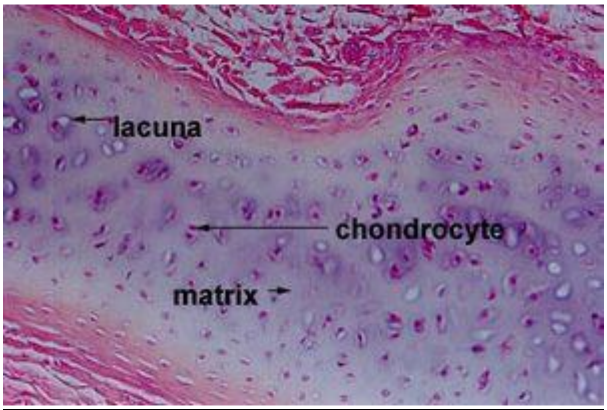
Structure and Functions of Cartilage

Introduction

Cartilage is a specialised connective tissue that plays a crucial role in joint function and movement. Unlike bone, cartilage is avascular (lacking blood vessels) and non-innervated (lacking a nerve supply), which significantly impacts its healing properties and clinical management. This article explains the structure and function of cartilage.

Cartilage Structure and Composition



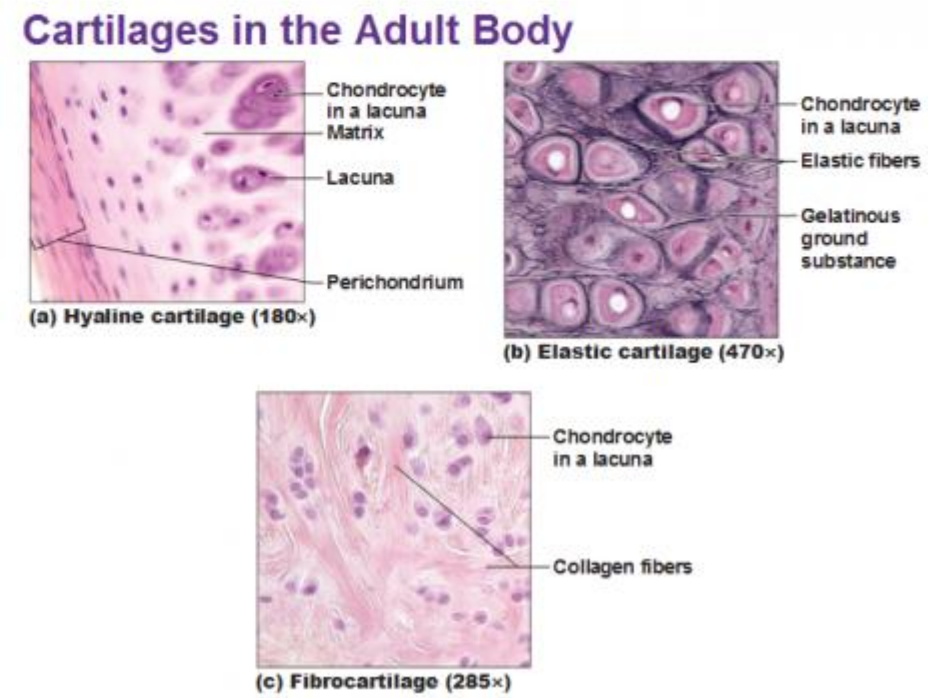
Cellular components of cartilage

Cartilage contains specialised cells called ***chondrocytes*** that maintain the tissue. These mature cells develop from *chondroblasts*, which are responsible for producing the extracellular matrix. Chondrocytes are situated in small chambers called *lacunae* within the *cartilage extracellular matrix* (see Figure).[1]

The **cartilage extracellular matrix** contains ***collagen fibres, ground substance, and water.*** The ground substance contains proteoglycans (such as aggrecan), glycoproteins, and hyaluronic acid. Water makes up approximately 70-80% of cartilage weight.

Most cartilage is surrounded by a fibrous sheath called the **perichondrium**, which has two layers. The outer fibrous layer of the perichondrium provides protection and mechanical support, while the inner cellular layer contains cells that are important for cartilage growth and maintenance.

Types of Cartilage



Types of cartilage

There are three types of cartilage: **fibrocartilage**, **elastic cartilage** and **hyaline cartilage**. They all have slightly different structures and functions.

Fibrocartilage

Fibrocartilage is the strongest of the three types of cartilage. It consists of dense masses of **Type I** collagen fibres interlinked with layers of hyaline cartilage matrix. It lacks a perichondrium, but includes a matrix that contains dense bundles of collagen fibres embedded with chondrocytes. This structure makes fibrocartilage durable, tough, and resistant to compressive forces.

Fibrocartilage is located in the intervertebral discs, menisci, fracture calluses, at the pubic symphysis, and at some tendon insertion sites. Fibrocartilage is a significant component of the **entheses**—i.e. the connective tissue between muscle, tendon or ligament and bone.

Elastic Cartilage

Elastic cartilage is both strong and elastic. It has a yellowish colour and is surrounded by a perichondrium. It contains chondrocytes, which sit within a matrix of **elastic fibres and Type II** collagen fibres. It provides support and maintains the shape of structures, such as the pinna or lobe of the ear and the epiglottis.

Hyaline Cartilage

Hyaline cartilage is the most common type of cartilage in humans. Its matrix contains closely packed **Type II** collagen fibres and proteoglycans, making it tough but slightly flexible. It is bluish-white and has a smooth surface. It reduces friction between surfaces while providing flexibility, support, and shock absorption. Hyaline cartilage is located on the articular surfaces, in the nasal cartilage, costal cartilage, and trachea.

Articular Cartilage

Articular cartilage is a type of hyaline cartilage.[5] It lines the ends of bones in movable joints. It is able to withstand shear and compressive forces. It is often described as having two main components: a **solid phase** and a **fluid phase**. However, recent research suggests articular cartilage functions as an integrated system where there are no clear distinctions between solid and fluid phases.[6] Despite this complexity, the biphasic framework remains useful for understanding cartilage structure and function.

The **solid phase** gives the cartilage its shape and strength. It is mainly made up of **Type II** collagen fibres, which are arranged differently depending on where they are in the cartilage. In the superficial zone, the collagen fibres are tightly packed and oriented parallel to the articular surface. This zone helps cartilage resist tensile forces. In the middle zone, collagen fibres are organised randomly. In the deep zone, collagen fibres are oriented vertically and anchor into the calcified cartilage. This zone provides the greatest resistance to compressive forces.

Other components of the solid phase include various proteins (e.g. fibronectin) and proteoglycans. Proteoglycans are large macromolecules that attract and retain water through their negative charges. This creates an osmotic swelling pressure that, combined with the collagen network, enables articular cartilage to resist compressive forces.

The fluid phase mainly contains water and dissolved salts (e.g., sodium, calcium, chloride, potassium). It brings nutrients to cells and removes waste products. The fluid phase enables cartilage to handle loads and provide low-friction movement.

Cartilage Nutrition and Healing

Blood Supply and Lymphatics

Cartilage is avascular and alymphatic. It, therefore, receives nutrition and removes waste via diffusion from surrounding tissues (e.g. synovial fluid, blood vessels in the surrounding perichondrium).[7] Compressive forces enhance nutrient flow.[4]

Nerve Supply

Cartilage is also aneural (i.e. it does not have a direct nerve supply). Therefore, pain associated with cartilage pathology is most commonly caused by irritation of surrounding structures.[4]

Cartilage Repair and Regeneration

Articular cartilage has limited ability to heal or repair, but mechanical loading can play a role in cartilage health and regeneration. Moderate amounts of movement and physical activity support nutrient flow and chondrocyte activity, promoting repair. However, excessive or abnormal loading leads to cartilage degeneration and damage through wear and tear.

Clinical Significance

Many degenerative, inflammatory and congenital conditions can impact cartilage, including osteoarthritis, spinal disc herniation, traumatic rupture/detachment, achondroplasia, costochondritis and neoplasm.

Osteoarthritis of the weight-bearing joints is the most common form of arthritis in adults. It leads to pain, reduced range of motion, decreased mobility and functional limitations. Rehabilitation interventions, including physical activity and physiotherapy, play an important role in managing osteoarthritis. If you would like to learn more about osteoarthritis, please see: General Overview of Osteoarthritis for Rehabilitation Professionals.

Cartilage Health and Exercise

Participation in certain sports may increase the risk of osteoarthritis, such as activities that involve torsional loading, rapid acceleration and deceleration and repetitive high-impact activities or prolonged over-training.

However, **moderate loading through exercises is beneficial for joint health**, as it promotes enhanced production of matrix molecules, increased cartilage volume and improved nutrient diffusion.

The following exercises may help maintain cartilage health:

- aerobic activities (e.g. walking)
- controlled resistance training
- range of motion exercises
- weight-bearing activities within tolerance

Please see Osteoarthritis and Exercise if you would like to read more about the benefits of exercise for people with osteoarthritis.

Cartilage Repair Therapies

As mentioned, cartilage has a limited ability to self-heal. Various medical interventions have been proposed to aid cartilage repair, including:

- stem cell therapy: mesenchymal stem cells show promise
- tissue engineering: developing scaffolds for cartilage regeneration
- growth factors: to enhance natural repair processes

- gene therapies: deliver therapeutic genes to target cells
- biological approaches: to address cartilage's limited healing potential