Done by:

H I S T I C S T e a m

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Part Three:

Cartilage, Bone & Muscle

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1. Cartilage:

- A specialized type of connective tissue that is firm and pliable.
- Avascular, with no nerve fibers & no lymphatic vessels (nourished by diffusion).
- Formed of cells and extra cellular matrix that is secreted by chondroblasts.
- Covered by Perichondrium, that is vascular.

1.1 Hyaline Cartilage:

- Most abundant cartilage in the body.
- Form the cartilage template of many bones during embryonic development.
- Sites:
  - Articular cartilage of most bones.
  - Nose, larynx, trachea and bronchi.
  - Costal cartilage.
  - Fetal skeleton.
- Growth of cartilage:
  1. Appositional growth:
     - By differentiation of chondroblasts in perichondrial (increase in width).
  2. Interstitial growth:
     - By mitosis of chondrocytes that form isogenous groups (increase in length).

• Structure:

A) Perichondrium:

1. Outer fibrous layer:
   - Dense collagenous (type I) C.T.
   - Contain fibroblasts & blood vessels.
2. Inner chondrogenic layer:
   - Contain chondrogenic cells that differentiate into chondroblasts.

- Articular cartilage is devoid of perichondrium.

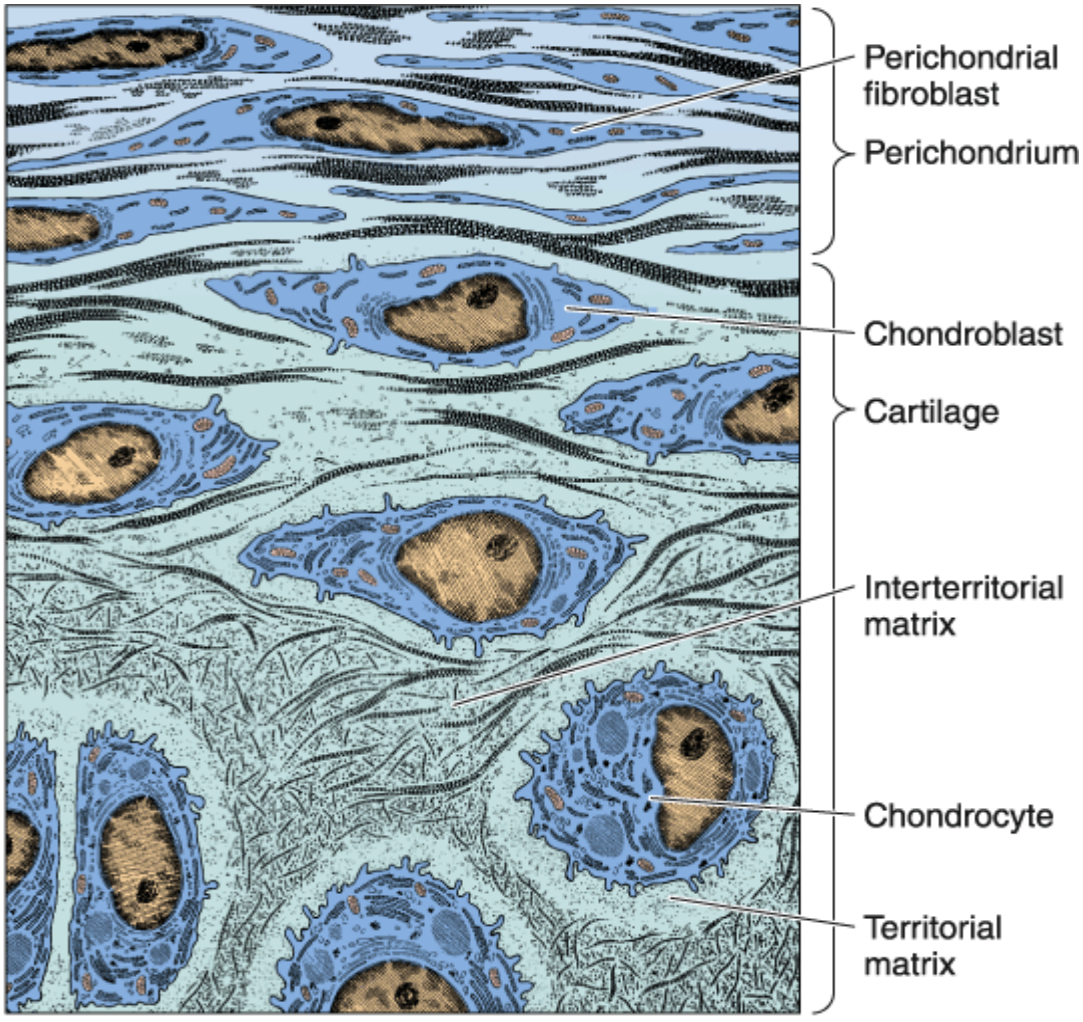
B) Cartilage Cells:

1. Chondrogenic cells:
   - Spindle-shaped cells.
   - Derived from mesenchymal cells.
   - Differentiate into: Chondroblasts and Osteoprogenitor cells.
   - Ovoid nucleus with one or two nucleoli.
   - Cytoplasm is sparse
   - Under E/M:
     - Small Golgi apparatus.
     - Few mitochondria.
     - Some RER.
     - Abundance of free ribosomes.
2. Chondroblasts:
   - Derived from: Mesenchymal cells & Chondrogenic cells.
   - Basophilic cells.
   - Under E/M:
     - Rich in RER & secretory vesicles.
     - Well-developed Golgi complex.
     - Numerous mitochondria.
3. Chondrocytes:
   - They are chondroblasts that are surrounded by matrix.
   - Peripheral chondrocytes are ovoid & deeper ones are more rounded.
   - Large nucleus with a prominent nucleolus.

- Young chondrocytes:
  - Oval and peripherally located.
  - Found single in lacunae.
  - Pale-staining cytoplasm with many mitochondria & RER.
  - Well-developed Golgi apparatus.
  - Glycogen.
- Older chondrocytes:
  - Abundance of free ribosomes.
  - Found single in lacuna or in cell nest (isogenous group).
  - Nucleus: central, rounded, vesicular.

C) Cartilage Matrix:

- Components:
  - Collagen type II fibrils (Don't form bundles).
  - Proteoglycans.
  - Glycoproteins, **e.g.** Chondronectin.
  - GAGs: Chondroitin-4-sulfate & Chondroitin-6-sulfate.
  - Extracellular fluid.
- Under L/M:
  - Pale basophilic.
  - Divided into:
    - Territorial matrix: Around each lacuna (Poor in collagen).
    - Interterritorial matrix: The rest of matrix (Rich in collgen).



1.2 Elastic Cartilage:

- Under L/M:
  - Identical to hyaline cartilage, EXCEPT that it contains an abundant network of elastic fibers in:
    - The outer fibrous layer.
    - The matrix.
    - The territorial matrix.
  - Chondrocytes are more abundant and larger.
- Sites:
  - Ear pinna.
  - Auditory tubes.
  - Epiglottis.
  - Larynx.

1.3 Fibrocartilage:

- Under L/M:
  - Chondrocytes are usually arranged in rows.
  - Separated by bundles of coarse collagen fibers type I (acidophilic).
- No perichondrium.
- Sites:
  - Intervertebral disk.
  - Symphysis pubis.
  - Attached to bone.
- Chondrocytes originate from fibroblasts.
- Has scanty matrix.

Intervertebral disk:

- Contain a gelatinous center called the nucleus pulposus, which is composed of cells from the notochord and laying in hyaluronic acid-rich matrix.
- The nucleus pulposus is surrounded by the annulus fibrosus, which are layers of fibrocartilage.

2. Bone:

• Specialized C.T. whose extracellular matrix is calcified surrounding cells that secreted it.
• Covered by Periosteum (noncalcified).

2.1 Structure:

1. Bone matrix:

• Decalcified bone matrix is acidophilic.
• Shows collagen type I and the bone cells.
• The bundles of collagen in the matrix form parallel layers called bone lamellae.
• Under L/M:
- Bone lamellae separated by osteocytes inside lacunae.
- Bone lamellae form trabeculae.
• Composition:
A. Inorganic Matrix:
• Composed of calcium and phosphorus, which form hydroxapatite crystals
• Other components: Bicarbonate, citrate, Mg, Na, and K.
B. Organic Matrix:
• Collagen, mostly type I (from osteoblasts).
• Glycoproteins (osteocalcin, osteopontin)
• Protein, **e.g.** sialoprotein.
• Chondroitin sulfate.

2. Cells of bone:

A. **Osteoprogenitor:**
• Derived from embryonic mesenchymal cells.
• Can undergo mitosis.
• Under L/M:
- Spindle-shaped.
- Oval pale nucleus
- Scanty Cytoplasm.
- Rich in RER.
• Sites:
1. Periosteum (inner layer).
2. Endosteum.
3. Lining of Haversian canals.
• Differentiate into: Osteoblasts or Chondrogenic cells.

B. **Osteoblasts:**
• Derived from osteoprogenitor cells.
• Under L/M:
- Cuboidal or low columnar.
- When active:
• Cytoplasm is basophilic, abundant RER, Golgi apparatus & secretory vesicles.
• Dividing cells.
- Separated from calcified matrix by non calcified later known as osteoid.
- Have receptors for parathyroid hormone.
- Have processes to connected that connect to other cells.
• Function: Synthesis of bone matrix.

C. **Osteocytes:**
• Derived from osteoblasts.
• Under L/M:
- Flattened nuclei and poor in organelles.

- Located in lacunae.
- Canaliculi are tunnel-like spaces radiating from lacunae that have cytoplasmic processes.
- Cytoplasmic processes form gap junctions with other osteocytes.
- Periosteocytic space contains extracellular fluid between the plasmalemma and the walls of the lacunae & canaliculi.

• Function: Bone maintenance.

D. **Osteoclasts:**

• Under L/M:
- Acidophilic cytoplasm.
- Multinucleated cells (~50)
- Found in Howship's lacunae.

• Originate from monocytes.

• Active osteoclasts have 4 morphological regions:

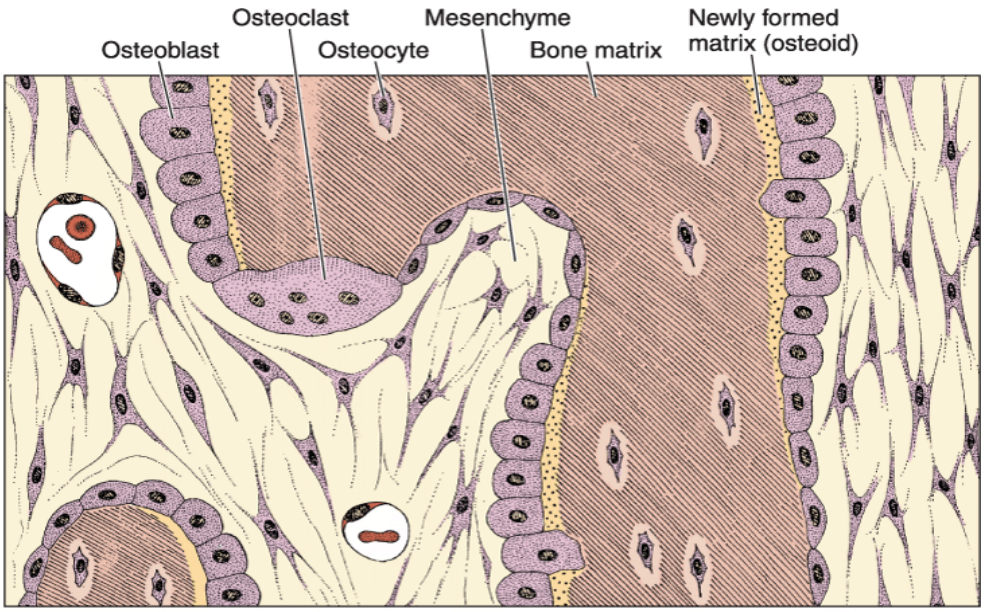
A. The basal zone: • Located away from Howships' lacunae. It contains the nuclei and most organelles as Glogi apparatus and centrioles.

B. The ruffled border: • Responsible for bone resorption through its finger-like processes which are active & dynamic.

C. The clear zone: • Surround the ruffled border. Free of organelles but contains actin filaments.

D. The vesicular zone: • Between basal zone & ruffled border. It contains endocytotic lysosomes & exocytotic vesicles.

• Function: Resorption of bone.



3. Periosteum:

• It's inserted into the bone by Sharpey's fibers.

1- Outer fibrous layer.

2- Inner osteogenic layer:

• Contain: Osteoprogenitor cells.

4. Endosteum:

• It lines the central cavity of the bone.

• Formed of a monolayer of osteoprogenitor cells & osteoblasts.

• Contain: Osteoprogenitor cells.

2.2 Classification of Bones:

1. Gross Classification:

A. Compact Bone:

- Very dense bone outside surface.
- Bone Matrix:
    - A. Outer Circumferential Bone Lamellae.
        - Deep to the periosteum.
        - Form the outermost region of the diaphysis.
        - Contain Sharpey's fibers.
    - B. Inner Circumferential Bone Lamellae.
        - Encircles the marrow cavity
    - C. Osteons (Haversian canals system).
        - Cylindrical longitudinal structures, each is composed of:
            1. Concentric bone lamellae.
            2. Haversian canal running in the center.
            - Volkmann's canal: Oblique or transverse canals that interconnect with Haversian canals.
    - D. Interstitial Lamellae.

B. Cancellous Bone (Spongy Bone):

- Porous portion lining the marrow cavity.
- Formed of branching bony trabeculae and spicules jutting into marrow cavities.
- No haversian system but irregular arrangements of lamellae.
- Bone Marrow Cavities (spaces) are irregular space in between bone trabeculae of spongy bone.

2. Microscopic Classification:

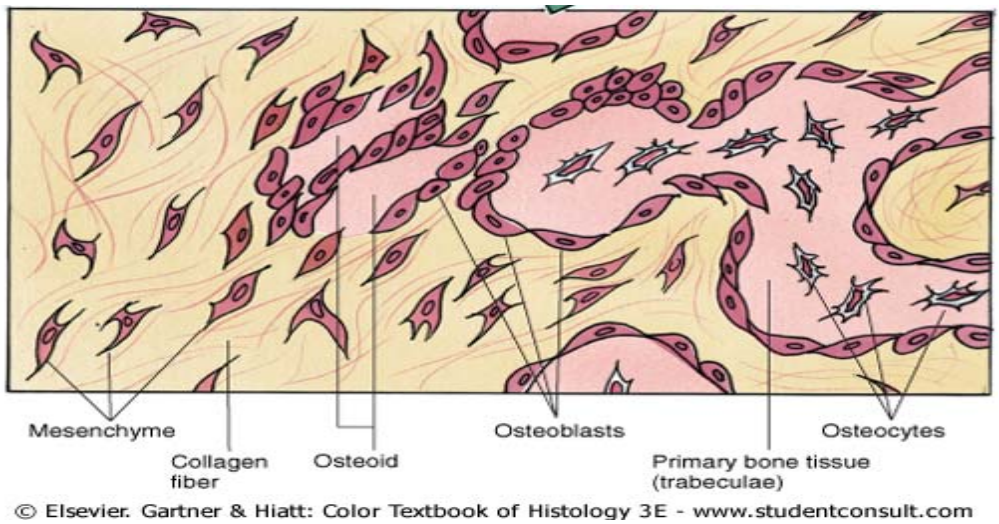
A. Primary Bone:

- Immature bone formed during fatal development.
- Abundant osteocytes & irregular bundles of collagen.
- Has fewer minerals than secondary bone.

B. Secondary Bone:

- Mature bone composed of parallel or concentric lamellae.
- Osteocytes in their lacunae are dispersed between and within lamellae.
- Canaliculi connect lacunae and cytoplasmic processes of different osteocytes.
- Matrix is more calcified than primary bone, so it is stronger.

2.3 Histogenesis:



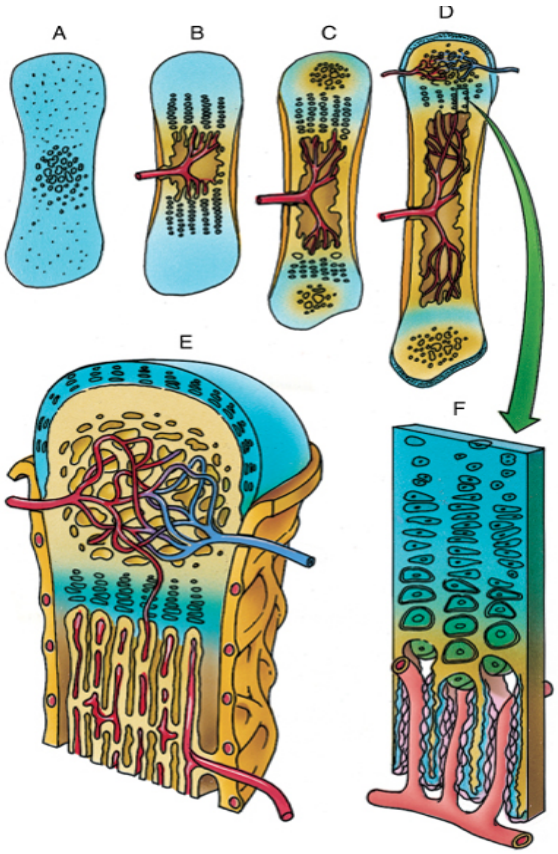
Intermembranous Ossification:

• Occur within mesenchymal tissues that are vascularizied.
• It forms flat bones.
• Mesenchymal cells change into Oosteoblasts which secrete bone matrix and form trabeculae & spicules, and then calcification changes them into osteocytes.
• Osteoclasts remove part of the bone to form Marrow spaces (Ex: Frontal bone, Maxilla).

Endochondral Ossification:

• Hyaline Cartilage is formed first and then replaced by bone. (Long bones)

1. Hyaline cartilage is formed; chondrocytes hypertrophy, accumulate glycogen and become vacuolated. The cartilage matrix becomes calcified.
2. Blood vessels enter the perichondrium of the middle of the diaphysis of the cartilage, so chondrogenic cells become osteoprogenitor cells forming osteoblasts. Perichondrium becomes periosteum.
3. Osteoblasts secrete bone matrix, forming the subperiosteal bone collar, which prevents the diffusion of nutrients to the chondrocytes causing them to die leaving cavities.
4. Osteoclasts in the ossification centre remove part of the new bone to form the bone marrow cavity.
   • Blood vessels and osteoblasts from the periosteum enter the cavities to form the primary ossification center in the diaphysis.
5. Osteoprogenitor cells divide to form osteoblasts that secrete bone matrix on the surface of calcified cartilage.



6. The subperiosteal bone becomes thicker and grows in each direction towards the epiphysis. Osteoclasts resorb the calcified cartilage enlarging the marrow cavity. The cartilage of diaphysis is replaced by bone except for the epiphseal platesm which is responsible for the continued growth of the bone.

Epiphyseal Growth Plate of Cartilage

• After ossification, a piece of cartilage called Epiphyseal growth plate remains between the epiphysis and diaphysis.
• Ossification of the growth plate continues up to the age of 20 years.
• The growth plate increases the length of bone because its cartilage continues to grow.

Ossification of Epiphyseal Plate

Zones of ossification of epiphyseal plate :
• Zone of cartilage reserve (resting).
• Zone of proliferation of chondrocytes.
• Zone of hypertrophy of chondrocytes.
• Zone of calcification of cartilage.
• Zone of ossification (formation of bone on the calcified cartilage matrix).
• Zone of resorption by osteoclasts.
- Bone grows in width by appositional growth.

3. Muscle:

- Muscle cells are called muscle fibers.
- Muscle membrane is called sarcolemma.
- The cytoplasm is called sarcoplasm.
- The ER is called sarcoplasic reticulum.
- The mitochondria are called sarcosomes
- Types of skeletal muscles:
    - Skeletal muscles (striated or voluntar).
    - Cardiac muscles (heart muscle or myocardium).
    - Smooth muscles (non-striated, involuntary or visceral).

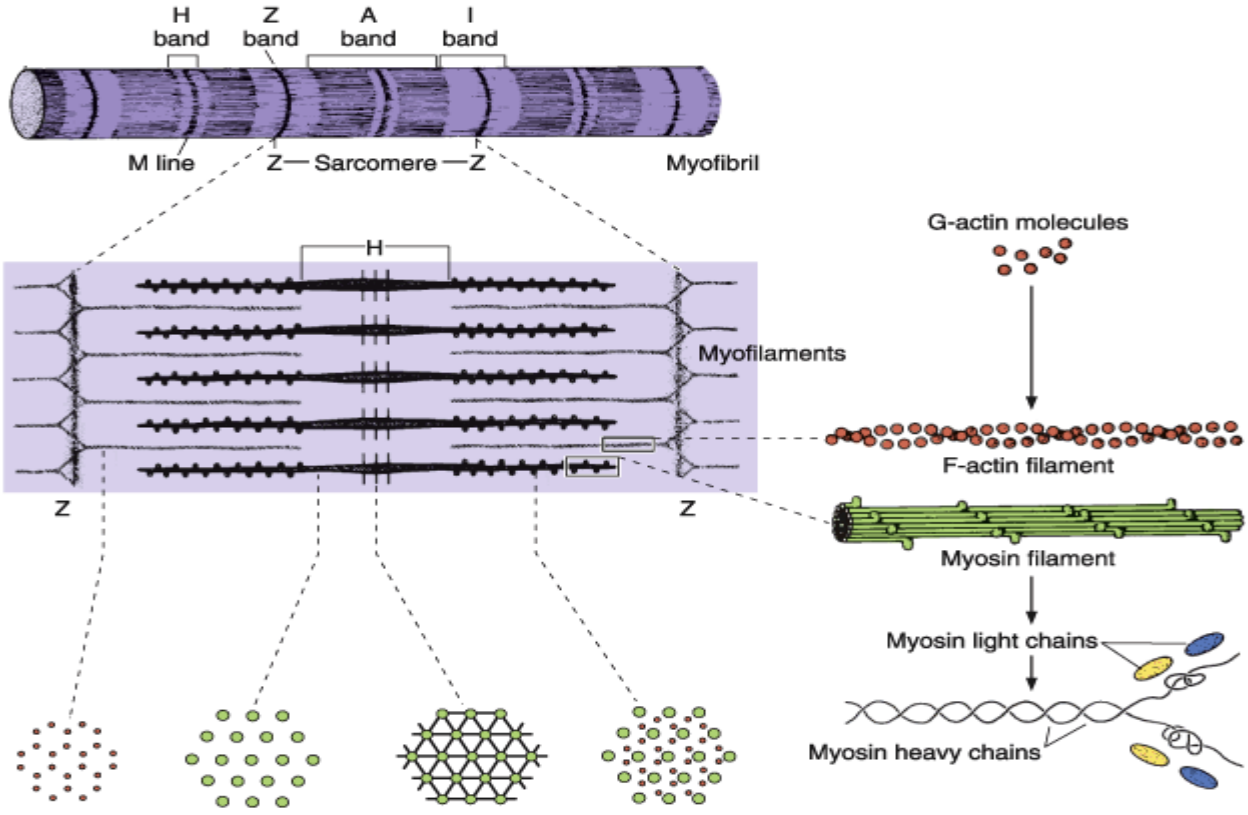
3.1 Skeletal Muscle:

- Pink to red due to rich vascular supply and presence of myoglobin pigments.
- 3 Types: Red, White and Intermediate.
    - According to: Fiber diameter, quantity of myoglobin, no. of mitochondria, concentration of enzymes, extensiveness of sarcoplasmic reticulum and the rate of contraction.

Investments of Skeletal Muscles:

1. Epimysium: Dense irregular C.T. surrounding the entire muscle.
2. Perimysium: Dense C.T. around each bundle of muscle fibers.
3. Endomysium: Delicate C.T. composed of reticular fibers & external lamina surrounding each muscle fiber.
    - Contain continuous blood capillaries and lymph vessels.
    - Muscle fibers are arranged in regular bundles.

- Under L/M:
    - Cylindrical & Multinucleated.
    - Nuclei are oval & peripheral.
    - Show cross (transverse) striations (due to myofibrils).
    - Sarcoplasm is acidophilic.



- Under E/M:
  - Sarcomere:
    - Striations are formed of dark bands (A bands) and light bands (I bands).
    - The center of each dark band is occupied by a pale area (H band) which is bisected by M line.
    - Each light band is bisected by a dark line (Z line or disk).
    - The region of the myofibril between two successive Z disks is the contractile unit of skeletalmuscle.
      - M line consists of myomesin & C protein.
  - Sarcolemma form long tubular invaginations within the fibers (Transverse or T tubules).
  - T tubules: Encircles the boundaries of the A-I bands of each sarcomere in every myofibril.
  - Sarcoplasmic reticulum (S.R.):
    1. Terminal cisternae: 2 lateral portions of S.R.
    2. Sarcotubules: Branching network of S.R around each myofibril.
  - Triad: Formed by T tubule & 2 terminal cisternae, which allow a wave of depolarization to spread from the surface to the terminal cisternae (Store Ca).
  - Myofibrils:
    - Fomred of thin myofilaments (actin-7nm) & thick myofilaments (myosin-15nm).
    - Thin filaments originate at Z disk and project towar the center of the two adjacent sarcomeres. Thick filaments are integrated into thin filaments.
    - Are held with one another by desmin and vimentin (intermediate filaments) & attached to sarcolemma by dystrophin.
    - In relaxed muscle, the thick filaments do not extend the entire length of sarcomere and thinfilaments don not meet in the midline.
    - H band is devoid of thin filaments.
  - Mitochondria: Numerous, elongated with many cristae.
  - Myoglobin: More in red fibers than in white fibers.
  - Glycogen granules.

• Important Events during Contractions:

1. The Z disks move closer to each other.
2. The I band becomes narrow.
3. The H band is extinguished.
4. The A band remains unaltered.

3.2 Cardiac Muscle:

- Under L/M:
  - Have cross (transverse) striations.
  - Mononucleated (may be binucleated).
  - Nuclei are oval & central.
  - Elongated & branched cells that is parallel to each other
  - Have intercalated disks.
  - Mitochondria: About 40%.
  - Lipofuscin pigments.
- Under E/M:
  - Intercalated disks:
    - 1- Straight.
    - 2- Steplike (stepwise) pattern.
      - Junctions:
        1. Transverse Portions: Fascia adherents & Macula adherent (desmosomes).
        2. Lateral portions: Rich in gap junctions.
  - T tubules (x2.5 the diameter of skeletal muscles T tubules):

1. Are more numerous and larger (wider) in ventricular muscle.
2. Are found at the level of Z lines.
• Dyads (sarcomeres in the vicinity of the Z line).

- Sarcoplasmic reticulum:
  - Not well developed.
- Mitochondria: Occupy 40% of the sarcoplasmic volume.
- Glycogen.
- Lipofuscin pigment granules (aging pigment).
- Secretory granules: More in right atrium & atrial natriuretic factor.

3.3 Smooth Muscle:

• Each cell is surrounded by an external lamina that has reticular fibers.
• Usually form sheets which are frequently arranged in two layers, **e.g.** digestive & urinary systems.
• Under L/M:
- Don't show cross striations.
- Fusiform.
- Central, oval single nucleus.

• Under E/M:
- Don't have T tubules or sarcomere.
- Abundant intermediate filaments coursing through the sarcoplasm.
- Abundant gap junctions.
- Dense bodies (DB):
1. Membrane-associated.
2. Cytoplasmic.
• Both contain α-actinin (thus similar to Z lines).
• Both actin & intermediate filaments insert to the DB.

• Functions:
- Contractile activity.
- Synthesis of extracellular products, **e.g.** collagen, elastin & proteoglycans.

3.4 Regeneration of Muscle:

• Skeletal muscle fibers (cells):
- Can not divide.
- Limited regeneration by satellite cells (located in the surface of the muscle).

• Cardiac muscle cells:
- Have almost no regenerative capacity beyond early childhood.
• After myocardial infraction, fibrobalsts inveds the damged region to form fiberous C.T.

• Smooth muscle fibers (cells):
- Can divide.
- Pericytes can differentiate to SMC.
• Active regenerative response.

Related cells:

Myoepithelial cells:
- Modified to assist the delivery of the secretory products into the ducts of the gland
- Flat cells with long processes.
- Stimulated by oxytocin and acetylcoline.
- Contain actin and myosin.

Myofiberoblasts:
- Rich in actin and myosin.
- Can contract.
- Prominent in wound contarction.