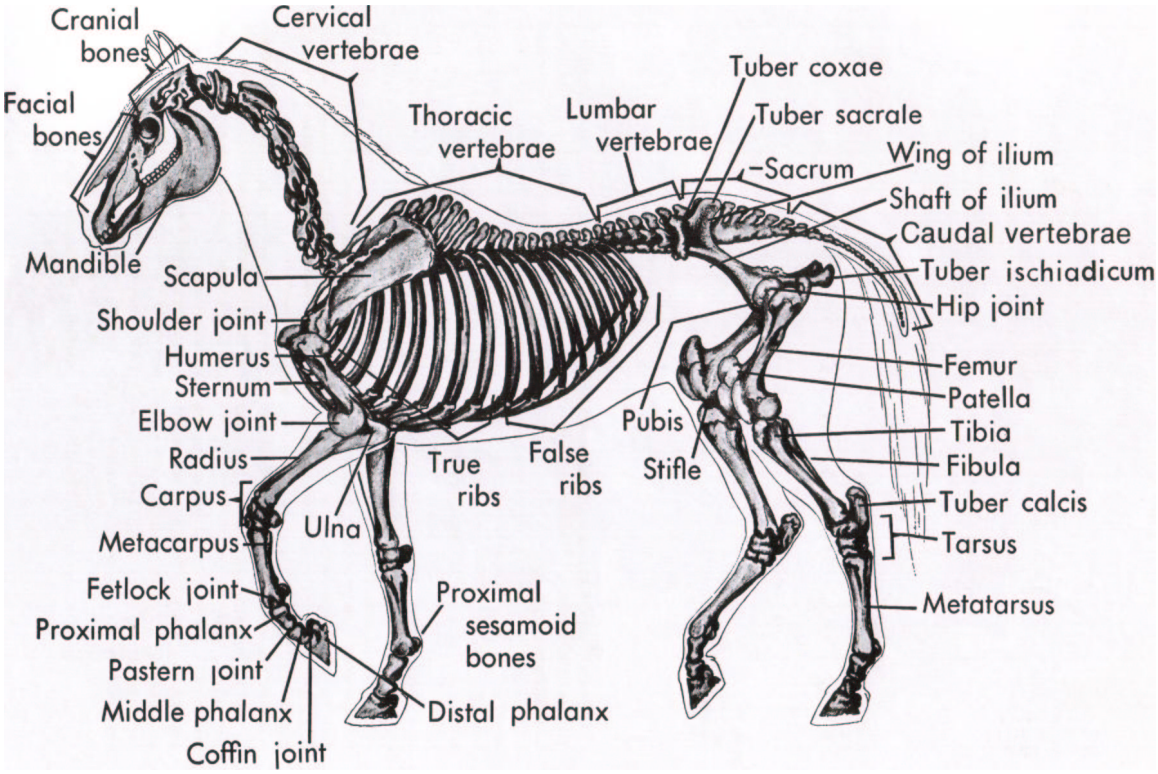
Skeletal System
ANS 215
Physiology and Anatomy of Domesticated Animals

I. Bones

A. Cellular structures whereby the extracellular fluid environment of the cell is surrounded by a rigid, calcified frame.
B. Framework of one bone, when combined with all the other bones of the body comprise the skeleton
C. Skeleton gives an identifiable form to an animal and provides protection for the cranial, thoracic, abdominal and pelvic viscera.
D. Medullary cavity of the bones is the principal location of blood formation.
E. Calcified regions of bone act as a "sink" and a "source" for many of the required minerals (cations and anions) of the body.
F. Because of attachment of muscles to bone many body parts can be moved.
G. Bones are dynamic structures that are capable of accommodating to different loads and stresses by remodeling.
H. Function can be restored to broken bones by the process of bone repair.

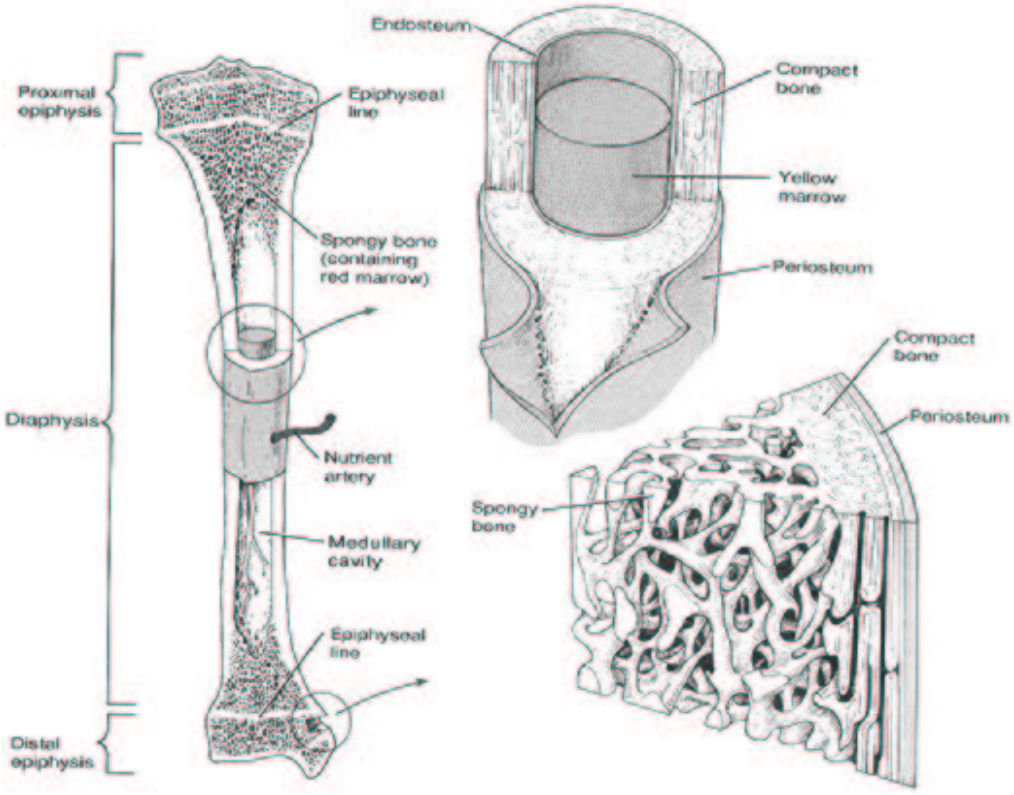
II. Structure and Function

A. Bones of the body are basically similar among animals, but vary according to size, shape, and number.
B. Bones of the skeleton are classified as belonging to either the axial skeleton or appendicular skeleton.
    1. Axial skeleton – lies on the long axis (midline) of the body
        a. skull
        b. vertebrae
        c. ribs
        d. sternum
    2. Appendicular skeleton is made up of the bones of the front (pectoral) and hind (pelvic) limbs as well as their respective pectoral girdle (shoulder) and pelvic girdle (pelvis).
        a. pectoral girdle
            i. scapula
            ii. clavicle
            iii. coracoid
        b. pelvic girdle
            i. ilium
            ii. ischium
            iii. pubis

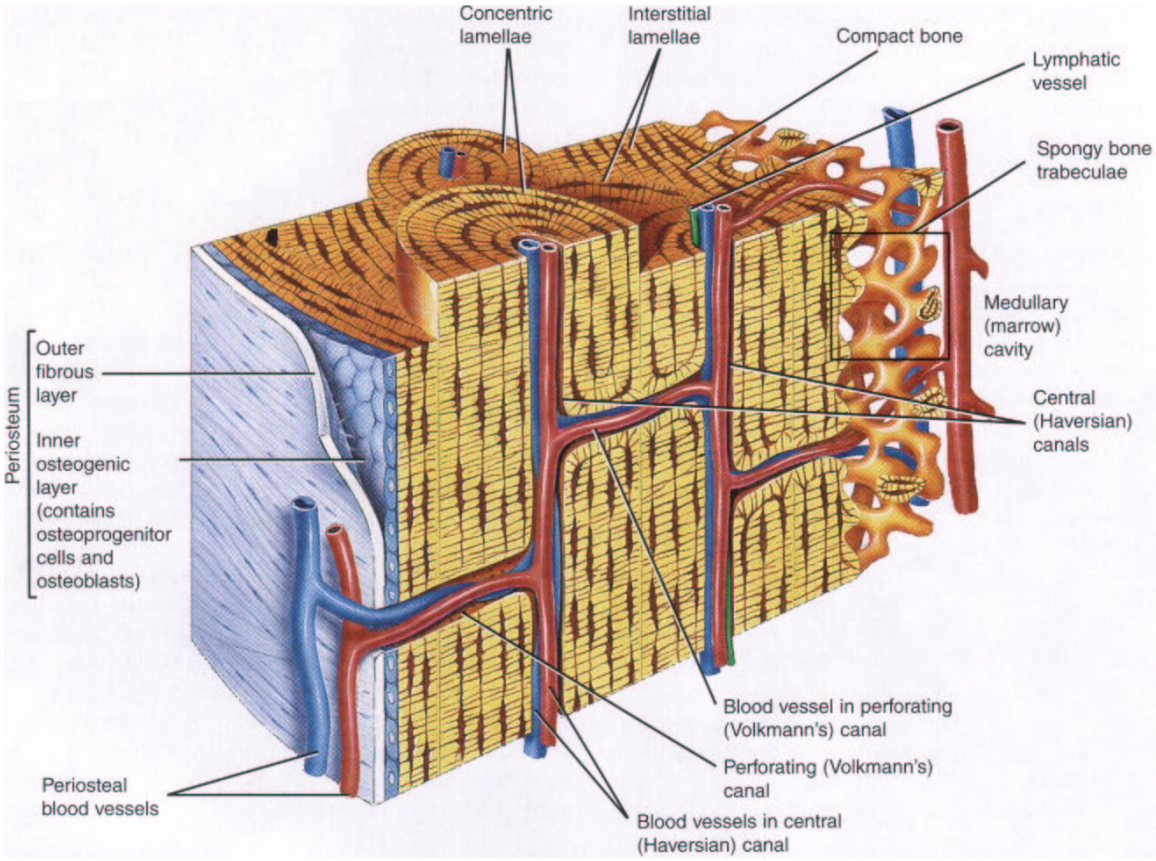


C. Long bones

1. Composed of compact bone and spongy bone.
2. Compact bone appears to be solid while spongy bone has the appearance of a sponge.
3. In spongy bone, there are trabecular (spicules) of mineralized tissue, and the empty spaces between the trabeculae are filled with bone marrow in living animals.
4. Rigidity and strength of long bones is not only due to the hardness of the compact bone, but also by the scaffolding arrangement of the trabeculae which are generally parallel to lines of stress and ace as pillars for stress points.



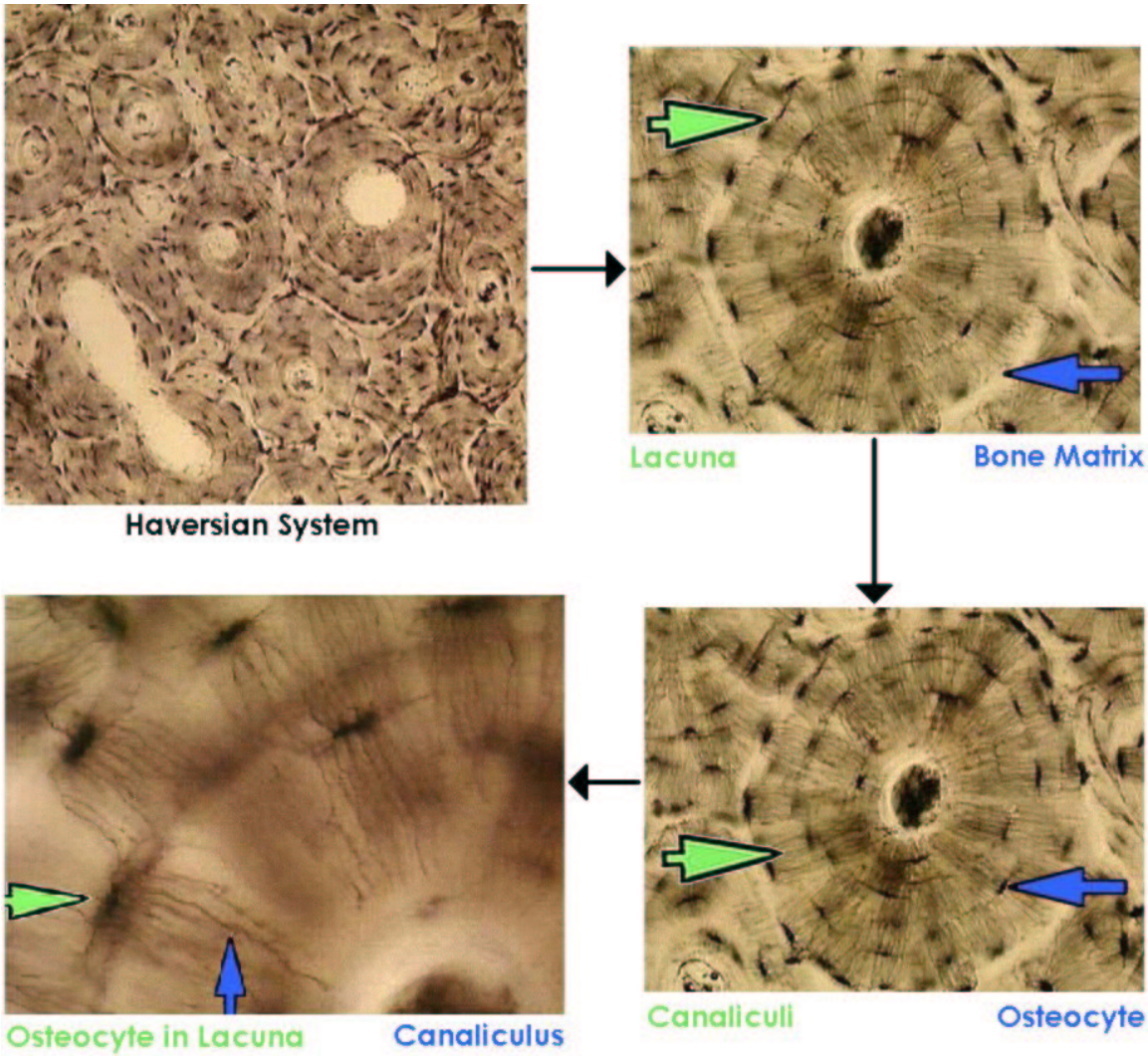
5. Epiphysis of a long bone is at either end of a long bone.
    a. consists chiefly of spongy bone with a thin outer layer of compact bone
    b. Epiphyseal plate (physis) is composed of hyaline cartilage and represents the point of growth in a longitudinal direction.
        i. Hyaline cartilage is normal type. Matrix is glassy-bluish white and somewhat translucent.
        ii. In mature animals, the cartilage has been replaced by bone and epiphyseal lines remain where the plate last existed.
6. Diaphysis is the cylindrical shaft of a long bone between either epiphysis.
    a. contains marrow (medullary) cavity surrounded by a thick wall of compact bone.
        i. Site of red blood cell production
7. Metaphysis is the expanded or flared part of the bone at the ends of the diaphysis.
8. The contact area of the bone that articulates with its neighboring bone at a moveable joint is covered with articular cartilage
9. With exception of the joint surfaces, all other outer surfaces of the bone are covered with periosteum.



10. Periosteum is composed of an outer fibrous layer and an inner cell-rich layer containing osteoblasts.
    a. osteoblasts synthesize and secrete the organic substance of bone
    b. osteoblasts participate in the mineralization of the organic matrix
11. Periosteum is responsible for the increase in diameter of bones and also functions in the healing of fractures.
12. Endosteum is the lining tissue of all surfaces of the bone that face the medullary cavity and also the trabeculae of the bone
    a. only 1 cell layer thick and the cells can become osteoblasts when stimulated
13. Channels that run parallel to the long axis of the bone are the Haversian canals, which contain blood vessels that communicate with blood vessels serving the external surfaces and marrow cavity.
    a. Volkmanns canals are perpendicular to the long axis of the bone and contain the blood vessels which communicate with vessels in the haversian canals.

D. Haversian System

1. The unit of structure of compact bone
    a. composed of central haversian canal surrounded by concentric layers of bone, the lamellae
2. Bone cells (osteocytes) are contained within small cavities known as lacunae (little lakes).
3. Osteocytes communicate with each other and with the haversian canal through a branching network of canals known as canaliculi.
4. Interstitial fluid for the osteocytes is contained within the lacunae and canaliculi. It diffuses through the canalicular network from the blood vessels in the canals for maintenance of the osteocytes.
5. Haversian systems are absent in spongy bone, but concentric lamellae with enclosed lacunae and osteocytes with intercommunicating canaliculi are present.



E. Bone Cells

1. Four different types of cells are associated with bone however they should all be considered as different functional states of the same cell type.
    a. osteoprogenitor cells
        i. Comprise the population of cells in the innermost layer of the periosteum, the endosteal lining cells of the marrow cavities, and the lining cells of the haversian canals and Volkman's canals.
    b. osteoblasts
        i. Differentiated bone forming cells responsible for the production of bone matrix. Its secretion of collagen and ground substance makes up the initial unmineralized bone or osteoid.
        ii. also associated with calcification of the matrix
    c. osteocytes
        i. mature bone cell and represents a transformed osteoblast. It is enclosed by the bone matrix that it had previously laid down.
        ii. Osteocytes maintain the bone matrix and are able to synthesize and resorb matrix to a limited extent
        iii. They extend their cytoplasmic processes through the canaliculi to contact by means of gap junctions similar to processes of neighboring cells.
    d. osteoclasts
        i. Large, motile, often multinucleated bone resorbing cells.
        ii. Their precursors are stem cells in blood producing tissue of bone, marrow and spleen.
            - stem cells differentiate into bone-resorbing monocytes and then fuse with others to form large multinucleated osteoclasts.
        iii. Considered to be members of the diffuse mononuclear phagocyte system

III. Composition of Bone

A. Adult bone is 25% water, 45% mineral, and 30% organic matter.
B. Calcium constitutes about 37% of the mineral content of bone.
C. Phosphorus accounts for 18% of the mineral content of bone.
D. Organic fraction of bone is about 90% collagen which is converted to gelatin when heated in an aqueous solution.

IV. Bone Formation

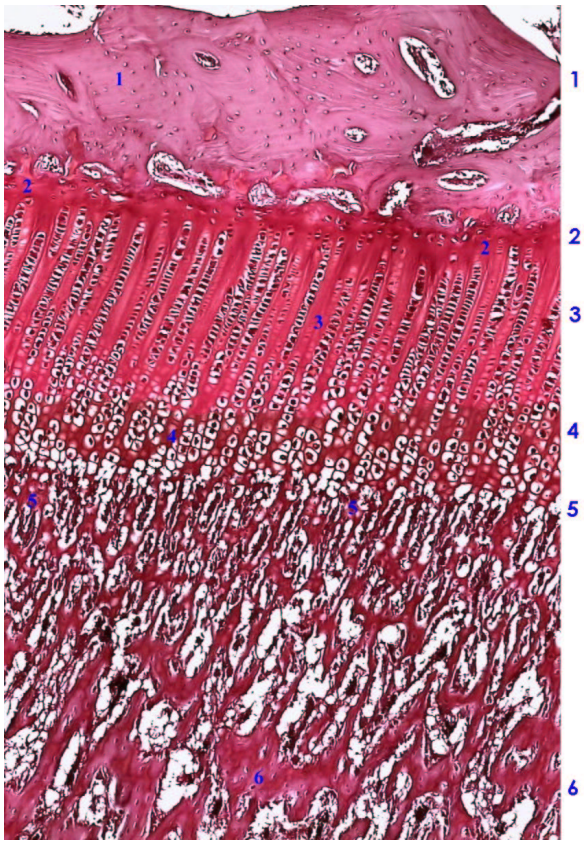
A. Classified according to the environment in which it is formed

1. heteroplastic
    a. formed in tissue other than skeleton
2. endochondral
    a. develops from cartilage, preformed in the fetus, but continues after birth from cartilage plates located between the metaphysis and epiphysis, and from the periosteum that surrounds the cortex
3. intramembranous
    a. formed without intervention of cartilage, These bones are preformed in a fibroid membrane which is then infiltrated with osteoid tissue that later becomes calcified.
        i. Flat bones of the skull
        ii. Mandible
        iii. Clavicle

B. Remodeling of bone
    1. Established on the preexisting bone
    2. Mechanism of remodeling is identical whether the original bone was formed by endochondral or intramembranous ossification.
    3. Sequence of actual bone formation during remodeling consists of osteoblasts laying down osteoid tissue, which is subsequently ossified

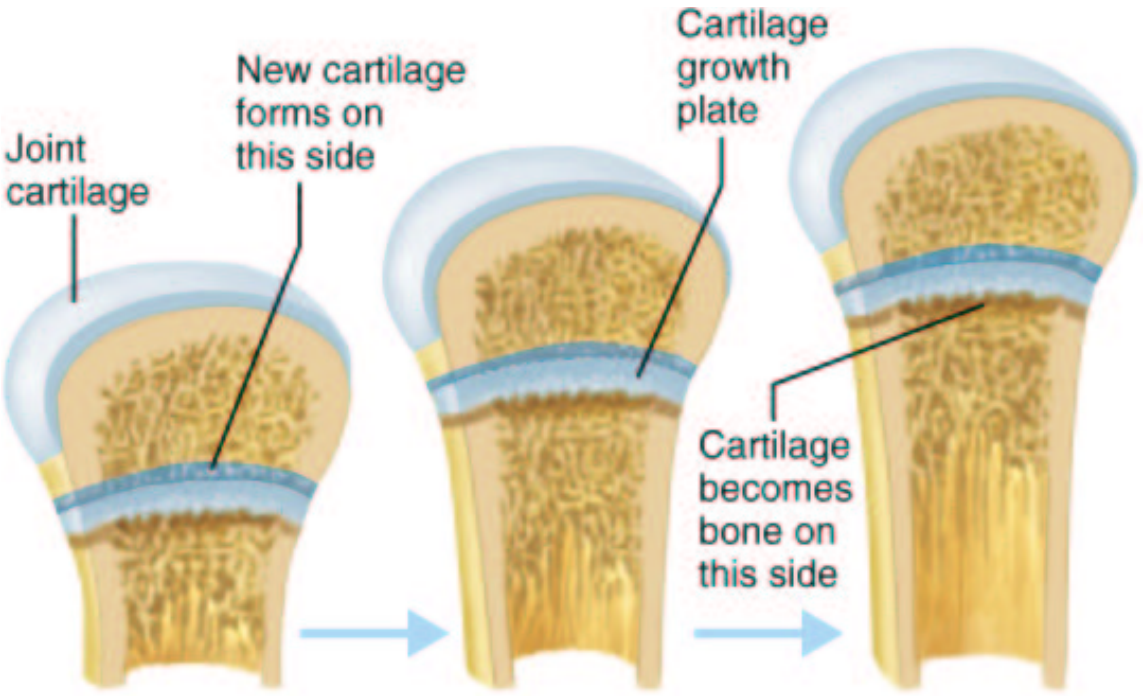
V. Growth of Long Bones After Birth

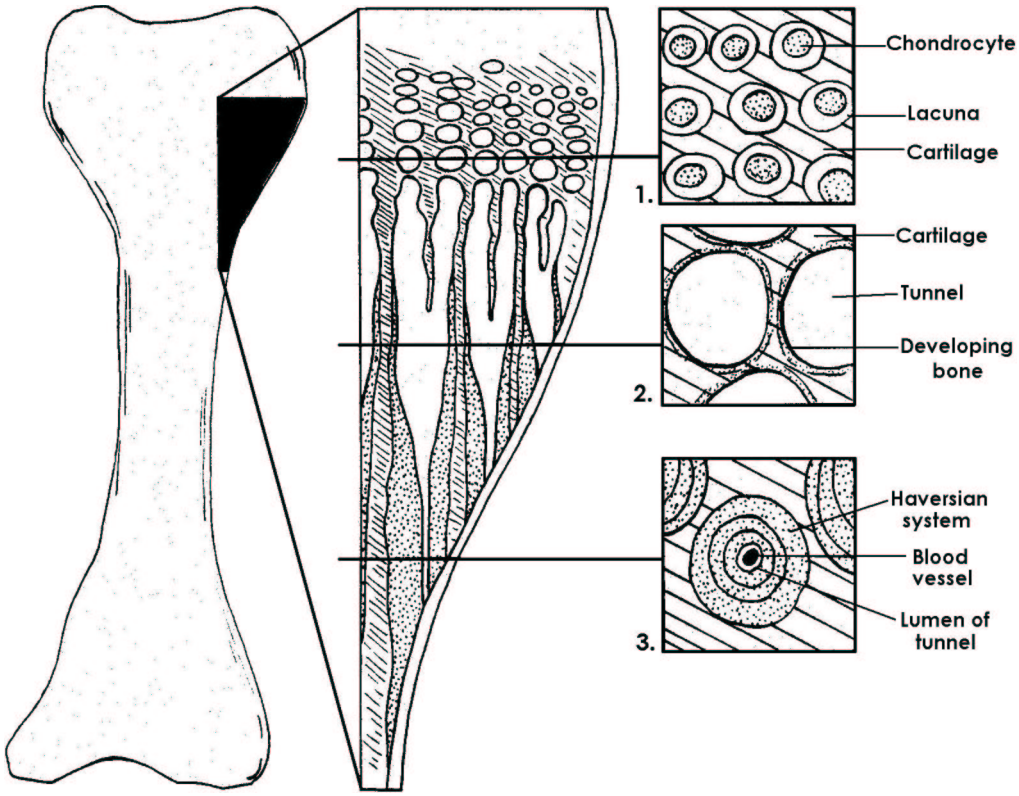
A. Increase in bone length depends on the presence of a cartilage plate (epiphyseal plate), wherein four zones are recognized which extend from the epiphysis to the diaphysis.
    1. Zone of reserve cartilage
    2. Proliferation
    3. Hypertrophy
    4. Calcified matrix



Endochondral Ossification:
1 – epiphyseal bone, 2 – zone of reserve cartilage, 3 – zone of proliferation, 4 – zone of hypertrophy, 5 – zone of calcification, 6 – zone of ossification

B. Beyond the zone of calcified matrix are the developing trabeculae that comprise the spongy bone of the metaphyses.
C. Cartilage does not have a blood supply and nutrition of the cartilage cells (chondrocytes) depends on diffusion of extracellular fluid from its source to the chondrocytes that lie with their lacunae.
D. Unlike osteocytes, chondrocytes are still able to divide after they have become embedded in cartilage matrix.
E. When chondrocytes from the zone of reserve cartilage undergo division, the chondrocytes become organized into distinct columns and a zone of proliferation is recognized that is directed towards the diaphysis.
F. Each division of cells brings about larger cells; thus the zone of hypertrophy.
    1. This has the effect of compressing the matrix into linear bands between the columns of hypertrophied cells.
G. After several divisions, the hypertrophied cells become further removed from the epiphyseal plate and become active in bringing about calcification of the cartilage matrix.
H. Calcification, coupled with increasing distance from the nutritional source causes the chondrocytes to die, and the matrix becomes the zone of calcified matrix.



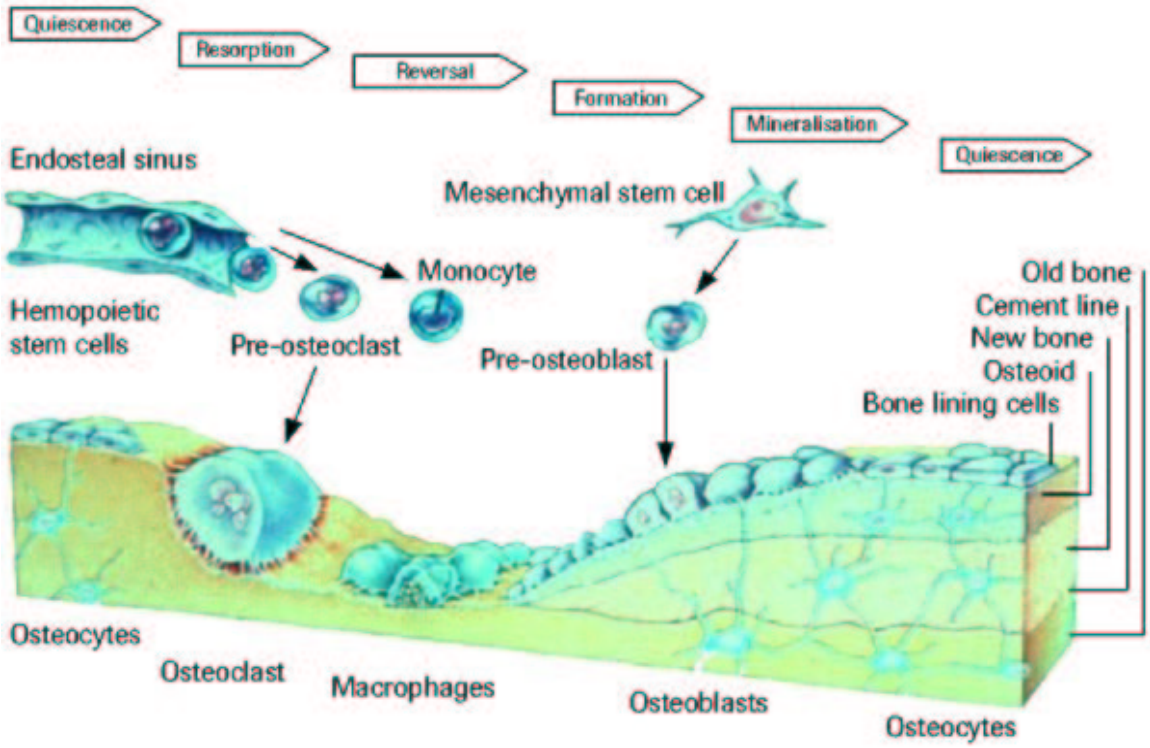


1 – Chondrocytes in their lacunae in the zone of hypertrophy.
2 – Tunnels formed in the zone of calcified matrix.
3 – Haversian system transforming tunnels into compact bone.

H. A cross section of this level would show tunnels that now exist where nests of hypertrophied cells previously occupied the space between linear bands of compressed cartilage matrix.
I. The tunnels are then invaded by capillaries from the diaphysis and then osteoblasts line up along the sides of the tunnels and deposit bone on their inner surface.
J. The osteoblasts continue to divide whereby each division of osteoblasts pushes the original osteoblast layer closer to the capillary in the center.
K. Concentric lamellae of bone substance are thus established with osteocytes occupying lacunae and canaliculi.
L. After several layers of bone (concentric lamellae) have been deposited, the tunnel is reduced to a narrow canal, which contains a blood vessel, some osteoblasts or osteogenic cells, and perhaps a lymphatic
    1. This is the haversian system
M. While a long bone is growing in length, it is also growing in width. New layers are being added to the outside of the shaft at the same time bone is dissolved away from the inside of the shaft.
    1. Shaft of bone becomes wider but not thicker
    2. Bone formed from the periosteum and endosteum accounts for the outer and inner circumferential lamellae

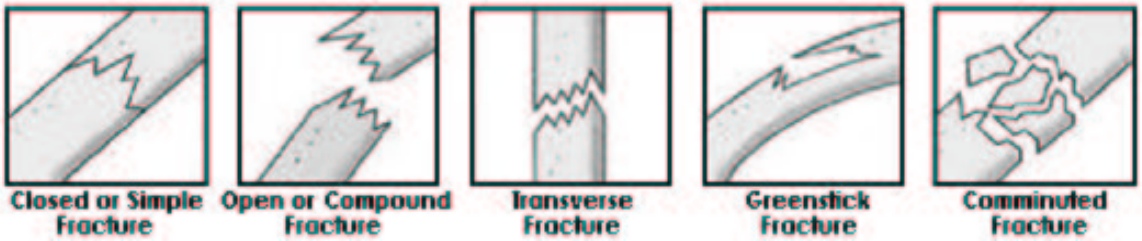
VI. Bone Remodeling

A The two processes of appositional growth and bone resorption are the only ways the shape and size of bone can change during prenatal and postnatal life.
B. During growth, haversian systems are being formed, resorbed, and remolded.
C. The general process for new haversian systems is initiated generally by osteoclasts concurrently with invasion of blood vessels. New tunnels are thus formed by erosion through the endosteal surface that are oriented with the long axis of the shaft.
D. In addition to the remodeling that occurs to accommodate growth, remodeling also occurs in response to stress placed upon bones.



VII. Bone Repair

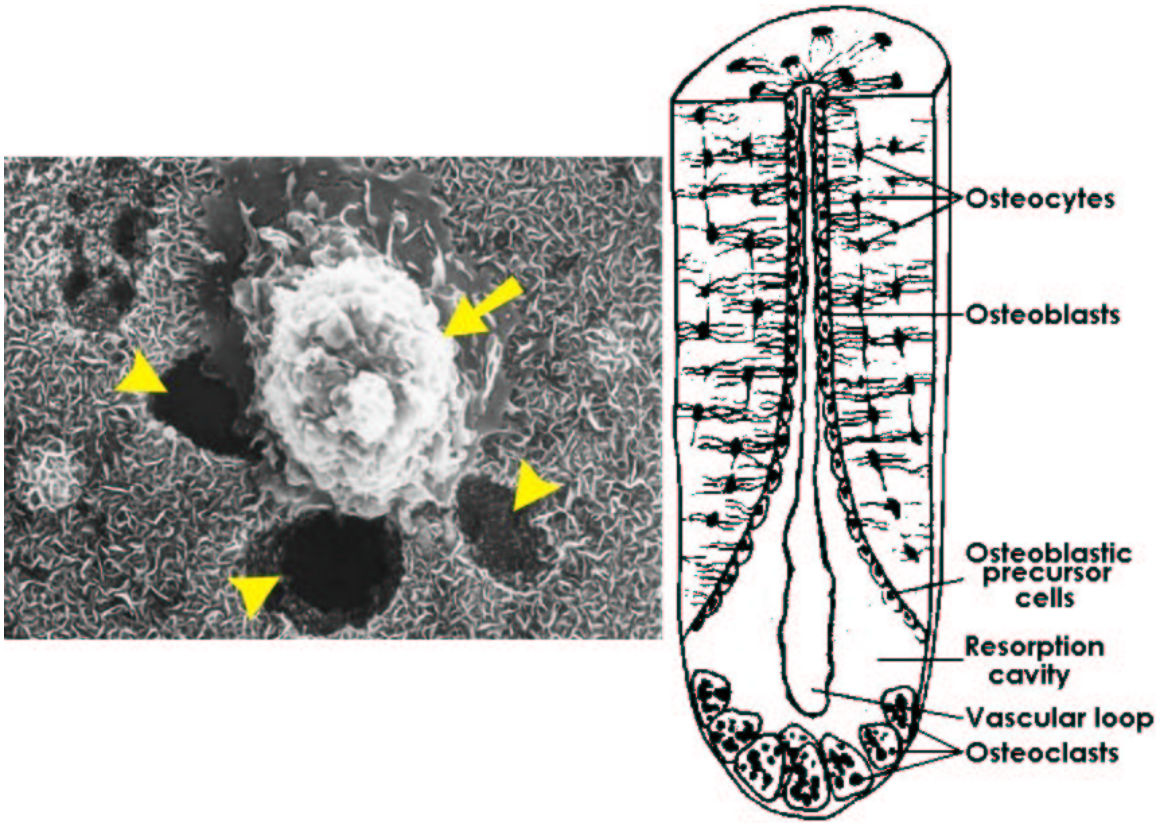
A. Bone fractures result in disruption of the blood supply and the osteocytes begin to die leading to necrosis of the periosteum and marrow. This is followed by and acute inflammatory reaction that brings phagocytic cells into clear blood clots and necrotic tissue.

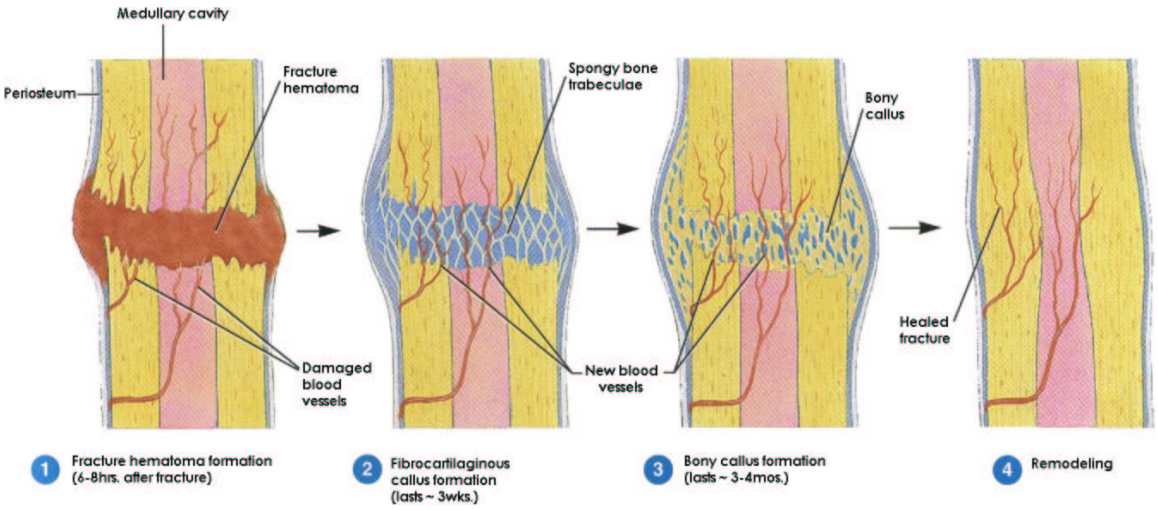


B. The most common type of bone repair involves the formation of a callus
   1. This type takes place when broken ends are not aligned.
   2. A collar of repair tissue forms around the external surface of each broken end.
   3. When a bridge is formed across the break it is known as the external callus
      a. healthy intact periosteum is source of osteogenic cells for the external callus

   4. Depending on the richness of the periosteal capillaries, the callus will

be composed of either spongy bone or cartilage. When cartilage is formed it is subsequently replaced by bone.

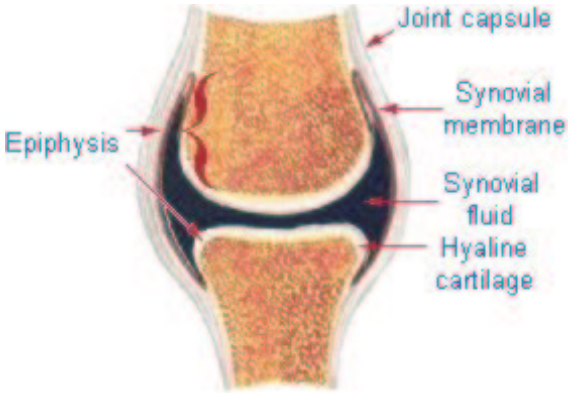




VIII. Joints and Synovial Fluid

A. Connection between any of the skeletons rigid component parts is known as a joint, also described as an articulation.
    1. Study of joints is termed arthrology and inflammation of joints is termed arthritis.
    2. Arthritis is a common malady among domestic animals.

B. Synovial joints are those that allow surfaces to slide past one another
    1. Facilitated by the presence of articular cartilage on each bone surface of the articulation and by presence of synovial fluid.
    2. Synovial joint is enclosed by a joint capsule
    3. Synovial fluid is contained within the joint capsule and is secreted by its inner membrane, the synovial membrane
    4. Outer layer of the joint capsule is a fibrous layer that extends from the periosteum of each bone and contributes to the stability of the joint. A meniscus within the joint capsule serves a cushioning function.



C. The synovial membrane is a vascular connective tissue that lines the inner surface of the joint capsule, but does not cover the bearing surfaces (articular cartilage).
    1. Synoviocytes within the synovial membrane synthesize synovial fluid by an active, energy-requiring process.
    2. Chief functions of synovial fluid are joint lubrication and nourishment of the articular cartilage
    3. Sticky, viscous fluid, often egg-white in appearance, usually alkaline and ranges from colorless to deep yellow.
    4. Color and viscosity vary with location of joint
        a. viscosity due to almost entirely hyaluronic acid
        b. Evaluation of synovial fluid is a diagnostic aid

D. Adult articular cartilage is usually hyline in nature, avascular, aneural, and has an acellular matrix that surrounds a relatively small number of cells called chondrocytes.
    1. Highly specialized connective tissue with biochemical and biophysical properties that enable it to play a dual role as shock absorber an load bearing surface.
    2. During the growth period, articular cartilage provides the growth zone for endochondral ossification in the epiphysis.
    3. During growth, articular cartilage is capable of regeneration and thus repairs defects that arise.

4. When growth ceases, it loses much of its ability to repair
5. Cartilage is resilient and elastic. It becomes thinner when compressed and regains its thickness by taking up synovial fluid.

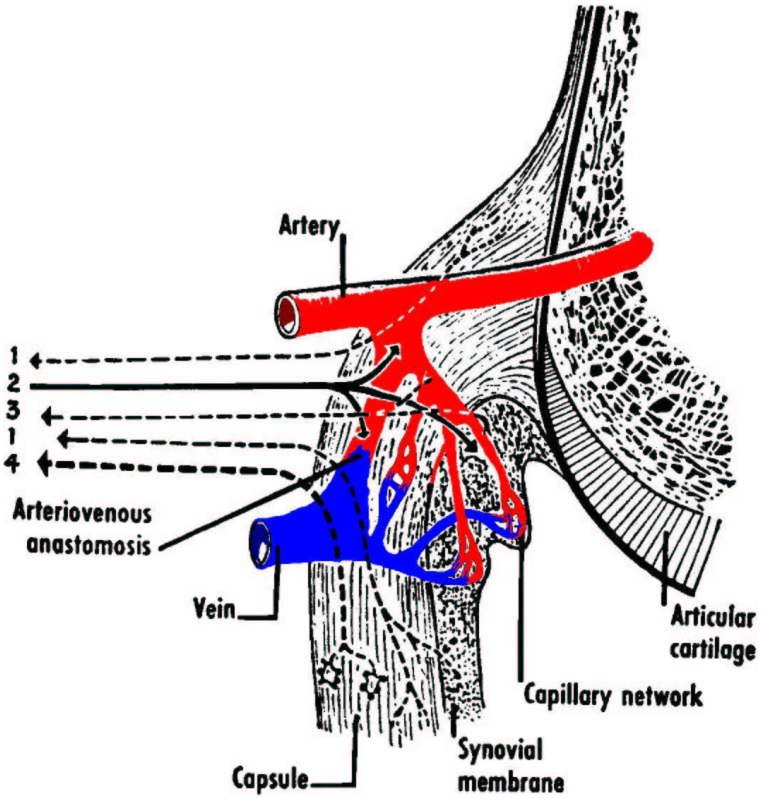
E. Fluids that lubricate a synovial joint are the synovial fluid and fluid pressed from the articular cartilage when compressed.

1. Substances in synovial fluid responsible for the lubrication are hyaluronic acid and lubricin.
2. Both substances are secreted by synovial membrane

IX. Blood, Lymph, and Nerve Supply of Joints

A. Arteries that supply a joint and adjacent bone generally have a common origin.

1. Usually enter the bone near the line of capsule attachment and form a network around the joint.
2. Capillaries from this network supply nutrients to the joint
3. Lymph vessels are associated with the blood vessels
4. Nerve supply to a joint has two principal functions
    a. Pain and reflex responses associated with joint disease
    b. Role in posture, locomotion , and kinesthesia



Blood and nerve supply of a synovial joint. An artery is shown supplying the epiphysis, joint capsule, and synovial membrane. Note the arteriovenous anastomosis. The articular nerve contains (1) sensory fibers from the capsule and synovial membrane, (2) autonomic fibers, (3) sensory fibers from the adventitia of blood vessels and (4) proprioceptive fibers from Ruffini endings and from small lamellated corpuscles (not shown). Arrows indicate direction of conduction.