

# Ligament

Ligament is the most widespread type of connective tissue in the human body. It contains **cells surrounded by a large amount of intercellular material**, which has a gel-like consistency and is **reinforced by fibers**. The main function of the ligament is to connect epithelial tissue with other tissues (e.g. muscle).

## Tissue cells

### Cells fixed

We include cells that are **permanently settled** in the ligament. Their precursor is a classical mesenchymal cell. Fixed cells include: *fibroblast*, *fibrocyte*, *myofibroblast*, *reticular cell*, *melanocyte*, and *adipocyte*.

### Stray cells

Cells that entered the tissue **only secondarily**. The origin is primarily blood cells. Stray cells include: *heparinocytes*, *macrophages* and *plasma cells*.

## Fixed cells

### Fibroblast

It is a basic cell that is **mitotically and synthetically** active. It is capable of creating all types of **fibrous and amorphous** intercellular matter (collagen, elastin, GAG, multiadhesive glycoproteins, etc.) It is among **the most widespread cell types** in fibrous tissue. Like other fixed cells, it arises from *mesenchyme*. **Elongated, star-shaped** with many irregular projections. Roughly in the middle of the cell lies a large ovoid nucleus containing pale euchromatin with prominent basophilic nucleoli. Inside the cell there is a massively developed GER and the Golgi complex. The cytoplasm of the fibroblast is **basophilic**. Once the fibroblast is surrounded by the newly synthesized extracellular matrix, it becomes a **fibrocyte**.

### Fibrocyte

A **resting form** of a fiber cell that arises from a *fibroblast* surrounded by an *extracellular matrix*. It **loses its synthetic and mitotic activity** and becomes **the structural support** of the ligament. The cell is spindle-shaped and smaller than a fibroblast. It contains a small longitudinal nucleus that is smaller and darker than that of a fibroblast and its cytoplasm is **acidophilic** (less GER than that of a fibroblast). Fibrocytes **can retrograde into fibroblasts** (e.g. during wound healing).

### Myofibroblast

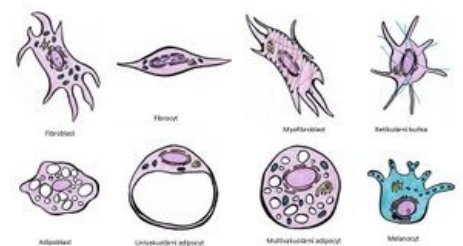
It closely resembles a *fibroblast*, but has some properties in common with smooth muscle. It produces  *$\alpha$ -smooth muscle actin*, which is anchored in *dens bodies* along the cell edge. *Actin* anchored in this way runs across the cell and **enables its contraction**. It differs from a muscle cell in that it **does not have a basement membrane**.

### Reticular cell

A variant of *fibroblast* specialized in the **formation of reticular fibers**, which arise from type III collagen precursors. It arises from *mesenchyme*. It is **star-shaped with very long projections** that touch each other to form **a three-dimensional network**. The projections of the reticular cells are in contact with the reticular fibers. This connection creates **a support network** for wandering cells (*macrophages*, *lymphocytes*, *hematopoietic cells*). Reticular cells are found mainly in the peripheral lymphatic organs, except for the thymus, in which it forms supporting tissue.

### Melanocyte

An irregularly shaped **pigment cell** that arises from **neuroectoderm** (not mesenchyme!!). Inside the cell, the brown pigment *melanin* is synthesized and collected. The cells contained in the ligament are star-shaped. Some melanocytes **communicate with epithelial cells** by means of projections (pigment release). Such cells form protrusions only in the part that communicates with the epithelium. On the opposite side of the cell lies the nucleus. The cell also contains mitochondria, GER and SER.



Cells fixed

### Fat cell (adipocyte)

It is found either singly or in small groups in the ligament. The precursor is **an adipoblast** (from a *mesenchymal* precursor cell). It belongs to conspicuously **large cells** in the connective tissue. They pick up neutral lipids from the bloodstream, which they **collect** (in the form of triglycerides), **enable their metabolism** and **release** them

back. They are **separated** from the surrounding structures by **an external lamina**, which resembles the basal lamina of the epithelium. The adipocyte is the basic component of adipose tissue and can make up up to 30% of body weight. On normal histological preparations, adipocytes appear as empty cells (fats were extracted during preparation of the preparation).

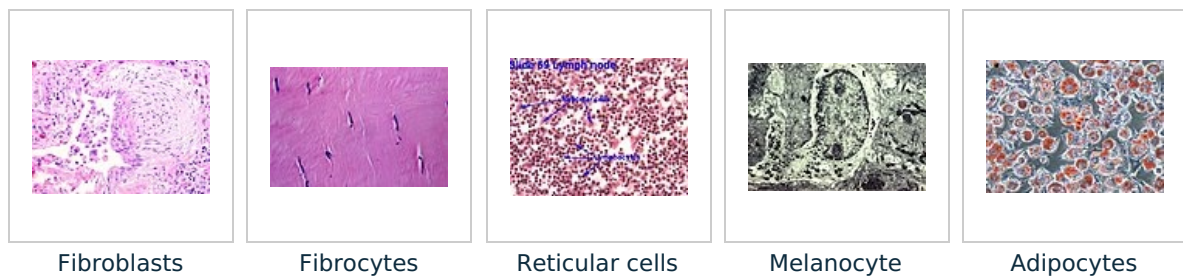
According to the form of fat storage inside the cell, we divide adipocytes into two groups - *multivacuolar* and *univacuolar*.

### Univacuolar adipocyte

A spherical cell that is mostly made up of **one large fat droplet**. The cytoplasm together with the heavily flattened nucleus and other cell organelles is **pushed to the periphery** of the cell. The *GER* and *Golgi complex* are poorly developed, while the *SER* is massively developed. It also contains pinocytotic vesicles and *microtubules*. Univacuolar adipocytes form the main component of **white adipose tissue**.

### Multivacuolar adipocyte

A cell containing a large number of **tiny droplets of fat**. The spherical nucleus is located irregularly, rather in the center of the cell. There is a large number of mitochondria in the cytoplasm. It forms the main component of **brown adipose tissue**. They convert chemical energy into heat (the thermoregulatory function of brown adipose tissue in newborns).

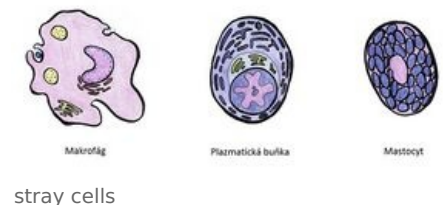


## Stray cells

They are formed in **the red bone marrow**. Their precursor cell is a *hemocytoblast*. They reach the ligament through the bloodstream.

### Macrophage (histiocyte)

It differentiates from blood **monocytes**, which mature into macrophages after penetrating the tissue. The shape of the cell is **variable**, forming a large number of projections. Inside the cell there is a kidney-shaped nucleus, a large number of lysosomes and elements of the cytoskeleton. *GER* and *Golgi complex* are massively developed. Histiocytes move **amoeboidally**. It belongs to the monocytemacrophage system, therefore it has **the ability of phagocytosis**.



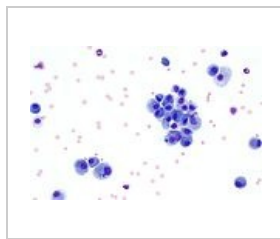
Macrophages are part of the immune system. They are able to phagocytose **damaged** or **dead cells**, possibly **foreign cells, particles** and **microorganisms**. They create highly reactive particles with the ability to destroy absorbed organisms. They release anti-inflammatory mediators. They occur mainly in the sparse connective tissue along the capillaries.

### Plasma cell (plasmocyte)

Plasma cells are ovoid to spherical cells. Their characteristic appearance is due to **the eccentrically placed nucleus**, which is shifted to one pole of the cell. In the nucleus, dark *heterochromatin* alternates with light *euchromatin*, creating a bow-shaped arrangement. They contain a large amount of cytoplasm, which is filled with rich *GER* (intensive proteosynthesis). Near the nucleus, there is a bright part of the cytoplasm, which corresponds to the location of the *Golgi apparatus*. **They arise from B-lymphocytes** and are responsible for **humoral immunity** (production of antibodies). There are very few of them in the connective tissue, they are mostly contained in places where bacteria and foreign substances easily penetrate into the body.

### Mast cell (heparinocyte)

A relatively **large ovoid-shaped cell**, also called a *mast cell*. Their cytoplasm is filled with large **basophilic granules**. Basophilic granules are filled primarily with heparin and histamine, which show metachromasia (when stained, the resulting shade of color is different from the dye used), stained with toluidine blue. They occur in the thin collagenous tissue of the mucous membranes of the organs of the digestive and respiratory systems. They are important for the correct course of the inflammatory reaction. It mediates **the body's allergic reaction** to an antigen. The mast cell membrane has an affinity for IgE. When antigen binds to IgE, **basophilic granules are washed out** (degranulation) into the intercellular space. This phenomenon can also occur when irritated by chemical or physical influences.



Macrophages



Plasmacyte

# Intercellular mass of ligament

## Ligament fibers

### Collagen fibers

Macroscopically, they have a white to silver color. They are not branched, have **high tensile strength**, but are **not very stretchy**. They contain amino acids: glycine, proline, hydroxyproline. Since glycine is the smallest amino acid, it enables the spatial arrangement of collagen into **a triple helix**.

We distinguish several types of collagen

- **Collagen I** - (most common type, 90%) - Made up of fibrils that form **bundles of fibers**. The individual fibers are **strong and resistant** to tension. Contained in *the joint, it forms an organic component of bone tissue, ligaments, tendons, and fascia*.
- **Collagen II** - thin, very fine, hard-to-see fibers that **do not form bundles**. Contained in *hyaline and elastic cartilage*.
- **Collagen III** - together with reticular cells, participates in the construction of the **support network of lymphatic organs**. Contained in *the walls of arteries, veins and lymphatic vessels, it forms the fibers of lymphatic organs and bone marrow*.
- **Collagen IV** - does not form fibrils, instead it forms **flat cross-linked layers**. It forms a layer in *the lamina densa in the basement membrane, or in the outer lamina of epithelia, endothelium, muscle, fat and glial cells*.
- **Collagen V** - occurs **together with type I collagen**, it is only present in small amounts, but its presence can **affect the properties** of collagen I. Contained, for example, in *the placenta*.
- **Collagen VII** - enables cohesion between the basal cells of the epithelium, lamina densa and lamina fibroreticularis. It occurs in *the basement membrane of the multi-layered squamous epithelium*.

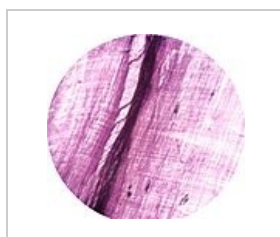
### Elastic fibers

These fibers are produced by **fibroblasts and smooth muscle cells**. The main component is **elastin**, which has a yellowish color, so even the accumulation of elastic fibers appears yellow. Contains amino acids: *glycine, proline, valine, desmosine and isodesmosine*. In tension, they are **less resistant** than fibrillar fibers, but they are much more **flexible**. They have the ability to stretch and retract up to twice their resting length. The fibers are branched and can connect into spatial networks.

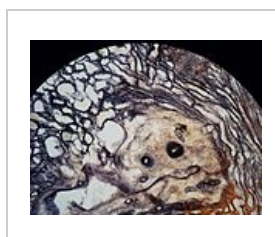
Elastic fibers are found, for example, as **elastic membranes of the walls of large arteries**, to a lesser extent also in medium-sized arteries, in the wall of the bronchi, in the yellow ligaments between the vertebrae and in the wall of the vagina. In histology, we stain elastic fibers with *orcein, resorcin-fuchsin, or Verhoeff's iron hematoxylin*.

### Reticular fibers

Fibers with **a thin diameter and low contrast**, for that reason they are not very noticeable. They are produced by *reticular cells, fibroblasts and smooth muscle cells*. It serves as a skeleton for lymphatic structures, at the same time it creates a network that contains lymphocytes. In histological preparations, they can be visualized using the **PAS reaction**. It occurs, for example, in the **lymph nodes**, bone marrow, spleen, and forms lymphatic organs (*with the exception of the thymus - reticular epithelium!*).



Collagen fibers



Reticular fibers

## The base material is amorphous

The empty spaces between the cellular and fibrous components are filled by amorphous matter. It is viscous, colorless, translucent with a high water content. It consists mainly of glycosaminoglycans (GAG), proteoglycans (PG) and multiadhesive proteins. These substances can bind a large amount of water.

## Glycosaminoglycans

A complex of proteins and polysaccharides, also known as mucopolysaccharides. Long linear chains composed of a large number of disaccharide units. They occur mainly as sulfonated. GAGs condition the basophilia and hydrophilicity of the amorphous mass.

One of the most important GAGs is **hyaluronic acid**. A very long and strongly hydrophilic GAG molecule. It conditions a thinner consistency of the fiber. It is **the main component of the fiber**. It binds to itself a large amount of water, due to which it forms a viscous gel. A large amount of water **affects the diffusion** of substances through the intercellular space. It also serves as an important **immunological barrier** (defense against microbes). It occurs in all types of connective tissue, especially *the vitreous, cartilage and synovial fluid*.

## Proteoglycans

Composed of **a protein fiber** to which **at least one GAG chain** is covalently bound. They influence the diffusion of substances in the tissue. They occur in the interstitial space of connective tissue and other tissues, on cell surfaces and as a component of the lamina basalis. The most common PGs include: aggrecan, versican, perlecan, decorin, lumican, syndecan, serglycin.

## Multiadhesive proteins

Glycoproteins that form mediators between the cell and the matrix. Among them we include:

- *Fibronectins* - formed by fibroblasts, reticular cells, macrophages, endothelium and other cells, binding to the matrix is carried out by, for example, collagen and reticular fibers;
- *laminins* - produce all types of cells, form the lamina basalis, can form molecular networks, the most important adhesion molecules of the basal lamina, bind through proteins and proteoglycans.

# Types of fiber

## Mesenchyme

Embryonic tissue arising from the mesoderm is **the basis for the development** of all types of connective tissue, blood elements, smooth muscle and blood and lymphatic vessels. It contains undifferentiated mesenchymal cells. The projections of these cells are connected to each other by communication links (gap junctions) and thus creates a spatial network. The empty spaces of the network are filled with **a jelly-like matrix**, which is made up mainly of water-binding hyaluronate.

Occurrence: *Embryonic tissue*

## Jelly-like tissue

A type of connective tissue that **mainly contains amorphous matter** (hyaluronate). In smaller quantities, fine collagen and reticular fibers. The cell component contains fibroblasts.

Occurrence: *Pulp ligament, umbilical cord (Wharton's jelly), iris*

## Thin collagenous tissue

**The most common type of tissue** in the human body. It contains a smaller amount of fibers than cells and basic matter. The most abundant cells are fibroblasts and macrophages. Collagen fibers mainly of type I and III, as well as elastic and reticular fibers. The thin collagenous tissue has a fine consistency, is flexible and well vascularized. It serves as **a supporting, nourishing component** and a mediator for the exchange of substances between blood and cells.

Occurrence: *Spaces between muscle fibers and fascia, support of epithelial tissues, papillary layer of the dermis, covers lymphatic and blood vessels, in serous membranes, in glands and mucous membranes*

## Dense collagen tissue

Ligament similar in composition to sparse collagen ligament, but **collagen fibers predominate** in it at the expense of amorphous matter. It is less flexible and more resistant to mechanical influences. The most frequently occurring cells are fibrocytes and fibroblasts, but to a lesser extent than in the sparse collagenous tissue.

According to the arrangement of fibers, dense collagenous tissue can be divided into:

### Organized

Strong, parallel arranged collagen I fibers. The arrangement serves for high mechanical resistance in unidirectional load, which allows good tensile strength. Furthermore, there is a smaller amount of elastic fibers and proteoglycans in the matrix. Between the fibers there is a tiny amount of fibroblasts (tendinocytes), which create winged protrusions through which they communicate with each other (gap junctions).

Occurrence: *Tendons, retinacula*

### Disorganized

Collagen I fibers that form a three-dimensional network. This guarantees greater strength of the fiber under mechanical stress in all directions.

Occurrence: *Dermis, coverings of organs, sclera*

### Reticular ligament

Specialized sparse connective tissue. It serves as **a framework for bone marrow and lymphatic organs** (lymph nodes, spleen). Reticular cells are **star-shaped** and touch each other with their projections. It thus creates a **three-dimensional network**. Reticular cells are capable of producing **type III collagen**, proteoglycans and adhesion proteins. **Stray cells** can develop in the resulting meshes between cells. Reticular fibers contain collagen type III as well as collagen type I. The fibers are **surrounded by projections** of reticular cells. They thus create a supporting structure to which the reticular cells are attached.

Occurrence: *Bone marrow, lymph nodes, spleen*

### Elastic ligament

Bundles of strong, **parallel-arranged** elastic fibers, accompanied by a small amount of collagen fibers (so that the elastic fibers do not break under heavy stress). Flat fibroblasts are found between the fibers. The elastic tissue is **very flexible** and has a yellowish color due to the large number of elastic fibers.

Occurrence: *ligg. flava spine, lig. suspensorium penis, lig. vocals*

### Adipose tissue

It consists primarily of adipocytes, which are able to synthesize lipids (triacylglycerols) in the form of fat droplets. Each adipocyte has its own basal lamina and is surrounded by reticular fibers (for this reason, they are quite distinct on the preparations).

Adipose tissue occurs in two forms:

#### White fatty tissue

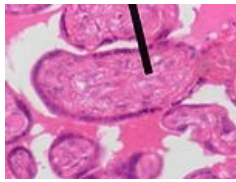
A sparse connective tissue in which **univacuolar adipocytes** predominate. Between them, there are collagen and reticular fibers that create **fibrous septa** and thus separate the adipocytes into individual fat lobules. Lipids inside adipocytes are stored as **energy stores** and released when needed by the body. It also serves as **an insulating layer** against heat loss, **a building material** (foot) or **to maintain an organ in its position** (eyeball, kidney). Structural fat is used for energy production only under extreme conditions (e.g. anorexia nervosa, chronic malnutrition, cachectic cancer). Adipocytes themselves are capable of producing various agents and **hormones**.

Occurrence: *Under the skin, covering the organs of the abdominal cavity, inside the eye socket, fat body in the face, foot, around the coronary vessels of the heart.*

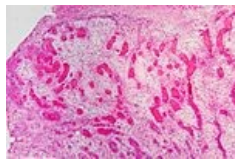
#### Brown fatty tissue

A specialized type of fatty tissue. It contains **multivacuolar adipocytes**, which are brown in color. This brown coloring is primarily due to **a large number of mitochondria**. Mitochondria in brown adipose tissue are specialized for generating heat (not ATP). Occurrence: *Mainly in newborns and infants in the interscapular region, in adults very rarely, for example in the neck and supraclavicular region.*

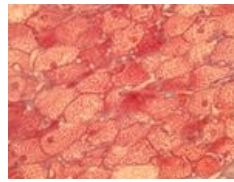
 For more information see adipose tissue.



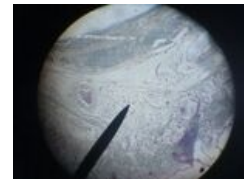
Mesenchyme



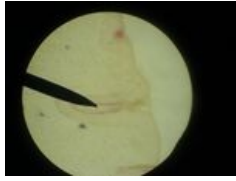
Thin connective tissue



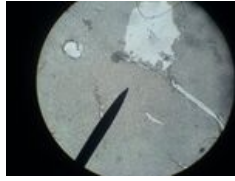
Brown adipose tissue



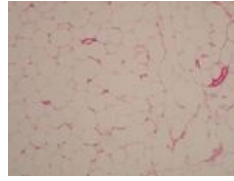
Collagen ligament



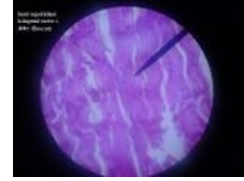
Adipose tissue - HE



Reticular ligament



White adipose tissue



Tendo- HE

## Links

### Related articles

- Cartilage
- Bone
- Epithelium
- Binders

### References

- JUNQUEIRA, L. Carlos, José CARNEIRO a Robert O. KELLEY. *Základy histologie*. 7. vydání. Jinočany : H & H, 1997. 502 s. a LANGE medical book; ISBN 80-85787-37-7.
- BALKO, Jan, Zbyněk TONAR a Ivan VARGA, et al. *Memorix histologie*. 1. vydání. Praha : TRITON, 2016. 529 s. ISBN 978-80-7553-009-7.