

Chapter 7. Skeletal System

Part 1. Bone Structure & Classification

1 Learning Objectives

By the end of this section, you should be able to ...

- 1. **Classify bones** into long, short, flat and irregular categories, giving at least three examples and typical functional features of each.
- 2. Describe the microscopic and macroscopic architecture of compact (cortical) and spongy (cancellous) bone.
- 3. **Explain how structure relates to function**—e.g., why trabeculae in spongy bone align with lines of stress.
- 4. **Relate bone structure to common clinical scenarios** encountered in physiotherapy (fracture mechanics, osteoporosis, internal fixation principles).

2 Types of Bones (Gross Classification)

| Category | Defining Features | Classical Examples | Functional Highlights | PT Significance |
|--------------------|-------------------------------------------------------------------------------|---------------------------------------------|-------------------------------------------------------|-----------------------------------------------------------------|
| Long Bones | Length ≫ width; shaft (diaphysis) with two expanded ends (epiphyses) | Humerus, femur, tibia, phalanges | Levers for movement; marrow cavity for haematopoiesis | Gait analysis, lever-arm considerations in exercise loading |
| Short Bones | Length ≈ width; cube- shaped | Carpals, tarsals | Shock absorption, complex gliding motions | Mobilisation of inter-carpal stiffness; proprioceptive training |
| Flat Bones | Thin, flattened, often curved | Cranial bones, sternum, ribs, scapula | Protection, broad surface for muscle attachment | Postural taping over scapula, rib mobilisation for ventilation |
| Irregular Bones | Complex shapes, don't fit other groups | Vertebrae, sacrum, maxilla, calcaneus | Mixed functions—weight-bearing, neural protection | Spinal manipulation techniques, calcaneal alignment in gait |
| | | | | |

Accessory & Sesamoid Bones: Patella (largest sesamoid) reduces tendon friction and modifies leverage—clinically relevant for eccentric loading protocols.

3 Bone Structure

3.1 Gross Anatomy

- Diaphysis: Thick compact bone forming a rigid tube; encloses medullary cavity (yellow marrow).
- Metaphysis: Flared zone with active growth plate (physis) in children—site of many paediatric fractures.
- Epiphysis: Spongy core covered by a thin compact shell; articular cartilage caps joint surfaces.
- Periosteum: Dense fibrous membrane; Sharpey's fibres anchor tendons—important in traction injuries.
- **Endosteum:** Delicate internal lining; houses osteogenic cells for remodelling.

3.2 Compact (Cortical) Bone

- Osteon (Haversian system) = concentric lamellae surrounding a central canal carrying vessels & nerves.
- **Lamellae orientation** alternates → resists torsion (like plywood).
- Volkmann's canals connect adjacent osteons and medullary cavity.
- Lacunae with osteocytes maintain matrix; canaliculi permit nutrient diffusion—explains slow healing when

[©] Ayurvite Wellness Pvt Ltd. All rights reserved. This PDF is for personal use only Unauthorized reproduction, distribution, or commercial use is strictly prohibited.

AYURVED BHARATI®

compromised.

3.3 Spongy (Cancellous or Trabecular) Bone

- Trabeculae: Needle-like struts aligned along stress lines (Wolff's law).
- Marrow spaces: Red marrow in adults (pelvis, vertebrae, ribs); key for erythropoiesis.
- · No true osteons; nutrients diffuse via canaliculi from endosteal vessels—faster turnover, high metabolic activity.

| Feature | Compact Bone | Spongy Bone | |
|---------------|-----------------------------------------|------------------------------------------|--|
| Density | 1.8-2.0 g/cm ³ | 0.4-0.8 g/cm ³ | |
| Organisation | Osteons, tightly packed | Trabecular network | |
| Location | Diaphyses, outer cortex of all bones | Epiphyses, vertebral bodies, pelvis | |
| Function | Strength for weight-bearing, protection | Shock absorption, metabolic (marrow) | |
| Clinical Note | Stress fractures in runners (tibia) | Osteoporotic crush fractures (vertebrae) | |
| | | | |

4 Structure-Function-Clinical Correlation

| Scenario | Structural Basis | Physiotherapy Considerations |
|----------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------|
| Green-stick fracture in children | Diaphyseal compact bone thin; high periosteal elasticity | Gentle mobilisation post-cast; avoid physeal stress |
| Osteoporosis | Trabecular thinning, cortical porosity ↑ | Progressive resistance & weight-bearing to stimulate osteoblasts |
| Intramedullary nailing | Uses medullary canal of long bone; preserves periosteal blood supply | Early weight-bearing protocols due to load- sharing design |
| Stress shielding after plating | Rigid plate bypasses natural load; bone weakens (Wolff's law reversed) | Graduated loading & plate removal timing education |

5 Microscopic Players in Bone Health

- Osteogenic cells → progenitors in periosteum/endosteum.
- **Osteoblasts** → lay down osteoid; stimulated by mechanical loading, IGF-1.
- **Osteocytes** → mechanosensors inside lacunae; orchestrate remodel.
- Osteoclasts → resorb bone under PTH influence; excessive activity ⇒ osteoporosis.

PT Pearl: Mechanical strain sensed by osteocytes triggers osteoblast activity—hence progressive loading is the non-pharmacological cornerstone of bone health.

6 Self-Check Quiz (answers immediately below)

1. Which bone category does the scapula belong to, and why?

Answer: Flat bone—it is thin, possesses two parallel compact layers with a spongy core, and provides a broad surface for muscle attachment.

2. Name two structural differences between compact and spongy bone and link each to a functional outcome.

Answer:

- a) Organisation—compact has osteons \rightarrow high compressive strength; spongy has trabeculae \rightarrow dissipates loads.
- b) Density—compact is dense → protects marrow; spongy is lighter → reduces skeletal weight for efficient movement.
- 3. Explain Wolff's law in one sentence.

Answer: Bone remodels its architecture in response to the magnitude and direction of mechanical stresses placed

[@] Ayurvite Wellness Pvt Ltd. All rights reserved. This PDF is for personal use only. Unauthorized reproduction, distribution, or commercial use is strictly prohibited.

upon it.

4. Why do vertebral bodies fracture more often than long-bone diaphyses in osteoporosis?

Answer: Vertebrae consist largely of metabolically active spongy bone, which undergoes accelerated trabecular thinning in osteoporosis, whereas long-bone cortices are thicker and denser.

5. State one reason periosteum is clinically important in fracture healing.

Answer: The periosteum houses osteogenic cells and blood vessels that generate external callus, accelerating union.

7 Suggested Lab Activities

Activity **Purpose**

Cross-section Microscopy Identify osteons vs. trabeculae on prepared slides.

Bone Density Simulation Use foam models to demonstrate stress distribution; relate to osteoporotic collapse.

Surface-mark diaphysis, metaphysis, epiphysis on a peer's tibia; discuss common injury **Palpation Mapping**

8 Key Take-Home Points

- Bone type and internal architecture are tailored to mechanical demands; rehabilitation must respect these
- Compact bone confers strength; spongy bone confers resilience and metabolic function.
- Physiotherapists use this knowledge to choose loading parameters, protect growth plates, and educate on fracture prevention.

Part 2. Axial Skeleton - Skull & Vertebral Column

1 Learning Objectives

After finishing this part you should be able to ...

- 1. Identify the 22 skull bones (8 cranial, 14 facial) and palpate at least eight clinically significant surface landmarks.
- 2. Describe characteristic features of each vertebral region—cervical, thoracic, lumbar, sacral, coccygeal—and recognise atypical vertebrae (C1, C2, C7, T12, L5).
- 3. Explain biomechanical functions of the axial skeleton in posture, load transmission and protection of neural tissue.
- 4. Apply anatomical knowledge to common physiotherapy scenarios such as cervical mobilisation, postural reeducation and core-stability training.

2 Skull: Bones & Landmarks

2.1 Cranial vs. Facial Bones

Cranial Bones (8) Facial Bones (14)

Frontal (1) Nasal (2) Parietal (2) Maxilla (2) Temporal (2) Zygomatic (2) Occipital (1) Mandible (1) Sphenoid (1) Lacrimal (2)

[@] Ayurvite Wellness Pvt Ltd. All rights reserved. This PDF is for personal use only Unauthorized reproduction, distribution, or commercial use is strictly prohibited.

AYURVED BHARATI®

Facial Bones (14) Cranial Bones (8)

Ethmoid (1) Palatine (2)

Inferior nasal concha (2)

Vomer (1)

2.2 Key Surface Landmarks (Palpable / Radiological)

| Landmark | Location & Description | Clinical / PT Relevance |
|-----------------------------------------|------------------------------------------------------------------|----------------------------------------------------------------------|
| Glabella | Smooth area between eyebrows on frontal bone | Goniometric alignment in cervical flexion ROM |
| Supra-orbital notch/foramen | Superior orbital rim | Sensory nerve block site for headache therapy |
| Mastoid process | Posteroinferior to external auditory meatus on temporal bone | Attachment for sternocleidomastoid – stretch & trigger-point release |
| Zygomatic arch | Bridge from temporal to zygomatic bones | TMJ biomechanics; caution in K-taping |
| External occipital protuberance (inion) | Midline bump on occipital bone | Posture plumb-line reference |
| Temporomandibular joint (TMJ) | Condylar process of mandible + mandibular fossa of temporal bone | Mobilisation techniques for trismus |
| Pterion | Junction of frontal, parietal, temporal, sphenoid bones | Thin "weak point" - helmet fit education |
| Mental foramen | Lateral to mandibular midline | Sensory testing of mental nerve in neuropathy |

PT Pearl: When treating cervico-genic headache, palpate the sub-occipital region around the inion to locate myofascial trigger points in rectus capitis posterior muscles.

3 Vertebral Column Overview

| Region | # Typical Vertebrae | Distinctive Features | Typical ROM Contribution | Clinical Highlights |
|----------------------------|------------------------|-----------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------------------------------------------------------|
| Cervical (C1-C7) | 7 | Small bodies, bifid spinous (C2-C6), transverse foramen; C1 (Atlas) no body, C2 (Axis) dens | Greatest flex-ext & rotation (occiput-C1 nodding; C1-C2 50 % rotation) | Whiplash injuries, vertebral-artery safety in manipulations |
| Thoracic (T1-T12) | 12 | Costal facets for ribs; long downward spinous; heart-shaped body | Rotation > flex-ext; rib cage limits mobility | Postural kyphosis, rib mobilisation for ventilation |
| Lumbar (L1-L5) | 5 | Massive kidney-shaped bodies; mamillary processes; sagittally oriented facets | Flex-ext dominant; limited rotation | Disc herniation at L4/5, L5/S1; core stabilisation focus |
| Sacrum (S1-S5 fused) | 5 fused | Triangular bone, promontory, ala, sacral canal/hiatus | Transmits weight to pelvis; minimal motion (SIJ nutation/counternutation) | Pregnancy-related SIJ pain, pelvic floor synergy |
| Coccyx (Co1-Co4) | 3–5 fused | Rudimentary tailbone; anterior curvature | Muscle attachment (levator ani, gluteus maximus) | Coccygodynia management (cushions, posture) |

Normal Spinal Curves

• **Primary (kyphotic):** Thoracic, sacral – present at birth.

[@] Ayurvite Wellness Pvt Ltd. All rights reserved. This PDF is for personal use only Unauthorized reproduction, distribution, or commercial use is strictly prohibited.



• **Secondary (lordotic):** Cervical (develops with head control), lumbar (with standing). Curve integrity underpins shock absorption; exaggerated curves alter load distribution and are a central target in postural retraining.

4 Atypical & Special Vertebrae (Quick Notes)

| Vertebra | Unique Trait | PT Significance |
|-------------------------|-------------------------------------------------------------|------------------------------------------------------------------------------|
| C1 (Atlas) | No body/spinous; posterior arch groove for vertebral artery | Avoid extreme rotation-extension during mobilisation |
| C2 (Axis) | Dens acts as pivot | Transverse ligament stability essential; screen before high-velocity thrusts |
| C7 (Vertebra prominens) | Long non-bifid spinous easily palpable | Baseline for measuring thoracic kyphosis angle |
| T12 | Transitional: costal facets + lumbar-like inferior facets | Zone of increased stress – common in compression fractures |
| L5 | Wedge-shaped; facets coronally oriented | Predisposed to spondylolisthesis; modify extension exercises |

5 Structure-Function-Clinical Correlation

| Feature | Structural Basis | Functional Outcome | PT Application |
|-----------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Trabecular orientation in vertebral bodies | Vertical struts + horizontal cross-bars | Resists compressive loads | Vertebral fractures indicate compromised trabeculae - prescribe axial loading within tolerance |
| Intervertebral disc (nucleus pulposus + annulus fibrosus) | Fibrocartilaginous cushion | Allows movement while distributing pressure | McKenzie extension for posterolateral disc prolapse |
| Facet joint orientation | Cervical ≈ 45° to horizontal; thoracic ≈ 60°; lumbar ≈ 90° | Dictates regional ROM bias | Mobilisation direction follows facet plane (e.g., PA glide on thoracic spinous for rotation) |
| Ligamentum nuchae & supraspinous ligament | Elastic midline ligaments | Passive head support | Stretch assessment in forward- head posture |

6 Self-Check Quiz (Answers follow immediately)

1. Name the four bones that meet at the pterion.

Answer: Frontal, parietal, temporal, sphenoid bones.

2. Which cervical vertebra lacks a body and what clinical movement primarily occurs at its joint with the

Answer: C1 (Atlas); the atlanto-occipital joint enables nodding (flexion-extension).

3. List two bony landmarks used to assess thoracic kyphosis angle with an inclinometer.

Answer: Spinous process of **C7** and spinous process of **T12**.

4. Why are lumbar vertebrae more prone to disc herniation than thoracic vertebrae?

Answer: Larger compressive loads, greater flevion-extension range, and absence of rib-cage st

Answer: Larger compressive loads, greater flexion-extension range, and absence of rib-cage stabilisation increase annulus stress.

5. State one feature that distinguishes typical thoracic vertebrae from cervical vertebrae.

Answer: Presence of **costal facets** on the thoracic vertebral bodies and transverse processes for rib articulation (absent in cervical vertebrae).

[©] Ayurvite Wellness Pvt Ltd. All rights reserved. This PDF is for personal use only Unauthorized reproduction, distribution, or commercial use is strictly prohibited.







7 Suggested Lab / Practical Activities

Activity Learning Focus

Skull Bone Jigsaw Assemble disarticulated skull; identify and label landmarks.

Spinous Palette PalpationPalpate and mark C7, T3, T7, T12, L4 on a peer; correlate with surface anatomy. **Facet-Plane Modelling**Use cardboard models to mimic facet orientations; demonstrate permitted motions.

Curve Analysis with Plumb Line Assess sagittal curves; design corrective exercise set.

8 Key Take-Home Points

- The skull protects neural tissue and provides leverage for mastication, speech, and cervical movement.
- The **vertebral column is regionally specialised**—cervical mobility, thoracic stability with respiration coupling, lumbar load bearing.
- Knowledge of landmarks and curves guides safe manual therapy, ergonomic instruction, and exercise design.
- Atypical vertebrae and junctional zones (C0-C2, C7-T1, T12-L1, L5-S1) are biomechanical hotspots for dysfunction—screen carefully.

Part 3. Appendicular Skeleton

1 Learning Objectives

By the end of this part you will be able to ...

- 1. **List every bone** in the appendicular skeleton and classify them by region.
- 2. **Locate and palpate major landmarks** of the clavicle, scapula, humerus, radius, ulna, hand bones, pelvis, femur, tibia, fibula and foot bones.
- 3. Explain how bony architecture supports function & movement at the shoulder, elbow, wrist/hand, hip, knee and ankle/foot.
- 4. **Relate anatomical knowledge to physiotherapy practice** (fracture rehabilitation, joint mobilisation, post-surgical precautions, exercise prescription).

2 Shoulder Girdle (Pectoral Girdle)

Bone Key Landmarks Functional / Clinical Notes

Clavicle Sternal & acromial ends, shaft with conoid tubercle

First bone to ossify; S-shaped for shock absorption; mid-shaft # common – figure-8 brace

Spine, acromion, coracoid, supraspinous & Scapula infraspinous fossae, glenoid cavity, inferior angle, medial & lateral borders

Glenoid orientation allows 180 ° overhead reach; serratus anterior attaches to medial border – winging test

PT Pearl — Scapulohumeral rhythm ($\approx 2:1$ GH: scapulo-thoracic) depends on free motion at the acromioclavicular & sternoclavicular joints; taping or mobilisation often targets these.

3 Bones of the Upper Limb

| Region | Bone | Landmark Highlights | Physiotherapy Significance |
|--------|---------|------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Arm | Humerus | Head, anatomical & surgical necks, greater/lesser tubercles, deltoid tuberosity, radial (spiral) groove, medial & lateral epicondyles | Radial-nerve palsy in spiral-groove #; shoulder ER strength test uses greater tubercle palpation |

[©] Ayurvite Wellness Pvt Ltd. All rights reserved. This PDF is for personal use only. Unauthorized reproduction, distribution, or commercial use is strictly prohibited.



| Region | Bone | Landmark Highlights | Physiotherapy Significance |
|----------|-----------------|-------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| Fore-arm | Radius | Head, neck, radial tuberosity, styloid process, Lister's tubercle | Distal radius # ("Colles") influences wrist biomechanics; radial-head mobilisation restores pronation-supination |
| | Ulna | Olecranon, trochlear & radial notches, coronoid process, styloid process | Olecranon bursitis management; screw-home mechanism at elbow via trochlear notch |
| Hand | Carpals (8) | Proximal row: Scaphoid, Lunate, Triquetrum, Pisiform. Distal row: Trapezium, Trapezoid, Capitate, Hamate | Scaphoid # risk of AVN; carpal-tunnel roof = flexor retinaculum over scaphoid-pisiform & trapezium-hook-of-hamate |
| | Metacarpals (5) | Base, shaft, head | Boxers' $\#=5^{\text{th}}$ MC neck; weight-bearing on bars needs MCP extension stability |
| | Phalanges (14) | Proximal, middle (none in thumb), distal | Grip-strength retraining; mallet finger injuries at distal- phalanx extensor insertion |

Mnemonic for carpals (lateral → medial, proximal then distal): "She Looks Too Pretty; Try To Catch Her."

4 Pelvic Girdle

| Component | Landmarks | Notes for PT |
|-------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Hip (Innominate) Bone = Ilium + Ischium + Pubis | ASIS, AIIS, PSIS, PIIS, iliac crest, ischial tuberosity, pubic symphysis, acetabulum, obturator foramen | ASIS used for pelvic tilt cueing; ischial tuberosity = hamstring origin & sitting pressure point |
| Sacrum (see axial part) integrates with ilia at SIJs | Promontory, ala, sacral canal, sacral hiatus | Nutation/counternutation affect pelvic floor & lumbar load |

Functional Ring — Pelvis transmits weight from spine \rightarrow lower limbs; weakness in gluteal sling often manifests as Trendelenburg gait.

5 Bones of the Lower Limb

| Region | Bone | Landmark Highlights | Physiotherapy Angle |
|--------|-----------------|----------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| Thigh | Femur | Head with fovea, neck, greater & lesser trochanters, intertrochanteric line, linea aspera, medial/lateral condyles & epicondyles | Neck-shaft angle \approx 125 ° (coxa vara/valga); GT palpation for bursitis; distal fractures risk genu valgum deformity |
| Knee | Patella | Base, apex, medial & lateral articular facets | Patellofemoral alignment taping; eccentric loading for tendinopathy |
| Leg | Tibia | Medial & lateral condyles (plateau), tibial tuberosity, anterior crest, medial malleolus | Osgood-Schlatter at tuberosity; weight-bearing axis; ankle joint mortise stability |
| | Fibula | Head, shaft, lateral malleolus | Common-peroneal nerve at neck (care with taping); lateral-collateral support of ankle |
| Foot | Tarsals (7) | Talus, Calcaneus, Navicular, Cuboid, Medial / Intermediate / Lateral Cuneiforms | Talus = keystone of ankle dorsiflexion; calcaneal tuberosity = Achilles insertion |
| | Metatarsals (5) | Base (MT V styloid), shaft, head | March # (2 nd MT); fore-foot loading in gait analysis |
| | Phalanges (14) | Proximal, middle, distal (hallux lacks middle) | Hammer toe deformity rehab; proprioception drills |

Arch Mechanics: Medial longitudinal arch (calcaneus \rightarrow MT I) maintained by plantar fascia—relevant in plantar-fasciitis stretching protocols.

[©] Ayurvite Wellness Pvt Ltd. All rights reserved. This PDF is for personal use only. Unauthorized reproduction, distribution, or commercial use is strictly prohibited.



6 Structure-Function-Clinical Correlation (Selected Examples)

| Bone / Complex | Structural Feature | Functional Pay-off | PT Implication |
|-----------------------|-----------------------------------------------|-----------------------------------------|----------------------------------------------------|
| Scapula + Clavicle | Only bony link to axial skeleton is SC-joint | Wide ROM for upper-limb positioning | Scapular-setting exercises vital post- fracture |
| Humerus | Spiral groove for radial nerve | Allows nerve to travel in safe corridor | Check wrist-drop after humeral # |
| Femoral Neck | Trabecular "calcar" supports compressive load | Efficient load transfer during gait | Post-THR precautions to avoid femoral-neck stress |
| Tibia Plateau | Menisci deepen shallow articular surface | Shock absorption & stability | Post-meniscectomy proprioceptive retraining |
| Calcaneus | Longest moment arm for Achilles tendon | Propels gait push-off | Heel-raise strength ratio assessment |

7 Self-Check Quiz (with Answers)

1. Which carpal bones form the floor of the carpal tunnel?

Answer: Scaphoid and trapezium (radial side) plus hamate and pisiform (ulnar side) create the concavity; the flexor retinaculum roofs it.

- 2. Name two bony landmarks used when measuring true leg length.
 - Answer: Anterior-superior iliac spine (ASIS) and medial malleolus.
- 3. Why is the neck of the femur vulnerable to avascular necrosis?

Answer: Retinacular branches of the medial circumflex femoral artery run along the neck; intracapsular fractures disrupt these vessels, compromising blood supply to the head.

- 4. Which fore-arm bone primarily rotates around the other during pronation-supination?
 - **Answer:** The radius rotates around the fixed ulna.
- State one reason that clavicle fractures are almost always mid-shaft.

Answer: The mid-shaft is the thinnest, least reinforced segment and is subjected to bending forces from muscle pulls and falls onto the outstretched hand.

8 Suggested Practical / Lab Activities

| Activity | Goal |
|------------------------------|----------------------------------------------------------------------------------------------|
| Landmark Palpation Relay | Students locate & mark 20 appendicular landmarks in < 5 min. |
| Bone Box Mystery | Identify isolated bones by feel, then match to radiograph. |
| | Compare intramedullary nail vs. plate biomechanics on femur models; discuss rehab timelines. |
| Arch-Support Analysis | Use pressure mat to relate tarsal alignment to plantar pressure patterns. |

9 Key Take-Home Points

- The appendicular skeleton enables mobility while the axial skeleton provides stability; optimal movement requires harmony of both.
- Landmarks guide assessment, mobilisation and exercise cueing; memorise and palpate them regularly.
- Common injury sites correspond to anatomical weak points (mid-clavicle, scaphoid waist, femoral neck, tibial tuberosity).
- Physiotherapists integrate bone knowledge with muscle, ligament and nerve anatomy to create safe, effective rehabilitation plans.

[@] Ayurvite Wellness Pvt Ltd. All rights reserved. This PDF is for personal use only. Unauthorized reproduction, distribution, or commercial use is strictly prohibited.