Bones are main organs:
- osseous tissue
- dense regular and irregular CT, plus bone marrow

Skeletal system = __________, ___________, ____________

Functions of the Skeletal System

1. Protection
   - Protection: Skeleton protects vital organs such as the brain.
   - Brain

2. Mineral storage and __________
   - Mineral storage and acid-base homeostasis: Bone stores minerals such as Ca²⁺ and PO₄³⁻, which are necessary for electrolyte and acid-base balance.

3. Blood cell formation: (hematopoeisis or hemopoiesis)
   - Blood cell formation: Red bone marrow is the site of blood cell formation.
   - Forming blood cells in red bone marrow

4. Fat storage: in yellow bone marrow of
   - Fat storage: Yellow bone marrow stores triglycerides.
   - Fat in yellow bone marrow

5. Movement: bones are sites for skeletal muscle attachment
   - Movement: Muscles produce body movement via their attachment to bones.
   - Muscle attached across joint

6. Support: supports weight and provides
   - Support: The skeleton supports the weight of the body.

Bone Structure Classification (based on shape)

1. Long bones
   - longer than they are wide;
   - include most bones in arms and legs

2. Short bones
   - roughly cube-shaped
   - include carpals and

Figure 6.1 Functions of the skeletal system.

Figure 6.2a Classification of bones by shape.
Bone Structure

3. Flat bones
   - thin and broad bones
   - ribs, pelvis, sternum and __________________

4. Irregular bones
   - include _________ and certain skull bones

5. Sesamoid bones
   - located within _________ - patella (kneecap)

Bone Structure

Structure of long bone:
   • Periosteum
     - membrane surrounds outer surface
   • Perforating fibers (Sharpey’s fibers)
     - anchors periosteum firmly to bone surface
   • Diaphysis _________
   • Epiphysis - _________ of long bone (proximal & distal)
   • Articular cartilage – hyaline cartilage
   • Marrow cavity – contains bone marrow (red or yellow)
   • Endosteum – thin membrane lining marrow cavity

Bone Structure

• Compact bone
  - hard, dense outer region
  - allows bone to resist stresses (compression & twisting)

• Spongy bone (__________ bone)
  - found inside cortical bone
  - honeycomb-like framework of bony struts;
  - resist forces from many directions

Bone Structure

• Structure of short, flat, irregular, and sesamoid bones
  - covered by periosteum
  - diploë = two outer layers of thin compact bone with middle layer of spongy bone
  - sinuses = air-filled spaces
Bone Marrow Transplantation (p. 187)

- Diseases of blood
- Needle is inserted into pelvic bone
- Recipient’s marrow is destroyed
- Complications
  - Many recipients can return to a healthy life if transplant “takes”

Microscopic Structure

Extracellular matrix of bone:
- **Inorganic matrix** (65%)
  - consisting of __________ (hydroxyapatite salts of Ca & P)
- **Organic matrix** (35%)
  - osteoid
  - consists of collagen fibers and usual ECM

Bone Cells

**Bone cells:**
- Osteogenic – differentiate into osteoblasts
- Osteoblasts – __________
- Osteocytes – mature bone cells in lacunae
- Osteoclasts
  - bone __________
  - secrete acid and enzymes

Histology of Bone

**Structure of compact bone:**
- Osteon (Haversian system)
  - Lamellae = concentric rings of thin layers of bone
  - Central canal = contains blood vessels & nerves
  - Lacunae = __________ for osteocytes
  - Canaliculi = __________
  - Perforating canals (Volkmann’s canals) perpendicular to central canal

Figure 6.6 Types of bone cells.

Bone Cells

Figure 6.7 Functions of osteoblasts and osteocytes.

Histology of Bone

Figure 6.9 Structure of compact bone.
Histology of Bone

• Structure of spongy bone
  – usually not wt. bearing
  – not organized into osteons
  - trabeculae

Intramembranous Ossification

• Intramembranous ossification
  – forms many __________ (bones of skull and clavicles)
  – formed within a mesenchymal ___________
  – spongy bone ossifies before outer compact bone layers
  – forms primary ossification center
  – __________ = areas of incomplete intramembranous ossification

Endochondral Ossification

• Endochondral ossification (Figure 6.12):
  – Bone development for all bones below head except __________
  – Many bones complete ossification by age 7

Ossification

• Ossification (osteogenesis)
  - Process of bone formation
  - Begins in embryonic period and continues throughout adulthood
  - cartilage template
  - fibrous CT
  - BONE
  - [fetal “skeleton”]
  - [14 weeks]
Endochondral Ossification

- Endochondral ossification
  - Bones begin within hyaline
  - Hyaline cartilage model made of chondrocytes, collagen, and ECM surrounded by CT perichondrium
  - Cartilage breaks down
  - Collar formation (periosteum)
  - Ossification center mid-diaphysis
  - Secondary ossification centers at

Most bones of skeleton formed this way.

Endochondral Ossification

Cartilage remains at epiphyseal plate and articular ends.

Osteoporosis and Healthy Bones (p. 192)

- Most common bone disease in U.S
- Diagnosed by bone density measurement
- Causes – dietary (calcium and/or vitamin D deficiency)

Growth in Length

- Long bones lengthen via longitudinal growth; involves division of (not osteocytes or osteoblasts) in epiphyseal plate
- Bone growth takes place at epiphysis on side closest to diaphysis
Growth in Length

- **Epiphyseal plate**
  1. **Zone of reserve cartilage** – (found closest to epiphysis) contains cells that are not directly involved in bone growth but can be recruited for cell division if need arises.
  2. **Zone of proliferation** - consists of actively dividing chondrocytes by endochondral ossification.
  3. **Zone of hypertrophy and maturation** (next region closer to diaphysis) contains mature chondrocytes.
  4. **Zone of calcification** (second to last region) contains dead chondrocytes, some of which have been calcified. *Calcified cartilage is replaced with bone.*
  5. **Zone of ossification** (last region) consists of calcified chondrocyte and osteoblasts.

- Longitudinal growth continues at epiphyseal plate as long as mitosis continues in zone of proliferation:
  - Mitotic rate slows around ages of 12-15 years old
  - Between ages of 18-21 epiphyseal plate is closed
  - *____________ is a calcified remnant of epiphyseal plate.*

---

**Achondroplasia (p. 199)**

- Most common cause of dwarfism; gene defect
- Defective gene produces an abnormal growth factor receptor
- Bones form and grow abnormally;
- Long-term problems

---

Growth in Width

- **Appositional growth** = ____________
  - Osteoblasts, lay down new bone
  - Appositional growth does not result in immediate formation of osteons; instead, new circumferential lamellae are formed.
  - Bones may continue to increase in width even after epiphyseal plates have closed and bone is no longer lengthening.

---

**Role of Hormones in Bone Growth**

- **________________ (GH)** – secreted by anterior pituitary gland; enhances protein synthesis and cell division in most all tissues, including bone
- _______________ - pronounced effect on bone growth:
  - Increases appositional growth in males
  - Increases *rate of mitosis in epiphyseal plate*; leads to “growth spurts” in teenage years
- **Estrogen** also plays a role in bone growth:
  - *Increases rate of longitudinal growth* and *inhibits* osteoclasts
  - Accelerates closure of epiphyseal plate at much faster rate than testosterone → average height differences between genders

---

*Figure 6.14 Growth at the epiphyseal plate.*
Gigantism and Acromegaly

- Excess GH can produce two conditions, depending on when in life it develops; both generally caused by a _______ that secretes hormone

- **Childhood** – condition is __________

- **Adulthood** – condition is __________

---

Bone Remodeling

- **Bone remodeling** = new bone is formed by bone ________ and old bone is removed by bone ________
  - Maintenance of calcium ion homeostasis
  - Replacement of old brittle bone with newer bone
  - Adaptation to tension and stress

---

Bone Remodeling

- **PTH** (parathyroid hormone from parathyroid gland) stimulates effects that ________ blood Ca\(^{2+}\) levels
  - Increases osteoclast activity
  - Increases absorption of calcium from gut
  - Inhibits calcium loss in urine

- **Calcitonin** (from thyroid gland) causes ________ blood Ca\(^{2+}\) levels
  - Inhibits osteoclasts
  - Increases calcium loss in urine

---

Bone Remodeling

- Factors influencing bone remodeling are summarized:

---

Bone Remodeling

- **Factors influencing bone remodeling are summarized:**

---

Figure 6.15 Structure of the epiphyseal plate.

Figure 6.16 Factors that influence bone remodeling.
Bone Repair

Fractures:
- Simple fractures vs fractures
  - Spiral
  - Compression
  - Comminuted
  - Avulsion
  - Greenstick
  - Epiphyseal plate
Skeletal System = _______ bones plus cartilages
- Axial (80 bones)
- Appendicular (126 bones)

Structure of the Skeletal System and Skeletal Cartilages

- Axial skeleton
  – Skull, vertebral column, thoracic cage (ribs, sternum),

- Appendicular skeleton
  – Bones of pectoral girdle, upper limb, pelvic girdle, and lower limb

  Pectoral girdle — _______________; anchors upper limb to trunk

  Pelvic girdle — _______________ bones; anchors lower limb to trunk

Bone Markings

<table>
<thead>
<tr>
<th>Bone Marking</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canal (meatus)</td>
<td>Openings in bony structures</td>
<td>Nasal, temporal, sphenoid</td>
</tr>
<tr>
<td>Condyle</td>
<td>One of two articulations</td>
<td>Femoral head, humeral head</td>
</tr>
<tr>
<td>Head</td>
<td>The apex of an anatomical landmark</td>
<td>Acromion process, greater tuberosity</td>
</tr>
</tbody>
</table>

Table 7.1 Bone Markings
Overview of Skull Structure

- Skull = 22 bones organized in two groups:
  - Cranial bones – collectively known as cranium, composed of _____ bones
    (STEP OFF my skull)
    - Frontal -1
    - Occipital -1
    - Ethmoid -1
    - Sphenoid – 1
    - Parietal – 2
    - Temporal - 2

Overview of Skull Structure

- Facial bones = ____ bones
  - Maxillary – 2
  - Zygomatic -2
  - Nasal -2
  - Lacrimal -2
  - Palatine -2
  - Inferior nasal concha -2
  - Mandible -1
  - Vomer -1

Overview of Skull Structure

- Sinuses = ________, membrane-lined spaces; paranasal sinuses = frontal, ethmoid, sphenoid, maxillary

Cavities of the Skull

- Orbit – FLEZMS 7 fused bones; form walls that encase eyeball, lacrimal gland, and their associated blood vessels, muscles, and nerves (Figure 7.11)
  - Frontal bone
  - Lacrimal
  - Ethmoid
  - Zygomatic
  - Maxilla
  - Sphenoid bone
  - and _______ bones
The Fetal Skull

Fontanel (soft spot) = area of incomplete

Hyoid Bone

• Hyoid
  – doesn’t articulate with any other bones
  – C-shaped bone
  – Provides numerous muscle attachment points involved in

Forensic Skull Anatomy

Overview of the Vertebral Column

Vertebral column (spine) – composed of about bones (vertebrae)
  • 7 cervical – located in _______
  • 12 thoracic – articulate with _______
  • 5 lumbar – in _______
  • 5 fused sacral (collectively called sacrum)
  • 3–5 fused coccygeal (collectively called coccyx)
Overview of the Vertebral Column

- **Spinal curvatures** – C-shaped vertebral column of newborn → S-shaped secondary curvatures as infant grows.
  - **Primary curvatures** (________ and sacral) present during fetal development.
  - **Secondary curvatures** (________ and lumbar) develop after fetal period.

Overview of the Vertebral Column

- **Abnormal spinal curvatures:**
  - **Scoliosis** – abnormal _________ curvatures
  - **Lordosis** (swayback) – exaggerated cervical and _________ curvatures
  - **Kyphosis** (hunchback) – exaggeration of _________ curvature.

Structure of the Vertebrae

- **Cervical** (7) – smallest vertebrae
  - _________ foramina allows passage of vertebral arteries and veins
  - **C1** (_______)
    - Lacks vertebral body
    - Articulates with occipital condyles and **C2**
  - **C2** (_______)
    - **Dens** (odontoid process) protrudes from body
    - Allows for rotational movement of head at neck; (shaking your head “no”)

Structure of the Vertebrae

- **Thoracic vertebrae** (12)
  - Long spinous processes
  - **Superior** and **inferior costal facets** (articulate with **head of rib**)
  - **Transverse costal facets** on transverse processes (articulate with _________ on rib)

Structure of the Vertebrae

- **Lumbar vertebrae** (5) – largest and heaviest of all vertebrae (_________)
**Structure of the Vertebrae**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Cervical Vertebrae</th>
<th>Thoracic Vertebrae</th>
<th>Lumbar Vertebrae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Shape</td>
<td>Triangular</td>
<td>Triangular</td>
<td>Triangular</td>
</tr>
<tr>
<td>Spinous Process</td>
<td>Short and bulbous</td>
<td>Long and slender</td>
<td>Long and slender</td>
</tr>
<tr>
<td>Sacrum</td>
<td>5 fused sacral vertebrae</td>
<td>Sacral promontory – bony projection at anterior margin of base (superior aspect)</td>
<td>Sacral foramina – 4 pairs of holes allows for</td>
</tr>
<tr>
<td>Coccyx</td>
<td>4 fused (3-5) vertebrae</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Intervertebral Discs**

- **Intervertebral disc** = fibrocartilage pad found between bodies vertebrae
- **Nucleus pulposus** = jelly-like substance; shock absorber
- **Anulus fibrosus** = outer ring of

**Herniated Disc (p. 238)**

- A tear in anulus fibrosus can allow nucleus pulposus to protrude, a condition known as a **herniated disc** (commonly called a **slipped disc**)
- Bulging nucleus pulposus **compresses** nerve
- Treatments

**Study Boost: Remembering Skull Bones and Vertebrae**

- **PEST OF 6 (six cranial bones):** Parietal, Ethmoid, Sphenoid, Temporal, Occipital, Frontal
- **Virgil Is Now Making My Pet Zebra Laugh (facial bones):** Vomer, Inferior nasal conchae, Nasal, Mandible, Maxillae, Palatine, Zygomatic, Lacrimal
- **For Easier Sinus Memorization (paranasal sinuses):** Frontal, Ethmoidal, Sphenoidal, Maxillary
- **Breakfast at 7, lunch at 12, dinner at 5 (number of vertebrae):** 7 cervical, 12 thoracic, and 5 lumbar
The Thoracic Cage

- **Thoracic cage**
  - **sternum**
    - Manubrium – superiormost
    - Body - middle
    - Xiphoid process - inferior

Rib cage = 12 pairs of ribs and their costal cartilages

- Ribs 1–7 (___ ribs or vertebrosternal ribs) attach to sternum via their costal cartilages
- Ribs 8–12 (___ ribs) not directly attached to sternum
  - Vertebrochondral ribs 8–10 – attached to cartilage of 7th rib
  - ___ or vertebral ribs 11 & 12
    - are not attached to sternum

The Sternum and CPR (p. 239)

- Cardiopulmonary resuscitation (CPR)
  - Correct placement of hands on sternum is critical

The Pectoral Girdle

- **Pectoral girdle** – clavicle and scapula
- **Clavicle**
  - Sternal end
  - Acromial end

- **Scapula**
  - Acromion
  - Coracoid process
  - Subscapular fossa (anterior aspect)
  - Glenoid cavity (articulates with head of humerus)
  - Spine (___ ridge)
  - Supraspinous fossa
  - Infraspinous fossa
The Humerus

- **Humerus**
  - **head** articulates with **glenoid cavity** at shoulder joint
  - **neck** is a groove surrounding head
  - **proximal diaphysis**

- **greater & lesser tubercle** lateral and anterior to head

- **olecranon fossa**
- **coronoid fossa**
- **capitulum**
- **trochlea**

Bones of the Forearm

**Bones of forearm (antebrachium)**

- **Radius**
  - head, neck, radial tuberosity, styloid process

- **Ulna**
  - trochlear notch, olecranon, coronoid process, radial notch, styloid process

Bones of the Wrist: Carpals

**Wrist (carpus)**

- Scaphoid, Lunate, Triquetrum, Pisiform
  - proximal

- Trapezium, Trapezoid

Bones of the Hand and Fingers: Metacarpals and Phalanges

- **Metacarpals** – 5 each hand
- **Phalanges** – 14 each hand
  - proximal, middle, and distal

- **Thumb**
  - proximal & distal phalanx

Wrist Fractures (p. 247)

- Wrist is the most frequently injured region of upper limb;

- Fractures

  - **Colles fracture**

Bones of the Pelvic Girdle and Lower Limb

- **Pelvic girdle**
  - coxal bones (also known as os coxae)
  - Articulates with **sacrum** (axial skeleton)

- **Pelvis**
  - bowl-shaped sacrum and two coxal bones; creates boundary for pelvic cavity

- **Pelvic inlet** – oval opening formed by sacrum and pelvic girdle

- **Pelvic brim** – bony ridge surrounding inlet that defines boundaries between greater and lesser pelvis
Bones of the Pelvic Girdle and Lower Limb

- Each _________ is composed of 3 fused bones: ilium, ischium, and pubis.

Female and male pelvis differ between genders:
- Female pelvis (adapted for childbirth) is wider and shallower than male.

**Shape of greater pelvis:**
- Pelvis is wider in females with flared iliac crests.
- Increases distance between ASIS.

**Coccyx and sacrum:**
- Female sacrum is wider and shorter than male sacrum.
- While female coccyx is more movable and more posterior than male.

Pelvic inlet and outlet:
- Female inlet is usually wider and oval-shaped whereas male inlet is narrow and heart-shaped; female outlet is generally wider than male.

**Acetabula:** generally farther apart in females and pointed more anteriorly than in males.

Pubic arch:
- Angle measured in females = ________
- Male arch measures between ____________

Bones of the Pelvic Girdle

- Femur – largest and strongest bone
  - Head articulates with _________ at hip joint.
  - Neck.
  - Greater and Lesser trochanters.
  - Linea aspera.
  - Medial and a lateral condyles.
  - Patellar surface.

The Femur and Patella
Bones of the Leg: Tibia and Fibula

- **Tibia** (______ bone) larger bone, wt. bearing
  - Tibial tuberosity
  - Medial malleolus

- **Fibula** (______ bone)
  - Lateral malleolus

Bones of Ankle and Foot: Tarsals, Metatarsals, and Phalanges

- **Tarsals** – 7 short bones
  - **Proximal tarsals**: ______, calcaneus, and navicular
  - **Distal tarsals** medial to lateral: 3 cuneiforms (medial, intermediate, lateral) and cuboid

- **Metatarsals** – 5 in each foot

- **Phalanges**
  - 14 in each foot

The Study Boost: Remembering Bones of the Arm and Leg

**Carpals:** Stop Letting The People Touch The Cadaver’s Hand
- Scaphoid, Lunate, Triquetrum, Pisiform, Trapezium, Trapezoid, Capitate, Hamate
  (Mentions “hand”, so remember that it describes carpals, not tarsals; trapeziUM is by thUMb)

**Tarsals:** College Needs Me In Lab Classes
- Talus, Calcaneus, Navicular; Medial, Intermediate, & Lateral cuneiform, Cuboid
Articulations (joints) = where bones meet
- allow __________
- provide __________
- allow long bones to _________ (epiphyseal plate)

Functional Classification
Based on ________:
• Synarthrosis – no movement between articulating bones
• Amphiarthrosis – small amount of movement between articulating bones
• Diarthrosis – freely moveable, allowing a wide variety of specific movements

Structural Classification
Based on their __________ features:
• Fibrous joints – dense regular collagenous CT; (synarthroses or amphiarthroses)
• Cartilaginous joints – cartilage; (synarthroses or amphiarthroses)
• Synovial joints – fluid-filled joint capsule with hyaline cartilage at articular ends; (diarthrosis)

Fibrous Joints
3 types:
• Suture
• Gomphosis
• Syndesmosis
Suture - fibrous CT __________ of cranium; immoveable joint
Figure 8.1a The three types of fibrous joints.

FIGURE 8.1b The three types of fibrous joints.

Fibrous Joints
• Gomphosis – tooth in bony socket (periodontal ligament); ___________ joint
• Syndesmosis – joint between tibia & fibula, ulna & radius (interosseous membrane);

Cartilaginous Joints
2 types:
• Synchondrosis
• Symphysis
Synchondrosis - hyaline cartilage;
Synarthroses (epiphyseal plate, 1st sternocostal and costochondral joints); __________
Epiphyseal Plate Fractures (p. 260)

• Epiphyseal plate in a child’s long bone is one of the weakest parts of a developing skeleton;

• Treatment

Fibrous Joints

• Symphysis – fibrocartilaginous pad; amphiarthrosis
  – ____________ – Pubic symphysis

Synovial Joints

Synovial Joints:
  – Joint cavity (synovial cavity) – space found between articulating bones
  – Articular capsule – double-layered structure
    • Outer fibrous layer
    • Inner synovial membrane → synovial fluid (lubricates, metabolic fcn., shock absorber)
  – ____________ cartilage – hyaline cartilage; covers all exposed articulating bones within a joint
  – Diarthrosis

Structural Elements

Figure 8.3 Structure of a typical synovial joint.

Stabilizing and Supporting Factors

• Synovial joints allow more mobility
  – less stable than other joint types
  - structures that provide additional stabilization:
    Ligament – dense regular CT connects ____________
    Tendon - dense regular CT connects ____________

Bursae and tendon sheaths provide stabilization forces

Bursitis (p. 264)

• Bursitis
  – Most common sites of bursitis
  – Clinical features
Arthritis

- Arthritis – defined as inflammation of one or more joints which results in pain and limitations of joint movement:
  - Osteoarthritis (OA) – most common; associated with injuries, and advanced age; characterized by pain, joint stiffness, and lost mobility
  - Rheumatoid arthritis (RA) – associated with joint destruction;
  - Gouty arthritis – joint damage due to inflammatory reaction to crystals deposits

Movements at Synovial Joints

- Gliding movements – sliding motion between articulating surfaces
- Flexion, Extension, Hyperextension
- Abduction, Adduction
- Circumduction, Rotation
- Inversion, Eversion
- Supination, Pronation
- Dorsiflexion, Plantar flexion

Types of Synovial Joints

- Plane joint (gliding joint) – most simple and least mobile articulation between flat surfaces of two bones
- Hinge joint – convex articular surface of one bone interacts with concave depression of second bone

Figure 8.11a The six types of synovial joints and motion allowed at each.

Figure 8.11c The six types of synovial joints
Types of Synovial Joints

- **Saddle joint** – each bone’s articulating surface has both a concave and convex region

- **Ball-and-socket joint** – spherical surface of one bone fits into cup-shaped depression in second bone

**Figure 8.11** The six types of synovial joints.

Specific Hinge Joints

**Elbow** – very stable hinge joint (Figure 8.13):

- **Humeroulnar joint** – articulation between trochlea of humerus and trochlear notch of ulna

- **Humeroradial joint** – articulation between capitulum of humerus and head of radius

**A&P Flix: Movement at the Elbow**

- **Knee:**

  - **Joint** – articulation between femoral and tibial condyles
  - **Patellofemoral joint** – articulation between posterior surface of patella and anterior patellar surface of femur

  - **Medial and lateral meniscus** – fibrocartilage pads between femoral and tibial condyles
  - **Tibial collateral ligament** (medial collateral) – connects femur, medial meniscus, and tibia to one another to provide medial joint stabilization
Specific Hinge Joints

A&P Flix: Movement at the Knee Joint

Knee Injuries and the Unhappy Triad (p. 276)

Specific Hinge Joints

- Shoulder (____________) – ball-shaped head of humerus and glenoid cavity:
  - Glenoid labrum – fibrocartilaginous ring; increases depth of glenoid cavity to provide more stability
  - Biceps brachii tendon - helps keep head of humerus within glenoid cavity
  - Rotator cuff, providing most of joint’s structural stabilization: __________, infraspinatus, subscapularis, and __________

A&P Flix: Movement at the Glenohumeral Joint
Specific Hinge Joints

- **Hip** – acetabulum and ball-shaped head of femur:
  - Acetabular labrum – fibrocartilaginous ring that helps to stabilize head of femur within acetabulum

A&P Flix: Movement at the Hip Joint

Hip Joint Replacement Surgery (p. 279)

- **Hip replacement** – surgical procedure that replaces a painful damaged joint with an artificial prosthetic device
- Severe arthritis, trauma, fractures, and bone tumors can all progress to point where hip joint replacement is an option

- Total replacement
- Partial replacement