Cartilage
Lec . 6

Second year

Histology

L. Hadeel Kamil

Cartilage

Cartilage is a flexible connective tissue found in many areas in the bodies of humans and other animals, including the joints between bones, the rib cage, the ear, the nose, the bronchial tubes and the intervertebral discs. It is not as hard and rigid as bone but is stiffer and less flexible than muscle.

Cartilage is a specialised type of connective tissue.
consists, like other connective tissues, of cells and extracellular components.
does, unlike other connective tissues, not contain vessels or nerves.
is surrounded by a layer of dense connective tissue, the perichondrium.
Cartilage is rather rare in the adult humans, but it is very important during development because of its firmness and its ability to grow rapidly. In developing humans, most of the bones of the skeleton are preceded by a temporary cartilage "model". Cartilage is also formed very early during the repair of bone fractures.

Cells of cartilage

1. Chondroblasts

- less differentiated cartilage cells, originate from non-differentiated mesenchyme;
- have a flattened shape; a well-developed rough endoplasmic reticulum in a basophilic cytoplasm;
- **function** - elaboration of cartilage intercellular matter; under certain circumstances chondroblasts are capable of producing matrix-degrading enzymes - collagenase, elastase, hyaluronidase;
- *reside* in the internal layer of periosteum and in the depth of matrix - within lacunes;
- chondroblasts mature into chondrocytes.

2. Chondrocytes

- differentiated cartilage cells;
- round or angular shapes, with advancing cellular age chondrocytes progressively lose their rough endoplasmic reticulum;
- **function** - elaboration of cartilage intercellular matter; under certain circumstances chondroblasts are capable of producing matrix-degrading enzymes - collagenase, elastase, hyaluronidase
- *reside* in the depth of matrix - within minute special cavities lacunes
- sometimes the number of cartilage cells in one lacune is more than one, it is the consequence of cell division;
- quite often the division id accomplished through amitosis; such cellular groups are called **isogenic groups**

Chondrogenesis

- In embryogenesis, the skeletal system is derived from the mesoderm germ layer. Chondrification (also known as chondrogenesis) is the process by which cartilage is formed from condensed mesenchyme tissue, which differentiates into chondroblasts and chondrocytes. These cells begins secreting the molecules that form the extracellular matrix.
- Early in fetal development, the greater part of the skeleton is cartilaginous. This *temporary* cartilage is gradually replaced by bone (Endochondral ossification), a process that ends at puberty. In contrast, the cartilage in the joints remains unossified during the whole of life and is, therefore, *permanent*.

Mineralization

- Adult hyaline articular cartilage is progressively mineralized at the junction between cartilage and bone.
- It is then termed *articular calcified cartilage*.
- A mineralization front advances through the base of the hyaline articular cartilage at a rate dependent on cartilage load and shear stress. Intermittent variations in the rate of advance and mineral deposition density of the mineralizing front, lead to multiple "tidemarks" in the articular calcified cartilage.
- Adult articular calcified cartilage is penetrated by vascular buds, and new bone produced in the vascular space in a process similar to endochondral ossification at the physis. A *cement line* demarcates articular calcified cartilage from subchondral bones.

Repair

- Once damaged, cartilage has limited repair capabilities. Because chondrocytes are bound in lacunae, they cannot migrate to damaged areas. Also, because hyaline cartilage does not have a blood supply, the deposition of new matrix is slow. Damaged hyaline cartilage is usually replaced by fibrocartilage scar tissue. Over the last years, surgeons and scientists have elaborated a series of cartilage repair procedures that help to postpone the need for joint replacement.
- In a 1994 trial, Swedish doctors repaired damaged knee joints by implanting cells cultured from the patient's own cartilage. In 1999 US chemists created an artificial liquid cartilage for use in repairing torn tissue. The cartilage is injected into a wound or damaged joint and will harden with exposure to ultraviolet light

Tropocollagen type II is the dominant form in collagen fibres of almost all types of cartilage.

As the amount of matrix increases the chondroblasts become separated from each other and are, from this time on, located isolated in small cavities within the matrix, the lacunae.

The matrix appears structureless because the collagen fibres are too fine to be resolved by light microscopy (~20nm), and because they have about the same refractive index as the ground substance. Collagen accounts for ~ 40% of the dry weight of the matrix.

The matrix near the isogenous groups of chondrocytes contains larger amounts and different types of glycosaminoglycans than the matrix further away from the isogenous groups.

This part of the matrix is also termed territorial matrix or capsule. In H&E stained sections the territorial matrix is more basophilic, i.e. it stains darker.

The remainder of the matrix is called the interterritorial matrix. Fresh cartilage contains about 75% water which forms a gel with the components of the ground substance. Cartilage is nourished by diffusion of gases and nutrients through this gel.

Growth occurs by two mechanisms

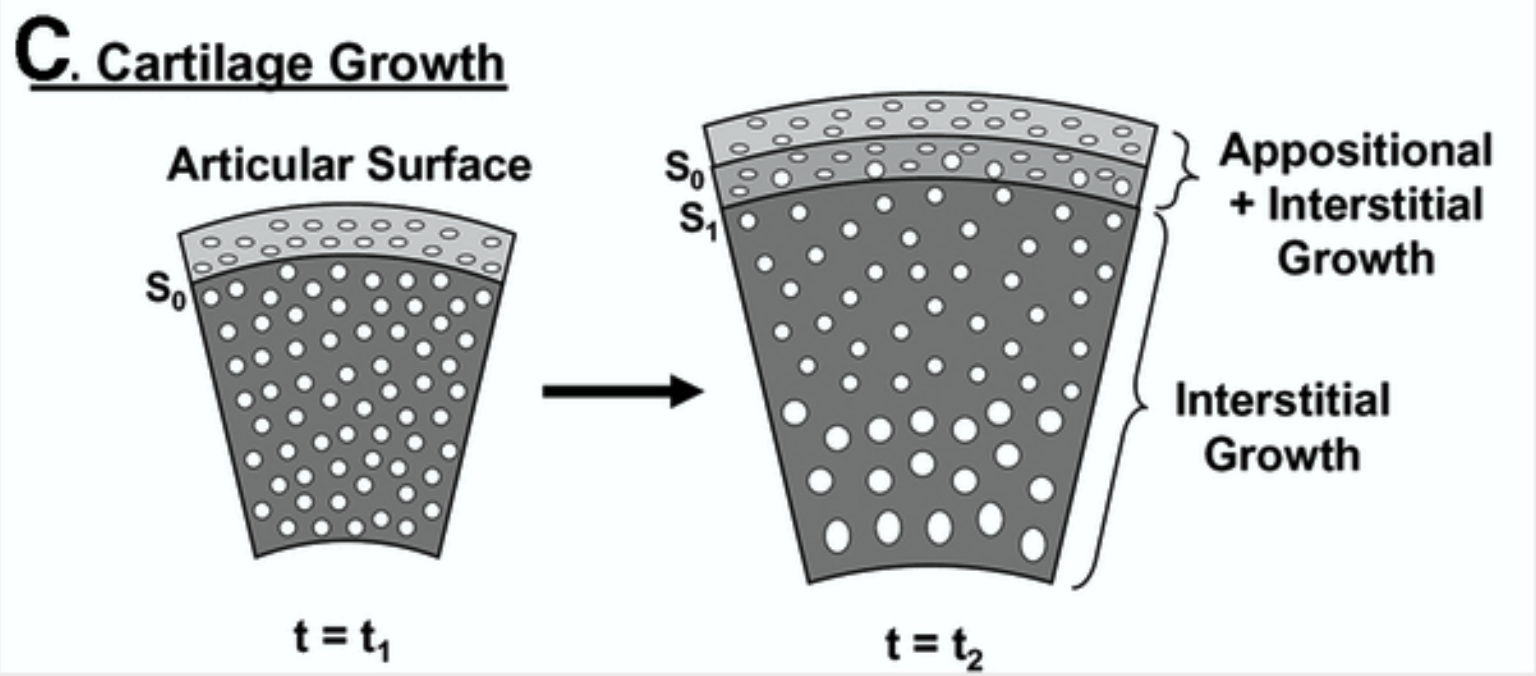
Interstitial growth - Chondroblasts within the existing cartilage divide and form small groups of cells, isogenous groups, which produce matrix to become separated from each other by a thin partition of matrix. Interstitial growth occurs mainly in immature cartilage.

Appositional growth - Mesenchymal cells surrounding the cartilage in the deep part of the perichondrium (or the chondrogenic layer) differentiate into chondroblasts. Appositional growth occurs also in mature cartilage.

Like all protein-producing cells, chondroblasts contain plenty of rough endoplasmatic reticulum while they produce matrix. The amount of rough endoplasmatic reticulum decreases as the chondroblasts mature into chondrocytes. Chondrocytes fill out the lacunae in the living cartilage.

Growth mechanisms

- appositional growth. Growth by the addition of new layers on those previously formed, characteristic of tissues formed of rigid materials.
- Interstitial growth from a number of different centers within an area; in contrast with appositional growth, it can occur only when the materials involved are nonrigid, such as cartilage.



(*A*) Interstitial growth is illustrated as a material occupying region R_1 at $t = t_1$ and R_2 at $t = t_2$. (*B*) Two-sided appositional growth at surface S_0 results in no growth within regions R_1 and R_2, but formation of new regions R_3 and R_4. (*C*) Cartilage growth potentially includes both interstitial growth by matrix accretion and chondrocyte hypertrophy and appositional growth by proliferation of cells in the superficial-most layer demarcated by S_0.

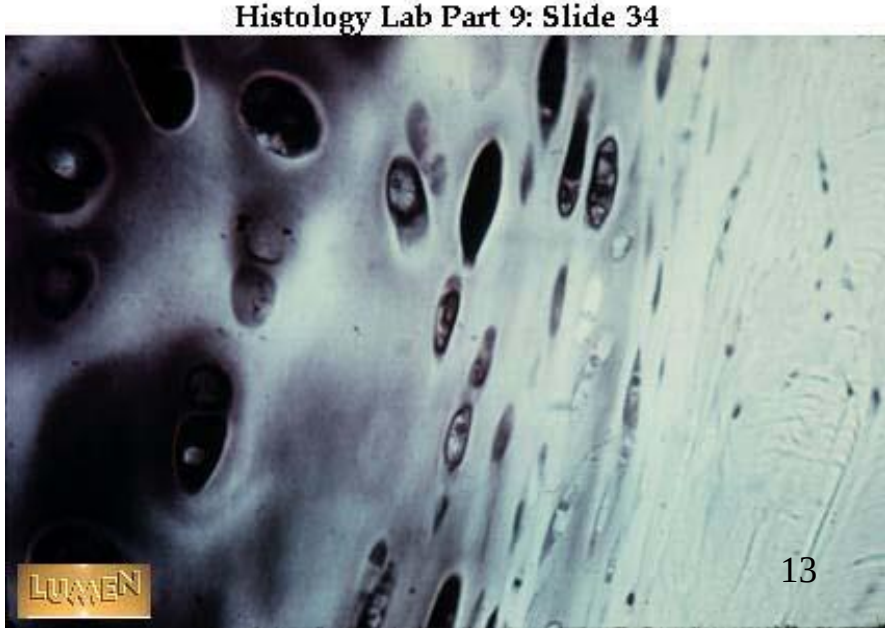
Bioengineering Cartilage Growth, Maturation, and Form

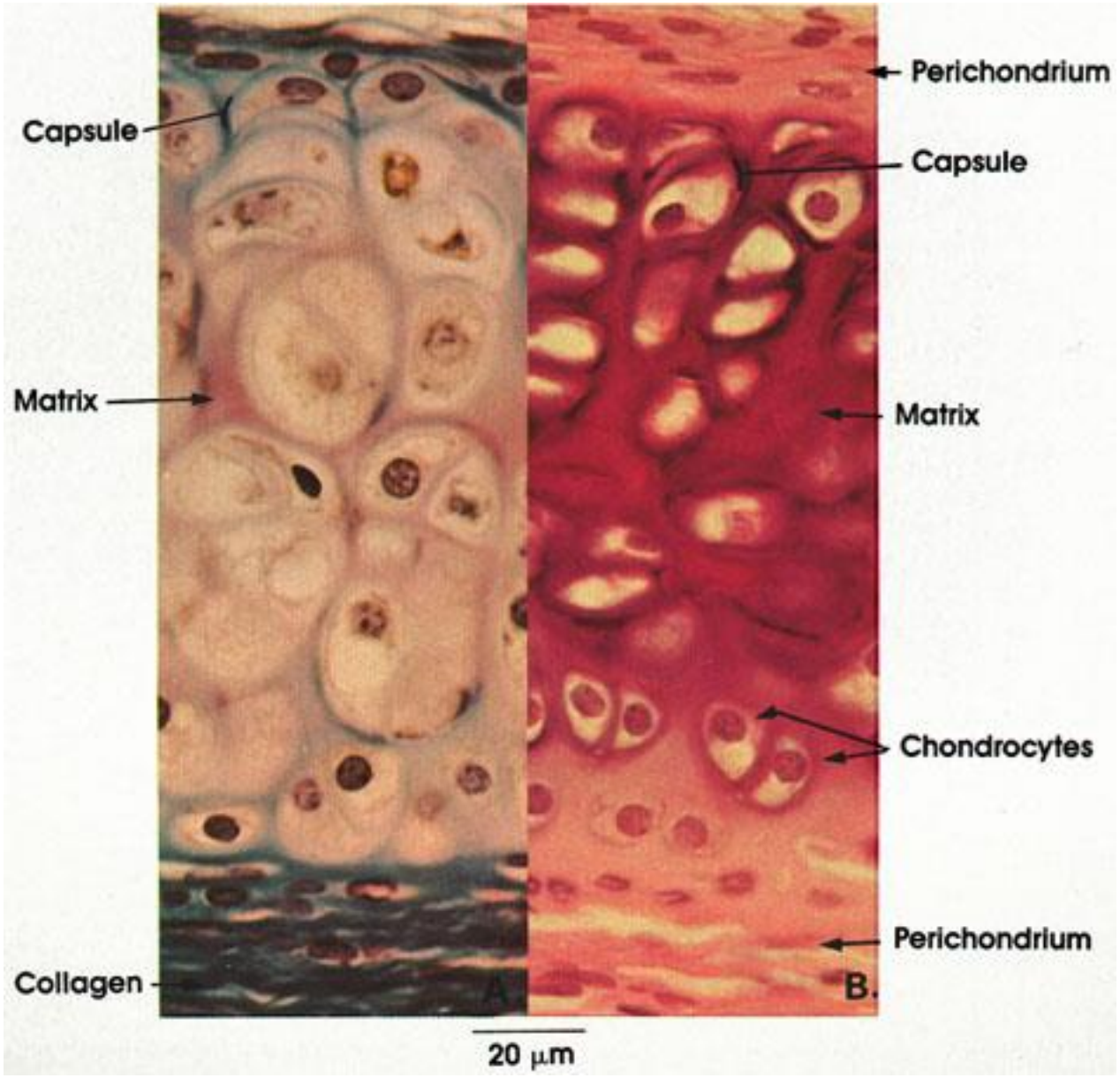
Gregory M Williams, Stephen M Klisch and Robert L Sah

Hyaline cartilage

Hyaline cartilage is covered externally by a fibrous membrane, called the perichondrium, except at the articular ends of bones and also where it is found directly under the skin, i.e. ears and nose. This membrane contains vessels that provide the cartilage with nutrition.

If a thin slice is examined under the microscope, it will be found to consist of cells of a rounded or bluntly angular form, lying in groups of two or more in a granular or almost homogeneous matrix.




Capsule
Matrix
Collagen
A
Perichondrium
Capsule
Matrix
Chondrocytes
Perichondrium
B.
20 μm

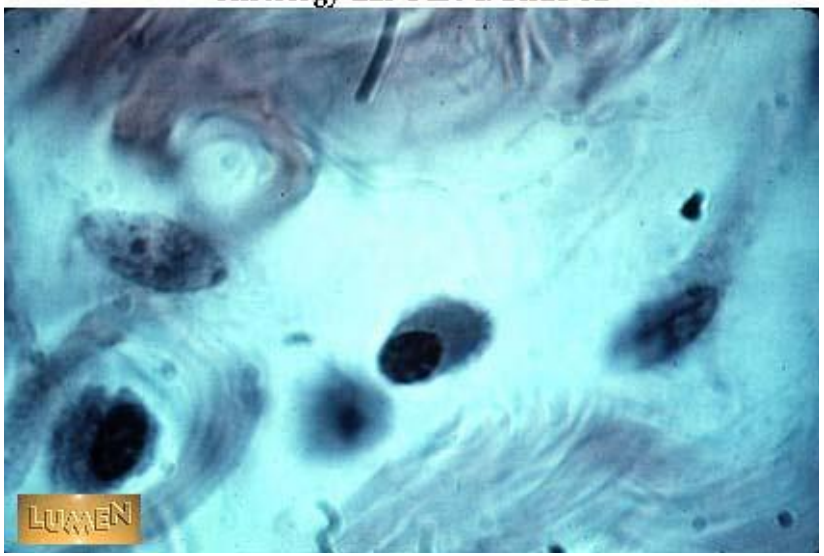
Cell consist of clear translucent protoplasm in which fine interlacing filaments and minute granules are sometimes present; embedded in this are one or two round nuclei, having the usual intranuclear network.
The cells are contained in cavities in the matrix, called cartilage lacunae; these are actually artificial gaps formed by the shrinking of the cells during the staining and setting of the tissue for observation.

The interterritorial space between the isogenous cell groups contains relatively more collagen fibers, causing it to maintain its shape while the actual cells shrink, creating the lacunae.

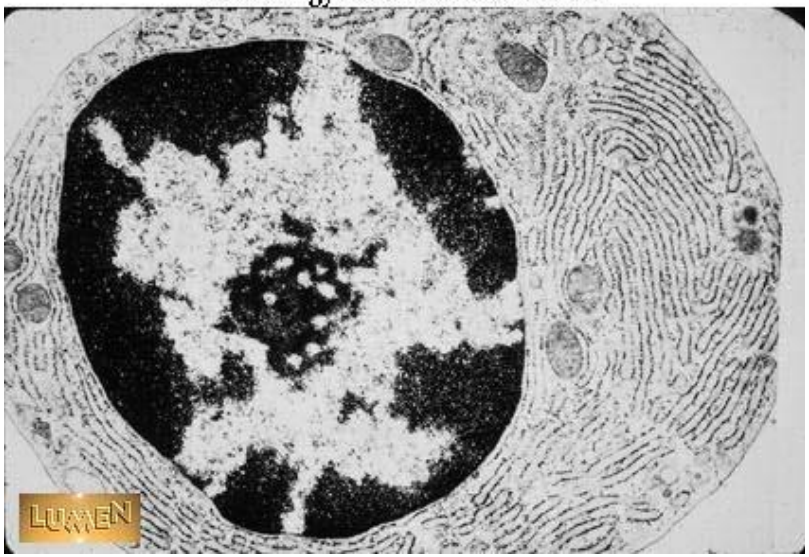
Each lacuna is generally occupied by a single cell, but during the division of the cells it may contain two, four, or eight cells. (see isogenous group)
Hyaline cartilage also contains chondrocytes which are cartilage cells that produce the matrix. Hyaline cartilage matrix is mostly made up of type II collagen and Chondroitin sulfate, both of which are also found in elastic cartilage.
Hyaline cartilage exists on the ventral ends of ribs; in the larynx, trachea, and bronchi; and on the articular surface of bones.

Chondrocytes

Histology Lab Part 4: Slide 32



Histology Lab Part 4: Slide 33

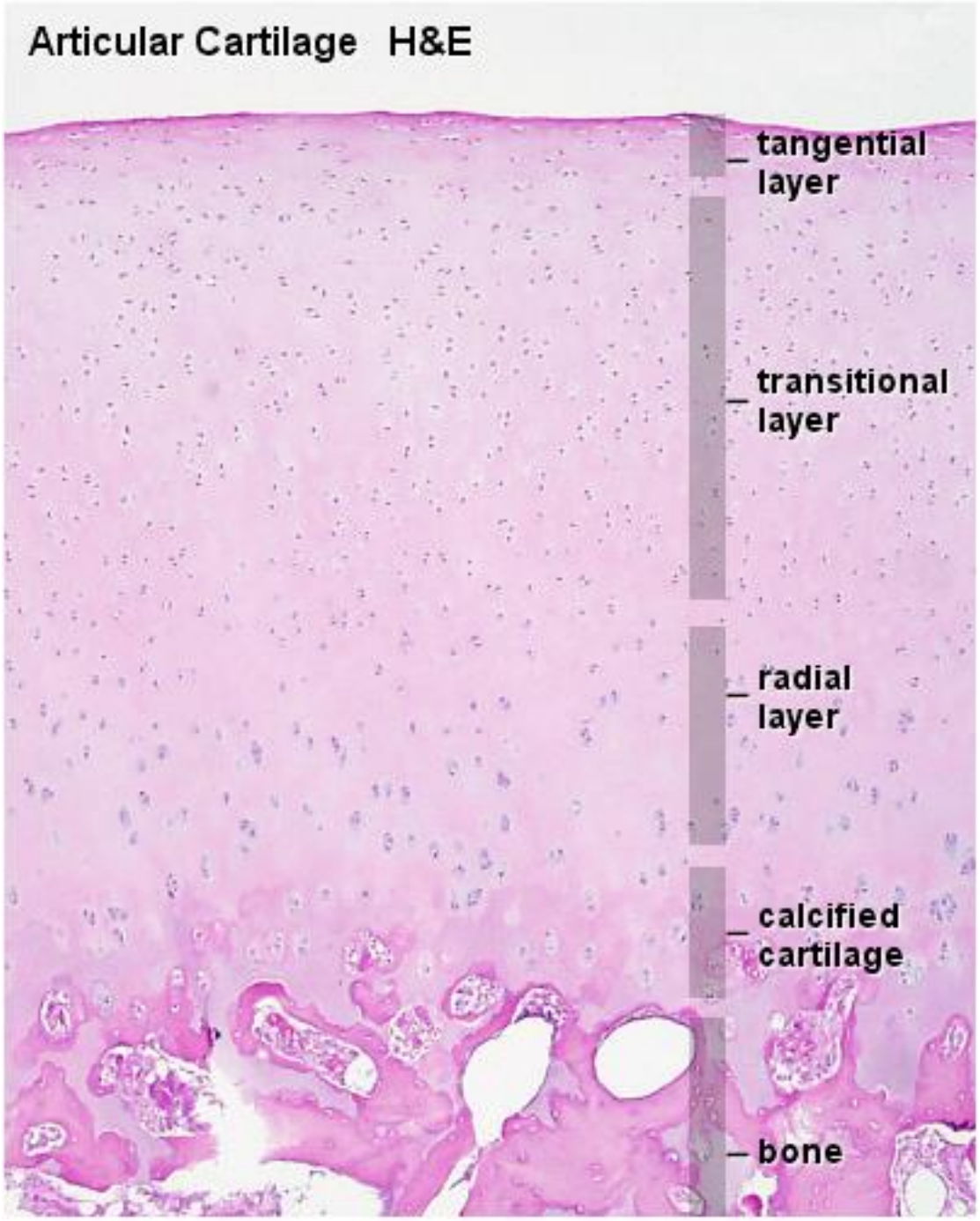


Pericellular matrix

Teritorial matrix

Interteritorial matrix

- Ground substance – basofilic, GAG attracts Na^+ and H_2O.
- Mechanical preasure release water, but negative charge in ground substance limits future deformation.

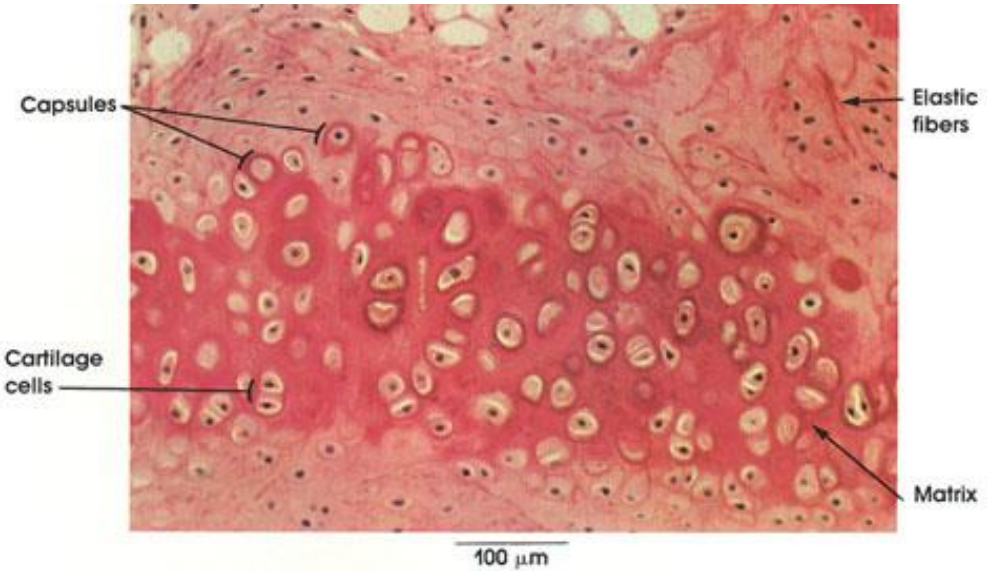

Articular Cartilage H&E
tangential layer
transitional layer
radial layer
calcified cartilage
bone

Elastic cartilage

Elastic cartilage or **yellow cartilage** is a type of cartilage present in the outer ear, Eustachian tube and epiglottis. It contains elastic fiber networks and collagen fibers. The principal protein is elastin.

Elastic cartilage is histologically similar to hyaline cartilage but contains many yellow elastic fibers lying in a solid matrix. These fibers form bundles that appear dark under a microscope. These fibers give elastic cartilage great flexibility so that it is able to withstand repeated bending. The chondrocytes lie between the fibres.

Elastin fibers stain dark purple/black with Verhoeff stain



http://www.meddean.luc.edu/lumen/MedEd/Histo/frames/histo_frames.html

http://www.vh.org/Providers/Textbooks/MicroscopicAnatomy/Section03/Plate0342.html

Fibrocartilage

- White **fibrocartilage** consists of a mixture of white fibrous tissue and cartilaginous tissue in various proportions. It owes its flexibility and toughness to the former of these constituents, and its elasticity to the latter.
- It is the only type of cartilage that contains type I collagen in addition to the normal type II.
- Fibrocartilage is found in the pubic symphysis, the annulus fibrosus of intervertebral discs, menisci, and the temporomandibular joints (TMJ).

- Purple- dense connective tisues
- Top and left – hyaline cartilage