O.A. Cherkas
P.A. Kobeza
D.G. Marchenko

Dnipro State Medical University, Dnipro, Ukraine

Надійшла: 24.01.2023
Прийнята: 15.01.2023

DOI: https://doi.org/10.26641/1997-9665.2023.1.77-85

UDC 612.11/.12:591.12

BASIC PRINCIPLES OF THE STRUCTURE AND ORGANIZATION OF CONNECTIVE TISSUE

Cherkas O.A. ✉, Kobeza P.A. ✉, Marchenko D.G. ✉ Basic principles of the structure and organization of connective tissue.
Dnipro State Medical University, Dnipro, Ukraine.
ABSTRACT. Background. Connective tissue is a diverse and vital component of the body, serving a wide range of functions that are essential for proper physiological and pathological processes. It plays an essential role in providing structural support, binding and connecting tissues and organs, and facilitating the transmission of nutrients, oxygen, and waste products between cells and blood vessels. Without connective tissue, the body would not be able to maintain its shape, withstand mechanical stress, or protect internal organs. This is essential for understanding certain health conditions and diseases. Many of them affect connective tissue, such as rheumatoid arthritis, scleroderma, and systemic lupus erythematosus. Knowledge of connective tissue is crucial in the development of medical treatments and procedures. **Objective** is to provide an in-depth understanding of this type of tissue and its functions in the body. This article may cover various topics related to connective tissue, including its structure, types and roles in the body. It also discusses the different types of cells found in connective tissue, such as fibroblasts and macrophages, and how they contribute to tissue maintenance and repair. **Methods.** Lecture-based teaching, microscope-based teaching, computer-based teaching, problem-based learning, group-based learning. To effectively study connective tissue composition and properties, students and teachers will need access to high-quality histology textbooks, online resources, microscopes, and tissue slides. **Results and conclusion.** One of the primary functions of connective tissue is to provide mechanical support to other tissues and organs in the body. This is achieved through the production of extracellular matrix (ECM), which is composed of fibers and ground substance. The fibers in ECM, such as collagen, elastic, and reticular fibers, provide tensile strength, elasticity, and resistance to compression, respectively. The ground substance, which is made up of glycosaminoglycans (GAGs) and proteoglycans, acts as a lubricant and shock absorber. Connective tissue also plays a critical role in wound healing and tissue repair. Another essential function of connective tissue is to transport substances between cells and blood vessels. Additionally, connective tissue cells such as fibroblasts and macrophages produce cytokines and chemokines, which regulate immune cell activity and facilitate the movement of immune cells through the tissue. In summary, connective tissue is necessary for the proper functioning of the body. It provides structural support, facilitates wound healing and tissue repair, and allows for the transport of nutrients and waste products between cells and blood vessels.
Key words: connective tissue, fibroblast, mast cell, plasma cell, macrophage, collagen, collagen fibers, elastic fibers, reticular fibers, ground substance.

Citation:
Cherkas OA, Kobeza PA, Marchenko DG. Basic principles of the structure and organization of connective tissue. Morphologia. 2023;17(1):77-85.
DOI: https://doi.org/10.26641/1997-9665.2023.1.77-85

Cherkas Olga ORCID 0000-0001-5422-0189
Kobeza Pavel ORCID 0000-0003-1113-4007
Marchenko Darya ORCID 0000-0001-7616-3613
✉ **helga.cherkas@gmail.com; kobeza.pavel@gmail.com; dasha19862305@ukr.net**

Introduction

Studying the composition and properties of connective tissue is an essential part of human histology education. Understanding the structure and functions of connective tissue is important for understanding the roles they play in supporting organs, providing mechanical strength, and contributing to the immune system. Here are some tips on how students can effectively study connective tissue composition and properties:

- Review the basics: Before diving into the details, it's important to have a solid understanding of the basics of connective tissue structure and classification. This includes understanding the different types of cells and fibers found in connective tissue, as well as the composition and functions of the ground substance.

- Use visual aids: Connective tissue can be complex, so visual aids such as diagrams, micrographs, and 3D models can be extremely helpful for understanding the structure and relationships between different components. Many histology textbooks and online resources provide high-quality visuals that students can use for studying.
- Attend practical classes: Histology practical classes are crucial for developing a hands-on understanding of connective tissue composition and properties. In these classes, students have the opportunity to observe tissue samples under a microscope and identify different cells, fibers, and ground substance components.
- Seek guidance from teachers: Histology teachers are experienced in teaching the subject and can provide valuable guidance and feedback. They can help students understand difficult concepts, interpret microscopic images, and provide further resources for studying.
- Practice, practice, practice: Like any other subject, studying connective tissue composition and properties requires practice. Students should aim to review and practice regularly to reinforce their understanding and identify areas where they may need further study.

To effectively study connective tissue composition and properties, students and teachers will need access to high-quality histology textbooks, online resources, microscopes, and tissue samples. Histology laboratories should be equipped with appropriate instruments and reagents for preparing and staining tissue samples, and teachers should provide clear instructions and guidelines for practical classes. Additionally, histology teachers should have expertise in the subject and be able to provide support and guidance to students.

The aim of the article on connective tissue would be to provide a comprehensive overview of this important tissue type and its functions in the body, as well as to explore its role.

Methods and materials

Histology is a subject that involves the study of the microscopic anatomy of tissues and organs. To teach the topic of connective tissue in a histology lesson, several methods and techniques can be used, including:

- Lecture-based teaching: This involves the teacher presenting information on connective tissue to students in a traditional lecture format. The lecture can be accompanied by visual aids such as slides, diagrams, and models to help students understand the topic better.
- Microscope-based teaching: This involves the use of microscopes to observe and study the structure of connective tissue under a microscope. The teacher can provide students with slides of different types of connective tissue, and they can observe and study the tissue under the microscope.
- Computer-based teaching: This involves the use of computer programs and software to teach the topic of connective tissue. The teacher can use interactive 3D models, virtual slides, and other computer-based tools to help students understand the topic better.
- Problem-based learning: This involves presenting students with real-world problems related to connective tissue and challenging them to solve the problems using their knowledge of the topic. This method encourages students to think critically and apply their knowledge to solve real-world problems.
- Group-based learning: This involves dividing students into small groups and assigning them tasks related to connective tissue. The group members work together to complete the task, which helps to develop teamwork and collaborative skills.

In practical classes of human histology, teachers need access to high-quality microscopes, slides, and other equipment required for studying connective tissue under the microscope. They also need to have a good understanding of the topic and be able to present the information in a clear and concise manner. Students need to be provided with clear learning objectives, study materials, and opportunities to practice and apply their knowledge of connective tissue. Practical classes should be designed to be interactive and engaging, allowing students to ask questions, discuss ideas, and explore the topic in more depth.

Content

Structural features of connective tissue. Connective tissue is a type of tissue that provides support and structure to the body. It is classified into various types based on the nature of the extracellular matrix, cell types, and fibers present. The following is a classification of the different types of connective tissue [1, 2]:

<u>Loose connective tissue</u>: This type of tissue has a loose arrangement of cells and fibers in the extracellular matrix. It is further divided into areolar, adipose, and reticular connective tissue based on the types of cells and fibers present.

<u>Dense connective tissue</u>: In this type of tissue, the extracellular matrix is densely packed with collagen fibers, providing great tensile strength. It is further divided into regular, irregular, and elastic connective tissue based on the arrangement of fibers.

<u>Cartilage:</u> This is a type of connective tissue that provides a smooth surface for joint movement. It is classified into hyaline, fibrocartilage, and elastic cartilage based on the composition of the extracellular matrix.

<u>Bone tissue</u>: Also known as osseous tissue, it provides support and protection. It is classified into compact and cancellous bone based on the arrange-

ment of the extracellular matrix.

Blood: This is a fluid connective tissue that is composed of blood cells and plasma. It is responsible for transporting nutrients, gases, and waste products throughout the body.

List of cells of connective tissue proper and their functions:

- Fibroblasts: These cells are the most common cells in connective tissue proper and are responsible for synthesizing and maintaining the extracellular matrix. They secrete collagen, elastin, and other extracellular matrix proteins, and play a key role in wound healing [1-3].
- Adipocytes: These cells are responsible for storing and releasing fat in the form of triglycerides. They also secrete various hormones that regulate metabolism, appetite, and other physiological processes [3].
- Macrophages: These cells are part of the immune system and play a key role in phagocytosis, the process of engulfing and digesting foreign particles, microorganisms, and dead cells. They also secrete cytokines, which are important signaling molecules that regulate immune responses [4].
- Mast cells: These cells are involved in the body's defense against pathogens and play a key role in allergic reactions. They contain granules that release histamine and other inflammatory mediators in response to injury or infection [5].
- Plasma cells: These cells produce and secrete antibodies, which are proteins that bind to and neutralize pathogens, toxins, and other foreign substances. They develop from B lymphocytes in response to an antigenic challenge [6].
- Mesenchymal stem cells: These cells have the ability to differentiate into various types of cells, including osteoblasts, chondrocytes, adipocytes, and myocytes. They play a key role in tissue repair and regeneration [7].

Fibroblasts are a type of cell that is commonly found in connective tissue. Although they have a similar appearance, there are actually several subtypes of fibroblasts that differ in their structure, functions, and origins:

1. Superficial fibroblasts: These are fibroblasts that are located close to the surface of the skin. They have a flattened shape and are responsible for synthesizing the extracellular matrix that gives the skin its strength and elasticity.
2. Reticular fibroblasts: These are fibroblasts that are found in lymphoid tissues such as the spleen, lymph nodes, and bone marrow. They have a more elongated shape than superficial fibroblasts and produce a delicate network of fibers called reticulin.
3. Peri-vascular fibroblasts: These are fibroblasts that are found in the walls of blood vessels. They play a key role in regulating blood vessel diameter and blood flow.
4. Activated fibroblasts: These are fibroblasts that have been stimulated by an injury or inflammation. They have a more rounded shape than quiescent fibroblasts and produce higher levels of extracellular matrix proteins, such as collagen and fibronectin, to help repair damaged tissue.

Fibroblasts have a characteristic spindle-shaped morphology, with a large nucleus and prominent rough endoplasmic reticulum (rER) and Golgi complex. They are responsible for synthesizing and maintaining the extracellular matrix, which is composed of fibers (such as collagen and elastin) and ground substance (such as glycosaminoglycans and proteoglycans). Fibroblasts also secrete growth factors and cytokines that play a key role in tissue repair and regeneration.

Fibroblasts are derived from mesenchymal stem cells, which can differentiate into various types of cells including osteoblasts, adipocytes, chondrocytes, and myocytes. During development, fibroblasts are derived from mesodermal cells that migrate to various tissues and differentiate into fibroblasts [8].

Macrophages are a type of immune cell that play a critical role in defending the body against infection and foreign substances. They are derived from monocytes, which are a type of white blood cell produced in the bone marrow.

Macrophages are characterized by their large size, irregular shape, and ability to engulf and destroy foreign particles and microorganisms through a process called phagocytosis. They also play a key role in antigen presentation, which is the process of displaying foreign substances to other immune cells in order to activate an immune response.

The structure of macrophages is complex and highly specialized. They have a large cytoplasmic volume, multiple nuclei, and a high degree of cellular heterogeneity. They also have numerous surface receptors that allow them to interact with other cells and molecules in the immune system.

The functions of macrophages are diverse and multifaceted. In addition to their role in phagocytosis and antigen presentation, macrophages also produce a wide range of cytokines and chemokines, which are signaling molecules that help to coordinate the immune response. They also play a key role in tissue repair and regeneration by secreting growth factors and other molecules that promote healing [9].

The mononuclear phagocyte system (MPS) is a collective term used to describe the network of cells and tissues in the body that are involved in the phagocytosis and removal of foreign substances and microorganisms. It includes monocytes, macrophages, and other related cell types such as dendritic cells and Kupffer cells. The MPS is an important component of the innate immune system, which provides rapid and nonspecific defense against a wide range of pathogens [10].

In summary, macrophages are a specialized type of immune cell that are derived from monocytes and play a critical role in defending the body against infection and foreign substances. They have a complex structure and diverse functions, including phagocytosis, antigen presentation, cytokine production, and tissue repair. The mononuclear phagocyte system is a network of cells and tissues that is involved in phagocytosis and removal of foreign substances and microorganisms [11].

Mast cells, also known as tissue basophils, are a type of immune cell that are involved in allergic reactions and inflammation. They are derived from hematopoietic stem cells in the bone marrow and are typically found in tissues that are in contact with the external environment, such as the skin and mucous membranes.

The structure of mast cells is characterized by their numerous granules, which are filled with a variety of bioactive molecules, including histamine, cytokines, and proteases. The granules are surrounded by a thin layer of cytoplasm and a plasma membrane. Mast cells also have a central nucleus and a complex network of cytoplasmic processes that allow them to interact with other cells and tissues in the body.

The primary function of mast cells is to mediate allergic reactions and inflammation. When stimulated by an allergen or other trigger, mast cells release their granules into the surrounding tissue, causing a range of effects, including vasodilation, smooth muscle contraction, and increased vascular permeability. These effects are mediated by the various bioactive molecules present in the granules, which can activate a variety of cells and pathways in the immune system [12].

The components of mast cell secretory granules include histamine, proteases such as tryptase and chymase, cytokines such as interleukin-4 (IL-4) and tumor necrosis factor (TNF), and chemokines such as interleukin-8 (IL-8). These molecules are released in response to a variety of stimuli, including physical injury, infection, and allergic reactions, and can have a range of effects on nearby cells and tissues [13].

In summary, mast cells are a type of immune cell that play a critical role in mediating allergic reactions and inflammation. They are derived from hematopoietic stem cells and are characterized by their numerous granules, which contain a variety of bioactive molecules. The components of their secretory granules include histamine, proteases, cytokines, and chemokines, which are released in response to a variety of stimuli and can have a range of effects on nearby cells and tissues [14].

Plasma cells are specialized cells of the immune system that are responsible for producing and secreting large amounts of antibodies, also known as immunoglobulins (Igs). These cells are derived from activated B lymphocytes, which have been stimulated by an antigen.

The structure of plasma cells is characterized by their abundant cytoplasm and large, ovoid nuclei. They are typically found in lymphoid tissues such as the spleen and lymph nodes, but can also be found in other tissues, particularly during an immune response.

The primary function of plasma cells is to produce and secrete antibodies, which are specialized proteins that recognize and neutralize specific antigens. The process of antibody production is known as the humoral immune response, and involves the activation and proliferation of B cells, followed by their differentiation into plasma cells [15].

During this process, B cells undergo a series of changes in gene expression and cellular morphology, ultimately resulting in the production and secretion of large amounts of antibodies. These antibodies are then released into the circulation, where they can bind to and neutralize their target antigens, thereby preventing or controlling infection.

Plasma cells are also capable of undergoing somatic hypermutation, a process by which the genetic sequence of the antibody molecule is modified in order to increase its affinity for its target antigen. This process allows the immune system to generate highly specific and effective antibody responses to a wide range of pathogens [16].

In summary, plasma cells are specialized cells of the immune system that are responsible for producing and secreting large amounts of antibodies in response to an antigen. They are derived from activated B cells and are characterized by their abundant cytoplasm and large nuclei. The primary function of plasma cells is to produce and secrete antibodies, which play a critical role in the humoral immune response [17].

Connective tissue fibers

Connective tissue fibers are specialized protein structures that provide strength, support, and flexibility to the tissue. There are three main types of connective tissue fibers: collagen fibers, elastic fibers, and reticular fibers.

Collagen fibers are the most abundant type of connective tissue fiber and provide tensile strength to the tissue. They are made up of the protein collagen and are highly resistant to stretching and tearing. Collagen fibers can be arranged in parallel bundles or in a mesh-like pattern, depending on the type of tissue. In addition to providing strength, collagen fibers also play a role in maintaining the structural integrity of the tissue and in regulating cell behavior through interactions with cell surface receptors.

Elastic fibers are composed of the protein elastin and provide elasticity and recoil to the tissue. They are found in tissues that require a high degree of flexibility, such as the skin, lungs, and blood vessels. Elastic fibers are able to stretch and recoil without breaking, allowing the tissue to deform and then return to its original shape. They are also able to withstand repetitive stretching and compression, making them well-suited for tissues that experience constant mechanical stress.

Reticular fibers are composed of a type of collagen called type III collagen and provide a supportive network for cells in certain tissues, such as the liver, spleen, and lymph nodes. They form a mesh-like pattern that supports cells and other structures within the tissue. Reticular fibers are also involved in cell signaling and can influence cell behavior through interactions with cell surface receptors.

Each type of connective tissue fiber has unique properties that contribute to the function and structure of the tissue. Collagen fibers provide tensile strength and structural support, elastic fibers provide elasticity and recoil, and reticular fibers form a supportive network. The composition and arrangement of these fibers vary depending on the type of tissue, allowing each tissue to perform its unique physiological function [18, 19].

Collagen fibers are a type of connective tissue fiber that provide tensile strength to tissues. They are composed of the protein collagen, which is secreted by fibroblasts and other specialized cells.

The structure of collagen fibers is complex and hierarchical. Collagen molecules are composed of three polypeptide chains that are tightly coiled together in a triple helix. These molecules are then cross-linked together to form collagen fibrils, which are about 10-300 nm in diameter. The fibrils are then organized into collagen fibers, which can be several micrometers in diameter.

Collagen fibers have several general properties that contribute to their function in tissues. They are highly resistant to stretching and tearing, which makes them well-suited for providing structural support to tissues. Collagen fibers are also able to withstand compressive forces, which helps to maintain tissue shape and prevent deformation. In addition, collagen fibers are relatively inert, meaning that they do not trigger an immune response in the body.

There are many different types of collagen fibers, each with a unique structure and function. Some types of collagen fibers are found primarily in skin and bone, while others are found in cartilage, tendons, and other connective tissues. The properties of collagen fibers vary depending on their composition and organization, which allows them to perform a wide range of functions in the body [20].

Overall, collagen fibers are an essential component of many tissues in the body and provide crucial support and strength. Their unique structure and properties make them well-suited for a wide range of physiological functions.

Collagen fibers are synthesized and degraded through a complex process involving multiple steps. The following is a brief overview of the main steps involved in collagen synthesis and degradation [21].

Collagen Synthesis:

1. Transcription: The first step in collagen synthesis is the transcription of the genes that encode the collagen protein. These genes are found in the cell nucleus and are transcribed into messenger RNA (mRNA).
2. Translation: The mRNA is then transported out of the nucleus into the cytoplasm, where it is translated into collagen protein by ribosomes.
3. Post-translational Modifications: After translation, the newly synthesized collagen protein undergoes several post-translational modifications, including the addition of hydroxyl and glycosylation groups, which help to stabilize and modify the protein structure.
4. Assembly: Once the collagen proteins are modified, they are assembled into triple helix molecules and transported to the extracellular space. In the extracellular space, the triple helix molecules are organized into collagen fibrils, which are then assembled into collagen fibers.

Collagen Degradation:

1. Proteolysis: Collagen fibers are degraded by a family of enzymes called matrix metalloproteinases (MMPs) and other proteases. These enzymes break down the triple helix structure of collagen fibers, allowing them to be broken down further.
2. Uptake: The degraded collagen fragments are then taken up by macrophages and other phagocytic cells.
3. Recycling: The collagen fragments are then recycled by the cell and used to synthesize new collagen fibers.

Overall, the synthesis and degradation of collagen fibers are complex processes involving multiple steps and cellular components. These processes are essential for maintaining the structural integrity of tissues and for allowing tissues to adapt and remodel in response to changes in the environment [22].

Reticular fibers are composed of type III collagen, which is a thinner and more delicate form of collagen compared to the type I collagen that forms the bulk of collagen fibers in connective tissue. In addition to type III collagen, reticular fibers also contain glycosaminoglycans, proteoglycans, and glycoproteins. The glycosaminoglycans and proteoglycans in reticular fibers contribute to the formation of a gel-like matrix that provides a supportive environment for cells such as blood cells, lymphatic cells, and adipocytes.

Reticular fibers are primarily found in reticular connective tissue, which is a type of loose connective tissue found in various organs such as the liver, spleen, lymph nodes, and bone marrow. In these organs, reticular fibers form a delicate network that provides structural support to the parenchymal cells and allows for the exchange of materials between the blood and the surrounding tissues [23].

Elastic fibers are a type of connective tissue fiber that provide tissues and organs with elasticity and resilience. They are composed of a central core of elastin surrounded by microfibrils made of fibrillin and other glycoproteins. The elastin core is responsible for the elastic properties of the fibers, while the microfibrils provide support and organization to the fibers [24].

Elastic fibers are highly flexible and can be stretched up to 150% of their original length without breaking. They are found in tissues that require elasticity, such as the skin, lungs, arteries, and ligaments. The elastic fibers in the skin, for example, allow it to stretch and return to its original shape after being stretched, while the elastic fibers in the lungs allow for the expansion and contraction of the lungs during breathing [25].

The synthesis and deposition of elastic fibers is regulated by specialized cells called fibroblasts and smooth muscle cells, which secrete the precursor molecules that are later assembled into elastic fibers by specialized cells called elastogenic cells [26]. Degradation of elastic fibers is primarily carried out by matrix metalloproteinases and elastases, which break down the elastin and microfibrils [27].

Overall, elastic fibers play an essential role in providing tissues with elasticity and resilience, and their proper synthesis and degradation are crucial for maintaining tissue function.

Ground substance is a gel-like substance that fills the space between the cells and fibers of connective tissue [28]. It is composed of a mixture of proteins and carbohydrates, including glycosaminoglycans (GAGs) and proteoglycans (PGs).

GAGs are long, unbranched polysaccharides composed of repeating disaccharide units [29]. The disaccharide units are composed of an amino sugar (either glucosamine or galactosamine) and a uronic acid (either glucuronic acid or iduronic acid). GAGs are negatively charged due to the presence of sulfate and/or carboxyl groups on the uronic acid residues. This negative charge allows GAGs to bind to positively charged molecules, such as ions or proteins. The major GAGs found in ground substance are hyaluronic acid, chondroitin sulfate, dermatan sulfate, keratan sulfate, and heparan sulfate.

PGs are complex molecules composed of a core protein to which GAGs are covalently attached. The GAG chains extend from the core protein like the bristles of a brush. PGs are typically large molecules that can occupy a large volume of space. They are responsible for the compressive strength of cartilage and provide a hydrated gel-like matrix for cells to reside in. The major PGs found in ground substance are aggrecan, versican, decorin, and syndecan [30].

Overall, the composition of ground substance provides a hydrated gel-like matrix that allows cells to migrate through and provides compressive strength to tissues.

Adipose tissue is a specialized connective tissue that plays an important role in energy metabolism and insulation. There are two main types of adipose tissue: white adipose tissue (WAT) and brown adipose tissue (BAT).

White adipose tissue (WAT) is the most common type of adipose tissue in the human body. It is composed of adipocytes, which store triglycerides and release them as free fatty acids when energy is needed. WAT is located throughout the body, with the largest depots in the subcutaneous tissue, abdominal cavity, and around organs such as the kidneys and heart. WAT also secretes adipokines, such as leptin and adiponectin, which regulate metabolism and inflammation.

In contrast**, brown adipose tissue** (BAT) is specialized for heat production and is more common in newborns and hibernating animals. BAT contains numerous mitochondria and is rich in uncoupling protein 1 (UCP1), which allows for non-shivering thermogenesis by dissipating the energy produced by mitochondria as heat. BAT is located primarily in the neck and upper back, but small amounts can also be found in adults in the subcutaneous tissue and around internal organs.

In terms of structure, WAT and BAT have different histological appearances. WAT adipocytes are typically unilocular, with a single large lipid droplet, while BAT adipocytes are multilocular, with multiple smaller lipid droplets. Additionally, BAT contains a higher density of blood vessels and sympathetic nerves, which are important for regulating thermogenesis [31, 32].

Overall, WAT and BAT have distinct functions and distributions in the body, with WAT primarily storing energy and secreting hormones, and BAT specialized for heat production. However, recent research has shown that both types of adipose tissue can be metabolically active and may play a role in the development of obesity, metabolic syndrome, and other metabolic disorders.

Reticular tissue is a specialized form of connective tissue characterized by a fine meshwork of reticular fibers and reticular cells. The reticular fibers are composed of type III collagen and glycoproteins and are arranged in a branching network that creates a supportive scaffold for the cells within the tissue. The reticular cells are a type of fibroblast that secrete the reticular fibers.

Reticular tissue is found in a variety of locations throughout the body, including the liver, spleen, lymph nodes, bone marrow, and adipose tissue. In the liver, it forms the framework for the sinusoids, which are the specialized capillaries that filter blood as it flows through the liver. In the spleen, reticular tissue forms the framework for the red pulp and helps to filter blood. In lymph nodes, it supports the lymphatic parenchyma and helps to filter lymph. In bone marrow, it provides support for developing blood cells. In adipose tissue, reticular cells are interspersed among adipocytes and contribute to the structure of the tissue [33, 34].

There is a type of connective tissue that is called **mucous connective tissue** or Wharton's jelly, which is present in the umbilical cord of developing fetuses.

Mucous connective tissue is characterized by its loose structure, which consists of a gelatinous ground substance called hyaluronic acid or mucopolysaccharide. The ground substance is composed of long chains of repeating disaccharide units, which are bound together by non-sulfated glycosaminoglycans, such as hyaluronic acid. The ground substance also contains collagen and elastic fibers that are arranged in a loose network.

Wharton's jelly is named after the English physician Thomas Wharton, who first described it in the 17th century. The structure of Wharton's jelly is composed of a gelatinous matrix, which is rich in mucopolysaccharides such as hyaluronic acid and chondroitin sulfate. It also contains various types of cells, including fibroblasts, macrophages, and undifferentiated mesenchymal stem cells [35]. The undifferentiated mesenchymal stem cells in Wharton's jelly have been found to be a rich source of multipotent stem cells, which have the potential to differentiate into various cell types, including bone, cartilage, fat, and muscle [36].

The gelatinous nature of Wharton's jelly provides cushioning and support for the umbilical cord, helping to protect the blood vessels and nerves that pass through it. Additionally, the presence of mesenchymal stem cells in Wharton's jelly makes it a valuable source of stem cells for research and potential therapeutic use [37].

Conclusion

Connective tissue is a fundamental type of tissue in multicellular organisms, including humans. It plays an essential role in providing structural support, binding and connecting tissues and organs, and facilitating the transmission of nutrients, oxygen, and waste products between cells and blood vessels.

One of the primary functions of connective tissue is to provide mechanical support to other tissues and organs in the body. This is achieved through the production of extracellular matrix (ECM), which is composed of fibers and ground substance. The fibers in ECM, such as collagen, elastic, and reticular fibers, provide tensile strength, elasticity, and resistance to compression, respectively. The ground substance, which is made up of glycosaminoglycans (GAGs) and proteoglycans, acts as a lubricant and shock absorber.

Connective tissue also plays a critical role in wound healing and tissue repair. During the inflammatory phase of wound healing, immune cells such as macrophages and neutrophils are recruited to the site of injury. These cells release growth factors that stimulate fibroblasts, a type of connective tissue cell, to migrate to the wound site and produce ECM. As the ECM accumulates, it provides a scaffold for the formation of new tissue, allowing the wound to heal.

Another essential function of connective tissue is to transport substances between cells and blood vessels. Blood vessels that run through connective tissue bring oxygen and nutrients to cells and remove metabolic waste products such as carbon dioxide. Additionally, connective tissue cells such as fibroblasts and macrophages produce cytokines and chemokines, which regulate immune cell activity and facilitate the movement of immune cells through the tissue.

In summary, connective tissue is necessary for the proper functioning of the body. It provides structural support, facilitates wound healing and tissue repair, and allows for the transport of nutrients and waste products between cells and blood vessels.

Prospects for further investigations

There are many exciting prospects for further investigations that could lead to significant advances in our understanding of the structure and function of the body, as well as new therapies for connective tissue disorders and injuries. There is still much to be learned about the molecular mechanisms that regulate connective tissue formation, maintenance, and remodeling. Researchers can study the signaling pathways, transcription factors, and epigenetic modifications that control connective tissue development and homeostasis.

Information on conflict of interest

There are no potential or apparent conflicts of interest related to this manuscript at the time of publication and are not anticipated.

References

1. Ross MH, Pawlina W, authors. Histology: A text and Atlas. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health; 2015. 974p.
2. Junqueira LC, Carneiro J, Kelley RO, authors. Basic histology: text & atlas. Indiana: McGraw-Hill Education; 2018. 560p.
3. Leslie P, Gartner and James L. Hiatt. Connective tissue. Color Textbook of Histology. 2007;1:111–129.
4. Murphy K, Weaver C. Janeway's immunobiology. Garland Science. 2017;2:70-79.
5. Weller PF. The immunobiology of eosinophils – new perspectives in health and disease. Nature Reviews Immunology. 2018;18(5):339-348.
6. Abbas AK, Lichtman AH, Pillai S. Cellular and molecular immunology. Elsevier. 2017;3(1):152-155.
7. Caplan AI. Mesenchymal stem cells: Time to change the name! Stem Cells Translational Medicine. 2017;6(6):1445–1451.
8. Hinz B. The role of myofibroblasts in

wound healing. Current Research in Translational Medicine. 2016;64(4):171–177.

9. Murray PJ, Wynn TA. Protective and pathogenic functions of macrophage subsets. Nature Reviews Immunology. 2011;11(11):723–737.

10. Gordon S, Martinez FO. Alternative activation of macrophages: Mechanism and functions. Immunity. 2010;32(5):593–604.

11. Auffray C, Sieweke MH, Geissmann F. Blood monocytes: Development, heterogeneity, and relationship with dendritic cells. Annual Review of Immunology. 2009;27(1):669–692.

12. Galli SJ, Tsai M. Mast cells in allergy and infection: Versatile effector and regulatory cells in innate and adaptive immunity. European Journal of Immunology. 2010;40(7):1843–1851.

13. Rivera J, Jilfillan A. Molecular regulation of mast cell activation. Journal of Allergy and Clinical Immunology. 2006;117(6):1214–1225.

14. Schwartz LB. Mast cells: functions and phenotypes. Biological research for nursing. 2007;8(4):305-313.

15. Amanna IJ, Slifka MK. Mechanisms that determine plasma cell lifespan and the duration of humoral immunity. Immunological Reviews. 2010;236(1):125–138.

16. Neuberger MS, Rajewsky K. Activation of mouse complement by monoclonal mouse antibodies. European Journal of Immunology. 2008;8(9):636-642.

17. Tangye SG, Tarlinton DM. Memory B cells: effectors of long-lived immune responses. European Journal of Immunology. 2009;39(8):2065-2075.

18. Alberts B, Johnson A, Lewis J, Raff M, Roberts K, Walter P. Molecular biology of the cell. 2007;3(7):54-69.

19. Guyton AC, Hall JE, authors. Textbook of Medical Physiology (11th ed.). Philadelphia: Saunders Elsevier; 2006. 612p.

20. Kielty CM, Hodson NW. Structure-Function Analysis of Collagen Types. Springer Science and Business Media. 2013;802:19-31.

21. Shoulders MD, Raines RT. Collagen structure and stability. Annual Review of Biochemistry. 2009;78(1):929–958.

22. Avila Rodríguez MI, Rodríguez Barroso LG, Sánchez ML. Collagen: A review on its sources and potential cosmetic applications. Journal of Cosmetic Dermatology. 2017;17(1):20–26.

23. Weiss L, Greaves M. Histology. Springer Science & Business Media. 2009;1:37-45.

24. Wagenseil JE, Mecham RP. Elastic fiber architecture in the cardiovascular system. Reviews of physiology, biochemistry and pharmacology. 2007;159:1-24.

25. Fung YC. Biomechanics: Circulation. Springer Science & Business Media. 2013;5(2):78-82.

26. Kielty CM, Shuttleworth CA. Synthesis and assembly of fibrillin-rich microfibrils. Humana Press. 2018;3:243-268

27. Li W, Liu J, Zhong W. Elastin degradation: an effective and versatile mechanism for tissue remodeling. Biomaterials science.2017;5(12):2335-2349.

28. Tortora GJ, Derrickson B. Principles of anatomy and physiology. John Wiley & Sons. 2017;4:151-159.

29. Laurent TC, Fraser JR. Hyaluronan. FASEB journal: official publication of the Federation of American Societies for Experimental Biology. 1992;6(7):2397-2404.

30. Iozzo RV. Matrix proteoglycans: from molecular design to cellular function. Annual review of biochemistry. 1998;67(1):609-652.

31. Rosen ED, Spiegelman BM. What we talk about when we talk about fat. Cell. 2014;156(1-2):20-44.

32. Nedergaard J, Cannon B. The changed metabolic world with human brown adipose tissue: therapeutic visions. Cell Metab. 2010;11(4):268-272.

33. Kumar V, Abbas AK, Aster JC. Robbins basic pathology. Elsevier. 2018;1:33-38.

34. Hall BK. Bones and cartilage: developmental and evolutionary skeletal biology. Academic Press. 2015;2:10-25.

35. Makhoul G, Atweh GF. Wharton's jelly-derived mesenchymal stem cells: isolation and characterization. Methods Mol Biol. 2019;2045:43-53. doi: 10.1007/978-1-4939-9728-2_5

36. Sarugaser R, Lickorish D, Baksh D. Human umbilical cord perivascular (HUCPV) cells: a source of mesenchymal progenitors. Stem Cells. 2005;23(2):220-229. doi: 10.1634/stemcells.2004-0166

37. Wu CC, Chen YT, Chen CH. Umbilical cord-derived mesenchymal stem cells: a potential therapeutic tool for ischemic stroke. Neural Regen Res. 2021;16(2):269-275.

Черкас О.А., Кобеза П.А., Марченко Д.Г. Основні принципи будови та організації сполучної тканини.

РЕФЕРАТ. Актуальність. Сполучна тканина — це різноманітний і життєво важливий компонент організму, який виконує широкий спектр функцій, необхідних для правильних фізіологічних і патологічних процесів. Він відіграє важливу роль у забезпеченні структурної підтримки, зв’язуванні та з’єднанні тканин і органів, а також полегшенні передачі поживних речовин, кисню та продуктів життєдіяльності між клітинами та кровоносними судинами. Без сполучної тканини організм не зміг би підтримувати форму, протистояти механічним навантаженням, захищати внутрішні органи. Це важливо для розуміння певних станів здоров’я та захворювань. Багато з них вражають сполучну тканину, наприклад ревматоїдний артрит, склеродермія та системний червоний вовчак. Знання сполучної тканини має вирішальне значення для розробки медичних методів лікування та процедур. **Мета** полягає в тому, щоб забезпечити поглиблене розуміння цього типу тканини та її функцій в організмі. Ця стаття може охоплювати різні теми, пов’язані зі сполучною тканиною, включаючи її структуру, типи та ролі в організмі. У ній також розглядаються різні типи клітин сполучної тканини, такі як фібробласти та макрофаги, і те, як вони сприяють підтримці та відновленню тканин. **Методи.** Лекційне навчання, навчання за мікроскопом, комп’ютерне навчання, проблемне навчання, групове навчання. Для ефективного вивчення складу та властивостей сполучної тканини студентам і викладачам знадобиться доступ до високоякісних підручників з гістології, онлайн-ресурсів, мікроскопів і слайдів тканин. **Результати та підсумок.** Однією з основних функцій сполучної тканини є забезпечення механічної підтримки інших тканин і органів тіла. Це досягається шляхом продукування позаклітинного матриксу, який складається з волокон і основної речовини. Волокна в матриксі (колагенові, еластичні та ретикулярні) забезпечують міцність на розтяг, еластичність і стійкість до стискання відповідно. Основна речовина, яка складається з глікозаміногліканів і протеогліканів, діє як мастило і амортизатор. Сполучна тканина також відіграє вирішальну роль у загоєнні ран і відновленні тканин. Іншою важливою функцією сполучної тканини є транспортування речовин між клітинами та кровоносними судинами. Крім того, клітини сполучної тканини, такі як фібробласти та макрофаги, виробляють цитокіни та хемокіни, які регулюють активність імунних клітин і полегшують рух імуноцитів через тканини. Таким чином, сполучна тканина необхідна для нормального функціонування організму. Вона забезпечує структурну підтримку, полегшує загоєння ран і відновлення тканин, а також забезпечує транспортування метаболітів між клітинами та кровоносними судинами.

Ключові слова: сполучна тканина, фібробласт, тучна клітина, плазматична клітина, макрофаг, колаген, колагенові волокна, еластичні волокна, ретикулярні волокна, основна речовина.