



# HISTOLOGY OF CARTILAGE

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## OUTLINE

- |                         |                                          |
|-------------------------|------------------------------------------|
| I. Learning Objectives  | IV. Cartilage Growth and Repair          |
| II. Cartilage           | V. Clinical Correlation : Osteoarthritis |
| A. Cartilage Cells      |                                          |
| B. Perichondrium        |                                          |
| C. Cartilage Matrix     |                                          |
| III. Types of Cartilage |                                          |
| A. Hyaline              |                                          |
| B. Elastic              |                                          |
| C. Fibrocartilage       |                                          |

## SUMMARY OF ABBREVIATIONS

| ABBREV | Meaning |
|--------|---------|
|--------|---------|

## LEGENDS

| Must know | Lecturer | Book | Presentation | Old Trans |
|-----------|----------|------|--------------|-----------|
| !         |          |      |              |           |

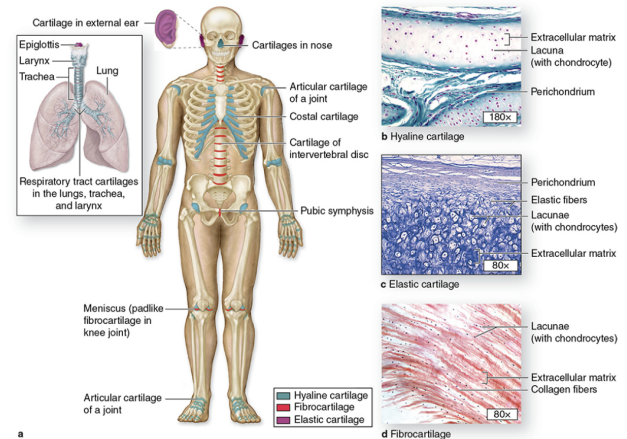
## LEARNING OBJECTIVES

At the end of the lecture, the student should be able to:

- ✓ Describe the general histologic organization of cartilage, bone, and muscle as specialized connective and contractile tissues.
- ✓ Identify the major cell types, extracellular matrix components, and structural organization characteristic of each tissue.
- ✓ Differentiate the three types of cartilage, the major types of bone, and the three types of muscle based on their microscopic features
- ✓ Correlate the microscopic structure of these tissues with their mechanical, metabolic, and physiologic functions.
- ✓ Interpret basic histologic images of cartilage, bone, and muscle using characteristic diagnostic features.
- ✓ Apply knowledge of normal histology to selected clinical conditions involving cartilage, bone, and muscle

## CARTILAGE

- A special form of connective tissue
- Develops from mesenchymal cells
- Components:
  - Cells
  - Fibers
  - Ground substance
  - Tissue fluid
- **Avascular** - Does not have a direct blood supply
  - How does it get nutrients if it does not have a blood supply?
    - The **Ground Substance** is part of the extracellular matrix, doon siya kumukuha ng nutrients para ma-sustain yung structure.
- General characteristics
  - Exhibits tensile strength
    - Dense type II collagen fibrils act like structural cables, resisting stretching, pulling, and tearing forces
  - Provides firm structural support for soft tissues
  - Allows flexibility without distortion
  - Resilient to compression

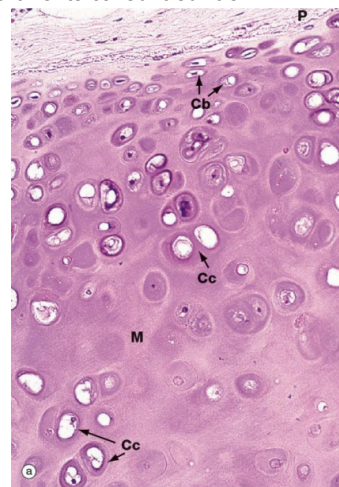


**Figure 1.** (a) There are three types of adult cartilage associated with areas of the skeleton, particularly in joints and where pliable support is useful, as in the ribs, ears and nose. Cartilage support of other tissues throughout the respiratory tract is also prominent. The photomicrographs show the key features of (b) hyaline cartilage, (c) elastic cartilage and (d) fibrocartilage. Dense connective tissue of perichondrium appears here with hyaline and elastic cartilage.

## CARTILAGE CELLS

### Chondroblasts

- Flattened shape, found in the perichondrium
- Resemble fibroblasts
- Differentiate to form chondrocytes
- Divide mitotically
- Secrete ground substance and fibrous extracellular material.
- As the cartilage grows, these cells become surrounded by the extracellular matrix and trapped in matrix compartments called **lacunae**.



**Figure 1.** Chondroblasts (Cb) in Hyaline Cartilage. Situated directly beneath the dense connective tissue sheath of the perichondrium (P), these active progenitor cells appear flattened. They actively synthesize and secrete ECM components until becoming fully entrapped within lacunae, where they mature into chondrocytes (Cc).

## Chondrocytes

- Gr. chondros, cartilage + kytos, cell
- Mature cartilage cells
- Ovoid cells with eccentric round nuclei
- Located within lacunae
- Produce and maintain cartilage ECM
- Appear either singly or in isogenous groups

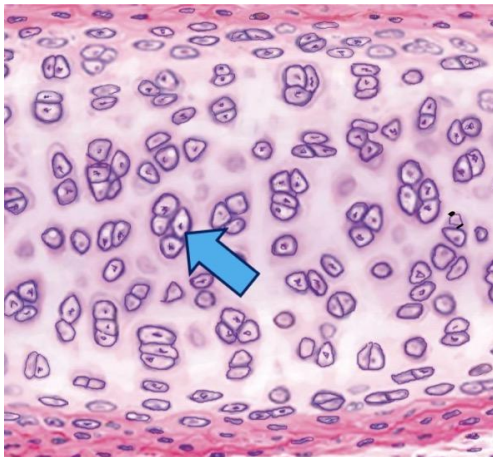
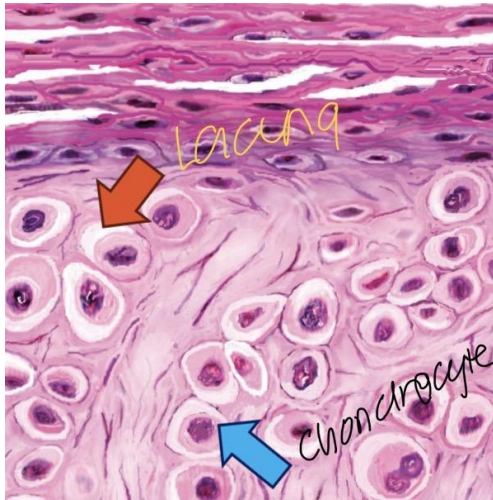


Figure2. Chondrocyte

## PERICHONDRIUM

- A sheath of dense, irregular connective tissue that invests the cartilage.
- Harbors the blood supply and a small neural component
- Layers:
  - Outer fibrous layer or peripheral layer
    - A dense vascular connective tissue with
    - Type I collagen
- Inner chondrogenic layer
  - Gives rise to chondroblasts that secrete cartilage

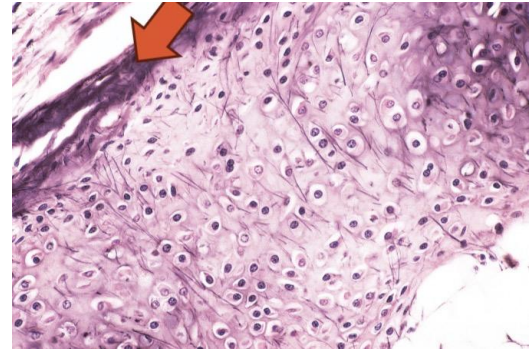


Figure 3. Perichondrium

## CARTILAGE MATRIX

- What are the substances that are woven together
- Type II Collagen
- Proteoglycans
- Glycosaminoglycans
- Hyaluronic Acid
  - Pag meron hyaluronic acid there's also water doon
- Water
- Territorial versus interterritorial matrix
- **Basophilic appearance** of cartilage matrix
  - These substances give the basophilic appearance of the cartilage matrix. Blue staining yung usually ginagamit dito, so the cartilage matrix usually appears blue under microscope.
  - Although mag H&E naman yung staining, hindi siya super pink na lalabas.

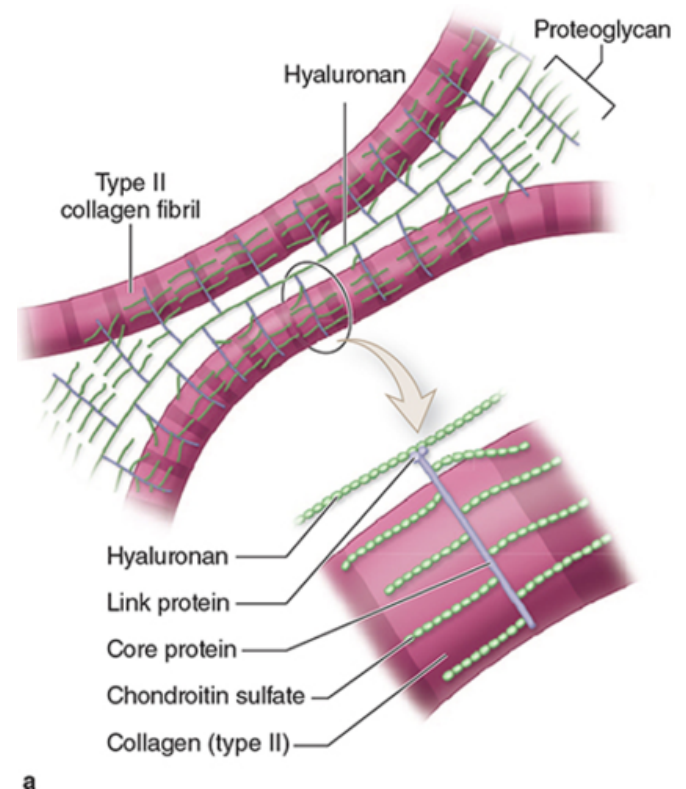


Figure 4. Cartilage Matrix

## Territorial Matrix

- The ECM immediately **around each lacunae**
  - Hahanapin 'yung mga lacunae to determine the territorial matrix. 'Yung clear space sa lacunae, 'yung laman noon is the territorial matrix.
- Contains mostly proteoglycans and sparse collagen

## Interterritorial Matrix

- ECM that is **more distant** from the lacunae
  - Hahanapin ito sa area na may mga chondroblast since malayo siya sa mga lacunae, wala masyadong lacunae.
- Contains more collagen
- May be less basophilic

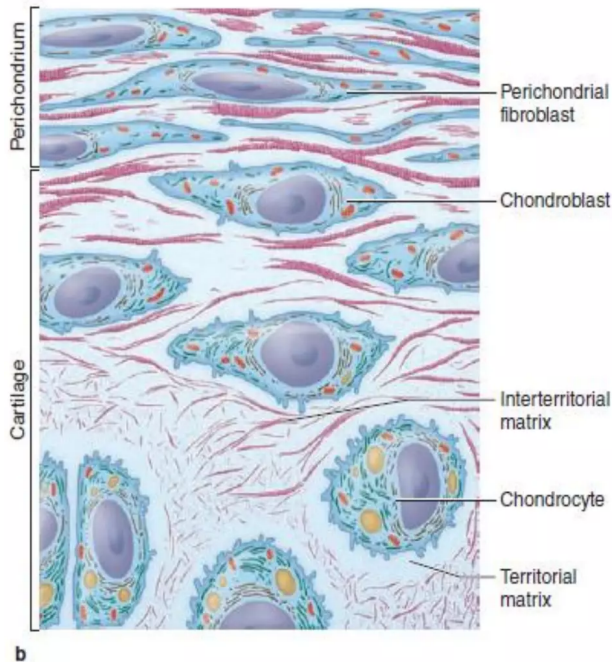


Figure 5. Territorial and Interterritorial Matrix

- since cartilage matrix is avascular, chondrocytes metabolize glucose mainly by anaerobic glycolysis
- nutrients from the blood diffuse to all the chondrocytes from the cartilage surface
  - limitation define the maximum thickness of hyaline cartilage, usually exists as small, thin plates

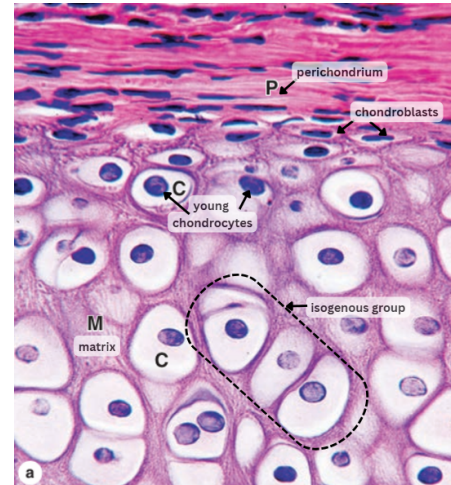
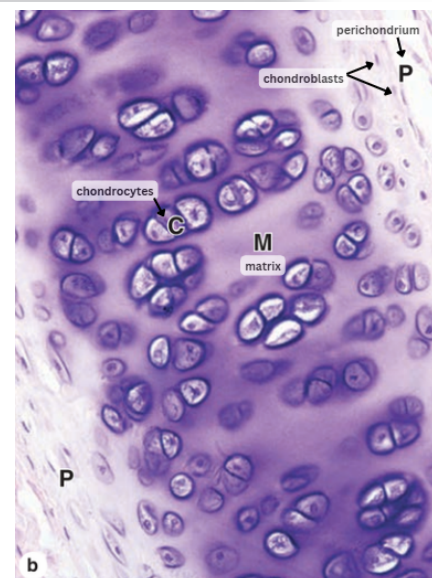
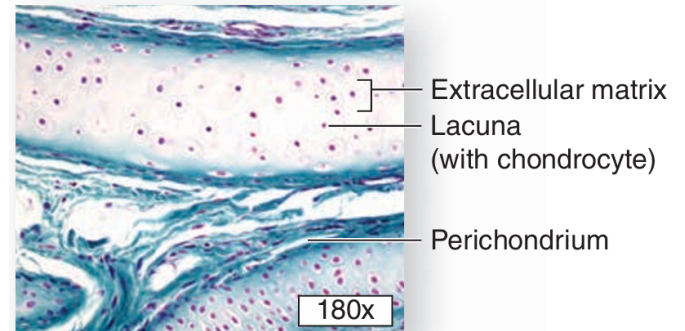


Figure 6. Cartilage cells of the Hyaline cartilage

- Perichondrium**
  - all hyaline cartilage has a perichondrium **except in the articular cartilage of joints**
  - important for growth and maintenance
  - outer region consists of Type I collagen
  - inner layer, adjoining the cartilage matrix contains mesenchymal stem cells
    - provide source for new chondroblasts that will differentiate into chondrocytes



## TYPES OF CARTILAGE

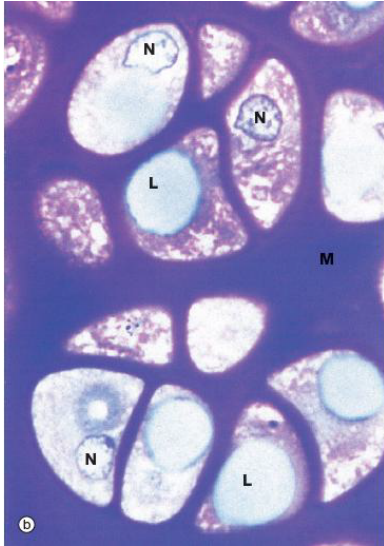
### HYALINE CARTILAGE

- most common type of cartilage
  - homogenous and semitransparent in fresh stat
- found in the nasal septum, larynx, tracheal rings, most articular surfaces and the sternal end of the ribs
- forms the precursor of bone in the developing skeleton
- Matrix**
  - Type II collagen (to remember: car-2-lage)
    - makes up 40% of its dry weight
  - Aggrecan
    - most abundant proteoglycan
  - Chondronectin
    - binds specifically to GAGs, collagen, integrins, mediating transient adherence of chondrocytes to ECM
- Cartilage Cells**
  - At the periphery:
    - young chondrocytes and chondroblasts have an elliptic shape, with the long axes parallel to the surface
  - At the deeper end:
    - cartilage cells become rounded and often appear in isogenous groups

**Figure 7. Hyaline cartilage**

- hyaline cartilage is susceptible to partial or isolated regions of calcification
  - accompanied by degenerative changes in the chondrocytes; common part of the aging process and in many respects resembles endochondral ossification by which bone is formed

### ELASTIC CARTILAGE



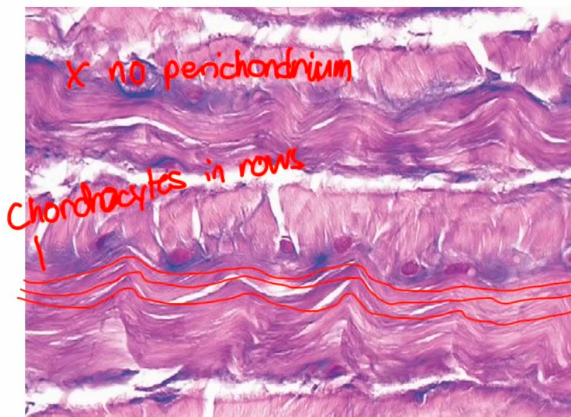
**Figure 8.** Elastic cartilage. (L = lipid droplets; N = nucleus)

- Resemble hyaline cartilage except that:
  - Its ECM contains **elastic fibers** and
  - its chondrocytes typically accumulate **lipid droplets**

**! BE VERY CAUTIOUS. very similar in characteristics ang hyaline and elastic, but the difference lies in the presence of elastic fibers and lipid droplets**  
 mahirap mahanap elastic fibers under H&E staining but take note of white lipid droplets  
 formation of elastic cartilage is not affected by diet, presence of lipid droplets are *de novo*

- Found in the:
  - External ear
  - Walls of the external auditory canal and auditory (Eustachian Tube)
  - Epiglottis
  - Arytenoid and corniculate cartilages of the larynx

### FIBROCARTILAGE



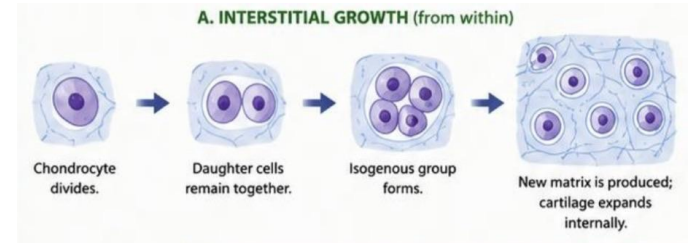
**Figure 9.** Fibrocartilage.

- Consists of alternating layers of hyaline cartilage matrix and thick layers of dense collagen fibers.
- Presence of chondrocytes in rows**
- Absence of typical perichondrium**
- location:
  - intervertebral discs
  - pubic symphysis
  - menisci

### CARTILAGE GROWTH AND REPAIR

#### CARTILAGE GROWTH

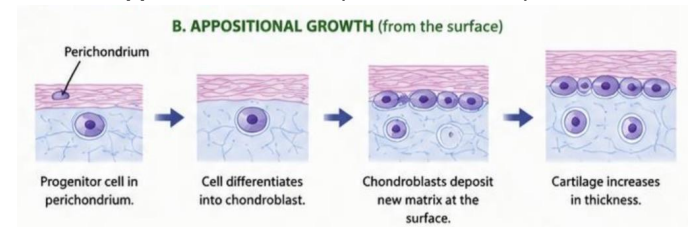
- Interstitial Growth (from within)**



**Figure 10.** Process of Interstitial Growth

- Yung chondrocytes makikita niyo nasa gitna ng matrix tapos magdi-divide pa siya at pagtapos undergoes mitosis at dadami siya kaya nagkakaroon ng isogenous groups PERO habang lumalaki sila naghihiwalay sila dahil mas maraming matrix and naproproduce sp 'yung nangyayari lumalaki ang cartilage from within so area ng matrix lumalaki o kumapagal

- Appositional Growth (from the surface)**



**Figure 11.** Process of Appositional Growth

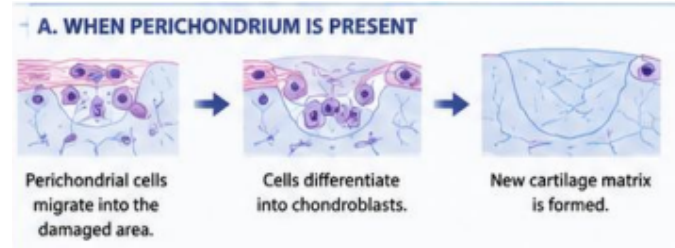
- Compared dito na yung growth sa edge or sa perichondrium. Dito siya sa periphery dumadami so 'yung area sa labas ayun 'yung kumakapal.

| INTERSTITIAL GROWTH              | APPOSITIONAL GROWTH              |
|----------------------------------|----------------------------------|
| From within                      | From the surface                 |
| Chondrocyte division             | Progenitor cell differentiation  |
| Isogenous groups                 | New chondroblasts                |
| Matrix expands internally        | Matrix added externally          |
| Important in growth plates       | Important postnatally            |
| Increases overall cartilage size | Particularly increases thickness |

- NOTE:** In both types of growth, synthesis of extracellular matrix (collagen + proteoglycans + water) is the major contributor to cartilage volume.
  - kahit madami 'yung chondrocytes or cell it doesn't mean anything in terms of cartilage growth dapat ECM and madami dahil ito nagproporvide ng bulk sa cartilage

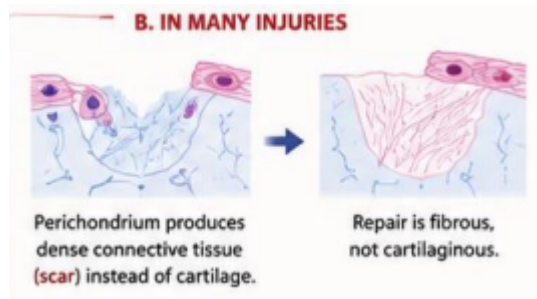
## CARTILAGE REPAIR

### • Perichondrium is Present



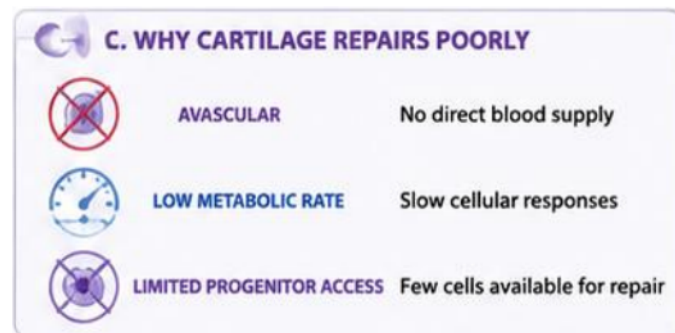
**Figure 12.** Process of Repair when Perichondrium is Present.

- 🧑‍🔬 The perichondrium functions to carry the blood vessels so when this is still present and because there is still blood vessels still present, blood can travel to the damaged areas and it can differentiate into chondroblasts to repair the damage



**Figure 13.** Process of repair when perichondrium is not present

- 🧑‍🔬 When perichondrium is totally damaged repair is harder. Wherein due to the avascular structure below it there are no nutrients and cells which leads to fibroblasts attempt to fix/repair the damage so they fill it up leading to fibrous repair. This makes the repair not cartilaginous and making it harder which is fibrous.



**Figure 14.** Reasons why cartilage repairs poorly

- 🧑‍🔬 No direct supply = avascular structure
- 🧑‍🔬 No metabolic rate = low of blood supply
- 🧑‍🔬 **Limtied progenitor acces = fewer cells available for repair**
  - 🧑‍🔬 This is because msot of them come from the periphery

## CLINICAL CORRELATION: OSTEOARTHRITIS

### • HISTOLOGY CLINICAL PEARL

- Articular cartilage lacks a perichondrium and is avascular → its capacity for repair is very limited.
- Therefore: progressive matrix damage can lead to irreversible cartilage loss and joint dysfunction.

|                                           |                                                       |
|-------------------------------------------|-------------------------------------------------------|
| ↓ Proteoglycan / aggrecan                 | ↓ Water retention → reduced resistance to compression |
| Disruption of Type II collagen network    | Loss of matric integrity                              |
| Cartilage fibrillation & fissuring        | Surface becomes rough                                 |
| Chondrocyte proliferation / cell clusters | Attempted repair                                      |
| Progressive cartilage loss                | Narrowing of joint space                              |
| Subchondral bone remodeling               | Sclerosis & osteophyte formation                      |

## REVIEW QUESTIONS

- The molecular basis for the shock absorbing properties of cartilage involves which of the following?
  - Sialic acid residues in the glycoproteins
  - Hydration of glycosaminoglycans
  - Electrostatic interaction of proteoglycans with type IV collagen
  - Ability of glycosaminoglycans to bind anions
  - Noncovalent binding of glycosaminoglycans to protein cores
- Which area in cartilage is relatively collagen-poor and proteoglycan-rich?
  - territorial matrix
  - epiphyseal plate
  - interterritorial matrix
  - fibrocartilage
  - perichondrium
- Which step occurs first in chondrogenesis?
  - appositional growth
  - formation of mesenchymal condensations
  - interstitial growth
  - conversion of chondroblasts to chondrocytes
  - secretion of collagen-rich and proteoglycan-rich matrix
- How does articular cartilage differ from most other hyaline cartilage?
  - undergoes mainly appositional growth
  - contains isogenous groups of chondrocytes
  - lacks a perichondrium
  - its matrix contains aggrecan
  - derived from embryonic mesenchyme
- A 66-year-old man who suffered from severe osteoarthritis is referred to an orthopedic surgeon for replacement of his right knee. He had been actively involved in both high school and intercollegiate football and had continued running until about the age of 45 as a form of relaxation and exercise. With the patient's permission, the removed joint is used by investigators performing a proteomic analysis of different joint tissues. The meniscus was found to contain almost exclusively type I collagen and aggrecan was undetectable. What is the most likely explanation for this result?
  - The meniscus normally consists of dense regular connective tissue, which contains primarily type I collagen.

| Histologic Change | Clinical Consequence |
|-------------------|----------------------|
|-------------------|----------------------|

- b. The meniscus normally consists of fibrocartilage, which contains only type I collagen.
- c. Elastic cartilage is normally replaced by fibrocartilage during aging and this process can be accelerated by exercise
- d. Osteoarthritic injury in the knee resulted in the chondrocytes of the meniscus switching from expression of genes for type II collagen to type I collagen.
- e. The meniscus had undergone repeated rounds of repair due to wear-and-tear during which its hyaline cartilage component was replaced by dense connective tissue.

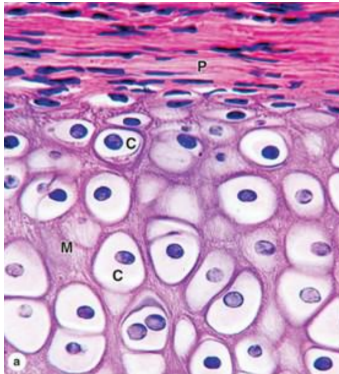
6. A 28-year-old woman visits the family medicine clinic complaining of loss of the sense of smell, nosebleeds, problems with swallowing, and hoarseness. She admits to "casual, social use" of cocaine on a regular basis since her sophomore year of college. A complete examination of her nose with a speculum and otoscope shows severe rhinitis (inflammation). There is also perforation and collapse of the nasal cartilage resulting in a "saddle nose" deformity. Erosions in the enamel of her front teeth are noted. The breakdown of the nasal cartilage releases collagen fibers primarily of which type?

- a. Type I
- b. Type II
- c. Type III
- d. Type IV
- e. Type VII

7. What distinguishes cartilage from most other connective tissue?

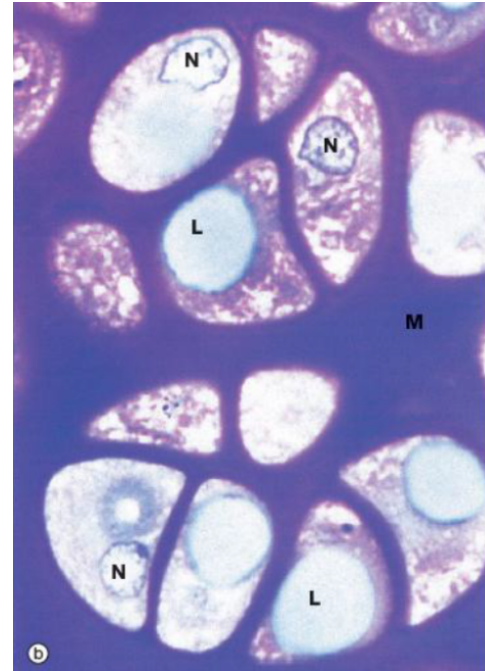
- a. its extracellular matrix is rich in collagen
- b. its predominant cell type is a mesenchymal derivative
- c. its predominant cell type secretes both fibers and proteoglycans
- d. it lacks blood vessels
- e. it functions in mechanical support

8. Identify "P" and which is not true about "P"



- a. Its outer region contains Type I collagen
- b. Found in all hyaline cartilages except in the articular cartilage of joints
- c. Its outer region contains Type II collagen
- d. It's important for growth and maintenance.

9. Identify "L" and at what type of cartilage is this usually found?



- a. hyaline cartilage
- b. elastic cartilage
- c. fibrocartilage

10. Which type of cartilage is found in the external ear?

- a. Hyaline cartilage
- b. Elastic cartilage
- c. fibrocartilage
- d. all of the above
- e. none of the above

11. Costal cartilage is composed of what type of cartilage

- a. hyaline cartilage
- b. elastic cartilage
- c. fibrocartilage
- d. all of the above
- e. none of the above

12. Which type of cartilage forms the symphysis pubis

- a. hyaline cartilage
- b. elastic cartilage
- c. fibrocartilage
- d. all of the above
- e. none of the above

**Answers:** 1b, 2a, 3b, 4c, 5e, 6c, 7d, 8 Perichondrium,C, 9 Lipid droplets,b, 10b, 11a, 12c

## APPENDIX

| FEATURE                            | HYALINE                                                                        | ELASTIC                                                                 | FIBROCARILAGE                                                           |
|------------------------------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------|
| <b>MATRIX</b>                      | Type II collagen + aggrecan;<br>homogeneous                                    | Type II collagen + aggrecan+<br>elastic fibers                          | Type II collagen + abundant<br>Type I collagen                          |
| <b>MAIN CELLS</b>                  | Chondroblasts & chondrocytes                                                   | Chondroblasts & chondrocytes                                            | Chondroblasts & fibroblasts                                             |
| <b>CHONDROCYTE<br/>ARRANGEMENT</b> | Isolated or small isogenous<br>groups                                          | Usually small isogenous<br>groups                                       | Often axial rows/ groups                                                |
| <b>PERICHONDRIUM</b>               | Present*<br>- Exception is articular<br>cartilage (absent here)                | Present                                                                 | Absent                                                                  |
| <b>KEY LOCATIONS</b>               | Trachea, bronchi, articular<br>cartilage, epiphyseal plates,<br>fetal skeleton | External ear, external acoustic<br>meatus, auditory tube,<br>epiglottis | Intervertebral discs, pubic<br>symphysis, menisci, tendon<br>insertions |
| <b>MAIN FUNCTION</b>               | Support + smooth, low-friction<br>surface                                      | Flexible support                                                        | Tensile strength + resistance<br>to compression                         |