An Introduction to the Skeletal System

• Skeletal system includes
  – Bones of the skeleton
  – Cartilages, ligaments, and connective tissues
6-1 The skeletal system has five primary functions
Functions of the Skeletal System

• Support
• Storage of minerals (calcium) and lipids (yellow marrow)
• Blood cell production (red marrow)
• Protection
• Leverage (force of motion)
6-2 Bones are classified according to shape and structure
Classification of Bones

• Bones are classified by
  – Shape
  – Internal tissue organization
  – Bone markings (surface features; marks)
Shapes of Bones

Figure 6-1

(a) Long bone
- Humerus

(b) Short bones
- Carpal bones

(c) Flat bone
- Parietal bone

(d) Irregular bone
- Vertebra
Structure of a Long Bone

• **Diaphysis**
  – The shaft
  – A heavy wall of compact bone, or dense bone
  – A central space called medullary (marrow) cavity

• **Epiphysis**
  – Wide part at each end
  – Articulation with other bones
  – Mostly spongy (cancellous) bone
  – Covered with compact bone (cortex)
Structure of a Long Bone

Figure 6-2

Proximal epiphysis

Diaphysis

Articular cartilage
Spongy bone
Blood vessels
Epiphyseal line
Marrow cavity
Endosteum
Compact bone
Periosteum

Distal epiphysis
Compact and Spongy Bone

• The Structure of Compact Bone
  – **Osteon** is the basic unit:
    • Osteocytes are arranged in **concentric lamellae**
    • Around a **central canal** containing blood vessels
    • Perforating canals:
      – perpendicular to the central canal
      – carry blood vessels into bone and marrow
Compact and Spongy Bone

Figure 6-3b

- Canaliculi
- Concentric lamellae
- Lacunae
- Central canals

LM × 272
Compact and Spongy Bone

• The Structure of Spongy Bone
  – Does not have osteons
  – The matrix forms an open network of **trabeculae**
  – Trabeculae have no blood vessels
  – The space between trabeculae is filled with **red bone marrow**:
    • Which has blood vessels
    • Forms red blood cells
    • And supplies nutrients to osteocytes
  – Yellow marrow
    • In some bones, spongy bone holds yellow bone marrow
    • Is yellow because it stores fat
Compact and Spongy Bone

• Cells in Bone
  – Make up only 2% of bone mass
  – Bone contains three types of cells:
    • Osteocytes
    • Osteoblasts
    • Osteoclasts
Compact and Spongy Bone

• **Osteocytes**

  – Mature bone cells that maintain the bone matrix
  – Live in lacunae
  – *Are between layers (lamellae) of matrix*
  – *Connect by cytoplasmic extensions through canaliculi in lamellae*
  – Do not divide

  – **Functions:**
    • To maintain protein and mineral content of matrix
    • To help repair damaged bone
Compact and Spongy Bone

• **Osteoclasts**
  – Secrete acids and protein-digesting enzymes
  – Giant, multinucleate cells
  – Dissolve bone matrix and release stored minerals (**osteolysis**)
  – Are derived from stem cells that produce macrophages
Compact and Spongy Bone

• Osteoblasts
  – Immature bone cells that secrete matrix compounds (osteogenesis)
  – Osteoid — matrix produced by osteoblasts but not yet calcified to form bone
  – Osteoblasts surrounded by bone become osteocytes
Ossification and appositional growth are mechanisms of bone formation and enlargement.
Bone Development

– Human bones grow until about age 25

– Osteogenesis:
  • Bone formation

– Ossification:
  • The process of replacing other tissues with bone
Intramembranous Ossification

- Produces **flat bones of the skull** and the mandible (lower jaw) and clavicle (collarbone)
Intramembranous Ossification

Figure 6-4

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Endochondral Ossification

• Ossifies bones that originate as hyaline cartilage
• Most bones originate as hyaline cartilage
• There are six main steps in endochondral ossification
Endochondral Ossification

**Figure 6-5**

STEP 1
Chondrocytes at the center of the growing cartilage model enlarge and then die as the matrix calcifies.

STEP 2
Newly derived osteoblasts cover the shaft of the cartilage in a thin layer of bone.

Enlarging chondrocytes within calcifying matrix

Cartilage model

Epiphysis

Diaphysis

Bone formation
Endochondral Ossification

**Figure 6-5**

- **Step 3:** Blood vessels penetrate the cartilage. New osteoblasts form a primary center of ossification.
- **Step 4:** The bone of the shaft thickens, and the cartilage near each epiphysis is replaced by shafts of bone.
- **Step 5:** Blood vessels invade the epiphyses, and osteoblasts form secondary centers of ossification.
Appositional Bone Growth

Figure 6-6
Requirements for Normal Bone Growth

• Process of Remodeling
  – The adult skeleton:
    • Maintains itself
    • Replaces mineral reserves
    • Recycles and renews bone matrix
    • Involves osteocytes, osteoblasts, and osteoclasts
  – Bone continually remodels, recycles, and replaces
  – Turnover rate varies:
    • If deposition is greater than removal, bones get stronger
    • If removal is faster than replacement, bones get weaker
Requirements for Normal Bone Growth

• Normal bone growth and maintenance require nutritional and hormonal factors
  – A dietary source of calcium and phosphate salts:
    • Plus small amounts of magnesium, fluoride, iron, and manganese
  – The hormone calcitriol:
    • Is made in the kidneys
    • Helps absorb calcium and phosphorus from digestive tract
    • Synthesis requires vitamin D₃ (cholecalciferol)
Requirements for Normal Bone Growth

• Normal bone growth and maintenance depend on nutritional and hormonal factors
  – Vitamin C is required for collagen synthesis and stimulation of osteoblast differentiation
  – Vitamin A stimulates osteoblast activity
  – Vitamins K and $B_{12}$ help synthesize bone proteins
  – Growth hormone and thyroxine stimulate bone growth
  – Estrogens and androgens stimulate osteoblasts
  – Calcitonin and parathyroid hormone regulate calcium and phosphate levels
Bone growth and development depend on a balance between bone formation and resorption and on calcium availability.
The Skeleton as a Calcium Reserve

• Bones store calcium and other minerals

• **Calcium** is the most abundant mineral in the body

  – **Calcium ions** are vital to:

    • Membranes
    • Neurons
    • Muscle cells, especially heart cells
The Skeleton as a Calcium Reserve

• **Parathyroid Hormone (PTH)**
  – Produced by parathyroid glands in neck
  – Increases calcium ion levels by:
    • Stimulating osteoclasts
    • Increasing intestinal absorption of calcium
    • Decreasing calcium excretion at kidneys

• **Calcitonin**
  – Secreted by C cells (parafollicular cells) in thyroid
  – *Decreases* calcium ion levels by:
    • Inhibiting osteoclast activity
    • Increasing calcium excretion at kidneys
Fractures

• Cracks or breaks in bones
• Caused by physical stress
Steps in the Repair of a Fracture

**STEP 1**
Immediately after the fracture, extensive bleeding occurs. Over a period of several hours, a large blood clot, or fracture hematoma, develops.

**STEP 2**
An internal callus forms as a network of spongy bone unites the inner edges, and an external callus of cartilage and bone stabilizes the outer edges.

---

Figure 6-7

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Steps in the Repair of a Fracture

**STEP 3**
The cartilage of the external callus has been replaced by bone, and struts of spongy bone now unite the broken ends. Fragments of dead bone and the areas of bone closest to the break have been removed and replaced.

**STEP 4**
A swelling initially marks the location of the fracture. Over time, this region will be remodeled, and little evidence of the fracture will remain.

Figure 6-7
6-5 Osteopenia has a widespread effect on aging skeletal tissue
Osteopenia

• Bones become thinner and weaker with age
  – Osteopenia begins between ages 30 and 40
  – Women lose 8% of bone mass per decade, men 3%
Osteopenia

• **Osteoporosis**
  – Severe bone loss
  – Affects normal function
  – Over age 45, occurs in:
    • 29% of women
    • 18% of men
6-6 The bones of the skeleton are distinguished by surface markings and are grouped into two skeletal divisions
<table>
<thead>
<tr>
<th>General Description</th>
<th>Anatomical Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevations and projections (general)</td>
<td>Process</td>
<td>Any projection or bump</td>
</tr>
<tr>
<td></td>
<td>Ramus</td>
<td>An extension of a bone making an angle with the rest of the structure</td>
</tr>
<tr>
<td>Processes formed where tendons or ligaments attach</td>
<td>Trochanter</td>
<td>A large, rough projection</td>
</tr>
<tr>
<td></td>
<td>Tuberosity</td>
<td>A smaller, rough projection</td>
</tr>
<tr>
<td></td>
<td>Tubercle</td>
<td>A small, rounded projection</td>
</tr>
<tr>
<td></td>
<td>Crest</td>
<td>A prominent ridge</td>
</tr>
<tr>
<td></td>
<td>Line</td>
<td>A low ridge</td>
</tr>
<tr>
<td></td>
<td>Spine</td>
<td>A pointed process</td>
</tr>
<tr>
<td>Processes formed for articulation with adjacent bones</td>
<td>Head</td>
<td>The expanded articular end of an epiphysis, separated from the shaft by a neck</td>
</tr>
<tr>
<td></td>
<td>Neck</td>
<td>A narrow connection between the epiphysis and the diaphysis</td>
</tr>
<tr>
<td></td>
<td>Condyle</td>
<td>A smooth, rounded articular process</td>
</tr>
<tr>
<td></td>
<td>Trochlea</td>
<td>A smooth, grooved articular process shaped like a pulley</td>
</tr>
<tr>
<td></td>
<td>Facet</td>
<td>A small, flat articular surface</td>
</tr>
<tr>
<td>Depressions</td>
<td>Fossa</td>
<td>A shallow depression</td>
</tr>
<tr>
<td></td>
<td>Sulcus</td>
<td>A narrow groove</td>
</tr>
<tr>
<td>Openings</td>
<td>Foramen</td>
<td>A rounded passageway for blood vessels or nerves</td>
</tr>
<tr>
<td></td>
<td>Canal or Meatus</td>
<td>A passageway through the substance of a bone</td>
</tr>
<tr>
<td></td>
<td>Fissure</td>
<td>An elongate cleft</td>
</tr>
<tr>
<td></td>
<td>Sinus</td>
<td>A chamber within a bone, normally filled with air</td>
</tr>
</tbody>
</table>
TABLE 6-1 An Introduction to the Surface Features of Bones

- Trochanter
- Head
- Neck
- Sinus (chamber within a bone)
- Canal
- Fissure
- Foramen
- Process
- Tubercle
- Head
- Sulcus
- Neck
- Crest
- Fossa
- Spine
- Line
- Tuberosity
- Fossa Trochlea
- Condyle
- Humerus
- Condyle
- Pelvis
- Ramus
The Skeleton

Figure 6-8

(a) Anterior view  (b) Posterior view

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Skeletal Divisions

• The **Axial Skeleton**
  – Forms the longitudinal axis of the body
  – Has 80 bones:
    • **The skull:**
      – eight *cranial bones*
      – fourteen *facial bones*
    • **Bones associated with the skull:**
      – six *auditory ossicles*
      – the *hyoid bone*
Skeletal Divisions

• The **Appendicular Skeleton**
  – 126 bones
  – Allows us to move and manipulate objects
  – Includes all bones besides axial skeleton:
    • The **limbs**
    • The supportive **girdles**
Figure 6-9

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6-7 The bones of the skull, vertebral column, and thoracic cage make up the axial skeleton
The Skull

• Cranial Bones
  – Enclose the cranial cavity
  – Which contains the brain:
    • And its fluids, blood vessels, nerves, and membranes

• Facial Bones
  – Superficial facial bones:
    • For muscle attachment
  – Deep facial bones:
    • Separate the oral and nasal cavities
    • Form the nasal septum
The Skull

![Skull diagram with labeled parts](image)

- Coronal suture
- Squamous suture
- Lambdoid suture
- External acoustic meatus
- Mastoid process
- Occipital bone
- Frontal bone
- Parietal bone
- Temporal bone
- Zygomatic bone
- Ethmoid bone
- Sphenoid bone
- Nasal bone
- Lacrimal bone
- Mandible

Figure 6-10

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The Skull

Figure 6-11a
Figure 6-11b

FRONTAL BONE
ZYGOMATIC BONE
VOMER
SPHENOID

MAXILLA
PALATINE BONE
Zygomatic arch

Styloïd process
Mandibular fossa
External acoustic meatus

TEMPORAL BONE
Mastoid process

Occipital condyle
Foramen magnum

Lambdoid suture
OCCIPITAL BONE
External occipital protuberance

(b) Inferior view
The Sectional Anatomy of the Skull

Figure 6-12a

(a) Horizontal Section

- Frontal Bone
- Ethmoid
- Sphenoid
- Temporal Bone
- Foramen magnum
- Crista galli
- Cribiform plate
- Sella turcica
- Parietal Bone
- Occipital Bone
The Sectional Anatomy of the Skull

Figure 6-12b
The Sectional Anatomy of the Skull

Figure 6-12c  (c) Sagittal section

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The Cranial Bones of the Skull

• The Frontal Bone
  – Functions of the frontal bone:
    • Forms the anterior cranium and upper eye sockets
    • Contains frontal sinuses
  – Foramina of the frontal bone:
    • **Supraorbital foramen:**
      – for blood vessels of eyebrows, eyelids, and frontal sinuses
    • **Supraorbital notch:**
      – an incomplete supraorbital foramen
The Cranial Bones of the Skull

• **The Parietal Bones**
  – Function of the parietal bones:
    • Forms part of the superior and lateral surfaces of the cranium
• **The Occipital Bone**
  
  – Function of the occipital bone:
    • Forms the posterior and inferior surfaces of the cranium
  
  – Marks of the occipital bone:
    • *Occipital condyles*: articulate with neck
    • *Foramen magnum*: connects cranial and spinal cavities
The Cranial Bones of the Skull

• The Temporal Bones
  – Functions of the temporal bones:
    • Part of lateral walls of cranium and zygomatic arches
    • Articulate with mandible
    • Surround and protect inner ear
    • Attach muscles of jaws and head
  – Articulations of the temporal bones:
    • Zygomatic bone
    • Sphenoid
    • Parietal bone
    • Occipital bone
    • Mandible
The Cranial Bones of the Skull

• The Sphenoid
  – Functions of the sphenoid:
    • Part of the floor of the cranium
    • Unites cranial and facial bones
    • Strengthens sides of the skull
    • Contains sphenoidal sinuses
The Cranial Bones of the Skull

• The Ethmoid

  – Functions of the ethmoid:
    • Forms anteromedial floor of the cranium
    • Roof of the nasal cavity
    • Part of the nasal septum and medial orbital wall
    • Contains *ethmoidal air cells* (network of sinuses)
The Bones of the Face

• The Maxillae

  – Functions of the maxillae:

    • Support upper teeth
    • Form inferior orbital rim
    • Form lateral margins of external nares
    • Form upper jaw and hard palate
    • Contain *maxillary sinuses* (largest sinuses)
The Facial Bones of the Skull

• The Palatine Bones
  – Functions of the palatine bones:
    • Form the posterior portion of the hard palate
    • Contribute to the floors of the orbits
The Vomer

- Function of the vomer:
  - Forms the inferior portion of the bony nasal septum
The Zygomatic Bones

- Functions of the zygomatic bones:
  - Contribute to the rim and lateral wall of the orbit
  - Form part of the zygomatic arch
The Facial Bones of the Skull

• The Nasal Bones
  – Functions of the nasal bones:
    • Support the bridge of the nose
    • Connect to cartilages of the distal part of the nose (external nares)
The Facial Bones of the Skull

• The Lacrimal Bones
  – Functions of the lacrimal bones:
    • The smallest facial bones
    • Form part of the medial wall of the orbit
The Facial Bones of the Skull

• The Inferior Nasal Conchae
  – Functions of the inferior nasal conchae:
    • To create air turbulence in the nasal cavity
    • To increase the epithelial surface area
    • To warm and humidify inhaled air
The Paranasal Sinuses

Frontal sinus
Ethmoidal sinuses
Sphenoidal sinus
Maxillary sinus

Figure 6-13
The Facial Bones of the Skull

• The Mandible
  – Function of the mandible:
    • Forms the lower jaw
  – Articulation of the mandible:
    • Mandibular fossae of the temporal bones
The Facial Bones of the Skull

• The Hyoid Bone

  – Functions of the hyoid bone:
    • Supports the larynx
    • Attaches muscles of the larynx, pharynx, and tongue
The Hyoid Bone

Greater horn

Lesser horn

Body

Figure 6-14
The Skull

• The Skull of Infants and Children
  – Grows rapidly
  – Is large compared to the body
  – Has many ossification centers
  – Fusion is not complete at birth:
    • Two frontal bones
    • Four occipital bones
    • Several sphenoidal and temporal elements
Fontanelles

- Fontanelles (sometimes spelled fontanels)
  - Are areas of fibrous connective tissue (soft spots)
  - Cover unfused sutures in the infant skull
  - Allow the skull to flex during birth:
    - **Anterior fontanelle:**
      - frontal, sagittal, and coronal sutures
    - **Occipital fontanelle:**
      - lambdoid and sagittal sutures
    - **Sphenoidal fontanelles:**
      - squamous and coronal sutures
    - **Mastoid fontanelles:**
      - squamous and lambdoid sutures
The Skull of a Newborn

Coronal suture
Sphenoidal fontanelle
NASAL BONE
MAXILLA
SPHENOID
MANDIBLE TEMPORAL BONE Mastoid fontanelle
FRONTAL BONE
PARIETAL BONE
Squamous suture
Lambdoid suture
OCCIPITAL BONE

(a) Lateral view

Figure 6-15a
The Skull of a Newborn

Figure 6-15b
The Vertebral Column

• The Spine or **Vertebral Column**
  – Protects the spinal cord
  – Supports the head and body
  – 26 bones:
    • 24 **vertebrae**, the **sacrum**, and the **coccyx**
The Vertebral Column

Figure 6-16
The Vertebral Column

• Spinal Curvature
  – **Thoracic and sacral curves:**
    • Are called **primary curves** (present during fetal development)
    • Or **accommodation curves** (accommodate internal organs)
  – **Lumbar and cervical curves:**
    • Are called **secondary curves** (appear after birth)
    • Or **compensation curves** (shift body weight for upright posture)
• Vertebral Anatomy

  – The **vertebral body** (*centrum*):
    • Transfers weight along the spine
  
  – The **vertebral arch**:
    • Posterior margin of **vertebral foramen**

  – The **articular processes**:
    • Lateral projections between laminae and pedicles
Vertebral Regions

• The Cervical Vertebrae
  – Small body (support only head)
  – Large vertebral foramen (largest part of spinal cord)
  – Transverse processes:
    • Are fused to costal processes
    • Which encircle transverse foramina (protect arteries and veins)
Vertebral Regions

• The Cervical Vertebrae
  – **Atlas** \((C_1)\):
    • Articulates with occipital condyles of skull
    • Has no body or spinous process
    • Has a large, round foramen within **anterior** and **posterior arches**
  – **Axis** \((C_2)\):
    • Supports the atlas
    • Has heavy spinous process
    • To attach muscles of head and neck
The Cervical Vertebrae

Figure 6-17a

(a) Typical cervical vertebra

Vertebral arch
Spinous process
Lamina
Superior articular process
Superior articular facet
Transverse foramen

Vertebral foramen
Pedicle
Transverse process
Body

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The Atlas and Axis

Figure 6-18

Atlas (C1)
Articulates with occipital condyles

Axis (C2)
Articulates with atlas

Dens (odontoid process)
Ligament

The atlas/axis complex
Vertebral Regions

• **Thoracic vertebrae** ($T_1$–$T_{12}$)
  
  – Have heart-shaped bodies
  
  – Long, slender spinous processes
  
  – Dorsolateral surfaces of body have **costal facets**:
    
    • Which articulate with heads of ribs
The Thoracic Vertebrae

Figure 6-17b

(b) Typical thoracic vertebra
Vertebral Regions

- **Lumbar vertebrae** (L₁–L₅)
  - Largest vertebrae
  - Oval-shaped bodies
  - Thicker bodies than T₁–T₁₂
  - No costal or transverse costal facets
  - Triangular vertebral foramen
The Lumbar Vertebrae

Figure 6-17c

(c) Typical lumbar vertebra

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Vertebral Regions

• The **Sacrum**
  – Is curved, more in males than in females
  – Protects reproductive, urinary, and digestive organs
  – Attaches:
    • The axial skeleton to pelvic girdle of appendicular skeleton
    • Broad muscles that move the thigh
  – The adult sacrum:
    • Consists of five fused sacral vertebrae
    • Fuses between puberty and ages 25 to 30
    • Leaving *transverse lines*
Vertebral Regions

• The **Coccyx**
  – Attaches ligaments and a constricting muscle of the anus
  – Mature coccyx:
    • Consists of three to five fused **coccygeal vertebrae**
  – First two coccygeal vertebrae:
    • Have transverse processes
    • Have unfused vertebral arches
The Sacrum and Coccyx

Figure 6-19

(a) Posterior surface

(b) Anterior surface

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The Thoracic Cage

• The Skeleton of the Chest
  – Supports the **thoracic cavity**:
    • Consists of:
      – thoracic vertebrae
      – ribs
      – sternum (breastbone)

• The Rib Cage
  – Formed of ribs and sternum
The Thoracic Cage

• Functions of the Thoracic Cage
  – Protects organs of the thoracic cavity:
    • Heart, lungs, and thymus
  – Attaches muscles:
    • For respiration
    • Of the vertebral column
    • Of the pectoral girdle
    • Of the upper limbs
The Thoracic Cage

• Ribs
  – Are mobile
  – Can absorb shock
  – Functions of ribs:
    • Rib movements (breathing):
      – affect width and depth of thoracic cage
      – changing its volume
The Thoracic Cage

• Ribs 1–7 (true ribs)
  – *Vertebrosternal ribs*
  – Connected to the sternum by *costal cartilages*

• Ribs 8–12 (false ribs)
  – Do not attach directly to the sternum
  – *Vertebrochondral ribs* (ribs 8–10):
    • Fuse together
    • Merge with cartilage before reaching the sternum
  – *Floating or vertebral ribs* (ribs 11–12):
    • Connect only to the vertebrae and back muscles
    • Have no connection with the sternum
The Thoracic Cage

• The **Sternum**
  
  – A flat bone
  
  – In the midline of the thoracic wall
  
  – Three parts of the sternum:
    
    • The manubrium
    
    • The sternal body
    
    • The xiphoid process
6-8 The pectoral girdle and upper limb bones, and the pelvic girdle and lower limb bones, make up the appendicular skeleton
The Pectoral Girdle

- Also called the shoulder *girdle*
- Connects the arms to the body
- Positions the shoulders
- Provides a base for arm movement
- Consists of
  - Two *clavicles*
  - Two *scapulae*
- Connects with the axial skeleton only at the manubrium
The Pectoral Girdle

• The Clavicles
  – Also called *collarbones*
  – Long, S-shaped bones
  – Originate at the *manubrium* (sternal end)
  – Articulate with the *scapulae* (acromial end)
The Clavicle

Figure 6-21
The Pectoral Girdle

• The **Scapulae**
  – Also called *shoulder blades*
  – Broad, flat triangles
  – Articulate with arm and collarbone
  – Anterior surface: the **subscapular fossa**
Figure 6-22

The Scapula
The Upper Limbs

• The upper limbs consist of the arms, forearms, wrists, and hands

*Note:* **arm** (*brachium*) = 1 bone, the **humerus**
The Upper Limbs

• The Humerus
  – Also called the *arm*
  – The long, upper arm bone
  – Articulates with the pelvic girdle
The Humerus

Figure 6-23

(a) Anterior surface

(b) Posterior surface
The Upper Limbs

• The Forearm (also Called the *Antebrachium*)
  – Consists of two long bones:
    • **Ulna** (medial)
    • **Radius** (lateral)
• The Ulna
  – The olecranon:
    • Superior end of ulna
    • Point of elbow
    • Superior lip of *trochlear notch*
    • Articulates with trochlea of humerus
  – The coronoid process:
    • Inferior lip of *trochlear notch*
The Upper Limbs

• The Radius
  – Lateral bone of forearm
  – Disk-shaped radial head above the neck
  – Radial tuberosity below the neck, attaches biceps
  – Articulations of the radius:
    • Ulnar notch:
      – distal end
      – articulates with wrist and radius
    • Styloid process:
      – stabilizes wrist joint
The Radius and Ulna

Figure 6-24
(a) Anterior view
(b) Pronation: Anterior view
The Upper Limbs

• Eight **carpal bones**
  – Four proximal carpal bones
  – Four distal carpal bones
  – Allow wrist to bend and twist
The Upper Limbs

• **Metacarpal Bones**
  – The five long bones of the hand
  – Numbered I–V from lateral (thumb) to medial
  – Articulate with proximal phalanges

• **Phalanges** of the Hands (14 Total Finger Bones)
  – **Pollex** (thumb):
    • Two phalanges (proximal, distal)
  – Fingers:
    • Three phalanges (proximal, middle, distal)
The Pelvic Girdle

- Made up of two hip bones (coxal bones)
- Strong to bear body weight, stress of movement
- Part of the pelvis
- Coxal bones
  - Made up of three fused bones:
    - Ilium (articulates with sacrum)
    - Ischium
    - Pubis
The Pelvic Girdle

• The Coxal Bone
  – The acetabulum:
    • Also called the *hip socket*
    • Is the meeting point of the ilium, ischium, and pubis
    • Is on the lateral surface of the hip bone (coxal bone)
The Pelvis

Figure 6-26 a, c

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The Pelvis

Figure 6-26b
The Pelvic Girdle

• Comparing the Male Pelvis and Female Pelvis
  – Female pelvis:
    • Smoother and lighter
    • Less prominent muscle and ligament attachments
    • Pelvis modifications for childbearing:
      – enlarged pelvic outlet
      – broad pubic angle (>100°)
      – less curvature of sacrum and coccyx
      – wide, circular pelvic inlet
      – broad, low pelvis
      – ilia project laterally, not upwards

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Pelvis of a Male and a Female

Figure 6-27

Male

- 90° or less pubic angle
- Pelvic outlet, relatively narrow

Female

- 100° or more pubic angle
- Pelvic outlet, relatively broad
The Lower Limbs

• Functions of the lower limbs
  – Weight bearing
  – Motion

Note: leg = lower leg; thigh = upper leg
The Lower Limbs

• Bones of the Lower Limbs
  – Femur (thigh)
  – Patella (kneecap)
  – Tibia and fibula (leg)
  – Tarsals (ankle)
  – Metatarsals (foot)
  – Phalanges (toes)
The Femur

Figure 6-28

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The Lower Limbs

• The Patella
  – Also called the *kneecap*
  – A sesamoid bone
  – Formed within tendon of *quadriceps femoris*
  – **Base** attaches *quadriceps femoris*
  – **Apex** attaches *patellar ligament*
• The **Tibia**
  
  – Also called the *shinbone*
  
  – Supports body weight
  
  – Larger than fibula
  
  – Medial to fibula
The Lower Limbs

• The **Fibula**
  – Attaches muscles of feet and toes
  – Smaller than tibia
  – Lateral to tibia
The Tibia and Fibula

Figure 6-29
The Lower Limbs

• The Ankle
  – Also called the *tarsus*:
    • Consists of seven *tarsal bones*
  – Bones of the ankle:
    • *Talus*:
      – carries weight from tibia across trochlea
    • *Calcaneus* (heel bone):
      – transfers weight from talus to ground
      – attaches calcaneal (Achilles) tendon
The Lower Limbs

- **Metatarsal Bones of the Foot**
  - Five long bones of foot
  - Numbered I–V, medial to lateral
  - Articulate with toes
The Lower Limbs

• Phalanges of the foot
  – Phalanges:
    • 14 bones of the toes
  – Hallux:
    • Big toe or great toe, two phalanges (distal, proximal)
  – Other four toes:
    • Three phalanges (distal, medial, proximal)
Figure 6-30a

(a) Superior view, right foot

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Bones of the Ankle and Foot

Figure 6-30b

(b) Medial view, right foot
6-9 Joints are categorized according to their range of motion or anatomical organization
An Introduction to Articulations

• Articulations
  – Body movement occurs at **joints** (articulations) where two bones connect

• Joint Structure
  – Determines direction and distance of movement (**range of motion**)
  – Joint strength decreases as mobility increases
Classification of Joints

• Functional Classifications
  – Synarthrosis (immovable joint):
    • No movement
    • Fibrous or cartilaginous connections
    • May fuse over time
  – Amphiarthrosis (slightly movable joint):
    • Little movement
    • Fibrous or cartilaginous connections
  – Diarthrosis (freely movable joint):
    • More movement
    • Also called synovial joints
    • Subdivided by type of motion
<table>
<thead>
<tr>
<th>FUNCTIONAL CATEGORY</th>
<th>STRUCTURAL CATEGORY</th>
<th>DESCRIPTION</th>
<th>EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synarthrosis (no movement)</td>
<td>Fibrous Suture</td>
<td>Fibrous connections plus interlocked surfaces</td>
<td>Between the bones of the skull</td>
</tr>
<tr>
<td></td>
<td>Gomphosis</td>
<td>Fibrous connections plus insertion in bony socket (alveolus)</td>
<td>Between the teeth and jaws</td>
</tr>
<tr>
<td></td>
<td>Cartilaginous Synchondrosis</td>
<td>Interposition of cartilage plate</td>
<td>Epiphyseal cartilages</td>
</tr>
<tr>
<td>Amphiarthrosis (little movement)</td>
<td>Fibrous Syndesmosis</td>
<td>Ligamentous connection</td>
<td>Between the tibia and fibula</td>
</tr>
<tr>
<td></td>
<td>Cartilaginous Symphysis</td>
<td>Connection by a fibrous cartilage pad</td>
<td>Between right and left halves of pelvis; between adjacent vertebrae of spinal column</td>
</tr>
<tr>
<td>Diarthrosis (free movement)</td>
<td>Synovial</td>
<td>Complex joint bounded by joint capsule and containing synovial fluid</td>
<td>Numerous; subdivided by range of motion (Figure 6-35)</td>
</tr>
</tbody>
</table>
Synovial Joints

Figure 6-31a

- Medullary cavity
- Spongy bone
- Periosteum
- Fibrous joint capsule
- Synovial membrane
- Articular cartilages
- Joint cavity (containing synovial fluid)
- Compact bone
Synovial Joints

Figure 6-31b
6-10 Anatomical and functional properties of synovial joints enable various skeletal movements
Types of Movements

• Gliding
  – Two surfaces slide past each other:
    • Between carpal or tarsal bones

• Angular Motion
  – **Flexion:**
    • Angular motion
    • Anterior–posterior plane
    • *Reduces* angle between elements
  – **Extension:**
    • Angular motion
    • Anterior–posterior plane
    • *Increases* angle between elements
Types of Movements

• Angular Motion
  – Hyperextension:
    • Angular motion
    • Extension past anatomical position
Types of Movements

Figure 6-32
Types of Movements

• Angular Motion
  – Abduction:
    • Angular motion
    • Frontal plane
    • Moves *away from* longitudinal axis
  – Adduction:
    • Angular motion
    • Frontal plane
    • Moves *toward* longitudinal axis
Types of Movements

Figure 6-32
Types of Movements

Adduction

Abduction

Figure 6-32
Types of Movements

• Angular Motion
  – Circumduction:
    • Circular motion without rotation
    • Angular motion
Types of Movements

Figure 6-32

Circumduction

(d)
Types of Movements

• Rotation
  – Direction of rotation from anatomical position
  – Relative to longitudinal axis of body
  – Left or right rotation
  – Medial rotation (inward rotation):
    • Rotates toward axis
  – Lateral rotation (outward rotation):
    • Rotates away from axis
Types of Movements

Figure 6-33a
Types of Movements

• Rotation
  – Pronation:
    • Rotates forearm, radius over ulna
  – Supination:
    • Forearm in anatomical position
Types of Movements

Figure 6-33b

Supination

Pronation

(b)
Types of Movements

- **Special movements**
  - Inversion:
    - Twists sole of foot medially
  - Eversion:
    - Twists sole of foot laterally
  - Dorsiflexion:
    - Flexion at ankle (lifting toes)
  - Plantar flexion:
    - Extension at ankle (pointing toes)
Types of Movements

• Special Movements
  – Opposition:
    • Thumb movement toward fingers or palm (grasping)
  – Protraction:
    • Moves anteriorly
    • In the horizontal plane (pushing forward)
  – Retraction:
    • Opposite of protraction
    • Moving anteriorly (pulling back)
Types of Movements

• Special Movements at Synovial Joints
  – Elevation:
    • Moves in superior direction (up)
  – Depression:
    • Moves in inferior direction (down)
Types of Movements

Eversion  Inversion

Dorsiflexion (ankle flexion)

Plantar flexion (ankle extension)

Opposition

Figure 6-34
Types of Movements

Figure 6-34

Retraction  Protraction

Depression

Elevation

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A Structural Classification of Synovial Joints

- Gliding
- Hinge
- Pivot
- Ellipsoid
- Saddle
- Ball-and-socket

A Functional Classification of Synovial Joints
A Structural Classification of Synovial Joints

- **Gliding Joints**
  - Flattened or slightly curved faces
  - Limited motion (nonaxial)

- **Hinge Joints**
  - Angular motion in a single plane (monaxial)

- **Pivot Joints**
  - Rotation only (monaxial)
A Structural Classification of Synovial Joints

Figure 6-35 a,b,c
A Structural Classification of Synovial Joints

• Ellipsoid Joints
  – Oval articular face within a depression
  – Motion in two planes (biaxial)

• Saddle Joints
  – Two concave, straddled (biaxial)

• Ball-and-Socket Joints
  – Round articular face in a depression (triaxial)
6-11 Intervertebral articulations and appendicular articulations demonstrate functional differences in support and mobility
Intervertebral Articulations

- Intervertebral Articulations
  - C₂ to L₅ spinal vertebrae articulate:
    - At inferior and superior articular processes (gliding joints)
    - Between adjacent vertebral bodies (symphyseal joints)
Intervertebral Articulations

Figure 6-36
The Shoulder Joint

• Also called the *glenohumeral joint*
  – Allows more motion than any other joint
  – Is the least stable
  – Supported by skeletal muscles, tendons, ligaments

• Ball-and-socket diarthrosis

• Between head of *humerus* and *glenoid cavity* of *scapula*
The Elbow Joint

- A stable hinge joint
- With articulations involving humerus, radius, and ulna
The Elbow Joint

Figure 6-38
The Hip Joint

• Also called *coxal joint*

• Strong ball-and-socket diarthrosis

• Wide range of motion
The Hip Joint

Figure 6-39a

Greater trochanter
Reinforcing ligaments
Joint capsule

(a) Anterior view
The Hip Joint

Figure 6-39b

- Acetabulum
- Articular cartilage
- Synovial membrane
- Joint capsule
- Femur
- Fat pad
- Ligament of the femoral head
- Joint capsule

(b) Sectional view
The Knee Joint

- A complicated hinge joint
- Transfers weight from femur to tibia
- Articulations of the knee joint
  - Two femur–tibia articulations:
    - At medial and lateral condyles
    - One between patella and patellar surface of femur
The Knee Joint

Figure 6-40a

(a) Anterior, flexed
The Knee Joint

Figure 6-40b

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6-12 The skeletal system supports and stores energy and minerals for other body systems
The Skeletal System in Perspective

Functional Relationships Between the Skeletal System and Other Systems
The Integumentary System synthesizes vitamin D₃, essential for calcium and phosphorus absorption (bone maintenance and growth).

The Skeletal System provides structural support.
The Muscular System stabilizes bone positions; tension in tendons stimulates bone growth and maintenance.

The Skeletal System provides calcium needed for normal muscle contraction; bones act as levers to produce body movements.
The Nervous System regulates bone position by controlling muscle contractions.

The Skeletal System provides calcium for neural function; protects brain, spinal cord; receptors at joints provide information about body position.
The Endocrine System regulates skeletal growth with growth hormone, thyroid hormones, and sex hormones; calcium mobilization regulated by parathyroid hormone and calcitonin. The Skeletal System protects endocrine organs, especially in brain, chest, and pelvic cavity.
The Cardiovascular System provides oxygen, nutrients, hormones, blood cells; removes waste products and carbon dioxide.

The Skeletal System provides calcium needed for cardiac muscle contraction, blood cells produced in bone marrow; axial skeleton protects heart and great vessels.
The Lymphatic System

- The Lymphoid System’s lymphocytes assist in the defense and repair of bone following injuries.
- The Skeletal System’s bone marrow produces and stores lymphocytes and other cells of the immune response.
The Respiratory System provides oxygen and eliminates carbon dioxide. The Skeletal System surrounds and protects lungs; movements of ribs important in breathing.
The Digestive System

- The Digestive System provides nutrients, calcium, and phosphate.
- The Skeletal System protects portions of liver, stomach, and intestines.
The Urinary System conserves calcium and phosphate needed for skeletal system growth; disposes of waste products.

The Skeletal System provides some protection for kidneys and ureters; pelvis protects urinary bladder and proximal urethra.
The Reproductive System’s sex hormones stimulate growth and maintenance of bones; surge of sex hormones at puberty causes acceleration of growth and closure of skeletal system (pelvis).

The Skeletal System (pelvis) protects reproductive organs of female, protects portion of ductus deferens and accessory glands in males.