S. S. College, Jehanabad

Department: Zoology

Class: M.Sc. Semester II

Subject: Zoology

Topic: Histology of mammalian cartilage

Mode of teaching: Google classroom & WhatsApp

Date & Time: 03.10.2020 & 10:30

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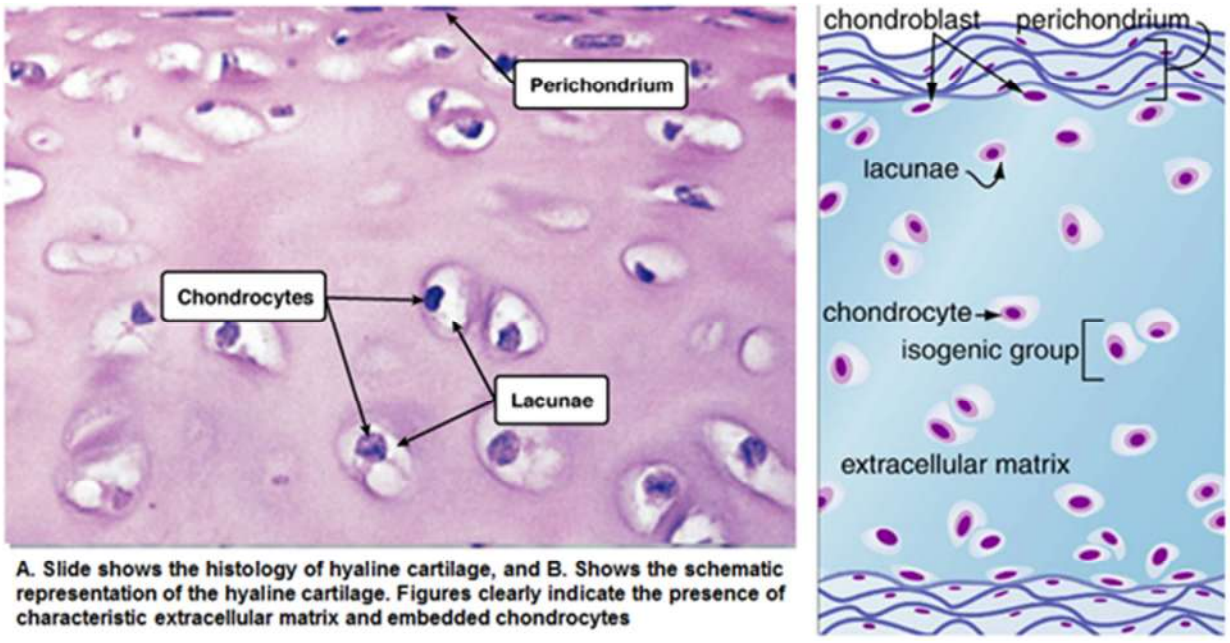
HISTOLOGY OF MAMMALIAN CARTILAGE

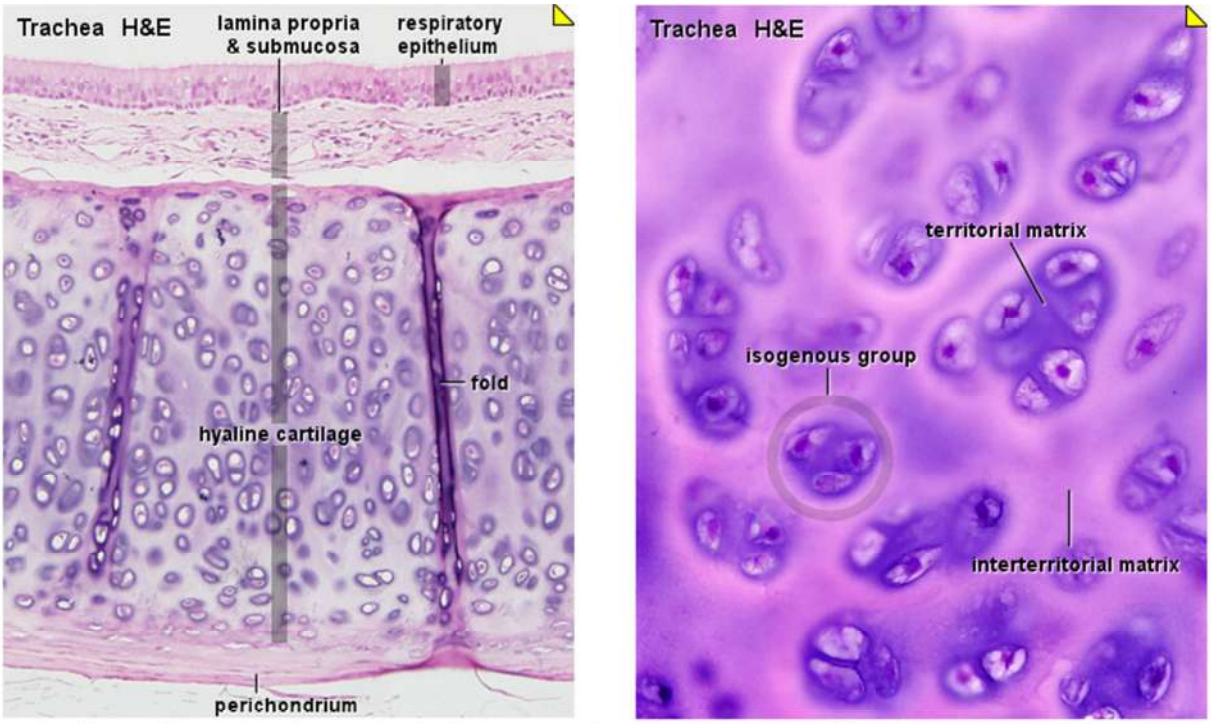
Cartilage is specialized form of connective tissue composed of cells embedded in a gel-like extracellular matrix. Therefore, it is a form of connective tissues that consists of chondrocytes and gel-like extracellular matrix and has a rigid consistency. Extracellular matrix consists of fibrillar and amorphous components. It has some specific characteristics – it is flexible and also strong, avascular without nerve supply. It forms mechanical support of soft tissues as soft tissues lack skeleton or bony support and is important for bone development from fetal period until puberty.

The surface of cartilage is covered by perichondrium except articular capsule which lacks perichondrium. It contains 60 % of water and 40 % of organic tissue (about 60 % is attributed to collagen and 40 % to proteoglycans). Collagen provides tensile strength and durability to the cartilage; however, proteoglycans are also important and it also stiffness to the cartilage. Role of proteoglycans in the stiffness of cartilage have been shown by injecting papain (an enzyme that digests the protein cores of proteoglycans) into the ears of a rabbit, it has been observed that the ears lost their stiffness and droop after a few hours. According to composition of extracellular matrix, three types of cartilage are distinguished: hyaline cartilage, elastic cartilage and fibrocartilage. These cartilages differ in terms of concentration of collagen and elastin fibers.

Hyaline cartilage: It is most common type of cartilage. It covers articular surfaces, connection between ribs and sternum, walls of trachea and bronchi or temporary skeletal system later replaced by bone. Specifically, it is present in childhood in epiphyseal plate which is responsible for elongation of bones. Its basic tissue consists chiefly of amorphous component. Hyaline cartilage is covered by vascular innervated perichondrium formed by dense collagenous connective tissue and fibrocytes. Due to the high vascularization, the perichondrium is able to ensure the nutrition of cartilage. *Articular surfaces are not covered by perichondrium and their nutrition is provided by diffusion from synovial fluid*. In hyaline cartilage, dominant component of extracellular matrix is collagen. It is translucent and bluish-white in colour.



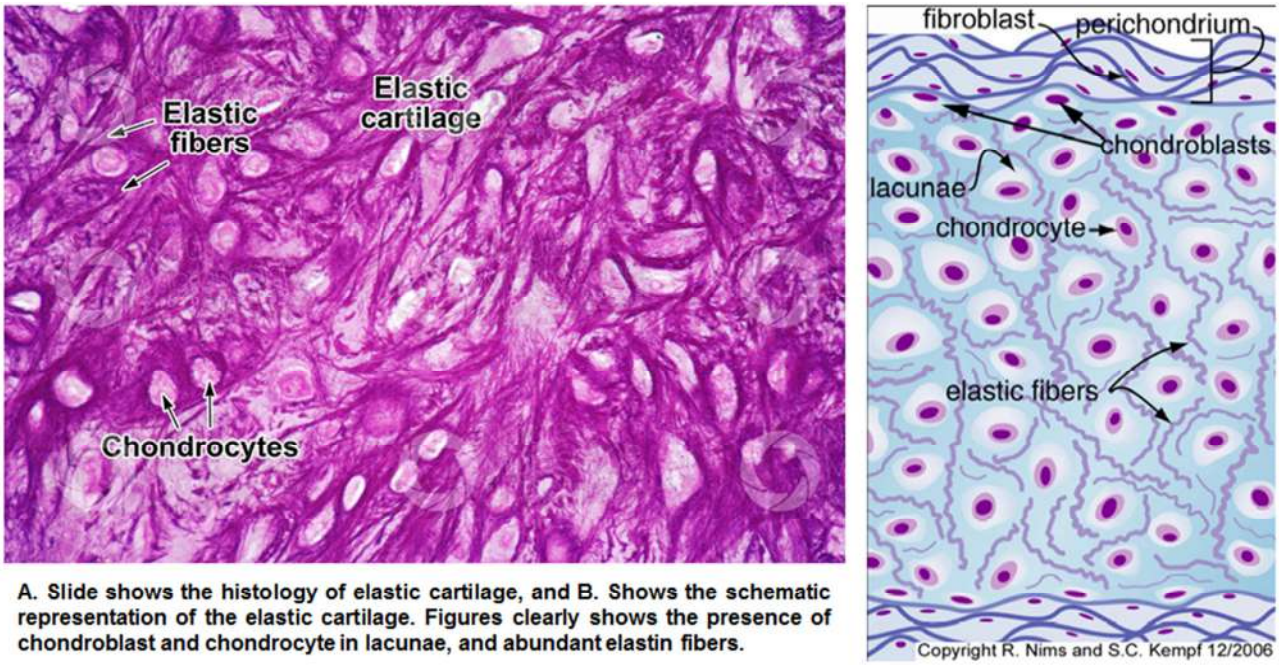
A. Slide shows the histology of hyaline cartilage, and B. Shows the schematic representation of the hyaline cartilage. Figures clearly indicate the presence of characteristic extracellular matrix and embedded chondrocytes



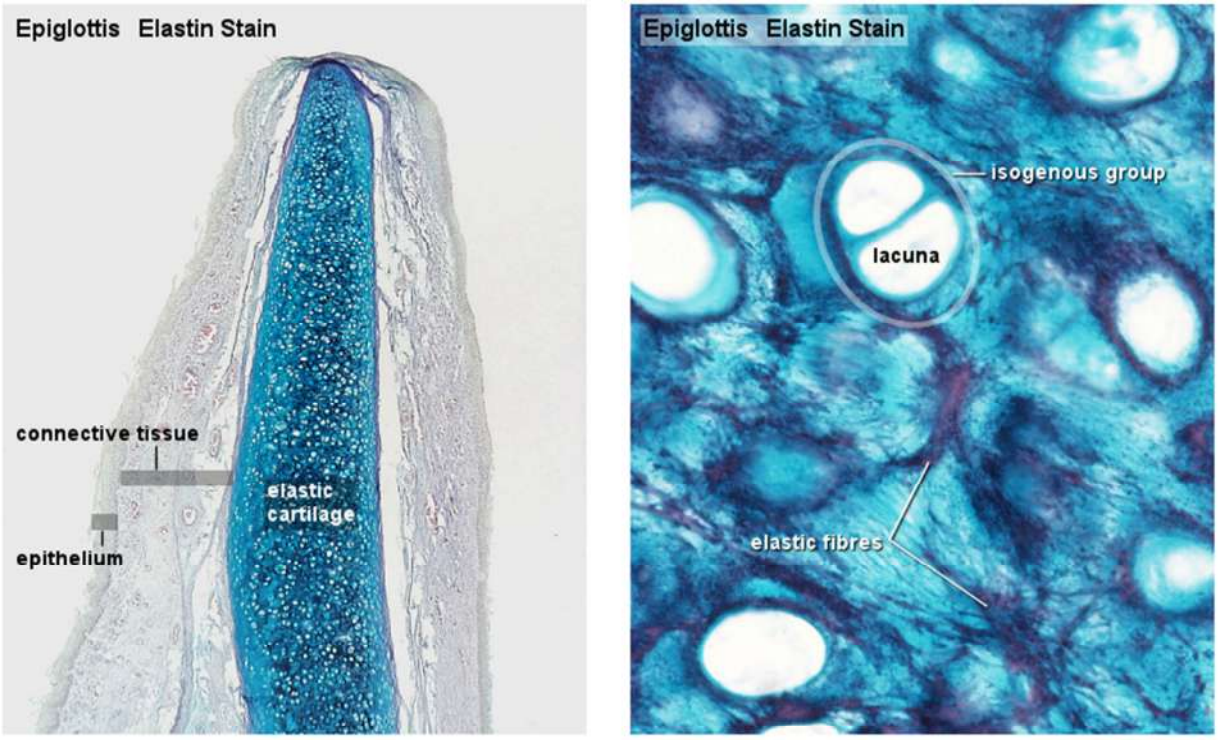
Hyaline cartilage of trachea stained with hematoxylin and eosin staining. Right is the enlarged view of the part of the left image.

Source: *https://www.lab.anhb.uwa.edu.au/mb140/CorePages/Cartilage/Cartil.htm*

Elastic cartilage: Elastic cartilage is present more rarely than hyaline. Unlike to hyaline cartilage, it is elastic and flexible, and exhibits yellowish color. It is found in auricle, epiglottis and small cartilages of larynx. It consists of chondrocytes embedded in lacunae, type II collagen and numerous elastic fibers. It does not calcify.



A. Slide shows the histology of elastic cartilage, and B. Shows the schematic representation of the elastic cartilage. Figures clearly shows the presence of chondroblast and chondrocyte in lacunae, and abundant elastin fibers.



Elastic cartilage of epiglottis stained with metachromatic staining. Right is the enlarged view of the part of the left image.

Source: *https://www.lab.anhb.uwa.edu.au/mb140/CorePages/Cartilage/Cartil.htm*

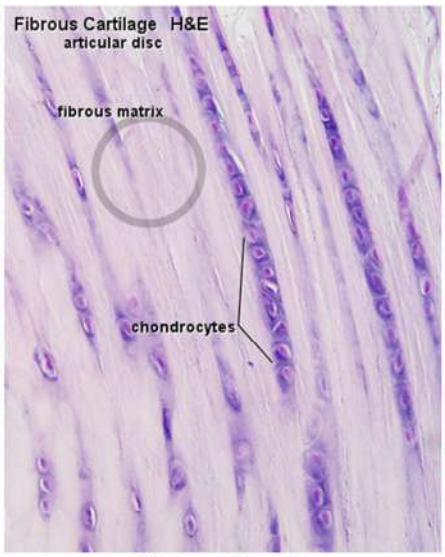
Fibrocartilage: Fibrocartilage, which is also known as fibrous cartilage, is present in symphysis or intervertebral discs. In another word, it is found mainly at connection of tendons to bone. It contains less amorphous component, and is predominated with fibrillar component which is composed of densely arranged irregular collagen connective tissue made of type I and type II collagen fibres. It resists compression and shear forces. Chondrocytes are found dispersed as they do not form isogenic groups[1].

Articular cartilage: It is specialized form of hyaline cartilage. It transforms the articulating ends of the bones into lubricated, wear-proof, slightly compressible surfaces, which exhibit very little friction. It is not surrounded by a perichondrium and is partly vascularized. Depending on the arrangement of chondrocytes and collagenous fibers, it is divided into several zones. These zones of articular cartilage are as follows;

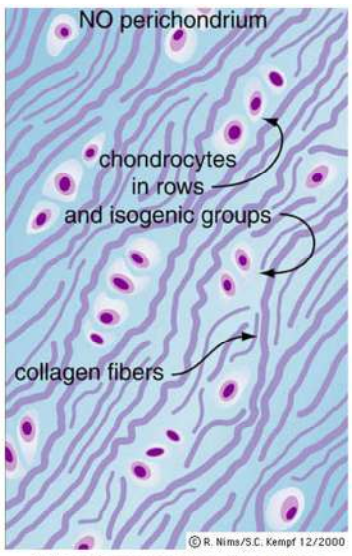
- ***Tangential zone:*** In this zone, chondrocytes are rather small and flattened parallel to the surface. The most superficial part (lamina splendens) is devoid of cells. Collagen fibres in the matrix of the tangential layer are very fine. They run parallel to the surface of the cartilage. *Similar to the collagen fibres of the skin, the general orientation of collagen fibers in articular cartilage is determined by tensile and compressive forces at the articulating surfaces.*

[1] **Isogenic group** or **isogenous group** is a cluster of chondrocytes that are formed through division of a single progenitor cell. The isogenic group is found in hyaline and elastic cartilage, which grows by interstitial growth.

Histology of fibrocartilage of intervertebrtal disc stained with hematoxylin and eosin staining

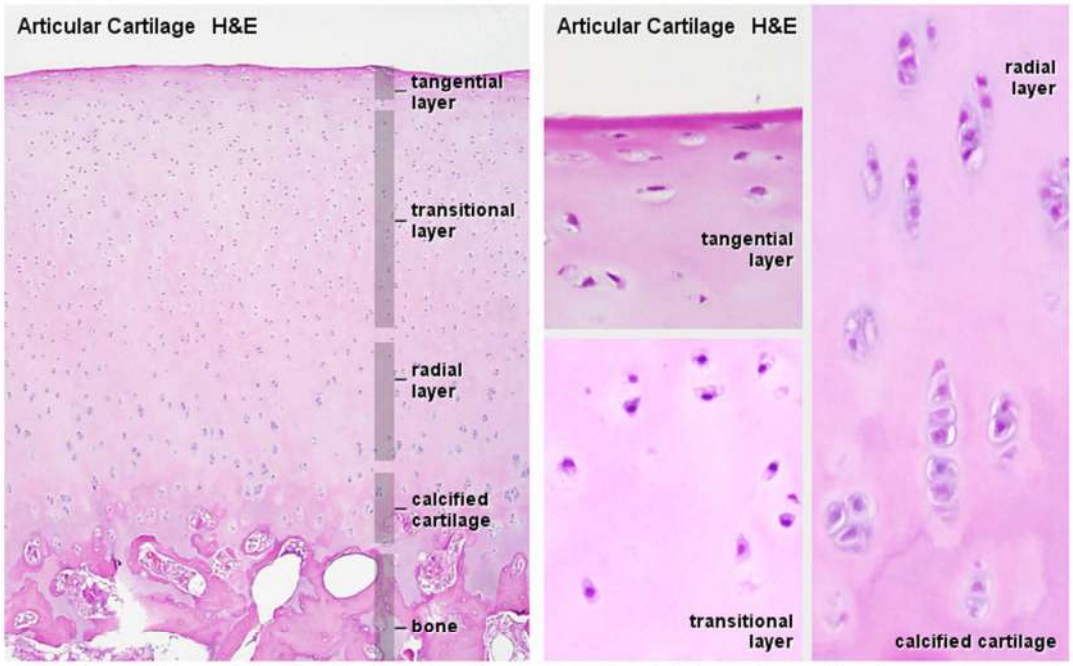


Histology of fibrocartilage



Schematic representation fibrocartilage

- ***Transitional zone:*** In this zone, chondrocytes are slightly larger, round. Chondrocytes may occur both singly and in isogenous groups. Collagen fibers take an oblique course through the matrix of the transitional zone.
- ***Radial zone:*** In this zone, chondrocytes are fairly large that form radial columns, i.e. the stacks of cells are oriented perpendicular to the articulating surface. The course of the collagen fibers follows the orientation of the chondrocyte columns.
- ***Calcified cartilage layer:*** It rests on the underlying cortex of the bone. The matrix of the calcified cartilage layer stains slightly darker in hematoxylin and eosin staining than the matrix of the other layers.



Articular cartilage stained with hematoxylin and eosin staining. The slide shows clear and distinguishable zone of articular cartilage. Source: *https://www.lab.anhb.uwa.edu.au/mb140/CorePages/Cartilage/Cartil.htm*

The main source of nourishment for articular cartilage is the synovial fluid, which fills the joint cavity. Additional small amounts of nutrients are derived from blood vessels that course through the calcified cartilage close to the bone.

Structure and formation of cartilage

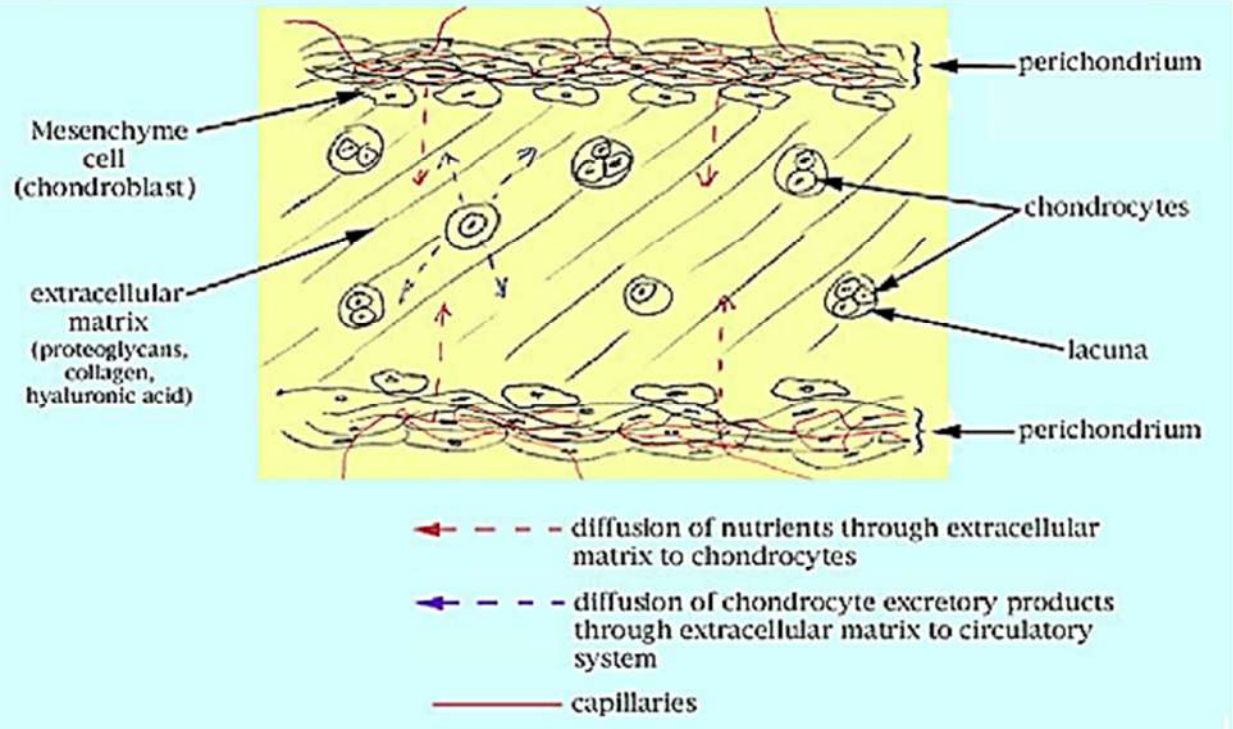
The main function of cartilage is to support softer tissues. Additionally, it is also very important in the formation and healing of injured long bones of the arm and leg through endochondral ossification. The qualities of the different types of cartilage depend on differences in the concentration of collagen and elastin fibers in the extracellular matrix and on the proteoglycan molecules that these fibers are associated with.

Cartilage is devoid of blood vessels. Thus the nutrition of cells within the cartilage matrix is dependent on the diffusion of nutrients from blood capillaries in the perchondrium and/or adjacent tissues through the matrix.

Hyaline and elastic cartilages are surrounded by a connective tissue capsule called the **perichondrium** that contains the capillaries from which the nutrients diffuse into the cartilage matrix. Articular hyaline cartilage and fibrocartilage do not have a perichondrium.

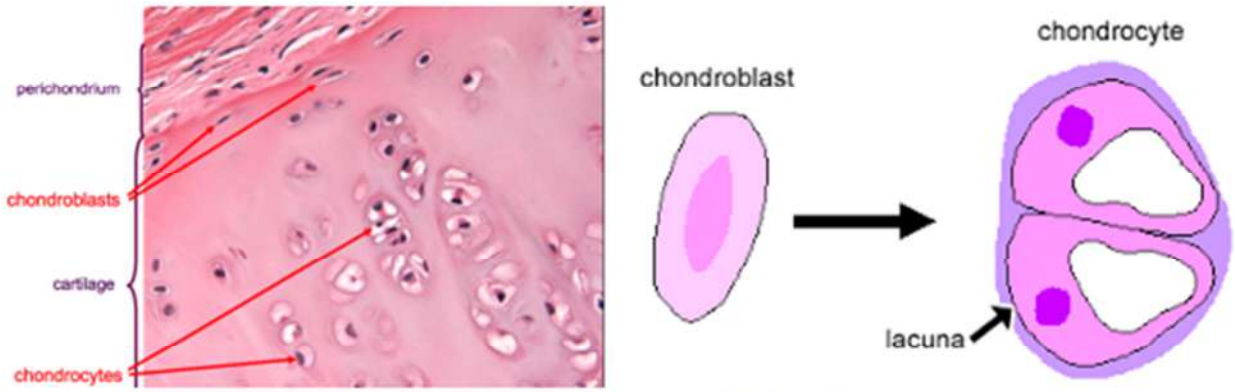
Components of cartilage

Universal composition of cartilage is chondrocytes and extracellular matrix which contains fibers. These components of cartilage vary depending upon the types of cartilage.



There are three main components of cartilage, which are as follows;

- **Perichondrium:** It is vascularized connective tissue sheath surrounding cartilage (except in case of articular cartilage). It is rich in collagen and contains fibroblast cells that secrete the materials for the collagen fibers. Inner layer (next to cartilage matrix) contains cells that are thought by some to be fibroblasts and by others to be undifferentiated mesenchyme cells. In either case, these cells can differentiate to form chondroblasts.
- **Chondroblasts:** These are immature cartilage cells which secrete extracellular matrix. These cells are not yet rigidly embedded in that matrix.
- **Chondrocytes**: These are mature cartilage cells that are embedded in rigid extracellular matrix. These cells reside in small spaces within the matrix that are called lacunae. There may be more than one cell in a lacuna. Living chondrocytes have an eliptic shape in which organelle systems in cytoplasm are typical of cells that secrete. Chondrocytes in hyaline cartilage that are grouped together are called isogenic groups.

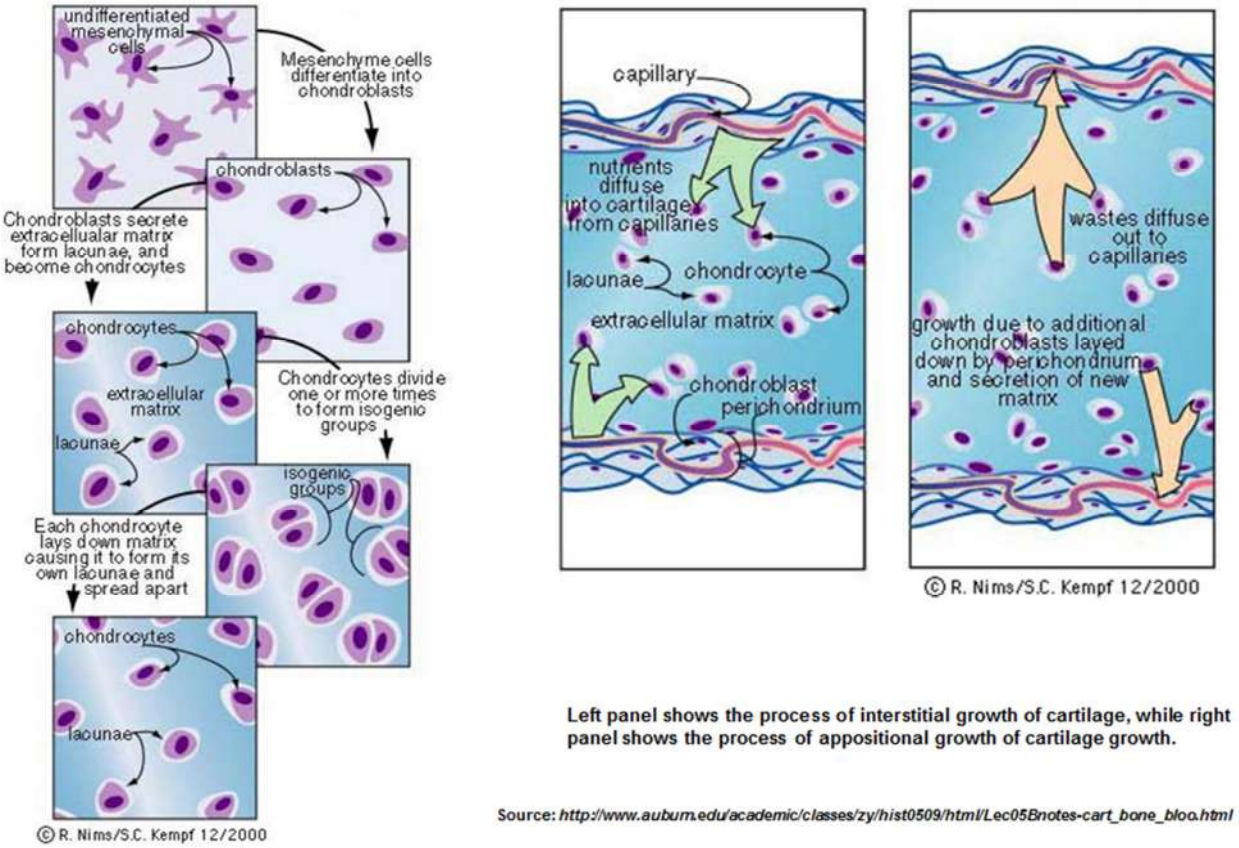


Cells of the cartilage. Chondroblasts fuse to form a chondrocyte.

Histogenesis of cartilage

As the embryo develops, mesenchymal cells aggregate into closely knit clusters and differentiate into chondroblasts. These cells begin to secrete collagen and mucopolysaccharide matrix containing chondroitin sulfate. The matrix secretion causes the chondroblasts to be pushed apart. As this occurs, the cartilage cells will divisions which result in small clusters of chondroblasts within the developing matrix. These clusters of chondroblast cells start to secrete matrix and therefore it is pushed away from each other. This sort of growth of cartilage is termed **interstitial growth** due to the fact that the extracellular matrix is secreted into spaces between the cells.

Other type of growth is termed as Growth of cartilage can also be **appositional**, that is a layer of chondroblasts can lay down matrix at the outer edge of a mass of cartilage. As the cartilage continues to grow, the central regions become more rigid due to various secretory products and the cells in this region become embedded in rigid matrix and take on the characteristics of mature chondrocytes. The outer edge of the cartilage mass becomes invested with additional mesenchymal cells that differentiate into fibroblasts to form a specialized connective tissue covering for the cartilage known as perichondrium. Chondroblasts that differentiate from mesenchyme cells at the inner edge of the perichondirum also secrete matrix causing appositional growth of the cartilage mass. Similar histogenesis can result in elastic (external ear) or fibrous cartilage (intervertebral discs) in other parts of the body.



Left panel shows the process of interstitial growth of cartilage, while right panel shows the process of appositional growth of cartilage growth.

Source: *http://www.auburn.edu/academic/classes/zy/hist0509/html/Lec05Bnotes-cart_bone_bloo.html*

- Hydration (water content) of cartilages affects their mechanical characteristics e.g. elasticity. Cartilage during load exhibits biphasic behavior resembling the sponge. The water in the basic tissue is freely bonded and during load is water quickly pushed out which causes the change of cartilage shape (e.g. flattening). Subsequently, the higher rigidity of fibrillar component involves which prevents from another change of cartilage shape.
- The amorphous component is represented by glycosaminoglycans = GAG (hyaluronic acid, karatan phosphate, chondroitin phosphate), proteoglycans and structural proteins.

Degeneration and regeneration of cartilage

Due to the fairly poor access of nutrients to the chondrocytes they may atrophy in deep parts of thick cartilage. Water content decreases and small cavities arise in the matrix, which often leads to the calcification of the cartilage. This further compromises nutrition. The chondrocytes may eventually die, and the cartilage is gradually transformed into bone.

Chondrogenic activity of the perichondrium is limited to the period of active growth before adulthood. Although chondrocytes are able to produce matrix components throughout life, their production cannot keep pace with the repair requirements after acute damage to hyaline or articular cartilage. If these cartilages are injured after the period of active growth, the defects are usually filled by connective tissue or fibrous cartilage. The extracellular matrix of these "repair tissues" is only poorly integrated with the matrix of the damaged cartilage.

Fortunately, cartilage is rather well suited for transplantation - the metabolism of the chondrocytes is rather slow, the antigenic power of cartilage is low, and it is difficult, if not impossible, for antibodies or cells of the immune system to diffuse through the matrix into the cartilage.

References

1. http://www.auburn.edu/academic/classes/zy/hist0509/html/Lec05Bnotes-cart_bone_bloo.html
2. http://fblt.cz/en/skripta/iv-pohybova-soustava/1-funkcni-morfologie-kosti-a-chrupavky/
3. https://web.duke.edu/histology/MoleculesCells/CartilageBone/CartilageBone.html
4. http://www.siumed.edu/~dking2/ssb/skeleton.htm

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