Chapter 06
Lecture and Animation Outline

To run the animations you must be in Slideshow View. Use the buttons on the animation to play, pause, and turn audio/text on or off.

Please Note: Once you have used any of the animation functions (such as Play or Pause), you must first click on the slide’s background before you can advance to the next slide.

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes and animations.
Chapter 6-Skeletal System

Functions
1. Support
2. Protect
3. Movement
4. Storage
5. Blood cell production
Components of Skeletal System

- Bone

- Cartilage: 
  reduce friction and model for bone formation

- Tendons: 
  attach bone to muscle

- Ligaments: 
  attach bone to bone
Background Information

- Bones, cartilage, tendons, and ligaments are connective tissues.

- **Proteoglycans:**
  - large polysaccharides attached to proteins
  - part of ground substance
  - store water
• Bone’s extracellular matrix is collagen and minerals (flexible and able to bear weight)

• Cartilage’s extracellular matrix is collagen and proteoglycans (good shock absorber)

• Tendons and ligaments’ extracellular matrix is collagen (very tough)
Classification of Bones

• Based on shape:
  long, short, flat, irregular

• Type of bone tissue:
  compact and spongy (cancellous)
Bone Shapes

• **Long:**
  - Ex. Femur, tibia, fibula

• **Short:**
  - Ex. Carpals, tarsals, phlanges

• **Flat:**
  - Ex. Ribs, sternum, skull

• **Irregular:**
  - Ex. Vertebrae and facial
Long Bone Structures

- **Diaphysis:**
  - shaft
  - compact bone tissue (on outside)

- **Epiphysis:**
  - ends
  - spongy bone tissue

- **Articular cartilage:**
  - covers epiphyses
  - reduces friction
- **Epiphyseal plate:**
  - site of growth
  - between diaphysis and epiphysis

- **Medullary cavity:**
  - center of diaphysis
  - red or yellow marrow
- **Periosteum:** membrane around bone’s outer surface

- **Endosteum:** membrane that lines medullary cavity
Compact Bone Tissue

- **Location:**
  outer part of diaphysis (long bones) and thinner surfaces of other bones

- **Osteon:**
  - structural unit of compact bone
  - includes lamella, lacunae, canaliculus, central canal, osteocytes

- **Lamella:**
  rings of bone matrix
- Lacunae: spaces between lamella
- Canaliculus: tiny canals
  - transport nutrients and remove waste
- Central canal: center of osteon
  - contains blood vessels
Osteocytes in lacunae

Canaliculi

Blood vessels within a central (Haversian) canal

Blood vessels connecting to a central canal

Blood vessels within the periosteum

Periosteum

Lamellae on surface of bone

Lamellae between osteons

Concentric rings of lamellae

Central canal

Osteon

Lacunae

Canaliculi

Osteon

Blood vessel connecting to a central canal between osteons

(a) © Trent Stephens

(b)
**Spongy Bone Tissue**

- **Cancellous bone**
- **Location:** epiphyses of long bones and center of other bones
- **Trabeculae:** interconnecting rods, spaces contain marrow
- **No osteons**
Bone Cells

- Osteocytes: maintain bone matrix

- Osteoblasts: build bone

- Osteoclasts: carve bone
Bone Formation

• **Ossification:**
  process of bone formation

• **Osteoblast’s role:**
  - build bone
  - after an osteoblast becomes surrounded by bone matrix it becomes an osteocyte
• **Ossification center:**
  where bone formation begins

• **Primary ossification center:**
  - where bone 1\textsuperscript{st} begins to appear
  - forms diaphyses

• **Secondary ossification center:**
  forms epiphyses
Intramembranous Ossification

- Bone formation within connective tissue membranes
- Osteoblasts build bone
- Ex. Skull bones
Figure 6.5 Bone Formation in a Fetus
Endochondral Ossification

• Bone formation inside cartilage

• Cartilage models are replaced by bone

• Ex. All bones (except skull)
Steps in Endochondral Ossification

1. Chondroblasts build a cartilage model, the chondroblasts become chondrocytes.
2. Cartilage model calcifies (hardens).
3. Osteoblasts invade calcified cartilage and a primary ossification center forms diaphysis.
5. Original cartilage model is almost completely ossified and remaining cartilage is articular cartilage.
1. A cartilage model, with the general shape of the mature bone, is produced by chondrocytes. A perichondrium surrounds most of the cartilage model.

2. A bone collar is produced, and the perichondrium of the diaphysis becomes the periosteum. The chondrocytes enlarge, and cartilage is calcified.

3. A primary ossification center forms as blood vessels and osteoblasts invade the calcified cartilage. The osteoblasts lay down bone matrix, forming trabeculae.

4. Secondary ossification centers form in the epiphyses of long bones.
Calcified cartilage is replaced by bone.

Chondrocytes divide and enlarge.

Epiphyseal plate

Bone of diaphysis

Length of bone increases.

Thickess of epiphyseal plate remains unchanged.

Bone is added to diaphysis.

Epiphyseal side

Diaphyseal side

Summary:

1. New cartilage is produced on the epiphyseal side of the plate as the chondrocytes divide and form stacks of cells.
2. Chondrocytes mature and enlarge.
3. Matrix is calcified, and chondrocytes die.
4. The cartilage on the diaphyseal side of the plate is replaced by bone.

(a): © Ed Reschke/Peter Arnold, Inc./ Photolibrary.com; (c): © Bio-Photo Assocs/Photo Researchers, Inc.
Bone Growth

• Infancy and youth:
  - long bones lengthen at epiphyseal plate
  - long bones widen by adding more lamella

• End of bone growth (in length):
  epiphyseal plate is replaced by an epiphyseal line
Bones grow through the process of appositional growth—the formation of new bone on the surface of older bone or cartilage.
Bone Remodeling

• What is it?
  - removal of existing bone by osteoclasts and deposition of new bone by osteoblasts
  - occurs in all bones
  - responsible for changes in bone shape, bone repair, adjustment of bone to stress, and calcium ion regulation
Bone Repair

1. Broken bone causes bleeding and a blood clot forms.
2. Callus forms which is a fibrous network between 2 fragments.
3. Cartilage model forms first then, osteoblasts enter the callus and form cancellous bone this continues for 4-6 weeks after injury.
4. Cancellous bone is slowly remodeled to form compact and cancellous bone.
1. When a bone is broken, a clot forms in the damaged area.

2. Blood vessels and cells invade the clot and produce a network of fibers and cartilage called a callus.

3. Osteoblasts enter the callus and form spongy bone.

4. Most of the spongy bone is slowly remodeled to form compact bone and the repair is complete.

PROCESS Figure 6.8 Bone Repair
Bone and Calcium Homeostasis

• Bone is a major storage site for calcium
• Movement of calcium in and out of bone helps determine blood levels of calcium
• Calcium moves into bone as osteoblasts build new bone
• Calcium move out of bone as osteoclasts break down bone
• Calcium homeostasis is maintained by parathyroid hormone (PTH) and calcitonin
Blood Small intestine

Osteoblasts promote $Ca^{2+}$ deposition in bone.

Vitamin D Stimulates osteoclasts

Inhibits osteoclasts

Calcitonin

osteoclasts promote $Ca^{2+}$ uptake from bone.

Osteoblasts promote $Ca^{2+}$ deposition in bone.

1. Decreased blood $Ca^{2+}$ stimulates PTH secretion from parathyroid glands.
2. PTH stimulates osteoclasts to break down bone and release $Ca^{2+}$ into the blood.
3. In the kidneys, PTH increases $Ca^{2+}$ reabsorption from the urine. PTH also stimulates active Vitamin D formation.
4. Vitamin D promotes $Ca^{2+}$ absorption from the small intestine into the blood.
5. Increased blood $Ca^{2+}$ stimulates calcitonin secretion from the thyroid gland.
6. Calcitonin inhibits osteoclasts, which allows for enhanced osteoblast uptake of $Ca^{2+}$ from the blood to deposit into bone.
Hematopoietic Tissue

• What is it?
  tissue that makes blood cells

• Red marrow:
  location of blood forming cells

• Yellow marrow:
  mostly fat
• Location of hematopoietic tissue in newborns: most bones (red marrow)

• Location of hematopoietic tissue in adults:
  - red is replaced with yellow marrow
  - red marrow is mainly in epiphyses of femur and humerus
Bone Anatomy

• Foramen:
  - hole
  - Ex. Foramen magnum

• Fossa:
  - depression
  - Ex. Glenoid fossa

• Process:
  - projection
  - Ex. Mastoid process
• **Condyle:**
  - smooth, rounded end
  - Ex. Occipital condyle

• **Meatus:**
  - canal-like passageway
  - Ex. External auditory meatus

• **Tubercle:**
  - lump of bone
  - Ex. Greater tubercle
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<th>Term</th>
<th>Description</th>
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<td><strong>Major Features</strong></td>
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<tr>
<td>Body, shaft</td>
<td>Main portion</td>
</tr>
<tr>
<td>Head</td>
<td>Enlarged (often rounded) end</td>
</tr>
<tr>
<td>Neck</td>
<td>Constricted area between head and body</td>
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<tr>
<td>Condyle</td>
<td>Smooth, rounded articular surface</td>
</tr>
<tr>
<td>Facet</td>
<td>Small, flattened articular surface</td>
</tr>
<tr>
<td>Crest</td>
<td>Prominent ridge</td>
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<tr>
<td>Process</td>
<td>Prominent projection</td>
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<tr>
<td>Tubercle, or tuberosity</td>
<td>Knob or enlargement</td>
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<tr>
<td>Trochanter</td>
<td>Large tuberosity found only on proximal femur</td>
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<td>Epicondyle</td>
<td>Enlargement near or above a condyle</td>
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<td><strong>Openings or Depressions</strong></td>
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<td>Foramen</td>
<td>Hole</td>
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<td>Canal, meatus</td>
<td>Tunnel</td>
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<td>Fissure</td>
<td>Cleft</td>
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<tr>
<td>Sinus</td>
<td>Cavity</td>
</tr>
<tr>
<td>Fossa</td>
<td>Depression</td>
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</table>
Axial Skeleton

• **Mastoid process:**
  attached to neck muscles

• **External auditory meatus:**
  ear canal

• **Nasolacrimal canal:**
  - canal between nasal cavity and eye
  - conducts tears
• **Styloid process:**
  attachment site for tongue

• **Mandibular fossa:**
  depression where lower jaw and skull meet

• **Glenoid fossa:**
  where humerus meets scapula
• **Hard palate:**
  roof of mouth

• **Foramen magnum:**
  hole where spinal cord joins brainstem
• **Zygomatic:**
  cheek bone

• **Mandible:**
  lower jaw

• **Maxilla:**
  upper jaw
Figure 6.12  Skull and Face

(a) Frontal view of the skull. (b) Bony landmarks of the face.
Figure 6.14  Floor of the Cranial Cavity
The roof of the skull has been removed, and the floor is viewed from above.
Vertebral Column

- 7 cervical vertebra
- 12 thoracic vertebra
- 5 lumbar vertebra
- 1 sacrum
- 1 coccyx

**Atlas:**
- 1\textsuperscript{st} vertebra
- holds head

**Axis:**
- 2\textsuperscript{nd} vertebra
- rotates head
Figure 6.18  Vertebra
Figure 6.19 Regional Differences in Vertebrae

The posterior portion lies at the top of each illustration.
Figure 6.20 Sacrum

(a) Anterior view

(b) Posterior view

- Sacral promontory
- Anterior sacral foramina
- Vertebral canal (sacral canal)
- Articular facet (articulates with fifth lumbar vertebra)
- Median sacral crest
- Posterior sacral foramina
- Sacral hiatus
- Coccyx
Functions of Vertebral Column

• Support

• Protect spinal cord

• Movement
Thoracic Cage

- Protects vital organs
- 12 pair of ribs
- **Sternum:**
  - breastbone
- **True ribs:**
  - attach directly to sternum by cartilage
- **False ribs:**
  - attach indirectly to sternum by cartilage
- **Floating ribs:**
  - not attached to sternum
Figure 6.21 Thoracic Cage
Pectoral Girdle

- Scapula: shoulder blade
- Clavicle: collar bone
Figure 6.23 Right Scapula and Clavicle

(a) Right scapula, anterior view. (b) Right scapula, posterior view. (c) Right clavicle, superior view. (d) Photograph of the right scapula and clavicle from a superior view, showing the relationship between the distal end of the clavicle and the acromion process of the scapula.
Upper Limb Bones

- Humerus: upper limb
- Ulna: forearm
- Radius: forearm
- Carpals: wrist
- Metacarpals: hand
Figure 6.22  Bones of the Pectoral Girdle and Right Upper Limb
Figure 6.25  Right Humerus
Figure 6.26 Right Ulna and Radius
(a) Anterior view of the right ulna and radius. (b) Proximal ends of the right ulna and radius.
Figure 6.27  Bones of the Right Wrist and Hand
Pelvic Girdle

• Where lower limbs attach to body
• Pelvis:
  includes pelvic girdle and coccyx
• Ischium:
  inferior and posterior region
• Ilium:
  most superior region
• Acetabulum:
  hip socket (joint)
Figure 6.30 Pelvis

- Sacroiliac joint
- Iliac crest
- Sacral promontory
- Anterior superior iliac spine
- Coccyx
- Acetabulum
- Pubic symphysis
- Obturator foramen
- Subpubic angle

Anterosuperior view
Figure 6.32 Comparison of the Male Pelvis to the Female Pelvis

(a) In a male, the pelvic inlet (red dashed line) and outlet (blue dashed line) are small, and the subpubic angle is less than 90 degrees. (b) In a female, the pelvic inlet (red dashed line) and outlet (blue dashed line) are larger, and the subpubic angle is 90 degrees or greater. (c) A midsagittal section through the pelvis shows the pelvic inlet (red arrow and red dashed line) and the pelvic outlet (blue arrow and blue dashed line).
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<th>Area</th>
<th>Description of Difference</th>
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<tr>
<td>General</td>
<td>Female pelvis somewhat lighter in weight and wider laterally but shorter superiorly to</td>
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<td></td>
<td>inferiorly and less funnel-shaped; less obvious muscle attachment points in female than</td>
</tr>
<tr>
<td></td>
<td>in male</td>
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<tr>
<td>Sacrum</td>
<td>Broader in female, with the inferior portion directed more posteriorly; the sacral</td>
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<tr>
<td></td>
<td>promontory projects less anteriorly in female</td>
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<tr>
<td>Pelvic inlet</td>
<td>Heart-shaped in male; oval in female</td>
</tr>
<tr>
<td>Pelvic outlet</td>
<td>Broader and more shallow in female</td>
</tr>
<tr>
<td>Subpubic angle</td>
<td>Less than 90 degrees in male; 90 degrees or more in female</td>
</tr>
<tr>
<td>Ilium</td>
<td>More shallow and flared laterally in female</td>
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<tr>
<td>Ischial spines</td>
<td>Farther apart in female</td>
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<td>Ischial tuberosities</td>
<td>Turned laterally in female and medially in male</td>
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<td>(not shown in figure 6.32)</td>
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Lower Limb Bones

• Femur:
  thigh
• Patella:
  knee cap
• Tibia:
  large lower leg
• Fibula:
  small lower leg
• Tarsals: ankle

• Metatarsals: foot

• Phalanges: toes and fingers
Figure 6.29  Bones of the Pelvic Girdle and Right Lower Limb
Figure 6.34  Bones of the Leg

The right tibia and fibula are shown.
Figure 6.35  Bones of the Right Foot
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<td><strong>Axial Skeleton</strong></td>
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<td><strong>Thoracic Cage</strong></td>
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<td><strong>Skull</strong></td>
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<td>Ribs</td>
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<td>Braincase</td>
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<td>Sternum (3 parts, sometimes considered 3 bones)</td>
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<td>TOTAL THORACIC CAGE</td>
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<td>Scapula</td>
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<td>Clavicle</td>
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<td>Ethmoid</td>
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<td>Lacrimal</td>
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<td>TOTAL GIRDLE AND UPPER LIMB</td>
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<td>Inferior nasal concha</td>
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<td><strong>Pelvic Girdle</strong></td>
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<td>Coxal bone</td>
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<td>Tibia</td>
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<td>Coccyx</td>
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<td>TOTAL VERTEBRAL COLUMN</td>
<td>26</td>
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Articulations

• What are they?
  where 2 bones come together (joint)

• Synarthrosis:
  - nonmovable joint
  - Ex. skull

• Amphiarthrosis:
  - slightly movable joint
  - Ex. Between vertebrae

• Diarthrosis:
  - freely movable joint
  - Ex. knee, elbow, wrist
Superior view

(a)

Lateral view

(b)
<table>
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<tr>
<th>Class and Example of Joint</th>
<th>Structures Joined</th>
<th>Movement</th>
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<td><strong>Plane</strong></td>
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<td>Acromioclavicular</td>
<td>Acromion process of scapula and clavicle</td>
<td>Slight</td>
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<td>Carpo-metacarpal</td>
<td>Carpals and metacarpals 2-5</td>
<td>Multiple axes as a group</td>
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<td>Costovertebral</td>
<td>Ribs and vertebrae</td>
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<td>Intercarpal</td>
<td>Between carpal bones</td>
<td>Slight</td>
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<td>Intermetatarsal</td>
<td>Between metatarsal bones</td>
<td>Slight</td>
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<td>Intertarsal</td>
<td>Between tarsal bones</td>
<td>Slight</td>
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<tr>
<td>Intervertebral</td>
<td>Between articular processes of adjacent vertebrae</td>
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<td>Sacroiliac</td>
<td>Between sacrum and coxal bone (complex joint with several planes and synchondroses)</td>
<td>Slight</td>
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<td>Tarsometatarsal</td>
<td>Tarsal bones and metatarsal bones</td>
<td>Slight</td>
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<td><strong>Saddle</strong></td>
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<td>Carpo-metacarpal</td>
<td>Carpal and metacarpal of thumb</td>
<td>Two axes</td>
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<td>Intercarpal</td>
<td>Between carpal bones</td>
<td>Slight</td>
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<td>Sterno-clavicular</td>
<td>Manubrium of sternum and clavicle</td>
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<tr>
<td><strong>Hinge</strong></td>
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<td>Cubital (elbow)</td>
<td>Humerus, ulna, and radius</td>
<td>One axis</td>
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<td>Knee</td>
<td>Femur and tibia</td>
<td>One axis</td>
</tr>
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<td>Interphalangeal</td>
<td>Between phalanges</td>
<td>One axis</td>
</tr>
<tr>
<td>Talocrural (ankle)</td>
<td>Talus, tibia, and fibula</td>
<td>Multiple axes; one predominates</td>
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<td><strong>Pivot</strong></td>
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<td>Atlas and axis</td>
<td>Rotation</td>
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<td>Proximal radioulnar</td>
<td>Radius and ulna</td>
<td>Rotation</td>
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<td>Distal radioulnar</td>
<td>Radius and ulna</td>
<td>Rotation</td>
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<td><strong>Ball-and-socket</strong></td>
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<td>Coxal (hip)</td>
<td>Coxal bone and femur</td>
<td>Multiple axes</td>
</tr>
<tr>
<td>Humeral (shoulder)</td>
<td>Scapula and humerus</td>
<td>Multiple axes</td>
</tr>
<tr>
<td><strong>Ellipsoid</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atlanto-occipital</td>
<td>Atlas and occipital bone</td>
<td>Two axes</td>
</tr>
<tr>
<td>Metacarpophalangeal</td>
<td>Metacarpal bones and phalanges</td>
<td>Two axes</td>
</tr>
<tr>
<td>Metatarsophalangeal</td>
<td>Metatarsal bones and phalanges</td>
<td>Two axes</td>
</tr>
<tr>
<td>Radiocarpal (wrist)</td>
<td>Radius and carpal bones</td>
<td>Multiple axes</td>
</tr>
<tr>
<td>Temporomandibular</td>
<td>Mandible and temporal bone</td>
<td>Multiple axes; one predominates</td>
</tr>
</tbody>
</table>
Types of Movement

- **Flexion**: bending
- **Extension**: straightening
- **Abduction**: movement away from midline
- **Adduction**: movement toward the midline
- **Pronation**: rotation of the forearm with palms down
- **Supination**: rotation of the forearm with palms up
- **Rotation**: movement of a structure about the long axis
Figure 6.41 Types of Movement
(a) Flexion and extension of the elbow. (b) Flexion and extension of the neck. (c) Abduction and adduction of the fingers. (d) Pronation and supination of the hand. (e) Medial and lateral rotation of the arm. (f) Circumduction of the arm.
Figure 6.10 Complete Skeleton
Bones of the axial skeleton are listed in the far left- and right-hand columns; bones of the appendicular skeleton are listed in the center. (The skeleton is not shown in the anatomical position.)
Effects of Aging on the Skeletal System and Joints

1. Decrease Collagen Production
2. Loss of Bone Density
3. Degenerative Changes
Bone is living tissue. Bone building is far from complete when a baby is born. During growth from infancy to adulthood, bone is increased in size, strength and hardness.