ADDIS ABABA UNIVERSITY COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE

VETERINARY HISTOLOGY I COURSE FOR FIRST YEAR DVM STUDENTS

COURSE DESCRIPTION:

Was

Both

Theoretical, Interactive learning

and

practical sessions

But, Now due to pandemic COVID-19, students should be able to read more and interpreted what should have to be included under the course

LECTURES:

The course deals with

- ✱ cell and tissue structures,
- ✱ methods of studying histology and
- ✱ general principles and Emphasis is paid to histology of :

➢ **tissues:**

- ❑ epithelial tissue,
  - ❑ connective tissues,
  - ❑ nervous tissue,
  - ❑ muscle tissue and
  - ❑ endocrine system.

INTERACTIVE LEARNING

- Active discussion
- Presentations
- Group work

PRACTICALS

- Microscopy,
- histological techniques (the paraffin technique)
- study of different basic tissues of the body,
  - epithelium
  - connective tissues
  - muscle tissues
  - nervous tissues

- **Studying the normal microscopic structure of the animal body is the basis for understanding:**
  - ☛ abnormal microscopic lesions (histopathology),
  - ☛ body functions,
  - ☛ immunology,
  - ☛ clinical pathology and
  - ☛ several other disciplines in veterinary medicine.

COURSE OBJECTIVES:

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

- Have knowhow the general principles of microscopic anatomy;
- describe and interpret the microscopic structural organizations of different tissues and cells
- Understand normal structure of different body systems
- correlate these structures to their function;
- predict the application of histology in different disciplines and practical situations.

INTRODUCTION

Historical Background of Histology

A French scientist called Bichat (1771-1804) dissected human body

- He observed grossly various layers and structures with different texture.
- He called the various structures- tissue
- After visual observation he applied various techniques

1. Putrefaction 3.Cooking

2. Maceration 4.Chemical disintegration

- Tissue is derived from the French word, tissu which means "weave or texture".

- Prior to the late 1700s, “tissue” did not refer to organic, cellular layers, but rather to anything woven or textured.

- So, for example, a fine, lightweight fabric was called a tissue, or a group of connected falsehoods is referred to as a "tissue of lies".

- It's important to realize that all Bichat’s work was done without a microscope
- Bichat based his descriptions of tissues on the results of gross dissection (what he saw with his “naked” eyes).
- Based on such observations, he described 21 “weaves” or “textures” that he called tissues - Bichat’s 21 textures.

- Based on effects of the above different techniques he classified human tissues into several types.

- Though he was not correct, he laid a foundation for establishment of Histology.

- Antony van lee hook was the first person to show the application of microscope to the study of tissue.

- Based on the work of Lee van hook, scientists start to study tissues using microscope and histology is established as a separate discipline.

CONCEPTS OF HISTOLOGY

Anatomy:

- Is the branch of biomedical science that deals with the **external and internal structure** of the organism.

- The science of anatomy is subdivided into sub disciplines based up on the **nature of the components parts** and **the methods** by which they are studied.

1.**Goss anatomy:** the study of gross structural features that are accessible to naked eye that are studied by **direct visual** inspection, palpation, and/or dissection

2.**Microscopic anatomy(histology);** study of structures that are not visible with out the use of microscope.

3.**Developmental anatomy (embryology)-**which study about embryogenesis

- **Histology (microscopic anatomy):** encompassed the study of the structured that **aren't visible** to the unaided eye. The term histology, is derived from the Greek terms
- Etymologically;
  - ✧ *Histos* means *tissue*
  - ✧ *Logos* means *study*

Therefore, histology means **the study of tissues**

- Today the concept of histology as a subject includes for more than just the study of tissues, but includes ***understanding*** *of the* ***structure and function*** *of cells, tissues, organs and organ system****,*** *which can be described as****"*** ***Microscopic Anatomy.****"*

Relationship with other subjects

- The modern histology is a sophisticated science concerned with tissue **structure** and **function** from broad and multidisciplinary approaches

- Advance in physics and engineering led sequentially to the development of various optical instruments used in histology:
  - the scanning electro microscope and other sophisticated optical instruments.
  - The transmission and the scanning electro microscope are tools of ultrasturctural, cytology, a body of knowledge, encompassed by histology.

- Similarly, in sights from in **organic chemistry**, **organic chemistry**, **biochemistry,** and **biophysics** have been applied to cells and tissues.

- Histology then includes the specialized sub disciplines of **histochemistry** and **cytochemistry**.

- In addition, histology also helps to get knowledge on basic building block for **understanding disease processes**. The responses of cells and tissues to the insults associated with disease process are the parts of **histopathology.**

- Histology is also related to physiology because one should be familiar with normal cells & tissues functions.
- It is also a prerequisite for pathology (study of changes in organs, tissues & cells due to disease).
- Histopathology; microscopic study of diseased tissues.

The ultimate goals of Histology are:

- To know the general & specific feature of tissues & organ
- To identify mammalian tissue quickly & accurately
- To understand how tissues are organized at all structural levels.
- To Study tissue death and regeneration.
- To study various tissue reaction to injury or invading organism.

METHODS OF HISTOLOGY

- Examination of tissue at microscopic level is conducted mainly through **biopsy** & **autopsy.**

- Biopsy: histological examination of tissue taken from life organism.
  - Provides valuable information about the disease process while

- **Autopsy**: histological study of tissue after death of an organism.
  - It reveals tissue changes that have led the organism to death.

Methods of Histology cont…

1) Methods of direct observation of living cells and tissues

– living cells and tissues with out chemical (Fresh, uncolored direct method, **Cell/ tissue culture, Transparent viewing chamber**

▪ living cells and tissue after chemical treatment (**vital and supravital stain, Cell- fraction and centrifugation,**)

2) Method of studying killed tissues

– (**The paraffin technique**)

1. Methods of direct observation of living cells and tissues

- Generally living cells and tissue are difficult to examine microscopically, because they are relatively transparent and thick.
- But there are different methods for studying living cells and tissues.
- This method is done by two processes:-

A. Examination of living cells and tissues with out any chemical treatment

◈ **Fresh, uncolored direct method:**

- bits of tissues or drops of blood taken from a freshly anaesthetized animal are spread on a glass slide and examined under a microscope.
- Often saline solution is used to keep the tissue moist.
- The type of microscope used can be **dark – field or phase contrast microscope**.

Methods of direct observation of living cells and tissues

Cell culture

- means of direct observation of living cells.
- It permits the continual observation, manipulation and testing of explanted cells without any jeopardy to the donor organism.

✓ For this purpose living cells are removed from an organism cultured (e.g kept a live and allowed to multiply) in aseptic conditions with appropriate nutrient and environmental conditions.

Cell culture

- ❖ It is used to study:
- ✓ Cell metabolism
- ✓ Cellular differentiation
- ✓ Cellular transformation
- ✓ Cytogenesis
- ✓ Cell to cell interaction
- ✓ Host – parasite relation ship and other biological studies

Transparent viewing chamber:

- permit an extended period of observation neurovascularization, cellular differentiation and movement, other vital process are studied by these techniques. In this method, for example, holes are made in rabbits ear and covered with glass discs.
- Through the glass one can see the growth of blood vessels and nerves directly under the microscope. The anterior chamber of the eye is a naturally occurring viewing chamber that is used in this approach

B. Examination of living cells and tissue after chemical treatment

- The selective uptake of vital and supravital stain used to understand the function of cells, cellular organelles and inclusions and extracellular materials.
- These stains have a low toxicity; they are injected into the living organism (vital) or applied to living cells extirpated from the organism (supravital).

Cont..

Vital and super vital staining techniques

- Used to understand the function of some cellular organelles and inclusions and extra cellular material.

- They are also useful to examine living cells because they have low toxicity.

- **Vital stain**- inoculation of staining materials in to living organism .
- Lithium carmine and trypan blue are vital dyes and utilized to study phagocytosis

Cont…

- **Supper vital staining**- injection of staining materials into living cells extirpated from the organism.

- Janus green and neutral red are super vital stains used to study mitochondria and lysosomes.

CELL- FRACTION AND CENTRIFUGATION:

- cell organelles can be separated in layer of different specific gravity by homogenizing (crushing) the cells in a homogenizer.

- The separation and purification of subcellular fractions through differential centrifugation and density gradient centrifugation are valuable aids for the study of biochemical and metabolic phenomena.
- After centrifugation cell organelles or fractions get arranged in different layers and the layers are separated mechanically to get the desired organelle (fraction).

2. Method of studying killed tissues

- Living cells and tissues are difficult to examine because they are relatively transparent and thick.
- This problem is reduced, when thin sections of tissue are obtained, stained and examined.

- Tissues and cells for microscopic examinations are usually killed by careful fixation .
- to minimize alternations of *in vivo* morphology then the tissues will be embedded in a material that facilitates thin sectioning.
- It has the advantage of being relatively permanent, and it can be filed for future reference

The paraffin technique

- The technique is a simple and reliable procedure

- the most common method used for preparation of specimens for:
  - histology courses,
  - diagnostic histopathology and
  - morphological research

paraffin technique

- Acquisition
- Fixation
- Dehydration
- clearing
- Infiltration/ Embedding
- Sectioning
- Staining
- Examination (microscopy)
- Interpretation and conclusion.

1. Acquisition

❖ The following points are very important

- Knowledge of gross anatomy
- Identification of desired sample
- Removal of sample must be atraumatically.
- excessive handling and poor extirpation techniques change morphology of tissue.

Acquisition of sample

- Most critical step
- Tissue must be removed rapidly and automatically since most living tissues are fragile and in the shortens time possible to inactivate the enzymes responsible for autolysis
- The use of dull and dirty scalpels or scissors and excessive pressure or traction applied with thumb forceps during sampling can induce drastic alteration to the components.

Tissue cassettes

2. Fixation (Chemical fixation)

- purpose of chemical fixation is stopping post mortem autolysis.
- Fixatives denature proteins; inactivate enzymes through which autolytic changes modified.
- Actions of fixatives are broad to react with all biochemical components of cells.
- Some chemical agents are **coagulative fixatives**

  e.g. Ethanol & Methanol

A 10% solution of neutral- buffered formalin commonly used fixative.

Fixation can be done

- By exposing tissue to chemical preservative
- It can be active or passive
- Active process of fixation(perfusion fixation)
- Involves replacing body fluids with a perfusates (saline) followed by fixative.
- It has the advantage of preserving large mass thoroughly and relatively evenly.
- Best method in sampling animal tissue

Multiple functions fixative:

- Prevent post – mortem degeneration of cells (autolysis) because these fixatives denature protein, they inactivate the autolytic enzymes
- Stabilizes structural components of cells and tissues in as near in vivo conditions as possible
- Enhance staining by acting as mordant
- Facilitate sectioning of tissues by hardening them
- Minimize the leaching of many constituents that result from subsequent processing.
- Protect the histologist through the antiseptic properties of these substances.

The frequently used fixative include:

- formaldehyde,
- glutaldehyde,
- paraformaldehyde,
- ethyl alcohol,

- acetic acid, picric acid,
- potassium dichromate,
- mercuric chloride,
- chromatic acid and
- osmic acid.

Types of fixatives

divided into two:-

- coagulative fixatives
- additive fixatives

Coagulative fixatives

- induce morphological changes in cells or tissues
  - E.g. ethanol and methanol.

ADDITIVE FIXATIVES:

- induce fixation by chemically reaction with the components of the cell.
- They don’t induce the marked morphological changes, characteristics of the coagulative fixatives.
- E.g. The aldehydes (formaldehyde, paraformaldehyde and glutaraldehyde)

- A 10% solution of neutral – buffered formalin is the most common fixative.
- The most ideal ratio of fixative volume to tissue volume is about **10:1**
- The actual time required for complete fixation to occur varies with the **diffusion properties of the fixative**, the **concentration of the fixative** and **the density of the tissue.**
- Most formaldehyde fixation is achieved with 24 hours.

3. Dehydration

- To infiltrate paraffin in to sample to permit sectioning, 75% of water, which occurs in most tissue, must be removed.
- The sample is dehydrated as a preparatory stage to embedding.

  E.g. Ethanol, Dioxane, Buthanol and Isopropanol
- Dehydration is usually sufficient when no more than 3-4% of water remains in the tissue after the surrounding dehydrating

- It is carried out for **two** purposes:
  - To prepare the specimens as blocks for embedding in a non aqueous medium
    - In order to get good embedding it is necessary to remove at least 95% of the water in tissue
  - To prepare them as cut section for permanent mounting

Technique for dehydration:

- A series of containers is set up and dehydrating fluid placed in them. The specimens are transferred from one fluid to the next at intervals, and progress from the least concentrated to the most concentrated dehydrating fluid.
- The reagents used most extensively for dehydration is ethyl alcohol (95% absolute alcohol) and Other dehydrating reagents include acetone, dioxane, isopropyl alcohol and tertiary butyl alcohol.

Tissue processor

Tissue processor

Tissue processor (12 cylinders)

4. Clearing:

- means the use of a fluid that serves as an intermediary wetting agent between dehydration and embedding in paraffin
- because most of these fluids do render tissues almost transparent
- serves to eliminate from the specimen the greater part of the fluid in which it was immersed previously.

- Clearing agents include **xylene** (most commonly used), toluene, and benzene.

- Generally, dehydrating and embedding agents aren't miscible in each other, clearing agents are substance that are miscible in dehydrating and embedding agent

- thus the clearing agents replaces the dehydrating fluid and the embedding agent replace the clearing substance.

Cont..

- Most commonly used dehydrating agent is ethanol.
- subjected to increased concentration of alcohol until total dehydration is achieved with absolute alcohol (99.97% ethanol).
- Commonly employed clearing agents are xylene, toluene and benzene

Cont..

- Generally dehydrating and embedding agents are not miscible in each other but clearing agents are miscible in dehydrating fluid and the embedding agents.
- Therefore clearing agents replaces dehydrating agents & embedding agent replaces clearing substances.

5. Infiltration (Impregnation):

- The objective of infiltration is to make the tissue firm and rigid consistency for sectioning.

- This step includes the infiltration of the tissue while embedding the agent is in solid form when the temperature is lowered below the melting point of the agent.

- Infiltrating agents include paraffin (50-68^{0}C melting point) resin, agar and gelating.

6. Embedding

- Permits the specimen to be sectioned sufficiently thin
- The cleared specimens are processed through solutions containing increasing concentrations of paraffin.
- Commercial mixtures of purified paraffin and plastic polymers are effective embedding materials.
- The infiltrated samples placed in to molds surrounded with paraffin and cooled; the blocks are then ready for sectioning.
- The size that someone wants to section measured in micrometer.

7. Sectioning

- After the paraffin has hardened, the molds are removed and the blocks are trimmed expose the embedded tissue.
- Then they are mounted on a microtome and thin shavings (sections) are removed from cutting surface.
- These sections form a ribbon,
- Ribbons may be floated on warm water bath, the specimen will be subsequently stretched, and picked up on slides.
- The rotary microtome permits the precision on cutting 1µm in increments. Most specimen are sectioned at 5-7µm.

8. Staining Methods

- **Principles of staining:** Cellular and tissue components are sufficiently similar optically that study is impossible without some enhancement of their optical properties staining the tissue components facilitate this enhancement of optical properties.

Cont..

- Sections of paraffin- embedded materials fixed to glass slides
- Paraffin must be removed before staining by the reverse order of the previous procedure (passing the sectioned tissue in xylene, graded concentration of alcohol (with decreasing concentration).
- Then the slide is stained with the appropriate staining reagents
- A cover – slip is applied to produce **permanent preparation.**

Principles of staining (Why staining ?)

- Cellular and tissue components are sufficiently **similar optically** that study is impossible without some enhancement of their optical properties staining the tissue components facilitate this enhancement of optical properties.

Stains of d/t types

- **very selective**, having high specificity for certain cellular and tissue components.
- **selectively** stain cellular components and extra-cellular materials.
- **not selective,** generally stain cellular and extra-cellular tissue components.

    e. g. Hematoxylin (H) and eosin (E)

Basic and Acidic stains

- Most stains are salts that dissociate in water described as acidic or basic salts.
- If the coloring component is the acidic radical, then the stain is designated as **acidic stain**.
- If the coloring component is in the basic radical, then the stain is designated as **basic stain**.
- The basic cellular components react with acidic stains through the neutralization reaction that results in formation of colorful salts and water.
- The basic components of tissues and cells are **acidophilic**
- Acidic components of cells and tissues are **basophilic**; they have affinity for basic days

Hematoxylin and Eosin (H-E)

- Neutralization is mechanism of the H and E stain
- Hematoxylin , the basic dye ,imparts a bluish purple to acidic cellular components **nucleus** (chromatin).
- Eosin, the acidic dye , imparts pink to red color to basic cellular components such as cytoplasm and numerous extra cellular products

Romanowsky stains

- Romanowsky stains are dye combinations that contain methylene blue and eosin.
- Common variants include Wright's stain, Jenner's stain, Leishman stain and Giemsa stain.
- Methylene blue oxidized readily to form azure dyes.
- Combination of methylene blue and azure dyes (azure A, B, & C) are called polychrome methylene blue.
- polychrome methylene blue has a broad staining range for acidic components.
- Eosin is the acidic counter-stain.
- All are used to examine blood or bone marrow samples.

Periodic Acid- Schiff Stain (PAS)

- Primarily used to identify glycogen in tissues.
- Involves two steps to achieve reactivity
- The 1st reaction is Periodic acid oxidizes 4- amino alcohols and/ or 1,2 glycol groups to aldehyde.

- These aldehydes are then subjected to Schiff reagent.
- Reaction of aldehydes with the reagent forms a complex that restores the ***magenta*** color.

- Hematoxylin is the usual counter-stain.
- Many carbohydrates and carbohydrate- protein complexes give a positive reaction with PAS.

Additional methods in Histological studies

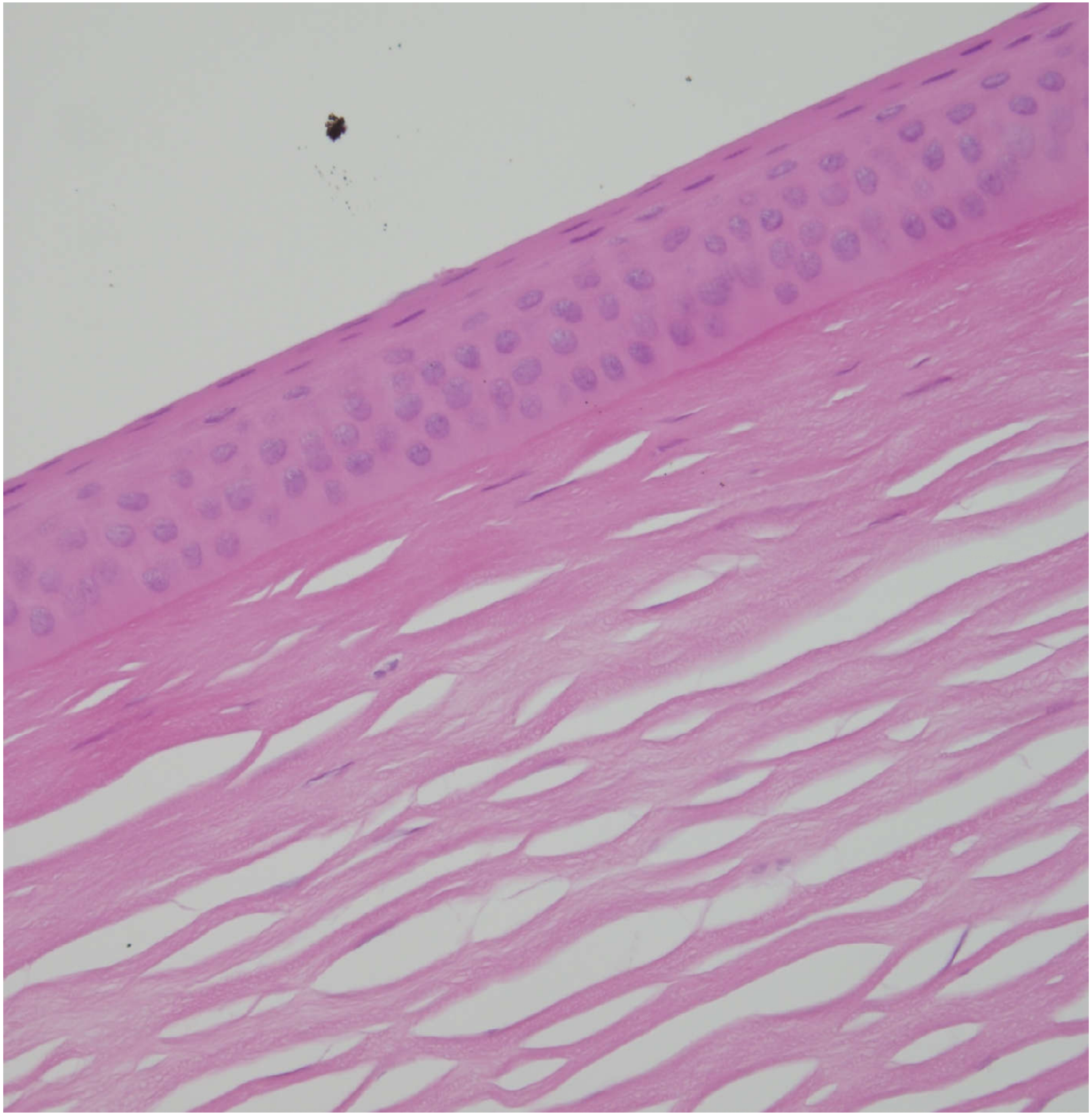
- *Freezing techniques*: fixation of cells and tissues may cause some alteration of morphology and function and the tissue processing times is too long. In order to reduce these problems, freezing has been developed.
- Histochemistry and cytochemistry: The principle is enhancing the visualization of cellular and tissue components by forming chemical complex with the staining reagents used in the technique.
- Autoradiography: Staining of the sections allows the visualization of component of cells that are labeled with radioactive substance with light microscope. It is useful for histological studies of dynamic cellular processes
- o **Immunohistochemical stains:** Staining depending on antibody antigen reaction . Antibody against a particular macromolecule created and localised by reaction with the macromolecule. Visualized by labeling the antibody with a fluorescent dye

Tissue Fixation & Processing

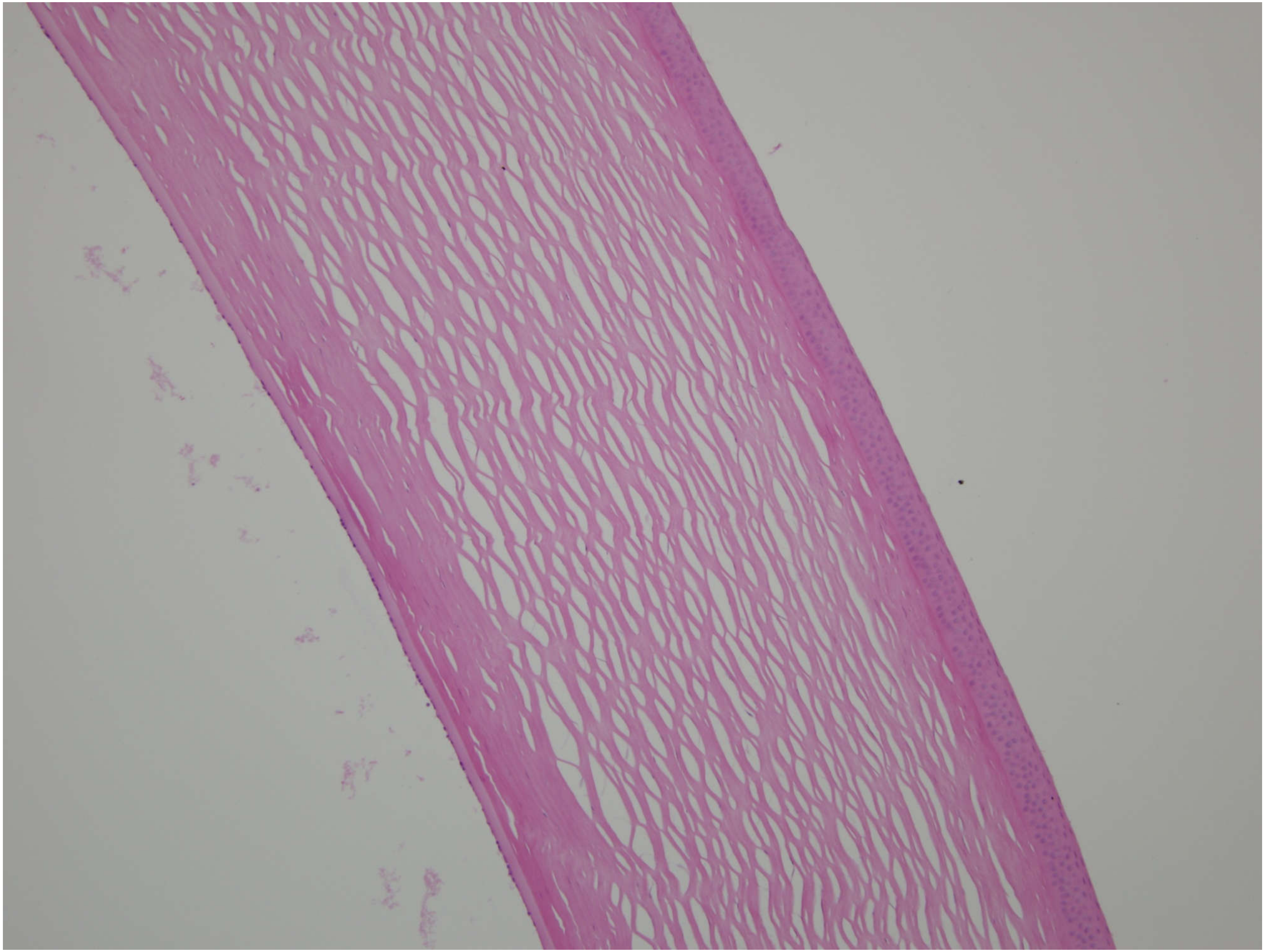
- 10 % Neutral-buffered formalin
    - 37% aqueous solution of formaldehyde = 100% formalin
    - Cross-links proteins
    - Tissue </= 1 cm in thickness
- Infiltrated with paraffin
    - Dehydrated through graded series of ETOH
    - Replaced by paraffin
- Embedded in paraffin
    - Final positioning of tissue
- Sectioning
    - Cut at 3-5 µm

Tissue Staining

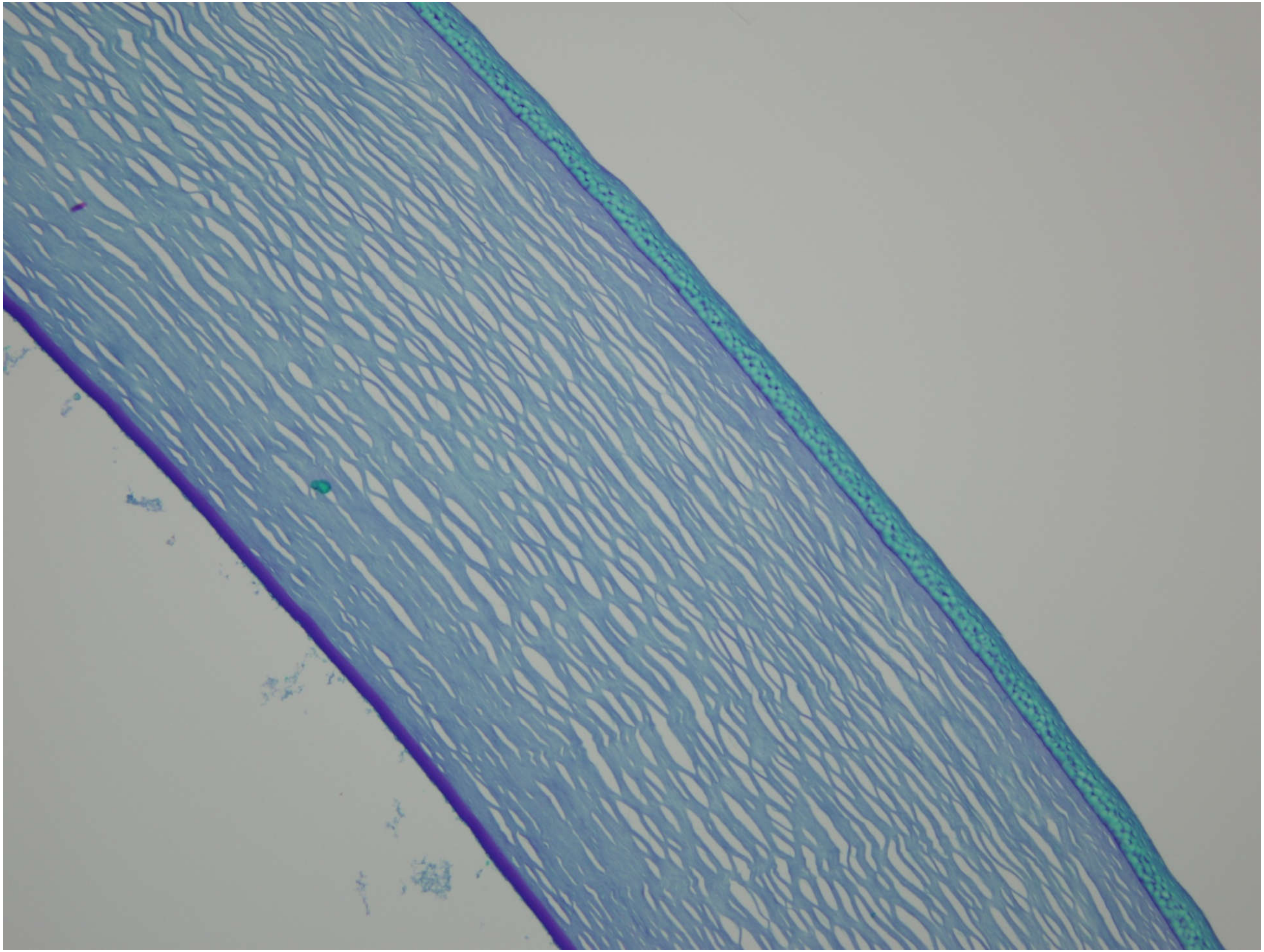
- Hematoxylin & Eosin
  - “The” default light microscopic stain
  - Hematoxylin: basic, blue
    - Stained tissue (e.g.. nuclei) = basophilic
  - Eosin: acidic, red
    - Stained tissue (e.g.. cytoplasm) = eosinophilic
- Histochemical Stains
  - Stains specific molecules
    - PAS: carbohydrates (basement membranes, glycogen)
    - Perl's stain: iron
- Immunohistochemical Stains
  - Specific antibody used to identify specific antigens in tissue
    - Constitutive antigens (e.g. intermediate filaments, T-cells & B-cells)
    - Infectious agents (e.g. viral antigens)



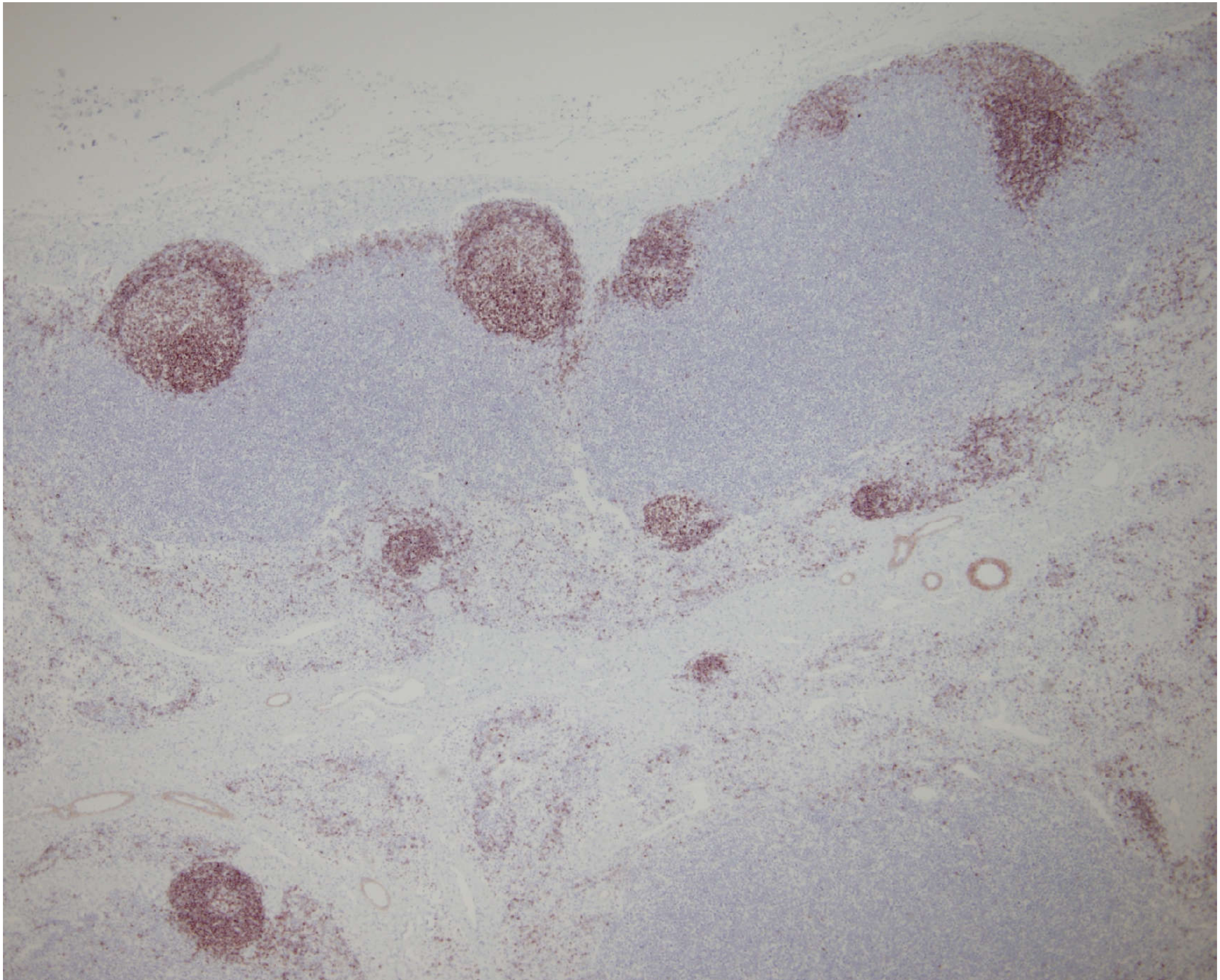
Cornea: HE stain.



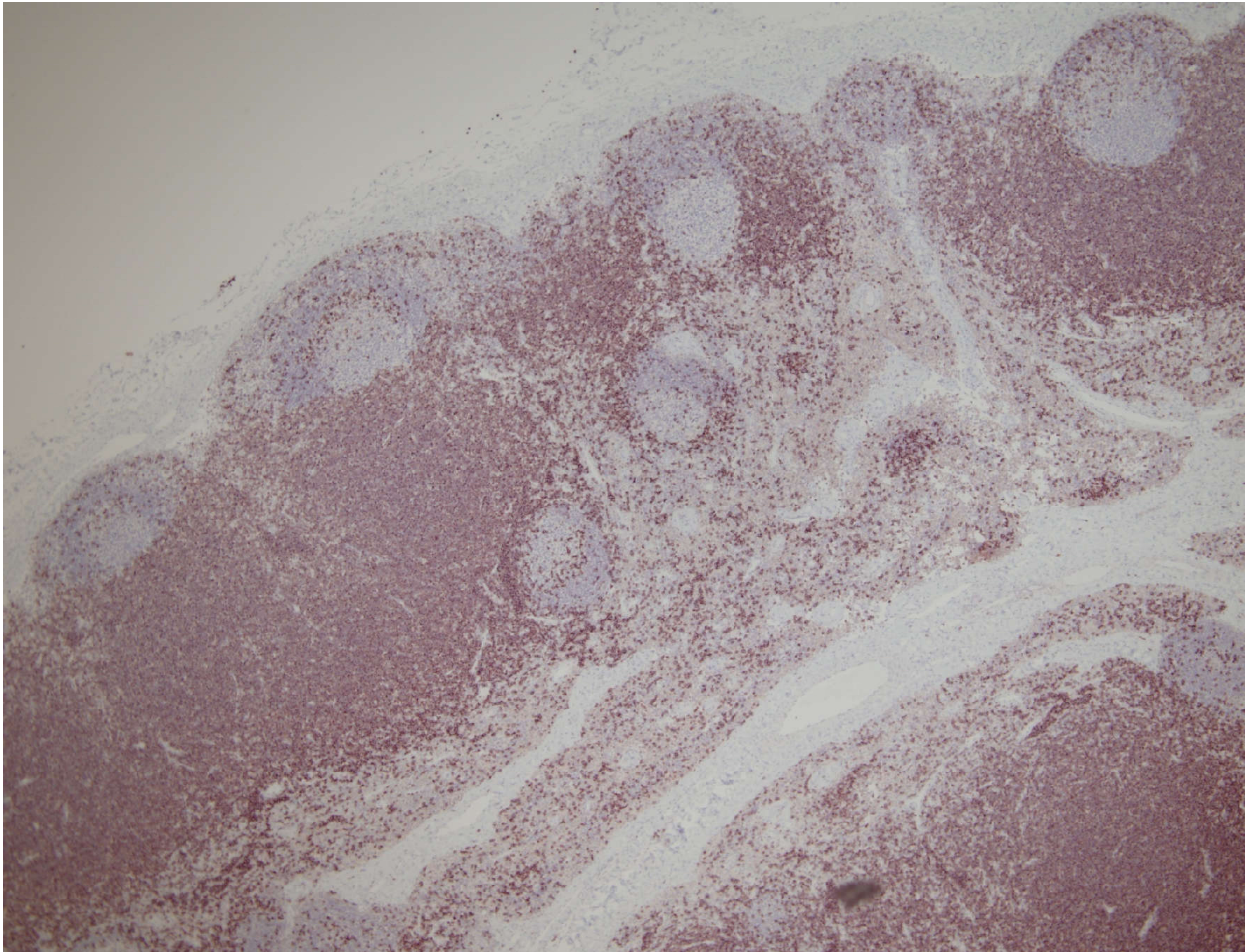
Cornea: HE stain.



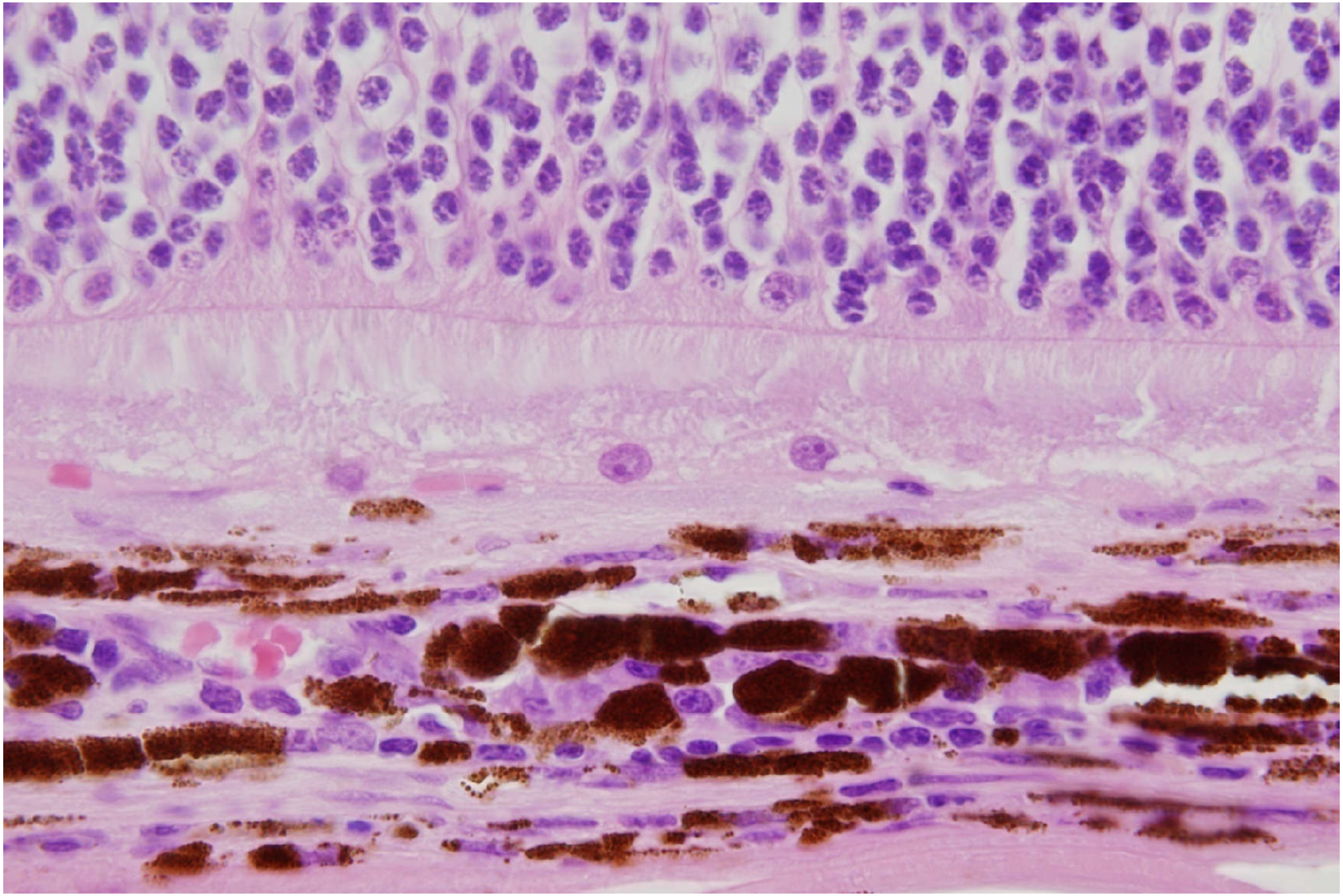
Cornea: PAS stain for basement membranes.



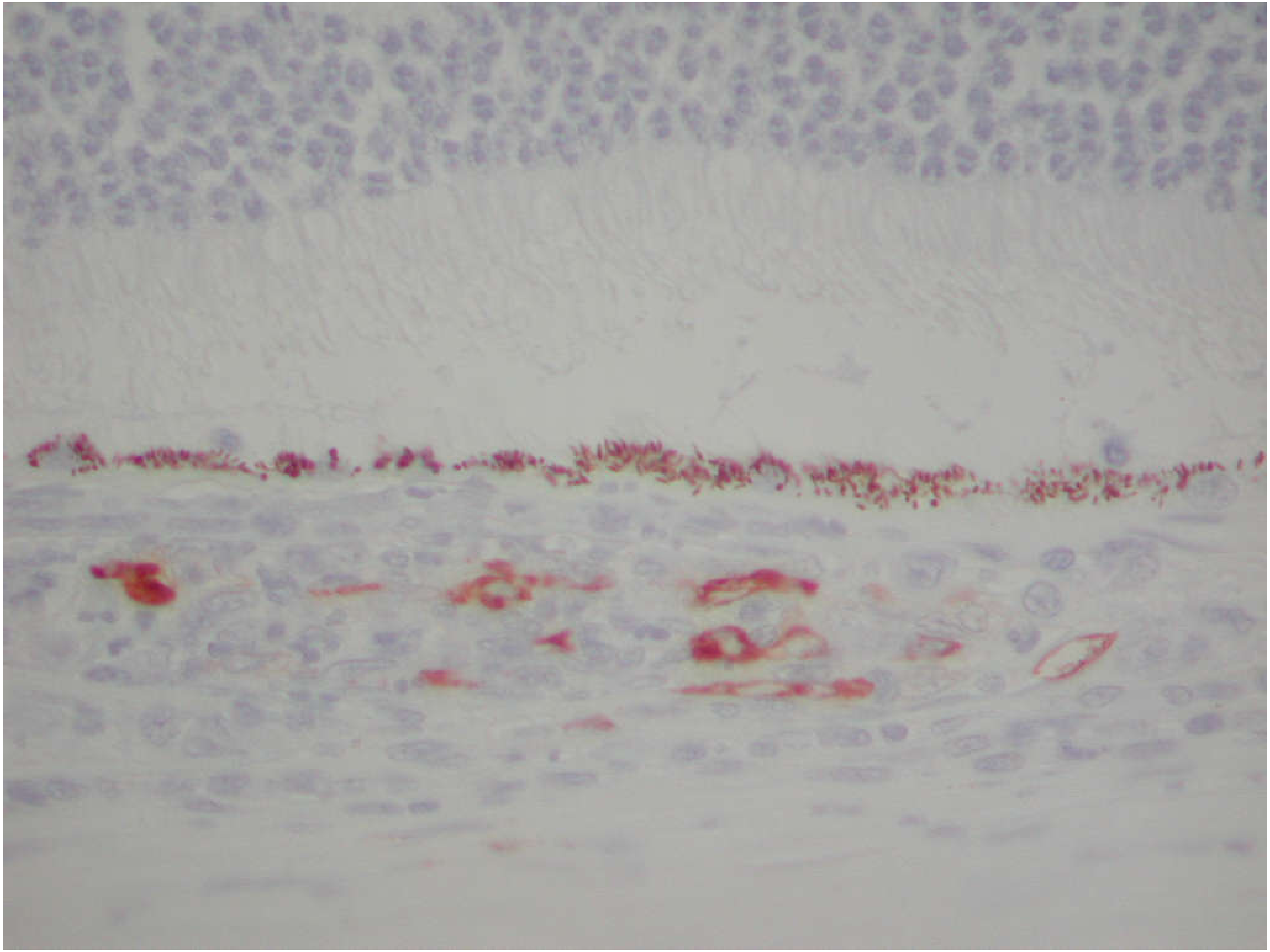
Lymph node: Immunohistochemical stain (IHC) for B-cells (CD79).



Lymph node: Immunohistochemical stain (IHC) for T-cells (CD3).



Choroid & retina: HE stain.



Choroid & retina: immunohistochemical stain for FIP virus.

Microscopy and interpretation

A Brief History of the Microscope:

- First microscopes were constructed in the Netherlands during the late 1500s.
- Actual inventor uncertain, but credit is often given to Zacharias Janssen; however, other possible inventors are Hans Lippershey (inventor of the first real telescope) and Zacharias' father, Hans Janssen
- Due to poor lens quality, the early compound microscopes (ones that used two lenses) could only magnify an object up to 20 or 30 times its normal size.
- The first big microscopy advances came in 1665, when Robert Hooke published the *Micrographia*, a collection of copper-plate illustrations of objects he had observed with his own compound microscope.
- He coined the term 'cell' when looking at a piece of cork under 30x magnification.

Cont…

- In the late 1660s, Antony van Leeuwenhoek began to grind his own lenses and make simple microscopes.
- Each microscope was really a powerful magnifying glass rather than a compound microscope.
- Leeuwenhoek's hand-ground lenses could magnify an object up to 200 times!
- He observed animal and plant tissue, sperm cells and blood cells, minerals, fossils, and much more.
- He also discovered nematodes and rotifers (microscopic animals), and he discovered bacteria while looking at samples of plaque from his own and others' teeth.

Cont…

- **1700-1800s**: Not much change in the basic microscope design occurred, but better lenses were crafted (using purer glass and different shapes) to solve problems like color distortion and poor image resolution.
- In the late 1800s, Ernst Abbe discovered that oil-immersion lenses prevented light distortion at highest magnification power.
- These are still used today on **1000x-objective** microscopes.

Cont…

- **1900s till now**: In 1931, a pair of German scientists invented the electron microscope.
- This kind of microscope directs a beam of speeded-up electrons at a cell sample; as the electrons are absorbed or scattered by different parts of the cell, they form an image that can be captured by an electron-sensitive photo plate.
- This model enables scientists to view extremely small parts, magnified as much as one million times.

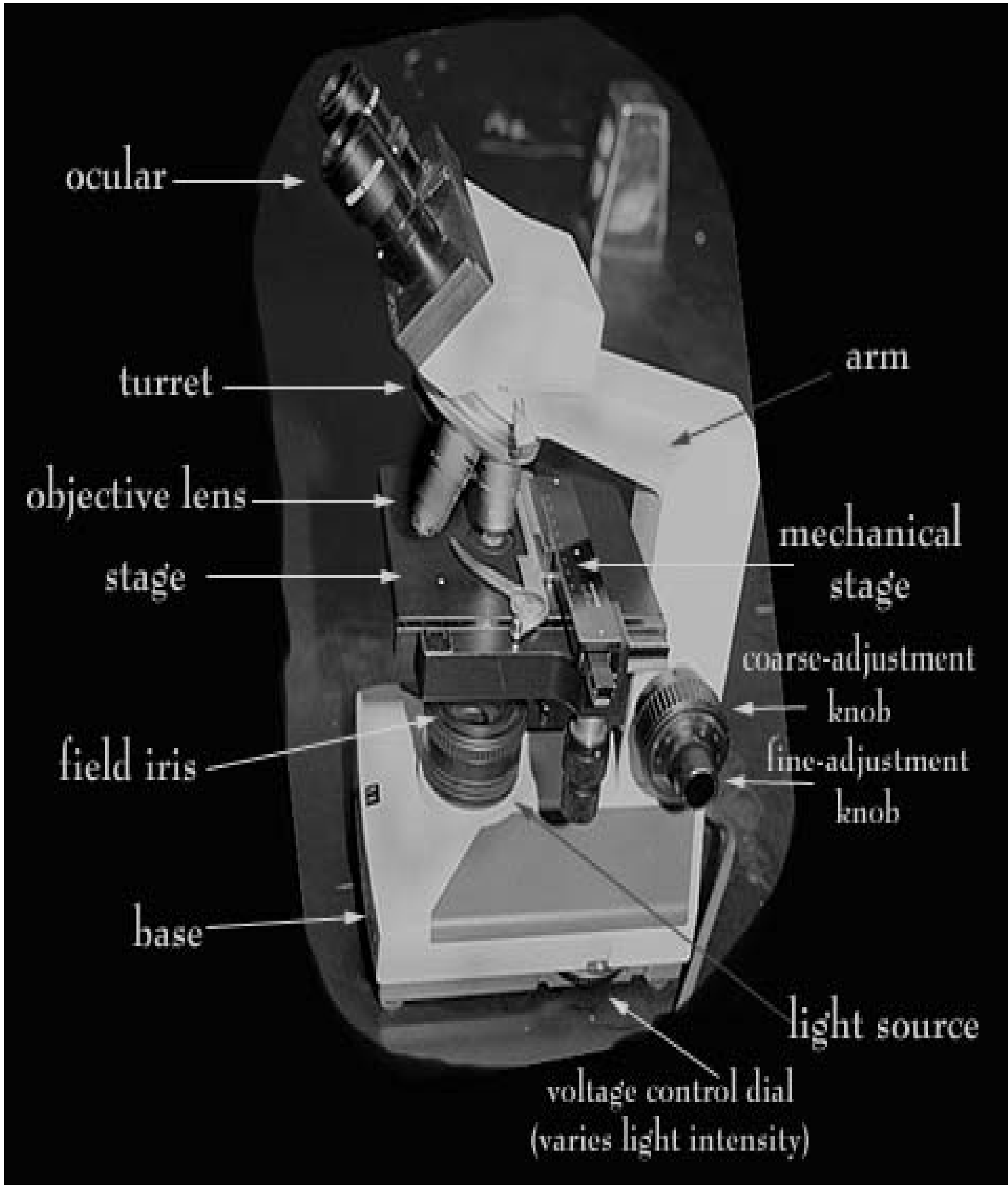
Microscopy and interpretation

Microscopy is the study of microscopes

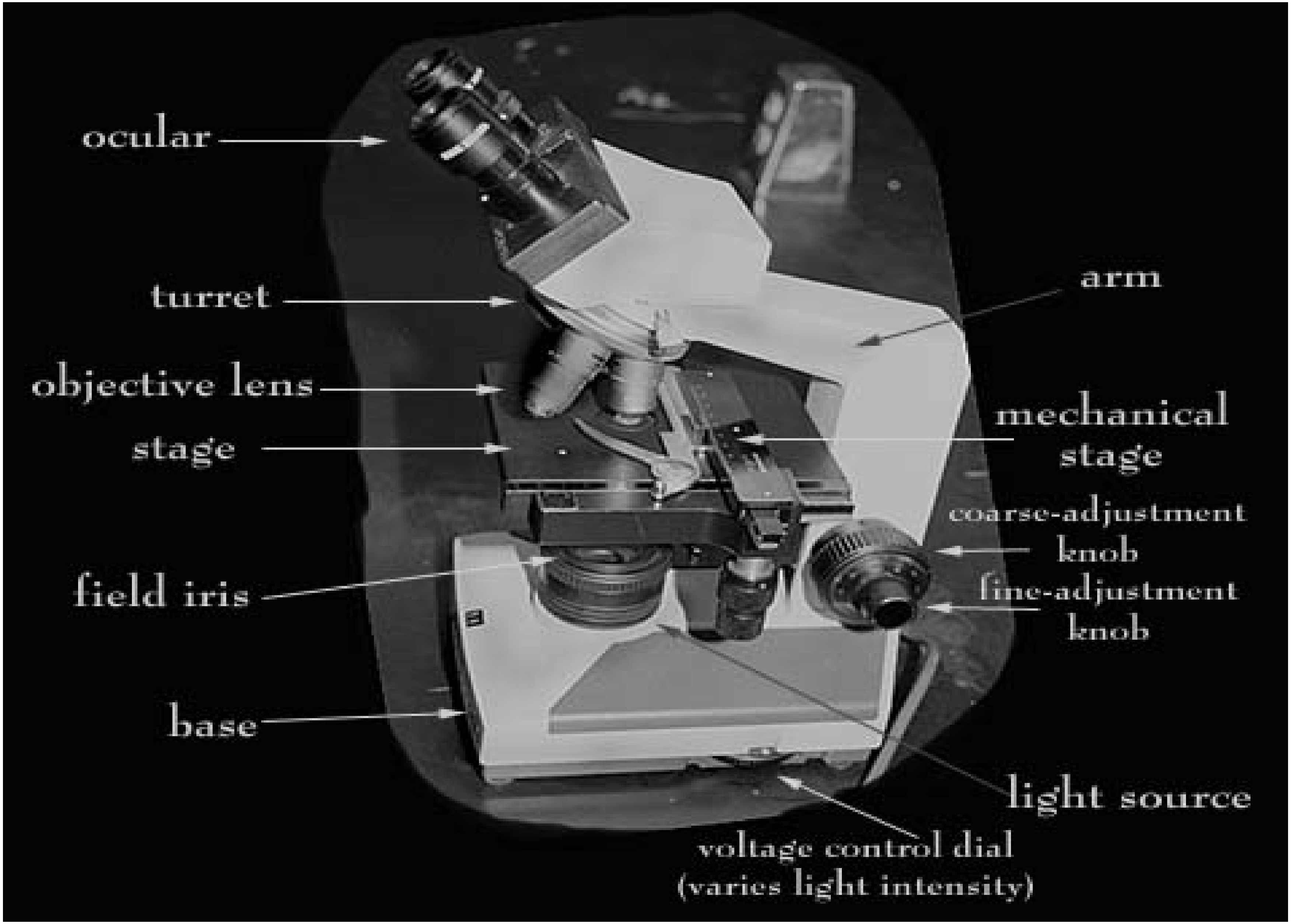
1. **Parts of Light microscope**:

* Eye lens (7x, **10x**, 15x)
* Coarse adjustment
* Fine adjustment
* nose piece
* arm
* tube
* Stage
* Mirror-diaphragm-condenser
* objective lens (10x, 40x, 100x)

- **Eyepiece Lens:** the lens at the top that you look through. They are usually 10X or 15X power.
- **Tube**: Connects the eyepiece to the objective lenses
- **Arm**: Supports the tube and connects it to the base
- **Base**: The bottom of the microscope, used for support
- **Illuminator:** A steady light source (110 volts) used in place of a mirror.



- **Stage:** The flat platform where you place your slides. Stage clips hold the slides in place.
- **Revolving Nosepiece or Turret**: This is the part that holds two or more objective lenses and can be rotated to easily change power.
- **Objective Lenses**: Usually there are 3 or 4 objective lenses on a microscope.
  - They almost always consist of 4X, 10X, 40X and 100X powers.
  - When coupled with a 10X (most common) eyepiece lens
  - we get total magnifications of 40X (4X times 10X), 100X , 400X and 1000X .


ocular
turret
objective lens
stage
field iris
base
arm
mechanical stage
coarse-adjustment knob
fine-adjustment knob
light source
voltage control dial (varies light intensity)

Types of Microscope

Light microscope

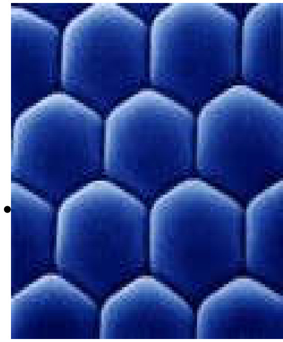
- ***Bright- field microscopy***: Is a microscope most commonly used in histology and has bright microscopic fields.

- ***Dark field microscopy***: usual condenser is replaced by one that causes light to strike the image at an oblique angle without any direct illumination reaching the objective lens.
  - Cells and other tissue components appearing bright against a dark background.
  - Dark- field microscopes enable to examine living, unstained specimen(structures, motility)

ELECTRON MICROSCOPY:

- Sophisticated, advanced and latest and the source of illumination is electron.
- Electrons have a much smaller wavelength than light, so they can resolve much smaller structures.
- Images are received on a fluorescence screen or photographic plate.

There are two types of electron microscope:



- Scanning microscope: helps to study tissues from out side.

✓ It helps the display of three-dimensional images.

- Transimissition electron microscope: depending on the beams penetrates inside the tissue.
  - The size, shape and arrangement of the particles which make up the specimen as well as their relationship to each other on the scale of atomic diameters.

Ultraviolet microscope:

- utilizes an **ultraviolet radiation source** that emits radiation with wavelengths between 1000 A°and 3000 A°.
- Resolution of this system is beetween500 A°and 1500 A°.
- Primary application is in microsphectrophotometry as an adjunct to histochemical studies.

Fluorescence microscopy

- This is a form of visible light microscopy in which an ultraviolet emitter is used as the light source.
- It involves the use of fluorescent dyes that are either present in the specimen or applied on the specimen.

- These dyes have the ability to absorb UV-light and re-emit (reflect) it in the form of visible light.

- It is used in fluorescent antibody techniques.

PHASE-CONTRAST MICROSCOPE

- it is a modified conventional microscope that requires a special condenser (Zernike condenser) and a phase plate positioned behind objective lenses.

POLARIZING MICROSCOPE

- it can resolve structures of a cell less than $2000A^0$ apart
- It is fitted with a material called polarioids, which make the light rays polarize in one direction and enhance the visibility of the point of interest in detail.

Functions of Microscope

- **Magnification:** ability to magnify objects
  - Ocular (10X) X objective lenses (4X, 10X, 40X or100X)
  - Light microscope: Use ordinary light rays and magnifies up to 1250X
  - Electron Microscope: Use electron beams and magnifies up to 250,000X.
- ***Resolving power*** (R p) is the capacity of a microscope to clearly differentiate between two near points.
  - The display of closely spaced objects as separate images is the resolving power of a lens or lens system.
  - Resolution is mathematically defined as: $\mathbf{R=0.61\lambda/NA}$.
  - Numerical aperture (**NA**)–measure of the ability of a microscope to collect diffracted light from fine details in the object

Cont…

- Resolution is mathematically defined as

  $R=0.61\lambda/NA$.

- o Numerical aperture (NA)–measure of the ability of a microscope to collect diffracted light from fine details in the object

Cont..

- The resolving power (R inA°) is determined by the wavelength (λ in A°) of the illuminating source and the numerical aperture (NA) of the objective lens.
- Usually the wavelength of light microscope is 5000 A° and NA in good oil immersion is 1.4.

$$RP=\frac{0.61X5000\ A^\circ}{1.4}=2200\ A^\circ,$$

- But if the closeness is higher than resolution power one has to use another microscope.

Interpretation

- Ability of microscope must be taken into consideration.
- Color and morphology of specimen must be related with staining procedure.
- The tendency “to want to see more” by going directly to the highest magnification usually results in lack of orientation for the novice.
- Each increment in magnification should always be accompanied progressively or gradually from narrower field of vision.

Artifacts in Histological Section

- structures or features in tissue that interfere with normal histological examination.
- These are not always present in normal tissue and can come from outside sources.
- interfere with histology by changing the tissues appearance and hiding structures.
- A number of artifacts that appear in stained slides may result from
  - ➲ Improper fixation
  - ➲ Type of fixative
  - ➲ Poor dehydration and paraffin infiltration
  - ➲ Improper reagents and poor microtome sectioning

Artifacts can categorized in to two

Pre-histology

- These are features and structures that have being introduced prior to the collection of the tissues.

Post-histology

- result from tissue processing. Processing lead to changes like shrinkage, color changes caused in a laboratory,,
- the majority of post histology artifacts can be avoided or removed after being discovered.

CELL BIOLOGY

INTRODUCTION TO THE CELL

- **Cytology**: is the study of cells. *is the branch of life science that deals with the study of cells in terms of* ***structure, function*** *and* ***chemistry***
- Both living and non-living things are composed of molecules made from chemical elements such as C, H, Oxygen and Nitrogen.
- The organization of these molecules into cells is one feature that distinguishes living things from all other matter.

Cell Theory

Cell Theory consists of **three** principles:

a. All living things are composed of one or more cells.

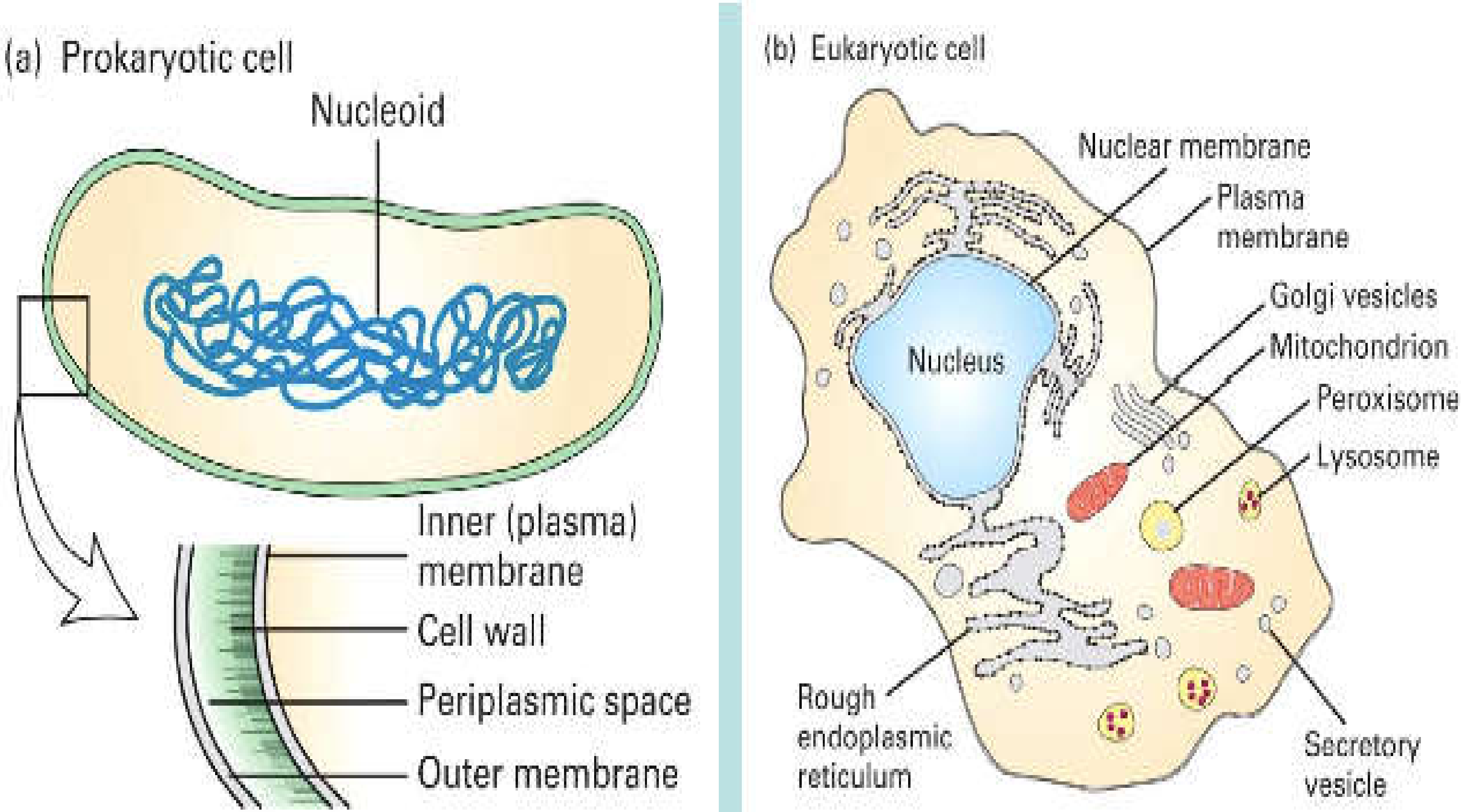
b. Cells are the basic units of structure and function in an organism.

c. Cells come only from the replication of existing cells.

PROKARYOTES AND EUKARYOTES

- Organisms whose cells normally contain a nucleus are called **Eukaryotes**;
- Those (generally smaller) organisms whose cells lack a nucleus and have no membrane-bound organelles are known as **Prokaryotes**.

PROKARYOTES AND EUKARYOTES



	Prokaryotes	Eukaryotes
Typical organisms	bacteria	Protoctista, fungi, plants, animals
Typical size	~ 1-10 µm	~ 10-100 µm (sperm cells) apart from the tail, are smaller)
Type of nucleus	Nuclear body **No nucleus**	real nucleus with nuclear envelope
DNA	circular (ccc DNA)	linear molecules (chromosomes) with histone proteins
Ribosomes	70S	80S
Cytoplasmatic structure	very few structures	highly structured by membranes and a cytoskeleton
Cell movement	Flagellae/cilia made of flagellin	flagellae and cilia made of tubulin
Mitochondria	none	1 - 100 (though RBC's have none)
Chloroplasts	none	in algae and plants
Organization	usually single cells	single cells, colonies, higher multicellular organisms with specialized cells
Cell division	Binary fission (simple division)	Mitosis (normal cell replication) Meiosis (gamete production)

PARTS OF THE EUKARYOTIC CELL

- The structures that make up a Eukaryotic cell are determined by the specific functions carried out by the cell.
- Nevertheless, Eukaryotic cells generally have three main components:

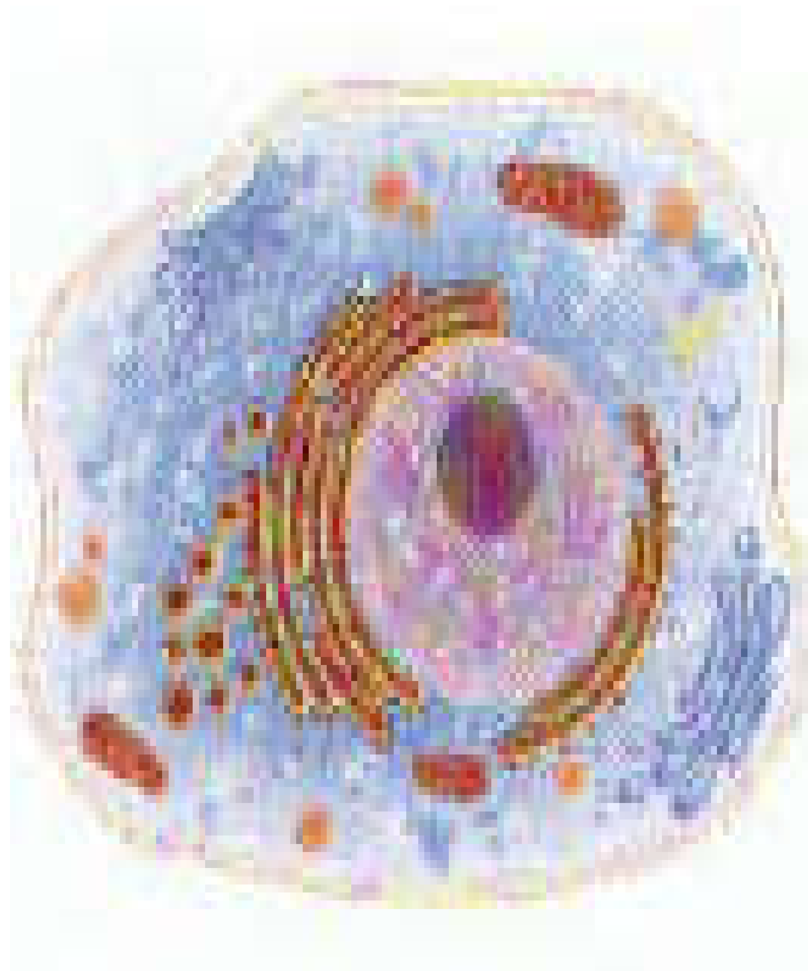
✓ *A cell membrane,*

✓ *a nucleus, and*

✓ *a variety of other organelles*.

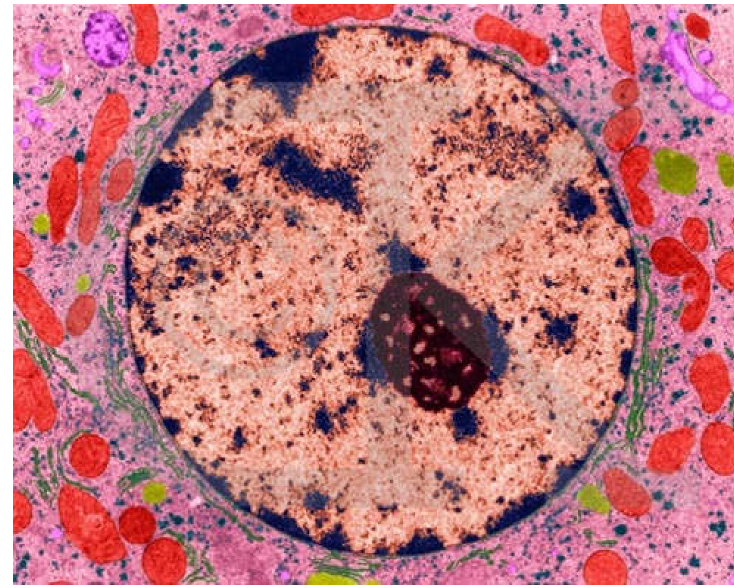
CYTOPLASM

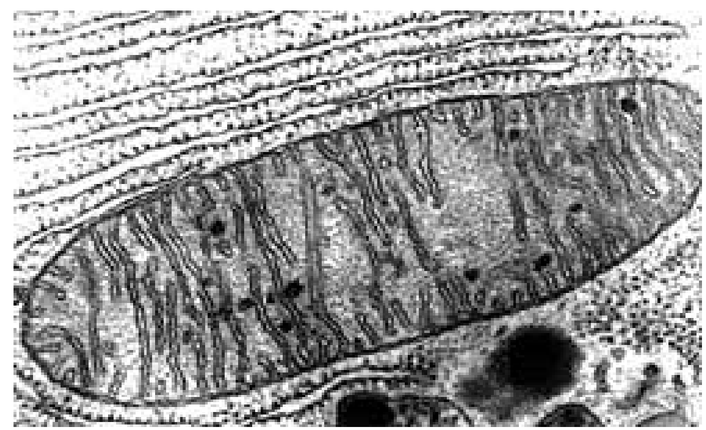
1. Everything within the cell membrane which is not the nucleus is known as the **cytoplasm**.
2. Cytosol is the jelly-like mixture in which the other organelles are suspended, so cytosol + organelles = cytoplasm.
3. Organelles carry out specific functions within the cell. In Eukaryotic cells, most organelles are surrounded by a membrane, but in Prokaryotic cells there are no membrane-bound organelles.



Cell Organelles

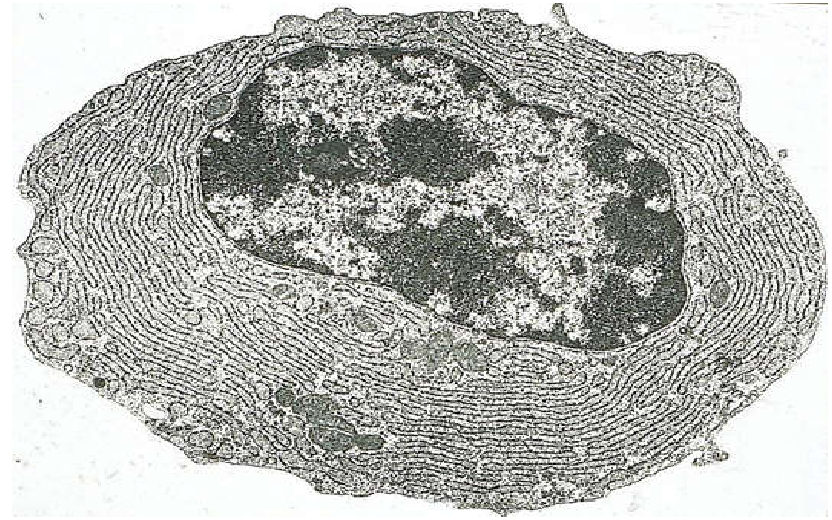
- Nucleus
  - Nuclear envelope
  - Chromatin and DNA
  - Nucleolus
- Mitochondria
  - Double membrane
  - Mitochondrial (maternal) DNA
  - "Power House" of the cell
    - Food converted into energy
      - Adenosine triphosphate (ATP)
    - Consumes Oxygen, produces CO_2

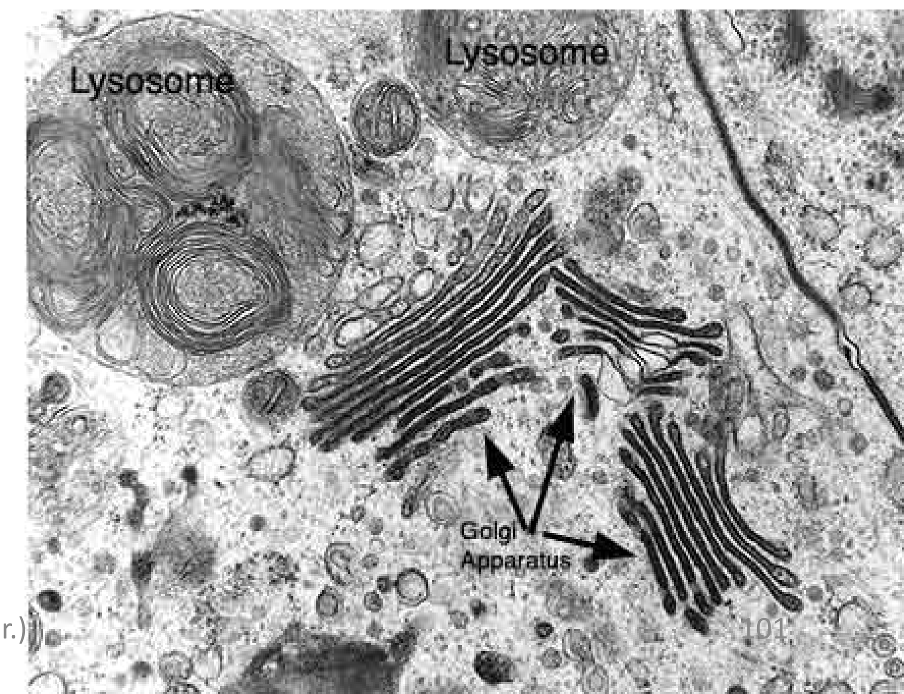




Cell Organelles

- Endoplasmic Reticulum
  - Site where cell membrane and exported material is made
  - Ribosomes (rough ER):- Make protiens
  - Smooth ER:- make lipids
- Golgi Apparatus
  - Receives and modifies &
  - Directs new materials
- Lysosomes
  - Intracellular digestion
  - Releases nutrients
  - Breakdown of waste





Cell Organelles

- Peroxisomes
  - Hydrogen Peroxide generated and degraded
- Cytosol
  - Water based gel
  - Chemical reactions
- Cytoskeleton
  - Filaments (actin, intermediate and microtubules)
  - Movement of organelles and cell
  - Structure/strengthen cell
- Vessicles
  - Material transport
  - Membrane, ER, Golgi derived vessicles

Cytoplasmic matrix

- The **cytoplasmic matrix** is the substance in which the following cellular components are suspended:-

➢ the nucleoid

➢ ribosomes

➢ macromolecules (NA, proteins, RNAs, carbohydrates, fats)

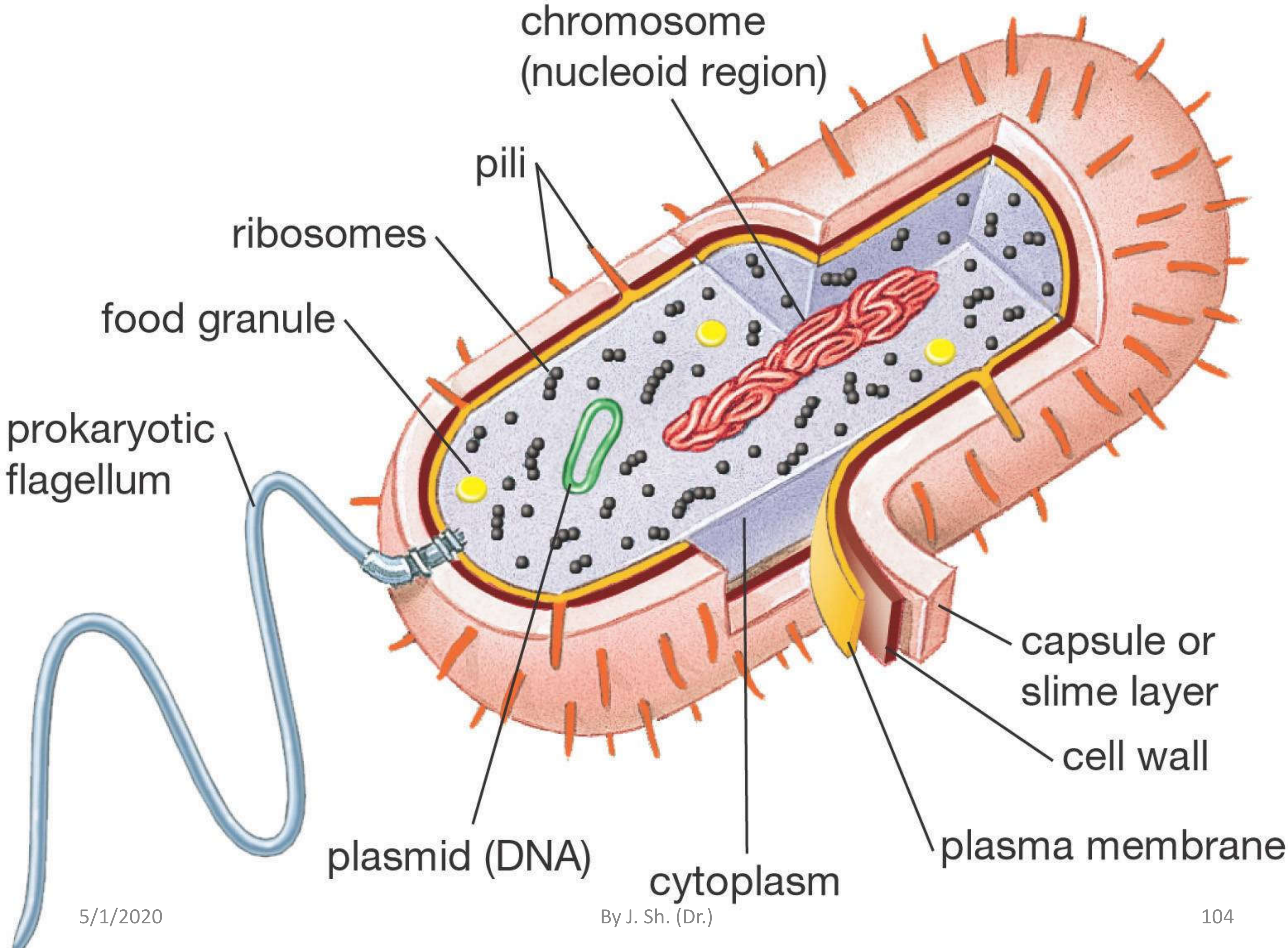
➢ inclusion bodies

➢ It lacks organelles bound by lipid

➢ Vitamins and inorganic ions

➢ is largely water (about 70% of bacterial mass is water)

➢ Until recently, it was thought to lack a cytoskeleton.


chromosome
(nucleoid region)
pili
ribosomes
food granule
prokaryotic
flagellum
capsule or
slime layer
cell wall
plasma membrane
cytoplasm
plasmid (DNA)

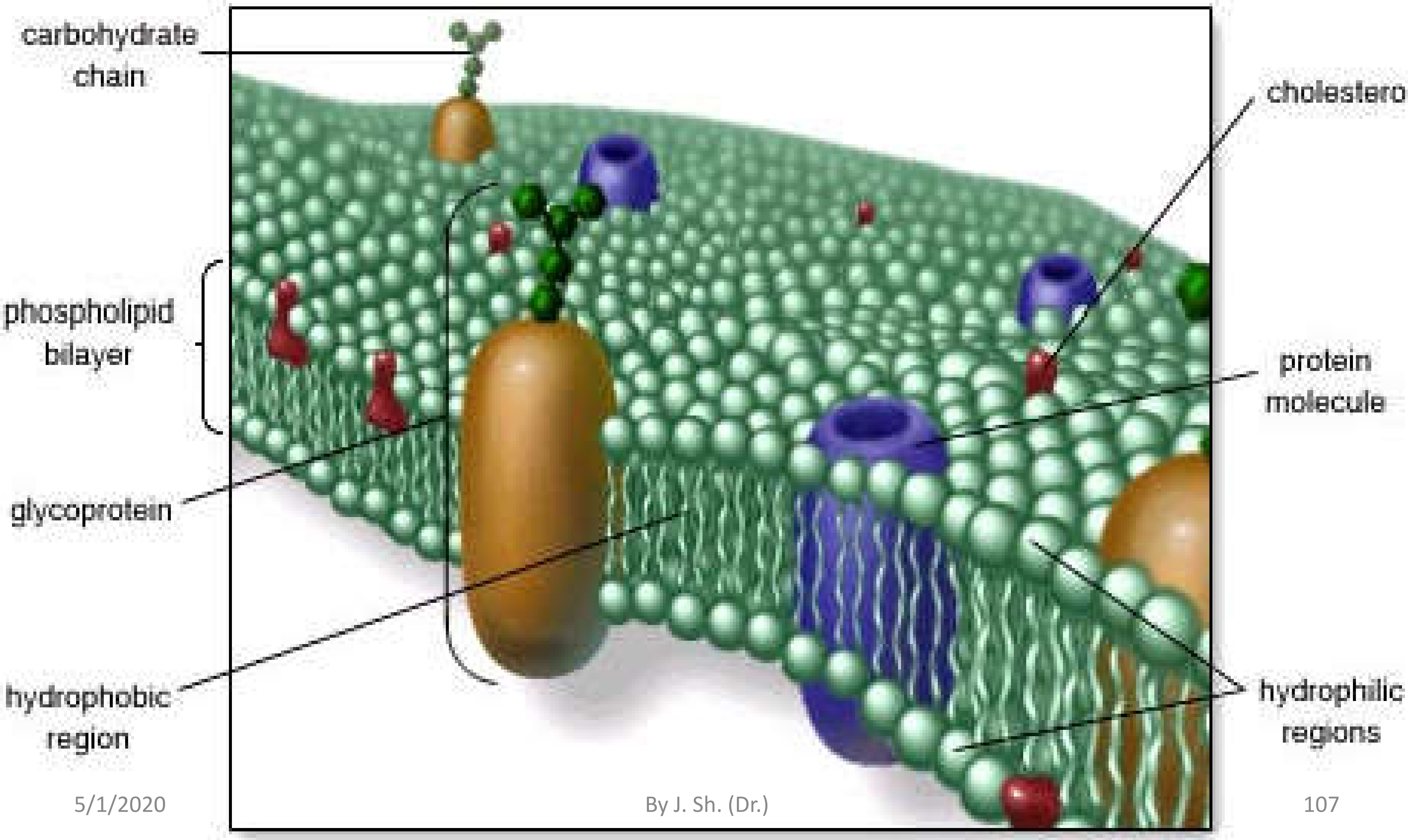
Plasma membrane

- The cytoplasmic membrane of bacterial cells is a bimolecular lipid leaflet of phospholipid molecules aligned at their hydrophobic ends.
- The polar phospholipids are hydrophilic and face the external of the membrane and the internal or cytoplasmic side of the membrane.
- The hydrophobic ends face the interior of the plasm

Cont…

- The cell membrane serves as a permeability barrier. The most important numerous proteins integrated into its structure include:
- ✓ Permeases:- enzymes for the biosynthesis of the cell wall
- ✓ transfer proteins for secretion of extracellular proteins
- ✓ sensor or signal proteins and
- ✓ respiratory chain enzymes
- The procaryotic plasma membrane also is the location of a variety of crucial metabolic processes:
- ➢ *respiration,*
- ➢ *photosynthesis, and*
- ➢ *the synthesis of lipids and cell wall constituents*.

Phospholipid bilayer



Cell wall

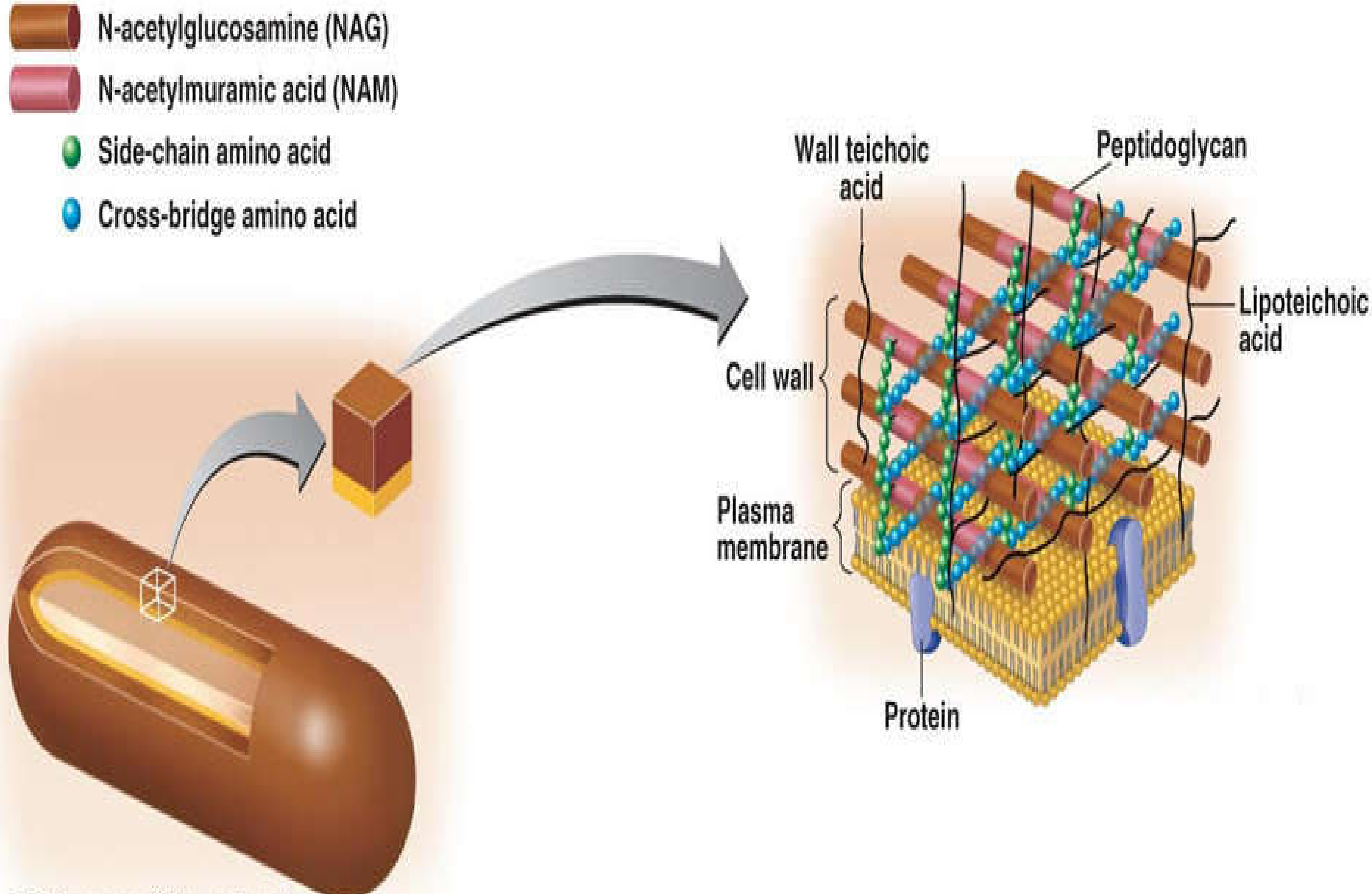
- ❖ It is one of the most important procaryotic structures for several reasons:
- ✓ it helps to determine the shape of the cell;
- ✓ it helps to protect the cell from osmotic lysis;
- ✓ it can protect the cell from toxic substances

CONT…

- The wall of a bacterium is classified in two ways:

1. Gram positive bacteria

- Gram-positive bacteria normally have cell walls that are thick and composed primarily of peptidoglycan. Peptidoglycan in gram positive bacteria often contains a peptide interbridge.
- In addition, gram-positive cell walls usually contain large amounts of **teichoic acids.**

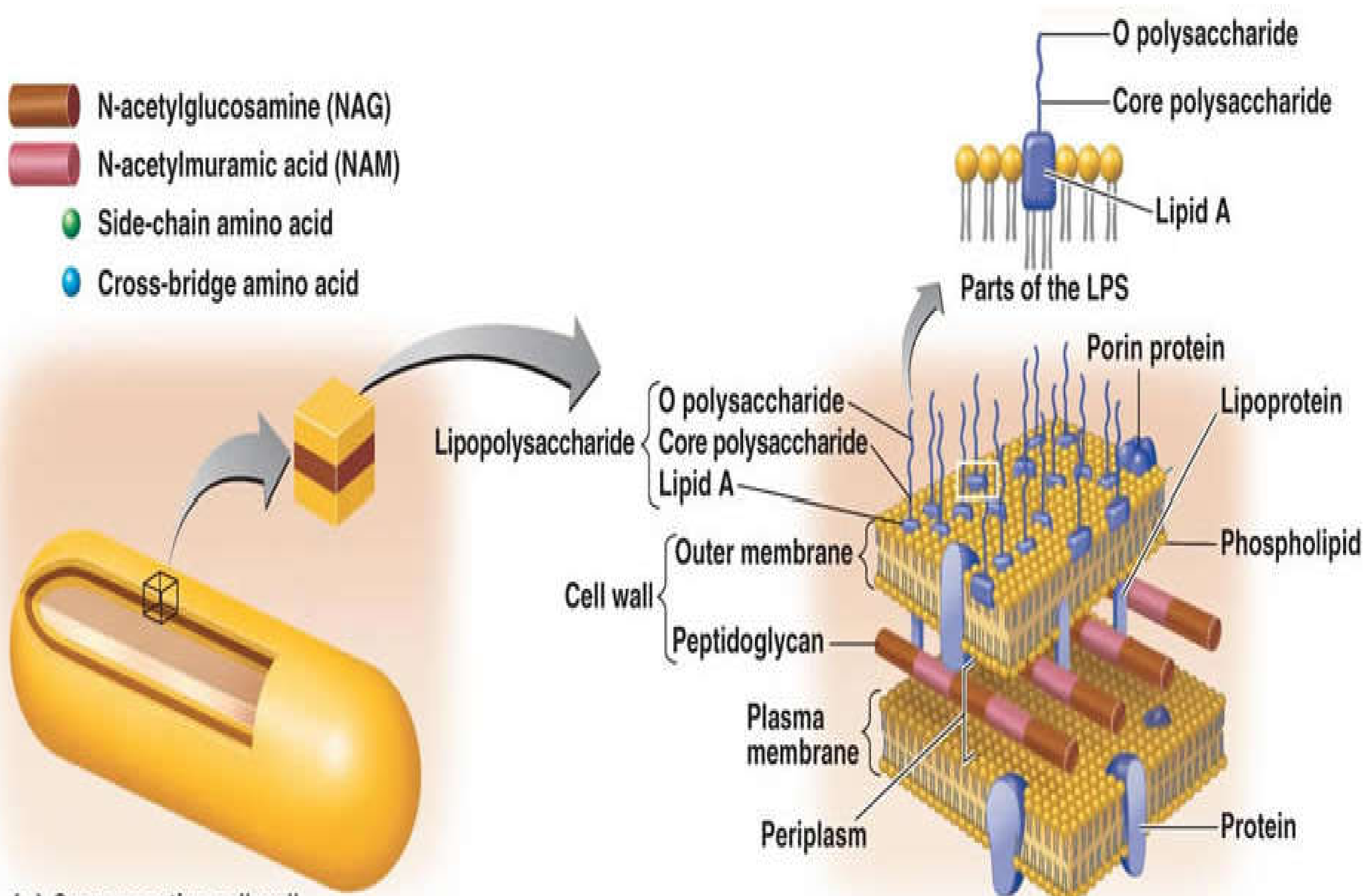


(b) Gram-positive cell wall

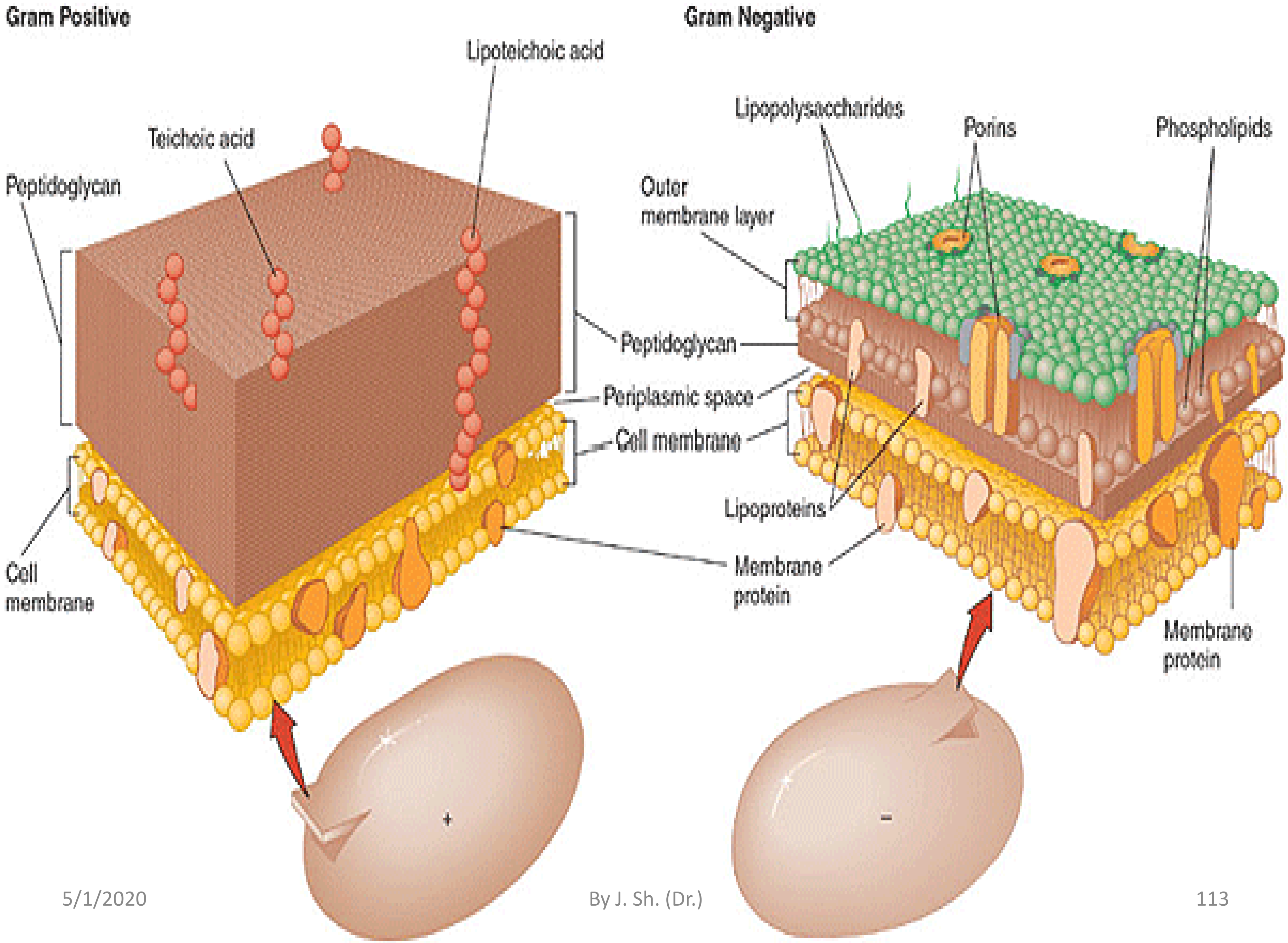
Cont…

2. Gram-negative.

- A gram-negative cell wall is thin.
- The inside is made of peptidoglycan.
- The outer membrane is composed of phospholipids and lipopolysaccharides.



(c) Gram-negative cell wall


Gram Positive
Lipoteichoic acid
Teichoic acid
Peptidoglycan
Cell membrane
+
Gram Negative
Lipopolysaccharides
Porins
Phospholipids
Outer membrane layer
Peptidoglycan
Periplasmic space
Cell membrane
Lipoproteins
Membrane protein
Membrane protein
-

Cytoplasm & Organelles

- Endoplasmic Reticulum
- Ribosomes
- Golgi Apparatus
- Lysosomes
- Phagosomes/Autophagosomes/Phagolysosomes
- Endosomes
- Cytoskeleton
- Mitochondria
- Proteasomes
- Inclusions
- Secretory granules
- Cytoplasmic Matrix (cytosol)

Cytoplasm & Organelles

- Endoplasmic Reticulum
  - Cytocavitary network
  - Smooth ER; Rough ER
- Ribosomes
  - rRNA; protein production
  - Polyribosomes; RER
- Golgi Apparatus
  - Stacks of flat cisternae
  - Carbohydrate production & packaging
- Cytoskeleton
  - Thin filaments (actin): contractile bundles, network, terminal web
  - Intermediate filaments: structural support (keratin, vimentin, GFAP, neurofilaments, desmin)
  - Microtubules: intracellular transport pathways
  - Linked to extracellular matrix by transmembrane glycoproteins (e.g. integrin)

A Generalized Cell

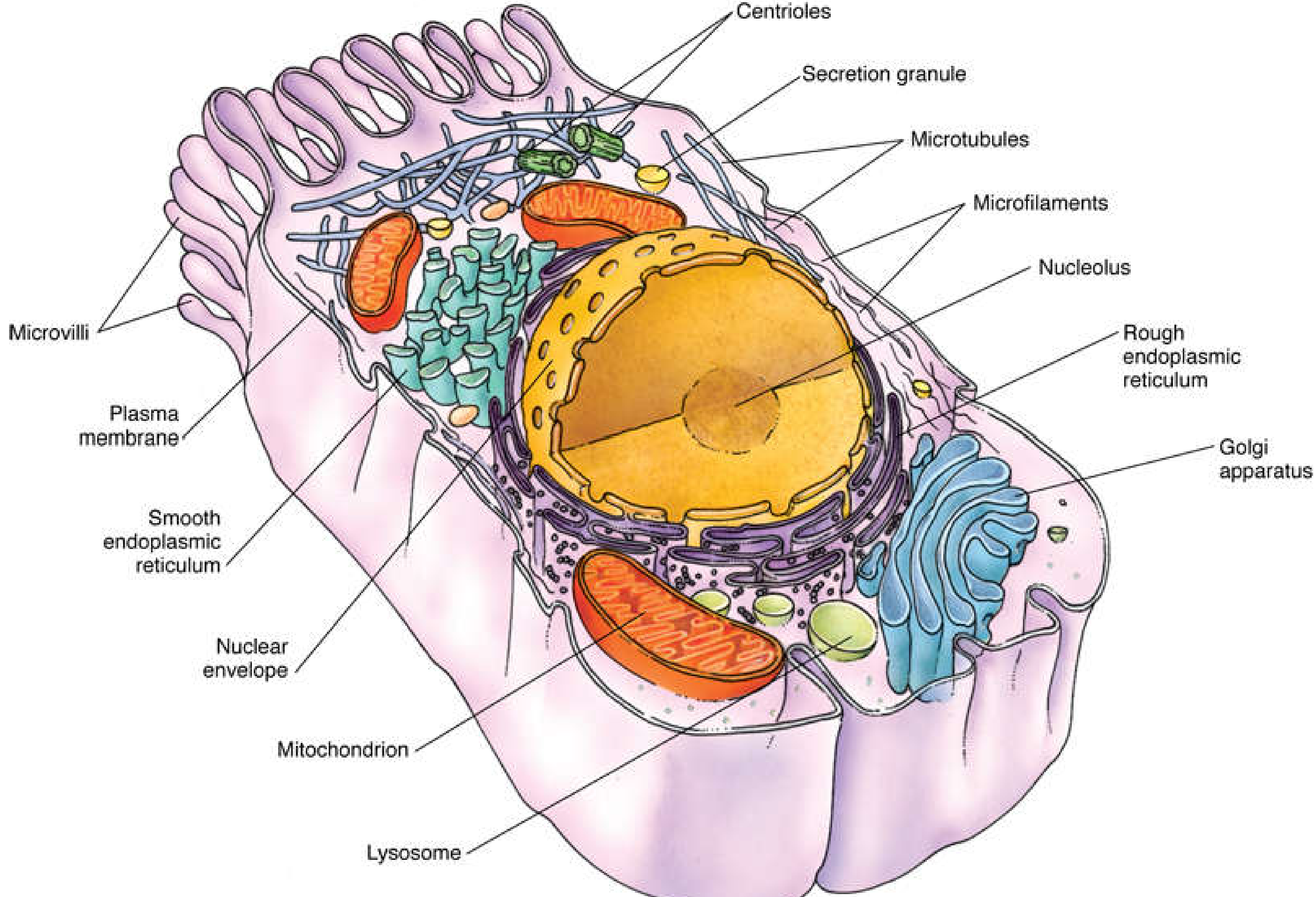
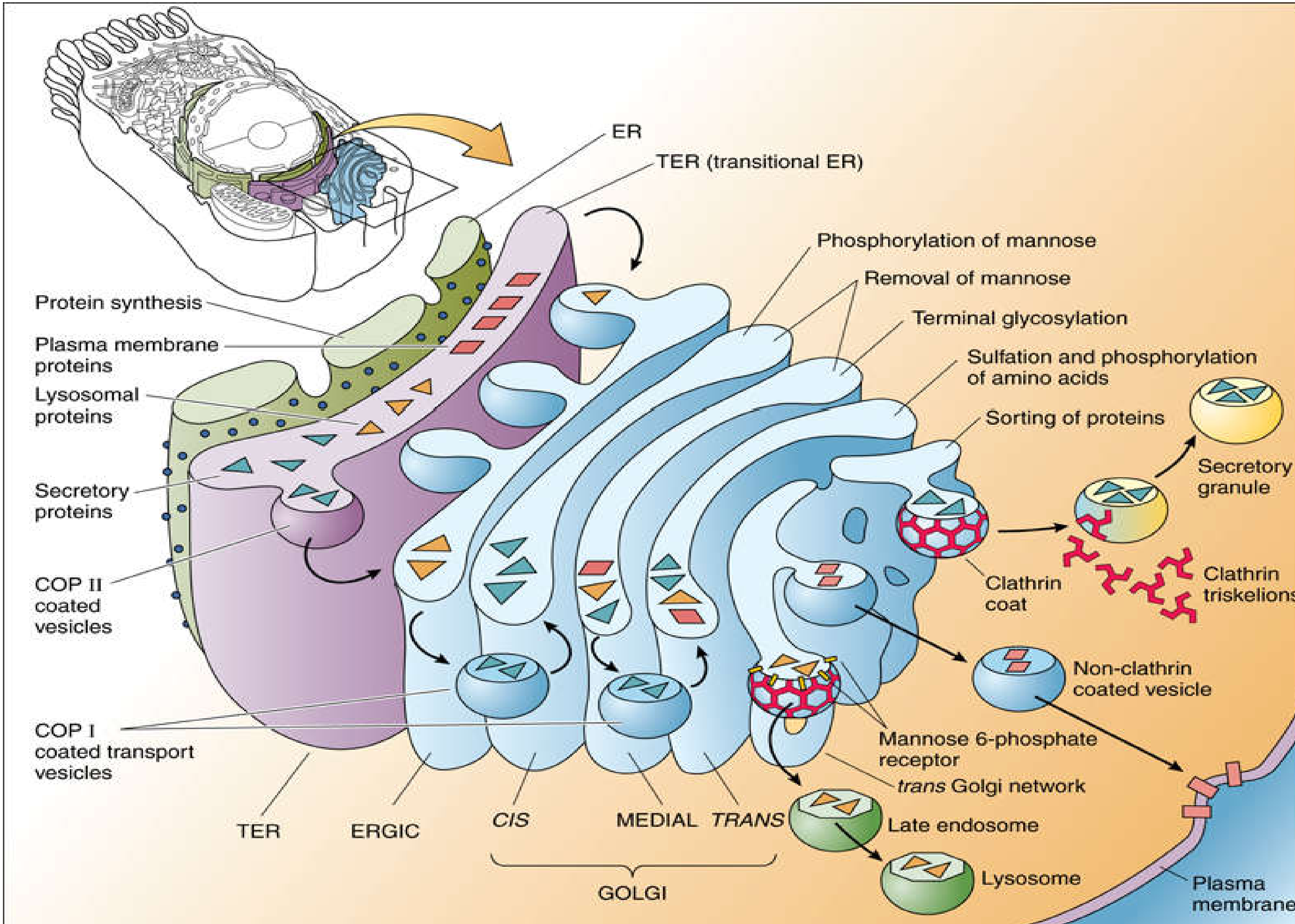
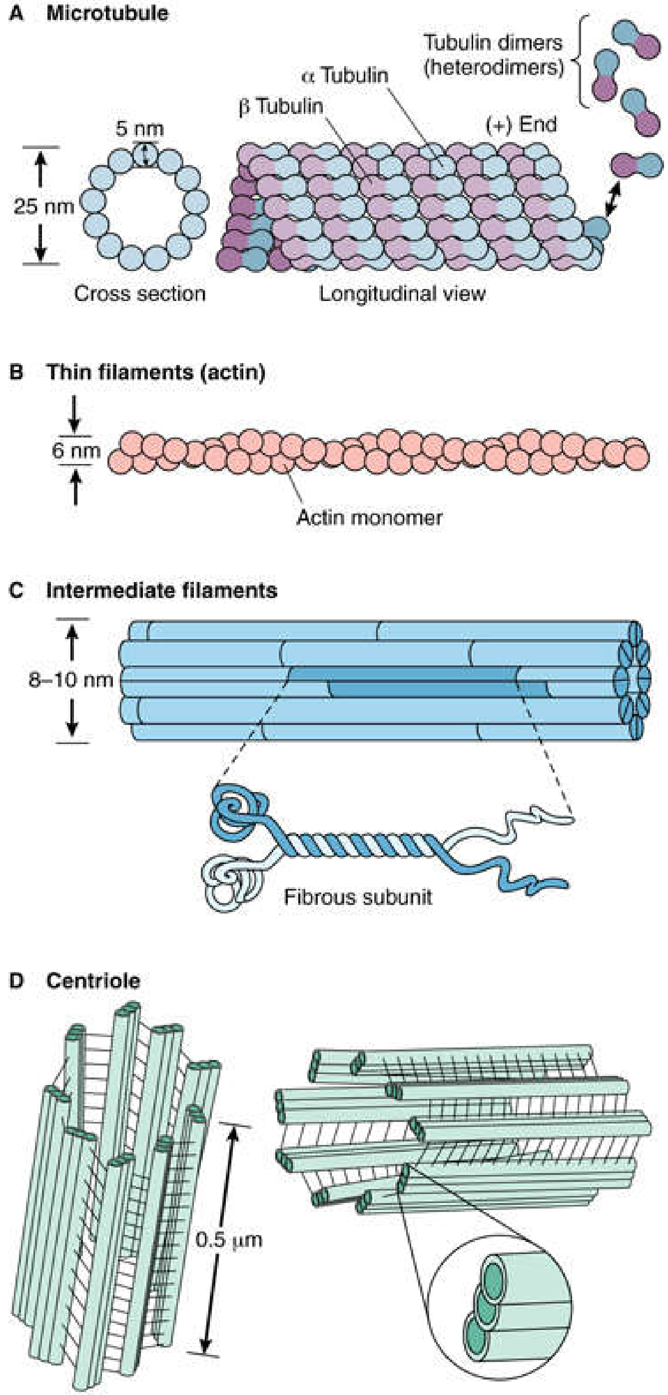


Figure 2–5 Three-dimensional illustration of an idealized cell, as visualized by transmission electron microscopy. Various organelles and cytoskeletal elements are displayed.

Rough Endoplasmic Reticulum and Golgi Apparatus



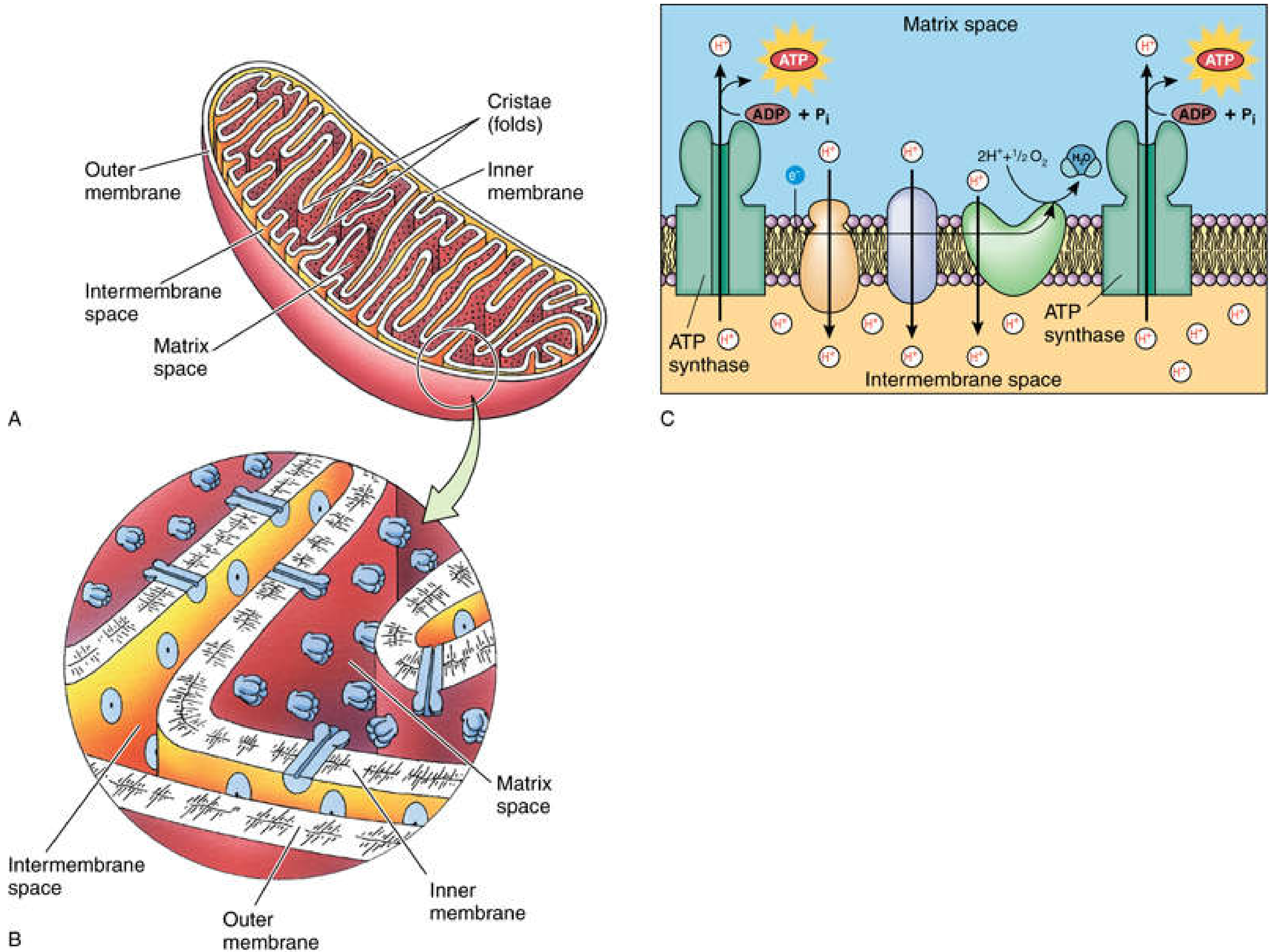
Cytoskeleton



Cytoplasm & Organelles

- Mitochondria
  - Site of oxidative phosphorylation (ATP production)
  - Elongate structure; self-replicating
- Lysosomes
  - Membrane-bounded vesicles
  - Contain +/- 40 hydrolytic enzymes; acidic pH
- Phagosome/Autophagosome/Phagolysosome
  - Vesicle formed from plasma membrane that contains phagocytosed particulate material
  - APs: vesicle derived from ER that surrounds senescent organelles for removal
  - Usually fuses with lysosome → phagolysosome
  - Ends up as a Residual body
- Endosomes
  - Series of vesicles that traffic within the cytoplasm
- Proteasomes
  - Protein complex that degrades ubiquinated proteins

Mitochondrion



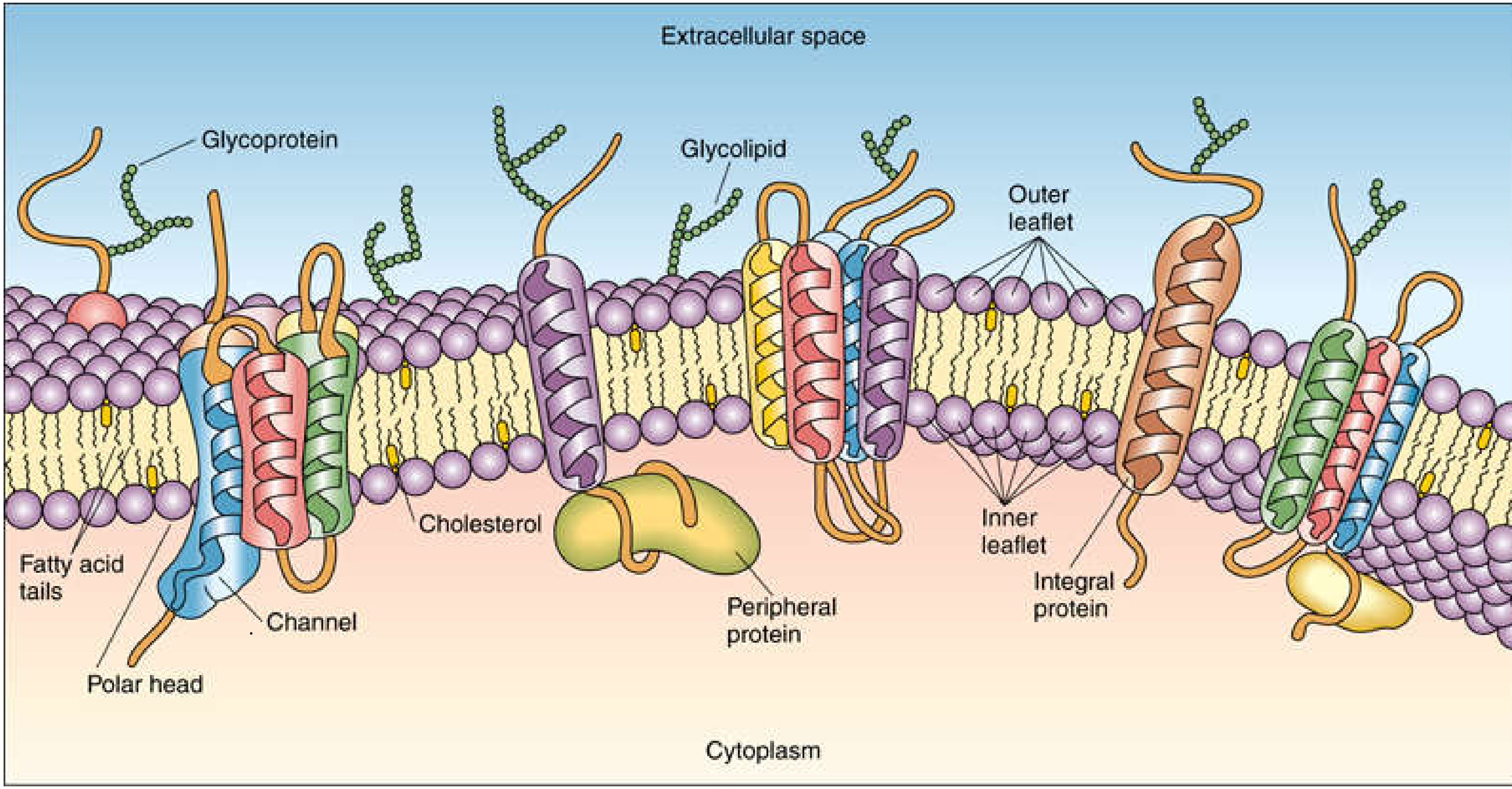
Cytoplasm & Organelles

- Inclusions
  - Glycogen
  - Lipid
  - Lipofuscin: “wear & tear” pigment
  - Viral proteins
- Cytoplasmic Matrix (cytosol)
  - Fluid component of cytoplasm that surrounds all of the organelles
- Secretory Granules
  - Membrane-bounded vesicles that contain products for secretion at cell surface
    - Peptide hormones
    - Neurotransmitters
    - Chemical mediators
    - enzymes

Plasma Membrane

- Phospholipid bilayer; fluid mosaic model
- Glycocalyx; surface layer of CHO molecules
- Microvilli
- Cilia
- Cell – Cell Junctions
- Pseudopodia
- Transmembrane proteins → intracellular signaling
- Selectively permeable barrier
- Membrane transport
    - Ion channels
    - Carrier proteins
- Receptor-mediated endocytosis

Cell Membrane – Fluid mosaic model



Each cell is bounded by a **cell membrane** (also known as the **plasma membrane** or **plasmalemma**) that functions in:

- Maintaining the structural integrity of the cell
- Controlling movements of substances in and out of the cell (selective permeability)
- Regulating cell–cell interactions
- Recognition, via receptors, antigens, and foreign cells as well as altered cells
- Acting as an interface between the cytoplasm and the external milieu
- Establishing transport systems for specific molecules
- Transducing extracellular physical or chemical signals into intracellular events.

Nucleus

- Nuclear envelope
  - Double layer membrane; outer layer is RER
  - Nuclear pore complexes
- Euchromatin
  - Lacy genetic material; DNA coiled around histones
  - Site of active transcription
- Heterochromatin
  - Condensed genetic material next to nuclear envelope
  - Inactive genetic material
- Nucleolus
  - Dense round structure within nucleus
  - 1-3 depending on protein production activity of cell
  - Involved in rRNA & ribosomal subunit synthesis

Organic Molecules of Cells

- Proteins
- Carbohydrates
- Lipids
- Nucleic acids

Proteins

- Most diverse and complex macromolecules in the cell
- Used for structure, function and information
- Made of linearly arranged amino acid residues
  - “folded” up with “active” regions

Types of Proteins

1) Enzymes – catalyzes covalent bond breakage or formation
2) Structural – collagen, elastin, keratin, *etc*.
3) Motility – actin, myosin, tubulin, *etc*.
4) Regulatory – bind to DNA to switch genes on or off
5) Storage – ovalbumin, casein, *etc*.
6) Hormonal – insulin, nerve growth factor (NGF), *etc*.
7) Receptors – hormone and neurotransmitter receptors
8) Transport – carries small molecules or irons
9) Special purpose proteins – green fluorescent protein, *etc*.

Lipids

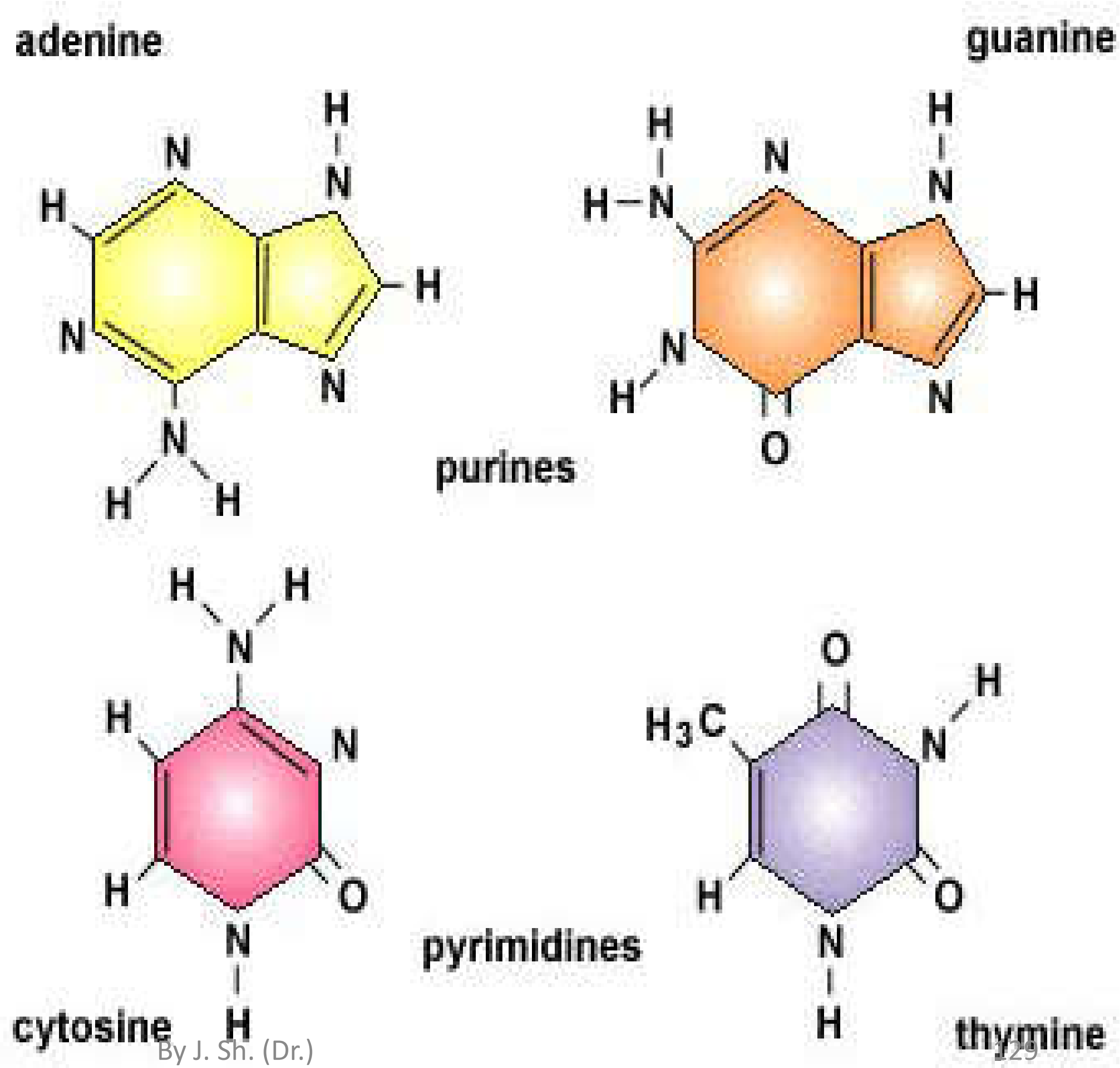
- Hydrophobic molecules
  - Energy storage, membrane components, signal molecules
  - Triglycerides (fat), phospholipids, waxes, sterols

Carbohydrates

- Sugars, storage (glycogen, starch), Structural polymers (cellulose and chitin)
- Major substrates of energy metabolism

Nucleic Acids

- DNA (deoxyribonucleic acid) and RNA encode genetic information for synthesis of all proteins
- Blue print

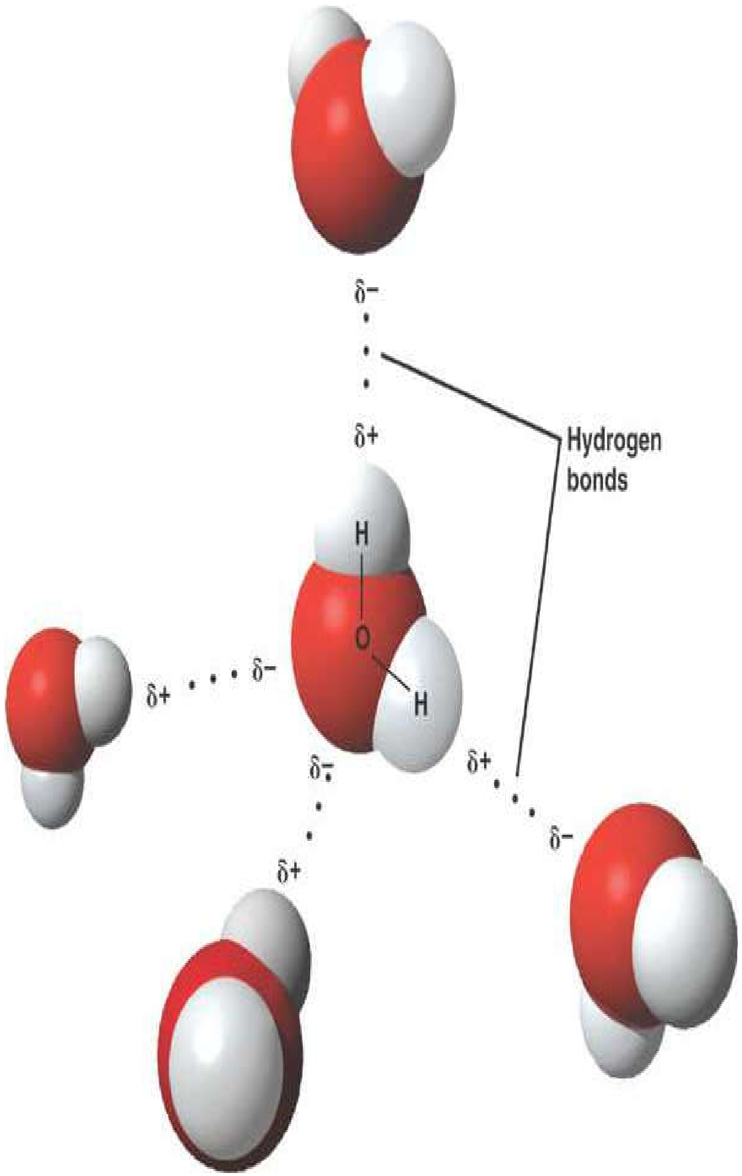


Water Molecule

- Polarity of H_2O allows H bonding
- Water disassociates into H^+ and OH^-
- Imbalance of H^+ and OH^- give rise to "acids and bases"

  - Measured by the pH

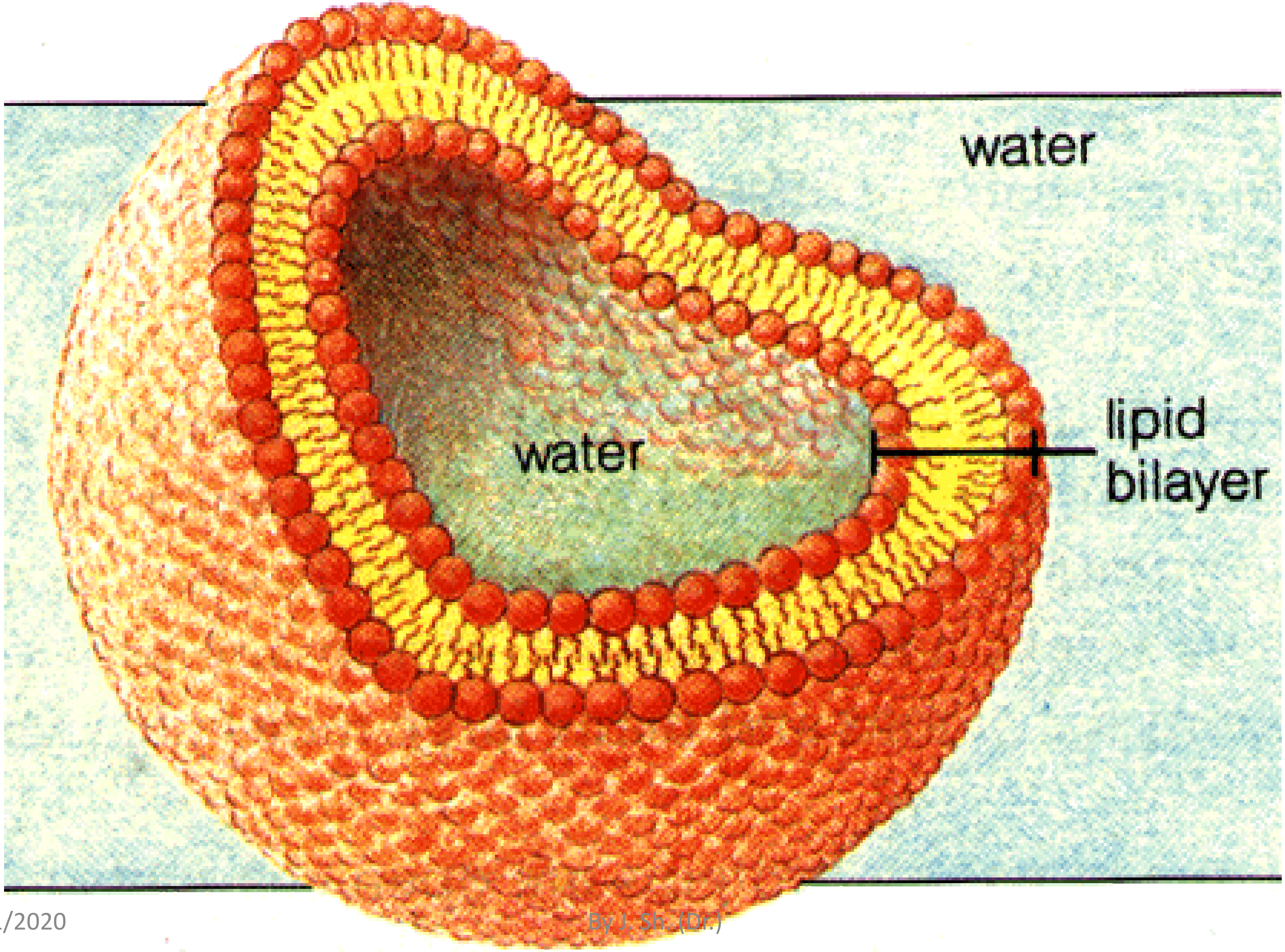
- pH influence charges of amino acid groups on protein, causing a specific activity
- Buffering systems maintain intracellular and extracellular pH



Water Molecule

- Hydrophobic "Water-fearing"
  - Molecule is not polar, cannot form H bonds and is "repelled" from water
  - Insoluble
- Hydrophillic "Water-loving"
  - Molecule is polar, forms H bonds with water
  - Soluble

Cell Membrane

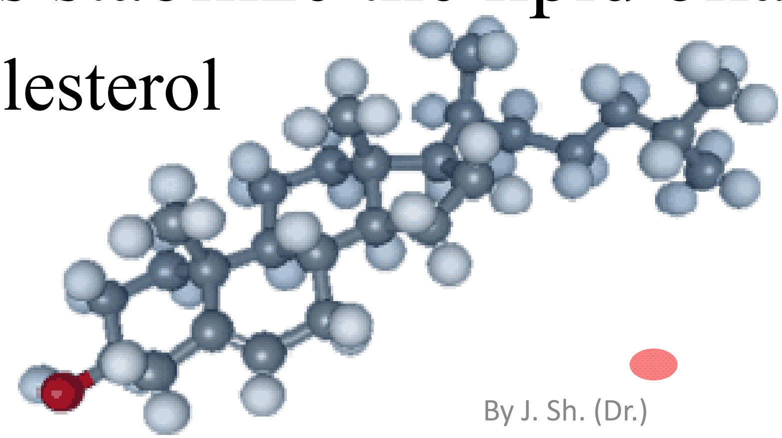


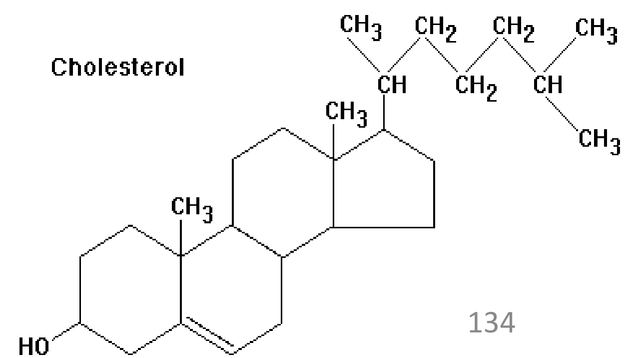
Cell Membrane Composition

- Plasma membrane encloses cell and cell organelles
- Made of hydrophobic and hydrophillic components
  - Semi-permeable and fluid-like
  - “lipid bilayer”

Cell Membrane Composition

- Integral proteins interact with “lipid bilayer”
  - Passive transport pores and channels
  - Active transport pumps and carriers
  - Membrane-linked enzymes, receptors and transducers
- Sterols stabilize the lipid bilayer
  - Cholesterol





Functions of the cell membrane

- The cell membrane is the part of the cell that regulate the exchange of molecules and ions between its internal and external environment.
- This occurs by several ways:

*1. **Passive Diffusion***

2. **Facilitated *Diffusion***

3. Active Transport

4. Selective transport

5. Endocytosis

6. Exocytosis

Cont…

1. Passive Diffusion:

- this involves the entrance of small molecules into the cytoplasm.
- It depends on the presence of a concentration gradient across the plasmalemma (e.g., diffusion of lipid soluble substances, oxygen, CO2, water and small ions).

Cont…

2. **Facilitated Diffusion*:*** this type of diffusion is also concentration-dependent and involves the transport of large water-soluble molecules such as glucose and amino acids. It requires the presence of carriers to which the molecules have to bind in order to pass through the plasmalemma.
3. **Active Transport*:*** this process requires the utilization of energy provided as ATP. (e.g., sodium-potassium pump).

Cont…

4. **Selective transport:** it depends on the presence of specific cell surface receptors to pick up specific molecules into the cytoplasm (e.g., hormones).

5. **Endocytosis**

- Endocytosis involves either the engulfment of solid particles (phagocytosis) or minute droplet of fluid (pinocytosis).
- The engulfed material is surrounded first by cytoplasmic extensions called pseudopodia.

Cont…

- When the particles become completely surrounded, the plasma membrane fuses and the membrane surrounding the engulfed particles forms a vesicle, known as a phagosome or endocytotic vesicle, which detaches from the cell membrane to float freely within the cytoplasm.
- Once the phagosome enters the cytoplasm it fuses with the lysosomes and their contents are subjected to enzymatic digestion.

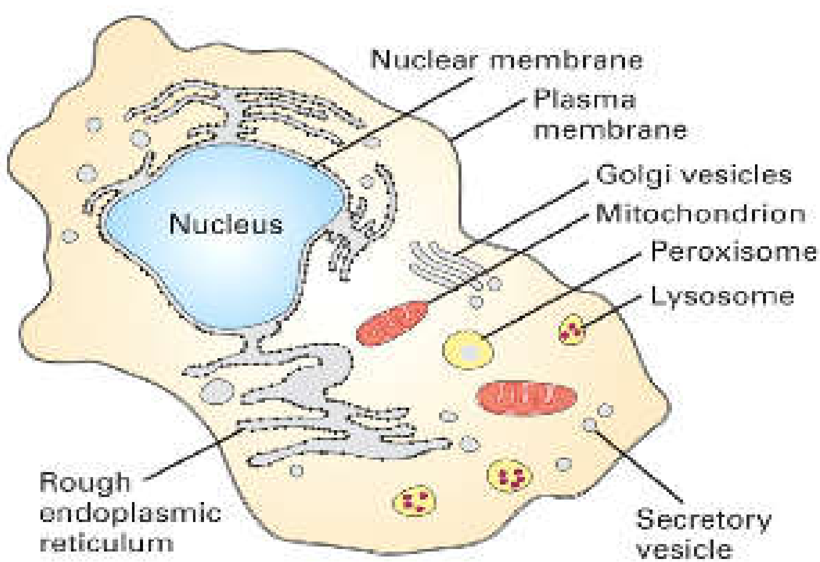
COnt…

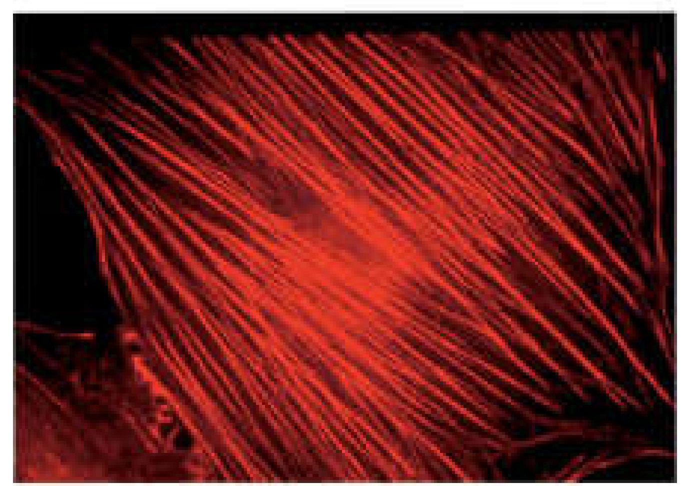
6. Exocytosis

- Exocytosis (Exo = out) is the process by which some membranous vesicles located within the cytoplasm fuse with the plasma membrane and release their contents outside the cell.
- It occurs in many secretory processes.

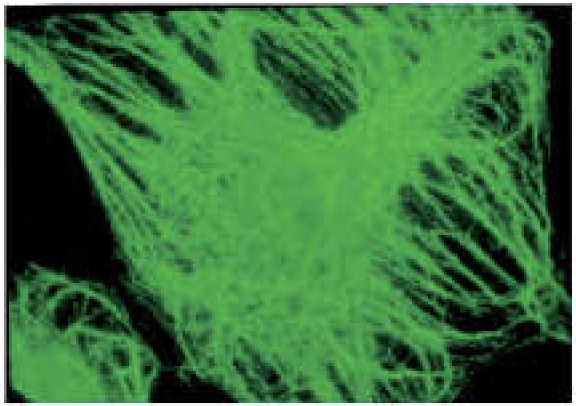
The Cytoskeleton

- The cytoskeleton, a component of structural functions, is critical to cell motility.
- Cells have three types of filaments that are distinguishable by the diameter.
- Actin filaments (microfilaments): **5-9** nm diameter with twisted strands.

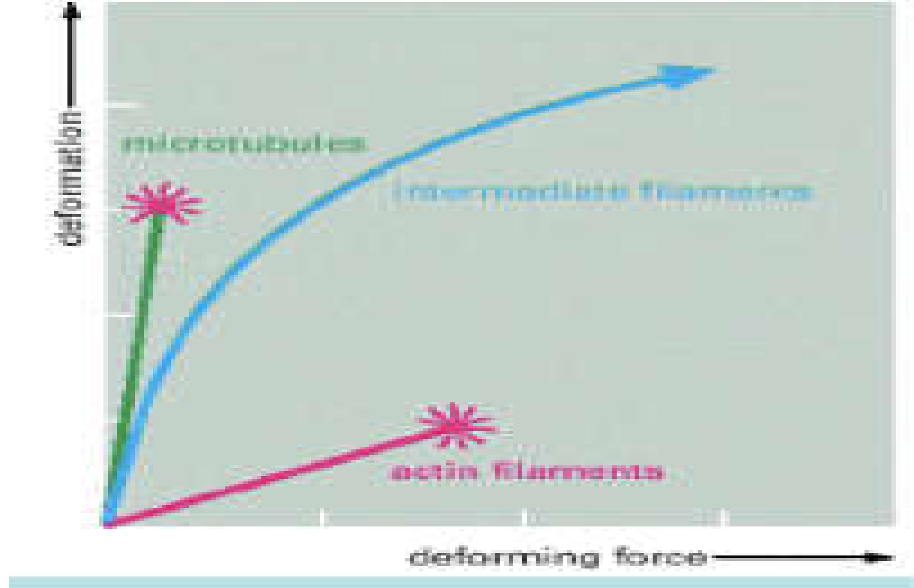




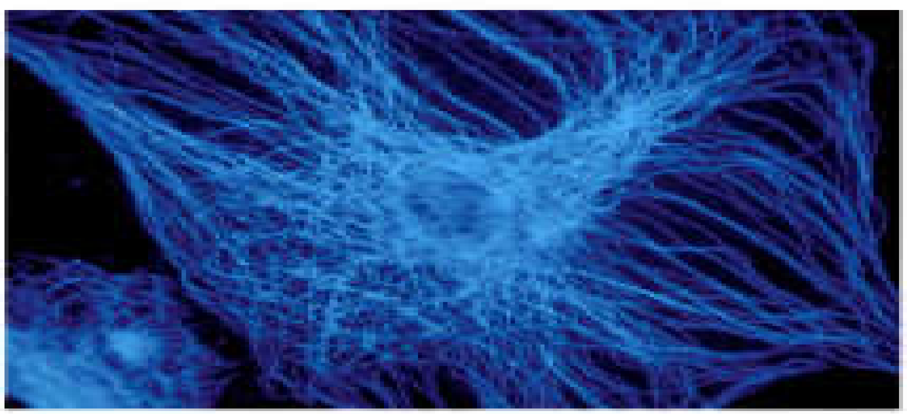
Microfilaments



Intermediate filaments

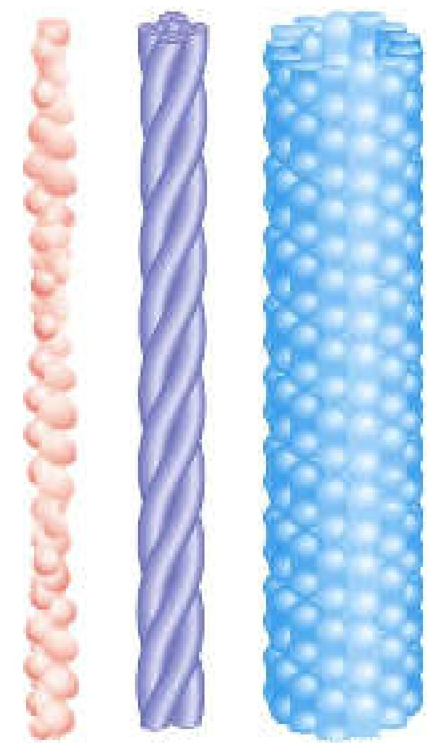


Intermediate Filaments: 9-nm diameter



Microtubules

Microtubules: hollow tube-like structure
~ 24 nm diameter



Cell Locomotion

Why do we care about cell locomotion?

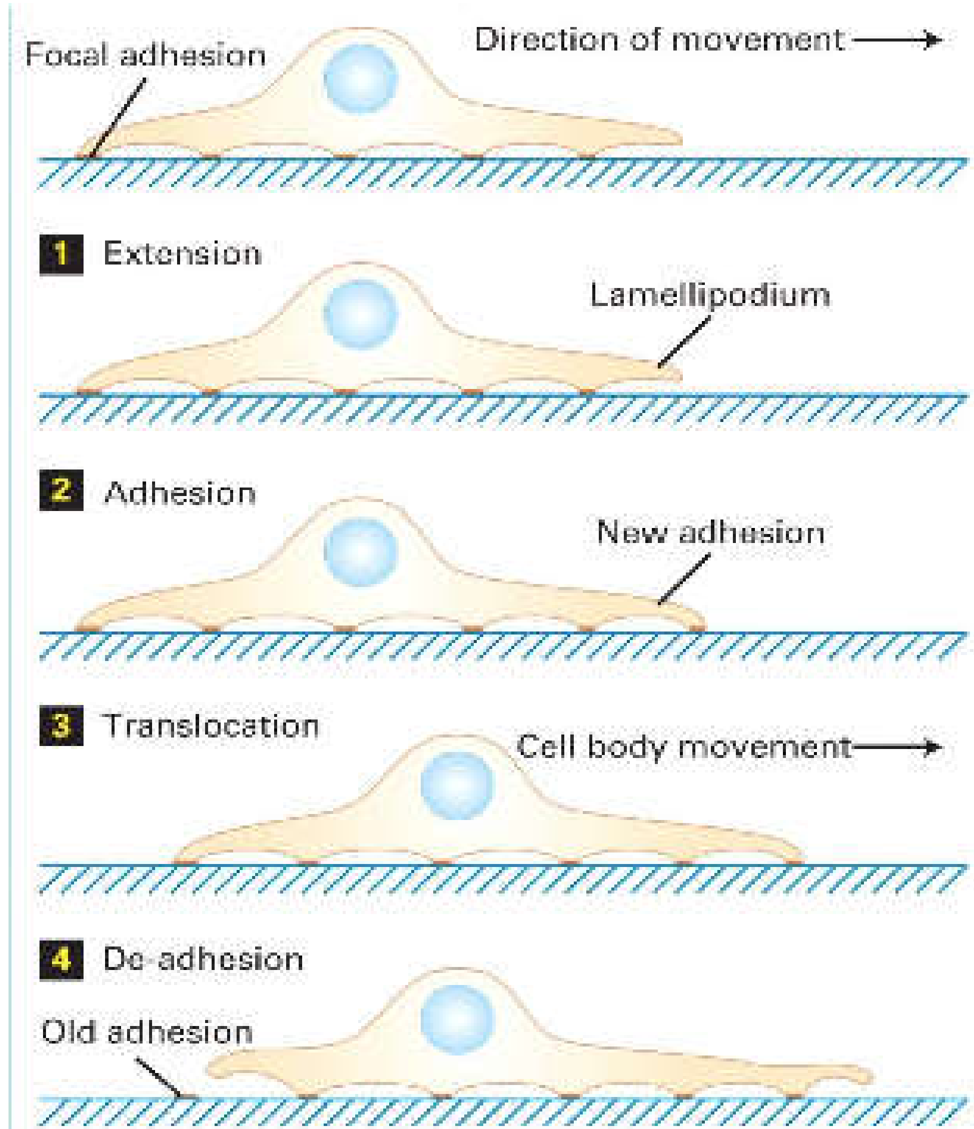
- ✓ Host defense
- ✓ Angiogenesis
- ✓ Wound healing
- ✓ Cancer metastasis
- ✓ Tissue engineering

Steps:

a. Protrusion

b. Adhesion

c. Traction



- External signals must dictate the direction of cell migration.
- Cell migration is initiated by the formation of large membrane protrusion.
- Video microscopy showed that G-actin polymerizes to F-actin. (Drugs can alter this process).
- Actin exists as a globular monomer (G-actin) and;

  A filamentous polymer (F-actin) protein.
- The addition of Mg^{2+}, K^{+} or Na^{+} to a solution of G-actin induces the formation of F-actin and this process is reversible.
- Elastic mechanical property of actin filament.

HISTOLGY PROPER

EPITHELIAL TISSUE

Introduction

- ***An epithelium is a* society of cells in functional association that** covers and lines all free body surfaces.

- Epithelial cells are held together in intimate contact with each other as well as to the underlying connective tissue.

- These contacts are mediated by small amounts of extracellular components and a number of plasma membrane specializations on the contact surfaces.

In most instances, these specializations represent integral membrane proteins that are linked to cytoplasmic proteins via specific peripheral proteins.

Thus, an epithelium is a tissue that consists mainly of cells with a relatively small amount of **extracellular matrix (ECM).**

Epithelium: lining & covering cells

May be derived from any germ layer

Epithelium

- General Functions:
  - Protection: desiccation, abrasion, microbial invasion
  - Selective permeability: ion transport, barrier on mucosal surfaces
  - Absorption: nutrients
  - Secretion: exocytosis, glandular secretions, ions
  - Sensation: sensory receptors of inner ear, tongue
- General Structure:
  - Polarity: specific orientation relative to other cells & basal lamina
    - Apical surface; Basolateral surface
  - Have intercellular junctions
  - Produce a basal lamina: attaches to adjacent connective tissue

Definition & properties

- The term epithelium is derived from two Greek words *epi* means "upon another" and *theleo* means "tissue grows"
- Epithelium covers the **body surface (surface epithelium)**, forms the external and internal linings of body surfaces, cavities and tubes and other structures such as hair, hooves and horns and constitutes **most glands (glandular epithelium)**
- Since all epithelia are not penetrated by blood vessels, the cell is dependent on the **diffusion** of oxygen and metabolites from the adjacent connective tissue

General Features of Epithelium

- It may originate from all three embryonic germ layers (ectoderm, mesoderm and endoderm).
- It is composed of high number of closely applied cells with very little intercellular substances.
- It is separated from the underlying connective tissue by a basement membrane.

- It is avascular, blood and lymph vessels do not penetrate the basement membrane.
- Thus, it receives its nutritional support by **diffusion**.
- The epithelial cells have high capacity for regeneration.
- The epithelium can change from one form to another in a process called **metaplasia**.

Special Features of Epithelium:

Cilia- (singular= cilium, Latin= eyelash)- hair-like appendages attached to the apical surface of cells that act as sensory structures or to produce movement.

Goblet cells- specialized cells that produce mucus to lubricate and protect the surface of an organ

Villi- (singular= **villus**, Latin= shaggy hair)- finger-like projections that arise from the epithelial layer in some organs. They help to increase surface area allowing for faster and more efficient adsorption.

Microvilli- smaller projections that arise from the cell's surface that also increase surface area. Due to the bushy appearance that they sometimes produce, they are sometimes referred to as the **brush border** of an organ.

Epithelium: Classification

- Specialized Features
  - Keratinized
  - Non-Keratinized
  - Ciliated
  - Secretory

All epithelial cells types share the following characteristics:

1. Close apposition of cells.

2. Free surface of epithelial cells is adjacent to the space.

3. Basal surface is adjacent to connective tissue.

4. Sheets of epithelial cells may be modified into tubes forming glands.

5. Absence of blood vessels within epithelial layer

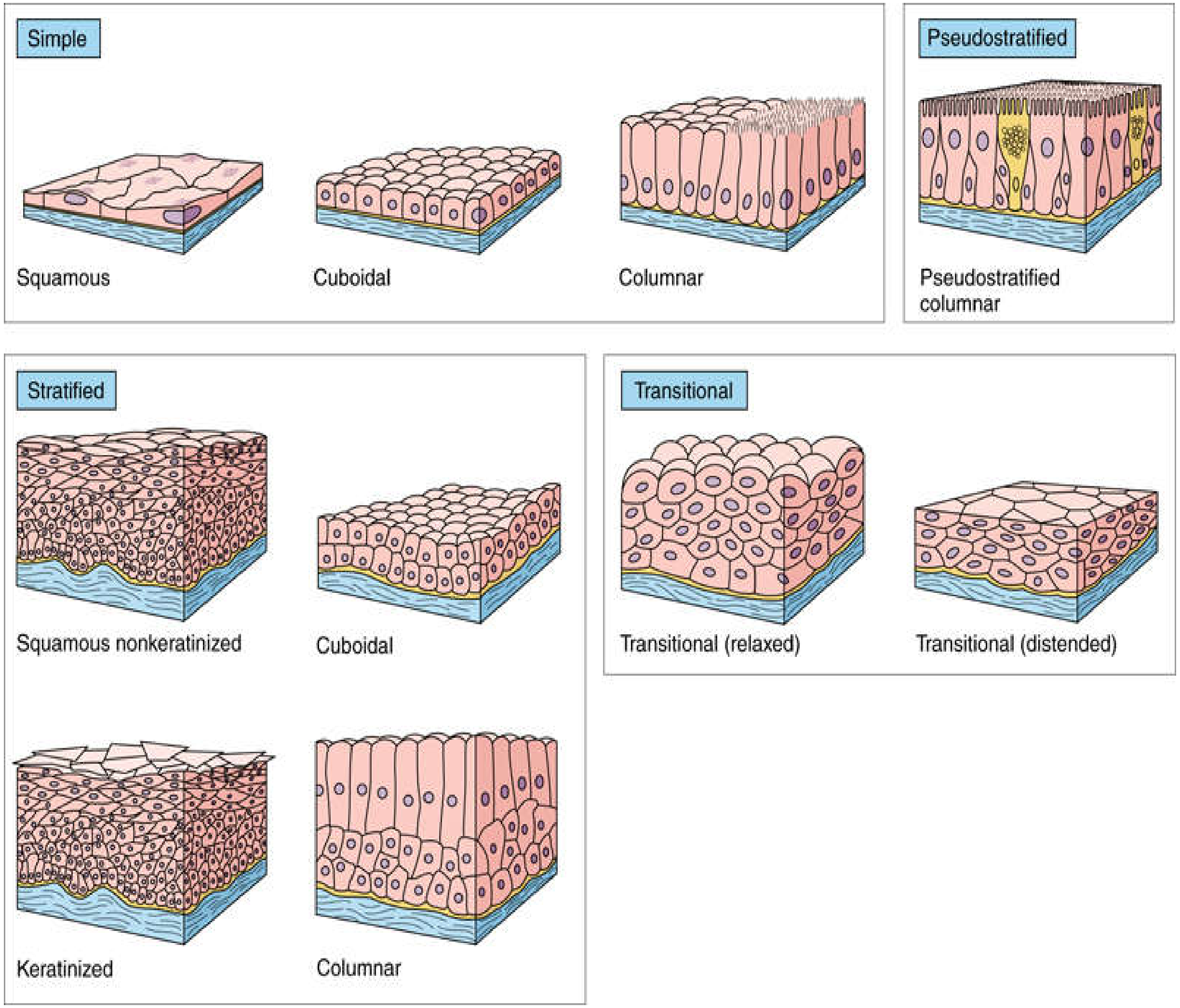
Function of Epithelium

- **Protection** (skin, digestive, respiratory epithelium) from various insult: Mechanical, microbial, desiccative UV radiation.
- **Absorption** (digestive, renal tubules, long epithelium.
- **Secretion** (mucous secreting epithelia, glandular epithelium, endocrine epithelium).
- **Excretion (**renal tubule epithelium)
- **Sensory function:-** through receptors in the epithelium
- **Reproductive function** germinal epithelium of gonads.
- **Formation of barrier** (blood air barrier)

Epithelium: Classification

- Number of Layers
  - Simple: single layer
    - Endothelium, mesothelium, renal tubules
  - Stratified: multiple layers
    - Epidermis, corneal epithelium
  - Pseudostratified: single layer but nuclei are at different levels (appears stratified but isn't)
    - Tracheal & bronchial mucosa
- Shape of Cell
  - Squamous: flat, plate-like
    - Endothelium
  - Cuboidal: cube-like; height & width are similar
    - Glandular ducts
  - Columnar: tall; height greater than width
    - Enterocytes on villus tips
  - Transitional: pillow-shaped
    - Only in urinary tract; urinary bladder mucosa
  - Pseudostratified: tall but irregular shapes
    - Tracheal & bronchial mucosa

Classification of Epithelia



different Types of epithelia.

Epithelial membranes are classified according to the number of cell layers between the basal lamina and the free surface and by the morphology of the epithelial cells;

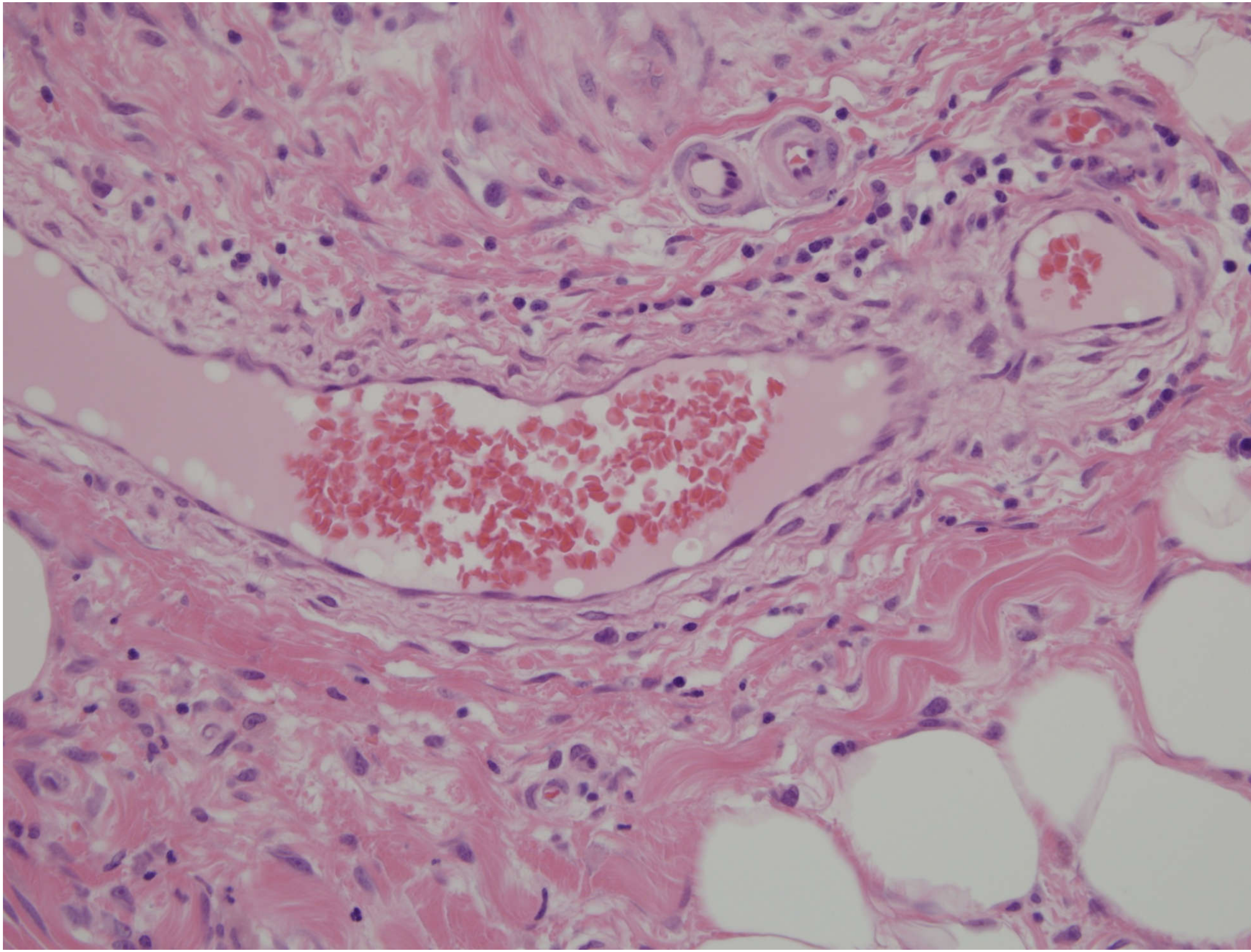
If the membrane is composed of a single layer of cells, it is called **simple epithelium**;

if it is composed of more than one cell layer, it is called **stratified epithelium**.

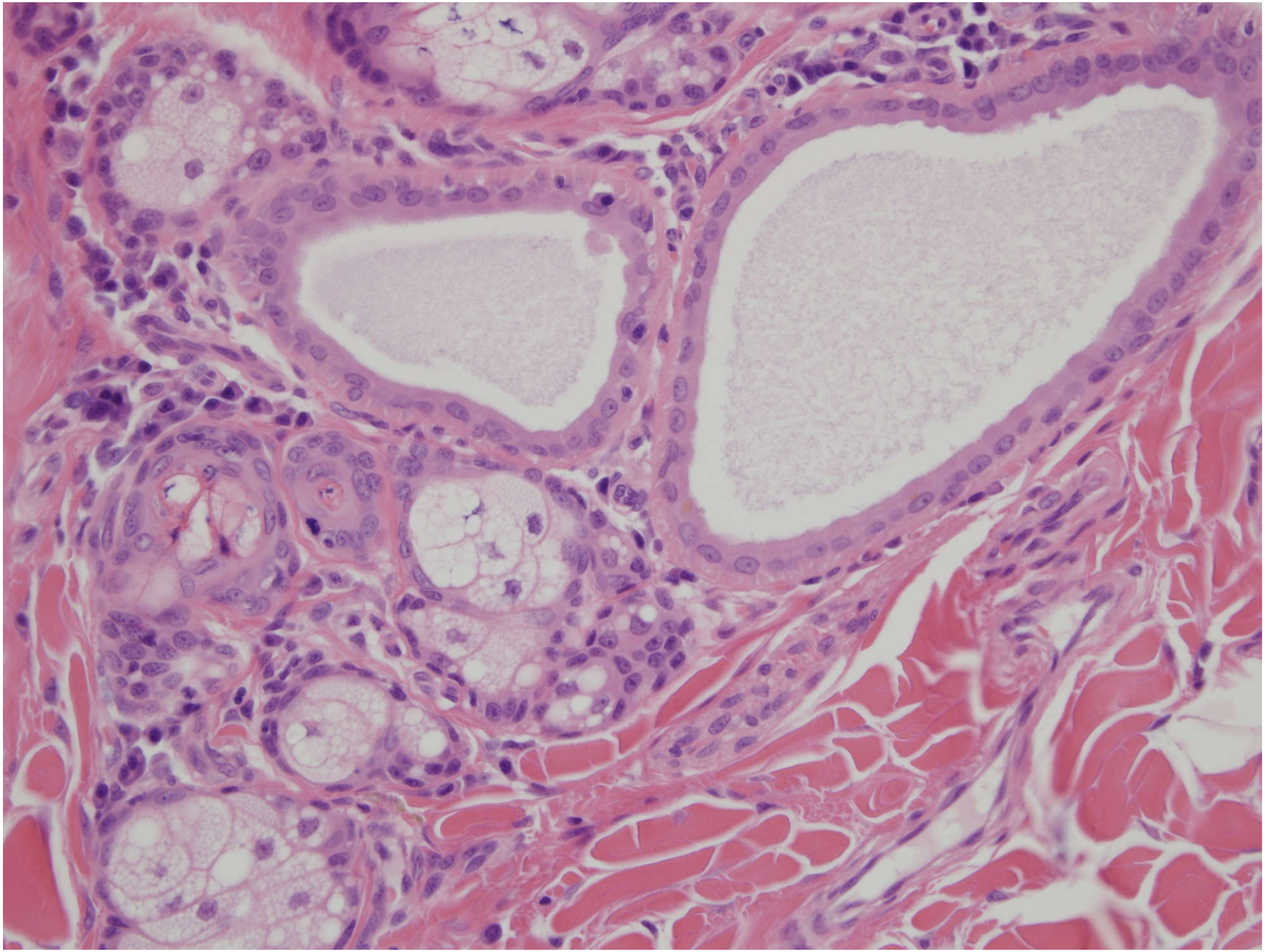
The morphology of the cells may be **squamous** (flat), **cuboidal**, or **columnar** when viewed in sections taken perpendicular to the basement membrane.

Stratified epithelia are classified by the morphology of the cells in their superficial layer only.

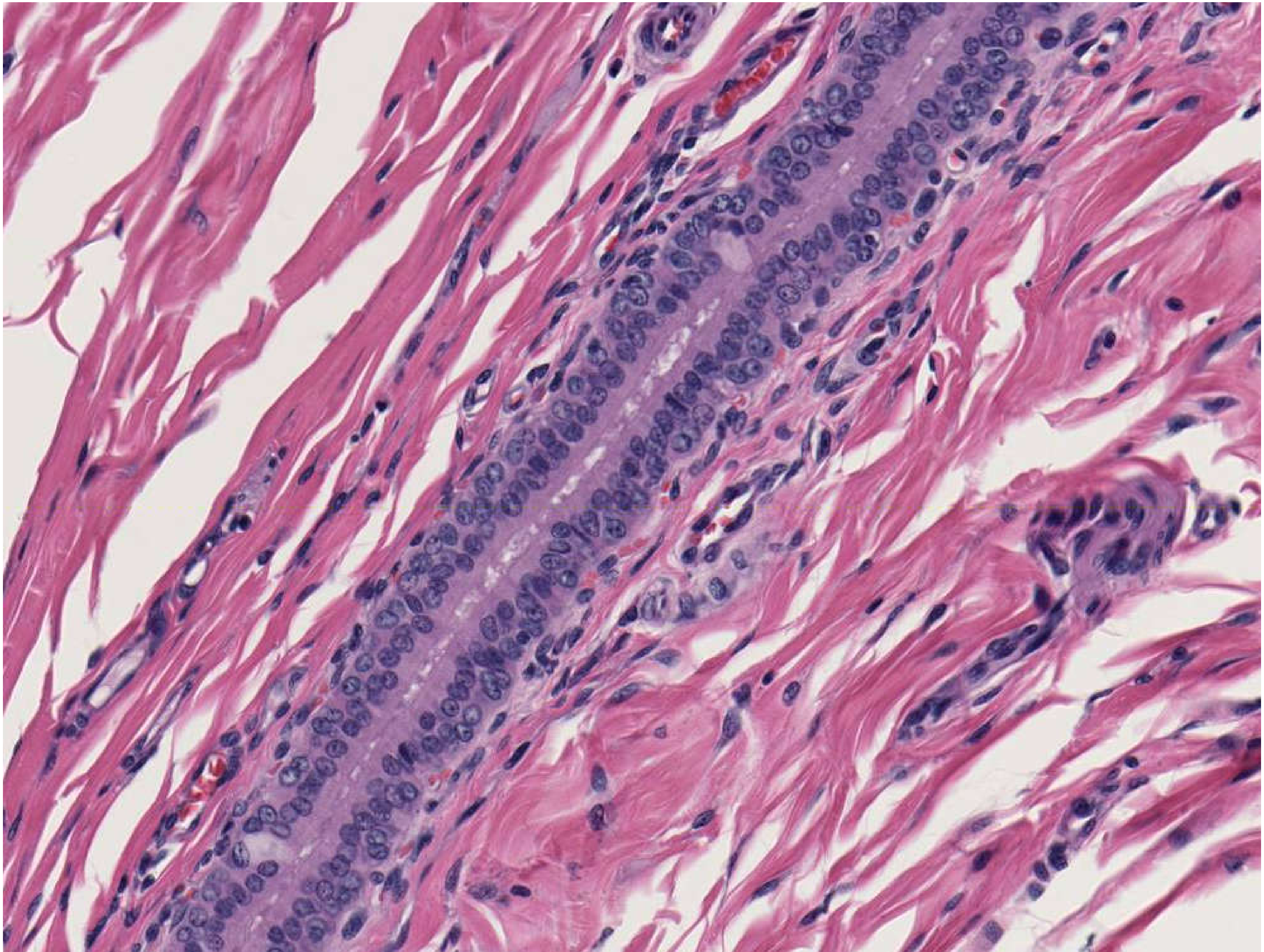
In addition to these two major classes of epithelia, which are further identified by cellular morphology, there are two other distinct types: **pseudostratified and transitional**.

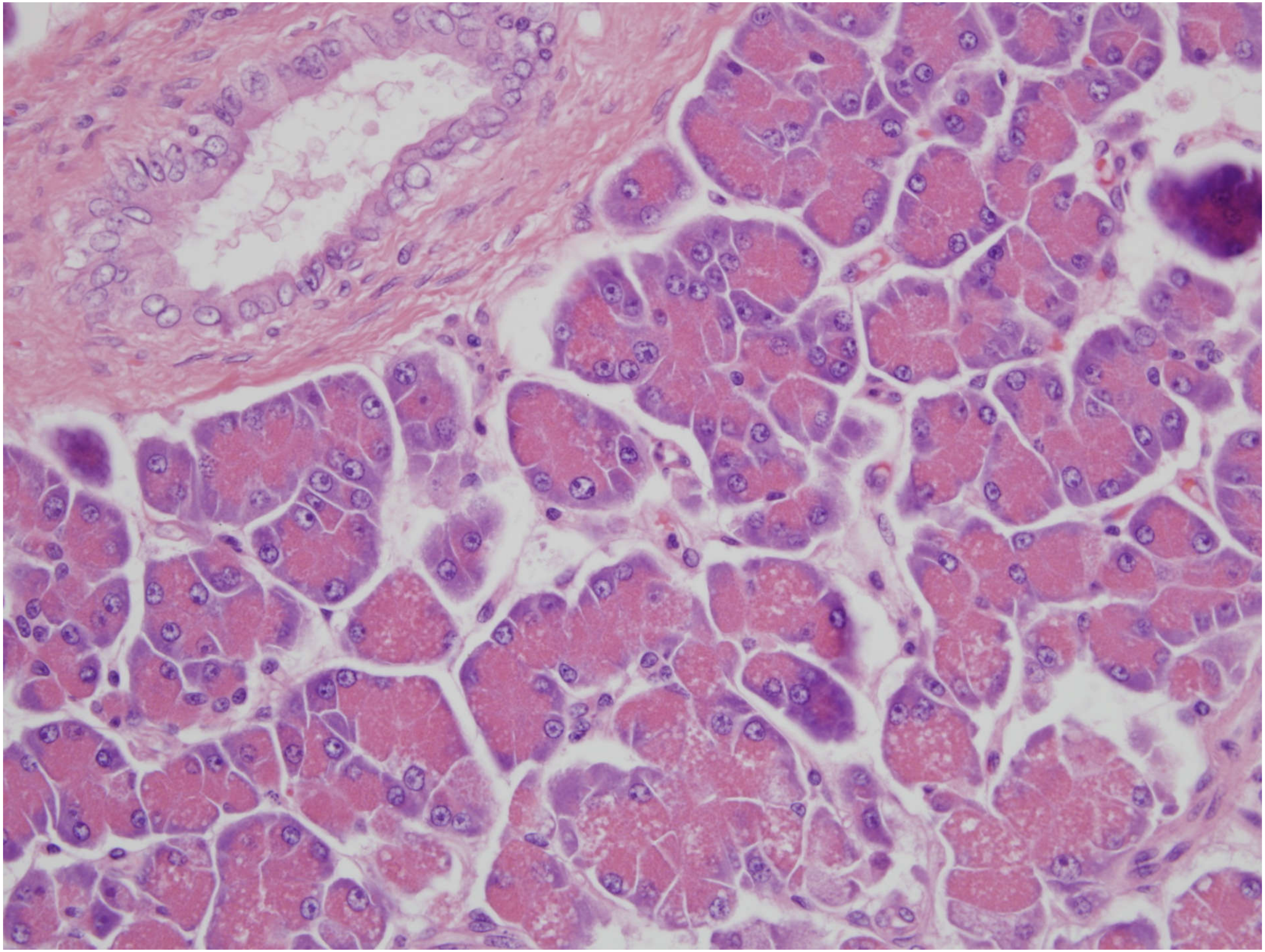


Vein and small arterioles – simple squamous epithelium (endothelium)

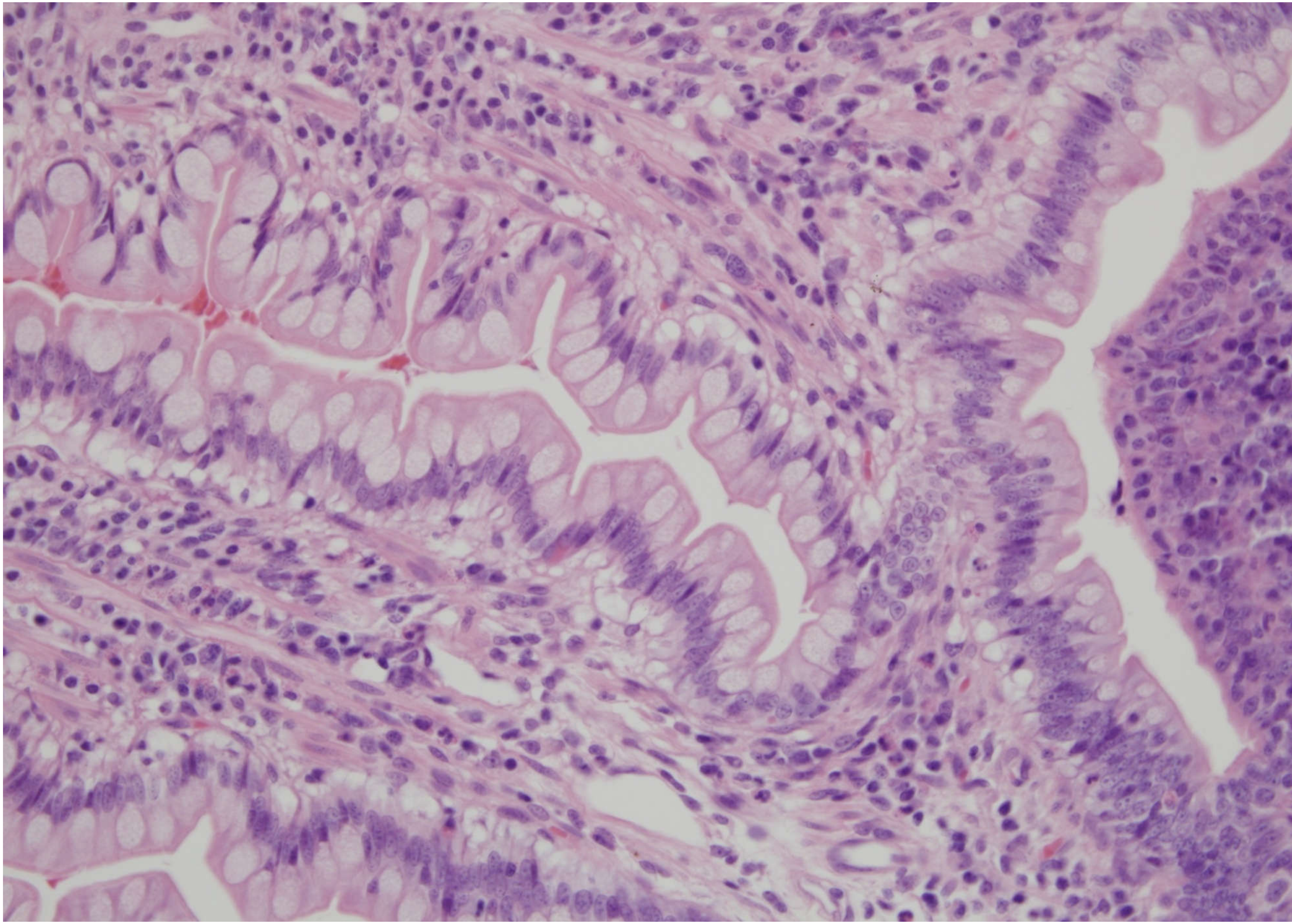


Apocrine sweat glands – simple cuboidal epithelium

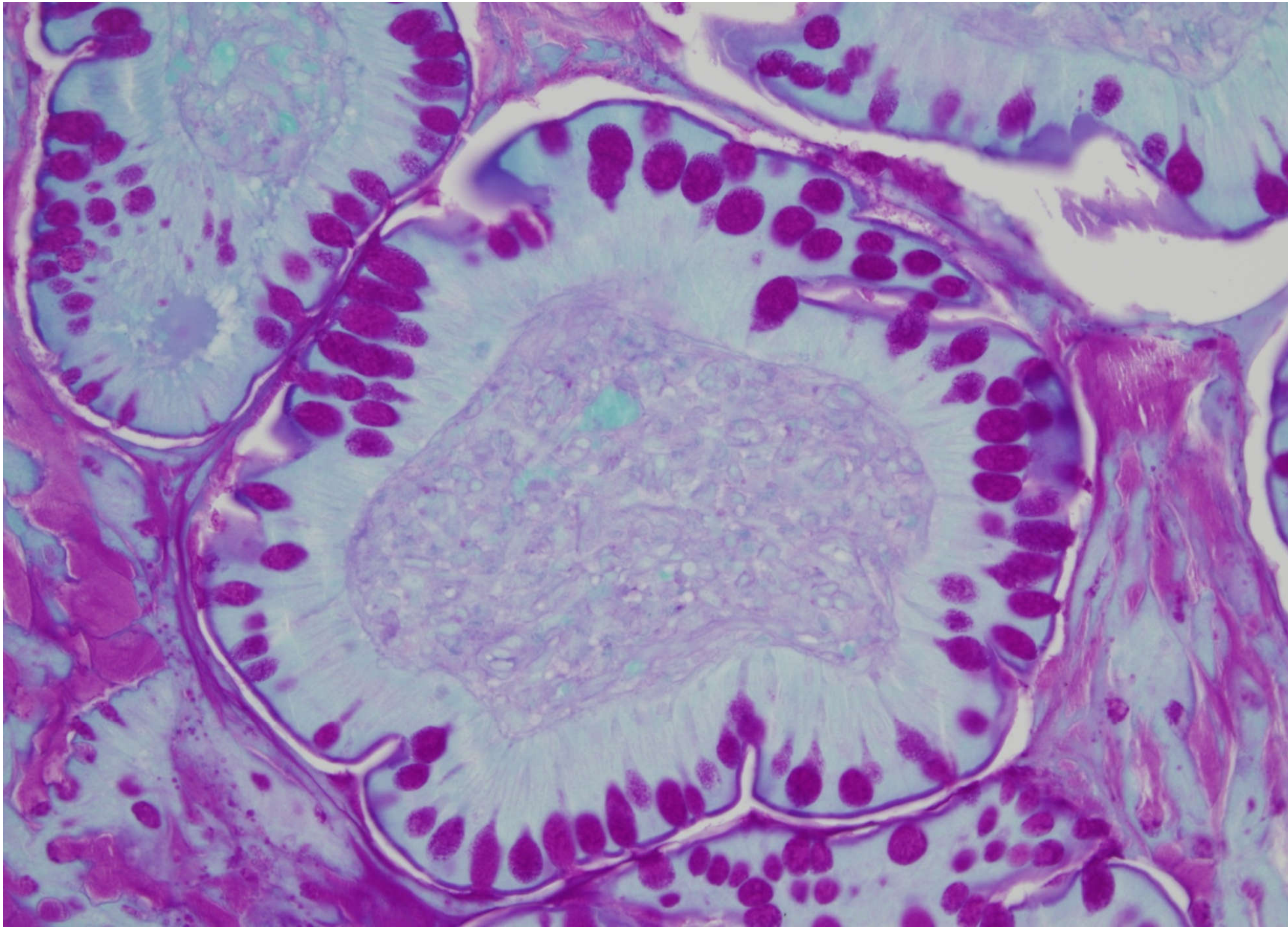

Salivary gland duct – double layered cuboidal epithelium



Exocrine pancreas; acini & duct – simple cuboidal epithelium in duct; secretory epithelium in acini

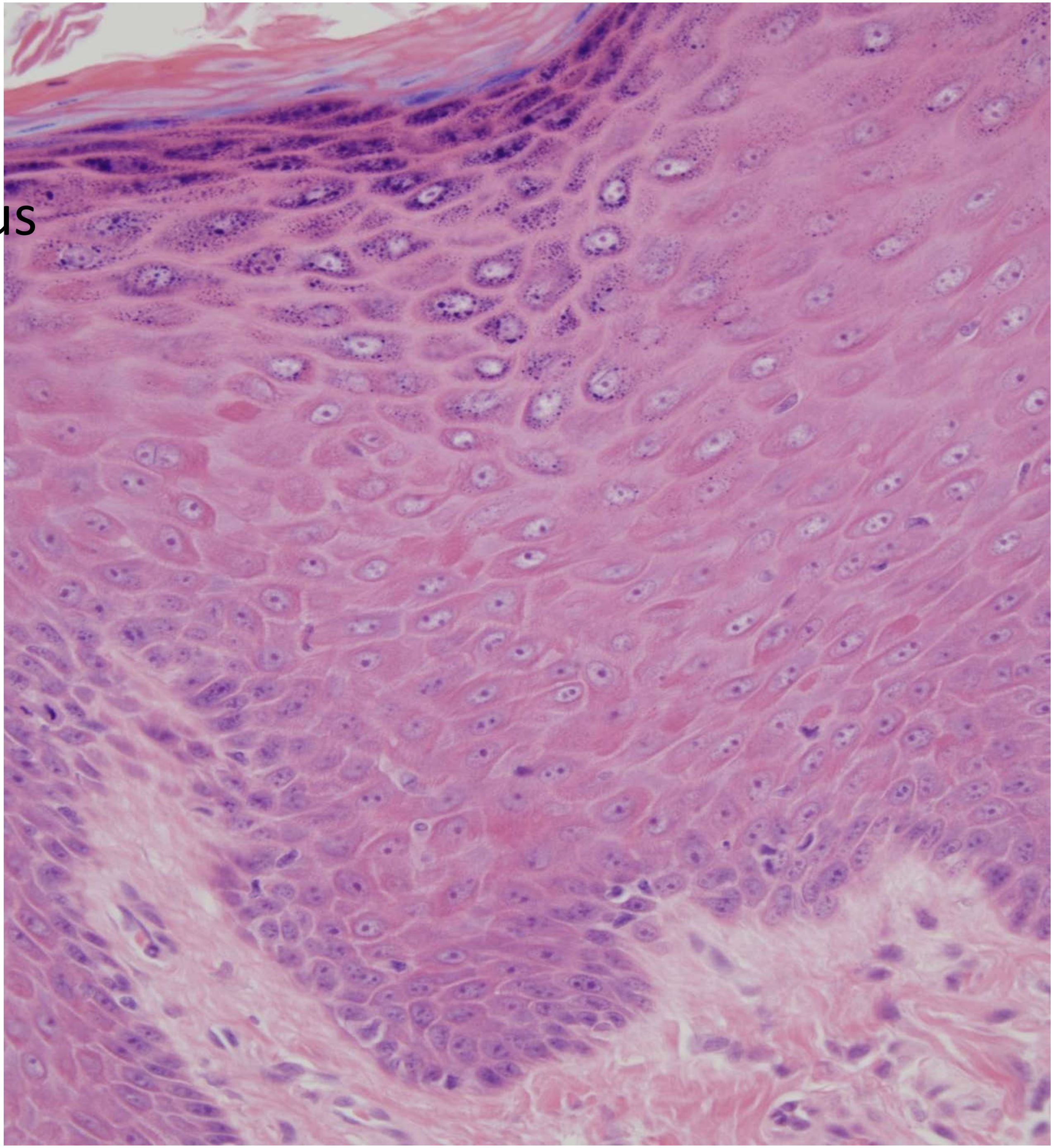


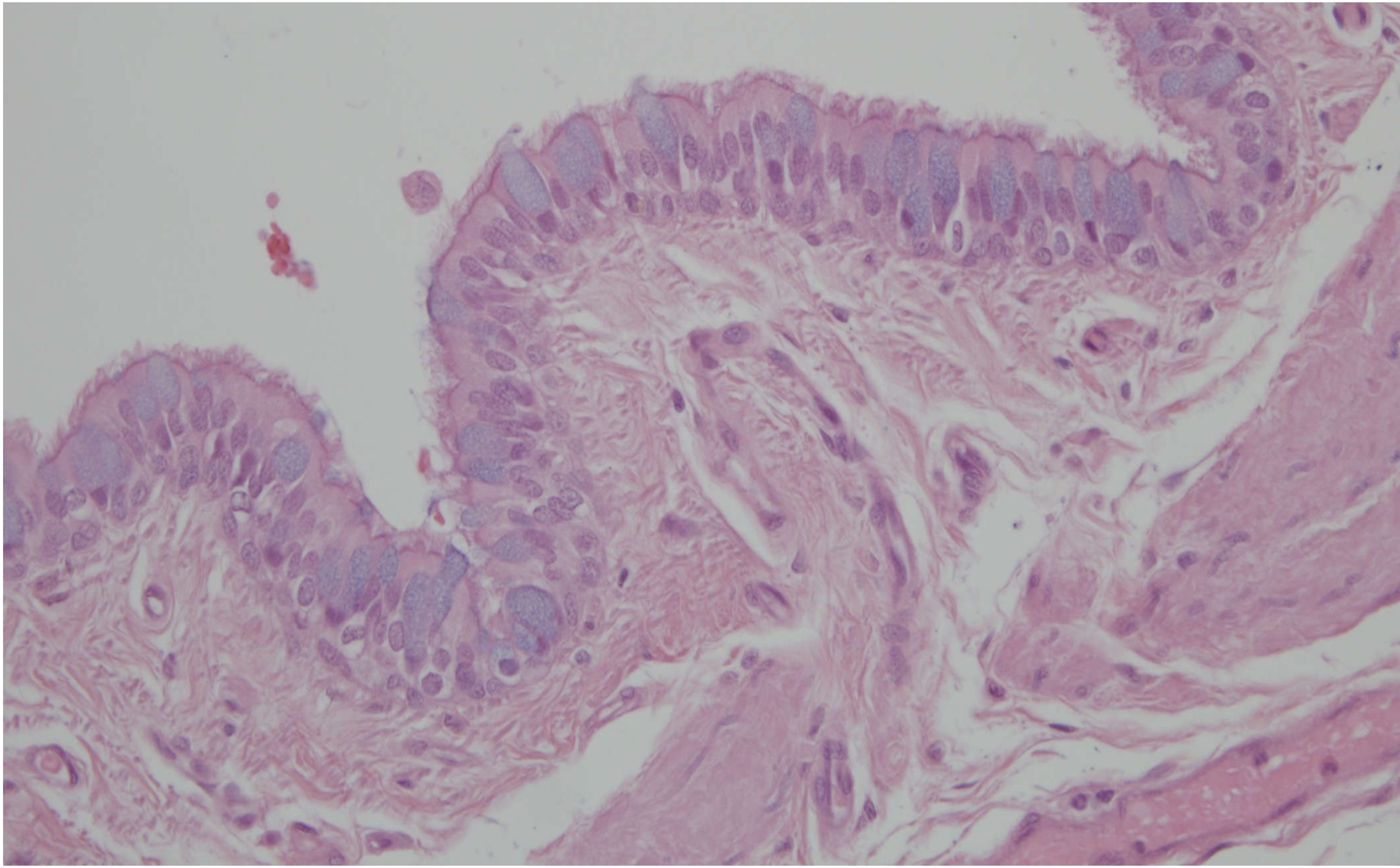
Small intestinal villus (ileum) – simple columnar epithelium with brush border & goblet cells



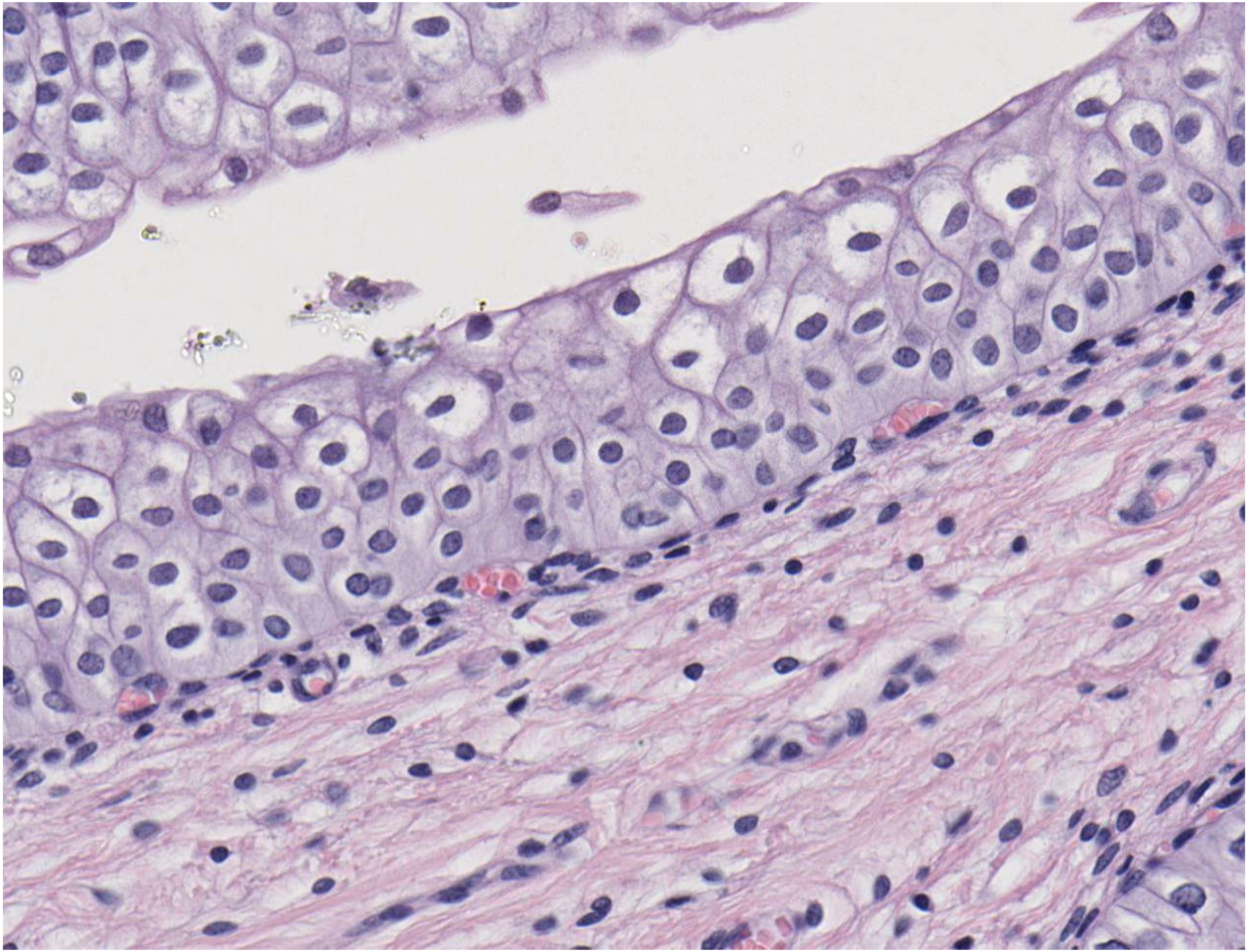
PAS stain of cross-section of intestinal villus – brush border & goblet cells stain magenta

Epidermis – stratified squamous epithelium (keratinized)





Bronchus – pseudostratified ciliated columnar epithelium with goblet cells



Ureter – transitional epithelium

1. Broad Classification of Epth.

- Epithelium is typically classified into **three** categories:

➢ *surface,*

➢ *glandular,*

➢ *special*

a. Surface epithelia are simply defined as those epithelia that cover and line all body surfaces.

- They are also the varieties that are given specific names based largely on their **layers** and cell **shape**

b. Glandular epithelia represent all the varieties of epithelia that are specialized for **secretion [L. *secretus =to separate], which is the*** process by which cells release specific substances onto their apical surfaces.

- These cells may be located within the surface epithelium or at some distance, but are still connected to the surface via ducts.

- In some instances, they may lose these connections (e.g., thyroid epithelium).

- Glandular epithelium is primarily involved in secretion is often arranged in to structures called **glands.**
- Glands are invaginations of epithelial cells formed during embryonic development.
- Exocrine glands are connected to the surface glands by ducts (e.g. salivary glands)
- whereas endocrine glands lack ducts that connect to surface epithelia and release their secretions in to blood directly (e.g. thyroid gland).

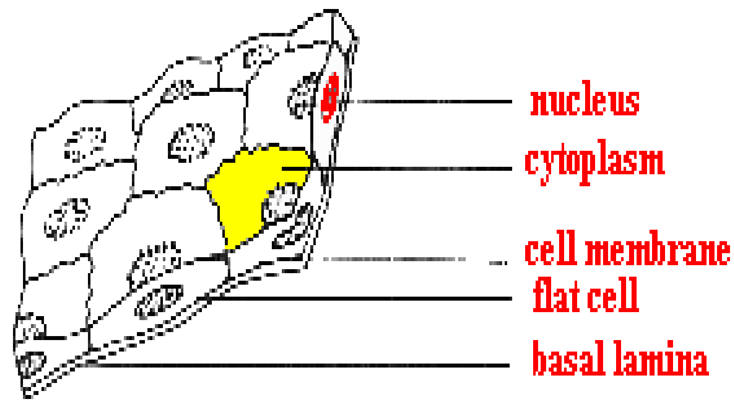
c. Special epithelia may also be classified as surface or glandular, but have specialized functions. Examples of these include:

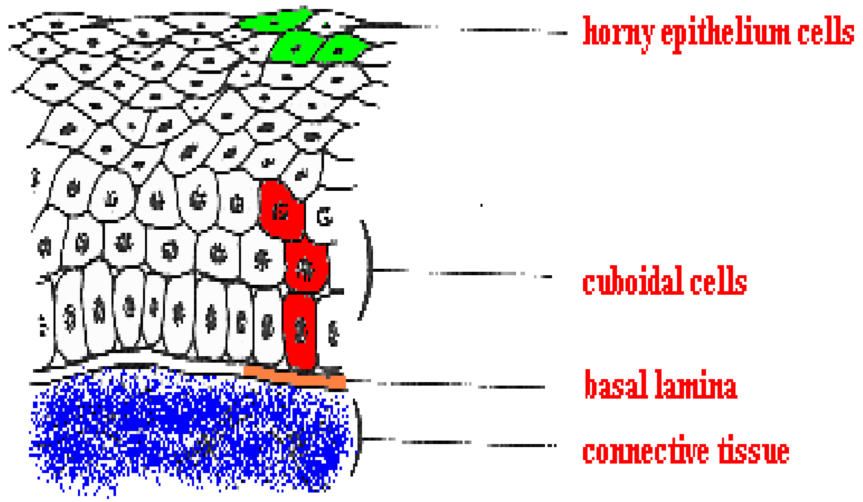
- neuroepithelium (e.g., gustatory, olfactory),
- reproductive epithelium (e.g., seminiferous epithelium), and
- myoepithelium (epithelial cells specialized for contraction).

Surface epithelium

Based on the number of cell layers

- single layered **(simple epithelium)**
- several layers **(stratified epithelium)**

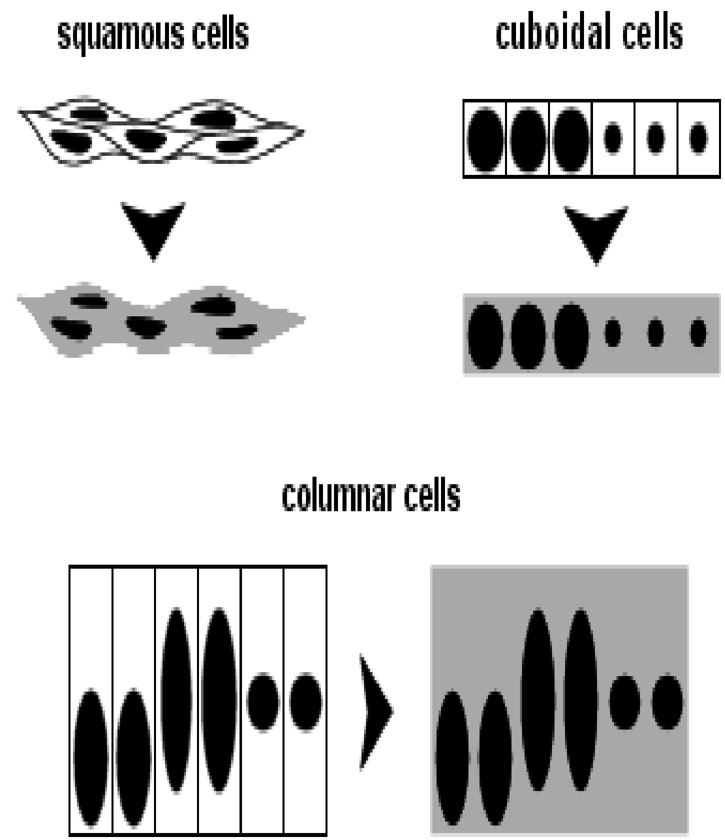




The shape of the cells:

- flattened (**squamous**)
- square or cube **(Cuboidal)**
- column shape

/height is greater than the width/ **(Columnar)** shaped



The presence or absence of specialties such as cilia and keratin:

- ciliated/non ciliated
- keratinized/non keratinized
  - ✓e.g. ciliated columnar epithelium; stratified keratinized squamous epithelium.

NB: In stratified epithelium the shape of the outer most layers of cells determines the descriptive classification.

Based on the number of layers:

- **Simple epithelium:** Is any single layer of epithelial cells resting on the basement membrane.
- **Stratified epithelium:** is composed of two or more layers of cells with only the basal cell layers resting on the basement membrane.
- **Pseudostratified epithelium:** is one cell layer (simple lining) appearing as more than one layer, all cells touch the basement membrane.
- **Transitional epithelium:** is capable of varying the number of layers that are apparent.

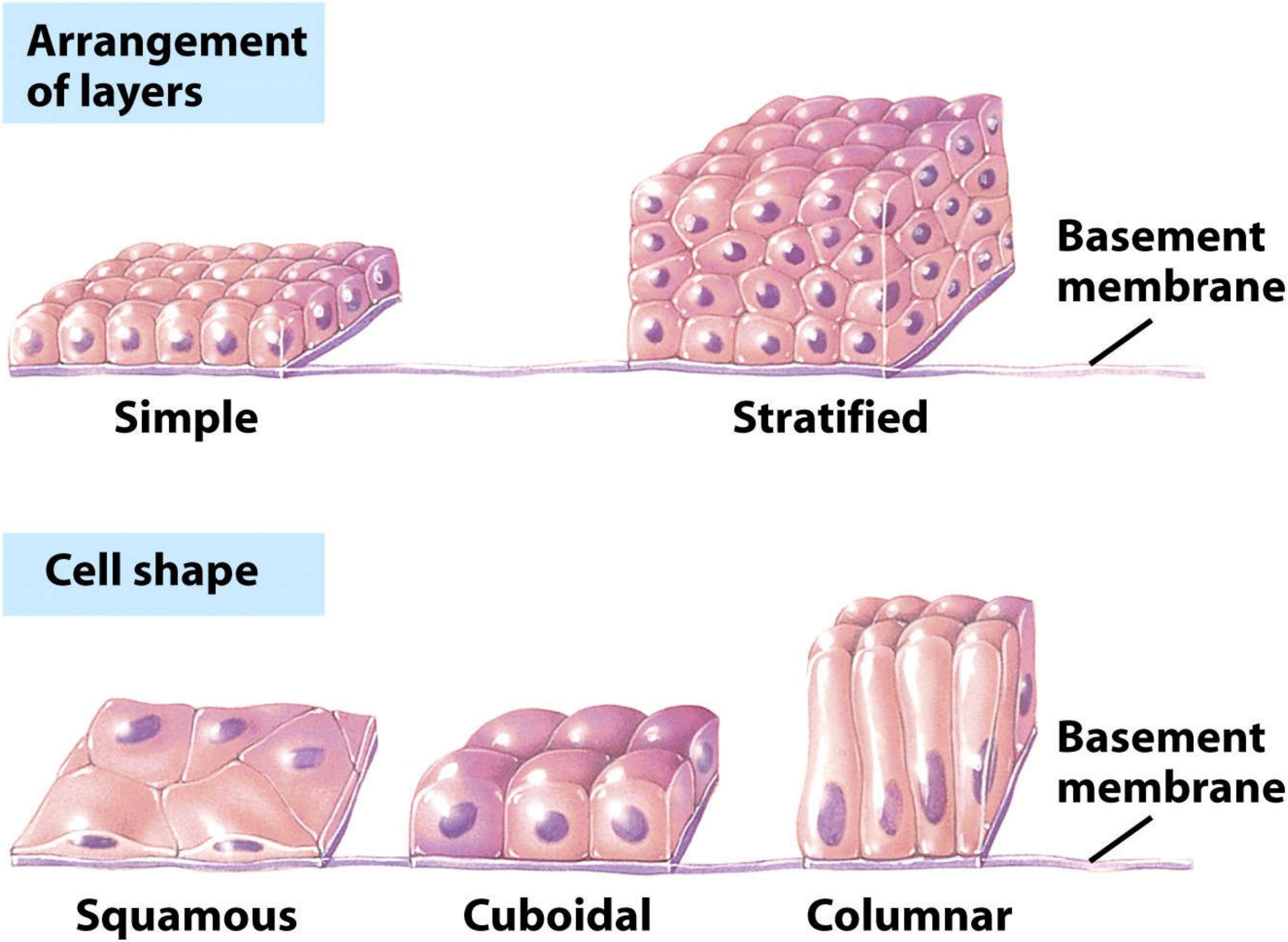


Figure 4-2 Anatomy and Physiology: From Science to Life

Cont…

- Classification of epithelium is based on the shape of the cells and the arrangement of the cells within the tissue.
- Typically, the arrangement of the cells is stated first, then the shape, and is followed by “epithelium” to complete the naming (Ex. Simple Squamous Epithelium).

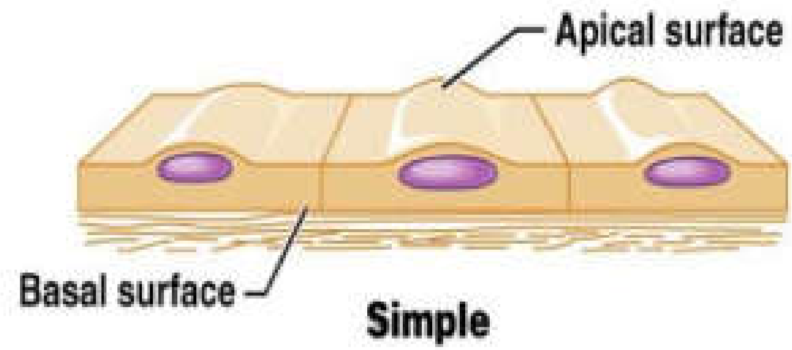
Arrangements:

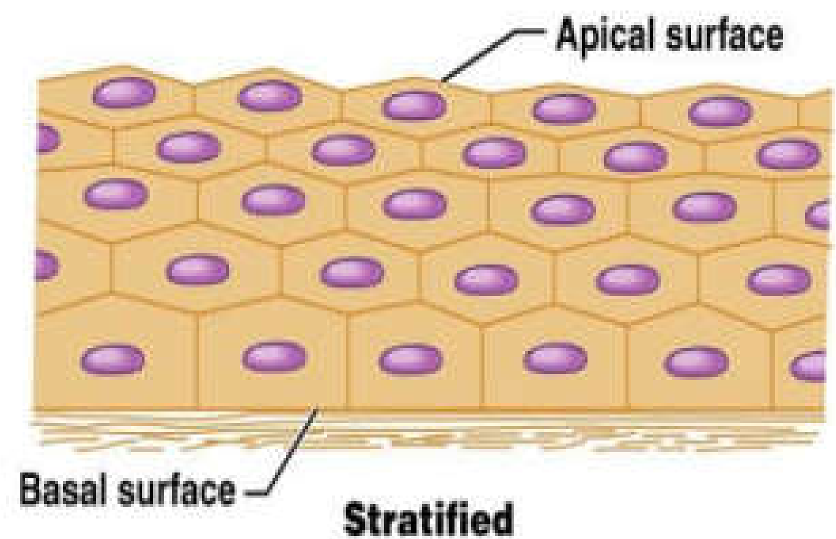
Simple- Cells are found in a single layer attached to the basement membrane

Stratified- Cells are found in 2 or morelayers stacked atop each other

Pseudostratified- a single layer of cells that appears to be multiple layers due to variance in height and location of the nuclei in the cells.

Transitional- cells are rounded and can slide across one another to allow stretching



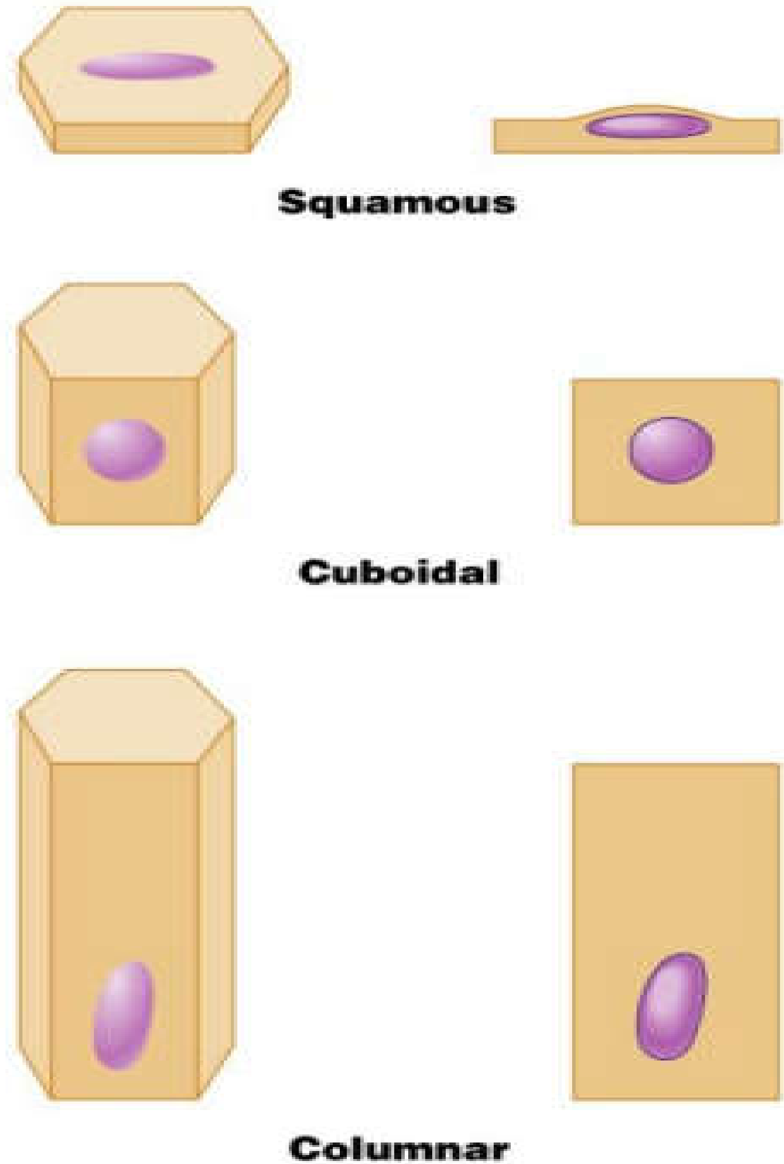


Shapes:

Squamous- (Latin, *squama*-scale)- flat, thin, scale-like cells

Cuboidal- cells that have a basic cube shape. Typically the cell's height and width are about equal.

Columnar- tall, rectangular or column shaped cells. Typically taller than they are wide.



Simple epithelium

- ✓ formed of single layer of epithelial cells

Simple squamous epithelium

- ➢ formed of flat, smooth, thin cells, nuclei are flat and central

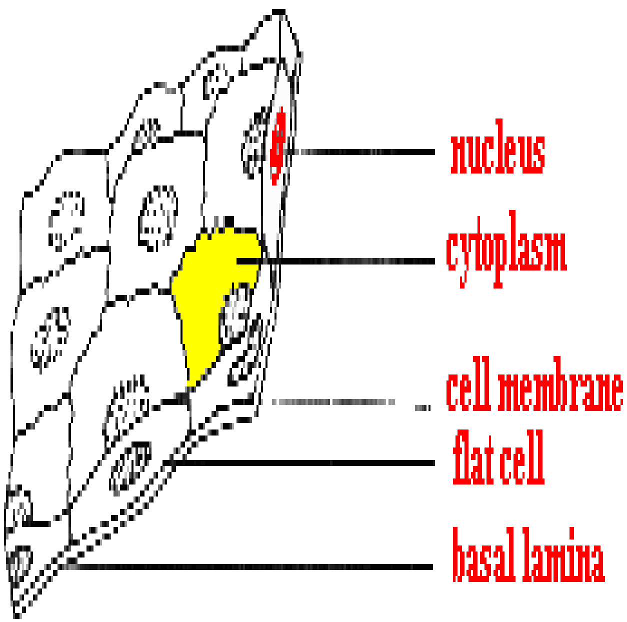
Simple squamous epithelium

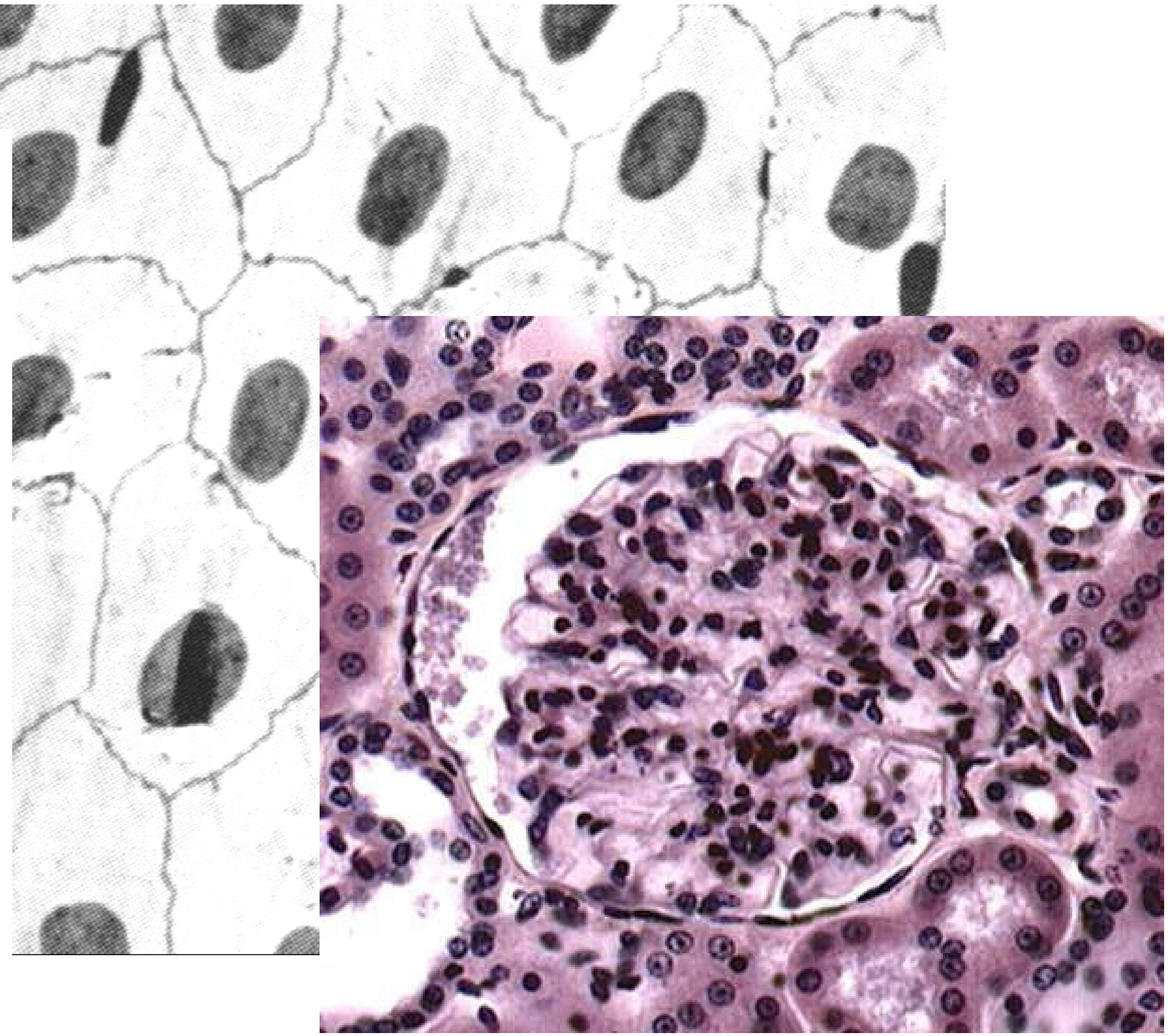
- consists of a single layer of squamous cells (thin, flat, scare like cells).
- thin and found in areas of easily permeable to molecules or lining surfaces involved in passive transport (diffusion) of
  - either gases (as in lungs)
  - or fluids like lining blood vessels.
- Simple squaqmous epithelium lining internal surfaces such as, blood vessel and lungs, is often referred to as **endothelium.**

- Simple squamous epithelium also forms part of serous lining of cavities (the pericardium, pleura) and this epithelium is known as **mesothelium**

- ***<u>Sites:</u>***
- **pneumocyte type I-simple** epithelial cells lining the alveoli
- in side lining of blood vessels called **endothelium**
- serous membrane (pleura, peritoneum, pericardium) called **mesothelium, mesenchymal epi (eye,ear)**

SIMPLE SQUAMOUS EPITHELIUM



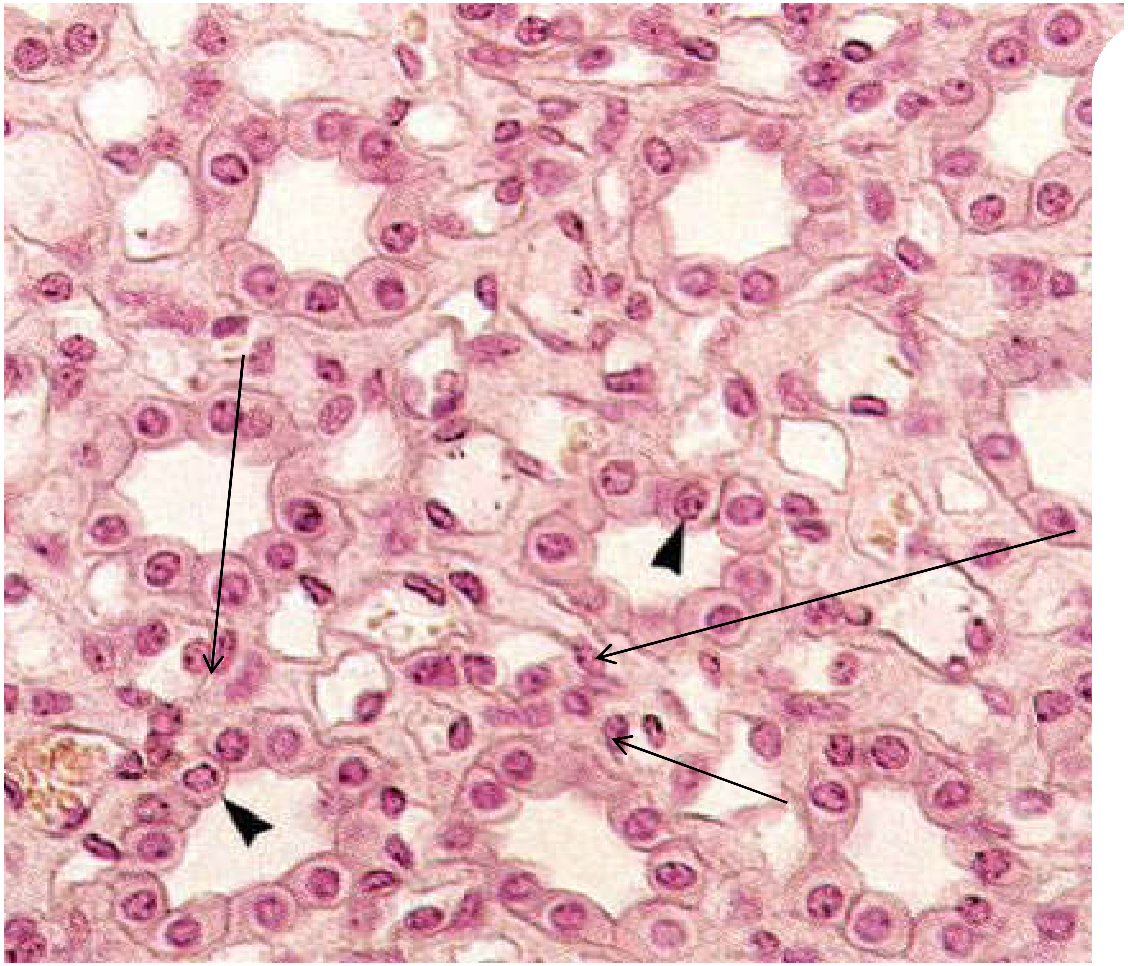


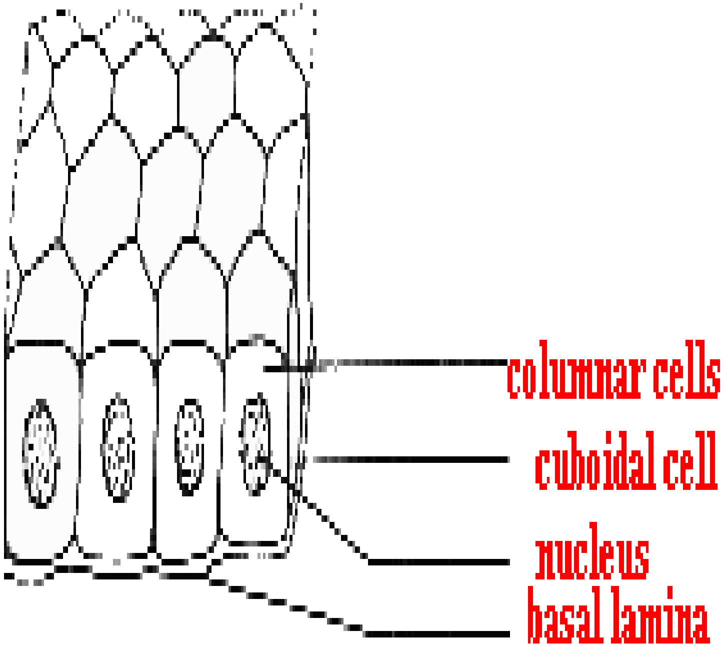
Simple Cuboidal epithelium:

- formed of cells in cubical shape
- the nuclei are central and round
- ***<u>Sites:</u>***
- Lines many small ducts of the body
- Proximal and Distal convoluted tubules of kidney
- Thyroids follicles
- ovary (before puberty)
- pigment epithelium of the eye.

➢ *has an absorptive or secretary function.*

Simple cuboidal EP.





***Simple columnar epithelium*:**

- palisade (tall) cells with basal and oval nuclei

Sub types:

❖ simple columnar (secretory)

-Secrete mucus ex. in stomach

❖ Simple columnar (absorptive) presence of

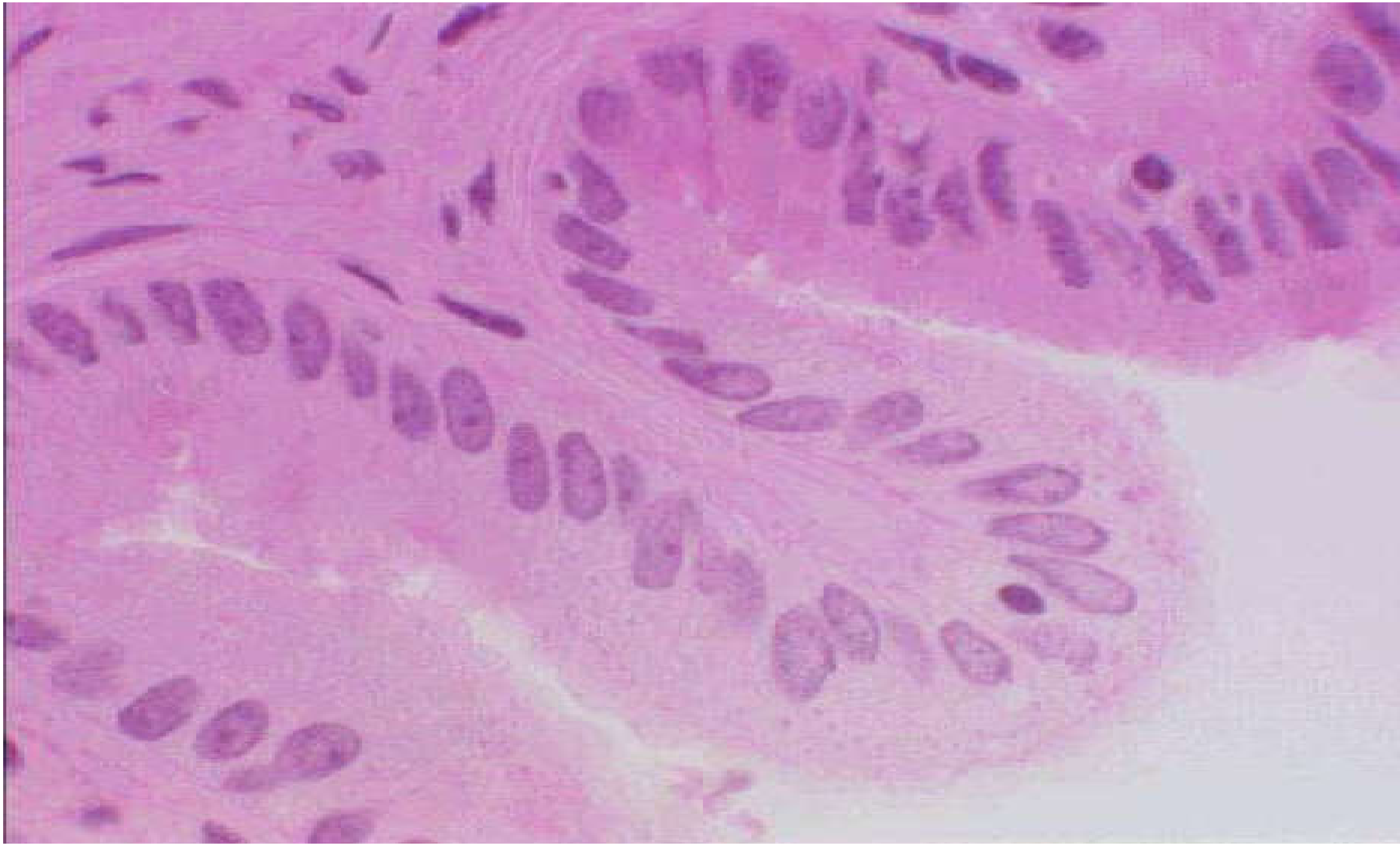
✓ Microvilli ex. intestine

❖ Simple columnar (ciliated)

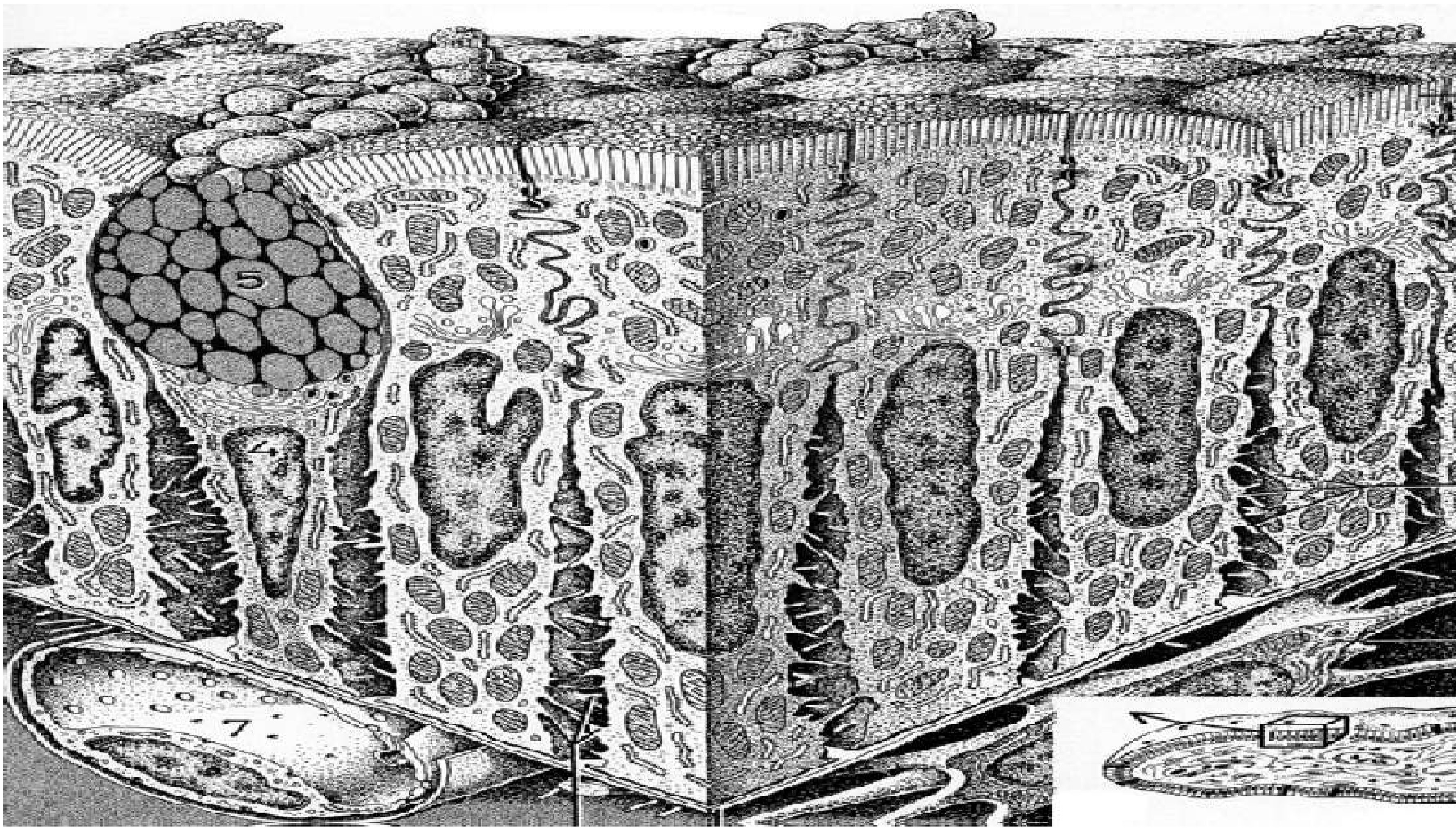
✓ found in the uterus and fallopian tube.

- Consists of single layer of columnar cells and some have cilia extending from the free extremity that helps to move any foreign materials
- Remove foreign materials from respiratory system (ciliated) e.g. trachea
- Absorptive functions E. g, the small and large intestine.
- secretary functions- e.g. digestive glands

SIMPLE COLUMNAR CELLS



COLUMNAR CELLS



Stratified epithelium:

- consist of more than one layer of cells
- the basal layer rests on the basement membrane
- basal areas are sites of cell proliferation (mitosis)
- the epithelium is named according to the top layer not the basal layer
- Stratified cells can usually withstand large amounts of stress. Thus, have mainly protective function
- These types of epithelia are poorly suited for secretion and absorption.

Stratified columnar epithelium

- The most widely distributed strastified epithelium
- withstand the more swear and tear than simple epithelium.
- The sole main function is protection for the underlying tissue.

Two types:

- ***Non-keratinized (non cornified)***
- ***Keratinized (cornified) or dry***

Non-keratinized (non cornified)

- protect underlying tissue and withstand abrasion but poorly withstand desiccation
- it is not immediately exposed to external epithelium but remains moistened and
- lines upper digestive tract (oral cavity, pharynx and esophagus) the eye (conjunctiva, cornea) and reproductive system uterus, cervix and vagina).

Keratinized (cornified)

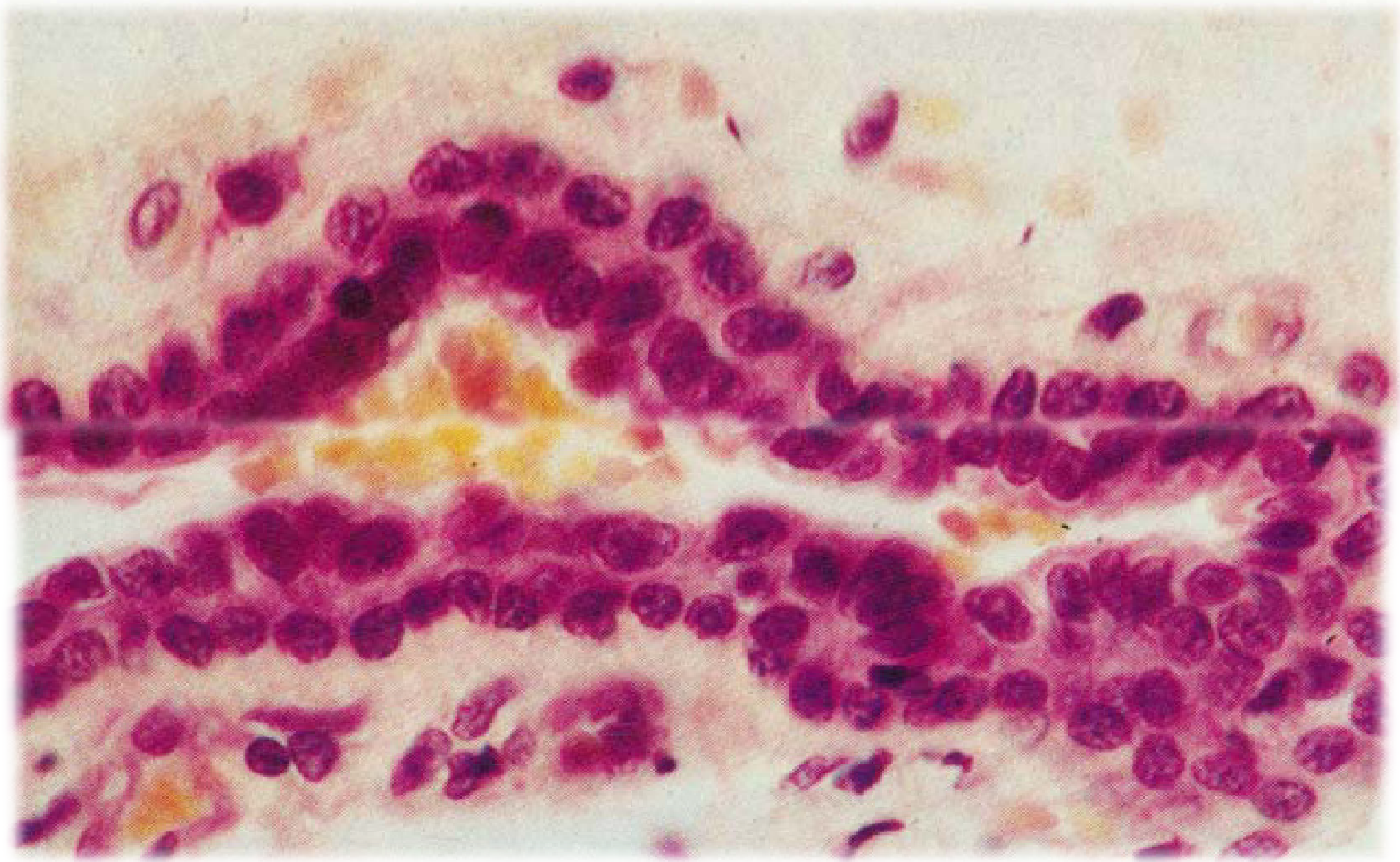
- covers surface of the skin (epidermis) which withstand abrasion and desiccation
- Keratinization proceeds by subsequent death of cells in the layers of the epithelium.
- The keratinizing epithelium of epidermis consists of five layers of cells include:

- **The basal layer (stratum basale)-** single layer of cuboidal to columnar cells
- **Stratum spinosum (the proliferative or germinative**)- two or more layers of cells with spiny process
- **Stratum granulosum (external to st. spinosum**)- cells containing detectable keratin granules
- **St. lucidum (next to st. granulosum**)- thin transparent layer involved in cell death
- **St. corneeum (the outermost/most superficial layer)-** composed of many layers of dead scaly like cells lacking nucleus

***Stratified cuboidal epithelium*:**

- is thin and found as tissue between simple and stratified epithelium
- lining anal canal, female urethra upper respiratory tract.
- Usually consists of two layers (bilayered) and it lines the ducts of exocrine ducts such as mammary, salivary and sweet glands.

. St. cuboidal epi



Stratified columnar epithelium:

- lines large ducts of exocrine glands having usually a basal layer of cuboidal to columnar cells.
- It consists of several layers of columnar cells found in urethra, in parotid, mandibular, salivary and in the lacrimal sac and ducts.

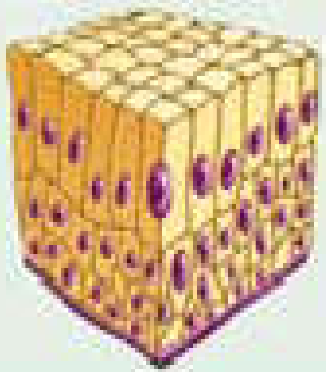
Ciliated : in fetal oesophagus

non-ciliated: fornix of conjunctiva, larger ducts of some glands; Serous watery secretion

St. columnar epi.

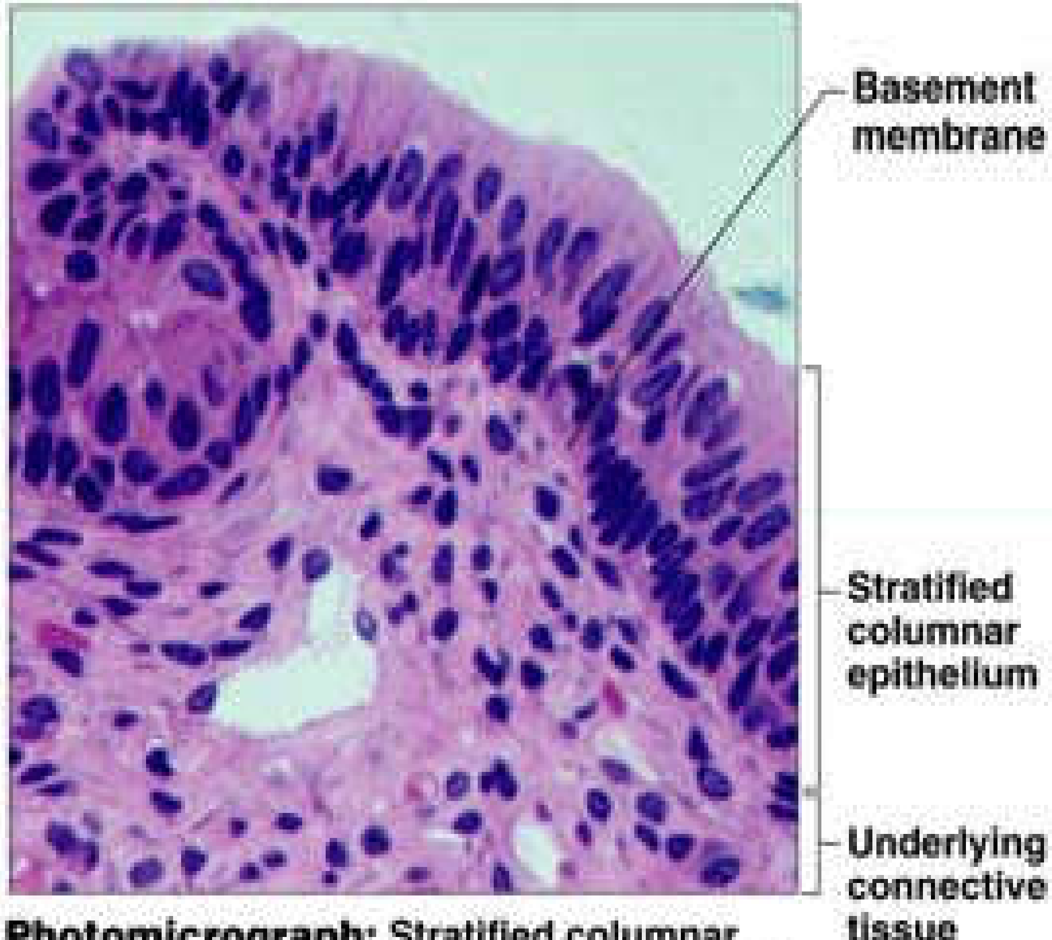
(g) Stratified columnar epithelium

Description: Several cell layers; basal cells usually cuboidal; superficial cells elongated and columnar.



Function: Protection; secretion.

Location: Rare in the body; small amounts in male urethra and in large ducts of some glands.



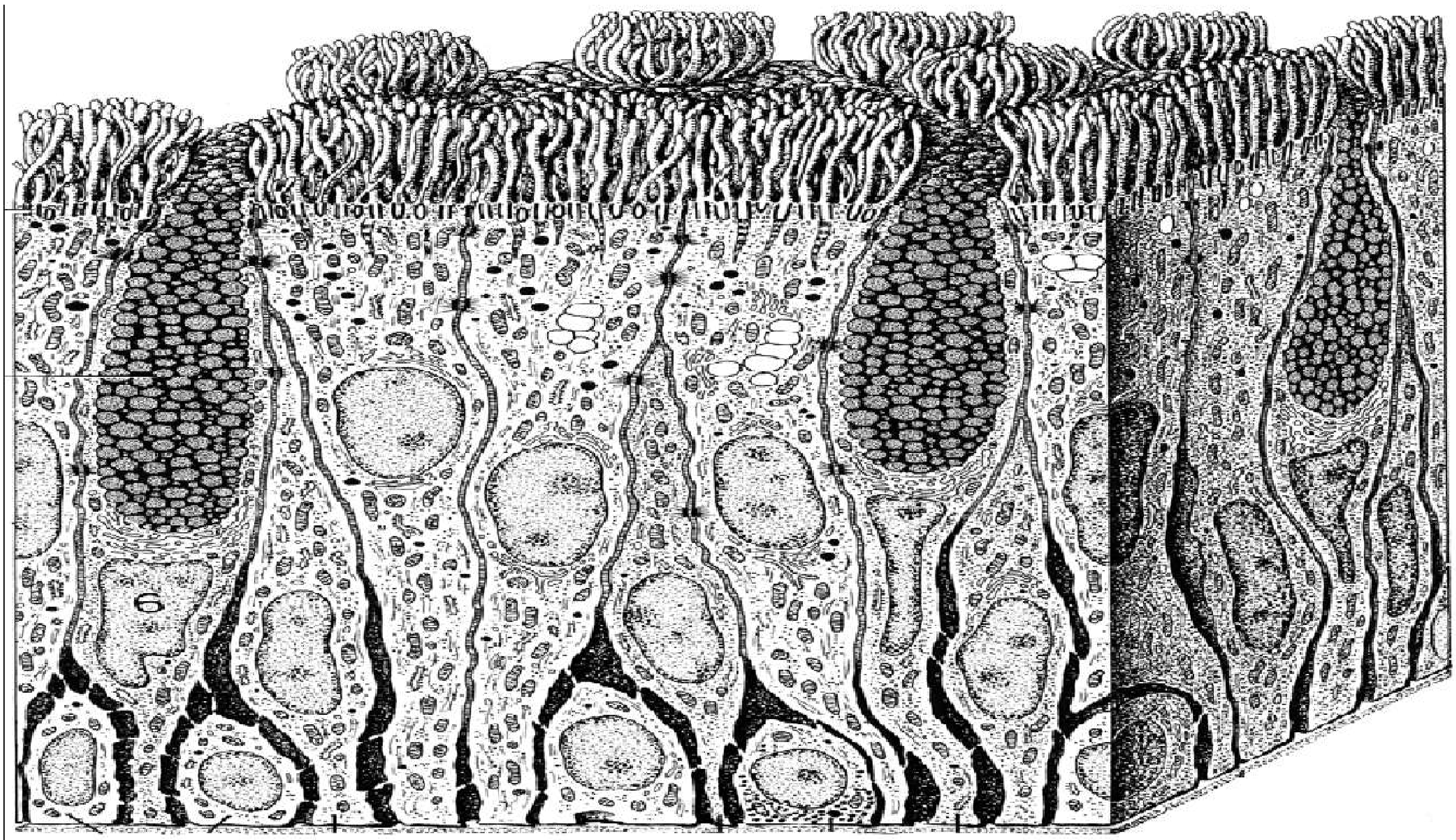
Photomicrograph: Stratified columnar epithelium lining of the male urethra (460×).

Pseudostratified Epithelia

- Give the false appearance of being stratified
- but in effect consist of a single layer of irregular cells
- All in contact with the basal lamina.
- The term is used mainly (pseudo stratified columnar epithelium)

- The typical epithelial type of much of the respiratory tract.
- This epithelium also is ciliated and is an example of a heterogeneous epithelium .
- The nuclei of adjacent cells are not orderly arranged but appear at different levels.

Pseudostratified ep.



Transitional epithelium:

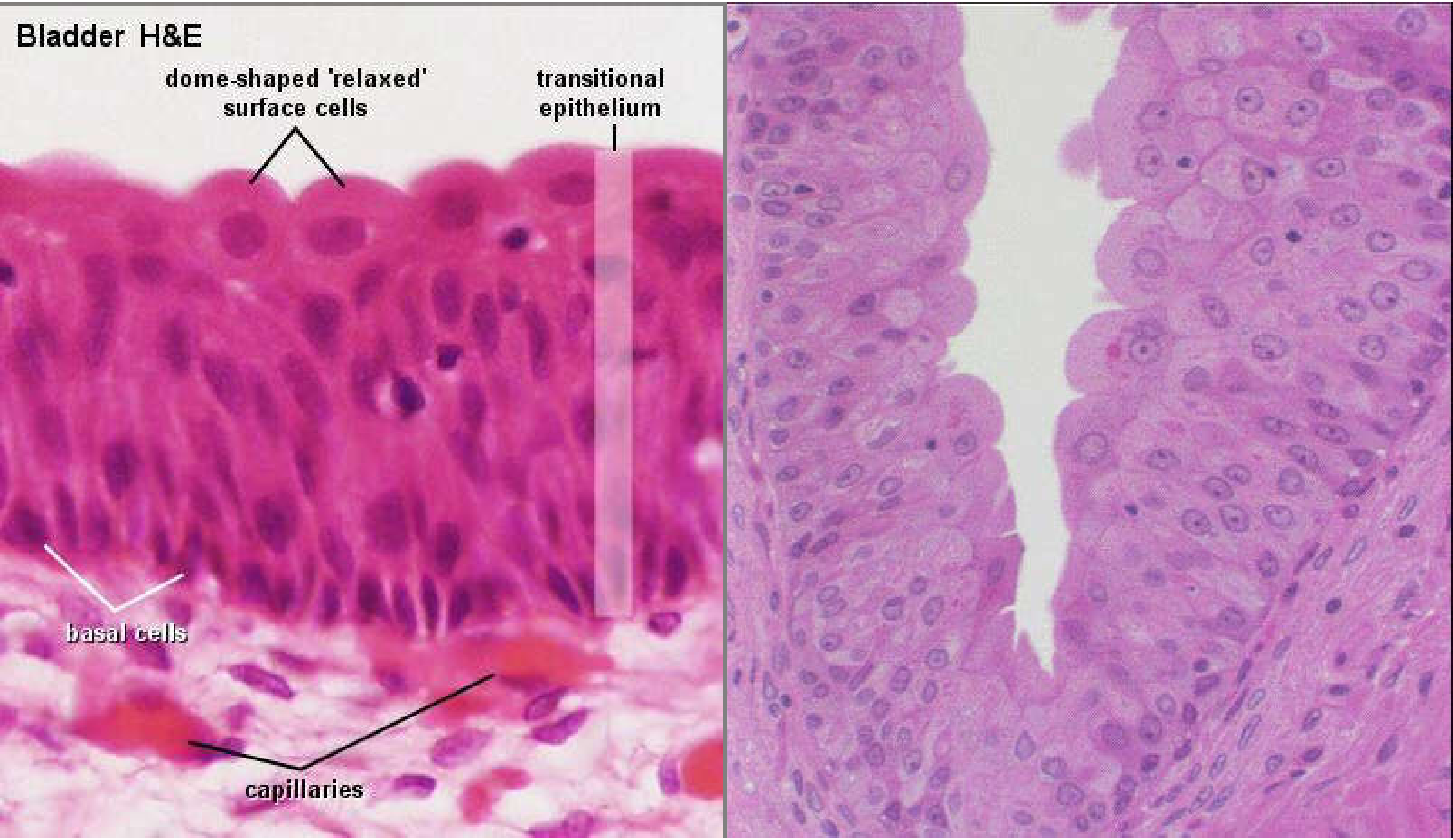
- Type of epithelium found lining organs that can stretch
- the urothelium that lines the bladder and ureter of mammals.
- Since the cells can slide over each other
- Its appearance depends on whether the organ is distended or contracted:

- if distended, appears as if there are only a few layers;
- when contracted, it appears as if there are several layers(thicker).
- Dome shaped cells, sometimes binuclated
- flask (pear shaped cells)
- no junction between cells

Transitional Epithelium:

- named because it has intermediate (transitional) feature between stratified squamous and cuboidal epithelium.
- It is restricted to urinary system since it accommodates the variation of internal pressure in the system.
- It lines hollow organs capable of considerable distention, such as the urinary bladder.
- Transitional epithelium, when
  - it is relaxed (non distended state), has 4-5 layers of cells and surface cells are cuboidal to columnar
  - it is stretched (distended state), has 2-3 layer of cells and the surface cells become markedly flattened (squamous).

Transitional ep



Example	Location	Shape (form)	Function
Transitional epithelium	Bladder	Layer with no specific shape, Cells can stretch	Allow bladder to stretch as it fills
Simple squamous	Lungs, blood vessels	Flat and thin layer	Increase flow and absorption rate through tubes
Stratified squamous	Skin, esophagus, mouth cervix	Several layers of thin flat cells	Provide protection from abrasions
Simple columnar	Digestive tract	One cell layer of rectangular cells mixed with goblet (mucous – producing) cells	Aid in digestion with mucous production

GLANDULAR EPITHELIUM

- tissue that makes up the secretory portion of glands.
- modified for secretion

specialized epithelium.

function of glandular epithelium is secretion.

hormones, digestive enzymes, mucus, sweat, oil, and milk.

they are classified depending up on different criteria.

According to presence or absence of ducts

- **Exocrine gland**: glands containing ducts .
- release their secretion apically (directly on epith surface) or via ducts
  - ✓ salivary glands,
  - ✓ sweat glands,
  - ✓ mammary glands
- **Endocrine glands**: duct less glands
  - ✓ ,release their products basally and convey their secretion directly to the blood.

Ex. pituitary,
- ✓ thyroid,
- ✓ adrenal

- **Mixed gland**: having both exocrine and endocrine glands
  - ✓ Ex. pancreas

According to the number of cells

- **Unicellular glands**
- E.g. Goblet cell
- secrete mucus and are easily visualized in sides of the small intestine.
- ✓ found in trachea,
- ✓ small and large intestine,
- ✓ pancreatic bile duct
- **Multicellularal glands**
- Liver
- Salivary
- pituitary

c. According to the type of secretion

- **Serous–** produces a thin watery, protein-rich secretion
- Has the following characteristics;

✓ cells are pyramidal
✓ Boundaries indistinct
✓ Lumen narrow
✓ Watery secretion
✓ has large number of cells
✓ with round, centrally located nucleus
✓ cells exhibit a well-defined polarity.
✓ basal region, serous cells display an intense basophilia ...

Conti..

- apical region contain secratory granules (zymogen granules)
- Adjacent serous cells are joined together by junctional complexes and.
- usually form a spherical mass of cells called an **acinus**
- ✓ ex. Parotid salivary gland, pancreas

Mucous

secrete strongly hydrophilic glycoproteins called mucins

viscous secretions that have a lubricating or protective function

Mucous cells also display a distinct polarity

the apical cytoplasm is predominantly mucinogen granules

Cont…

- that do not stain with H&E sections
- base of the mucous cells also contains rER.
- Mucous cells are most often organized as tubules

Has the ff charact.

- Their nuclei are basally located
- boundaries are distinct
- lumen is wide
- mucus secretion
- has small number of cells (5-6)

✓ Ex. sub lingual gland

Cont…

- ✓ **Mixed**
- ✓ These glands have both serous and mucous cells

  E.g submandibular gland

According to mode of secretion

- **Merocrine gland:**
- the most common
- Secretory granules gather at the apical region of the cell.
- the granule fuses with apical membrane-exocytosis

▪ No destruction to the cell membrane, during the process of secretion

Ex. salivary gland

Cont…

- **Apocrine gland:**
- A rare type of secretion
- a portion of the plasma membrane buds off the cell, containing the secretion
- Destruction of apex during secretion

  Ex. lactating mammary gland

Cont…

Hollocrine gland

- Granules fill the cell until the entire cell becomes "bloated" with secretory products.
- the whole cell is discharged into the lumen.
- the cell degenerates and the secretory products are released
- This secretion consists of disintegrated cells of the gland itself.
- Total destruction of the whole cell

  Ex. sebaceous

According to shape of secretory part

The glandular portion may be

- ✓ **tubular**
- ✓ **acinar**
- ✓ **tubulo-acinar**

- If the glandular portion branches, then the gland is called a **branched gland (compound)**.

1. Tubular

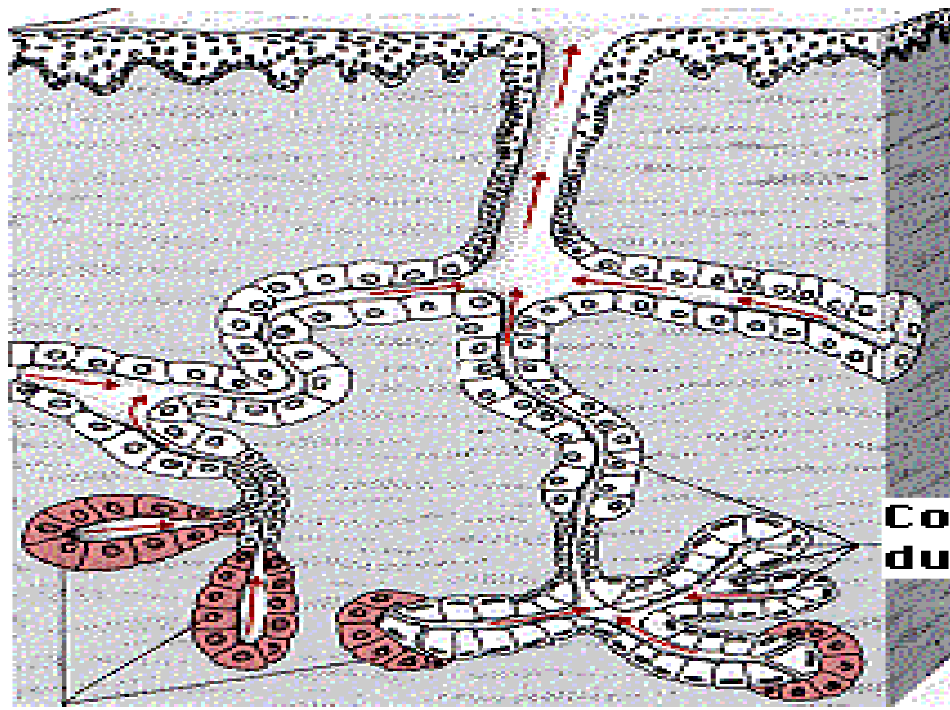
   An elongated group of secretory cells with a tube-shaped lumen

2. **Acinar** (or alveolar)

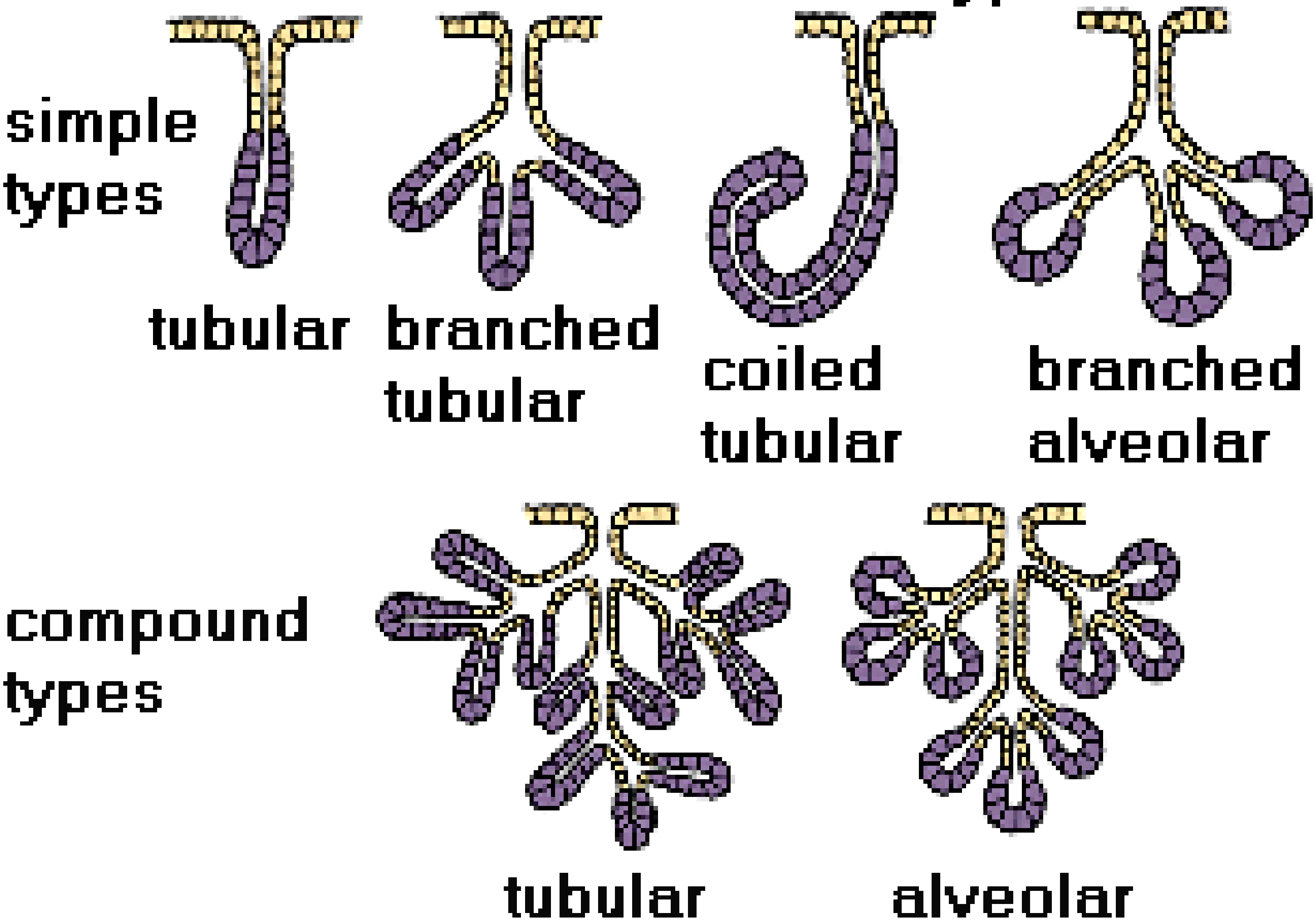
3.Tublo- alveolar

Some of the secretory cells are arranged as acini (alveoli) and others as tubules.

ex. salivary gland, pancreas



Exocrine Gland Types



Myoepithelial Cells

- are contractile cells lie parallel to the length of an exocrine gland's duct.
- form the initial portion of the duct system
- Also lie on secretory portion of glands.
- are instrumental in moving the secretions toward the excretory duct.
- contraction of these cells accelerates the secretions along the duct system

TISSUE

main components of tissue

TISSUE- collection of cells by which one type predominates

Tissue consists of

- Cells
- **Intercellular products**-
  (cell products located between the cells)
- **Intercellular Fluid-**
  (fluid flows between the tissues)

Extracellular matrix

Four main types of tissue in the body

1. Epithelial tissue   2. Connective tissue

3. Muscle tissue   4. Nervous tissue

Tissue differences

- ❖the types and functions of their cells,
- ❖the characteristics of extracellular material that surrounds the cells
- ❖the relative amount of space occupied by cells versus matrix.

e.g. mus*cle and epithelium-* cells are so close together that the matrix is scarcely visible while in *CT,* the matrix usually occupies much more space

Connective tissue

INTRODUCTION

- Derived from mesoderm → mesenchyme
- Composed of cells & ECM
- Connective tissue serve as a connecting link for binding, supporting and strengthening all other body tissues together.
- ❖ Derived from mesoderm
- ❖ have great
- morphologic, topographic and structural diversity.
- Types
  - Non-specialized CT (Connective tissue proper)
  - Specialized CT

Functions

- **Structural support**
- **Metabolic functions**
- **Defensive functions**

  - Main function-**Binding of organs**

- Provide framework for the structures of other organs (**cartilage and bones).**

- Physical protection (**the cranium, ribs, and sternum protect delicate organs such as brain, lungs, heart)**

- Movement
  - Bones provide the lever system for the body movement, cartilage, movement of vocal cords
- Thermoregulation
- Storage
  - Fat -body's major energy reserve,
  - calcium and phosphorus –bone
- Transport
  - blood , gases, nutrients,, wastes, hormones
- Defense and repair mechanism
  - White blood cells

Connective tissue is formed by:

- Cells
- Fibers
- Amorphous ground substances(**AGS**)

Extracellular matrix (ECM)

Connective tissue can be:-

I. connective tissue proper CTP)or special connective tissue
II. Embryonic connective tissue

I. Embryonic connective tissue

Can be

- mesenchymal connective tissue
- Gelatinous connective tissue

mesenchymal connective tissue

- Composed of irregularly shaped mesenchemal cells
- is precursor of the most connective tissue cells.
- it is composed of spindle shaped cells .

Cont…

- cells have regular, oval nuclei
- Mesenchyme cells are only found in embryos
- some mesenchyme-like cells persist in adult connective tissue.
- E.g the pericytes (perivascular cells) of blood capillaries.

Basic Embryology

- Implantation → Blastocyst → 3 germ layers → Tissue differentiation → Organogenesis
- All tissues are derived from one of these germ layers
- Organs contain several tissues from different germ layers
- Germ layers
  - Ectoderm
  - Mesoderm
  - Entoderm (endoderm)

Ectoderm

- Tissues derived from ectoderm
  - Neural tube → CNS
  - Otic placode → sensory epithelium of inner ear
  - Lens placode → lens of eye
  - Corneal epithelium
  - Peripheral nervous system; adrenal medulla
  - Sensory epithelium of nasal cavity
  - Epidermis, nails & adnexa (hair follicles, sweat & sebaceous glands)
  - Anterior pituitary gland
  - Ameloblasts → enamel of teeth

Mesoderm

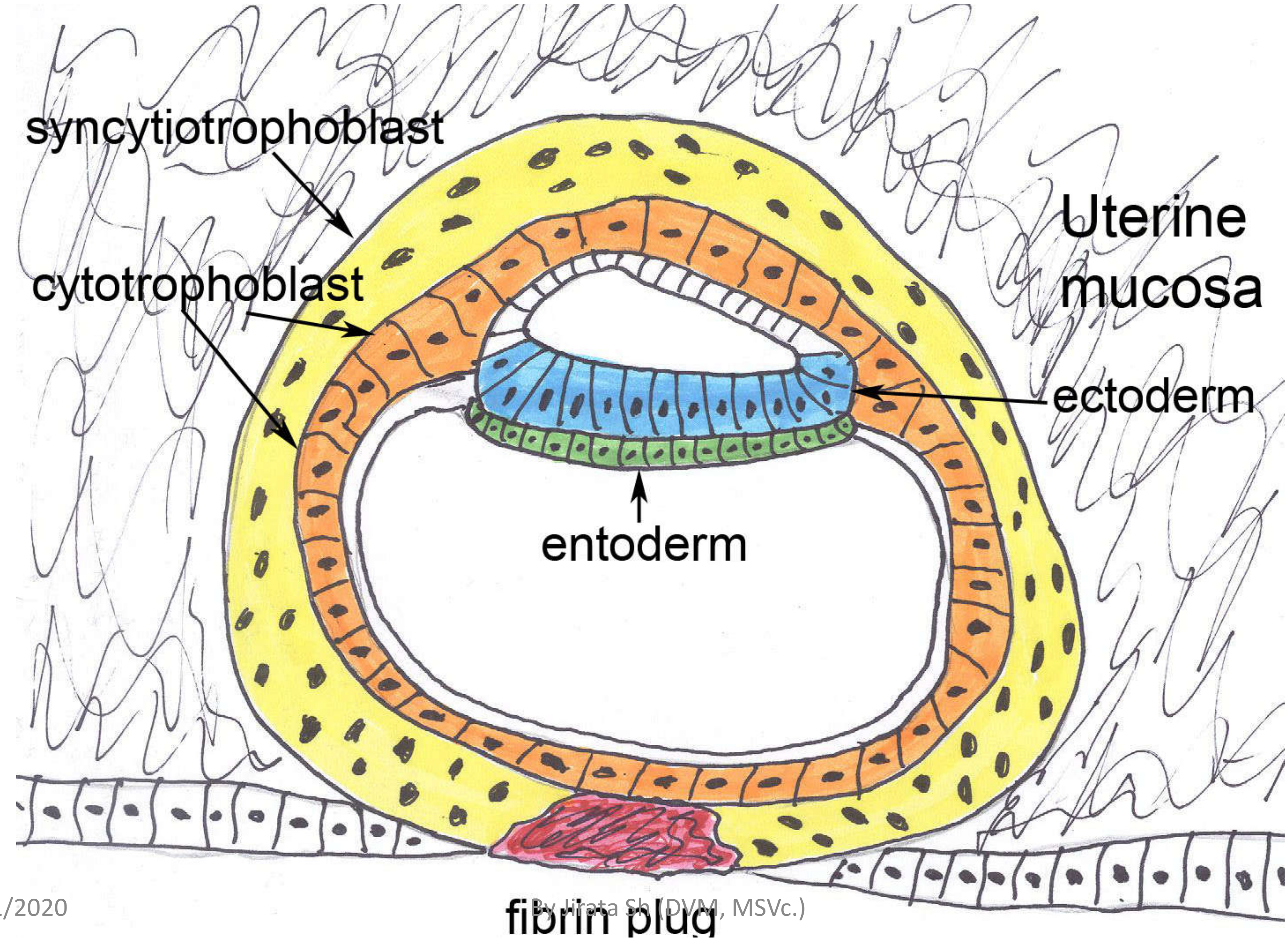
- Tissues derived from mesoderm
  - Somites = mesodermal tissue blocks along neural tube
    - Mesenchyme → fibrous connective tissue, smooth muscle
    - Sclerotome → bone, cartilage
    - Dermatome → dermis
    - Myotome → skeletal muscle
    - Nephrotome → excretory units of kidney
  - Mesothelium → peritoneum, pleura, pericardium
  - Blood vessels & heart (endothelium, smooth & cardiac muscle)
  - Lymphatic system (lymphocytes, vessels, nodes, spleen)
  - Bone marrow & blood cells
  - Gonads, uterus, ductus deferens
  - Adrenal cortex

Entoderm

- Tissues derived from entoderm
  - Epithelial lining & glands of GI tract
  - Epithelial lining & glands of lower urinary tract (collecting ducts → urethra)
  - Epithelial lining & glands of respiratory tract
  - Epithelial lining of Eustachian tube & middle ear
  - Thyroid & parathyroid glands
  - Epithelial component of thymus
  - Liver
  - Exocrine pancreas

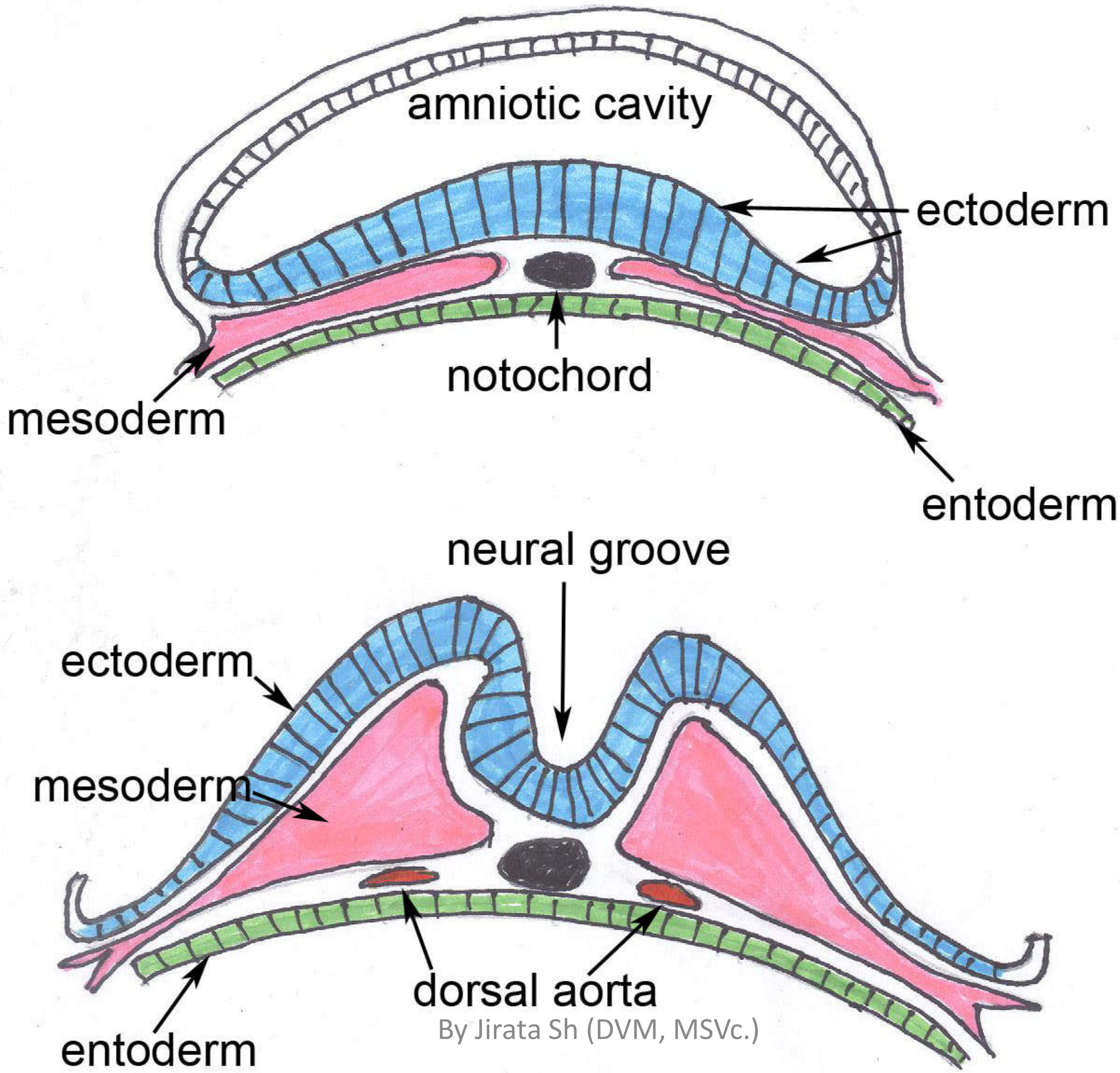
Basic Embryology

- Blastocyst imbedded within endometrium; 9-10 days



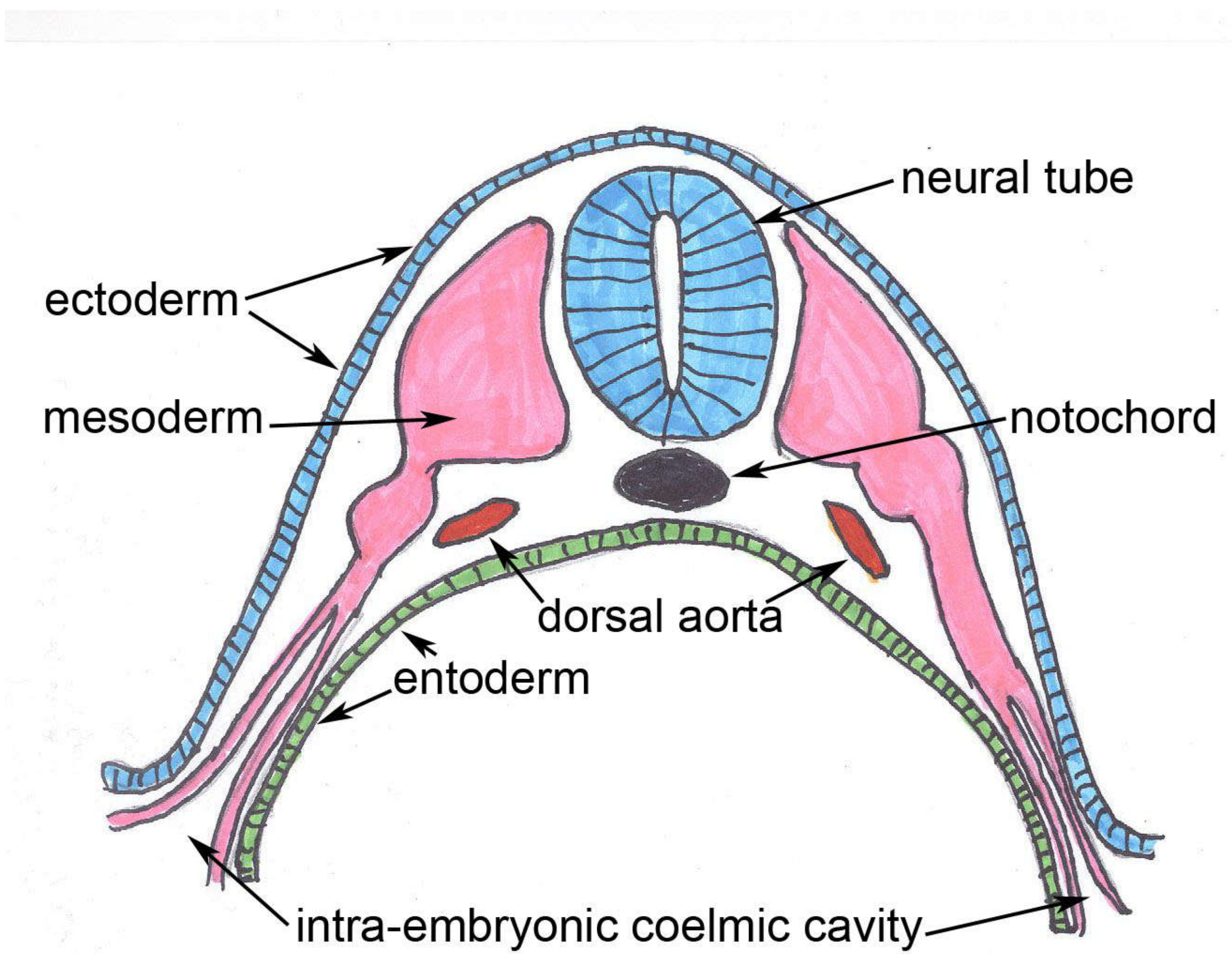
Basic Embryology

- Embryo cross-sections at 17 & 19 days



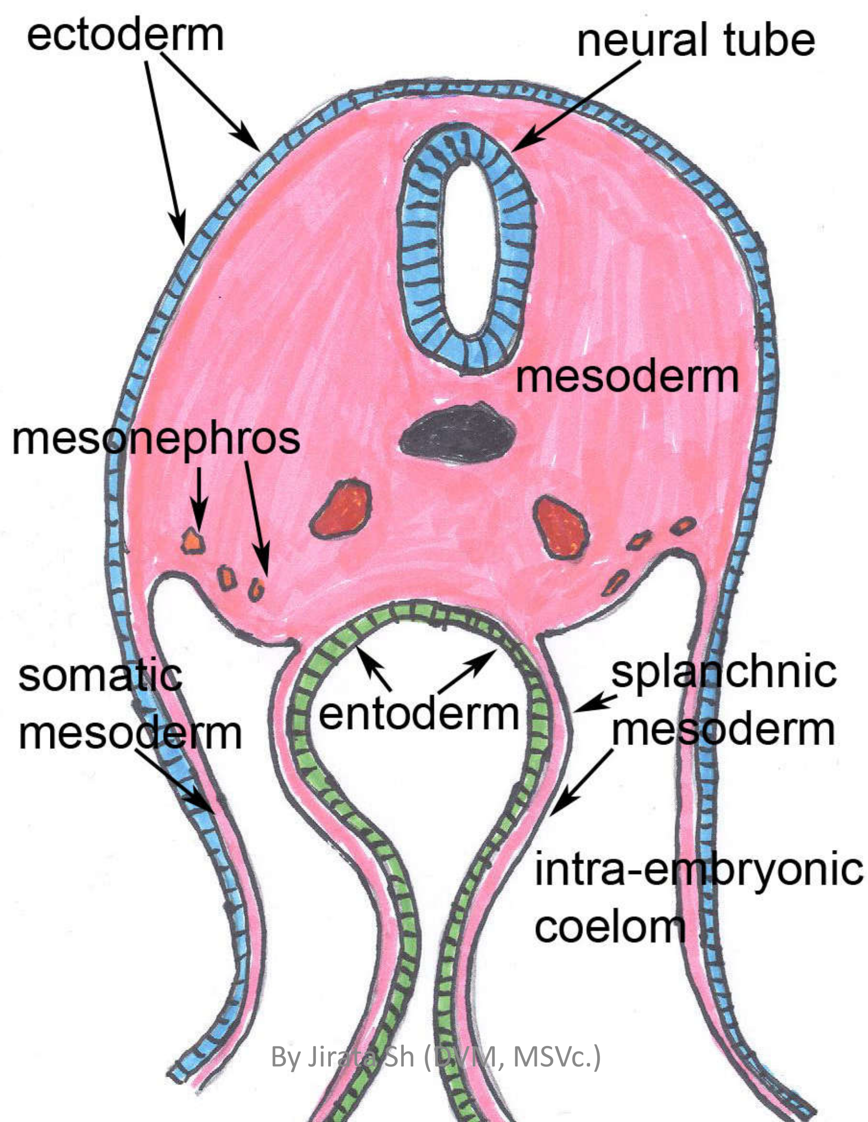
Basic Embryology

- Embryo cross-section at 20 days



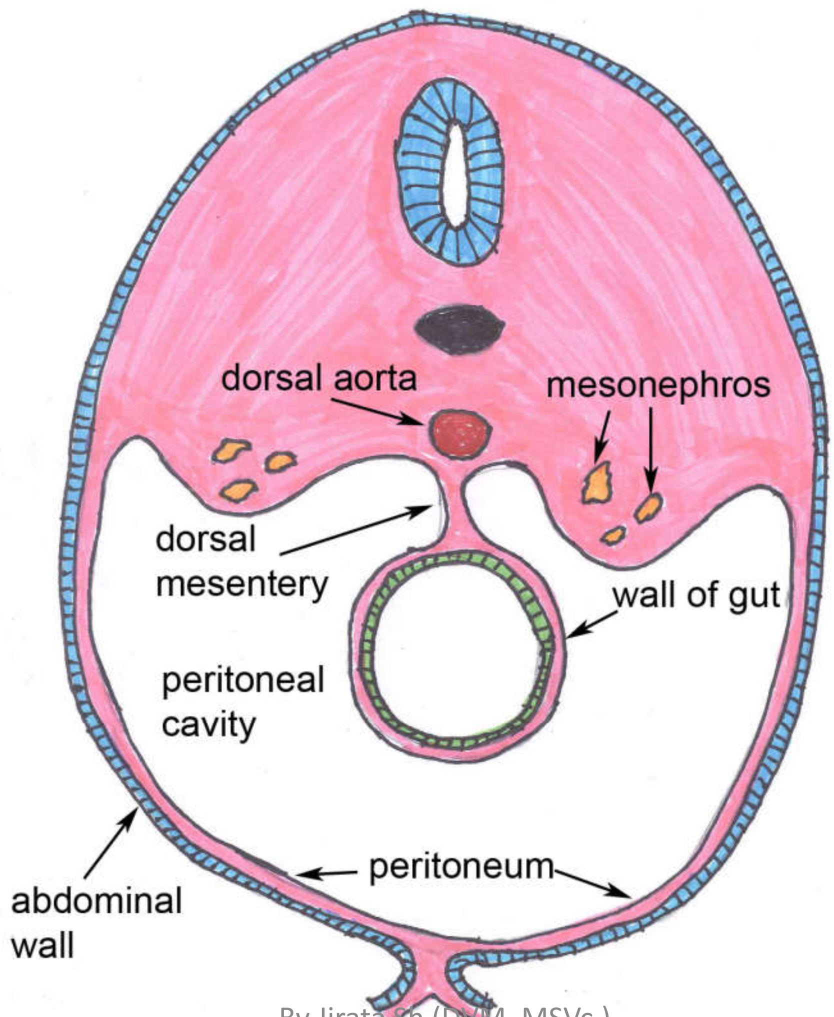
Basic Embryology

- Embryo cross-section at 21 days; mesonephros level



Basic Embryology

- Embryo cross-section at 28 days; mesonephros level



II. Gelatinous connective tissue

- also called mucus connective tissue
- found primarily in the embryonic hypodermis and umbilical chord.
- Characterized by stellate fibroblasts,
- Form network whose meshes are occupied by a viscous, gel like amorphous ground substance.

Adult connective tissue

- CT consists of heterogeneous group of cells
- copious amount of ECM.
- CT and supportive tissues composed of 3 main structures

  CT-cells

  CT-fibers

  Amorphous ground substance
- Cells of different types of CT posses varying structural characteristics
- CT fibers and amorphous ground substance –extra cellular matrix

Connective tissue cells

1. Fixed or resident cells

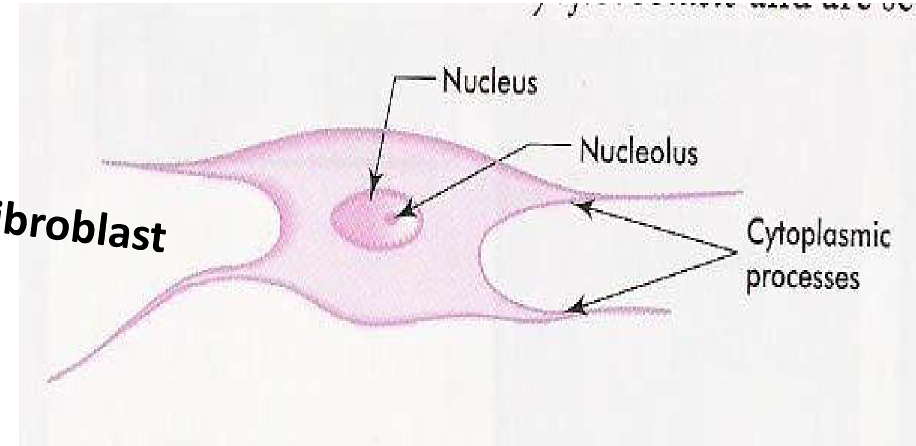
- ❖ Cells that are frequently encountered in CT.
- ❖ involved in production of CT fibers and AGS
- ❖ tissue repair and storage of nutrients
- ❖ These cells include
  - fibroblast (fibrocytes)- **synthesize of ECM**
  - adipose cells- **Fat is stored as a source of energy**

Cont..

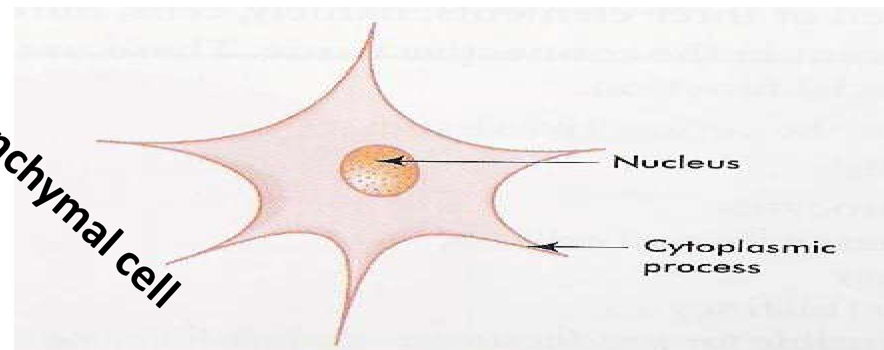
A. Fixed cells (intrinsic cells)

- 1. Fibroblast
- 2. Mesenchymal cells
- 3. Adipocyte
- 4. Pigment cells

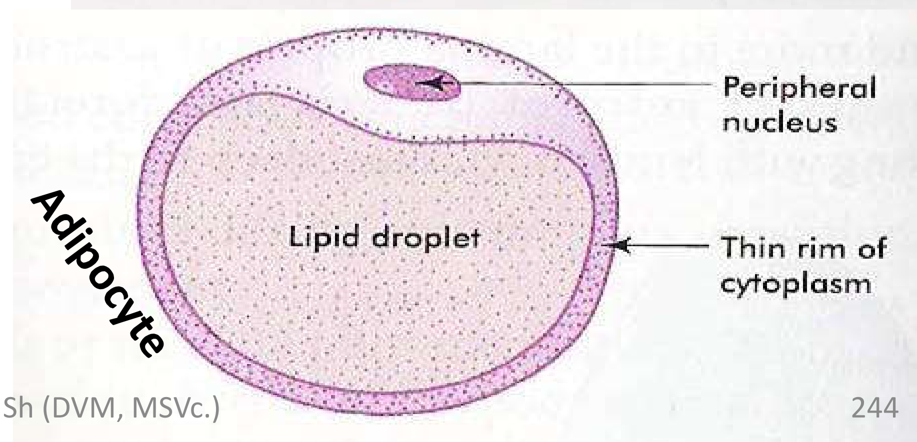
Fibroblast



Mesenchymal cell



Adipocyte



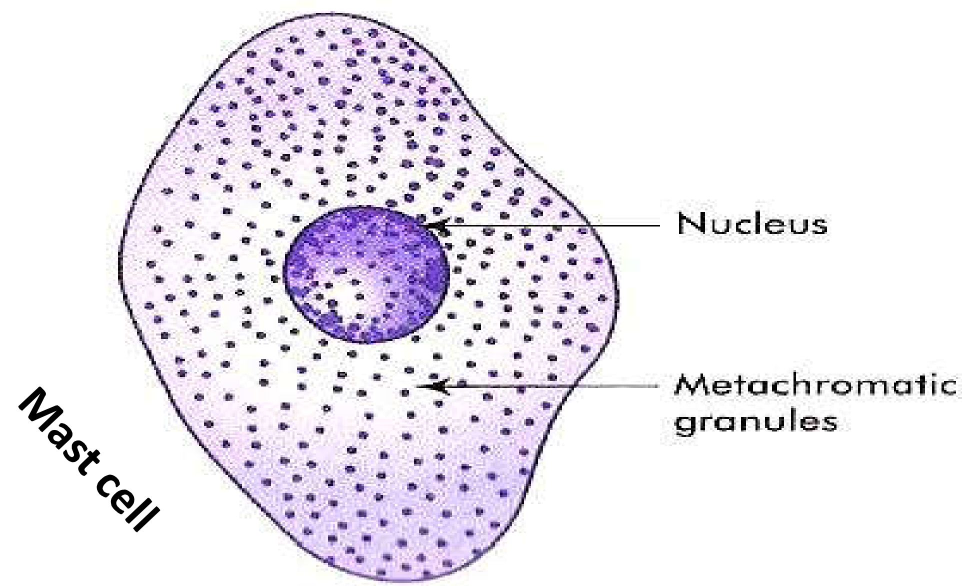
2. Free or transient cells

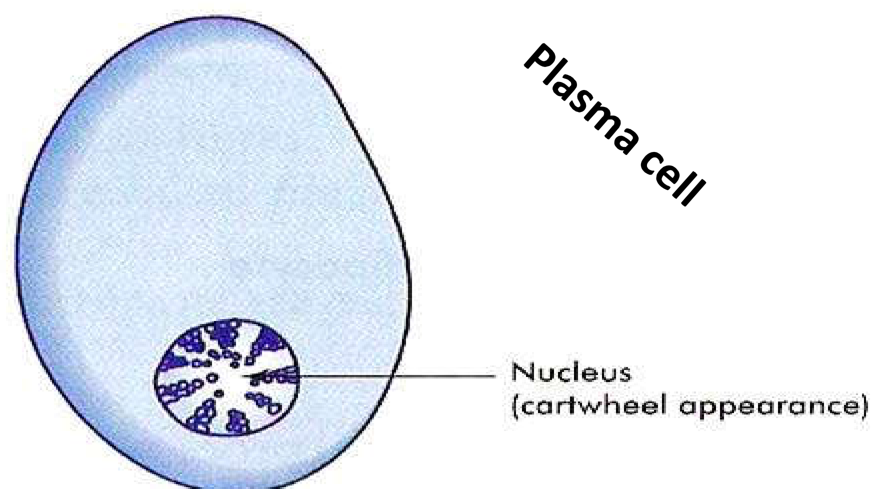
- less frequently encountered
- most of them have protective role
- They include:
  - Macrophages- **Phagocytosis**
  - Leuckocytes - **body defense cells**
  - mast cells- **mediate inflammation (allergic reactions)**
  - plasma cells- **secrete antibodies (markers)**
  - melanocytes- **Pigment producing cells**

Cont…

B. Free cells (extrinsic cells)

- 5.Macrophage (histiocyte)
- 6. Mast cell
- 7. Plasma cells
- 8. Leucocytes





Connective tissue fibers

- There are three CT fibers types:

A. Collagen

B. Reticular

C. Elastic fibers

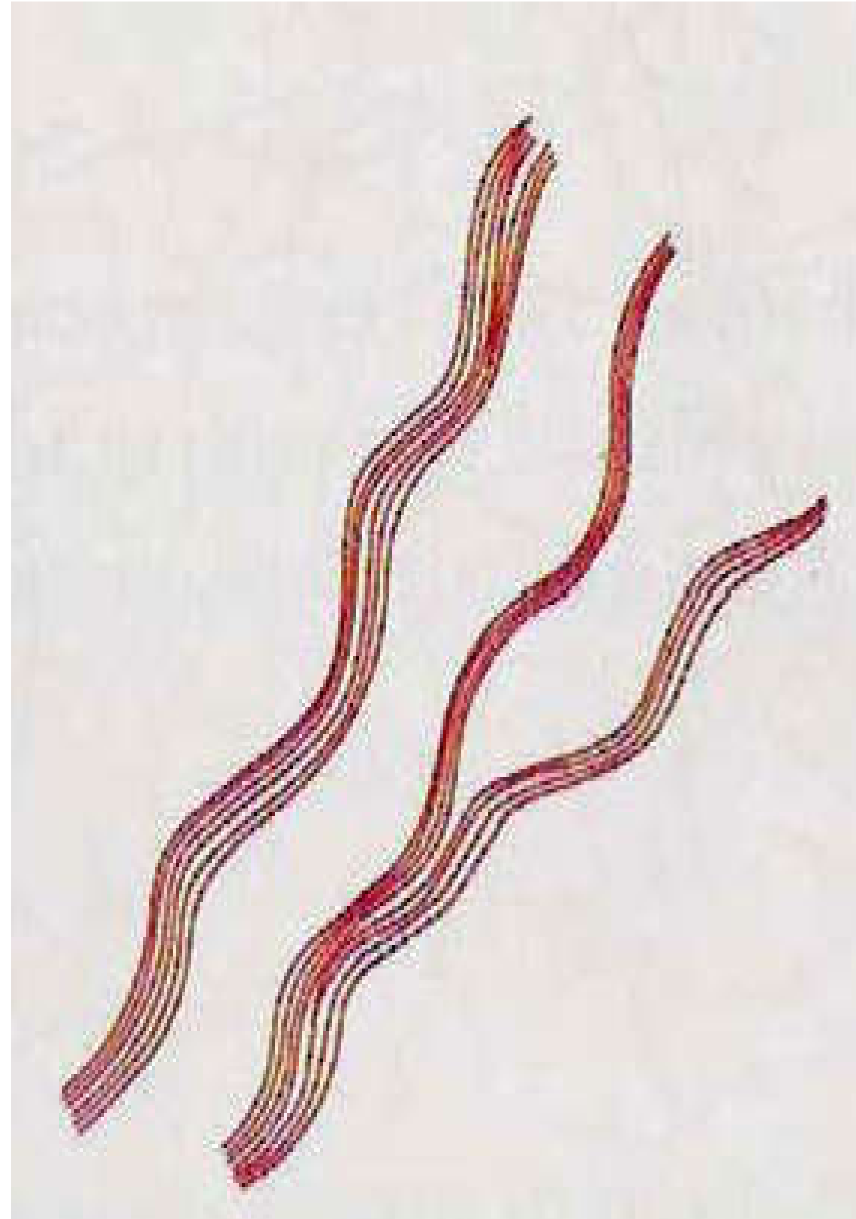
A. Collagen fibers

- composed of subunits collagen fibrils
- It is about 25% of the body’s protein = most abundant type
- In fresh tissue= have a glistening white appearance = white fibers
- The collagen molecules are produced by fibroblasts
- They are flexible, therefore, they can adapt to movements and changes in size of the organs in which they are found
- They have also a high tensile strength and thus can be stretched to 5% of their original length.
  - Ex. Tendons, ligaments, deep layer of the skin (dermis), capsules

Cont..

White coloured when fresh

- •Do not branch
- •Found in abundance in bone, cartilage, tendon & ligament
- •Strong, flexible & inelastic
- •Present in bundle
- •Collagen protein form fibres
- •Fibres are composed of fibril formed by microfibrilar subunits
- •Micro fibrils are made up of tropocollagen
- •Synthesized by fibroblast
- after staining they are acidophilic



Types of Collagen fibre

- **more than 12 different types of collagen**
- **the most common types are types I toV**
- •**Type 1**-bones & tendons (is present in bones (oestoblasts) tendons and in capsules formed by fibroblasts only)
- •**Type 2**-cartilage (hyaline & elastic) & **formed by chondroblast not visible (not detectable easily)**
- •**Type 3**-reticular fibres
- •**Type 4**-basement membrane (epi & endo)
- •**Type 5**-blood vessels (present in placenta)

Synthesis of Collagen fibre

Amino acids

↓

Procollagen

↓

Three chains

↓

Tropocollagen

↓

Collagen

Cont..

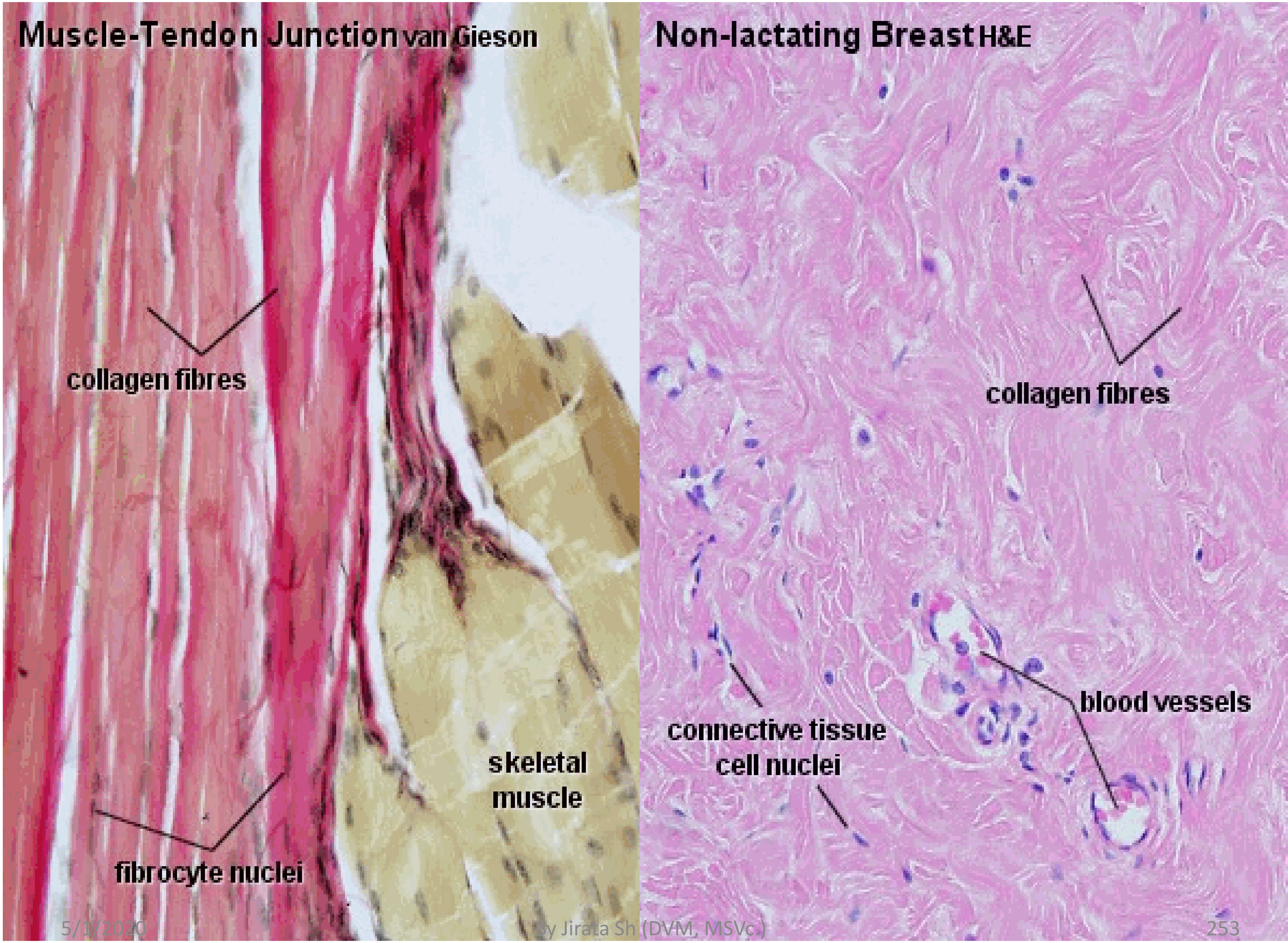
- The **main amino acids** of collagen are:

❖ glycine

❖ *proline*

❖ hydroxyproline

❖ hydroxylysine


Muscle-Tendon Junction van Gieson
collagen fibres
skeletal muscle
fibrocyte nuclei
Non-lactating Breast H&E
collagen fibres
blood vessels
connective tissue cell nuclei

B. Reticular fibers

- are actually individual collagen fibers coated by proteoglycans and glycoprotein.
- short, branching and anostomising fibers forming a network (or a meshwork)

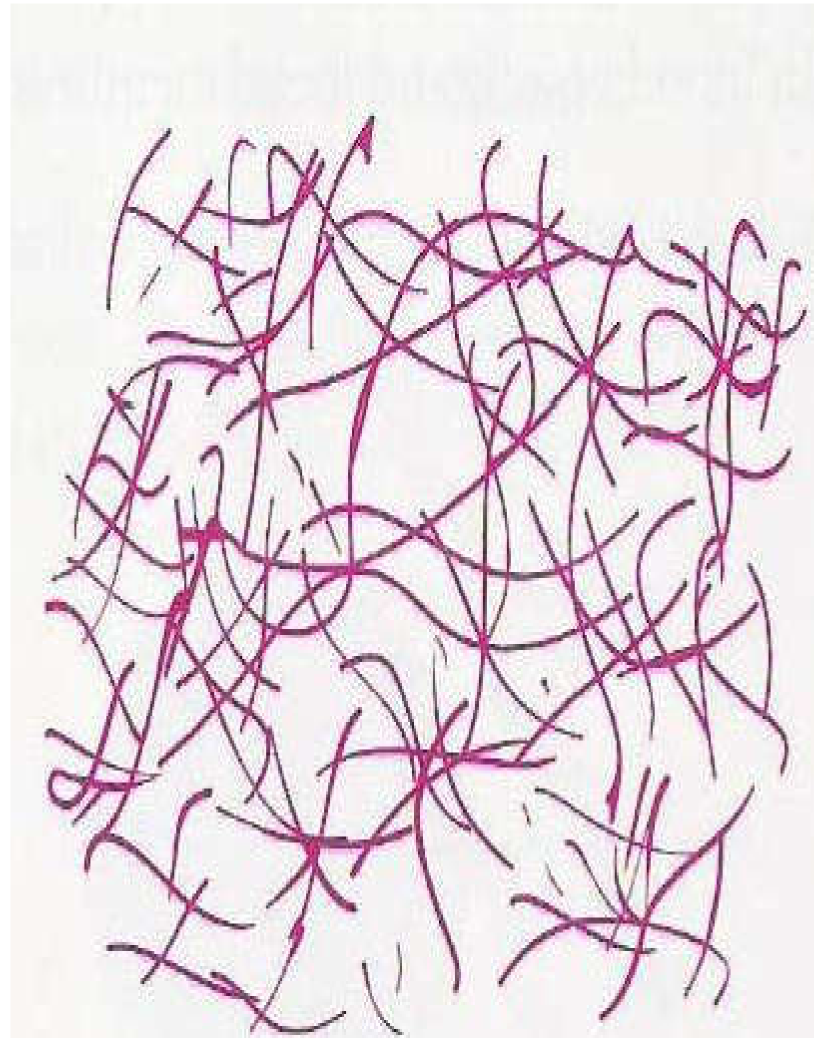
- These fibers form a delicate flexible network around the following structures: Capillaries, m/s fibers, nerves, adipose cells and hepatocytes.

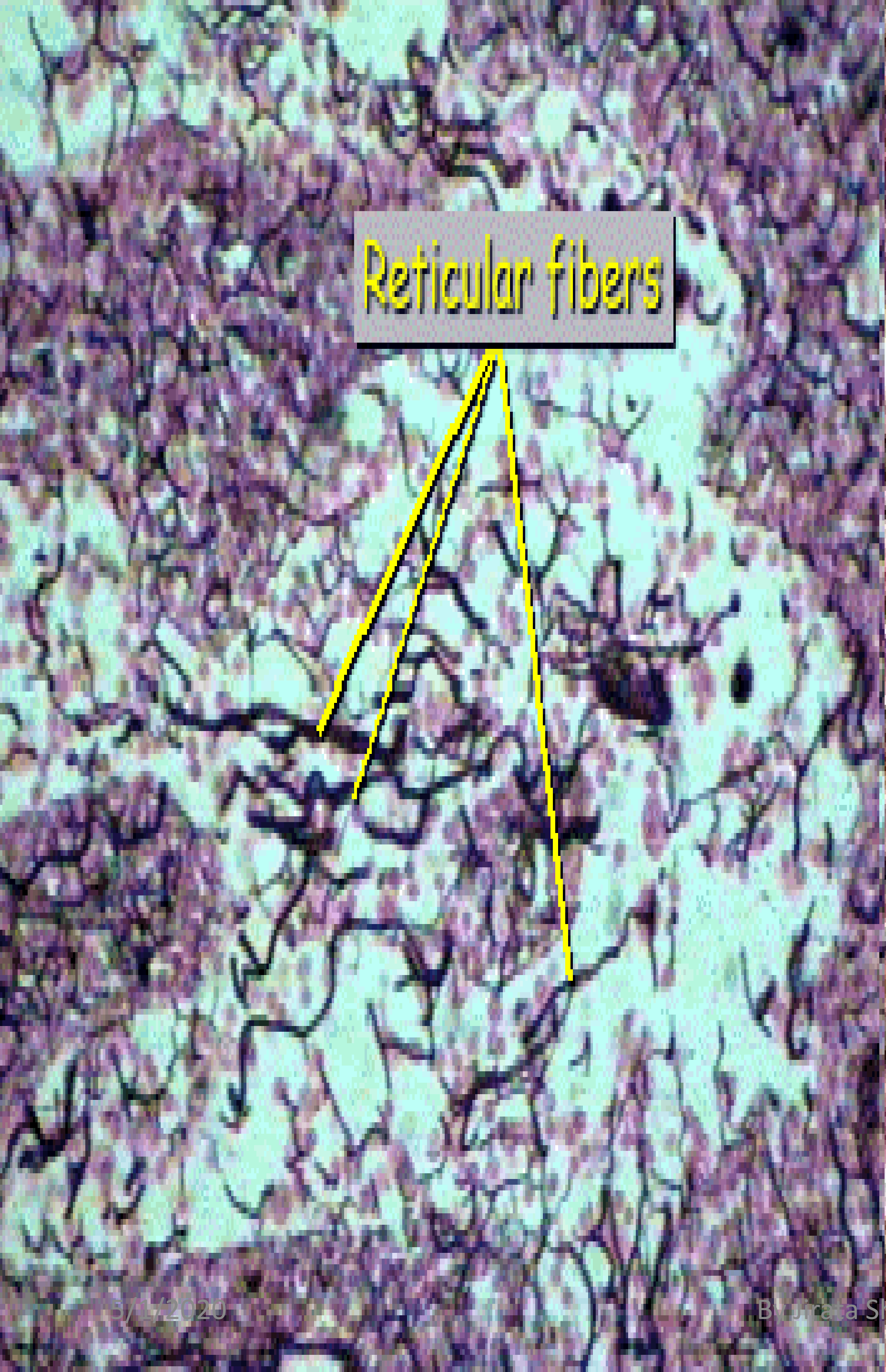
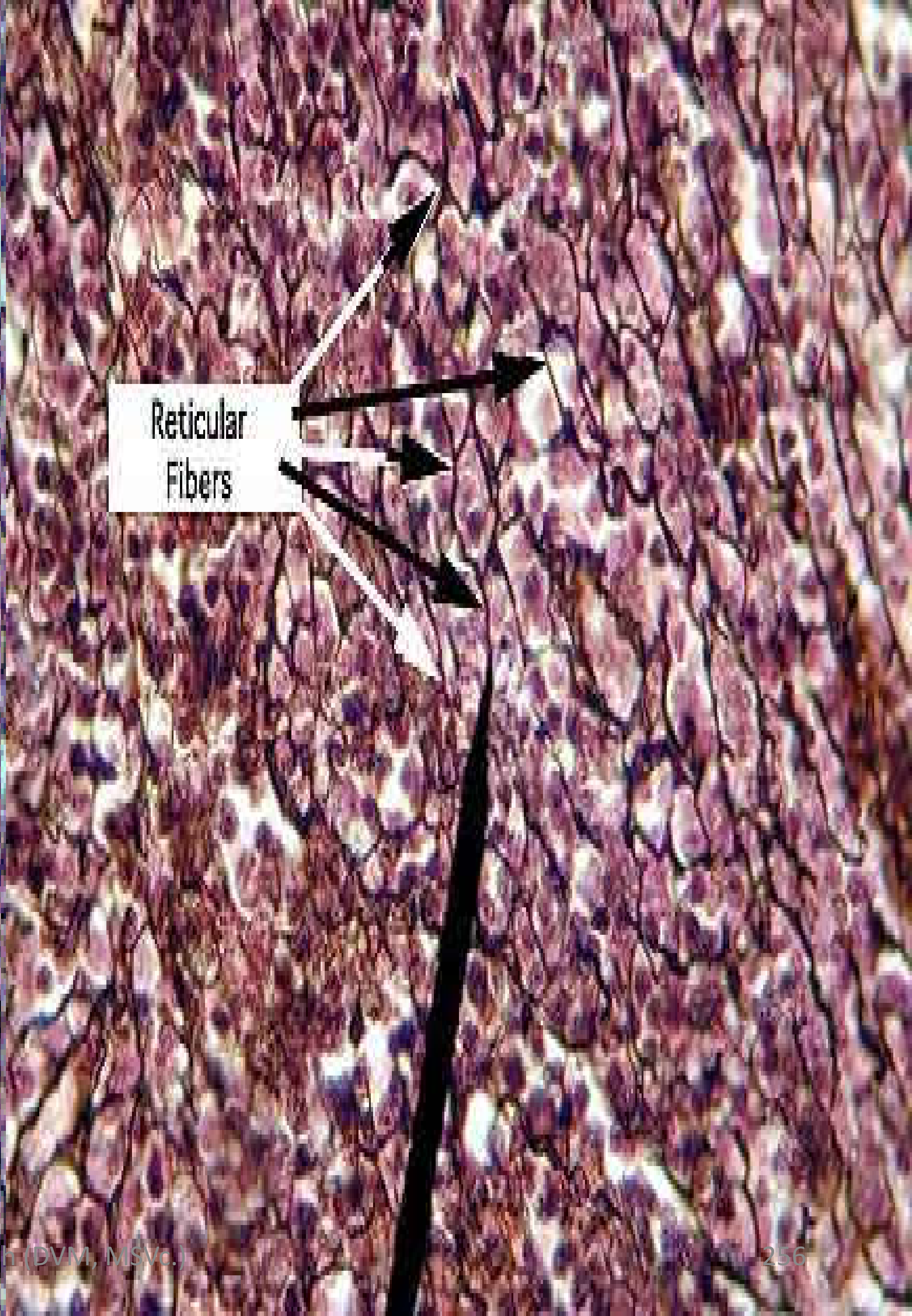
- They serve as a scaffolding to support cells or cell groups of Endocrine, lymphatic & blood forming organs.

- They are thin and not visible with routine H- E staining methods.
- Therefore, a special stain, silver impregnation is required to make them visible.

Reticular fibres

- •Fine delicate strands
- •Immature collagen fibre (type - 3)
- •Synthesized by fibroblasts
- •Provide support and strength
- •Framework of lymphoid tissue
- •In organ capsules of liver, kidney & endocrine glands
- Not visible in routine histological preparations
- •Stained by silver salts (argyrophilic)

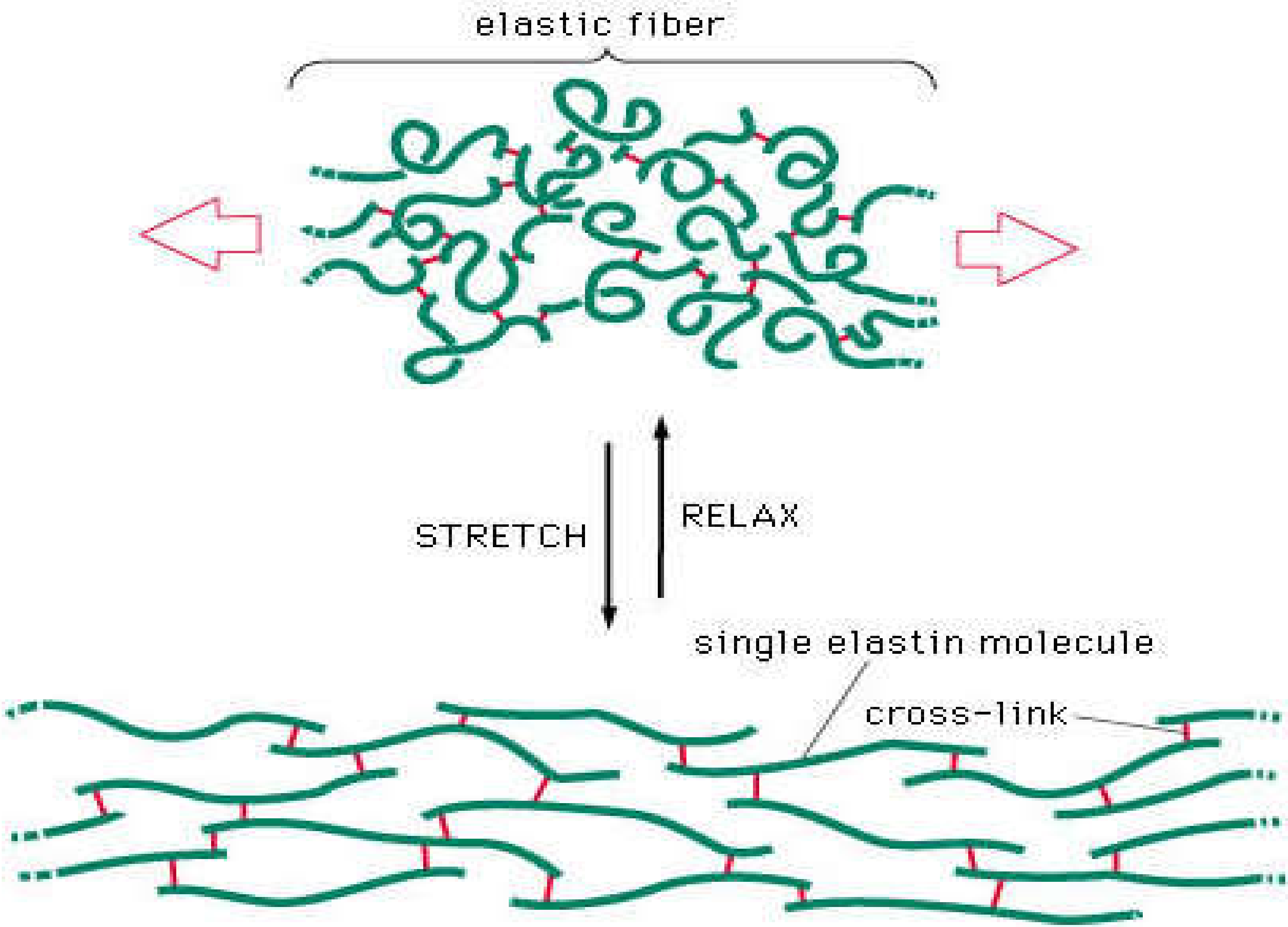



Reticular fibers

Reticular
Fibers

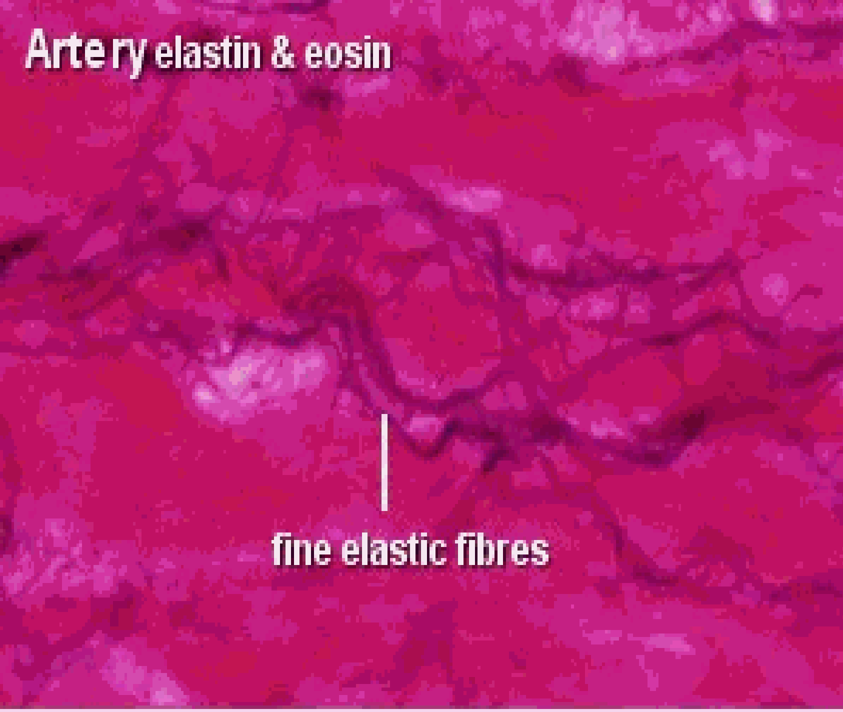
C. Elastic fibers

- They usually occurs as individual branching & anatomizing fibers
- They are made of a protein called ***elastin*** whose coiled structure allows it to stretch and recoil like rubber band.
- Fresh elastic fibers are yellowish – yellow fibers
- Stains: yellow with **Van Giesan**
- Elstin is synthesized by fibroblasts and smooth muscles cells.
- Elastic fibers can be stretched as 25x their original length
- Therefore, they are found in organs whose normal function requires elasticity

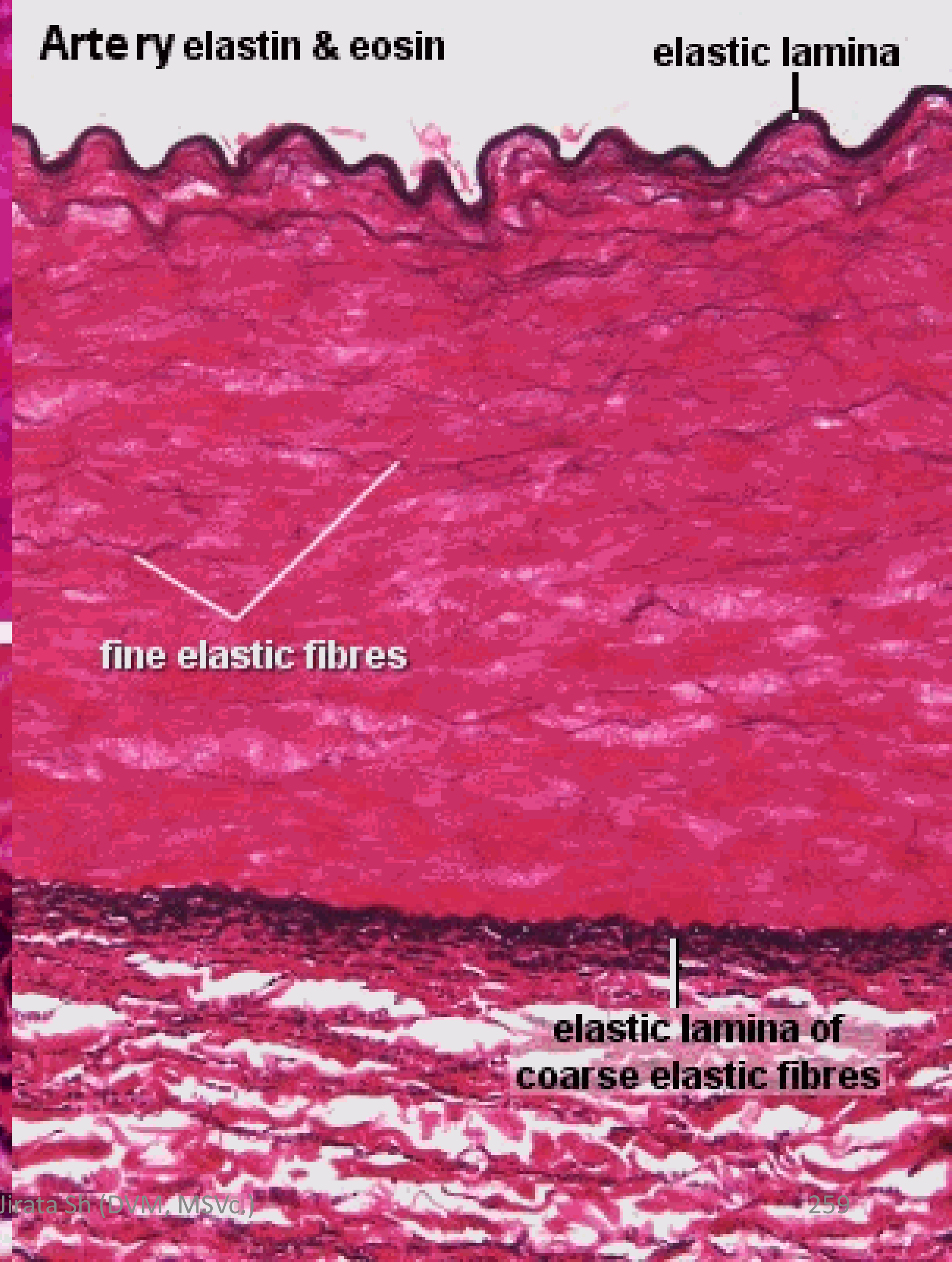
Example: external ear, vocal cords, trachea, lungs, ligamentum nuchae, skin & arteries.


elastic fiber
STRETCH
RELAX
single elastin molecule
cross-link

(B)


Artery elastin & eosin
fine elastic fibres


coarse elastic fibres


Artery elastin & eosin
elastic lamina
fine elastic fibres
elastic lamina of
coarse elastic fibres

Amorphous ground substance (AGS):

- The cells and fibers of CT are embedded in an AGS composed predominantly of proteoglycans.

- They are **seven** major types of proteoglycans.

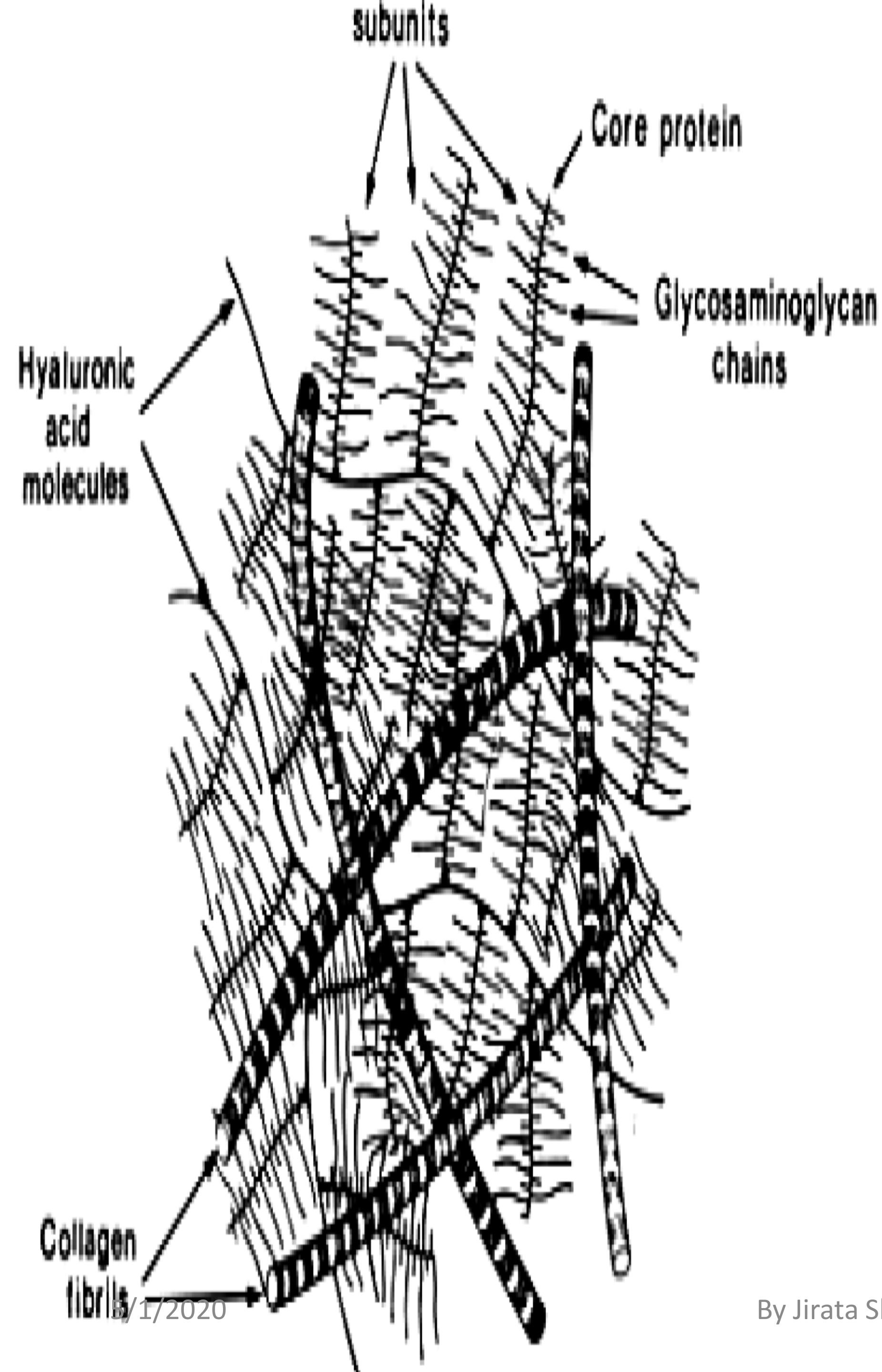
* **Hyaluronic acid:** It is a non – sulphated glcosaminoglycan that is not linked to a protein. It is large, long molecule that forms networks whose space is filled with tissue fluids. ***The resulting gel is abundant in vitreous humor of the eye, synovial fluid, umbilical cord, loose CT, skin and cartilage.***
* **Chondrotin – 4- sulphate**
* **Condrotin -6- sulphate**
  – Chordrotin slphates are abundant in cartilage, arteries, skin and cornea

* **Dermatin sulphate** is found in skin, tendon, ligamentum nuchae, sclera and lung.
* **Keratin salphate** is present in cartilage, bone and cornea
* **Heparan sulphate** is found in arteries and the lung
* **Heparin** is found in most cells, lung, liver and skin

NB:-

- All the above except "**Hyaluronic acid:** " are of sulphated variety

- The proportion of the various proteoglycans in a given type of CT determine the **morphologic and functional** properties of that tissue



- The proportion of these all AGS determine the morphological appearance and the functional properties of CT.
- Ground substance may be highly modified in the special forms of CT
- In blood, the ground substance lacks stabilizing molecules.
- Hence- free-flowing ground substance *plasma*.
- In skeletal tissue, the ground substance may become mineralized by deposition of calcium salts.
- We call this rigid ground substance *bone*.
- In cartilage, the ground substance is much more solid than in ordinary connective tissue but still retains more resiliency than bone.

CLASSIFICATION O F CONNECTIVE TISSUE

All connective tissues are classified based on the **arrangement** and **proportions** of their cellular and intercellular components in to three broad categories of:

1. Embryonic connective tissue:

- Gelatinous (Mucus (umbilical cord)
- Mesenchymal (developing embryo & fetus)

• 2. Connective tissue proper:

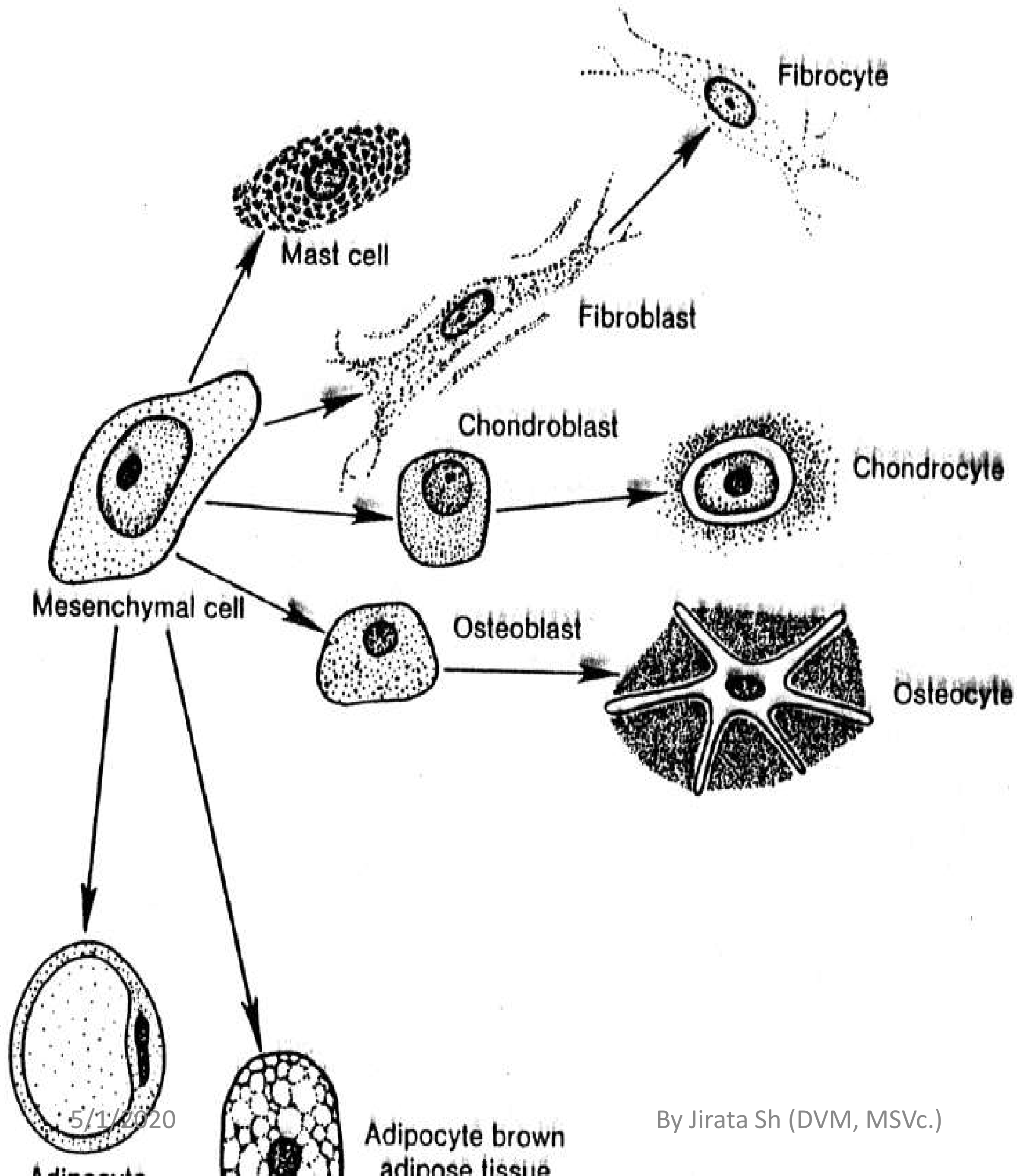
- Loose connective tissue (Areolar tissue)
- Adipose tissue
- Reticular tissue

Cont…

❖ ***Dense connective tissue:***

- Irregular dense connective tissue
- Regular dense connective tissue
- Elastic connective tissue
- **3. Specialized connective tissue:**
- Bone
- Cartilage
- Blood

OF CT CELLS



ORIGINS

- Nearly all CT cells have common stem
- Some variant of the fibroblast is always present

CT proper

- the most diverse type of connective tissue

- Connective tissue proper is classified based on type and amount of CT fibers, AGS and CT cells in to:

A. Loose connective tissue (areaolar CT)

- A high population of CT cells than fibers

- CT fibers which are *loosely and randomly arranged*

- More common type

- Found subcutaneously and interstitially within most organ systems
  - ➢ between muscle fibers and sheaths
  - ➢ around bundles of peripheral nerve fibers & adipose tissue and
  - ➢ abundant in lymphatic and blood vessels.
- Loose connective tissue serves
  - ❖ to connect one tissue with the other and
  - ❖ provides defense and tissue repair by the help of transient cells.

Cells of loose CT

- The fixed Cells of loose CT include:
  - Fibrocytes,
  - Pericytes,
  - Adipose (fat) cells

- The free (transient) cells of loose CT include:
  - ❑Macrophages (histocytes)
  - ❑Mast cells
  - ❑Plasma cells
  - ❑Melanocytes

Dense CT

- more **CT fibers** than cells (Fibroblasts/fibrocytes are the most common) and AGS

- Two types:

Dense regular CT

- Delineated by the presence of closely packed extracellular fibers that are arranged in the same plane and direction

- Less flexible and more resistant to stress

- Constitute the structures of tendons and ligaments

- They occurs as collagen tendons ligaments as well as elastic ligaments

Dense irregular CT

- It is composed of fibers, predominantly collagen, which are arranged in different planes and directions
- Has the same cell population as loose CT but fibrocytes are more abundant than others.
- Dense irregular CT is found in the **propria** of the initial portion of digestive system, the capsule of lung, liver, kidney, speen and testis. nm/s and skin fascia, aponeurosis, joint capsule, pericardium, and dermis

Reticular CT

- It is composed of stellate reticular cells and a complex three directional network of reticular fibers.
- Forms the stroma (CT frame work) for the parenchyma of all lymphatic organs (spleen, lymph node, and tonsils), diffuse lymphatic tissues, liver, kidney and bone marrow.

<u>Adipose (fat) tissue</u>

- It is special type of CT dominated by fat cells (adipocytes) plays a role in thermoregulation (insulation) and energy metabolism

based on color, vascularity, structure and function, types of fat are recognized

Supportive connective Tissue

- The includes cartilage and bone, which are specialized for supportive role

Cartilage

- Cartilage is composed of cells (chondrocytes), fibers and like ground substance.
- The chondrocytes occur singly or in pairs with in lake spaces called **lacunae.**
- Cartilage is a vascular, alymphatic. Hence, blood supply is by diffusion from adjacent capillaries (perichondrium). Therefore, healing is slow.

- The surface of cartilage is covered by dense irregular CT called perichondrium. The predominant fiber of the cartilage is collagen.

- Based on different structural characteristics of the fibers and amorphous ground substance 3 types if cartilage are recognized hyaline, elastic and fibrocartilage

Hyaline cartilage:

- chondrocytes have a spherical nucleus with one or more nucleoli.
- The AGS is a firm gel laced within collagen fibers. The amorphous ground substance contains chondroitin sulphate, keratin sulphate and hyaluronic acid.

- Hyaline cartilage is found on the articular surface of bones, it provides support in nose, larynx, trachea & bronchi. It also forms most of the skeleton of the embryo.

Elastic cartilage:

- This type of cartilage posses a dense network of elastic fibers in addition to all structural components of hyaline cartilage.

- It is found in organs where elasticity is required like external ear, external audotiry canal and epiglottis

Fibrocartilage

- It occurs less frequently and found in the intervertebral disks.
- It is characterized by the presence of numerous collagen fibers
- The amorphous ground substance is abundant around the cells
- It also lacks a distinct perichondrium.
- It lacks the flexibility of the other cartilage types.

The bone

- It is a supportive CT tissue with cells and fibers embedded in a hard, unbending substance (bone matrix).
- A hard connective tissue that serves to support, attachment, leaverage, protection and mineral storage having great strength and rigidity and limited elasticity.
- Unlike cartilage, bone closely associated with cardiovascular system and has afferent association with nervous system and provide attachment areas for muscle and organs.
- Bone is surrounded by periosteum, which includes blood vessels thick dense fiberous connective tissue (capsule) and cells (osteogenic cells which give rise to osteoblasts).
- The internal space of bone, the marrow cavity, where the stem cells of blood are housed and are lined by edosteum, which consists of osteogenic cells and loose connective tissue.

Function

- Protection soft organs like brain heart lung… (skull, ribs,)
- Hemopoiesis (blood cell formation)
- Reservoirs for minerals such as calcium & phosphorous

- Major cells of bone are
  - **Osteoblasts**- responsible for active synthesis components of cells (prebone or osteod)
  - Once the osteoblasts has entered the bone matrix they are called **osteocytes.** They are matured osteoblast cells that are surrounded by lacunae.
  - **Osteoclast** is multinucleated giant cell that is involved in the resorption and remodeling of bone tissue.
- The ECM of mature compact bone is made up of greater **inorganic** salts than **organic matrix**. collagen makes 90% of the organic component and the rest is being proteoglaycans and non-collagen molecules which are involved in bone mineralization.
- The mineral component of the bone mainly consists of calcium and phosphate in the form of hydroxyapatite crystals.

BLOOD

✓Blood -Is viscous or fluidly connective tissue of the body

✓ It has no fiber

It is formed of **formed elements** and plasma(matrix).

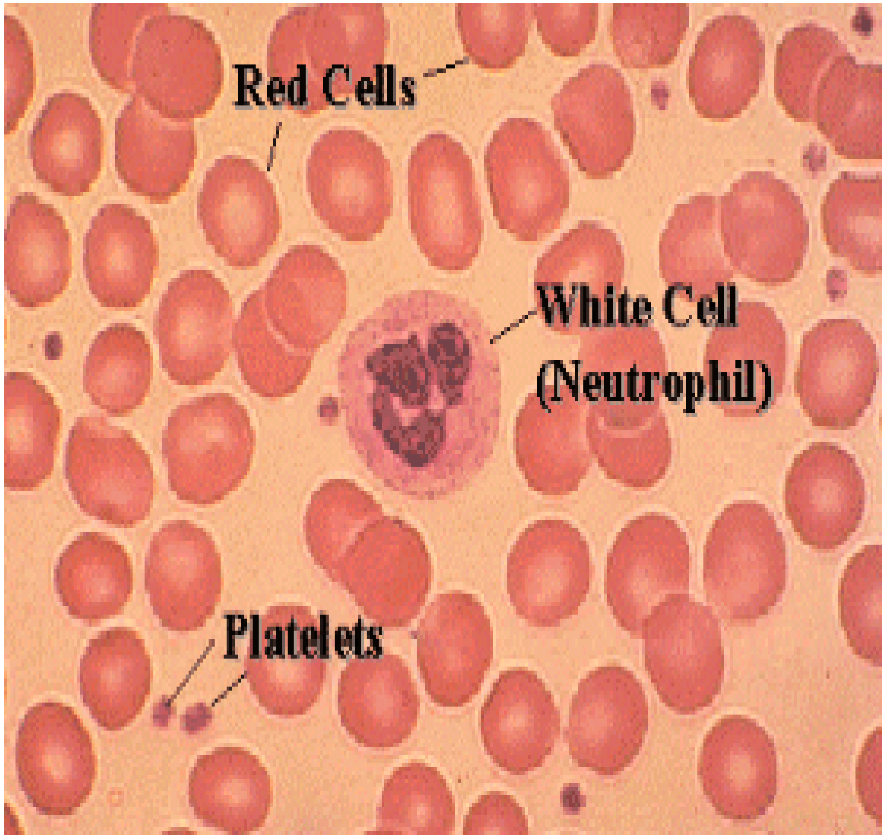
Formed elements are blood cells(**RBC, WBC,Platelets).**

1.BLOOD CELLS

A. Erythrocytes (Red blood cells)

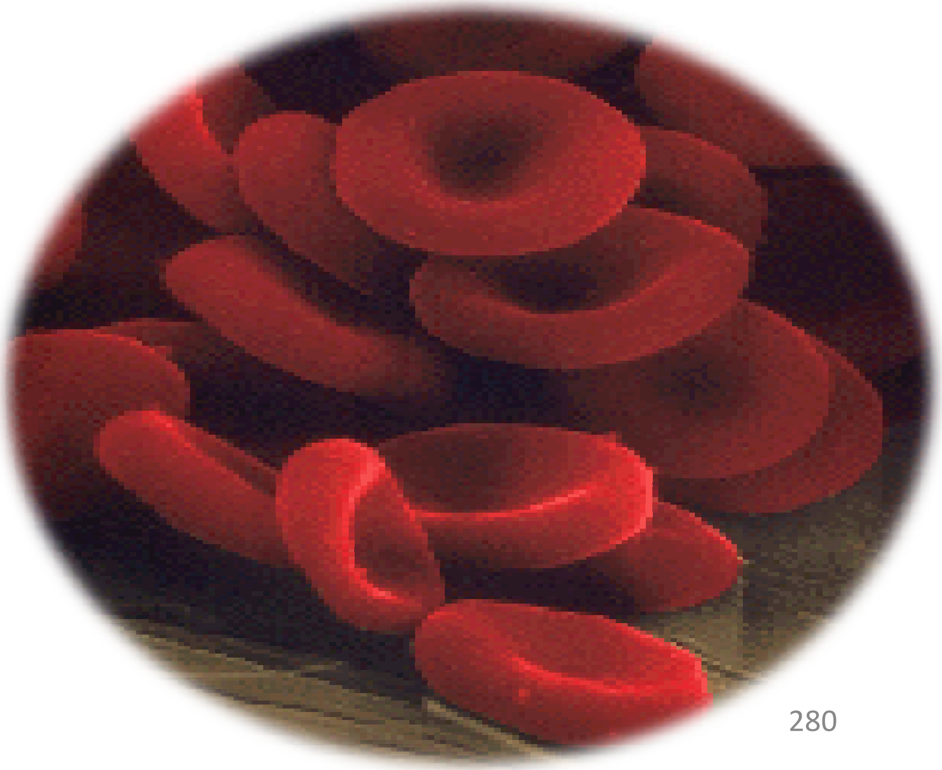
- ❖ Discoid shape or biconcave
- ❖ Degree of concavity varies among species
  - ✈Typically concave in cattle ,sheep and dogs
  - ✈ Horse and cats have shallow concavity

- ❖ Mature RBC is devoid of nucleus in most domestic animals except birds.
- ❖ It Cannot reproduce (average lifespan = about 120 days).
- ❖Size and number of RBCs various among species of animals.
  - ❖Dog have large sized RBC(on average 7.2nm in diameter)
  - ❖goats have the smallest rbc(4.1nm on average)
  - ❖size and number of rbc are generally inversely related.
    - ✈ dogs have small number of rbc
    - ✈goats have large number of rbc.



Functions of RBCs:

- ✓ Carriers oxygen (due to presence of HB)



- ✓ Transport of carbon dioxide from different tissue to lungs (due to presence of carbonic anhydrase)

WBC

- Leucocytes (leuco- white,cytes-cells)=white blood cells
- There are five types of leucocytes and all are categorized in to two. G**ranular** and A**granular** .
- Total leukocyte count **(**TLC) =4,000-11,000 per ml
- **Leukocytosis** is the formation of many leukocytes over 13,000.
- **Leukocytosis** can be due to
  - physiological increase:
  - Pathological increase: due to some acute infetious diseases
- Since leukocytes are different, leukocyte count may be:

1. TLC: a figure to express total number.
2. DLC: Differential leucocyte count express percentage.

- E.g. For eosinophils =number of E.counted /TLCX100 =X%
- For neutrophils =N/TLCX100=Y%

Cont'…

- Leucopoenia: is the decrease in the total number of leucocytes below the normal standard.

A. Granular leucocytes

- **I. Neutrophils** (polymorphoneuclear leucocytes):
  - Main cells of leukocytes.
  - DLC for neutrophils=7, 000/11000x100=65%.
  - **Have Multilobed nuclei (2-5) lobes**
  - Size 10-12 µm
  - Their granules are neutrophilic (neither eosinophilic nor basophilic).
  - They are phagocytic cells.

- **Neutrophilia**: is leukocytosis (increased number of neutrophils) (over 70%)
- ✓ Neutropenia: is leucopenia due to decrease in number of neutrophils. e.g. in Salmonellosis

- **Eosinophils:**
  - Few in number.
  - DLC.is 2-5%.
  - Size: large, up to14µm. i.e. 10-14 µm
  - Have bilobed nuclei
  - Have eosinophilic granules (stains red with eosin)
  - contain large amounts of bright red granules in their cytoplasm.
  - They have lysosomes producing histaminase

  FUNCTION

- ✓ They phagocytose antigen-antibody complexes
- ✓ help initiate and sustain inflammation

Clinical disorders

- **Eosinophilia**: is increase in number of eosinophils over 5%.

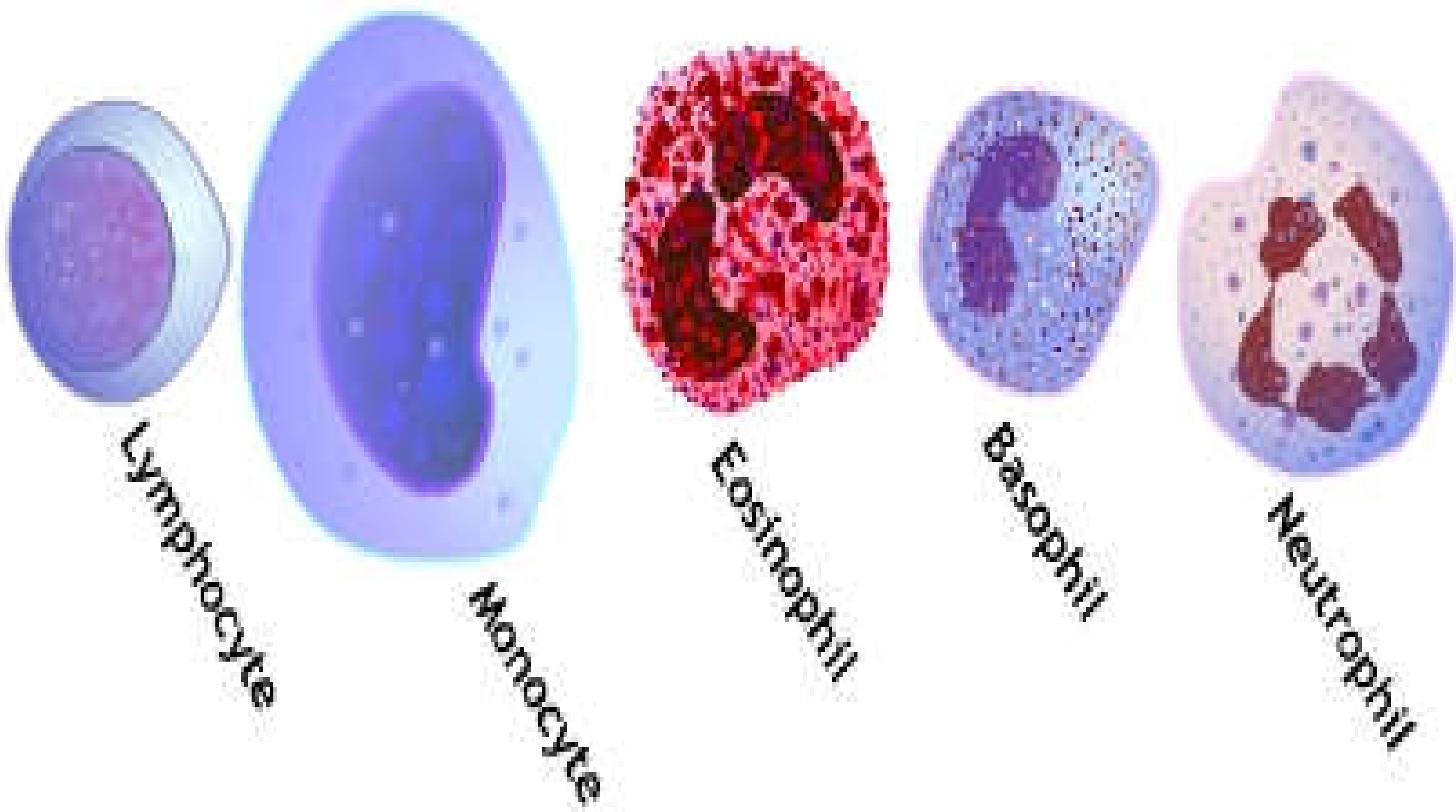
  Ex. in allergic conditions, parasitic infestation
- **Eosinopenia:** is decrease in number of eosinophils less than 2%.

  E.g. due to cortisone in take (anti-inflammatory drug)

- **3. Basophiles**
- Have basophilic granules (lysosomes)
- Has Basophilic cytoplasm
- Prominent blue-staining cytosol granules that nearly obscure the nucleus.
- Small in number, 0-1%
- May not be fined in normal periferal blood
- Its nucleus is s-shaped.
- Basophilia: increase in number of basophiles

  Ex. due to allergic conditions, parasitic infections, etc
- The basophilic granules are lysosomes.
- Function- Secretion of heparin anticoagulantand (anti allergic compound?)
- Along with mast cells, play a role in inflammation and allergic responses.

The five types of WBCs



A granular leucocytes:

- They have no or few granules
- **1. Lymphocytes** ;are characterized by high nucleus to cytoplasm ratio

✓ Types of white blood cell consisting of T cells and B cells

✓ Can be of three types (according to their size)

small, medium, and **large**

Cont'…

2.Monocytes

- ✓ **has a single well-defined nucleus**
- ✓ **Monocytes are the largest of the leukocytes, and constitute about 5% of the white blood cell population.**
- ✓ **Their nuclei are typically indented, with a kidney-bean shape.**
- ✓ About **8**% in their number
- ✓ Size: 18(20)µm largest of all
- ✓ Indent nucleus and basophilic cytoplasm
- ✓ Frosted glass appearance
- ✓ Monocytosis: increase in number of monocytes (>**2**%) due to some diseases.

Platelets (thrombocytes)

- ✓ Thrombopoesis -formation of platelets
- ✓ Are oval cells with a central dark part called chromere and peripheral pale (light) area called hyalomere.
- ❖ Functions: Hemostasis(preventing blood loss)
  - ✓ Blood coagulation
  - ✓ Blood agglutination
  - ✓ Secretion of serotonin (which is a vasoconstrictor substance)
  - ✓ Clot retraction

Plasma:

It is extracelular matrix of connective tissue blood
plasma=water + dissolved solutes

1.Water - serves as transport medium; carries heat

❖ Dissolved solutes:

1.Proteins

Albumins

- 60-80% of plasma proteins
- most important in maintenance of osmotic balance

• produced by liver

Globulins

Alpha & beta

- Some are important for transport of materials through the blood

Gamma globulins are immunoglobulins (antibodies)

- produced by lymphocytes

Fibrinogen

- important in clotting
- produced by liver

–

CONT'..

2 -Inorganic constituents (1% of plasma) - e.g., sodium, chloride, potassium, & calcium

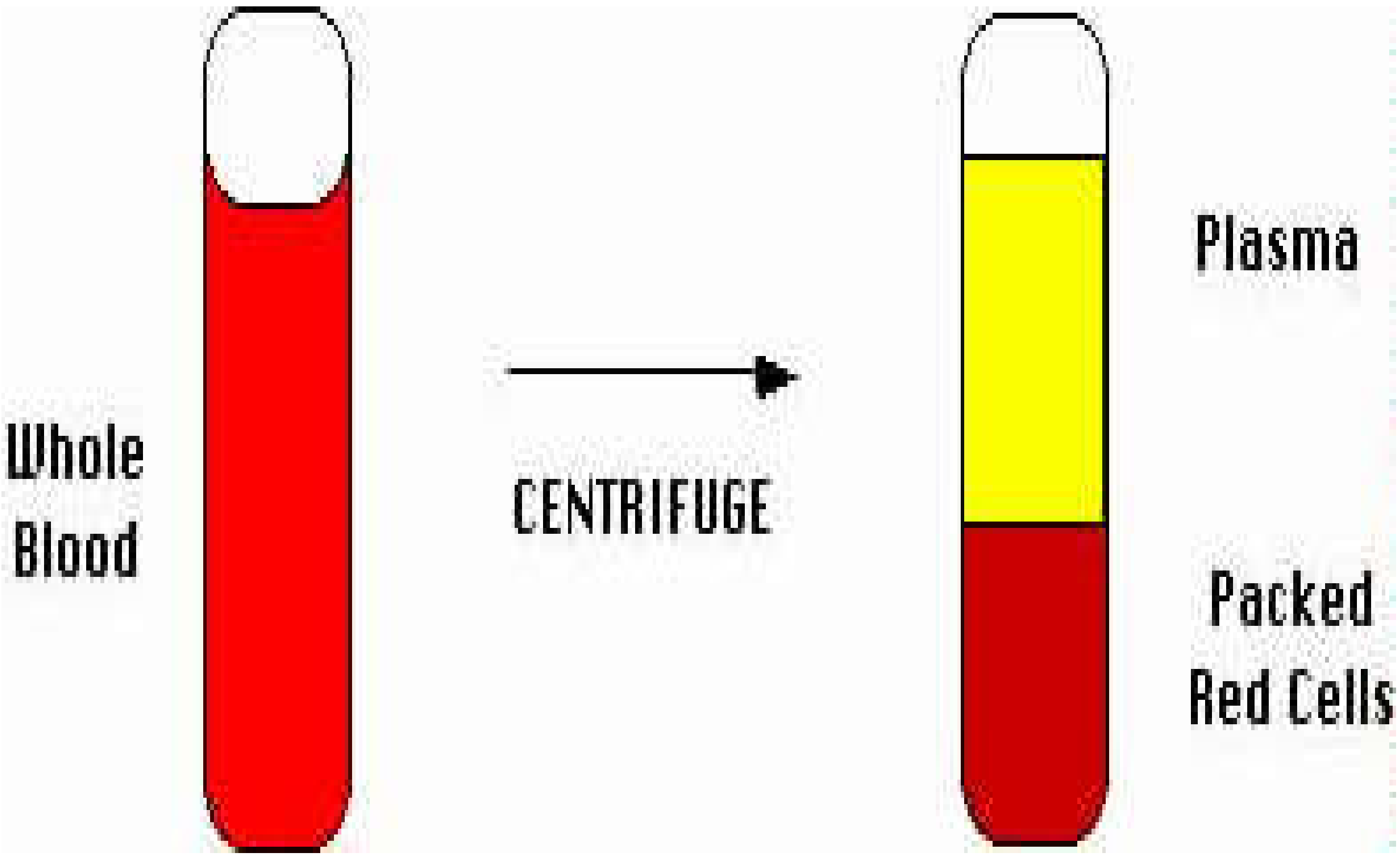
3 Nutrients - glucose, amino acids, lipids & vitamins

4 Waste products - e.g., nitrogenous wastes like urea

5 Dissolved gases - oxygen & carbon dioxide

6. Hormones

BLOOD



Muscle Tissue

Muscular Tissue

- Embryological origion- mostly mesodermal except some parts as muscle of iris (ectodermal)
- myoepithelial cell (basket cell).

Function

- generates physical force needed to make body structures to move
- maintains posture
- generates heat

Important Terminology

- **muscle cell/ muscle fiber/ myocytes).**
- Cell membrane/plasmalema/sarcolema
- Cytoplasm /sarcoplasm- contains typical organelles, contractile elements and elongated m/s fibers and enclosed by fine reticular fibers.
- Within each sarcoplams of muscle fibers the principal contractile structures are **myofilaments**, which form band or striations become organized in skeletal and cardiac and therefore striated.
- Endoplamic reticulum/sarcoplamic reticulum

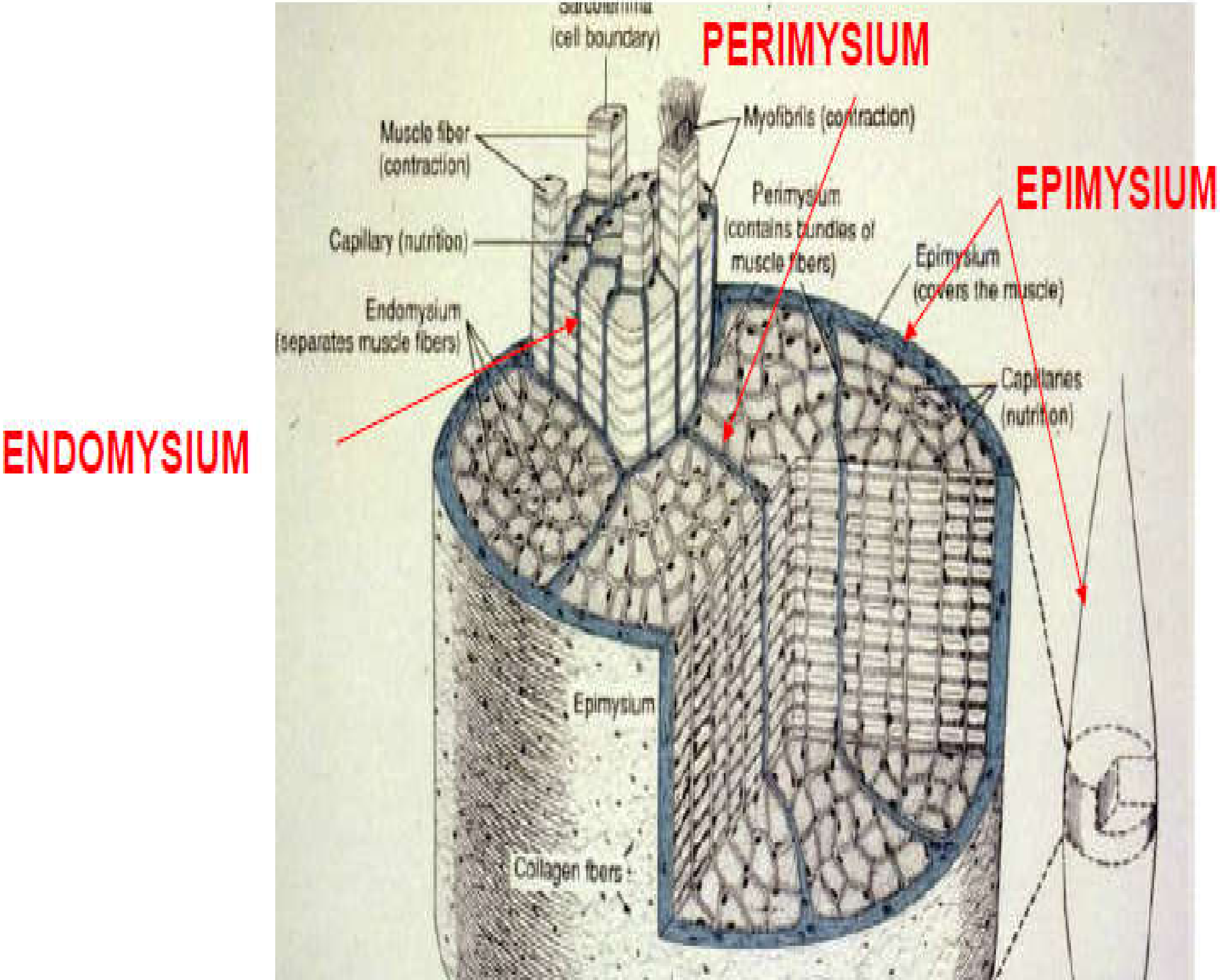
Mitochondoria/sarcosomes

Function- locomotion

- Expression of secretion from glands
- Blood mov't
- Mv't of materials through the digestive system

what are Connective tissue elements surrounding muscle fibers?

- Individual muscle fibers are surrounded by a delicate layer of reticular fibers called the **endomysium**.
- Groups of fibres are bundled into fascicles by a thicker CT layer called the **perimysium**.
- The collection of fascicles that constitutes one muscle is surrounded by a sheath of dense CT called the **epimysium**, which continues into the tendon.
- Blood vessels and nerves are found in the CT associated with muscle.
- The endomysium contains only capillaries and the finest neuronal branches.



(cell boundary)
PERIMYSIUM
Muscle fiber
(contraction)
Myofibrils (contraction)
EPIMYSIUM
Perimysium
(contains bundles of
muscle fibers)
Capillary (nutrition)
Epimysium
(covers the muscle)
Endomysium
(separates muscle fibers)
Capillaries
(nutrition)
ENDOMYSIUM
Epimysium
Collagen fibers

- **Functionally,** m/s may be voluntary or involuntary never attached to bones

- **Structurally,** it may be smooth / non striated/ or striated
  - Smooth m/s - non straighted, involuntary
  - Skeletal m/s - straighted, voluntary
  - Cardiac- straighted, involuntary

Each of the **three** types of muscle tissue are distinguished from one another by

- Shape and size of muscle fiber
- Number and location of nuclei
- Organization of contractile elements
- Type of innervations

Skeletal muscle

- Skeletal muscle is composed of long bundles of parallel **muscle fibers.** Individual muscle fibers are oriented in *unbranched,* parallel array and are separated from one another by loose CT and collected together and form **muscle fascicles**.

- The cell is **multinucleated** with peripheral position to the sarcolema. Within each muscle fiber the sacoplams, cylinder like structures are arranged in that extend manner throughout the entire length of the cell and are called **myofibrils**.

- Most other organelles of the cell, such as mitochondria, smooth endoplasmic reticulum are located b/n adjacent myofibrils. The sarcoplasm also contains an abundance of glycogen which stores energy as red pigment (**myoglobin)**.

- Each myofibril is a bundle of parallel protein microfilaments called **myofilaments**. There are Thick, Thin and Elastic myofilaments.

- The collection of myofibrils gives rise to striation when seen under light microscope. The striations are due to the highly arranged myofilaments of **actin** and **myosin** for unit of muscular contraction in the myofibrils so individual striations viewed as single entities.

- Cross striations, or, are oriented perpendicularly to the long axis of the muscle fiber.

- Under light microscope the striations have been designated as bands (dark and light bands).
- The most intensively stained band is called **A or Anisotropic band.**
- Within each A band, there is a zone which is stains lighter than the A bane is known as **H band.**

- **I or isotropic band** is lighter region, which is dissected by Z-line or disk.
- The region between two Z lines is called **Sarcomere,** the smallest repeating unit in the myofibrils.
- Each musle fiber is a surrounded by basal lamina and associated with reticular fibers that acollectively comprise the **endomysium**

The A, I and Z (thinnest)

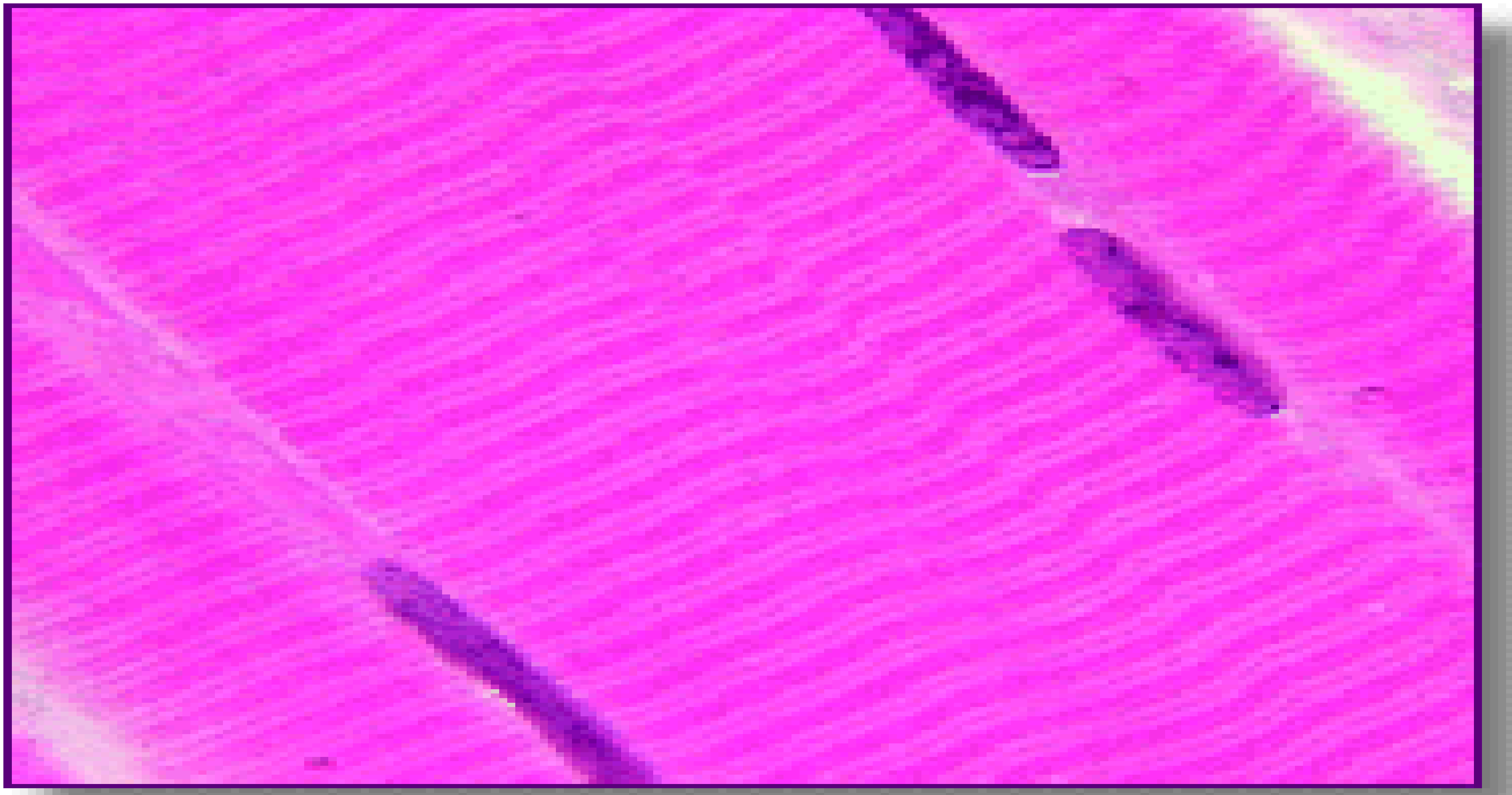
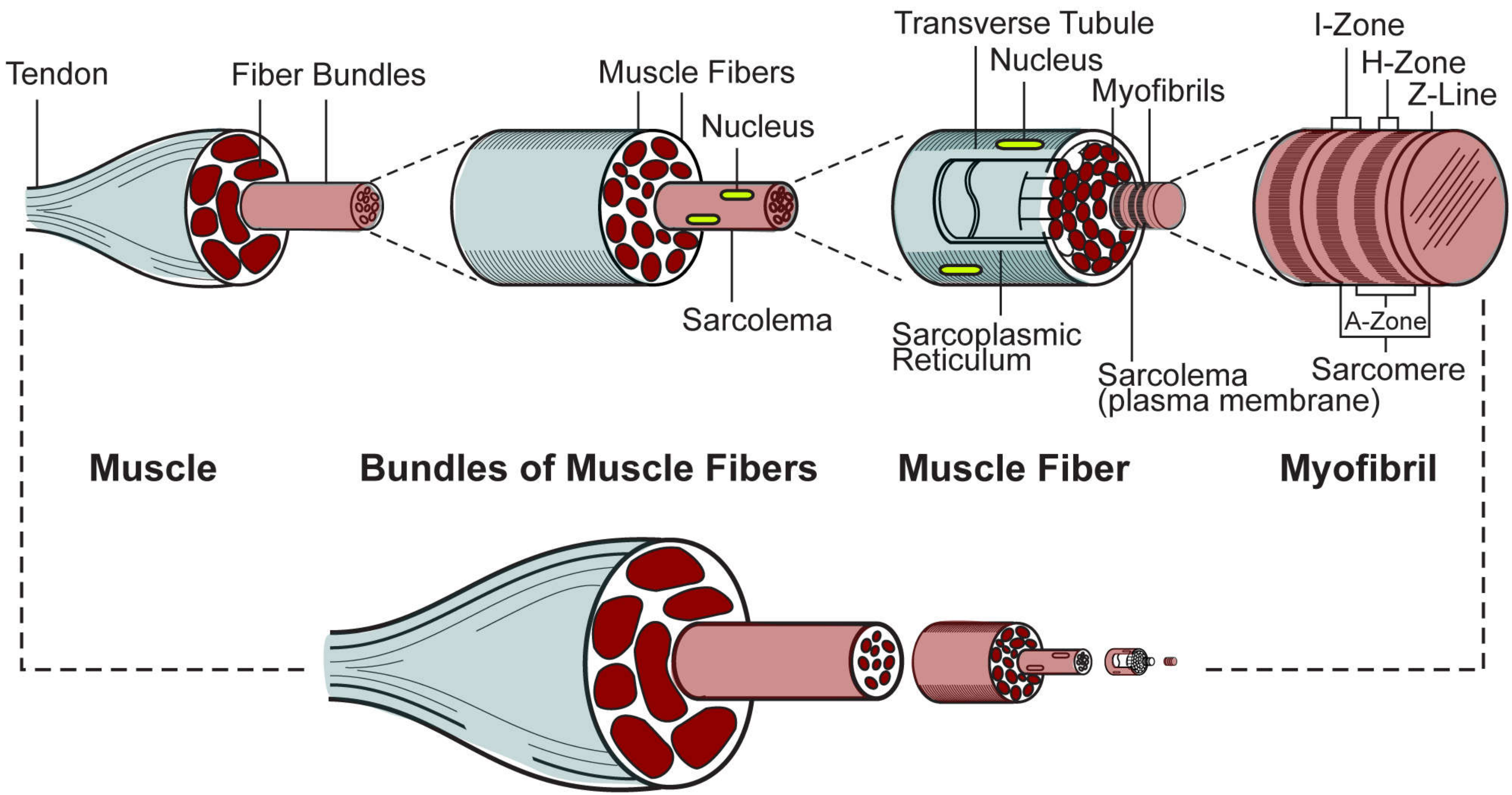
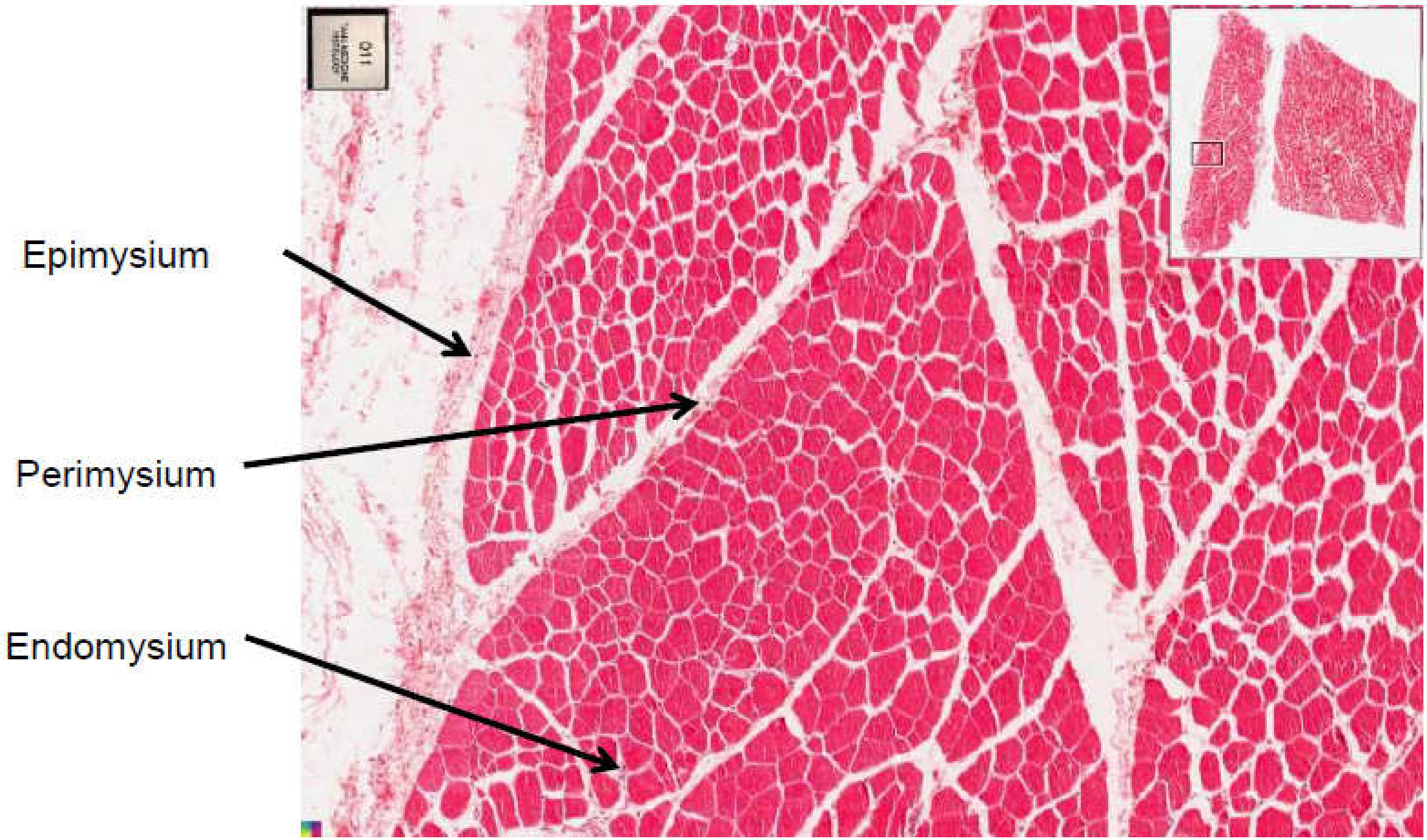


Figure 1

Structure of Skeletal Muscle



Skeletal Muscles (longitudinal section)



Cardiac Muscle

- It constitutes most of the heart. Cardiac m/s striated like skeletal m/s but myocytes are shorter and thicker, they branch like a "Y" and each myocyte is linked to several others at its ends.

- The linkage, called **intercalated discs,** appear as thick dark lines in stained tissue sections separiating each muscle fibers. One to two centrally located nucleus within the sarcoplasm.

- An intercalated disc has electrical gap junctions that allow each myocyte to directly stimulate its neighbors, and mechanical junctions that keep the myocytes from pulling apart when the heart contracts (appear dark transerve lines.

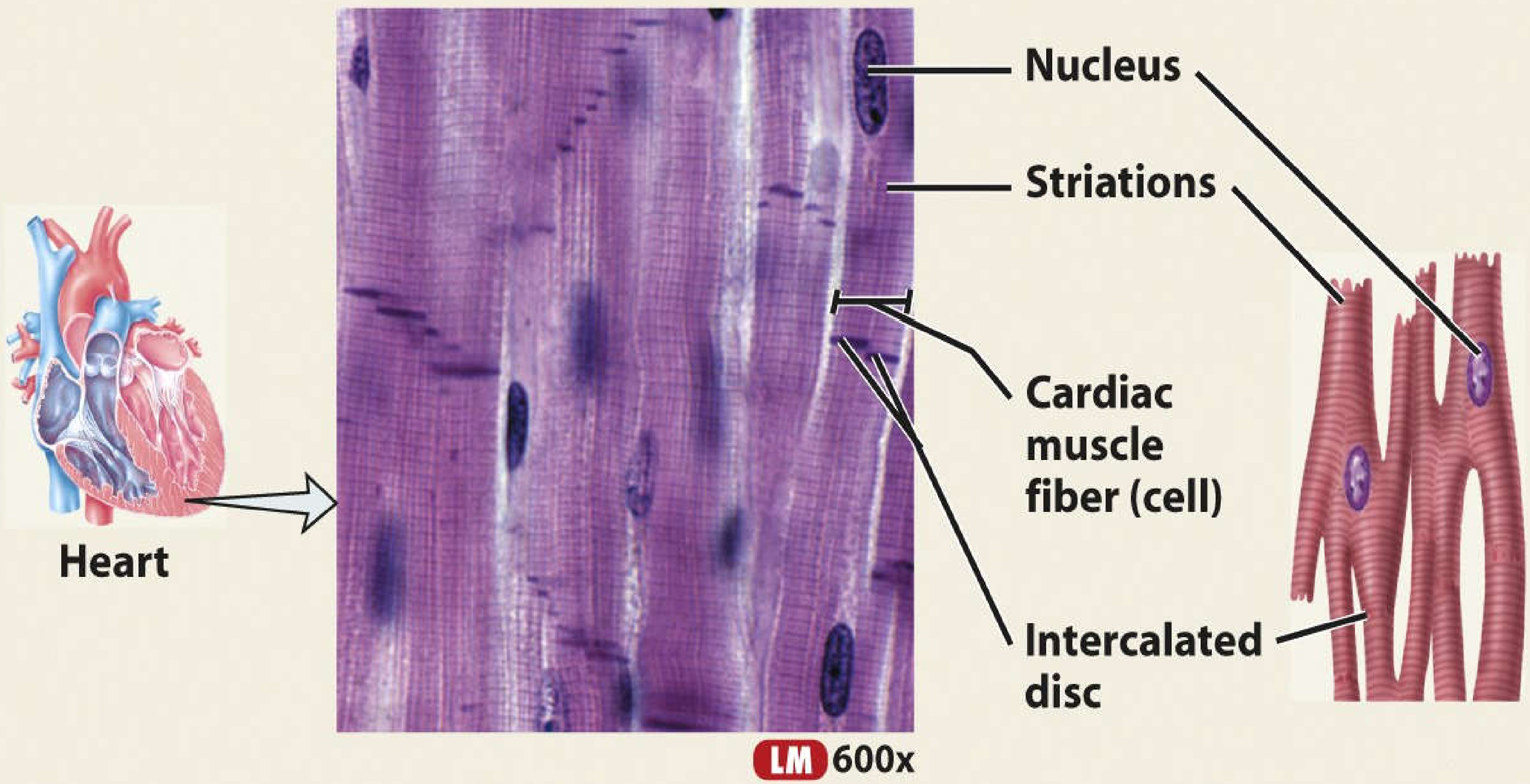
Table 4.3 Muscle Tissues

B. Cardiac Muscle Tissue

Description: Branched striated fibers with one or two centrally located nuclei; contains intercalated discs; involuntary control.

Location: Heart wall.

Function: Pumps blood to all parts of the body.



Longitudinal section of cardiac muscle tissue

Cardiac muscle fibers

Smooth muscle

- Lacks striations and involuntary spindle shaped.
- Smooth m/s cells are fusiform thick in the middle and tapered at the ends) and relatively short.
- Have only one, centrally place nucleus.
- Although thick and thin filaments are both present they aren’t aligned each other and produce no visible striations or sarcomers.
- Z discs are absent; instead, the thin filaments are attached by way of the cytoskeleton to dense bodies (little masses of protein scattered throughout the sarcomplasm and on the inner face of sarcolemma)

- Unlike skeletal & cardiac m/s smooth m/s is capable of mitosis and hyperplasia of the tissue and organs like pregnant uterus can grow by adding more myocytes and injured smooth m/s regenerates well.

- Smooth muscles are located in different parts of the body like
  - Small amount Iris,
  - in the skin,
  - most of it is called visceral m/s,
  - forms layers in the walls of digestive, respiratory and urinary tract, blood vessels, uterus.

- Smooth muscle is involuntary in action and innervated by both sympathetic and parasymphathetic nerves of autonomous nervous system.

Table 4.3 Muscle Tissues

C. Smooth Muscle Tissue

Description: Spindle-shaped (thickest in middle and tapering at both ends), nonstriated fibers with one centrally located nucleus; involuntary control.

Location: Iris of the eyes and walls of hollow internal structures such as blood vessels, airways to the lungs, stomach, intestines, gallbladder, urinary bladder, and uterus.

Functions: Constriction of blood vessels and airways, propulsion of foods through gastrointestinal tract, contraction of urinary bladder and gallbladder.

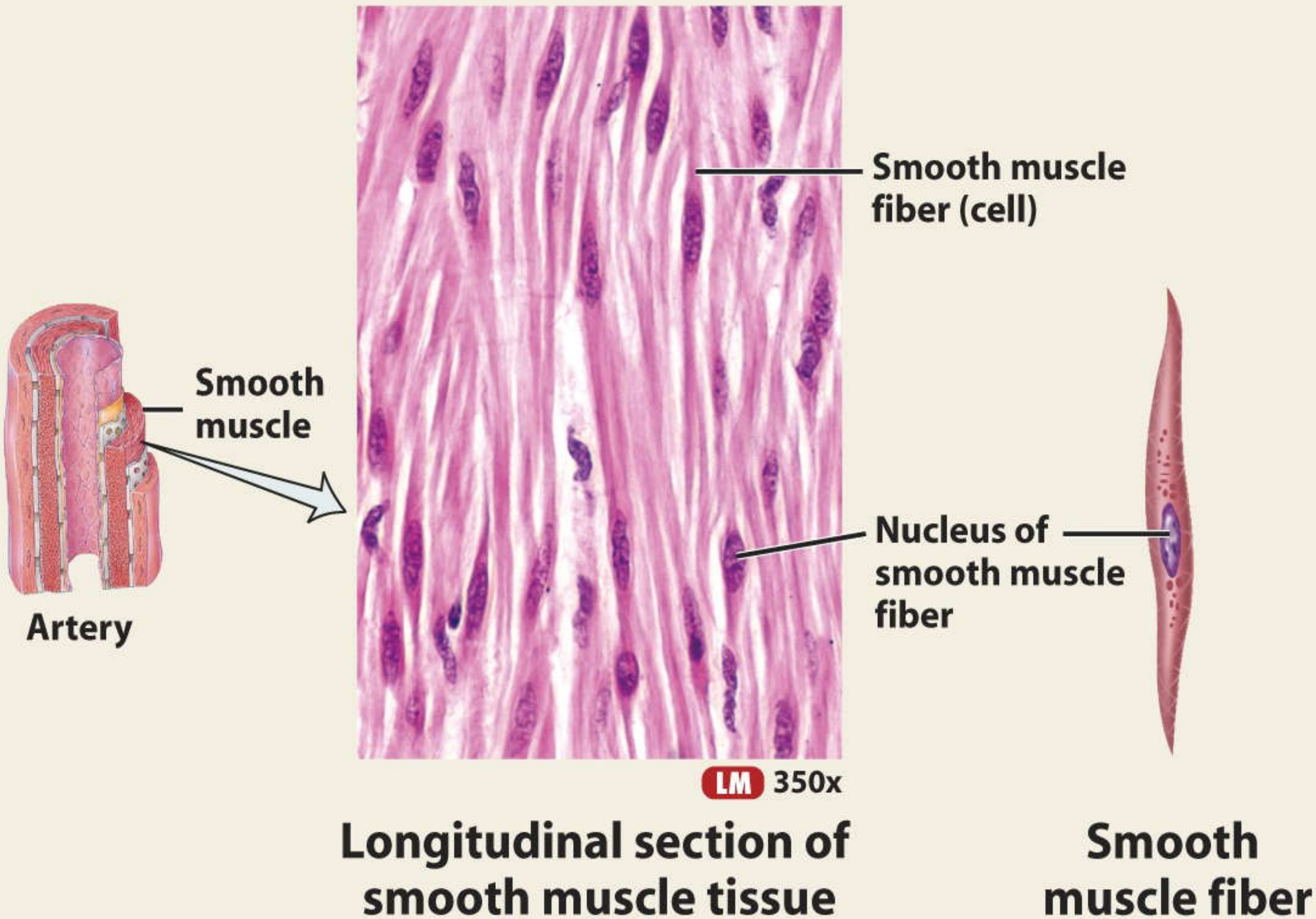


Table 4-3 part 3 Anatomy and Physiology: From Science to Life

Muscle Tissue

- Muscle cells specialized for contraction with apparatus of actin and myosin proteins.
- 3 types:

Skeletal Muscle	Smooth Muscle	Cardiac Muscle
Longitudinal sections - Peripheral nuclei - Striations - No branching	Longitudinal sections - Central nuclei (often fusiform) - Meshwork appearance of cells - No striations	Longitudinal sections - Central nuclei (often elongated) - Striations - Branching cells - Intercalated discs
Cross section - Peripheral nuclei - Massive cytoplasm	Cross section - Central nuclei - Low cytoplasm to nucleus ratio	Cross section - Central nuclei - High cytoplasm to nucleus ratio

The nervous tissue

Nervous Tissue

The nervous system is derived from embryonic neuroctoderm

Divided in to:

- **Central NS:** brain and spinal cord
- **peripheral NS:** spinal and cranial nerves including associated nerve roots and ganglia

Central nervous system (CNS)

- It consists of the brain and spinal cord. The nerve cell bodies (perikarya) of the CNS are found in group (“nuclei”). Brain consists of the brain stem, cerebelium, and a cerebrum. When CNS is sliced one can identify white matter and grey matter.

- **White matter** lacks perikarya, but has many processes of neurons. The white appearance is the result of the myelin that envelops many of the neuronal process. The neuroglia are also found in the white matter and the nuclei seen in white matter belong to the neuroglia.

- ***Gray matter*** contains perikarya, neuroglia and complicated network of process (axons, telodendrites, and glial process). Gray matter in the cerebrum and cerebellum is called cortex.

A. The Brain

- ✓ The brain is made up of numerous distinct regions
- ✓ including the cerebral cortex, cerebellum,, hypothalamus and brainstem.
- ✓ It has virtually no connective tissue, and is a relatively soft, gel-like organ.
- ✓ An important histological difference between the brain and spinal cord is the distribution of gray and white matter.
- ✓ In brain, *gray* matter surrounds *white* matter (in contrast to spinal cord).

conti

- ✓ The brain is a complex structure containing laminated (layered) as well as non-laminated structures.
- ✓ The *cerebral cortex* and the *cerebellum* are laminated structure.
- ✓ 1.***cerebral cortex*** is a highly folded structure with different laminated regions sub serving different roles.
- ✓ the final integration of sensory (vision, auditory, smell etc.) information, learning, memory etc. and the initiation of voluntary motor responses.
- ✓ 2.The ***cerebellum*** is also a folded and laminated structure.
- It plays a critical role in the control of movements

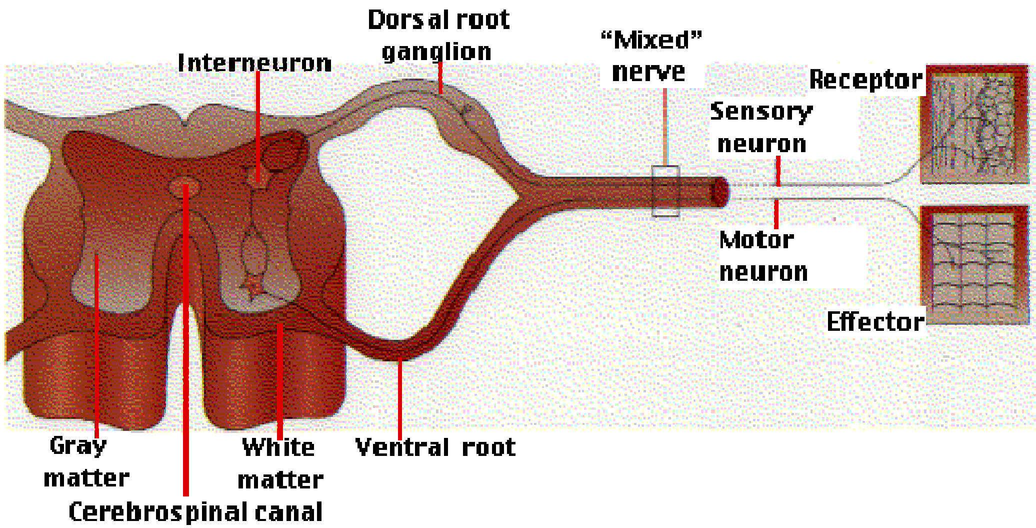
B. Spinal cord

- Spinal cord can be divided into segments based on the location transverse section of the spinal cord reveal a central canal surrounded by H-shaped profile of gray matter.

- Spinal cord bilaterally divided by ventral median fissure and dorsal median septum spinal gray matter may be divided into nucle which generally aren’t distinct.

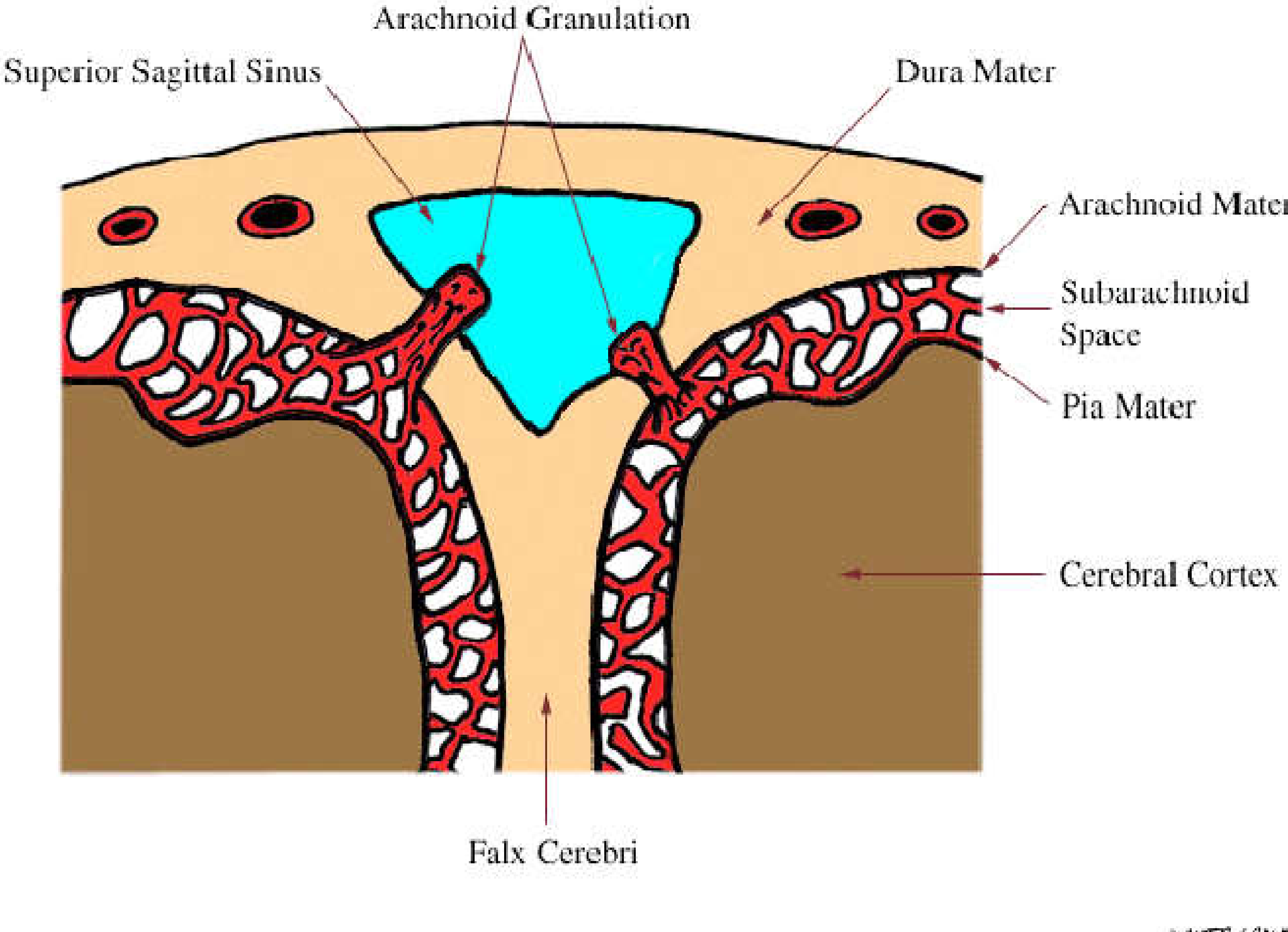
- Nerves existing in the spinal cord (efferent nerves) located ventrally whereas afferent nerves

Butterfly shaped spinal cord



- The connective tissue lining the central nervous system internal to the skull and vertebral columns is called **meninges**. Meninges consists o f three fibrous layers
    - **Duramatter**- the outer most layer. Two layers:
- Periosteal dura – external layer which is continuous with periosteum of the skull bones
- Meningial dura – internal thick layer of dense ct with fibroblasts
- Within the vertebral column the dura matter is separated from the periosteum of the vertebrae by an **epidural space**, which is composed of network of blood vessels.
    - **arrachinoid** –comprises an external membrane of connective tissue and direct contact with dura matter and trabeculae extending to pia matter
- **subdural space-** loosely arranged interface between duramatter and arachnoid which is site of fluid space such as blood during injury.

THE MENINGES



Cerebrospinal fluid

- It is a clear watery fluid resembles plasma but, less protein
- Produced by discrete vascular beds known as **chorid plexi** within the ventricles of the brain

Blood brain barrier is selective barrier made up of endothelial cells forming tight junction between the blood vessels/ capillaries and the cerebrospinal fluid. Different carrier proteins facilitate the transport of molecules

Peripheral Nervous System (PNS)

- It consists of cranial and spinal nerves including all **roots, distal branches, and ganglia.** A nerve is a bundle of nerve fibers wrapped in fibrous connective tissue.

- Individual fibers are surrounded by a thin CT layer known as **Endoneurium.**

- Fibers are grouped in bundles (fasciled), which are also surrounded by a CT called **perineurium.** The multiple fascicles of a nerve are bound

- Ganglia are groups of nerve cell bodies (perikarya) outside CNS.

- Ganglia serve as relay stations to transmit nerve impulses; one nerve enters and another exits from each ganglion.

Cells of nervous tissue

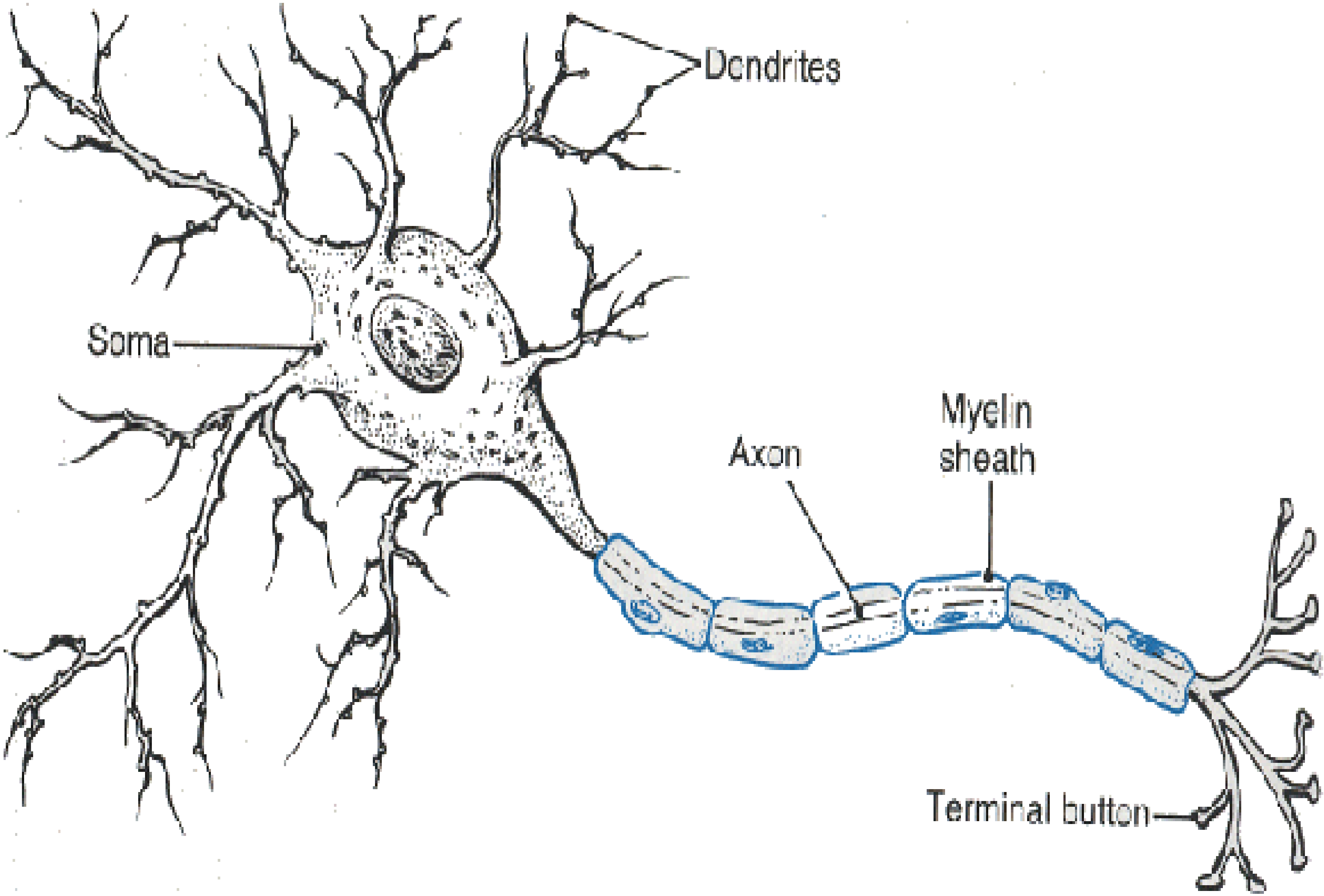
- Neuron (nerve cell)
  - receive or transmit impulses
  - interconnections (at least 1000 each)
- Neuroglia (supporting cells)
- more numerous than neurons
- support neurons in various ways

Neuron (nerve cell)

- A neuron has distinct regions depending on its specific function of the part:
- **Dendritic zone:** a zone that consists of Cell body (perikaryon), which nurture the cell, and the dendrites, where excitation is initially received. The zone feature a large surface area produced by highly branched processes called dendrites (dendr = tree, ite= little)

- **Axon:** which conducts excitation between dendritic and telodendritic zones and it is an elongated cylinder with few branches

- **Telodendritic zone** (axon's terminations): where excitation is transmitted to another cell. It is also branched has localized expansions (terminal bulbs) for storage and release of transmitter molecules


Dendrites
Soma
Axon
Myelin sheath
Terminal button

Cell body

- The control center of the neuron is its some (cell body/ perikaryon)
- It has a single, centrally located nucleus with a large nucleolus
- The portion of the cell body that gives rise to the axon is called the axon hillock.

- The cytoplasm within the perikaryon, contains clusters of free ribosome and rough endoplasmic reticulum called **Nissl bodies,** mitochondria (synthesize neurotransmitters), lysosomes, a Golgi complex, and cytoskeleton that consist of dense mesh of microtubules and neurofiberlis).

- ***Dendrites***: Are highly branched processes of multipolar neurons, and the main trunk has organelle content similar of the cell body. Some neurons have numerous dendritic spines, which serve a synaptic function that bring stimuli from the environment to the body.
- **Axon** is typically a long cylindrical process with few, if any, branches along its course (collateral branches) and multiple terminal branches telodendriticzone (axon's teriminals). Cytologically dendritis are nearly similar to cell bodies having nissl bodies, mitochondria, neurofilaments, and neurotubules except Golgi apparatus.

- The axons originate from axon hillock of the cell body. The hillock is a conical region devoid of nissl substance, it feauters neurofilameus and grouped microtubules that proceed the axon. Axoplasma (cytoplasm of axon) contain mitochondria, SER, and actin filaments that form the subaxolemma network within the axolema (cell membrane of axon). Some axons are **myelinated**. Myelin begins distal to the initial segment and is arranged in a series of

- **Synapses** are specialized areas of contact between neurons where one neuron is able to influence the excitability of another neuron. Morphologically, a synapse involves a pre-synaptic element (Posses specific receptors for the transmission of impulse), synaptic cleft (contain filamentous protein mater at that binds together presynaptic and postsynaptic membrane) and post synaptic elements (characterized by increased plasmalemmal density). Synapse can be axo – dendritic, axo – somatic, axo – axonic. Dendro – dendritic

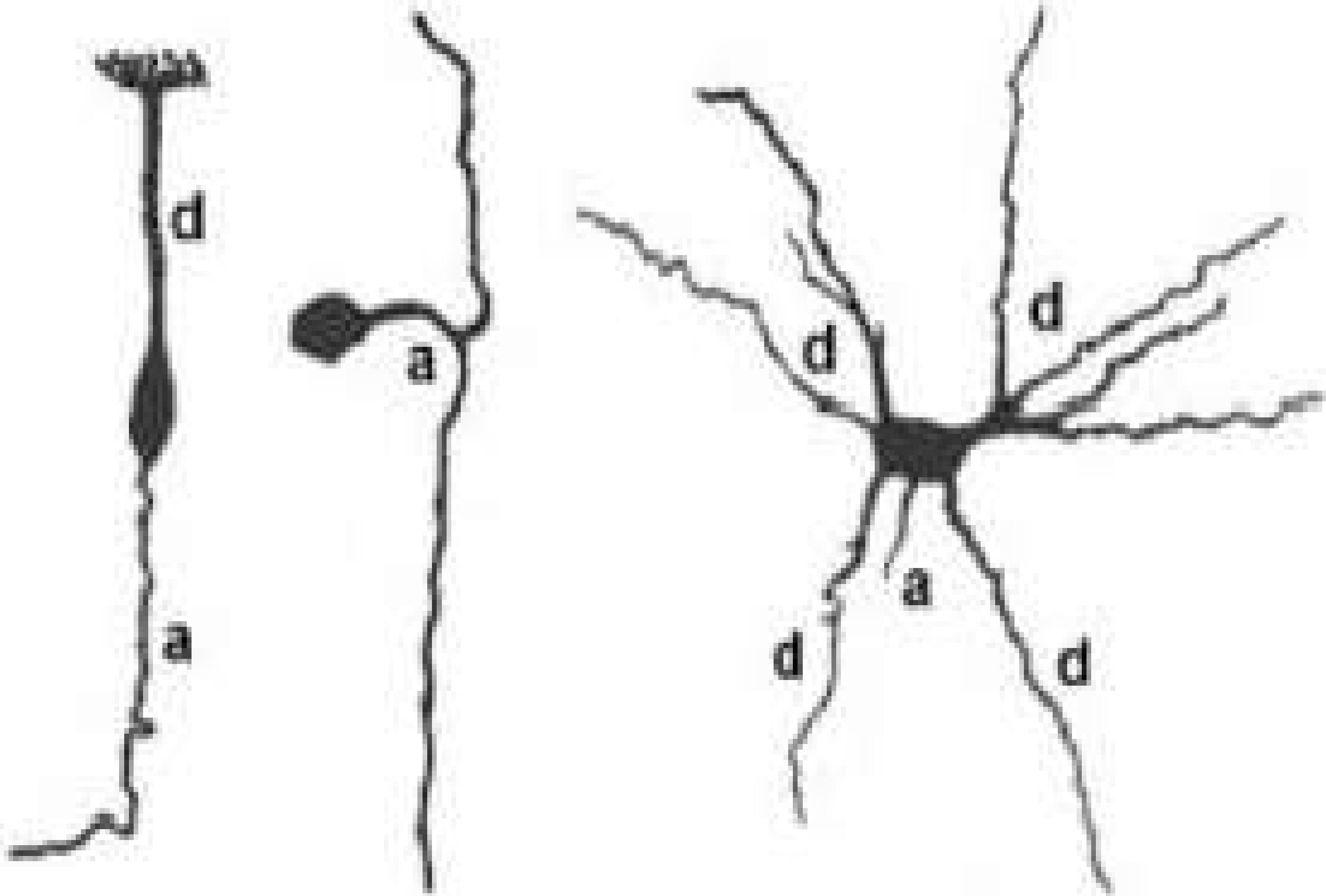
- **Neurotransimitors** consists of a variety of signaling moleculesthat can act directly receptor

Morphological classification of neurons

- Neurons can be classified according to the size, number and shape of their process. The following classification is based on the number of processes extending from the cellbodies as follows:
- **Unipolar** (pseudounipolar) neurons have a single process (axon)
  - They carry signal to the spinal cord
  - The neurons have cell bodies in spinal and cranial sensory ganglia,
- **Bipolar neurons:** Have two process (one dendrite and one axon)
  - These are very rare and have a limited distribution in the body. They are present in special sensory structures including the retina, olfactory epithelium, and vestibular and cochear nerves.
- **Multiple neurons:** Posses several processes (several dendrietes and a single axon). Nearly all the billion of neurons comprising the CNs are multipular neurosn can classified further into long axon (type I neuron) and these

According to the their function

- Sensory (afferent) neurons: convey impulses from receptors to CNS
- Motor (efferent) neurons: convey impulses from CNS or ganglia to muscles, glands and other cells
- Interneurons: located in CNS, establish networks of neuronal circuits (%99 of all neurons)



1 2 3 4

Neuroglial Cells

- Functions:
- – physical support for neurons
- – production of myelin
- – repair of neuronal injury
- – metabolic exchange between blood vessels and the neurons

Peripheral neuroglia	Central neuroglia
Schwann cells	Astrocytes
Satellite cells	Oligodendrocytes
Enteric neuroglia	Microglial cells
Müller's cells	Ependymal cells

Neuroglia

- There are 6 kinds of neuronglia, each with a unique function 4 occurs in CNS.
- **Oligo dendricytes (oligodendroglia):** The cells have processes that reach out to a nerve fiber and spirals around it. cell that mylinated axons and insulate the axon so that speeds up signal conduction.
- **Astrocytes (AStroglia):-** The largest neuroglia with long process may be branching & most abundant
- Cover the brain/ From supportive frame work
- Contribute to the blood brain barrier (participation)
- Nourish neurons (glucose – lactate)
- Form scars tissue to replace damaged nervous tissue
- **Ependyma cells:** resemble cuboidal epithelium that lines the internal cavities (ventricles) of the brain and spinal cord. Secrete and circulate CSF (have patches of cilia on their aplical surface).
- **Microglia:** are small macrophages that develop from monocytes
- Phagosize dead nervous tissues, microorganisms and other foreign materials
- **Schwan cells:** Envelop nerve fibers of PNS

Schwann cells

- Function:
- – Support myelinated and unmyelinated nerve fibers in the PNS
- – Produce the myelin sheath in the PNS – Aid in cleaning up the PNS debris
- – Guide the regrowth of PNS axons.

- Single Schwann cell myelinate only one axon
- Schwann cell can envelope several unmyelinated axons

Satellite cells

- Small cuboidal cells surrounding the neurons in the ganglia.
- Provide a controlled microenvironment around the neuron.

Astrocytes

Largest of the neuroglial cells

- Star-shaped cells with multiple processes
- Function; – provide structural and metabolic support for neurons
  – maintain the blood-brain barrier
- Contains bundles of intermediate filaments (glial fibrillary acidic protein)
- Exists as two types; – Protoplasmic astrocytes in the gray matter
  – Fibrous astrocytes in the white matter

Cont…

- **Protoplasmic Astrocytes**
- • Tips of some processes (vascular feet) come into contact with blood vessels (blood-brain barrier).
- • At the surface of brain and medulla spinalis, processes contact the piamater (subpial feet) to form the pia-glial membrane (glia limitans).
- **Fibrous Astrocytes**
- • Cells with relatively few, long and straight processes
- • Closely associated with blood vessels

Tissue Repair

ability to repair depends on

- ✓ extent of damage
- ✓ tissue type

epithelium

continuous capacity for renewal

connective

some have continuous capacity for renewal

others replenish less readily because of smaller blood supply

muscle

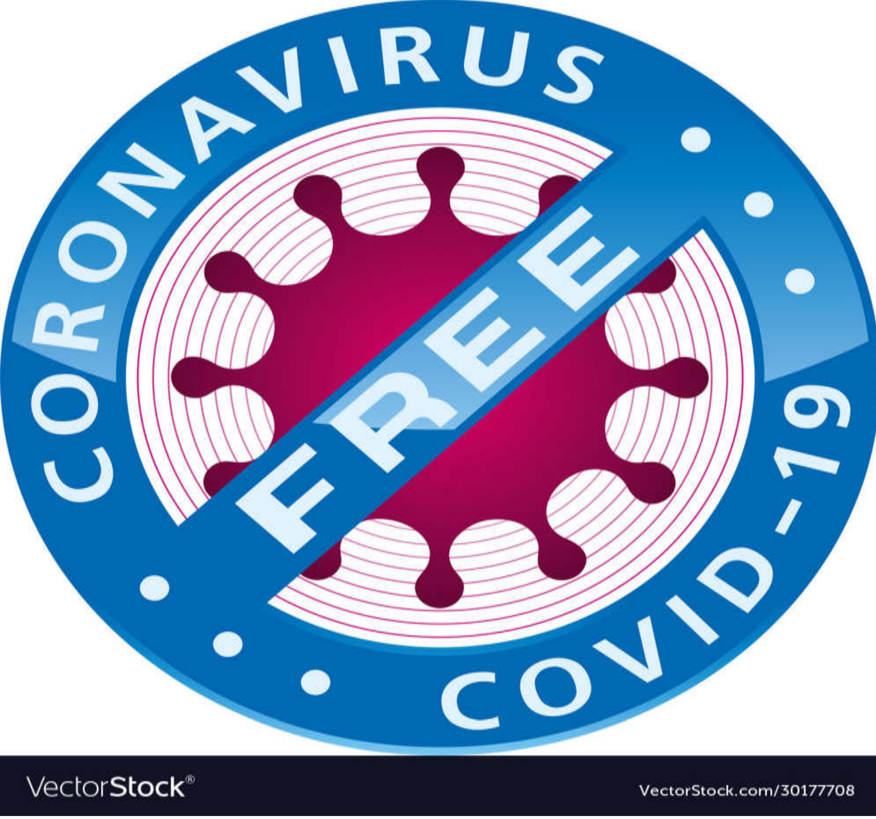
relatively poor capacity for renewal

nervous

poorest capacity for renewal

Tissue Repair

- New cells originate by cell division from
  - parenchyma (functioning part of tissue)
    - repair will be near-perfect reconstruction
  - stroma (supporting connective tissue)
    - repair will include new connective tissue and scar formation will occur
    - original function of tissue or organ is impaired
- tissue repair affected by
  - nutrition
  - blood circulation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