BCH 450
Biochemistry of Specialized Tissues

III. Cartilage, Bone & Teeth Tissue

Types of Connective Tissue Found in the Skeletal System

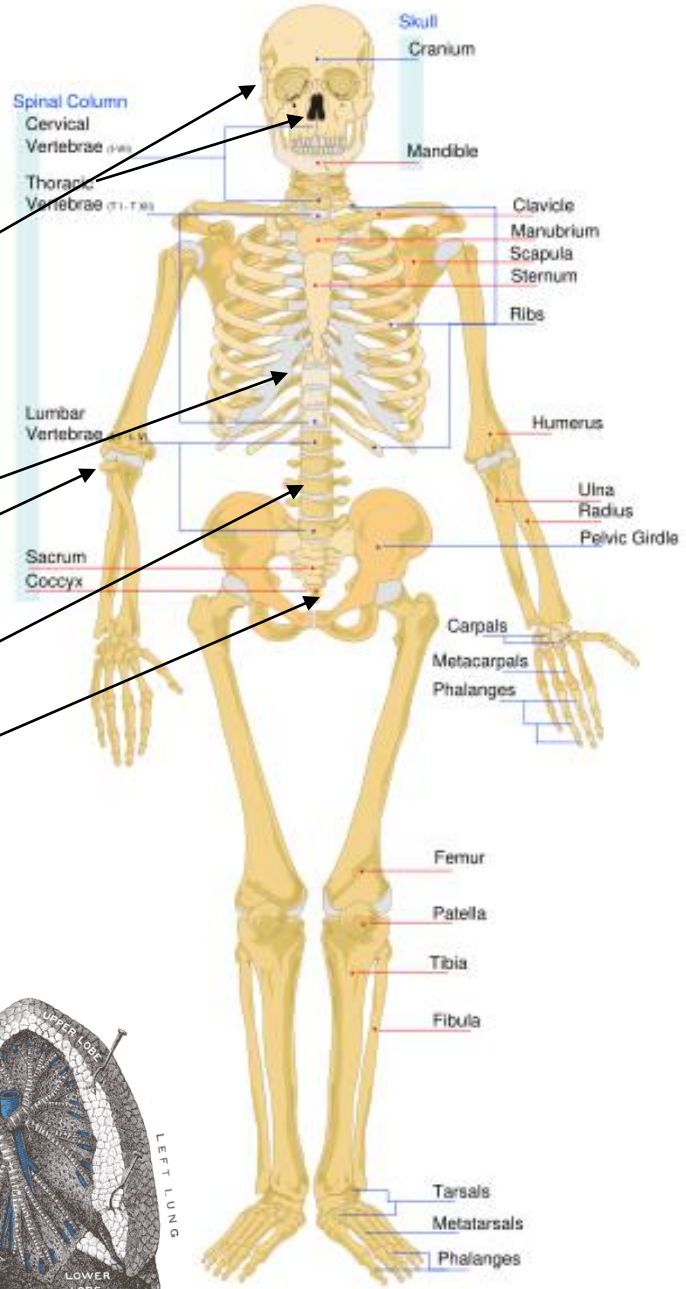
- **Cartilage**
- **Bone**

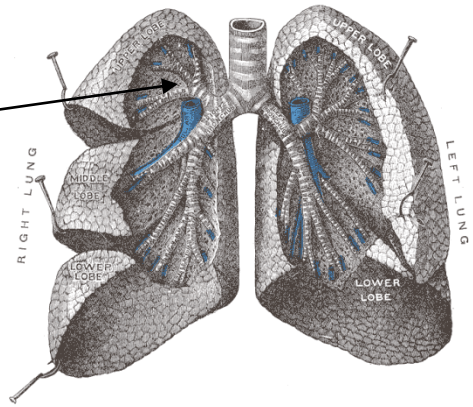
Each of these connective tissue types consists of:

1. living cells,
2. nonliving intercellular protein fibers,
3. an amorphous (shapeless) ground substance

Cartilage

- Location
  - Ear and nose,
  - Costal cartilage,
  - Movable joints,
  - Intervertebral disks,
  - Pubic symphysis,
  - Embryonic,
  - Respiratory system,





Cartilage **Tissue**

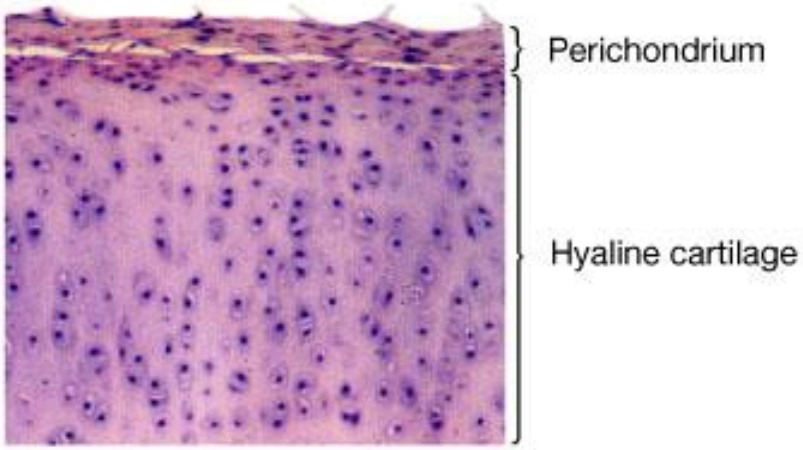
- **Specialized Connective Tissue**
  - Chondrocytes in lacunae
  - Solid ground substance and fibers
  - Avascular
  - No nerves
  - Perichondrium
  - 60-80% water resilient

Supporting connective tissues

- Cartilage and bone support the rest of the body
- **Cartilage**
  - Matrix is a firm gel containing chondroitin sulfate
  - Cells are called chondrocytes
  - Cells occupy small chambers called lacunae
  - There are three types:

1- hyaline 2- elastic 3- fibrocartilage

The Perichondrium and Types of Cartilage



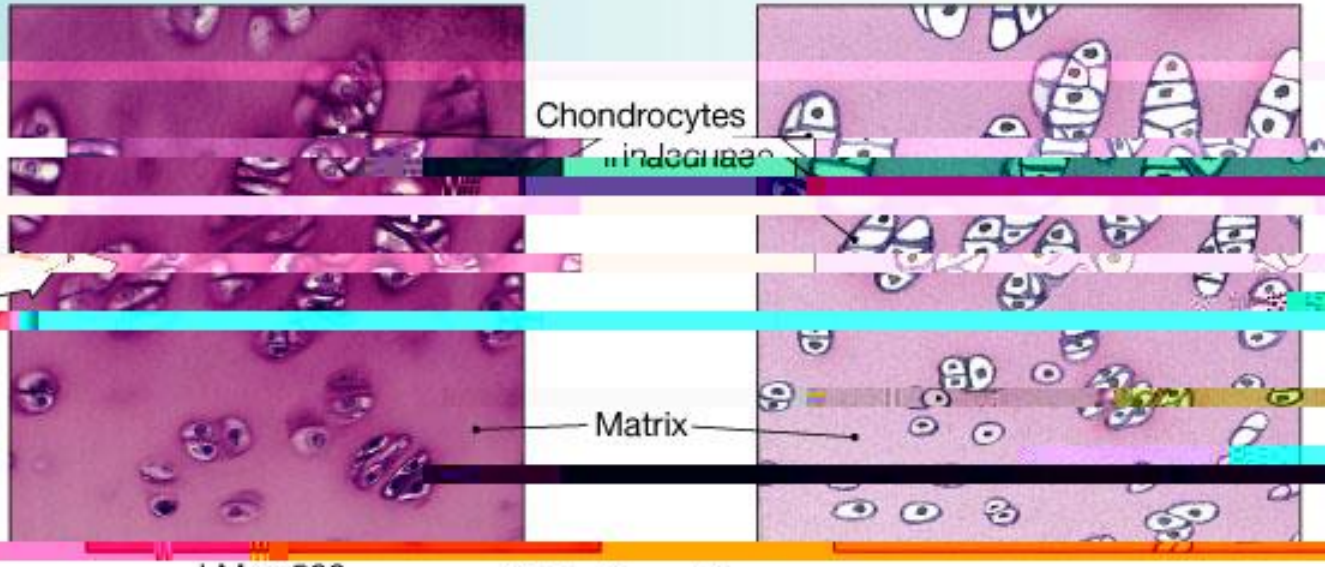
(a)

Hyaline Cartilage

HYALINE CARTILAGE

LOCATIONS: Between tips of ribs and bones of sternum; covering bone surfaces at synovial joints; supporting larynx (voice box), trachea, and bronchi; forming part of nasal septum

FUNCTIONS: Provides stiff but somewhat flexible support; reduces friction between bony surfaces



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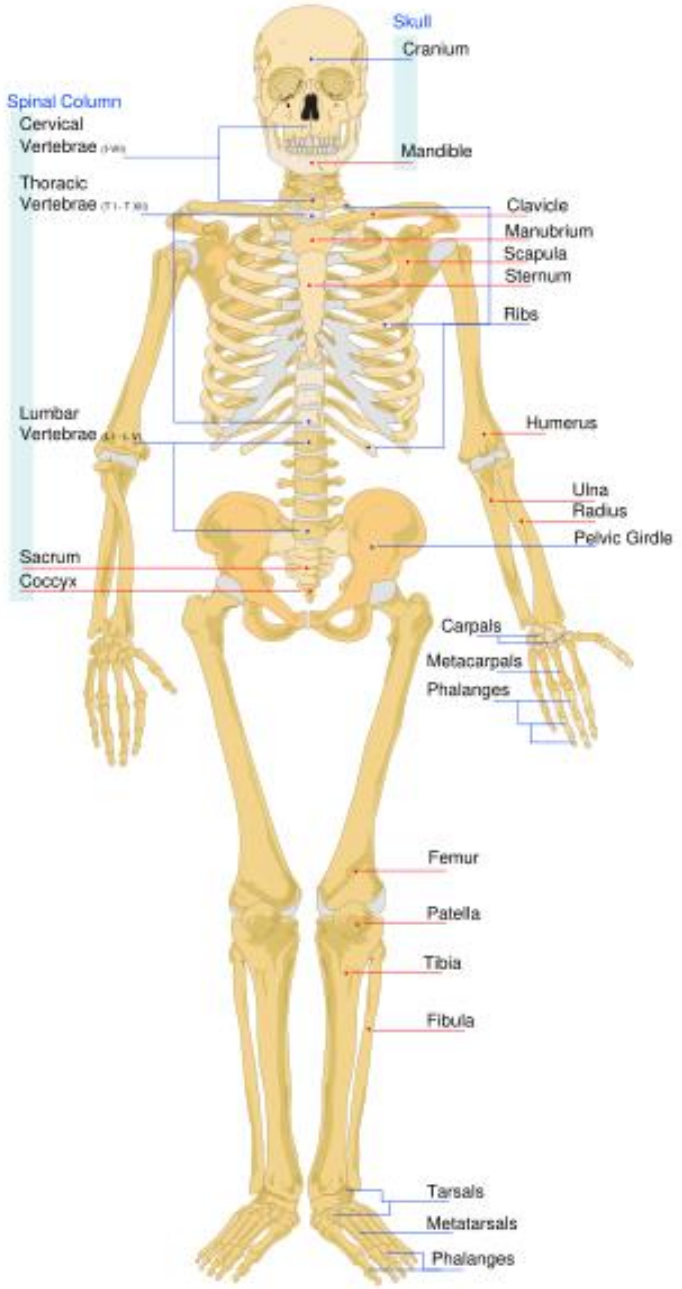
(b) Hyaline cartilage

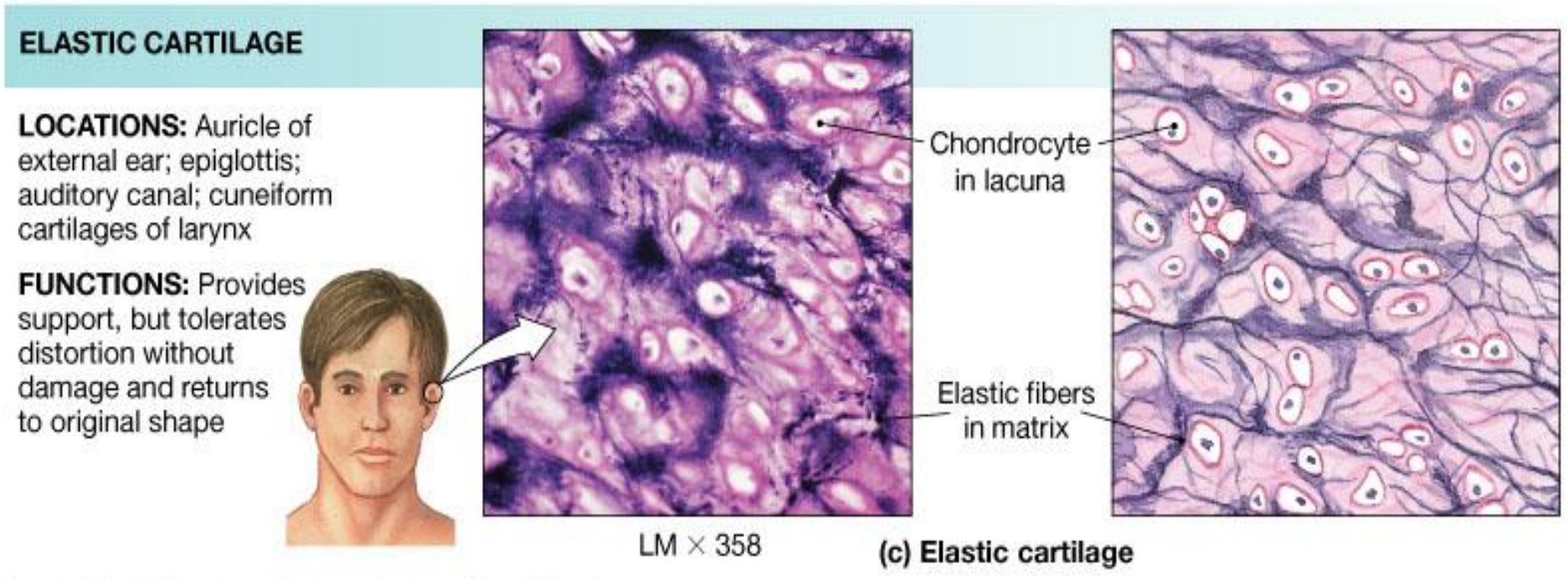
Hyaline Cartilage

- **Most abundant**
- Locations
  - Joints
  - Trachea
  - Costal cartilages
- Network of collagen fibers



The Perichondrium and Types of Cartilage

Elastic Cartilage

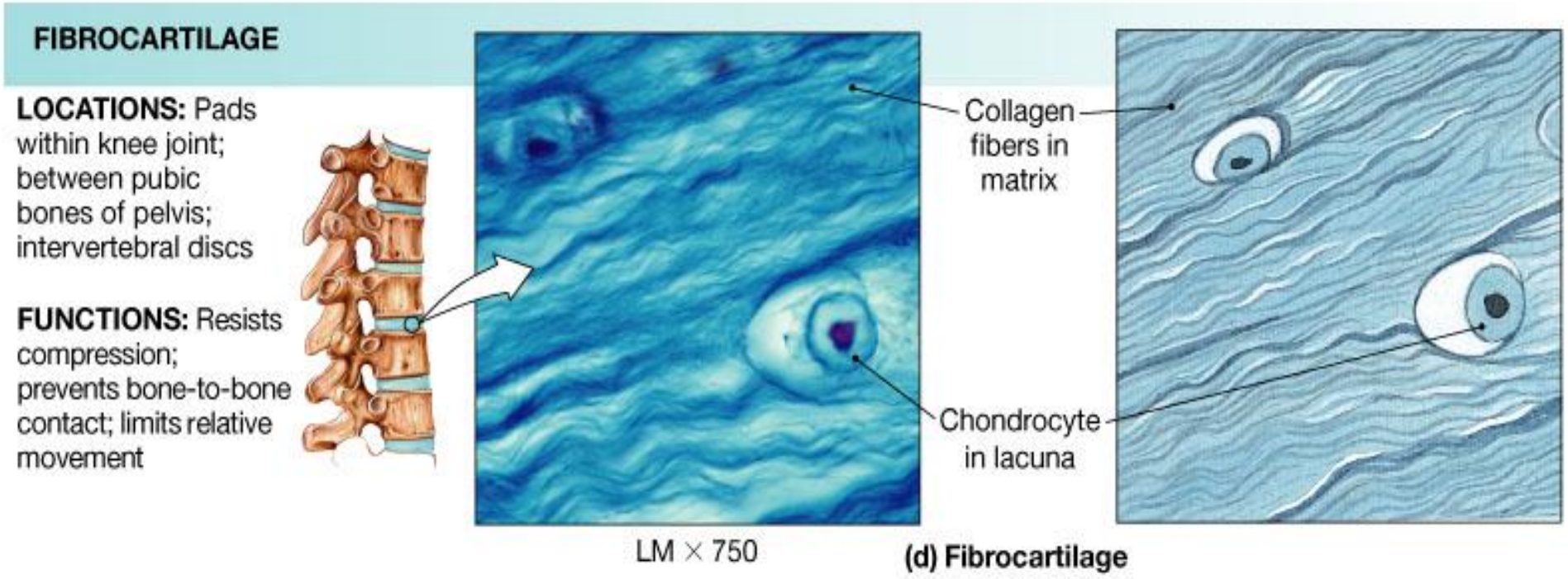


Elastic cartilage

- Contains elastic fibers
- Location
  - External ear
  - Epiglottis

The Perichondrium and Types of Cartilage

Fibro Cartilage



Fibro cartilages

- Bundles of collagen fibers in rows
- Locations:
  - Intervertebral disks
  - Pubic symphysis
  - Menisci

Cartilage: Function

- articular (or hyaline) cartilage covers bone surfaces within the joint capsule
- basic functions:
  - lubrication
  - prevents wear
  - despite common belief does not serve as a "shock absorber"

    very thin

    capacity negligible compared to muscles and bones

Cartilage: Composition

- **water contains dissolved inorganic salts**
- **tissues with high proteoglycan content has**
  - high water content
  - low hydraulic permeability
  - high compressive stress
  - damage to proteoglycans will result in increased water mobility and impaired mechanical function

Cartilage: Structure

- Split line patterns (preferred collagen fiber orientation)

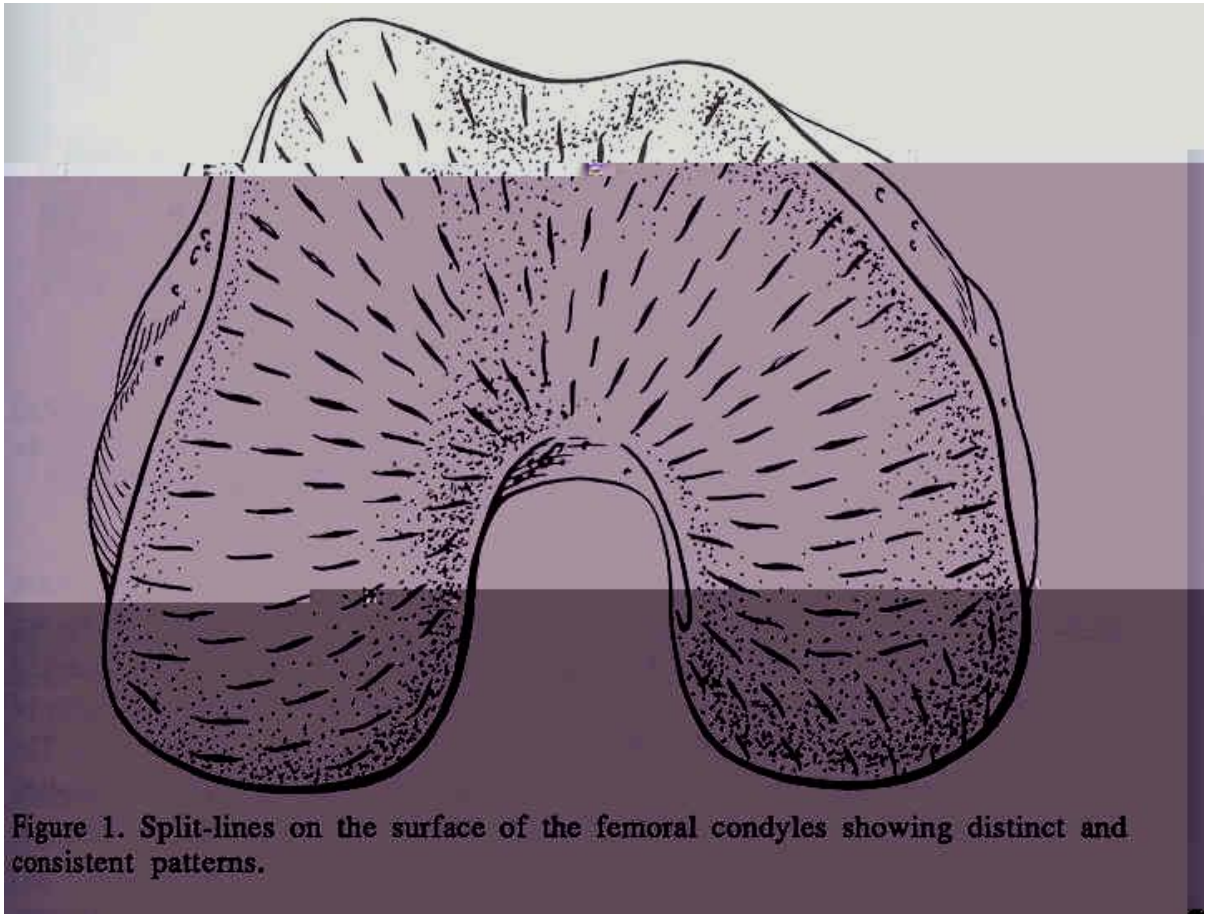


Figure 1. Split-lines on the surface of the femoral condyles showing distinct and consistent patterns.

Cartilage: Structure

- **Collagen orientation**
  - parallel to the surface on the superficial layer
  - oblique in the middle layer
  - perpendicular to the surface in the deep zone
- **Proteoglycan content**
  - increases from surface till the middle zone and diminishes towards the deep zone

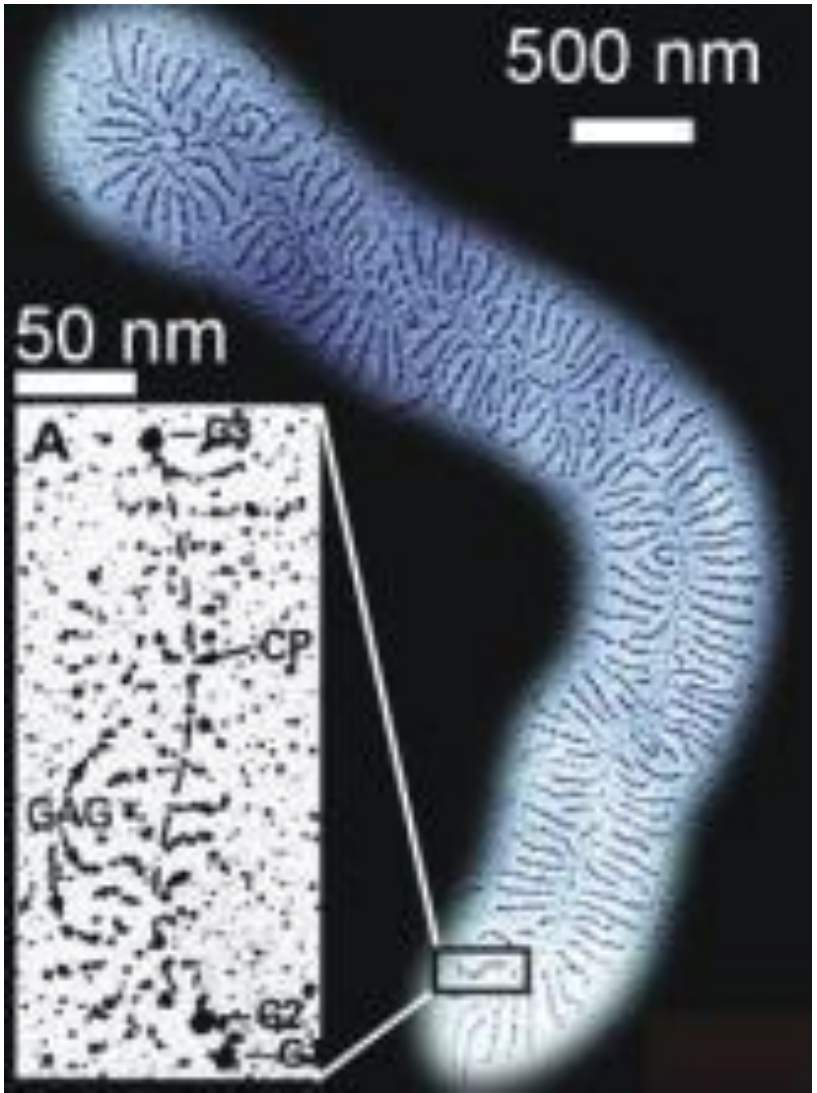
Cartilage: Structure

- **Water**
  - proteoglycans can hold water up to 50 times their weight
  - 70% of the water is bound to proteoglycans
  - remaining 30% bound to collagen
  - inorganic ions such as Ca, Na, Cl and K are dissolved
    - balance fixed charges on proteoglycans and generate swelling pressure

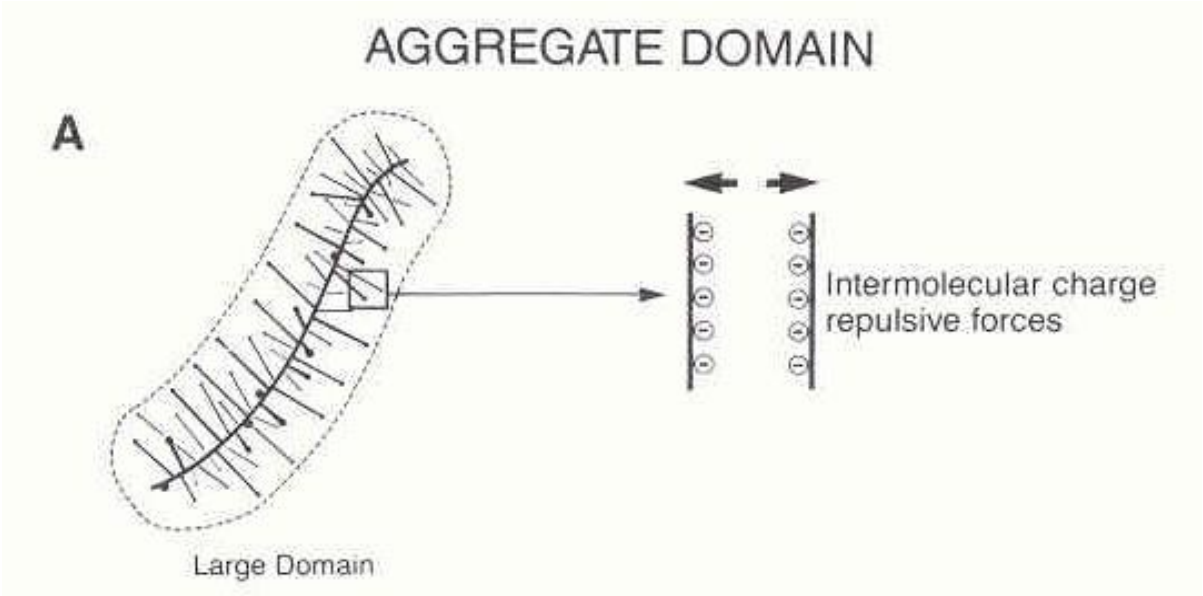
Cartilage: Structure

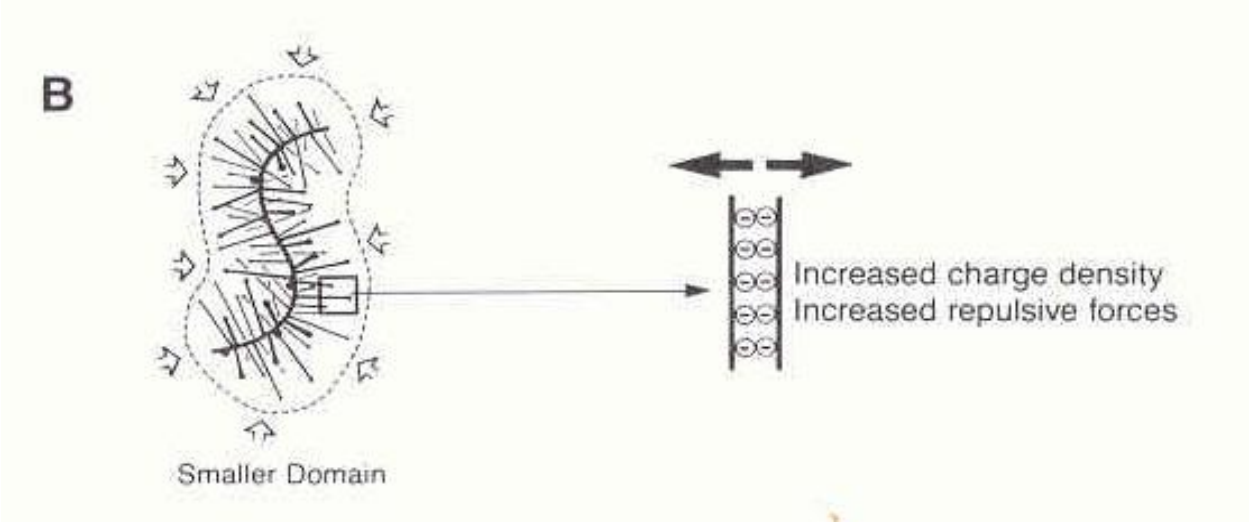
- proteoglycan-proteoglycan interactions
  - aggregation
    - entropically favored
    - cations are attracted to maintain electroneutrality resulting in osmotic swelling pressure (0.35 MPa)
    - negative charges on the GAG chains exert electrostatic repulsive forces on one another

Aggregated Proteglycans



Cartilage: Structure





Bone

Definition

- Connective tissue in which the intercellular matrix has been impregnated with inorganic calcium salts
- It has great tensile and compressible strength but is light enough to be moved by coordinated muscle contractions.

Composition

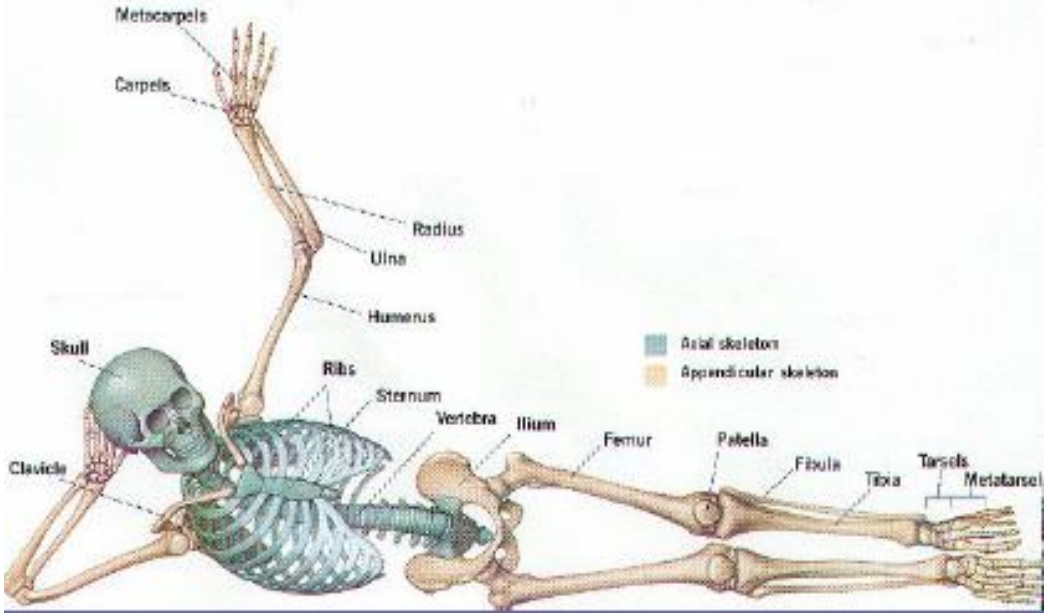
It contains two types of substances.

a- organic matter

b- inorganic salts.

Bone Function

- **Support body weight**
- **Protect soft organs (Skull)**
- **Movement at joints**
- **Storage of Ca^{++} and PO_4^{+++}**
- **Hematopoiesis (Blood cell formation)**



Bone Composition

- **35% cells,**
- **fibers (collagen),**
- **ground substance**
- **65% mineral salts mainly calcium phosphate precipitated around collagen fibers**

Types of Bone

- **Cancellous (Spongy) bone**
  - Found in the interior of bones
  - Composed of trabeculae, or spicules, of bone that form a lattice-like pattern

- **Compact (cortical) bone**
  - Forms the outer shell of a bone
  - Has a densely packed calcified intercellular matrix that makes it more rigid than cancellous bone

Types of Bone Cells

- Osteogenic cells
- Osteoblasts (Bone forming cells)
- Osteocytes (Mature bone cell)
- Osteoclasts (Large cells that break down or resorbe bone matrix)

Bone formation

- Osteogenesis – development of the skeleton and growth through adolescence (~18 females, ~21 males)
- Osteoblasts secrete osteoid
- Osteoid is miniralized (calcium phosphate precipitates)
- Osteoblasts become osteocytes
- Forms woven bone (immature)
- Periosteum formed
- Mature lamellar bone formed on surface

Classification of Bones

- **Long bones**
  - Found in the upper and lower extremities
- **Short bones**
  - Irregularly shaped bone located in the ankle and the wrist
- **Flat bones**
  - Composed of a layer of spongy bone between two layers of compact bone
  - Found in areas such as the skull and rib cage

Bone Growth

- **Regulated by:**
  - Growth hormone
  - Thyroid hormone
  - Sex hormones
  - Vitamins

Regulation of Bone growth

Hormones

- It is chemicals produced by the endocrine glands and secreted directly into the bloodstream to their target organs to control the activity of that organ.
- It can stimulate cartilage formation, Vitamin D production, cause the release of Ca^{2+} & PO_4^{3+} from bone, and sex hormones play a role in the termination of long bone growth
  - Estrogen: rapid and early growth
  - Androgens: later, slower growth

Hormonal Mechanism

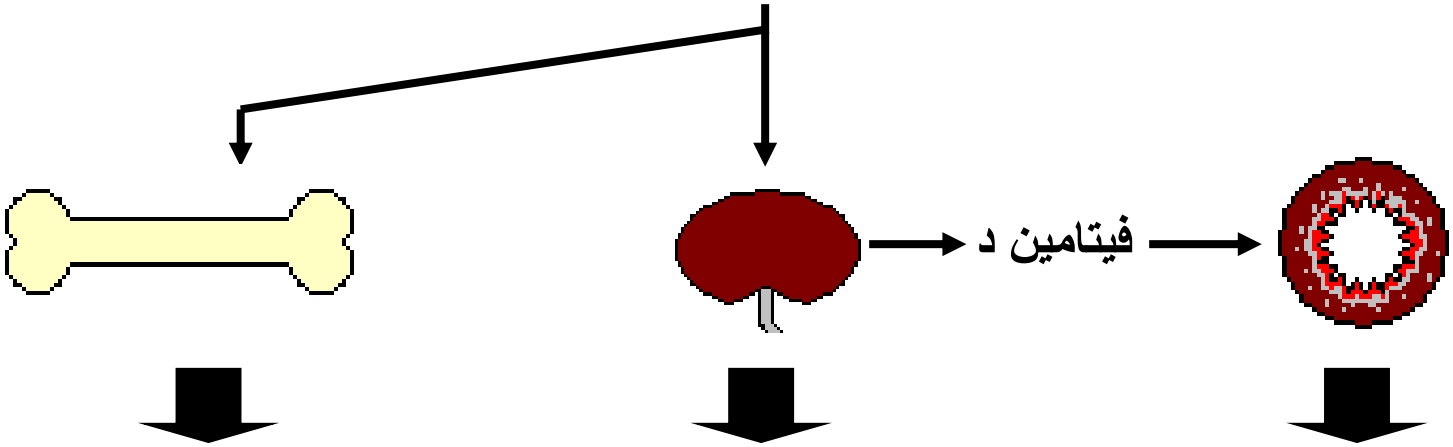
Rising blood Ca^{2+} levels trigger the thyroid to release calcitonin
Calcitonin stimulates calcium salt deposite in the bone
Falling blood Ca^{2+} levels signal the parathyroid glands to release Parathyroid hormone (PTH)
PTH signals osteoclasts to degrade bone matrix and release Ca^{2+} into the blood

Action of Parathyroid Hormone

- It increases intestinal absorption of calcium
- It increases intestinal absorption of Phosphate
- It decreases renal excretion of calcium
- It increases renal excretion of phosphate
- It increases bone resorption
- It decreases bone formation
- Promptly increases serum calcium levels
- It prevents increase in serum phosphate levels

تركيز منخفض للكالسيوم في الدم

إفراز الباراثورمون



تدفق الكالسيوم من العظام

تقليل الفقد في البول

تشجيع امتصاص الكالسيوم من الأمعاء

زيادة تركيز للكالسيوم في الدم

Action of Calcitonin

- It increases renal excretion of calcium
- It increases renal excretion of phosphate
- It decreases bone resorption
- It decreases serum calcium levels with pharmacologic doses
- It decreases serum phosphate levels with pharmacologic doses

Action of Vitamin D

- It increases intestinal absorption of calcium
- It increases intestinal absorption of Phosphate
- It increases renal excretion of phosphate

Regulation of Bone growth

Vitamin D

- 7-dehydrocholesterol located in the skin:
- It is formed in the presence of ultraviolet light
- Becomes Vit. D3 (cholecalciferol) in liver, Calcidiol in kidney

Deficiency:

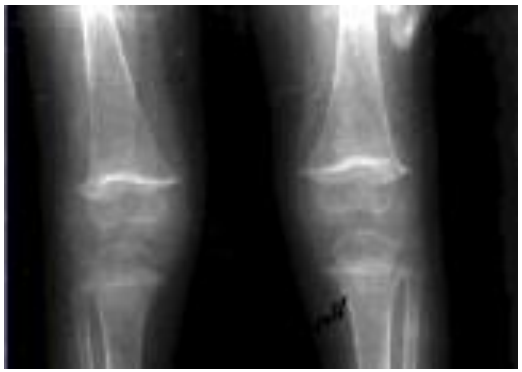
- Osteomalacia is bone degeneration (similar to rickets) in the elderly, who stay out of sun.
- Rickets is a softening and weakening of childrens' bones

Regulation of Bone growth

Vitamin C (ascorbic acid):

Lack of vitamin C leads to poor structure, less effective support, swollen & painful connective tissues. Wounds heal poorly (scar tissue is rich in collagen fibers). Gums bleed as connective tissue around teeth weakens

Scurvy is the vitamin C deficiency disease



Regulation of Bone growth

Vitamin A

- Retinol easiest for the body to use. Found in animal foods (liver, eggs and fatty fish).
- Beta-carotene is a precursor for vitamin A.
- The body needs to convert it to retinol or vitamin A for use.
- It is found in plant foods (orange and dark green veggies: carrots, sweet potatoes, mangos and kale).

Regulation of Bone growth

Vitamin A

- The body stores both retinol and beta-carotene in the liver, drawing on this store whenever more vitamin A is needed.
- It stimulates osteoblast activity, needed for cell division.
- *Too much* vitamin A linked to bone loss and increased risk of hip fracture.
- Excess vitamin A triggers an increase in osteoclasts and it may also interfere with vitamin D

Regulation of Bone growth

Vitamin B-12

- It is found in animal products (meat, shellfish, milk, cheese and eggs)
- It is important for blood formation and clotting
- Low levels is linked to loss of bone mass
- However deficiency is uncommon in younger women who are also at less risk of osteoporosis

Regulation of Bone growth

Vitamin K

- It is important for protein synthesis in bone
- Low intake of Vitamin K is associated with osteopenia (reduction of bone mass) and osteoporotic fracture (only in women?)