Elasticity and stiffness on subcellular level

Elasticity

Is the property of an object or material, which causes it to be restored to its original shape after distortion. It is said to be more elastic if it restores itself more precisely to its original configuration. A spring is an example of an elastic object, that, when stretched, exerts a restoring force which tends to bring it back to its original length. This force is proportional to the amount of stretch (Hooke's Law).

Stiffness

Is the extent to which an object can resist deformation responding to an applied force. The stiffness of a body is a measure of the resistance offered by an elastic body to deformation. For an elastic body with a single Degree of Freedom (for example, stretching or compression of a rod), stiffness is defined as follows:

$$K = F / \delta$$

In the formula above K is the stiffness, F stands for the applied force on the body and δ is the displacement (e.g. the change in length of a stretched spring)
On the subcellular level two main compounds, collagen and elastin, are responsible for the stiffness and elasticity different cells may be characterised of, depending on the amount, location and shape of the formers.

Extracellular matrix

Is a well-organised network of extracellular material in the closest space next to the plasmatic membrane. A substantial part of their volume is extracellular space, which is largely filled by an intricate combination of macromolecules constituting the extracellular matrix (ECM).
This matrix is composed of a variety of proteins and polysaccharides that are secreted locally and assembled into an organized meshwork in close association with the surface of the cell that produced them. In addition to polysaccharide chains of the class called glycosaminoglycans (GAGs), which are usually found covalently linked to protein in the form of proteoglycans, and fibrous proteins like fibronectin, and laminin, which have both structural and adhesive functions, collagen and elastin fibers make up a great deal of the ECM and determine the mechanical properties, such as elasticity and stiffness.

Collagens

Comprise a family of fibrous glycoproteins that are present only in the ECM. Collagens are found throughout the animal kingdom and are noted for their high tensile strength, that is, their resistance to pulling forces which , weight for weight, is greater than that of steel. It is estimated that a collagen fibre 1mm in diameter is capable of suspending a weight of 10 kg without breaking. Collagen is the single most abundant protein in human body (more than 25 % of all protein), a fact that reflects the widespread occurrence of extracellular materials and points out the great resiliency that characterises the human body. Collagen is produced primarily by fibroblasts, the cells found in various types of connective tissues, and also by smooth muscle cells and epithelial cells. To date, 27 distinct types of human collagen have been identified; each collagen type is restricted to particular locations within the body, but two or more different types are often present together in the same ECM. Mixing several collagen types within the same fibre provides additional functional complexity. It is likely that different structural and mechanical properties result from different mixtures of collagens in fibres. Although there are many differences among the numerous types of the collagen family, all share at least two important structural features:

- All collagen molecules are trimers consisting of three polypeptide chains, called alpha chains;
- Along at least part of their length, the three-polypeptide chains of a collagen molecule are wound around each other to form a unique, rod-like triple helix.

The mechanical properties of collagen are due to the large content of proline and lysine, whose residues are hydroxylated. The hydroxylated amino acids are important in maintaining the stability of the triple helix by forming hydrogen bonds between component chains. Thus, the properties of a particular tissue can often be correlated with the three-dimensional organization of its collagen molecules; for example, tendons, which connect muscles to bones, must resist tremendous pulling forces during times of muscular contraction and this anatomical structure of the human body contains an ECM in which the collagen fibrils are aligned parallel to the long axis of the tendon and thus parallel to the direction of the pulling forces.

Elastin

Is a protein in connective tissue that is elastic and allows many tissues in the body to resume their shape after stretching or contracting. Elastin helps skin to return to its original position when it is poked or pinched. Elastic fibres range in diameter from 0.1 to 10 µm; they consist of the amorphous protein elastin, in which are embedded many protein microfibrils composed of fibrillin. Elastic fibres can stretch to 150 % of their length without braking and return to their original length. Elastin is the major extracellular matrix protein in tissues such as the large arterial blood vessels, lung parenchyma, elastic ligaments and skin, where it is accepted to be principally responsible for the physical properties of extensibility and elastic recoil that are particularly important for the function of these tissues. Elastin is also the major matrix protein in some cartilaginous tissues such as ear cartilage, where the functional role of this protein is less evident. In common with most structural proteins elastin is synthesized as a monomer, tropoelastin, which is subsequently assembled into a stable, polymeric structure in the extracellular matrix. Polymeric elastin has the unusual property of being essentially insoluble in all reagents except those which break polypeptide bonds, and this persistent insolubility of elastin has been both a benefit in the isolation and purification of the protein and an impediment to its structural characterization. In addition, with the notable exception of the uterus, elastin, once laid down in its insoluble polymeric form in the extracellular matrix of tissues, does not turn over at any appreciable rate under normal circumstances. In effect, this means that the elastin present in the aorta of an older human is the elastin that was laid down during aortic development.

Links

Related articles

External links

Bibliography

Biologia cellulare e molecolare 3RD Edition, Gerald Karp, Edises Editore 2009
Baumgart F. (2000). "Stiffness--an unknown world of mechanical science?". Injury (Elsevier) 31. Retrieved 2012-05-04. "“Stiffness” = “Load” divided by “Deformation”"
http://ajplung.physiology.org/content/299/3/L301.abstract Functional consequences of the collagen/elastin switch in vascular remodeling in hyperhomocysteinemic wild-type, eNOS−/−, and iNOS−/− mice
http://www.ncbi.nlm.nih.gov/books/NBK26810/ The Extracellular Matrix of Animals