Flexibility and strength at the subcellular level

Flexibility and strength in non-cellular structures is important mainly for connective tissue, which is characterized by its large amount of intercellular mass. It is the intercellular mass that largely determines its physical properties. The intercellular mass of connective tissue can be divided according to its structure into **fibrous** and **amorphous** components.

Fibrous component

Collagen (Collagen and reticular fibers)

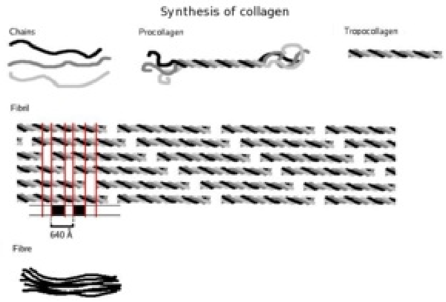
Collagen is a structural protein found in all types of connective tissue . At least 18 different forms of collagen are currently known, and more are still being discovered. From a physical point of view, the most important are **Collagen I**, **II** and **III**.

Structure

The basic building block of collagen fibres is the **tropocollagen** molecule (↔ 280 nm, Ø 1.5 nm). It consists of **three helically coiled polypeptid chains** (tropocollagen owes this arrangement to the regular repetition of glycinu molecules). The collagen -specific amino acids hydroxyproline and hydroxylysine occur here. Tropcollagen polymerizes longitudinally into protofibrils, from which bundles of fibrous structures called fibrils (Ø 20–75 nm) are formed laterally. Further aggregation can create wider structures, i.e. collagen fibers(Ø 0.2–20 µm). The tropocollagen molecules in the neighboring protofibrils are displaced from each other by 64 nm, which creates an interconnected step-like structure (transverse striations are then visible under the microscope).

Features and functions

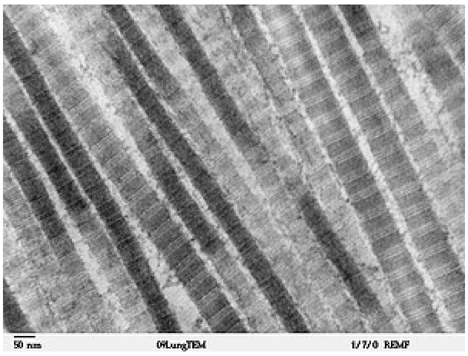
Collagen fibers are a flexible and very strong structure (they can withstand a load of up to 50 N per 1 mm 2), but they are not very elastic. These properties are mainly due to the specific arrangement of tropocollagen molecules. The strength of the fibers is supported by the specific amino acid hydroxyproline, which forms a large number of cross-links, thereby strengthening their structure.



Structure of collagen fibrils

- **Collagen I (KI)**

This type consists of the thickest fibers (Ø 1–20µm) and is therefore mainly found in heavily loaded structures such as tendons . In order to withstand the enormous load, this ligament contains a large number of parallel arranged KI fibrils, therefore it is called densely arranged collagenous ligament. However, KI also occurs in a less dense form as an interorgan lining (thin collagen fiber) or in fibrous cartilage or as part of the organic component of the bone matrix (osteid).


Collagen I

- **Collagen III (KIII)**

KIII also forms fibers, but with a significantly smaller diameter (Ø 0.2–2 µm). These are arranged in net-like structures and are called reticular fibers. Due to their diameter and structure, their strength is not as great as that of KI and they are mainly found as a supporting structure of some organs (red bone marrow). During wound healing, reticular fibres always appear first and only later are they replaced by collagen fibers.

- **Collagen II (KII)**

This type of collagen does not form fibers and is only found in the form of fibrils. It occurs in all types of cartilage and, thanks to its physical properties, forms its firm vault, maintains its shape and prevents its excessive deformation.

Elastic fibers

Elastic fibers have a thinner diameter (Ø 1–10 µm) than collagen fibers , branch more often and are found much less often in the human body. In the tissues, they are distinguished by their characteristic yellow color.

Structure

Elastic fibers consist of a central and peripheral part. The central part represents the amorphous glycoprotein elastin , which is formed by the polymerization of globular molecules of tropoelastin. Unlike collagen , elastin is poor in hydroxyproline. Elastin is surrounded by a layer of thin microfibrils (Ø 14 nm) composed of the glycoprotein fibrillin . Microfibrils contribute to the cohesion of the extracellular mass.

Properties

Elastic fibers are very flexible (they can stretch up to 200% of their original length), but much less strong than collagen fibers . The maximum tension that these fibers can withstand is around 3 N per 1 mm^2. The low strength is related to the lack of interlinking of the fibers by river bonds, which were provided by specific amino acids (hydroxyproline) in the collagen fibers. At the same time, the amorphous core of the elastic fiber adapts very easily and responds flexibly to the load.

Function

The elasticity of elastic fibers is mainly used in the body in combination with collagen fibers (e.g. in joint capsules), where they reduce their hysteresis (facilitate their return to their original position). They are found in larger quantities only in the ligamenta flava of the spine and the ligamentum suspensorium of the penis. Elastic fibers are also an integral part of elastic cartilage.

Amorphous component

Proteoglycans and Glycosaminoglycans (GAGs)

Proteoglycans are macromolecules consisting of a central protein component and peripherally attached GAGs. The whole structure resembles a brush for cleaning test tubes. Both small biglycans and decorin and large aggrecans can form the protein core, which are among the largest molecules in the human body and, thanks to this, give cartilage its resistance. GAGs include heparan sulfate, dermatan sulfate, chondroitin sulfate, keratan sulfate, and hyaluronic acid, which is the only one that does not form a bond with proteoglycans. All these structures are extremely hydrophilic and can be in contact withincrease its volume many times with water. In cartilage, for example, it therefore serves as an elastic cushion for shock absorption. At the same time, GAGs , with their viscosity, help to stabilize the entire structure of the given tissue, participate in cell nutrition and minimize friction in the joints (hyaluronic acid).

Multiadhesive Glycoproteins

This component ensures the cohesion of cells with the intercellular matrix and is therefore an important strength factor in connective tissues. These integrins include, for example, fibronectin, laminin, chondronectin, osteonectin, osteopontin, fibrillin and others.

Mineral substances

In the case of bone tissue, we also encounter this type of intercellular mass. These inorganic substances make up to 50% of the bone's dry weight and contribute to a large extent to its strength. Most often, these are calcium cations and phosphate anions, which together form hydroxyapatite crystals. The connection of these crystals with collagen fibers is the cause of bone strength, but mineral substances are also responsible for their fragility.

Links

Related articles

- Mechanical characteristics of connective tissue

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