Reference Manual

on

Forensic

Identification

Of

Skeletal Remains

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Rationale:

Forensic Anthropology is in its initial developmental stage in Nepal, with Forensic Pathologists being the major stakeholders in medico-legal investigations in the past. Following a decade long insurgency and series of extra-judicial killings, exhumations for retrieval of human skeletons in different parts of the country has now become a routine practice.

Although the subject Forensic Anthropology is in itself a speciality, the practical aspect of it in Nepal is currently dealt by forensic medical practitioners trained in the subject. As per the Muluki Ain 2020 B.S., Government Medical Officer are authorised to examine medico-legal cases related to death and perform an autopsy or anthropological analysis of the remains. Nepal Government's Medical Personnel distributed throughout the country are an integral part of the health care delivery system. After their selection through proper assessment of qualification and competence, these Medical officers are provided a two-week long training on medico-legal investigations in collaboration with National Health Training Centre before they are sent to different parts of the country. Their routine medico-legal duties on arrival include performing autopsies, estimate age through x-rays, examination of human skeleton remains, examination of victim of rape, examination of injuries, etc,

This document aims to provide a guideline for anthropological examination of human remains as a reference to be used by Government Medical Officers to assist in their duties. This document will not speak about the radiological and dental examinations for estimation of age. Those topics may be referenced in the guidelines for estimation of age. Similarly, it would be beyond the scope of this document to explore the field of forensic archaeology and crime scene investigation in detail. However, the authors feel that the physician in question should have a working knowledge of the basic needs in scene investigations of surface remains as well as buried remains and a basic outline will be provided. The authors feel the need to emphasise that the material on scene investigations is basic at best and the physician needs to familiarise with further references.

Introduction:

Forensic Anthropology is the application of the principles and knowledge of anthropology to assist in legal jurisprudence. Practical application of Forensic Anthropology assists forensic practitioners in assessing skeletal elements to develop scientific opinions regarding the examinee.

Dirkmaat defined Forensic Anthropology as “the scientific discipline that focuses on the life, the death, and the post life history of a specific individual, as reflected primarily in their skeletal remains and the physical and forensic context in which they are emplaced”.

The field of Forensic Anthropology gained prominence through investigations of clandestine graves in the Americas, to help identify victims of extra-judicial killings and disappearances by the various regimes throughout Central and South America.

Thomas Dwight was the first author to publish scholarly articles on identification from skeletal remains and is credited as the Father of Forensic Anthropology. He researched on three primary indicators to establish identity – age, sex and stature.

The first case where the knowledge and principles of Forensic Anthropology was used can be traced to the United States.

On the night of November 30th, 1849 a dismembered and partially burnt body was found by Ephraim Littlefield, janitor of the New Harvard Medical College. The pelvis, right thigh, and the lower left leg were recovered from the personal privy. A button, some coins, bone fragments, including a jaw bone with false teeth were recovered from the furnace. A torso was found inside a carton at the laboratory, with the heart and other organs missing and the right thigh was stuffed inside the torso.

Dr. Jeffries Wyman, an American naturalist and Hersey Professor of Anatomy at Harvard Medical College since 1847, and Dr. Oliver Wendell Holmes, Sr., Parkman Professor of Anatomy and Dean of Harvard Medical College, examined the bones.

They concluded that

- The remains were human
- They belonged to a single individual
- They were dismembered by someone who did not have a sound knowledge of anatomy and dissection
- The time of death was consistent with the time period of Dr. Parkman’s disappearance
- There was no residue of embalming on the body parts

Dr. Nathan Keep, a dentist, testified that the jawbone with false teeth found in the furnace belonged to Dr. George Parkman, his patient. He demonstrated jury how the jawbone fit exactly into a plaster impression that he had made of Dr. George Parkman's jaw.

These testimonies were used to confirm the identity of the recovered body as belonging to Dr. George Parkman and helped to convict Dr. John White Webster, a professor of Chemistry and Geology at Harvard Medical College.

Another case that was important in developing the field of Forensic Anthropology was the Leutgert case of 1897 in Chicago, Illinois.

Adolph Louis Leutgert was accused of murdering his wife, Louisa, who had disappeared on May 1st 1897. Following her brother, Diedrick Bicknese’s report to the police of the disappearance, Leutgert informed the police that his wife had run away with another man.

Investigations revealed that the couple had a turbulent history with regular reports of squabbling and violence. The police also found out that Leutgert had started courting a rich widow. The night watchman at the factory informed the police that he had seen the couple enter the factory at 10:30 pm on May 1st 1987. He was told to run an errand and take the night off by Leutgert. The police also discovered that Leutgert had purchased arsenic and potash a day before the disappearance of his wife.

The police conducted a thorough search of the premises and found two of Louisa rings, a corset and several bones. George A Dorsey, an assistant curator of anthropology at Field Museum and the first doctoral graduate in Anthropology, granted by Harvard University, assisted in the examination of the bones and found a metatarsal bone, toe phalanx, sesamoid and rib head. He concluded that the bones were human and belonged to a female.

Dorsey's evidence was extremely important in helping in convicting Leutgert as the defence was extremely adamant in expressing the lack of corpus delicti, stating that the bone fragments were the remnants of processing animal meat for manufacturing sausages.

The next few decades saw occasional consultations by Todd, Hrdlicka and Hooton; however, few publications are available of their experiences. In 1918, Harris H Wilder and Bert Wentworth published Personal Identification, outlining identification from fingerprints and facial reconstruction.

In 1919, Mildred Trotter and Goldine C. Gleser published studies on stature from long bones of Americans.

Between 1912 and 1938, Carl A. Hamann and T. Wingate Todd started what is now the Hamann-Todd collection, the world's largest collection of documented modern human skeletons, containing 3726 cadaver-derived human skeletons. The collection is housed at Cleveland Museum of Natural History.

Similarly between 1899 and 1941, Robert J. Terry started The Terry collection of dissecting-room cadavers. The collection is now housed in the Smithsonian Institution where it currently holds 1728 documented specimen.

In 1939 and 1943, Wilton Marion Krogman published two articles in FBI Law Enforcement Bulletin. This led to recognition of the contribution anthropologists could provide to medico-legal investigation and developed a still-standing relationship with the Smithsonian Institute.

In addition, teams of Physical Anthropologists were recruited by the US Army to help in identification of decomposed remains during World War II. Bodies could not be recovered before decomposed had advanced and identification became difficult. The U.S. Army established the Central Identification Laboratory in Hawaii with Charles E. Snow as the director. Mildred Trotter oversaw the lab following Snow's return. She worked on estimation of stature lengths of long bones.

Most Forensic Pathologists became acquitted with forensic anthropology through T. Dale Stewart's chapter on Identification in Gradwohl's Legal Medicine in 1954.

During the Korean War, a laboratory was established in Japan under T. Dale Stewart's leadership. With Stewart, Thomas McKern studied variability in skeletal remains to estimate age and published Skeletal Age Changes in Young American Males in 1957. This is still used for estimating age from skeletal remains.

In 1962, Krogman published Human Skeleton in Legal Medicine, which was the first book published in Forensic Anthropology.

During the Vietnam War, two mortuaries were operated in Vietnam by the US Army. After the war, on 23rd January 1973, these mortuaries were moved to Thailand .This was inactivated and moved from Thailand to Hawaii in 1976.

In 1972, Ellis R. Kerley and Clyde Collins Snow founded the Physical Anthropology Section was established in the American Academy of Forensic Sciences. In 1977, the American Board of Forensic Anthropology (ABFA) was formed, with Kerley serving as president. The objectives were to regulate the practice and increase legal acceptance of the field of Forensic Anthropology.

Essentials of Forensic Anthropology was published by Stewart in 1979. This has gone on to become one of the leading books in the field.

In 1981, William M. Bass started a body farm to study decomposition on human cadavers. The University of Tennessee Anthropological Research Facility has become a world-renowned facility for research in the field of Forensic Anthropology. As more information became available, it was observed that modern human skeletons were deviating from the standards studied by earlier skeletal collections. This resulted in the development of Forensic Anthropology databank which has been used to develop a computer program – Fordisk.

Bass published Human Osteology: A laboratory and Field Manual in 1987. Jane Buikstra and Douglas E. Ubelaker published Standards for data collection from human skeletal remains in 1994.

The Juvenile Skeleton was published by Louise Scheuer and Sue Black in 2004

The American Board of Forensic Anthropology was established to regulate the practice of Forensic Anthropology; however, this does not ensure consistency and reliability in the testimony of experts. To achieve this goal, the Scientific Working Group on Anthropology was co-sponsored by the Central Identification Laboratory and the Federal Bureau of Investigation and had its first meeting in 2008. The SWGANTH developed guideline for forensic anthropology to ensure quality and consistency of practice.

The SWGANTH was replaced by the subcommittee on Anthropology under the Scientific Area Committee on Crime Scene/ Death Investigation of the Organisation of Scientific Area Committees for Forensic Science under the Committee of National Institute of Standards and Technology in 2014 and held its first meeting in 2015.

Forensic Anthropology and Identification

As previously discussed, Forensic anthropology concerns the examination of human remains to determine the identity and assist in medico-legal investigations. As such, the analysis for identification can be divided into two categories:

- Primary indicators
- Identifiers

Primary indicators

The primary indicators are the basic information that should be estimated for every remains and include ancestry, gender, age and stature. The analysis can be subjective, and so leave room for differing interpretations by two different individuals. As a result, it would be preferable to use objective methods for analysis. However, this requires population specific data that is not available for Nepal. As such, the authors feel a combination of methods of subjective and objective analyses, using data from other population set, should be used to come to a conclusion. While this is not the best solution, the authors feel that the lack of research data for Nepal precludes the use of subjective analysis and the only way to ensure minimal bias in this method is by including objective methods, albeit from a different (but similar) population.

The primary indicators are not used to positively identify the remains. However, due to the large number of cases of missing persons, it is important to index and categorise the unidentified remains to ensure efficiency in the identification process. The primary indicators help by categorising the dead based on ancestry, gender, age and stature. This then assists in streamlining the analysis for identifiers.

Identifiers

While primary indicators do not assist in identifying the remains, it is an integral part of the identification process. It is also important to practice analysing for primary indicators before analysing identifiers. This is especially important in centres where large numbers of unidentified bodies are received on a regular basis, as well as during mass casualties. The adherence to the protocol on a day to day case will ensure that one is prepared when the need does arise, in case of disasters and catastrophes.

Identifiers require previous knowledge of the missing person which will be compared to the findings on the unidentified body to establish identity. As such, the analysis is comparative in its very nature. The identifiers can also be of two categories:

- Positive identifiers
- Presumptive identifiers

Positive Identifiers

The positive identifiers are those features that can identify the remains as belonging to an individual. These methods can be used for positive identification individually. They include:

- DNA profiling/fingerprinting
- Dactylography (finger print analysis)
- Comparison of ante-mortem and post-mortem dental and medical findings

While these aren't the only techniques to be used for positive identification, the other methods require a level of discretion to decide suitability and should be used in conjunction with one of the above methods or with multiple methods being employed to reduce error.

- Tattoos, scars, and other marks of identification
- Anthropometry – including hand, foot, ear, nose measurements etc.
- Casts/Prints – including rugoscopy, cheiloscopy, poroscopy etc.
- Pathology – including anomalies, deformities etc.

In addition, modern equipment and techniques, like CT scan, X-rays and immune-chemistry have now facilitated analysis of various aspect of the body, which were not available previously. The field of Forensic Radiology has only started being developed and has seen growth in leaps and bounds. Once again, discussion on the topic is beyond the scope of this document.

Factors like pathological conditions of bones, population relationship, factors for growth and development if present, traditional nutritional and dietary relationship of specific population can now be analysed. Elemental and isotope analyses can also be used not only for dating the specimen but also to corroborate the findings with developmental, nutritional and toxicological status of a population group. Any aberrations in genes can also be analysed and used for identification.

With advances in these complex analytical techniques, a multi-disciplinary approach has become a necessity for identification programs. In Nepal too, the medico-legal investigation of death has multiple stakeholders with Nepal police performing scene analyses, retrieval, and investigation as well as laboratory support. In most cases, the medical personnel are expected only to analyse the remains and provide opinions. This is, in most cases, without proper co-ordination between the different stake-holders. The government attorney's office co-ordinates with Nepal Police on investigation and analyses of reports, once again, without prior co-ordination with the medical personnel.

Anthropology in Nepal

Forensic Anthropology tends to use the field of anthropology for pursuit of justice, i.e. uses the study of human variations to estimate the identity. While traditional anthropology tended to study socio-cultural variations, biological anthropology extended this study of variation into human biology.

As such, Nepal is an extremely diverse nation with 130 castes, 123 different languages and 10 religions. While diversity is important to establish individuality, there is an adverse effect as well. Data used should be population specific and at present data for Nepalese population hardly exist, let alone for variation in the ethnic diversity of Nepal.

Some studies have been performed by forensic practitioners and we hope to include all the relevant available data.

Internal displacement is another concern when it comes to forensic identification. Internal migration could be due to various reasons. These include, work, education, conflict, disaster etc.

The 2011 census showed that 14.8 percent of native population migrated between districts. Intra-district migration data is not available, however, most of the unidentified bodies tend to be of a lower income and social status standing and would have moved to a bigger town or city for better economic prospects. The homeless are usually uncared for with no family members and this poses a problem for identification.

Year	Total Native Born	Migrants as a percent of native born		
		Inter-district	Inter-regional	Inter-zonal
1961	9,075,376	4.7	-	-
1971	11,218,535	-	4.5	4.0
1981	14,788,800	8.6	7.0	6.3
1991	18,046,302	9.6	7.8	6.8
2001	22,128,842	13.2	9.3	7.8
2011	25,524,611	14.8	10.4	8.2

Source: KC, 2003; Population and Housing Census-2011 Database, CBS, 2014.

Another concern for Nepal is the commingling of ethnicities as seen in modern metropolitans. Origins and ancestry have now been commingled to such a level that Mongolians from Himalayas and Aryans from Plains tend to be scattered throughout the country, with equal concentration in Kathmandu. Inter caste marriages although considered rare few decades back is an emerging way of cultural exchange now.

People in Nepal, who lived in specific isolated population groups few decades back, were mobilized initially by the decade long Maoists insurgency. With thousands disappeared and missing, the job of identifying an individual with Himalayan origin from commingled gene pool, whose dead body might be buried somewhere in the Plains makes the process even more complicated.

History of Forensic Anthropology in Nepal

Numerous exhumations have been conducted in Nepal in the past under various authorities. Exhumations in ongoing criminal investigations are governed by Muluki Ain and at present, the entire exhumation process is performed under the supervision of Nepal Police with locals working on the actual exhumation process. While the lack of qualified personnel precludes the use of unqualified and untrained personnel, they should at the very least follow scientific procedures. As such, the medical officer is technical leader of the investigation and should ensure that protocol is followed and standards maintained. This will assist in ensuring that the evidence is accepted in court.

The first case that followed internationally acceptable scientific standards was the exhumation at Panchkhal. The case has only recently been concluded by District Court Kavre Palanchowk, which sentenced the three accused to life imprisonment.

While scientific standards are now considered when Forensic Practitioners have been summoned to assist in recovery, this is usually not the case. The usual scenario is that the medical facility would receive either a box or bag of bones with a request to examine and answer some queries. The description of the scene and the recovery process that is provided is usually rudimentary at the best.

Just as Krogman published in the FBI bulletin emphasising the need to used scientific standards that have been internationally accepted, this guideline would like to impart, at the very least, the need to ensure adherence to standards as prescribed in various literature. As previously discussed, the scope of this document require a little brevity in the explanation of scene investigation. As such, we shall discuss recovery of surface remains in brief. For information on recovery of buried remains, the reader can consult 'Exhumation Guidelines (शवोत्खनन् मार्ग-निर्देशिका २०६९) published by National Human Rights Commission.

Logistic kit for examination of skeletal remains

Modified from Steyn M, Nienaber WC, İşcan MY. 2000. Excavation and retrieval of forensic remains. In: encyclopedia of forensic sciences. Eds. JA Siegel, PJ Saukko & GC Knupfer. Academic Press: London, 235–242.

Documentation:

- Notebook
- Felt tip and ball point pens
- Pencils
- Erasers
- Ruler
- Graph paper
- Scissors
- Permanent markers for writing on packaging
- Cameras
- Scale, indicating at least 50 cm with centimetric divisions for detail photographs
- Moulding agent such as plaster of Paris, silicone or dental material (for moulding possible footprints and tool marks)
- Suitable containers and a spoon or spatula for mixing the moulding agent
- Releasing agent, such as ski wax (to use during moulding)

Handling and packaging of remains and evidence:

- Containers and plastic bags, big and small, for insects, bones, teeth and physical evidence recovered
- Packaging material, such as bubble plastic, bags, screw top bottles and boxes
- Tape to seal containers
- Labels
- Rubber gloves and protective clothing if soft tissue is present
- Buckets with lid for decomposed materials
- Body bag.

Personal Protective Equipment (PPE):

- Gloves
- Eye protection
- Breathing apparatus or suitable dust masks or filters depending on the situation
- Closed suitable shoes
- Suitable protective clothing Tyvek or other specialised contamination suits where required
- First Aid kit containing suitable disinfectant and bandages to immediately treat small cuts and abrasion

Documentation:

Forensic analysis is a destructive process that destroys evidence. This makes meticulous documentation imperative to be of any investigative value. Therefore, the primary focus of any examination must be documentation,

It is absolutely inexcusable not to document at the time of examination, except in exceptional circumstances.

Initial Documentation:

Documentation should begin prior to cleaning of the remains and should include information on the type of packaging, seals used, any marking, state of remains etc.

In addition, additional information may also need to be recorded including

- Witness statements
- Report of scene of recovery of remains
- Methods and techniques employed for recovery

Sketches & Drawings:

Spatial relationships of evidence with the remains should be properly documented to allow reconstruction. With these considerations, the following must be recorded using sketches or diagrams

- Skeletal element involved and exact location
- Three-dimensional location and associations of evidence with anatomic features
- Other relevant information.

Catalogs:

Catalogs are inventories of sequential, numbered items relevant to the provenience and context of the scene. They also act as an organizational aid for inventory of evidence

Photographs:

Photography should be used extensively to supplement other forms of documentation. While photography provides an additional means of documentation, few photographers are skilled enough to be able to document all aspects of the process.

Preparation for Photography:

Following documentation of an undisturbed site or provenience, another photograph should be taken to capture as much detail as possible. This can be done by ensuring the following

- Clean the area of photograph to allow colour and texture to be differentiated
- Features and evidences should be cleared sufficiently to be clearly visible in images
- Objects should not have been altered except for minimal cleaning
- Use of a scale as well as case details

A scale is required when

- Photographing evidence in situ
- Evidence is the subject of the photograph

The size of a scale should be appropriate to the size of the subject being photographed. Scales should be positioned on the same plane as the subject

A scale is not required when:

- Photographing broad, oblique overviews of a site lens (however, subjects such as people or trees should be included to provide a general reference of size)
- Taking close-up photographs that have already been photographed with scale
- Photographs to assist catalog documentation

Documentation in the photography log should include:

- Make, model and unique identification number of camera
- File name or number (self-assigned number from the camera
- Photographer, date and time
- Short description of the subject of the photograph

Inventory for human bones

As such, the medical practitioner may encounter remains in various stages of post-mortem changes. Skeletisation may be incomplete and some tissue may still be attached to bone. Remains may be found in graves, and if these remains are very old, the bones may be brittle and fragile. All broken, burnt or deformed bones should be registered before being packaged for transportation. The condition of bone at the time of retrieval provides an insight for the investigation as well as helps the laboratory analysis by differentiating trauma sustained during transportation. This makes identification process more systematic and scientific.

On completion of the inventory one may be able to estimate human or non-human, minimum number of individuals, as well as condition of preservation.

Packaging

All recovered material should be packed and a chain of custody form filled before handing over to the Investigation Officer.

The packages should be documented with Evidence or Material Tags containing

- Unique Evidence/Bag number
- Date
- Item Description
- Initials of Collector/Technician

Metal and Non-degradable material can be stored in Plastic bags. However, materials that undergo decomposition should be dried of as far as possible, in shade, and packaged in paper envelopes for transportation.

Chain of Custody

All material recovered from the scene should be handed over to the Investigating Officer for safe-keeping during transportation. This process should be documented using a Chain of Custody Form.

Chain of Custody Form

सबुत हस्तान्तरण फारम

S.no.	Code No. संकेत नं	Sample description सबुतको विवरण	Signature हस्ताक्षर
1.			
2.			
3.			
4.			
5.			

सबुत बुझाउनेको नाम:
दर्जा:
मिति:
हस्ताक्षर:
छाप:

सबुत बुझिलिनेको नाम:
दर्जा:
मिति:
हस्ताक्षर:

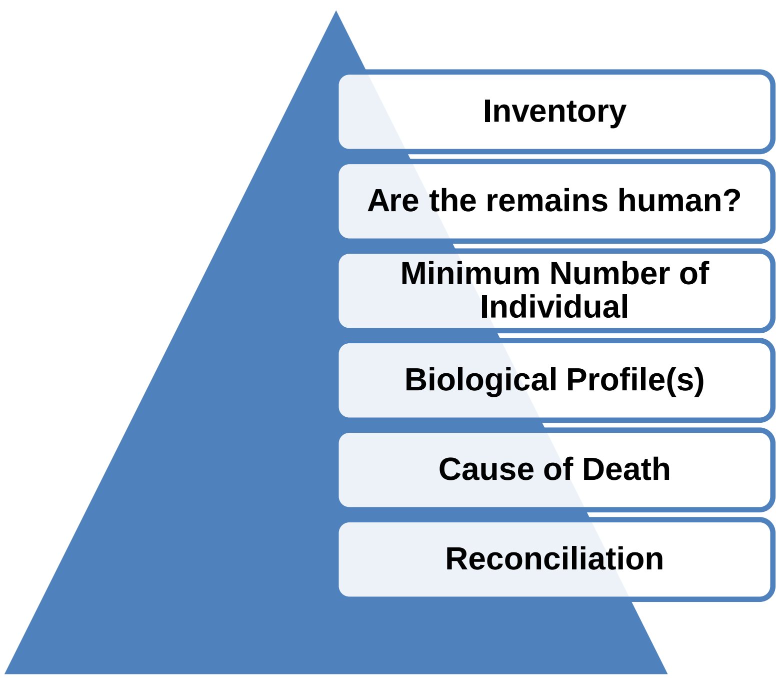
Laboratory Analysis of Skeletal Remains

Once the remains have been transported to the laboratory, the chain of custody should be completed and a copy provided to the police personnel delivering the remains. Another copy should be retained after being duly filled and signed by the police personnel as well as the laboratory personnel.

The laboratory personnel should verify the completeness and accuracy of all seals. The package should be verified with the requesting letter from Police or the field notes, if available.

Documentation of the state of package and seals is an important part of the entire documentation process as this shows the reliability and relevance of the material to be examined. Once the seals and package, including the packaging material, have been documented, the package is opened and the contents verified with the field notes, if available.

The material should then be documented using an inventory and photography.



Process of Identification

Are the remains human?

Identification of individual bones can be extremely difficult in some scenarios. Identification of fragmented bones even more so. However, it is important to identify remains as human or otherwise at the scene as well as in the laboratory to assist in complete recovery as well as accurate analysis.

Non-osseous items like wood may be mistaken for skeletal remains or vice a versa. Similarly, pieces of pottery may be mistaken for cranial fragments. However, what is even more troublesome to the untrained person is differentiation of human remains from animal bones or parts. In addition, identification can be further complicated by exposure to fire, environment etc. that results in taphonomic changes to the bones. Human bones can generally be differentiated from animal bones by examining the anatomy, gross structure and histology.

Osteology/Anatomy

Vertebrates comprise of approximately 4% of all living organisms. However, most vertebrates share a similar skeletal structure due to the common origins in evolution. There are however features inherent to each species to help differentiate.

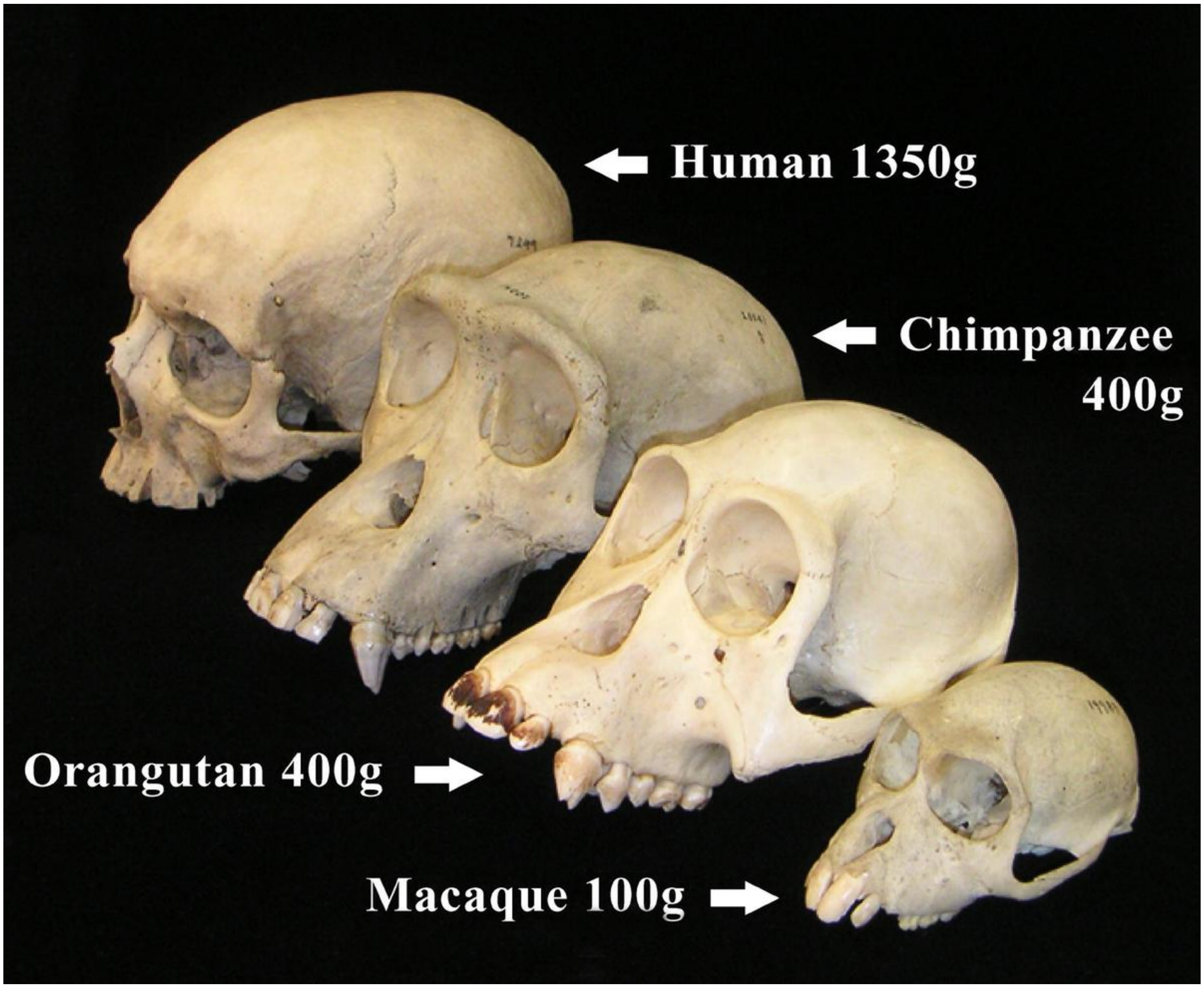
Cranium

The cranium of Homo sapiens is drastically different when compared to all animals. This is because humans have large brains in comparison to body size. The cranium is vertically oriented in human with the orbits placed in front and above the nasal aperture. While in animals, the cranium is horizontally oriented with the orbits lying more laterally and behind the aperture. Humans also have smaller facial dimensions when compared to a larger, more bulbous cranial vault.

The cranial vault is smoother due to decreased muscular developments of the vault. Humans also have larger and less curved cranial bones as compared to other primates. The inner table of the vault bones are also smoother in humans, occasionally being grooved by meningeal vessels. Humans also have the foramen magnum located inferiorly whereas most vertebrates, including some primates, have the foramen magnum located more posteriorly. Human chin also shows a lower degree of prognathism than animals.

	Human	Animal
Vault	Large and bulbous	Small
Face	Small	Large
Orbits	Anterior, above nasal aperture	Lateral, behind nasal aperture
Vault	Smooth external and internal	Pronounced muscular attachments
Foramen Magnum	Inferior	Posterior
Prognathism	Minimal	Pronounced

Cranial differences between humans and animals



Crania of Human, Chimpanzee, Orangutan and Macaque

Dentition

Teeth show great variation between different animals based on their dietary evolution and can be used effectively for differentiation.

Human have a generalised set of teeth with a mixture of incisors for slicing, canines for tearing, and molars for grinding. Herbivores have teeth that are flatter and have more rounded ridges for grinding. Carnivores on the other hand have extremely sharp canines with teeth have sharper ridges for shearing.

Although not a rule, many placental mammals have a generalised formula consisting of three incisors, one canine, four premolars, and three molars (3:1:4:3), whereas humans in general have two incisors, one canine, two premolars, and three molars (2:1:2:3) in each quadrant of the oral cavity.

They of course also have various degrees of care evident. However, this is less of a

	Human	Animal	
Diet	Omnivorous	Carnivorous	Herbivorous
Incisors	Large	Small	Horse – larger
Canines	Small, conical	Large, sharp	Small or missing
Molars	rounded cusps	sharp, pointed cusps	Furrows and ridges

Dental differences between humans and animals

Post-Cranium

The post-cranial skeleton is primarily dependent on movements during locomotion. As a result, quadruped lacks spinal curvature, have a long and narrow pelvis.

Humans have a central vertical axis, and the spinal column has four slightly opposing curves. The pelvis is broad and flat.

	Human	Animal
Vertebrae	Large, flat and broad body with short spinous processes	Small body with long spinous processes
Sacrum	Short and broad with 5 fused vertebrae	Long and narrow with 3 or 4 fused vertebrae
Pelvis	Broad and flat	Long and narrow

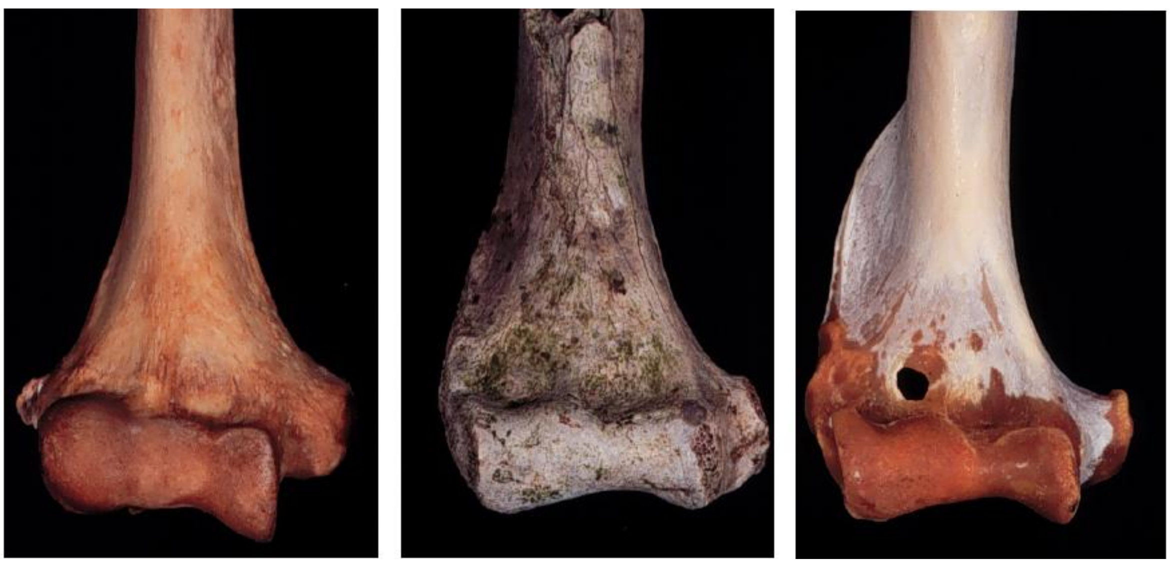
Axial Skeletal differences between humans and animals

Due to weight bearing on all limbs, the forelimbs of quadrupeds are as robust as the hind limbs, with as prominent muscular attachments. In addition, the radius and ulna, as well as the tibia and fibula, may be fused to increase strength and flexibility. Humans have an angled femur and robust tibia, with arched feet. The forelimbs have smaller musculature to allow for a greater range of motion. The difference is markedly less in bipeds. However, in most bipeds also, the forelimbs play some role during locomotion unlike in humans and so are more robust when compared to human forelimbs.

	Human	Animal
Forelimbs	Less robust	Robust
Radius and ulna	Not fused	Often fused
Femur	Longest bone	Similar length to other limb bones
Tibia and fibula	Not fused	Often fused or fibula absent
Foot	Arched, long and narrow	Broad, weight borne by toes

Post-Axial Skeletal differences between humans and animals

Bird bones are very different in shape from human bones, and also very light. Bird bones have very thin cortex and only minimal trabeculae. However it is important to remember that bird long bones may be particularly difficult to distinguish from human foetal bones.



Humerii of Human and Bear

Undeveloped bones before the completion of epiphyseal union are the commonest bones to be mistaken as non-human. The distinct difference between the appearance of adult, fully developed bones, with completed epiphyseal union, and infant bones confounds even the sharpest of the untrained minds. The unfused bones have indistinct ends or may be separated into segments.

In addition, infants may have more than 206 bones or bone segments due to the presence of multiple ossification centers. These segments may not be identifiable to a specific bone. Diaphyses of long bones are thin and brittle with absence of trabeculae. Cranial bones do not have diploe. The petrous part of temporal bone is separated from the other parts of the temporal bones and survives better than most other vault bones due to its increased density. Ribs of infants may be mistakenly identified as animal bones and may be discarded. The long bones of infants resemble the longs bones of a chicken.

It is therefore important to remember that what may appear to be non-human or non-bone osseous material may infant be a segment, unfused bone segment belonging to an infant.

Bone Macrostructure

Animals have less porous, thicker and denser bones than human. Cortical thickness of human humerus and femur, account for approximately one-fourth of the total diameter of the bone, while in animals, the cortical thickness accounts for approximately half of the total diameter of the bone.

Diaphyses in animal bones show a distinct lack of trabeculae, resulting in smoother medulla as compared to the web like pattern created by the trabeculae in human long bones. Vault bones in animals are thinner and more compact than human bones, which show a thin cortex with thick diploe.

	Human	Animal
Cortex	More porous	Less porous
	One-fourth of diameter	Half of diameter
Trabeculae	Trabeculae present, web-like medulla	Trabeculae absent – smooth medulla
Vault bone	Thick diploe, with thin cortical layers	Thinner, More compact

Differences in macro-structure of human and animals

Minimum Number of Individuals

The first step in analysis is to lay out all the skeletal remains in their anatomical position and to record in an inventory. This assists in determining the minimum number of individuals by ensuring that duplication of elements become evident. However, it is important to remember that duplication of elements may be a result of super-numerary development. For example, the presence of two skulls or two right humerii invariably indicates the presence of two individuals. At the same time, the presence of 13 pairs of ribs as well as 13 thoracic vertebrae may not indicate multiple individuals and may be the result of supernumerary development, resulting in 13 pairs of ribs and vertebrae in the same individual.

The analysis of the remains may also demonstrate incompatibility between elements on the basis of ethnicity, sex, age, size or other physical features like incompatibility between two adjoining articular surfaces or facets. For example, the occipital condyles should correspond in size and shape to the articular facets on the atlas. Similarly, the condylar fossa in the maxilla should correspond to the mandibular condyles.

Confusion arises when the elements are not intact and have two or more segments. In such situations, determination of the minimum number of individuals is assisted by examining the segments to compare the compatibility between the segments on the basis size, age etc. In addition, present of anatomical features that are present over both segments of the bone would indicate the presence of more than one individual. For example, the present of a complete radial groove on one segment of the humerus, with presence of a partial or fragmented radial groove on another segment indicates that the two segments could not have come from the same element.

The estimation of minimum number of individuals provides a conservative number and may not be truly representative. As a result, two other concepts have been developed to estimate the number of individuals.

The estimation of number of individuals becomes extremely difficult during examination of cremated remains. The degree of fragmentation and commingling may vary from commingling of elements of a single individual to commingling of multiple elements from multiple individuals.

Even when examining cremated remains allegedly belonging to one individual, the question invariably remains whether any remains of another individual are included, either due to fraudulent or negligent funerary care.

When massive accumulations of remains need to be analysed, it may not be feasible to estimate Probably Number and only Minimum Number estimates may be practical, even though MNI may grossly underestimate the number of individuals present.

Development of Biological Profile

The following section provides sample methods for determining biological profiles from skeletal and dental remains. In case a validated method not mentioned in this guideline is used, the report should contain references as well notes describing the method(s) used.

Biological profiles are determined by comparing the remains with various exemplars derived from populations of known individuals. The specificity and invariably depends on the type of remains, condition of preservation as well as the quantity of remains available.

Since methods are population and sub-population dependent, population specific studies should be used to determine the biological profile(s). The biological profile of an individual is determined by estimating the ancestry or race, sex or gender, age at death, stature, and individualizing traits. Among these, individualizing traits are used to specify the individual from within population groups and should be examined at the end.

Similarly, stature of an individual is primarily dependent on the age of the individual. For example, estimation of stature from regression equation of long bone measurements would result in extremely erroneous results if the age of the individual is not confirmed. Therefore, stature should be estimated after estimating age at death.

Estimation of Age of an individual will be affected by the sex of the individual. For example, epiphyseal union occurs earlier in females than in males. Gender therefore should be estimated before estimation of age at death.

Finally, it is important to realize that males from one race or ancestry may be smaller than the females of another race or ancestry. Therefore, ancestry should be the first variable that is estimated.

Assessment of Ancestry

Ancestry is determined by the environmental and cultural factors, in addition to the genetic makeup and people who historically shared a geographic origin and therefore still share some common genetic material are said to have a common ancestry. In other words, the human genotype, along with environmental and cultural factors, correlates to systematic and discernible patterns of phenotypic variation. Therefore, ancestry assessment is the process of classification of remains into one of several broad geographic groups based on these skeletal variations.

The variability of metric and/or non-metric features of the cranium and mandible present the primary basis for ancestry assessment. If the skull is missing or does not present features to definitely categorize the individual into different groups, post-cranial morphology may be used to assess ancestry.

Race is often confused with ethnicity and while traditional "racial" categories (i.e., Caucasoid, Mongoloid, or Negroid) have limited utility in research, individuals have traditionally been categorized by the military and law enforcement. Ethnicity, on the other hand, denotes a group of individuals with a common culture, language, religion, ideology etc.

It is therefore evident, that ethnicity does not necessarily constitute genetic variation and so determination of ethnicity based on skeletal morphological variations is generally not a productive exercise. As such, the determination of ancestry classifies the remains into one of three broad, geographical groups, namely African, Asian or European i.e. Negroid, Mongoloid or Caucasoid.

Following numerous research into ancestry, it has now become possible to include distinctions of social race/or ethnicity and an individual remain may be identified as belonging to one or more ethnicities - European (white); European (Hispanic); African (black); Asian (SE Asian); Asian (Hispanic); Asian (Pacific Islander).

It is also imperative to remember that the analysis may not be able to provide a final classification, in which case, the remains are classified as 'Indeterminate'. This may be due to insufficient data and/or ambiguous results.

Cranial Non-metric Traits

Bass and Rhine describe cranial non-metric traits represented in the three major races. Gill, on the other hand, assesses craniofacial traits for five geographic races: East Asian, Native American, Caucasian, Polynesian, and African American. Hefner studied the frequency distributions for 11 of the more commonly used non-metric traits.

Characteristic	East Asian	White	Black
Cranial index	Brachycephalic	Mesocephalic	Dolichocephalic
Post-bregmatic depression†	Absent	Absent	Present
Cranial sutures	Complex	Simple	Simple
Nasal aperture width†	Medium	Narrow	Broad
Nasal bone shape†	Plateau	Triangular	Low/rounded
Nasal profile	Concave	Straight	Straight/concave
Inter-orbital breadth†	Intermediate	Narrow	Wide
Anterior nasal spine†	Medium	Large	Small
Inferior nasal aperture†	Straight	Sill	Dull
Molar crenulations	Absent	Absent	Present
Incisor form	Shoveled	Blade	Blade
Facial prognathism	Moderate	Reduced	Extreme
Alveolar prognathism	Moderate	Reduced	Extreme
Malar form	Projecting	Retreating	Reduced
Zygomatico-maxillary suture†	Angled	Curved	Curved/angled
Palatal form	Elliptic	Parabolic	Hyperbolic
Transverse palatine suture†	Straight	Jagged	Anterior bulge
Orbit shape	Round	Rhomboid	Round
Mandible	Robust	Medium	Gracile
Chin form	Median	Bilateral	Median

*Modified from Gill (1998), Rhine (1990), and Hefner (2009)

† Frequency distribution of characteristics in bold are presented in Hefner (2009)

Primary trait complexes of the cranium and mandible.*

Dentition:

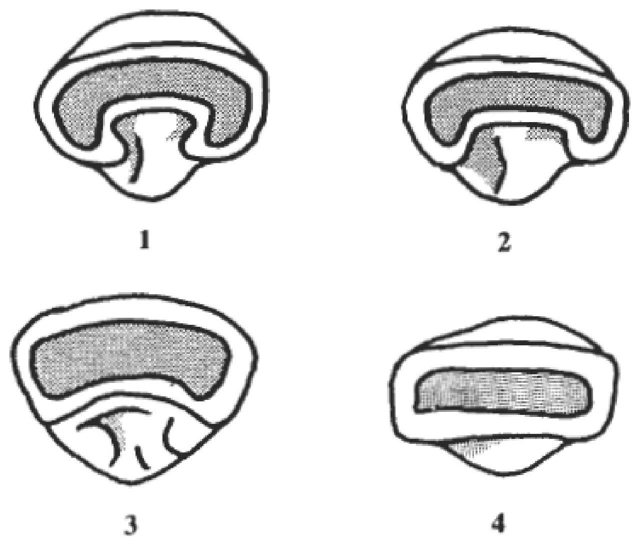
The shape and size of teeth demonstrate comparable variations in human populations. Teeth are resistant to changes and are usually well protected in traumatic events. Therefore, teeth are valuable in analyzing an individual's ancestry.

Dental Traits & Morphology

Dental traits and characters may assist in assessing ancestry. Known trait frequencies are used for assessment of ancestry. However, once again, using singular traits should be used with caution when estimating ancestry.

Shovelling of incisor teeth is one of the most common methods of distinguishing modern mongoloids. Hrdlicka proposed a four part scale for estimating shovelling.

1. Shovelled – lingual surface shows enamel rim with enclosed fossa being well developed
2. Semi-shovelled – distinct enamel rim; enclosed fossa is shallow
3. Trace of shovelling – distinct traces of a rim
4. No shovelling – no perceptible trace of rim or fossa



It should be remembered that the trait occurs at a frequency of 7 – 9% in Caucasoid and 85 – 99% in Native Americans. Suzuki and Sakai found that the frequency of shovelling ranges from Native Americans to Asiatic Mongoloids to Aleuts to Chinese to Japanese to Pacific Islanders.

Sex Estimation:

Sex estimation analyzes dimorphic variations of the pelvis, cranium and post-cranial skeleton. While there are variations between populations, dimorphic variations are invariably present within the populations and can be used to differentiate between the sexes.

Estimation of sex is typically based on two principles.

- Skeletal elements in males are larger and more robust, displaying more prominent muscular attachments than in females.
- Sexually dimorphic variations, preferably on the pelvis and skull. When the pelvis and skull are missing or incomplete, postcranial remains, usually the humerus and the femur, may be used.

It is important to remember that sexual dimorphism, while being genetically inherited, is affected significantly by hormones. This is evident from the lack of dimorphism in pre-pubertal individuals. Also, since the primary difference between the sexes is in the function of child-bearing, the most significant differences are seen in the pelvis.

Pelvis (Os Coxae or Innominates)

The bones of the pelvis are typically the best for the assessment of sex. Non-metric sex-estimation is generally initiated by an assessment of the overall size and shape of the pelvis. Generally, the male pelvis is more robust with prominent muscle attachments. The obturator foramen is larger and more oval shaped in males, whereas in females it is smaller and more triangular. The true pelvis is more spacious and less funnel-shaped in females than in males. The acetabulum is generally larger in males to accommodate a larger femoral head. The pelvic inlet is heart shaped in males and more elliptical or circular in females. The pubic symphysis is acute in males, while in females the sub-pubic angle is obtuse.

Several specific non-metric techniques are useful in determining sex in the pelvis.

Three Traits of Phenice

Phenice (1969) describes three characteristic areas of the pubis and ischio-pubic ramus that distinguish sex in 96% of cases.

- **Ventral arc** – a slightly elevated ridge of bone across the ventral surface of female pubis. Generally absent in males.
- **Sub-pubic concavity** – lateral curvature a short distance inferior to the symphysis, best observed from the dorsal surface. Rarely present in males.
- **Medial aspect of ischio-pubic ramus** – a ridge or narrow surface immediately below the symphyseal surface, present on the ischio-pubic ramus. The medial aspect of the ischio-pubic ramus is broad in males.

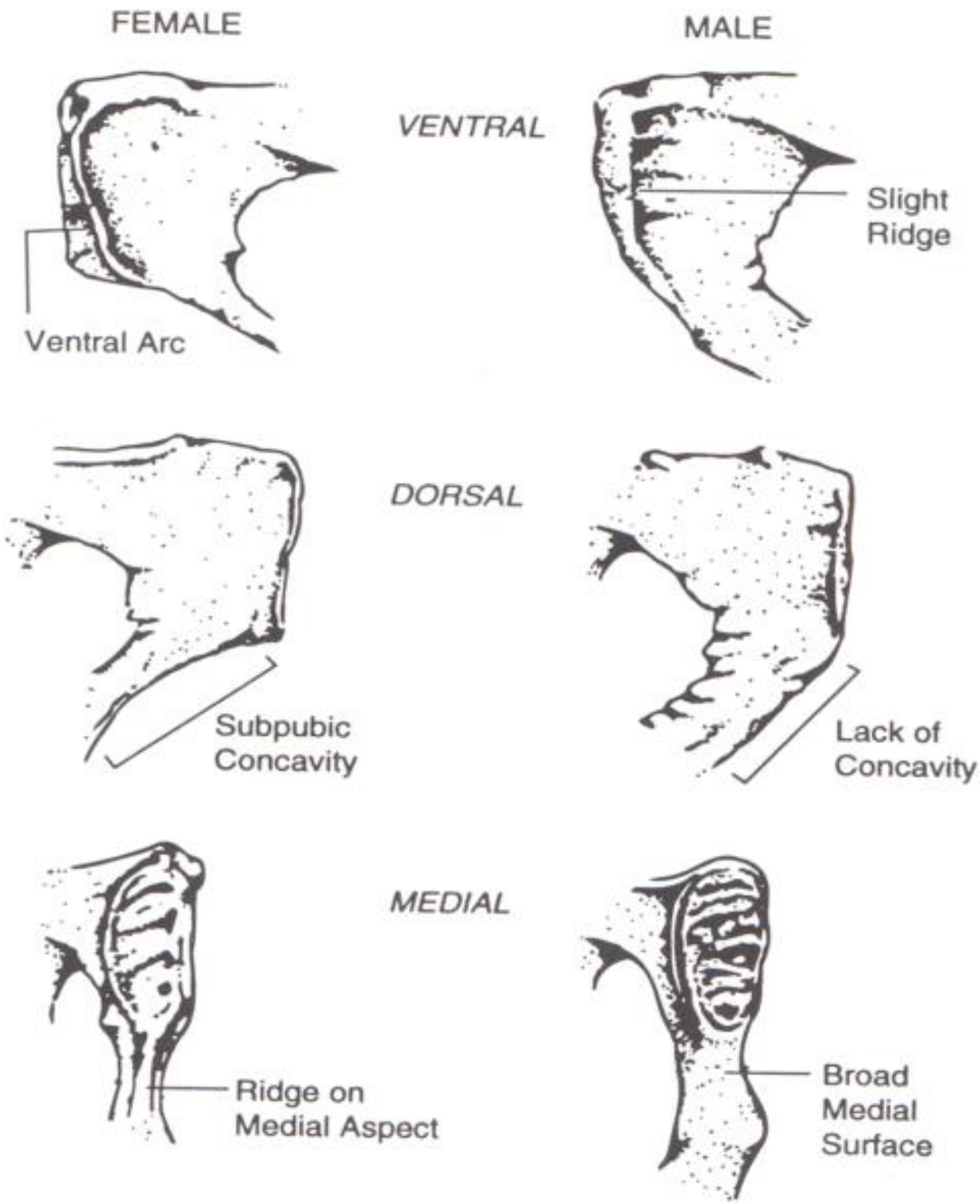
Buikstra and Ubelaker (1994) devised a scoring system for each of these traits.

0 Unobservable

1 Female

2 Ambiguous

3 Male.



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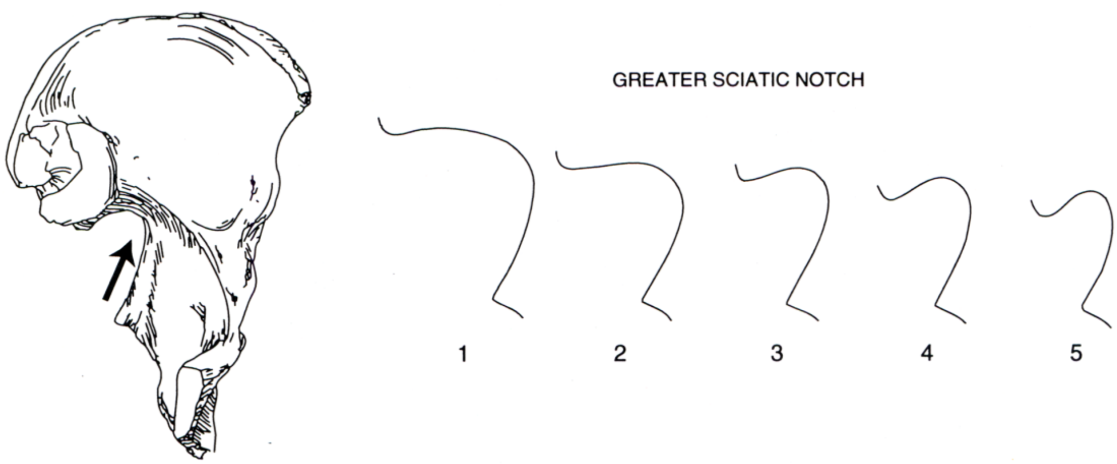
Sex Differences Using Phenice's Characteristics (Buikstra and Ubelaker 1994:17).

Other Characteristics

Buikstra and Ubelaker (1994) have devised a scoring system for recording sexual dimorphism in the sciatic notch.

- Typical female morphology
- Intermediate female
- Indeterminate
- Intermediate male
- Typical male morphology

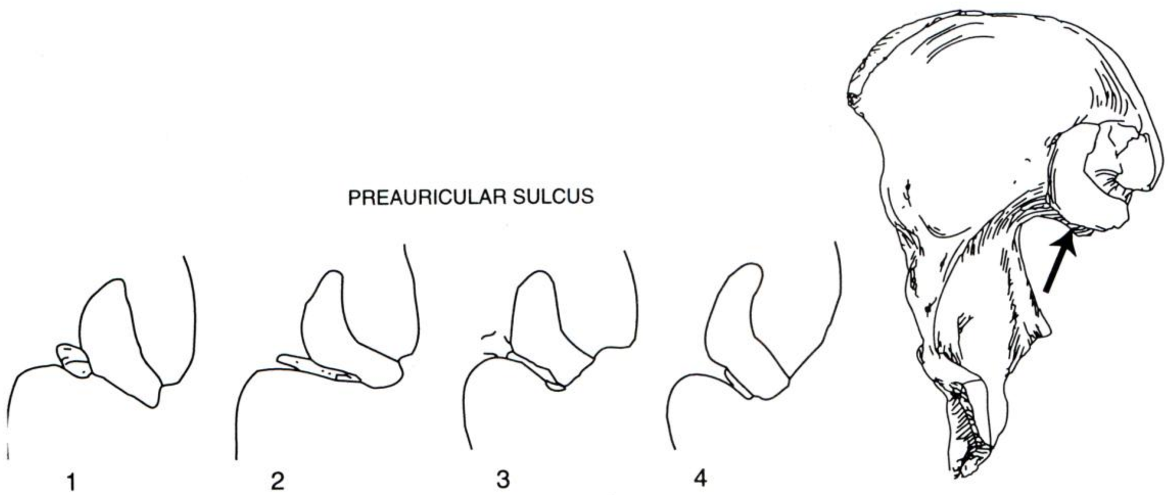
Walker showed that a score of 1 typically indicates a female, while a score of 3 or greater usually indicates a male. A score of 2 represents intermediate morphology, although a larger percentage of males typically exhibit this degree of expression than females. He also found that age-at-death and sciatic notch score showed a significant correlation. Younger individuals showed high propensity to exhibit more feminine morphology; this effect was more pronounced in males.



Scoring System for the Greater Sciatic Notch.
(Buikstra and Ubelaker 1994:18)

Buikstra and Ubelaker also devised a scoring system for the pre-auricular sulcus to record dimorphic variations:

- Absence of a pre-auricular sulcus.
- Pre-auricular sulcus is wide, typically exceeding 0.5 cm, and deep.
- Pre-auricular sulcus is wide, usually greater than 0.5 cm, but shallow
- Pre-auricular sulcus is well defined but narrow, less than 0.5 cm deep.
- Pre-auricular sulcus is narrow (less than 0.5 cm), shallow, with a smooth walled depression



Scoring System for the Pre-auricular Sulcus (Buikstra and Ubelaker 1994:19).

Skull

After the pelvis, the skull is typically the next best indicator for sex. Buikstra and Ubelaker developed a scoring system for five cranial features

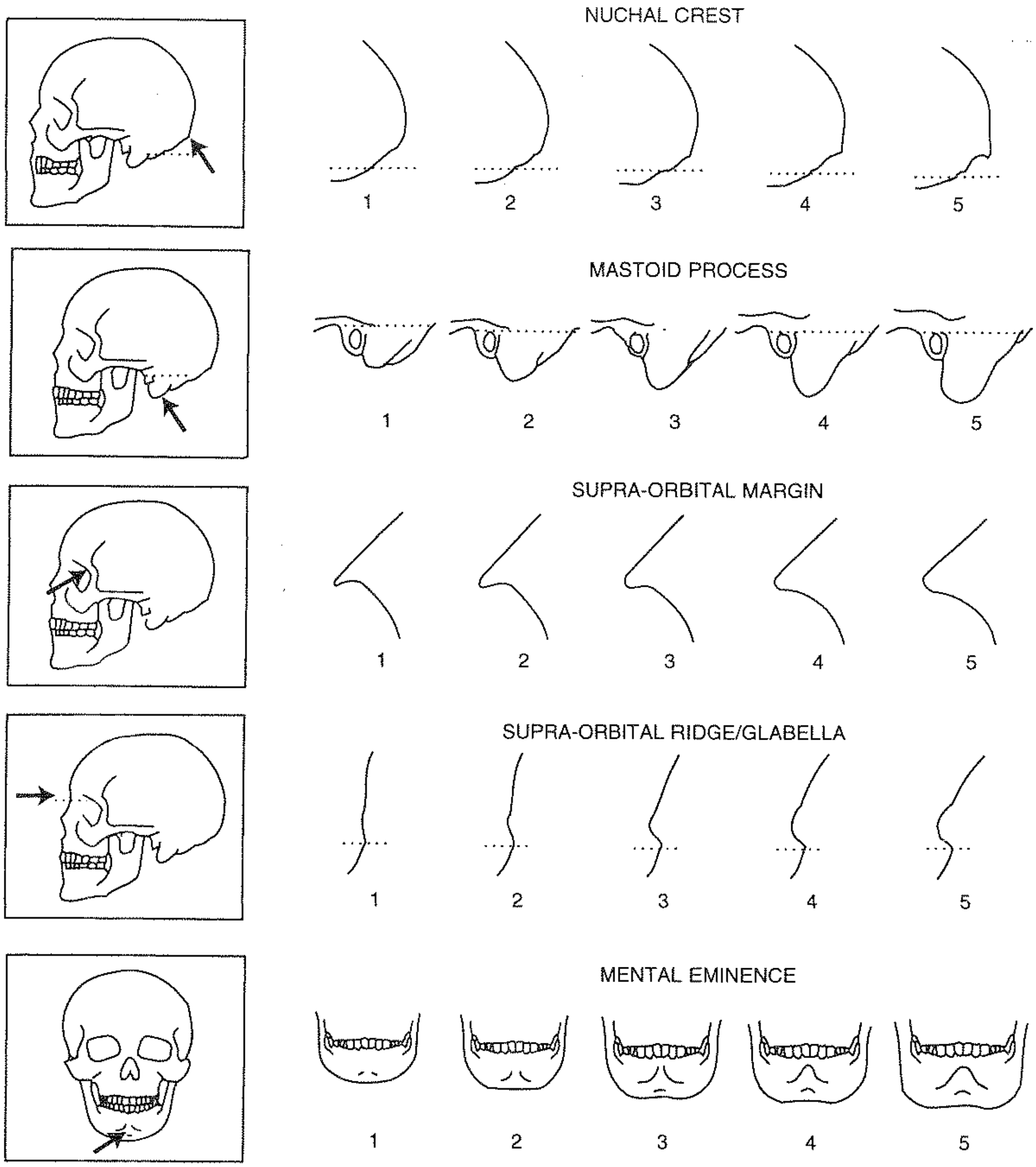
- Nuchal crest
- Mastoid process
- Supra-orbital margin
- Glabella
- Mental eminence

The scoring system consisted of 5 scores from 1 to 5 as follows:

1. Typical female morphology
2. Probable female – morphology is more likely female than male
3. Indeterminate – dimorphic features are ambiguous
4. Probable male – morphology is more likely male than female
5. Typical male morphology

	Male	Female
Supra-orbital ridges	Prominent	Smooth supra-orbital ridges
Supra-orbital margin	Blunt upper margins of eye orbits	Sharp upper margins of eye orbits
Palate and teeth	Large palate and teeth	Small palate and teeth
Skull	Rugged with prominent muscle attachments	Small, gracile, smoother, parietal and frontal bossing
Mastoid process	Large	Small
Frontal Sinuses	Large	Small
Chin	Square	Rounded

Some common dimorphic cranial traits



Scoring system for sexually dimorphic cranial features (Buikstra and Ubelaker 1994:20)

Age (Age-at-Death) Estimation

Age estimation of skeletal remains estimated the age of the individual at the time of death. This may vary considerably from the time the individual was missing. The teeth, mandible, pelvic bone, sternal rib ends, epiphyseal growth caps, as well as cranial and maxillary sutures are analyzed to estimate the age at death.

Other techniques and methods may be used to estimate the age at death and the choice of the method used will depend on the type of remains, condition of preservation of remains as well as other considerations. However, when methods other than those described below are used, the method employed should be suitably documented and referenced.

Estimation of age at death in foetal remains should primarily rely on the appearance of ossification centers. Addition investigations, where available, can be relied on, including but not limited to dental development as well as radiography.

In infants, children and adolescents, dental development, including eruption patterns as well as root calcification is the primary methods to be used for age estimation. At the same time, this is augmented by the examination of appearance of ossification centers. Adolescent remains should primarily examine dental maturation and skeletal maturation, especially epiphyseal union.

Mature remains are assessed based on the available age indicators.

Dental Examination

Dental remains (teeth and associated supporting jaw structures and dental prosthetic devices) can be extremely useful for estimation of age at death. Age estimation procedures typically are confined to the process of dental eruption and dental calcification. For both procedures, the dental age and age interval are determined by comparing with standard references.

Tooth	Eruption	Calcification of root
Central incisor		
Lower	6–8 months	1.5–2 years
Upper	7–9 months	1.5–2 years
Lateral incisor		
Upper	7–9 months	1.5–2 years
Lower	10–12 months	1.5–2 years
1st molar	12–14 months	2–2.5 years
Canine	17–18 months	2.5–3 years
2nd molar	20–30 months	3 years

Age estimation from Eruption of Deciduous Teeth
(Kishan Vij, Textbook of Forensic Medicine and Toxicology. 2011)

Tooth	Eruption	Calcification of root
1st molar	6–7 years	9–10 years
Central incisor	6–8 years	10 years
Lateral incisor	7–9 years	11 years
1st bicuspid	9–11 years	12–13 years
2nd bicuspid	10–12 years	12–14 years
	11–12 years	12–13 years
2nd molar	12–14 years	14–16 years
3rd molar	17–25 years	22–25 years

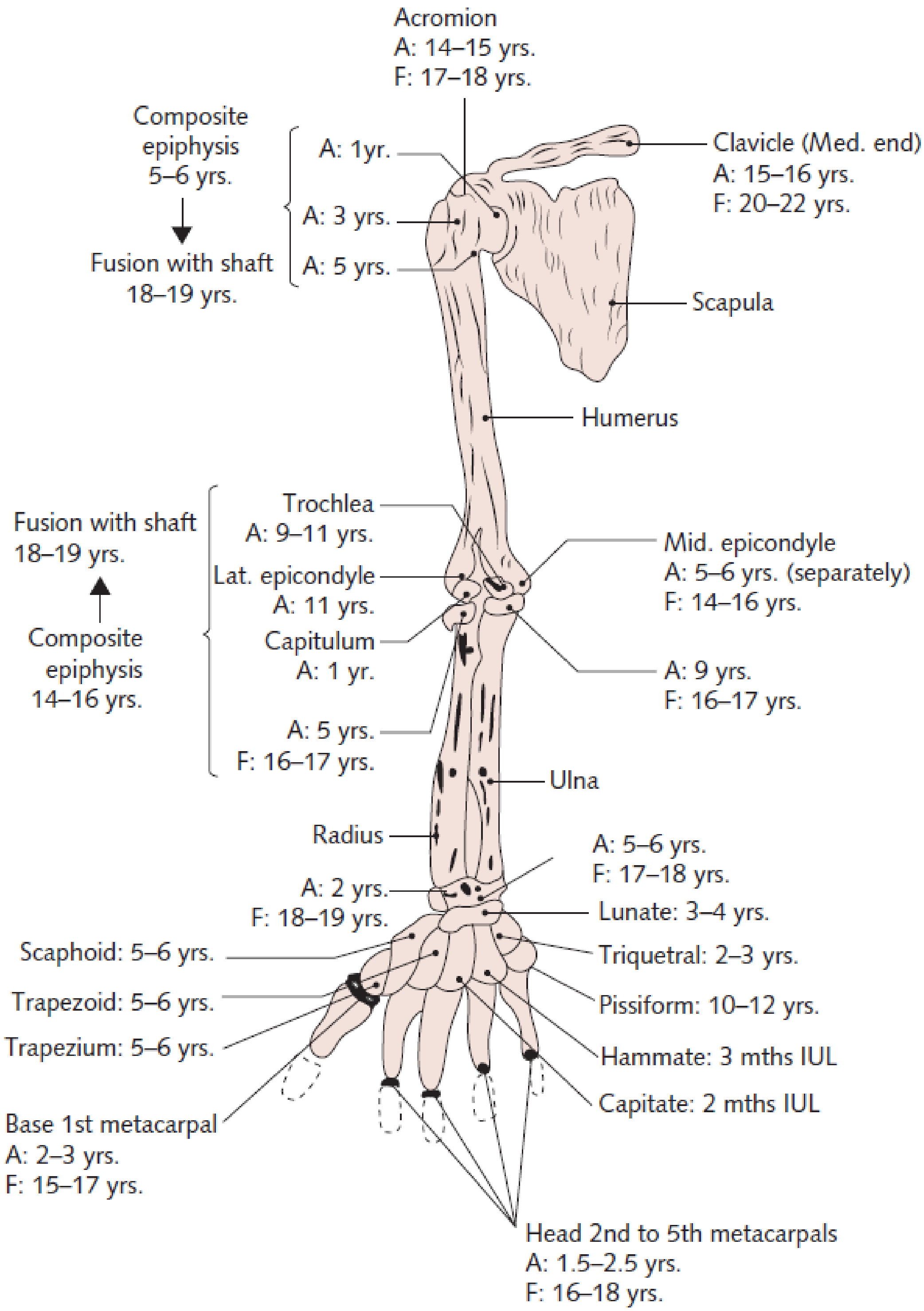
Age estimation from Eruption of Permanent Teeth
(Kishan Vij, Textbook of Forensic Medicine and Toxicology. 2011)

Epiphyseal Union:

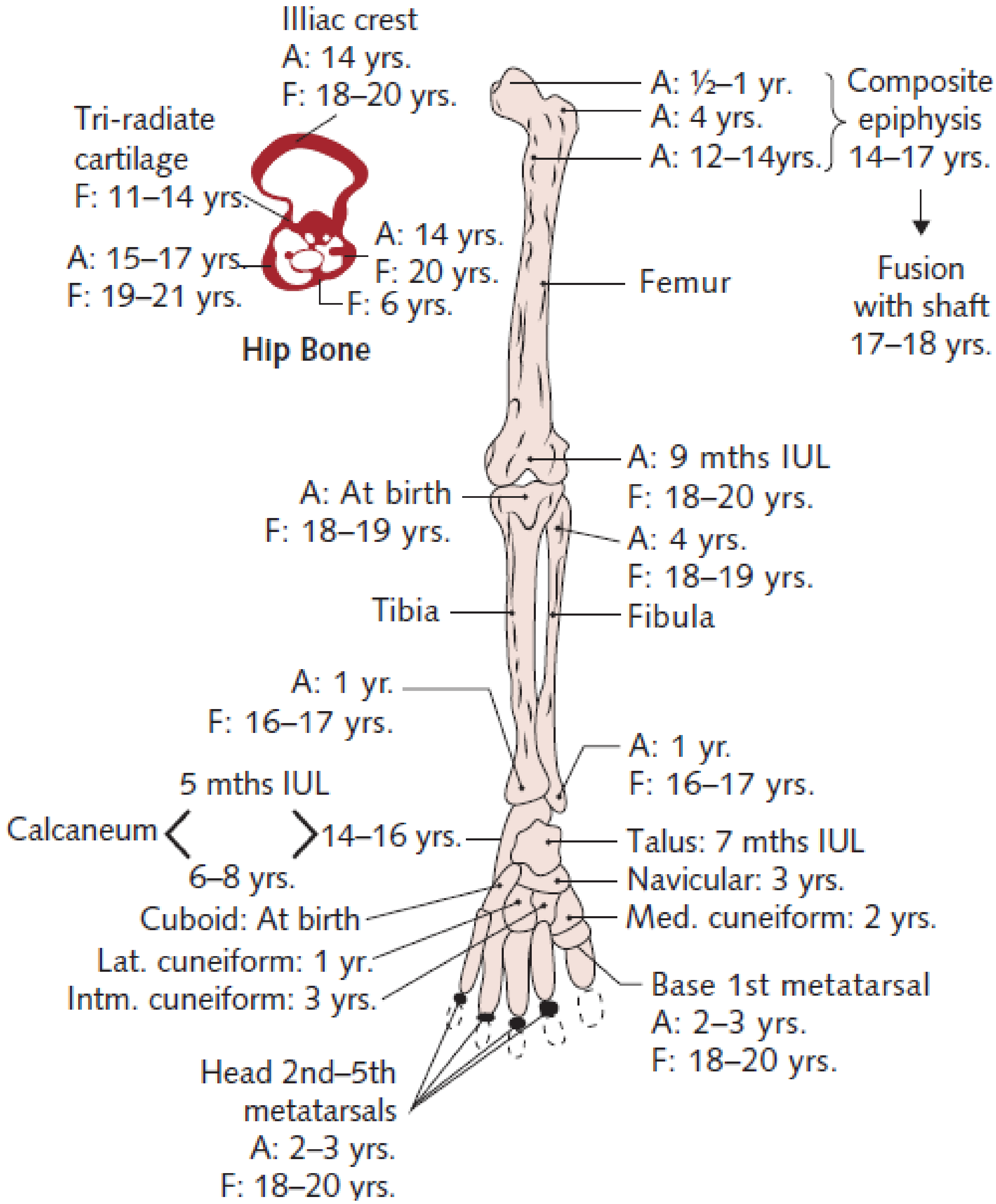
The skeletal system develops from centers of ossification. The human foetus has over 800 centers of ossification which combines together to result in around 450 centers at birth. These further combine and ossify to form 206 bones of the human body. The chronology of this development can be used to estimate age at death.

The methods employed include examination of epiphyses of long bones, stage of closure of skull sutures, developmental changes in the pubic symphyseal surfaces as well as the auricular surfaces of the pubic bone.

The stages of development of these changes are then compared to known reference standards to estimate the age of the individual.



Age estimation from upper limb
(Kishan Vij, Textbook of Forensic Medicine and Toxicology. 2011)



Age estimation from lower limb
(Kishan Vij, Textbook of Forensic Medicine and Toxicology. 2011)

Innominates:

In addition to the fusion of epiphyseal plates in long bones, the pubic bones can also assist in age estimation by examining the changes in the symphyseal surface of the pubic symphyses as well as the auricular surface.

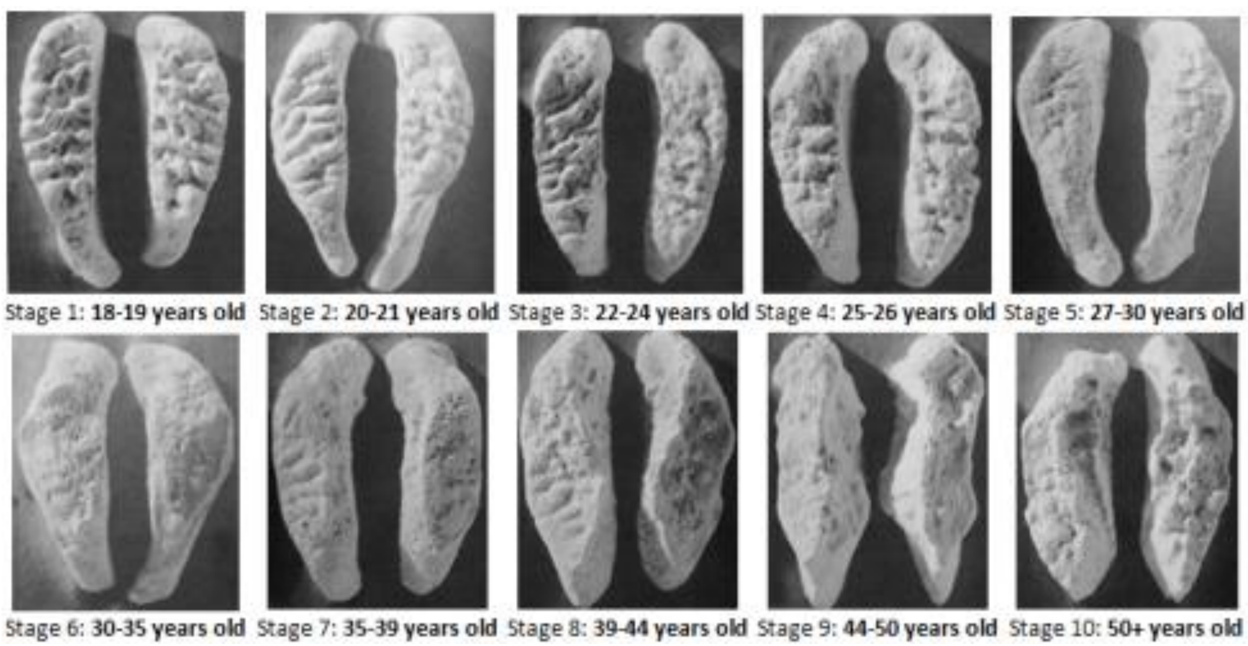
Pubic Symphyses

The symphyseal surface of the pubic bone show morphological changes that are dependent on age. In early adulthood, the surface shows a rugged appearance with horizontal ridges and grooves traversing it. As age progress, the surface becomes smoother and starts developing a rim around the middle years. The surface shows further degenerative changes in the elderly.

Todd's phases of symphyseal changes

These changes were first documented by Todd (1920) who conducted a study on 306 males of known age-at-death.

Using his observations, Todd identified ten phases of pubic symphysis age, ranging from eight/nine-teen years old to fifty-plus years.



Todd's ten phases of symphyseal changes

Suchey-Brooks Method

Todd's (1920) method only looked at males, as a result, the symphyseal surface of the pubic bones in both sexes were studied by S Brooks and JM Suchey.

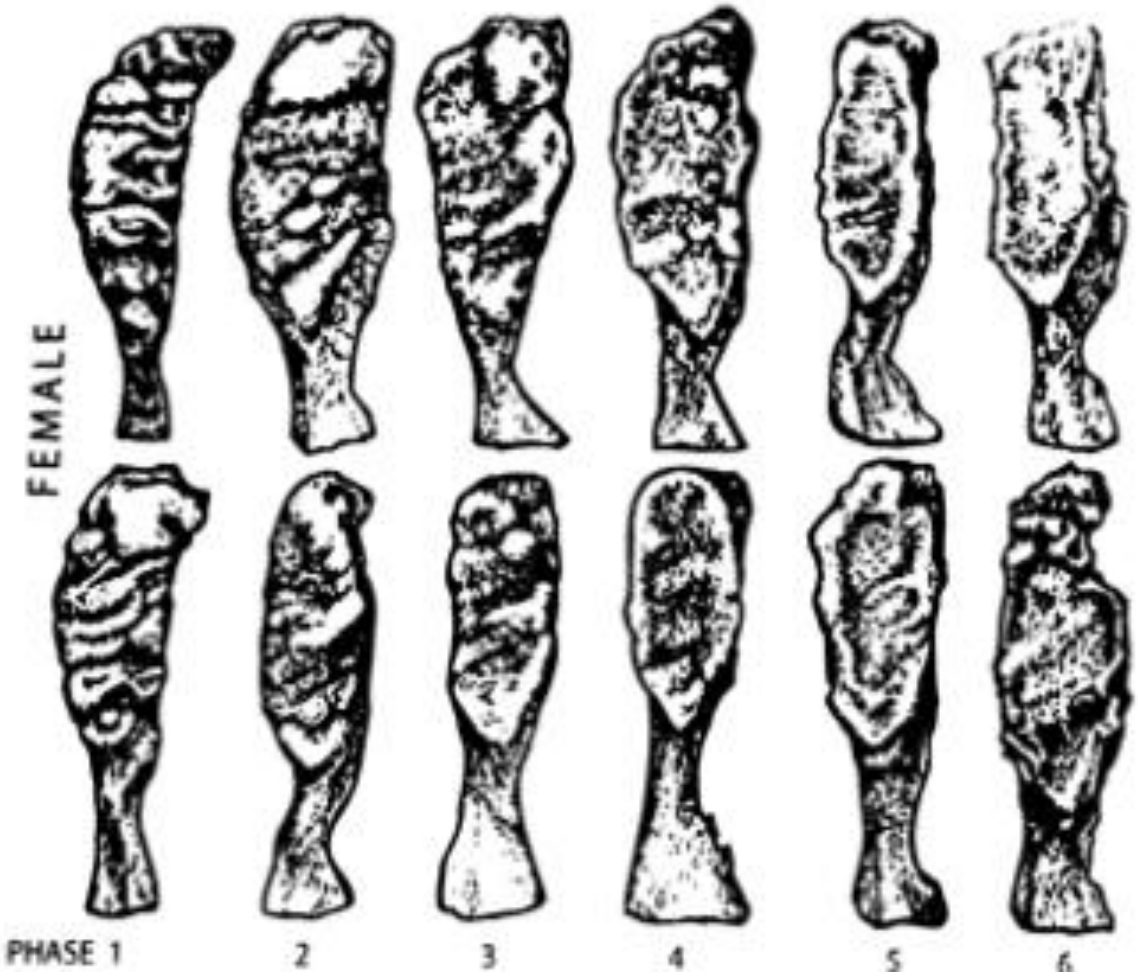
The Suchey-Brooks system (Brooks and Suchey 1990) is a 6-phase system (I-VI) that utilizes the entire symphyseal surface as one component. Two casts, representing early and advanced development, divide each age phase.

The six stages are as follows:

- **Lack of delimitation of either superior/inferior extremity**
  Symphyseal face has a billowing surface (ridges and furrows), which usually extends to include the pubic tubercle. The horizontal ridges are well-marked, and ventral bevelling may be commencing. Although ossific nodules may occur on the either extremity.
- **Commencing delimitation, with or without ossific nodules**
  Symphyseal face may still show ridge development. The ventral rampart may be in beginning phases as an extension of the bony activity at either or both extremities.
- **Ventral rampart in process of completion**
  There can be a continuation of fusing ossific nodules forming the upper extremity and along the ventral border. Symphyseal face is smooth or can continue to show distinct ridges. Dorsal plateau is complete. Absence of lipping of symphyseal dorsal margin; no bony ligamentous outgrowths.
- **Oval outline complete, upper ventral rim may present a break**
  Symphyseal face is fine grained, although old ridge and furrow remnants may still remain. Pubic tubercle is fully separated from the symphyseal face by definition of the upper extremity. The symphyseal face may have a distinct rim. Ventrally, bony ligamentous outgrowths may occur on inferior portion of pubic bone adjacent to symphyseal face. If lipping occurs, it will be slight and located on the dorsal border.
- **Symphyseal face completely rimmed, depression of face, relative to rim**
  Moderate lipping is usually found on the dorsal border with more prominent ligamentous outgrowths on the ventral border. There is little or no rim erosion. Breakdown may occur on superior ventral border.

- **Symphyseal face may show on-going depression as rim erodes**
  Ventral ligamentous attachments are marked. In many individuals the pubic tubercle appears as a separate bony knob. The face may be pitted or porous, giving an appearance of disfigurement with the on-going process of erratic ossification. Crenulations may occur. The shape of the face is often irregular at this stage.

The Suchey-Brooks method of six staging process for males



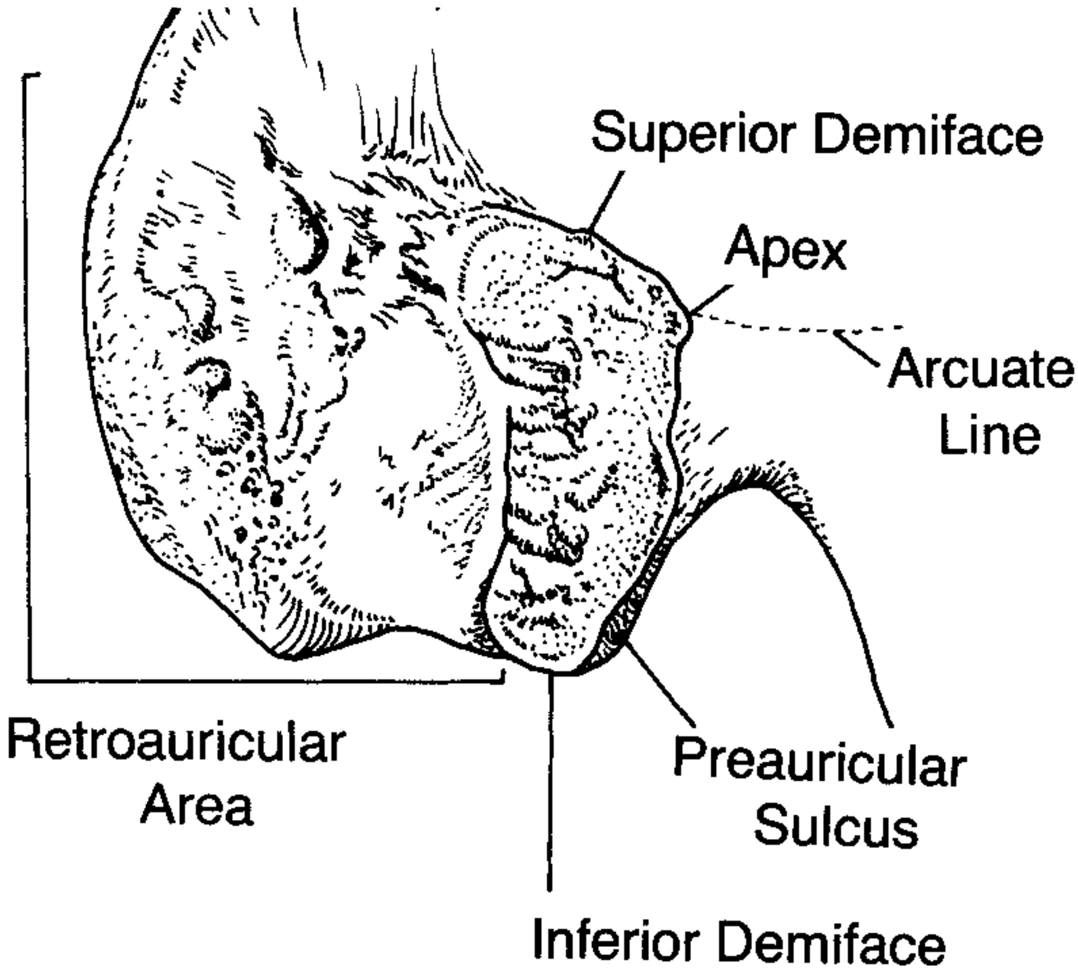
The Suchey-Brooks method of six staging process for females

	Males			Females		
Phase	**Mean**	**Std. Dev.**	**95% Range**	**Mean**	**Std. Dev.**	**95% Range**
1	18.5	2.1	15 – 23	19.4	2.6	15 – 24
2	23.4	3.6	19 – 34	25.0	4.9	19 – 40
3	28.7	6.5	21 – 46	30.7	8.1	21 – 53
4	35.2	9.4	23 – 57	38.2	10.9	26 – 70
5	46.6	10.4	27 – 66	48.1	14.6	25 – 83
6	61.2	12.2	34 – 86	60.0	12.4	42 – 87

Statistics for Suchey-Brooks phases

This pubis symphyseal surface method is often preferred over other aging methods due to the age-related changes on the pubis surface continuing after full adult stature has occurred, for example; epiphyseal closing method can only age early adulthood.

Auricular Surface:



Diagrammatic representation of the auricular surface

The following terms need to be defined before examining the auricular surface.

- **Auricular surface:**

  This is the area of sub-chondral bone forming the iliac portion of the sacroiliac joint.
- **Demifaces:**

  The superior portion lies above the arcuate line of the innominate bone, while that below this point is called the inferior demiface, or simply superior and inferior faces.
- **Apex:**
- This is the portion of the perimeter of the joint in immediate contact with the posterior terminus of the arcuate line.

- **Retro-auricular area:**

  The general area posterior to the auricular surface from which the lumbo-sacral and sacro-iliac ligament complex arises. It extends from the auricular surface posteriorly to the posterior inferior iliac spine, and superiorly till the insertion of the ilio-costalis.

- **Porosity:**

  Perforations of sub-chondral bone of the auricular surface are termed porosity. This should not to be confused with those arising from hyperostosis or osteopenia. The auricular surface, frequently present with small to large perforations, associated with age changes. These are "microporosity" (fine perforations) and "macroporosity"(less regular, large, generally oval perforations ranging from 1 to 10 mm in diameter).

- **Grain:**

  Grain refers to the gross appearance of the surface with respect to its fine structure as judged by the unaided eye. A heavily "grained" surface is one that resembles closely the surface of fine sandpaper.

- **Billowing:**

  Billowing in the examination of auricular surface represent the presence or absence of transverse ridging (usually running transversely across upper and lower faces). The "billows" may vary from large regular surface features, to fine grained just-visible ridges.

- **Density:**

  Density refers only to the surface appearance and not to the amount of bone actually present. A "dense" surface is one in which the sub-chondral bone appears compact, smooth,

General nature of surface changes in the auricular surface, dependent on age

- **Grain and density**

  Granularity of the auricular surface is usually retained till it is lost to other features. Granulations, however, become coarser as age progress. Thus a fine granularity of the auricular surface is an indicator of young age. In addition, this is usually associated with billowing and striae.

  Loss of granularity increases with age, however, this has been seen as early as 27 years, but the loss does not cover the entire surface. Complete loss of granularity may occur as early as the middle of the fourth decade, but does not become prevalent until about 45-50 years.

The general sequence, then, is from a fine to coarse granularity, with eventual loss to densification (the sub-chondral bone becomes highly compact and exhibits no grain).

- **Macroporosity**

  Many older auricular surfaces do not demonstrate this feature, but when present, it is a general indicator of age. It was first seen at age 38, but was found to be until the age of 50.

  It should not be confused with sub-chondral defects that can be present at any age. Macroporosity usually covers a significant portion of the surface, while sub-chondral defects are intermittent and not systemic.

- **Billowing**

  Billowing is usually present in younger individuals. It is defined as regular, generally transverse, undulations of the surface. It generally declines with increasing age between 25 and 40. The oldest age of occurrence was found at 50 years.

  It should not be confused with surface irregularities, which do not show a definite transverse pattern. It tends to reduce between 25and 30 and to be replaced by striations.

- **Striations (striae)**

  Transverse striations tend to replace billowing and characterize an individual in the fourth decade. They are rarely observed beyond the age of 50.They tend to be more marked on the lower face.

  Thus, a granular and slightly striated auricular surface without marked billowing (and other changes discussed below) is typical of age 35.

- **Apex**

  The edge of the auricular surface in the region of the apex is a diagnostic feature. It tends to be sharp and distinct until age 35, after which it may become broader (as a consequence of arthritic lipping) and vaguely triangular in form, or become blunted by the formation of a "rim."

  The degree to which the surface is raised from the innominate is not a reliable indicator of age and is more pronounced in the female. Formation of the pre-auricular sulcus causes the anterior lip of the lower face to become isolated and distinct. This should not be considered an indicator of age.

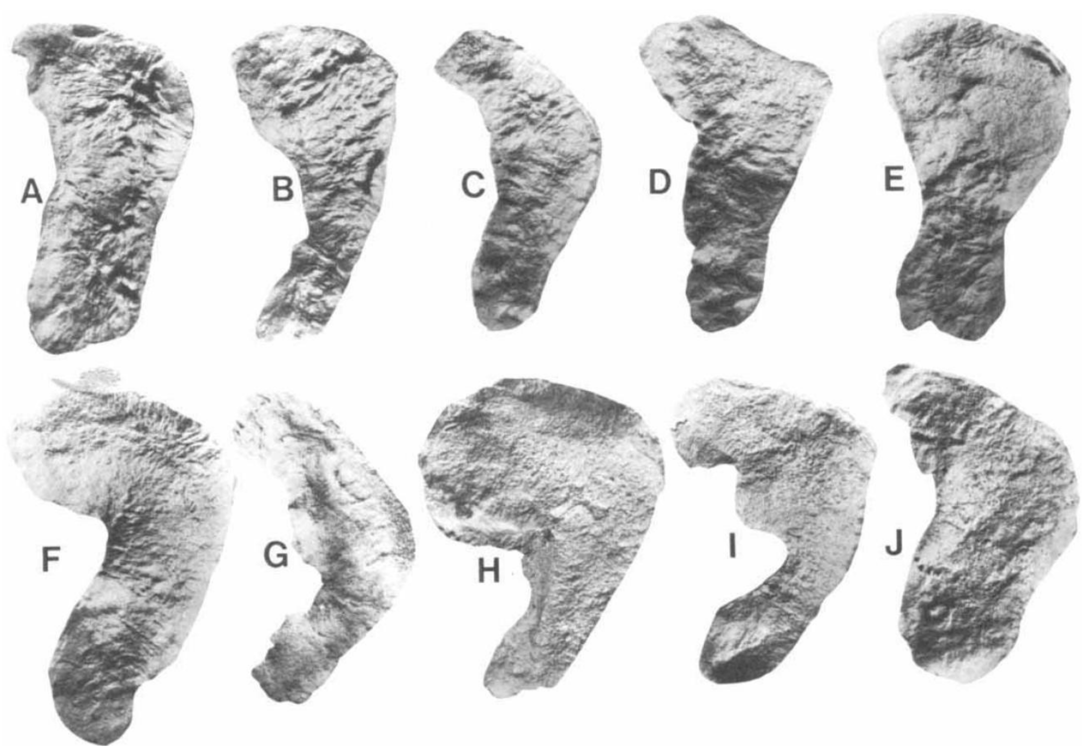
- **Retro-auricular Area**

  Activity in this area is an indicator of age. Young individuals show very smooth and undifferentiated surfaces posterior to the auricular surface. This includes lack of - an increase in porosity, fine to large osteophytes, and general surface irregularity.

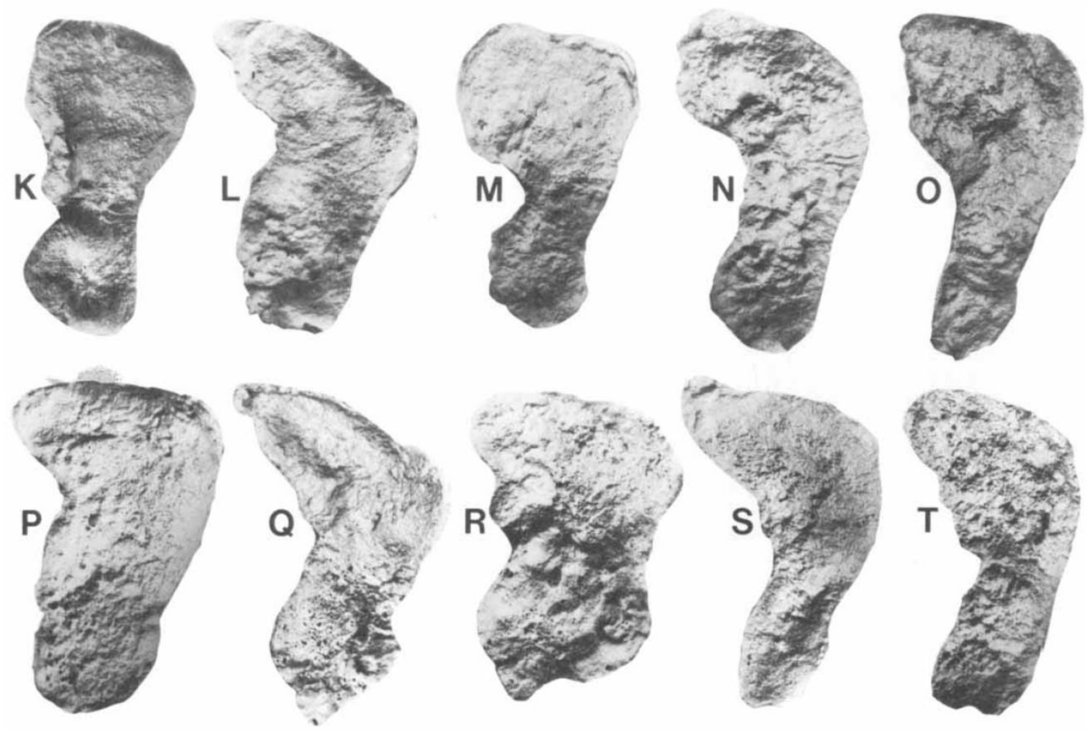
- **Transverse Organization**

  One of the principal features of younger auricular surfaces is a definitive organization of the surface. Both billows and striae show this definitive feature. As aging progresses such organization declines and the surface becomes more amorphous with no clear directional structure.

  This is an important factor, since remnants of billowing or striae may be seen in some areas of older surfaces, but these older individuals will lack a clear transverse organization.



Chronological stages of the auricular surface



Chronological stages of the auricular surface (continued)

Representative Modals – Lovejoy et al. Auricular Surface Aging

- **A (20 – 24 Years)**

  The auricular surface displays fine granular texture and marked transverse organization. There is no retro-auricular activity, apical activity, or porosity. The surface appears youthful and shows broad and well-defined billows, which impart the definitive transverse organization. Billows are well-defined and cover most of the surface. Sub-chondral defects are smooth-edged and rounded.

  Note: Distinct transverse billows and very fine granularity.

- **B, C (25 – 29 years)**

  Changes from the previous phase are not marked and are mostly reflected in slight to moderate loss of billowing, with replacement by striae. There is no apical activity, porosity, or retro-auricular activity. The surface still shows marked transverse organization. Granulation is slightly coarser.

  Note: Slight reduction of billows in B and demonstrable replacement by striae in C. Distinct transverse organization is evident in both.

- **D – F (30 – 34 years)**

  Both faces are largely quiescent with some loss of transverse organization. Billowing is much reduced and replaced definitely by striae. The surface is more coarse and granular, with no significant changes at apex. Small areas of microporosity may appear. Slight retro-auricular activity may occasionally be present. In general, coarse granulation supersedes and replaces billowing.

  Note: Smoothing of surface by replacement of billows by fine striae, but distinct retention of slight billowing on the lower face of all specimen (D–F). Loss of transverse organization and coarsening of granularity is evident.

- **G – I (35 – 39 Years)**

  Both faces are coarsely and uniformly granulated, with marked reduction of both billowing and striae. Striae may still be seen under close examination. Transverse organization is present but poorly defined. There is some activity in the retro-auricular area but this is usually slight. Minimal changes are seen at the apex, microporosity is slight, and there is no macroporosity. This is the primary period of uniform granularity.

  Note: Coarse granularity, absence of striae (still slightly visible in G and in one area of lower face of I). Further reduction of distinct transverse organization is evident.

- **J –M (40 – 44 Years)**

  No billowing is seen. Striae may be present but very vague. The face is still partially (coarsely) granular and there is a marked loss of transverse organization. Partial densification of the surface with loss of grain is present along with slight to moderate activity in the retro-auricular area. Macroporosity is not typically seen. Slight changes are usually present at apex. Some increase in microporosity is seen, depending upon the degree of densification. The primary feature is the transition from agranular to a dense surface.

  Note: Distinct presence of microporosity in J and simulation of billowing without transverse organization. Densification of lower face in L and upper face in M. Minor striae are still visible on upper face in L and lower face in K and M, but in both, expression is very slight and secondary to more distinctive age features.

- **N, O, S (45 – 49 Years)**

  Significant loss of granulation, with replacement by dense bone. No billows or striae are present. Changes at apex are slight to moderate but are almost always present. There is a distinct tendency for the surface to become dense. No transverse organization is evident. Most or all of any microporosity is lost to densification process. There is increased irregularity of margins with moderate retro-auricular activity and little or no macroporosity.

  Note: Distinct densification causing irregular surface and almost complete lack of transverse organization.

- **P – R (50 – 60 Years)**

  Marked surface irregularity becomes paramount. Surface, however, shows no transverse or other form of organization. Moderate granulation may be occasionally retained. No striae or billows are present. The inferior face generally is lipped at inferior terminus. Apical changes are almost invariable and may be marked. Increasing irregularity of margins is seen. Macroporosity is present in some cases but it is not requisite. Retro-auricular activity is moderate to marked in most cases.

  Q and R are opposite sides of same specimen and despite distinct differences in shape, age features are symmetrical.

  Note: Irregularity of surface, macroporosity of lower faces of all specimens, marked density, and absence of any youthful features.

- **T (60+ Years)**

  The paramount feature is a non-granular, irregular surface, with distinct signs of sub-chondral destruction. No transverse organization is seen and there is a definitive absence of any youthful features. Macroporosity is frequently present. Apical activity is usually marked but is not requisite for this age category. Margins become dramatically irregular and lipped, with typical degenerative joint change. The retro-auricular area becomes well defined with profuse osteophytes of low to moderate relief. There is clear destruction of sub-chondral bone, absence of transverse organization, and increased irregularity. Older specimens display further directional changes of this type.

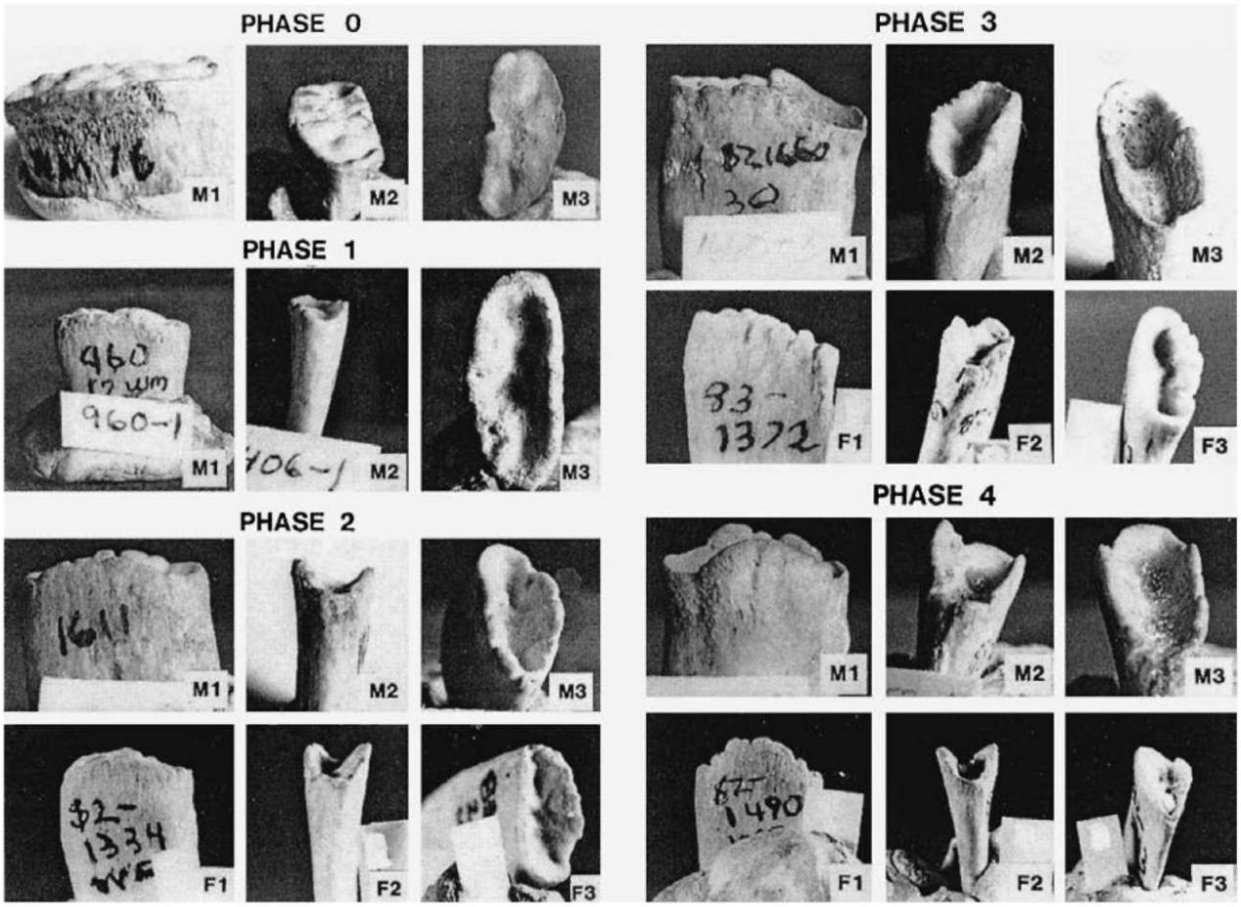
Ribs:

The Iscan et al. (1984, 1985) plastic cast sets for females and males are employed, regardless of the ancestral affinity. This system is a 9-phase system (0-8) that requires that the sternal end of the 4th rib be compared to three-dimensional casts of known age exemplars.

The aging process in the rib was assessed by studying changes at the costo-chondral junction of the fourth rib. The metamorphosis of the rib begins after the completion of growth at the sternal extremity at about 14 years in white females and 17 in their male counterparts. This is consistent with the generally earlier maturation of females. It is characterized by the disappearance of the epiphyseal line and the beginning of pit formation at the nearly flat, billowy surface of the sternal end of the rib. Within a few years, the pit has taken a definite V-shape and scallops appear on the rim of the bone. The pit gradually deepens and widens to a wide V (in females) or U shape in both sexes. The rounded edges of youth begin to thin and sharpen by the mid-30s. With increasing age, the rim becomes irregular, the interior of the pit becomes porous and the bone quality deteriorates until the ribs of most individuals over 70 years are thin and irregular with bony projection at the costo-chondral junction.

In general, the trend is from a nonporous billowed surface with rounded margins to one which becomes more porous, trending from V- to U-shape in contour, with thin walls and a degraded irregular margin.

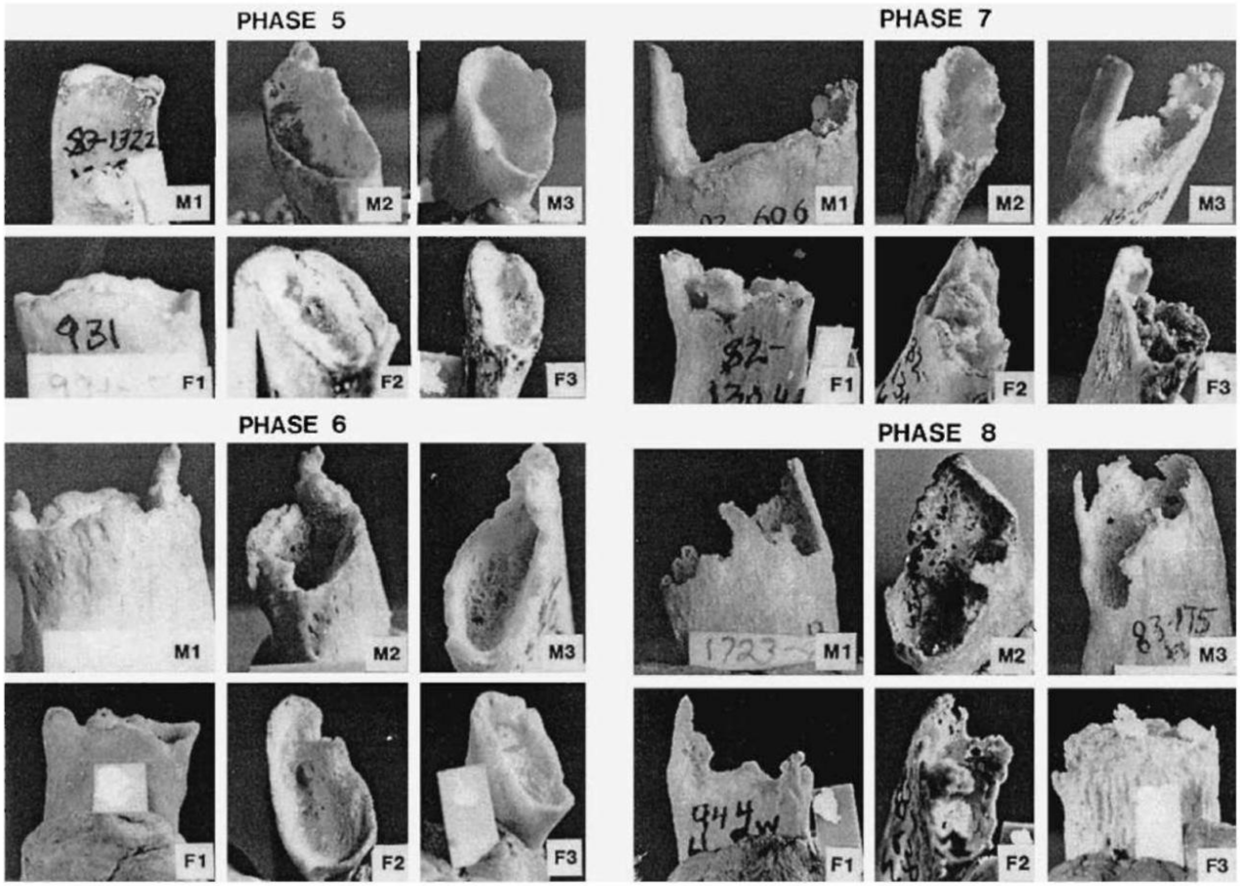
For each sex, Phase 0 is represented by one cast representing typical morphology at that phase, Phases 1-4 are represented by two casts for each phase exemplifying early and advanced development at that age, and Phases 5-8 are represented by three casts for each phase exemplifying early, average, and advanced development at each phase.



Phases 0 – 4 for Staging of Rib development

	Male			Female		
Phase	**Mean**	**Std. Dev.**	**95% Range**	**Mean**	**Std. Dev.**	**95% Range**
1	17.3	0.5	17 – 18	14.0	-	-
2	21.9	2.1	21 – 23	17.4	1.52	16 – 19
3	25.9	3.5	24 – 28	22.6	1.67	21 – 25
4	28.2	3.8	26 – 31	27.7	4.62	24 – 31
5	38.8	7.0	34 – 42	40.0	12.22	34 – 46
6	50.0	11.2	44 – 56	50.7	14.93	43 – 58
7	59.2	9.5	54 - 64	65.2	11.24	59 – 71
8	71.5	10.3	65 - 78	76.4	8.83	70 – 82

Conversion Table for Estimating age from Phases of Rib development



Phases 5 – 8 for Staging of Rib development

The published age-estimation procedures were developed for the 4th rib. The applicability to other ribs has not been clearly established. When the sequential position of the rib cannot be accurately determined, or is determined to be other than the 4th rib, an appropriate caveat should accompany the reported findings

Basi-Sphenoid Basi-occiput synchondrosis

Basi-occiput fuses with the basi-sphenoid by 18–20 years in females and by 20–22 years in males.

Skull Sutures

Estimation of age by sutural closure of skull is not reliable. It can be given only in the range of a decade. The usual reliability falls in the order of sagittal, lambdoid and then the coronal.

- Posterior one-third of sagittal suture at 30–40 years.
- Anterior one-third of sagittal and lower half of coronal at 40–50 years.
- Middle sagittal and upper half of coronal at 50–60 years.
- In the lambdoid suture, fusion activity starts late and the progress is also slow. The closure starts at 25–30 years near the asterion, and closure completes occurs at 55 years.

Sternum

		Appearance	Fusion
Manubrium		5–6 m (IU)	In old age (usually above 50 years with the body)
Body	1st segment 2nd segment 3rd segment 4th segment	5–6 m (IU) 7 m (IU) 7 m (IU) 10 m (IU)	14–25 years from below upwards
Xiphoid process		3 years	Around 40–45 years (with the body)

Sacrum

The five sacral vertebrae remain separated by cartilage until puberty; with the onset of puberty, ossification of inter-vertebral discs starts from below upwards and the fusion of the sacral segments become complete by 20–25 years.

General observations helping to estimate age in the elderly

Baldness or greying of hair does not carry much value in indicating age. Hair may turn grey usually after 40 years and silvery white in advanced old age. But greying of the hair may also occur in young age due to hereditary, climatic and other factors. Usually pubic hair does not turn grey before 50–60 years of age.

Arcus Senilis

An opaque zone around the periphery of cornea may be noticed after 40 years of age; it is seldom complete and circular before 60 years. Its formation is attributed to deposition of lipids—cholesterol, phospholipids, neutral fat and is considered to occur more in males (by 45–50 years) than in females (by 55–60 years). Width of Arcus does not have correlation with age.

Arcus Juvenilis appears as white lines around cornea in young adults suffering from hyperlipaemia.

Skeletal Changes

- Thyroid and cricoid cartilages tend to ossify by about 45–50 years.
- The greater cornu of the hyoid fuses with the body by about 40–50 years.
- The xiphi-sternum and manubrium unite with the body of the sternum respectively around 40 years and above 50 years.
- Lipping of bones frequently occurs around margins of the bodies of the lumbar vertebrae around 40–50 years, and atrophic changes occur in the inter-vertebral discs with diminution of joint space at about 50–60 years.
- Skull bones, with advancing old age, become lighter and thinner, increase becoming more susceptible to fracture.
- Long bones show thinning of the cortical layer with increase in size of the medullary canal with advancing age. In youth, the compact cortical layer is much thicker in comparison with the comparatively narrower medullary canal.

Stature

Fully's method:

Fully developed a method for estimating stature from a complete skeleton. The method uses the measurements of individual elements and factors soft tissue correction to estimate the stature.

Element	Measurement
Basion-Bregma height	
C2 (max. height of corpus) *	
C3 (max. height of corpus)	
C4 (max. height of corpus)	
C5 (max. height of corpus)	
C6 (max. height of corpus)	
C7 (max. height of corpus)	
T1 (max. height of corpus)	
T2 (max. height of corpus)	
T3 (max. height of corpus)	
T4 (max. height of corpus)	
T5 (max. height of corpus)	
T6 (max. height of corpus)	
T7 (max. height of corpus)	
T8 (max. height of corpus)	
T9 (max. height of corpus)	
T10 (max. height of corpus)	
T11 (max. height of corpus)	
T12 (max. height of corpus)	
T13 (max. height of corpus)	
L1 (max. height of corpus)	
L2 (max. height of corpus)	
L3 (max. height of corpus)	
L4 (max. height of corpus)	
L5 (max. height of corpus)	
L6 (max. height of corpus)	
S1 (anterior)	
Sub-total	

Element	Measurement		
	Left	Right	Mean
Femur (physiol. length)			
Tibia (max. length) **			
Talus + Calcaneus ***			
Sub total			
"Soft tissue" correction factors:			
IF ≤ 153.5 cm	+ 10 cm		
IF 153.6 – 165.4 cm	+ 10.5 cm		
IF ≥ 165.5 cm	+ 11.5 cm		
Total			

Trotter and Gleser Method

Trotter and Gleser developed regression equations for the establishment of stature from long bones.

	Male		Female	
Element	Equation	SD	Equation	SD
Femur	2.38 x Femur + 61.41	3.27	2.47 x Femur + 54.10	3.72
Tibia	2.52 x Tibia + 78.62	3.37	2.90 x Tibia + 61.53	3.66
Femur + Tibia	1.30 x (Femur + Tibia) + 63.29	2.99	1.39 x (Femur + Tibia) + 53.20	3.55
Humerus	3.08 x Humerus + 70.45	4.05	3.36 x Humerus + 57.97	4.45
Radius	3.78 x Radius + 79.01	4.32	4.74 x Radius + 54.93	4.24
Ulna	3.70 x Ulna + 74.05	4.32	4.27 x Ulna + 57.76	4.30
Fibula	2.68 x Fibula + 71.78	3.29	2.93 x Fibula + 59.61	3.57

Numerous studies have been conducted on the use of multiplication factors and as an example, the following table from Kishan Vij, Textbook of Forensic Medicine and Toxicology shows studies conducted in India. This also illustrates that need for population specific studies.

	For Bengal, Bihar and Orissa		For UP	For Punjab
	Male	Female	Male	Male
Femur	3.82	3.8	3.7	3.6
Tibia	4.49	4.46	4.48	4.2
Fibula	4.46	4.43	4.48	4.4
Humerus	5.31	5.31	5.3	5.0
Radius	6.78	6.7	6.9	6.3
Ulna	6.0	6.0	6.3	6.0

Multiplication Factors (Kishan Vij, Textbook of Forensic Medicine and Toxicology. 2011)

There is a dearth in the number of studies conducted on the Nepalese population. A few studies using per-cutaneous measurement or measurements on x-ray have been published. However, studies on bone measurements are fewer in number.

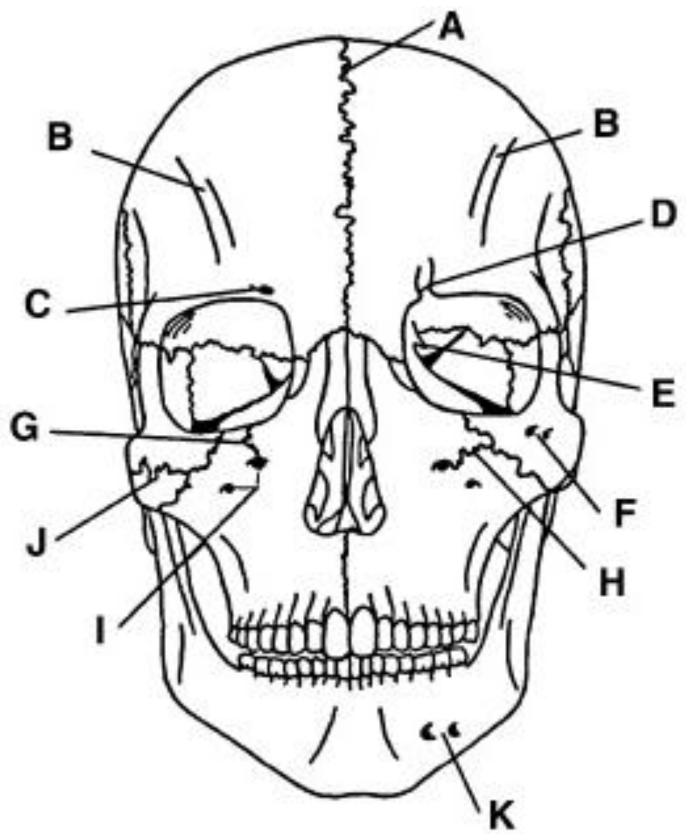
Shrestha et Al. published a study on the estimation of stature from cranial osteometric measurements. Cranial measurements were used to develop regression equations for estimating stature.

Sample	Regression model	R^2 value	S.E.E. (cm)
Total	38.82 + 4.14 x MCL + 4.23 x BZB	0.330	7.012
	19.533 + 3.949 x MCL + 1.894 x MCB + 4.026 x BZB	0.348	6.943
Male	81.60 + 2.48 x MCL + 2.37 x BZB	0.180	6.644
	69.062 + 2.420 x MCL + 1.078 x MCB + 3.214 x BZB	0.183	6.640
Female	68.24 + 3.48 x MCL + 2.12 x MCB	0.200	5.577
	61.247 + 3.664 x MCL + 2.309 x MCB–2.641 x MFB + 2.186 x BZB	0.241	5.538

Individualising traits

Once the allometric profile of the deceased has been developed, following establishment of the primary indicators, namely ancestry, sex, age and stature, the examination of the skeletal remains looks at skeletal variations – anomalies, abnormalities, pathologies etc. to establish individualizing traits.

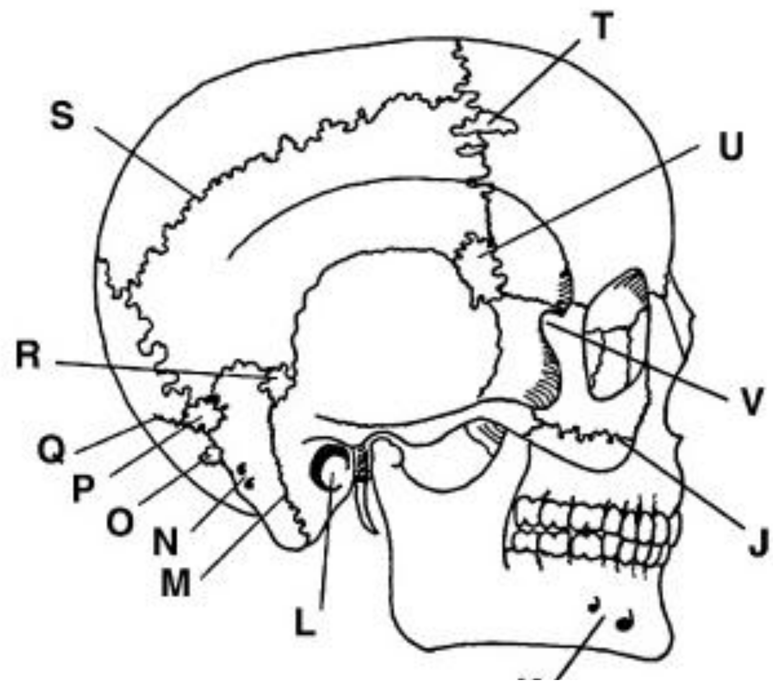
Several hundred non-metric traits of variations have been published over the years. Some common variations in the skull include



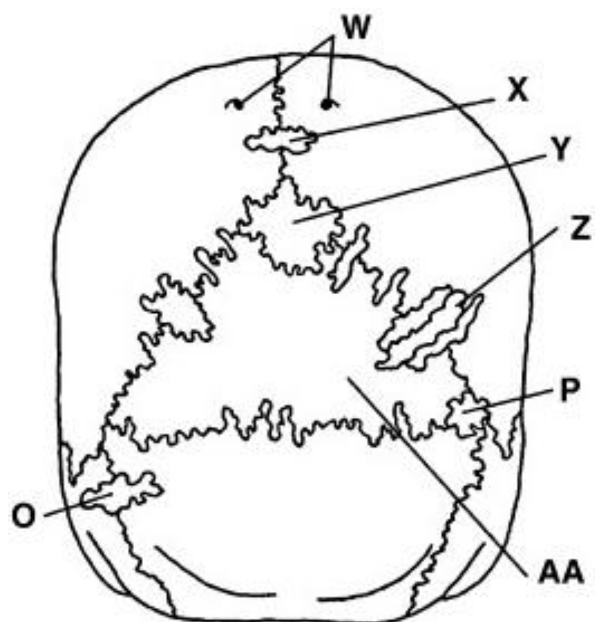
Anterior View of skull

A. Metopism
B. Frontal Grooves
C. Supra-orbital foramen
D. Supra-orbital notch
E. Trochlear spur
F. Zygomatic facial foramina
G. Infra-orbital suture from infra-orbital rim
H. Infra-orbital suture from Zygo-maxillary suture
I. Infra-orbital foramina
J. Os Japonicum (bi-partite zygomatic bone)
K. Mental Foramina

J. Os japonicum (bipartite zygomatic bone)
K. Mental foramina
L. Auditory exostosis
M. Squamo-mastoid suture
N. Mastoid foramina
O. Occipito-mastoid ossicle
P. Ossicle at asterion
Q. Sutura mendosa
R. Parietal notch bone
S. Bipartite parietal bone
T. Coronal ossicle
U. Epipteric bone
V. Marginal tubercle



Lateral view of Skull



Posterior view of Skull

O. Occipito-mastoid ossicle
P. Ossicle at asterion
W. Parietal foramina
X. Sagittal ossicle
Y. Ossicle at lambda
Z. Lambdoid ossicles (wormian bones)
AA. Os Inca.

In addition to non-metric variations, other features could be used to individualise the remains. These could include occupational stress markers.

Markers of occupational stress

Kenedy states that “markers of occupational stress are one expression of bone plasticity under pressure of extracorporeal and internal forces that are not attributable to disorders of disease, metabolism, biochemistry, as well as hormonal and enzymatic imbalances."

Recent anthropological works have proved that enthesopathies can assist in identification, by helping establish the occupation of the deceased. Occupational markers can mainly be divided into three categories:

Enthesopathic lesions (non-articular markers)

Osteoarthrosis (articular markers)

All three types of lesions are related with occupation and the level of physical stress the deceased was regularly exposed to.

Enthesopathies

Bone lesions at the sites of muscles or tendons insertions on the skeleton, or enthesopathies, are well known in sporting and occupational medicine to be associated with prolonged hyperactivity.

Enthesopathies occur more commonly in certain bones and associated with well-defined rheumatologic conditions. Physical activity, occupational or sporting, when specialised, implies repetition of movements. This stereotyped and repetitive motion causes hyper-solicitation and biomechanical constraints that cause micro-trauma. The consequent inflammatory or adaptive mechanism results in the development of markers. Enthesopathies are not necessarily the result of heavy work but more a consequence of repetitive work, especially before obtaining maturity.

Other individualizing features include implants, dental work, as well as trauma.

Trauma

All trauma to the skeletal remains should be documented in the inventory to help in the investigation of death. In addition, old skeletal trauma can also assist in the process of identification by providing corroborative evidences regarding identity.

Establishing the importance of skeletal trauma to a particular case is one of the more important functions of a forensic anthropologist. Perhaps the most important part of this aspect is the detection of the time the trauma was inflicted; whether the trauma occurred before, during, or after the death.

Ante-mortem Trauma

Of Ante-mortem trauma is the easiest of the three to detect. This is because of the signs of healing associated with ante-mortem trauma. A variety of factors influence the rate of healing, including overall health and nutritional status, location of fracture, as well as the severity of injury.

As a general rule. Even though healing begins immediately after the fracture, evidence of the healing processes can be seen only as early as one week after the injury. The fractured edges will start show evidence of remodelling in the first two to three weeks. Bony callus is seen around the sixth week after injury.

These ante-mortem injuries can assist in the confirmation of identity by radiographic comparisons or, through the presence of implants, plates and pins, which can be traced to the manufacturer or the doctor/surgeon responsible for the treatment. Ante-mortem fractures can also be useful in establishing a history of abuse.

Peri-mortem Trauma

Analysis of peri-mortem skeletal trauma is the most important aspect in understanding the events occurring at the time of death.

Peri-mortem fractures contain the same biomechanics that are present in ante-mortem fractures, but because of death, the natural process of healing never really takes place. These bio-mechanical changes can be used to differentiate peri-mortem fractures from post-mortem fractures occurring.

Wet bones are more elastic, resulting in the irregular edges of fractures, as opposed to the rather jagged or angled appearance associated with terminal breaks. While the elasticity of bone causes frequent “butterfly” fractures, where the force causes radiating fractures, which follows the tension stresses exerted when force is applied on the opposite side of the bone. This appearance, however, while more common in wet bones, can also sometimes be seen in post-mortem trauma.

Certain types of trauma to wet bones, such as gunshot wounds and blunt force traumas, will result in radiating fractures. Wet bones also tend to splinter.

Post-mortem Trauma

Post-mortem trauma assists in establishing the events that occurred to the remains from the time of death to the time of recovery and possibly afterwards. The differentiation of post-mortem trauma are critical in the understanding of whether they were caused intentionally to conceal crime, or occurred naturally because of plant, animal, and soil activity . The differentiation between peri-mortem and post-mortem is particularly important in cases in which remains are found at the scene of a fire. In those cases, understanding fractures that were caused by heat and those that were otherwise inflicted will help to determine if the fire was set as a means of concealing a homicide, or if the fire itself was the cause of death and was otherwise accidental.

Post-mortem trauma varies from their peri- and ante-mortem counterparts in that the biomechanics of the bone have changed. Whereas ante- and peri-mortem traumas occur in wet, elastic bones, bones in the post-mortem stage tend to be dry and rather brittle. As a result in, plastic deformation occurs when excessive force is applied to a bone and due to the absence of healing mechanisms; the bone does not remodel and can create a variety of changes, particularly in the fracture patterns.

While peri-mortem breaks tend to splinter, post-mortem breaks tend to shatter. Post-mortem fragments and fractures also tend to be more regular in shape, with straight sharp edges and a lack of evidence of bending.

Because peri-mortem fractures exist at deposition, there is also a difference in colour between peri-mortem and post-mortem fractures in bodies recovered from deposition sites. The ante-mortem and peri-mortem fractures take on the same colour as that of the surrounding bone, while post-mortem fractures tend to be lighter in colour.

The skull, being relatively hollow, can easily be crushed during the post-mortem phase. While gunshot trauma might not be confused with actual compression fractures, they can obscure gunshot traumas, making bullet trajectories difficult to discern. Gunshot wounds also tend to cause radiating fractures that radiate away from the entry and exit points. By examining for these radiating fractures, the presence of a gunshot wound and the trajectory of the bullet can be ascertained and distinguished from post-mortem trauma.

All of this information regarding trauma to the skeletal elements, if documented properly, can assist in corroborating the identity of the deceased.

Summary

Forensic anthropology, deals with the examination of the human remains to establish a story that describe the events in the life of the deceased, as well as the events surrounding the death and recovery to assist in the pursuit of legal justice.

The use of forensic anthropological techniques in the process of recovery of remains helps in establishing an objective, scientific method that is invaluable to the identification of the deceased. This includes thorough documentation of the entire process of recovery and can lead to valuable information regarding the association of various elements recovered.

The laboratory analysis of skeletal remains assists in the development of the biological profile of the deceased as well as to establishing markers of identification to help establish the identity. The biological profile includes the assessment of the skeletal remains for estimating the ancestry, sex, age and stature of the individual(s).

Ancestry is one of the primary indicators used to then help choose the appropriate models for establishing sex. The primary methods of estimating ancestry include examination for skeletal features as well as dental features.

Sex is the next primary indicator to be established and following the establishment of sex, the appropriate standards for either the male or female population should be used for estimating age. Sex is primarily determined based on non-metric dimorphism in the pelvis and skull of the deceased.

Age should be estimated using appropriate male or female reference exemplars. However, if the sex of the remains could be established with a reasonable degree of certainty, the age should be estimated using either a non-sex determined model or using both male and female references. Age can be estimated by examining skeletal or dental material.

Stature should be the last primary indicator to be estimated as the estimation of age of the individual as a sub-adult should preclude the regression equations to be used and the caution to be associated with the estimates. Stature estimation should primarily include measurements of long bones for regression equations.

Following the establishment of the biological profile, the individuals to be compared with should be a manageable number and the skeletal remains of the deceased should be examined for individualizing features including anomalies, abnormalities, pathologies, occupational stress markers etc. These should then be used as corroborative information for establishing the identity of the individual in question.

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