University of Gondar
College of Veterinary Medicine and Animal Sciences
Unit of biomedical science

A Course Guide for Veterinary Histology I

1. GENERAL INFORMATION

1.1. Module related information

Department owning and offering the course:	Biomedical Sciences	
Program:	Doctor of veterinary medicine	
Module title:	Veterinary Anatomy and Embryology	
Module code:	Vetm-M011	
Module number:	01	
Module ECTS:	27	
Course title:	Veterinary Histology I	
Course code:	Vetm1082	
Status of the course:	Core	
Course ECTS:	5	
Mode of delivery	Semester based	
Semester for course delivery:	II	
Target group of students:	YEAR I VETERINARY MEDICINE STUDENTS	
Instructors contact information:	Contact Hours: E-mail: Phone number:	Contact Hours: E-mail: Phone number:

1.2. Teaching method and assessment

Summary of Teaching Learning Methods	Summary of Assessment Methods
Lectures	Quizzes/Tests
Audiovisual demonstrations	Assignments
Reading assignments	Practical/laboratory work report
Individual and Group Presentations	Final examination 50% (Practical & written)

1.3. Schedule for Continuous Assessment

Note: The actual date will be specified later based on the academic calendar of the university.

1.4. Students workload

ECTS	Contact hour per week	Effective lecture hours	Lab/practical	Assessment and Home based activities	Total
5	**3**	**32**	**48**	**55**	**135**

2. Course description

Veterinary Histology is a branch of anatomy concerned with the visual examination of cells, intercellular structures as well as their organization in tissues and organs, by means of the microscope and by using appropriate preparations thin enough to transmit light or electrons. Studying the normal microscopic structure of the animal body is the basis for understanding abnormal microscopic lesions(histopathology), body functions, immunology, clinical Patholgy and several other disciplines in veterinary medicine. Veterinary Histology I deal with the tech niques of studying cells and tissues, cell biology and the four basic tissues of the body (epithelium, connective tissue, muscle and nervous tissue).

3. Course Objectives

By the end of this course, students will be able to:

- Recognize microscopically the principal cells, cellular organelles and tissues and their complex organizations and functions in the body.
- Interpret accurately the structural details in histological sections and be aware of morp hologic variations among domestic animal species as described in lectures.
- Relate the acquired information on the microscopic structure to function and vice versa, and deduct (postulate) function from a given structure.
- Use the knowledge gained in this course to explain the normal microscopic appearance of cells and tissues in contrast to abnormal ones due to artifacts (changes by technical errors) and pathological conditions.

- Develop professional attitudes and skills in handling histological preparations and the light microscope.

4. Course Assignments

Specific course assignments will be prepared by the instructor who is responsible for delivering the specific topics of the course**.**

5. Expectations

5.1. Preparation & participation:

Students are expected to:

- Come to class prepared with appropriate materials.
- Complete reading assignments and other activities on time.
- Plan their own learning.
- Work hard individually to meet the requirement of the course.
- Use their time for group work and home study effectively.
- Make active participation during discussions (must participate in class).
- Give constructive feedback to partners/group members and to listen to their comments.
- Strictly follow safety rules and instructions in the laboratory.
- Should attend all scheduled classes and other activities.
- Be punctual at all sessions.

6. Learning teaching methods: The teaching learning method includes class room lectures, demonstrations, individual laboratory work, and reading assignments and presentations.

7. GRADING POLICY AND ECTS GRADING SYSTEM

Raw Mark Interval[100%]	**Interval of number grade**	**Corresponding fixed number grades**	**Corresponding letter grade**	**Description**
[90,100]	4	4.0	A+	Excellent
[85,90)	3.5≤ X< 4.0	4.0	A	Excellent
[80,85)	3.0 ≤X <3.5	3.75	A-	Excellent

[75,80)	2.7≤X<3.0	3.5	B+	Very Good
[70,75)	2.5≤X<2.7	3.0	B	Very Good
[65,70)	2.3≤X<2.5	2.75	B-	Good
[60,65)	2.0≤X<2.3	2.5	C+	Good
[50,60)	1.7≤X<2.0	2.0	C	Satisfactory
[45,50)	1.3≤X<1.7	1.75	C-	Satisfactory
[40,45)	1.0≤X<1.3	1.0	D	Unsatisfactory
[30,40)	=1.0	0	Fx	Fail
[<30)	0.0	0.0	F	Fail

Explanations:

1. Excellent=refers to outstanding performance and only a few minor errors.
2. Very good=refers to above the average standard, but with some errors.
3. Good=refers to good, solid overall performance, but with some noticeable errors
4. Satisfactory=refers to the performance that satisfies minimum requirements.
5. Failed (Fx)= refers to improvements are required before the credit can be awarded
6. Failed (F)= refers to considerable future work is required

7. Course contents

Weeks	Activities	Topics	Reading /reference
1	**Lecture**	**7. Introduction to Histology** 1.1. Concepts of Histology 1.2. Relationship with other subjects	Basic histology.9th ed.pp.1.
2-3	**Lecture**	**8. Methods of histology** **2.1.** Microscopy and interpretation **2.2.** Methods of direct observation of living cells and tissues **2.3.** Methods of studying killed tissues	
	Laboratory work	Demonstration of microscope	
4-5	**Lecture**	**3. Cell biology** **3.1.** Structural and functional organization of the cell **3.2.** Properties of cell **3.3.** Cell division	✓ Basic histology.9th ed.pp.22-65, cell biology 1-61 ✓ Basic histology.9th ed.pp.1.
	Laboratory work	Animal cell examination	
At the end of these chapters students will take a test (test-1)			
6-7	**Lecture**	**4. Epithelial tissues** **4.1.** General characteristics **4.2.** Classification of epithelial tissues	Basic histology. 9th ed.pp.66-90,cell biology 62-72 and color atlas of basic histology pp.2-15 Basic histology. 9th ed.pp.66-90,cell biology 62-72 and color atlas of basic histology pp.2-15
	Laboratory work	Demonstration of different epithelial tissues	
	Lecture		

8	lecture	**4.3.** Types and classification of glandular epithelium	
	Laboratory work	Demonstration of different glandular epithelium	

At the end of these chapters students will take a test (test-2)

9	**Lecture**	**5. Connective and Supportive tissues** **5.1.** General characteristics	Basic histology. 9th ed.pp.91-152, cell biology 73-97&130 and color atlas of basic histology pp.16-51.
10	**Lecture**	**5.2.** Components of connective tissue 5.2.1. Cells 5.2.2. Fibres 5.2.3. Ground substances of connective tissue	
	Laboratory work	Connective tissue	
11-12	**Lecture**	**5.3.** Cartilage and bone **5.4.** Blood	
	Laboratory work	Cartilage, bone and blood	
13-14	**Lecture**	**6. Muscle Tissue** **6.1.** General characteristics **6.2.** Types of muscle tissue 6.2.1. Smooth muscle 6.2.2. Skeletal muscle 6.2.3. Cardiac muscle	Basic histology. 9th ed.pp.182-204, cell biology 98-114 and color atlas of basic histology pp.70-81.
	Laboratory work	Muscle Tissue	
At the end of these chapters students will take a test (test-3)			

15	**Lecture**	**7. Nervous tissue** **7.1.** General characteristics **7.2.** Neurons**,** Synapse, Neuroglia	Basic histology. 9th ed.pp.153-181, cell biology 115-129 and color atlas of basic histology pp.52-69.
	Laboratory work	Neurons**,** Synapse, Neuroglia	
16	**Lecture**	**7.3.** Types of nerve tissue 7.3.1. Central nervous tissue 7.3.2. Peripheral nervous tissue	
	Laboratory work	Demonstrate Central nervous tissue and Peripheral nervous tissue	

8. Required Text Books and Materials

Text Books:

1. Don A. Samuelson (2007): Textbook of Veterinary Histology, 1st edition

2. William J. Banks (1993): Applied Veterinary Histology, 3rd edition

3. Inderbir Singh (2004): Text book of Human Histology with Color Atlas, 5th edition

4. Luiz C. Junqueira and Jose Carneiro (2005): Basic Histology, 11th edition

5. Glaucia M. and Machado-Santelli (2004): Histology: A Color Atlas (Image in Focus)

6. Finn Geneser (2005): Color Atlas of Histology

7. JP Gunasegaran (2007): Textbook of Histology and a Practical Guide

Teaching Materials: Text books, Laptop, LCD projector, Chalk, Markers, Microscope, Prepared laboratory slides, Drawing charts and Boards and papers.

PART I: GENERAL HISTOLOGICAL PRINCIPLES

CHAPTER 1: CONCEPTS OF HISTOLOGY

1.1 The Subject Matter of Histology

Histology is the branch of science, which centers on the biology of cells and tissues within an organism. Histology (Gr. histo = tissue, logos = study) is the study of cells and extracellular matrix of tissues. Anatomy is divided into **gross anatomy,** which is visible to the naked eye and **Microscopic anatomy** that seen with the aid of microscopes. In the early times, microscopic anatomy was subdivided into cytology, histology and organology, study of cells, tissues and organs, respectively. Now days, histology involves the study of cells, tissues and organ-systems and their functions.

Histology complements the study of gross anatomy. It also provides a structural basis for the study of physiology. The correlation between structure and function makes histology understandable subject. In general, histology is a visual discipline and it combines observation with reasoning. Knowledge of the normal is a necessary base to the study of the abnormal (pathology). Hence, the study of histology is fundamental within veterinary medicine.

The small size of cells and matrix components makes histology dependent on the use of and improvements in microscopes. Advances in chemistry, physiology, immunology, and pathology and the interaction among these fields contribute to a better knowledge of tissue biology. Integration of knowledge in these field has resulted in the development of histochemistry, histophysiology. Immunohistochemistry, and histopathology, which help students for a better understanding of tissue biology.

1.2 The Tissues of the Body

Bichat, the French surgeon, who noticed characteristic, differences in texture between the many, parts and layers of the body, and he classified these as different tissues. Microscopic observations confirmed that the body is made up of different tissues and revealed that **cells** are constructed. Discoveries revealed the living cells posses a number of **functional attributes** that set them apart from inanimate objects. Such attributes vary in different tissues, suggesting that each tissue performed its own specific functions.

Fundamental physiological properties of cells are expressed in four basic tissues. The four basic tissues include;

Epithelial tissue - that serve a protective function for they cover external and line internal body surfaces.

Connective tissue

Nervous tissue

Muscle tissue

1.3 Composition of Animal Body Components

The three basic components of the body are;

1. Cells
2. Intercellular substances and
3. Various body fluids

Composition of cells: the living substance of a cell is called protoplasm. It consists of protein, carbohydrate, lipid (fat), nucleic acids, and inorganic materials dispersed in water to form a complex, semi fluid gel.

1. Proteins: represent the main constituent of cells. They can be present by themselves or in combination with carbohydrates (glycoproteins), lipids (lipoproteins) or nucleic acids (nucleoproteins). Proteins are macromolecules, made up of one or more components of polypeptide chains assembled from 20 different amino acids and their derivatives. Proteins in the food are broken down in the intestine, from which their constituent amino acids are absorbed into the blood stream and are carried to all parts of the body. Each cell of the body is then responsible for synthesizing its own particular proteins from the pool of amino acids.

Proteins play a key role in the regulation of metabolism. The sum totals of all the chemical reactions that proceed in a cell, conferring on it the properties of life, constitute its **metabolism**. Metabolic reactions involve either destruction or production of cell substance. Those concerned with the break down of cell substance are termed **catabolic**. Those concerned with the synthesis of new cell substances are termed **anabolic**. Growth is dependent on anabolic reactions exceeding catabolic reactions. The chemical reactions involved in metabolism are catalyzed by enzymes, all of which are proteins. Enzymes and hormones are proteins.

2. **Carbohydrates,** the major carbohydrates are glucose, the chief source of energy in animal cells, and glycogen, and the storage form of glucose. Complexes of carbohydrates and proteins form the main constituents of intercellular substances that bind cells together. Other carbohydrate protein complexes form some enzymes and antibodies.

3. **Lipids** serve as energy source; they also have important structural functions and are major components of the membrane systems of cells.
4. **Nucleic acids** are divided into two classes deoxyribonucleic acid (DNA) represents the genetic material and is found primarily but not exclusively in the nucleus. Ribonucleic acid (RNA) is present in the cytoplasm and nucleus and carries information from the nucleus to the cytoplasm. It also serves as a template for synthesis of proteins by the cell.

5. **Inorganic Materials** are integral component of protoplasm as proteins, carbohydrates and lipids; without them physiologic processes are impossible. Some of the inorganic constituents are calcium, potassium, sodium and magnesium present as carbonates, chlorides, phosphates and trace elements such as cobalt, manganese, zinc and other metals. Functions of inorganic materials in chide maintenance of intracellular and extracellular osmotic pressures, transmission of nerve impulses, contraction of muscle, adhesiveness of cells, activation of enzymes, transport of oxygen, and maintenance of the rigidity of tissues such as bone.

6. **Water** makes up as out 75% of protoplasm part of the water is free and available as a solvent for various metabolic processes, and part is bound to protein.

Properties of cells

Animal cells are characterized by several physiologic properties that distinguish it form inanimate material.

- **Irritability** is a fundamental property of all living cells and refers to the ability to respond to a stimulus.
- **Conductivity** refers to the ability of a cell to transmit a stimulus from the point of origin to another point on the cell surface or to other cells. It is most highly developed in nerve tissue.
- **Contractility** is the ability of a cell to change shape in response to a stimulus, indicated by a shortening of the cell in some direction. This property is most prominent in muscle tissue.
- **Absorption** involves transfer of materials across the cell membrane in to the interior of the cell. All cells show the ability to absorb material, some very selectively.

- **Metabolism** refers to the ability of a cell to break down absorbed material to produce energy.
- **Secretion** is the process by which cells elaborate and release materials for use else where
- **Excretion** is the elimination from cells of metabolic waste products.
- **Growth** of an organism can occur by increasing the amount of cytoplasm in existing cells or by increasing the number of cells
- **Reproduction** is division of cells

CHAPTER 2: HISTOLOGY AND METHODS OF STUDY

2.1 Microscopy

Several types of microscopes are available for the study of biological material. Microscopes may be classified by the types of light source used. In most general use, of course, is the optical microscope using visible light. The usefulness of any type of microscope depends not only upon its ability to magnify but more important, upon its ability to resolve detail. The useful magnification of an ordinary light microscope is about 1500 times (1500x). The resolving power is a measure of the capacity of the microscope to clearly separate two points close together. Beyond the resolving power of any microscope, two points will appear as one. The resolution with lens systems is limited to the wavelength of light and by the light gathering capacity of the objective lens. The resolving power of a well-constructed light microscope is about 0.2 m (Micrometer).

2.1.1. **Microscopes utilizing a visible light source**:

a. **The light (optical) microscope**: The light microscope acts as a two stage-magnifying device. An objective lens provides the initial magnification, and an ocular lens is placed so as to magnify primary image a second time, total magnification is obtained by multiplying the magnifying power of the objective and ocular lenses. An additional condensing lens is employed beneath the stage of the microscope to concentrate the light from its source into a very bright beam illuminating the object thus providing sufficient light for the inspection of the magnified image.

b. **Polarizing Microscope:** It was developed by mineralogists to study crystalline materials. Organization of some Biological structures that exhibit optical property known as double refraction (birefringence), for example, muscle fibers, certain connective tissues fibers, lipid droplets within the adrenal cortex, and the rods and cones of the retina can be examined using polarizing microscope.

c. **Phase- Contrast Microscope:** It provides a method whereby contrast is created by purely optical means. It is of no particular assistance in the study of fixed and stained preparations in which transparency differences are not important. It application is chiefly in the study of living cells and unstained tissues.

d. **Interference Microscope:** It depends upon the ability of an object to retard light. If sends two separate beams of light through the specimen and combined in the image plane. After recombination, difference in

retardation of the light results in interference that can be used to measure the thickness or refractive index of the object under investigation.

e. Dark field Microscope: It utilizes a strong, oblique light that does not enter the objective lens. Light reaches the object to be viewed at an angle. The field is therefore dark. Dark field examination is useful in the examination of small transparent objects, which are invisible in the glare of bright field illumination.

2.1.2. **Microscopes utilizing a non visible light source:**

In these microscopes images can be formed by rays other than visible light, In this instance images can not be viewed directly, they are made visible by means of a suitably sensitized photographic film. The rays used in these special microscopes have a shorter wavelength than that of visible light and thus permit higher resolution.

e.g. - Ultraviolet microscope /Fluorescence microscope
- Electron microscope

2.2. Preparation of Tissues

Cells, tissues and organs cannot be studied unless they are suitably prepared for microscopic examination. The methods of preparation are;

1. Methods involving the direct observation of living cells.
2. Methods employed with dead cells (fixed or preserved).

In the study of histology, fixed and stained preparations of tissues and organs, which are permanent, will be used for the most part. Living tissues are ore difficult to handle and are valuable for a short period only. In the living cell, structure and function may be studied simultaneously; Living cells may be seen to move, to ingest foreign material, occasionally to divide, and to carry on other functions.

2.3 Observation of Living Tissue

Free cells from a complex organism may be studied directly under the microscope while they are alive. Free cells are colorless, and structures within them lack contrast. This difficulty may be over come by using a phase – contrast microscope for instance animal blood can be studied in thin films while surrounded by their natural environment, plasma, In this way, amoeboid and phagocytic activity may be recognized within white blood cells.

Thin sections of thick organs such as liver and kidney may be viewed by transillumination with quartz rods, which produce a cold light and avoid coagulation of protoplasm. Prolonged preservation of living cells outside the body can be achieved by a technique known as tissue culture fragments of

tissue are removed aseptically, transferred to a physiological medium, and kept at a temperature normal for the animal from which the tissue was taken, The cultures can be placed in thin glass vessels or in hanging drops on a cover glass mounted over a hollow slide for observation under the microscope. In tissue cultures, growth, multiplication, and in some cases, differentiation of cells into other cell types can be observed directly, Tissue culture is a valuable method for the study of cancer and many viruses.

Two staining methods have been used successfully to living animals or surviving cells:

1. **In vital staining**: dyes are injected into the living animal. The activity of certain cells will result in the selective absorption of the coloring material by these cells. E.g. staining by ***trypan blue*** of macrophages on the basis of their ability to phagocytose foreign particles.
2. **Supravital staining**: Involves the addition of a dyestuff to a medium of cells already removed from the organism. E.g. staining of mitochondria in living cells by ***James green***, of lysosomes by neutral red, and of nerve fibers and cells by ***methyline blue***. Motion films made of individual living cells or of tissue cultures help to analyze processes such as mitosis, phagocytosis, and amoeboid movement.

2.4 Preparation of Dead Tissue

The convenient way to study histology is to use sections, each of which is a more or less permanent preparation. The production of a histological section involves the following procedures:

a. Removal of the specimen: for the best histological preparations, the material should be removed from an anesthetized animal or immediately after death of the animal.

b. Fixation: is to preserve protoplasm with the least alteration from the lwing state. Fixing fhids act as preservatives, inhibiting catalytic changes and bacterial growth. They coagulate protoplasm, rendering it insoluble, and harden the tissue so that sectioning is facilitated. Formal in, alcohol, mercuric bichloride, potassium bichromate and certain acids used as fixing agents. No single fixative possesses all the desirable qualities and many reagents are used in mixtures.

c. Embedding: The purpose of embedding is to provide rigid support to the tissue blocks so that they may be cut into thin sections. Prior to embedding. The fixed tissue is washed to remove excess fixative and then dehydrated by passing it through increasing strengths of ethyl alcohol or other dehydrating agent. Tissue is then cleared to remove dehydrating agent. Clearing agents include xylol, chloroforous and benzene, after clearing, the tissue is infiltrated with the embedding agent, usually paraffin or celloidin. After infiltration, the embedding agent is made to

solidify so that affirms homogenous mass containing the embedded tissue is obtained.

d. **Sectioning**: Tissue embedded in paraffin may be sliced/ Sectioned between 3 and 10 mm thick using a microtome. Each section is then transferred to a clean glass microscope slide on which a little egg albumin has been smeared.
e. **Staining**: The purpose of staining is to enhance natural contrast and to make m ore evident the various cell and tissue components and extrinsic material. Before staining the paraffin is removed from the section by placing in a paraffin solvent or decerating agent usually xylene. The section is passed through descending strengths of alcohol prior to staining. Hematoxylin and eosin is most frequently used to stain.
f. **Mounting**: After staining, excess dye is removed by washing with water or alcohol depending upon the soul vent of the dye, and section is dehydrated through ascending grades of alcohol. The section is then transferred to a solution of clearing agent. After removal from the clearing agent, a drop of mounting medium, for instance Canada balsam, which has a refractive index similar to that of glass, is placed on the section. The preparation is covered with a cover slip and allowed to dry.

2.5 Examination and Interpretation of Sections

The ability to interpret histological sections is a skill that must be developed. Histology must be learned principally from a study of sections, which for all practical purposes have no depth. A single section of an organ may give a false impression of its architecture. Thus, it is important to
use several sections taken in different planes in order to make an interpretation of the structure of complex organs. One must strive to interpret the functional significance of what one observes.
It must be appreciated that not all sections are perfect and accurate representations. Such alterations are termed **artifacts.** They may be due to;

1. Different chemicals used in the histological technique, result in shrinkage,
2. Folding or wrinkling of the section,
3. Defects caused by an imperfect knife. With any microscopic preparation, interpretation involves an appreciation of the staining techniques used.

CHAPTER 3: CYTOLOGY

3.1 Introduction to the Cell

Multicellular organisms are made up of two distinct structural elements; cells and those products of cells that form the intercellular substances. Cells are fundamental units of living material and show a variety of functional specialization that is essential for the survival of the organism. Each cell is a distinct entity; each contains all the machinery necessary for independent existence and is separated from its surroundings by an individual plasma membrane.

Cytology is the branch of anatomy that deals with cell structures and functions. It includes the identification and description of various cellular components and the physiological activities associated with each cell. Such knowledge has provided a better understanding of the nature of development, the physiological process carried on by the animal body, and changes that occur in the body as a result of maldevelopment, trauma, or disease.

3.2. Structural Organization of the Cell

Although cells differ in size, shape, and function, the protoplasm (contents of living cells) of each cell consists of two major components **nucleus** and **cytoplasm**. The nucleus contains the hereditary or genetic material and it is surrounded by cytoplasm and separated by a nuclear envelope. The cytoplasm is limited by a plasma (cell) membrane, which separates the cell from the external environment. The cytoplasm consists of several structures representing organelles and inclusions. The different organelles tend to be localized in discrete areas of the cytoplasm so that they and their associated metabolic processes remain separated from other components of the cell.

Cell shape is maintained by a three dimensional **cytoskeleton** that provides structural support for the cell and serves in cell motility and intracellular transport. The cytoskeleton consists of various microfilaments and microtubules. The organelles and inclusions are suspended in a medium called the **cytoplasm matrix** (cytosol). Nuclear material also is suspended in a structure less ground substance called the **karyolymph**.

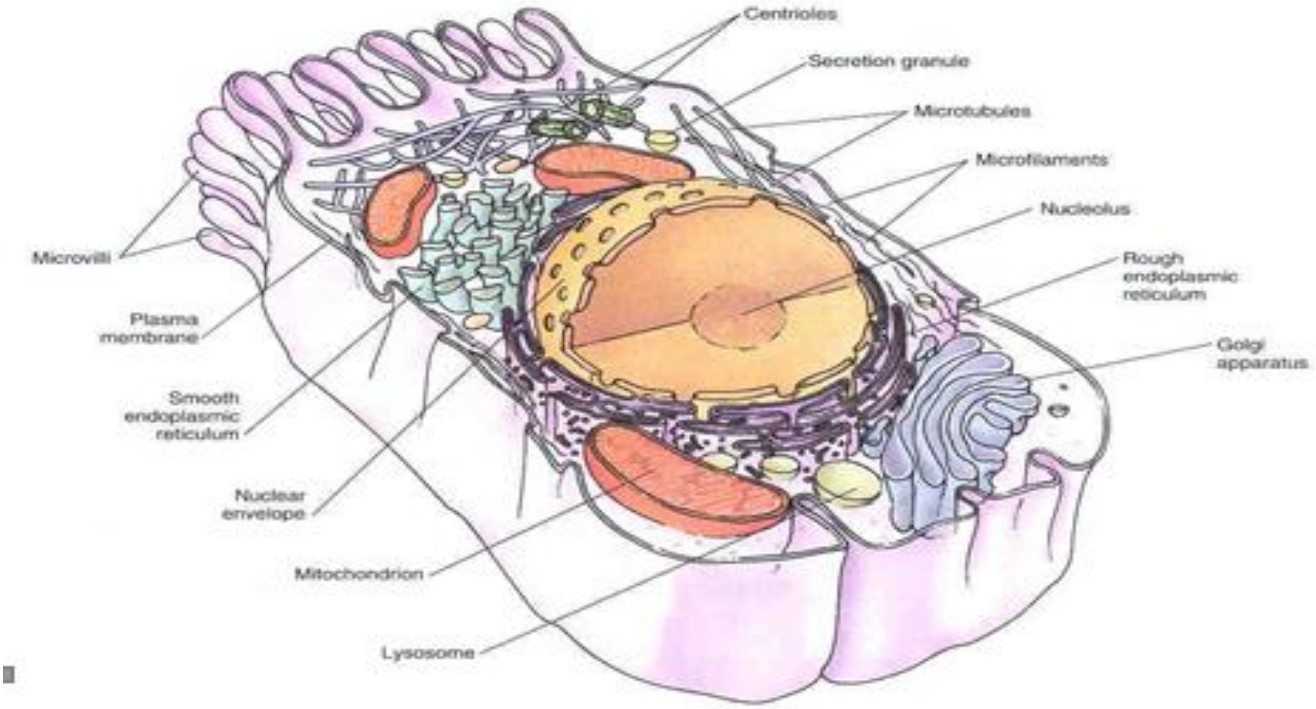


Fig. 3.1. Cell structure

3.3 Cytoplasmic organelles

Organelles are specialized units of the cell that perform specific functions and constitute part of the living substance of the cell. Organelles inclued structures like plasma lemma, smooth and rough forms of endoplasmic reticulum, ribosome's, Golgi complex, mitochondria, lysosomes, peroxisomes, and centrioles.

Many organelles are limited by membranes, similar in structure to the boundary of the cell itself. These membranes, including the cell membrane, are metabolically active sheets that are essential to the life of the cell. The membranes of organelles appear to have only minor cytology variations; they vary considerably in the chemical composition, enzymatic properties and functions.

3.3.1 Plasma (cell) membrane

Each cell is enclosed by a cell membrane that is 8-10 nm thick and has the typical trilaminar structure of the unit membrane. The cell membrane is composed of proteins, lipids, glycolipids, and carbohydrates. Lipid forms about 50% of the mass of the cell membrane. About half of the lipid content of the cell membrane is phospholipid. Each phospholipid molecule has a polar head region that is charged and an uncharged non-polar tail region that consists of two chains of fatty acids. The polar heads lie on both the inner and outer

surfaces of the cell membrane forming two parallel layers of phospholipid molecules lying tail to tail and forming a **phospholipid bilayer**.

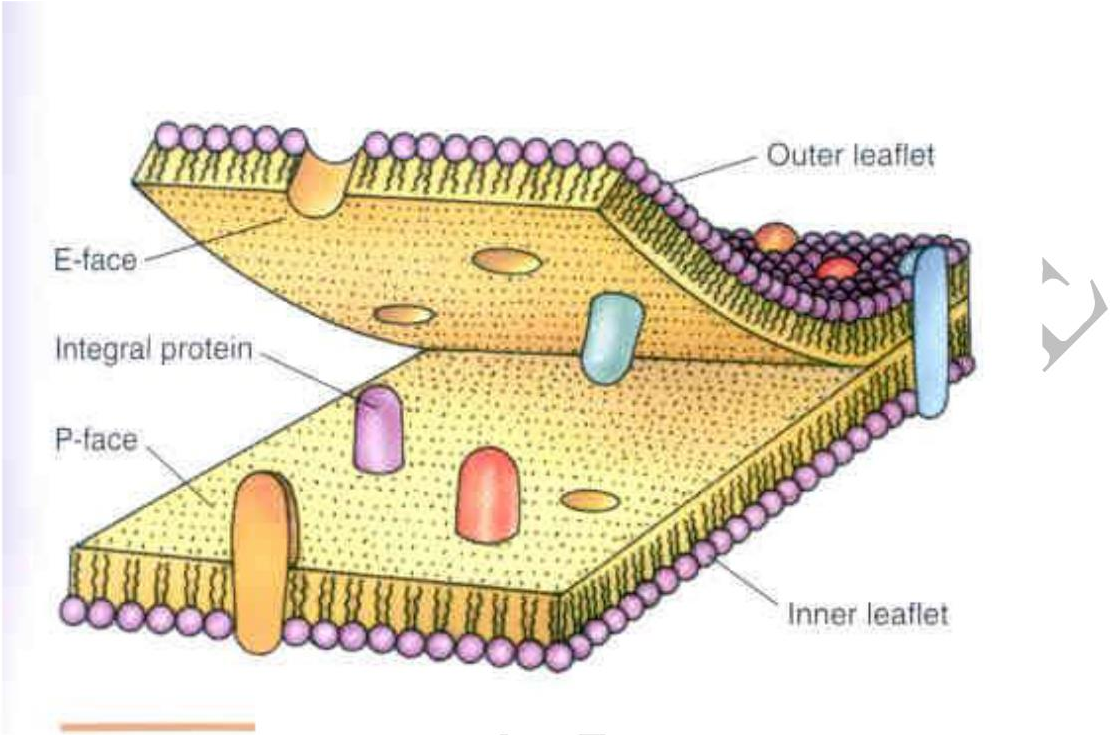


Fig. 3.2. Cell membrane

Because of the polar lipid composition of the cell membrane, it is highly permeable to substances such as oxygen, water, nitrogen and small-uncharged molecules. It is impermeable to charged ions such as potassium, sodium, chloride, calcium, and large uncharged molecules. Glycolipids in the cell membrane are important in cell-to-cell and cell to interstitial matrix interactions and also may play a role in immune reactions.

Membrane proteins function to transport molecules into or out of cells (membrane pump proteins, ion-channel proteins, carrier proteins), act as receptors for chemical signals between cells (hormone receptors) and generate messenger molecules that diffuse to the cytoplasm, attach elements of the cytoskeleton to the cell membrane, attach cells to the extracellular matrix, or may possess specific enzymatic activity when stimulated.

The cell membrane is a selectively permeable membrane in which ions and small water soluble molecules (amino-acids, glucose) must be pumped through protein lined channels that traverse the cell membrane to gain access to the cell interior. The cell membrane plays an active role in bringing macromolecular materials in to the cell (**endocytosis**), as well as discharging materials from the cell.

Phagocytosis is a form of endocytosis in which particulate matter is taken in to a cell. Fluid may be incorporated in to the cell in small cytoplasmic vesicles in a process called **pinocytosis.** Both phagoaytosis and pinocytosis can be seen by light microscope. Materials such as secretory granules are released from the cell by **exocytosis**, a process in which the limiting membranes of the granules fuse with the cell membrane before discharging their contents.

3.3.2 Ribosomes

Ribosomes are small uniformly sized particles of **ribonucleoprotein** and composed of large and small subunits. They may be attached to the membranes of the endoplasmic reticulum or be present as free ribosomes suspended in the cytoplasm unassociated with membranes. Free ribosomes often occur in clusters called polyribosomes in which ribosomes are united by a thread of ribonucleic acid (RNA) called **messenger RNA** (mRNA).

Free ribosomes are sites of **protein synthesis**, the protein formed being used by the cell itself rather than secreted. Messenger RNA is formed in the nucleus on a template of uncoiled deoxyribonucleic acid (DNA). During synthesis, mRNA enters the cytoplasm and attaches to ribosomes that move along the mRNA, translating the code and assembling amino acids in the proper order. Amino acids are brought to the ribosomes for incorporation in to the protein by **transfer RNA** (tRNA), another form of ribonucleoprotein. Formation of ribosomal RNA is directed by a specific region of a chromosome.

3.3.3 Endoplasmic Reticulum

The cytoplasm of almost all cells contains a continuous irregular network of membrane bound channels called endoplasmic riticulum. This organelle appears as anastomosing tubules, but the membranes form parallel, flattened saccules called **cisternae.** Smoth and granular forms of endoplasmic reticulum can be distinguished.

a. Granular (rough) endoplasmic ribiculum (GER) consists of an array of flattend cisternae bounded by a membrane. The outer surface is studded with numerous ribosomes. The granular endoplasmic reticulum is the site of protein synthesis for secretory and some organelle proteins. The proteins are synthesized by ribosomes on the external surface of the GER, and then enter the lumen of the reticulum, where they are isolated from the surrounding cytoplasm.

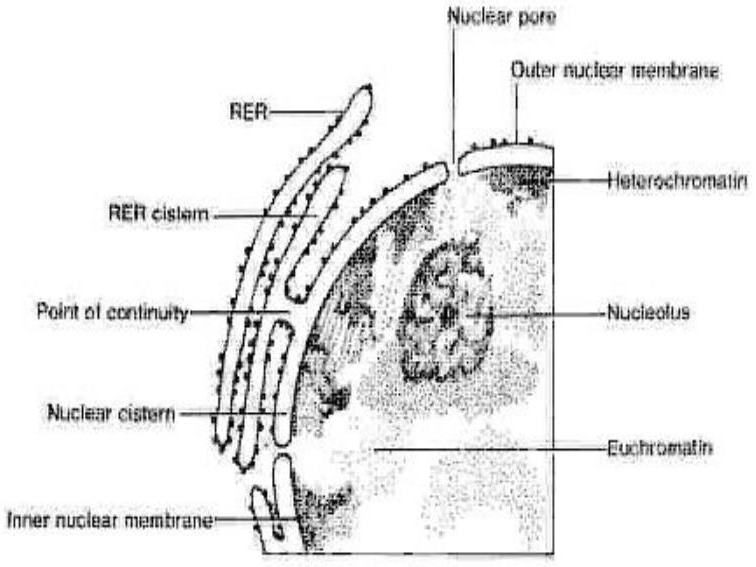


Fig. 3.3 Endoplasmic nuclear & nucleus

b. Smooth endoplasmic reticulum (SER) lacks ribosomes and consists of a system of interconnecting tubules with out cisternae. Protein secreting cells such as pancreatic acinar cells or plasma cells are characterized by an abundance of GER, where as smooth type predominates in cells that secrete steroid hormones. Granular endoplasmic reticulum is known to be involved in the synthesis of protein, but the exact role of SER remains obscure. Smooth endoplasmic reticulum has a role in the synthesis of membrane lipids and in the release and recapture of calcium ions during contraction and relaxation of striated muscle. In the liver, SER play role in detoxifying and degrading lipid soluble drugs and other harmony compounds circulating in the blood stream.

3.3.4 Golgi complex (apparatus)

The Golgi complex does not stain in ordinary histology preparations, nor is it visible in living cells; sometimes appear as a negative image a non-staining area of the cytoplasm usually close to the nucleus. The size and appearance of the Golgi complex vary with the type and activity of the cell and may be small and compact or large and netlike. Secretory products are concentrated in the Gogi complex, whose size varies with the activity of the cell.

The Golgi complex functions in the post-transitional modification and sorting of proteins and lipids synthesized by the endoplasmic reticulum. The Golgi complex can be subdivided into four functional compartments depending on the enzymes present within its cisternae. There appears to be a continuous movement of membrane through the cell, from endoplasmic reticulum to transport vesicles, to Golgi complex, to secrectory granules, and then to the cell membrane. Internalization of cell membrane occurs during phagocytosis, pinocytosis, and micro pinocytosis.

3.3.5 Lysosomes

Lysosomes are small, membrane bounded, dense bodies. More than 50 enzymes have been identified in lysosomes. Since they are active at an acid pH, lysosomal enzymes often are referred to as **acid hydrolases**. The limiting membrane of lysosomes protects the remainder of the cell from **autolysis**. The appearance of lysosomes varies according to the phase and activity state.

Primary lysosomes are those, which have been newly released at the Golgi complex and have not engaged in digestive activities. They usually remain within the cell and are not secreted.

Secondary lysosomes are vacuolar structures that represent sites of past or current lysosomal activity and include hetrophagic vacuoles, residual bodies, and cytolysosomes. Some cells, such as macrophages and some granular leukocytes of the blood, have a special capacity to engulf extracllular materials and destroy them. The process by which substances are taken in to the cell from the exterior environment and broken down by lysosomal activity is called **heterophagy**.

The extracellular material taken in to the cell is sequestered in a vacuole called **phagosome** and remains isolated from the cytoplasm. The membranes of the phagosome and lysosome fuse and the enzymes of the lysosome are discharged in to the phagosome. The combined primary lysosome and phagosome is called a heterophagic vacuole, a type of secondary lysosome. The lysosomal enzymes digest the material within the heterophagic vacuole and the non-degradable materials remain with in the vacuole called a **residual body**.

Autophagy refers to the lysosomal breakdown of cytoplasmic organelles in normal, viable cells. The lysosomal system is involved in the destruction of worn or damaged organelles and the remodeling of the cytoplasm. The absence of a specific lysosomal enzyme results in the accumulation of its normal substrate within the lysosome.

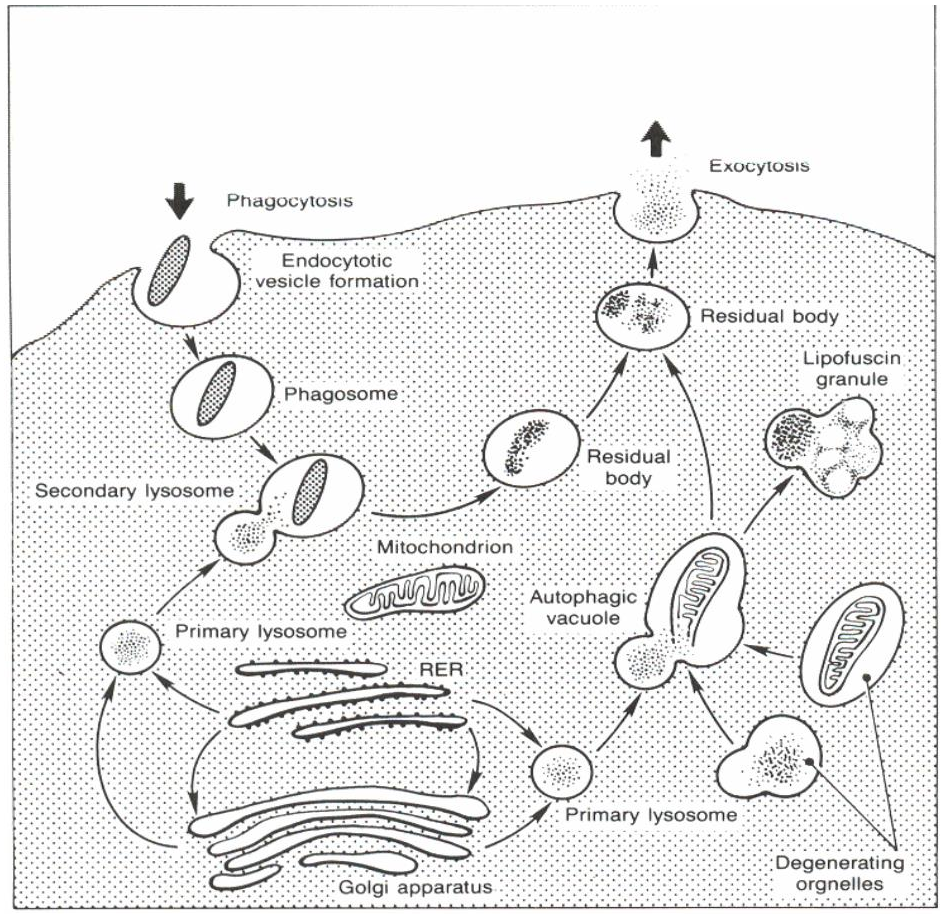


Fig. 3.4. Phagocytosis & endocytosis

3.3.6 Peroxisomes

Peroxisomes, or microbodies, comprise another class of membrane bound organelles; their internal structure varies and can be crystalline or dense called **nucleoids**. Peroxisomes lack acid hydrolases but do contain several enzymes that can remove hydrogen atoms from organic substrates and produce **hydrogen peroxide**, which is essential for many cellular functions and capable of destroying micro organisms, in excess is lethal to cells. Peroxisomes contain the enzyme **catalase**. Excess hydrogen peroxide is converted to water by catalase. Peroxisemes have been implicated in the oxidation of substrates, particularly very long chain fatty acids and are abundant in cells involved in steroid synthesis and cholestrol metabolism.

3.3.7 Energy production and storage

All cellular functions are dependent on a continuous supply of energy, derived from the sequential breakdown of organic molecules during the process of **cellular respiration**. The energy released during this process is ultimately stored in the form of **ATP** (Adinosine triphosphate) molecule. In all cells, ATP forms a pool of readily available energy for all the metabolic functions of the

cell. The main substrates for cellular respiration are simple sugars and lipids (glucose and fatty acids).

Cellular respiration of glucose (**glycolysis**) begins in the cytosol, where it is partially degraded to form pyruvic acid, yielding a small amount of ATP. Pyruvic acid then diffuses in to mitochondria, where in the presence of oxygen, it is degraded to Co_2 and water; this process yields large quantity of ATP, fatty acids pass directly in to the mitochondria where they are degraded to co2 and water. Glycolysis occurs in the absence of oxygen (anaerobic respiration). Whereas mitochondrial respiration is dependent on a continous supply of oxygen (aerobic respiration).

a. Mitochondria

Mitochondria are the principal organelles involved in cellular respiration in mammals and are found in large numbers in metabolically active cells like in the liver and skeletal muscle. Mitochondria are membranous structures that play a vital role in the production of energy required by cells. They are visible in lairing cells examined by phase contrast microscope. They can be stained in fixed tissues, appear as rods or thin filaments. Structurally, mitochondria in show a variety of shapes and sizes, but all are enclosed by two membranes, each of which has the typical trilaminar substructure.

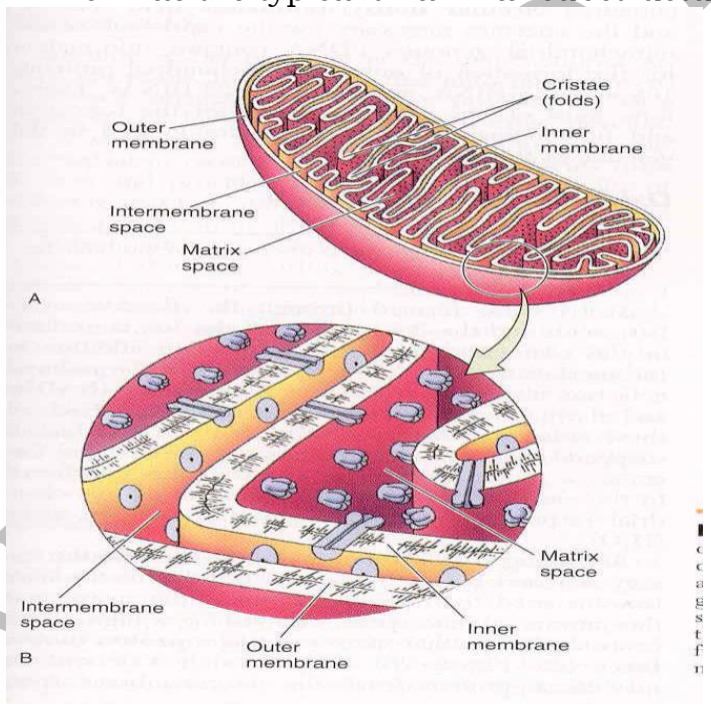


Fig. 3.5. Mitochondria

The outer mitochondria membrane is a continuous, smooth structure that completely envelops the organelle. An inner mitochondria membrane runs par allel to the outer membrane but is thrown in to numerous folds, the **cristae**, that extend into the interior of the numerous folds, the **cristae** that extend into the interior of the mitochondrion. The inner mitochondria membrane

surrounds the larger **intercristal space** that contains s slightly more electron-dengue material called the **mitochondrial matrix**. Enzymes of the Krebs cycle, responsible for the final break down of fatty acids, monosugars, and some amino acids, reside within the mitochondria matrix. The primary function of mitochondria is synthesis of ATP, the primary source of energy for cell activities. Mitochondria are unique among organelles because they contain their own complement of DNA and are capable of self-replication.

3.3.8. Centrioles

Under light microscope, centrioles appear as minute rods or granules located near the nucleus in a specialized region of the cytoplasm called the **centrosomes.** The wall of each centriole consists of nine subunits, each of which is made up of three fused microtubules; the subunits are referred to as **triplet**. Centrioles are self-replicating organelles that duplicate just before cell division.

3.3.9. Cytoskeleton

The cytoskeleton gives structural support to the cytoplasm and consists of microfilaments, intermediate filaments, microtubules, and a microtrabecular lattice. Interaction between the cytoskeleton and the cell membrane is essential for cell movement, intracellular transport, endocytosis, focal mobility of the cell membrane, maintenance of cell shape, stabilization of the cell junctions, and spatial orientation of enzymes and other molecules in the cytoplasm.

a) **Microfilaments:** cytoplasmic filaments are responsible for contractility. Filaments are best developed in muscle cells, where the proteins **actin** and **myosin** form two different types of filaments whose interactions are responsible for the contractile properties of muscle cells.
b) **Intermediate filaments:** are attached to the internal surface of the cell membrane at cell junctions and contribute to the cytoskeleton of the cell, providing support.
c) **Microtubules:** are straight or slightly curved, non-branching tubules. They are composed primarily of the protein **tubulin**, which occurs in alpha and beta forms, Microtubules can rapidly form or disappear depending on cell activity. They are scarce in resting cells but are present in large numbers in dividing cells, where they make up the mitotic spindle.

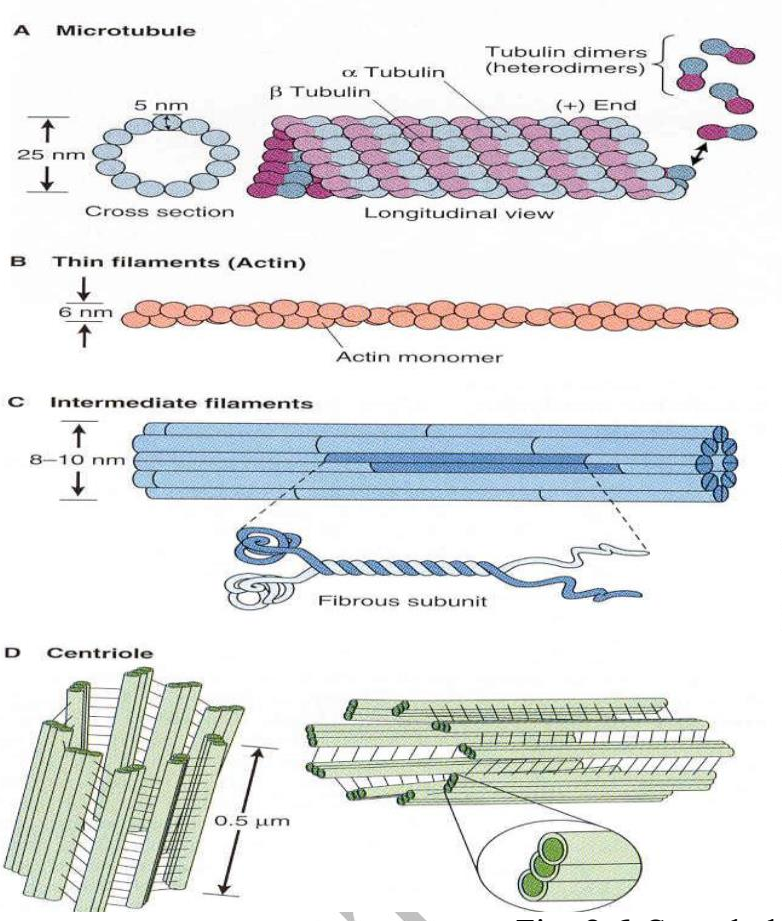


Fig. 3.6 Cytoskeleton

3.4. Cytoplasmic Inclusions

Inclusions are nonliving elements found in the cytoplasm and include such diverse materials as pigments granules, glycogen, lipid droplets, and crystals. They are not essential to the life or functioning of the cell and represent metabolic products, storage materials, or foreign substances taken into the cell from the environment.

a) **Pigment granules:** include melanin, hemosiderin and lipofuscin, each of which has its own inherent color. Melanin is formed and found in melanocytes. Hemosiderin drived from breakdown of hemoglobin present in red blood cells.

b) **Glycogen:** is a large glucose polymer and is the storage form of carbohydrate. It cannot be seen in usual tissue preparations unless selectively stained.

c) **Lipid:** Fat cells are the chief storage sites for lipid, but many other cell types store lipid droplets of various sizes. Lipid synthesized by a cell

accumulates in cytoplasmic droplets that lack a limiting membrane. Intracellular lipid serves as a source of energy.

3.5 Nucleus:

The nucleus is an essential organelle present in all complete cells, The only cytoplasmic structures in which nuclei are absent are mature mammalian erythrocytes and blood platelets; these should not be regarded as true cells. Generally, each cell has a single miclwa, but some parietal cells of stomach, cardiac muscle cells, and liver cells, may possess two nuclei. Giant cells such as ostcoclasts of bone, and skeletal muscle cells, may have several nuclei.

The nucleus contains all the information necessary to initiate and control the differentiation, maturation, and metabolic activities of each cell. The dividing nucleus is enclosed in a nuclear envelope and contains the chromatin material and one or two nucleoli.

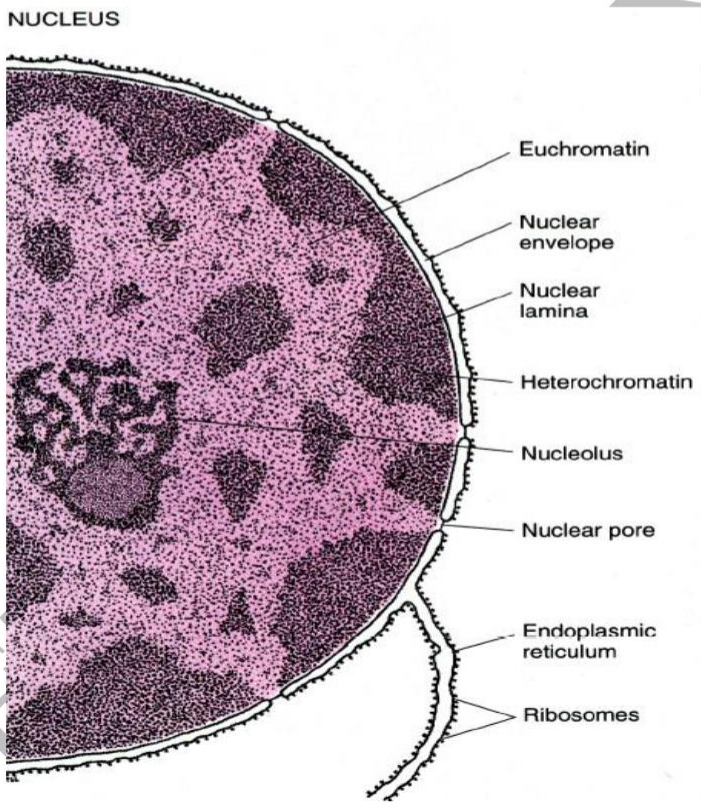


Fig. 3.7 Nucleus

3.5.1 Chromatin and chromosomes

Genetic information is stored in the molecule of DNA that makes up the chromosomes. Each chromosome contains a single long molecule of DNA that consists of two linear polymers of nucleotide subunits made up of a phosphate group, a pentose sugar (deoxyribose), and four organic bases (adenosine, cytosine, guanine, thymidine). The two polynucleotide chains interwine and

form the antiparallel double helix of the DNA molecule. Genetic information of the DNA molecule is encoded in the sequence of the bases.

Nuclear DNA is associated with a variety of proteins that form chromatin (histones and non-histone proteins). **Histones** are the most abundant proteins in the nucleus and form the inner core of a DNA-Protein complex called a **nucleosome**, the basic unit of the chromatin fiber. Histones are simple proteins that contain a high proportion of basic amino acids.

3.5.2 Nuclear envelope

The nuclear envelope consists of two concentric unit membranes, separated by a perinuclear space. The inner membrane is smooth, whereas the outer membrane contains numerous ribosomes on its cytoplasmic surface and is continuous with the surrounding endoplasmic reticulum. The nuclear envelope aids in organization of the chromatin and controls the two-way traffic of macromolecules between the nucleus and cytoplasm.

3.5.3 Nucleolus

A Nucleolus appears as a dense, well-defined body, contained within a nucleus. Nucleoli are sites where ribosomal RNA **(rRNA)** is synthesized. Since these sites (nucleolus-organizing regions) are located on five different chromosomes, any one cell may contain several nucleoli. Nucleoli lie free in the nucleus, not limited by a membrane. Nucleoli are found only in interphase nuclei and are especially prominent in cells that are actively synthesizing proteins.

3.5.4 Integrated function of cells in tissues, organs and systems

Cells are the functional units of all living organisms: in multicellular organisms, individual cells become specialized (differentiated) and grouped together to perform specific functions. Activities of the body are accomplished only through the action of cells. Some cells may perform several functions, but most are specialized for the performance of a single function. For instance, nerve cells conduct impulses; muscle cells contract; epithelial cells protect, absorb, and secret; adipose cells store fat; liver cells produce bile and store glycogen; bone cells form bone. Cells of similar morphology and function form **tissues**, which are homogenous in overall structure (eg. cartilage, bone and muscle). Al organism's very existence depends on the coordinated functioning of all the cells and tissues of the body.

Organs are discrete collections of tissues, which together perform certain specific functions (eg liver, kidney, eye, ovary). Tissues and organs constitute integrated functional systems forming major anatomical entities (e.g central nervous system, gastro-intestinal tract, urinary system, etc.) or be more diffusely arranged (e.g immune defense system, diffuse neuro-endocrine system).

Within tissues and organs, cells interact with one another in numerous ways during embryological development and growth, maintenance of structural integrity, response to injury (inflammation and repair), integration and control of tissue and organ functions and the maintenance of overall biochemical and metabolic integrity (homeostasis). This involves the elaboration of structural connection between adjacent cells (intercellular junctions) may also serve as conduits for information exchange in the form of electrical excitation or chemical messengers.

Some cells are indirectly bound to one another within tissues by extra cellular elements (e.g fibers of supporting /connective tissues) within tissues, cellular functions are integrated by a great variety of local chemical mediators (humoral factors). At the level of systems and the body as a whole, functions are coordinated via circulating chemical messengers (hormones) and/or via the nervous system.

3.6 Cell Cycle and Replication

The development of a single fertilized egg cell to from a complex, multicellular organism involves cellular replication, growth and progressive specialization /differentiation/ for a variety of functions. The mechanism of cellular replication in all cells is known as **mitosis**. Mitotic division of a single cell results in the production of two daughter cells; each genetically identical to the parent cell.

Following mitosis, daughter cells enter a period of growth and metabolic activity prior to furthier division, this time interval, the life cycle of an individual cell is called **cell cycle.** In the fully developed organism, the differentiated cells of some tissue (e.g neurons of the nervous system) lose the ability to undergo mitosis, such cells being described as **terminally differentiated**. In contrast, cells of certain other tissues, e.g the lining cells of gut and skin undergo continous cycles of mitotic division through out the life span of the organism. Between these extremes are cells such as liver cells, which do not normally undergo mitosis but retain the capacity to undergo mitosis should the need arise (facultative dividers).

Cell division and differentiation balanced by cell death both during the development and growth of the immature organism and in the nature adult; in these circumstances cell death occurs by a mechanism known as **apoptosis**.

The cell cycle is broadly divided into;

1. Mitosis (M phase) the stage of cell division, and
2. Interphase, the stage between divisions/ non-dividing phase, which usually occupies most of the life cycle of the cell.

The interphase is divided into three phases, the G1 (gap1) or preduplication phase, the period between previous mitosis and the beginning of DNA duplication most cells are in this stage while they perform their particular functions for example adult nerve cells never divide, but remain in the G1 phase during synthesis phase (S), DNA duplication occurs, resulting in two daughter chromosomes. Following completion of the S phase and before mitosis begins; the cell passes through a rather short G2 (gap 2) or post duplication phase.

3.6.1 Mitosis

Mitosis produces daughter cells that have a genetic content identical to that of the parent cell. All multicultural organisms grow by increasing the number of cells. The zygote, which is formed at conception, divides repeatedly and gives rise to all the cells of the body. Proliferation of somatic cells is the result of mitosis, which can be defined as the production of two daughter cells with exactly the same number of chromosomes and the same DNA content as the original parent cell.What determines if and when a cell divides is not known, but there are certain requirements that must be met before a cell can enter mitosis. There is some relations ship between cell mass and cell division.

Mitosis usually lasts from 30 to 90 minutes and involves division of the nucleus (karyokinesis) and the cytoplasm (cytokine sis). Both events take place during mitosis, but karyokinesis may occur without division of the cytoplasm, resulting information of multinucleated cells. Eg, megakaryocytic of bone marrow although mitosis is a continous process, for descriptive purposes it is divided into prophase, metaphase, anaphase, and telophase. The time between successive mitotic divisions constitutes interphase and is the period when the cell performs its usual functions.

a) **Interphase**: Replication of DNA occurs during interphase, before the cell visibly enters into mitosis. The double helix of the chrosome unwinds, and each strand acts as a template for the development of a complementary strand of DNA that contains an exact copy of the sequence of molecules in the original DNA.

b) **Prophase:** In prophase, the cell assumes a more spherical shape and appears more refractive, while in the nucleus, chromosomes become visible and appear as thread like structures. At prophase, each chromosome consists of two coiled subunits called **chromatids.** Chromatids are the functional units of chromosomes, and each contains a double strand of DNA.

Nucleoli become smaller and finally disappear, and the nuclear envelope breaks down. Simultaneously with the nuclear events, the centrioles replicate, and the resulting pairs migrate to the opposite poles of the cell.

c) **Metaphase**: The disappearance of the nuclear envelope marks the end of prohase and the beginning of metaphase, which is characterized by formation of the **mitotic spindle** and the alignments of chromosomes along the equator to form the **equatorial plate**, the mitotic spindle which pass from pole to pole of the spindle are called **continuous fibers**. Microtubules extend from the poles of the spindle to attach to Centromere of each chromosome and form the chromosomal fibers. The Centromere is a specialized region of unduplicated DNA and protein that holds together the chromatids of each chromosome and forms an attachment site for the chromosomal fibers. The final act of metaphase is duplication of the DNA at the centromer after which the centromeres split, the two chromatids of each chromosome separate and begin to migrate towards the centrioles at the opposite poles of the cell.

d) Anaphase: The initial separation of chromatids marks the beginning of anaphase. Movement of chromatids, which now are daughter chromosomes, is and active, dynamic process, but the mechanisms by which the movement is effected are not certain.

e) **Telophase**: As the daughter chromosomes reach their respective poles discontinuous portions of endoplasmic reticulum forms around each group of chromosomes and begin to re-form the nuclear envelope, that initiates telophase, when the nuclear envelope has been re-formed completely, the chrosomes uncoil and become indistinct, and the two nucleic reassume the interphase configuration.

The normal complement of nucleoli reappears and their development is associated with specific nucleolus organizing regions present on certain chrosomes. With this event karyokinesis is complete immediately after division; the daughter cells enter a phase of active RNA and protein synthesis, resulting in an increase in the volume of the nucleus and cytoplasm. The endoplasmic reticulum and the Golgi complex are restored to their original concentrations.

Clinical implications: Where mitotic figures are found in a suction, it means that these cells were actually dividing while the tissue who being taken. Mitotic cells are relatively uncommon in adult life except in tissues that are undergoing continuous cell renewal however. Cell division becomes more general in sites where damaged tissues are actively engaged in repair processes or regeneration, as well as under conditions of hormonal, stimulation. Any unusual abundance of mitotic cells that is not a normal response to some such stimulus can indicate and abnormal growth or tumor and corroborates a diagnosis of cancers.

6.3.2 Meiosis

In all somatic cells, cell division (mitosis) results in the formation of two daughter calls, each one genetically identical to the mother cell. Somatic cells contain a full complement of chromosomes (the diploid number), which function as homologous pairs.

The process of sexual reproduction involves the function of specialized male and female cells called gametes to form a **zygote**, which has the diploid number of chromosomes. Each gamete contains only half the diploid number of chromosomes; this half complement of chromosomes is known as the **haploid** number. The production of haploid cells involves a unique form of cell division celled meiosis, which occurs only in the germ cells of the gonads during the formation of gametes.

Meiosis involves two-cell division processed of which only the first is preceded by duplication of chromosomes.

1. **The first meiotic division**: Results in the formation of two daughter cells, this process differs from mitosis in two important respects;
   a. In mitosis each duplicated chromosome divides at the Centromere liberating two chromatids that migrate to the opposite ends of the mitotic spindles in the first meiotic division there in no such separation of chromatids but rather one duplicated of chromosome of each homologous pair migrates to each end of spindle. Then at the end of the first meiotic division, each daughter cell contains a half complement of duplicated chromosomes.

   b. During the first meiotic division, there is and exchanges of alleles between the chromatids of homologous pairs of duplicated chromosomes, this exchange, and results in chromatids with a different genetic constitution from those of the mother cell.

2. **The second meiotic division:**

Involves splitting of each chromosome at the centromere to liberate chromatids, which migrate to opposite poles of the spindle. Thus meiotic cell division of a single diploid germ cell gives rise to four haploid gametes. During both the first and second meiotic division, the cell passes through stages, which have many similar features of prophase metaphase, anaphase and telophase of mitosis; however, the process of meiotic cell division can be suspended for a considerable length of time.

CHAPTER 4: EPITHELIAL TISSUE

4.1 General characterstics

Epithelium is one of the four basic tissues. A basic tissue is a collection of cells of similar type that together with their associated extracellular substances are specialized to perform a common function.

Epithelium consists of closely aggregated cells with only minimal amount of intervening intercellular substances. Epithelium covers the entire body surfaces and lines the digestive, respiratory, cardiovascular and urogenital systems. Epithelial tissues have the following functions;

- Physical protection (skin)
- Selective diffusion (lung)
- Contractility (myoepitheltal cells)
- Sensation (neuron epithelium)
- Absorption (intestine)
- Secretion (epithelial cells of gland)

Epithelial cells are closely bound to one another by a variety of membrane specializations called **cell junctions**, which provide physical strength and mediate exchange of information and metabolites.

The interface between all epithelia and underlying supporting tissues is marked by a non-cellular structure known as **basement membrane,** which provides structural support for epithelia and constitutes a selective barrier to the passage of materials between epithelium and supporting tissue.

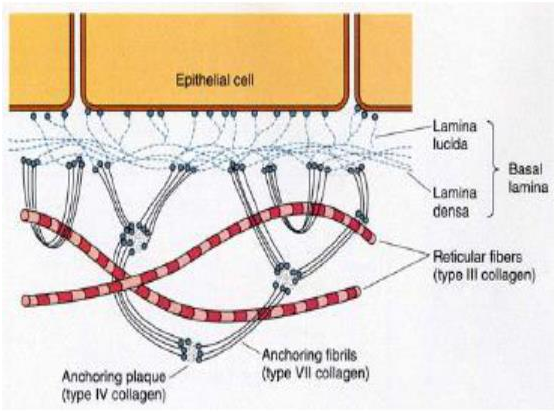


Fig 4.1 Basement membrane

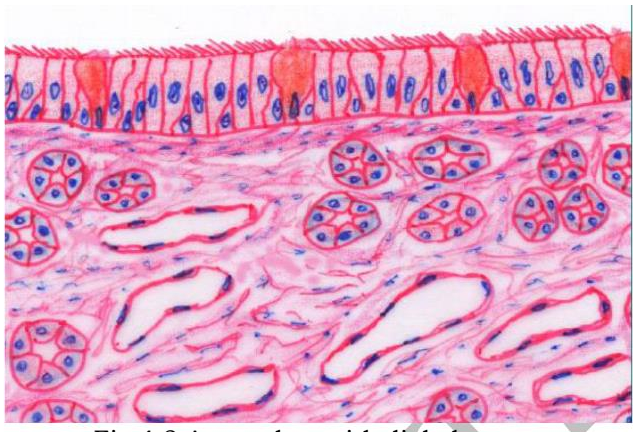


Fig 4.2 Avascular epithelial sheet

Basement membranes are never penetrated by blood vessels and thus epithelial are avascular and dependent on the diffusion of oxygen and metabolites across the basement membrane from adjacent supporting tissues. Epithelia may be derived from ectoderm, mesoderm or endoderm.

4.2 Classification of epithelia

Epithelia are traditionally classified according to three morphologic characteristics;

1. **The number of cell layers:** a single layer of epithelial cells is termed simple epithelium, where as epithelia composed of several layers are termed stratified epithelia
2. **The shape of the component cells:** this is based on the appearance in sections taken at right angles to the epithelial surface.
   - Squamous (thin plate like cells)
   - Cuboidal (cells in which the height and width are approximately equal
   - Columnar (cells in which the height is greater that the width).
   - In stratified epithelia the shape of the outer most layer of the cells determine the descriptive classification without regard to the shape of those in the deeper layers.
3. The presence of **surface specializations** such as cilia anal keratin E.g. the epithelial surface of skin is classified as stratified squamous keratinising epithelium since it consists of many layers of cell, the surface cells of which are flattened (squamous) in shape and covered by an outer layer of the porteinaceous material, keratin.

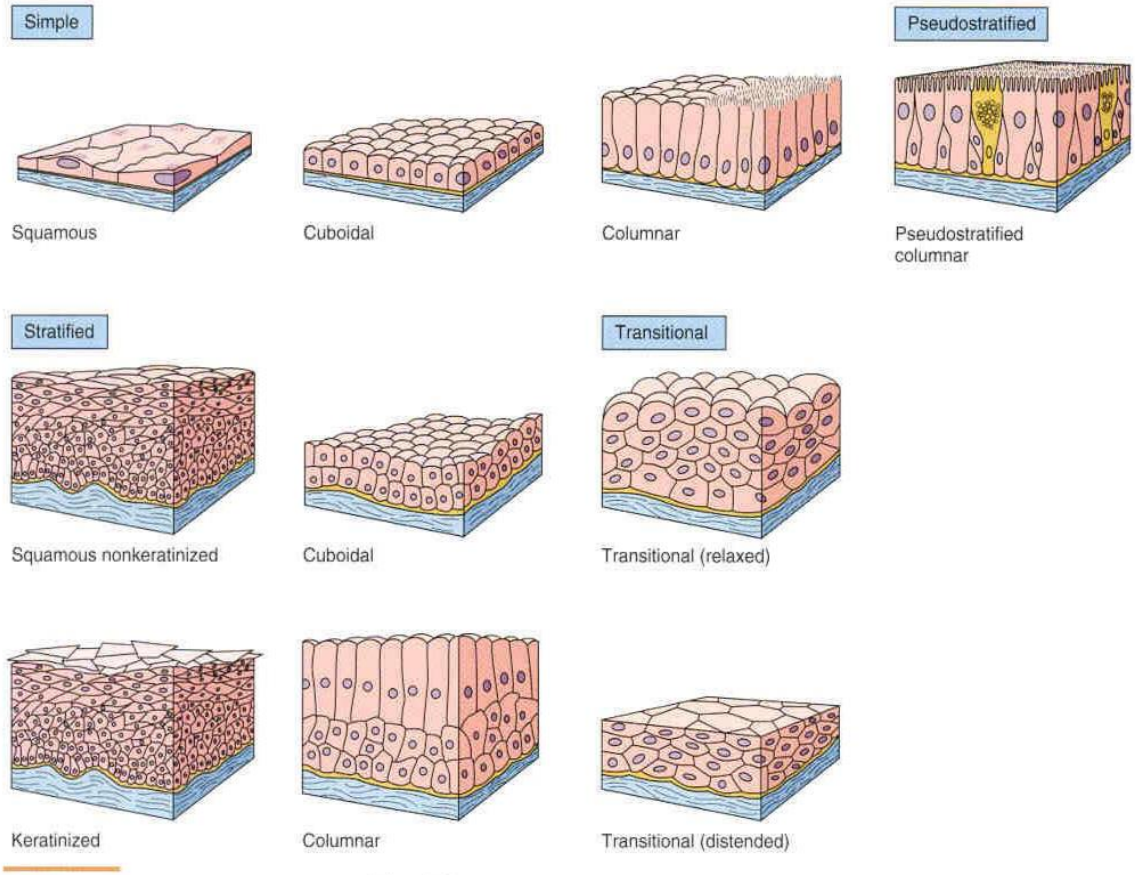


Fig 4.3 Epithelial layers

4.3 Simple epithelia

Simple epithelia are defined as surface epithelia consisting of a single layer of cells. They are found at interface involved in selective diffusion, absorption or secretion.

Simple epithelia provide little protection against mechanical abrasion and thus are not found on surface subject to such stresses. Simple epithelia may exhibit a variety of surface specialization such as **microvilli** and **cilia**, which facilitate their specific surface functions. The cells comprising simple epithelia range in shape from extremely flattened to tall columnar.

4.3.1 Simple squamous epithelium

Simple squamous epithelium is composed of flattened, irregularly shaped cells forming a continous surface. Simple squamous epithelium is found lining surfaces involved in passive transport (diffusions) of either gases (as in the lungs) or fluids (as in the wall of blood capillaries), forms the delicate lining of the pleural, pericardial and peritoneal cavities where it permits passage of

tissue fluid into and out of these cavities and also in parietal layer of bowman's capsule, thin segment of loop of henle and reti testis.

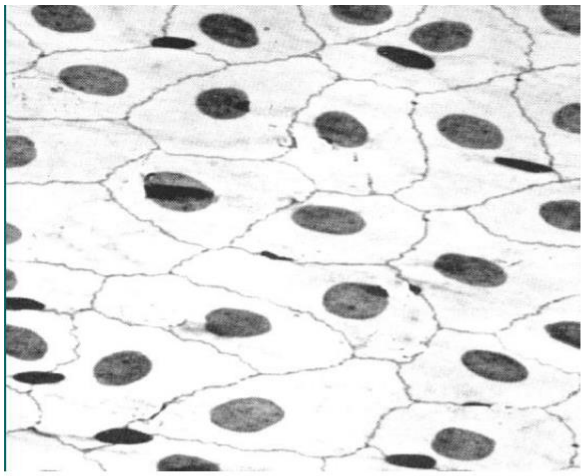


Fig 4.4 Simple squamous

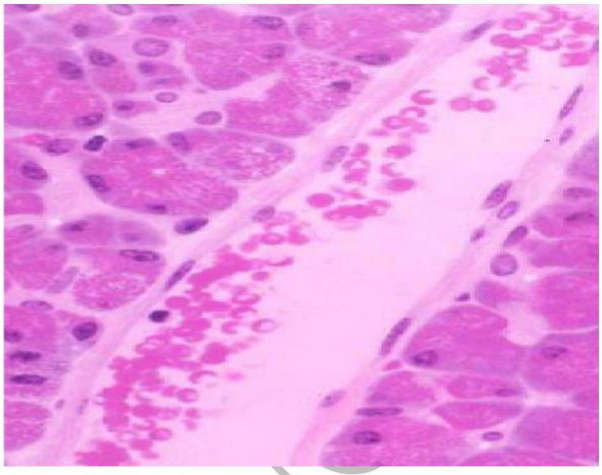


Fig 4.5 Blood vessel (squamus cell)

The term **mesothelium** is the special name given to the simple squamous epithelium that forms the serous membrane of the pleura, pericardium and peritoneum. **Endothelium** is the epithelium that lines the cardiovascular and lymph vascular system. **Mesenchymal epithelium** is special type of simple squamous epithelium that lines the subarachnoid and subdural spaces, the anterior chamber of the eye and the perilymphatic space of the ear.

4.3.2 Simple cuboidal epithelium

Simple cuboidal epithelium is a single layer of cells whose width and height are approximately equal. The nucleus is usually rounded and located in the center of the cell. These cells appear as squares in cross section but are more hexagonal when seen from the surface.

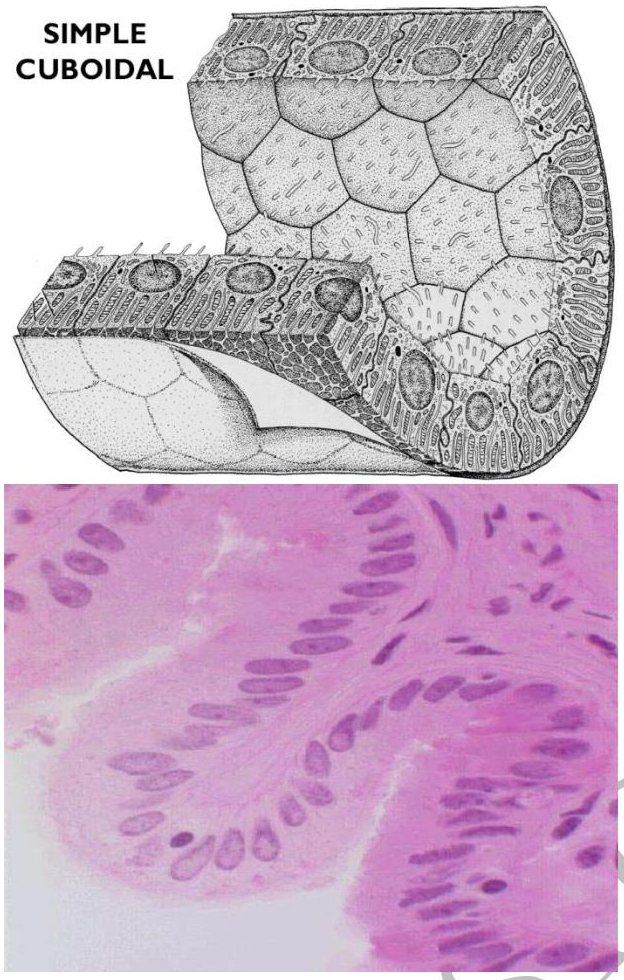


Fig 4.6 Simple cuboidal

Simple coubodal epithelium usually lines small ducts and tubules which may have excterory, secreory or absorptive functions; examples are the small collecting ducts of the kidney, salivary gland, pancreas, thyroid, choroids plexus, inner surface of capsule of the lens, covering surface of ovary and ciliary body.

4.3.3 Simple columnar epithelium

It consists of tall, narrow cells with considerably greater height than width. The nuclei are elongated and may be located towards the base, the center or occasionally the apex of cytoplasm. Simple columnar epithelium is most often found on highly absorptive surfaces and secretory surface. Eg, surface epithelium of stomach, small and large intestine, proximal and distal convoluted tubules of kidney, gall bladder, excretory ducts of glands, uterus, oviduct, small bronchi of lungs, and Paranasal sinuses.

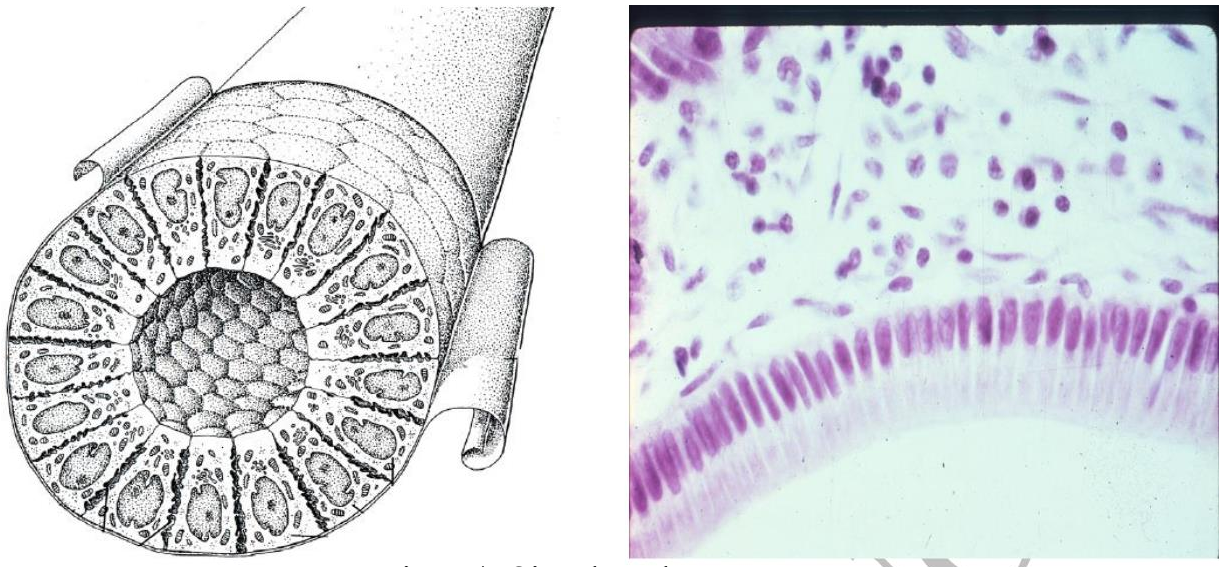


Fig. 4.7 Simple columnar

The luminal plasma membranes of highly absorptive epithelia cells are often arranged into numerous, minute, finger like projections called **microvilli**, which greatly increase the surface area of the absorptive interface.

4.3.4 Pseudostratified columnar ciliated epithelium

The term pseudostratified is derived form the appearance of this epithelium in section, which conveys the erroneous impression that there is more than one layer of cells. In fact, this is a true simple epithelium since all the cell rest on the basement membrane. The nuclei of these cells, however, are disposed at different levels, this creating the illusion of cellular stratification.

Pseudostratified columnar ciliated epithelium unlike stratified epithelium has one cell layer and cilia found in larger airways of the respiratory system, large excretory ducts of glands, portion of male urethra, epididymis and eustachian tube. In respiratory tract, the cilia propel a surface layer of mucus containing entrapped particles (e.g dust) towards the pharynx in what is often described as mucociliary escalator. It is one of the means of defense mechanism.

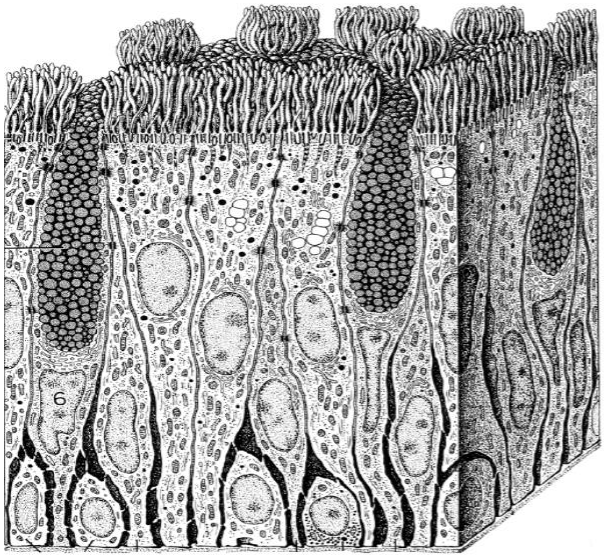


Fig 4.8 Pseudostratified epith

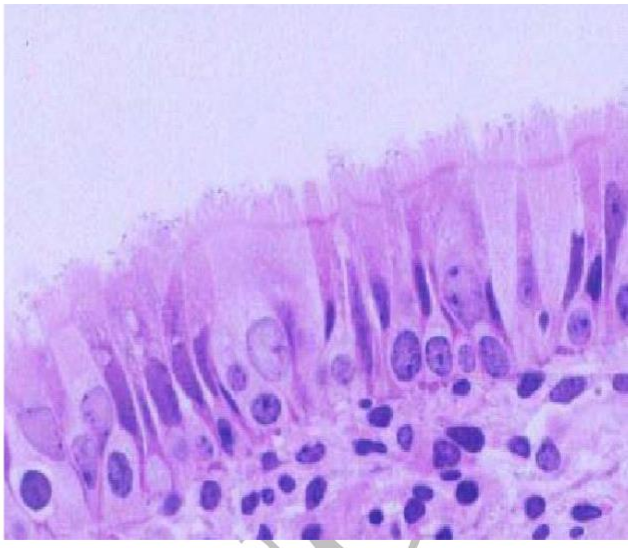


Fig 4.9 Respiratory tract

4.4 Stratified epithelia

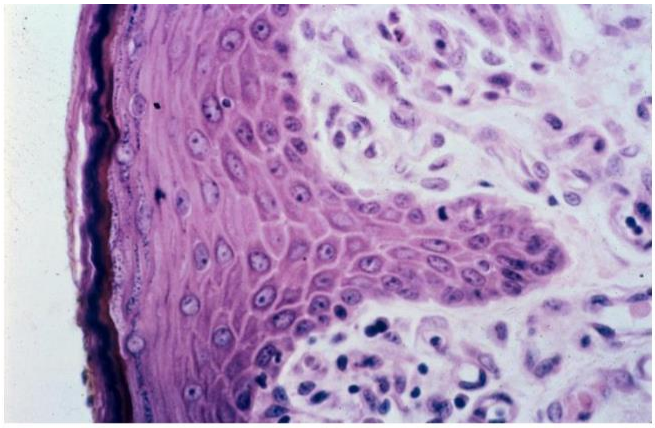
Stratified epithelia defined as epithelia consisting of two or more layers of cells. Stratified epithelia have mainly protective function and the degree and nature of the stratification are related to the kinds of physical stresses to which the surface is exposed, poorly suited for the functions of absorption and Secretion. The classification of stratified epithelia is based on the shape and structure of the surface cells since cells of the basal layer are usually cuboidal in shape.

4.4.1 Stratified squamous epithelium

It consists of a variable number of cell layers, which exhibits transition form a cuboidal basal layer to a flattened surface layer. It is well adapted to withstand abrasion since loss of surface cells does not compromise the underling tissue; it is poorly adapted to with stand desiccation. This type of epithelium lines the oral cavity, pharynx, esophagus, anal canal, uterine cervix and vagina, sites which are subject to mechanical abrasion but which are kept moist by glandular secretion and are called **wet or non keratinized stratified epithelium.**

4.4.2 Stratified squomous keratinzing epithelium

Constitutes the epithelial surface of the skin (epidermis) and is adopted to withstand the constant abrasions and desiccation to which the body surface is exposed. During maturation the epithelial cells accumulate cross-linked cytoskeletal proteins in a process called **keratinization** resulting in the formation of a tough, non-lining surface layer consisting of the protein **keratin**. Keratin is a water resistance protein that forms a protective barrier against the destructive forces of the environment.



4.10 Keratinized stratified squamus epith. of skin

4.4.3 Stratified cuboldal epithelium

It is a thin, stratified epithelium that usually consists of two or three layers of cuboidal or low columnar cells. This type of epithelium is usually contained to the lining of the larger excretory ducts of exocrine glands such as the salivary gland and portion of genital system. It is probably not involved in significant absorptive or secretory activity but merely provides a more robust lining that would be afforded by a simple epithelium.

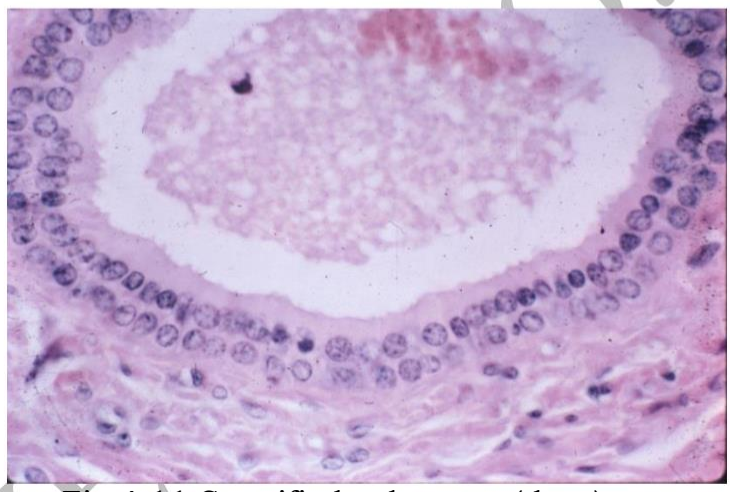


Fig 4.11 Stratified columnar (duct)

4.4.4 Stratified columnar epithelium

Consists of several layers of cells. The superficial layer of tall cells does not extend to the basement membrane. The deeper layers are composed of smaller polyhedral cells that do reach the surface. Stratified columnar epithelium is found in distal portion of the urethra, portion of upper respiratory tract, mandibular duct, lacrimal sac and duct and large excretory ducts of glands.

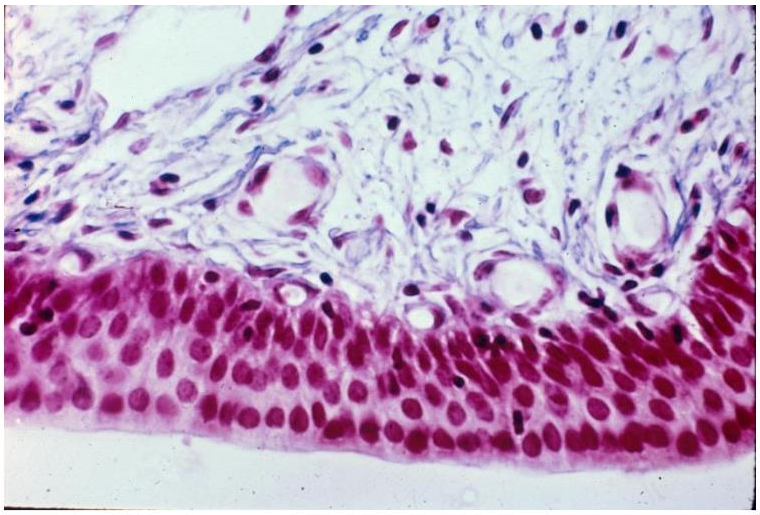


Fig 4.12 Stratified columnar epith

4.4.5. Transitional epithelium

Is a form of stratified epithelium almost excessively contained to the urinary tract in mammals where it is highly specialized to accommodate a great degree of strech and withstand the toxicity of urine. This epithelium type is so named because it has some features, which are intermediate (transitional) between stratified cuboidal and stratified squamous epithelia. Its appearance varies considerably depending on the degree of distension to which it is subjected.

In the contracted (not distended) state, transitional epithelium appears to be about four to five cell layers thick. The basal cells are roughly cuboidal, the Intermediate cells are polygonal and the surface cells are large, rounded and may contain two nuclear (binucleate). In the stretched state, transitional epithelium often appears only two or three cells thick (although the actual number of layers remain constant) and the intermediate and surface layers are extremely flattened.

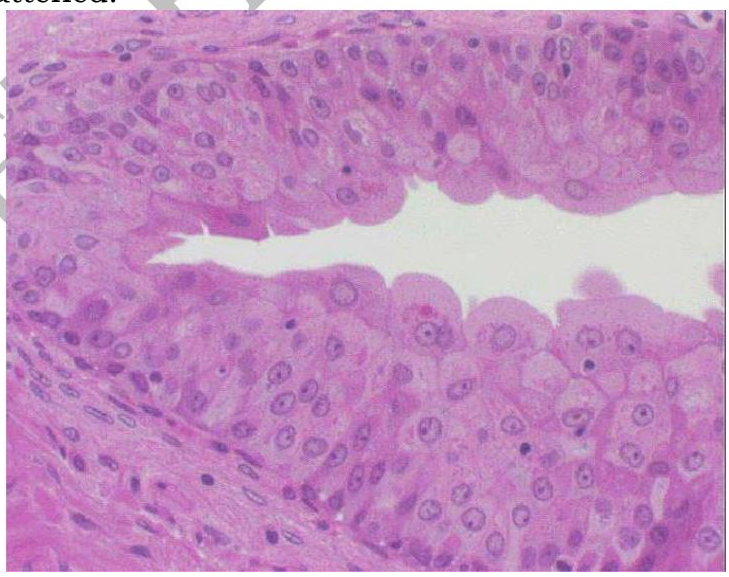


Fig. 4.13 Trabsitional epith (Urinary tract)

4.5 Specializations of epithelial membranes

4.5.1 Intercellular surface

The opposed surfaces of epithelial cells are linked by several different types of membrane and cytoskeletal specializations. These cell junctions permit epithelia to form a continuous cohesive layer in which all of the calls communicate and cooperate to achieve the particular functional requirements of the epithelium. Cell junctions are of three functional types;

a. The zonal occludens (tight junction): is a fusion of the external laminae of adjacent epithelial cell membranes bordering a lumen. It forms an impermeable seal around the perimeter of each cell, uniting them in an epithelial sheet. The zonal occludens junctions also is important in separating apical form basal-lateral cell membrane domains by preventing the migration of specialized membrane protein (receptors, transport proteins) in the plasma lemma.

b. Anexus (gap junctions): is a firm attachment point between adjacent cells. Gap junctions are circular intercellular contact areas containing hundreds of tiny pores, which permit passage of small molecules between adjacent cells. Molecules involved in such cytoplasmic interchange include ions responsible for electrical excitation of cell membranes, nutrients and chemical signaling agents.

c. The macula adherens (desmosome) act as a firm attachment point between adjacent-cell membranes and also as an anchoring point for numerous keratin filaments in the cytoplasm.

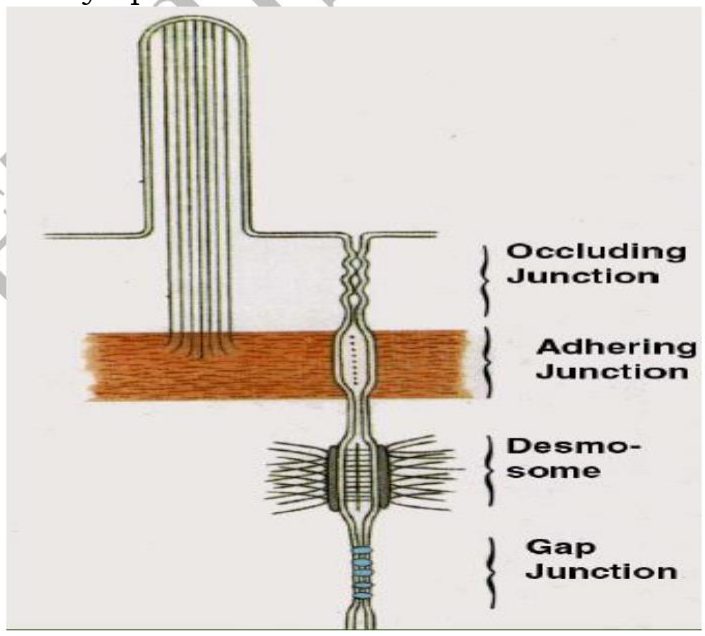


Fig. 4. 14 Epithelial junction

Cells in epithelia sheet often show special adaptations of apical or basis-lateral surface that increase the surface area of the cell or constitute motile that move material across the surface. Surface specializations include microvilli, cilia, stereocilia.

1. Microvili are short, often extremely numerous projections of the plasma membrane which cannot be individually resolved with the light microscope. In region of high concentration (small intestine, proximal convoluted tubule of the kidney). They form a microvilli border that greatly increases the surface area and absorptive capacity of the cell.

2. Cilia are large, elongated evaginations of the apical cell membrane and motile structures which are easily resolved by light microscopy. Cilia are numerous on epithelial cells that line much of the respiratory tract and parts of the female reproductive tract. Groups of cilia beat in one direction across the epithelial surface. In air waves mucus secreted by goblet cells traps debris form inspired air and cilia move the mucus up wards to wards the throat where it is swallowed thus keeping the airway clean. In oviduct, ciliary's action plays a part in transporting the ovum from the ovary down to wards the uterus.

3. Stereocilla are merely extremely long microvilli usually found strongly or in small numbers in odd sites such as the male reproductive tract, stereo cilia are not motile and thus quite inappropriately named. It is thought to facilitate absorptive processes in the epididymes.

4.6 Glandular epithelium

Epithelium, which is primarily involved in secretion is often arrange into structures called glands. Glands are merely invaginations of epithelial surface, which are formed during embryonic development by proliferations of epithelium into the underlying tissues. Glands, which maintain the continuity the epithelial surface discharging their secretions on to the free surface via a duct, are called exocrine glands. **Epithelial** tissue forms solid organs or isolated islands of epithelial sectetory such glands pass into the blood stream.

4.6.1 General Classifications of glands

Number of cells constituting a gland

a. Uni cellular gland

b. Multi cellular gland

-Intra-epithelial gland=occur with in the lining of the epithelium

-Extra-epithelial gland=occur deep in to the underlying tissue

Morphology of the gland

Mode of secretion (merocrine, Apocrine or Holocrine)

Number of cells constituting a gland

Unicellular glands consist of a single sectetory cells in a non-secretory epithelium. E.g. goblet cells found scattered among columnar epithelial cells of the respiratory and gastrointestinal tract.

The cell has an arrow and an expanded apex filled with sectetrory droplet, synthesize and secret mucus. It is a unicellular exocrine gland. Unicellular endocrine cells are numerous in the epithelial lining of the gastrointestinal tract and produce a number of peptide hormones and/or amines.

Multicellular glands: composed of more than on cell and most glands belong in this classification.

***Intraepithelial glands*:** are small clusters of secretory cells that lie within an epithelial sheet, clustered about small lumen.

***Extra epithelial glands*:** large accumulations of cells that have proliferated into the underlying connective tissue. Exocrine and endocrine glands are classified under multicellular glands.

Exocrine glands

Exocrine glands discharge their sectetory product vai duct on to an epithelial surface. Exocrine glands classified into two major characteristics;

1. The morphology of the gland
2. The means of discharge of secretory products from the cells.

The morphology of the gland

a. Simple glands: are defined as those with a single, unbranched duct. The secretory portions of simple glands have two main forms tubular or acinar (spherical).

I. **Simple tubular glands** have a single, straight tubular lumen into which the secretory products are discharged. E.g. large intestine glands
II. **Simple coiled tubular glands** each gland consists of a single tube, which is tightly coiled, in three dimensions. E.g. sweat gland
III. **Simple branched tubular glands** each gland consists of several tubular secretory portions, which converge on to a single, unbranched duct. E.g. stomach

IV. **Simple branched acinar gland** each gland consists of several sectetory acins, which empty in to a single secretory duct. E.g sebaceous glands.

b. Compound glands: have a branched dcut system and their secretory portions have similar morphologic forms to those of simple glands.

I. **Compound branched tubular glands** the secretory portions have a tubular form, which is branched. E.g Brunner's glands of duodenum

II. **Compound acinar glands** the secretory units are acinar in form and drain into branched duct system. E.g pancreas

III. **Compound tubulo-acinar glands** have three types of secretory units, namely branched tubular, branched acinar and branched tubular with acinar end-pieces. E.g. submandibular salivary gland.

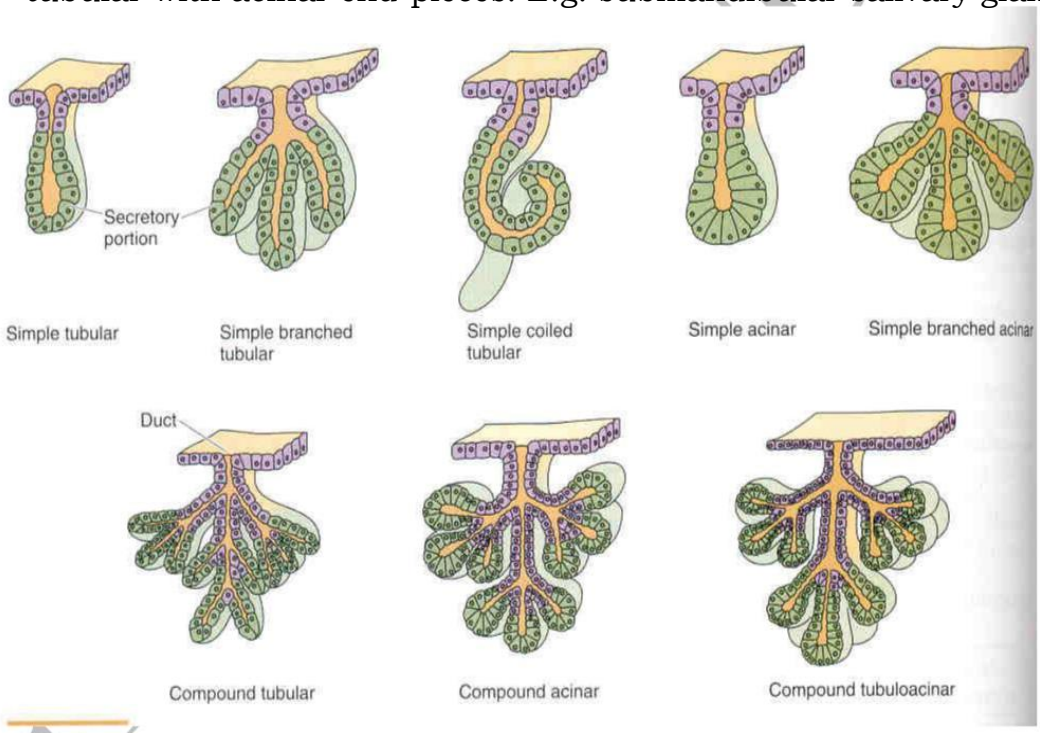


Fig 4.15 Morphology of glands

The mode of discharge of sectetory products

This occurs in three ways;

Merocrine secretion involves the process of exocytosis and is the most common form of secretion; proteins are usually the major secretory products.

Apocrine secretion involves the discharge of free, unbroken membrane bound vesicles containing secretory product. This is unusual mode of

secretion and applies to lipid secretory products in the mammary and some sweat glands.

Holocrinc secretion involves the discharge of whole secretory cells with subsequent disintegration of the cells to release the secretory product**.** Holocrine secretion occurs principally in sebaceous glands**.**

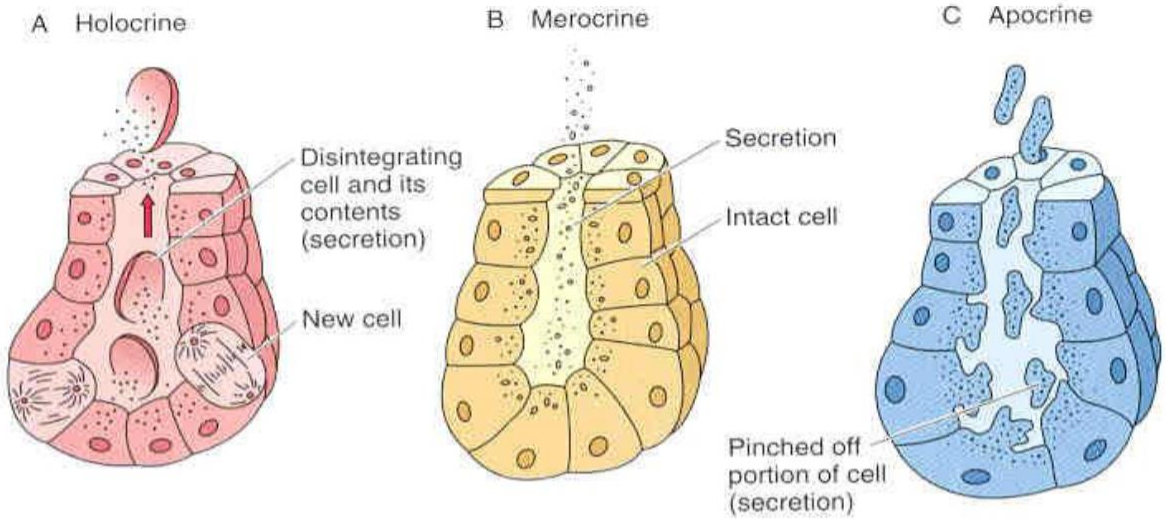


Fig. 4.16 Glandular secretion

The secretory portions of some exocrine glands are embraced by contractile cells, which lie between the secretory cells and the basement membrane. The contractile mechanism of these cells is thought to be similar to that of muscle cells and has given rise to the term myoepithelial cells, their contraction aid in expressing the products form the secretory units into the ductal system. It occurs in sweat, mammary, salivary glands and glands along the bronchi and eosophagus.

CHAPTER 5: GENERAL CONNECTIVE/SUPPORTING TISSUES

5.1 Introduction

Connective tissues are derived from mesenchyme (cells of mesoderm). Mesenchyme is typically a loose spongy tissue, which in early embryonic life is found as packing between structures developing from other germ layers. It is composed of **stellate** and **fusiform cells** forming a network and of an amorphous intercellular substance containing a few scattered fibers.

Mesenchymal cells have multiple developmental potentialities. They are able to differentiate along several different lines to produce many different kinds of connective tissue cells. Connective tissues differ form epithelium by the presence of abundant intercellular material or matrix. Matrix is composed of **fibers** and an **amorphous ground substance**.

In any type of connective tissue there are three elements to consider: the cells, the fibers and the amorphous ground substances. The elements are bathed in tissue fluid. Connective tissues provide the supporting formwork for organs and for the body itself and serve to connect distant structures as, for instance, in the connection of muscle to bone by tendons. Connective tissues bind organs and unite the organ components in to a functioning unit.

Connective tissues usually contain blood vessels and mediate the exchange of nutrients, metabolites and waste products between tissues and circulating system. Connective/supporting tissues occur in many different forms with diverse physical properties. In most organs, loose connective tissues act as a biological packing material between cells and other tissues with more specific functions.

Dense forms of connective tissue provide tough physical support in the dermis of the skin, comprise the robust capsules of organs such as the liver and spleen, and are sources of great tensile strength in ligaments and tendons. Cartilage and bone, the major skeletal components, are highly specialized form of supporting tissue.

Connective tissues have important metabolic roles such as the storage of fat (white adipose tissue) and the regulation of body temperature in the newborn (brown adipose tissue). Cells of the immune system enter support tissues where they assist in defense against pathogenic microorganisms. The process of tissue repair is largely a function of supporting tissues.

5.2 Organization

All supporting/connective tissues have two major constituents; **cells**, and **extracellular matrix**. The extracellular matrix is the dominant component and determines the physical properties of each type of connective tissue. Extracellular material consists of a matrix of organic material called **ground substance** with in which are embedded a variety of fibers. A group of structural **glycoproteins** comprises the third constituent of the extracellular matrix and mediates the interaction of cells with the other constituents.

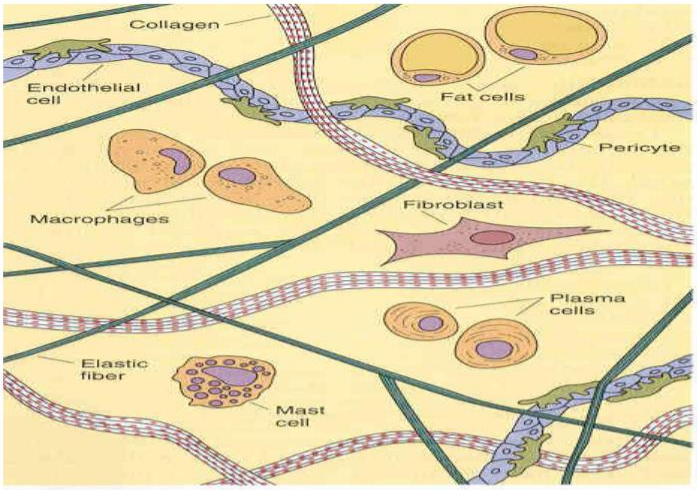


Fig. 5.1 Connective tissue components

5.3 The Cells of Connective Tissue

Connective tissue contains several different cell types. Some are indigenous to the tissues: Others are transients derived from blood. The cells may be divided according to their basic function.

a. **Cells responsible for synthesis and maintenance of the extracellular material** are derived from precursor cells in mesenchyme. The most common connective tissue cells are **fibroblasts**; large, flattened cells with elliptical nuclei that contain one or two nucleoli. The cell body is irregular and often appears stellate with long cytoplasm processes extending along the connective tissue fiber. The boundaries of the cell are not seen in most histological preparations, and the morphology varies with the state of activity.

   Myofibroblasts: are fibroblasts that contain aggregates of **actin** microfilaments and **myosin**, which have additional contractile function. There number increases following tissue injury. Myofibroblasts produce collagen, and their contractile activity contributes the rotation and shrinkage of early scar tissue.

b. **Cells responsible for the storage of and metabolism of fat** are known as **adipocytes** and may collectively form **adipose tissue**. Individual fat cells may be scattered through out loose connective tissue or may accumulate/ crowded to form adipose tissue. Each fat cell acquires so much lipid that the nucleus is flattened to one side of the cell and the cytoplasm forms only a thin rim around a large droplet of lipid. In ordinary sections, fat cells appear empty due to the loss of lipid during tissue preparation, and groups of fat cells have the appearance of chicken wire.

Stored fat with in adipocytes is derived from three main sources: dietary fat circulating in the blood stream as chylomicrons; triglycerides synthesized in the liver and transported in blood: and triglycerides synthesized from glucose within adipocytes. Adipose tissue is important in general metabolic processes in that it acts as a temporary store of substrate for the energy-deriving process of almost all tissues. The rate of fat depositions and utilization within adipose tissue is largely determined by dietary intake and energy expenditure.

C. **Cells with defense and immune functions** are also derived from mesenchyme. This group of cells includes the most cells and tissue macrophages as well as all types of white blood cells. Traditionally, these cells have been divided into two categories; **fixed** (intrinsic) cells and **wandering** (extrinsic) cells.
The intrinsic defense cells are the **tissue-fixed macrophages** (histiocytes) and mast cells. These macrophages are believed to be driven from circulating monocytes and resident in connective tissues.

Macrophages (**histiocytes**) are almost abundant as fibroblasts in connective tissue. They are actively phagocytic, ingesting a variety of materials like bacteria, tissue debris, and whole blood cells. Macrophages may interact with lymphocytes in combating infections. They can synthesize and release a number of factors such as interleukin-1 and 4, fibroblast growth factor, tumor necrosis factor, connective tissue enzymes such as collagenase and elastase. Regardless of where they are found, macrophages have a common origin from precursors in the **bone marrow**, and the monocytes of blood represent a transit form of immature macrophages.

Mast cells are functionally analogous to basophils but there are structural differences, which suggest that most cells are not merely basophils resident in the tissues. They are present in variable numbers in loose connective tissue and often collect along small blood vessels. They are large, ovoid cells with large granules that fill the cytoplasm. Two populations of mast cells are known to exist, connective tissue mast cells and mucosal mast cells.

Granules of mast cells contain heparin, a potent anticoagulant; **histamine**, an agent that cause vasodilation and increased permeability of capillaries and venules; and eosinophil chemotactic factor. Mast cells arise from bone marrow stem cells. They are numerous along small blood vessels and beneath the epithelia of the intestinal tract and respiratory system. Here they detect the entry of foreign proteins and initiate a local inflammatory response by rapidly discharging their secretory granules. Mast cells also can promote immediate **hypersensitivity reactions** (hay fever, anaphylaxia, asthma) following their release of secretory granules, which act as chemical mediators.

Plasma cells: are not common in most connective tissues but may be numerous in the **lamina propria** of the gastrointestinal tract and present in the lymphatic tissues. Plasma cells produce immunoglobulins (antibodies) that form an important defense against infections. They are a differentiated form of the B-lymphocytes.

The wandering category of defense and immune cells includes all the remaining members of the white blood cells series. Although leukocytes are usually considered as a constituent of blood, their principal site of a activity is outside the blood circulation, particularly with in loose connective tissues. Leukocytes are normally found only in relatively small numbers, but in response to tissue injury and other disease processes their numbers increase greatly.

The supporting tissues of those regions of the body, which are subject to the constant threat of pathogenic invasion, such as the gastrointestinal and respiratory tracts, contain a large population of leukocytes, maintaining constant surveillance.

Neutrophils are one type of leukocyte characterized by a lobed nucleus. They are avidly phagocytic for small particles and are numerous at sites of infections. They are major cellular component of pus.
Eosinophils: are characterized by lobed nuclei, but their cytoplasmic granules are larger, more spherical. These cells are phagocytic and have a special avidity for antigen-antibody complexes. They increase in number as a result of allergic or parasitic types of disease.

Lymphocytes: are characterized by a single, round, non-lobed nucleus. They are the smallest of the cells that migrate in to connective tissues. These cells form part of the immunologic defense system and may give rise to antibody-producing cells or elaborate non-specific factors that destroy foreign cells. Their number increase in areas of chronic inflammation.

Monocytes: are the blood-borne forerunners of tissue macrophages. Monocytes can fuse with one another to form multinucleated giant cells in an attempt to engulf objects that are too large or resistant to phagocytosis by a single cells.

5.4 Ground Substance (Matrix)

The fibers and cells of connective tissue are embedded in an amorphous material called **ground substances**. That is present as a transparent gel of variable viscosity. Tissue fluid is loosely associated with ground substance, thereby forming the medium for passage of molecules through out connective tissues and for the exchange of metabolites with the circulatory system. Ground substance consists of **glycoproteins**, **glycosaminoglycans**, and **proteoglycans** that differ in amount and type in different connective tissues.

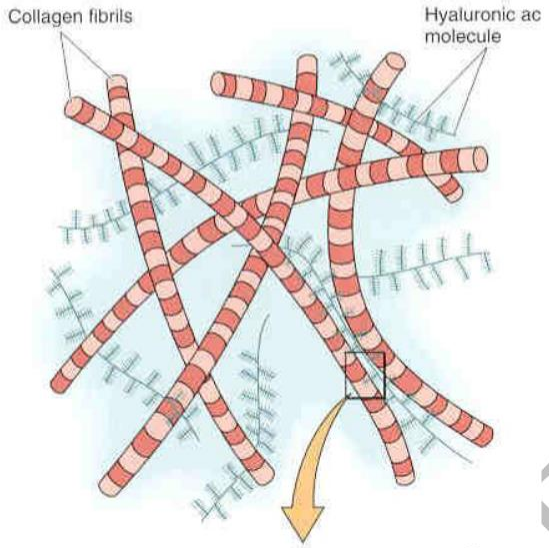


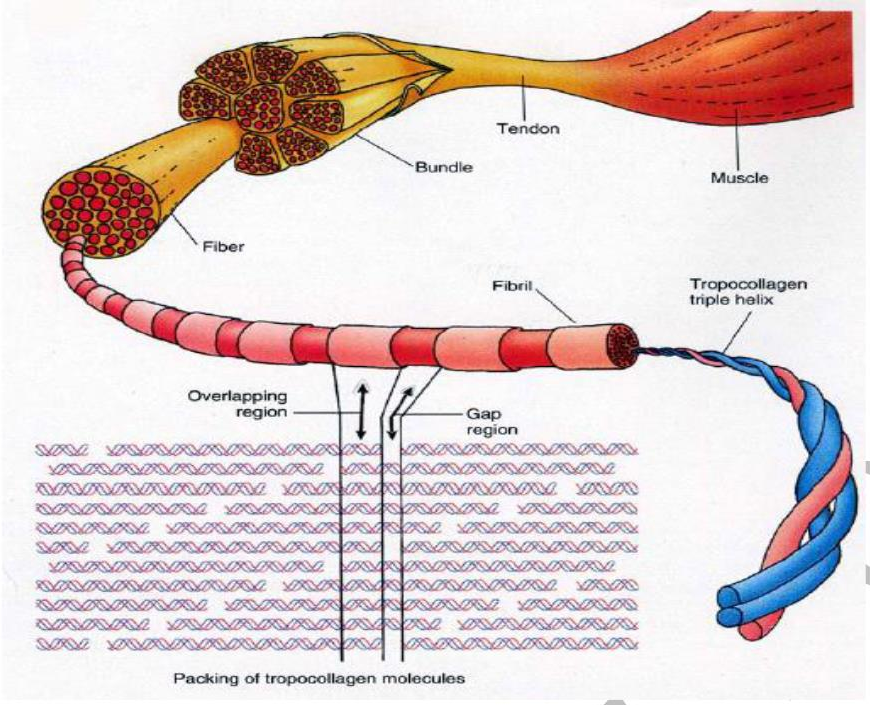
Fig. 5.2 Ground matrix

5.5 Fibers of connective tissue

The fibrous intercellular substances in connective tissue consists of collagen (including reticulin which was formerly considered a separate fiber type) and Elastic fibers.

5.5.1 Collagen fibers:

Collagen fibers are main fiber types present in all connective tissues and run an irregular course with much branching. Although flexible, collagenous fibers have extremely high tensile strength, the fibers vary in thickness and consist of parallel **fibrils**, each of which represents a structural unit. These unit fibrils are composed of macromolecules of **tropocollagen**. The tropocollagen molecules lie parallel to each other, overlapping by about one-fourth of their lengths, the overlap is responsible for the banding pattern.



Each molecule of tropocollagen consists of three polypeptide chains called **alpha units** arranged in a helix and linked by hydrogen bonds. In the extracellular matrix, the tropocollagen molecules polymerize to form collagen. Not all unit fibrils of the various collagens neither present a banded, fibrils appearance, nor are they arranged in a similar fashion. At least 19 different types of collagen have now been delineated on the basis of morphology, amino acid composition and physical properties.

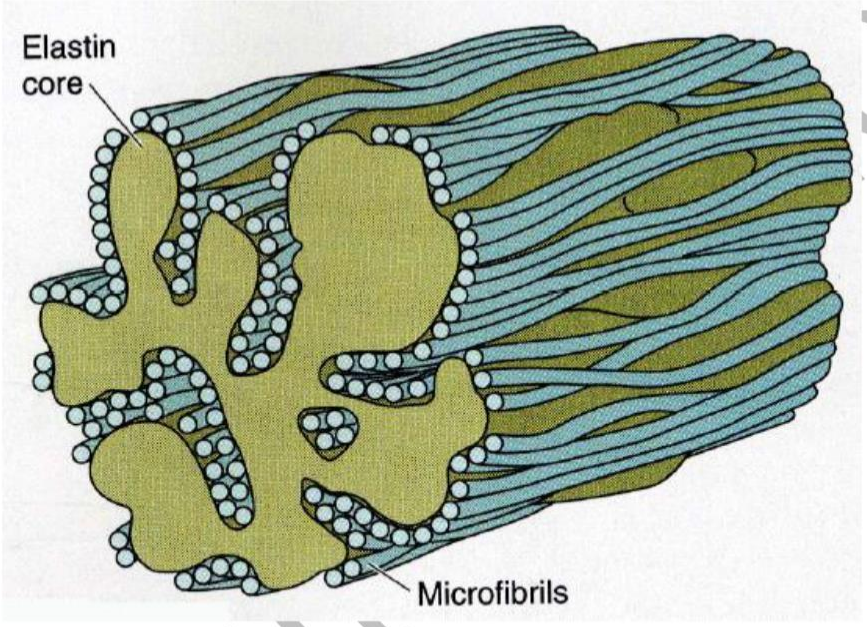
- **Type I collagen**: is found in fibrous connective tissue, the dermis of the skin, ligaments and bones, in a variable arrangement form loose to dense according to the mechanical support required.
- **Type II collagen**: is found in hyaline cartilage and consists of fine fibrils which are dispersed in the ground substance.
- **Type III collagen:** makes up the fiber type known as **reticulin** which was previously thought a separate fiber type because of its affinity for silver salts. Reticulin fibers form the delicate branched "**reticular**" supporting meshwork in highly cellular tissues such as the liver, bone marrow and lymphoid organs. Reticular fibers are not seen in routinely prepared sections but can be shown with silver stains or by the periodic acid-schiff (PAS) reagent.
- **Type V collagen**: forms anchoring fibrils that link to basement membrane, the remaining types of collagen are present in various specialized situations.

5.5.2 Elastic fibers (elastin)

Elastic fibers appear as thin, homogenous strands that are similar and more uniform size than collagen fibers. They cannot be distinguished in routine sections and require special stains to make them visible. Elastin is synthesized

by fibroblasts in a precursors form known as **tropoclastin**, which undergoes polymerization in the extracellular tissues.

In electron micrographs, elastic fibers are seen to consist of bundles of **microfibrils** embedded around an amorphous component called **elastin**. Their fibril consists of a non-sulfated glycoportein called **fibrillin.** Elastic fibers can stretch more than 130% of their original length, and their presence permits connective tissues to undergo considerable expansion or stretching with return to the original shape or size when the deforming force is removed. In addition to forming fibers, elastin may be present in fenestrated sheets as in some arterial walls. Elastin is present in large amounts in tissues such as lung, skin, urinary bladder and wall of blood vessels.



5.6 Structural Glycoproteins

Structural glycoproteins are a group of molecules composed principally of protein chains bound to branched polysaccharide. The structural glycoproteins include two fibril-forming molecules, **fibrillin,** and **fibronectin**, and a number of non-filamentous proteins including laminin, entactin and tenascin, which function as links between cells and extracellular matrix.

- **Fibrillin** is a constituent of elastic fibers where it appears to play role in the deposition of fibers and enhance adhesion between extracellular constituents.
- **Fibronectin** pays a part in controlling the deposition and orientation of collagen in extra cellular matrix and the binding of the cell to the extra cellular material. Cell membranes incorporate a group of transmemberane protein complexes called integrins, which act as cell adhesion molecules.

- **Laminin** is a major component of basement membranes, binding with specific cell adhesion molecules so as to form links between cell membranes %other constituents of the basement membrane.
- **Entactin** is non-fibrillary protein, which has the function of binding laminin to type IV collagen in basement membranes.
- **Tenascn** binds to integrins and is important in the embryo where it appears to be involved in control of nerve cell growth.

5.7 Basement Membranes

Basement membranes are sheet-like arrangements of extracellular matrix proteins, which act as an interface between the support tissues and parenchymal cells. They are associated with epithelial and muscle cells, as well as formining a limiting membrane around the central nervous system. In the context of muscle and nervous tissue the term **external lamina** may also be applied.

Epithelia in particular are almost entirely composed of closely packed cells with minimal intercellular material between them. The basement membrane provides structural support as well as binding the epithelium to the underlying connective tissue. Basement membrane is also involved in the control of epithelial growth and differentiation, forming an impenetrable barrier to down ward epithelial growth.

Epithelium is devoid of blood vessels and the basement membrane permit the flow of nutrients, metabolites and other molecules to and from the epithelium. In the kidney, the glomerular basement membrane is part of the highly selective filter for molecules passing from the bloodstream into the urine. Traditionally basement membranes were discovered as a unique epithelial structure, because of their critical association with epithelial structures and function but they are considered now as one of the connective tissues.

The main constituents of basement membranes and external laminae are the glycosaminoglycan (heparin sulphate), the fibrous protein (collagen type IV), and the structural glycoproteins (fibronectin, laminin and entactin). With the electron microscope, the basement membrane is seen to consist of three layers;

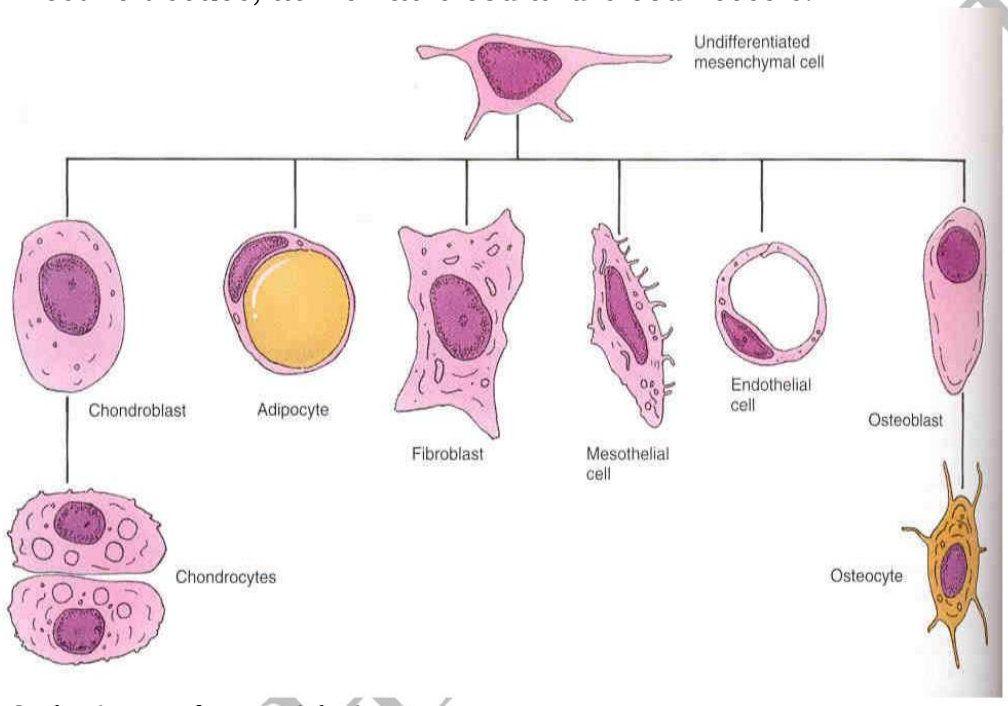
A. The lamina Lucida, electro lucent layer abuts the basal cell membrane of the parenchymal tissue;
B. The lamina densa, intermediate layer,
C. Lamina fibroreticularis broad, electrolucent layer beyond the lamina densa.

5.8 Loose Connective Tissue

5.8.1 Embryonic connective tissue

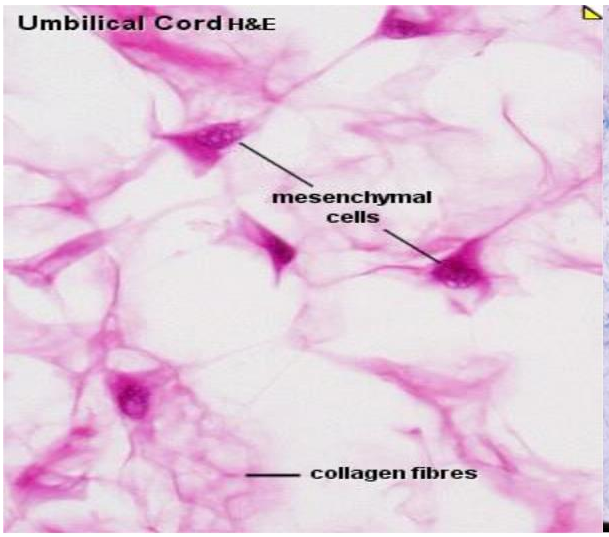
a. Mesenchyme

Mesenchyme is a loose, spongy tissue that serves as packing between the developing structures of the embryo. It consists of a loose network of state and spindle-shaped cells embedded in an amorphous ground substance with thin, sparse fibers. Mesenchyme cells undergo numerous mitotic cell divisions and continuously change their shape and location to adapt to the transformations that occur during embryonic growth. They can give rise to any of the adult connective tissues, as well as blood and blood vessels.

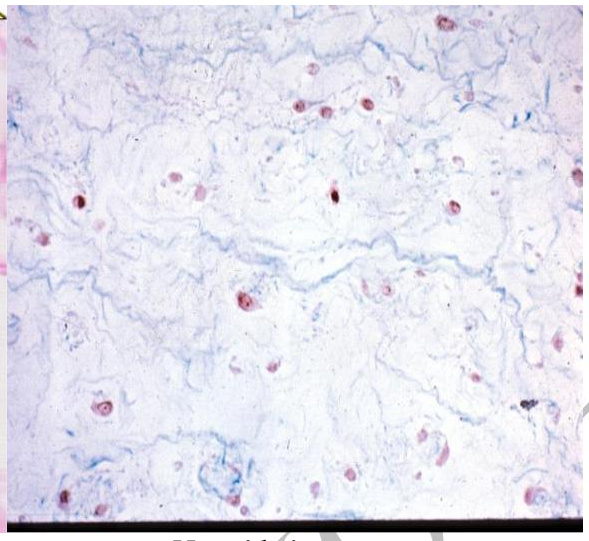


b. Gelatinous/Mucoid tissue

It occurs in many parts of the embryo but is particularly prominent in the embryonic hypodermis and umbical cord. It is characterized by stellate fibroblasts with long processes that make contact with those of neighboring cells, and the intercellular substance is soft and jelly-like and contains thin collagen fibers, In the adult animal, mucoid connective tissue occurs in the core of the papillae on the reticular folds, in the omasal laminae, in the bovine glans penis, and in the core of the rooster comb.



Mesenchymal tissue

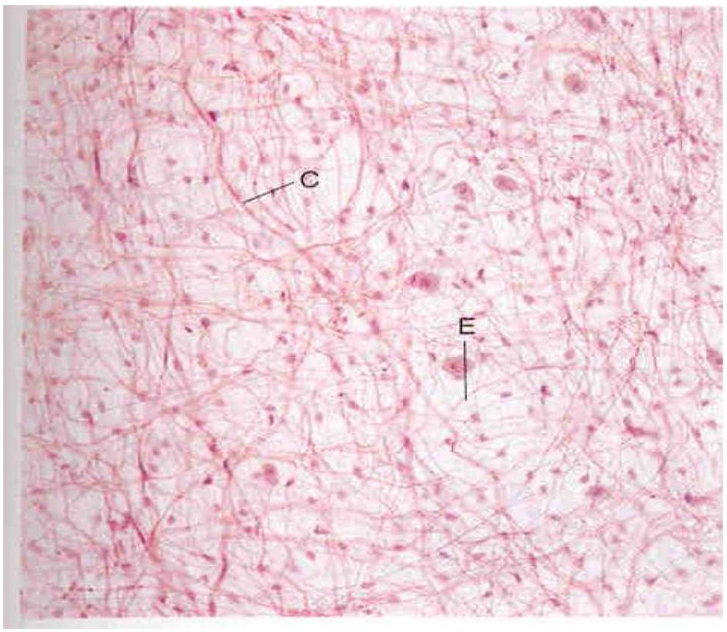


Mucoid tissue

5.8.2 Areolar/ Adult loose connective tissue

It is a loosely arranged connective tissue and is widely distributed in the adult animal. It contains collagen fibers and a few elastic fibers embedded in a thin, fluid-like ground substance. This kind of tissue forms the fascia that binds organs and organ components together. It forms helices about the long axes of expandable tubular structures such as the ducts of glands, the gastrointestinal tract, and blood vessels.

Loose connective tissue is present around blood vessels and nerves and between muscle bundles and the layers of smooth musculature of hollow organs. It is found beneath many epithelia, where it provides support and a vascular supply. Many important functions are carried out by loose connective tissue, that range from the purely mechanical, such as support to more sophisticated functions, such as tissue repair and defense activities (inflammation). Cells and ground substance is more abundant than fibers in loose connective tissue.

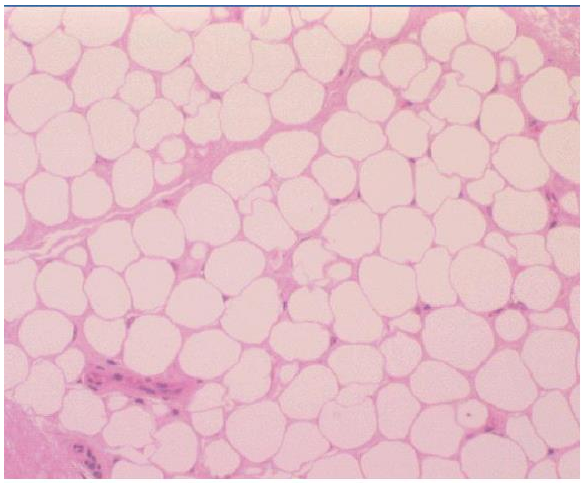


5.8.3 Adipose tissue

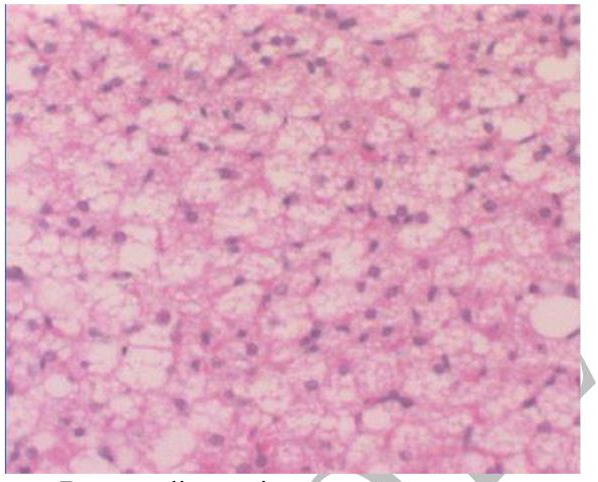
Adipose tissue differs from other connective tissue; Fat cells and not the intercellular substances predominated, and unlike other connective tissue cells, each fat cell is surrounded by its own basal lamina. Reticular and collagenous fibers also extend around each fat cell to provide a delicate supporting framework that contains numerous capillaries. In addition to performing insulating and mechanical functions, adipose tissue plays and important role in the metabolism of the organism. Two types of adipose tissue, **white** and **brown**, are distinguished in most mammals by differences in color, vascularity, structure and function.

White (unilocular) adipose tissue comprises up to 20-25% of total body weight in normal. It is distributed through out the body particularly in the deep layers of the skin. It acts as a thermal insulator under the skin and functions as a cushion against mechanical shock in such sites as around the kidneys.

Brown (multilocular) adipose tissue: is found in newborn mammals and some hibernating animals, where it plays an important part in body temperature regulation.



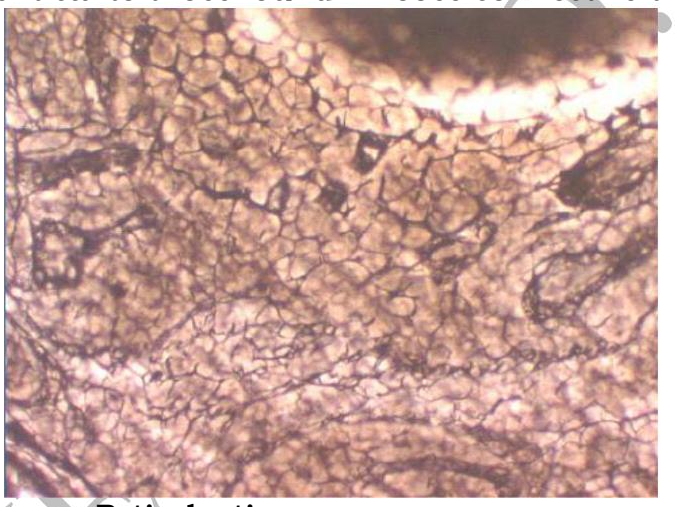
White adipose tissue



Brown adipose tissue

5.8.4 Reticular connective tissue

Reticular connective tissue is characterized by a cellular framework as seen in lymphatic tissues and bone marrow. Reticular cells are stellate, with processes extending along the reticular fibers to make contact with neighboring cells. The reticular cell is equivalent to the **fibroblast** of other connective tissues and is responsible for the production and maintenance of the reticular fibers, which are identical to those found in loose connective tissue.



Reticular tissue

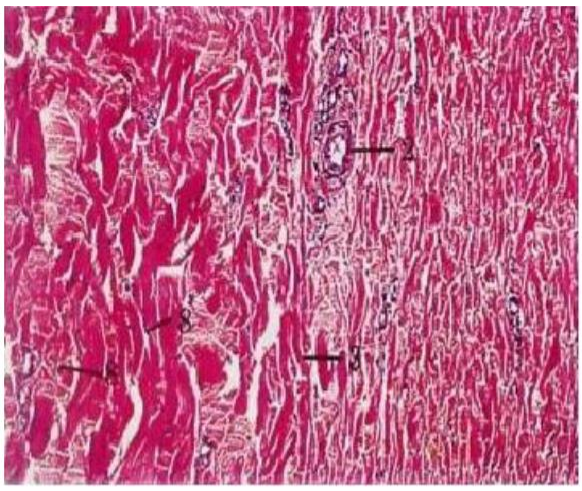
5.9 Dense Connective Tissue

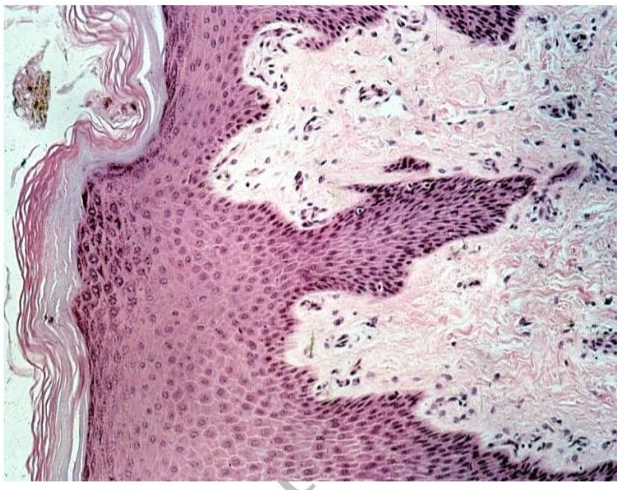
Dense connective tissue differs from loose connective tissue chiefly in the concentration of fibers and reduction of the cellular and amorphous ground substance. It is commonly classified into dense irregular and dense regular connective tissue.

5.9.1. Dense irregular connective tissue

It contains abundant, thick, collagenous bundles that are woven into a compact network. Among the collagen fibers is an extensive network of elastic

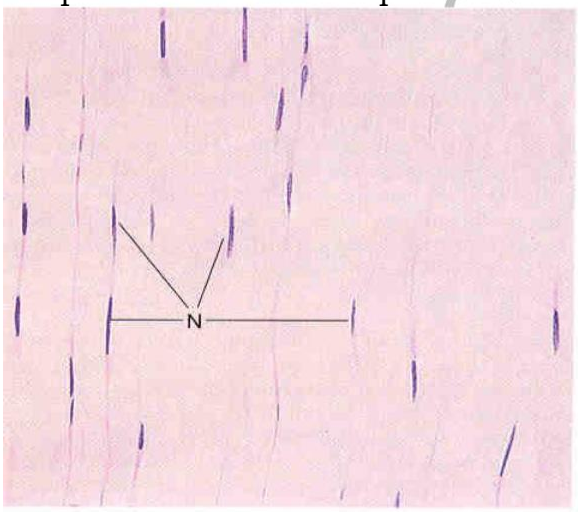
fibers. Dense irregular connective tissue is found in a variety of locations, such as the propria of the initial portions of the digestive system, the visceral pleura of the lung, the capsule of the various organs (spleen, liver, kidney, testis), fasciae, aponeuroses, joint capsules, pericardium, and dermis.

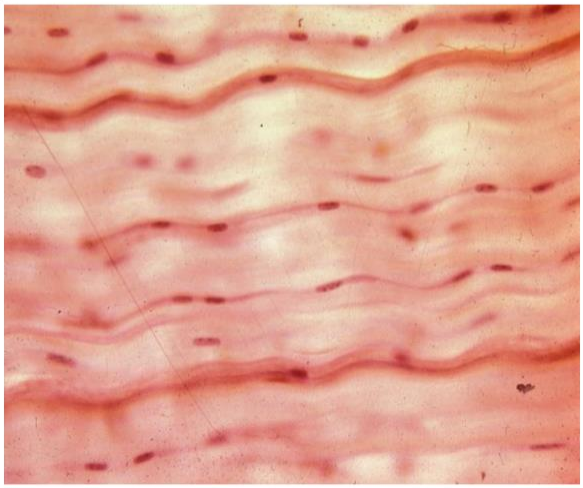




5.9.2 Dense regular connective tissue

It contains a predominance of collagen fibers arranged in bundles, but these have a regular, precise arrangement. The organization of the collagen bundles reflects the mechanical needs of tissue. Dense regular connective tissue occurs in two varieties, as collagen tendon and ligament and as elastic ligaments. In both types, the fibers are arranged in the same plane and direction, according to specific functional requirements.

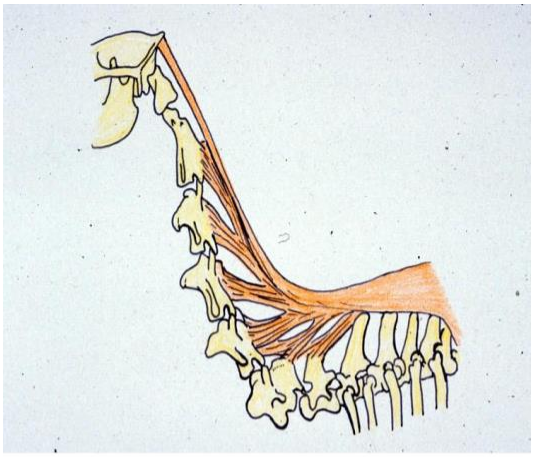




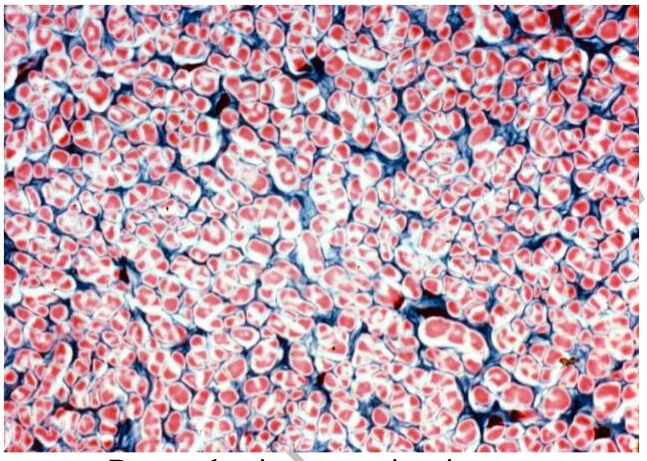
Dense regular connective tissue

Collagen tendons and ligaments: the great tensile strength of collagen tendons and ligaments is reflected in their structure. They consist of fascicles of parallels collagen fibers.

Elastic ligaments: branching and interconnected parallel elastic fibers surrounded by loose connective tissue make up elastic ligament. e.g ligamentum nuchae and elastic facial of the abdominal musculature of herbivores.



Nucheal elastic ligament



Dense elastic connective tissue

CHAPTER 6: SPECIAL CONNECTIVE TISSUE: SKELETAL TISSUES (CARTILAGE, BONE, AND JOINTS)

5.1 Cartilage

Cartilage is a semi-rigid form of supporting tissue. It contains the usual elements of connective tissue; cells, fibers and ground substances. proteoglycans, disposed in proteoglycan aggregates of 100 or more molecules, make up the ground substance and accounts for the solid, yet mixable, consistency of cartilage. sulphated glycosaminoglycans (chondroitin sulphate and keratin sulphate) predominate in the proteoglycan aggregates with molecules of the non-sulphated GAG, hyaluronic acid, forming the central backbone of the complex. The ground substance gives the cartilage its firm consistency and ability to withstand compression force. Collagen and elastic fibers embedded in the ground substance import tensile strength and elasticity.

The fibers and ground substance form the matrix. Cartilage differs from other connective tissues in that it lacks nerves, a blood supply, and lymphatic is nourished by diffusion of material from blood vessels in adjacent tissues. Based on differences in the abundance and type of fibers in the matrix; cartilage is classified into hyaline, elastic and fibrous cartilage.

5.1.1 Hyaline cartilage

Hyaline cartilage is the most common type that forms the costal cartilages, articular cartilage of joints and cartilage of the nose, larynx, trachea, and bronchi and the sternal ends of the ribs. It is also present in the growing ends of long bones. In the fetus, most of the skeleton is first laid down as hyaline cartilage. Cells of cartilage are called **chondroblasts/condrocytes** and reside in a small space called **lacunae** scattered in an amorphous matrix of ground substance reinforced by collagen fibers.

The collagen in hyaline cartilage rarely forms bundles but is present as a feltwork of slender fibrils. Collagen in cartilage appears to be less polymerized than in other tissues and only type II collagen is present. Except for the free surfaces of articular cartilages, hyaline cartilage is enclosed by a condensed sheath of connective tissue called **perichondrium** containing chondroblasts with cartilage forming potential, the outer layers of the perichondrium consists of well-vascularized, dense, irregular connective tissue that contains elastic and collagen fibers.

5.1.2 Elastic cartilage

Elastic cartilage contains branched elastic fibers in the matrix. Type II collagen fibers are present. Deep in the cartilage, elastic fibers form a dense, closely packed mesh that obscures the ground substance. The chondrocytes are similar to those of hyaline cartilage. Elastic cartilage is more flexible than hyaline cartilage and is found in the external ear, auditory tube, epiglottis, and smaller laryngeal cartilages.

5.1.3 Fibrous cartilage

Fibrous cartilage represents a transition between dense connective tissue and cartilage. It consists of alternating layers of hyaline cartilage matrix and thick layers of dense collagen fibers oriented in the direction of the functional stresses. It also consists of typical cartilage cells enclosed in lacunae, but only small amount of ground substance is present in the immediate vicinity of the cells. The chondrocytes lie singly, in pairs or in short rows between bundles of dense collagen fibers.

Fibrous cartilage lacks a perichondrium and merges into hyaline cartilage, bone or dense fibrous connective tissue. It is found in the intervertebral discs, some areticular cartilages, the symphasis pubis, and in association with dense collagenous tissue in joint capsules, ligaments and the connections of some tendons to bone.

5.1.4 Cartilage growth

Cartilage grows in two different ways. When we consider how a long bone develops and lengthens is that one of the ways in which cartilage grows is by interstitial growth.

- **Interstitial growth:** young chondrocytes embedded in cartilage matrix are able to divide and causes the cartilage matrix as a whole to expand from within called interstitial growth.
- **Appositional growth:** The other way in which cartilage grows is by having more matrix deposited on its surface. This growth depends on the formation of new matrix-secreting chondreoblasts at the cartilage surface.

5.1.5 Functions

Cartilage functions as a rigid yet light weigh and flexible supporting tissue. It forms the framework for the respiratory passages to prevent their collapse, provides smooth bearings at joints, and forms a cushion between the vertebrae, acting as a shock absorber for the spine. Cartilage is important in determining the size and shape of bones and provides the growing area in many bones. Its capacity for rapid growth while maintaining stiffness makes cartilage suitable for the embryonic skeleton. About 75% of the water in cartilage is bound to proteoglycans, and these compounds are important in the transport of fluids, electrolytes, and nutrients throughout the cartilage matrix.

5.2 Bone

Bone is a connective tissue specialized for support. It is composed of cells and predominantly collagenous extracellular matrix called **osteoid**. The matrix in the bone is mineralized and forms a dense and hard substance with high tensile, weight bearing, and compression strength. Despite its strength and rapidity, bone is a dynamic, living tissue constantly turning over, being renewed and reformed through out life.

5.2.1 Structure

Grossly, cancellous and compact forms of bone can be identified. **Cancellous (spongy) bone** consists of irregular bars or trabeculae of bone that branch and unite to form an interlacing network of bony rods, delimiting a vast system of small communicating spaces that in life are filled with bone marrow. **Compact (dense) bone** appears as a solid, continuous mass in which spaces cannot be seen with the naked eye. The two types of bone are not sharply delimited and merge into one another.

Except the articular surfaces and where tendons and ligaments insert, bone is covered by fibroblastic connective tissue called **periosteum**. The marrow cavity of the diaphysis (shaft) and the spaces with in spongy bone are lined by **endosteum**.

A fundamental characteristic of bone is the arrangement of its mineralized matrix into layers or plates called **lamellae.** Small ovoid, spaces, the **lacunae**, occur uniformly within and between the lamellae, each occupied by a single

bone cell or osteocyte. Slender tubules called **canaliculi** radiate from each lacuna and penetrate the lamellae to link up with the canaliculi of adjacent lacunae.

In compact bone, osteons or haversian systems make up the structural units of bone. Osteons consist of 8-15 concentric lamellae that surround a wide space occupied by blood vessels. In immature animals, the medullary cavities of most bones contain active (red) marrow, responsible for the production of the cellular elements of blood. **Interstitial lamellae** appear as angular, irregular bundles of lamellar bone that fill the spaces between osteons.

The outer and inner **circumferential lamellae** are present at the external surface the bone, beneath the periosteum and on the inner surface, just beneath the endosteum, respectively. The longitudinally oriented neurovascular channels at he center of osteons are the Haversian canals. They communicate with one another by oblique branches and transverse connections called **volkmann's canals** that penetrate the bone form the endosteal and periosteal surfaces. Spongy bone also shows a lamellar structure but differs from compact bone in that it is not traversed by blood vessels. Therefore, osteons are rare or lack the irregular rods of lamellar bone.

5.2.2 Cells of bone

Osteoblasts: are bone-forming cells, which synthesize osteoid and mediate its mineralization. They are found lined up along bone surfaces.

Osteocytes: are the chief cells found in mature bone and take the shape of the lacunae in which they are housed, they may assist in nutrition of bone. dsteocytes are also responsible for maintaing bone. Plays an active role in regulating calcium concentration in the body fluids, and is implicated in the resorption of bone.

Osteoclasts: are phagocytic cells which are capable of eroding bone and which are important, along with osteoblasts, in the constant turn over and refashioning of bone. They are large, multinucleated gaint cells; often lie within shallow depressions (how ship's lacunae) along the surface of the bone.

Ostcoblasts and osteocytes are derived form a primitive mesenchymal cell called **osteoprogenitor cell**. Osteoclasts are derived form the macrophage-monocyte cell line.

5.2.3 Bone matrix and mineralisation

Bone matrix forms the bulk of bone and consists of collagen, ground substance, and inorganic components. Mature compact bone is made up of about 70% inorganic salts and 30 % organic matrix by weight. The ground substance contains proteoglycans similar to that of cartilage but in a lesser

concentration and mainly consists of chondroitin sulphate and hyluronic acid. The ground substance controls the water content of bone and probably involved in regulating formation of collagen fibers in a form appropriate for subsequent matrix mineralization.

Collagen fiber makes up over 90% of the organic component. The non-collagen organic material includes osteoclacin, involved in binding calcium salts during mineralisation process, osteonectin that may serve in binding bone cells to the matrix.

The **inorganic component** is responsible for the rigidity of bone and consists of calcium phosphate and carbonate with small amounts of calcium and magnesium fluoride. The minerals are present as crystals with a hydroxyapatite structure and are present on and within the collagen at regular intervals along the fibers.

5.2.4 Bone development and growth

The fetal development of bone accurse in two ways, both of which involve replacement of primitive collagenous supporting tissue by bone. The two types of bone development are **intramembranous** and **endochondral**. The bones of the vault of skull, the maxilla and most of the mandible are formed by the deposition of bone is known as **intramembranous ossification** and the bones so formed are called **membrane bones**.

The long bones, vertebrae, pelvis and bones of the base of the skull are preceded by the formation of a continuously growing cartilage model which is progressively replaced by bone; this process is called **endochondral ossification** and the bones formed are called **cartilage bones.**

Bone can grow only by an appositional mechanism. Interstitial growth, as in cartilage, is impossible in bone because the presence of live salts in the matrix prevents expansion within the interior. Bone development in controlled by growth hormone, thyroid and sex hormones.

5.2.5 Functions

Bone forms the principal tissue of support and is capable of bearing great weight. It provides attachment for muscles of locomotion, carries the joints, serves as a covering to protect vital organs, and houses the hemopoietic tissue. Bone is the major store house of calcium and phosphorous in the body.

5.3 Joints

The sites where two or more components of the skeleton, whether bone or cartilage, meet are referred to as joints, or articulations. They may be either temporary or permanent. Temporary joints occur during the period of growth;

for instance, the epiphysis of a long bone is united to the bone of the shaft by hyaline cartilage of the epiphyseal disc. Such a joint disappears which growth ceases and the epiphysis fuses with the shaft. Most joints are permanent and they are classified on the basis of their structural features as fibrous, cartilaginous, or synovial.

5.3.1 Fibrous joints

Fibrous joints are those held together by dense fibrous connective tissue and permit little or no movement. **Sutures** are immovable fibrous joints found in the skull. They are temporary joints; with aging the fibrous connective tissue gradually is replaced by bone to form a permanent bony union (synostosis). The adjoining edges of the bones are highly irregular and interlock to create a firm union.

A **syndesmosis**, occurs at the interior tibiofebular joint, contains much more connective tissue that does a suture, allowing some what more movement. The third type of fibrous joint is the **gomphosis**, a peg-and-socket joint restricted to fixation of the teeth in to the jaws.

5.3.2 Cartilaginous joints

Cartilaginous joints are present when bones are united by a continuous plate of hyaline cartilage or a disc of fibro-cartilage. The hyaline cartilage of an **epiphyseal plate** forms a temporary joint uniting the shaft and epiphysis of a long bone during its development, such immovable joint called **synchondrosis** (primary joint).

Permanent or secondary joints are represented by **symphyses**, unions between the pubic bones (pubic symphysis) and between the vertebral bodies. The thin layer of hyaline cartilage that covered the articulating surfaces are joined to a central disc of fibrous cartilage. In the spine, specialized dieses of fibrous cartilage form the intervertebral discs, connections between adjacent vertebral bodies.

5.3.3 Synovial joints

In synovial joints, the participating bones are held together by an **articular capsule** and their opposed surface, covered with **articular cartilage**, are separated by an arrow interval containing synovial fluid. synovial joints are known as **diarthroses**. Synovial joints are complex, freely mobile joints capable of a wide range of motion. Most of the joints of the limbs are synovial joints.

Most of the joints of the limbs are synovial joints; the bones involved in the joint are contained within and linked by a **capsule** of dense over the articulating bones. The articular cartilages that covered the opposing bony surfaces provide low-friction gliding surfaces.

A synovial membrane that elaborates the lubricating synovial fluid lines the inner surface of the capsule. An **articular disc** may be imposed completely or partially between the articular surfaces, a partial disc is called a **meniscus**. Discs and meniscus are connected to the capsule and consists of fibrous cartilage.

Articular cartilages usually are hyaline in type although the matrixes contain abundant collagen fibers. They lack a perichondurim, and joint contact is made between the free, uncovered surfaces of the opposing cartilages. The deepest layer of the articular cartilage is calcified and firmly adherent to the underlying bone. Articular cartilage possesses no nerve fibers of blood vessels.

Sandoval membrane is a loose-textured, highly vascular connective tissue that lives the fibrous capsule and extends on to all intra articular surfaces. The articular cartilages, articular discs and meniscus are not covered by synovial membranes, The free surface of the synovial membrane consists of one to three layers of flattened synovial cells embedded in a granular, fiber free matrix. The synovial membrane is responsible for the production of synovial fluid. This fluid is viscous and acts as a lubricant and contributes to the nutrition of the articular cartilage.

5.4 Repair of cartilage and bone

5.4.1 Cartilage

The ability to regenerate an area of cartilage that has been lost or damaged is limited due to poor vascularity. Damaged regions of cartilage become necrotic and filled in by connective tissue from the perichondrium. Some of the connective tissue may slowly differentiate into cartilage, but most remains as dense irregular connective tissue that may later calcify or even ossify.

5.4.2 Bone

The size of the bone, the thickness of its compact bone, and the complexity of the fracture influence repair of a broken bone. After a fracture there is hemorrhage from ruptured blood vessels and clotting. Proliferating fibroblasts and capillaries invade the clot and form granulation tissue. The granulation tissue becomes dense fibrous tissue and later transforms in to a mass of cartilage that unites the fractured bones. Osteoblasts develop from the periosteum and endosteum and lay down spongy bone that progressively replaces the cartilage in a manner similar to endochondral ossification. Bony union of the fracture is achieved. The spongy bone undergoes reorganization into compact bone and excess bone is reabsorbed.

CHAPTER 7: SPECIAL CONNECTIVE TISSUE: BLOOD AND HAEMOPOIESIS

7.1 Components of Blood

Blood is defined as a special connective tissue, in which the extracellular substance is a fluid. Blood is a fluid tissue that circulates through vascular channels to carry nutrients to the cells and waste products to the excretory organs. The total volume of circulating blood is kept remarkably constant and is expressed relative to body weight (% or ml/kg). The blood volume of large domestic animals is about 8-11% and that of common laboratory animals, from mice to monkeys, is approximately 6-7% of their body weights.

Blood consists of a cellular component, the blood cells, and a protein rich fluid components, the plasma, the cellular component contains erythrocytes (red blood cells), thrombocytes (platelets), and leukocytes (white blood cells). The leukocytes in the blood of most vertebrates are five types; neutrophils, lymphocytes, monocytes, eosinophils, and basophils. The blood plasma contains 91.92 % water and 8-9% solutes (e.g. proteins, lipids, electrolytes).

Centrifuged or settled blood consists of three distinct layers. The layer, about 45 % of the blood volume, is red, consists of erythrocytes, and is called the **packed-cell volume** (PCV) or hematocrit. A thin gray-white middle layer, the buffy coat, lies above the erythrocytes and accounts for above 1% of the blood volume. The buffy coat is composed of platelets and leukocytes. The uppermost layer of centrifuged blood is the plasma, which contains proteins; albumin, globulin, and fibrinogen, serum is obtained from clotted or defibrinated blood and does not contain fibrinogen.

7.2 Structure of Blood Cells

7.2.1 Erythrocytes (Red blood cells)

Mature erythrocytes are non-nucleated biconcave discs; the degree of concavity varies among the domestic animals, typical biconcave erythrocytes are present in the dog, cow, and sheep; those in the horse and cat have a shallow concavity; and most of the erythrocytes of the goat and pig are flat. The mature erythrocyte has a central place area surrounded by orange (hemoglobinized) cytoplasm, the central pallor of erythrocytes is visible in the dog, less evident in cat and horse, and absent in the cow, sheep, goat and pig.

The size and number of erythrocytes vary among the animal species. The smaller the red cell, the greater the umber per unit volume of blood, the dog has the largest erythrocyte (7.0 Nm) and the goat has the smallest (4.1 Nm). Slight **anisocytosis** (variation in size) of erythrocytes is common among animal species, where as **poikilocytosis** (Variation in shape) is normally present in the goat and deer. Spindle, pear, rod, and triangular-shaped erythrocytes are seen in the goat. Erythrocytes of camel have a characteristic elliptic shape.

Erythrocytes adhere to each other and form chains, known as rouleau formation, is prominent in horse and cat blood, intermediate in dog and pig blood, and rare in blood of ruminants. Howell-jolly bodies and reticulocytes are seen in the dog and cat, but not present in horse and ruminants. Howell-jolly bodies are small, round, pyknotic, duphy basophilic DNA fragments with in erythrocytes and are derived from nuclear karyorrhexis. Reticulocytes are immature erythrocytes that appear polychromatic (pinkish-blue color) on wrights stained blood film. The erythrocytes are highly adapted for their principal function of oxygen and carbon dioxide transport.

7.2.2 Leukocytes (white blood cells)

In the blood for fewer leukocytes than are present erythrocytes. Based on the presence and type of granule in their cytoplasm and the shape of the nucleus, leukocytes are classified into two groups:

1. granulocytes (polymorphonuclear luckocytes); consisting of neutrophils, eosinophls, and basophiles
2. argranulocytes (mononuclear leukocytes), consisting of lymphocytes and monocytes.

Granulocytes have nucleic with two or more lobes, and they are named according to the staining characteristics of their specific cytoplasmic granules.

The eosinophils have pronounced acidophilic granules, basophils possers distinct basophilic granules, and neutrophils have neutral granule.

The proportion of different types of leukocytes varies among the animal species. Neutrophils predominate in the dog and cat, where as they exceed lymphocytes in horse. In ruminants and laboratory animals' lymphocytes are predominant. All granulocytes have a life span of a few days, dying by **apoptosis** (programmed cell death) in the connective tissue.

Agranulocytes don not have specific granules, but spherical cells. Leukocytes leave the capillaries by passing between endothelial cells and penetrating the connective tissue by means of a process called **diapedesis.** Diapedesis is increase in individuals infected by micro-organisms. The number of leukocytes in the blood varies according to age, sex, and physiologic conditions.

a. Neutrophils

Neutrophils constitute 40-75% circulating leukocytes. Mature neutrophils are 12-15 mm in diameter, with a nucleus consisting of 2-5 lobes linked by fine threads of chromatin. The cytoplasm is pale grayish blue and contains a moderate number of fine pinkish or pale granules, depending of the animal species. The immature neutrophil (band form (has a non segmented nucleus in the shape of a horse-shoe. The immature neutrophlis are normally restricted to the bone marrow but they may be release into the blood during the granulocytic response to a disease process.

Being highly motile and phagocytic, the principal function of neutrophils is in the acute inflammatory response to tissue injury where they ingest and destroy damaged tissue and invading microorganisms, particularly bacteria.

b. Eosinophils:
Eosinophils are far less numerous than neutrophils, constituting only 2-8% leukocytes in normal blood. They are 10-15 Nm in diameter and contains a characteristic bilobed nucleus or less dense and segmented than those of neutrophils. The size, shape, number, and staining characteristics of eosinophils vary among different species. Eosinophils of the sheep, goat, cow and pig have numerous, uniform, spherical granules that stain bright arrange and nearly fill the cell. The eosinoplils of the horse have the largest granules, stain bright orange, have a mulberry-like appearance, and fill the cell completely.

Eosinophils remain in the bone marrow for several days after production, and the majority enters the skin, pulmonary or gastro-intestinal mucosa from which they may migrate into local secretions. Their principal function is defense against parasites. Increased number of eosinophils in blood (eosinophilia) is associated with allergic reactions and helmlinthic (parasitic) infection.

c. Basophils
Basophils are rare in normal blood and account for 0-1.5% of the total leukocyte count. They are about 10-15 Nm in diameter and have a less heterochromatic nucleus than do other granulocytes. The nucleus is divided into irregular lobes, but the overlaying specific granules usually obscure the division. The size, number and staining reaction of granules vary among animal species. Basophilic specific granules contain heparin and histamine which secret substance that cause contraction of smooth muscle.

There is some similarity between granules of basophils and those of mast cells. Both cells can liberate their granule content in response to certain antigens. Despite the similarities they are not the same and originate from different stem cells in the bone marrow.

d. Lymphocytes

The number of circulating lymphocytes varies among the species, of the total leukocyte count. Lymphocytes account for 20-40% in ruminants, mice and rats, and 50-60% in pigs. Morphologically, lymphocytes are classified as small (6-9Nm) and large (9-15Nm) lymphocytes. Lymphocytes are the smallest cells in the white cell series, being slightly larger than erythrocytes. They are the second most common leukocytes in circulating blood; increased numbers are commonly seen during viral infections. Lymphocytes are characterized by a round, densely stained nucleus and small amount of pale basophils, non-granular cytoplasm. Small lymphocytes are present in the cow, sheep, and goat. Large lymphocytes represent activated B-lymphocyte en route to the tissues where they will become antibody secreting plasma cells, lymphocytes are the only leukocytes that return form the tissue back to the blood, after diapedesis,

e. Monocytes

Monocytes are the largest of the leukocytes (12-20 Nm diameter), and account for 3-8% of the total leukocyte count. They have a highly pleomorphic nucleus. The nucleus is oval, horse-shoe or kidney-shaped, eccentrically place, which is stained less intensely than that of other luckocytes. The chromatin is less condensed and has more fibrillar arrangement than lympholytes. The cytoplasm of monocyte is basophilic and contains very fine azurophilic granules (lysosomes), a bluish-gray color in stained smears.

Blood monocytes are precursor cells of the macrophages, large phagocytic cells of various types found in peripheral tissues and lymphoid organs. After crossing capillary walls and entering monocyte-macrophage system, consists of the circulating monocytes, their bone marrow precursors, and tissue macrophages both free and fixed (histocytes). The kupffer cells of the liver, microglia of the CNS, langerhans cells of the skin, antigen-presenting cells of the lymphoid organs and the osteoclasts of bone are included in the system.

7.2.3 Platelets (thrombocytes)

Blood platelets are non–nucleated, disc-like cell fragments, round or long bodies, 2-4Nm in diameter, with a pale-blue cytoplasm containing a cluster of reddish-purple (azurophlic) granules. Platelets originate from giant polyploid megakaryocytes that reside in the bone marrow. In stained blood smears, platelets often appear in clumps. Platelets promote blood clotting and help repair gaps in walls of blood vessels, preventing loss of blood.

Firstly, they form plugs to occlude sites of vascular damage by adhering to collagenous tissue at the margin of the wound: later the platelets plug is replaced by fibrin.

Secondly, they promote clot formation by providing a surface for the assembly of coagulation protein complexes that are responsible for thrombin generation.

Thirdly, platelets secrete factors that are involved in vascular repair.

7.3 Haemopoiesis

Haemopoiesis is the process by which mature blood cells develop form precursor cells. Bone marrow is the primary production site for all blood-cell lines in adult animals. Sustained haemopoietic activity depends on the ability of the marrow to attract and hold a pool of stem cells that are capable of differentiating into a variety of blood-cell types. The red marrow is haemopoietically active.

7.3.1 **Prenatal haemopoiesis**

Hemopoiesis begins in mammals in the wall of yolk sac (mesoderm) during intrauterine life. Later during development of the embryo, the hemopoietic cells migrate to the liver. Subsequently, the bone marrow, spleen, lymph nodes, and thymus of the embryo are seeded with haemopoietic, stem cells from the liver and become engaged in haemopoiesis.

7.3.2 **Postnatal hematopoiesis**

Bone marrow is the major site of haemopoiesis during late gestation and at parturition. Extramedullary (out side marrow) haemopeiesis persists in the liver and spleen for a few weeks after birth and gradually disappears. Early in life, all the bone marrow is hemaopeietically active and produces all blood cell lines. In adult animals, only the sternum, vertebrae, ribs, skull, and liver is progressively dominated by fat cells, so that in mature mammals much of the marrow is inactive and yellow in color, filled with fat cells,

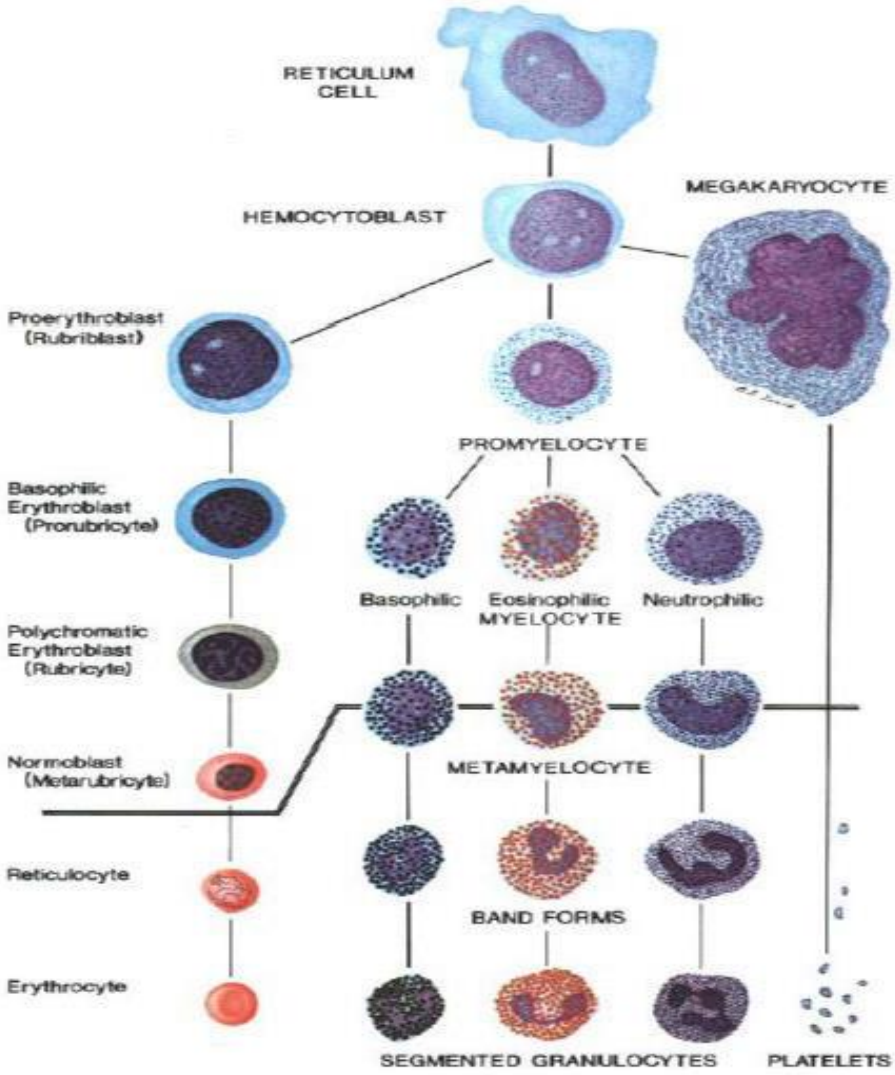
Bone marrow consists of a meshwork of vascular sinuses and highly branched fibroblasts with the interstices packed with haemopoietic cells. The production of blood cells by the bone marrow is estimated daily out put of about 2.5 billion erythrocytes, a comparable numbers of platelets, 50-100 billion granulocytes as well as large numbers of monocytes and immunologically naive lymphocytes. In addition to hemopoietic function, the bone marrow, along with the spleen and liver, is one of the major sites of removal of aged and defective erythrocytes from the circulation. Blood cells are produced in the hemopieotic compartment and reach the blood stream by crossing the wall of vascular sinuses.

7.3.3 **Bone marrow**

Bone marrow contains several types of self-replicating stem cells with different proliferating capacity. Stem cells are generally in a resting phase, but they proliferate and give rise to progenies that are capable of producing lymphocytes (lymphoid stem cells) and the other blood cells (myeloid stem cells).

The progenies of multipotent stem cells differentiate in to unipotent stem cells, each committed irreversibly to a specific cell lineage, such as erythrocytic, granulocytic, eosinophilic, and megakaryocytic cell lines.

Local microenvironment and humeral factors influence hemopoiesis and stimulate or suppress the proliferation and differentiation of single or multiple cells lineages.



7.3.4 **Erythropoiesis /red cell formation/**

Erythropoiesis is defined as the developmental process that leads to the formation of mature erythrocytes. The mass of circulating erythrocytes and marrow erythropoietic tissue is called the erythron. The first recognizable erythrocyte precursor is known as the **proerythroblast**, a large cell with numerous cytoplamic organelles and no haemoglobin.

Further stages of differentiation are characterized by decreasing cell size, progressive loss of organelles, and progressive increase in the cytoplasm

hemoglobin content. Hemoglobin synthesis begins during the early normoblast stage and is complete by the end of the reticulocyte stage. Cell division ceases with the early normoblast stage, after which the nucleus progressively condenses and is finally extruded at the late normoblast stage.

The process of erythropoiesis from stem cell to erythrocytes takes about one week. The rate of erythropoiesis is controlled by the hormon erythropotin secreted by the kidney and by the availability of red cell components particularly iron, folic acid, and vitamin B12 and protein precursors.

7.3.5 **Granulopoiesis /Granulocytes formation**

The maturational process that leads to production of mature granular leukocytes is called granulocytopoiesis. During this process the cells accumulate granules and the nucleus becomes flattened and indented, finally assuming the lobulated form seen in the mature cell. The stages commonly identified are myeloblast, promyelocyte, myelocyte, metamyelocyte, band form, and polymorphonuclear or segmented granulocytes.

The myeloblast is the earliest recognizable stage in granulopoiesis. Myeloblasts give rise to promyelocytes, which are characterized by the development of azurophilic granules (primary granules). The next stage in differentiation is the myelocyte, which is marked by the development of specific granules, the process continuing through a further three cell divisions. From the myelocyte state through the Metamyelocyte stage to the mature granulocyte forms, the nucleus becomes increasingly segmented.

The immediate precursors of mature granulocytes tend to have an irregular horse-shoe or sometimes ring-shaped nucleus and are termed **stab cells** or **band forms**.

On reaching maturity, neutrophils enter the bloodstream where some appear to become adherent to the endothelial walls of small vessels (marginated poll) entering the circulating pool in response to exercise and stress' exist from the circulation appears to occur in a random manner. The bone marrow contains a huge pool of stored neutropils which can be rapidly mobilized should the need arise. corticosteroids increase the rate of release from the bone marrow and reduce the rate of exit form the circulation.

7.3.6 Lymphopoiesis/lymphocyte formation

Only two precursor stages, the lymphoblast and the prohymphocyte, are recognizable in the development of lymphocytes, the main feature of lymphopoiestis is a progressive diminution in cell size. Unlike other blood cell types, lymphocytes also proliferate outside the bone marrow. This occurs in the tissues of the immune system (thymus and peripheral lymphoid organs splean, lymphnodes, tonsils, etc.)

7.3.7 Monopoiesis (Monocyte formation)

There is considerable evidence that monocytes and granulocytes have a common progenitor, the granulocyte-monocyte colony forming unit (CFU-GH) and that growth of colonies requires the presence of colony stimulating factors (csf) with functions analogous to that of erythroprotien in erythrpoiesis.

Two morphological precursors of moncocytes are recognized, monoblasts and promonocytes, with at least their cell divisions occurring before the mature monocyte stage is reached. Monopoiesis is characterized by reduction in a cell size and progressive indentation of the nucleus. Mature monocytes leave the bone marrow soon after their formation and there is no reserve pool as for neutrophils. Monocytes spend and overage of three days in the circulation before migrating by diapedesis in to the tissues in an apparently random fashion after which they are unable to re-enter the circulation.

7.3.8 Thrombopoiesis (platelet formation)

In adult animals, platelets originate in the red bone marrow by fragmentation of the cytoplasm of mature megakaryocytes (Gr. Mega=big and karyon=nucleus), which in turn, arise by differentiation of megakargyoblasts.

Megakaryocytes have a large irregular, multilobular nucleus containing clumbed-dispersed chromatin and devoid of nucleoli. The cytoplasm is filled with fine basophilic granules reflecting the profusion of cytoplasmic organelles.

The precursor of the megakaryocyte in the bone marrow is the mega karyoblast withch undergoes as many as seven reduplications of nuclear and cytoplasmic constituents with out cell division (endomitosis), each associated with increasing ploidy, nuclear lobulation and cell size.

Cytoplasmic maturation involves the elaboration of granules, vesicles and demarcation membranes and progressive loss of free ribosomes and rough endoplasmic reticulum.

Plateletes are formed by fragmentation of the megakaryocyte cytoplasm with the release of demarcated platelet fields; like platelets, they are very uneven in size. Mature megakaryocytes appear to enter the bone marrow sinusoids intact and pass to the pulmonary vascular bed where they fragment into platelets.

7.4 Functions of peripheral blood

Blood is important in the transport of materials through out the body, maintaining the acid base balance, and providing defense mechanisms. Transport functions include carriage of oxygen to all cells of the body, transport of nutrients, and removal of waste products of cell metabolism. Blood aids in regulating body temperature by dissipating heal-formed during metabolism and

distributes hormones, thus integrating the functions of the endocrine system. Through its buffering capacities blood helps maintain the acid-base balance and ensures and environment in which cells may function normally.

Transport of oxygen and carbon dioxide is a function of erythrocytes and their hemoglobin. The red cell plasma membrane provides mechanical protection as well as enzymes, which prevent irreversible oxidation of hemoglobin. The absence of a nucleus allows for a smaller cell and a more efficient distribution of hemoglobin with in the cell. The biconcave shape gives hemoglobin optimal accurse to the surface for gas exchange and allows the cell to under to increase in volume with out rupturing. An iron in the hemoglobin serves as the binding site for oxygen molecules.

Platelets have diverse functions concerned with maintaining the integrity of the blood vasculature. They can cover and temporarily plug small gaps in blood vessels. They play role in blood clotting, releasing factors that initiate the clotting process; they are necessary for clot retraction, which results in a firm, dense clot and reduces its bulk to prevent obstruction of the vessel.

Neutrophils are phagocytic and part of the first line of defense against bacterial infections. Azurophilic granules (lysosomes) are associated with phagocytosis for digestion of the ingested material. The cells also contains lysozyme, which hydrolyzes glycosides in bacterial cell walls, and peroxides, which complexes with hydrogen peroxide to release activated oxygen, and antibacterial agent hydrolyzes glycosides in bacterial cell walls, and peroxides, which complexes with hydrogen peroxide to release activated oxygen, and antibacterial agent.

Eosinophils have a special affinity for antigen-antibody complexes that bind complement and induce cell lysis. Enzymes such as histaminase released by eosinophils may dampen allergic responses by degrading histamine released from mast cells and basophils. Eosinophils have a major role in controlling parasitic infections. Eosinophils selectively interact with the larvae of some helminthic parasites and damage them by oxidative mechanisms.

Basophil granules have a high content of heparin (an anticoagulant), histamine, vasodilating agents, and slow-reacting substances (SRS). Histamine induces vasodilatation that increases vascular permeability. Basophils play a role in acute systemic allergic reactions; antigens that bind to specific sites on cell membrane cause degranulation with release of agents that cause smooth muscle spasm, mucous secretion, itching and rhinitis.

Lymphocytes are concerned primarily with the two major types of immune responses, humoral and cellular. The basis of humoral immunity is the production of antibodies and their diffusion through out the body fluids. As an antigen enters the body, it is complexed on the surface of B-cells. The antigen

is internalized and trigger's cell proliferation and the differentiation of the lymphocytes in to antibody-producing cells.

Cellular immunity depends on T-cells. In response to an antigen cells proliferate and release a variety of lymphokines that may inhibit macrophage migration from the site of the antigen, increase the activity of macrophages, interfere with virus replication, or lyse bacterial walls, T-cells recognize the antigen as foreign and concentrate it on their surfaces for before presenting it to B-cell,

Monocytes leave the blood and differentiate into tissue macrophages, they serve as tissue scavengers, ingesting and removing particulate matter, tissue debris, and infective agents and play a role in the immune response. Macrphages liberate antiviral agents and a number of enzymes that digest collagen, elastin, and fibrin.

The function of haemopoietic tissues is to provide blood with continuous replacement of cells. It provides the blood with small cells that can more easily circulate through fine capillary beds.

CHAPTER 8: MUSCLE

8.1 Introduction

Muscle is the basic tissue in which the property of contractility is preeminent. The purpose full movements of the body and the maintenance of posture are the result of contractions of muscles attached to the skeleton. Muscular

contraction is responsible for beating of the heart, breathing, constriction of blood vessels, movements of the intestines, emptying of the bladder and other vital processes.

The unit of structure of muscle is **the muscle cells**, which because of its elongated shape also called a **fiber**. Functionally the shape of the cell is important because of a greater unidimensional contraction can be achieved by an elongated cell than by a globular cell of the same volume, with in a muscle mass the fibers are oriented in the direction of movement.

Muscle cells can be divided in to three types;

Skeletal muscle
Smooth muscle
Cardiac muscle

8.2 Skeletal muscle

Skeletal muscle is composed of extremely elongated, multinucleate contractile cells, often described as muscle fibers, bound together by collagenous supporting tissue. Individual muscle fibers vary considerably in diameter form 10 to 100 m and may extend through out the whole length of a muscle reaching up to 35 cm in length.

Skeletal muscle is responsible for the movement of the skeleton and organs such as the globe of the eye and the tongue. Skeletal muscle contraction is controlled by large motor nerves, individual nerve fibers branching with in the muscle to supply a group of muscle fibers collectively described as a motor unit. Excitation of any one motor nerve results in simultaneous contraction of all the muscle fibers of the corresponding motor unit.

The individual muscle fibers are grouped together into elongated bundles called **fasciculi** with delicate supporting tissue called **endomysium** occupying the spaces between individual muscle fibers. Each fascicle is surrounded by loose collagens tissue called **perimysium**. Most muscles are made up of many fasciculi and the whole muscle mass is invested in a dense collagenous sheath called the **epimysium**. Large blood vessels and nerves enter the epimpsium and divide to ramify throughout the muscle in the perimysium and endomysium. The arrangement of the contractile proteins gives rise to the appearance of prominent cross-striations in some histological preparations and hence the name striated muscle is often applied to skeletal muscle. Skeletal muscle is specialized for relatively force full contractions of short duration and under fine voluntary control.

8.2.1 Striations of skeletal muscle fiber

They are composed of alternating broad light I bands and dark A bands. The fine dark lines called Z bands can be seen bisecting the light I bands. The Z bands are the most electron dense and divide each myofibril in to numerous contractile units, called **sarcomeres**, arranged end to end. The sarcomere is the interval between two adjacent Z-lines.

The sarcomere consists of two types of myofilament, **thick filament** and **thin filament**. The thick filaments, which are composed mainly of the protein ***myosin***, are maintained in register by their attachment to a disc-like zone represented by the M line. Similarly the thin filaments, which are composed mainly of the protein ***actin,*** are attached to a disc like zone represented by the Z line. The I and H bands, both areas of low electron density, represent areas where the thick and thin filaments do not overlap one another.

The thin and thick filaments remains constant in length irrespective of the state of contraction of the muscle since contraction is not due to a shortening of individual filaments, it must be due to an increase in the amount of over lap between the filaments.

During contraction the A band remains constant in width, in contrast the I band decrease in size as thin filaments penetrate the A band concomitantly, the H-band (parts of the A band with only thick filaments) diminished in width as the thin filaments completely overlap the thick filaments. The net result is that each sarcomere, and consequently the whole cell (fiber) is greatly shortened. The widely accepted ***sliding filament theory*** proposes that under the influence of energy released form ATP, the thick and thin filaments slide over one another, thus causing shortening of the sarcomere.

8.3. Smooth muscle

Smooth muscle fibers are elongated, spindle-shaped cells with tapered ends, which may occasionally be bifurcated. Smooth muscle fibers are generally much shorter than skeletal muscle fibers and contain only one nucleus, which is elongated and centrally located in the cytoplasm at the widest part of the cell. The fibers vary in length indifferent organs, form 20 m in small blood vessels to 500 to 600 m in the pregnant uterus.

This type of muscle forms the muscular component of visceral structures such as blood vessels, the gastrointestinal tract, the uterus and the urinary bladder giving rise to the alternative name of **visceral muscle**. Since smooth muscle is under the inherent autonomic and hormonal control, it is also described as **involuntary muscle.**

Smooth muscle is specialized for continuous contractions of relatively low force, producing diffuse movements resulting in contraction of the whole muscle mass rather that contraction of individual motor unit. Contractility in an inherent property of smooth muscle, occurring independently of neurological innervation often in arrhythmic or wave like fashion. Superimposed on this inherent contractility are the influences of the autonomic nervous system, hormones and local metabolites, which modulate contractility to accommodate changing functional demands.

Smooth muscle fibers are bound together in irregular branching fasciculi and these fasciculi, rather than individual fibers are the functional contractile units. With in the fascicule, individual muscle fibers are arranged roughly parallel to one another with the thickest part of one cell lying against the thin parts of adjacent cells. The contractile proteins of smooth muscle are not arranged in myofibrils as in skeletal and cardiac muscle, and thus visceral muscle cells are not striated and in the usual histological preparations appear homogeneous. Between individual muscle fibers and between fascicule there is a network of supporting collagens tissue.

The contraction mechanism of smooth muscle differs from that of striated muscle. Because the contractile proteins arranged in acriss-cross lattice inserted around the cell membrane, contraction results in shortening of the cell, which assumes a globular shape in contrast to its elongated shape in the relaxed state.

Unitary smooth muscle present in the walls of hallow viscera (e.g gut, ureter, fallopian tube), cells tend to generate their own low level of rhythmic contraction, which may also be stimulated by stretch and is transmitted from cell to cell via the gap junctions, such smooth muscle is richly innervated by the autonomic nervous system, which increases or decreases levels of spontaneous contraction rather than actually initiating it. This is termed tonic smooth muscle and is characterized by slow contraction, no action potential and low content of fast myosin.

A second arrangement of smooth muscle is typified by that in the iris of the eye. Here, rather than simply modulating spontaneous activity, autonomic innervations precisely controls contraction, resulting in opening and closing of the pupil. Similar neurally controlled or multiunit smooth muscle is found in the vasdeferens and some large arteries. This is termed **phasic smooth muscle** and is characterized by rapid contraction associated with an action potential.

8.4. Cardiac muscle

Cardiac muscle fibers are essentially long cylindrical cells with one or at most two nuclei, centrally located with the cell. The fibers may divide at their ends

before joining to adjacent fiber and thus from a network of branching fibers. Between the muscle fibers, delicate collagenous tissue analogous to the endomysium of skeletal muscle supports the extremely rich capillary network necessary to meet the high metabolic demands of strong continuous activity.

Cardiac muscle exhibits many structural and functional characteristics intermediate between those of skeletal and visceral muscle. Like the former, its contractions are strong and utilize a great deal of energy, and like the latter the contraction are continuous and initiated by inherent mechanism, although they are modulated by external autonomic and hormonal stimuli. Cardiac muscle provides for the continuous, rhythmic contractility of the heart.

Cardiac muscle fibers have an arrangement of contractile proteins similar to that of skeletal muscle and are consequently striated in similar manner. How ever, this is often difficult to visualize with light microscope due to the irregular branching shape of the cells and their myofibril.

Between the ends of adjacent cardiac muscle cells are specialized intercellular junctions called intercalated discs which not only provide points of anchorage for the myofibrils but also permit extremely rapid spread of contractile stimuli from one cell to another and provide areas of low electrical resistance for the rapid spread of excitation through out the myocardium.

The intercalated disc is an interdigitating junction and consists of three types of membrane-to-membrane contact;

Fascia adherens: the predominant type of contact.

The actin filaments at the ends of terminal sarcomeres insert in to the fasciae adherents and there by transmit contractile forces from cell to cell.

Desmosomes occur less frequently and provide anchorage for intermediate filaments of the cytoskeleton

Gap (nexus) junctions are present mainly in the longitudinal portions of the interdigitations and are sites of low electrical resistance through which excitation passes from cell to cell.

8.5 Regeneration of muscle tissue

The three types of adult muscle have different potentials for regeneration after injury. **Cardiac muscle** has virtually no regenerative capacity beyond early child hood. Defects or damage (e.g infracts) in heart muscle are generally replaced by the proliferation of connective tissue forming myocardial scars.

In skeletal muscle, although the nuclei are incapable of under going mitosis, the tissue can under go limited regeneration. The source of regenerating cells is believed to be the satellite cells. The satellite cells are a sparse population of

mononucleated spindle shaped cells that lie with in the basal lamina surrounding each mature muscle fiber. They are considered to be in active myoblasts that persist after muscle differentiation. After injury or certain other stimuli, the normally quiescent satellite calls become activated, proliferating and fusing to form new skeletal muscle fibers. The regenerative capacity of skeletal muscle is limited, how ever, after major muscle trauma or degeneration.

Smooth muscle is capable of an active regenerative response, after injury, viable mononucleated smooth muscle cells and pericytes from blood vessels under go mitosis and provide for the replacement of the damaged tissue.

CHAPTER 9: NERVOUS TISSUE

9.1 Introduction

Nervous tissue consists of nerve cells (neurons) and supporting cells (neuoglia). Nerve cells are highly specialized to react to stimuli and conduct the excitation from one region of the body to another. The nervous system shows both irritability and conductivity, properties that are essential to the functions of nervous tissue to provide communication and to coordinate body activities. Thus the function of the nervous system is to receive stimuli from both the internal and external environments, which are then analyzed and integrated to produce appropriate, coordinated responses in various effector organs.

Nerve tissue is distributed through out the body as an integrated communications network. Anatomically, the nervous system is divided into the central nervous system (CNS) consisting of the brain and the spinal cord; and the peripheral nervous system (PNS) composed of nerve fibers and small aggregates of nerve cells called **nerve ganglia.**

Nervous tissue specialized to perceive external stimuli are called a **receptor**, from which sensory stimuli are carried by the peripheral nervous system to the central nervous system. Other neurons, the effectors, conduct nerve impulses from the CNS and other tissues, where they elicit an effect. The specialized contacts between neurons are called **synapses**; the impulses are transferred between nerve cells by electrical couplings or chemical transmitters.

Functionally, the nervous system is divided into **somatic nervous system**, which is involved in voluntary functions, and the **autonomic nervous system**,

which exerts control over many involuntary functions. By creating, analyzing, identifying and integrating information, the nervous system generates two great classes of functions, stabilization of the intrinsic conditions (e.g. blood pressure, o_2 and co_2 content, PH, blood glucose levels, and hormone levels) of the organism within normal ranges; and behavioral patterns (e.g feeding, reproduction, defense, interaction with other living creatures).

9.2 Neurons

Nerve cells or neurons are independent structural and functional units of nervous tissue. They are responsible for the reception, transmission, and processing of stimuli. Neurons are usually large and complex in shape, consist of three parts; the cell body; or the perikaryon, which represents the tropic center for the whole nerve cell and is also receptive to stimuli the dendrites, which are multiple elongated processes specialized in receiving stimuli from the environment. Sensory epithelial cells, or other neurons, and the axon, which is a single process, specialized in generating or conducting nerve impulses to other cells (nerve, muscle and gland cells).

Action potentials arise in the cell body as a result of integration of afferent (incoming) stimuli; action potentials are then conducted along the axon to influence other neurons or effector organs. Axons are commonly referred to as nerve fibers. In general the cell bodies of all neurons are located in the central nervous system.

9.3 Basic Neuron Types

Neurons have a wide variety of shapes, which fall in to three main patterns according to the arrangement of the axon and dendrites with respect to the cell body. The most common form is the multipolar neuron in which numerous dendrites project from the cell body; the dendrites may all arise from one pole of the cell body or may extend from all parts of the cell body. In general, intermediate, integratory and motor neurons conform to this pattern. Bipolar neurons have only a single dendrite, which arises from the pole of the cell body opposite to the origin of the Oxon. Their unusual neurons act as receptor neurons for the senses of smell, sight and balance.

Most other primary sensory neurons are described as pseudo-unipolar neurons since a single dendrire and the oxon arise form a common stem of the cell body. As a general rule, neuron impulses are conveyed along dendrites tow wards the nerve cell body (afferent) whilst oxons convey impulses away form the nerve cell body (efferent).

Neurons are terminally differentiated cells and are completely incapable of cell division and replacement in the event of cell death. However, regeneration of

oxons and dendrites can occur in the event of damage, provided the neuron cell body remains viable.

Neurons can be classified according to their functional roles. Motor (efferent) Neurons control effector organs such as muscle fibers and exocrine and endocrine glands; sensory (efferent) neurons are involved in the reception of sensory stimuli from the environment and form with in the body.

In the central nervous system, nerve cell bodies are present only in the gray matter, while matter contains neuronal processes but no nerve cell bodies. In the peripheral nervous system, cell bodies are found in ganglia and in some sensory regions (e.g olfactory mucosa).

9.4 Cell body (perikaryon)

The cell body contains the nucleus and surrounding cytoplasm, exclusive of the cell processes, the perikaryon of most neurons receives a great number of nerve endings that convey excitatory or inhibitory stimuli generated in other nerve cells.

Most nerve cells have a spherical, usually large, euchromatic (pale-staining) nucleus with a prominent nucleus. The cell body contains a highly developed rough endoplasmic reticulum. Rough endoplasmic reticulum and free ribosmoes appear under light microscope as a basophilic granular area called Nissl bodies. Neurofilaments are abundant in perikaryons and cell processes. Nerve cells occasionally contain inclusions of pigments such as lipofuscin.

9.5 Nerve processes (dendrites and axons)

Nerve processes are cytoplasmic extension of the cell body and occur as dendrites and axons. Each neuron has several dendrites that extend form the perikaryone and form branch like extensions,/dendrites increase the receptive area of the cell. Most neurons have only one axon; a very few have no axon at all. All axons originate form a short pyramid-shaped region, the axon hillock. The plasma membrane of the Oxon is called axolemma. All axon branches are known as collateral branches.

9.6 Synaptic communication

The synapse (Gr.synapsis-union) is responsible for the unidirectional transmissions of nerve impulses.synapses are the sites where contact occurs between neurons or between- neurons and other effector cells (eg. Muscle and glands cells). The function of the synapse is to convert an electrical signal (impulse) from the presynaptic cell into a chemical signal that can be transferred to the postsynaptic cell releasing chemical messengers.

9.7 Neuroglia

Neurons from a relatively small proportion of the cells in the central nervous system. Most of the cells are non-neuronal supporting cells called neuroglia. Neuroglia account for over half the weight of the brain. They are smaller than neurons and found scattered among neurons and their processes. Neuroglia includes ependymal cells, astrocytes, oligodendrocytes, and microglia. Astrocytes and oligodendrocytes are called **macroglia**.

a. Astrocytes are star shaped cells with many branching cytoplasmic processes, visible only after impregnation techniques. They are important as supporting or structural element in the CNS. After brain damage, astrocytes remove neuronal debris and form a 'seal' around damaged areas, some times leading to scarring.

b. Oligodendrocytes are smaller than astocytes with fewer, shorter cell processes. They occur mainly in two locations, in the gray matter closely associated with the cell body of neurons (perineuronal satellite cells).,and among bundles of axons in white matter (interfascicular oligodendrocytes). They are responsible for myelin formation, extending to wrap-around nerve fibers in a spiral fashion they have several processes and forms myelin sheaths around several adjacent nerve fibers.

c. Microglia are small, elongated cells with short, spiny processes, they lie in both white and gray matter, usually near blood vesicles, they are the main source of phapoeytic cells in CNS.

d. Ependyma are cells lining the cavities (ventricles of brain and central canal of the spinal cord. They are cuboidal epithelial type with few cilia.

9.8 Ganglia

A collection of nerve cell bodies located outside the CNS is called a **ganglion**, although not all ganglia lie outside the CNS. Ganglia are of two main types: those of the craniospinal group (**sensory ganglia**), and those of the autonomic nervous system (visceral, **motor ganglia**). Each ganglion has a connective tissue capsule, which may be quite dense around large ganglia.

a. Sensory ganglia: receives afferent impulses that go to the CNS. Two types of sensory ganglia exist. Some are associated with cranial nerves (cranial ganglia); others are associated with the dorsal root of the spinal nerves and are call spinal ganglia.

Schwann cells

Schwann cells have same function as oligodendrocytes but are located around axons on the peripheral nervous system. A single schwann cell forms myelin around one axon, in contrast to the ability of oligodendrocytes to branch and serve more than one neuron and its processes.

b. Autonomic ganglia: They appear as bubous dilatations in autonomic nerves. Some are located within certain organs, especially in the walls of the digestive tract, where they constitute the intramural ganglia. They have multipolar neurons. The neurons are frequently enveloped by a layer of satellite cells.

9.9 The central nervous system

The central nervous system consists of the cerebrum, cerebellum, and spinal cord; it has virtually no connective tissue and is therefore a relatively soft gel-like organ.

White and gray matter: when sectioned, the cerebrum, cerebellum and spinal cord show regions of white (white matter) and gray (gray matter). The differential distribution of myelin in the central nervous system is responsible for these differences. The main component of white matter is myelinated axons and the myelin-production oligodendrocytes.

Gray matter contains neuronal cell bodies, dendrites, and the initial unmyelinated portions of the axons and glial cells, this is the region where synapses occur. Gray matter is prevalent at the surface of the cerebrum and cerebellum, forming the cerebral cerebellar cortex, where as while matter is present in more central regions. Aggregates of neuronal cell bodies forms lands of gray matter embedded in the while matter are called nuclei.

Neurons of some regions of the cerebral cortex register afferent (sensory) impulses; in other regions, efferent (motor) neurons generate motor impulses that control voluntary movements, cells of the cerebral cortex are related to the integration of sensory information and the initiation of voluntary motor responses.

The cerebral cortex has three layers; an outer molecular layer, a central layer of large purkinje cells, and an inner granule layer. They purkinje cells have a conspicuous cells body and their dendrites are highly developed.
In cross sections of the spinal cord, white matter is peripheral and gray matter is central, assuming the shape of an H. In the horizontal bar of this H is an opining, the central canal, which is a remnant of the lumen of the embryonic

neural tube. It is lined by ependymal cells, the gray matter of the legs of the H forms the anterior horns, those contain motor neurons whose axons make up the ventral roots of the spinal nerves. Gray matter forms the posterior horns, the arms of the H, which receive sensory fibers form neurons in the spinal ganglia (dorsal root)

9.9.1 Meninges:

The CNS is protected by the skull and the ventral column. It is also encased in membranes of connective tissue called the meanings, starting with the outer most layer, the meanings are the duramater, arachnid, and pia matter. The arachnoid and the pia matter are linked together and are often considered a single membrane called the pia arach neid.

Dura matter: is the external layer and is composed of dense connective tissue continuous with the perioseum of the skull. It is separated from the arachnoid by the thin subdural space. The internal and external surface of dura mater in the spinal cord is covered by simple squamus epithelium of mesenchymal origin.

Arachnoid: has two components; a layer in contact with the duramatter, and a system of trabeculae connecting the layer with the pia mater. The cavities between the trabeculae from the subarachnoid space, which is filled with cerebrospinal fluid and is completely separated form the subdural space. This space forms a hydrautic cushion that protects the CNS from trauma. The arachnoid is composed of connective tissue devoid of blood vessels.

Pia matter: is a loose connective tissue containing many blood vessels. Although it is located close to the nerve tissue, it is not in contact with nerve cells or fibers. It forms a thin layer of neuroglia processes forming a physical barrier at the periphery of the CNS that separates the CNS from the cerebro spinal fluid.

Blood vessels penetrate the CNS through tunnels covered by pia mater-the perivascular space.

9.10 Peripheral Nervous system

The peripheral nerves are anatomical structures, which may contain any combination of afferent or efferent nerve fibers of either the somatic or autonomic nervous systems. The cell bodies of fibers coursing in peripheral nerves are either located in the CNS or in ganglia in peripheral sites.

The main components of the peripheral nervous system are the nerves, ganglia, and nerve endings. Each peripheral nerve is composed of one or more bundles

(fascicles) of nerve fibers. within the fascicles, each individual nerve fiber, with its investing schwann cell, is surrounded by a delicate packing of loose vascular supporting tissue called endoneurium.

Each fascicle is surrounded by a condensed layer of robust collagenous tissue called the perineurium.In peripheral nerves consisting of more than one fascicle, a further layer of loose collagenous tissue called the epineurium binds the fascicles together and is condensed peripherally to form a strong cylindrical sheath.

Peripheral nerves receive a rich blood supply via numerous penetrating vessels from surrounding tissues and accompanying arteries.

9.11 Peripheral nerve endings

Nerve endings increase the surface contact area between nervous and non-nervous structures and allow stimuli to be transmitted from nerve endings to musceles, causing them to contract, or to epithelial cells, causing them to secrete. When stimulated, dendrites at the periphery generate impulses that are transferred along the nerve fibers to sensory ganglia and ultimately to the central nervous system.

Peripheral efferent (motor) nerve fibers can be divided into somatic and visceral efferent groups. Somatic efferent fibers end in skeletal muscle as small, oval expansions called motor-end plates. Visceral efferent nerve fibers stimulate smooth muscle, cardiac muscle, and glandular epithelium. Visceral motor endings of smooth muscle terminate as two or more swellings that pass between individual muscle cells.

Terminal peripheral nerve fibers that are excitable to stimuli are receptors and can transform chemical and physical stimuli in to nerve impulses. Receptors vary in morphology, may be quite complex, and often are grouped in to free (naked), diffuse, and encapsulated nerve endings.

9.12 Nerve fibers

Nerve fibers consist of axons enveloped by a special sheath derived from cells of ectodermal origin. Nerve fibers exhibit differences in their enveloping sheaths, related to whether the fibers are part of CNS or PNS.

Most axons in adult nerve tissue are covered by single or multiple folds of a sheath cell. In peripheral nerve fibers the sheath cell is the schwann cell, and in central nerve fibers it is the oligodendrocyte. Axons of small diameter are usually unmyelinated nerve fibers. Progressively thicker Axons are generally sheathed by increasingly numerous concentric wrappings of the enveloping

cell, forming the myelin sheaths. There fibers are known as myelinated nerve fibers.