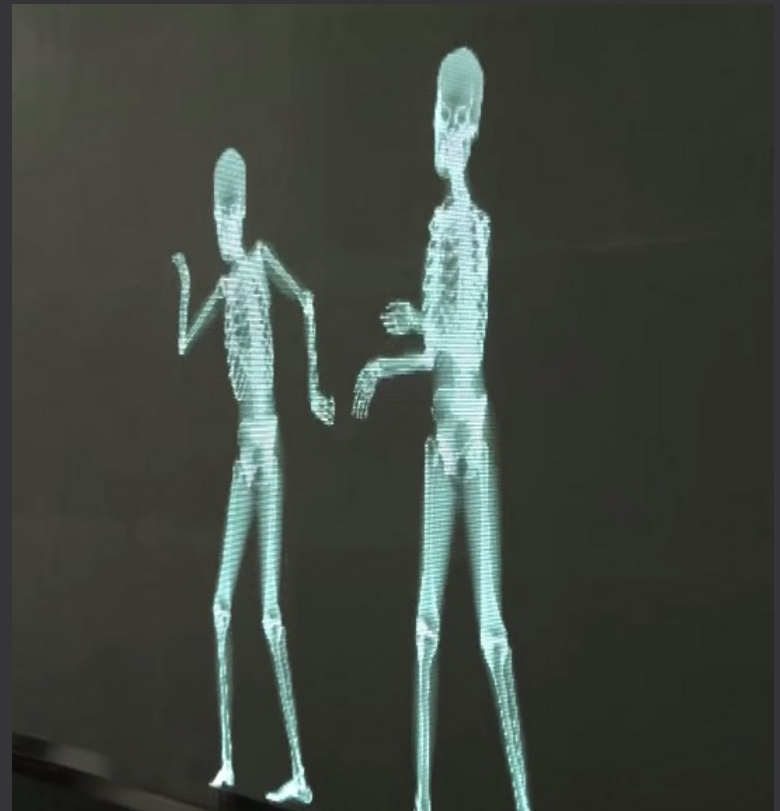


Human Anatomy & Physiology – Skeletal System



Body without form



Introduction

The skeletal system can be divided into two functional parts:

- **Axial Skeleton (Purple)** – Vertebral column, skull, ribs and sternum.
- **Appendicular Skeleton (Pink)** – Shoulder and hip girdles and bones of the upper and lower limbs.



Function of bone

- **Protection** – Body organs (e.g. skull, ribs)
- **Support** – Suspension and attachment of soft tissue structures
- **Locomotion** – Joint formation and muscle attachment
- **Blood cell formation** – Marrow cavities of long bones
- **Regulation and Storage** for salts (e.g. Calcium)

Classification of bone

According to shape:

- **Long bones** – Tubular in shape
- **Short bones** – Small, regular shape
- **Irregular bones** – Many exaggerated prominences
- **Flat bones** – thin and curved around body
- **Sesamoid bones** – Small and regular shaped, situated in tendons or ligaments at sites of stress

Gross Anatomy - Bone Markings

- Superficial surfaces of bones reflect stresses on them
- There are three broad categories of bone markings
 - Projections for muscle attachment
 - Surfaces that form joints
 - Depressions and openings

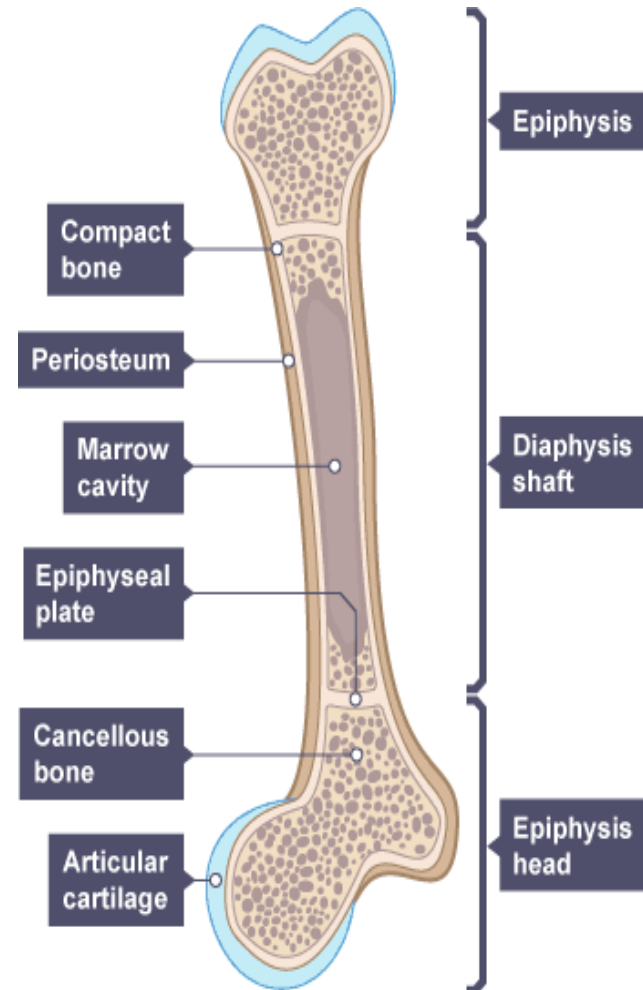
Name of Bone Marking	Description	Illustration
PROJECTIONS THAT ARE SITES OF MUSCLE AND LIGAMENT ATTACHMENT		
Tuberosity (too"be-ros"ĩ-te)	Large rounded projection; may be roughened	The illustration shows three different bones with various markings labeled. On the left is a view of the right half of a human pelvis, showing the Iliac crest, Ischial spine, and Ischial tuberosity. In the center is a Coxal bone. On the right is a Femur of thigh, showing the Trochanter, Intertrochanteric line, Adductor tubercle, and Medial epicondyle. At the bottom is a Vertebra showing a Spinous process.
Crest	Narrow ridge of bone; usually prominent	
Trochanter (tro-kan'ter)	Very large, blunt, irregularly shaped process (the only examples are on the femur)	
Line	Narrow ridge of bone; less prominent than a crest	
Tubercle (too'ber-kl)	Small rounded projection or process	
Epicondyle (ep"ĩ-kon'dil)	Raised area on or above a condyle	
Spine	Sharp, slender, often pointed projection	
Process	Any bony prominence	

Components of bone

- **Cells:** Osteoblasts, Osteocytes and Osteoclasts – growth, removal and repair.
- **Extracellular Matrix:**
 - **Organic elements:** (35% of the matrix) Glycoproteins and collagen – strength and rigidity.
 - **Inorganic elements:** (65% of the matrix) Mineral salts (mainly calcium salts and phosphates) – strength and hardness.

General structure of bone

- **Epiphysis** – ends, spongy bone contains red marrow, compact bone, articular cartilage at end
- **Diaphysis** – middle, compact bone, medullary cavity-contains yellow marrow (fat)
- Bone enclosed in periosteum (apart from at joints), which is continuous with tendons and ligaments and contains blood vessels



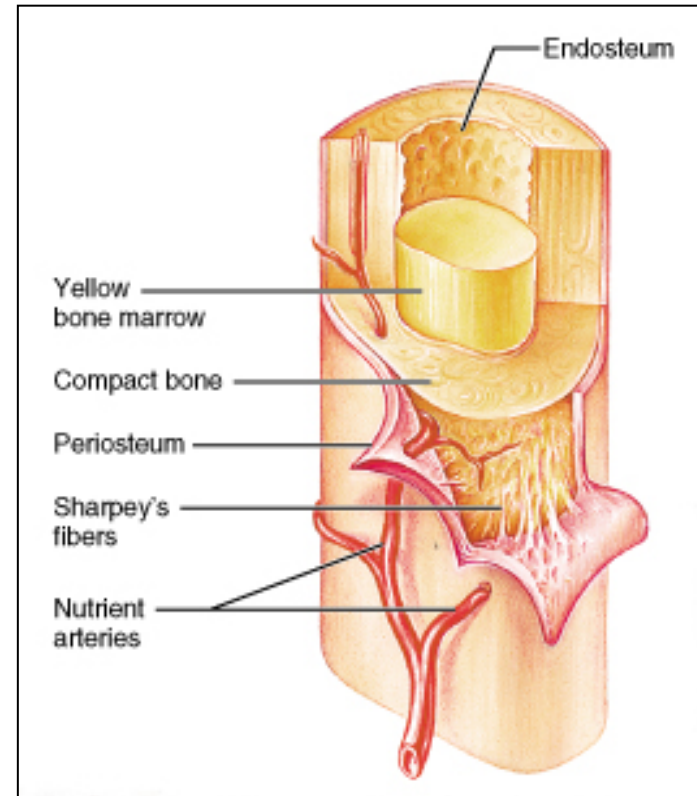
Bone Membranes

- Periosteum

- Provides anchoring points for tendons and ligaments
- Double-layered protective membrane, supplied with nerve fibers, blood, and lymphatic vessels entering the bone via nutrient foramina.
- Inner osteogenic layer is composed of osteoblasts and osteoclasts

- Endosteum

- Delicate CT membrane covering internal surfaces of bone
- Covers trabeculae of spongy bone
- Lines canals in compact bone
- Also contains both osteoblasts and osteoclasts

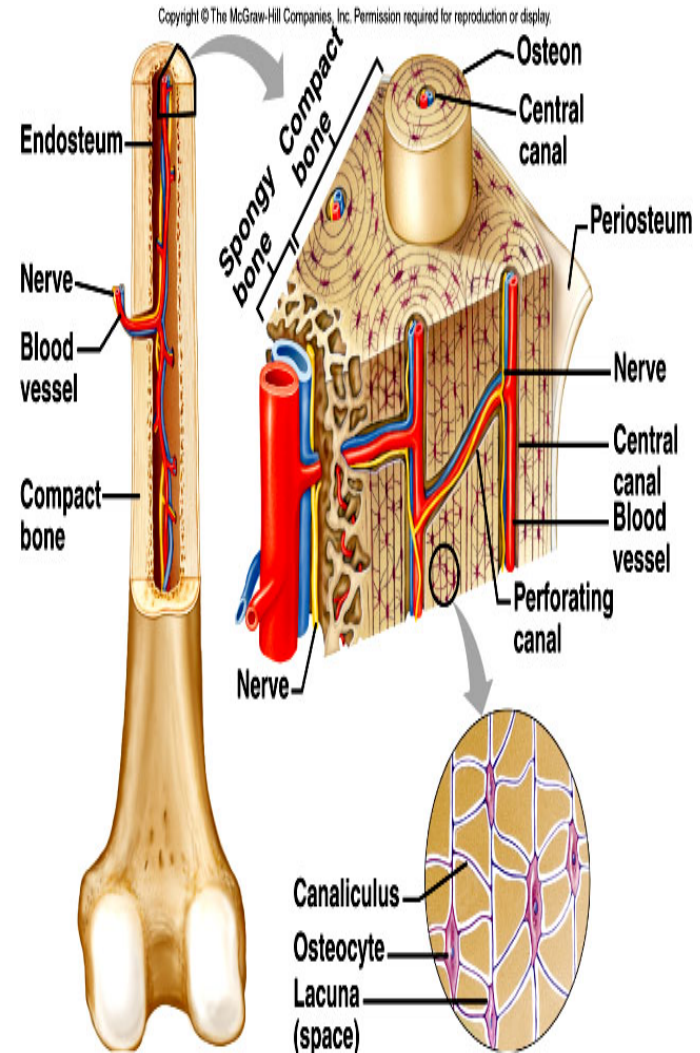


Types of bone

- The two types of bone are **compact bone** and **spongy bone**.
- They are distinguished by the relative amount of solid matter and by the number and size of spaces they contain.
- All bones have a thin layer of compact bone around a central mass of spongy bone.

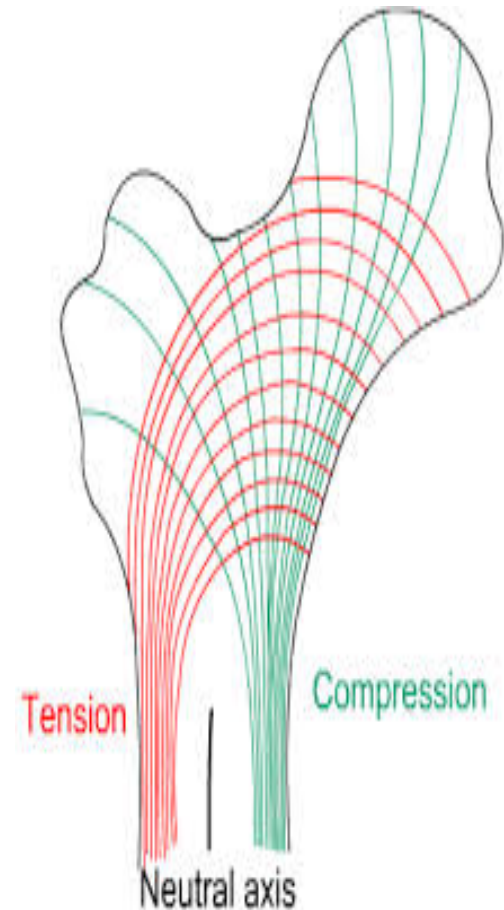
- 80% of skeletal mass
- Located in the outer layers of the bone
- Osteon – the structural unit of compact bone
- Lamellae – column-like matrix tubes composed of collagen and crystals of bone salts
- Arranged in a highly organised microscopic circular structure called haversian systems
- These systems have a central vascular supply (Haversian canal) and also contain bone cells (osteocytes), nerves and lymph vessels
- The osteocytes arrange themselves in small channels (canaliculi) which are positioned as successive circles around the haversian canal
- Between each two canaliculi is a matrix of bone mineral, which together form a Lamella

Compact bone



Spongy (Cancellous) bone

- Spongy bone is lighter and less dense than compact bone
- It consists of plates (trabeculae) and bars of bone adjacent to small, irregular cavities that contain red bone marrow
- The canaliculi connect to the adjacent cavities, instead of a central Haversian canal, to receive their blood supply
- It may appear that the trabeculae are arranged in a haphazard manner but, they are organised to provide maximum strength similar to braces that are used to support a building.
- The trabeculae of spongy bone follow the lines of stress and can realign if the direction of stress changes



Cells in Bone

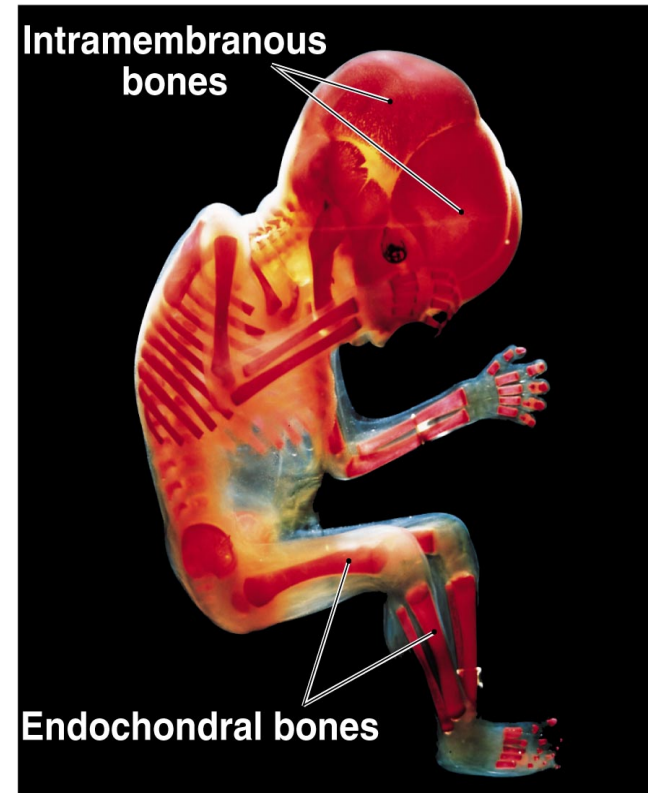
- Osteoprogenitor cells – precursors to osteoblasts
- Osteocytes - mature bone cells between lamellae
- Osteoclasts - bone-destroying cells, break down bone matrix for remodeling and release of calcium
 - Source of acid, enzymes for osteolysis
 - Calcium homeostasis
- Osteoblasts - bone-forming cells
 - Responsible for osteogenesis (new bone)
 - Source of collagen, calcium salts

Bone Development

- Osteogenesis or Ossification – the process of bone tissue formation that leads to:
 - The formation of the skeleton in embryos
 - Bone growth until early adulthood
 - Bone thickness, remodeling, and repair

Formation of the Skeleton

- Before week 8, the skeleton of a human embryo consists of fibrous membranes and hyaline cartilage
- Endochondral ossification – bone forms by replacing hyaline cartilage, uses hyaline cartilage “bones” as patterns
- Intramembranous ossification – bone develops from a fibrous connective tissue membrane (Flat bones).



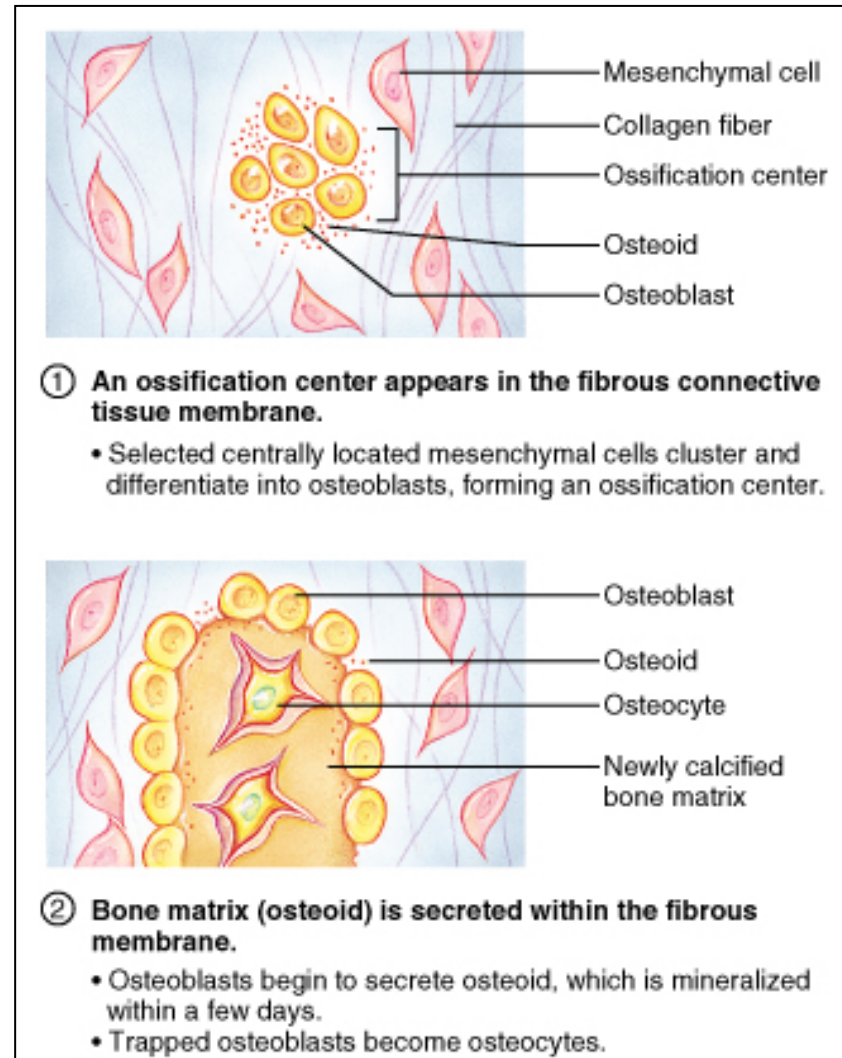
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Bone Formation and Growth

- Intramembranous Ossification
 - Ossification—Process of converting other tissues to bone
 - Forms flat bones of skull, mandible, clavicle
 - Stem cells differentiate to osteoblasts
 - Produces spongy bone, then compact bone

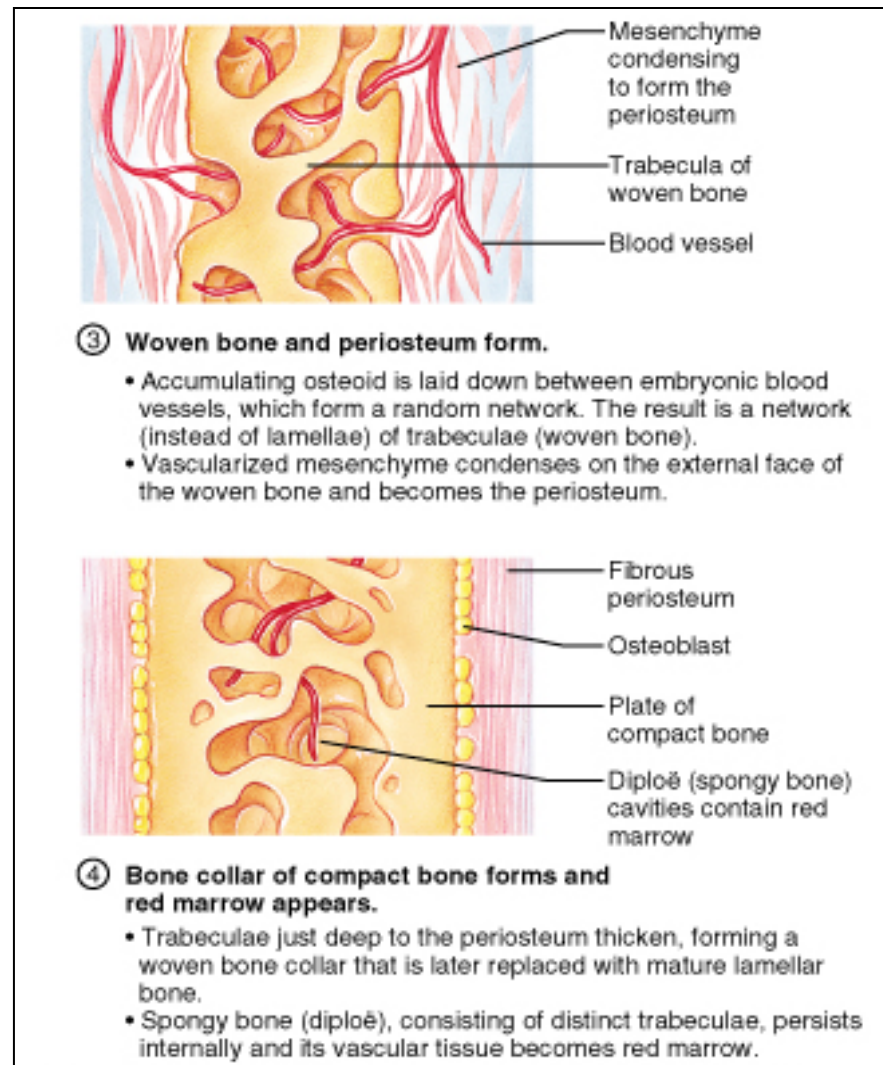
Intramembranous Ossification

- An ossification centre appears in the fibrous connective tissue membrane
- Osteoblasts secrete bone matrix within the fibrous membrane
- Osteoblasts mature into osteocytes



Intramembranous Ossification

- The bone matrix develops into trabeculae.
- The trabeculae formed from various ossification centres fuse with one another to create spongy bone.
- Eventually the spaces between trabeculae fill with red bone marrow.



Bone Formation and Growth

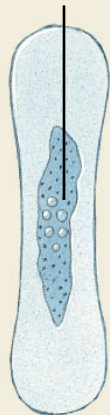
- Endochondral Ossification
 - Most bones formed this way
 - Cartilage model replaced by bone
 - Replacement begins in middle (diaphysis)
 - Replacement follows in ends (epiphyses)

Endochondral Ossification

STEP 1

Chondrocytes at the center of the growing cartilage model enlarge and then die as the matrix calcifies.

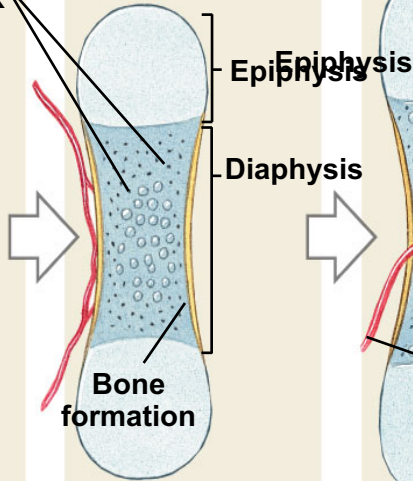
Enlarging chondrocytes within calcifying matrix



Cartilage model

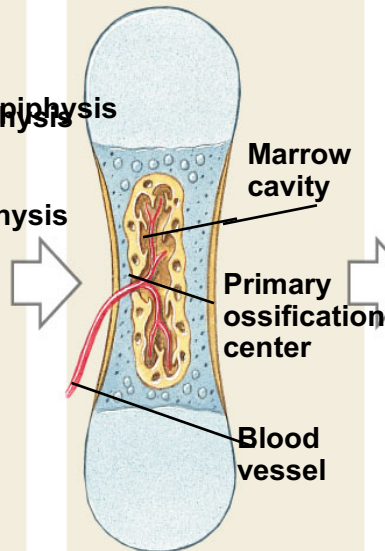
STEP 2

Newly derived osteoblasts cover the shaft of the cartilage in a thin layer of bone.



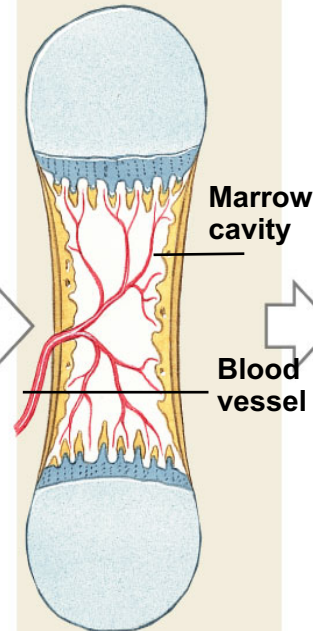
STEP 3

Blood vessels penetrate the cartilage. New osteoblasts form a primary ossification center.



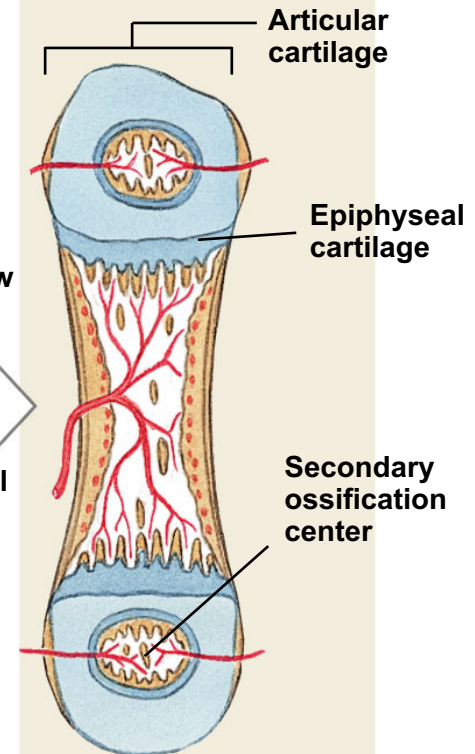
STEP 4

The bone of the shaft thickens, and the cartilage near each epiphysis is replaced by shafts of bone.

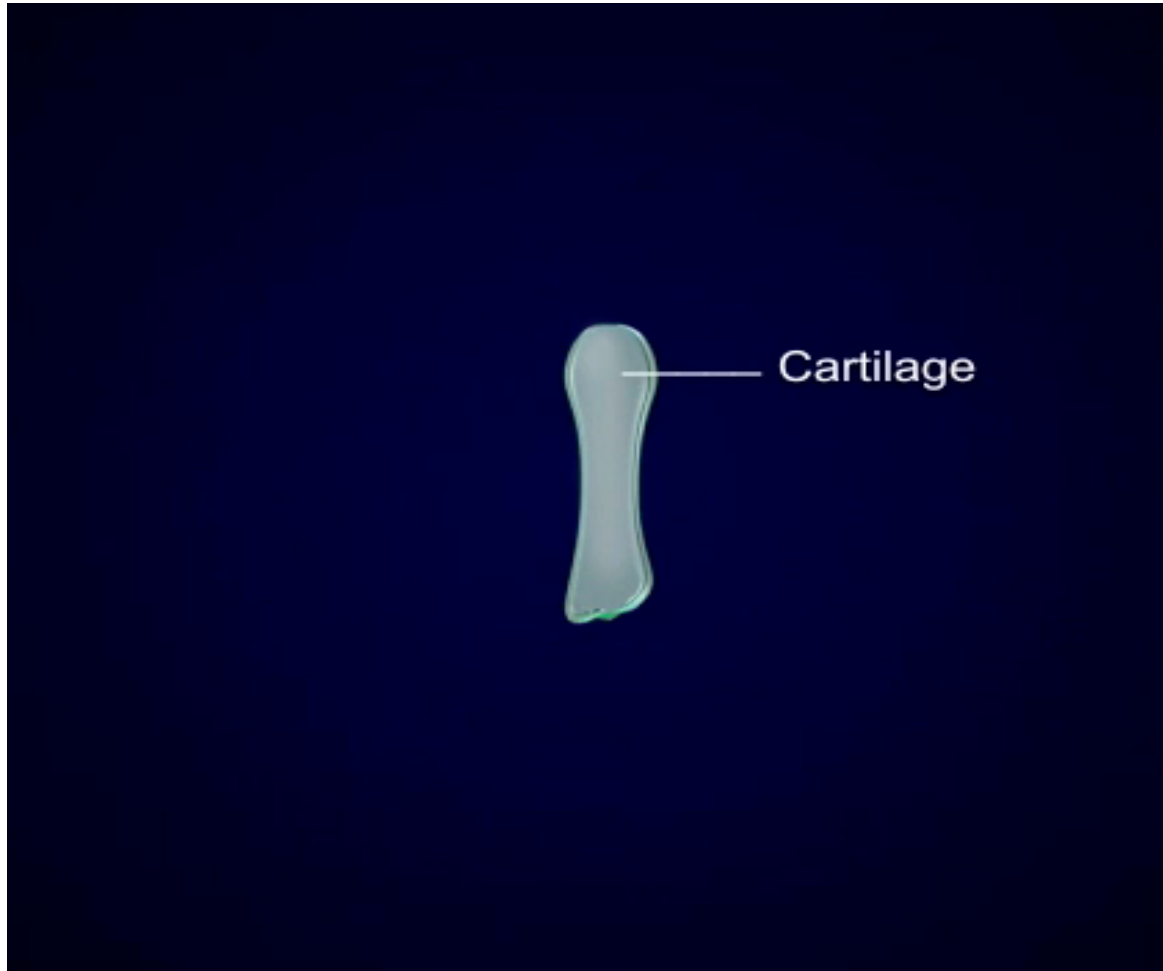


STEP 5

Blood vessels invade the epiphyses and osteoblasts form secondary centers of ossification.

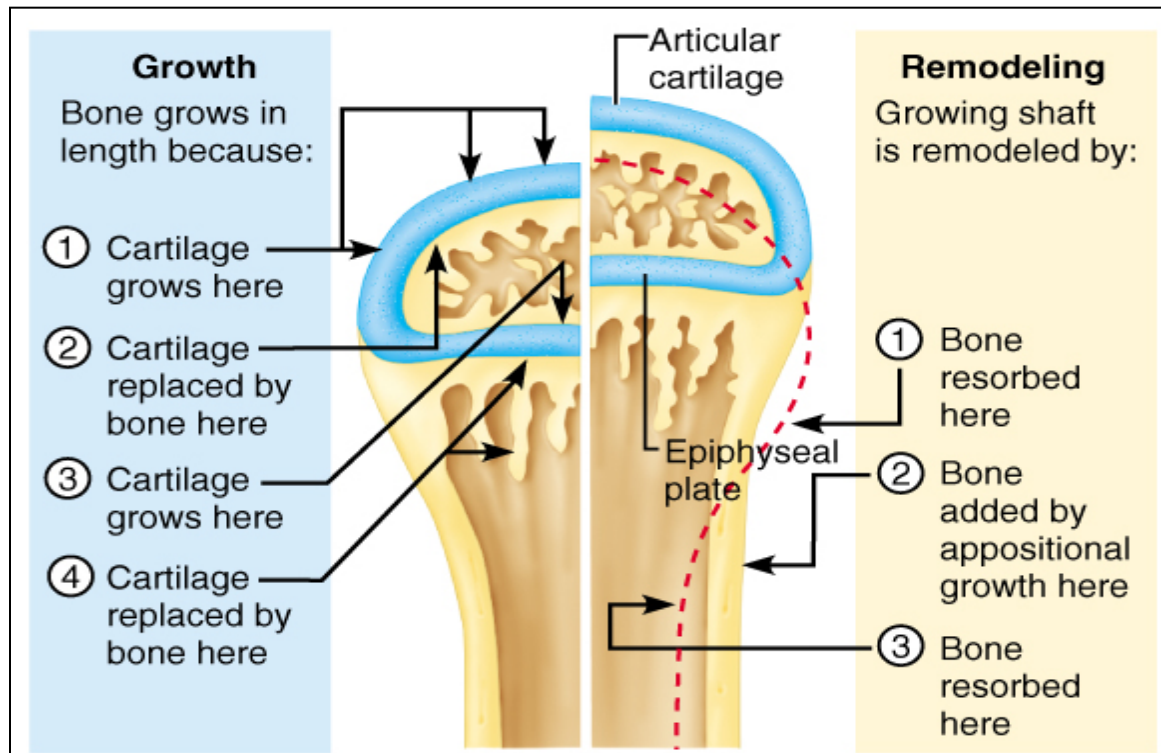


Endochondral Ossification



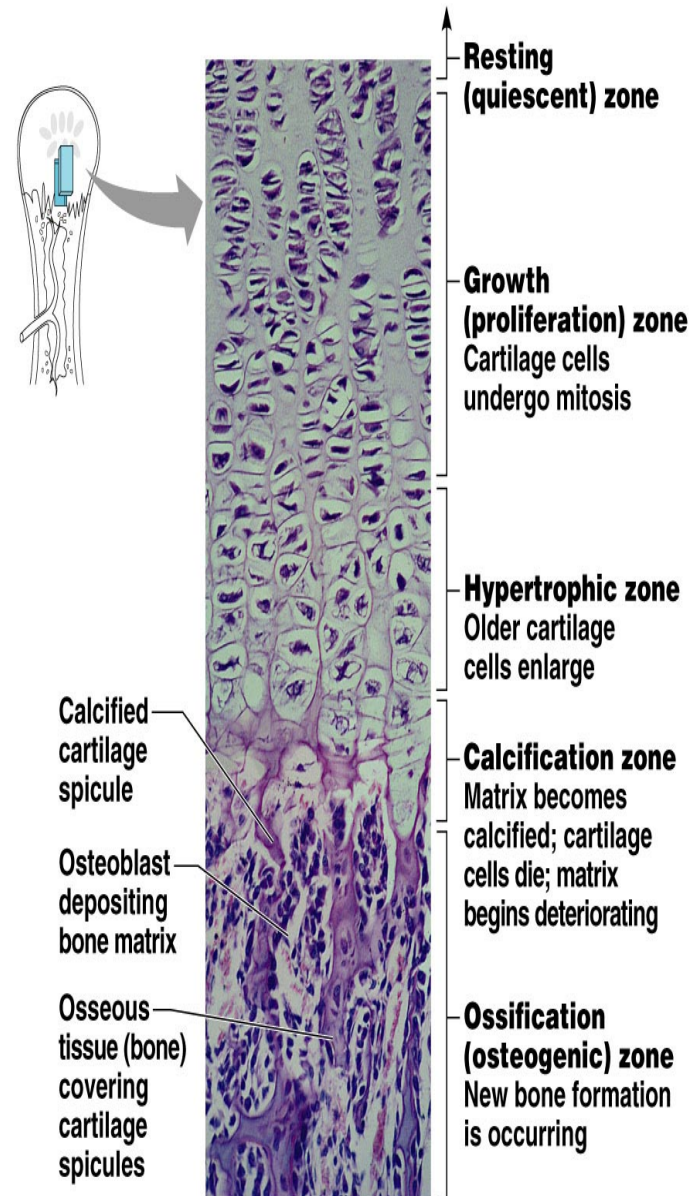
Longitudinal Bone Growth

- Longitudinal Growth (interstitial) – cartilage continually grows and is replaced by bone
 - Bones lengthen entirely by growth of the **epiphyseal plates**
 - Cartilage is replaced with bone CT as quickly as it grows
 - *Epiphyseal plate maintains constant thickness*



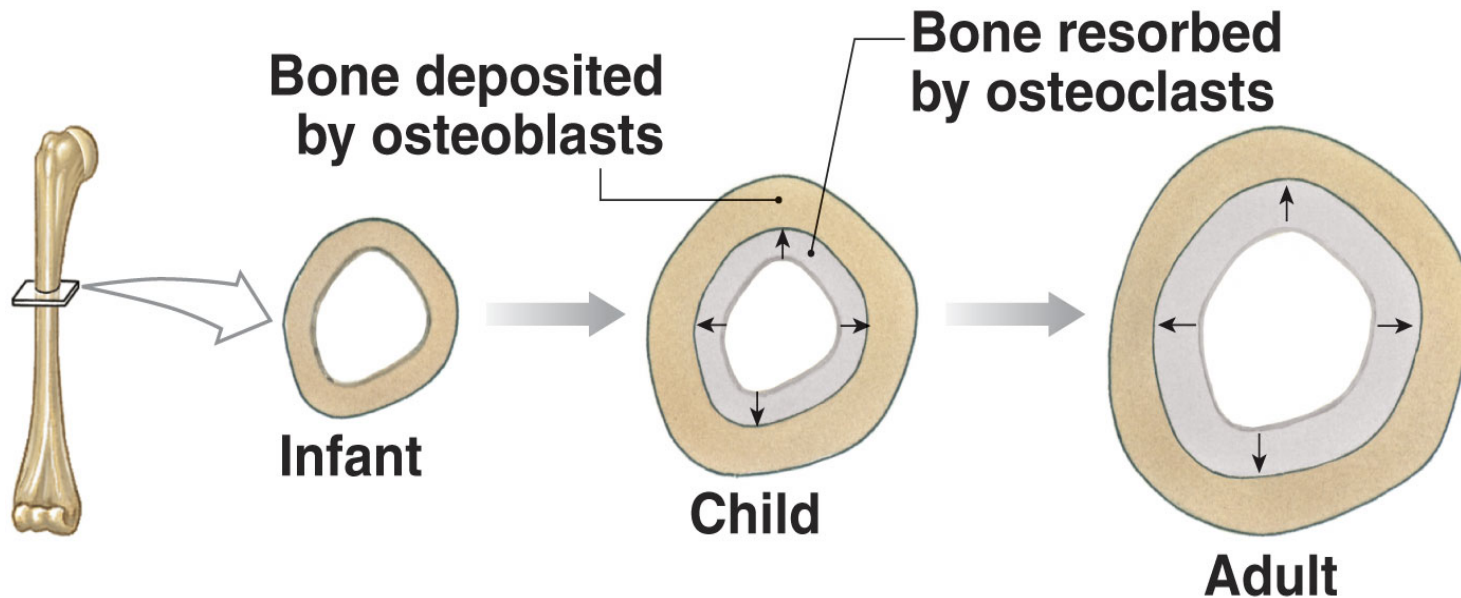
Epiphyseal Plate

- Cartilage is organized for quick, efficient growth
- Cartilage cells form tall stacks
 - **Chondroblasts** at the top of stacks divide quickly
 - Pushes the epiphysis away from the diaphysis
 - Lengthens entire long bone
- Older chondrocytes signal surrounding matrix to calcify, then die and disintegrate
 - Leaves long **trabeculae** (spicules) of calcified cartilage on diaphysis side
 - **Trabeculae** are partly eroded by osteoclasts
 - **Osteoblasts** then cover trabeculae with bone tissue
 - Trabeculae finally eaten away from their tips by **osteoclasts**



Appositional Bone Growth

- Growing bones widen as they lengthen
- Appositional growth – growth of a bone by addition of bone tissue to its surface
- Bone is resorbed at endosteal surface and added at periosteal surface
 - Osteoblasts – add bone tissue to the external surface of the diaphysis
 - Osteoclasts – remove bone from the internal surface of the diaphysis

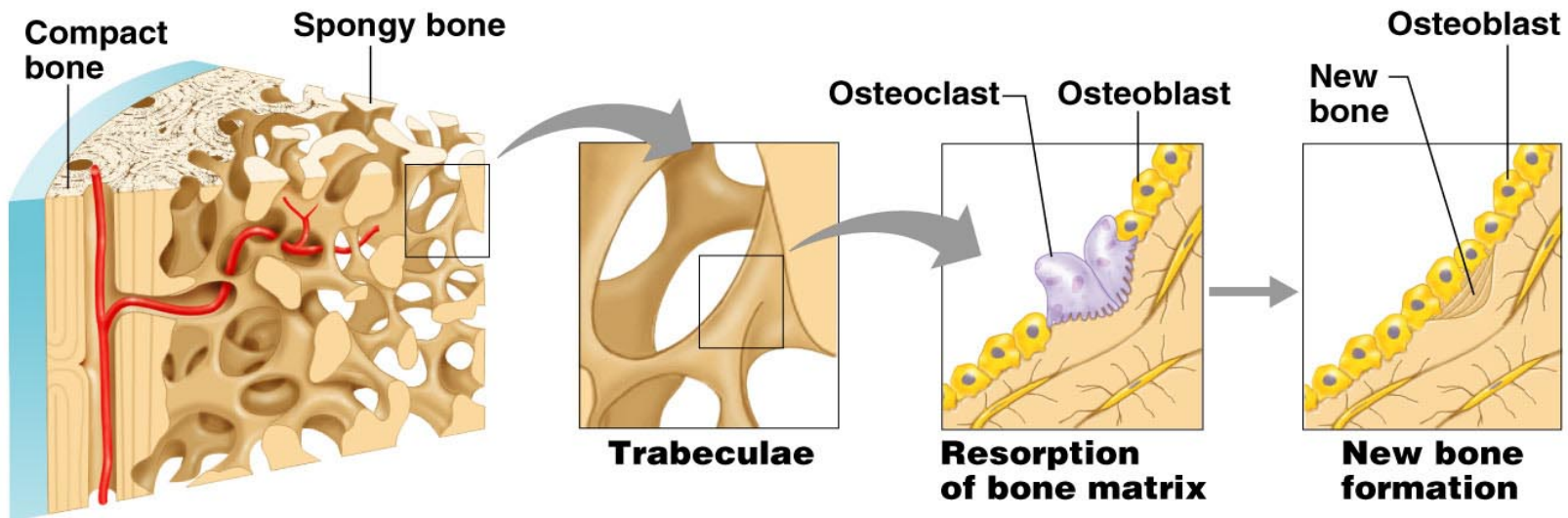


Bone - Remodeling/Homeostasis

- Role of Remodeling in Support
 - Remodeling—Continuous breakdown and reforming of bone tissue
 - Shapes reflect applied loads
 - Mineral turnover enables adapting to new stresses
- What you don't use, you lose. The stresses applied to bones during exercise are essential to maintaining bone strength and bone mass

Bone Remodeling

- Bone is active tissue – small changes in bone architecture occur continuously – 5 to 7% of bone mass is recycled weekly – spongy bone is replaced every 3-4 years and compact bone approximately every 10 years
- Remodeling Units – adjacent osteoblasts and osteoclasts deposit and reabsorb bone at periosteal and endosteal surfaces

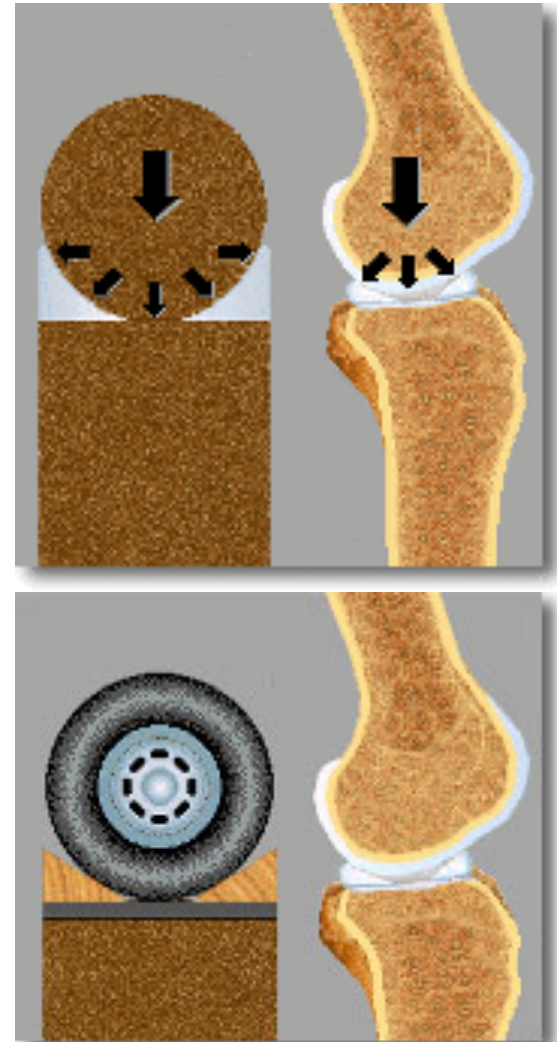


Types of cartilage

- Hyaline
- White Fibrocartilage
- Yellow Fibrocartilage

Articular Cartilage: Primary Functions

- Transmits applied loads across mobile surfaces
- Lines the ends of bones
- surfaces roll or slide during motion
 - Hyaline cartilage is fluid-filled wear-resistant surface
 - It reduces friction coefficient to 0.0025.



Articular Cartilage: Histology

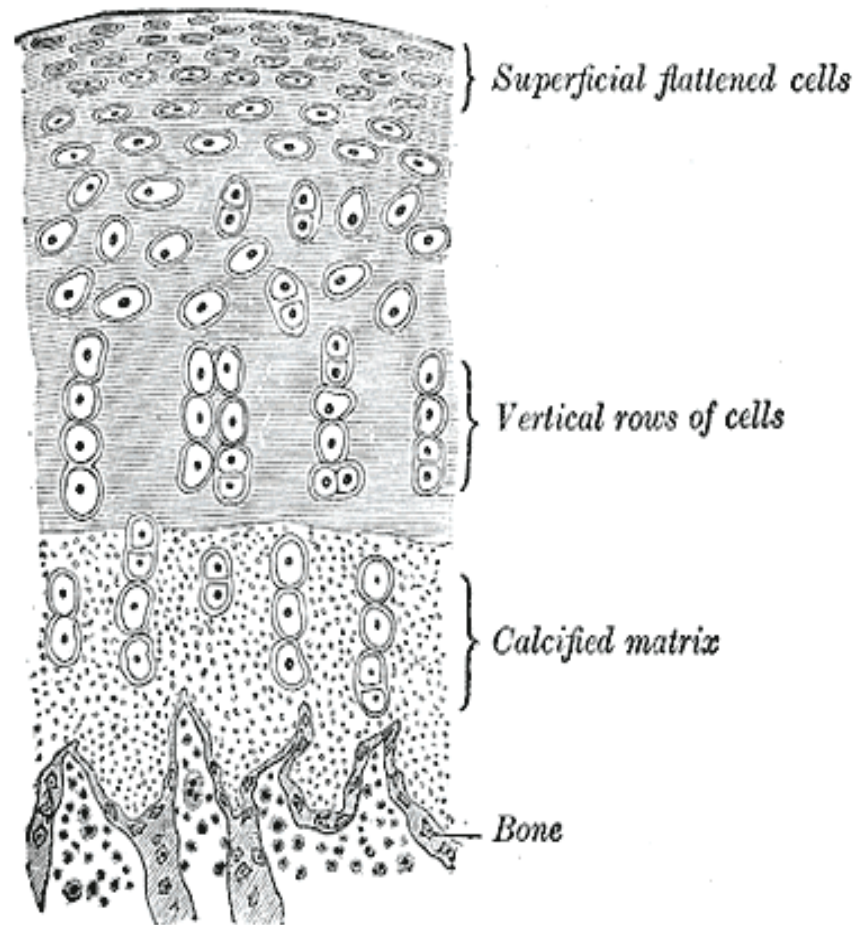
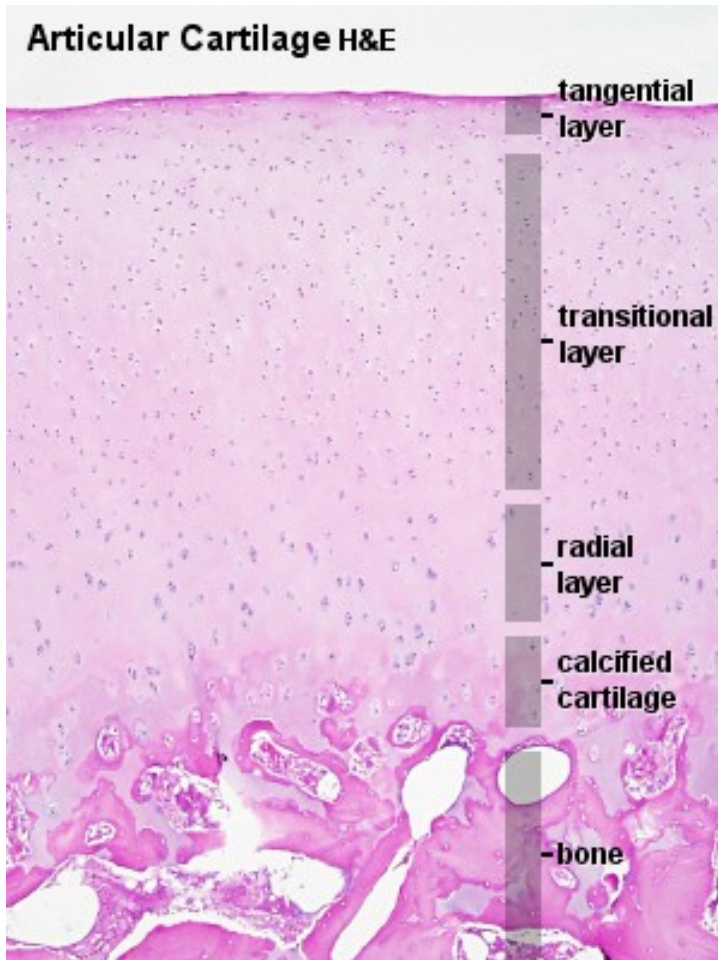


By volume: 1% chondrocytes and 99% matrix

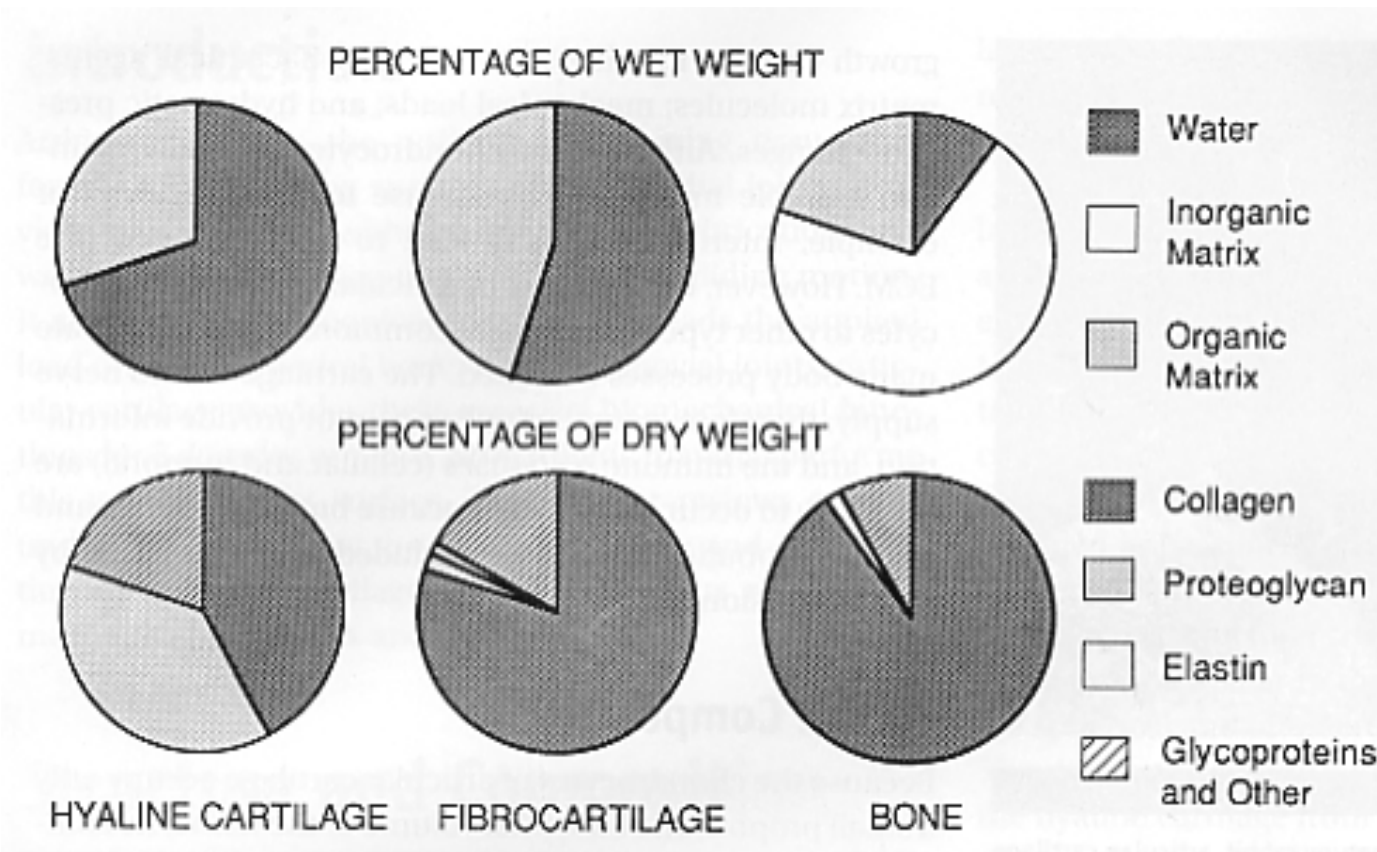
- Chondrocytes produce collagen, proteoglycans, etc. as needed
- Release enzymes to break down aging components.

Articular Cartilage: Chondrocytes

- Chondrocytes vary in size, morphology and arrangement
- Changes with depth at tissue

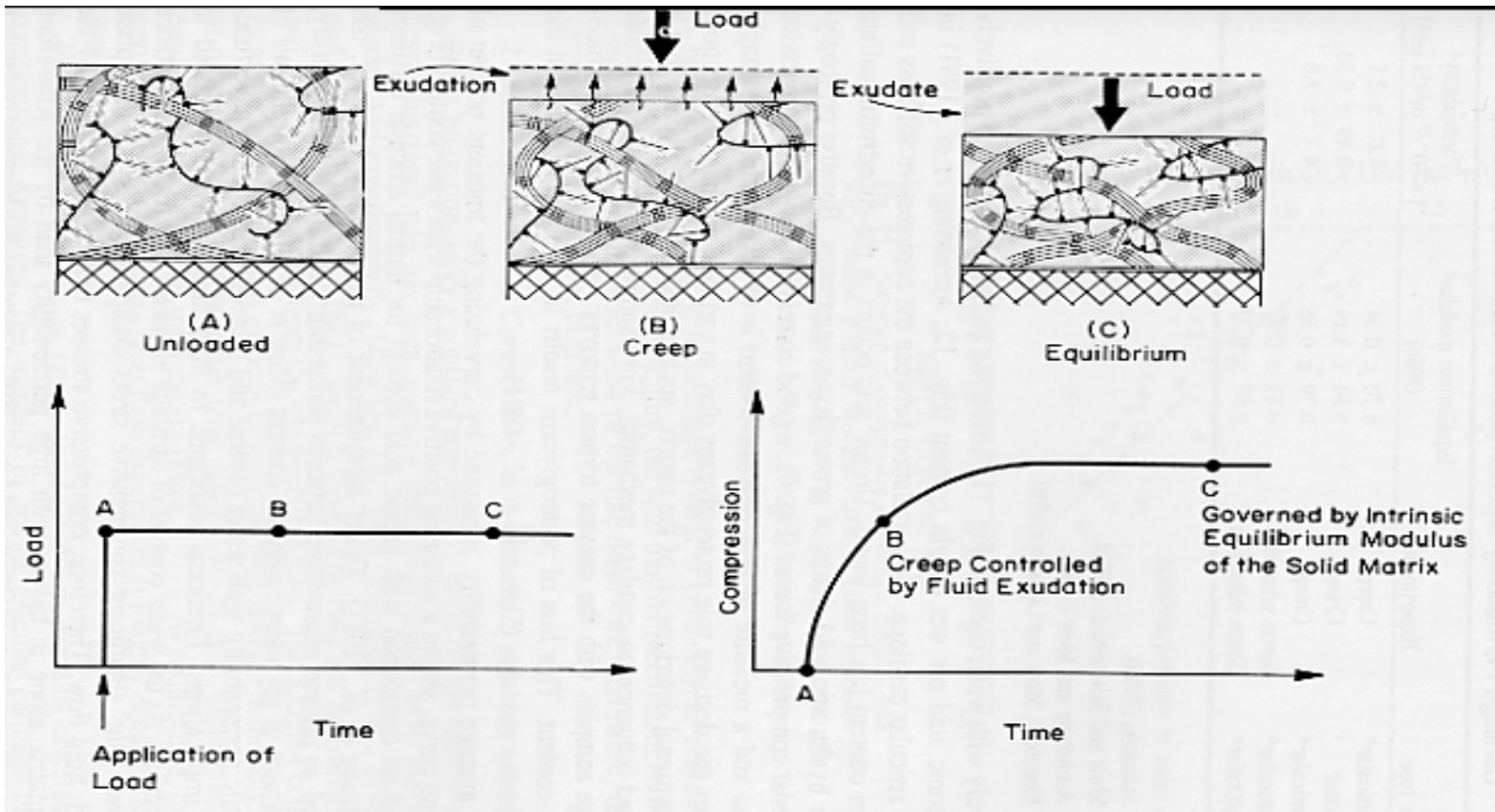


Articular Cartilage: Composition



Note that articular (hyaline) cartilage has the highest proportion of water and also the highest proteoglycan content

Compressive force

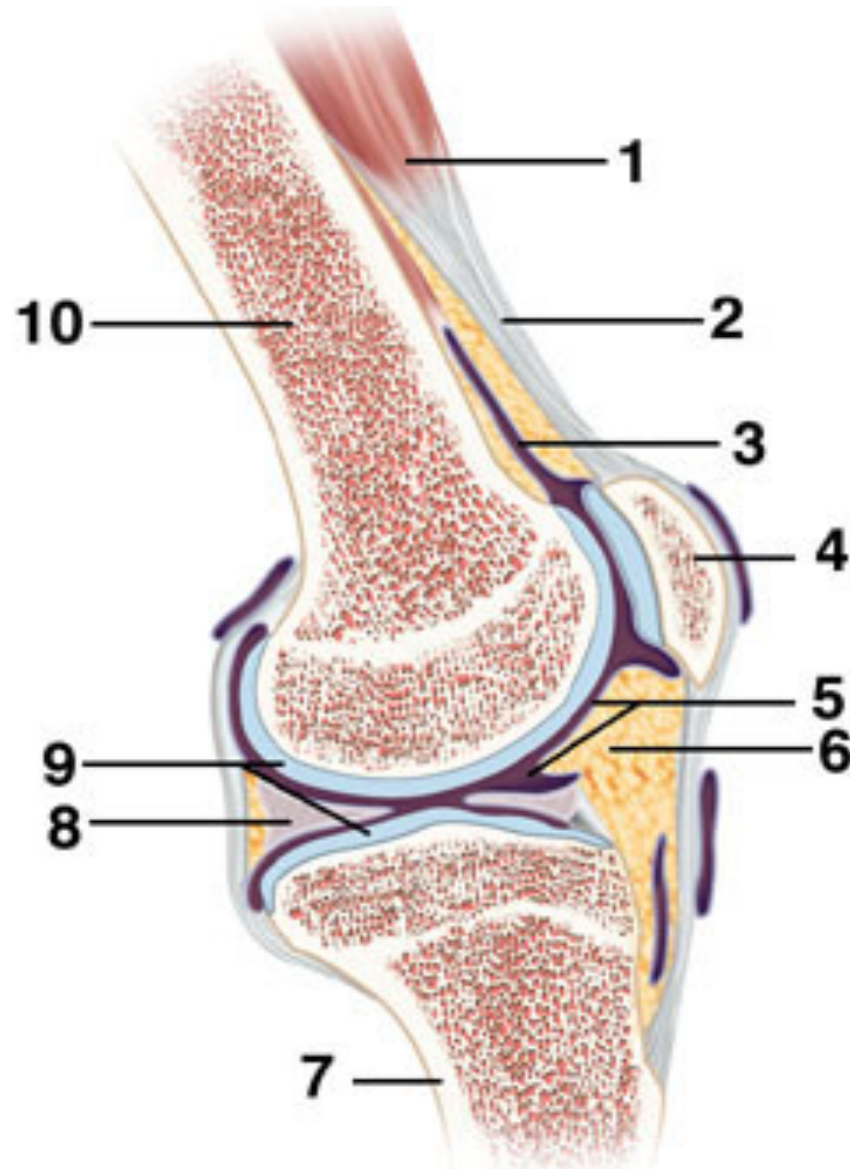


Copious exudation of fluid at start but the rate of exudation decreases over time from points A to B to C

Function of cartilage

- **Shock Absorption** – Joints
- **Movement** – friction free
- **Stability** – improve congruency of surfaces

Tasks - Socrative



Extra Reading

- Anatomy and physiology
 - Rod R. Seeley Trent D Stephens; Philip Tate
- Mechanical Factors in Bone Growth and Development
 - D. R. CARTER, M. C. H. VAN DER MEULEN, and G. S. BEAUPRI (1996)