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).

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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.

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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

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/cm³	0.4–0.8 g/cm³
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)

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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

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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.

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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 → high compressive strength; spongy has trabeculae → 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

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.

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

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8 Key Take-Home Points

- Bone type and internal architecture are tailored to mechanical demands; rehabilitation must respect these differences.
- 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

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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 re-education and core-stability training.

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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)

Cranial Bones (8)	Facial Bones (14)
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.

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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.

- **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.

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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

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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

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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 skull?**
   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 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).

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7 Suggested Lab / Practical Activities

Activity	Learning Focus
Skull Bone Jigsaw	Assemble disarticulated skull; identify and label landmarks.
Spinous Palette Palpation	Palpate 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.

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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

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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).

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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
Scapula	Spine, acromion, coracoid, supraspinous & 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 (≈ 2 : 1 GH : scapulo-thoracic) depends on free motion at the acromioclavicular & sternoclavicular joints; taping or mobilisation often targets these.

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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

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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' # = 5th 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."*

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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 → lower limbs; weakness in gluteal sling often manifests as Trendelenburg gait.

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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 ≈ 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 # (2nd 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 → MT I) maintained by plantar fascia—relevant in plantar-fasciitis stretching protocols.

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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.
5. **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.
Fracture Fixation Workshop	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.

PDF generated on 14 Jan 2026, 10:48 am IST