

7th
Edition

FORENSIC MEDICINE & TOXICOLOGY

FOR MEDICAL STUDENTS
INCLUDING CLINICAL &
PATHOLOGICAL ASPECTS

Fully updated edition with BNS,
BNSS and BSA Criminal Laws

As per the Revised Competency
Based Medical Education
Curriculum (NMC)

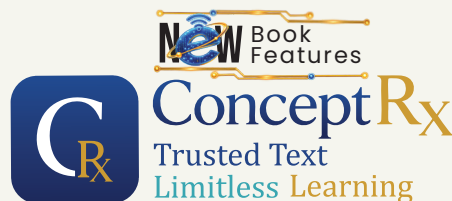
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Age, sex, stature and identity clues getting mixed up? Smart Notes organize the essentials for fast forensic recall. Scan now.

CHAPTER

Identification I

05



LEARNING OBJECTIVES

Must know

1. Identification, types, medico-legal importance
2. Corpus delicti
3. Cephalic index
4. Nuclear sexing, Barr body, Davidson body
5. Disorders of sexual development with examples
6. Klinefelter and Turner syndrome
7. Eruption of temporary and permanent teeth
8. Gustafson's method
9. Spacing of jaw, superadded and successional teeth, period of mixed dentition

10. Age estimation: Ossification of long bones
11. Fusion of skull sutures
12. Estimation of stature
13. Tattoo marks, scars, medico-legal importance
14. Medico-legal importance of age
15. Male and female—skull, pelvis and mandible (Diff.)
16. Age changes in mandible (Diff.)

Desirable to know

1. Stack, Boyde and Miles' method of age estimation
2. Age changes in symphysis pubis
3. Sexual development in adolescents

■ Definitions

❖ **Identification:** Determination of the individuality of a person based on certain physical, biological, and/or circumstantial characteristics.

❖ **Identity:** Set of characteristics that individualize a person.

Identification involves confirming identity through features such as age, sex, stature, ancestry, scars, deformities, fingerprints, dental records, DNA, or personal belongings.

It can be:

- Complete (absolute):** Absolute fixation of the individuality of a person.
- Partial (incomplete):** Ascertainment of only some facts (e.g., ancestry, sex, age or stature) about the identity, while the others remain unknown.

Identification is necessary in:

1. *Living persons* pertaining to:

Criminal cases	Civil cases
◆ Persons accused of assault, murder or rape ◆ Interchange of newborn babies in hospitals ◆ Impersonation ◆ Absconding soldiers and criminals	◆ Marriage ◆ Passport/license ◆ Inheritance ◆ Insurance claim ◆ Missing persons ◆ Disputed sex

2. *Dead people:*

- i. In cases of fire, explosion and accidents.
- ii. When an unknown dead body is found on the road, fields, railway compartment or water.
- iii. In cases of decomposed body.
- iv. In cases of mutilated body.
- v. Skeleton.

Before identifying the patient in the court, the doctor should verify the identification marks noted by him.

FM4.1

Define and describe corpus delicti.

CORPUS DELICTI

Corpus delicti ('body of crime') refers to the principle that it must be proven that a crime has actually occurred before a person can be convicted of committing the crime. The prosecution must show a specific injury or loss occurred, and that injury or loss resulted from criminal activity. In a charge of homicide, it includes:

- i. Positive identification of the dead body (victim).
 - ii. Proof of its death by criminal act of accused.
- ❖ The term includes body of the victim, bullet or clothing showing marks of the weapon, spilled blood or photographs showing fatal injuries.

- ❖ The main part of corpus delicti is the establishment of identity of the body and infliction of violence in a particular way, at a particular time and place by the person or persons charged with crime and none other.
- ❖ The identification of a dead body and proof of corpus delicti is essential before a sentence is passed in murder trials, as false or coerced confessions, unclaimed, decomposed bodies or portions of a dead body (such as a forearm or a leg) or bones are sometimes produced to support a false charge.
- ❖ Courts do not allow a conviction based only on a suspect's out of court confession. The state must find separate, outside evidence to show the crime is real.

Medico-legal significance: This stops false confession or police coercion from putting innocent people in jail.

Identification Data

In living and dead both

1. Race (ancestry) and religion
2. Sex
3. Age
4. Teeth
5. General development and stature
6. Anthropometric measurements
7. Fingerprints, lip prints and footprints
8. External peculiarities, like scar or tattoo
9. Hair, blood, DNA
10. Personal effects: Clothes, pocket contents

In living only

1. Handwriting
2. Speech and voice
3. Gait, manner and habit
4. Memory and education

- ❖ Sex, age, ancestry and stature are primary characteristics of identification because they are fundamental biological attributes (remain unaltered even after death) that can be reliably determined even from incomplete remains and significantly reduce the range of possible identities.
- ❖ Method of identification using biometric features includes fingerprints, hand geometry, face, voice, iris or retina scan, etc.
- ❖ Biochemical method of identification can be DNA analysis, bomb curve analysis, stable isotope analysis.

FM4.1

Define and describe establishment of identity of living persons including race, religion, complexion, sex.

RACE (ANCESTRY) AND RELIGION

Race: Biological grouping within the human population classified according to genetically transmitted differences.

Important in cases of mass disasters, e.g., in case of railway accidents or air crashes, when persons of different ancestries are traveling together.

* Negroid, Caucasoid, and Mongoloid are obsolete racial classifications and are no longer used in modern science. They originated from outdated 18th-century racial typologies that treated humans as distinct biological races. Modern anthropology instead use ancestry, geographic origin, and population variation, which better reflect continuous human genetic diversity.

It is determined by:

- Clothing:** Traditional Indian dress is different from Western dress.
- Complexion:** Skin is black in Negroes, brown in Indians and fair in Europeans (Caucasian).
- Eye:** Indians have dark or brown iris, while Negroes have dark brown, and Europeans have blue or gray iris.
- Hair:** Ethnic variations are discussed in Chapter 6. Indians have black, long and fine hair, which is rounder and thicker than Caucasians or Negroes.
- Skull: Cephalic Index** (formulated by Swedish anatomist Anders Retzius) or *index of breadth or cranial index* is the percentage of breadth to length in any skull.

$$CI = \frac{\text{Maximum transverse breadth of skull}}{\text{Maximum anteroposterior length of skull}} \times 100$$

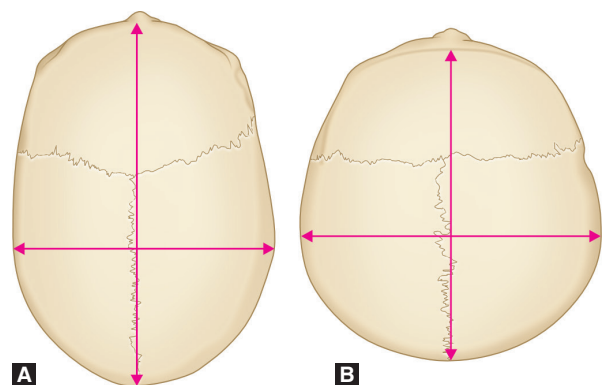
Length and breadth are measured by spreading calipers.

- It is useful anthropologically to find out racial difference (ancestry) from skull shape. Skull can be classified into three types based on cephalic index (CI)—dolichocephalic, mesaticephalic brachycephalic, (Table 5.1).
- Since, the Indian skull is Caucasian with few African characters, we take the value for Europeans, i.e., 75–79.9 (mesaticephalic skull).
- CI is also useful in estimating the age of fetuses for legal and obstetrical reasons.

*Difference between Europeans, Asians and African skull is given in Diff. 5.1.**

Table 5.1: Different types of skull based on cephalic index (Figs. 5.1A and B)

Type of skull	Cephalic index	Race
Dolichocephalic (long-headed)	70–74.9	Negroid (African) (Aryans, Aborigines, Negroes)
Mesaticephalic (medium-headed)	75–79.9	Caucasoids (Europeans, Chinese, Indians)
Brachycephalic (short-headed)	80–84.9	Mongoloids (Asian) (Mongolians, Native Americans)



Figs. 5.1A and B: Cephalic index: (A) Dolichocephalic skull; (B) Brachycephalic skull

Differentiation 5.1 European, Asian and African skull

S.No.	Feature	Europeans (Caucasians)	Asians (Mongols)	Africans (Negroes)
1.	Skull	Rounded	Square	Narrow and elongated
2.	Forehead	Raised	Inclined	Small and compressed
3.	Face	Straight lower face—orthognathism	Large and flattened, malar bones prominent	Jaw projecting—prognathism, malar bones prominent
4.	Orbits	Triangular	Small, round	Square
5.	Nasal opening	Narrow and elongated	Rounded	Broad
6.	Palate	Triangular	Rounded or horseshoe shaped	Rectangular
7.	Nasal index	<0.48	0.48–0.53	>0.53

- vi. **The indices of long bones** may also help in identifying ancestry, e.g., brachial index (radiohumeral index), intermembral index, humerofemoral index and the crural index (tibiofemoral index).

IMPORTANT NOTE

- ◆ **Brachial index** = (Length of Radius/Length of Humerus) × 100
For Indians: 76.5, Europeans: 74.5, Africans: 78.5
- ◆ **Crural index** = (Length of Tibia/Length of Femur) × 100
For Indians: 86.5, Africans: 86.2, Europeans: 83.3
- ◆ **Humerofemoral index** = (Length of Humerus/Length of Femur) × 100
For Indians: 71.1, Europeans: 69, Africans: 72.4
- ◆ **Intermembral index** = (Length of Humerus + Radius/Length of Femur + Tibia) × 100
For Indians: 67.3, Europeans: >70, Africans: <70.5

- ❖ **Facial index** = (Morphological facial height/bizygomatic breadth) × 100
Facial height is measured from nasion to gnathion, and bizygomatic breadth between the two zygions. <80 is hypereuryprosopic (very broad), 80–84.9 euryprosopic (broad), 85–89.9 mesoprosopic (medium), 90–94.9 leptoprosopic (long), and >95 hyperleptoprosopic (very long).
- ❖ **Nasal index** = (Nasal width/nasal height) × 100
Nasal width is the maximum distance between the nostrils, while nasal height is measured from nasion to subnasale. 55–69.9 is leptorrhine (narrow), 70–84.9 mesorrhine (medium), and 85–99.9 platyrrhine (broad/flat).
 - **Europeans:** Facial index usually 85–95 (mesoprosopic to leptoprosopic); nasal index generally 55–70 (leptorrhine).
 - **Africans:** Facial index often 85–100+ (mesoprosopic to hyperleptoprosopic); nasal index generally 85–100+ (platyrrhine).
 - **Americans:** Native Americans tend to have facial indices around 85–95 and nasal indices around 70–85 (mesorrhine).

IMPORTANT NOTE

'Mongolian spots': These hyperpigmented spots or patches are most often found over the lumbosacral region of infants, and occur in people of different races (90% of Native Americans, 80% of Asians and 10% of whites) which help in racial identification.



Identify this instrument. Mention its uses.

**Religion**

- ❖ **Hindu males** are not circumcised, may have sacred thread, necklace of wooden beads, caste marks on forehead, tuft of hair on back of the head and piercing of ear lobes.
- ❖ **Muslim males** are normally circumcised, have marks of corns and callosities on lateral aspect of knees and feet due to their posture during prayer.
- ❖ **Hindu females** put on saris, vermilion on head, silver toe ornaments, tattoo marks, nose ring aperture in left nostril and few openings for ear rings along the helix.
- ❖ **Muslim females** put on trousers, no vermilion mark, nose ring in the septum, several openings on the helix for ear rings and no tattoo marks.

SEX

- ❖ **Sex:** Biological term denoting the genetic, physiologic and anatomical characteristics of an individual, based on which we can identify ourselves into 'males' and 'females'.

- ❖ **Gender:** Sociological construct that denotes how an individual identifies according to social norms (social roles, position and behavior), based on which an individual exhibits 'masculine' or 'feminine' qualities. It is the sexual identity of an individual from birth to puberty and adulthood.*
- ❖ **Intersex:** Intermingling of sexual characters of either sex in one individual to a varying degree including the physical form, reproductive organs and sexual behavior.

In normal cases, in the living:

- ◆ **Most certain evidence of sex:** Possession of ovaries in females, and testes in males.
- ◆ **Highly probable evidence of sex:** Possession of sexual structures, e.g., developed breasts and vagina in females, and male distribution of hair and penis in males.
- ◆ **Presumptive evidence of sex:** Outward appearance of individual features, contours of face, clothes, voice and figure.

Reasons for Sex Determination

- i. **Identification in living:** Sex is important in any chain of identity data and determination of the individuality of a person.
- ii. **Participation in sports:** Sex segregation in sports is based on the long-term endogenous androgen exposure of men at puberty that lead to the physiological gap with women.
- iii. For deciding whether an individual can *exercise certain civil rights* extended to one sex only.
- iv. For deciding questions relating to legitimacy, divorce, paternity, marriage, erectile dysfunction, rape and affiliation.

At present, there are three frequent circumstances wherein determination of sex has become necessary—sports, pre-employment and sex specific crimes. Routinely at birth, identifying biological sex of an individual is based on 'external genitalia' (*phenotype sex*), i.e., whether it is penis and scrotum (in males) or vulva and vagina (in females).

Identification of 'sex' of an individual may become problematic in:

- i. **Intersex:** They can be natural or acquired ('hijras' are castrated before puberty and 'zenanas' are castrated after puberty). They may have features resembling one sex and the internal gonads could be of other sex or of both sexes (true hermaphrodite).
- ii. **Transvestism:** It is the practice of wearing the clothes of the opposite gender.
- iii. **Transgender:** It is denoting or relating to an individual whose self-identity does not conform unambiguously to conventional notions of male or female gender. It is a state of one's gender identity or gender expression



Figs. 5.2A and B: (A) Transsexual/transgender; (B) Vaginal reconstruction

- not matching one's assigned sex which may result in gender dysphoria.
 - iv. **Transsexuals:** Individuals who have undergone sex change surgeries or sex reassignment (male-to-female or female-to-male) (**Figs. 5.2A and B**).**
 - v. **Concealed sex:** Individuals who hide their real sex for a motive by cross dressing.
 - vi. **Advanced decomposition and skeleton:** Sex can be determined in decomposed body by identifying uterus or prostrate, which resist putrefaction.
- Identification of biological sex in concealed sex and transvestism can be easily done by physical examination, but difficulty arises in cases of ambiguous genitalia wherein the external genitalia are a combination of both sexes.

Sex Verification Tests

- i. **Physical morphology:** External examination is done to determine the sex (**Diff. 5.2**).
- ii. **Nuclear sexing or sex chromatin or microscopic test:** Buccal epithelial cells or hair follicle cells are examined microscopically to detect the presence of 'Barr body'.
- iii. **Gonadal biopsy:** Detection of 'internal gonads and sex chromosomes' (*genotype sex*), i.e., the identification of testes and XY sex chromosomes (in males), or ovary and XX sex chromosomes (in females) is a *confirmatory method* of determining sex.
- iv. **Gene-based test:** Polymerase chain reaction (PCR) is used to detect SRY gene (sex-determining region of the Y-chromosome) and/or the DYZ1 region of Y chromosome which is diagnostic. SRY gene is expressed in a small group of somatic cells of the developing gonads, and it is responsible for the expression of a

* To identify whether an individual is 'male' or 'female', the correct terminology is 'sex verification tests' and not 'gender verification tests' or 'femininity testing'.

** As per ICD-11, transsexuals and transgender are considered under **gender incongruence** which is characterized by a marked and persistent incongruence between an individual's experienced gender and the assigned sex.

Differentiation 5.2 Determination of sex from physical/morphological feature

S.No.	Feature	Male	Female
1.	General built	Muscular, strong, stout	Less muscular, delicate, slender
2.	Scalp hair	Short, thick, coarse	Long, fine, thin
3.	Facial hair	Present	Absent
4.	Pubic hair	Thick, coarse, extends upwards with apex at umbilicus (rhomboidal)	Thin, fine, horizontal, covers mons veneris (triangular)
5.	Adam's apple	Prominent	Less prominent
6.	Shoulders	Broader than hip	Narrower than hip
7.	Waist	Not well-defined	Well-defined
8.	Trunk	Abdominal segment smaller	Abdominal segment larger
9.	Thorax	Dimensions more	Dimensions less
10.	Thighs	Cylindrical	Conical due to short femur and greater fat
11.	Breasts	Not developed	Developed after puberty
12.	Uterus and vagina	Absent	Present
13.	Penis	Present	Absent
14.	Gonads	Testes	Ovaries

male-specific cell membrane component (the H-Y antigen) and induces them to become Sertoli cells.

- v. **Assay of testosterone levels** also helps in differentiating the sex of an individual. For females, they should have levels <10 nmol/L (lower than the lower limit of normal for male).

Usually, combinations of all these tests are carried out to determine the 'sex' of the individual.

Nuclear Sexing

Definition: It is a method of sexing cells which may help in determining sex in doubtful cases, decomposed and mutilated bodies and fragmentary remains (**Table 5.2**).

Histological Examination

- i. **Barr body (sex chromatin):** It is the condensed, inactive, single X-chromosome found in the nuclei of somatic cells of most females and whose presence is the basis of sex determination tests. In XO (Turner's syndrome) there will be none, and in XXX there will be two Barr bodies. It is seen during mitosis in the interphase nucleus as dark staining, small planoconvex mass of chromatin lying near the nuclear membrane (**Fig. 5.3**). Buccal smear is usually used.

IMPORTANT NOTE

Murray Barr and Edward Bertran while working on stained sections of nerve cells in cats noticed a tiny, dark staining blob that was always present only in the nucleus of the female cats and never in the males. It was subsequently determined to be inactive X-chromosome, and came to be known as **Barr body**.

- ii. **Davidson-Smith body:** In females, neutrophil leukocytes contain an attachment of drumstick form (**Fig. 5.4**). A drumstick consists of a small nuclear mass

Table 5.2: Chromatin positivity in males and females

Test	Male (%)	Female (%)
Barr body	0–4	20–80
Davidson body	0	3
Fluorescent feulgen	0–2	50–70
Quinacrine dihydrochloride	45–80	0–4

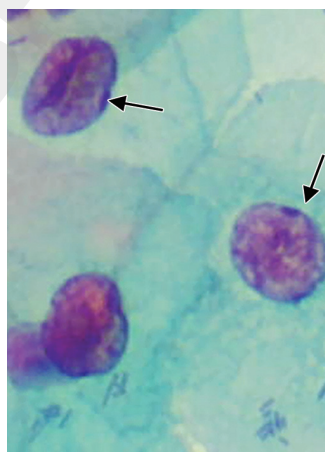


Fig. 5.3: Barr body (arrows)



Fig. 5.4: Davidson body in neutrophil (arrow)

of about 1.5μ in diameter, attached to the body of the nucleus by means of a thin filament.

- ❖ Sex chromosomes (XX or XY) can be determined in the cells that are dividing, e.g., bloodstains, cartilage, bone marrow, teeth pulp and hair root.
- ❖ In decomposed bodies, sex chromatin is difficult to make out.
- ❖ Hair follicles are important for cell sexing since they resist putrefaction, and both Barr body and Y-chromosome can be demonstrated.
- ❖ **Quinacrine dihydrochloride** is used to stain the Y-chromosome, which appears as a bright fluorescent body in the nucleus, commonly referred to as the F-body.

- ❖ **Fluorescent Feulgen reaction** using Acriflavin Schiff reagent is used for staining X-chromosome (Barr body) that is seen as bright yellow or greenish-yellow spot in nuclei under UV light.

DISORDERS OF SEXUAL DEVELOPMENT

Disorder of sexual development (DSD) is a broad term encompassing any condition where external genitalia are atypical in relation to chromosome and gonads. It results from some defect in embryonic development. Previously, Davidson divided 'intersex' into four groups:

- Gonadal agenesis
 - Gonadal dysgenesis
 - True hermaphroditism
 - Pseudohermaphroditism
- ❖ Currently, the term DSD is used to substitute the obsolete nomenclature of 'intersex', 'hermaphrodite' and 'pseudohermaphrodite', since they are based only on identifying the gonads and they fail to take into consideration whether those gonads are functioning or not.
 - ❖ Moreover, the nomenclature was perceived to be pejorative or stigmatizing by some affected families.
 - ❖ The karyotype is used as a prefix to define the category of DSD, replacing the earlier terminology of male or female pseudohermaphroditism (now known as XY DSD or XX DSD, respectively).

The new terms and possible diagnosis in such cases are given in **Table 5.3** and **Flowchart 5.1**. Some of these are briefly described below:

- Ovotesticular DSD (true hermaphroditism):** It is a rare condition; also known as double-sex or bisexual. Both ovarian and testicular tissues are present. External genitalia of both sexes exist in one individual, but sex chromatin may be either male or female pattern (46XX

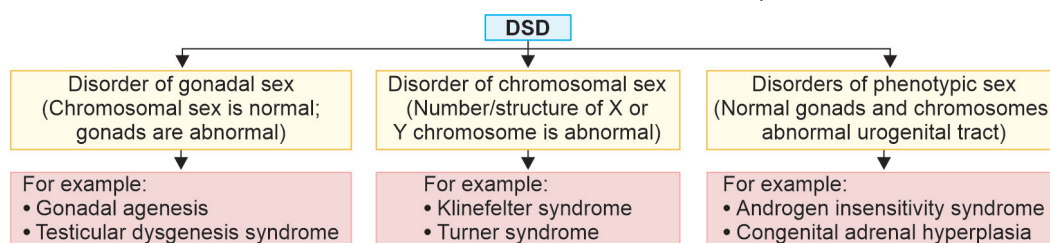
or 46XY or mosaics). True hermaphroditism is very similar to mixed gonadal dysgenesis. The karyotype could be 46XX/46XY or 46XX/47XXY.

- Sex chromosome DSD (gonadal dysgenesis):** It refers to a defect in gonad formation that is characterized by a progressive loss of primordial germ cells in the developing gonads of an embryo with consequent formation of hypoplastic and dysfunctioning gonads composed mainly of fibrous tissue—**streak gonads**. External sexual characters are present, but testes or ovaries fail to develop at puberty. Some examples are:
 - Klinefelter syndrome:** It is the most common sex chromosome disorder associated with male hypogonadism, most common presentation being 47XXY karyotype (**Box 5.1 and Fig. 5.5A**).
 - Prevalence is 1:500 to 1:1000 males, chances are more with increasing maternal age.
 - These individuals are anatomically male, but fail in external genitalia examination, and have false positive Barr body testing.
 - Turner syndrome (congenital ovarian hypoplasia syndrome):** First described by Henry Turner (1938), it is the most common sex chromosome disorder associated with female hypogonadism with 45XO karyotype (prevalence 1:2000 to 2500 newborns females) (**Box 5.2 and Fig. 5.5B**).
 - These individuals are anatomically female, pass in external genitalia examination, but have false negative Barr body testing.
 - Swyer syndrome:** The individuals with pure gonadal dysplasia and a 46XY karyotype will display variable degrees of undermasculinization, dependent upon the amount of testicular dysplasia. Both XX and XY gonadal dysgenesis are due to mutation or deletion of part of the sequence of the SRY gene.

Table 5.3: Classification of disorders of sexual development (DSD)

Old name	New name	Possible diagnosis
True hermaphrodite	Ovotesticular DSD	46XX/46XY or 45X/46XY
Male pseudohermaphrodite	46XY DSD	Androgen insensitivity syndrome 5- α -reductase deficiency
Female pseudohermaphrodite	46XX DSD	Congenital adrenal hyperplasia
XX male or XX sex reversal	46XX testicular DSD	
XY sex reversal	46XY complete gonadal dysgenesis	
Gonadal dysgenesis	Sex chromosome DSD	45XO Turner 47XXY Klinefelter

Flowchart 5.1: Classification of disorders of sexual development (DSD)

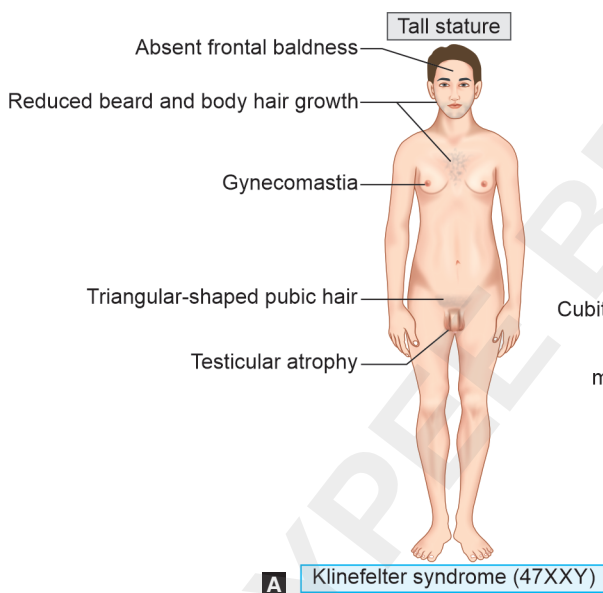


BOX 5.1 Klinefelter syndrome**Clinical features**

- ◆ Delay in onset of puberty, gynecomastia at puberty.
- ◆ Axillary and pubic hair are absent, hair on chest and chin are reduced.
- ◆ Signs of eunuchoidism, tall stature and abnormal body proportions (decreased upper to lower segment ratio).
- ◆ Firm, fibrotic, small testes and non-tender to palpation. Erectile dysfunction, loss of libido and azoospermia.
- ◆ Mental deficiency and other abnormalities, such as clinodactyly or synostosis.
- ◆ Problems with coordination and behavioral difficulties including immaturity, poor judgment, shyness, etc.

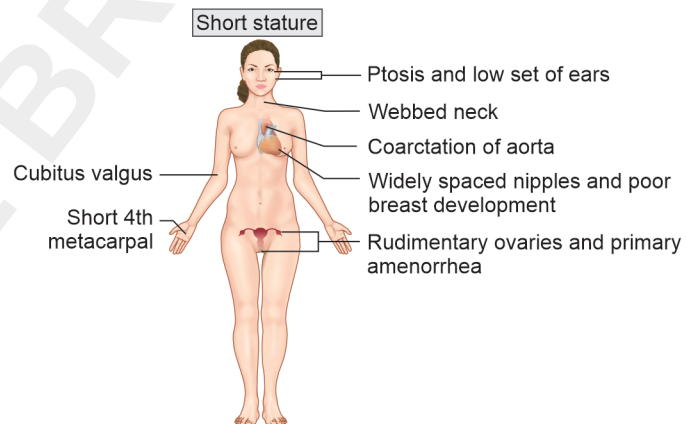
Diagnosis: Karyotyping using lymphocytes or fibroblasts or prenatally from amniocytes or chorionic villi, or by determining the presence of RNA for X-inactive-specific transcriptase (XIST) in peripheral blood leukocytes by PCR. Serum testosterone is low, and FSH, LH and estradiol are elevated.

Histological features: Testicular dysgenesis with hyalinization and fibrosis of seminiferous tubules.

**A** Klinefelter syndrome (47XXY)**BOX 5.2 Turner syndrome****Clinical features**

- ◆ Short stature (*most common feature*).
- ◆ Micrognathia, high-arched palate, webbed neck, low hairline.
- ◆ Ptosis with low-set ears, widely spaced nipples.
- ◆ Cubitus valgus (wide carrying angle), short fourth and fifth metacarpals and metatarsals, hyperconvex nails.
- ◆ Lymphedema of hands and feet, pigmented nevi and keloid formation.
- ◆ Learning disability, often involving visual-spatial skills without typical mental retardation.
- ◆ **Cardiovascular anomalies:** Coarctation of the aorta and aortic stenosis.
- ◆ **Renal abnormalities:** Hydronephrosis, horseshoe kidney, hypertension.
- ◆ Increased urinary gonadotropin excretion.
- ◆ **Sexual infantilism** due to gonadal dysgenesis with primary amenorrhea.
- ◆ High incidence of osteoporosis, type II diabetes.

Diagnosis: Evaluation for childhood short stature often leads to the diagnosis. Hypogonadism is confirmed in girls who have high serum levels of FSH and LH. A karyotype showing 45XO establishes the diagnosis.

**B** Turner syndrome (45XO)**Figs. 5.5A and B:** Features seen: (A) Klinefelter; (B) Turner syndrome

- iv. **Mosaicism:** It is a genetic abnormality with mixture of cells with XX and XY, or X and XY sex chromosomes. Accordingly, there may be false positive or false negative Barr body tests depending on number of X chromosomes.
3. **Androgen receptor deficiency:** Androgen insensitivity is caused by receptors that are insensitive to androgens, particularly testosterone. As a result, even though they are genetically male (46XY DSD) and possess testes, but fail to develop male characteristics. These individuals are born and raised as girls and have female gender identity. They would fail the Barr body test as they have only one X chromosome. It can be:

- i. **Complete androgen insensitivity syndrome (CAIS),** previously known as *testicular feminization syndrome* (most common form).
 - It is an X-linked recessive condition resulting in failure of normal masculinization of the external genitalia.
 - They have female external genitalia with normal labia, clitoris and vaginal introitus with normal size breasts but with primary amenorrhea and scanty or absent axillary and pubic hair.
 - Internally, there is a short blind-pouch vagina with absence of uterus, fallopian tubes and ovaries.
- ii. **Incomplete androgen insensitivity:** The phenotype may range from mildly virilized female external

genitalia (clitoromegaly without other external anomalies) to mildly undervirilized male external genitalia (hypospadias and/or diminished penile size) with gynecomastia. They tend to be tall.

In both cases, affected individuals have normal testes with normal production of testosterone and normal conversion to dihydrotestosterone (DHT), which differentiates this condition from 5- α reductase deficiency.

4. **5- α reductase deficiency (5-ARD):** This is an autosomal recessive sex-limited condition resulting in the inability to convert testosterone to DHT. Since, DHT is required for the normal masculinization of the external genitalia in utero, genetic males with 5-ARD deficiency are born with ambiguous genitalia.
 - The individual presents with a clitoral-like phallus, markedly bifid scrotum, pseudovaginal blind-ending introitus with perineoscrotal hypospadias and a rudimentary prostate.
 - Uterus and fallopian tubes are absent.
 - Testes are intact and are usually found in the inguinal canal or scrotum or occasionally in the abdomen.
 - At puberty, musculature, body and facial hair develop owing to normal levels of testosterone.
 - These individuals fail in external examination of genitals and fail in Barr body testing.
5. **Congenital adrenal hyperplasia (CAH):** It is a condition wherein adrenal glands produce excessive amounts of testosterone in females.
 - These individuals develop secondary male characteristics but are genetically female (46XX, DSD), lacking testes and male reproductive organs (masculinized females).
 - Among the various forms of CAH, the 21-hydroxylase deficiency resulting from mutations or deletions of CYP21A is most common, but sexual ambiguity can also be seen in defects in 17-hydroxylase, 3 β -hydroxysteroid dehydrogenase, 17-ketosteroid reductase and 11 β -hydroxylase.
 - Phenotypically female at birth, but do not develop breasts or menstruate in adolescence; they may present with hypertension.
 - Genital anomalies range from complete fusion of the labioscrotal folds and a phallic urethra to clitoromegaly, partial fusion of the labioscrotal folds, or both. These individuals fail in external examination of genitals but would have positive Barr body testing.

The Supreme Court has directed that all documents (including voter/Aadhar card) should have a third category marked 'transgender or third gender'. It would only apply to transgender people but not to gays, lesbians or bisexuals.

IMPORTANT NOTE

- ◆ Men with Klinefelter syndrome are at a higher risk of autoimmune diseases, diabetes mellitus, leg ulcers,

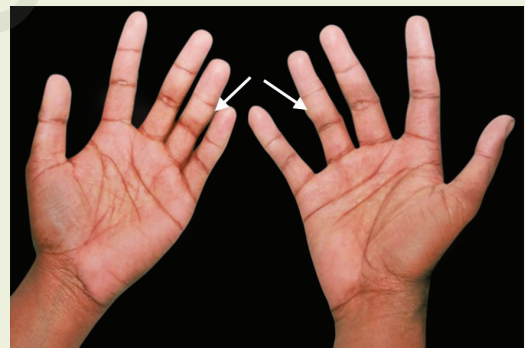
osteopenia and osteoporosis, tumors (breast and germ cells), gonadotroph adenoma and gonadotroph hyperplasia liver adenoma, systemic lupus erythematosus (SLE), rheumatoid arthritis and Sjögren syndrome.

- ◆ **Hypergonadotropic hypogonadism** (defective development of testes or ovaries and associated with excess pituitary gonadotropin secretion) is seen in Klinefelter syndrome, Noonan syndrome, viral orchitis (mumps), cytotoxic drugs, testicular syndrome or androgen insensitivity syndrome and testicular irradiation. In women with hypergonadotropic hypogonadism, the most common cause is Turner syndrome.
- ◆ Cardiovascular disease is the most common cause of death in adult women with Turner syndrome. Most common heart defects are bicuspid aortic valve (30% of children), coarctation of the aorta (5–10%) and aortic dissection. Other anomalies seen are hypoplastic left-heart syndrome, partial anomalous pulmonary venous drainage and atrial septal defects.



A 15-year-old female patient presented with complaint of primary amenorrhea. Clinically, she was short with prominent epicanthal folds, low hairline, multiple facial nevi and a small fourth finger of both hands. Previous images of USG pelvis revealed a steaky uterus with non-visualized ovaries. What is your diagnosis?

2



SEX FROM SKELETAL REMAINS

- ❖ Recognizable sex differences appear after puberty *except* in the pelvis. In pelvis, sex features are independent of each other, and one may even contradict the other in same pelvis.
- ❖ Among the long bones, *femur is most useful for sex determination* [larger and higher neck-shaft angle (collo-diaphyseal angle) in males, femur head diameter (males >45 mm; females <41 mm), oblique length (447–459 mm in males; females 409–426 mm), and bicondylar width (males >78 mm; females <72 mm)].
- ❖ The sex of long bones can be determined on the basis of medullary index from tibia, humerus, ulna and radius. Sternum is least useful.

The accuracy in sexing from adult skeletal remains is given in **Table 5.4** (as reported by Wilton M Krogman).

Traits diagnostic of sex from skeleton are given in **Diff. 5.3 to 5.6 and Table 5.5**.

Summary of various indices is given in **Table 5.6**.

Table 5.4: Accuracy of sexing based on skeletal remains

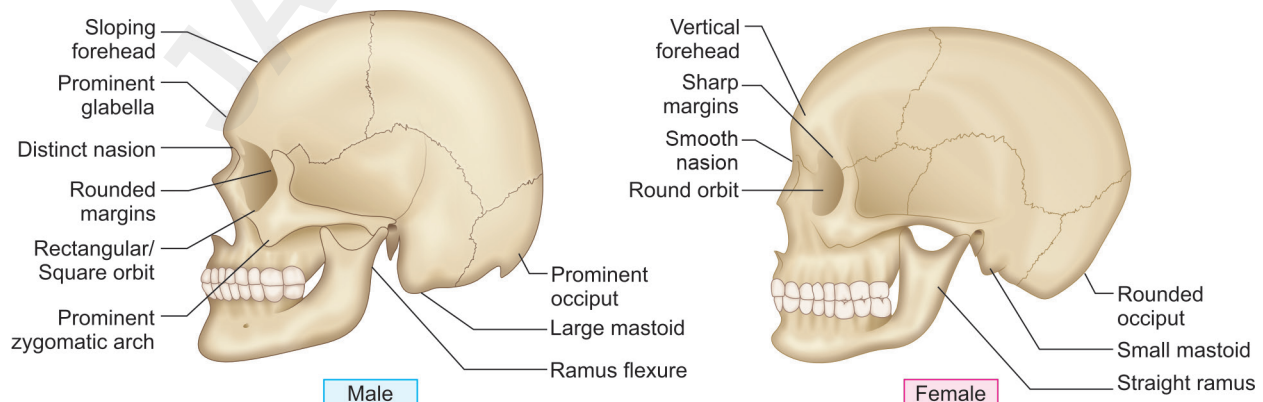
Skeletal remains	Accuracy in sexing (%)
Entire skeleton	100
Skull + pelvis	98
Pelvis alone (best single bone)	95
Skull alone	92
Long bones	80–85
Long bones + pelvis	98

IMPORTANT NOTE

- ◆ The **preauricular sulcus** is characteristic of the *female pelvis*. The pelvic portion of the anterior sacroiliac ligament is attached to it. Its prominence results from obstetrical trauma during the course of delivery (wider pelvic dimensions due to pregnancy and parturition) which allows for differentiation between nulliparous women and males vs females who have given birth.
- ◆ **Ashley's rule:** It is used to know the *sex of the sternum* for Europeans. Also known as '149 rule'—male sternum is >149 mm and female sternum is <149.

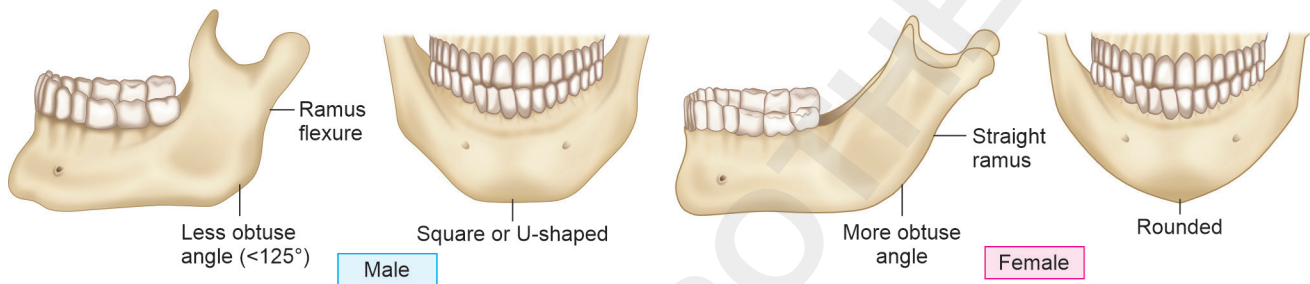
Differentiation 5.3 Male and female skull (Fig. 5.6)

S.No.	Feature	Male skull	Female skull
1.	General appearance	Larger, heavier, rugged, marked muscular ridges	Smaller, lighter, walls thinner, smoother
2.	Cranial capacity	More capacious (1450–1550 cc)	Less capacious (1300–1350 cc)
3.	Forehead	Receding, irregular, rough, less rounded	Vertical, round, full, infantile, smooth
4.	Glabella	Prominent	Less prominent
5.	Supraorbital/supraciliary margin	Thick and rounded	Sharp
6.	Supraorbital ridge	Pronounced, 'loaf shaped' ridge	Smooth, little or no projection
7.	Frontonasal junction (Nasion)	Distinct angulation	Smoothly curved
8.	Orbits	Square, small	Rounded, large
9.	Mastoid process	Large, round, blunt	Small, smooth, pointed
10.	Nuchal crest	Well-defined ledge or hook of bone (rugged)	Absent or slight (smooth)
11.	Frontal and parietal eminence	Less prominent	Prominent
12.	Zygomatic arch	Prominent	Not prominent
13.	Occipital area (muscle markings and protuberance)	Prominent	Not prominent
14.	Digastric groove	Deep	Shallow
15.	Condylar facet	Long, narrow	Short, broad
16.	Palate	Large, U-shaped, broad	Small, parabolic
17.	Foramen magnum	Relatively large, long	Small, round
18.	Mental eminence	Large projection	Little or no projection
19.	Nasal aperture	High, thin sharp margins	Lower, wider, rounded margins
20.	Suprameatal crest	Present (extends)	Absent (no extension)

**Fig. 5.6:** Male and female skull

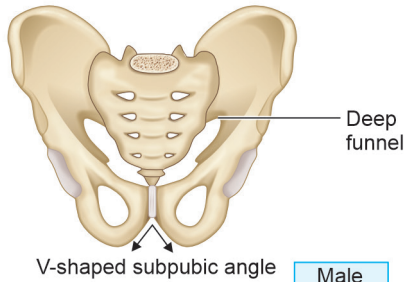
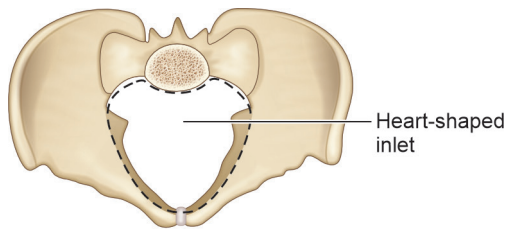
Differentiation 5.4 Male and female mandible (**Fig. 5.7**)

S.No.	Feature	Male mandible	Female mandible
1.	General appearance	Larger, thicker	Smaller, thinner
2.	Chin (symphysis menti)	Square or U-shaped	Rounded
3.	Angle of body with ramus (gonial angle)	Less obtuse (<125°), prominent	More obtuse (>125°), not prominent
4.	Ramus flexure	Rearward angulation of the posterior border of ramus	Straight ramus
5.	Angle of mandible	Everted	Inverted
6.	Body height at symphysis	Greater	Smaller
7.	Ascending ramus	Greater breadth	Smaller breadth
8.	Muscular markings	Prominent	Not prominent

**Fig. 5.7:** Male and female mandible**Differentiation 5.5** Male and female pelvis (**Figs. 5.8 and 5.9**)

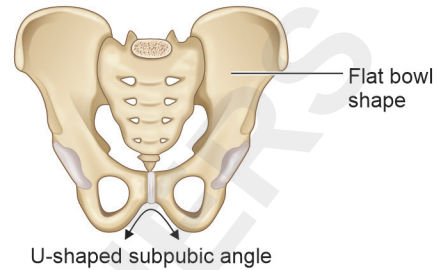
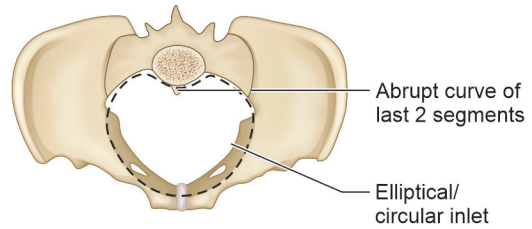
S.No.	Feature	Male pelvis	Female pelvis
1.	General appearance	Massive, rougher, prominent muscular markings	Less massive, slender, smoother, muscular markings not prominent
2.	Shape	Deep funnel with heart shaped inlet	Flat bowl shaped with elliptical/circular inlet
3.	Preauricular sulcus (attachment of anterior sacroiliac ligament)	Not frequent, narrow, shallow	More frequent, broad, deep
4.	Subpubic angle	V-shaped, sharp angle, 70–75°	U-shaped, rounded, broader angle, 90–100°
5.	Greater sciatic notch (Fig. 5.11)	Narrow, deep, small	Broad, shallow, large
6.	Ventral arc	Absent	Present
7.	Subpubic contour	Straight	Concave
8.	Medial aspect of ischiopubic ramus	Broad and flat	Sharp, ridged
9.	Pelvic cavity	Conical, funnel shaped	Broad, round
10.	Pelvic outlet	Smaller	Larger
11.	Body of pubis (Fig. 5.10)	Narrow, triangular	Broad, rectangular, pits on posterior surface, if borne children*
12.	Ischial tuberosity	Inverted	Everted
13.	Iliopectineal line	Well-marked, rough	Rounded, smooth
14.	Obturator foramen (Fig. 5.10)	Large, oval, base upwards	Small, triangular, apex forwards
15.	Acetabulum	Large, 52 mm diameter	Small, 46 mm diameter
16.	Ilium	High and vertical	Low and flaring
17.	Auricular surface (Fig. 5.11)	Raised	Flat

* Three features to determine whether parturition occurred: (i) dorsal pitting, (ii) scarring of the preauricular groove, (iii) scarring of the groove for the interosseous ligament (interosseous groove).



Male

Fig. 5.8: Male pelvis



Female

Fig. 5.9: Female pelvis

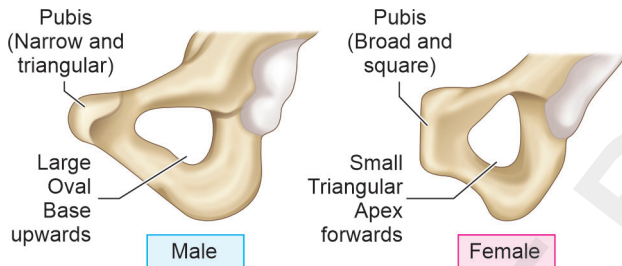


Fig. 5.10: Pelvis: Obturator foramen

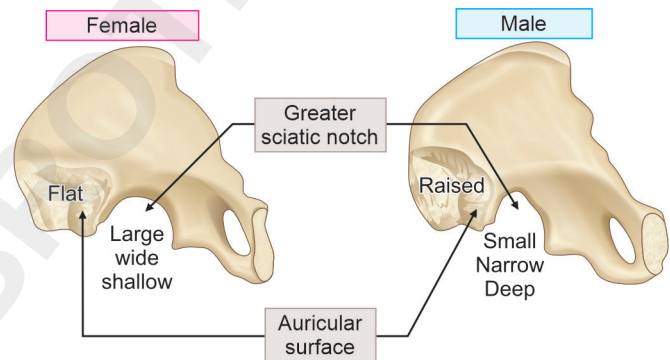


Fig. 5.11: Pelvis: Greater sciatic notch and auricular surface

Differentiation 5.6 Male and female sacrum (Fig. 5.12)

S.No.	Feature	Male sacrum	Female sacrum
1.	General appearance	Long, heavier, rough, narrow	Short, lighter, smooth, broad
2.	Breadth of body of 1st sacral vertebra	More than breadth of one side ala	Less than breadth of one side ala
3.	Inner curvature	Uniformly curved anteriorly	Abruptly curved at the last two segments
4.	Sacroiliac articulation	Large, extends up to 3rd segment	Small, extends up to 2-2½ segment
5.	Sacroiliac joint surface	Large, less sharply angulated	L-shaped, elevated anteriorly

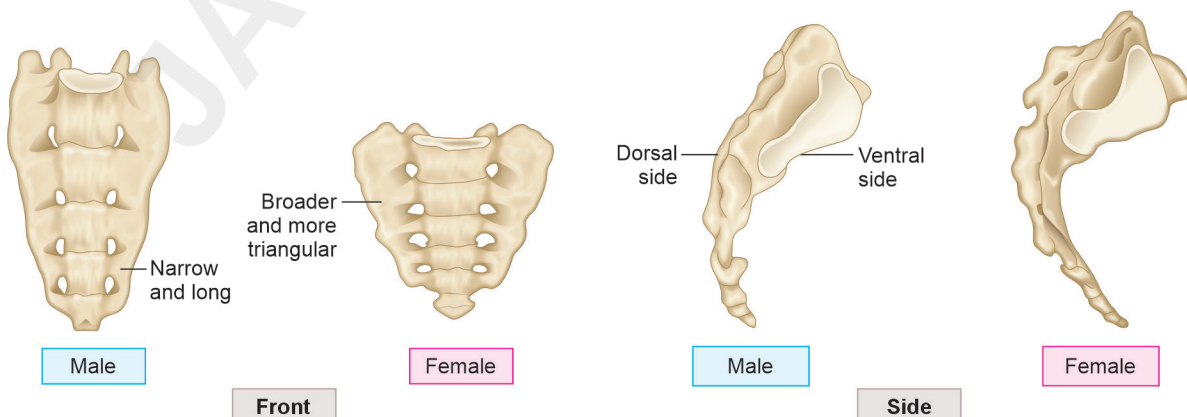


Fig. 5.12: Sacrum

Table 5.5: Diagnostic indexes for determination of sex

S.No.	Index	Formula	Male	Female
1.	Washburn/Ischiopubic index (Best index)	$\frac{\text{Length of pubis}}{\text{Length of ischium}} \times 100$	73–94 (average 75)	91–115 (average 100)
2.	Sciatic notch index	$\frac{\text{Width of sciatic notch}}{\text{Depth of sciatic notch}} \times 100$	145	166
3.	Sternal index	$\frac{\text{Length of manubrium}}{\text{Length of body}} \times 100$	46.2	54.3
4.	Corporobasal index	$\frac{\text{Breadth of body of 1st sacral vertebra}}{\text{Breadth of base of sacrum}} \times 100$	>42	<42
5.	Sacral index	$\frac{\text{Transverse diameter of base of sacrum}}{\text{Anterior length of sacrum}} \times 100$	<114	>114
6.	Chilotic line index	$\frac{\text{Sacral part of chilotic line}}{\text{Pelvic part of the chilotic line}} \times 100$	>100	<100
7.	Kimura's base-wing index (Alar index)	$\frac{\text{Width of wing (ala of sacrum)}}{\text{Width of base (transverse diameter of body of S1)}} \times 100$	65	80

Table 5.6: Indices useful for identification

Race (ancestry)	Sex	Species
Cephalic index	Ischiopubic index	Medullary index
Nasal index	Sciatic notch index	
Brachial index	Chilotic line index	
Crural index	Ilium index	
Intermembral index	Sacral index	
Humero femoral index	Kimura's base-wing index	
Facial index	Corporobasal index	
	Sternal index	

FM4.2, 4.3

Define and describe age determination using teeth-eruption, decay, bones-ossification centers.

AGE

Age determination can be done through many means, and an analysis of all possible age-related attributes is best for an overall estimate. Some of the utilized features include:

- Dental eruption
- Epiphyseal unions
- Pubic symphyseal morphology
- Cranial suture closures
- Mandibular and sacral changes
- Miscellaneous
 - Secondary sexual characters
 - Age-related degenerative conditions.

Is this a male or female skull? Give reasons.



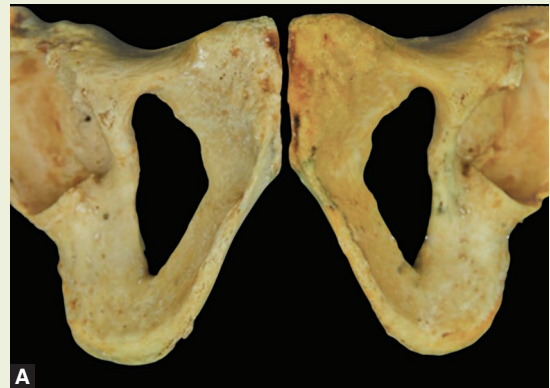
3



Which one of these statements is true?



4





1. (A) is male pelvis and (B) is female pelvis
2. (A) is female pelvis and (B) is male pelvis
3. Both (A) and (B) are female pelvis
4. Both (A) and (B) are male pelvis

■ Dentition in Determining Age

Age can be determined by using the criteria like eruption and calcification of teeth, Demirjian method, Stack's method, Miles method, Boyde's method and Gustafson's method.

- ❖ Teeth are especially useful to determine age in children and adolescents since the developmental stages are well known and characterized. Radiological analysis of dental development is preferred over morphological analysis.
- ❖ Alveolar cavities which contain teeth are formed around the 3–4th month of intrauterine life (IUL).
- ❖ At birth, rudiments of all the temporary teeth and the 1st permanent molars may be found in jaw.
- ❖ Each tooth has a crown, neck and a root embedded in jaw bone (**Fig. 5.13**).
- ❖ Teeth are composed of *dentin* covered on the crown by enamel and on the root by cementum which is attached to the alveolar bone by periodontal membrane. Tooth enamel is the hardest substance in the body containing primarily hydroxyapatite (crystalline calcium phosphate).
- ❖ Mineralization proceeds from crown tips down the sides of the tooth.

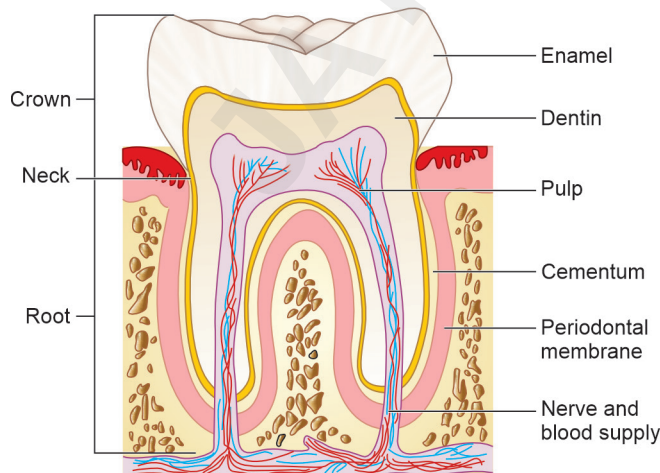


Fig. 5.13: Parts of a tooth

- ❖ Root mineralization does not begin until crown formation is complete and root formation ceases with the reduction of apical foramen. As the root becomes longer, the crown erupts through the bone.
- ❖ Mineralization of deciduous dentition begins in utero, early in 2nd trimester, and root formation of third molar may not be complete until 20 years of age.
- ❖ During eruption of a permanent tooth, the overlying root of its deciduous predecessor simultaneously undergoes absorption, until only the crown remains. The unsupported crown then falls off.
- ❖ Age of eruption of teeth depends upon:
 - i. Heredity
 - ii. Environment
 - iii. Nutrition
 - iv. Endocrine factors.

Each individual has two sets of teeth (Diff. 5.7)

- i. Temporary/deciduous/milk teeth
- ii. Permanent teeth

Temporary teeth

- ❖ **20 in number:** 4 incisors, 2 canines and 4 molars in each jaw (**Table 5.7** and **Fig. 5.14**).
- ❖ The eruption of the deciduous teeth commences at about 6–7 months after birth and is completed about 2nd–3rd year. The lower central incisors antecede those of the upper. However, upper lateral incisor erupts earlier than its lower quadrant counterpart.
- ❖ In ill-nourished children, especially in rickets, dentition may be delayed.
- ❖ In congenital syphilis, teeth may be premature or even present at birth.

Permanent teeth: 32 in number—4 incisors, 4 pre-molars, 2 canines and 6 molars in each jaw (**Table 5.7** and **Fig. 5.15**).

Developmentally teeth are divided into two sets:

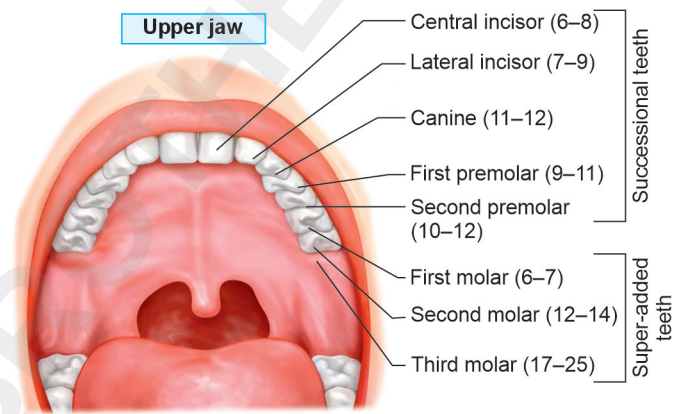
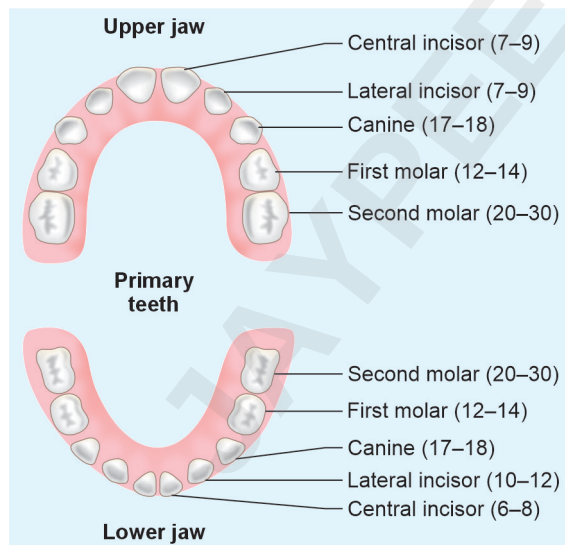
- a. **Super-added permanent teeth:** These teeth do not have deciduous predecessors. All permanent molars belong to this category (6 in each jaw).
- b. **Successional permanent teeth:** These teeth erupt in place of deciduous teeth, e.g., permanent premolars erupt in place of deciduous molars (10 in each jaw).
 - ❖ Usually permanent tooth erupts first in lower jaw.
 - ❖ Permanent teeth appear few months earlier in girls than in boys.
 - ❖ Eruption of teeth is useful in estimating age up to 15 years. The third molar (wisdom tooth) erupts after this time, but is so variable in eruption that it is not a reliable age indicator.
 - ❖ However, the developmental characteristics of eruption and mineralization of 3rd molars are useful for age estimation. The assessment distinguishes between the stages of alveolar eruption, gingival eruption, and having reached the occlusal plane. The latter two stages can be determined by oral visual inspection and do not require

Differentiation 5.7 Temporary and permanent teeth

S.No.	Feature	Temporary teeth	Permanent teeth
1.	Size	Smaller, lighter, narrower, except temporary molars which are longer than permanent premolars	Heavier, stronger, broader, except permanent premolars
2.	Direction of anterior teeth	Vertical	Inclined forward
3.	Crown color	China-white	Ivory-white
4.	Neck	More constricted	Less constricted
5.	Ridge	Present at the junction of the crown and the root	Not present
6.	Root	Roots of molars are smaller, more divergent	Roots of molars are larger, less divergent
7.	Incisors	Smooth incisal edge	Ridged, especially on incisal surface
8.	Radiology	Presence of tooth germ beneath tooth will suggest that tooth is temporary	No such thing visible in case of permanent teeth

Table 5.7: Eruption of deciduous and permanent teeth

Tooth	Deciduous teeth (months)	Permanent teeth (years)
Central incisor	6–8 (lower, 1st to erupt) 7–9 (upper)	6–8
Lateral incisor	7–9 (upper) 10–12 (lower)	7–9
First premolar	Absent	9–11
Second premolar	Absent	10–12
First molar	12–14	6–7 (1st to erupt)
Canine	17–18	11–12
Second molar	20–30 (2–2½ years)	12–14
Third molar	Absent	17–25

**Fig. 5.15:** Eruption of permanent teeth (in years)**Fig. 5.14:** Eruption of deciduous teeth (in months)

an X-ray. The mineralization of third molars is assessed with an orthopantomogram.

- ❖ The mandibular third molar is the most commonly impacted tooth in the mouth and is closely followed by maxillary third molar, maxillary canine and mandibular canine respectively.

- ❖ If, in the jaw all 3rd molars are present, then the age is over 18 years, but their absence gives no certain idea about age.

Spacing of Jaw

After eruption of 2nd molars, the ramus of mandible grows behind to make room for the eruption of 3rd molar teeth which is known as *spacing of the jaw*.

Period of Mixed Dentition

Starting from the day of eruption of first permanent molar till before the eruption of last permanent canine—both temporary and permanent teeth are present in the jaw. This duration is known as *period of mixed dentition* (Table 5.8 and Figs. 5.16A and B). Usually, it is between 6 and 11 years, but may persist until 12–13 years.

- ❖ From 6 to 11 years, the total number of teeth remains 24 because as and when a tooth erupts, it displaces another and the number remains constant.
- ❖ There is addition of teeth from the age of 12–14 years, when the second molar erupts and the total number becomes 28. Then, the number remains constant till 17 years and again 4 more teeth are added from 17–25 years and the number becomes 32.

Table 5.8: Number of teeth with age*

Age (years)	Number of teeth	
2.5–5	20	(All deciduous)
6	21–24	(Eruption of 1st permanent molars)
7–9	24	(12 permanent—8 incisors, 4 molars) (12 deciduous—4 canines, 8 molars)
10	24	(16 permanent—8 incisors, 4 molars, 4 premolars) (8 deciduous—second molars and canines)
11	24	(20 permanent—8 incisors, 4 molars, 8 premolars) (4 deciduous—canines)
12–14	25–28	(Eruption of 2nd permanent molars)
14–17	28	(All permanent)
17–25	29–32	(Eruption of 3rd molars)

* Total number of permanent teeth = (Age in years–5) × 4

Estimation of age from teeth beyond 25 years

The various methods that can be used to determine age from teeth are:

- ◆ Gustafson's method
- ◆ Aspartic acid racemization
- ◆ **Chemical method:** Estimation of nitrogen content of enamel (increases with age), carbonate content (decreases with age) and concentration of ions—Cu, Se and Fe (increases with age).
- ◆ Miles' method
- ◆ Radiocarbon dating of tooth enamel

- ❖ Of the non-destructive methods (where tooth is not required to be taken out), assessing stages of development of mineralization of the teeth using radiographs are more reliable than those using tooth counts.
- ❖ *Amino acid racemization* is considered to be most reliable destructive method of dental age estimation.



Gustafson's Method

- ❖ Age estimation consists of microscopic examination of longitudinal section of central part of the tooth to assess changes in teeth as a result of wear and tear with advancing age.
- ❖ Estimate age between 25 and 60 years (applicable only in adults).
- ❖ Useful only while examining a *dead body or skeletal remains*, as teeth need to be extracted for examination.
- ❖ It is based on criteria given in **Table 5.9** and **Figures 5.17**.
- ❖ Anterior teeth are more suitable than posterior teeth. Merit decreases from incisors to premolars, molars are quite unsuitable.
- ❖ All changes are absent at 15 years. Error is ± 10–15 years. Limit of error increases above 50 years of age.

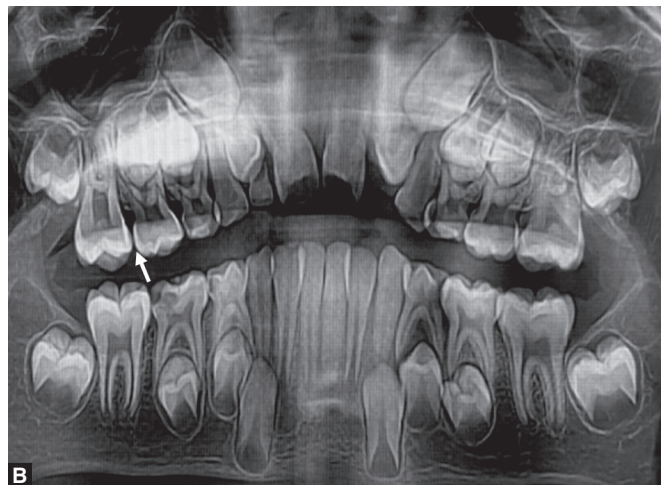
Other Information from Teeth

Sex determination

- i. *Visual and microscopic:* Mandibular canines show the greatest dimensional differences with larger teeth in males than in females. Optical scanner and radiogrammetric measurements of root length and crown diameter of mandibular permanent teeth help in sex determination.
 - Identifying Y-chromosome in dental pulp tissue using quinacrine and fluorescent microscopy.
 - Isolation of sex-specific banding patterns in DNA profiles of X and Y-chromosomes.
- ii. *Sex determination from enamel protein:* Amelogenin (AMEL) is a major protein found in human enamel. It has a different signature in male and female.

Race (ancestry)

- i. 'Shovel-shaped' upper central incisors can be found in most Asians (Mongoloids) and Americans. In Europeans, lateral incisor in upper jaw is smaller than the central, especially in females.



Figs. 5.16A and B: Mixed dentition: (A) 7–8-years-old child (permanent incisors and temporary canines can be seen); and (B) 9-years-old child (orthopantomogram showing erupted permanent incisors and first molars with retained primary teeth, developing permanent canines/premolars, and resorption of primary tooth roots.)

[Courtesy (A) Naveen Oberoi, Dept of Dentistry, BJS Dental college, Ludhiana; and (B): Vineet Galhotra, Dept of Dentistry, DMCH, Ludhiana]

Table 5.9: Gustafson's criteria (Fig. 5.17)

S.No.	Changes	Description
1.	Attrition	Wearing down of occlusal surface due to mastication, first involving enamel, then dentin and lastly pulp
2.	Periodontosis	Retraction of gum margin and loosening of tooth exposing the neck and adjacent parts of roots
3.	Secondary dentin	Progressive infilling of the dental pulp cavity decreases the size of cavity and may completely obliterate it
4.	Cementum apposition	Cementum increase in thickness around the root due to changes in tooth position; continuously deposited throughout life and forms incremental lines
5.	Root resorption	Involves both cementum and dentin. Starts at apex and extends upwards. <i>Least reliable of all criteria</i>
6.	Root transparency	Occurs in root from below upwards in lower jaw and above downwards in upper jaw due to rarefaction of the dentin tissue. <i>Most reliable of all criteria</i>

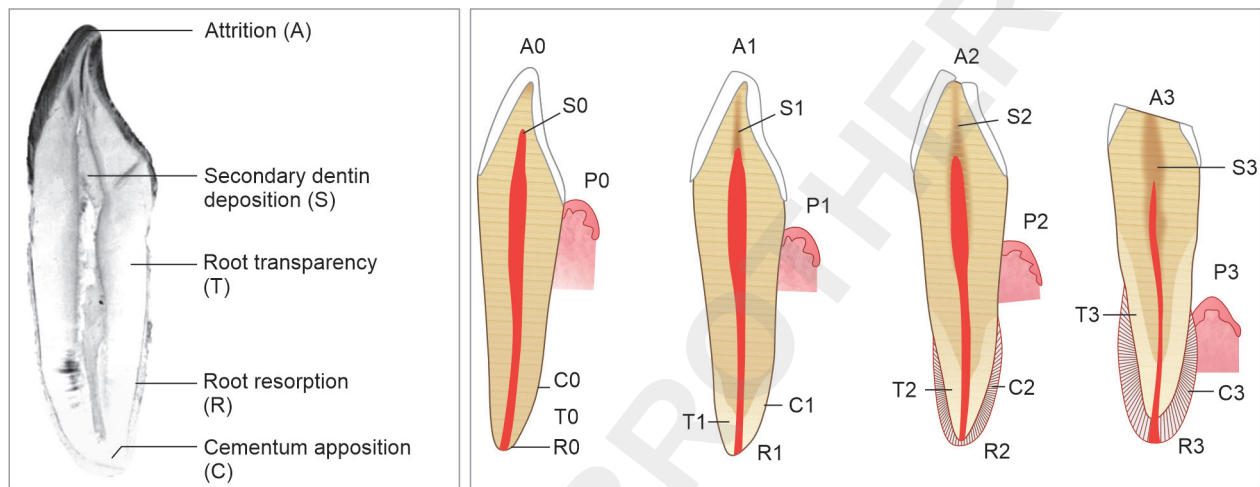


Fig. 5.17: Gustafson's method and its criteria. Scoring system: Each factor is scored 0–3 (absent → marked); total score (0–18) is calculated. Age (years) = $11.43 + (4.56 \times \text{total score})$

- ii. *Carabelli's cusp* (seen in whites), *taurodontism* (bull tooth) and *enamel pearls* (common in Asians) have been listed as racial determinants.

IMPORTANT NOTE

- ♦ **Carabelli's tubercle** is an anomalous cusp on the lingual surface of maxillary first permanent molars, most commonly seen among Europeans (75–85%) (50% of American whites and 34% of Afro-Americans).
- ♦ **Taurodontism** is an aberration of teeth that lacks the constriction at the level of the cemento-enamel junction characterized by elongated pulp chambers and apical displacement of bifurcation or trifurcation of the roots, giving it a rectangular shape.
- ♦ **Enamel pearls** are small nodules of enamel on the root surface of permanent maxillary molar.
- ♦ Taurodontism, especially in maxillary molars, enamel pearls on premolars and congenital lack of upper 3rd molars are commonly seen in Asians (*Mongoloids*).

❖ Occupation and habits

- Cobblers or tailors usually show notched upper incisors from wear and tear.
- Dark brown stains on the back of incisors are seen in 'cigarette smokers'.

- ❖ **Social status:** From general cleanliness, dentures and dental fillings by gold, silver or other metal.

IMPORTANT NOTE

- ♦ **Stack's method:** Method to estimate the age from sum of the weight of the erupting teeth of *fetus and infant* (from 5 months in utero to postnatal age of 7 months).
- ♦ **Boyde's method:** Estimate age of dead infants, based on counting the number of cross striations in the enamel of teeth (incremental lines) from *neonatal line* (darkest band) onwards. Neonatal line is formed soon after birth.
- ♦ **Demirjian method:** Dental age estimation in children based on assessment of maturity score of lower left permanent mandibular teeth (except 3rd molar) using an orthopantomogram.
- ♦ **Lamendin method:** Periodontosis and translucency of root are taken into consideration for estimation of age at death for adults by analyzing single-rooted teeth—considered better than Gustafson's method.
- ♦ **Miles' method:** Amount of wear on all three permanent molars is assessed for age estimation. Miles also developed a formula to determine age at death by measuring the thickness of enamel and dentin from neonatal line and divided it by daily rate of formation.
- ♦ **Histological technique:** The amount of dentin laid down after the formation of the neonatal line (incremental lines) in deciduous dentition, and counting of cross-striations and striae of Retzius in primary and secondary enamel may help in

finding the chronological age. Once enamel depositions are complete, the use of cemental annulations rings can be used.

- ◆ **Aspartic acid racemization:** During the course of aging, L-forms of amino acids (in crown dentin) are transformed by racemization to D-forms. Thus, the extent of racemization of amino acids may be used to estimate the age. Of all amino acids, aspartic acid racemization is most commonly used for age estimation.
- ◆ **Radiocarbon analysis of tooth enamel:** Method to determine the year of tooth formation based on levels of radiocarbon present in tooth enamel.

AGE FROM OSSIFICATION OF BONES

- ❖ The clavicle is the first bone to ossify in the body from two membranous primary ossification centers during the 5–6th postovulatory week (3rd to 4th week after conception). A secondary center forms in the sternal end between 15–17 years and fuses by 20–22 years. In majority of the bones, primary centers of ossification appear between 7th and 12th weeks of IUL. By the age of 11–12th week of IUL, there are 806 centers of ossification.
- ❖ The process of appearance and union has a sequence and time (approximate age ranges) (**Table 5.10 and Fig. 5.18**).

Table 5.10: Appearance of ossification centers (in males)

S.No.	Bone	Centers of ossification	Age of appearance	Age of union
1.	Sternum	Manubrium 1st sternbrae 2nd and 3rd sternbrae 4th sternbrae Xiphisternum	5th month IUL 5th month IUL 7th month IUL 10th month IUL 3rd year postnatal	60–70 years (Manubriosternal joint) (From below upwards; 3rd and 4th–15 years; 2nd and 3rd–20 years; 1st and 2nd–25 years) (With body)
2.	Clavicle	Medial end	15–17 years	20–22 years
3.	Scapula	Coracoid base Acromion process	10–11 years 14–15 years	14–15 years 17–18 years
Upper Limb				
4.	Humerus	Head Greater tubercle Lesser tubercle Capitulum Trochlea Lateral epicondyle Medial epicondyle	1 year 3 years 5 years 1 year 9–10 years 10–11 years 5–6 years ^y	At 5–6 years, the three fuses together (<i>conjoint epiphysis</i>) and at 17–18 years, fuses with the shaft At 14–15 years, all three fuses with the shaft* 16 years
5.	Radius	Upper end Lower end	5–6 years 1–2 years	15–17 years 17–19 years
6.	Ulna	Upper end (olecranon) Lower end	8–9 years 5–6 years	15–17 years 17–19 years
7.	Carpals	Pisiform	9–12 years	—
Lower Limb				
8.	Hip bone	Ischiopubic rami Triradiate cartilage Iliac crest [§] Ischial tuberosity	— — 15–16 years 16–17 years	7 years 12–14 years 19–21 years 20–22 years
9.	Femur	Head Greater trochanter Lesser trochanter Lower end	1 year 4 years 14 years (puberty) 9 months IUL	17–18 years 14–15 years 15–17 years 17–18 years
10.	Tibia	Upper end Lower end	At birth 1 year	17–18 years 16–17 years
11.	Fibula	Upper end Lower end	4 years 2 years	17–18 years 16–17 years
12.	Tarsals	Calcaneum Talus Cuboid	5th month IUL 7th month IUL 9th month IUL	

* Ossification centers of lateral epicondyle, capitulum and trochlea fuse with each other at about 13–14 years to form a conjoint epiphysis which fuses with shaft at about 14–15 years.

^y Sequence of appearance of elbow ossification centers: **CRITOE**: Capitulum → Radial head → Internal (medial) epicondyle → Trochlea → Olecranon → External (lateral) epicondyle.

[§] Radiographically, Risser classification is used to grade skeletal maturity of ossification and fusion of iliac crest on a scale of 0–5. Risser 0 indicates that there is significant amount of growth remaining, while Risser 5 indicates skeletal maturity.

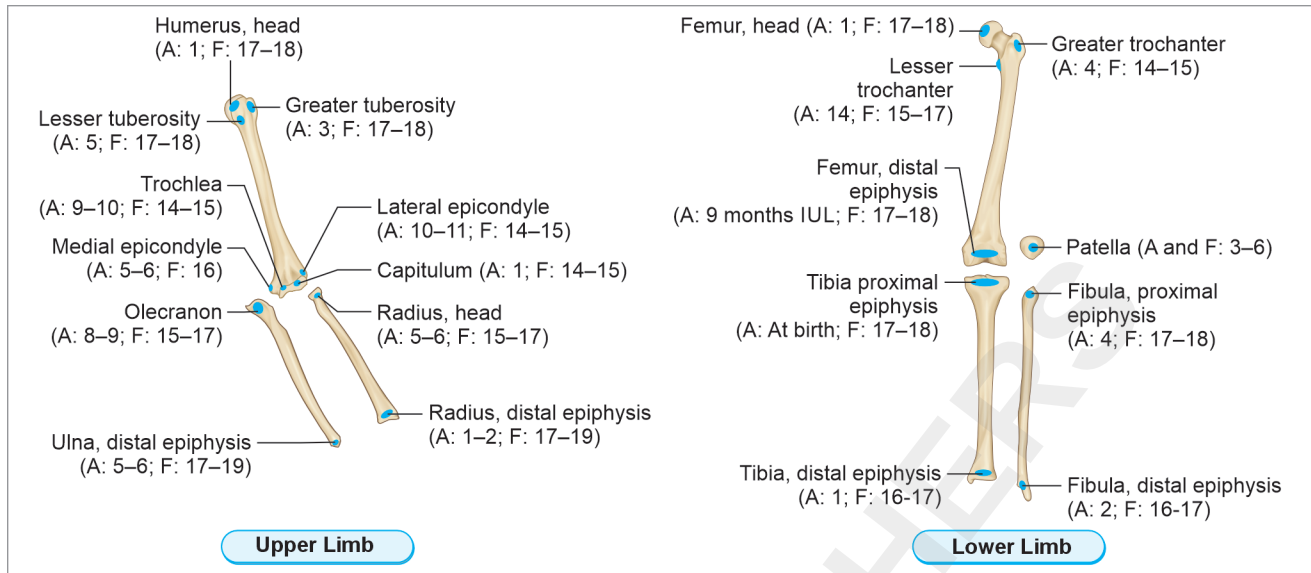


Fig. 5.18: Appearance (A) and fusion (F) of ossification centers of upper and lower limbs (in years).

- ❖ Ossification begins centrally in an epiphysis and spreads peripherally as it gets bigger.
- ❖ Process of union of epiphysis and diaphysis is called *fusion*. Union is a process not an event.
- ❖ Some researchers have used five grades of epiphyseal union: unobservable (0), beginning (1), active (2), recent (3) and complete (4), and these offer a possibly more accurate estimate of age.
- ❖ Capitate and hamate ossifies during infancy (1 year), the former preceding the later. Between 2 and 6 years, the number of carpal bones present on X-ray represents the approximate age in years, e.g., three carpal bones—3 years (**Fig. 5.19**).
- ❖ X-rays of elbow, wrist, clavicle and shoulder joints (upper extremity) and pelvis, knee and ankle joints (lower extremity) are usually recommended to determine the age before 25 years of age.
- ❖ Radiography of the hand and wrist is the commonest modality used to calculate bone age of a child.

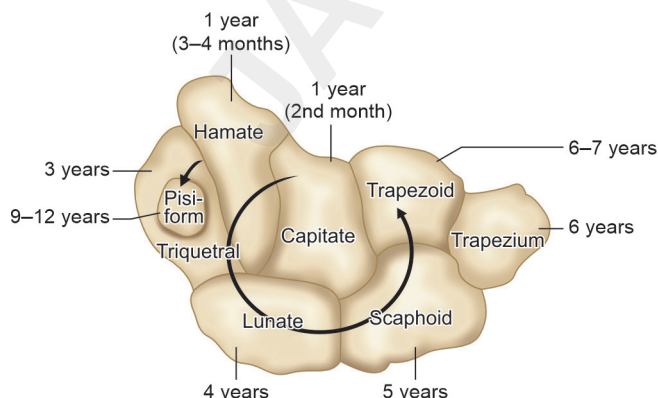


Fig. 5.19: Sequence of (left wrist dorsal aspect) ossification of carpal bones (simplified)

Table 5.11: Radiological age determination (before 25 years)

S.No.	Site for X-ray (region)	Age (years)	
		Female	Male
1.	Elbow	13–14	15–16
2.	Wrist	16–17	18–19
3.	Shoulder	17–18	18–19
4.	Iliac crest	18–19	19–21
5.	Ischial tuberosity and inner end of clavicle	21–22	21–23

- ❖ Following the wrist skeletal development, the assessment of the ossification stage of the medial clavicular epiphysis is quite helpful, as the clavicles are the last long bones to ossify in the skeleton. Ossification stage of the medial clavicular epiphysis is done using thin-slice CT (*method of choice*) and evaluated according to a 5-stage classification system.
- ❖ Determination of age based on the union of epiphyses with a range of ± 6 months is given in **Table 5.11**. In females, epiphyseal union occurs 1–2 years earlier than males.
- ❖ If all the epiphyses of all the long bones are united, the person is most probably over 25 years of age.

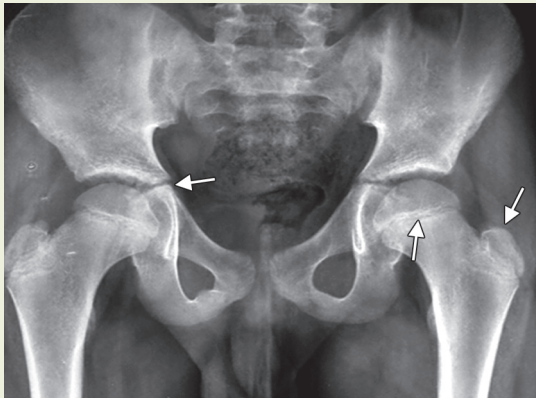
BONE AGE ESTIMATION

- ❖ Age estimation is mainly done by a board of forensic physicians, radiologists, dentists and pediatricians.
- ❖ Currently, the essential components of age estimation is given in **Box 5.3**.
- ❖ Bone development is influenced by a number of factors, including nutrition, hormonal secretions, genetics, differences in ethnicity, socioeconomic status and accelerated development or developmental disorders. Other factors include: variability among methods, degree



- A. Estimate the age of this person from the given radiograph.
B. Observe the pelvic bone. What could be the age of this person? Give reasons.

5



A.



B.

BOX 5.3 Age assessment protocol

- ◆ Medical history and physical examination to assess the physical development and to rule out development-related illnesses and medications.
- ◆ Dental examination with orthopantomogram.
- ◆ X-ray examination of the left hand and wrist joint.*
- ◆ Thin-slice CT of the medial end of clavicle (indicated if there is complete ossification of wrist).

of variability in the estimation of skeletal maturation, and dispersion of the values of skeletal maturation.

- ❖ Pre-existing illnesses can lead to a developmental delay and thus to an underestimation of age.
- ❖ Endocrine disorders that lead to accelerated skeletal maturity include: precocious puberty, adrenogenital syndrome and hyperthyroidism. Physical examinations should specifically look for gigantism, acromegaly, dwarfism, virilization in girls, dissociated virilism in boys, goiter and exophthalmos.

Recent advances in skeletal age assessment

- ◆ *Radiographic methods* remain the gold standards. A correct positioning is essential because poor positioning can change the appearance of some bones. It is also preferable to employ scoring methods to these techniques and percentiles rather than bone age in years and months.
- ◆ *CT visualization* of the clavicle has been extensively studied but requires a high dose of radiation.
- ◆ *Magnetic resonance imaging (MRI)* based methods are being developed but require more research to evaluate the reliability and validity.
- ◆ *Ultrasound imaging* has some limitations that include operator dependence, lower intra-rater and inter-rater reliability of assessment and difficulties with standardization of documentation and imaging transfer.

- ◆ The iliac bone and femoral head have also been studied for computation of bone age, but no standardized methods have yet been generated.
- ◆ *Computerized bone age estimation system*: The use of automated bone age determination system in Europe (BoneXpert) has been validated for various ethnicities and children with endocrine disorders.
- ◆ *Artificial intelligence and machine learning*: Deep learning models are now being developed to perform automated bone age estimation (including adult height based on ossification patterns), significantly reducing inter-observer variability and processing time compared to manual methods.

AGE DETERMINATION IN ADULTS OVER 25 YEARS

After the age of 25 years, estimation of age becomes more uncertain.

■ Symphyseal Surface of Pubis

- ❖ The pubic symphyseal face in the young is characterized by an undulating surface, such as the crenulated surface of a typical non-fused epiphyseal plate.
- ❖ This surface undergoes a regular progressive change from 18 years onwards.
- ❖ It is the *single best criterion* for determining age-at-death for individuals from third to fifth decade.
- ❖ Morphologic changes seen in males with increasing age are given in **Table 5.12** and **Figure 5.20** (Todd; Suchey-Brooks methods).

■ Skull Suture Closure

- ❖ This method estimates age utilizing the degree of closure, union or ossification of the cranial sutures (**Table 5.13** and **Fig. 5.21**).

* *Left-hand X-ray* is the standard for bone age assessment since it allows comparison with the *Greulich and Pyle Atlas*, ensures uniformity and standardization, is less likely to be injured as it is usually the non-dominant hand, and minimizes radiation exposure to the dominant hand. Advances such as MRI-based and AI-assisted evaluations now adapt its criteria to modern, radiation-free and population-specific contexts.

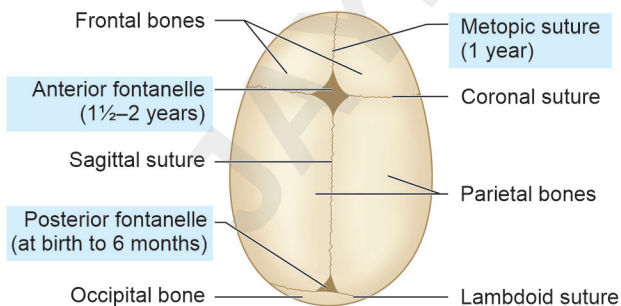
Table 5.12: Age determination from pubic symphysis (in males)

Age	Features
<20 years	Compact bone near its surface
About 20 years	◆ Surface markedly irregular/uneven ◆ Ridges runs transversely across articular surface
25–40 years	◆ Ridges gradually disappear ◆ Surface has granular appearance ◆ Outer and inner margins completely defined
40+ (Early 5th decade)	Oval smooth surface with raised upper and lower ends
Late 5th decade	Narrow beaded rim develops on margin
50+ (6th decade)	Erosion of surface and breakdown of ventral margins
60+ (7th decade)	Surface becomes irregularly eroded

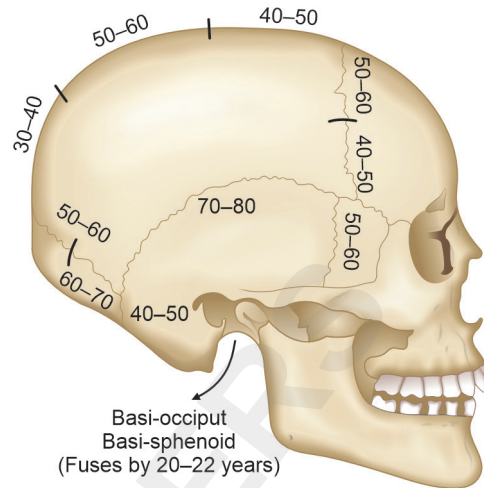
Note: If male criteria are used for females, the age would be underestimated by about 10 years.

**Fig. 5.20:** Changes in pubic symphyseal surface with age**Table 5.13:** Age determination from skull suture closure

S.No.	Suture closure	Age
1.	Posterior fontanelle (occipital)	At birth to 6 months
2.	Anterior fontanelle (bregma)	1½–2 years
3.	Two halves of mandible	1–2 years
4.	Metopic suture (between frontal bones)	1 year (3–9 months), may remain unfused
5.	Basiocciput and basisphenoid	18–20 years (females) 20–22 (males)
6.	Lambdoid suture	45–50 years
7.	Parieto-temporal	60–70 years

**Fig. 5.21:** Normal skull of the newborn

- ❖ The closure of the skull sutures is considered to be a reasonably reliable index of age estimation between 25–40 years of age (*useful in living also*).
- ❖ Closure of skull sutures begins on the inner side (endocranially) 5–10 years earlier than on the outer side (ectocranially). The closure of ectocranial suture is

**Fig. 5.22:** Age (in years) of skull suture closure

variable and it may not close at all (lapsed union). It is more commonly seen in sagittal suture.

- ❖ The most successful estimate of age is done from **sagittal suture**, followed by lambdoid and then coronal. The sutures start closing on the inner side at about 25 years of age. On the outer side, posterior one-third of sagittal suture closes at about 30–40 years; anterior one-third of sagittal and lower half of coronal at about 40–50 years; and middle of sagittal and upper half of the coronal at about 50–60 years (**Fig. 5.22**).
- ❖ Lambdoid suture starts closing between 25 and 30 years and complete closure occurs between 65 and 70 years.
- ❖ Last skull suture to close is the **temporoparietal suture** (70–80 years)
- ❖ A **lateral head skiagram** is preferable for observing the sutures.

Age Estimation from Mandible

It is given in **Diff. 5.8** and **Figure 5.23**.

Sacrum

The five sacral vertebrae remain separated by cartilage until puberty, and with the onset of puberty, ossification of intervertebral discs starts from below upwards and fusion becomes complete by 20–25 years.

General Features in Estimation of Age

It includes secondary sexual characters, baldness or graying of hair, arcus senilis and skeletal changes.

Secondary Sexual Characters

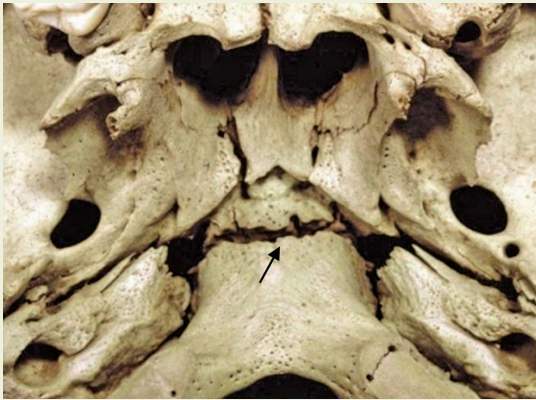
- ❖ The secondary changes for estimation of age are not very helpful, but give an estimate of prepubertal and pubertal ages.
- ❖ Best known is the **Tanner staging**, which give sequential physical and physiological changes during puberty. A summary of important findings is given in **Diff. 5.9**.



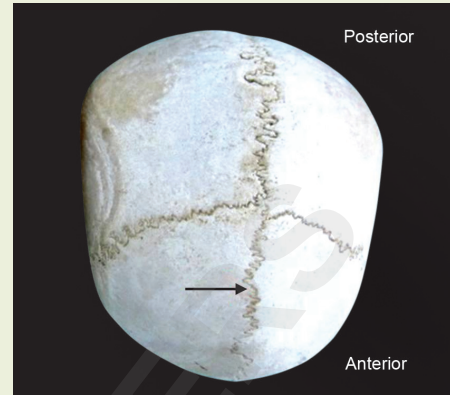
A. Can you estimate the age by observing the base of skull?

B. Identify the suture. What is the approximate age of fusion?

6



A.



B.

Differentiation 5.8 Mandibles of infancy, adult and old age (Fig. 5.23)

S.No.	Feature	Infancy	Adult	Old age
1.	Body	Shallow	Thick and long	Shallow
2.	Ramus (medico-legal angle)	Short, oblique, forms obtuse angle with body	Less obtuse angle (almost right angle)	Obtuse angle with body (about 140°)
3.	Mental foramen	Opens near the lower margin and directed forwards	Opens midway between upper and lower margins and directed horizontally backwards	Opens near the alveolar margin
4.	Condylod process	At a lower level than coronoid process	Elongated and projects above coronoid process	Neck is bent backwards

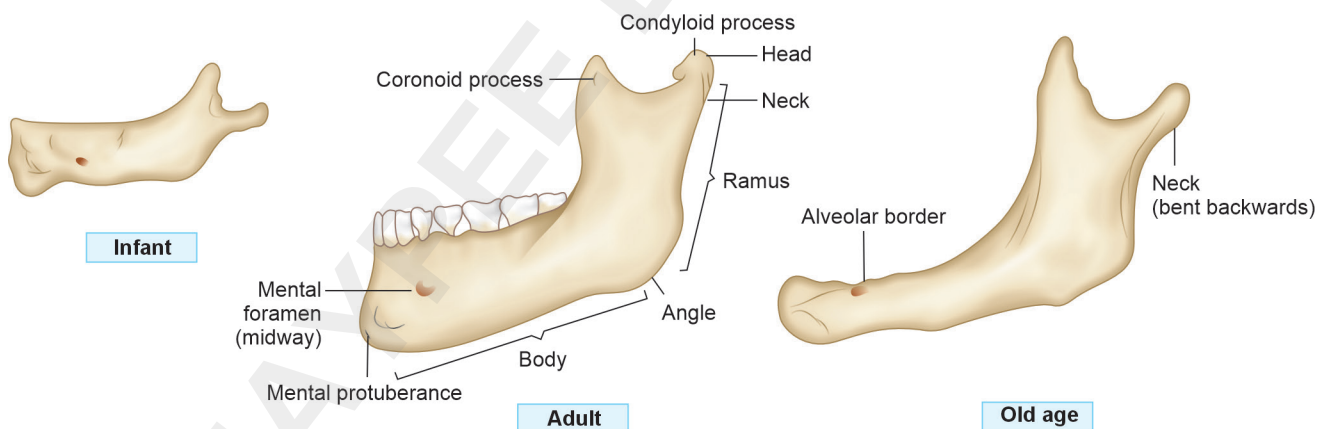


Fig. 5.23: Mandible at different ages

Differentiation 5.9 Summary of sexual development

S.No.	Feature	Girls	Boys
1.	Onset	10–12 years	12–14 years
2.	First sign	Breast development (thelarche)	Testicular enlargement (gonadarche)
3.	Growth spurt	Early (10–11 years)	Late (12–13 years)
4.	Sexual maturity	Menarche: 13–14 years	Spermarche: 15 years
5.	Order of maturity	Thelarche → pubarche → peak growth velocity → menarche	Testicular development → pubarche → axillary hair → beard

Older Years

Many non-pathogenic conditions, such as arthritis and osteoporosis become more prevalent and pronounced in old age and can be used as corroborative evidence in the determination of age.

- i. Baldness or graying of hair does not carry much value in calculating age. But, pubic hair does not turn gray before 50–55 years.
- ii. **Arcus senilis:** Opaque zone around periphery of cornea may be noticed as a result of lipoid degeneration after 50 years, but is not complete before 60 years.
- iii. **Pterygia:** Localized, elevated yellow-white areas that develop on the conjunctiva and cornea. Located most often nasally but sometimes temporally, and are usually bilateral. Pterygia are generally found in middle-aged or elderly individuals.
- iv. **Skeletal changes**
 - Thyroid and cricoid cartilage (1st tracheal ring) tend to ossify by about 45–50 years.
 - Greater cornu fuse with the body of hyoid by 40–45 years.
 - Xiphisternum and manubrium unite with the body of sternum around 40 years and above 50 years respectively.
 - Lipping of lumbar vertebrae occurs around 40–50 years (osteophytosis) and atrophic changes occur in intervertebral disc with diminution of joint space at about 50–60 years.
 - Radiological thinning of the cortex and progressive rarefaction of apex of medullary cavity of head of humerus and femur are helpful in determination of the age.
 - Skull bones with advancing age tend to become lighter and thinner.

X-rays of skull, vertebrae and sternum are used to determine age in old people.

IMPORTANT NOTE

- ◆ **Phase changes in the sternal rib (İşcan method):** Age estimation based on sequential morphological changes at the sternal end (costochondral joint) between the rib and sternum of the 4th rib, specifically its pit depth, shape, and wall/rim. These changes are similar to those that occur on the pubic symphyseal face.
- ◆ **Cortical bone histology:** Age estimation based on calculating the rate of osteon turnover or replacement osteon from midshaft of long bone sections. Best correlation come from the fibula, then femur and tibia.
- ◆ **Harris lines:** These are the small growth lines within the bones. No two individuals have the same pattern, i.e., they are unique. Identification of a person is possible from these lines.
- ◆ **Age estimation from bone marrow:** The normal cellularity varies with age. The marrow is approximately 100% cellular during the first 3 months of life, slowly declining in cellularity until 30 years of age, then it remains at about 50%. This can give an estimation of different age groups (newborn, child, adults and elderly) but not the exact age of the person.

FM4.3

Describe medico-legal aspects of age.

MEDICO-LEGAL IMPORTANCE OF AGE

Age estimation is important for issues pertaining to illegal trafficking (child labor), legal medicine (kidnapping/human trafficking/illegal migration), sexual exploitation, criminal cases, adoption of individuals without birth certificates, and natural or mass disasters. Medico-legal importance of various age groups is given in **Table 5.14**.

- ❖ **Evidence:** Competency for giving evidence depends upon understanding, but not on age. A child of any age can give evidence, if the court is satisfied that the child is truthful (**Sec. 124 BSA**).
- ❖ **Criminal abortion:** A woman who has passed the childbearing age cannot be charged of procuring criminal abortion.
- ❖ **Identification:** An approximate age is important in any chain of identity data.
- ❖ **Impotence and sterility:** A boy is sterile though not impotent before puberty; woman becomes sterile after menopause.

FM4.1

Define and describe stature.

STATURE

- ❖ **Stature** is the natural vertical measurement of a living person in an upright position, taken from the bottom of the feet to the top of the head.
- ❖ Stature estimation from skeletal remains is a common parameter in forensics used to aid in the identification of dead bodies.
- ❖ Stature varies at different times of day by 1.5–2 cm. It is less in the afternoon and evening due to reduced elasticity of intervertebral discs and the longitudinal vertebral muscles.
- ❖ After the age of 30, the natural process of senile degeneration causes gradual decrease in stature by 0.6 mm/year on average.
- ❖ On an average, the body lengthens after death by about 2 cm, due to complete loss of muscle tone, relaxation of large joints and loss of tensioning effect of paraspinal muscles on intervertebral discs.
- ❖ If the body has been dismembered or skeletonized, the approximate stature may be determined by:
 - i. Length of entire skeleton and 2.5–4 cm for thickness of soft parts.
 - ii. Length from tip of middle finger to the tip of the opposite finger when arms are fully extended [Stature $\approx$ Arm span $\times$ 0.97(M) or 0.98(F)].
 - iii. Twice the length of one arm with 30 cm added for two clavicles and 4 cm for sternum.

Table 5.14: Medico-legal importance of various age groups

Age	Medico-legal importance
5 years	Custody of a minor who is below 5 years is with the mother
7 years	Below this age, child is not responsible for his criminal act, as he does not understand the nature and consequences of his act (Sec. 20 BNS)
7–12 years	A child may or may not be held responsible for his act by the court, depending upon whether the child has attained sufficient maturity to understand the nature and consequence of the act (Sec. 21 BNS)
10 years	If a child below this age is removed from his lawful guardian for purpose of robbing movable property from his possession, it will amount to kidnapping (Sec. 97 BNS)
12 years	◆ Age of consent for general physical examination including medico-legal examination ◆ A child under this age need not take oath ◆ A child under 12 years cannot give valid consent to suffer any harm which may occur from any act done in good faith and for his benefit (Sec. 27 BNS) ◆ If a child under 12 years is guilty under the Indian Railways Act, 1889 for his willful negligent act or omission, then his father or guardian has to execute a bond for such amount and such period for the good conduct of the child (no punishment is awarded to child)
14 years	Employment: Prohibition of child below this age in any employment even as a domestic help (except in non-hazardous family business or as an artist, actor, singer, sports) and is a cognizable offense (CLPR Act 2016)
14–18 years	Adolescents are not allowed in hazardous occupation (mining, inflammable substances, explosives etc) but can work in non-hazardous industries.
16 years	◆ Learner license to drive a vehicle of 50 cc engine and without any gear ◆ Child offenders (16–18 years) committing heinous offenses (e.g. rape, murder) can be tried in Children's court after preliminary assessment.
17 years	Admission in a medical college
18 years	◆ Statutory rape: Intercourse with a girl below this age, irrespective of whether with or without her consent amounts to rape ◆ Judicial punishment: Below this age, an offender is child and is tried in a Juvenile court, and if convicted, sent to reformatory school (no imprisonment or death sentence) ◆ Age of majority except when the individual is under guardianship of the court of Wards ◆ Age of marriage for females ◆ Can cast vote (in India, UK, US, Australia and most of the countries) ◆ Mentally sound person can make a valid will (testamentary capacity) ◆ Age for permanent license to drive a private motor vehicle ◆ Taking out or enticement of a <i>child</i> (boy or girl <18 years) below this age from custody of her guardian amounts to kidnapping [Sec. 137 (1) BNS] ◆ Can be employed in any authorized job in a factory ◆ Can give valid consent to suffer any harm which may result from an act not intended or not known to cause death or grievous hurt (Sec. 25 BNS) ◆ Minimum age for entering a government service ◆ A pregnant female can give valid consent for termination of pregnancy (MTP Act) ◆ A person can authorize the removal of organ from his body for therapeutic purposes (Transplantation of Human Organs Act) ◆ Abetment to suicide of a person below this age is severely punishable (imprisonment up to 10 years to life imprisonment and fine) (Sec. 107 BNS) ◆ Procurement of a <i>child</i> under this age for illicit intercourse is punishable [10 years imprisonment and fine (Sec. 96 BNS)
21 years	◆ Age of marriage for males ◆ If a girl below this age (or a boy <18 years) is 'imported' to India from foreign country for the purpose of illicit intercourse, the act amounts to kidnapping (Sec. 141 BNS) ◆ Person under the guardianship of the Court of Wards attains majority
25 years	◆ Age for contesting membership of Parliament and other legislative bodies ◆ Age limit for entering in some government services ◆ According to Punjab Excise Act, a person below this age cannot buy and consume liquor
35 years	◆ Minimum age for appointment as President, Vice-President and Governor of States in India ◆ Prenatal diagnostic tests/procedures cannot be conducted if the pregnant female is below this age (PCPNDT Act)
55–65 years	Age of retirement from services under the government, statutory bodies, autonomous bodies/institutes or from judiciary services

- iv. Length from vertex to the symphysis pubis is roughly half of stature.
- v. Length from sternal notch to symphysis pubis multiplied by 3.3.

■ Stature from Bones

The methods in use to determine the stature can be divided into:

- a. Least squares regression equation and other regression principles.
- b. Stature: bone length ratios.
- c. Skeleton height and adjustment for missing soft tissue.

Sex and race of the individual should be taken into account while applying these methods:

- ❖ When whole skeleton is not available, but one or the other long bones are available, then regression equations are used.
- ❖ **Karl Pearson's regression formula** (first reported in 1899) is the most commonly used method to determine the stature based on long bones. The formula for femur being: Stature (cm) = $81.306 + 1.88 \times F$ (length of femur cm in males). More accurate regression formula being Stature (cm) = $65.53 + (2.32 \times \text{femur length of males in cm})$
- ❖ Several authors have offered regression equations, viz. Breiteringer, Telkkä, Dupertius and Hadden, Trotter and Gleser, and Muñoz. They are derived for one population (usually Europeans and North Americans) and as such not suitable for Indians. Moreover, these formulae are not valid for children.
- ❖ Combination of bones is more reliable than a single bone, and long bones of lower limb (femur and tibia) give better estimate than upper limbs (humerus and radius).
- ❖ **Multiplication factors to calculate stature** for femur: 3.8–3.9 (*most accurate*); tibia 4.4–4.6; fibula 4.5–4.7; humerus 5.3–5.5; radius 6.5–6.7; ulna 6.4–6.7 (approximately).
- ❖ In taking measurements of bones, their lengths are measured using Hepburn type osteometric board (Fig. 5.24).
- ❖ A simple rule of thumb is that humerus is 20%, tibia 22%, femur 27% and the spine 35% of an individual's height in life.

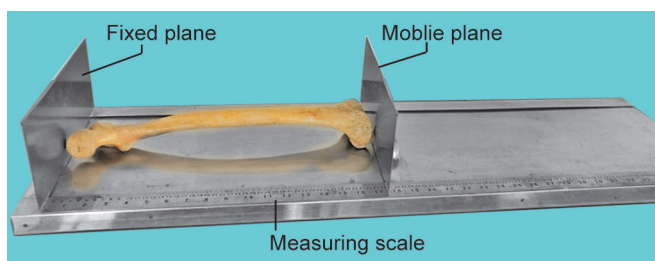


Fig. 5.24: Osteometric board

FM4.5

Describe and discuss identification of criminals, unknown persons, dead bodies from scars and tattoos.

SCARS

Definition: It is a fibrous tissue covered by epithelium without hair follicles, sweat glands or pigment, produced from the healing of a wound.

- ❖ Scar is formed, if injury is at the level of dermis and below.
- ❖ The most superficial wounds which involve the epidermis, e.g., superficial burns or abrasions will heal by epithelialization alone without scar formation.

Examination: Good lighting is essential. Description of scars should include number, site, size and shape, level it bears to the body surface, fixed or free, smoothness or irregularity of the surface, color, presence or absence of glistening, tenderness, condition of the ends—whether tapering or not, and the probable direction of the original wound.

■ Characteristic of Scars

Wound/injury	Features
Lacerated and infected wounds	Firm, irregular and attached to deeper tissues
Incised wounds	Linear scars
Stab wound (knife)	Oval, elliptical, depressed, triangular, irregular scar
Bullet wound	Circular depressed scar
Burns and corrosive acids	Irregular scar
Scalds	Spotted appearance
Vaccination scars	Circular or oval, flat or slightly depressed

Growth: Scars produced in childhood grow in size, especially if situated on chest or limbs.

Age of scars: Refer to Table 5.15.

Erasure: Scar can be erased by excision and skin grafting.

Table 5.15: Age determination of scars

Features	Duration
Firm union, reddish/bluish scar	5–6 days
Pale, soft and sensitive (tender)	2 weeks–2 months
Tough, brownish, glistening, wrinkled and little tender	2–6 months
Tough, white, glistening, corrugated and non-tender	>6 months

■ Medico-legal Importance

- i. Identification of the individual.
- ii. Shape of scar may indicate the nature of weapon or agent that caused injury.
- iii. Age of scar indicates time of infliction of injury which may have value as circumstantial evidence.

- iv. If a person is disfigured by scar due to assault, it constitutes grievous hurt (**Sec. 116 BNS**).
- v. Striae gravidarum and linea albicantes may indicate previous pregnancy in females.
- vi. To charge an enemy with assault, a person may attribute scar due to disease as those of wound.
- vii. Scars on wrist or throat may indicate previous attempts at suicide.
- viii. Linear needle scars indicate an IV drug abuser, and depressed scars a skin popper.



TATTOO MARKS

Definition: Tattoos (Tahitian or Polynesian *tatau*: to mark or strike) are designs made in the skin by multiple small puncture wounds with needles dipped in coloring matter which is attached to an oscillating unit.

Dyes used: Indigo, cobalt, carbon, vermilion, cadmium, selenium, Prussian blue and India ink.

- ❖ Color, design, size and situation should be noted.
- ❖ The permanency of tattoo marks depends upon the type of dye used, the depth of its penetration and the part of body tattooed. Permanent tattoos are obtained if:
 - i. Black, blue and red dyes are employed.
 - ii. The dye penetrates the dermis.
 - iii. The part of body is protected by clothing.
- ❖ A latent (faded) tattoo mark becomes visible by rubbing that part and examining with magnifying lens. The use of high contrast photography, computer image enhancement, UV lamp or infra-red photography is also helpful for identifying faded tattoos.
- ❖ Tattoos are recognized even in decomposed bodies and bodies recovered from water when the epidermis is removed (**Fig. 5.25**).
- ❖ Since some pigment migrates from the tattoo site to the body's lymph nodes, pigmentations of the axillary lymph nodes in upper extremities tattoos could be identified with the naked eye during autopsy.

Complications: Septic inflammation, abscess, gangrene, syphilis, hepatitis B, AIDS, leprosy and tuberculosis.



Fig. 5.25: Tattoos seen when epidermis is removed

Classification of Tattoos

The American Academy of Dermatology distinguishes five types of tattoos:

- i. **Traumatic tattoos** ('*natural tattoos*') resulting from injuries (road traffic injuries) or close range firearm (unburnt gunpowder) or pencil lead; these are *unintentional* and *unwanted* tattoos.
- ii. **Amateur tattoos** are applied by anyone at home, using a needle and a single color carbon based ink, e.g., India ink applied at varying depths.
- iii. **Professional tattoos** (using both traditional methods and modern tattoo machines) are created by a trained tattoo artist at a salon or tattoo parlor which contains several colors and applied uniformly beneath the skin.
- iv. **Cosmetic tattoos** (also known as '*permanent makeup*') camouflage skin discolorations, such as birthmarks (hemangiomas) or scars, tattooing 'hair follicles' into bald areas or corneal tattooing (using India Ink) carbon particles, or metallic salts (e.g., gold or platinum chloride) in perforating injury.
- v. **Medical tattoos** are used for indicating a medically relevant condition or body location, e.g., medical alert tattoos (like insulin-dependent diabetes mellitus or drug allergy), blood group tattoo, reconstructive surgery (nipple-areola complex in mastectomy), delineating the radiation field, and endoscopic tattoos for directing endoscopic procedures.

Erasure of Tattoo

Recent Methods

- i. **Picosecond lasers** are the most advanced method, providing faster tattoo clearance with fewer sessions and minimal skin damage.
- ii. **Q-switched Nd: YAG lasers** are widely used and effective, especially for black and dark-colored inks.
- iii. **Combination or fractional laser techniques** are used for resistant tattoos, while **surgical excision** is limited to small tattoos.

Older/Obsolete Methods

- ❖ **Dermabrasion:** Mechanical removal of the skin to eliminate tattoos, causing scarring and infection.
 - ❖ **Production of burns by red-hot iron:** Removal of pigment by cauterization, causing severe burns and permanent scarring.
 - ❖ **Scarification:** Deliberate cutting of tattooed skin to remove pigment, often resulting in disfiguring scars.
 - ❖ **Carbon dioxide snow:** Freezing of skin to destroy pigment, associated with tissue damage and scarring.
 - ❖ **Electrolysis:** Electrical destruction of tattooed skin, causing pain and poor cosmetic outcomes.
 - ❖ **Caustic or corrosive substances:** Chemical burns produce inflammation and superficial scarring to remove pigment, e.g., papain in glycerin.
- Chronic eczema may also cause the tattoo designs to disappear.

Medico-legal Importance

It helps in knowing the:

- i. **Identity** of a person, particularly the dead or decomposed individual—his name or spouse's or friend's; date of birth or joining of service.

- ii. **Religion and nationality:** Designs of Cross or Christ (in Christians), and Hanuman or Lord Krishna (in Hindus).
- iii. **Political affiliations**, e.g., hammer and sickle, lotus or right hand.
- iv. **Ancestry:** Tattooing on the chest and limbs is common amongst the Japanese.
- v. **Profession/occupation:** Some gangs have certain specific emblems of tattoo marks. Some occupations, e.g., coal miners leave visible tattoo marks on the hands and face.
- vi. **Behavioral characteristics:** Tattoos have been associated with high-risk behaviors including alcohol and drug use, violence, carrying weapons, sexual activity, eating disorders and suicide.
 - Erotic tattoos of the sexual fanatic, blue bird design on the extensor surface of the web of thumb of homosexuals, number 13 inside the lower lip of drug pushers, addict type of tattoo marks to conceal injection sites.
- vii. It may also represent **social status** of that individual.

HIGH YIELD POINTS

- ◆ Sex, age, ancestry and stature are primary characteristics of identification.
- ◆ **Determination of race of individual:** Cephalic index.
- ◆ Indian skull is European (Caucasian) with few African characters, CI—75–79.9 (mesaticephalic skull).
- ◆ **Disorder of sexual development:** External genitalia atypical in relation to chromosome and gonads.
- ◆ **Most certain evidence of sex:** Possession of ovaries in females and testes in males.
- ◆ **Confirmatory method of sex determination:** Gonadal biopsy (identification of sex chromosomes).
- ◆ In females, Barr body (sex chromatin) is the inactive, condensed X-chromosome found in the cells.
- ◆ In XO (Turner's syndrome) there will be no Barr body, and in XXX there will be two Barr bodies.
- ◆ XX or XY can be determined in the cells that are dividing, e.g., bloodstains, cartilage, bone marrow, tooth pulp and hair root.
- ◆ *Davidson body* can be seen in the neutrophils of females.
- ◆ Quinacrine dihydrochloride is used to stain Y-chromosome (referred to as f-body).
- ◆ Fluorescent Feulgen reaction using Acriflavin Schiff reagent is used for staining X-chromosome.
- ◆ *Streak gonads* are seen in gonadal dysgenesis.
- ◆ **Most common DSD associated with male hypogonadism:** Klinefelter syndrome (47XXY).
- ◆ **Most common DSD associated with female hypogonadism:** Turner syndrome (45XO).
- ◆ **Complete androgen insensitivity syndrome (testicular feminization syndrome):** X-linked recessive condition; failure of normal masculinization in genetically male (46XY DSY) individual. Negative Barr body testing.
- ◆ **Most common cause of congenital adrenal hyperplasia:** 21-hydroxylase deficiency.
- ◆ **Accuracy of sexing based on skeletal remains:** Entire skeleton: 100%; Skull + Pelvis –98%; Pelvis alone (*best single bone*): 95%.
- ◆ **Important features to differentiate sex in skull:** Supraorbital margin and ridge, nasion and nuchal crest.
- ◆ **Important features to differentiate sex in pelvis:** Pre-auricular sulcus, sub-pubic angle and greater sciatic notch.
- ◆ Pre-auricular sulcus is prominent in females.
- ◆ Males have more corporobasal index and chilitic line index.
- ◆ Females have more sternal index, ischiopubic index, alar index and sciatic notch index.
- ◆ **Ashley's rule (149 rule):** Determination of sex from sternum for Europeans.
- ◆ **First temporary tooth to appear:** Lower central incisor (6–8 months).
- ◆ **First permanent tooth to appear:** First molar (6–7 years).
- ◆ **Last temporary tooth to fall:** Canine.
- ◆ Eruption of temporary teeth is completed by 2½ years.
- ◆ Mixed dentition is seen in: 6–11 years of age.
- ◆ Total number of teeth between 6 and 12 years: 24.
- ◆ Number of permanent teeth present at 8 years: 12.
- ◆ Permanent molars are super-added permanent teeth.
- ◆ Permanent premolars are successional permanent teeth.

- ◆ *Stack method* of dental age estimation is used for infants.
- ◆ **Gustafson's method:** Age estimation (beyond 25 years) based on microscopic examination of wear and tear of tooth in dead body/skeletal remains.
- ◆ **Most reliable criteria of Gustafson's method:** Root transparency.
- ◆ **Most reliable non-destructive method of estimation of age from tooth:** Mineralization of teeth to assess stages of development using radiographs.
- ◆ **Most reliable destructive method:** Amino acid racemization.
- ◆ 'Shovel-shaped' upper central incisors, taurodontism, enamel pearls and congenital lack of upper 3rd molars seen in Mongoloids.
- ◆ 'Carabelli's cusp' is seen in Europeans (Caucasian).
- ◆ Clavicle—first bone to ossify during the 5–6th postovulatory week (start of 2nd month of pregnancy).
- ◆ The first bone to ossify in the wrist is capitate (1 year).
- ◆ Between 2–6 years, the number of carpal bones present on X-ray represents the age in years, e.g., three carpal bones—3 years.
- ◆ Pisiform gets ossified by 9–12 years of age.
- ◆ Commonest modality to determine bone age of a child: X-ray of hand and wrist.
- ◆ **Last long bone to ossify in the skeleton** (helps in age estimation): Medial clavicular epiphysis (22–25 years).
- ◆ **Best bone to determine age-at-death from third to fifth decade:** Symphyseal surface of pubis.
- ◆ **Most successful age estimation from skull suture closure:** Sagittal suture.
- ◆ **Last fontanelle to close:** Anterior fontanelle (1½–2 years).
- ◆ **Last skull suture to close:** Temporoparietal suture.
- ◆ **Best method to estimate age based on secondary sexual characters:** Tanner staging.
- ◆ **First pubertal change:** Breast development (in females) and testicular enlargement (in males).
- ◆ Child <7 years is not held criminally responsible (**Sec. 20 BNS**).
- ◆ Child below 12 years is not required to take oath.
- ◆ Child <14 years cannot be employed for any type of work (not even domestic help).
- ◆ Person attains majority at 18 years (21 years if under guardianship of Court of Wards).
- ◆ Juvenile offender is a person who has committed a crime and is <18 years of age.
- ◆ Female <18 years and male <21 years cannot marry.
- ◆ A person can cast vote at 18 years.
- ◆ **Consent:** Can give valid consent for general physical and medico-legal examination at ≥12 years; any major diagnostic or operative procedure, donating organs and consent for sexual intercourse is ≥18 years.
- ◆ **Kidnapping:** Taking away a child (boy or girl <18 years) by illegal means.
- ◆ Child of any age can give evidence, if the court is satisfied that the child is truthful.
- ◆ **Most common method to determine the stature from long bones:** Karl Pearson's regression formula.
- ◆ *Hepburn's osteometric board* is used to measure the length of long bones.
- ◆ For estimation of stature, femur is more reliable among the long bones.
- ◆ **Multiplication factors to calculate stature:** Femur: 3.8–3.9 (*most accurate*).
- ◆ Corneal tattooing can be done with gold or platinum chloride.
- ◆ Tattoos can be identified from pigmentations of regional lymph nodes.

Interesting Case Study

Tattoo Mark in Identification (The Shark Arm Case, 1935)

In 1935, a shark on display in an aquarium in Sydney, Australia vomited up a human arm. The arm was well preserved and it had a tattoo of two boxers. It had a rope tied around its wrist. A medical examination showed it had not been bitten off—there were no tooth marks and the limb had been cleanly removed at the shoulder with a blade. The police started a homicide investigation.

A man recognized the description of the tattoo in the news paper and told police the arm might belong to his brother James Smith. He had gone missing weeks before. The police were able to obtain fingerprints from the hand and matched with Smith.

Police found out that Smith had last been seen drinking with person called Patrick Brady. Then, they went to a cottage hired by Brady. The owner of the cottage said that a mattress and a tin trunk had gone missing. The police also found evidence that Smith had worked for a man named Reginald Holmes. He was a wealthy boat builder but was also involved in drug smuggling. He admitted Smith had worked for him. However the two men had fallen out and, the police believed, Smith had been blackmailing Holmes. He was killed to silence him. The police arrested Patrick Brady and Reginald Holmes. Holmes told police that Brady had killed Smith and brought the severed arm to his house, and tried to blackmail him with it, threatening to kill him too if he did not pay him money.



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