Introduction to Skeletal Tissues

I. Skeletal Cartilages (p. 176; Marieb Fig. 6.1)

A. Basic Structure, Types, and Locations (p. 176; Marieb Fig. 6.1)
   1. Skeletal cartilages are made from cartilage, surrounded by a layer of dense irregular connective tissue called the perichondrium.
   2. Hyaline cartilage is the most abundant skeletal cartilage, and includes the articular, costal, respiratory, and nasal cartilages.
   3. Elastic cartilages are more flexible than hyaline, and are located only in the external ear and the epiglottis of the larynx.
   4. Fibrocartilage is located in areas that must withstand a great deal of pressure or stretch, such as the cartilages of the knee and the intervertebral discs.

B. Growth of Cartilage (p. 176)
   1. Appositional growth results in outward expansion due to the production of cartilage matrix on the outside of the tissue.
   2. Interstitial growth results in expansion from within the cartilage matrix due to division of lacunae-bound chondrocytes and secretion of matrix.

II. Classification of Bones (pp. 176-178; Marieb Figs. 6.1-6.2)

A. There are two main divisions of the bones of the skeleton: the axial skeleton, consisting of the skull, vertebral column, and rib cage; and the appendicular skeleton, consisting of the bones of the upper and lower limbs, and the girdles that attach them to the axial skeleton (pp. 176-177; Marieb Fig. 6.1).

B. Shape (pp. 177-178; Marieb Fig. 6.2)
   1. Long bones are longer than they are wide, have a definite shaft and two ends, and consist of all limb bones except patellas, carpals, and tarsals.
   2. Short bones are somewhat cube-shaped and include the carpals and tarsals.
   3. Flat bones are thin, flattened, often curved bones that include most skull bones, the sternum, scapulae, and ribs.
   4. Irregular bones have complicated shapes that do not fit in any other class, such as the vertebrae and coxae.

III. Functions of Bones (pp. 178-179)

A. Bones support the body and cradle the soft organs, protect vital organs, allow movement, store minerals such as calcium and phosphate, and house hematopoietic tissue in specific marrow cavities.

IV. Bone Structure (pp. 179-184; Marieb Figs. 6.3-6.6; Marieb Table 6.1)

A. Gross Anatomy (pp. 179-181; Marieb Fig. 6.3, 6.4; Marieb Table 6.1)
   1. Bone markings are projections, depressions, and openings found on the surface of bones that function as sites of muscle, ligament, and tendon attachment, as joint surfaces, and as openings for the passage of blood vessels and nerves. (Different types of markings are not covered in lecture.)
   2. Bone Textures: Compact and Spongy Bone
      a. All bone has a dense outer layer consisting of compact bone that appears smooth and solid.
      b. Internal to compact bone is spongy bone, which consists of honeycomb, needle-like, or flat pieces, called trabeculae.

3. Structure of a Typical Long Bone
    a. Long bones have a tubular bone shaft, consisting of a bone collar surrounding a hollow medullary cavity, which is filled with yellow bone marrow in adults.
    b. Epiphyses are at the ends of the bone, and consist of internal spongy bone covered by an outer layer of compact bone.
    c. The epiphyseal line is located between the epiphyses and diaphysis, and is a remnant of the epiphyseal plate.
    d. The external surface of the bone is covered by the periosteum. (Two layers: fibrous layer, composed of connective tissue, and the osteogenic layer, composed of osteoblasts and osteoclasts).
    e. The internal surface of the bone is lined by a connective tissue membrane called the endosteum.
4. Structure of Short, Flat, and Irregular Bones
    a. Short, flat, and irregular bones consist of thin plates of periosteum-covered compact bone on the outside, and endosteum-covered spongy bone inside, which houses bone marrow between the trabeculae.
5. Location of Hematopoietic Tissue in Bones
    a. Hematopoietic tissue of bones, red bone marrow, is located within the trabecular cavities of the spongy bone in flat bones, and in the epiphyses of long bones.
    b. Red bone marrow is found in all flat bones, epiphyses, and medullary cavities of infants, but in adults, distribution is restricted to flat bones and the proximal epiphyses of the humerus and femur.

B. Microscopic Anatomy of Bone (pp. 181-182; Marieb Figs. 6.5, 6.6)
1. The structural unit of compact bone is the osteon, which consists of concentric tubes of bone matrix (the lamellae) surrounding a central Haversian canal that serves as a passageway for blood vessels and nerves.
    a. Volkmann's canals lie at right angles to the long axis of the bone, and connect the blood and nerve supply of the periosteum to that of the central canals and medullary cavity.
    b. Osteocytes occupy lacunae at the junctions of the lamellae, and are connected to each other and the central canal via a series of hair-like channels, canaliculi.
2. Spongy bone lacks osteons but has trabeculae that align along lines of stress, which contain irregular lamellae.

C. Chemical Composition of Bone (pp. 182-184)
1. Organic components of bone include cells (osteoblasts, osteocytes, and osteoclasts) and osteoid (ground substance and collagen fibers), which contribute to the flexibility and tensile strength of bone.
2. Inorganic components make up 65% of bone by mass, and consist of hydroxyapatite, a mineral salt that is largely calcium phosphate, which accounts for the hardness and compression resistance of bone.

V. Bone Development (pp. 184-187; Marieb Figs. 6.7-6.10)

A. Formation of the Bony Skeleton (pp. 184-186; Marieb Figs. 6.7, 6.8)
1. Intramembranous ossification forms membrane bone from fibrous connective tissue membranes, and results in the cranial bones and clavicles.
2. In endochondral ossification bone tissue replaces hyaline cartilage, forming all bones below the skull except for the clavicles.
    a. Initially, osteoblasts secrete osteoid, creating a bone collar around the diaphysis of the hyaline cartilage model.
    b. Cartilage in the center of the diaphysis calcifies and deteriorates, forming cavities.
    c. The periosteal bud invades the internal cavities and spongy bone forms around the remaining fragments of hyaline cartilage.

   d. The diaphysis elongates as the cartilage in the epiphyses continues to lengthen and a medullary cavity forms through the action of osteoclasts within the center of the diaphysis.
   e. The epiphyses ossify shortly after birth through the development of secondary ossification centers.

B. Postnatal Bone Growth (pp. 186-187; Marieb Figs. 6.9-6.10)
   1. Growth in length of long bones occurs at the ossification zone through the rapid division of the upper cells in the columns of chondrocytes, calcification and deterioration of cartilage at the bottom of the columns, and subsequent replacement by bone tissue.
   2. Growth in width, or thickness, occurs through appositional growth due to deposition of bone matrix by osteoblasts beneath the periosteum.
   3. Hormonal Regulation of Bone Growth
      a. During infancy and childhood, the most important stimulus of epiphyseal plate activity is growth hormone from the anterior pituitary, whose effects are modulated by thyroid hormone.
      b. At puberty, testosterone and estrogen promote a growth spurt, but ultimately induct the closure of the epiphyseal plate.

VI. Bone Homeostasis: Remodeling and Repair (pp. 187-193; Marieb Figs. 6.10-6.13; Marieb Table 6.2)

A. Bone Remodeling (pp. 188-190; Marieb Figs. 6.10-6.12)
   1. In adult skeletons, bone remodeling is balanced bone deposit and removal, bone deposit occurs at a greater rate when bone is injured, and bone resorption allows minerals of degraded bone matrix to move into the blood.
      a. Bone deposition is accomplished by osteoblasts (immature bone cells).
      b. When osteoblasts become trapped within the matrix, they are called osteocytes.
      c. Bone resorption is accomplished by osteoclasts, modified macrophages that are descendents of immune system cells. They are not related (in a "family" sense) to osteoblasts and osteocytes (which are developmentally related to each other).
   2. Control of Remodeling
      a. The hormonal mechanism is mostly used to maintain blood calcium homeostasis, and balances activity of parathyroid hormone and calcitonin.
      b. In response to mechanical stress and gravity, bone grows or remodels in ways that allow it to withstand the stresses it experiences.

B. Bone Repair (pp. 190-193; Marieb Fig. 6.13; Marieb Table 6.2)
   1. Fractures are breaks in bones, and are classified by: the position of the bone ends after fracture, completeness of break, orientation of the break relative to the long axis of the bone, and whether the bone ends penetrate the skin.
   2. Repair of fractures involves four major stages: hematoma formation, fibrocartilaginous callus formation, bony callus formation, and remodeling of the bony callus.

The Axial Skeleton (selections)

I. The Skull (pp. 203-218; Marieb Figs. 7.1-7.12; Marieb Table 7.1)

A. The skull consists of 22 cranial and facial bones that form the framework of the face, contain cavities for special sense organs, provide openings for air and food passage, secure the teeth, and anchor muscles of facial expression (p. 203).

B. Except for the mandible, which is joined to the skull by a movable joint, most skull bones are flat bones joined by interlocking joints called sutures (p. 203).

C. Overview of Skull Geography (p. 203)

1. The anterior aspect of the skull is formed by facial bones, and the remainder is formed by a cranium, which is divided into the cranial vault, or calvaria, and cranial base.
2. The cavities of the skull include the cranial cavity (houses the brain), ear cavities, nasal cavity, and orbits (house the eyeballs).

D. The cranium consists of eight strong, superiorly curved bones (pp. 203-211; Marieb Figs. 7.2-7.7).

1. The frontal bone articulates posteriorly with the parietal bones via the coronal suture and extends posteriorly to form the superior wall of the orbits and most of the anterior cranial fossa.
2. The parietal bones are two large, rectangular bones on the superior and lateral aspects of the skull, which form the majority of the cranial vault.
   a. The four largest sutures of the skull are located where the parietal bones articulate with other bones: the coronal, sagittal, lambdoid, and squamous sutures.
3. The occipital bone articulates with the parietal, temporal, and sphenoid bones, forming most of the posterior wall and base of the skull.
   a. The foramen magnum, a large opening through which the brain connects to the spinal cord, is located in the base of the occipital bone.
4. The temporal bones articulate with the parietal bones and form the inferolateral aspects of the skull and parts of the cranial floor.
   a. The temporal bone is characterized by the external auditory meatus and petrous region, which house the ear.
5. The sphenoid bone spans the width of the middle cranial fossa, and articulates with all other cranial bones.
6. The ethmoid bone lies between the sphenoid and nasal bones, and forms most of the bony area between the nasal cavity and the orbits.
7. Sutural bones are groups of irregularly shaped bones or bone clusters located within sutures that vary in number and are not present on all skulls. Formation of sutural bones is due to multiple ossification centers that form during intramembranous ossification.

II. The Vertebral Column (pp. 218-226; Marieb Figs. 7.13-7.18; Marieb Table 7.2)

A. General Characteristics (pp. 218-221; Marieb Figs. 7.13-7.14)

1. The vertebral column consists of 26 irregular bones, forming a flexible, curved structure extending from the skull to the pelvis that surrounds and protects the spinal cord. It provides attachment for ribs and muscles of the neck and back.
2. Divisions and Curvatures

a. The vertebrae of the spine fall in five major divisions: seven cervical, twelve thoracic, five lumbar, five fused vertebrae of the sacrum, and four fused vertebrae of the coccyx.
b. The curvatures of the spine increase resiliency and flexibility of the spine.
c. The cervical and lumbar curvatures are concave posteriorly, and the thoracic and sacral curvatures are convex posteriorly.

3. The major supporting ligaments of the spine are the anterior and posterior longitudinal ligaments, which run as continuous bands down the front and back surfaces of the spine. They support the spine and prevent hyperflexion and hyperextension.
4. Intervertebral discs are cushionlike pads of fibrocartilage (covered with articular cartilage) that act as shock absorbers and allow the spine to flex, extend, and bend laterally.

B. General Structure of Vertebrae (p. 221; Marieb Fig. 7.15)

1. Each vertebra consists of an anterior body and a posterior vertebral arch that, together with the body, form the vertebral foramen through which the spinal cord passes.
2. The vertebral arch gives rise to several projections: a median spinous process, two lateral transverse processes, and paired superior and inferior articular processes.

C. Regional Vertebral Characteristics (pp. 221-225; Marieb Figs. 7.16-7.18; Marieb Table 7.2)

1. Cervical vertebrae are the smallest vertebrae. They typically have an oval body, a short, bifid spinous process, a large, triangular vertebral foramen, and a transverse foramen.
   a. The atlas has no body or spinous process. It has articular facets on the superior and inferior surface that articulate with the skull superiorly, and the second cervical vertebra, the axis, inferiorly.
   b. The second cervical vertebra has a body, spine, and other typical vertebral processes, as well as a knoblike dens projecting superiorly from the body.
   c. When the atlas and axis are viewed in place (*i.e.*, articulated with each other), the dens on the axis serves as the atlas's missing body.
2. Thoracic vertebrae all articulate with ribs, and gradually transition between cervical structure at the top, and lumbar structure toward the bottom.
   a. Thoracic vertebrae have a roughly heart-shaped body, which bear two facets on each side for rib articulation: a circular vertebral foramen and superior and inferior articular processes.
3. Lumbar vertebrae are large vertebrae that have kidney-shaped bodies, a triangular vertebral foramen, short, thick pedicles and laminae, and short, flat, hatchet-shaped spinous processes.
4. The sacrum forms the posterior wall of the pelvis. It is formed by five, fused vertebrae in adults, and articulates with the fifth lumbar vertebra superiorly, the coccyx inferiorly, and the hip bones laterally.
5. The coccyx (tailbone) is a small bone consisting of four, fused vertebrae that articulate superiorly with the sacrum.

III. The Thoracic Cage (pp. 226-228; Marieb Figs. 7.19-7.20)

A. The thoracic cage consists of the thoracic vertebrae dorsally, the ribs laterally, and the sternum and costal cartilages anteriorly. It forms a protective cage around the organs of the thoracic cavity, and provides support for the shoulder girdles and upper limbs (p. 226; Marieb Fig. 7.19).

B. Sternum (pp. 226-227; Marieb Fig. 7.19)

1. The sternum (breastbone) lies in the anterior midline of the thorax, and is a flat bone resulting from the fusion of three bones: the manubrium, body, and xiphoid process.

C. Ribs (pp. 227-228; Marieb Fig. 7.20)

1. The sides of the thoracic cage are formed by twelve pairs of ribs that attach posteriorly to the thoracic vertebrae and curve inferiorly toward the anterior body surface.
2. The superior seven pairs of ribs are called vertebrosternal ribs. They attach directly to the sternum via individual costal cartilages.
3. The lower five pairs of ribs either attach indirectly to the sternum (vertebrochondral ribs) or lack a sternal attachment entirely (vertebral ribs).

The Appendicular Skeleton (girdles only)

I. The Pectoral (Shoulder) Girdle (pp. 228-231; Marieb Figs. 7.21-7.22, 7.25; Marieb Table 7.3)

A. The pectoral (shoulder) girdle consists of the clavicle, which joins the sternum anteriorly, and the scapula, which is attached to the posterior thorax and vertebrae via muscular attachments (p. 229; Marieb Fig. 7.22).
   1. The pectoral girdles are very light and have a high degree of mobility due to the openness of the shoulder joint and the free movement of the scapula across the thorax.

B. The clavicles (collarbones) extend horizontally across the thorax, articulating medially with the sternum at their sternal ends, and laterally with the scapula at their acromial ends, bracing the arms and scapulae laterally (p. 229; Marieb Figs. 7.22, 7.25).

C. The scapulae (shoulder blades) are thin, flat bones that lie on the dorsal surface of the ribcage, articulating with the humerus via the glenoid cavity, and the clavicle via the acromion (pp. 229-231; Marieb Figs. 7.22, 7.25).

II. The Pelvic (Hip) Girdle (pp. 237-239; Marieb Figs. 7.27, 7.30; Marieb Tables 7.4-7.5)

A. The pelvic girdle attaches the lower limbs to the axial skeleton. It is formed by a pair of coxal (pelvic) bones, each consisting of three separate bones: the ischium, ilium, and pubis, that are fused in adults (p. 237).

B. The ilium forms the superior region of the coxal bone. It articulates with the sacrum, and also with the ischium and pubis anteriorly (p. 237).

C. The ischium forms the posteroinferior portion of the coxa (pp. 237-239).

D. The pubic bones form the anterior portion of the coxae. They are joined by a fibrocartilage disc, forming the midline pubic symphysis (p. 239).

E. Pelvic Structure and Childbearing (p. 239; Marieb Table 7.4)
   1. The female pelvis is modified for childbearing. It tends to be wider, shallower, lighter, and rounder than the male pelvis.

2. The pelvis consists of a false pelvis, which is part of the abdomen and helps support the viscera, and a true pelvis, which is completely surrounded by bone and contains the pelvic organs.

III. Developmental Aspects of the Skeleton (pp. 246-248; Marieb Figs. 7.33-7.35)

A. Curvatures of the Spine (p. 247).
   1. The primary curvatures (thoracic and sacral curvatures) are convex posteriorly and are present at birth.
   2. The secondary curvatures (cervical and lumbar curvatures) are convex anteriorly and are associated with the child's development.
   3. The secondary curvatures result from reshaping the intervertebral discs.