Chapter 7 - Skeletal System

7.1 Introduction

A. Bones contain a variety of very active tissues.
B. Each bone is made up of several types of tissues and thus is an organ.
C. Bone functions include: muscle attachment, protection and support, blood cell production, and storage of minerals.

7.2 Bone Structure

A. Bone Classification
   1. Bones differ in size and shape, yet are similar in several ways.
B. Parts of a Long Bone (Figs. 7.1-7.2)
   1. Expanded ends of bones that form joints with adjacent bones are called epiphyses.
   2. Articular cartilages (hyaline cartilage) cover the epiphyses.
   3. The shaft of the bone is the diaphysis.
   4. A tough layer of vascular connective tissue, called the periosteum, covers the bone and is continuous with ligaments and tendons.
   5. A bone's shape makes possible its function; bony processes or grooves indicate places of attachment for muscles.
   6. Compact bone makes up the wall of the diaphysis; the epiphyses are filled with spongy bone to reduce the weight of the skeleton.
   7. The diaphysis contains a hollow medullary cavity that is lined with endosteum and filled with marrow.
C. Microscopic Structure (Fig. 7.3)
   1. Bone cells (osteocytes) are located within lacunae that lie in concentric circles around osteonic canals.
   2. Osteocytes pass nutrients and gasses in the matrix through canaliculi.
   3. Intercellular material consists of collagen and inorganic salts.
   4. In compact bone, osteocytes and intercellular material are organized into osteons that are cemented together.
   5. Osteonic canals contain blood vessels and nerve fibers, and extend longitudinally through bone.
   6. Osteonic canals are interconnected by transverse perforating canals.
   7. Unlike compact bone, the osteocytes and intercellular material in spongy bone are not arranged around osteonic canals.

7.3 Bone Development and Growth

A. Bones form by replacing connective tissue in the fetus.
B. Some form within sheet like layers of connective tissue (intramembranous bones), while others replace masses of cartilage (endochondral bones).
C. Intramembranous Bones (Fig. 7.4)
   1. The flat bones of the skull form as intramembranous bones that develop from layers of connective tissue.
   2. Osteoblasts deposit bony tissue around themselves.
   3. When these cells are completely enclosed in the deposited bony tissue they are called osteocytes.
   4. Cells of the membranous connective tissue that lie outside the developing bone give rise to the periosteum.
D. Endochondral Bones (Figs. 7.5,7.6)
   1. Most of the bones of the skeleton fall into this category.
   2. They first develop as hyaline cartilage models and are then replaced with bone.

3. Cartilage is broken down in the diaphysis and progressively replaced with bone while the periosteum develops on the outside.
4. Cartilage tissue is invaded by blood vessels and osteoblasts that first form spongy bone at the primary ossification center in the diaphysis.
5. Osteoblasts beneath the periosteum lay down compact bone outside the spongy bone.
6. Secondary ossification centers appear later in the epiphyses.
7. A band of hyaline cartilage, the epiphyseal plate, forms between the two ossification centers.
8. Layers of cartilage cells undergoing mitosis make up the epiphyseal plate.
9. Osteoclasts break down the calcified matrix and are replaced with bone-building osteoblasts that deposit bone in place of calcified cartilage.
10. Epiphyseal plates are responsible for lengthening bones while increases in thickness are due to intramembranous ossification underneath the periosteum.
11. A medullary cavity forms in the region of the diaphysis due to the activity of osteoclasts.

E. Homeostasis of Bone Tissue
1. Osteoclasts tear down and osteoblasts build bone throughout the lifespan with the processes of resorption and deposition, with an average of 3% to 5% of bone calcium exchanged annually.

F. Factors Affecting Bone Development, Growth, and Repair
1. Some factors that influence bone development, growth and repair include nutrition, hormonal secretions, and physical exercise.

7.4 Bone Function

A. Support and Protection
1. Bones give shape to the head, thorax, and limbs.
2. Bones such as the pelvis and lower limbs provide support for the body.
3. Bones of the skull protect the brain, ears, and eyes.

B. Body Movement (Fig. 7.7 a,b)
1. Bones can act as levers.
   a. A lever has four components: a rigid bar, a pivot or fulcrum, an object that is moved against resistance, and a force that supplies energy.

C. Blood Cell Formation
1. Two kinds of marrow occupy the medullary cavities of bone.
   a. Red marrow functions in the formation of red blood cells, white blood cells, and platelets, and is found in the spongy bone of the skull, ribs, sternum, clavicles, vertebrae, and pelvis.
   b. Yellow marrow, occupying the cavities of most bones, stores fat.

D. Storage of Inorganic Salts (Fig 7.8)
1. The inorganic matrix of bone stores inorganic mineral salts in the form of calcium phosphate that is important in many metabolic processes.
2. Calcium in bone is a reservoir for body calcium; when blood levels are low, osteoclasts release calcium from bone.
3. Calcium is stored in bone under the influence of calcitonin when blood levels of calcium are high.
4. Bone also stores magnesium, sodium, potassium, and carbonate ions.
5. Bones can also accumulate harmful elements, such as lead, radium, and strontium.

7.5 Skeletal Organization (Fig. 7.9; Tables 7.1; 7.2)

A. The axial skeleton consists of the skull, hyoid bone, vertebral column (vertebrae and intervertebral discs), and thoracic cage (ribs and sternum).

B. The appendicular skeleton consists of the pectoral girdle (scapulae and clavicles), upper limbs (humerus, radius, ulna, carpals, metacarpals, and phalanges), pelvic girdle (coxal bones articulating with the sacrum), and lower limbs (femur, tibia, fibula, patella, tarsals, metatarsals, phalanges).

7.6 Skull (Fig. 7.10)

A. The skull is made up of 22 bones, including 8 cranial bones, 13 facial bones, and the mandible.

B. Cranium (Figs. 7.10-7.13)

1. The cranium encloses and protects the brain, provides attachments for muscles, and contains air-filled sinuses that reduce its weight.
2. Features of the frontal bone include supraorbital foramina and frontal sinuses.
3. Parietal bones lie at the sides of the skull and join at the sagittal suture.
4. Features of the occipital bone include the lambdoidal suture, foramen magnum, and occipital condyles.
5. Each temporal bone includes the squamosal suture, external auditory meatus, mandibular fossae, mastoid process, styloid process, and zygomatic process.
6. Features of the winged sphenoid bone include the sella turcica and sphenoidal sinuses.
7. Features of the ethmoid bone include the cribriform plates, a perpendicular plate, superior and middle nasal conchae, ethmoidal sinuses, and the crista galli.

C. Facial Skeleton (Figs. 7.11-7.15)

1. The 13 immovable facial bones and mandible form the basic face and provide attachments for muscles of mastication and expression.
2. The maxillae form the upper jaw, hard palate, floor of the orbits, sides of the nasal cavity, house the upper teeth, and contain large maxillary sinuses.
3. Palatine bones are L-shaped bones located behind the maxillae that form the floor of the nasal cavity and hard palate.
4. Zygomatic bones make up the cheekbones and join with the temporal bones to form the zygomatic arches.
5. The lacrimal bones form part of the medial walls of the orbits.
6. Nasal bones form the bridge of the nose.
7. The vomer bone makes up a portion of the nasal septum.
8. Inferior nasal conchae are fragile, scroll-shaped bones that support mucous membranes within the nasal cavity.
9. The mandible, or lower jawbone, supports the lower teeth and includes a mandibular condyle, coronoid process, and alveolar arch.

D. Infantile Skull (Fig. 7.16)

1. The infantile skull is incompletely developed and features fontanels, or soft spots to aid passage through the birth canal.
2. Other features include a small face with prominent forehead and large orbits.

7.7 Vertebral Column (Fig. 7.17)

A. The vertebral column, from skull to pelvis, forms the vertical axis of the skeleton.

B. It is composed of vertebrae separated by intervertebral disks.

C. A Typical Vertebra (Fig. 7.18)

1. A typical vertebra has a drum-shaped body that supports the weight of the

head and trunk.

2. Extending from the body are pedicels, laminae, a spinous process, and vertebral arch that surrounds the vertebral foramen.
3. Articulating surfaces include the superior articulating processes and inferior articulating processes; transverse processes provide points of attachment for muscles.
4. Intervertebral foramina provide passageways for spinal nerves.

D. Cervical Vertebrae (Fig. 7.17-7.19)

1. These seven bones are the smallest of the vertebrae that comprise the neck and support the head.
2. The first vertebra is the atlas, which appears as a bony ring and supports the head.
3. The second vertebra is the axis, with its toothlike dens that pivots within the atlas.
4. Features that separate cervical vertebrae from the rest are the bifid spinous processes and transverse foramina.

E. Thoracic Vertebrae (Figs. 7.17, 7.18b)

1. Twelve thoracic vertebrae articulate with the ribs.
2. These bones are larger and stronger than the cervical vertebrae.

F. Lumbar Vertebrae (Figs. 7.17, 7.18c)

1. The five massive lumbar vertebrae support the weight of the body.

G. Sacrum (Fig. 7.20)

1. The sacrum is a triangular structure at the base of the vertebral column made up of five vertebrae fused into one bone.
2. The spinous processes of these vertebrae fuse to form a ridge of tubercles that have dorsal sacral foramina along their sides.
3. On the ventral surface of the sacrum, four pairs of pelvic sacral foramina provide passageways for nerves and blood vessels.

H. Coccyx (Fig. 7.20

1. The coccyx is the lowermost portion of the vertebral column and is composed of four fused vertebrae.

7.8 Thoracic Cage (Fig. 7.21)

A. The thoracic cage includes the ribs, thoracic vertebrae, sternum, and costal cartilages.

B. It supports the pectoral girdle and upper limbs, functions in breathing, and protects thoracic and upper abdominal organs.

C. Ribs

1. Normally, there are 12 pairs of ribs that attach to the thoracic vertebrae.
2. The first seven pairs of ribs are true (or vertebrosternal) ribs that join the sternum directly by their costal cartilages.
3. The remaining five pairs are false ribs: the first three pairs are vertebrochondral ribs, and the last two pairs are floating ribs.
4. Features of a typical rib include a shaft, costal groove, anterior (sternal) end, head, neck, and tubercle.
    a. The head articulates with the vertebrae; the tubercle articulates with the transverse process of the thoracic vertebrae.

D. Sternum (Fig 7.21)

1. The sternum (breastbone) is located along the anterior midline of the thoracic cage.
2. It consists of an upper manubrium, middle body, and lower xiphoid process.

7.9 Pectoral Girdle (Figs. 7.22-7.23)

A. The pectoral girdle makes an incomplete ring that supports the upper limbs.
B. It is made up of two scapulae and two clavicles.
C. Clavicles (Fig. 7.22)
    1. The clavicles are elongated S-shaped bones located at the base of the neck that function to brace the scapulae.
D. Scapulae (Figs. 7.22, 7.23)
    1. The scapulae are flat, triangular bones on either side of the upper back.
    2. A spine divides the scapula into unequal portions.
    3. The spine leads to the acromion process (articulates with clavicle) and coracoid process (provides attachments for limb and chest muscles).
    4. The glenoid cavity articulates with the head of the humerus.

7.10 Upper Limb

A. Bones of the upper limb form the framework for the arm, forearm, and hand.
B. Humerus (Fig. 7.24)
    1. The humerus makes up the upper arm, extending from the scapula to the elbow.
    2. It articulates with the scapulae at its head, with the radius at the capitulum, and with the ulna at the trochlea.
    3. Other features of the humerus include the greater and lesser tubercles, intertubercular groove, anatomical and surgical necks, deltoid tuberosity, epicondyles, coronoid fossa, and olecranon fossa.
C. Radius (Fig. 7.25)
    1. The radius is located on the thumb side of the forearm, extending from the elbow to the wrist.
    2. The flattened head of the radius pivots with the humerus.
    3. Other features of the radius include the radial tuberosity and styloid process.
D. Ulna (Fig. 7.25)
    1. The ulna is the longer of the two bones making up the forearm and has a trochlear notch that articulates with the humerus.
    2. Other features of the ulna include the olecranon process, coronoid process, radial notch, head of the ulna, and styloid process.
E. Hand (Fig. 7.26)
    1. The wrist of the hand is made up of eight carpal bones bound into a carpus.
    2. The framework of the hand is made up of five metacarpal bones.
    3. The fingers are composed of three phalanges in each finger except the thumb, which lacks the middle phalanx.

7.11 Pelvic Girdle (Fig. 7.27)

A. The pelvic girdle consists of the two coxal bones and the sacrum; it supports the trunk of the body on the lower limbs.
B. The pelvic girdle supports and protects the lower abdominal and pelvic organs.
C. Each hip bone (Fig. 7.28) is made up of three bones: iilium, ischium, and pubis, that are fused in the region of the acetabulum, the cuplike depression that articulates with the head of the femur.
D. The ilium is the largest and most superior portion of the coxal bone and joins the sacrum at the sacroiliac joint.
    1. Features of the ilium include the iliac crest, and anterior superior iliac spine.
E. The ischium forms the L-shaped portion that supports weight during sitting.
    1. Features of the ischium include the ischial tuberosity and ischial spine.
F. The pubis comprises the anterior portion of the coxal bones and articulates at the

pubic symphysis .

1. The large opening, the obturator foramen (Fig. 7.28) lies within each pubis.

G. The greater pelvis is above the pelvic brim and the lesser pelvis is below it.

H. Structural differences between males and female pelves can be found in Table 7.3.

7.12 Lower Limb (Figs. 7.30, 7.31)

A. The bones of the lower limb provide the framework for the thigh, lower leg, and foot.

B. Femur (Fig. 7.30)

1. The femur, or thighbone, extends from the hip to the knee and is the longest bone in the body.
2. Its head articulates with the acetabulum; it articulates with the tibia at the medial and lateral condyles.
3. Other features of the femur include the fovea capitis, neck, and greater and lesser trochanters.
4. The patella (kneecap) is located in the tendon that passes over the knee.

C. Tibia (Fig. 7.31)

1. The tibia (shinbone) supports the weight of the body and articulates with the femur (medial and lateral condyles) and with the tarsal bones of the foot.
2. Its anterior tibial tuberosity is the point of attachment for the patellar ligament.
3. Other features of the tibia include the medial malleolus (inner ankle).

D. Fibula (Fig. 7.31)

1. The fibula is a slender bone lying lateral to the tibia; it does not bear body weight.
2. The lateral malleolus forms the lateral ankle.

E. Foot (Figs. 7.32-7.33)

1. The ankle is composed of seven tarsal bones, forming a tarsus.
   a. The talus articulates with the tibia and fibula.
   b. The calcaneus supports the body weight.
2. The instep of the foot consists of five metatarsal bones and provides an arch.
3. Each toe is made up of three phalanges, with the exception of the great toe, which lacks a middle phalanx.

7.13 Joints (Table 7.4)

A. Joints (articulations) are the functional junctions between bones.

B. Joints enable a wide variety of body movements.

C. Joints can be classified according to the degree of movement possible and can be immovable, slightly movable, or freely movable.

D. Joints can also classified according to the type of tissue that binds them together.

E. Fibrous Joints (Fig. 7.34)

1. Fibrous joints are held close together by dense connective tissue and are immovable (sutures of skull) or only slightly movable (joint between the distal tibia and fibula).

F. Cartilaginous Joints

1. Hyaline cartilage or disks of fibrocartilage unite the bones in cartilaginous joints.
2. Intervertebral disks between vertebrae help absorb shock and are slightly movable.
3. Other examples of cartilaginous joints include the symphysis pubis and the first rib with the sternum.

G. Synovial Joints (Figs. 7.35-7.36)

1. Most joints of the skeleton are synovial joints, which are more complex than fibrous or cartilaginous joints.
2. The articular ends of bone in a synovial joint are covered with hyaline cartilage.
3. A joint capsule consists of an outer layer of dense connective tissue that joins the periosteum, and an inner layer made up of synovial membrane.
    a. Synovial fluid has the consistency of egg whites and lubricates articulating surfaces within the joint.
4. Some synovial joints contain shock-absorbing pads of fibrocartilage called menisci.
5. Some synovial joints have fluid-filled sacs called bursae. (Fig. 7.36)
6. Based on the shapes of their parts and the movements they permit, synovial joints can be classified as follows:
    a. A ball-and-socket joint (Figs. 7.37a) consists of a bone with a globular or egg-shaped head articulating with the cup-shaped cavity of another bone; a very wide range of motion is possible; examples include the hip and shoulder joint.
    b. A condylar joint consists of an ovoid condyle fitting into an elliptical cavity, permitting a variety of motions; an example is the joint between a metacarpal and a phalange. (Fig. 7.37b)
    c. Gliding joints occur where articulating surfaces are nearly flat or slightly curved, allowing a back-and-forth motion; the joints of the wrist and ankle, as well as those between vertebrae, are gliding joints. (Fig. 7.37c)
    d. In a hinge joint (Fig. 7.37d), a convex surface fits into a concave surface, as is found in the elbow and phalange joints; movement is in one plane only.
    e. In a pivot joint, a cylindrical surface rotates within a ring of bone and fibrous tissue; examples include the joint between the proximal ends of the radius and ulna. (Fig. 7.37e)
    f. A saddle joint forms where articulating surfaces have both concave and convex areas, permitting a wide range of movements; the joint between the trapezium and the metacarpal of the thumb is of this type. (fig 7.37f)

H. Types of Joint Movements (Figs. 7.38-7.40)

1. When a muscle contracts, its fibers pull its movable end (insertion) toward its stationary end (origin), causing movement at a joint.
2. These terms describe movements that occur at joints: flexion, extension, dorsiflexion, plantar flexion, hyperextension, abduction, adduction, rotation, circumduction, pronation, supination, eversion, inversion, retraction, protraction, elevation, and depression.