriella Pepe, N.R.G., & Guanti, G.A. (2005). Large interstitial deletion encompassing the amelogenin gene on the short arm of the Y chromosome. *Human Genetics 116*: 395–401

Zapico, S., & Ubelaker, D.H. (2013). Applications of physiological bases of ageing to forensic sciences. Estimation of age-at-death. *Ageing Res. Rev. 12,* 605–617

Zasshi, N.H. (1997). *The Japanese Journal of Legal Medicine.* 51(2):89-94

3.11 ANSWERS/ HINTS TO CHECK YOUR PROGRESS

1) The difference between human and animal bones can be established at the level of their morphology, histology and molecular structure. Human bone are more gracile, less dense, small in size and thickness as compared to large animal. In addition the presence, absence or fusion of some skeletal elements also helps in identification such as furculum (Wishbone) is present in birds and not in humans. Histological features such as uneven distribution of the osteon, their elliptical shape, less cortical thickness and more porosity in the human bone helps in differentiating it from other animal's bones. Animal osteon tends to have a more circular shape, orderly arranged and has a folded over pattern known as plexiform arrangement imparting a different appearance from human haversian system. Finally, DNA analysis can also be undertaken to discern the taxonomic profiling of the bone.

2) The visual analysis of human pelvic bone, skull and long bone can help in sex determination. Pelvic bone features such as size, texture of the bone, positioning of Ilium, Subpubic angle, depth of pubic symphysis, pelvic cavity and others varies markedly between male and female. Likewise features on the skull such as shape of forehead, orbits, zygomatic arch, supraorbital ridges etc. helps in distinguishing between male and female skull. Together pelvic bone and skull provide 98% accurate estimation of sex. Long bones on the basis of their robustness can also indicate male versus female sex.

3) Molecular methods include DNA based molecular markers to ascertain sex of the individual from the skeletal remains. For this first DNA is extracted from the samples followed by PCR method which yields multiple copies of selected locus on the DNA. For sex determination AMELX gene and SRY gene is present on Y chromosomes of male are most frequently used. Since females have two copies of X chromosomes (XX) and male possess one X and one Y chromosome so gel electrophoretic images from the samples yields two different bands in case of male sample whereas female samples exhibit similar bands. SRY gene is present only on Y chromosomes of male. Therefore samples showing bands for the SRY gene indicate male samples.

4) Among the list of chemical methods, amino acid racemization, Millard reaction and 14C radiocarbon estimation methods are most common. Amino acid racemization is based on the conversion of L form of amino acid to D form. This *in situ* chemical reaction of conversion of one form to another is called racemisation and the progress of conversion for a protein molecule provides information on time elapsed since the synthesis of the protein and indirectly informs about the age at the time of death. Millard Reaction also known as browning reaction is based on yellowing or browning of the tissues and bones due to reaction between free amino acids and reducing sugars. Radiocarbon Method involves estimation of 14C in the skeletal remains to indirectly estimate age at the time of death. It is based on the principle of having the same concentration of 14C in living tissues as the atmospheric 14C which starts depleting from the time of death.

5) Ancestry attribution is considered as a challenging task for forensic anthropologists as human population has more intra population variation than inter-population so it is difficult to classify samples in true exclusive categories. in addition the sex and age of the individual influence the bone development and may influence the results therefore it is advised to determine to carry out sex and age determination of the skeletal remains before ancestry ascertainment. The skeletal remains from people of mixed ancestry also possess challenge as they do not fit into any category and therefore a number of features should be considered indicating predominant ancestral population contribution.

6) Humerus or any other bone is analysed for ancestry assessment by first estimating the complete length of the bone. In case the complete humerus is recovered than bone length is easily measured however if fragmented bones are recovered than different segments of the bones are measured as

   Segment 1: Measurement from the most proximal point of the head to the most distal point of the circumference of the head.

Segment 2: Distances between the most distal point of the circumference of the head and the most proximal margin of the olecranon fossa.

Segment 3: Measurement of olecranon fossa from its most proximal to distal part.

Segment 4: Distance between the most distal margin of the olecranon fossa, and the most distal point of the trochlea.

Depending upon the segment or segments measured, appropriate regression formulae are used to determine the complete bone length from incomplete humerus bone. The estimated length of the bone is further used to calculate the living stature by using another set of regression formulae which are ancestry and sex specific.

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