CARTILAGE

Introduction

Cartilage is specialized connective tissues possesses a firm pliable matrix that resists mechanical stresses. The cartilage is neither vascularized nor supplied with nerves or lymphatic vessels; however, the cells receive their nourishment from blood vessels of surrounding connective tissues by diffusion through the matrix.

The flexibility and resistance of cartilage to compression permit it to function as a shock absorber, and its smooth surface permits almost friction-free movement of the joints of the body as it covers the articulating surfaces of the bones.

There are three types of cartilage according to the fibers present in the matrix (Table 1): **Hyaline cartilage**, **Elastic cartilage,** and **Fibrocartilage**

Table 1	Types of Cartilage			
Type	**Fibers**	**Chondrocytes arrangement**	**Perichondrium**	**Location**
Hyaline	Type II collagen	Mostly in groups (isogenous groups)	Yes, except: articular cartilages and epiphyses	Articular ends of long bones, nose, larynx, trachea, bronchi, ventral ends of ribs
Elastic	Type II collagen and elastic fibers	Mostly in groups (isogenous groups)	Yes	Pinna of ear, walls of auditory canal, auditory tube, epiglottis, cuneiform cartilage of larynx
Fibro-cartilage	Type II and Type I collagen	Most are small and sparsely arranged in parallel columns or rows	No	Intervertebral disks, articular disks, pubic symphysis, insertion of some tendons

The perichondrium

The **perichondrium** is a connective tissue sheath covering that overlies most cartilage. It has an *outer fibrous layer* and *inner cellular layer* whose cells secrete cartilage matrix. The perichondrium is vascular, and its vessels supply nutrients to the cells of cartilage.

Perichondria are present in elastic and most hyaline cartilages, but absent in fibrocartilage.

Hyaline Cartilage

Hyaline cartilage, a bluish-gray, semitranslucent, pliable substance, is the most common cartilage of the body.

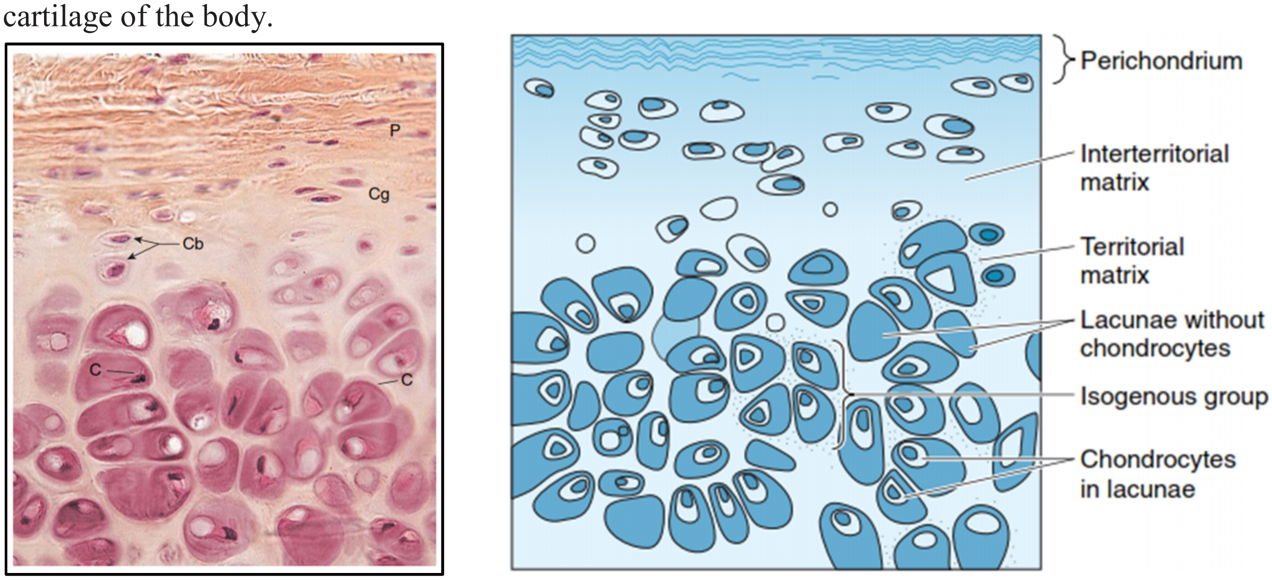


Figure.1: *Light micrograph of hyaline cartilage (left). Observe the large ovoid chondrocytes (C) trapped in their lacunae. Above them are the elongated chondroblasts (Cb), and at the very top is the perichondrium (P) and the underlying chondrogenic (Cg) cell layer*.

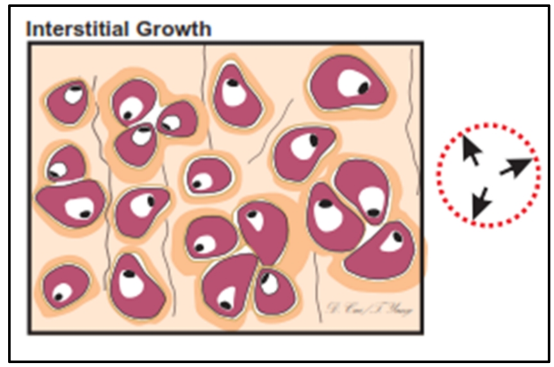
Histogenesis and Growth of Hyaline Cartilage

In the region where cartilage is to form, individual mesenchymal cells retract their processes, round up, and congregate in dense masses called **chondrification centers.**

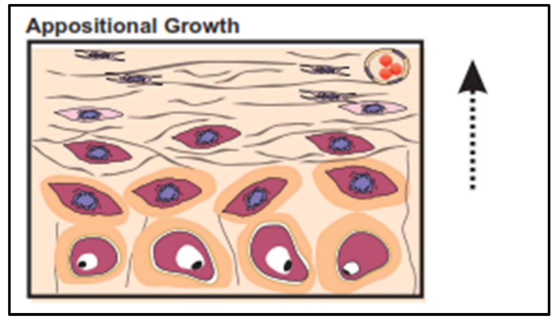
These cells differentiate into **chondroblasts** and commence secreting the typical cartilage matrix around themselves. As this process continues, the chondroblasts become entrapped in their own matrix in small individual compartments called **lacunae**.

Chondroblasts that are surrounded by this matrix are referred to as **chondrocytes** (Fig. 1). These cells are still capable of cell division, forming a cluster of two to four or more cells in a lacuna. These groups are known as **isogenous groups** and represent one, two, or more cell divisions from an original chondrocyte.

As the cells of an isogenous group manufacture matrix, they are pushed away from each other, forming separate lacunae and thus enlarging the cartilage from within. This type of growth is called **interstitial growth.** Mesenchymal cells at the periphery of the developing cartilage differentiate to form fibroblasts. These cells manufacture a dense irregular collagenous connective tissue, the perichondrium, responsible for the growth and maintenance of the cartilage.



The chondrogenic cells in the perichondrium undergo division and differentiate into chondroblasts, which begin to elaborate matrix. In this way cartilage also grows by adding to its periphery, a process called **appositional growth.**



Interstitial growth occurs only in the early phase of hyaline cartilage formation. Articular cartilage lacks a perichondrium and increases in size only by interstitial growth.
This type of growth also occurs in the **epiphyseal plates** of long bones, where the lacunae are arranged in a longitudinal orientation parallel to the long axis of the bone; therefore, interstitial growth serves to lengthen the bone.
The cartilage in the remainder of the body grows mostly by apposition, a controlled process that may continue during the life of the cartilage.

➢ Cartilage cells

Three types of cells are associated with cartilage: chondrogenic cells, chondroblasts, and chondrocytes (see Fig.1).

1. **Chondrogenic cells** are spindle-shaped, narrow cells that are derived from mesenchymal cells. These cells can differentiate into both chondroblasts and osteoprogenitor cells.
2. **Chondroblasts** are derived from two sources: mesenchymal cells located within the center of chondrification and chondrogenic cells of the inner cellular layer of the perichondrium.
3. **Chondrocytes** are chondroblasts that are surrounded by matrix. Those near the periphery are ovoid, whereas those deeper in the cartilage are more rounded.

➢ Matrix of Hyaline Cartilage

The semitranslucent blue-gray matrix of hyaline cartilage contains up to 40% of its dry weight in collagen. In addition, it contains proteoglycans, glycoproteins, and extracellular fluid. Because the refractive index of the collagen fibrils and that of the ground substance are nearly the same, the matrix appears to be an amorphous, homogeneous mass with the light microscope.
The matrix of hyaline cartilage contains primarily **type II collagen,** type II collagen does not form large bundles, although the bundle thickness increases with distance from the lacunae. Fiber orientation appears to be related to the stresses placed on the cartilage. For example, in articular cartilage, the fibers near the surface are oriented parallel to the surface, whereas deeper fibers seem to be oriented in curved columns.
The matrix is subdivided into two regions: the **territorial matrix**, around each lacuna, and the **interterritorial matrix** (see Fig.1).
A small region of the matrix immediately surrounding the lacuna is known as the **pericellular capsule.** It has been suggested that the pericellular capsule may protect chondrocytes from mechanical stresses.

➢ Histophysiology of Hyaline Cartilage

The smoothness of hyaline cartilage and its ability to resist forces of both compression and tension are essential to its function at the articular surfaces of joints. Because cartilage is avascular, nutrients and oxygen must diffuse through the water of hydration present in the matrix. The inefficiency of such a system necessitates a limit on the width of cartilage. There is a constant turnover in the proteoglycans of cartilage that changes with age.

➢ Clinical Correlations

Hyaline cartilage degenerates when the chondrocytes hypertrophy and die and the matrix begins to calcify. This process is a normal and integral part of endochondral bone formation; however, it is also a natural process of aging, often resulting in less mobility and in joint pain.
Cartilage regeneration is usually poor except in children. Chondrogenic cells from the perichondrium enter the defect and form new cartilage. If the defect is large, the cells form dense connective tissue to repair the scar.

Elastic Cartilage

Because of the presence of elastic fibers, elastic cartilage is somewhat yellow and is more opaque than hyaline cartilage in the fresh state (see Table. 1). In most respects, elastic cartilage is identical to hyaline cartilage and is often associated with it.

The outer fibrous layer of the perichondrium is rich in elastic fibers.

The matrix of elastic cartilage possesses abundant, fine to coarse branching elastic fibers interposed with type II collagen fiber bundles, giving it much more flexibility than the matrix of hyaline cartilage (Fig. 2).

The chondrocytes of elastic cartilage are more abundant and larger than those of hyaline cartilage. The matrix is not as ample as in hyaline cartilage, and the elastic fiber bundles of the territorial matrix are larger and coarser than those of the interterritorial matrix.

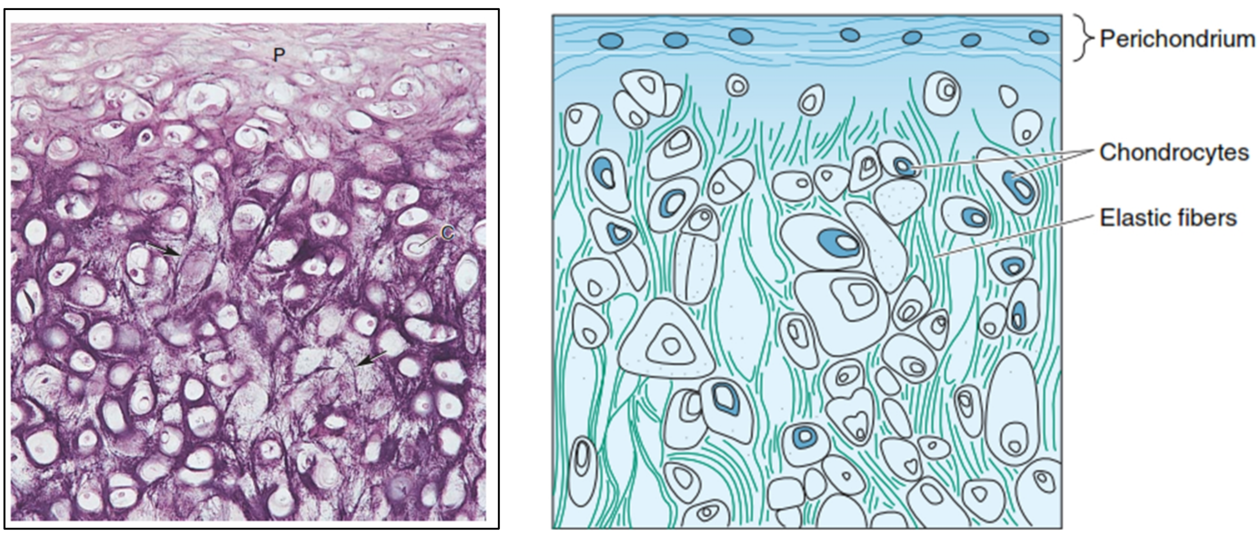
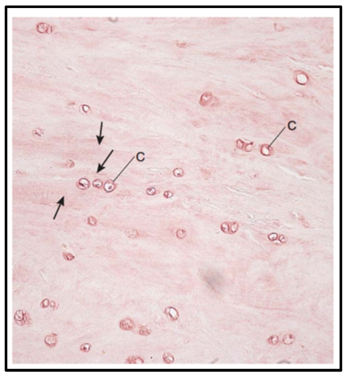


Figure. 2: *Light micrograph of elastic cartilage (left). Observe the perichondrium (P) and the chondrocytes (C) in their lacunae (shrunken from the walls because of processing), some of which contain more than one cell, evidence of interstitial growth. Elastic fibers (arrows) are scattered throughout.*

Fibrocartilage

Fibrocartilage is associated with hyaline cartilage and with dense connective tissue, which it resembles. Unlike the other two types of cartilage, fibrocartilage does not possess a perichondrium. It displays a scant amount of matrix (rich in chondroitin sulfate and dermatan sulfate), and exhibits bundles of type I collagen, which stain acidophilic (Fig.3).

Chondrocytes are often aligned in alternating parallel rows with the thick, coarse bundles of collagen, which parallel the tensile forces attendant on this tissue (see Table. 1). Chondrocytes of fibrocartilage usually arise from fibroblasts that begin to manufacture proteoglycans. As the ground substance surrounds the fibroblast, the cell becomes incarcerated in its own matrix and differentiates into a chondrocyte.



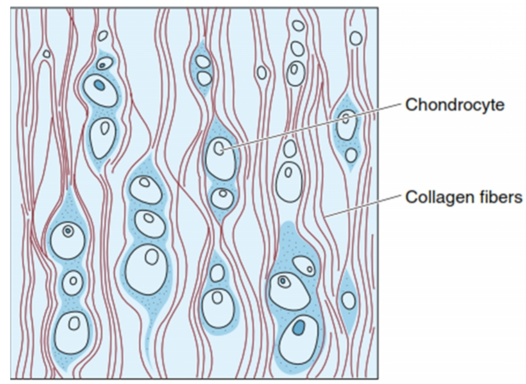
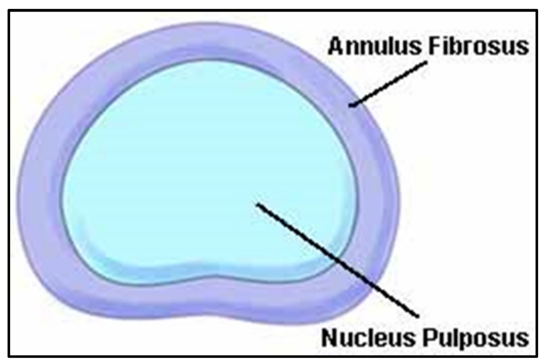


***Figure.3**: Light micrograph of fibrocartilage (left). Note alignment of the chondrocytes (C) in rows interspersed with thick bundles of collagen fibers (arrows).*

Intervertebral disks represent an example of the organization of fibrocartilage. They are interposed between the hyaline cartilage coverings of the articular surface of successive vertebrae.



Each disk contains a gelatinous center, called the **nucleus pulposus,** which is composed of cells, derived from the notochord. These cells disappear by the 20th year of life. Much of the nucleus pulposus is surrounded by the **annulus fibrosus**, layers of fibrocartilage whose type I collagen fibers run vertically between the hyaline cartilages of the two vertebrae. The fibers of adjacent lamellae are oriented obliquely to each other, providing support to the gelatinous nucleus pulposus. The annulus fibrosus provides resistance against tensile forces, whereas the nucleus pulposus resists forces of compression.

Clinical Correlations

A ruptured disk refers to a tear or break in the laminae of the annulus fibrosus through which the gel-like nucleus pulposus extrudes. This condition occurs more often on the posterior portions of the intervertebral disks, particularly in the lumbar portion of the back, where the disk may dislocate, or slip. A “slipped disk” leads to severe, intense pain in the lower back and extremities as the displaced disk compresses the lower spinal nerves.

JOINTS

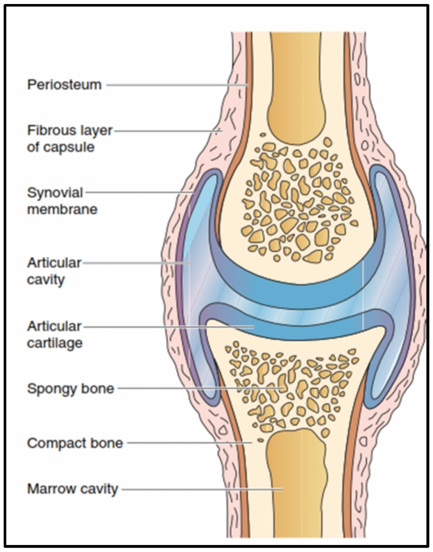
Bones articulate or come into close proximity with one another at joints, which are classified according to the degree of movement available between the bones of the joint.

Those that are closely bound together with only a minimum of movement between them are called **synarthroses.**

Joints in which the bones are free to articulate over a fairly wide range of motion are classified as **diarthroses.**

There are three types of **synarthrosis joints** according to the tissue making up the union:

1. **Synostosis.** There is little if any movement, and joint-uniting tissue is bone (e.g., skull bones in adults).
2. **Synchondrosis.** There is little movement, and joint uniting tissue is hyaline cartilage (e.g., joint of first rib and sternum).
3. **Syndesmosis.** There is little movement, and bones are joined by dense connective tissue (e.g., pubic symphysis).



Most of the joints of the extremities are diarthroses. The bones making up these joints are covered by persistent hyaline cartilage**,** or articular cartilage**.** Usually, ligaments maintain the contact between the bones of the joint, which is sealed by the **joint capsule.**

The **capsule** is composed of an outer **fibrous layer** of dense connective tissue, which is continuous with the periosteum of the bones, and an inner cellular **synovial layer,** which covers all nonarticular surfaces. Some prefer to call this a **synovial membrane.**

Two kinds of cells are located in the synovial layer:

1. **Type A cells** are macrophages displaying a well-developed Golgi apparatus and many lysosomes but only a small amount of RER. These phagocytic cells are responsible for removing debris from the joint space.
2. **Type B cells** resemble fibroblasts, exhibiting a well-developed RER; these cells are thought to secrete the **synovial fluid.**

Synovial fluid contains a high concentration of **hyaluronic acid** and the glycoprotein **lubricin** combined with filtrate of plasma. In addition to supplying nutrients and oxygen to the chondrocytes of the articular cartilage, this fluid has a high content of hyaluronic acid and lubricin that permits it to function as a lubricant for the joint. Moreover, macrophages in the synovial fluid act to phagocytose debris in the joint space.