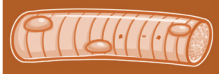

NOTES
BONES, JOINTS, & CARTILAGE

SKELETAL SYSTEM ANATOMY & PHYSIOLOGY

osms.it/skeletal-system-anatomy-physiology

SKELETAL BASICS

- 206 bones in skeleton
- Separated into axial, appendicular skeleton

Axial skeleton

- Vertical axis of body; 80 bones (22 in skull, 33 vertebrae, 24 ribs, 1 sternum)

Appendicular skeleton

- Supports limbs; pectoral girdle (clavicles, scapulae) holds humeri, pelvic girdle (hip bones) holds femora; 126 bones (4 in shoulders, 6 arms, 54 hands, 2 hips, 8 legs, 52 feet)

TYPES OF BONES

Long bones

- Length > width
- Humerus, radius, ulna (in arms); metacarpals, phalanges (hands, fingers); femur, tibia, fibula (legs); metatarsals, phalanges (feet, toes)
- Primarily responsible for height

Short bones

- Similar length, width
- Carpal bones (in wrists); tarsal bones (ankles)
- Support hands, feet

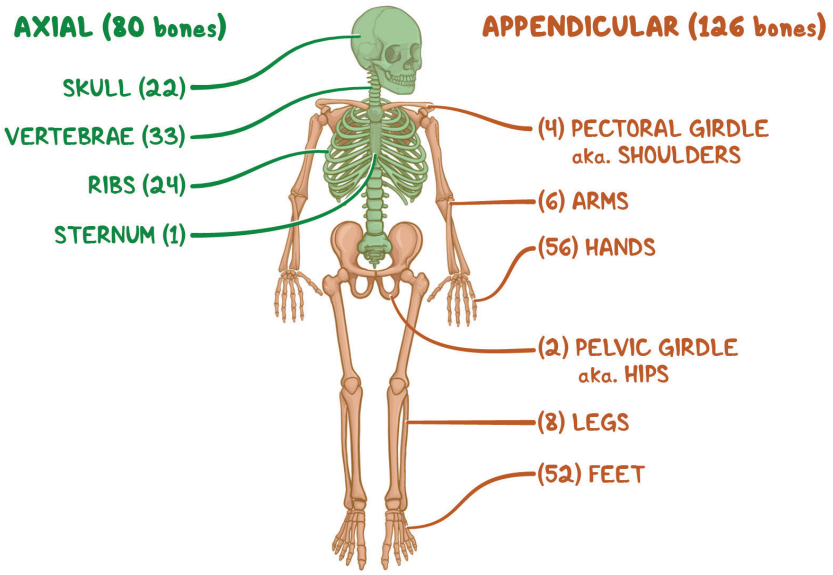

Figure 48.1 Overview of skeleton.

Flat bones

- Thin, sometimes curved
- Skull bones; scapulae, sternum, ribs
- Protect vital organs

Sesamoid bones

- Embedded in tendons, shaped like giant sesame seeds
- Pisiform bone (in wrists); patella (knees)
- Support, protect, give additional leverage to tendons

Irregular bones

- Facial bones; mandible; vertebrae; sacrum, coccyx

SURFACE FEATURES OF BONES

Sites of muscle, ligament attachment

- *Tubercle, tuberosity:* small bumps on bone, serve as attachment sites for muscles; large tubercle → tuberosity; deltoid tuberosity (on humerus)
- *Process:* bony prominence; xiphoid process (sternum)
- *Crest:* narrow ridge; iliac crest (ilium)

Projections

- Part of joints
- *Condyle:* rounded, articular projection; lateral, medial condyles (femur); epicondyle → raised portion on/above condyle (lateral, medial epicondyles)
- *Ramus:* arm-like section; mandibular ramus (mandible)

Openings, passageways, depressions

- *Foramen:* holes in bone, allow blood vessels/nerves through; foramen magnum (in occipital bone of skull)
- *Canal/meatus:* tunnels, allow blood vessels/nerves through; optic canal (sphenoid bone); external auditory meatus (temporal bone of ear)
- *Sinuses, cavities:* empty spaces within/between bones; nasal cavity, paranasal sinuses
- *Fossa:* depressions where other structures rest; hypophyseal fossa (sphenoid bone)

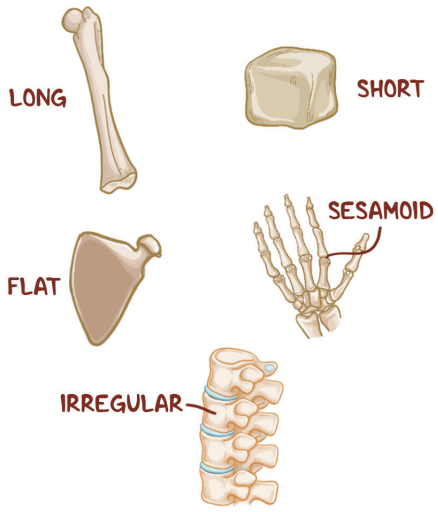

Figure 48.2 Types of bones.

STRUCTURE OF BONE

Cortical/compact bone

- Surrounded by periosteum
- Contains pipe-like structures called osteons
- Osteons contain hollow centers (Haversian canals) for nerves, blood cells; connected laterally by Volkmann's canals
- Osteon walls made of bone matrix (type I collagen reinforced with hydroxyapatite), produced by osteoblast cells
- Some osteoblasts get trapped in bone matrix → mature into osteocytes → repair old/broken bone
- Osteoclast cells secrete enzymes → break down bone matrix → release calcium, phosphate into blood

Trabecular/spongy bone

- Similar material to cortical bone
- Looser structure; branching rods called trabeculae
- Contains bone marrow, consists of hematopoietic stem cells ("red marrow"), adipocytes/fat cells ("yellow marrow")
  - Appendicular bones often contain red marrow at tips, yellow marrow in hollow medullary cavity (center)
  - Axial bones mostly red marrow

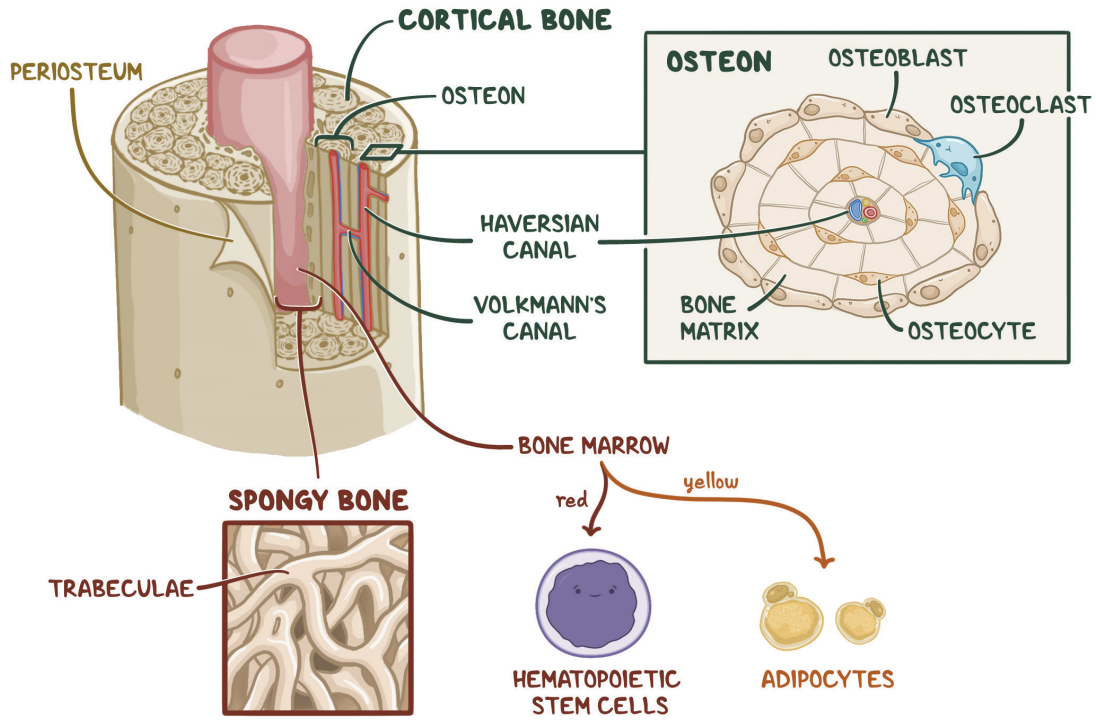

Figure 48.3 Bone cross-section showing structure which consists of cortical bone and spongy bone. Spongy bone contains two types of bone marrow, each made up of a different kind of cell.

CARTILAGE

osms.it/cartilage

WHAT IS CARTILAGE?

- Strong, flexible connective tissue
  - Comprises part of nose, ears
  - Provides cushioning between joints
  - Supports/connects body parts (e.g. costal cartilage connects ribs to sternum)
- *Perichondrium:* connective tissue that wraps around cartilage
  - Outer layer contains fibrous connective tissue, blood vessels
  - Inner layer contains chondroblasts → secrete proteins that make extracellular matrix
- *Extracellular matrix:* protein fibers (collagen for strength; elastin for flexibility) suspended in viscous gel (water, proteoglycan aggregates)
  - *Chondrocytes:* chondroblasts trapped in lacunae (small holes) of matrix; maintain, repair extracellular matrix
  - *Proteoglycan aggregates:* hyaluronan (long chain of hyaluronic acid molecules) with hundreds of proteoglycans (proteins + long chains of glycosaminoglycan sugars—GAGS) branching off

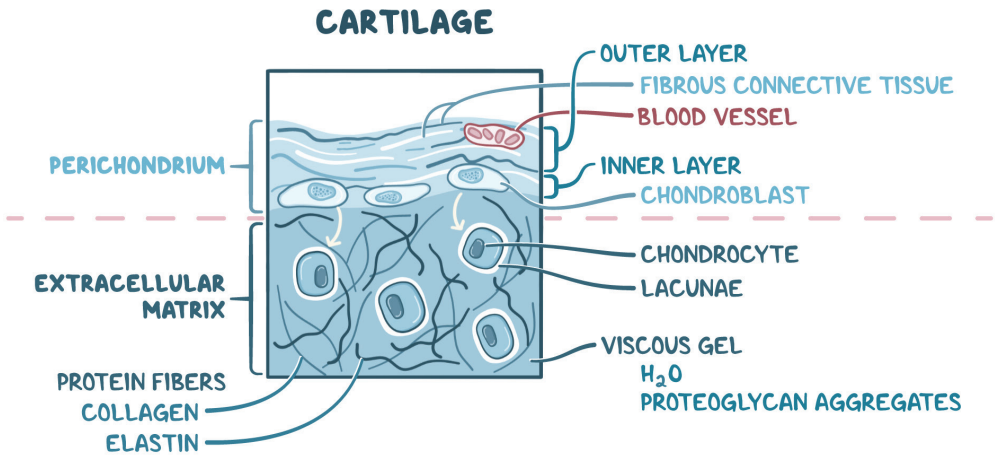

Figure 48.4 Cross-section through cartilage showing its histological structure. Perichondrium wraps around extracellular matrix. Chondroblasts originally in perichondrium become chondrocytes as they become trapped in the extracellular matrix.

TYPES

- Three main cartilage types

Elastic cartilage

- Least common type
- ↑ chondrocyte density; ↓ protein fiber density (mostly loose elastin fibers, some type II collagen fibers)
- Softest, most flexible cartilage
- Ear pinnae, throat epiglottis

Hyaline cartilage

- Most common type
- Medium chondrocyte density; medium protein fiber density (mostly type II collagen fibers, some loose elastin fibers)
- Stronger, but less flexible cartilage; ↓ friction surface
- Embryonic skeleton (eventually replaced by bone); nose; larynx walls; tracheal, costal cartilages; growth plates; articular cartilages

Fibrocartilage

- ↓ chondrocyte density; ↑ protein fiber density (mostly type I collagen fibers)
- Most tensile strength; resistant to compression, stretching; ↓ flexible
- Meniscus of knee, spinal intervertebral discs

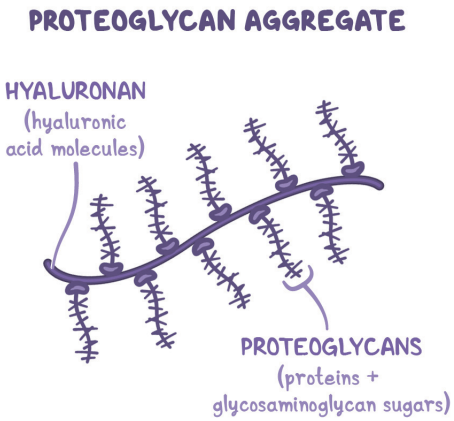

Figure 48.5 Proteoglycan aggregate, found in viscous gel of the extracellular matrix.

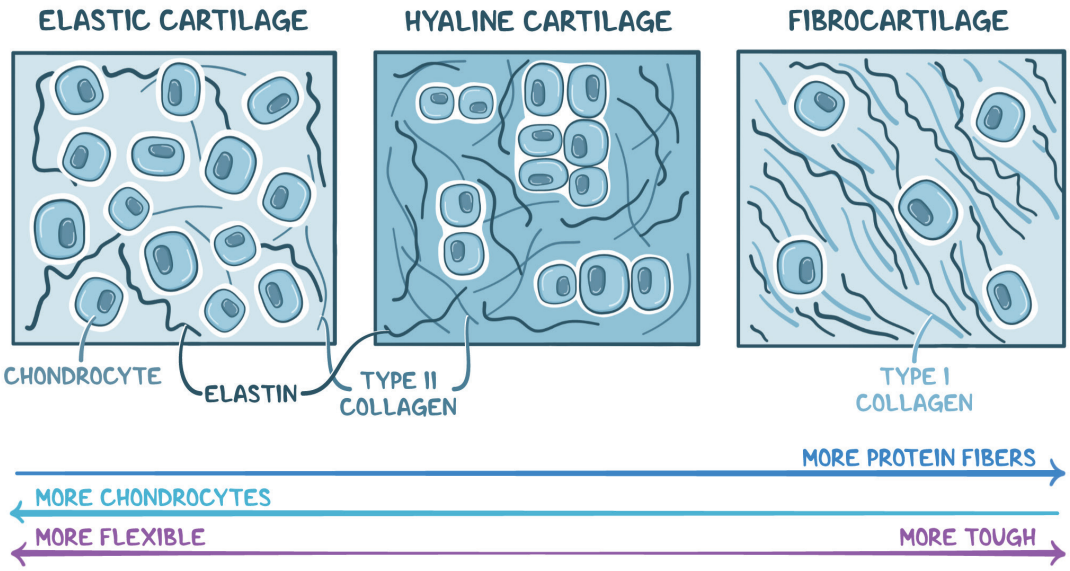

Figure 48.6 Histology, characteristics of the three main cartilage types.

GROWTH PATTERNS

- Two cartilage growth patterns
- Both growth patterns present in growing bones of children, teenagers (e.g. femur)
  - Chondrocytes in growth plate → interstitial growth → cartilage lengthens → osteoblasts turn cartilage into bone
  - Articular cartilage on tips of bone experience both appositional, interstitial growth

Appositional growth

- Chondroblasts secrete new matrix on existing surfaces → cartilage expands, widens

Interstitial growth

- Chondrocytes secrete new matrix within cartilage → cartilage grows in length

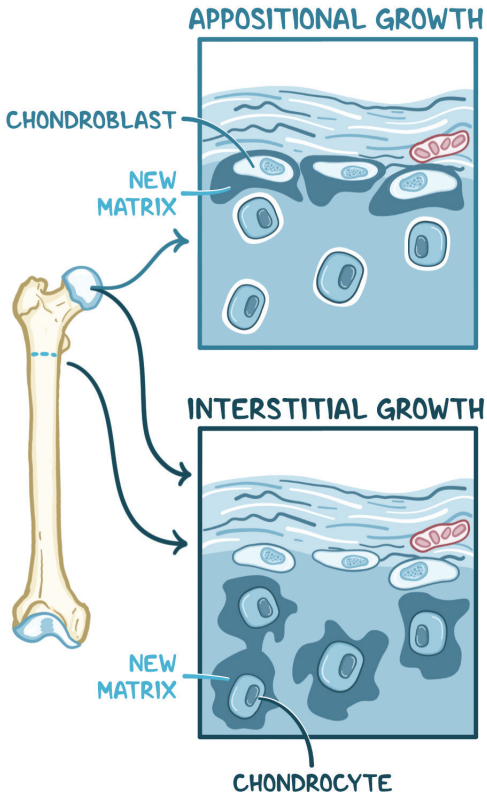

Figure 48.7 The two cartilage growth patterns. Both types of growth occur in articular cartilage. In the growth plate, only interstitial growth occurs.

BONE REMODELING & REPAIR

osms.it/bone-remodeling-repair

BONE REPAIR

- Old bone removed/resorbed (broken down) before new tissue replaces it
  1. Osteoblasts sense microcracks, secrete receptor activator of nuclear factor κβ ligand (RANKL)
  2. RANKL binds to RANK receptors on monocytes → causes them to fuse, form multinucleated osteoclast cells
  3. Osteoclasts secrete lysosomal enzymes (mostly collagenase) → digest collagen in bone matrix → create surface holes (Howship's lacunae), hydrochloric acid → dissolves hydroxyapatite into soluble calcium, phosphate
  4. Osteoblasts secrete osteoprotegerin → deactivates RANKL, slows down osteoclast activity (before osteoclast apoptosis), osteoid seam (mostly collagen) → fill in Howship's lacunae
  5. Calcium, phosphate deposit on seam forming hydroxyapatite
  6. Some osteoblasts get trapped within lacunae → turn into osteocytes

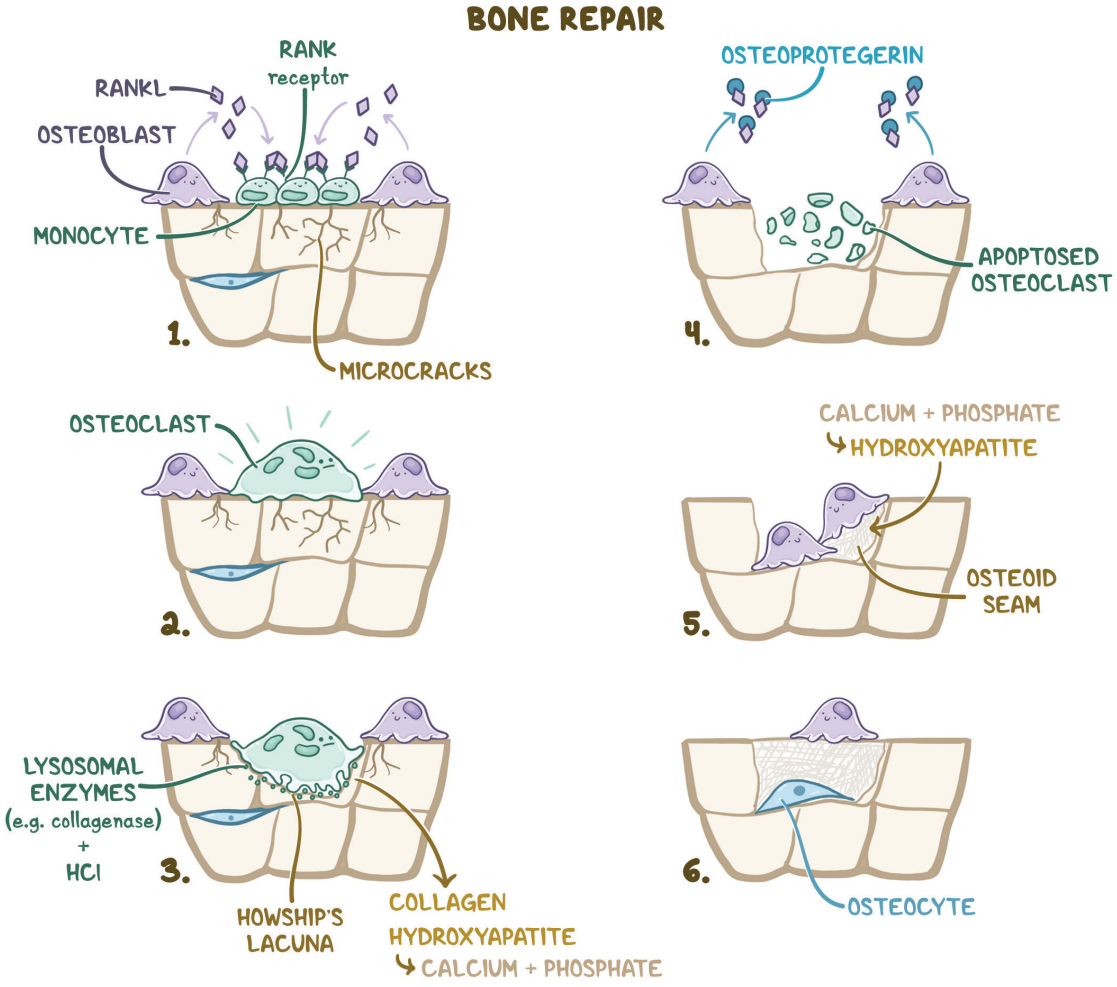

Figure 48.8 Summary of bone repair.

REMODELING FACTORS

- Hormonal
  - Parathyroid hormone enhances bone resorption
  - Calcitonin inhibits bone resorption
  - Vitamin D (→ ↓ calcitonin) enhances bone resorption
- Mechanical (physical stress)
  - *Wolff's law:* bones that bear more weight remodel more

FIBROUS, CARTILAGE, & SYNOVIAL JOINTS

osms.it/fibrous-cartilage-synovial-joints

TYPES

- Classification based on movement of three main groups
  - *Fibrous joints*: no movement
  - *Cartilaginous joints*: some movement
  - *Synovial joints*: freely movable

FIBROUS JOINTS

- Synarthrosis/fixed joints
- Bones are connected by ligaments

Three main categories (based on location)

- *Sutures*: junctions between adjacent skull bones; Sharpey's fibers connect bones; fixed (non-fused in babies → partially movable)
- *Gomphoses*: peg-and-socket joints for teeth; periodontal ligaments connect roots of teeth to sockets; slightly movable
- *Syndesmoses*: remaining fibrous joints; connected by interosseous membrane (e.g. between radius, ulna); slightly movable

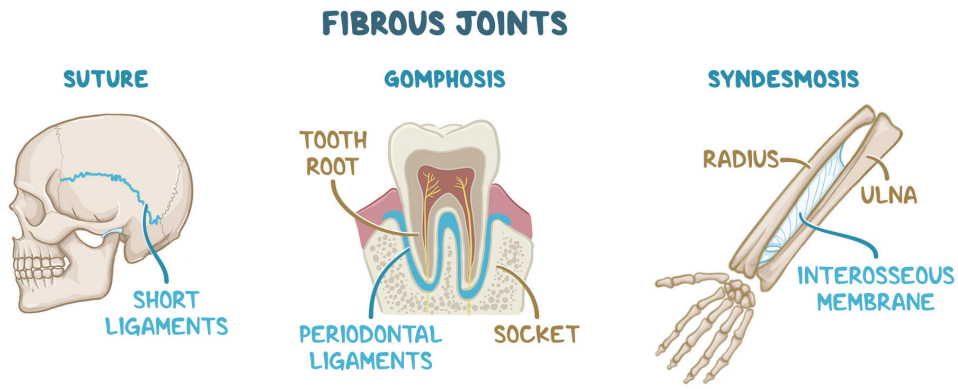

Figure 48.9 Three main categories of fibrous joints.

CARTILAGINOUS JOINTS

- Hyaline cartilage connects bones, stretches to allow some movement
- *Synchondrosis*: costochondral joint, where cartilage attaches rib to sternum; growth plates between bone diaphysis, epiphysis
- *Symphysis*: symphysis pubis in pelvic bone (fibrous cartilage)
  - ↑ strength, ↓ flexibility

SYNOVIAL JOINTS

- Joint capsule connects bones
  - Composed of outer fibrous capsule, inner synovial membrane
  - Filled with synovial fluid: lubricates joint, absorbs shock; made of hyaluronic acid, lubricin, proteinases, collagenases
  - Articular cartilage covers tips of bones (same function)
- Allow for abduction, adduction, rotation about axis

Six main categories (based on structure, movement)

- *Hinge joints*: allow movement only in one axis (e.g. between humerus, ulna)
- *Pivot joints*: allow for rotation (e.g. between head of radius, groove of ulna)
- *Plane (gliding) joints*: allow flat bones to glide across one another (e.g. in carpal, tarsal bones)
- *Ball and socket joints*: allow all movements (e.g. shoulder joint)
- *Condyloid (ellipsoid) joints*: allow most movements, but not rotation (e.g. metacarpophalangeal, metatarsophalangeal joints)
- *Saddle joints*: allow most movements, with limited rotation (e.g. carpometacarpal joint)

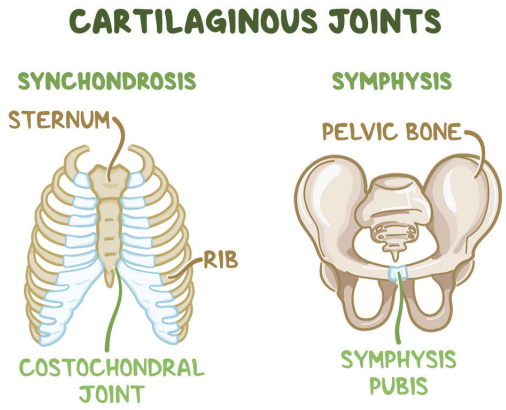

Figure 48.10 The two categories of cartilaginous joints (with examples).

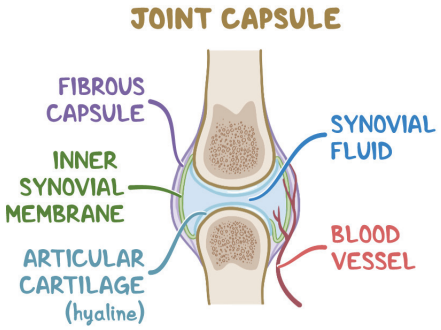

Figure 48.11 Synovial joint cross-section showing joint capsule.

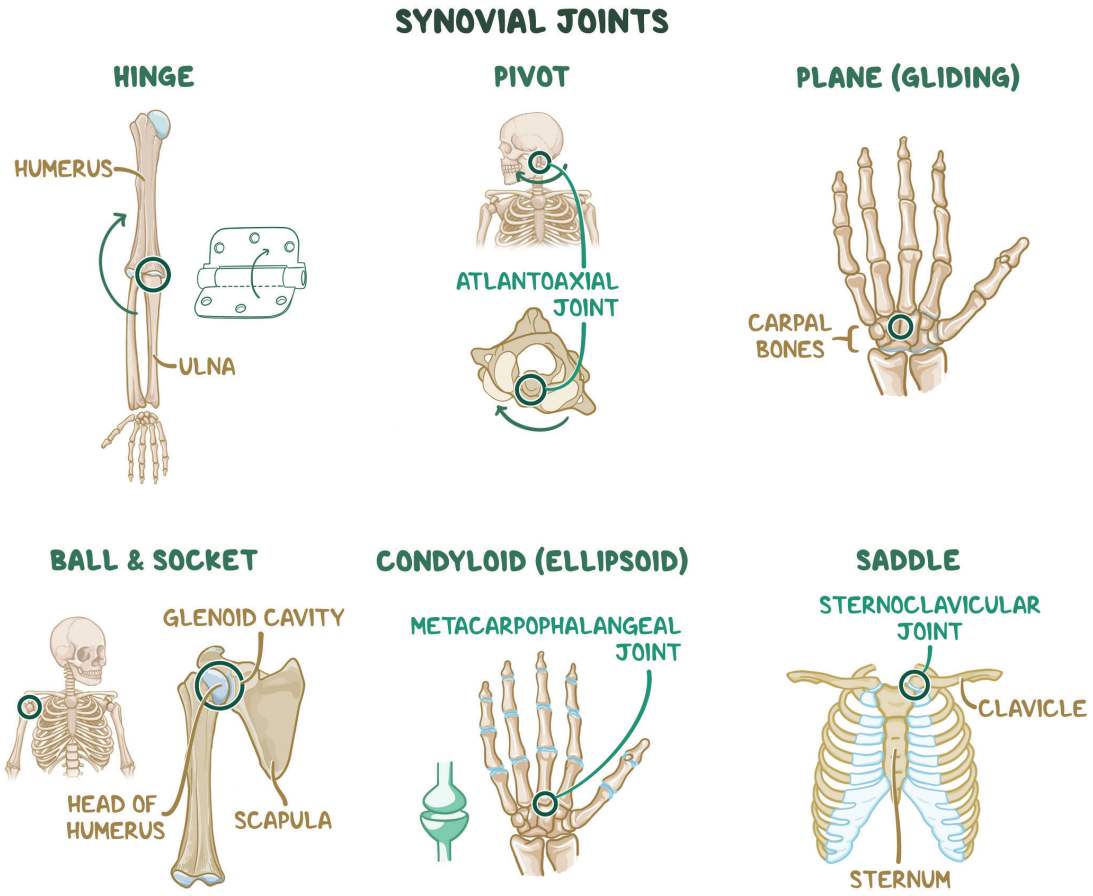

Figure 48.12 The six categories of synovial joints (with examples). Joints circled in green.