1. Introduction to Cells, Tissues, and Microscopy

VIBS 443 and VIBS 602

Undergraduate – Graduate
Histology Lecture Series

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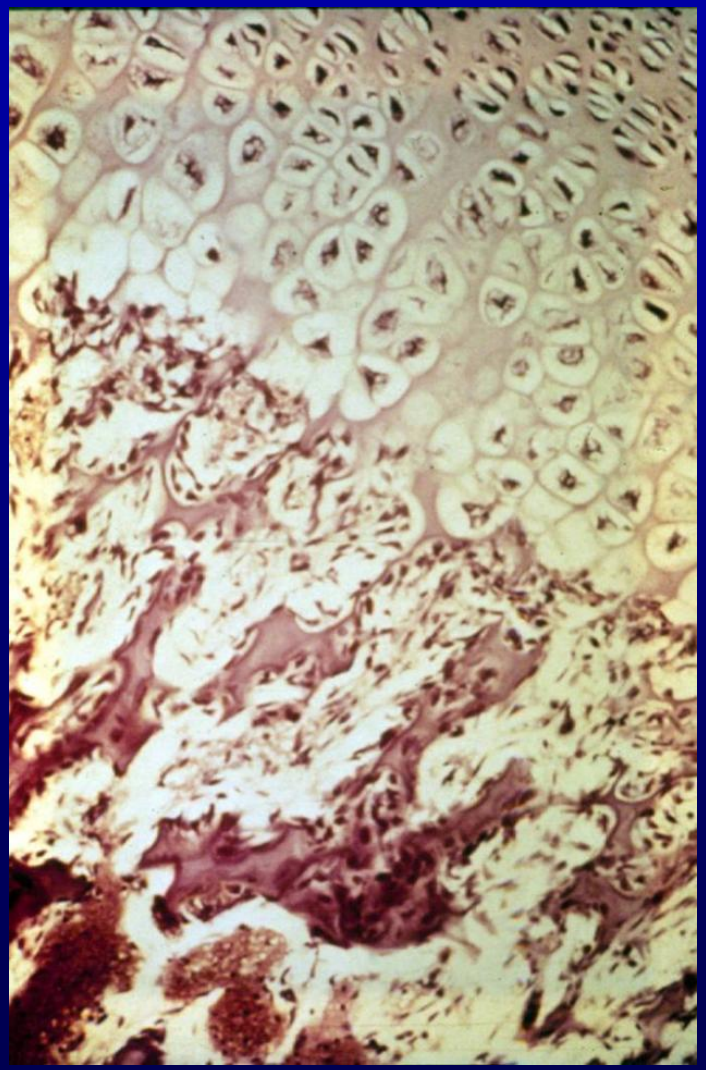


Figure 1–5. Photograph of the Zeiss model EM 10 electron microscope. (Courtesy of Carl Zeiss Co.)

OBJECTIVES

1. *Preview cellular ultrastructure*
2. *Preview cells, tissues, and organs*
3. *Overview of light and electron microscopy*
4. *Preparation of specimens – types of visions*
5. *Section orientation*

Introduction to HISTOLOGY

PROTOPLASM – Living Substance

CELL – Smallest unit of protoplasm

Simplest animals consist of a single cell.

TISSUE – Groups of cells with same general function and texture (texture = tissue)

e.g., muscle, nerve, connective tissue, epithelium

ORGAN – Two or more types of tissues; larger functional unit

e.g., skin, kidney, intestine, blood vessels

ORGAN SYSTEM - Several organs

e.g., respiratory, digestive, reproductive systems

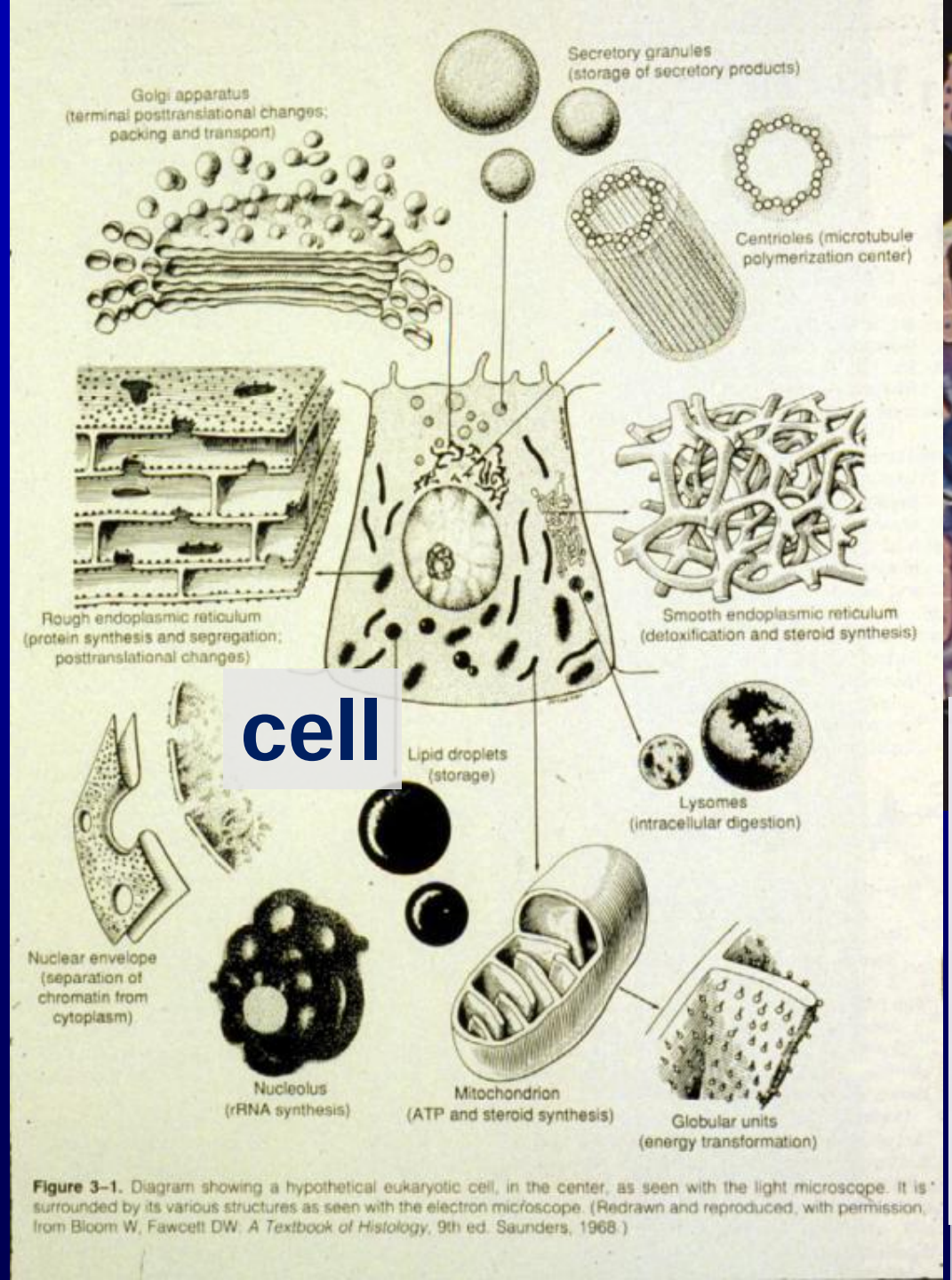
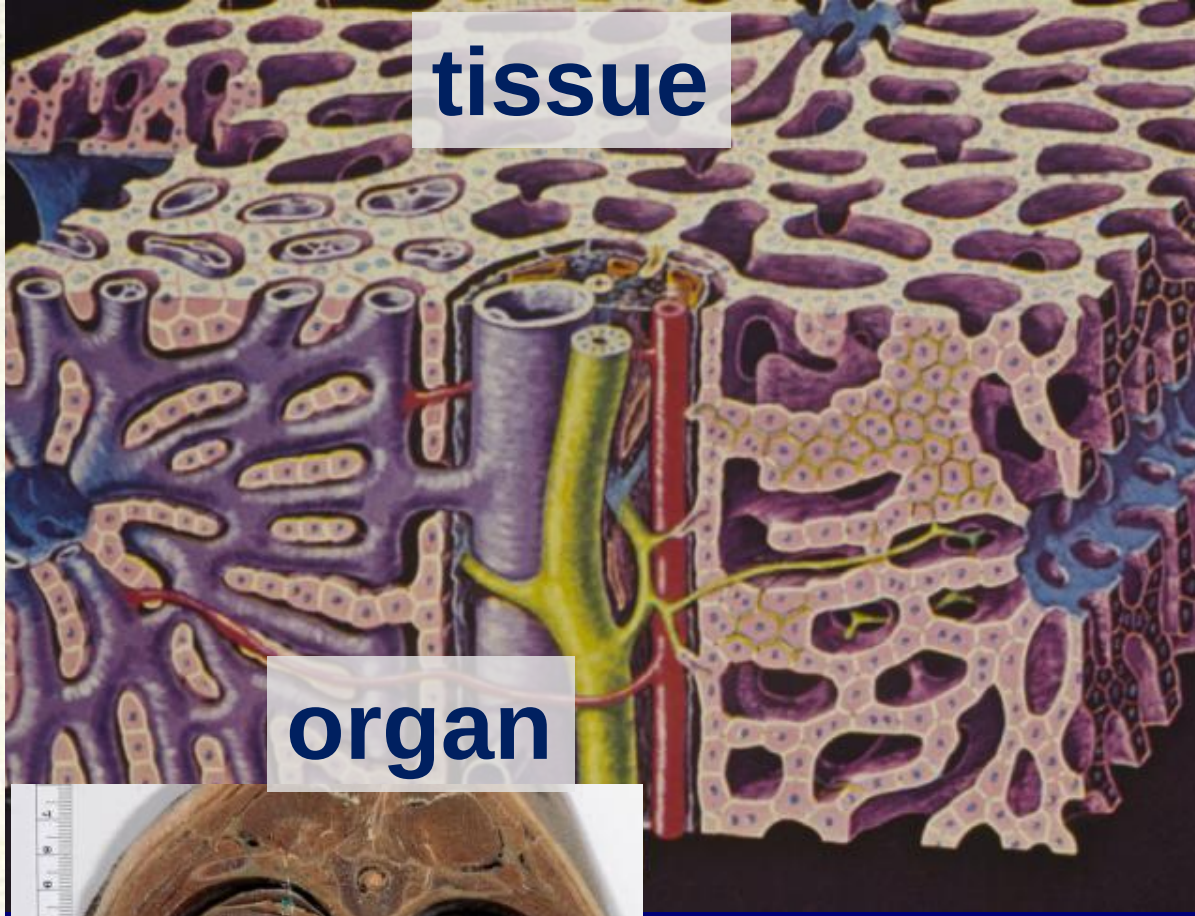


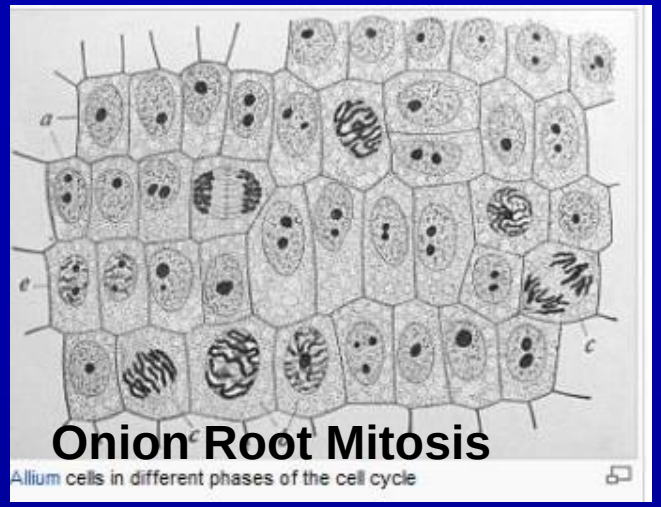
Figure 3–1. Diagram showing a hypothetical eukaryotic cell, in the center, as seen with the light microscope. It is surrounded by its various structures as seen with the electron microscope. (Redrawn and reproduced, with permission, from Bloom W, Fawcett DW: *A Textbook of Histology*, 9th ed. Saunders, 1968.)



tissue

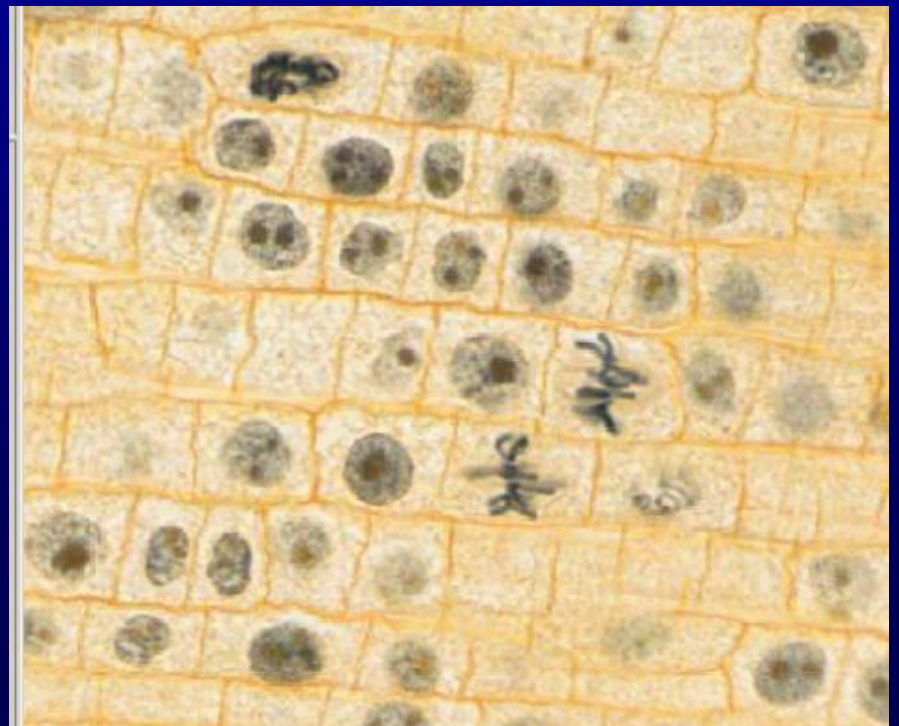
organ

organ system



In the 1660s, Robert Hooke looked through a primitive microscope at a thinly cut piece of cork. He saw a series of walled boxes that reminded him of the tiny rooms, or *cellula*, occupied by monks, and he coined the word "**cell**."

Cells in a → plant



Although animal cells do not have cell walls like plants, cells are the "building blocks of life" of both.

Cell Theory

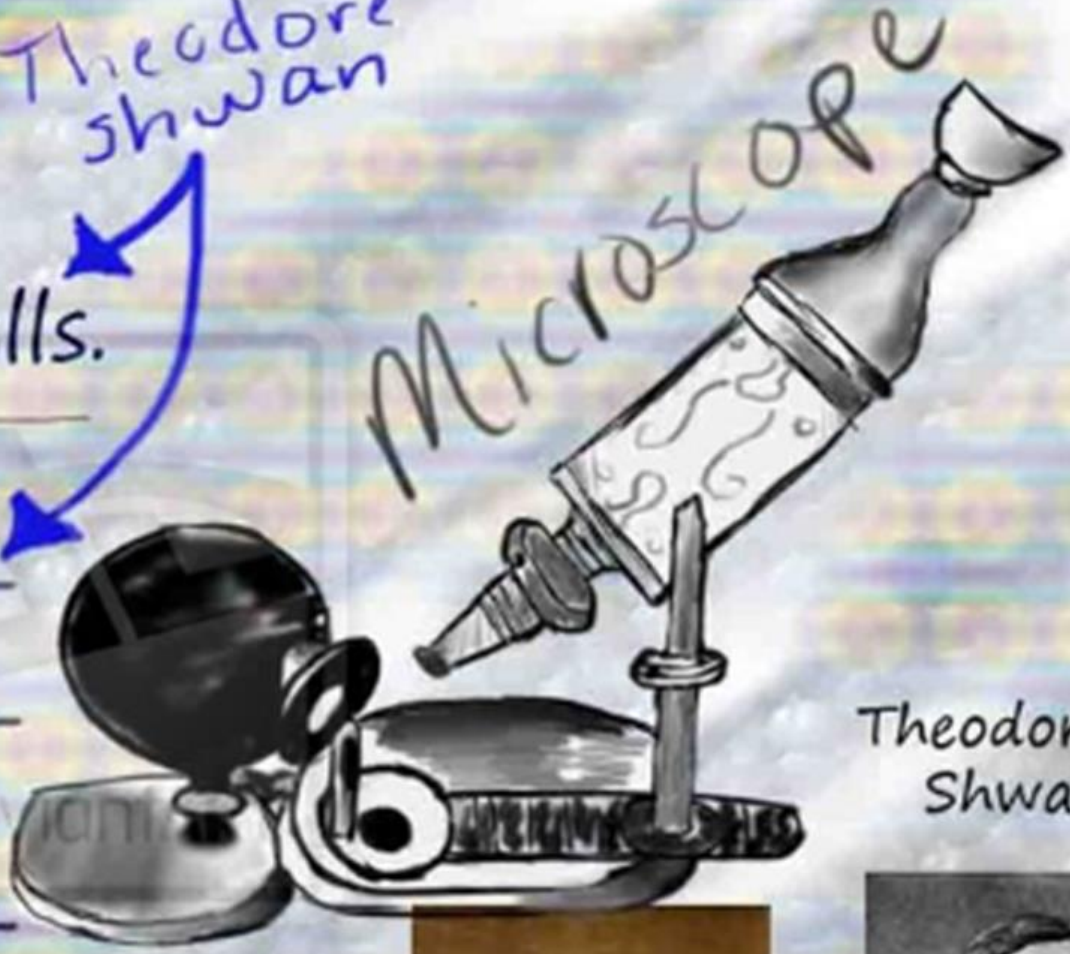
1. All organisms are made of 1 or more cells.

2. Cells are the basic building blocks of life.

3. All cells come from existing cells.

Theodore Shwan

Rudolf Virchow



Rudolf Virchow

Theodore Shwann

The Cell Theory

1. All living things are made up of one or more cells

2. Cells are the basic unit of structure and function

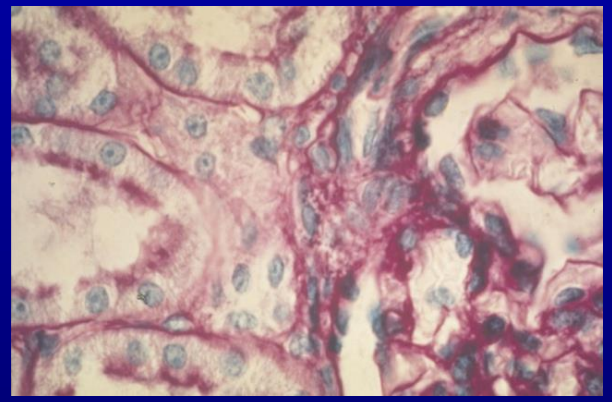
3. All cells come from pre-existing cells

4. Cells contain the hereditary information which is passed from cell to “daughter” cell during cell division

5. All cells are basically the same in chemical composition

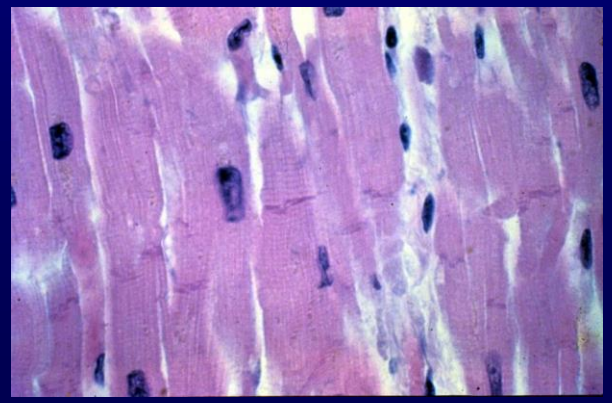
FOUR BASIC TYPES OF TISSUES IN THE BODY

Epithelium

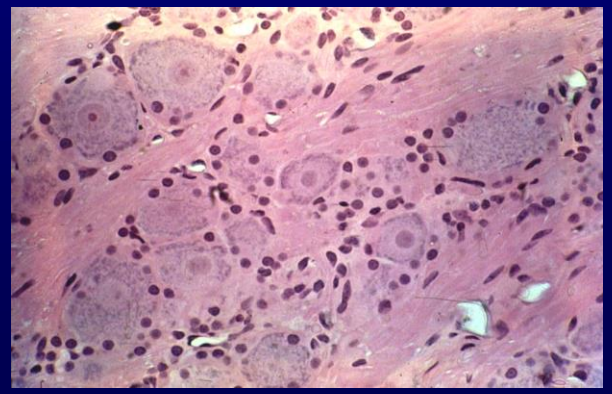


Connective tissue

Muscular tissue



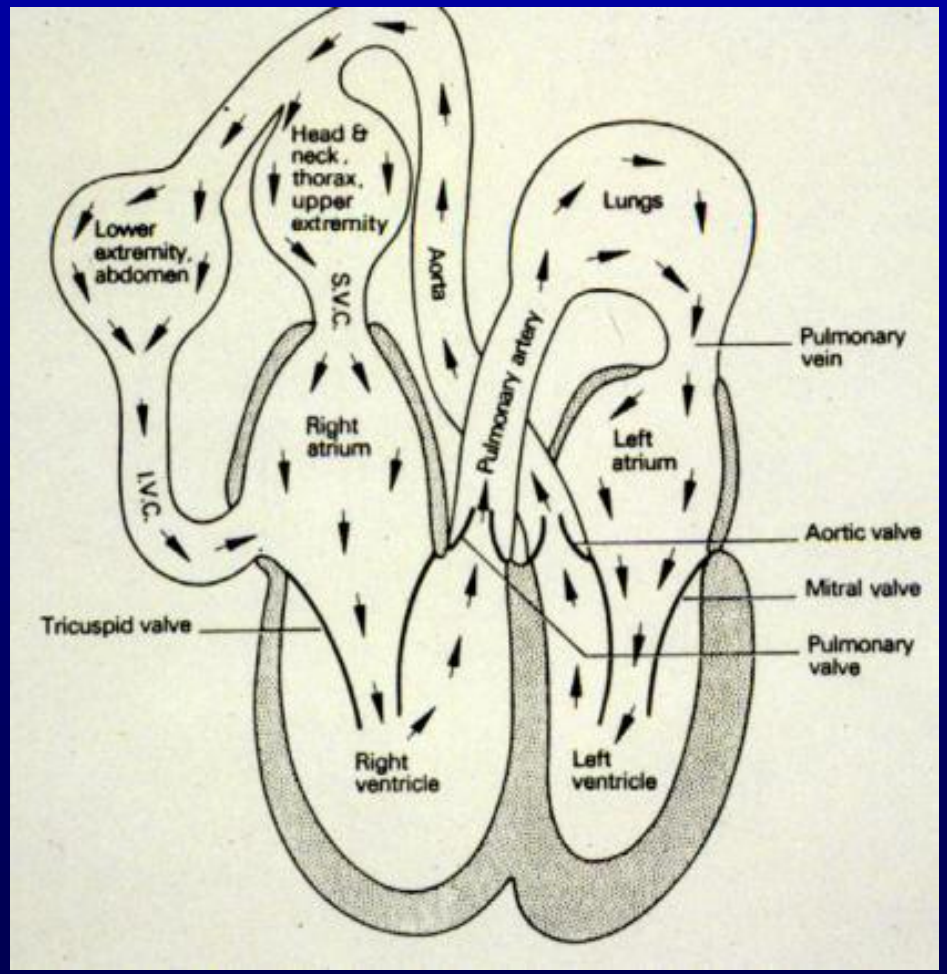
Nervous tissue

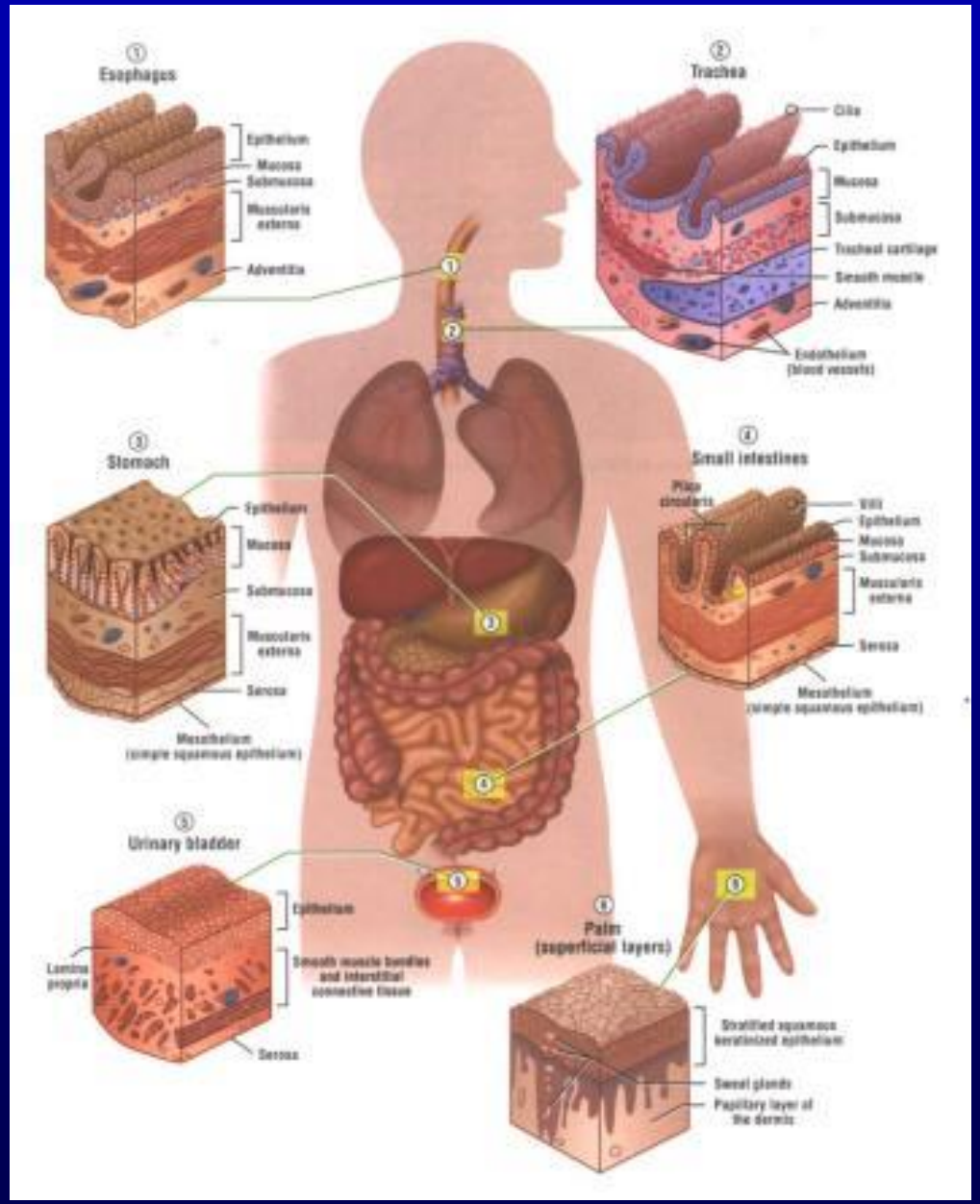


Epithelium

Functions:

Cover organs, line viscera and blood vessels, secretory cells of glands

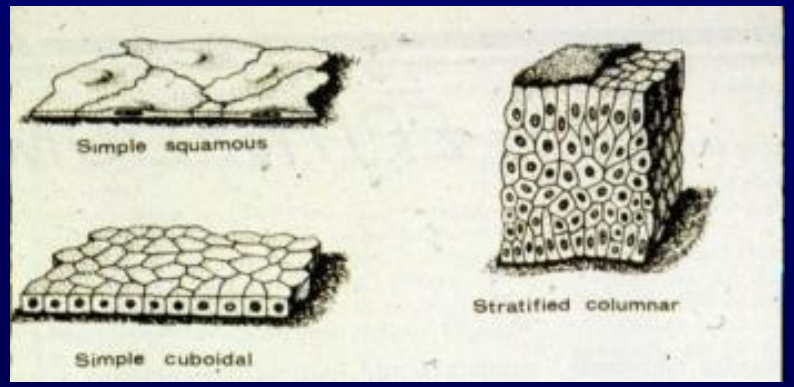


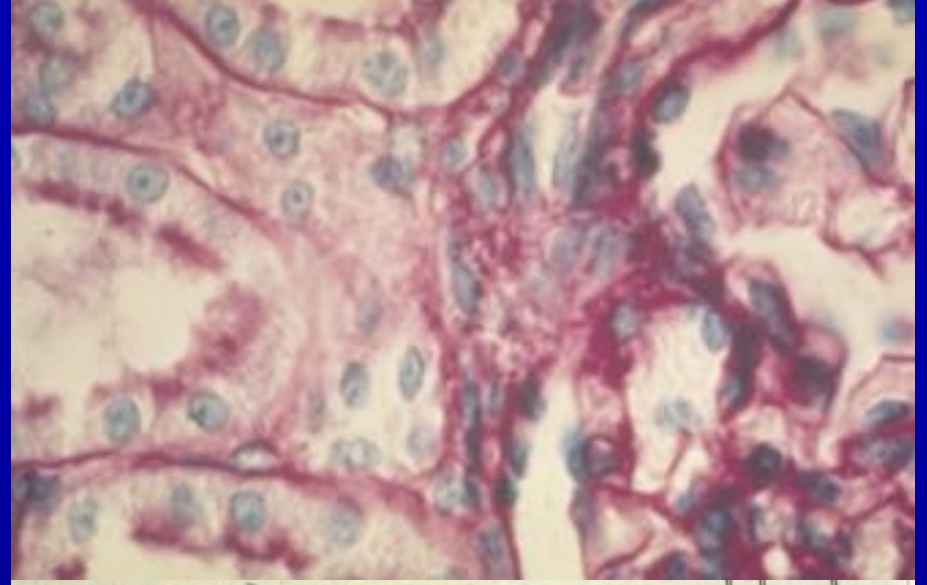


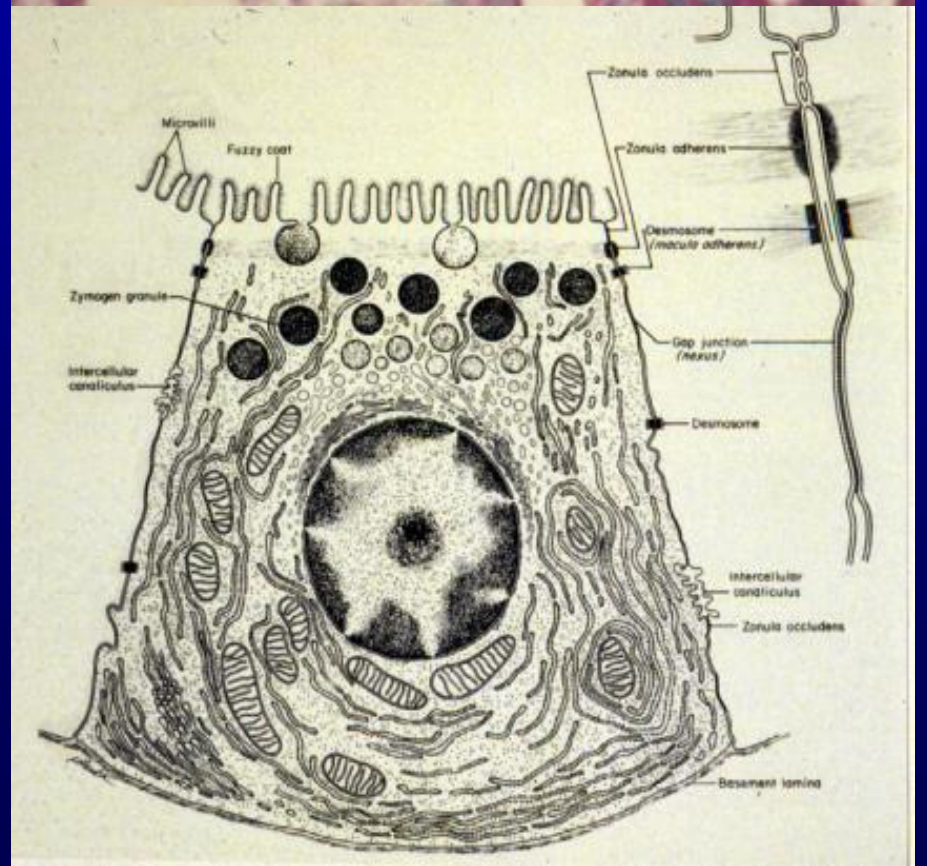
Epithelium

Distinguishing features and distribution:

- Always sit on a basement membrane, but come in a variety of configurations: classified on the basis of their shape and of the surface cells and whether one (simple) or more (stratified) layers of cells are stacked upon each other.
- These cells are always attached to their neighbors by desmosomes, tight junctions, and gap junctions.



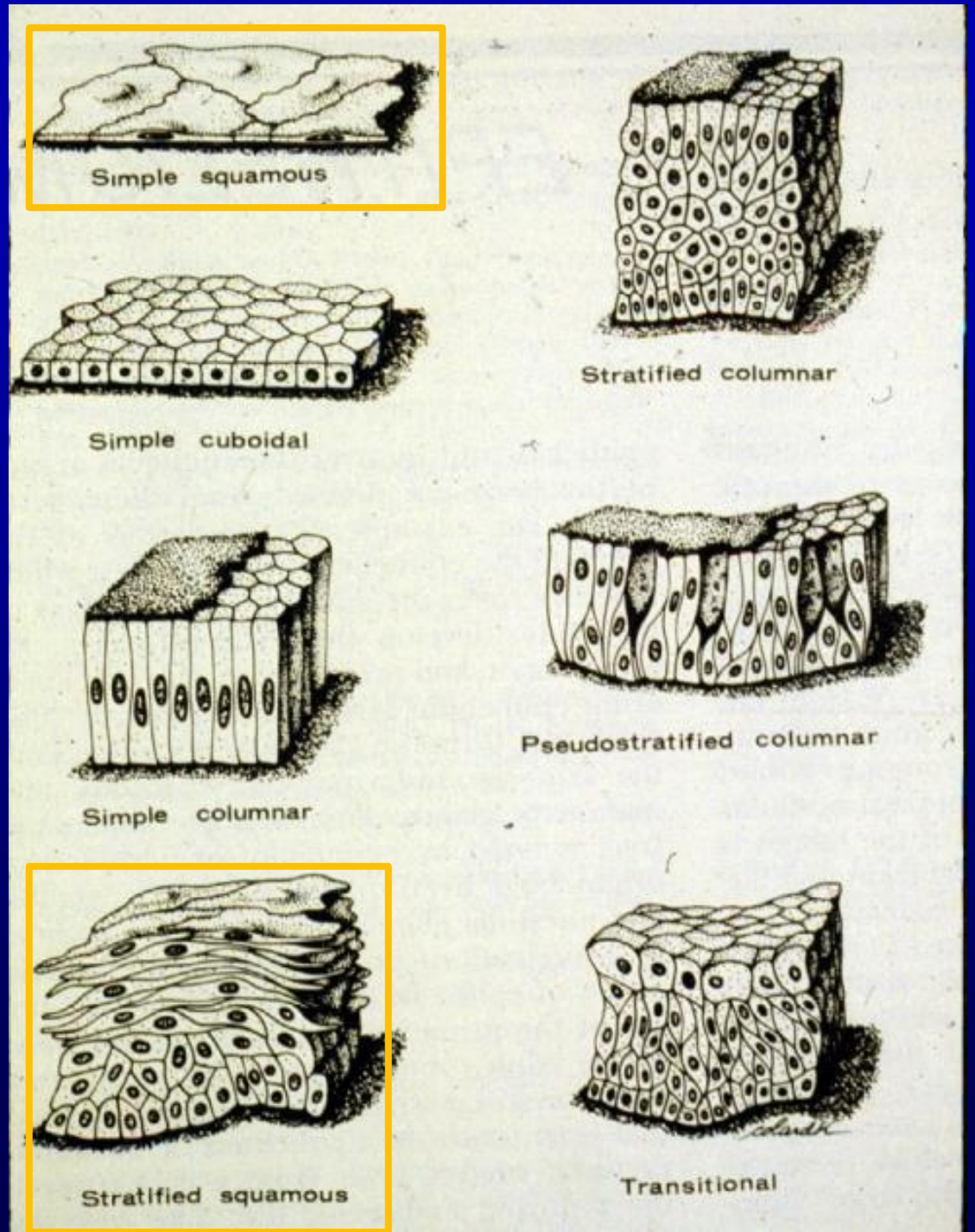




Epithelium
Histological Identification

Simple Squamous –
single layer of flat cells (blood vessels, covering of organs)

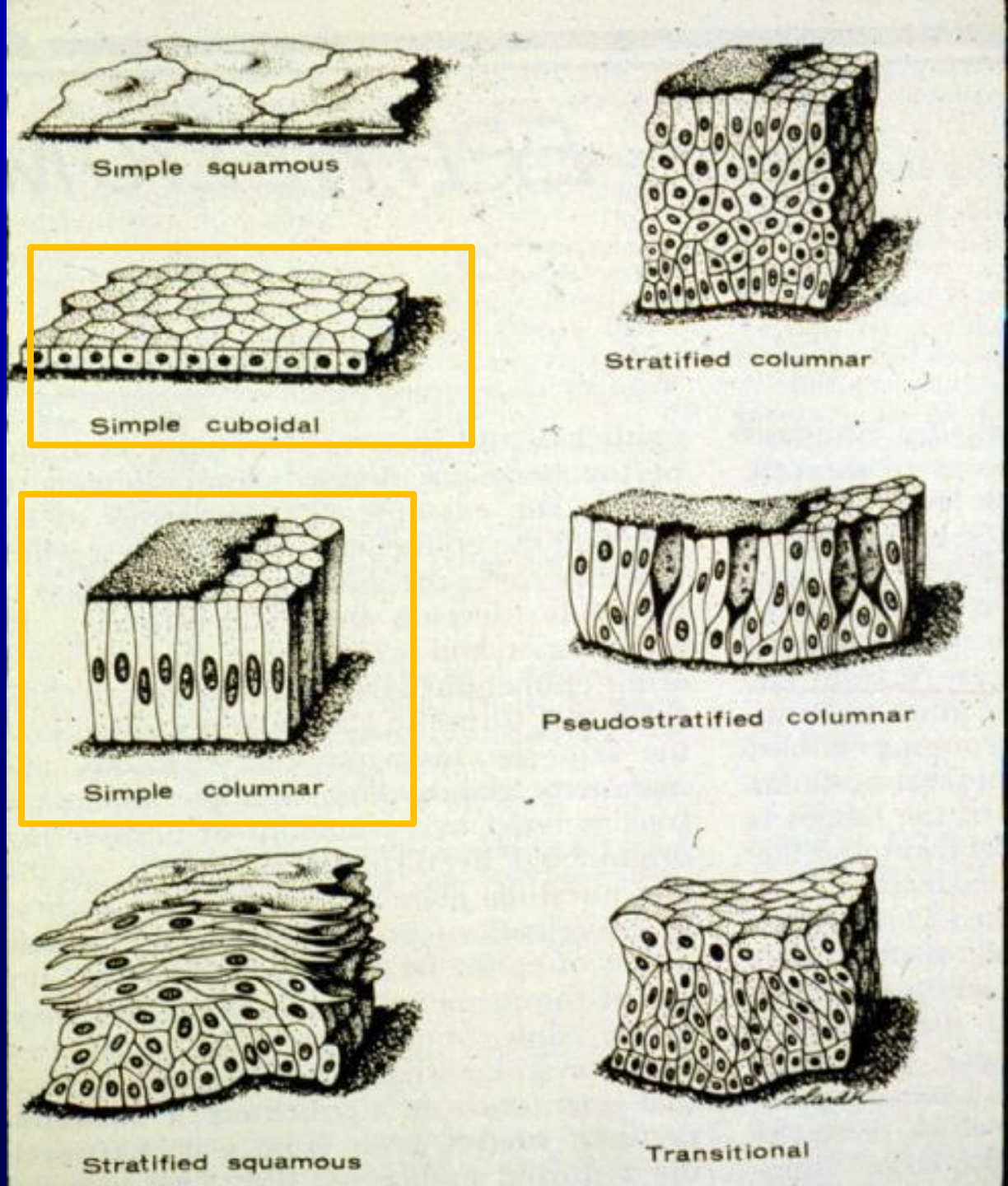
Stratified Squamous –
Multiple layers of cells with flat ones at the surface (skin, gums)



Epithelium
Histological Identification

Simple cuboidal – Single layer of square cells (kidney tubules, liver cells, many others)

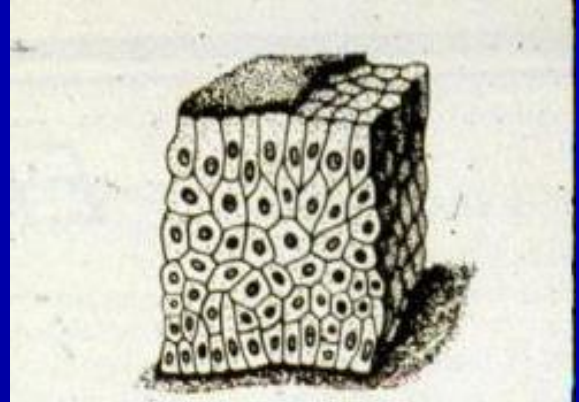
Simple columnar – Single layer of tall, thin cells (intestinal epithelium)

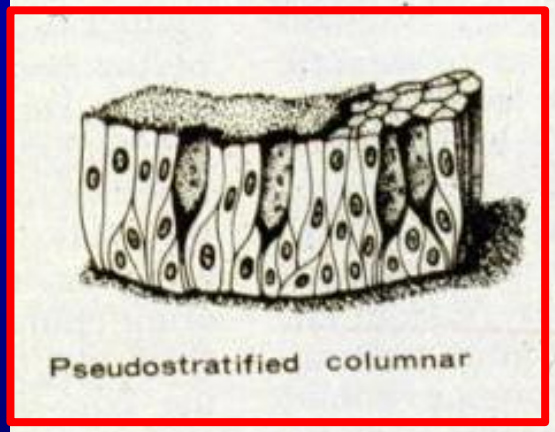


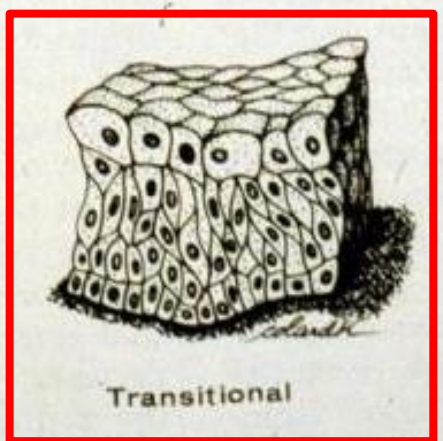
Epithelium
Histological Identification

Pseudostratified columnar – single layer of tall, thin cells packed together in such a jumble that they seem to be in layers, although all of the cells reach the basement membrane (respiratory passage)

Transitional – stratified cuboidal epithelium of urinary passages

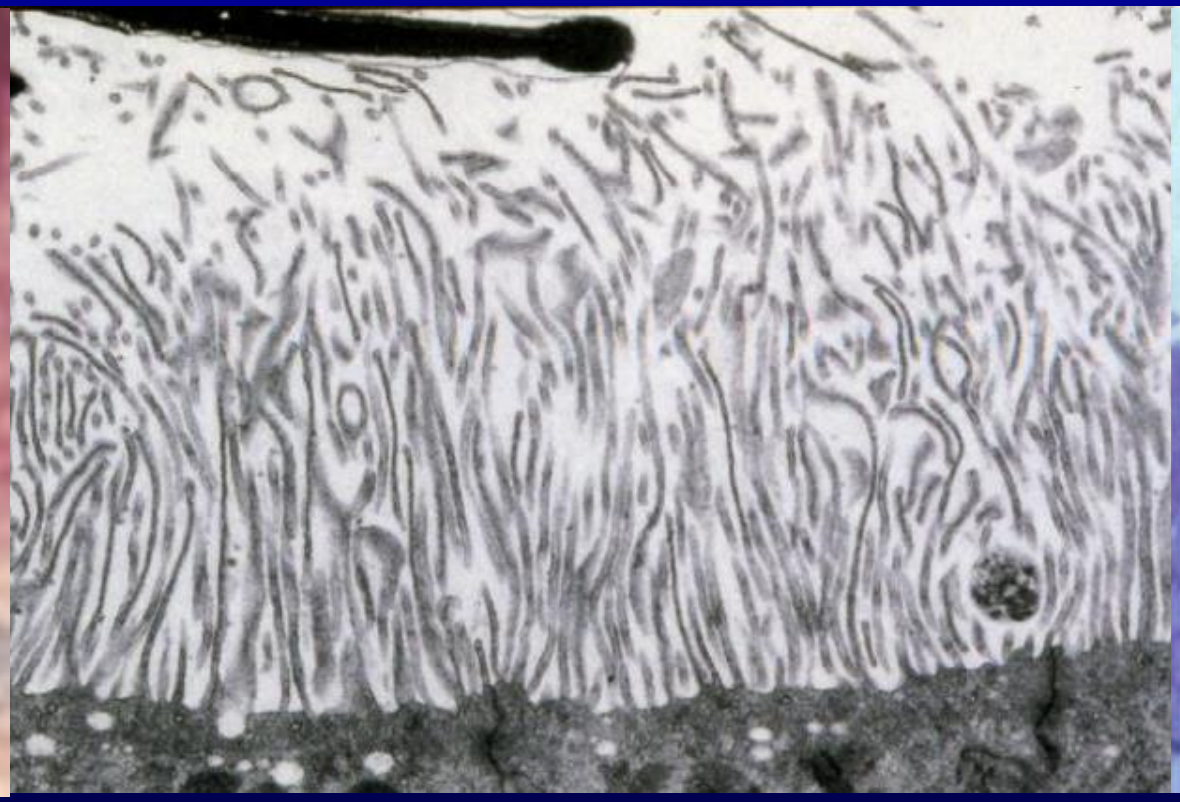


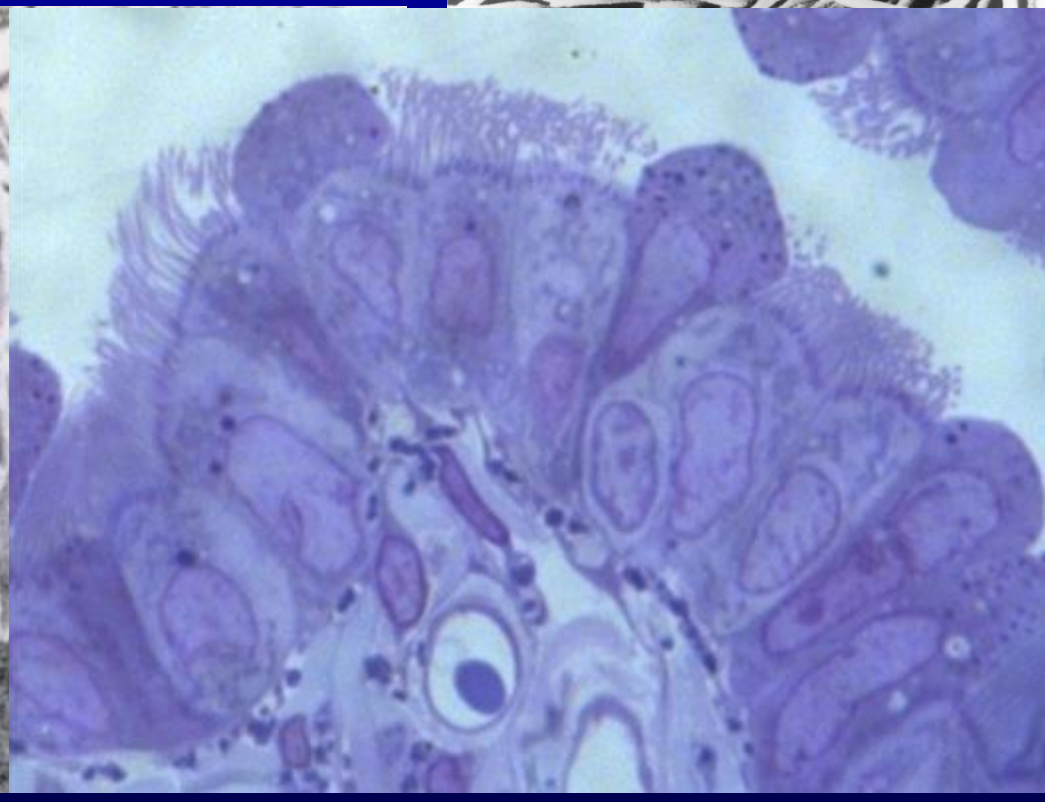


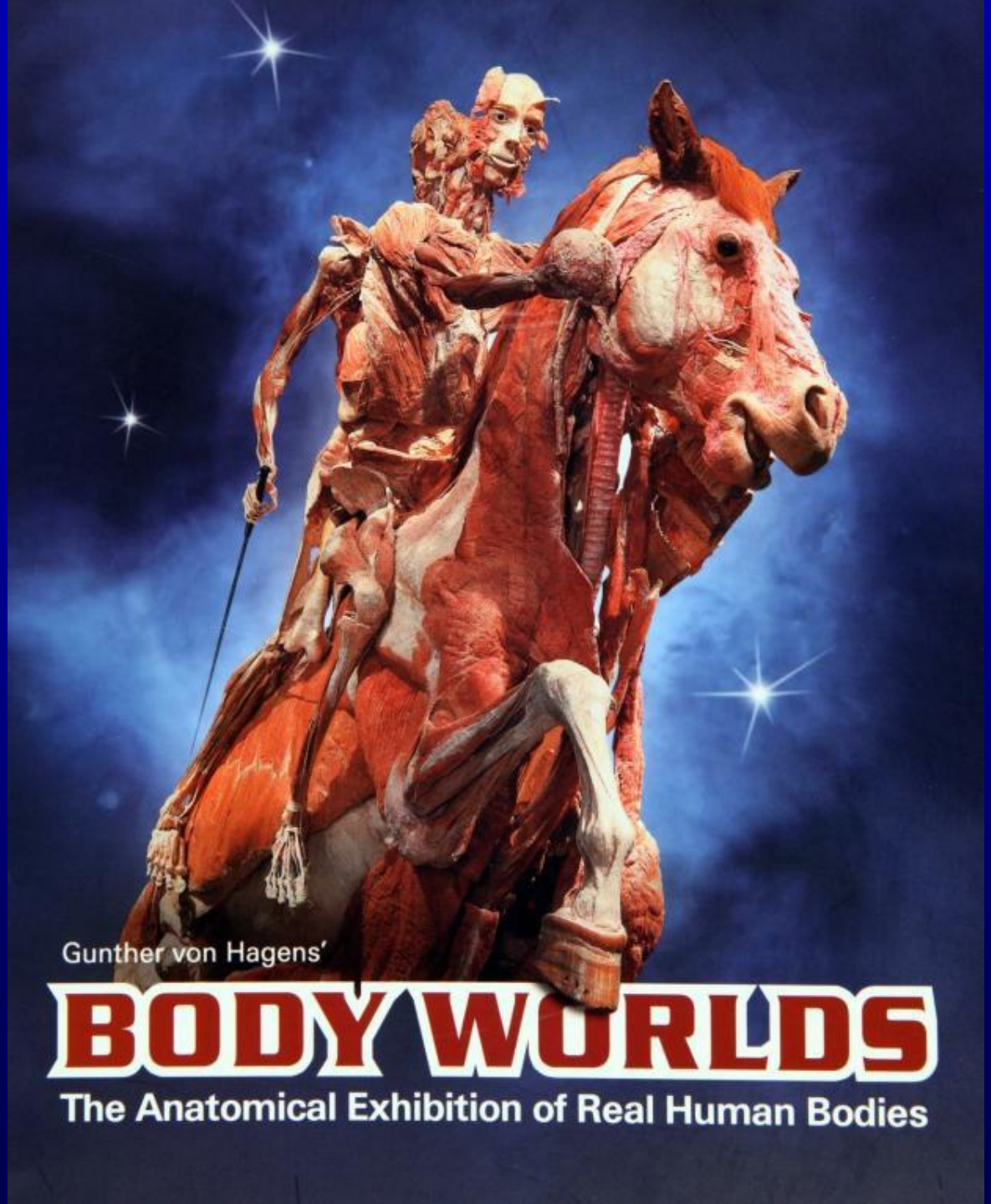


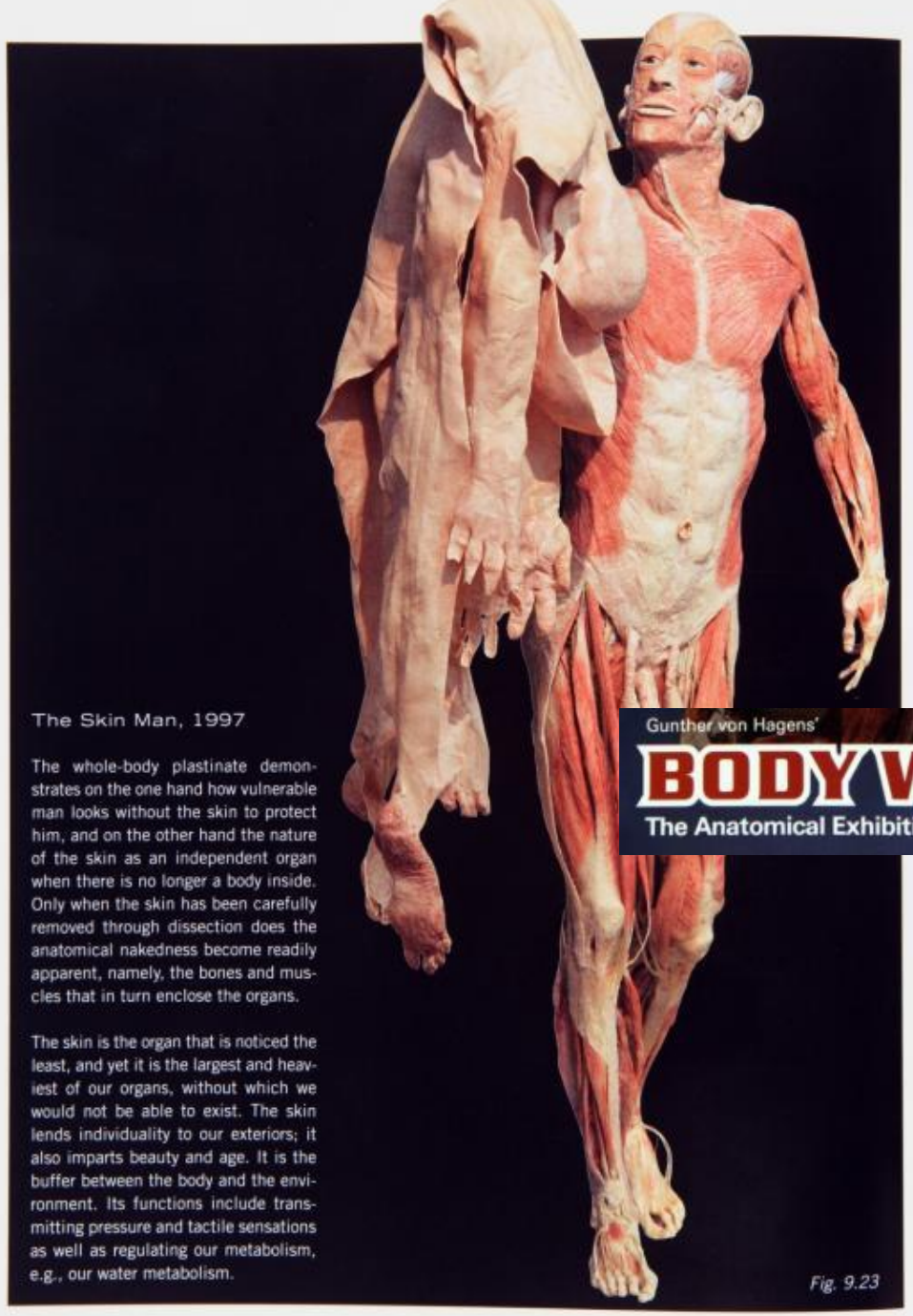
Epithelium
Histological Identification

Some epithelia have **surface specializations** such as numerous microvilli or cilia.






Gunther von Hagens'
BODY WORLDS
The Anatomical Exhibition of Real Human Bodies

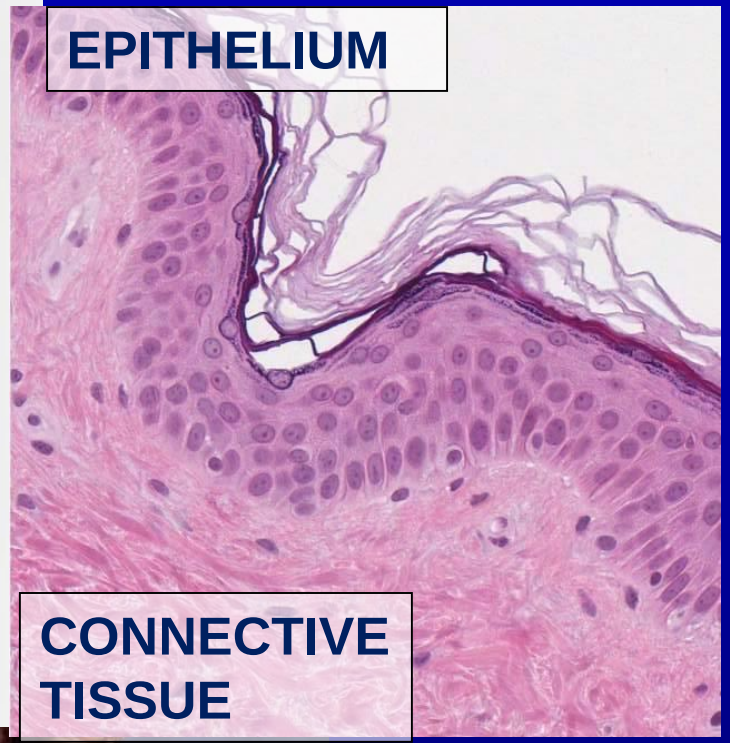


The Skin Man, 1997

The whole-body plastinate demonstrates on the one hand how vulnerable man looks without the skin to protect him, and on the other hand the nature of the skin as an independent organ when there is no longer a body inside. Only when the skin has been carefully removed through dissection does the anatomical nakedness become readily apparent, namely, the bones and muscles that in turn enclose the organs.

The skin is the organ that is noticed the least, and yet it is the largest and heaviest of our organs, without which we would not be able to exist. The skin lends individuality to our exteriors; it also imparts beauty and age. It is the buffer between the body and the environment. Its functions include transmitting pressure and tactile sensations as well as regulating our metabolism, e.g., our water metabolism.

Fig. 9.23



Gunther von Hagens'
BODY WORLDS
The Anatomical Exhibition of Real Human Bodies

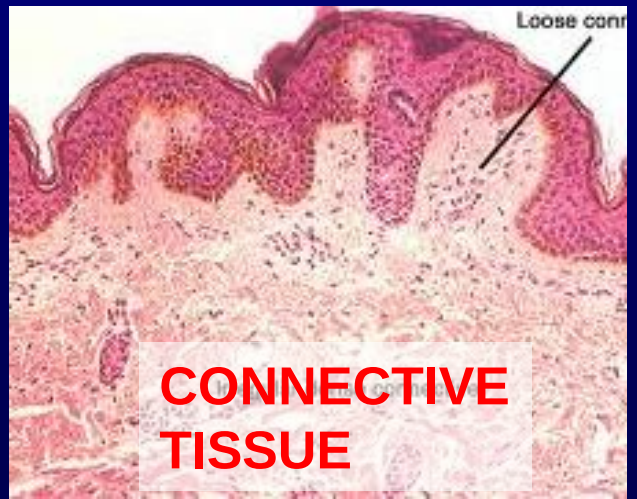
Skin

Gunther von Hagens' BODY WORLDS

Connective Tissue

Function:

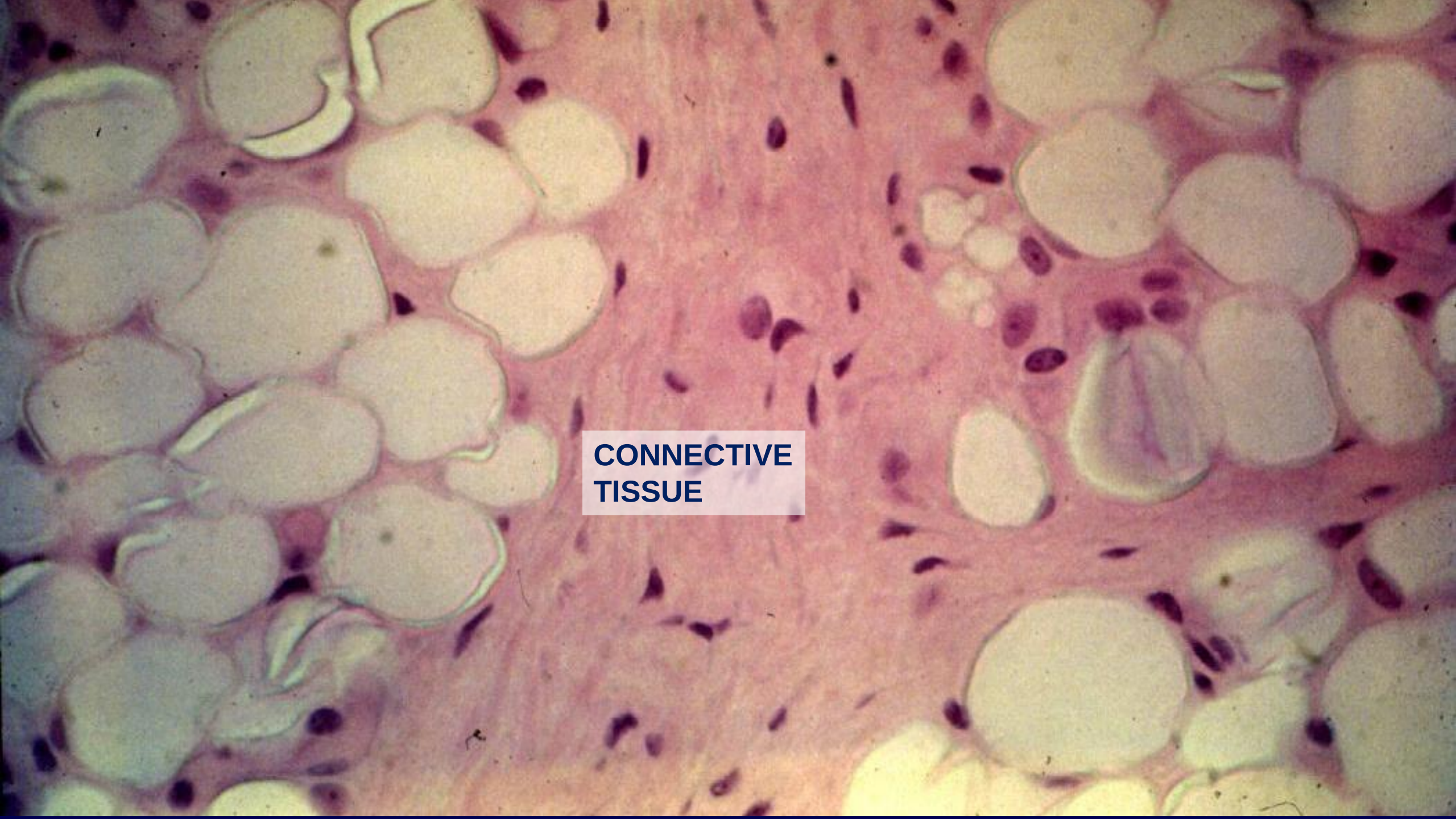
the histological glue which binds the other tissues together to form organs, specializations include blood, cartilage, and bone.

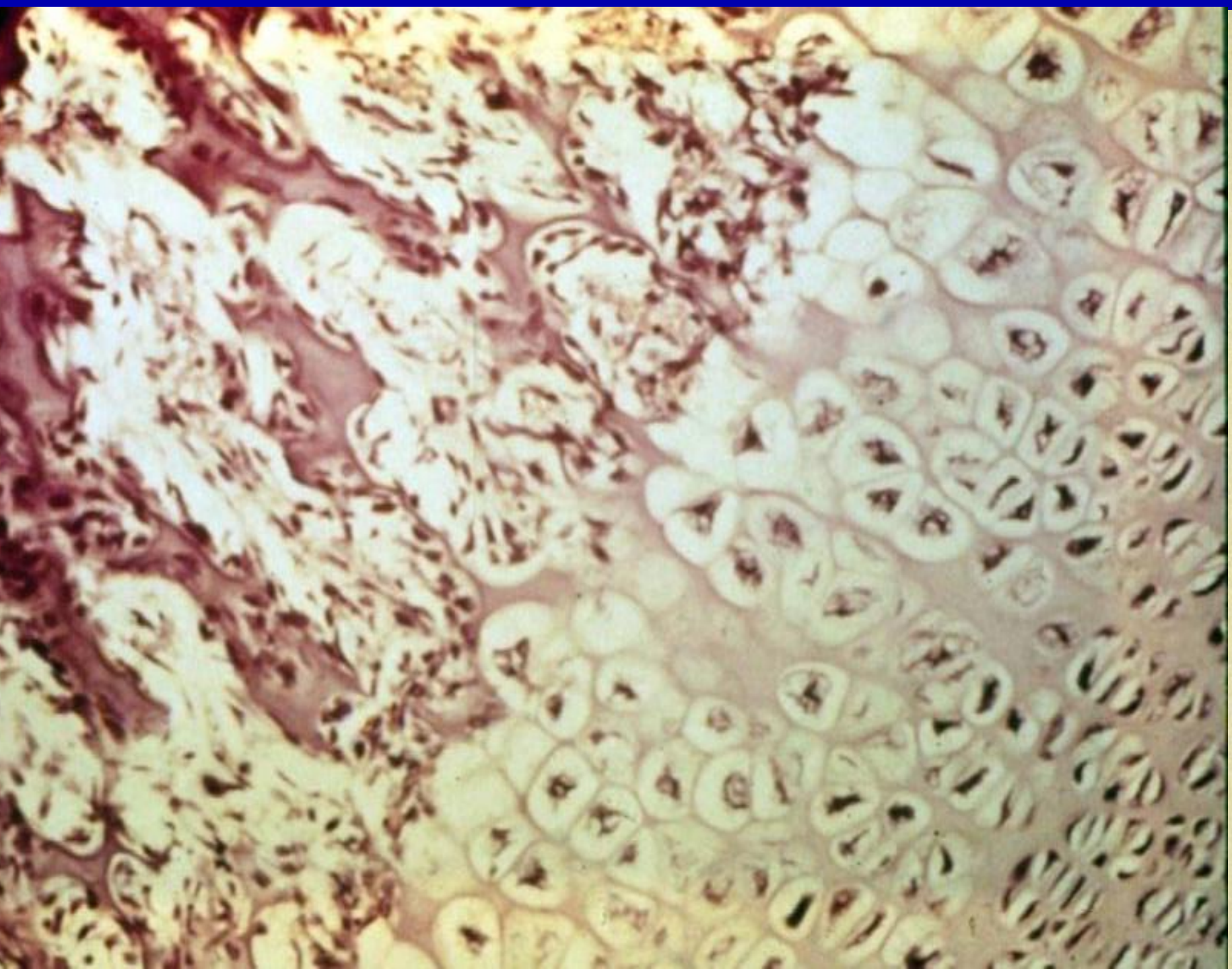


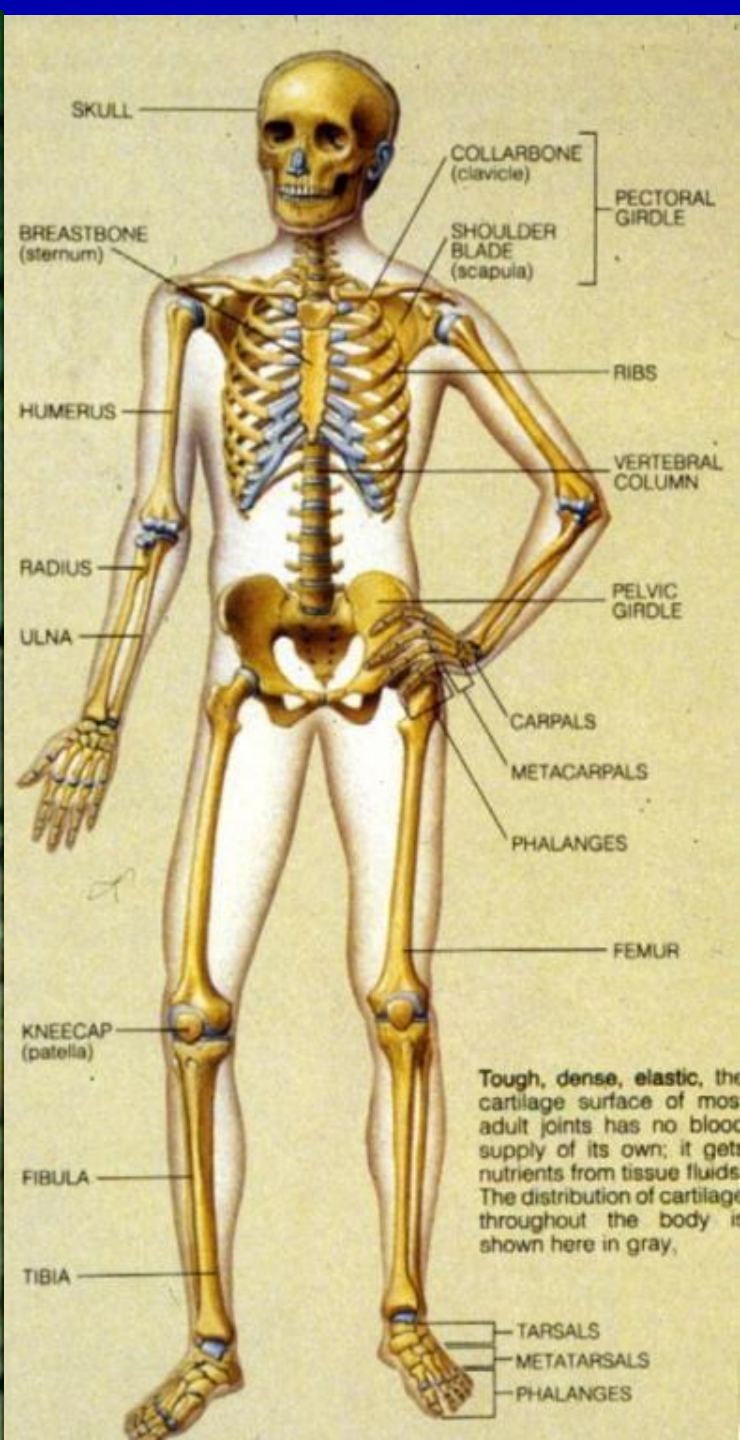
Connective Tissue

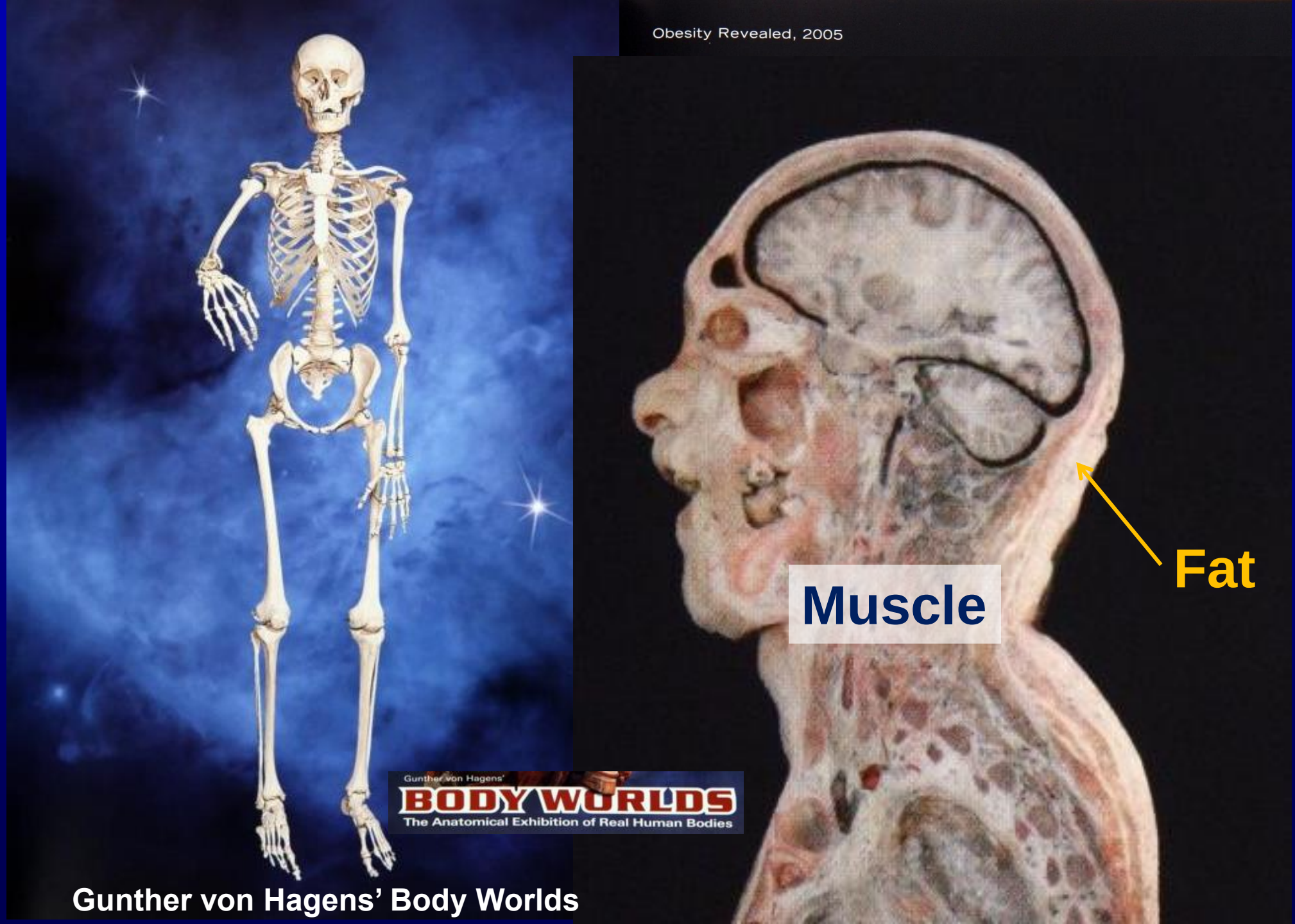
Distinguishing features and histological identification:

- **Loose connective tissue** – sparse collagen and elastic fibers, plentiful cells including fibroblasts, leukocytes
- **Dense connective tissue** – concentrated collagen, few cell
- **Cartilage** – avascular homogeneous matrix of collagen and protein-polysaccharides with few cell
- **Bone** – calcified collagen matrix with few cells trapped in the caves of bone


CONNECTIVE
TISSUE




SKULL
COLLARBONE (clavicle)
PECTORAL GIRDLE
BREASTBONE (sternum)
SHOULDER BLADE (scapula)
RIBS
HUMERUS
VERTEBRAL COLUMN
RADIUS
PELVIC GIRDLE
ULNA
CARPALS
METACARPALS
PHALANGES
FEMUR
KNEECAP (patella)
Tough, dense, elastic, the
cartilage surface of mos
adult joints has no blood
supply of its own; it gets
nutrients from tissue fluids
The distribution of cartilage
throughout the body i
shown here in gray.
FIBULA
TIBIA
TARSALS
METATARSALS
PHALANGES



Gunther von Hagens' Body Worlds

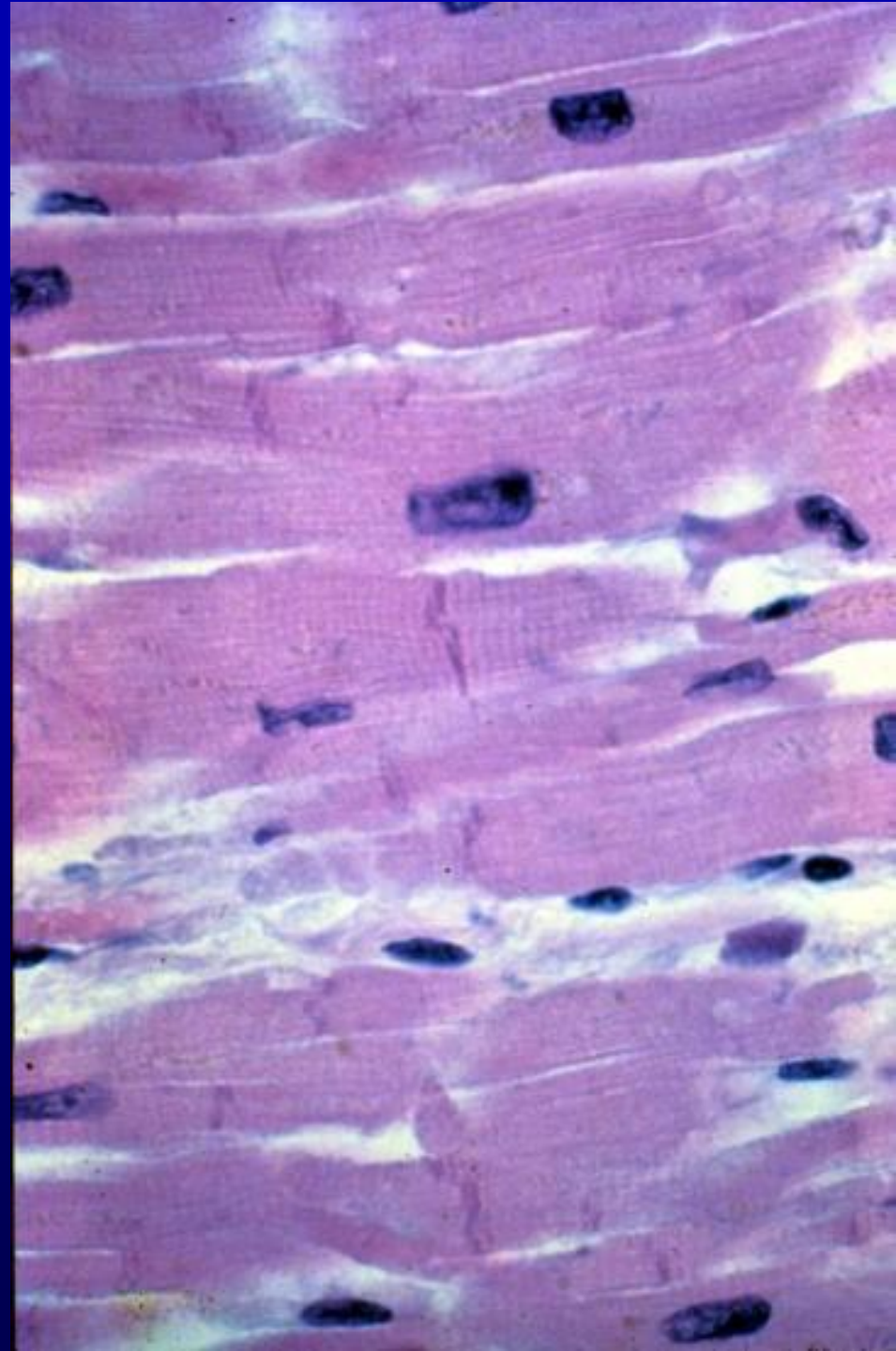
Muscle

Function:

generation of contractile force.

Distinguishing features:

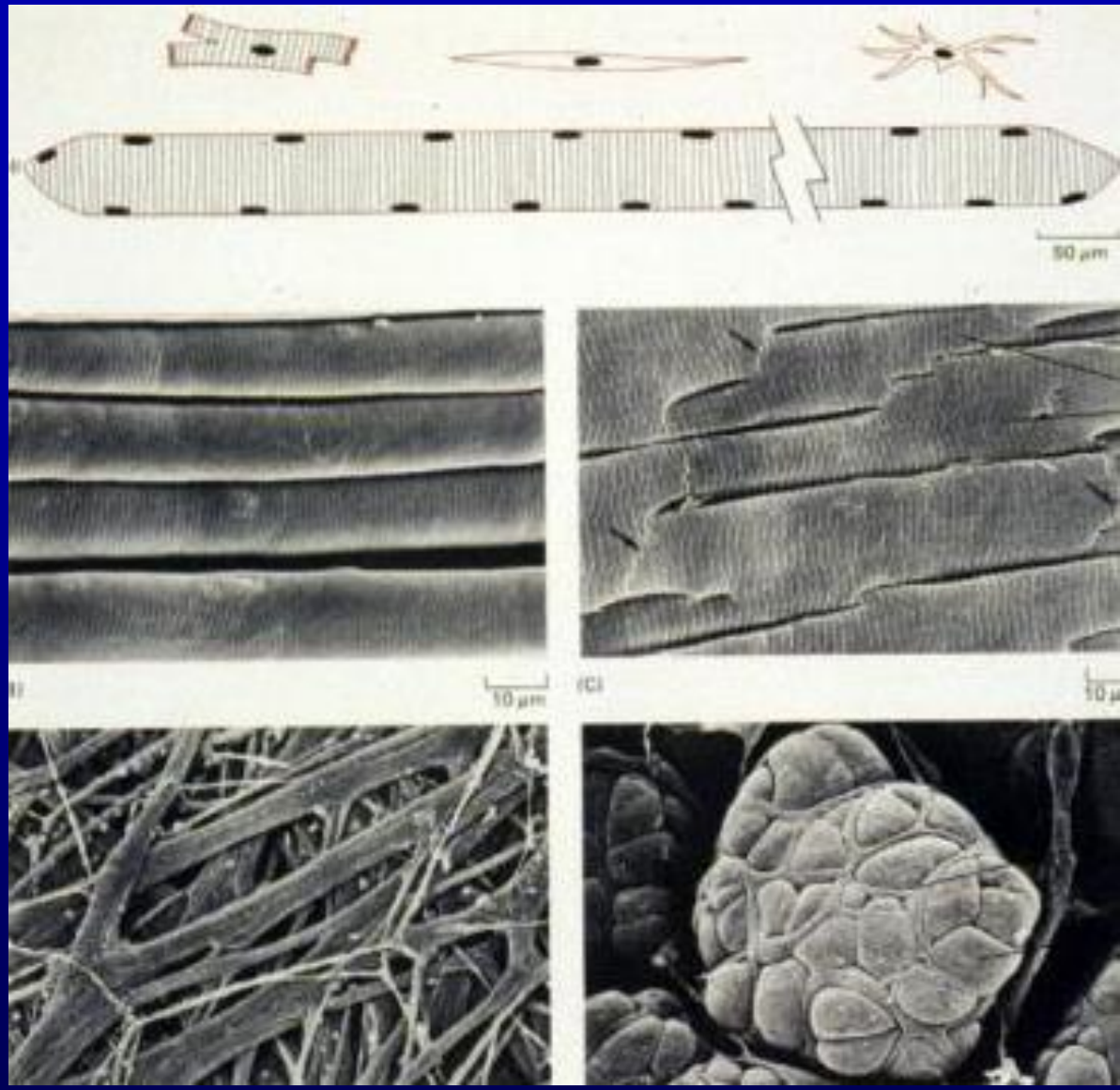
- High concentration of contractile proteins actin and myosin arranged either diffusely in the cytoplasm (smooth muscle) or in regular repeating units called sarcomeres (striated muscles, e.g., cardiac and skeletal muscles).



Muscle

Histological identification:

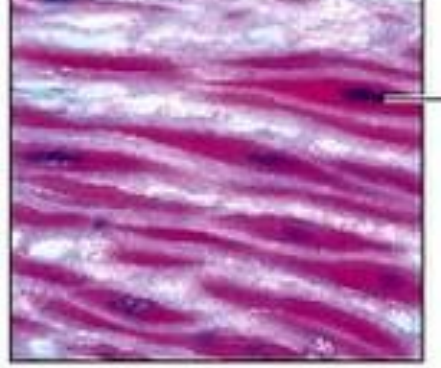
- **Skeletal muscle** – very long cylindrical striated muscle cells with multiple peripheral nuclei
- **Cardiac muscle** – short branching striated muscle cells with one or two centrally located nuclei
- **Smooth muscle** – closely packed spindle-shaped cells with a single centrally placed nucleus and cytoplasm that appears homogeneous by light microscopy



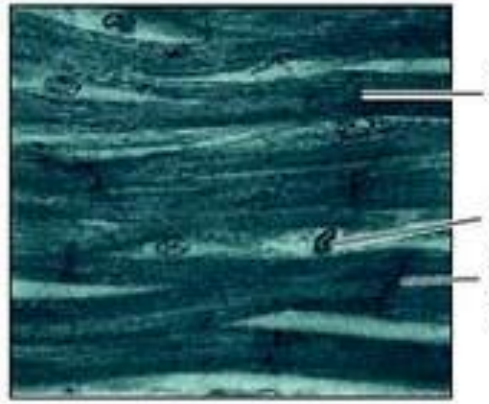
Muscle

Distribution:

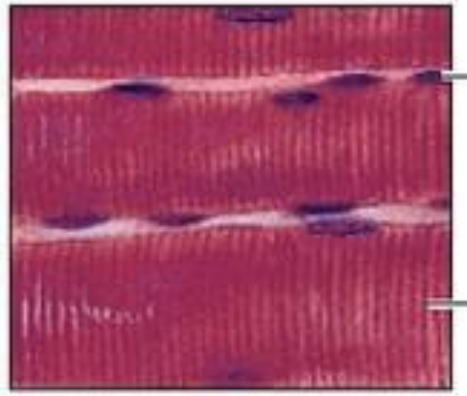
- **Skeletal** – striated muscles mostly associated with the skeleton
- **Cardiac** – striated muscles associated with the heart
- **Smooth** – fusiform cells associated with the viscera, respiratory tract, blood vessels, uterus, etc.



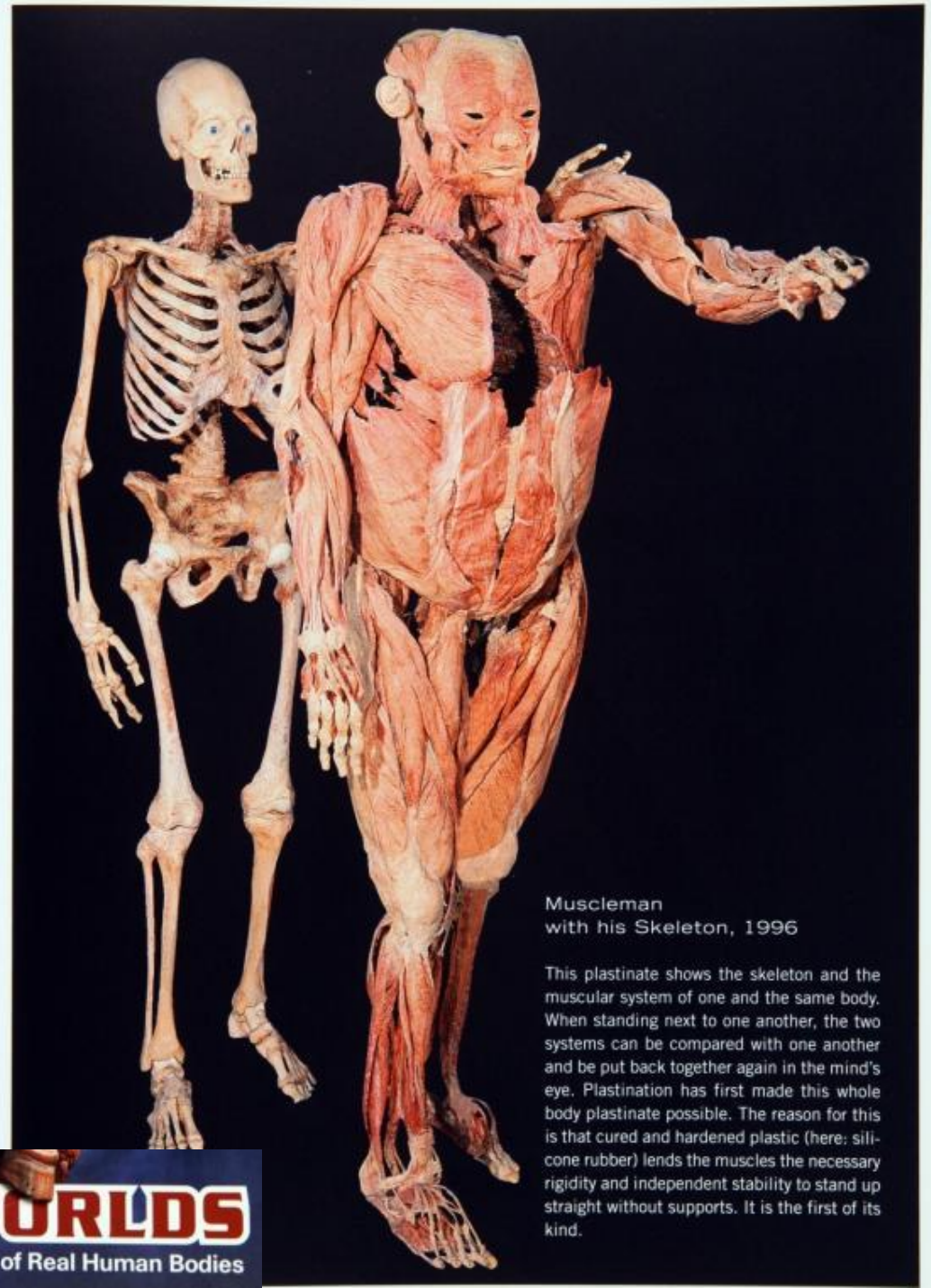
(a) Smooth muscle tissue



(b) Cardiac muscle tissue



(c) Skeletal muscle tissue



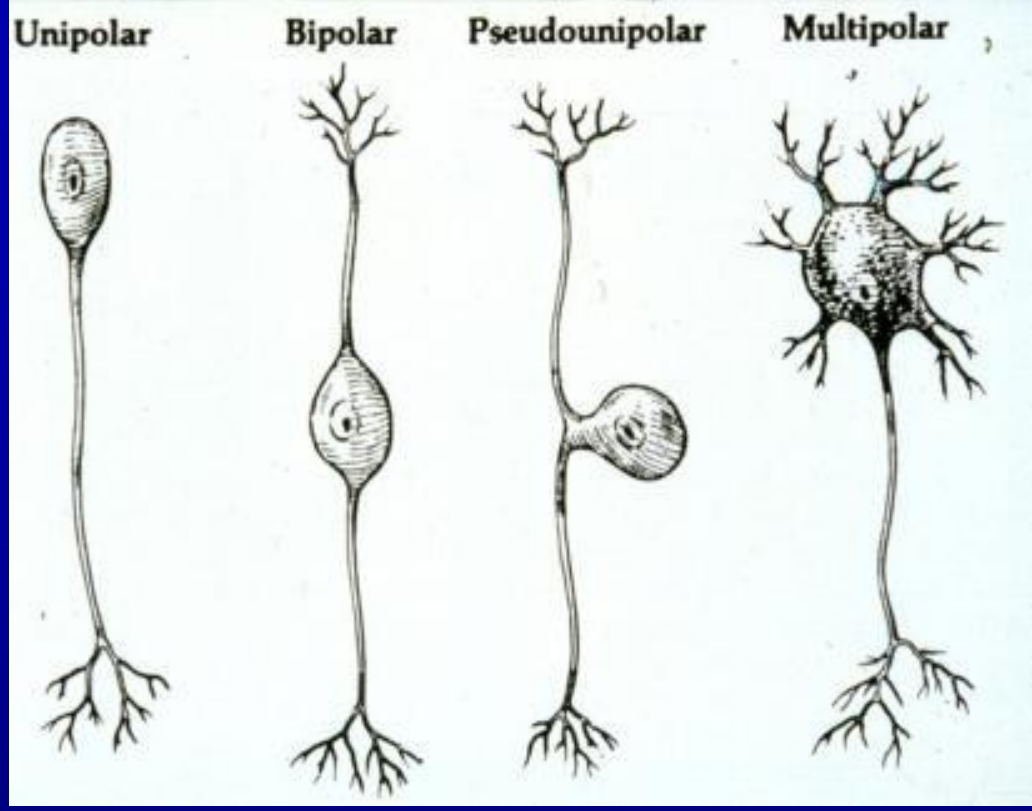
Muscleman
with his Skeleton, 1996

This plastinate shows the skeleton and the muscular system of one and the same body. When standing next to one another, the two systems can be compared with one another and be put back together again in the mind's eye. Plastination has first made this whole body plastinate possible. The reason for this is that cured and hardened plastic (here: silicone rubber) lends the muscles the necessary rigidity and independent stability to stand up straight without supports. It is the first of its kind.

Smooth muscle

NERVOUS TISSUE

Nervous Tissue



Functions:

specialized for the transmission, reception, and integration of electrical impulses

Distinguishing features:

- neurons – very large excitable cells with long processes called axons and dendrites. The axons make contact with other neurons or muscle cells at a specialization called a synapse where the impulses are either electrically or chemically transmitted to other neurons or various target cells (e.g., muscle). Others secrete hormones.

Nervous Tissue

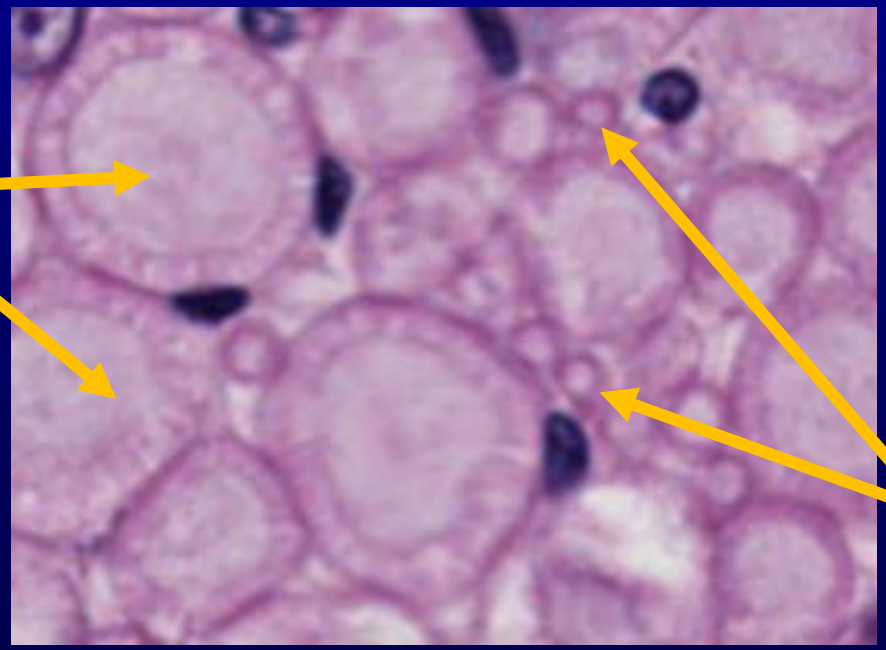
Bipolar
neurons
of inner ear

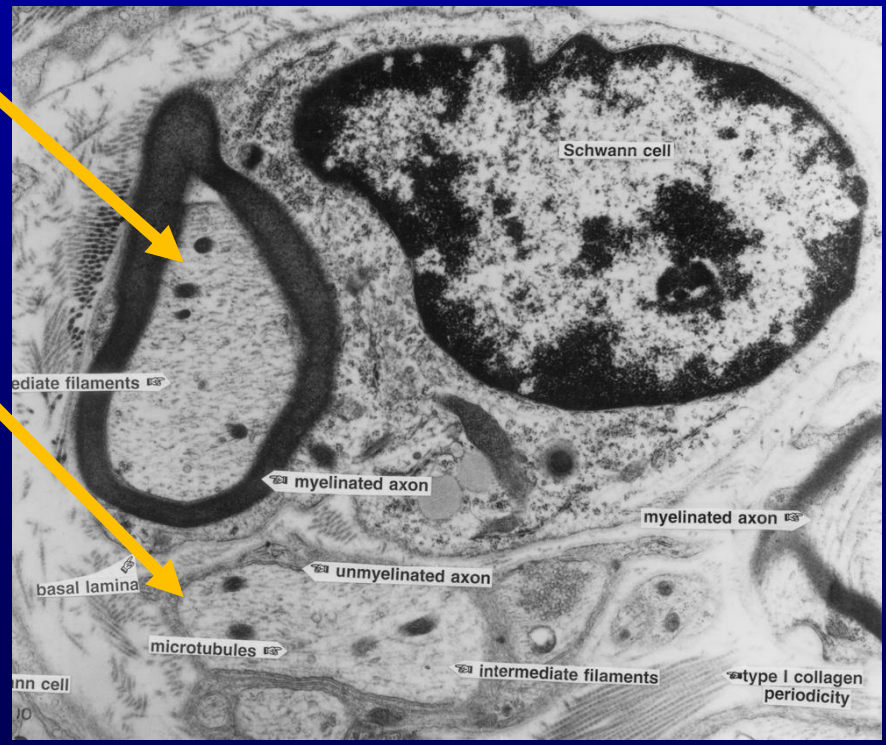
Nervous Tissue

Glial cells – the supporting cells of nervous tissue.

Nerves – collections of neuronal processes bound together by connective tissue. Axons may be coated by a myelin sheath ("**myelinated**") or simply protected by being cradled in an indentation of a glial cell ("**unmyelinated**").

Myelinated

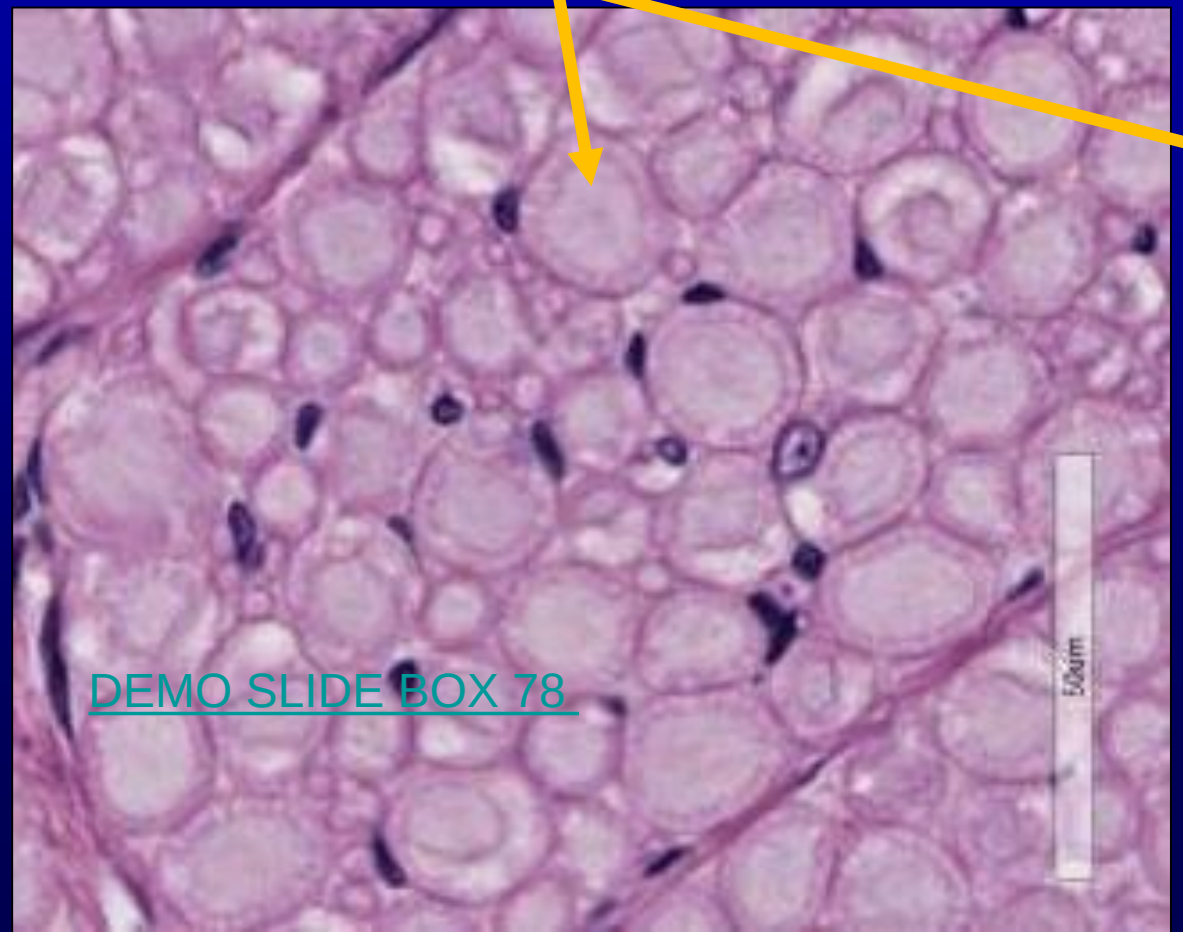


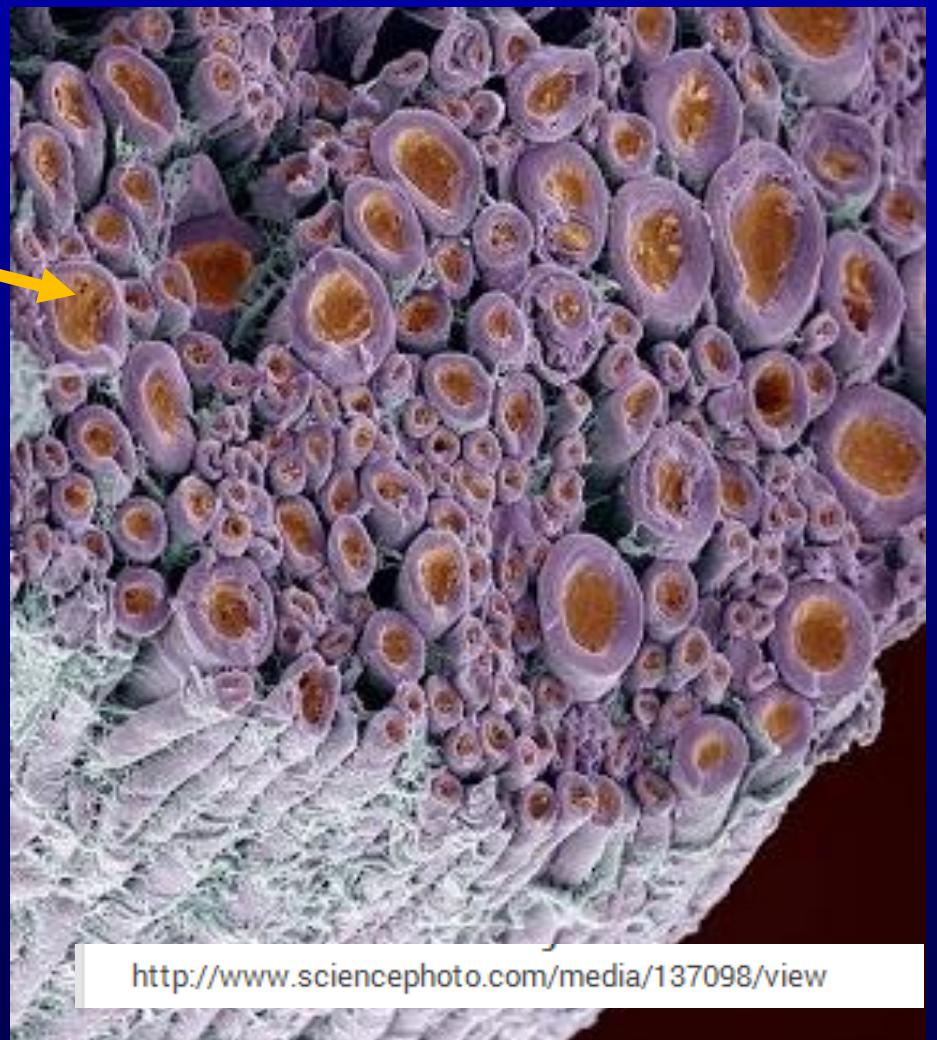


Unmyelinated?

Nervous Tissue

Nerves – collections of neuronal processes bound together by connective tissue. Axons may be coated by a myelin sheath ("myelinated")

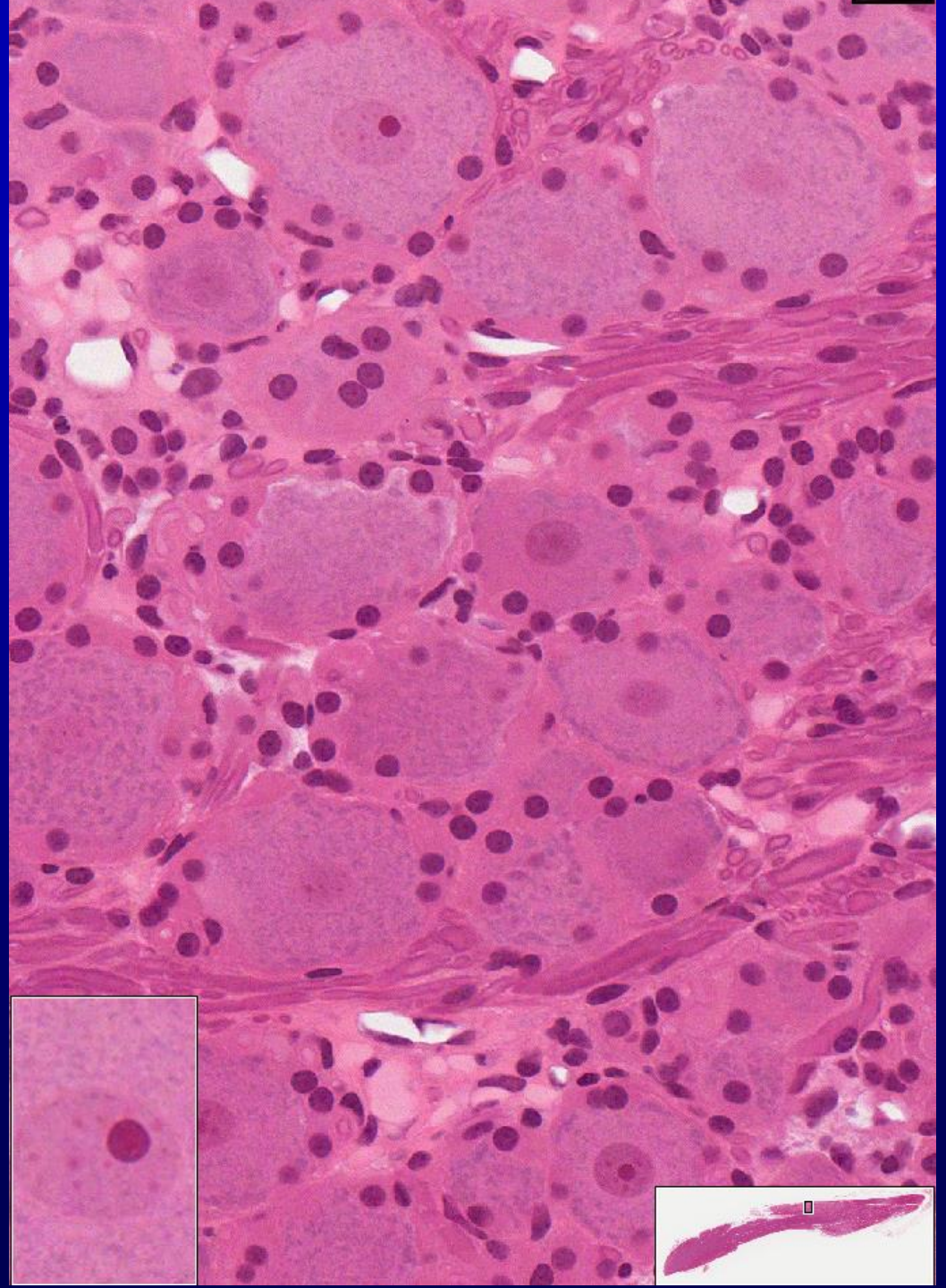




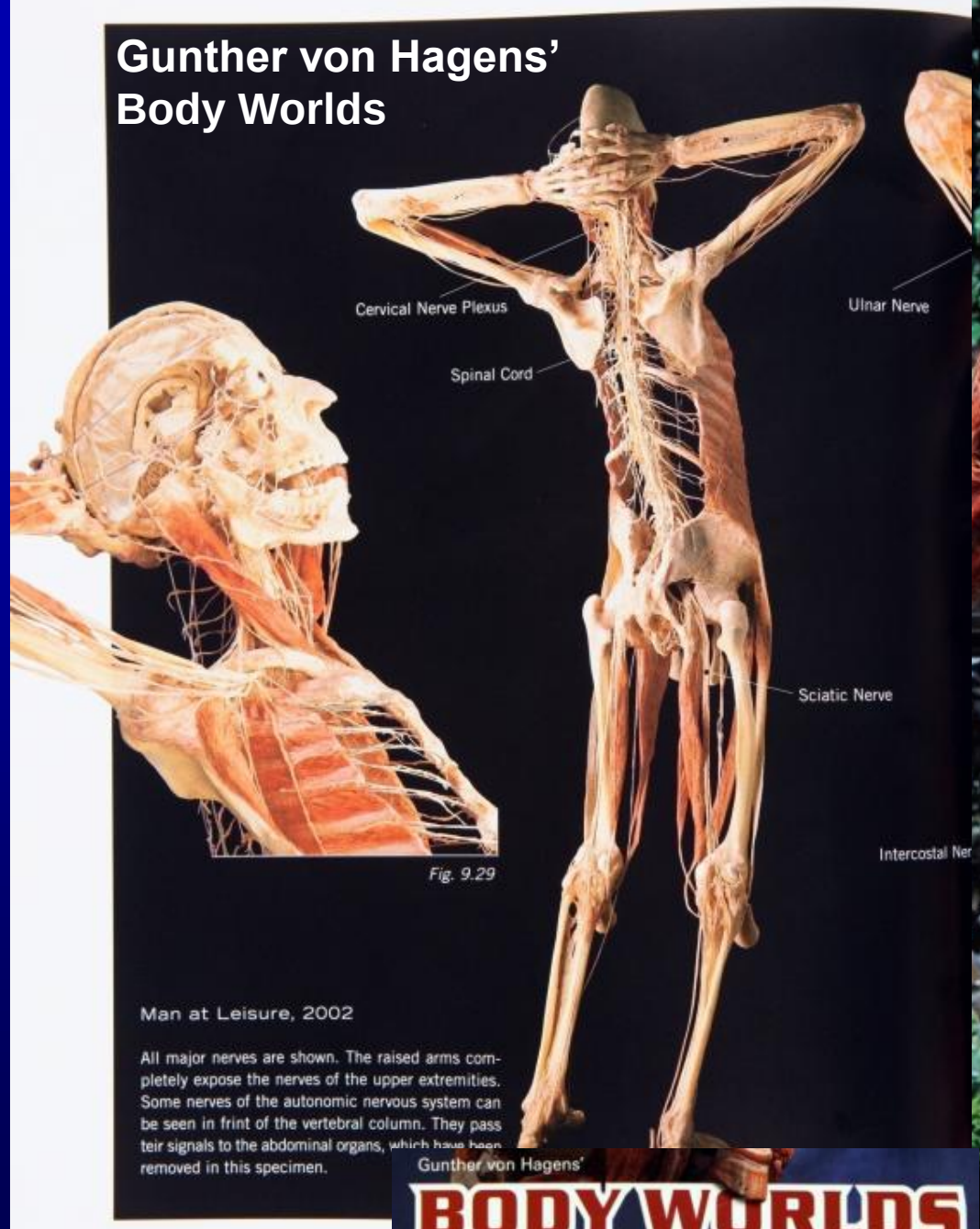
Nervous Tissue

Distribution:

- Comprise the central nervous system
- Individual peripheral nerves are found throughout the body
- Individual neurons and clusters of neurons (called ganglia) are found in most organs



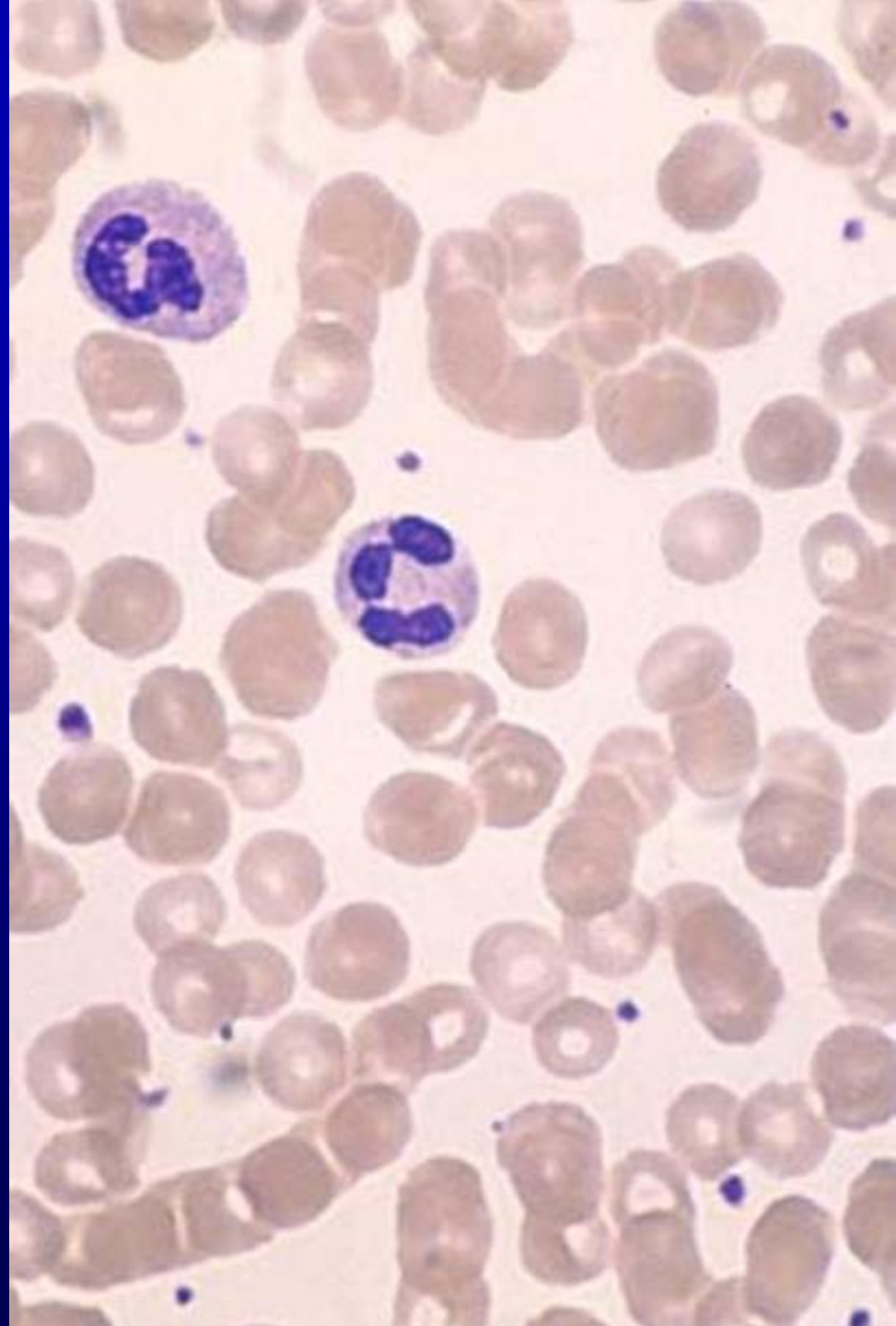
Gunther von Hagens' Body Worlds



Blood cells -functions
(classified as connective tissue)

Functions:

- **Red cells** – carry oxygen to the tissues and CO_2 from tissues
- **White cells** – transient inhabitants of the blood which are manufactured in bone marrow and pass through the blood to connective tissue where they participate in defense against biological and chemical invaders
- **Platelets** – blood clotting

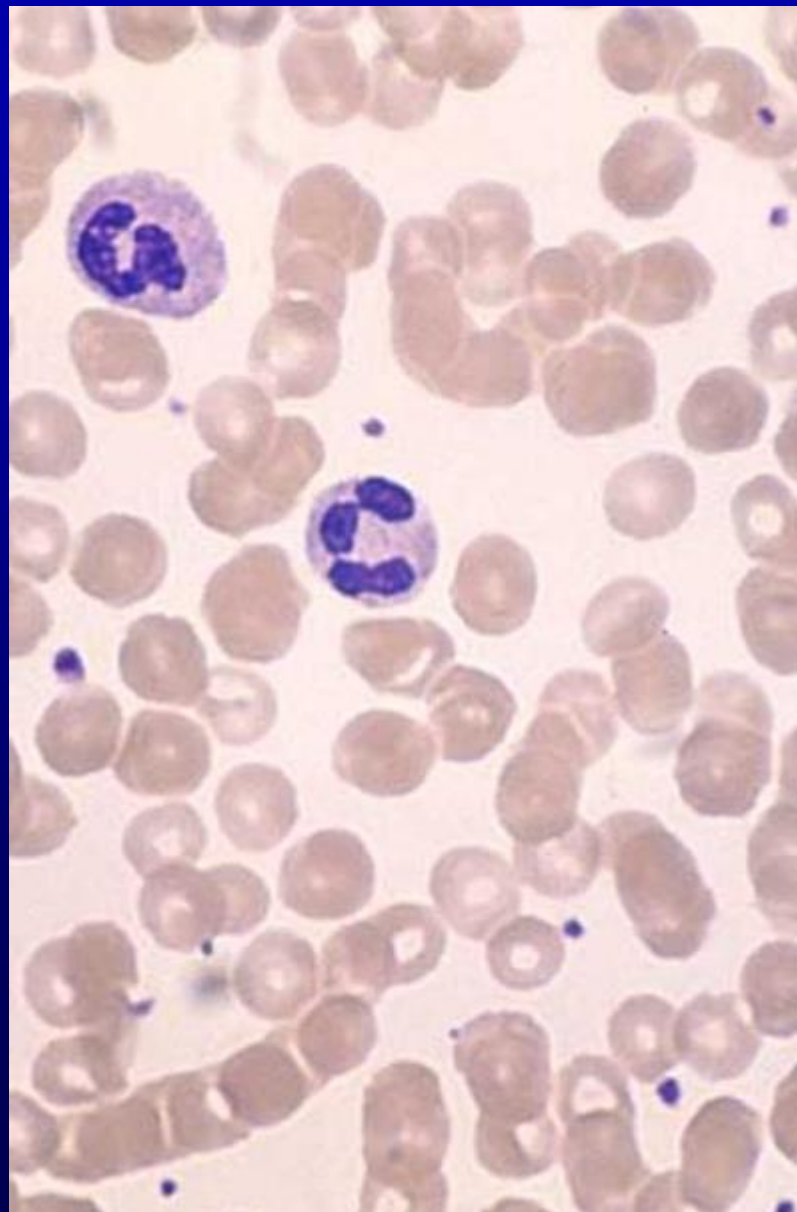


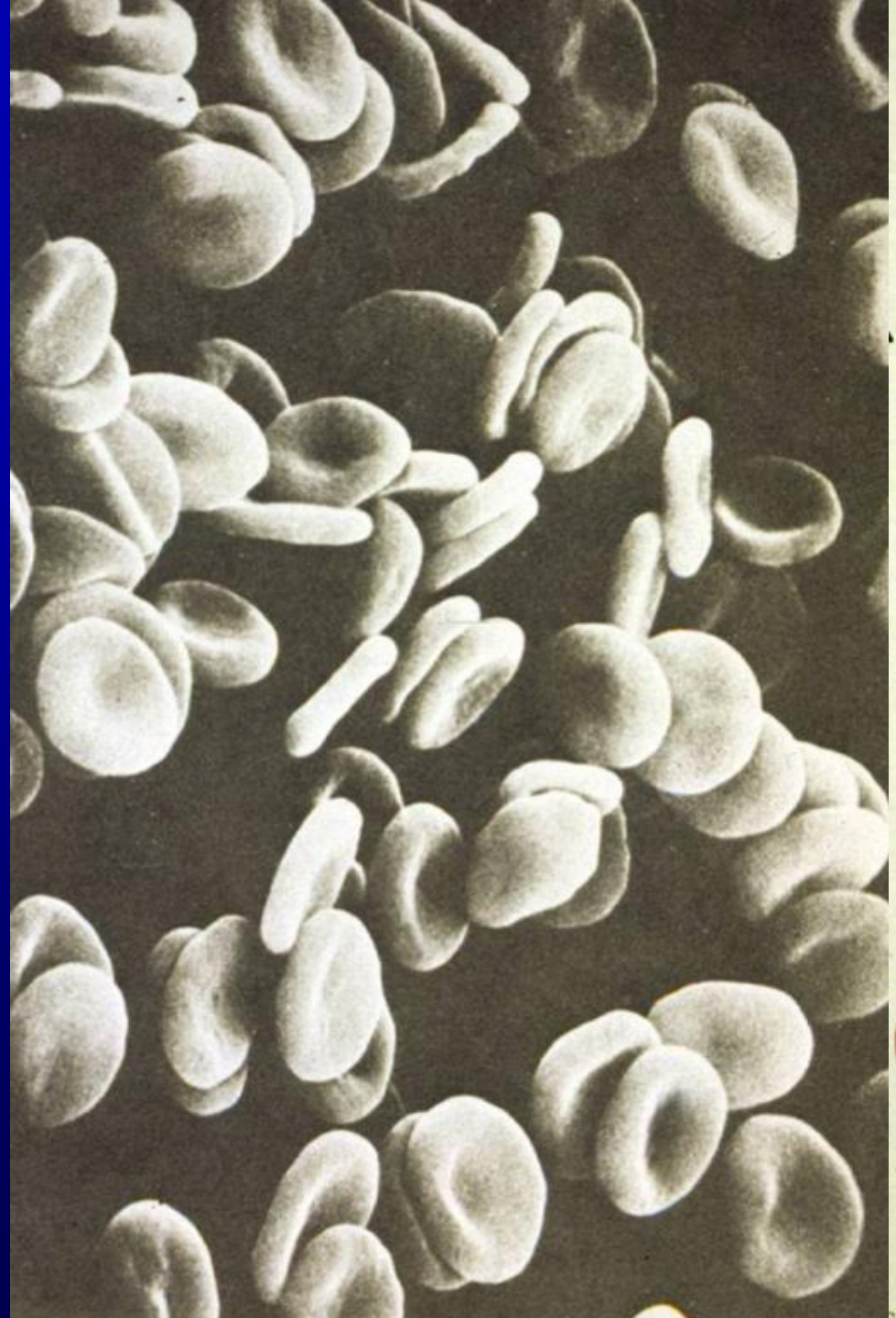
Blood cells

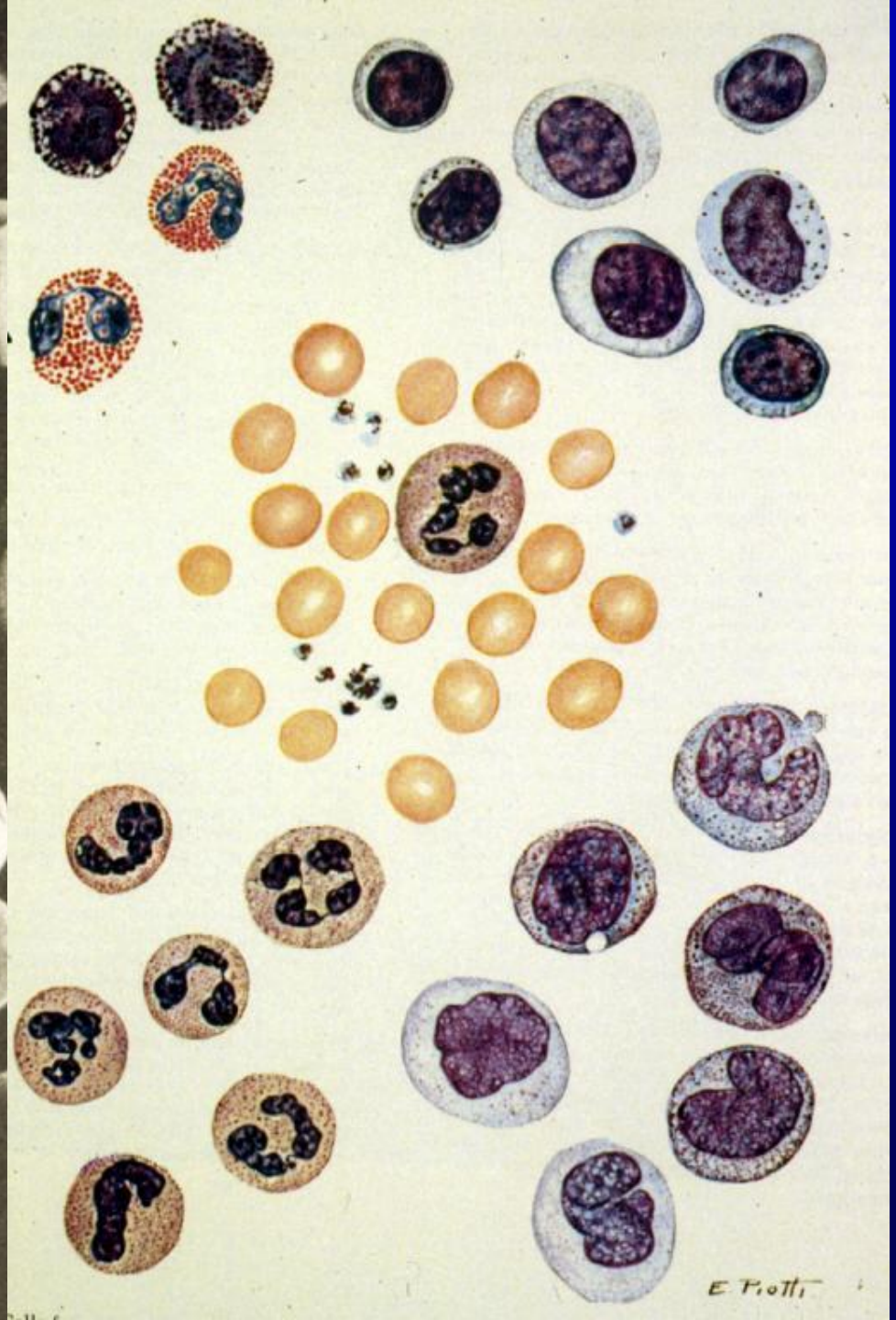
(classified as connective tissue)

Distinguishing features and histological identification:

- **red cells** – biconcave discs containing hemoglobin
- **white cells** – granulocytes have one of three different types of granules and lobed nuclei; lymphocytes and monocytes have few granules and round or indented nuclei
- **platelets** – anucleate cell fragments produced by megakaryocytes in the bone marrow



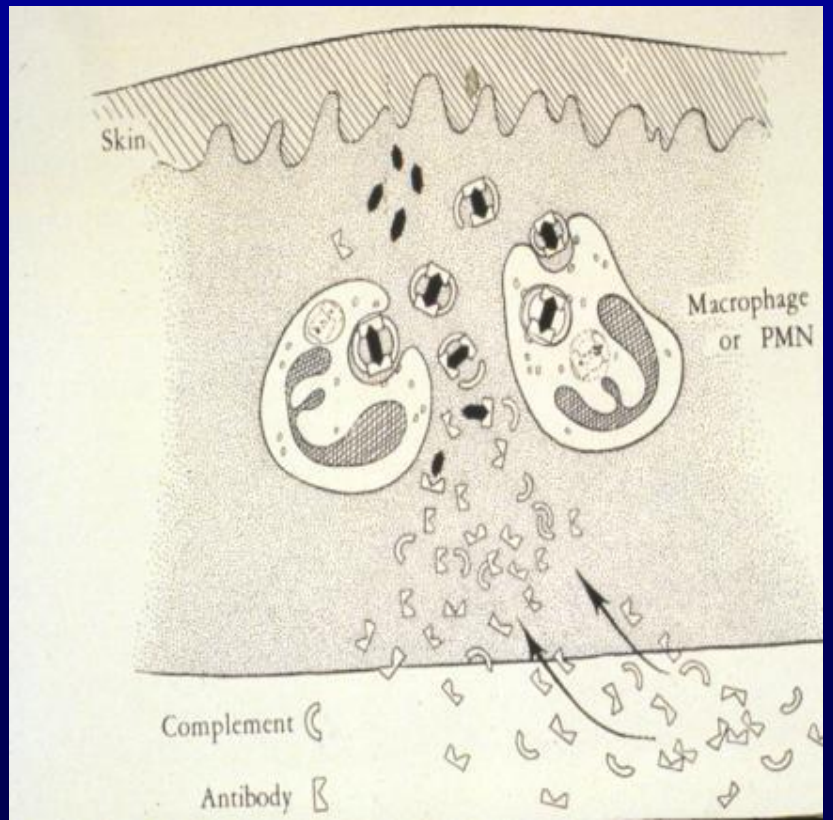



E. Piotti

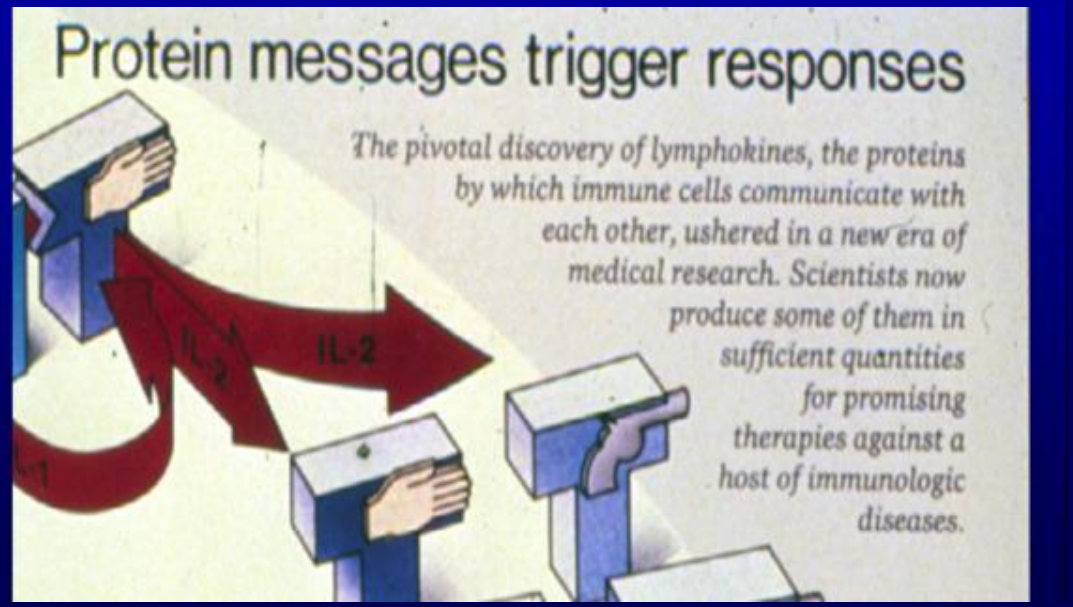
LYMPHOID TISSUE

Functions:

responsible for the "immune response" to foreign invaders which is mediated by either antibody produced by the cells or by the cells themselves.



Amplification of the immune response: factors (lymphokines) and other cell types involved

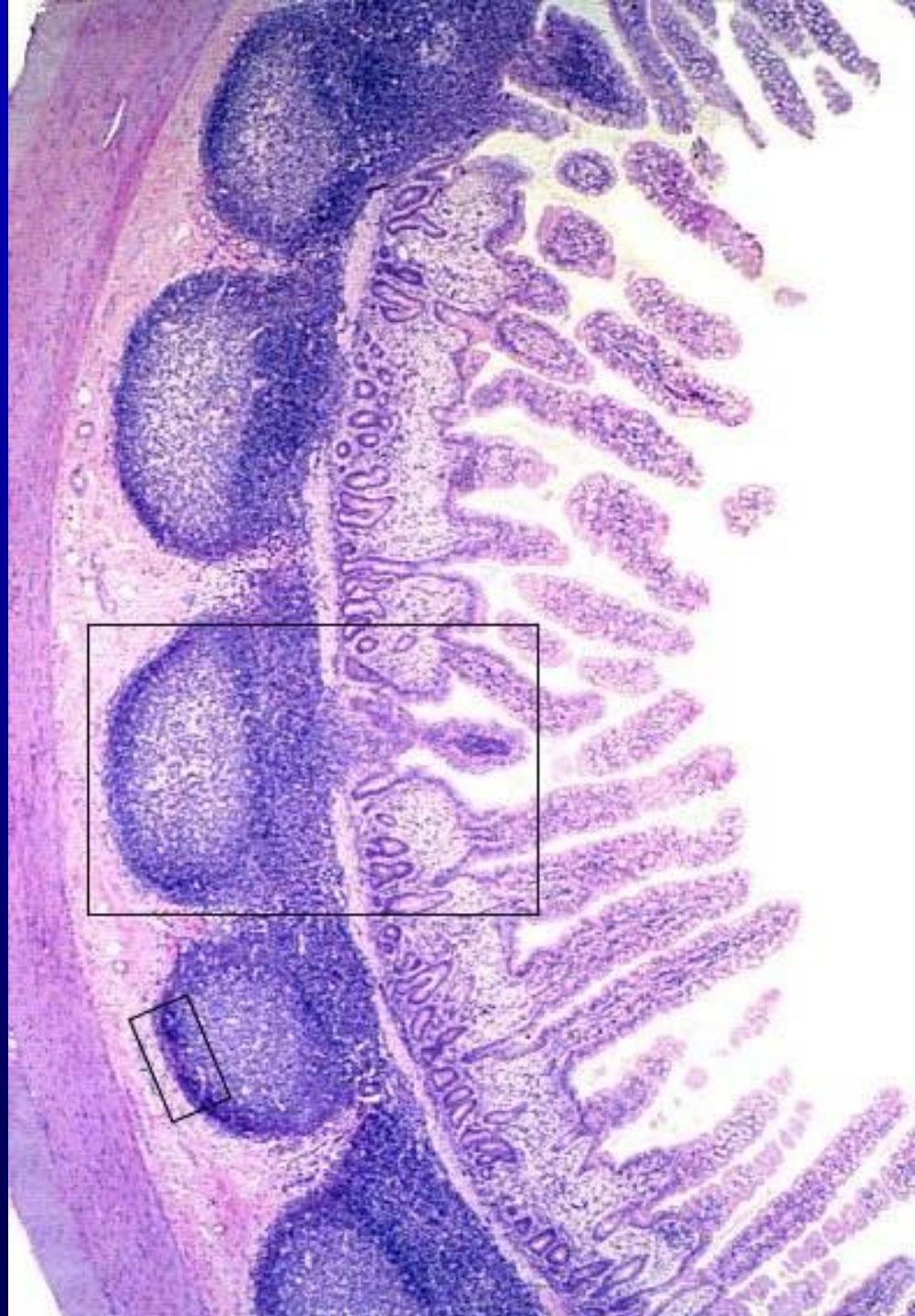


Lymphoid Tissue

Distinguishing features and histological identification: clusters of lymphocytes free in the connective tissue or surrounded by a connective tissue capsule as in a lymph node

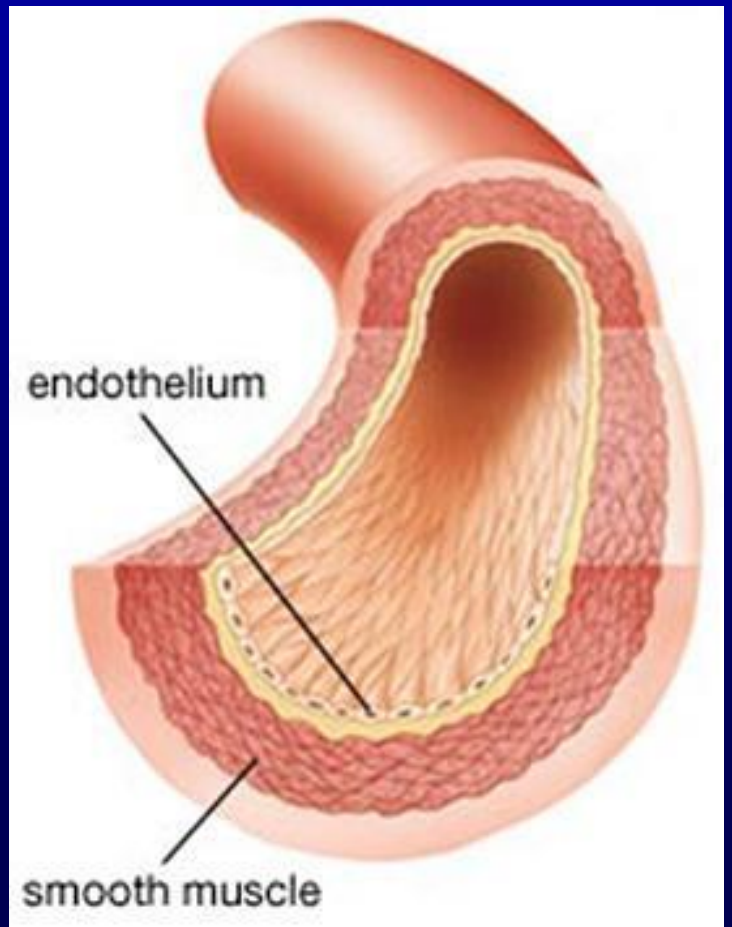
Distribution:

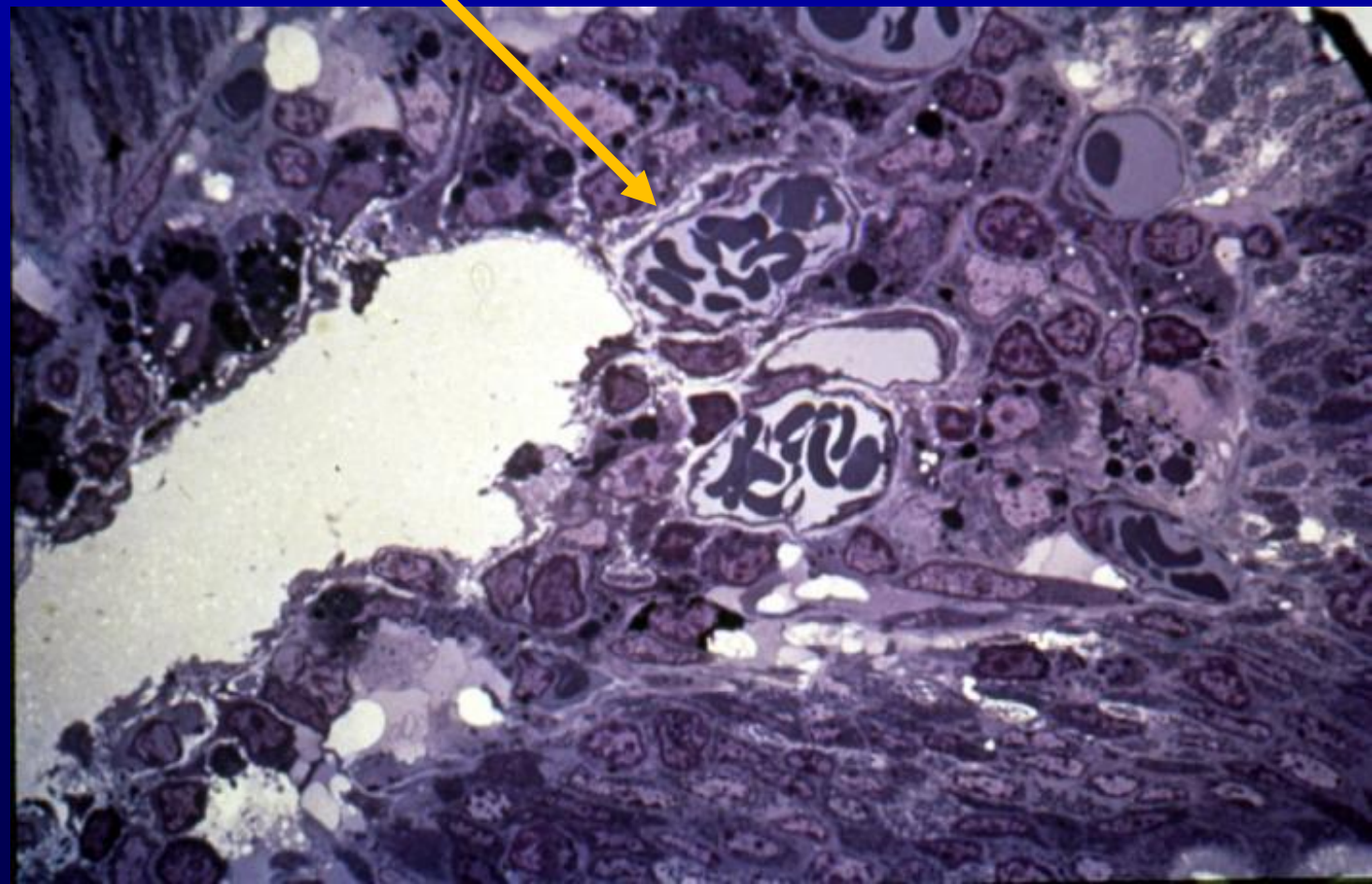
in primary lymphoid organs (spleen, thymus, lymph nodes); along alimentary canal and respiratory passages.



Blood Vessels

Not one of the four basic tissues, but necessary to learn at this stage; All blood and lymph vessels are lined with endothelium (a simple squamous epithelium)

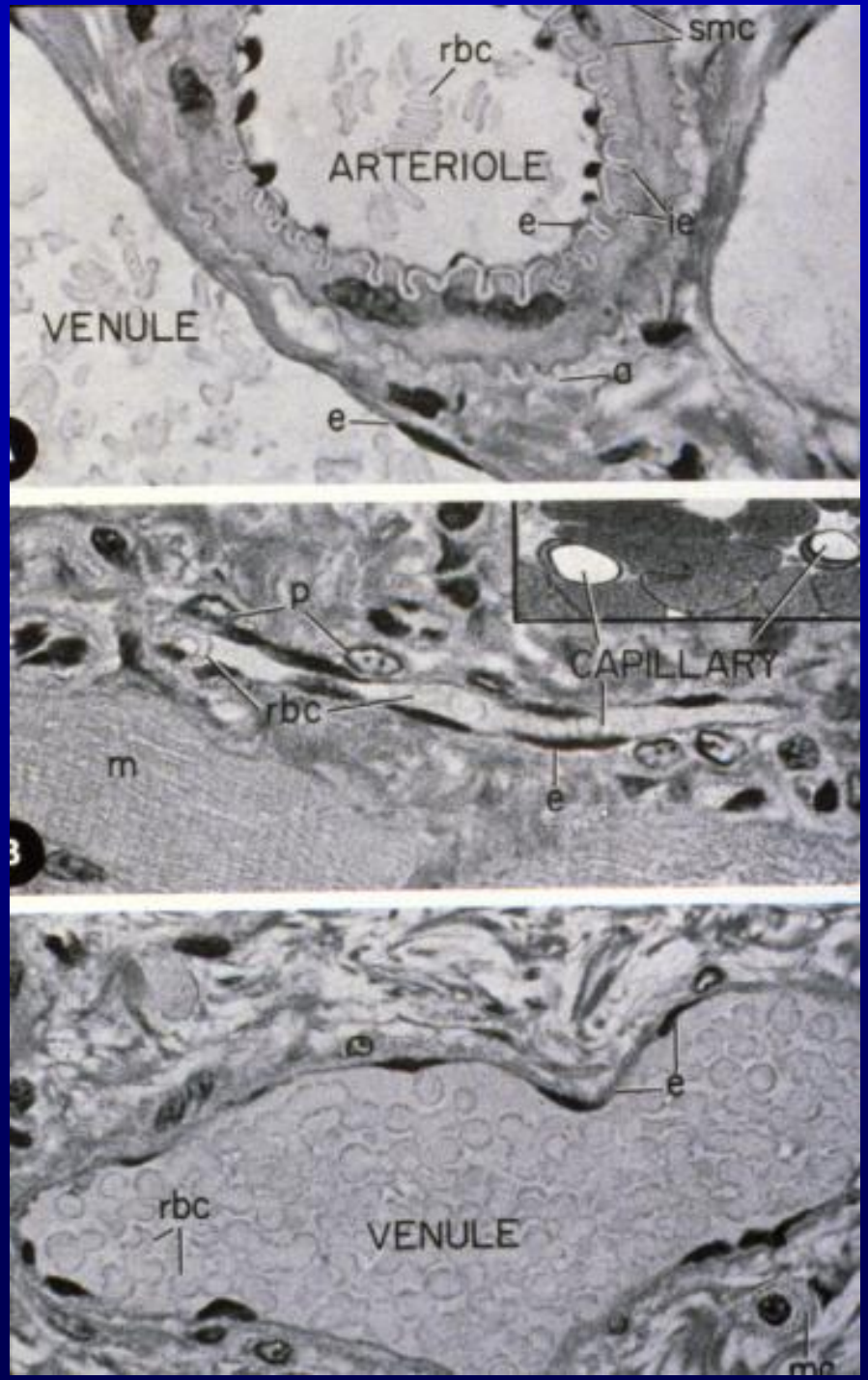




Blood Vessels

Histological identification:

- **Artery** – thick wall composed of smooth muscle plus some connective tissue surrounding a small lumen
- **Capillary** – narrow tube lined with a single endothelial cell
- **Vein** – large lumen relative to thickness of connective tissue and smooth muscle wall
- **Lymphatic** – small thin walled vessels which carry lymph



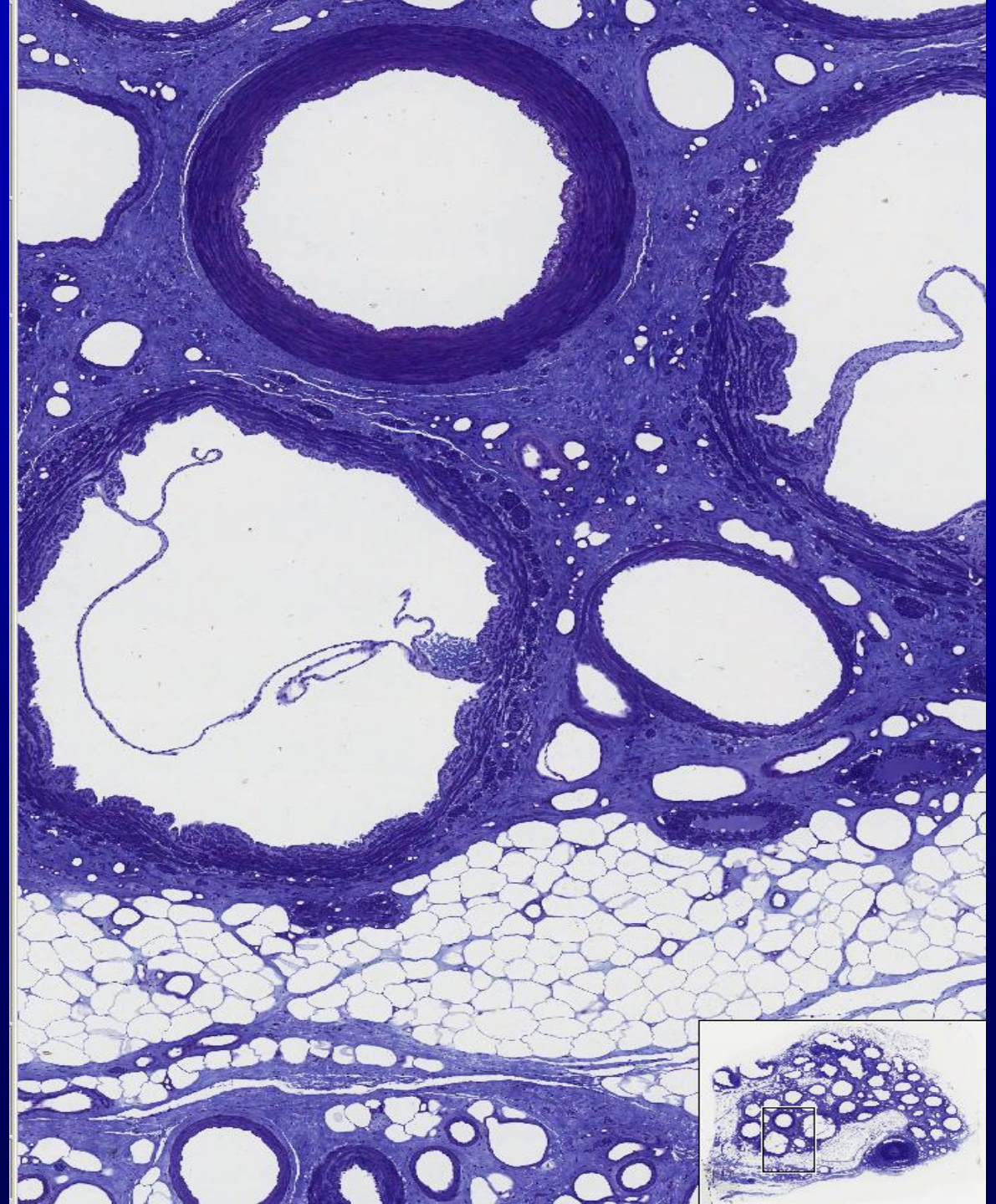


Fig. 10.7

Configuration of Arteries of the Thoracic Organs

In the area of the aortic arch, the arteries diverge to supply blood to the head, the upper extremeties and the upper half of the torso.

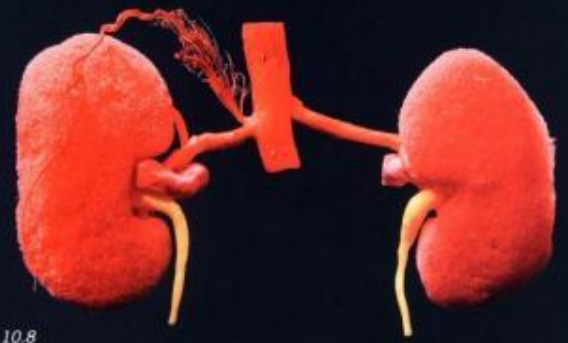


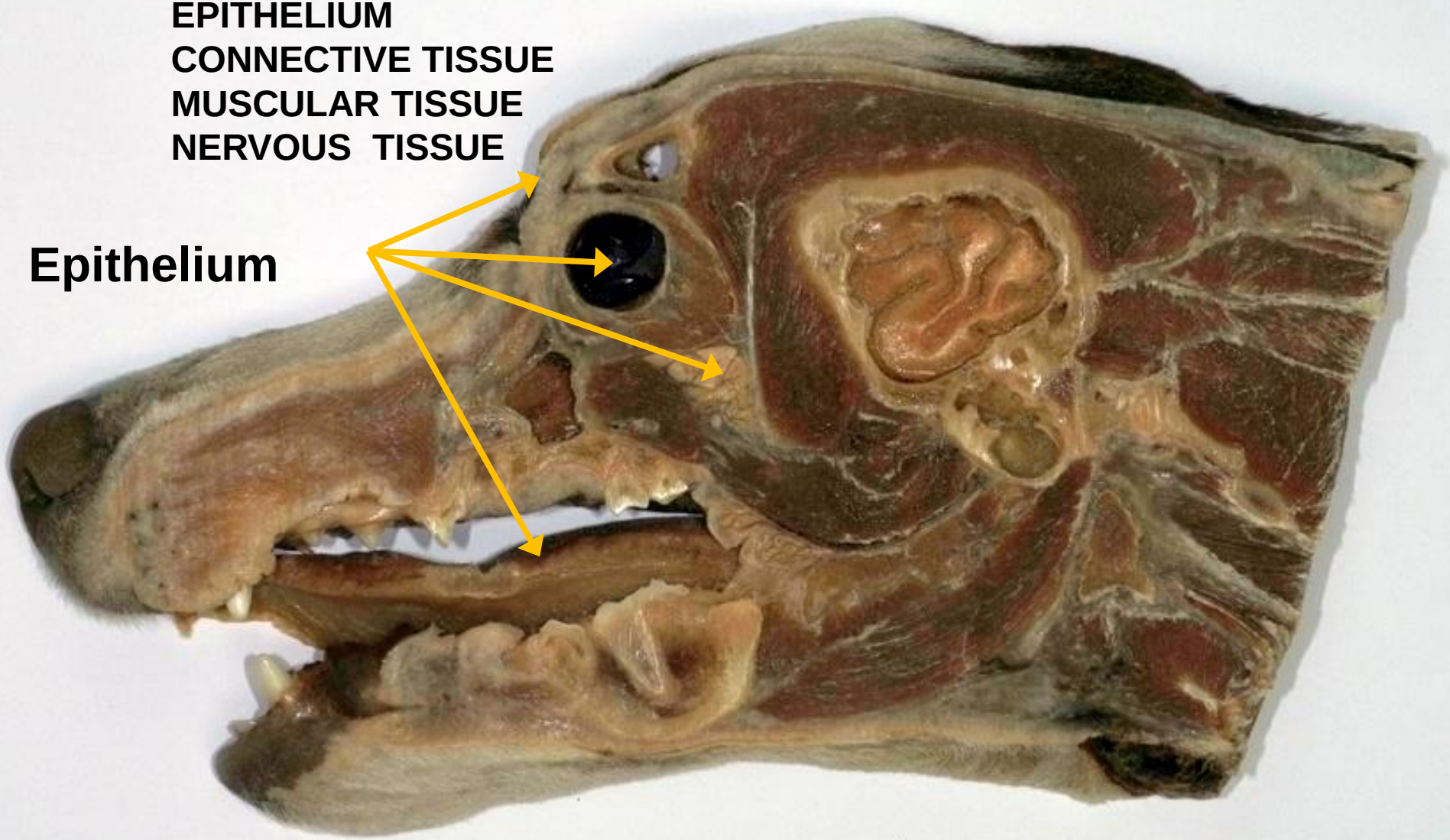
Fig. 10.8

Configuration of the Renal Arteries

Shown are the renal arteries (view from the rear) and the ureters that drain urine from the kidneys (yellow). The renal arteries flow into extremely fine capillary tufts or glomeruli (Malpighian or renal corpuscles) in the kidney tissue, which then filter the incoming blood.

Where are these basic tissues located?

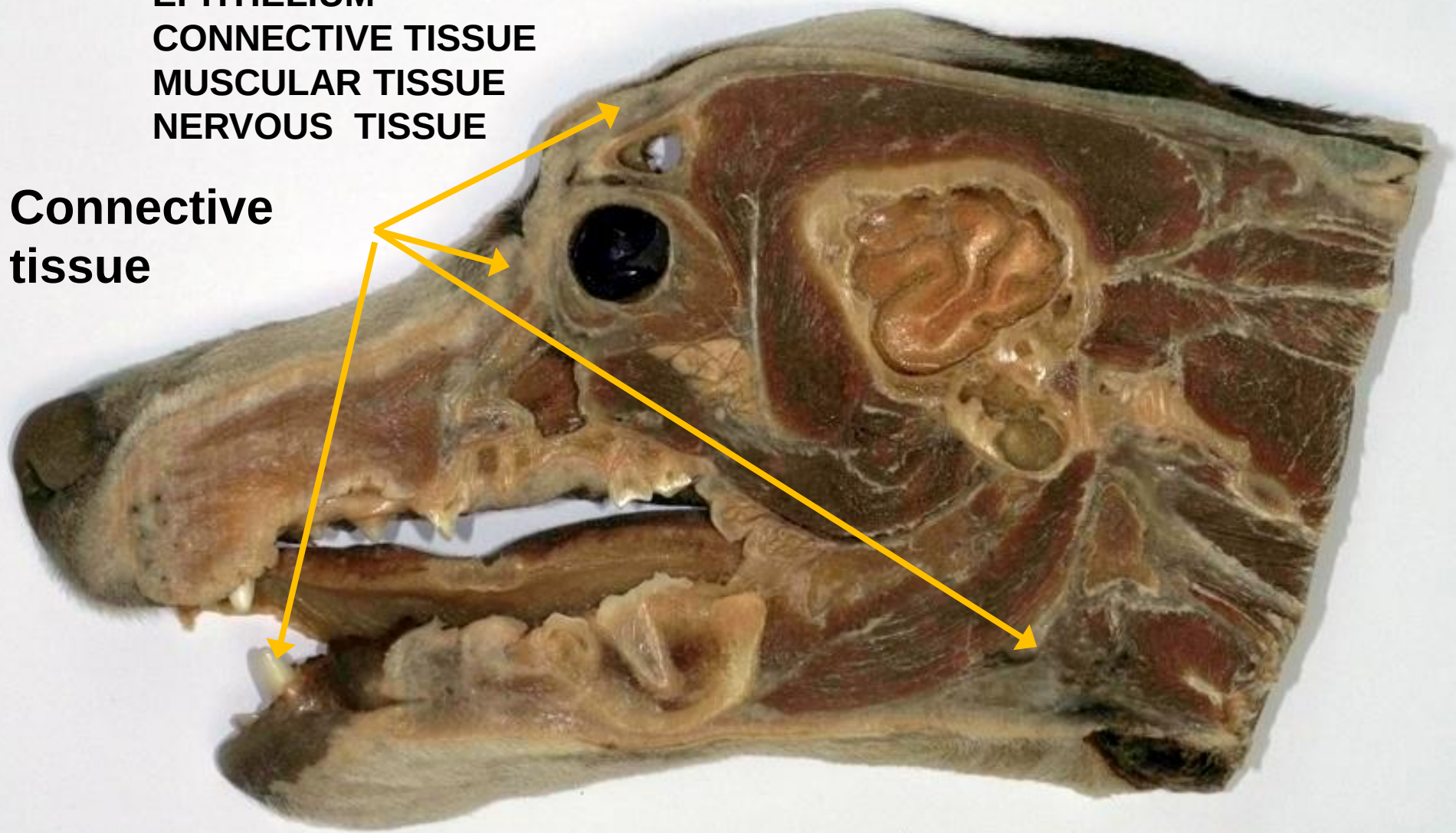
EPITHELIUM
CONNECTIVE TISSUE
MUSCULAR TISSUE
NERVOUS TISSUE



Where are these basic tissues located?

EPITHELIUM
CONNECTIVE TISSUE
MUSCULAR TISSUE
NERVOUS TISSUE

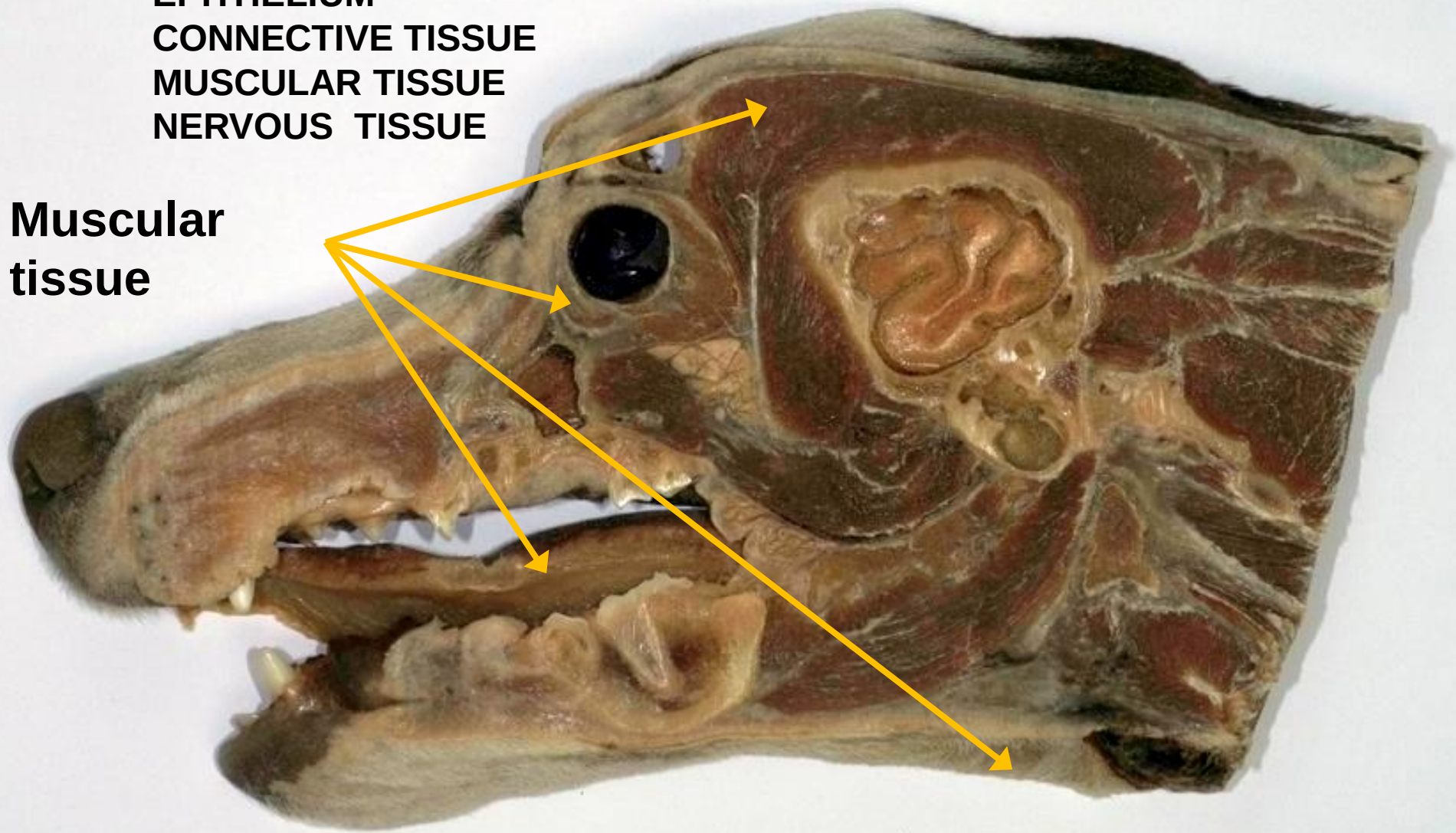
Connective tissue



Where are these basic tissues located?

EPITHELIUM
CONNECTIVE TISSUE
MUSCULAR TISSUE
NERVOUS TISSUE

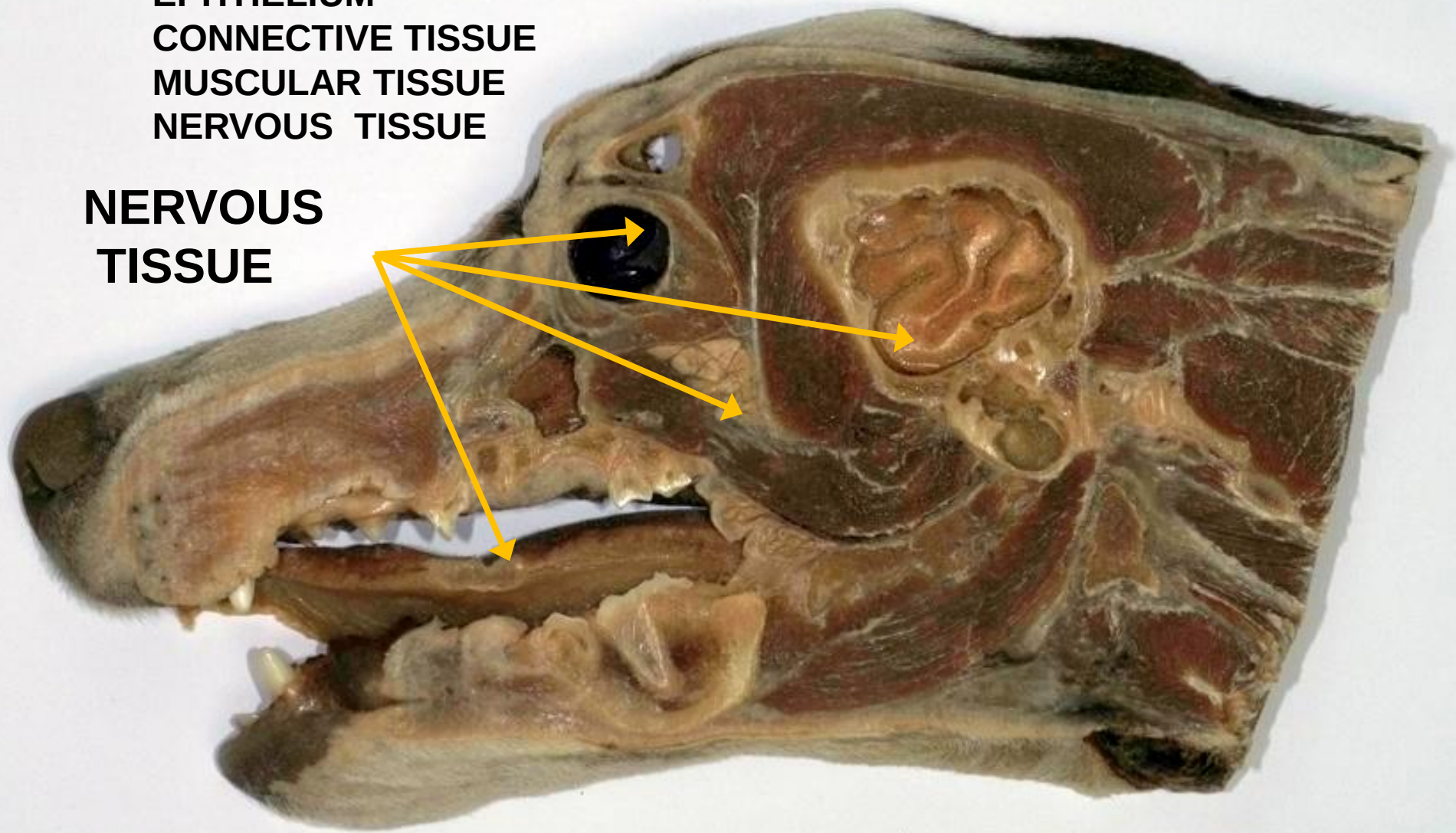
Muscular tissue

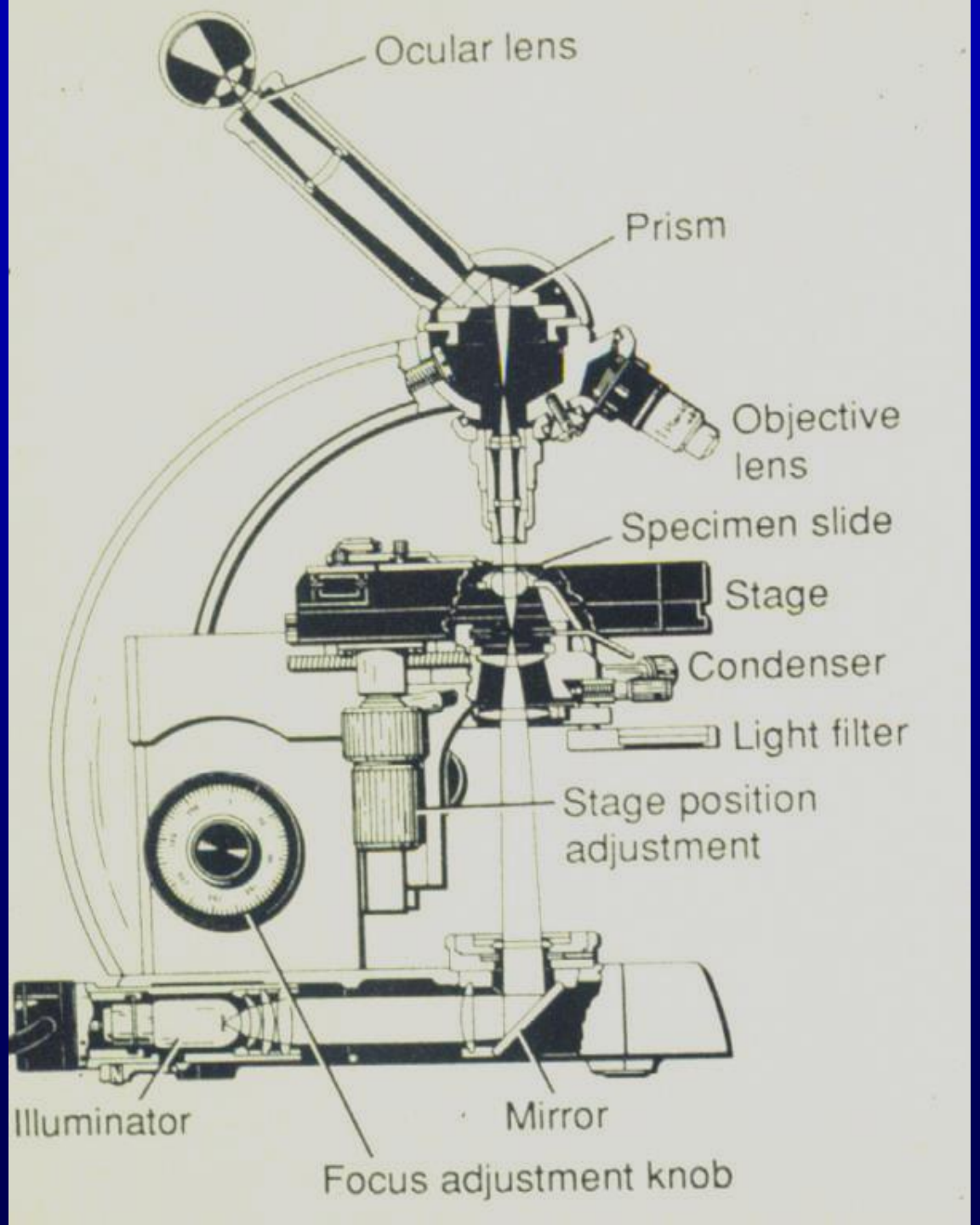


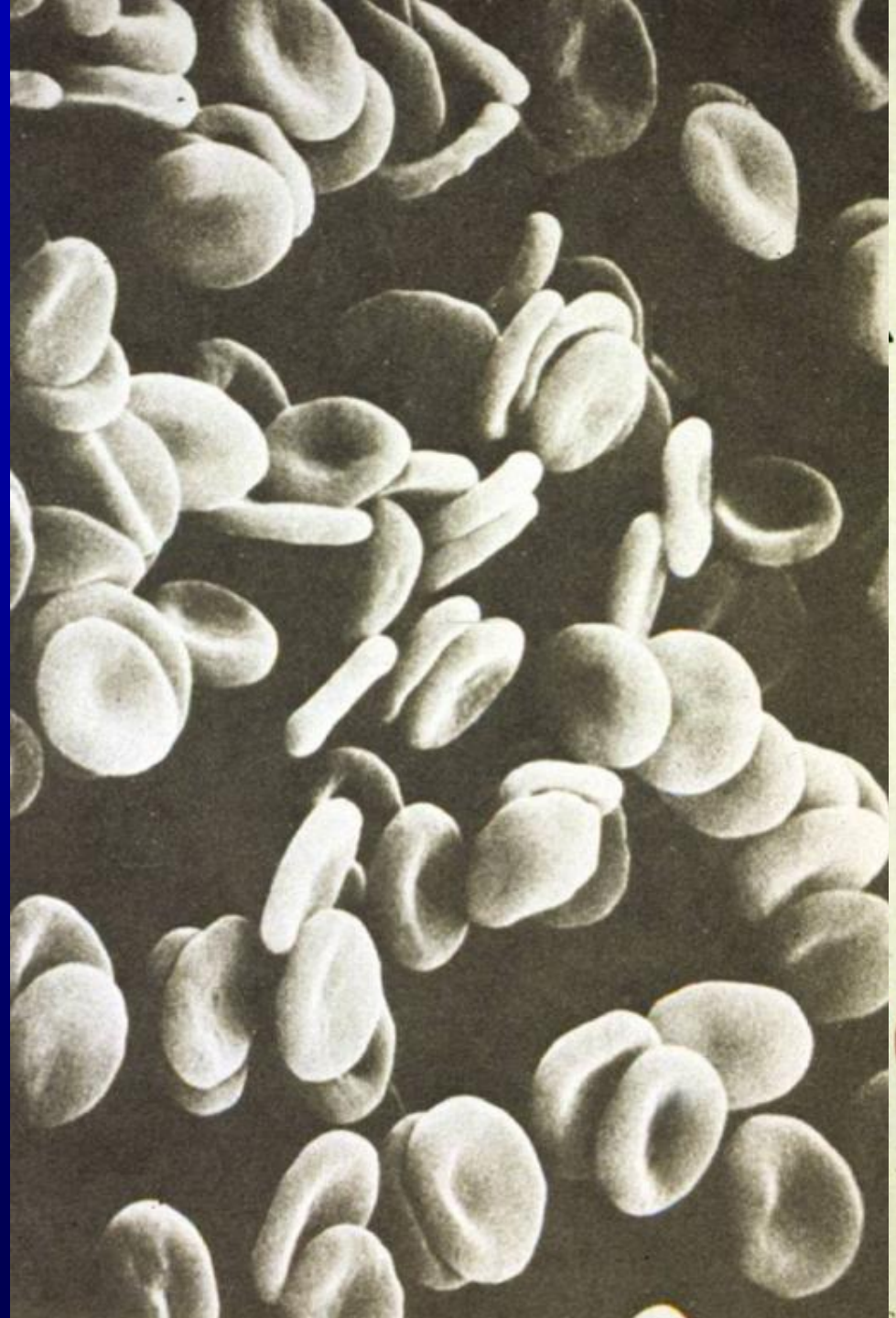
Where are these basic tissues located?

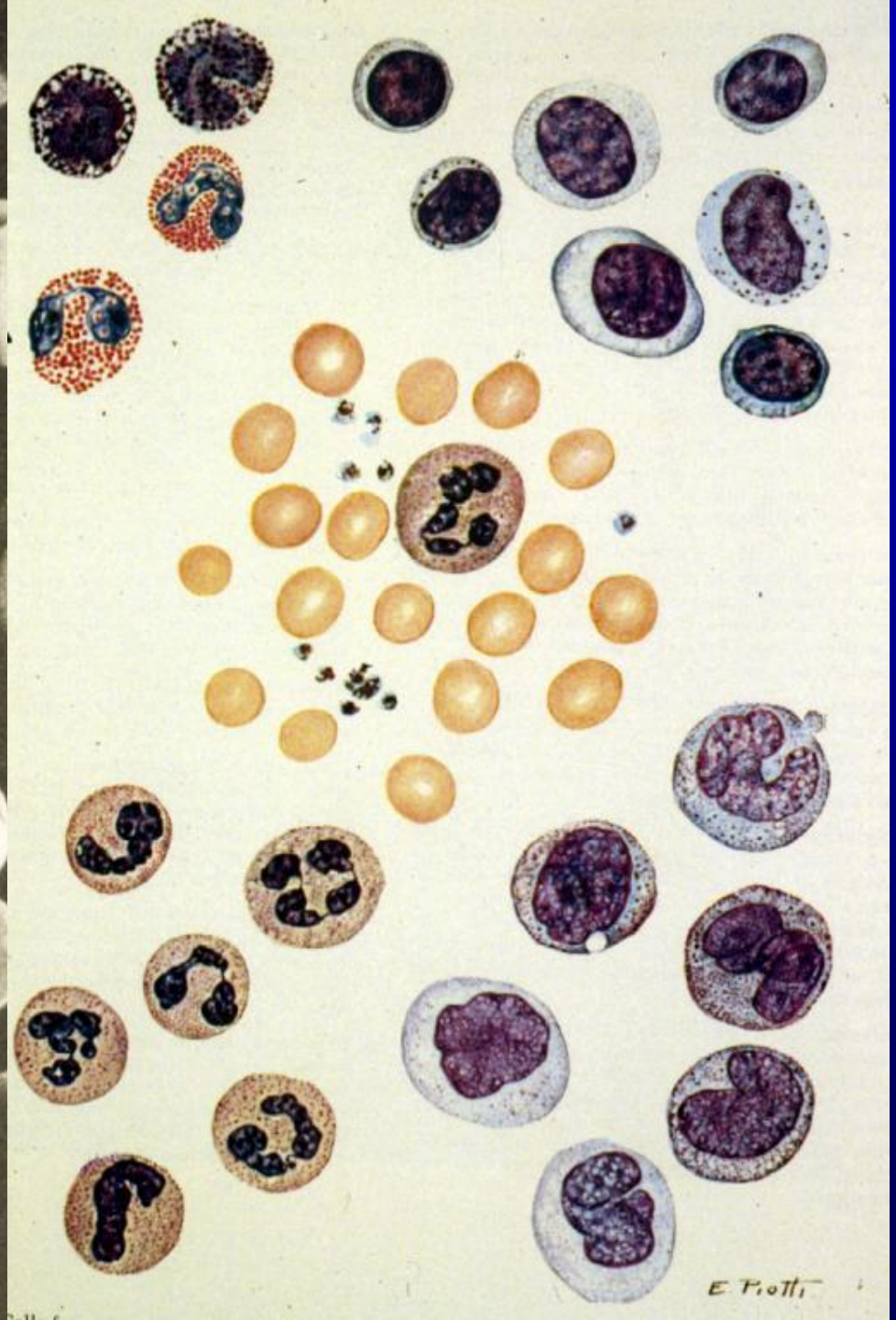
EPITHELIUM
CONNECTIVE TISSUE
MUSCULAR TISSUE
NERVOUS TISSUE

NERVOUS TISSUE




Ocular lens
Prism
Objective lens
Specimen slide
Stage
Condenser
Light filter
Stage position adjustment
Illuminator
Mirror
Focus adjustment knob




E. Piotti

Magnification vs. Resolution

1. Magnification - increase in image size
2. Resolution - smallest distance between two points that can be seen (distinguished)

Magnification vs. Resolution

1. magnification - increase in image size
2. resolution - smallest distance between two points that can be seen (distinguished)

Calculated by:

0.61 (wavelength) / numerical aperture

0.25 um for light microscope

0.1 nm for electron microscope

Sample Preparation

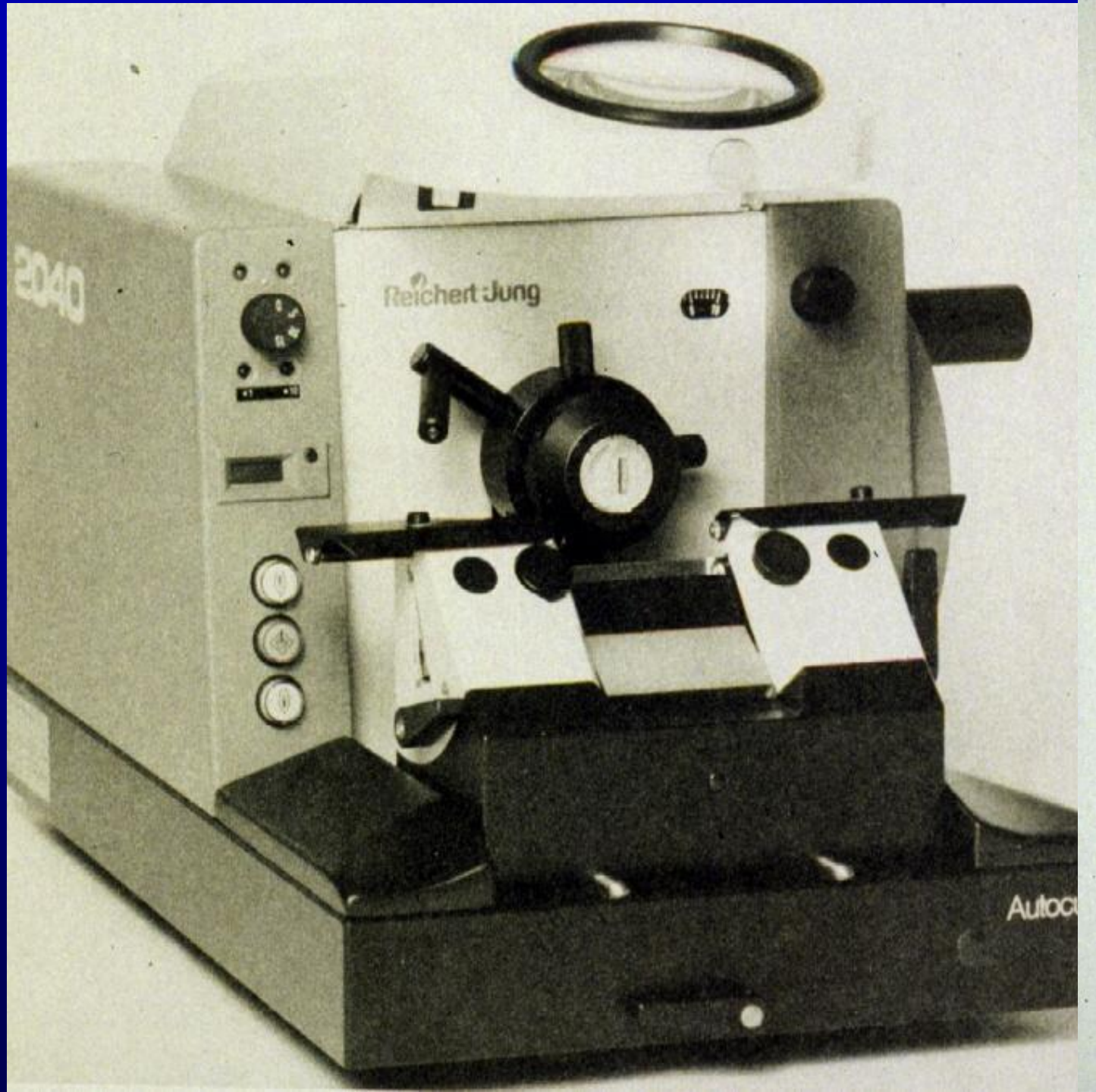
1. Fixation
2. Embedding
    A. Paraffin
    B. Plastic

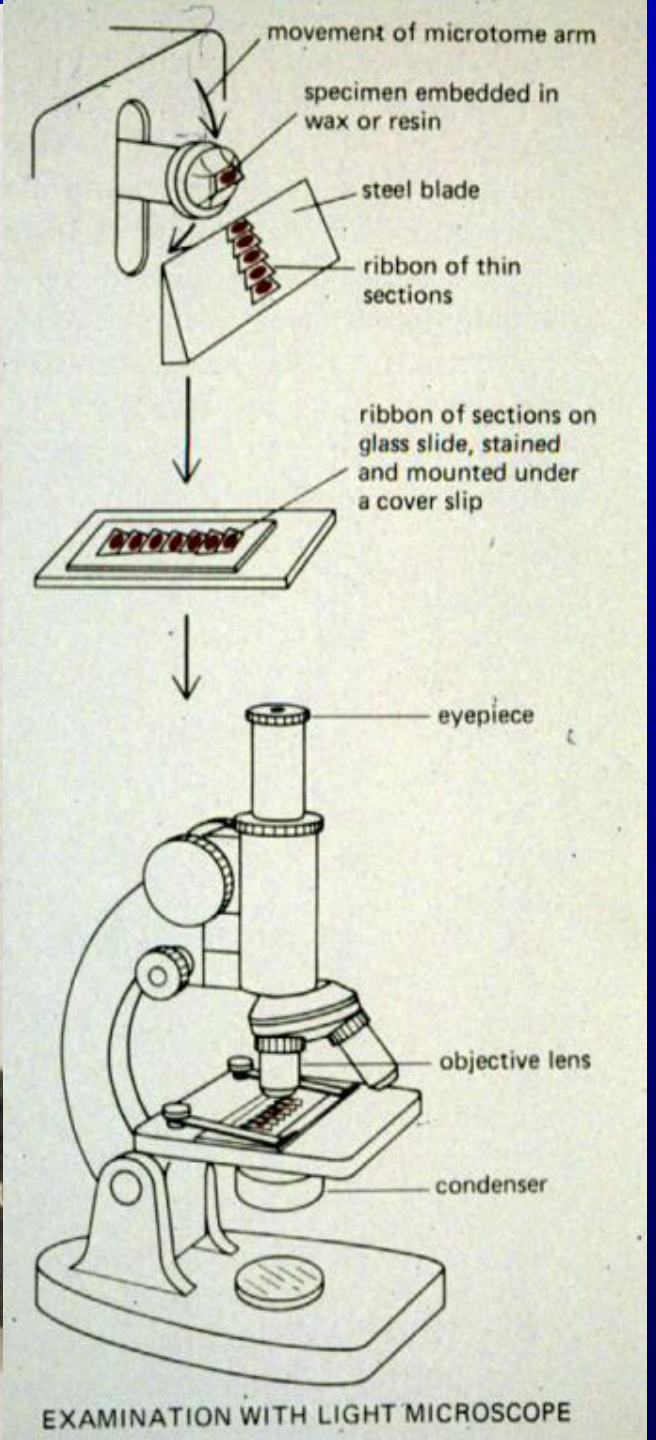
Sample Preparation

1. Fixation
2. Embedding
   A. Paraffin
   B. Plastic
3. Sectioning
   A. 0.5 um for Light Microscopy
   B. 60-80 nm for Electron Microscopy

Table 1–2. Typical sequence of procedures in preparing tissues for observation under the light microscope. Following embedding in paraffin blocks, the tissues can be sectioned with a microtome (Fig 1–1).

Stage	Purpose	Duration
1. Fixation in simple or compound fixatives (Bouin's fluid, Zenker's formalin)	To preserve tissue morphology and molecular composition	About 12 h, according to the fixative and the size of the piece of tissue
2. Dehydration in graded concentrated ethyl alcohol (70% up to 100% alcohol)	To replace tissue water with organic solvents	6–24 h
3. Clearing in benzene, xylene, or toluene	To impregnate the tissues with a paraffin or a plastic resin solvent	1–6 h
4. Embedding in melted paraffin at 60 °C or plastic resin at room temperature	Paraffin or resin penetrates all intercellular spaces and even into the cells, making the tissues more resistant to sectioning	1–3 h



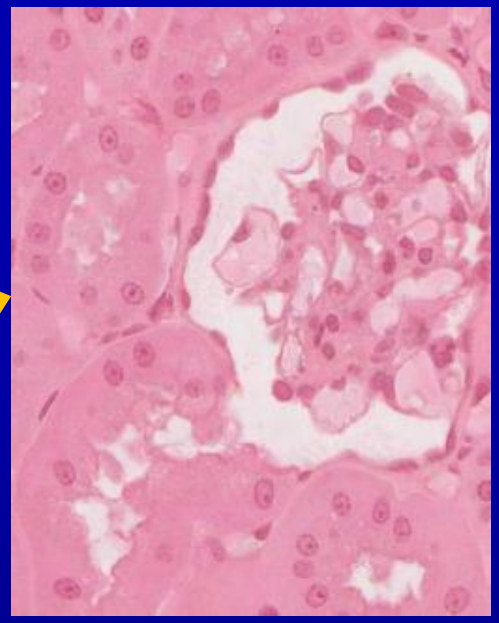


EXAMINATION WITH LIGHT MICROSCOPE

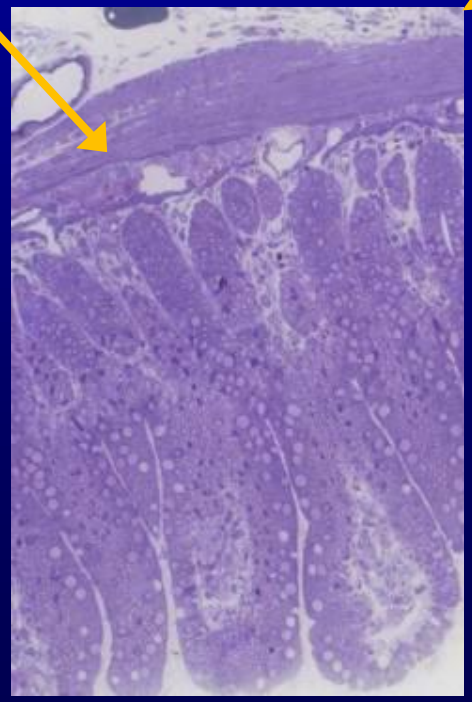
Sample Preparation

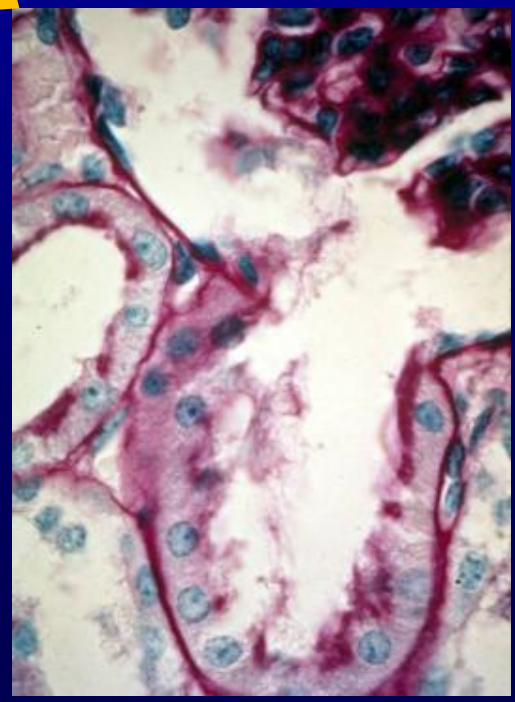
Staining

1. **Light Microscopy**
   - A. Hematoxylin and Eosin (H&E)
   - B. Periodic Acid/Shiff (PAS)
   - C. Toluidine Blue



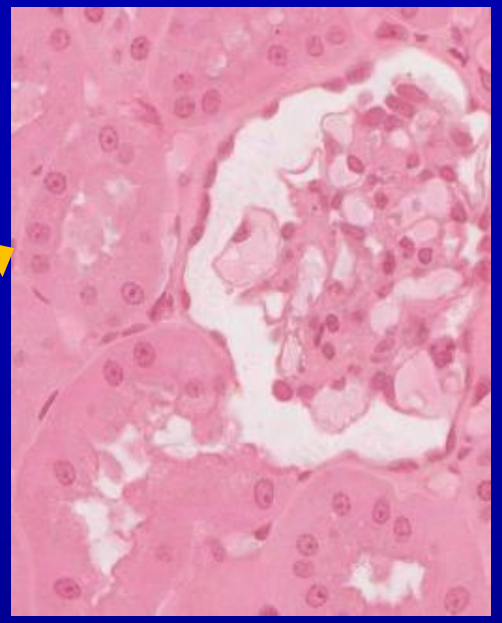
2. **Electron Microscopy (TEM)**
   - A. Osmium
   - B. Lead Citrate





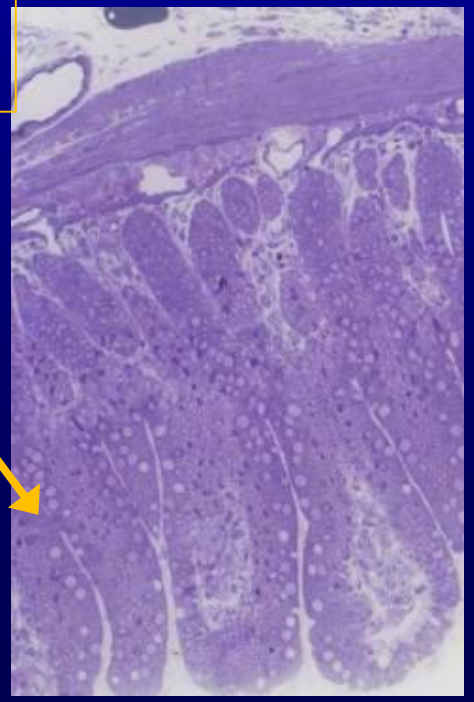
Staining

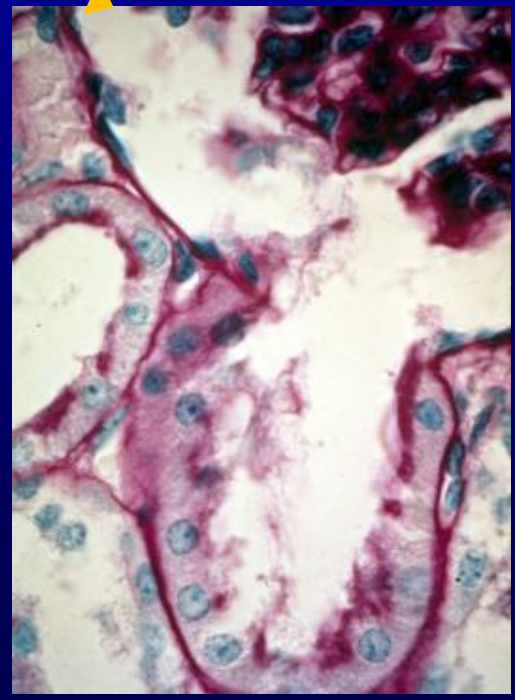
1. Light Microscopy
   A. Hematoxylin and eosin (H&E)



   B. Periodic Acid/Shiff (PAS)

Color provides clues



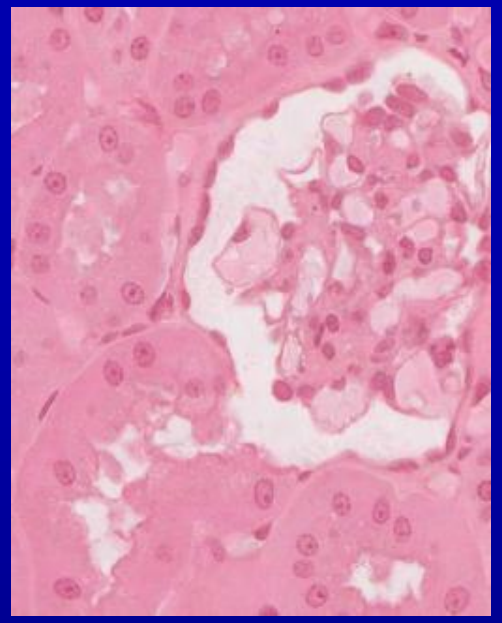


   C. Toluidine Blue

Shape
Size
Intensity of staining

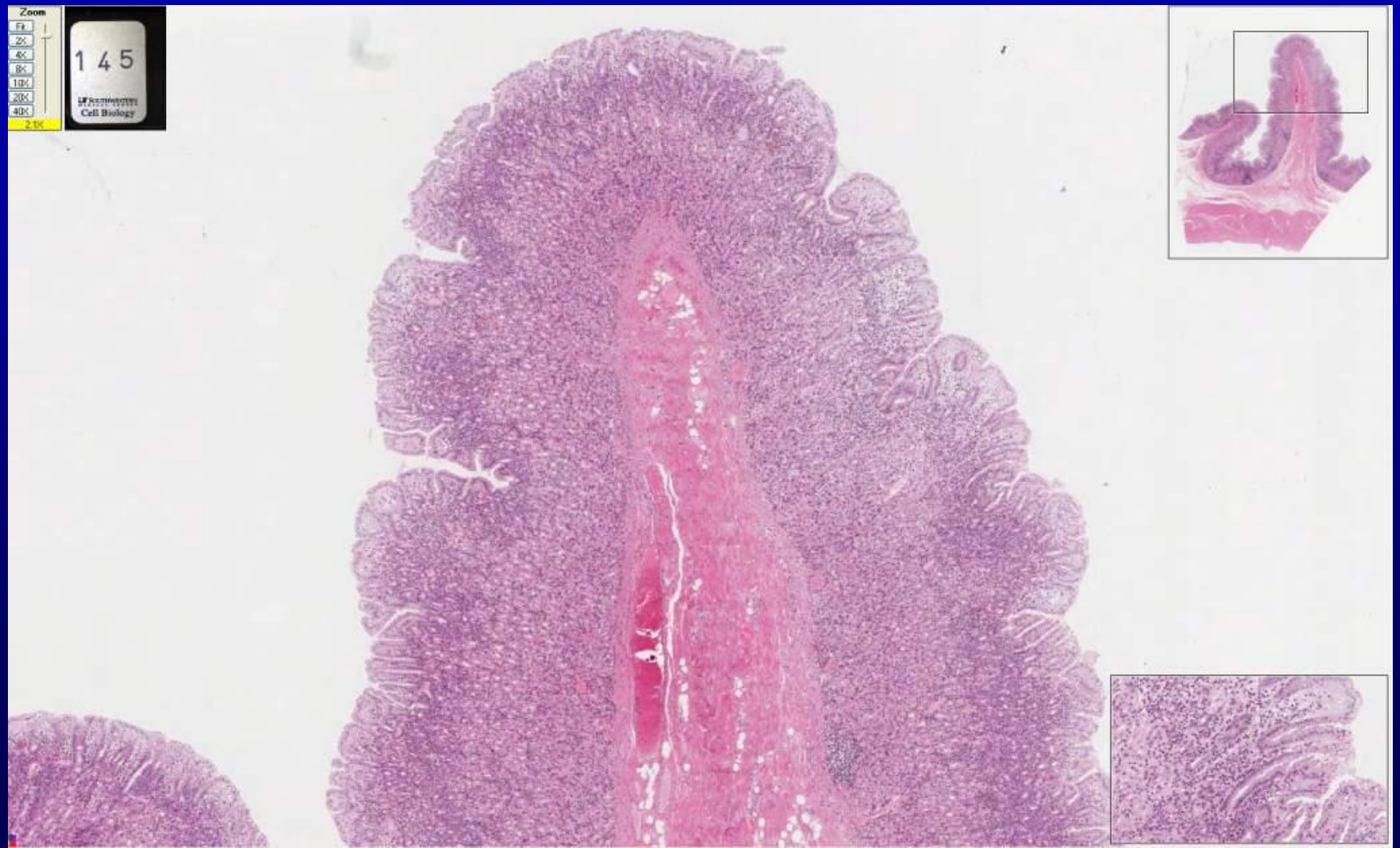
Staining

1. Light Microscopy
   A. Hematoxylin and Eosin (H&E)
   B. Periodic Acid/Shiff (PAS)
   C. Toluidine Blue

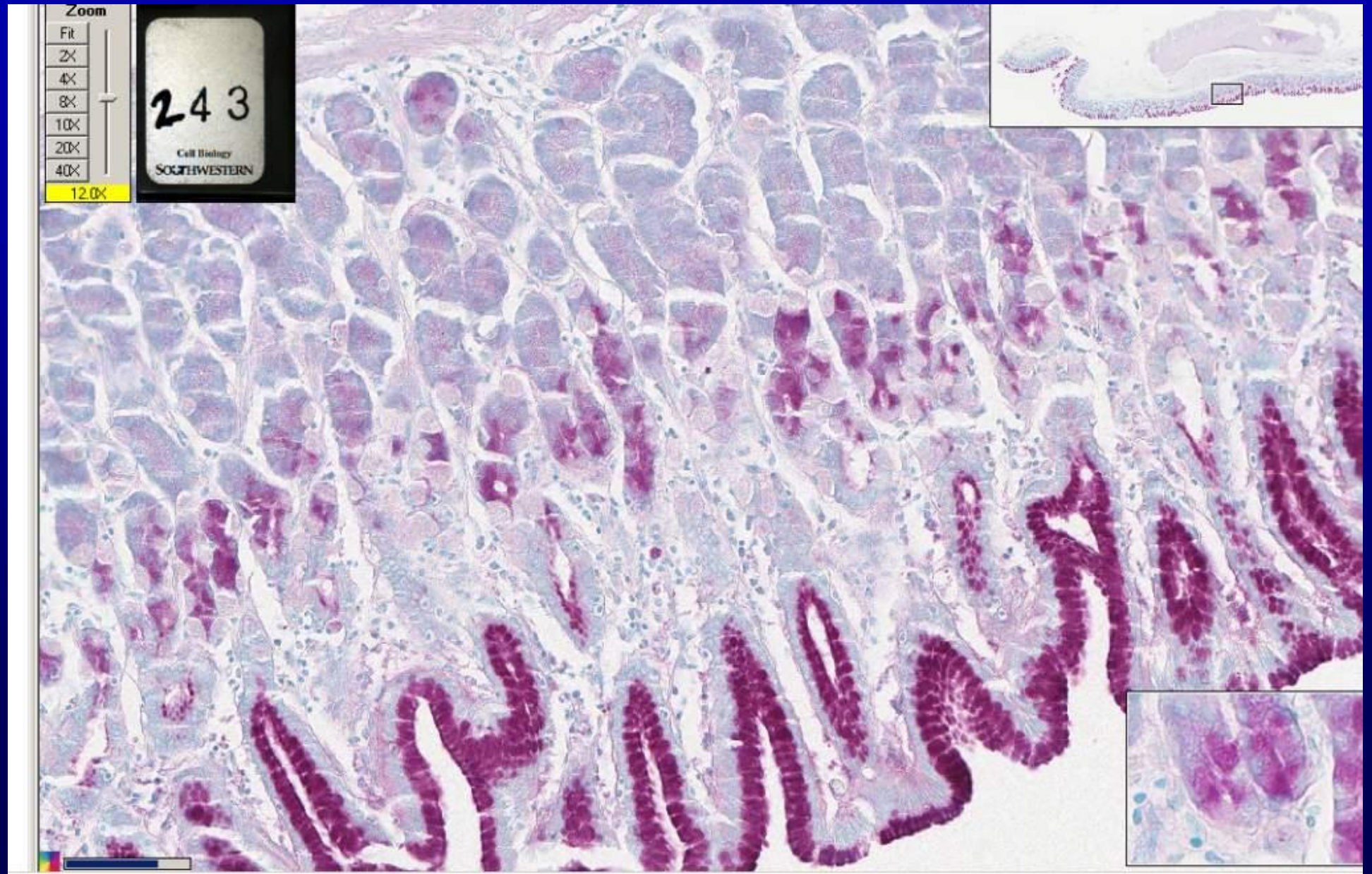


2. Electron Microscopy (TEM)
   A. Osmium
   B. Lead Citrate

145 Fundic stomach (H&E)

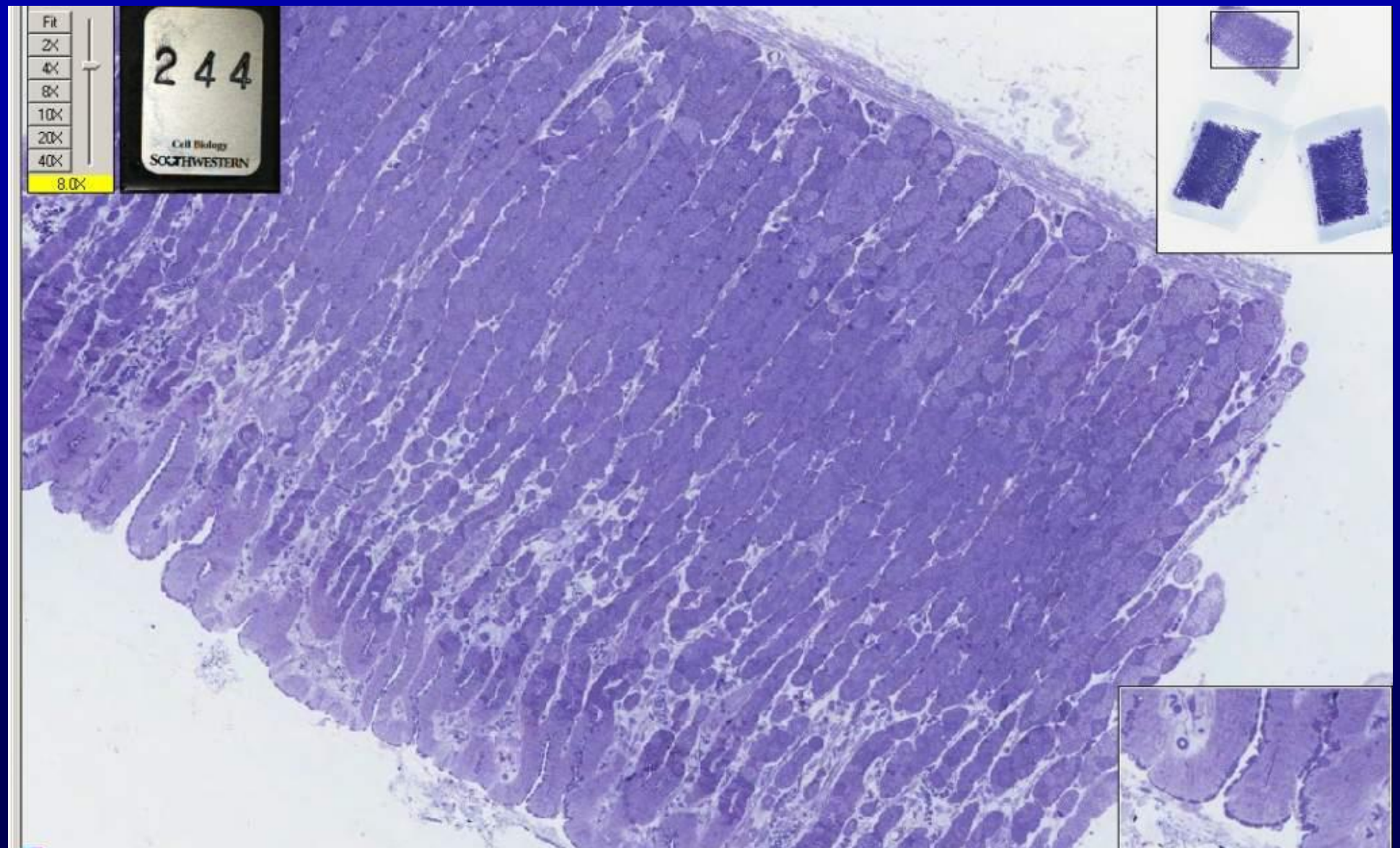


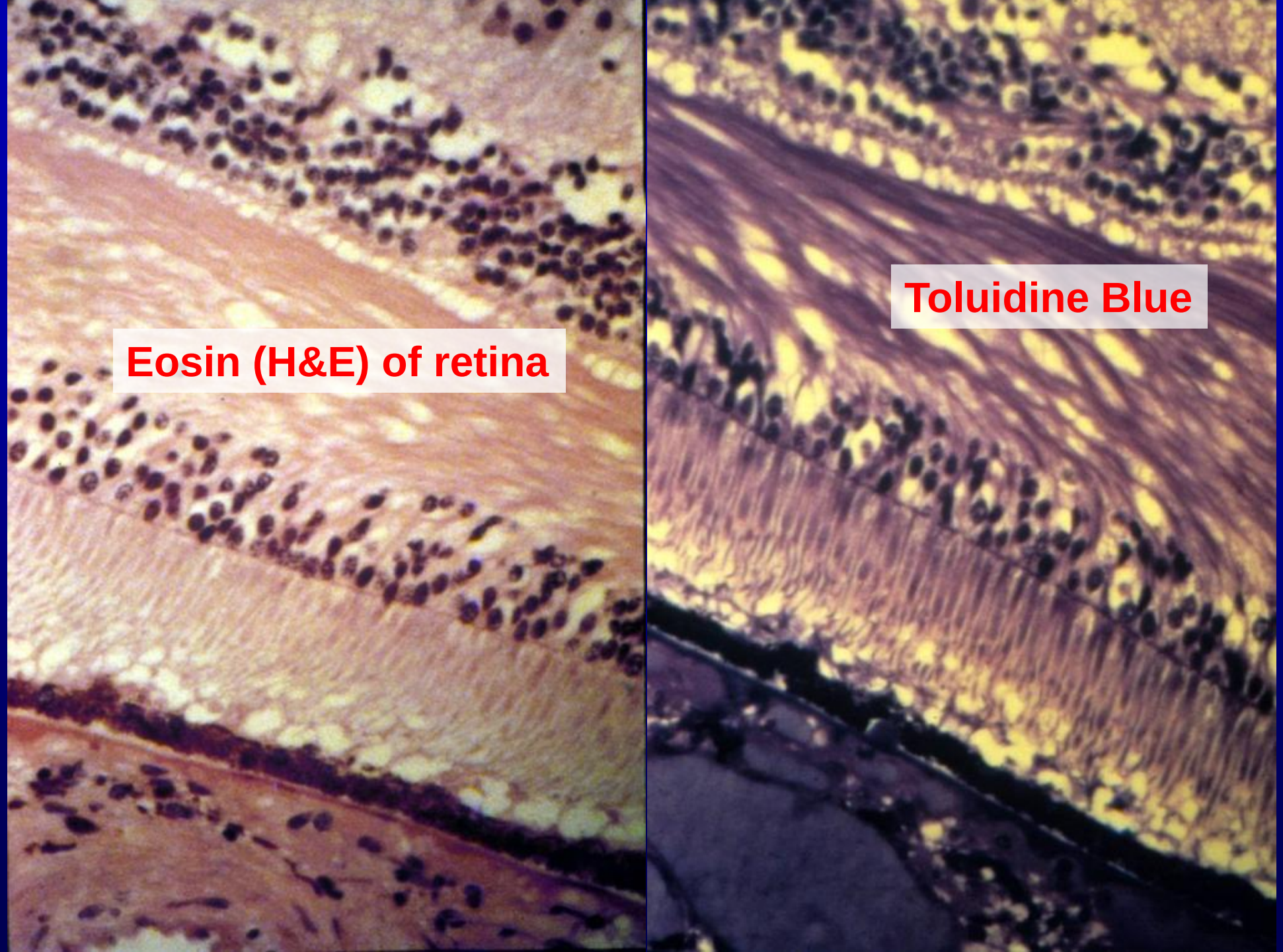
243 Fundic stomach, monkey (PAS)

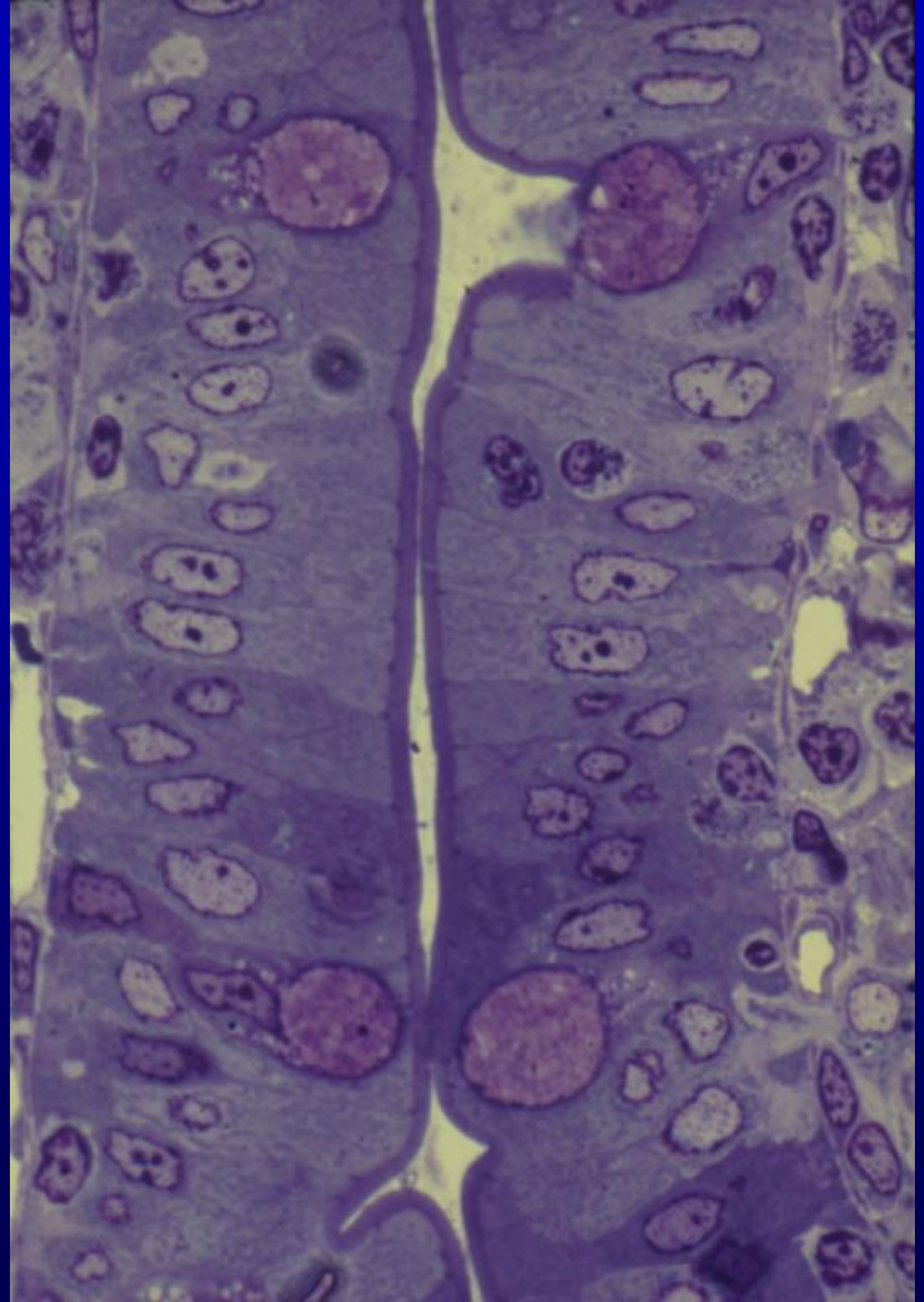


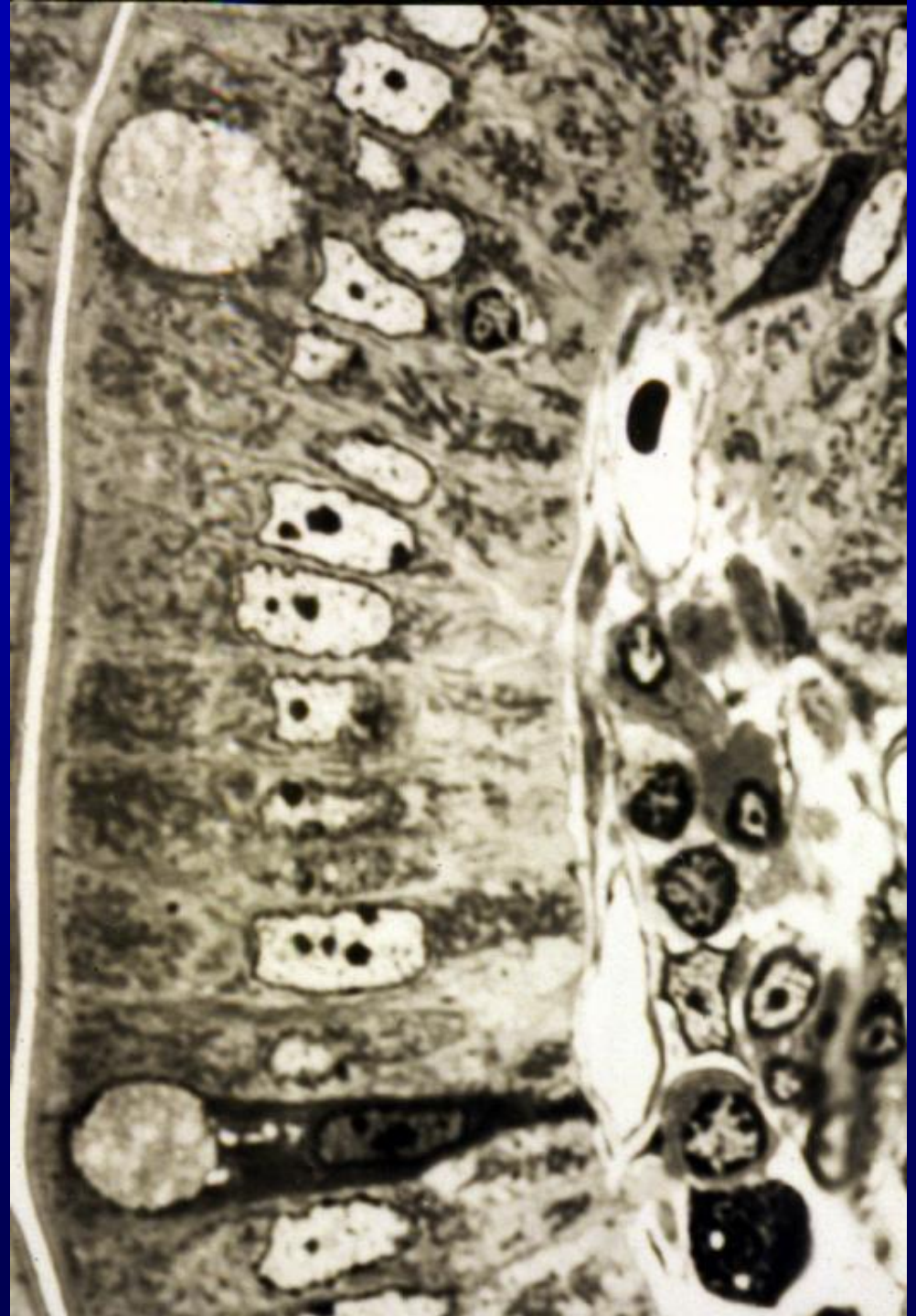
244

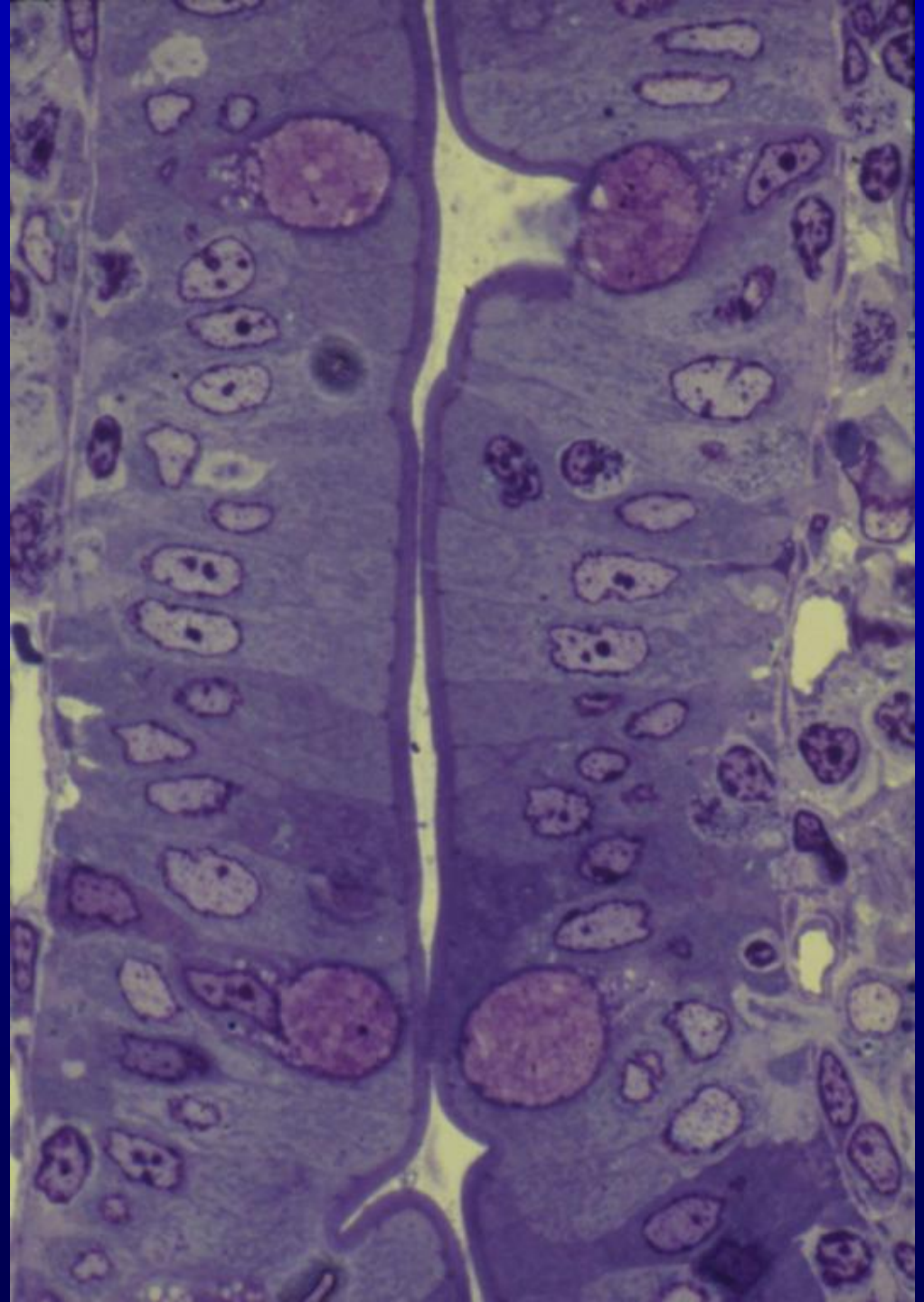
Surface mucus cells of Fundic stomach, rabbit (toluidine blue)

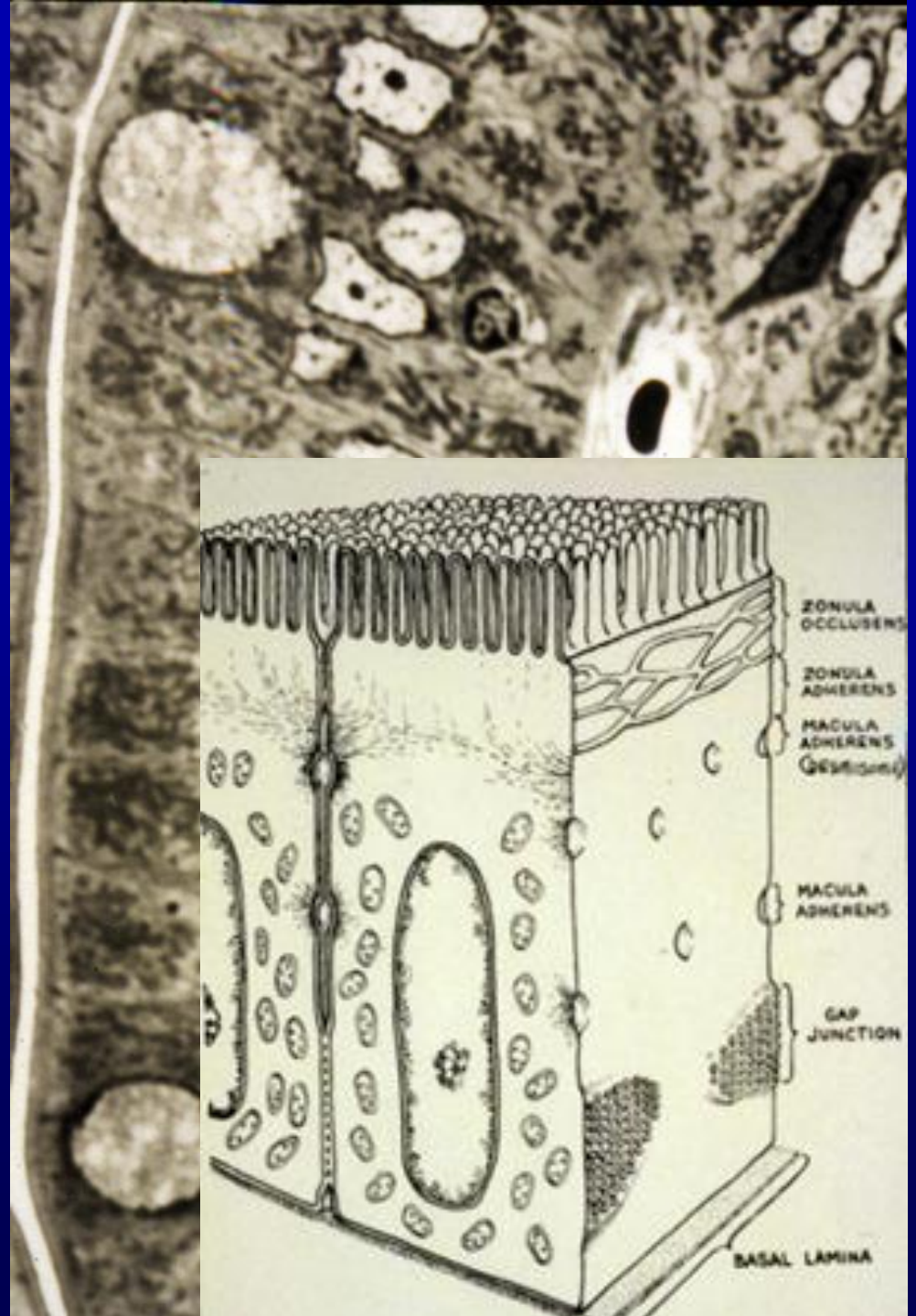


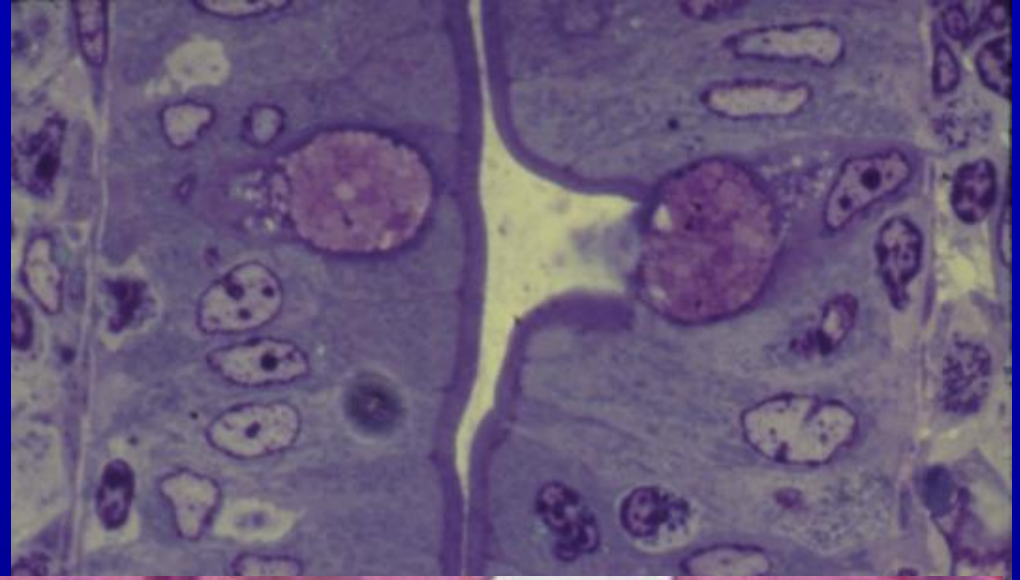

Eosin (H&E) of retina
Toluidine Blue

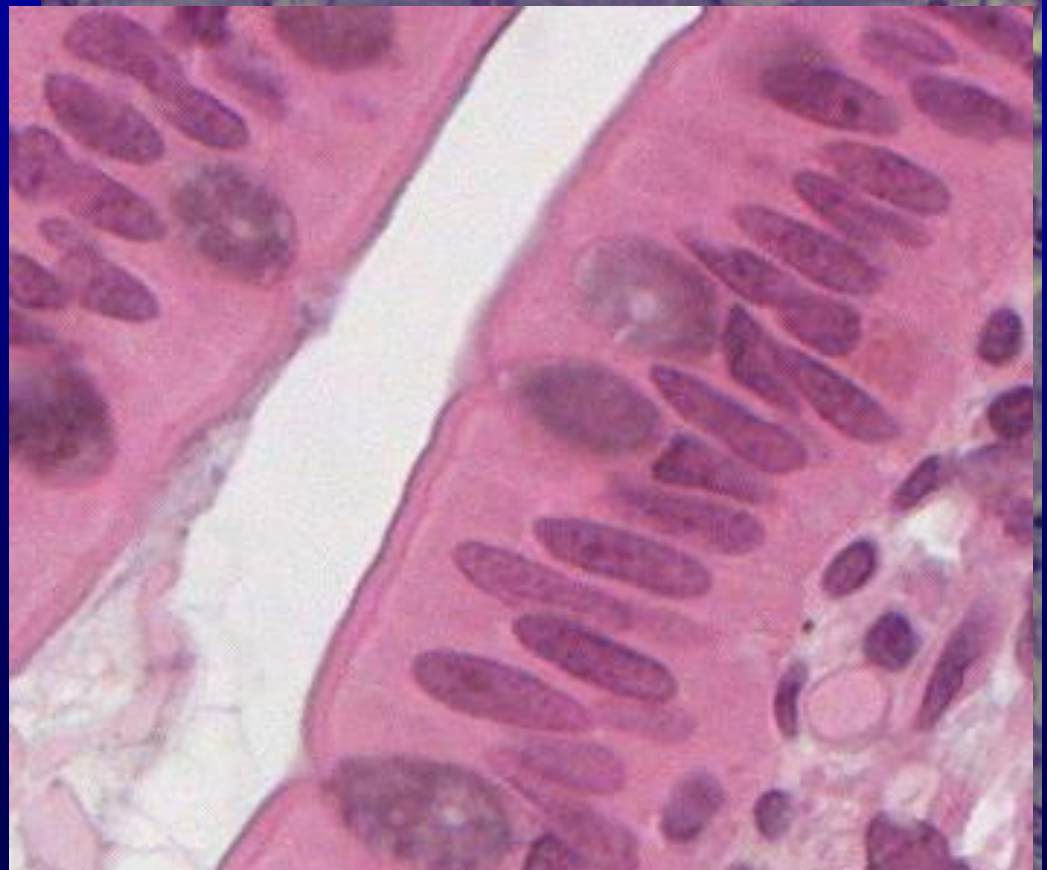


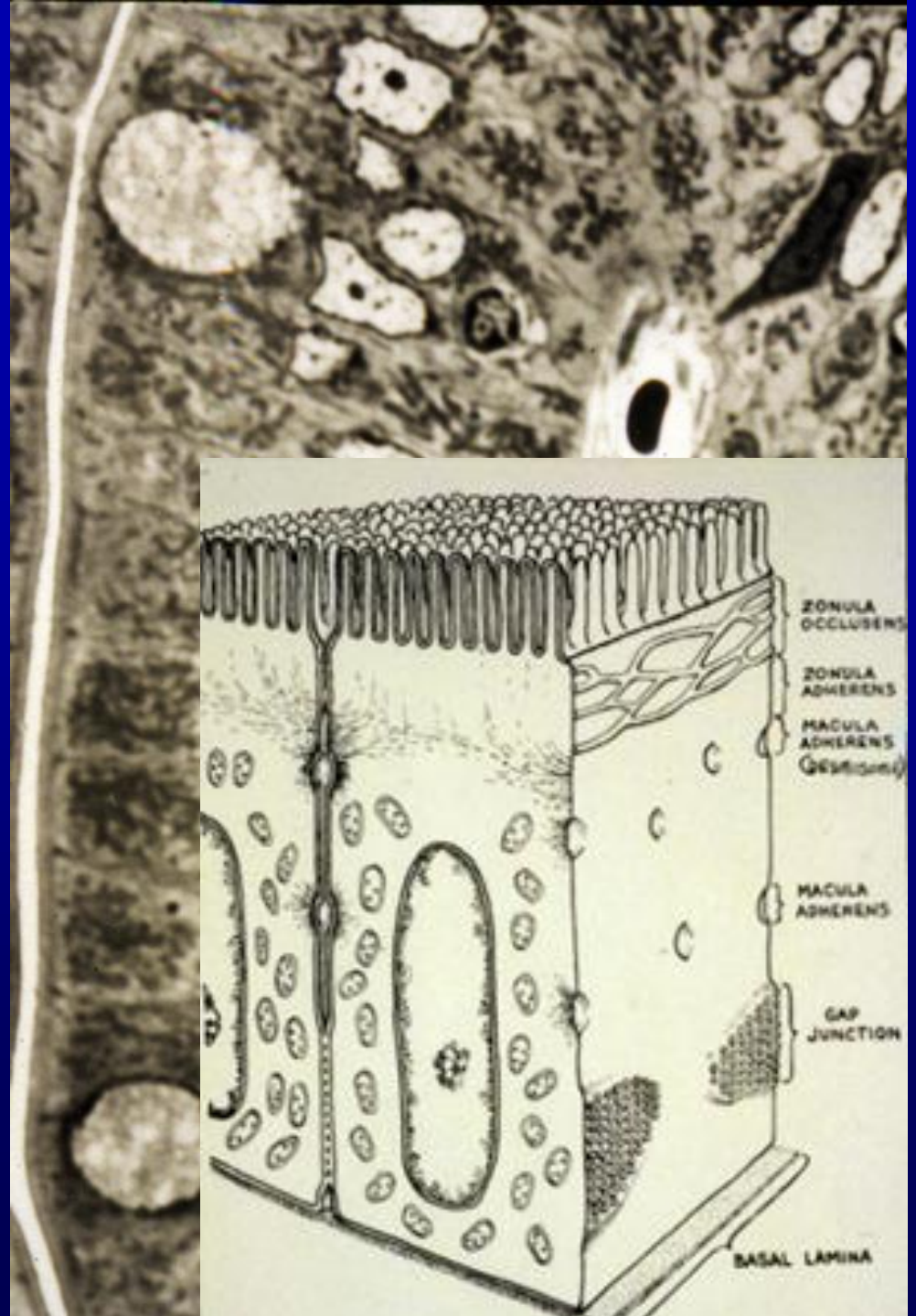





ZONULA OCCLUDENS
ZONULA ADHERENS
MACULA ADHERENS
MACULA ADHERENS
GAP JUNCTION
BASAL LAMINA






ZONULA OCCLUDENS
ZONULA ADHERENS
MACULA ADHERENS
MACULA ADHERENS
GAP JUNCTION
BASAL LAMINA

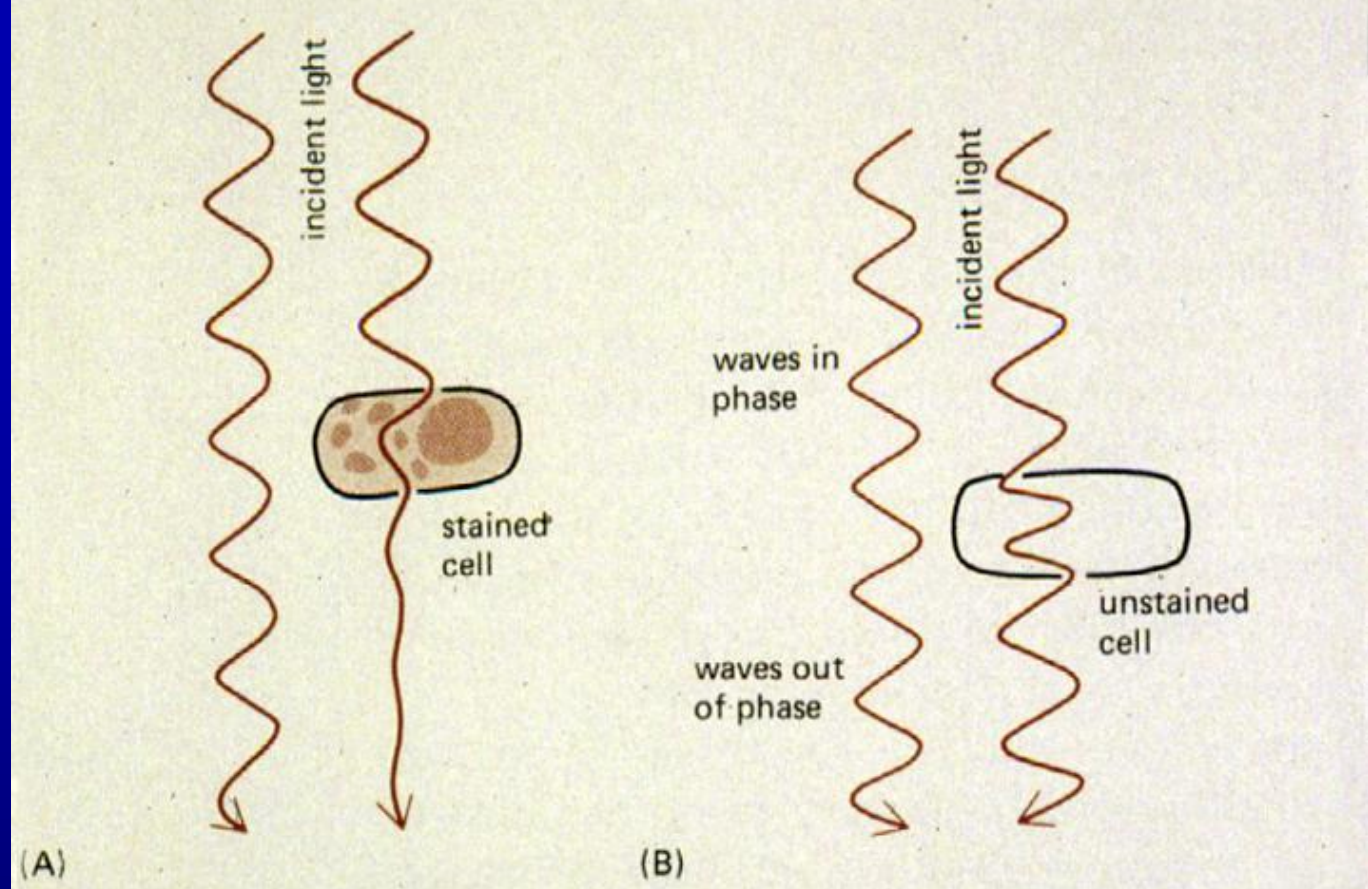
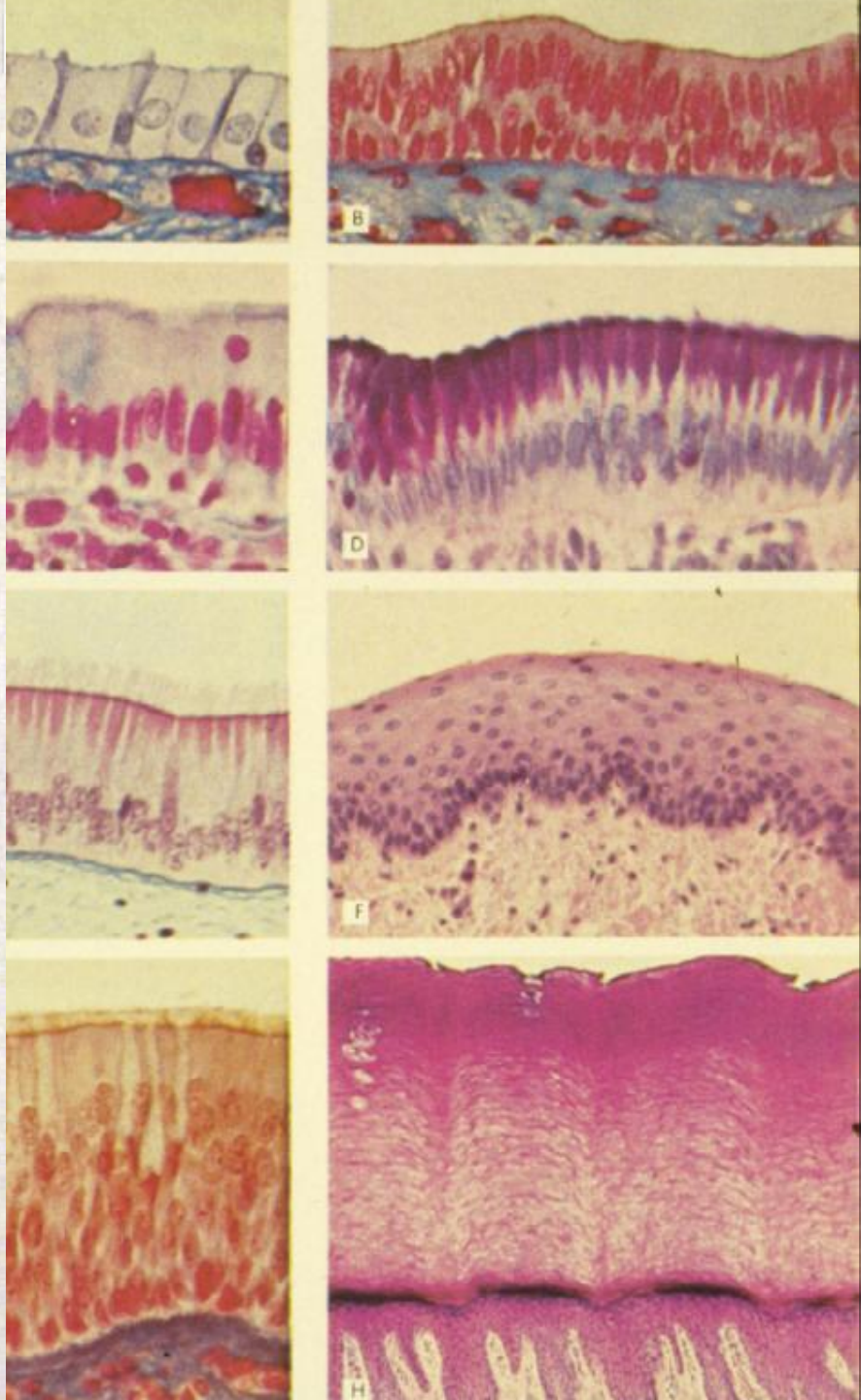
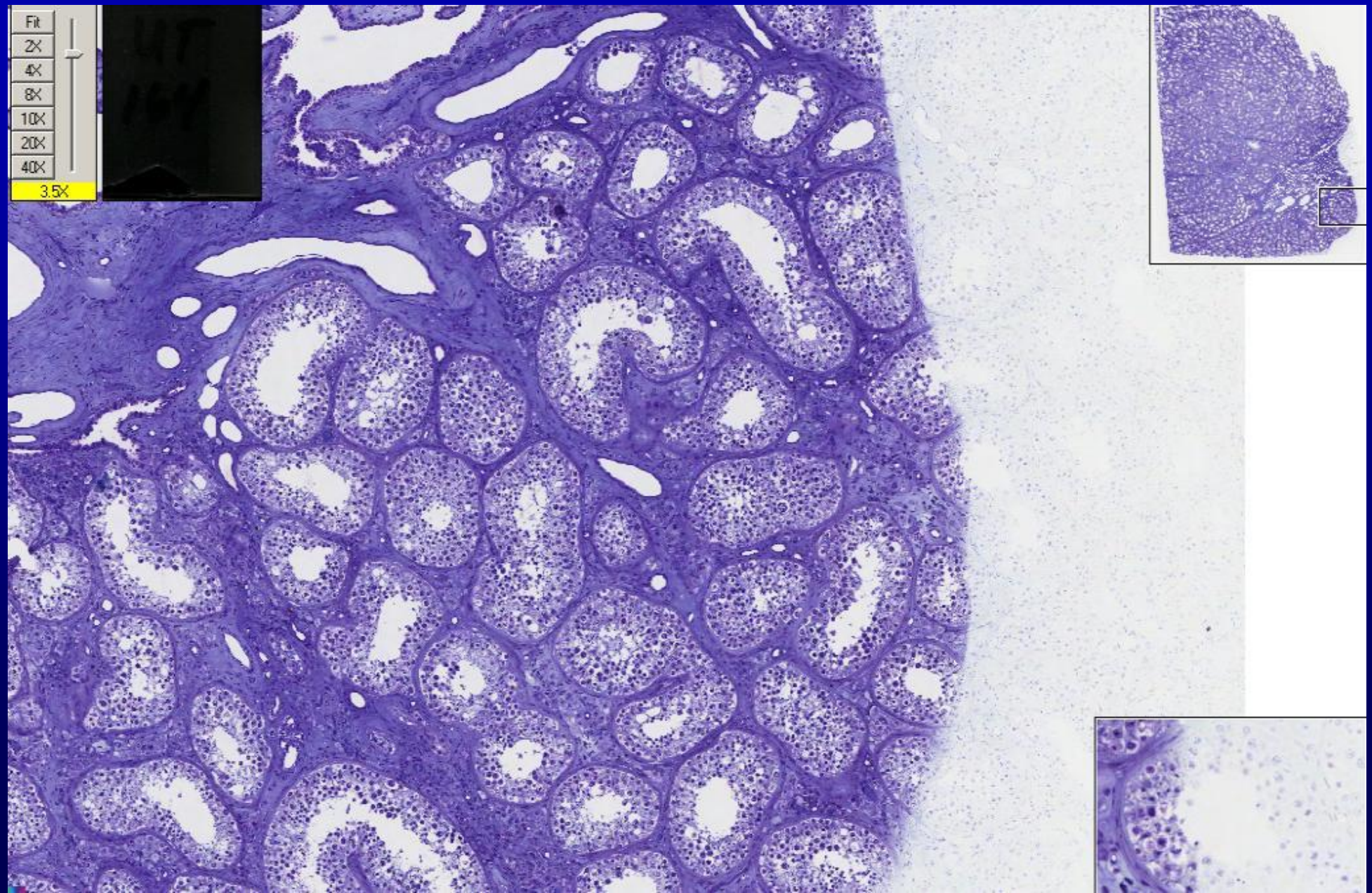


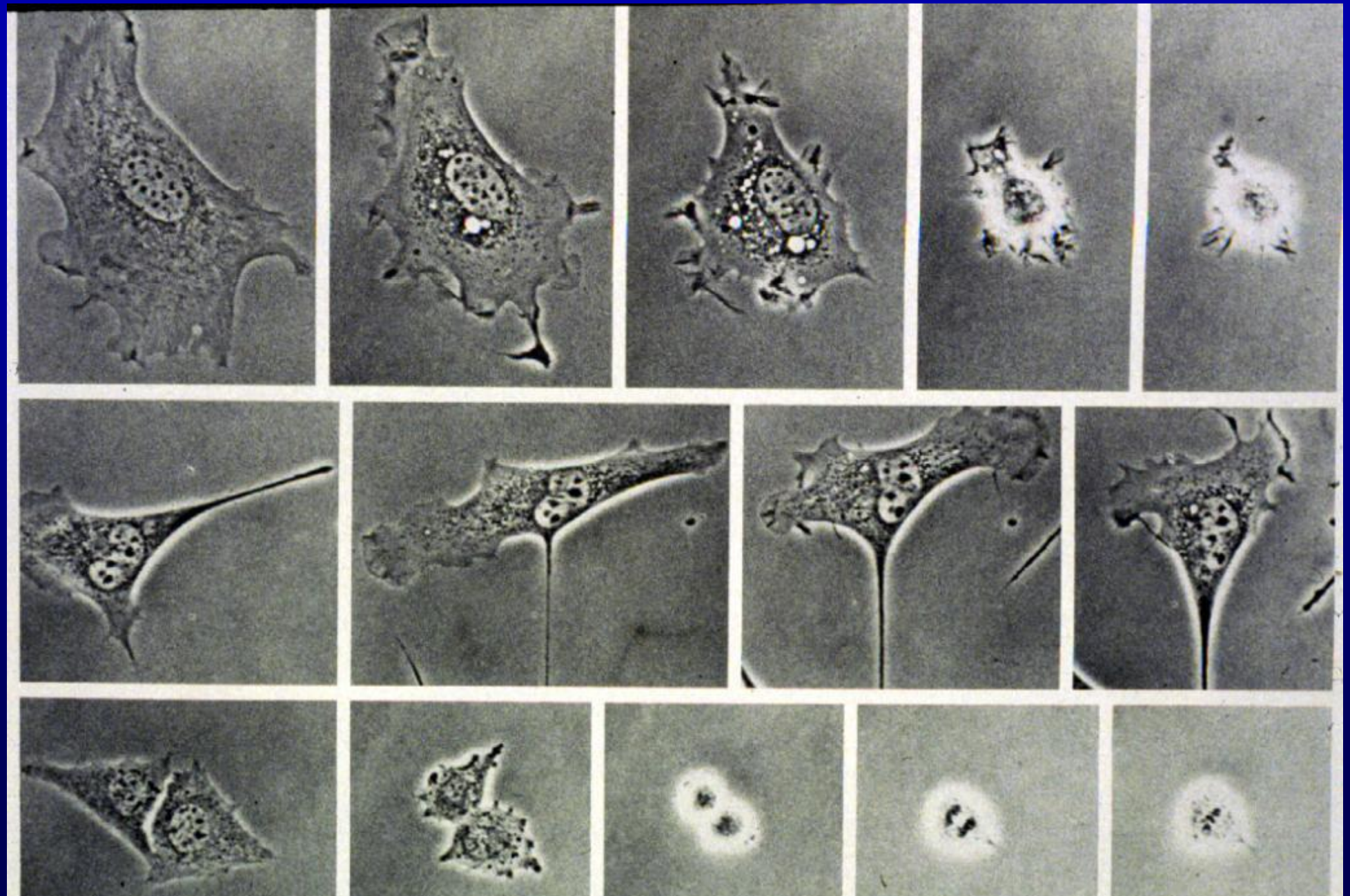
Figure 4–5 The stained portions of the cell in (A) reduce the amplitude of light waves of particular wavelengths passing through them. A colored image of the cell is thereby obtained that is visible by direct observation. Light passing through the unstained, living cell (B) does not undergo a major change in amplitude, and many details cannot, therefore, be seen directly; however, changes occur in the phase of this light that are exploited in phase-contrast and differential-interference-contrast microscopy to produce a high-contrast image.



19709 Transparency of unstained tissue



Phase Contrast



Dead stained cells

Bright Field

Live unstained cells

Phase Contrast

Nomarksi

“differential interference contrast”

Dark Field

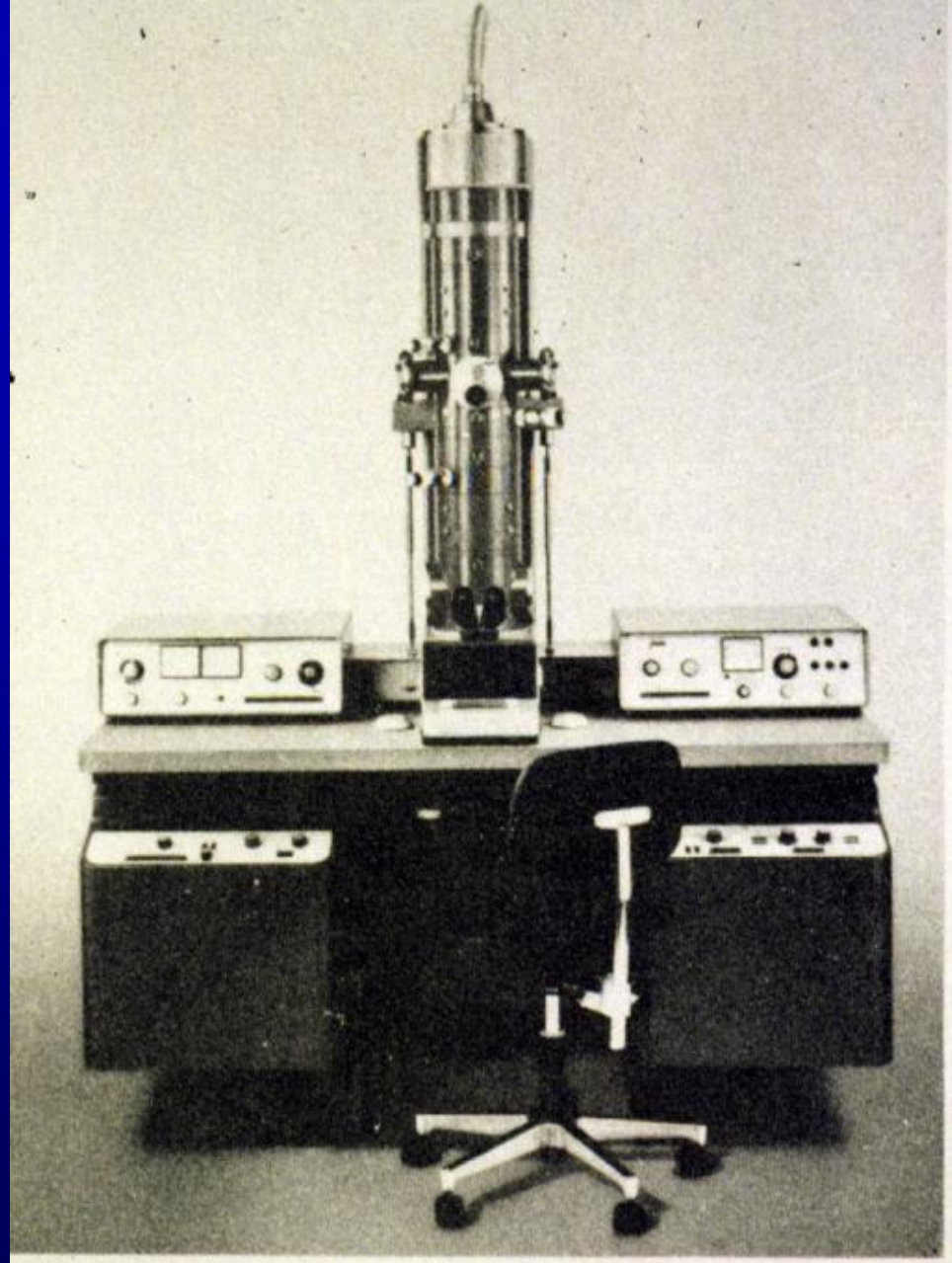
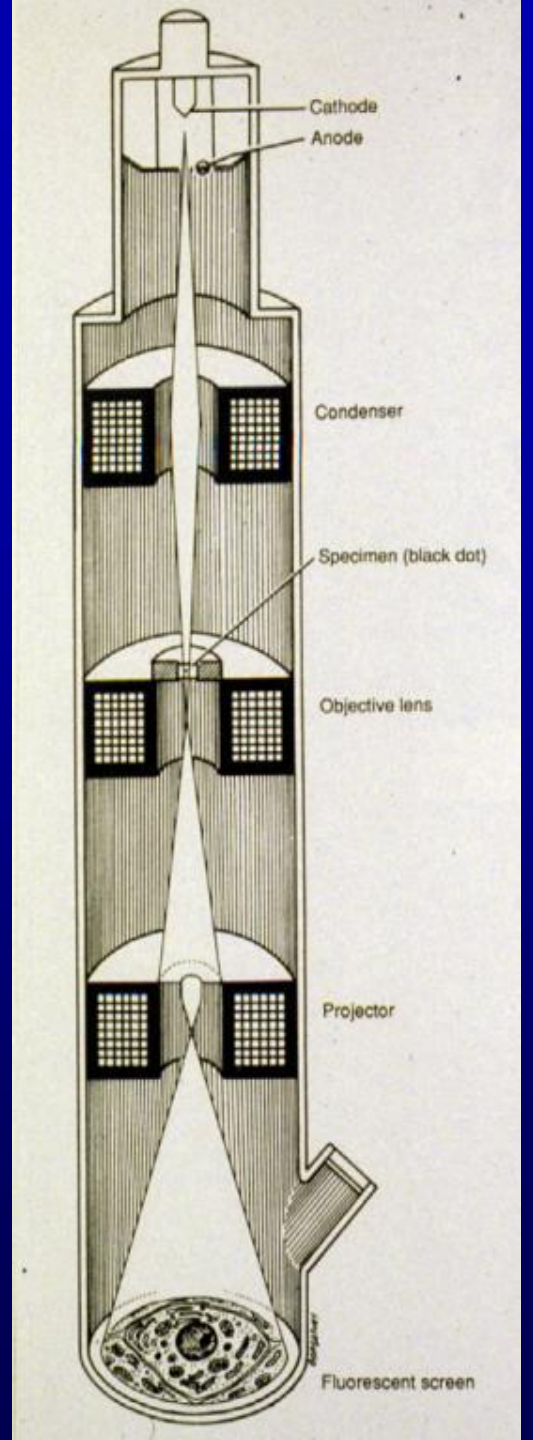
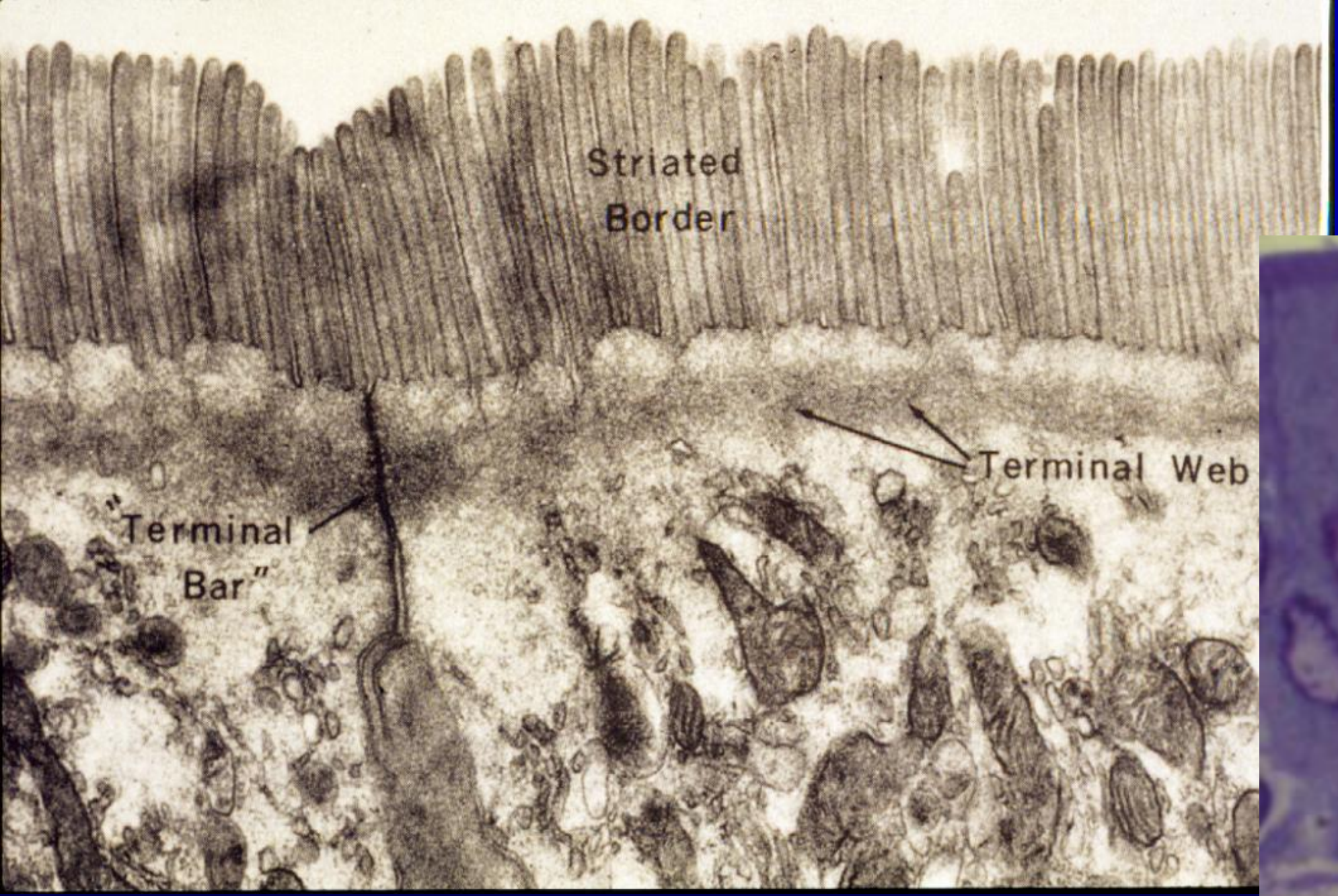
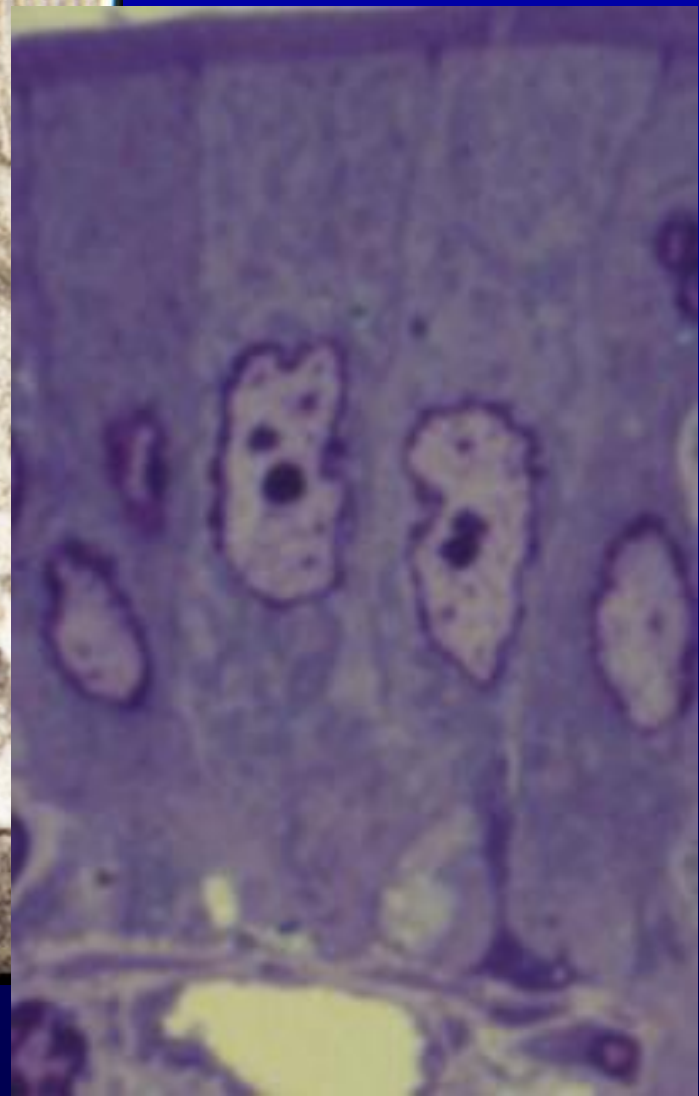
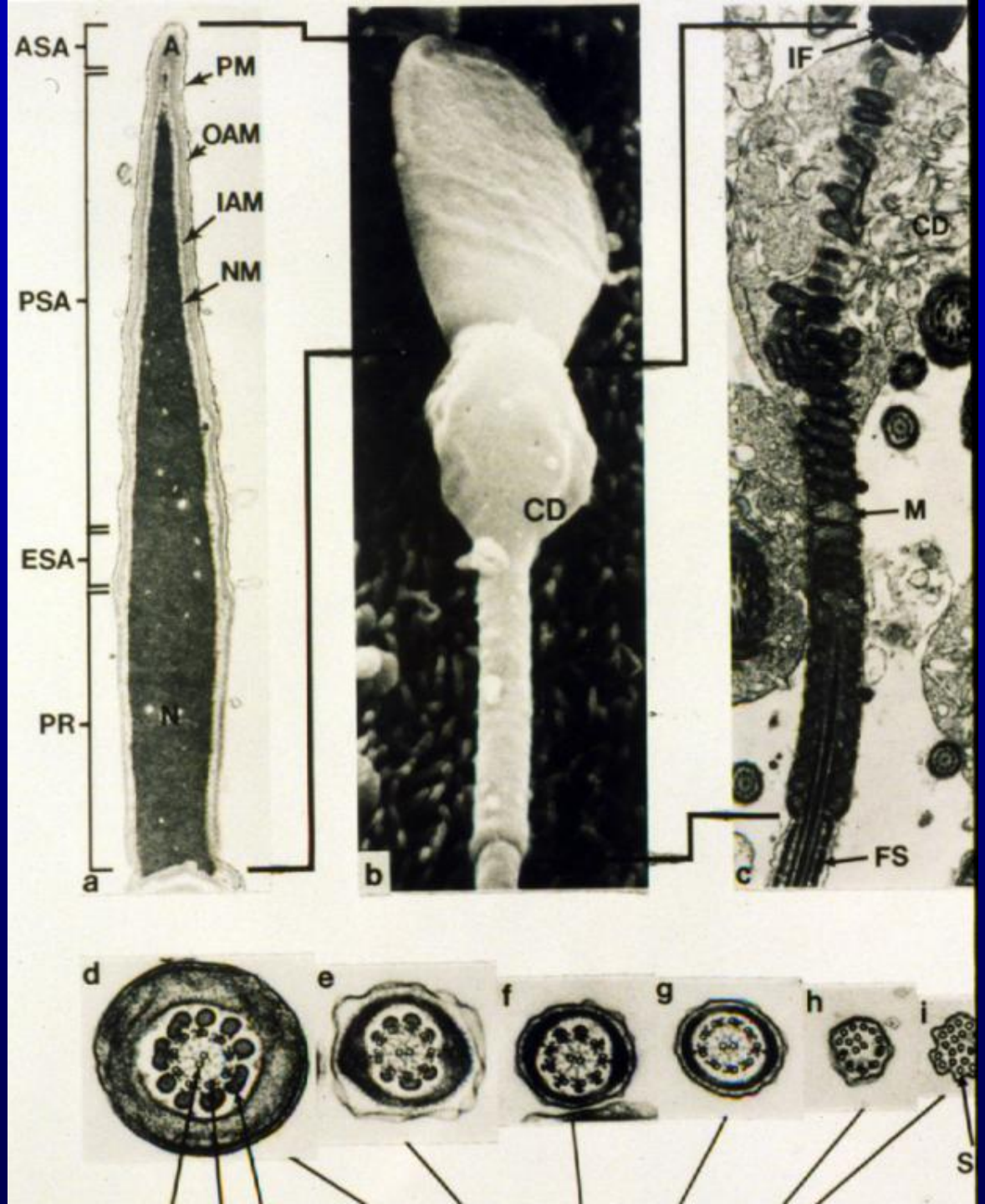


Figure 1–5. Photograph of the Zeiss model EM 10 electron microscope. (Courtesy of Carl Zeiss Co.)




Striated
Border
Terminal Web
"Terminal
Bar"




ASA
PSA
ESA
PR
A
PM
OAM
IAM
NM
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CD
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IF
CD
M
FS
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i
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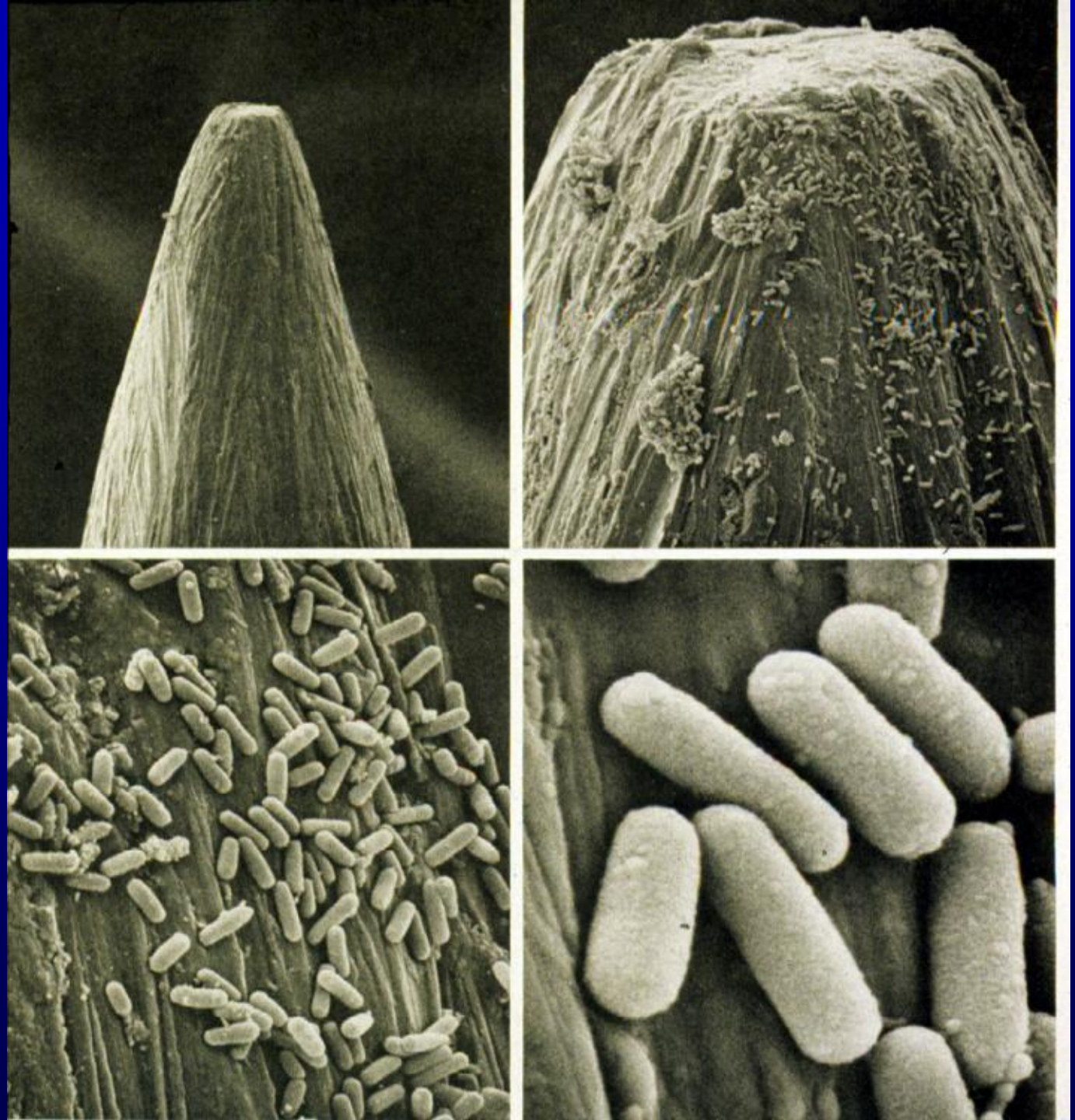
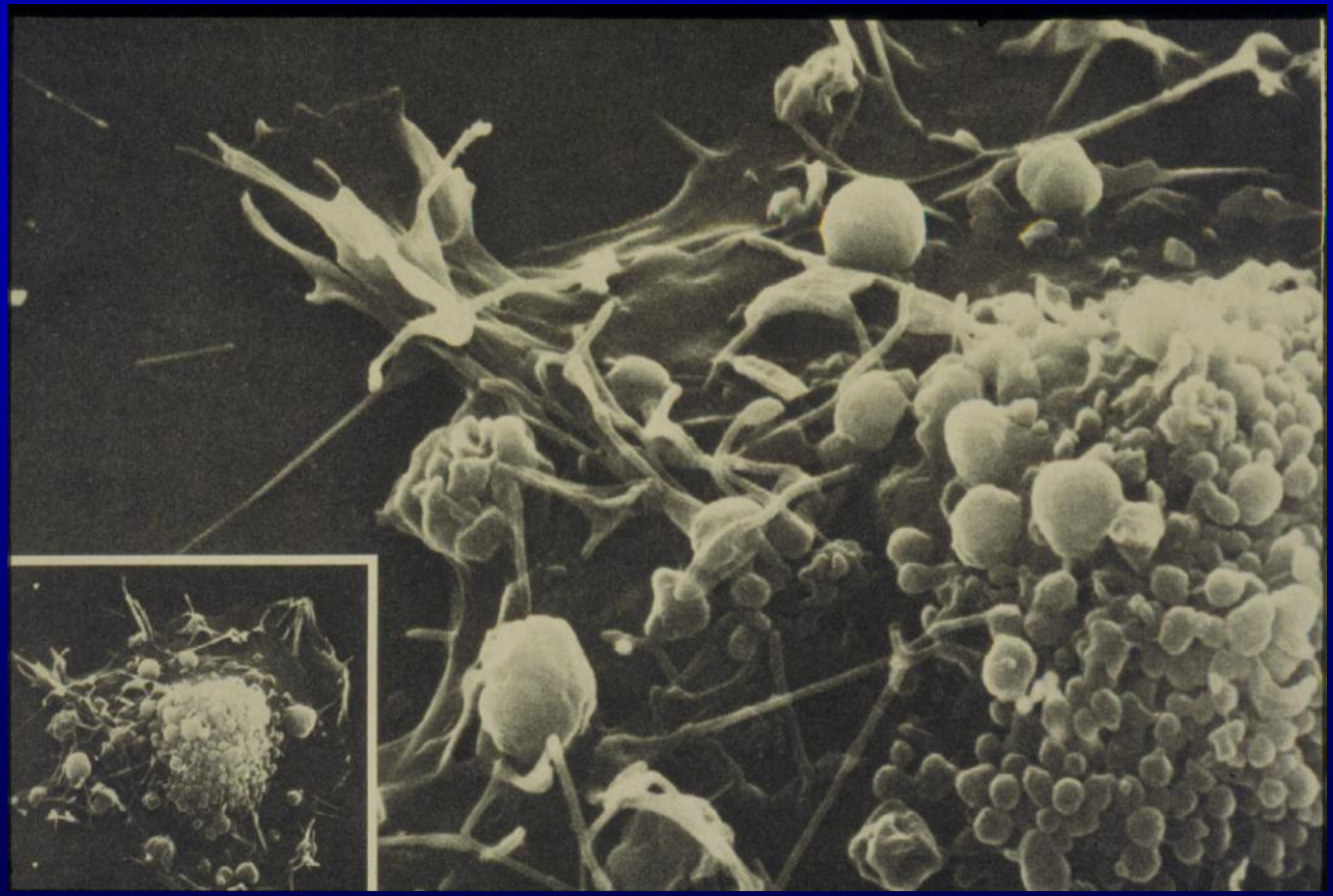
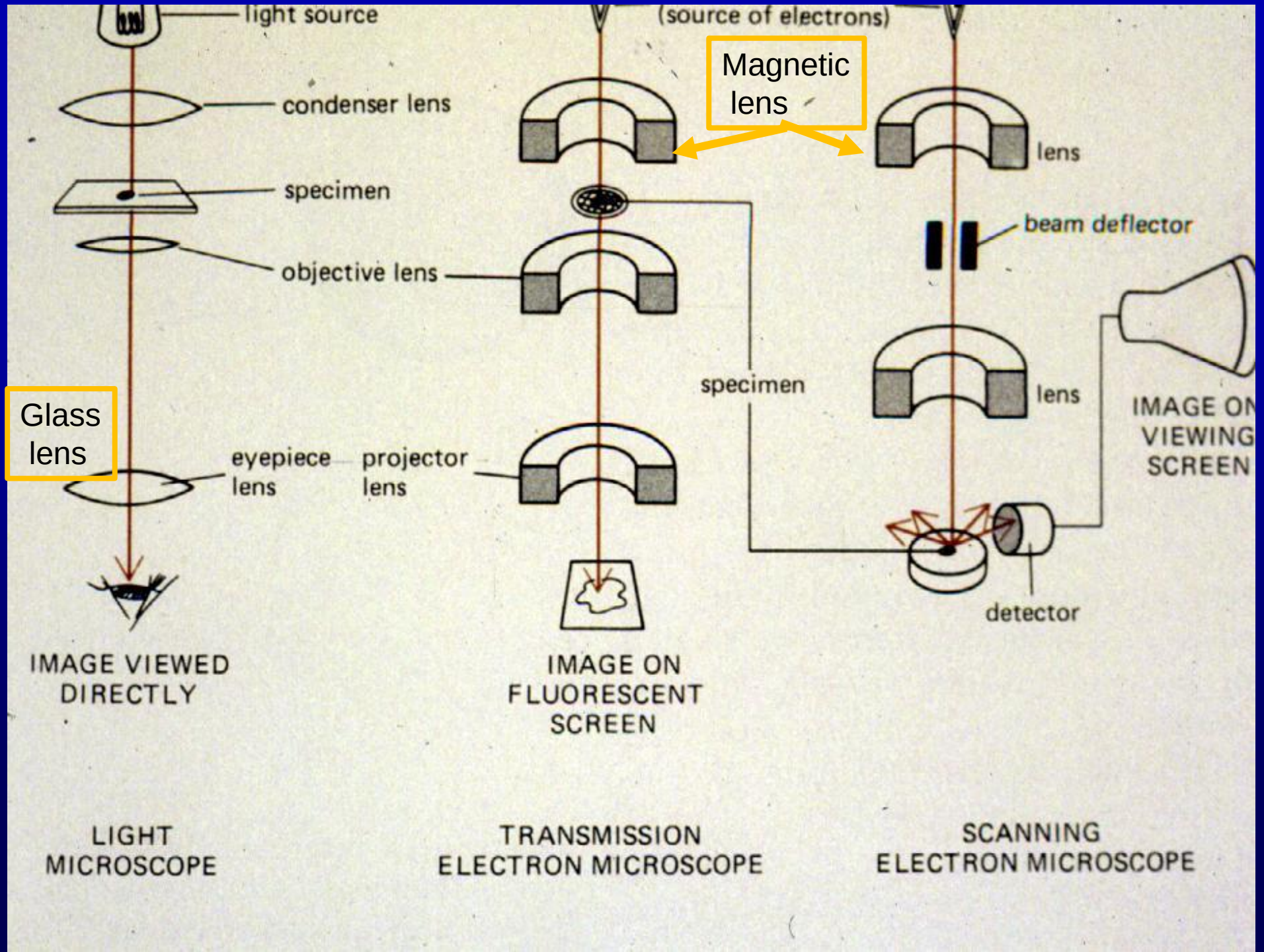





light source
condenser lens
specimen
objective lens
Glass lens
eyepiece lens
IMAGE VIEWED DIRECTLY
LIGHT MICROSCOPE
(source of electrons)
Magnetic lens
projector lens
specimen
IMAGE ON FLUORESCENT SCREEN
TRANSMISSION ELECTRON MICROSCOPE
lens
beam deflector
lens
IMAGE ON VIEWING SCREEN
detector
SCANNING ELECTRON MICROSCOPE

Other Light and Electron Microscope Procedures

- Immunofluorescence
- Autoradiography
- In Situ Hybridization (ISH)
- Freeze Fracture
  - (Membrane Analysis)

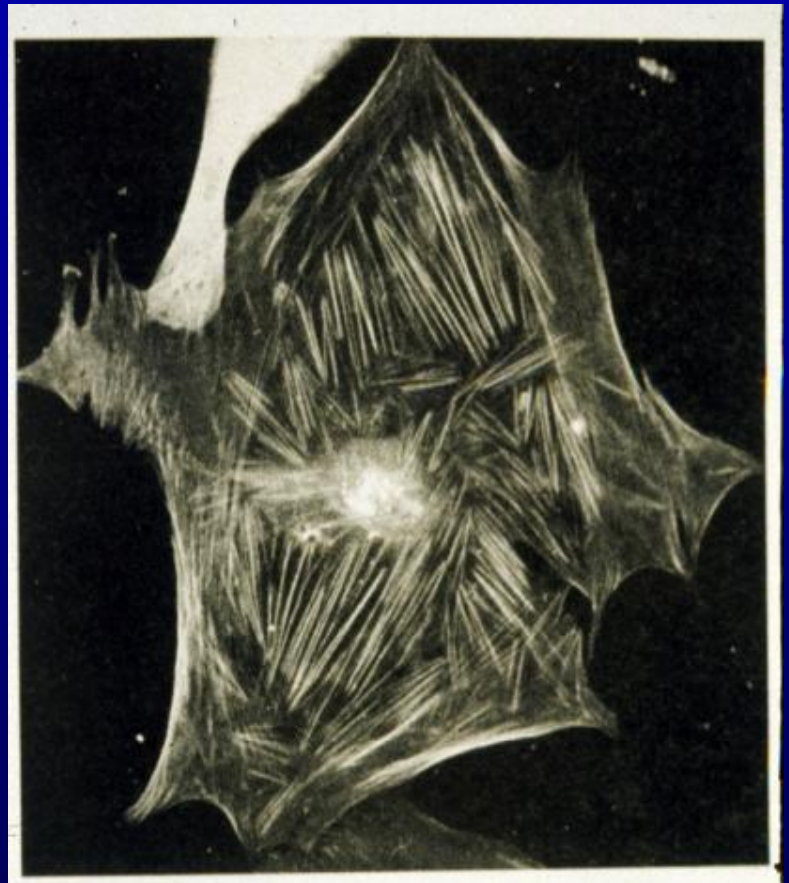
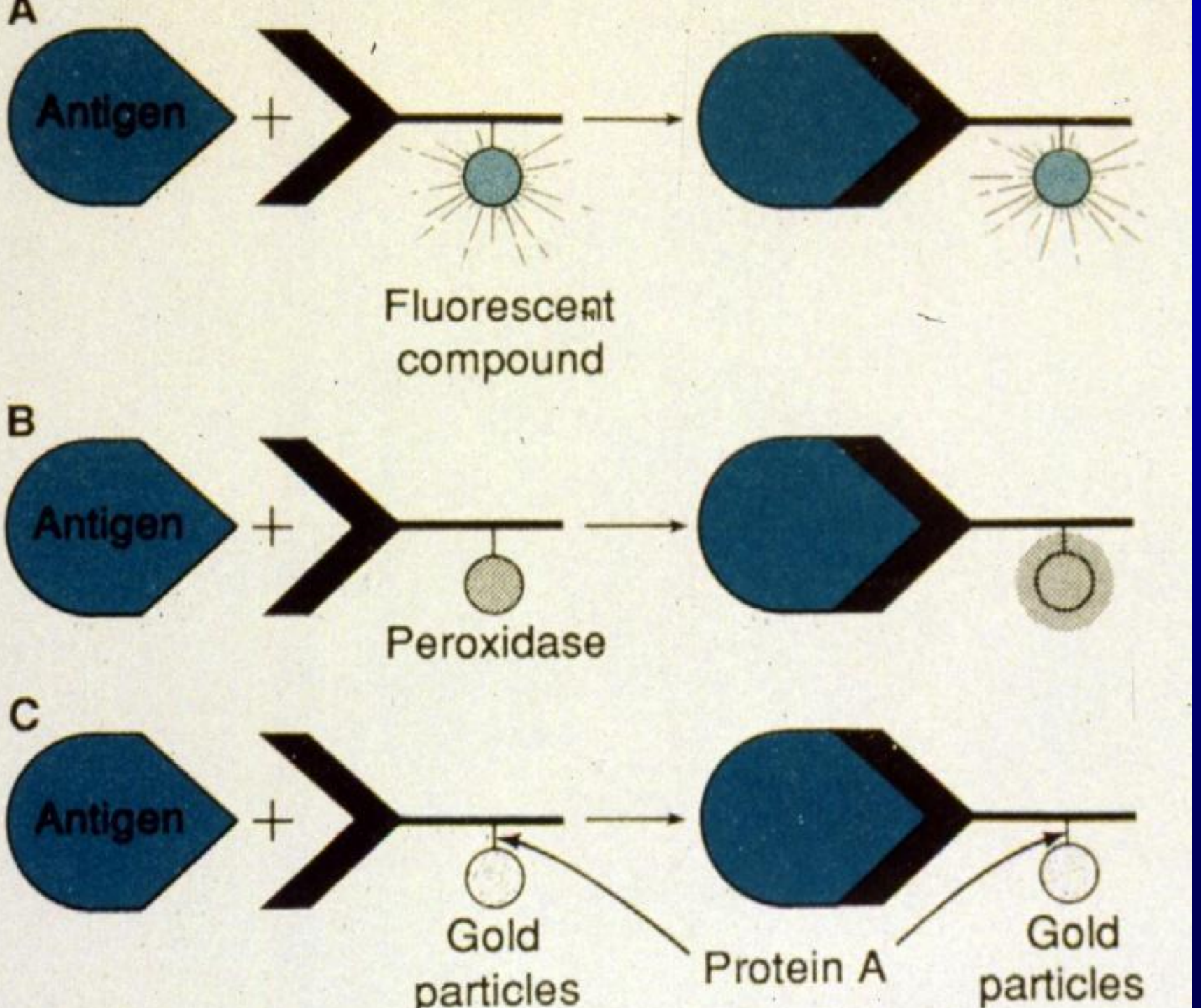
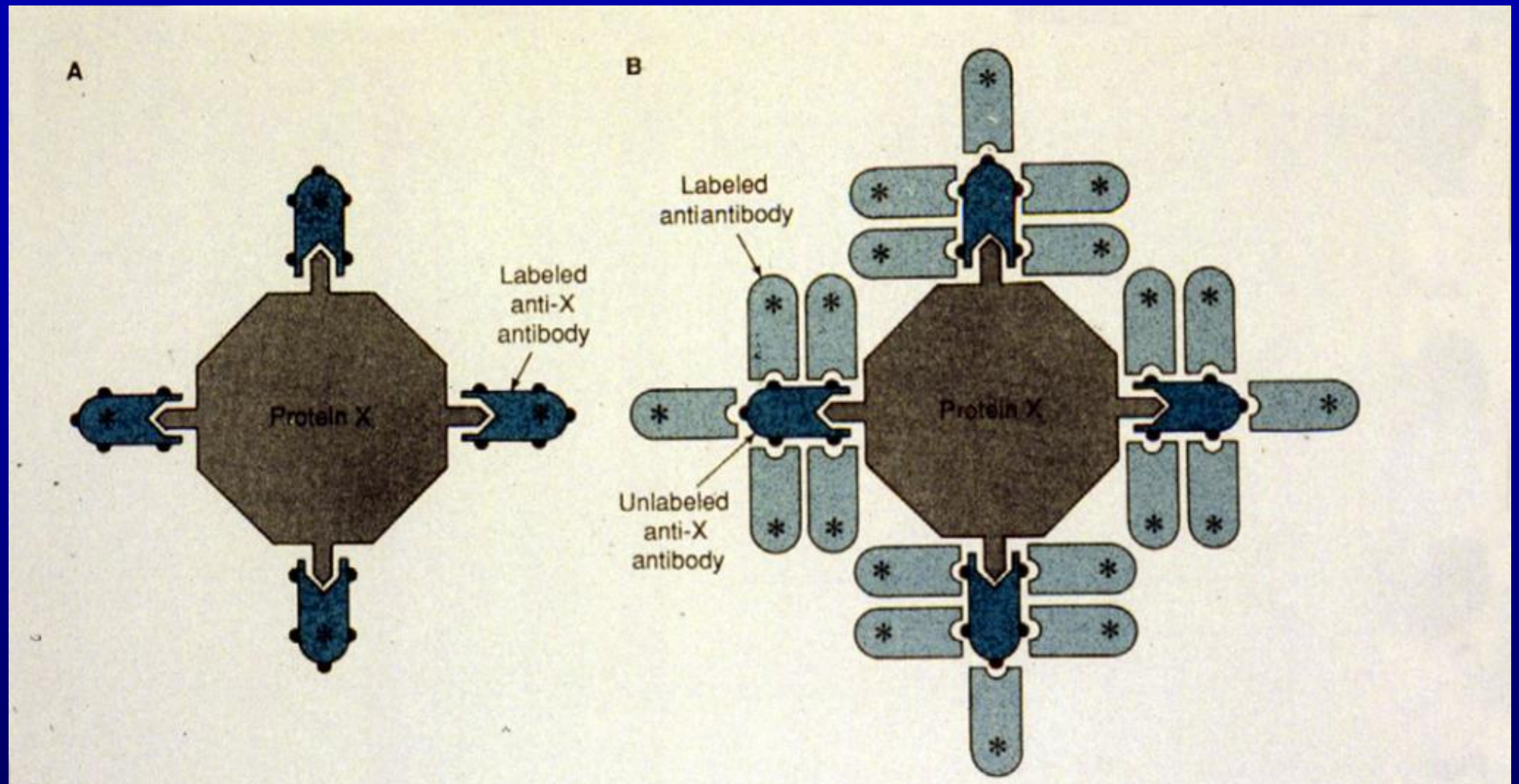


Figure 2–9. Actin fibrils composed of aggregates of actin filaments in the cytoplasm of a cultured human fibroblast preincubated in fluorescent actin antibody. × 1767. (Reproduced, with permission, from E Lazarides: *J Cell Biol* 1975; **65**:549.)


A
Antigen
+
Fluorescent compound
B
Antigen
+
Peroxidase
C
Antigen
+
Gold particles
Protein A
Gold particles



e 2–11. The direct **(A)** and indirect **(B)** techniques of immunocytochemistry. In the direct technique, a labeled antibody binds to an antigen present in the cells. In this case, each antigen molecule binds a few antibody cules. In the first step of the indirect technique, nonlabeled anti-*x* antibody is bound to the antigen; in the second the labeled antiantibody then binds to the anti-*x* antibody. Because each anti-*x* antibody binds several molecules


AUTORADIOGRAPHY
self radioactive

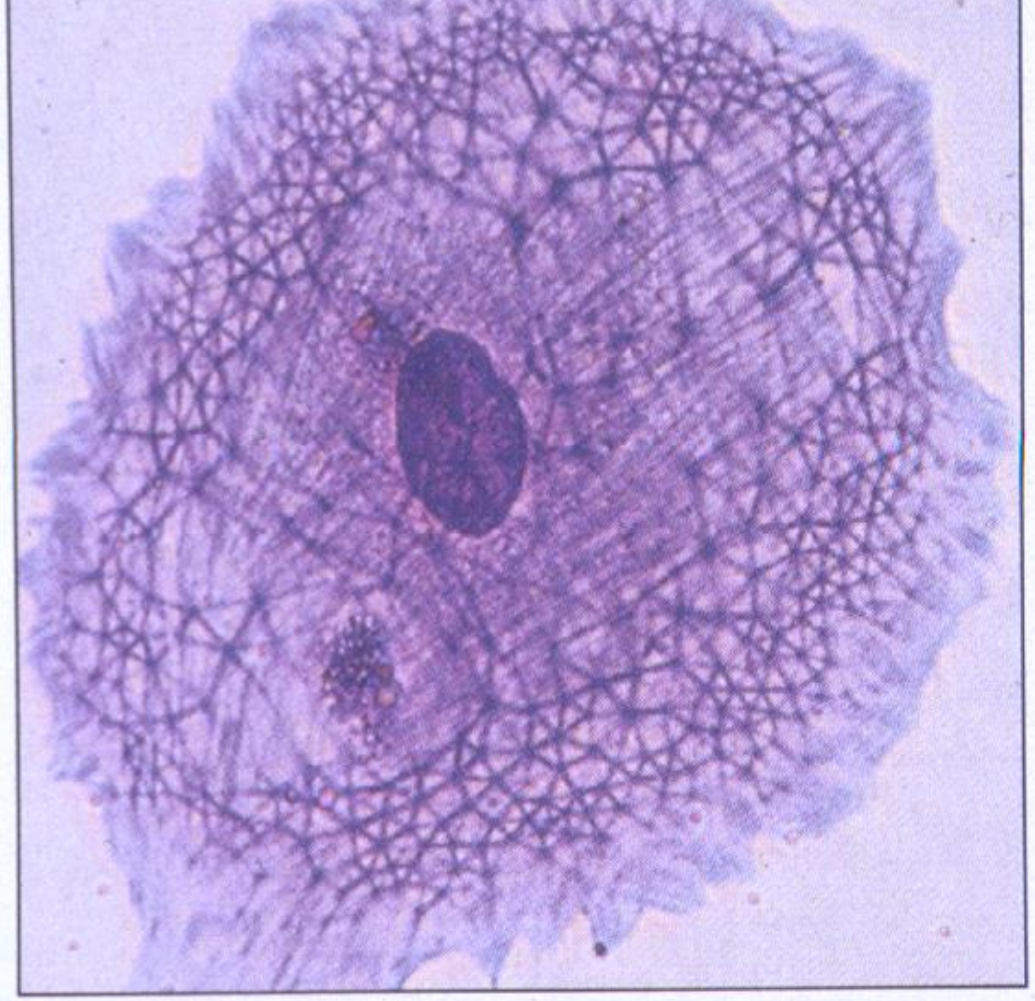
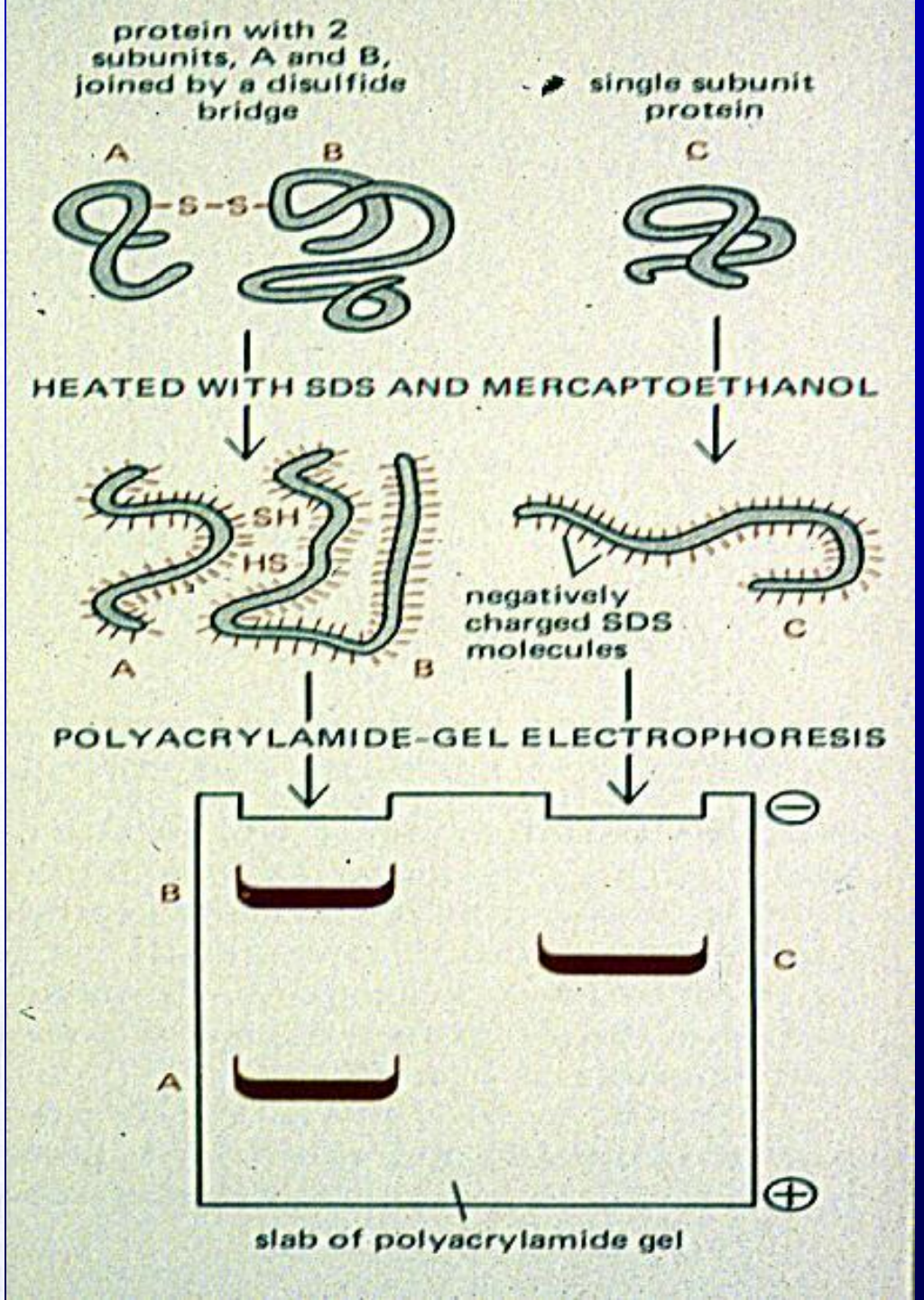


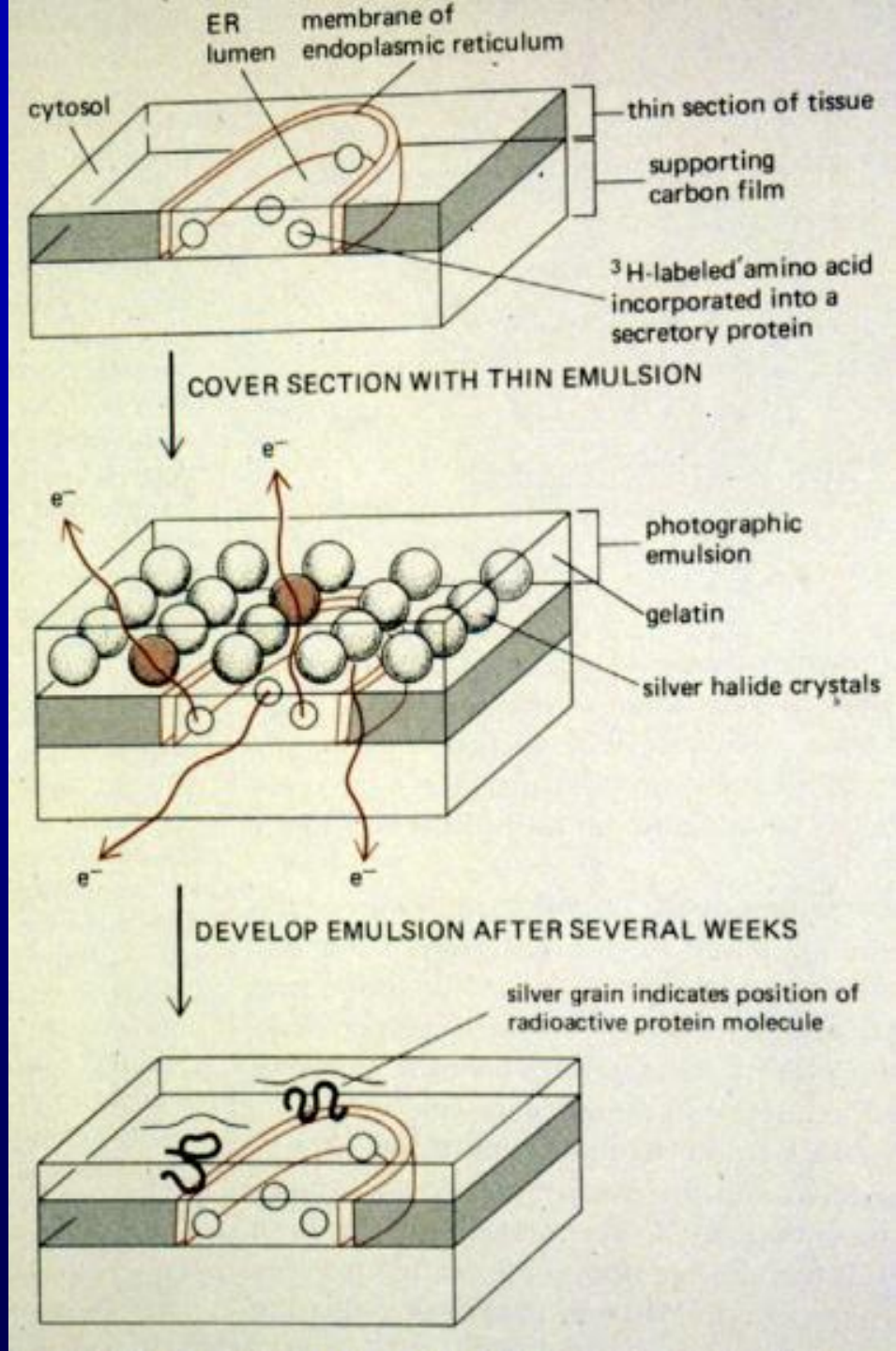
Figure 16–1 The cytoskeleton. A cell in culture has been fixed and stained with Coomassie blue, a general stain for proteins. Note the variety of



Evidence for protein pathway

Autoradiography

Procedure to localize a product (e.g., protein) within a cell or gel that is self-radioactive due to the cell's incorporation of radioactive precursors (e.g., radioactive amino acids) into that product that is visualized in a photographic emulsion.



Autoradiography vs Fluorography Terminology

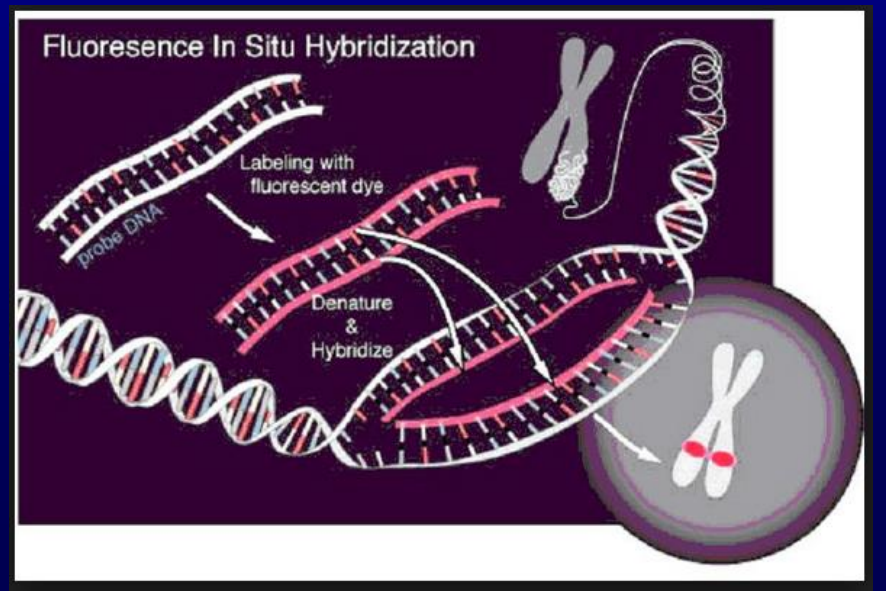
Autoradiography is the direct exposure of film by beta particles or gamma rays.

Fluorography is the exposure of film by secondary light that was generated by the excitation of a fluor or a screen by a beta particle or a gamma ray.

In situ hybridization

- ***In situ* hybridization (ISH)** is a type of hybridization that uses a labeled complementary DNA or RNA strand (i.e., probe) to localize a specific DNA or RNA sequence in a portion or section of tissue (*in situ*).

Source: http://en.wikipedia.org/wiki/In_situ_hybridization



Photomicrograph of a section of human epithelial tumor (condyloma) in which in situ hybridization with the DNA of the human papilloma virus type II (HPVII) was performed. Observe dark staining of several nuclei, indicating the presence of the genome of this virus in the tumor, suggesting its possible participation in the genesis of the tumor.

Figure 2–13. Photomicrograph of a section of human epithelial tumor (condyloma) in which in situ hybridization with the DNA of the human papilloma virus type II (HPVII) was performed. Observe dark staining in several nuclei, indicating the presence of the genome of this virus in this tumor, suggesting its possible participation in the genesis of the tumor. (Courtesy of JE Levi.)

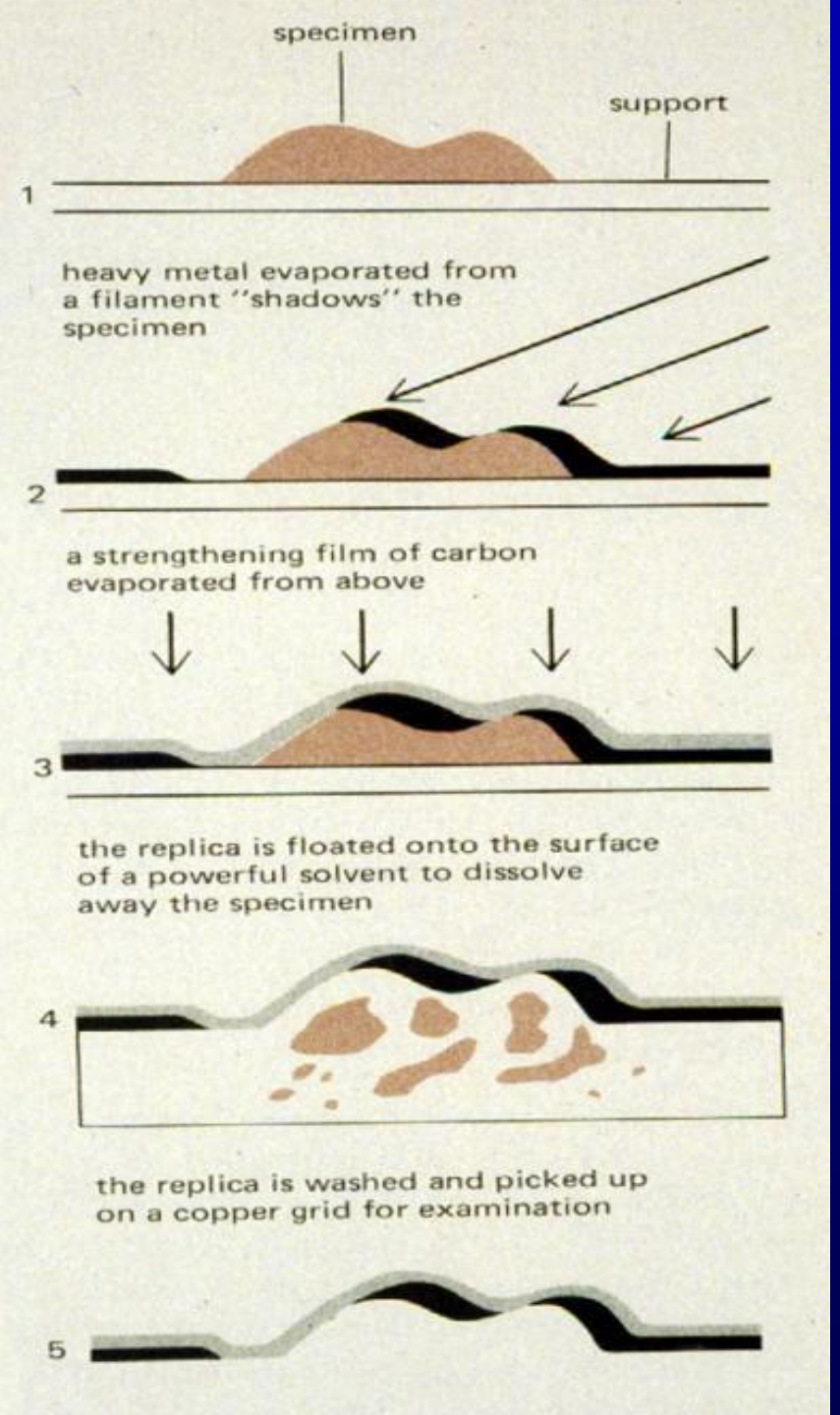
Carbon Replica

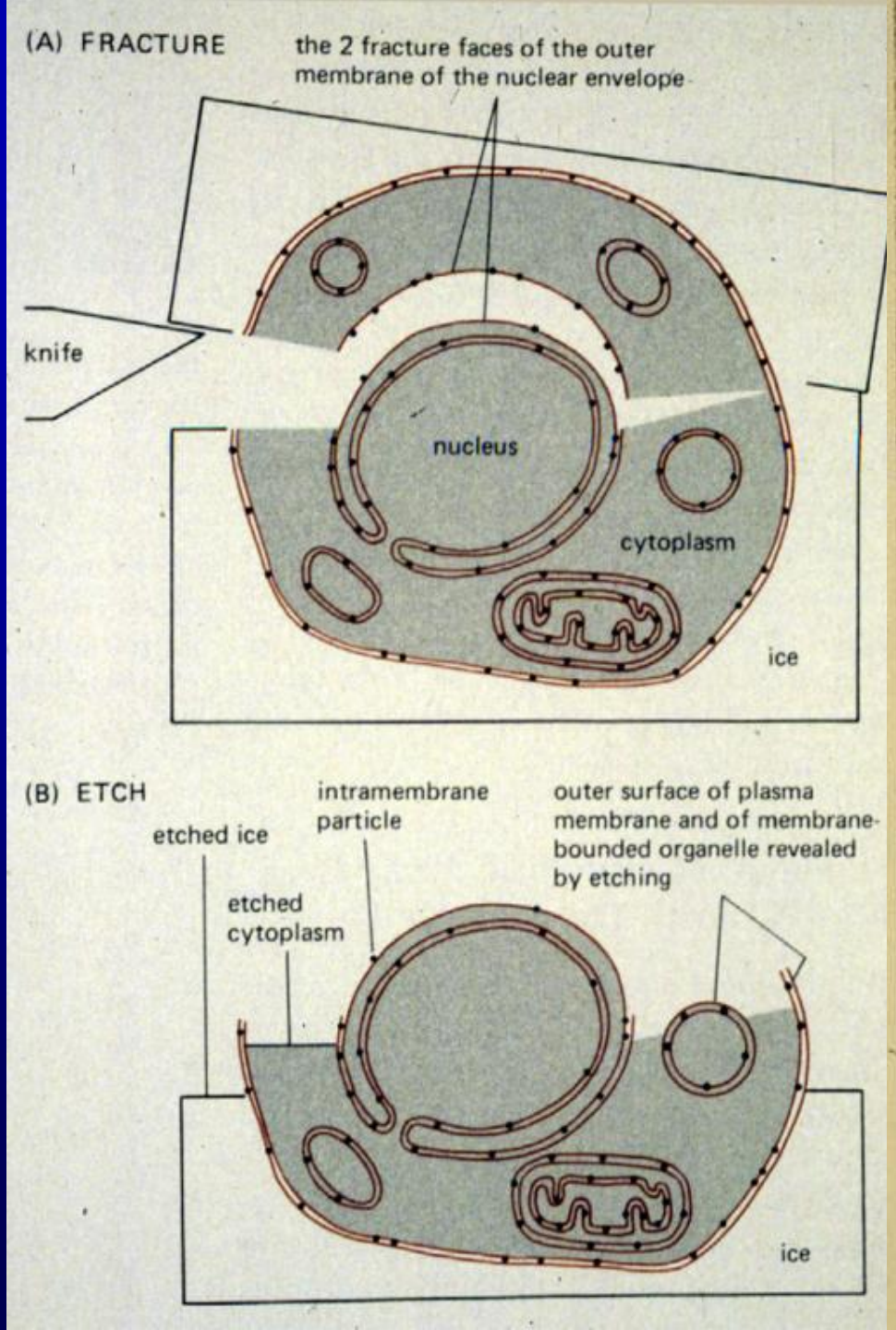
1. Heavy metal evaporated from a filament “shadows” the specimen.

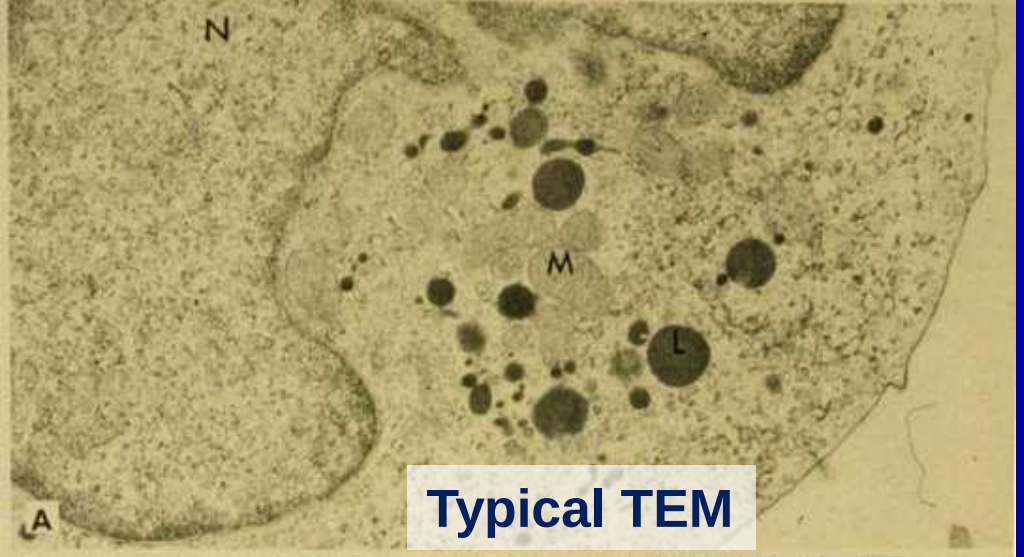
2. A strengthening film of carbon evaporated from above.

3. The replica is floated onto the surface of a powerful solvent to dissolve away the specimen.

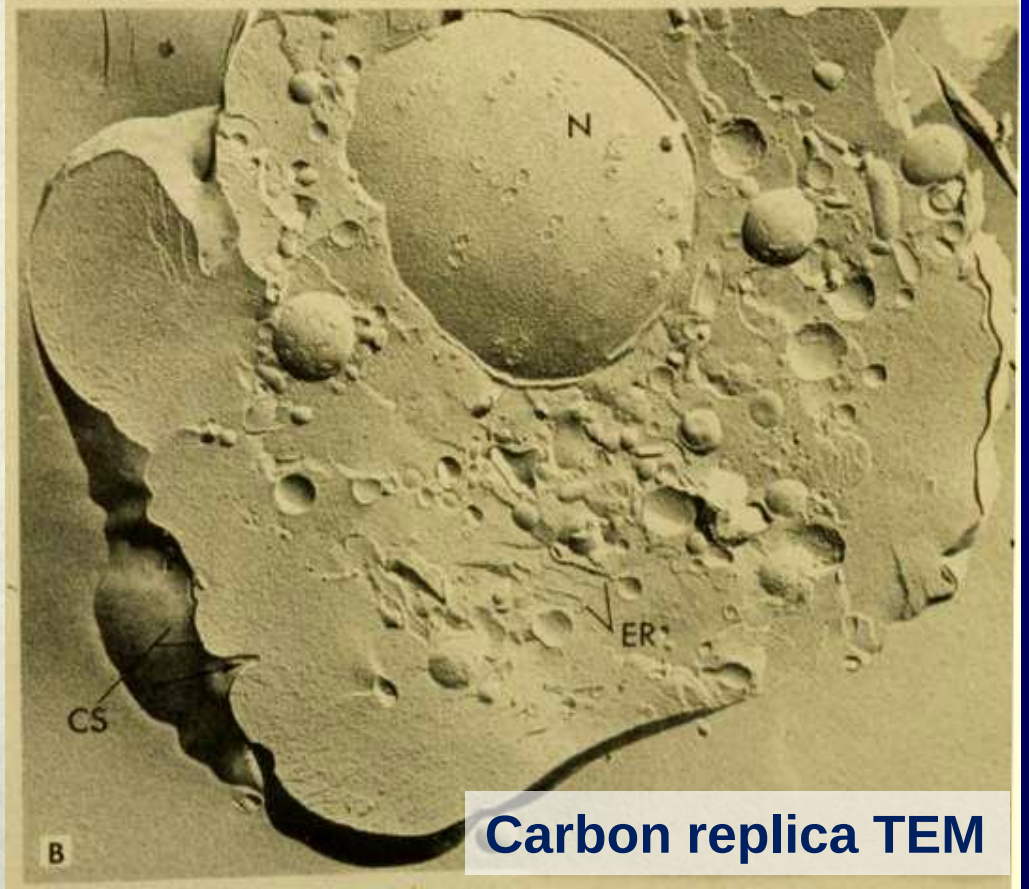
4. The replica is washed and picked up on a copper grid for examination.





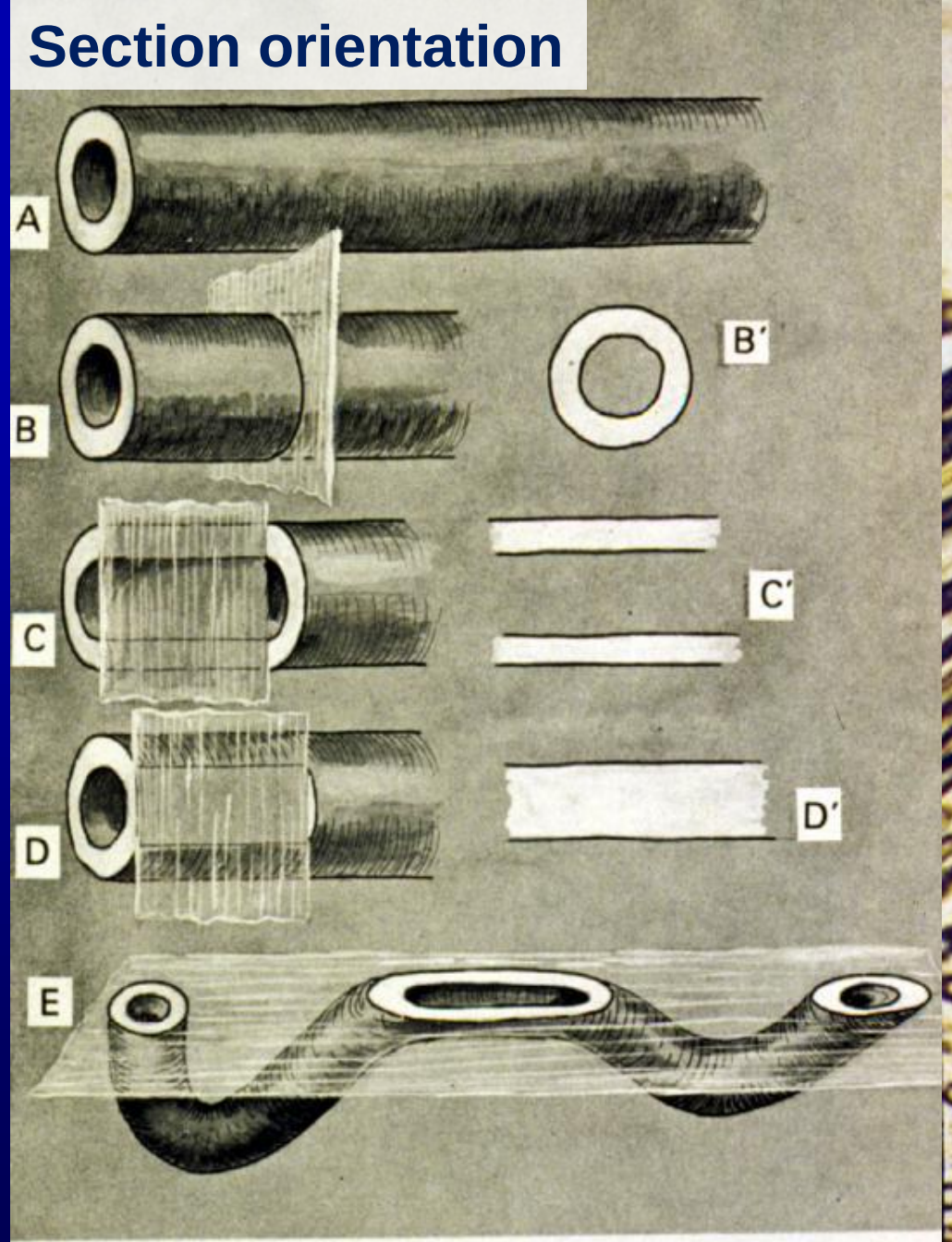


Typical TEM

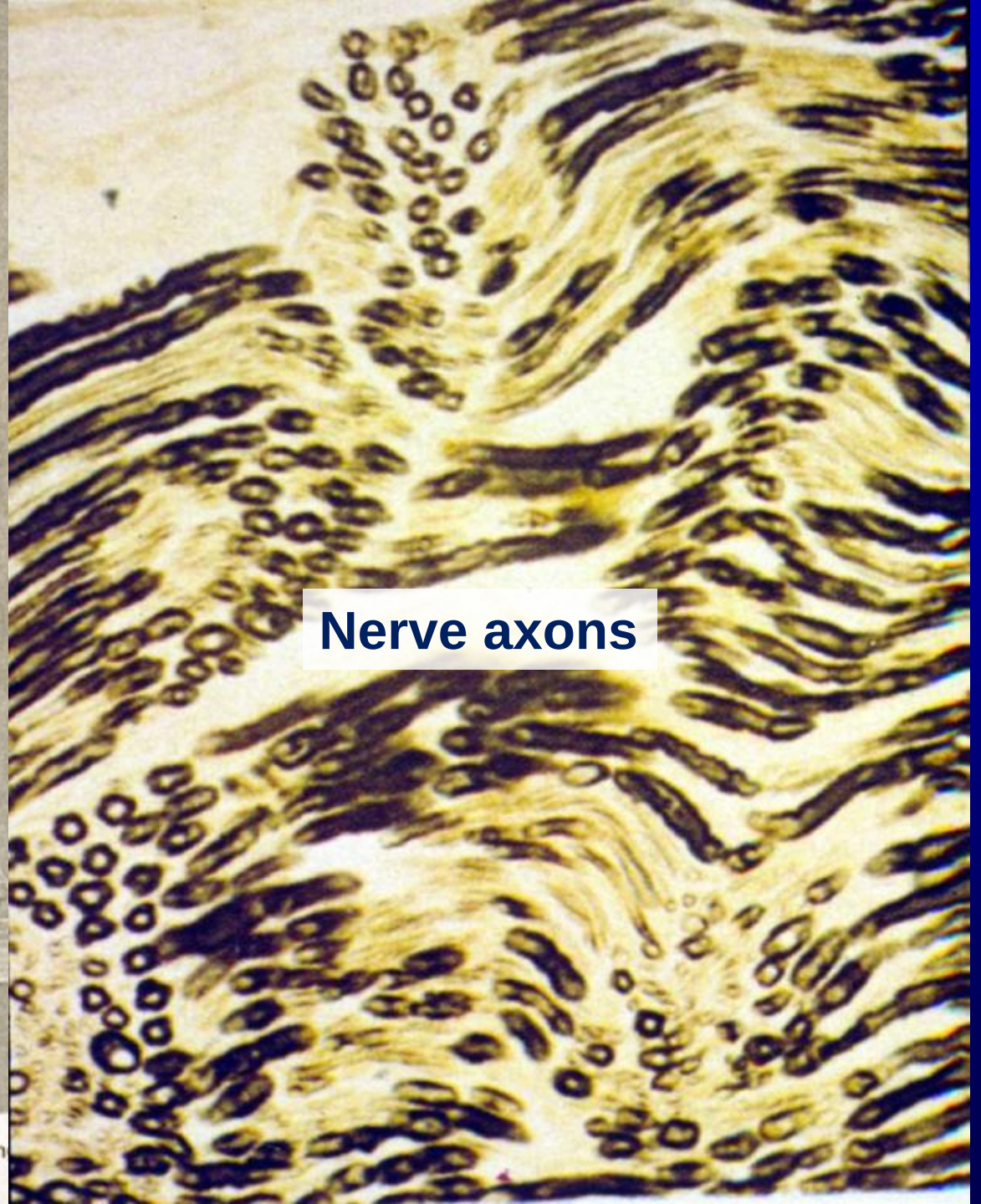


Carbon replica TEM

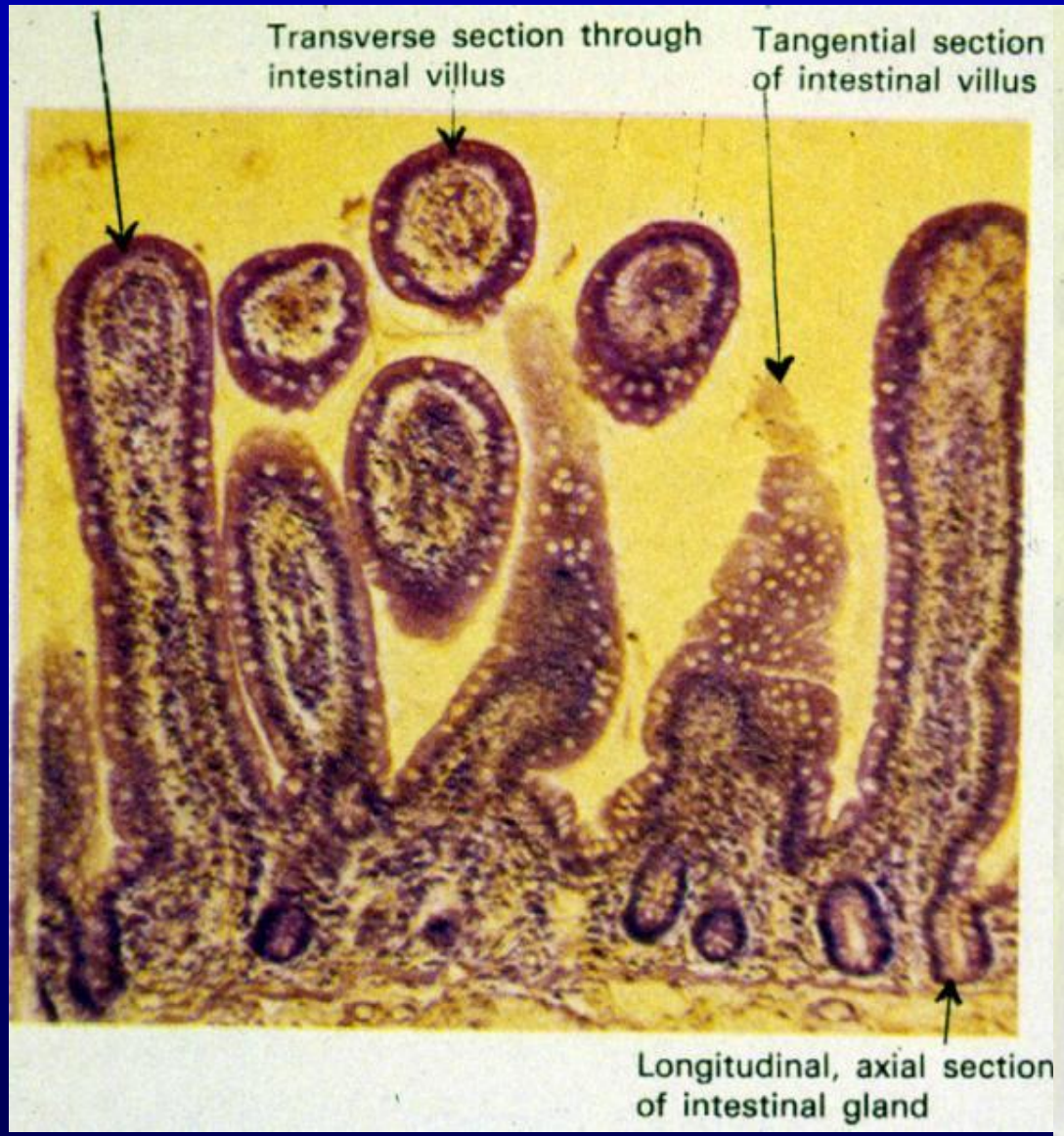
Section orientation



. I-3. Various directions of cutting tubes. B, Transverse (cross) section; C, lon
ction; D, tangential section; E, a curved tube cut.



Nerve axons



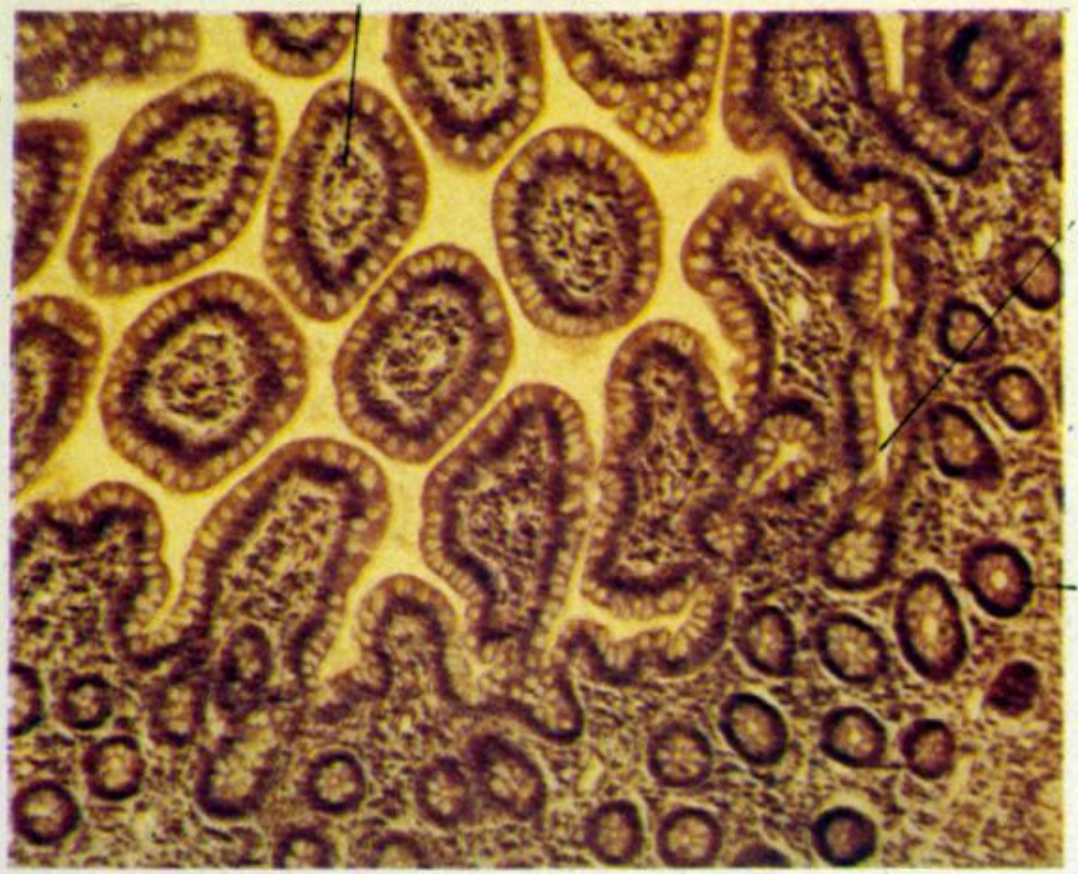


Fig. I-5. Section almost tangential through the wall of the and glands are cut nearly transversely. H&E.

Section Orientation

Plane of section can make it look as if there are more layers of cells than there are, but it can never make it look like there are less than the actual number.

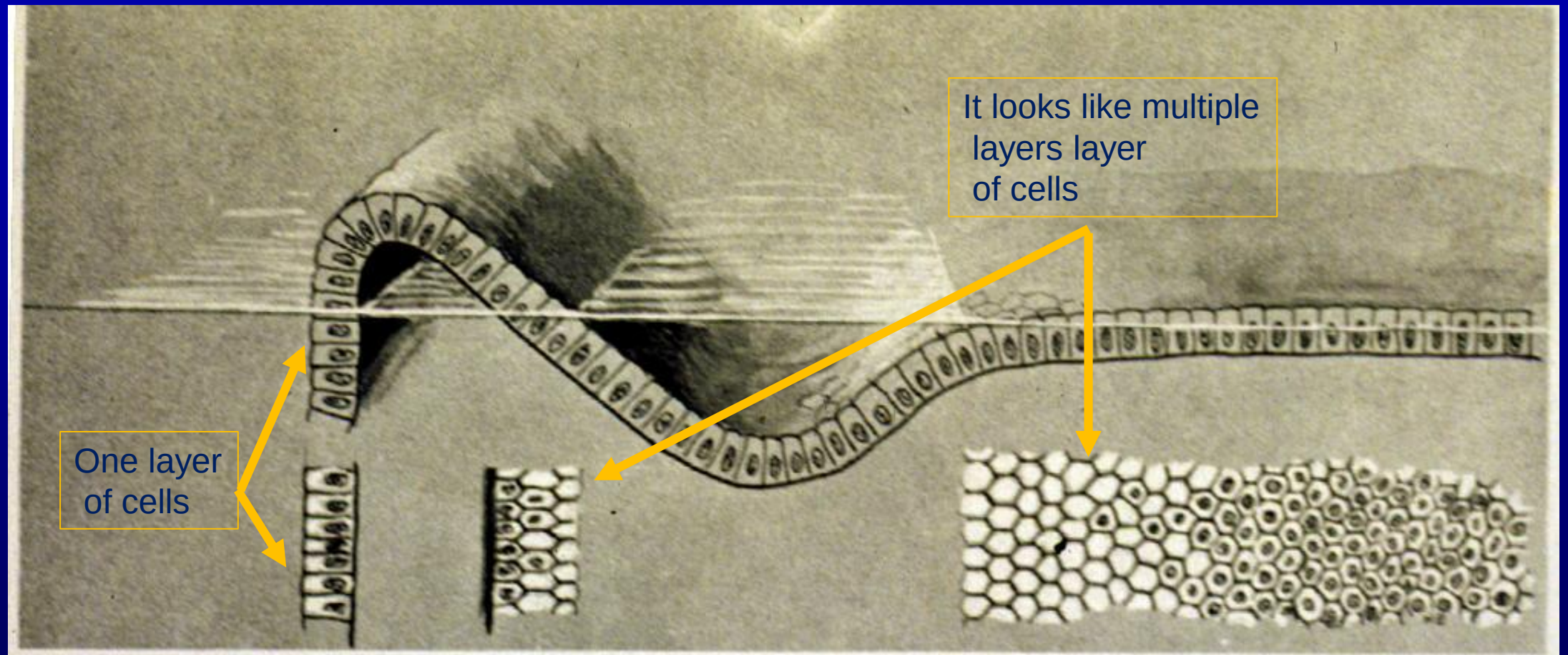
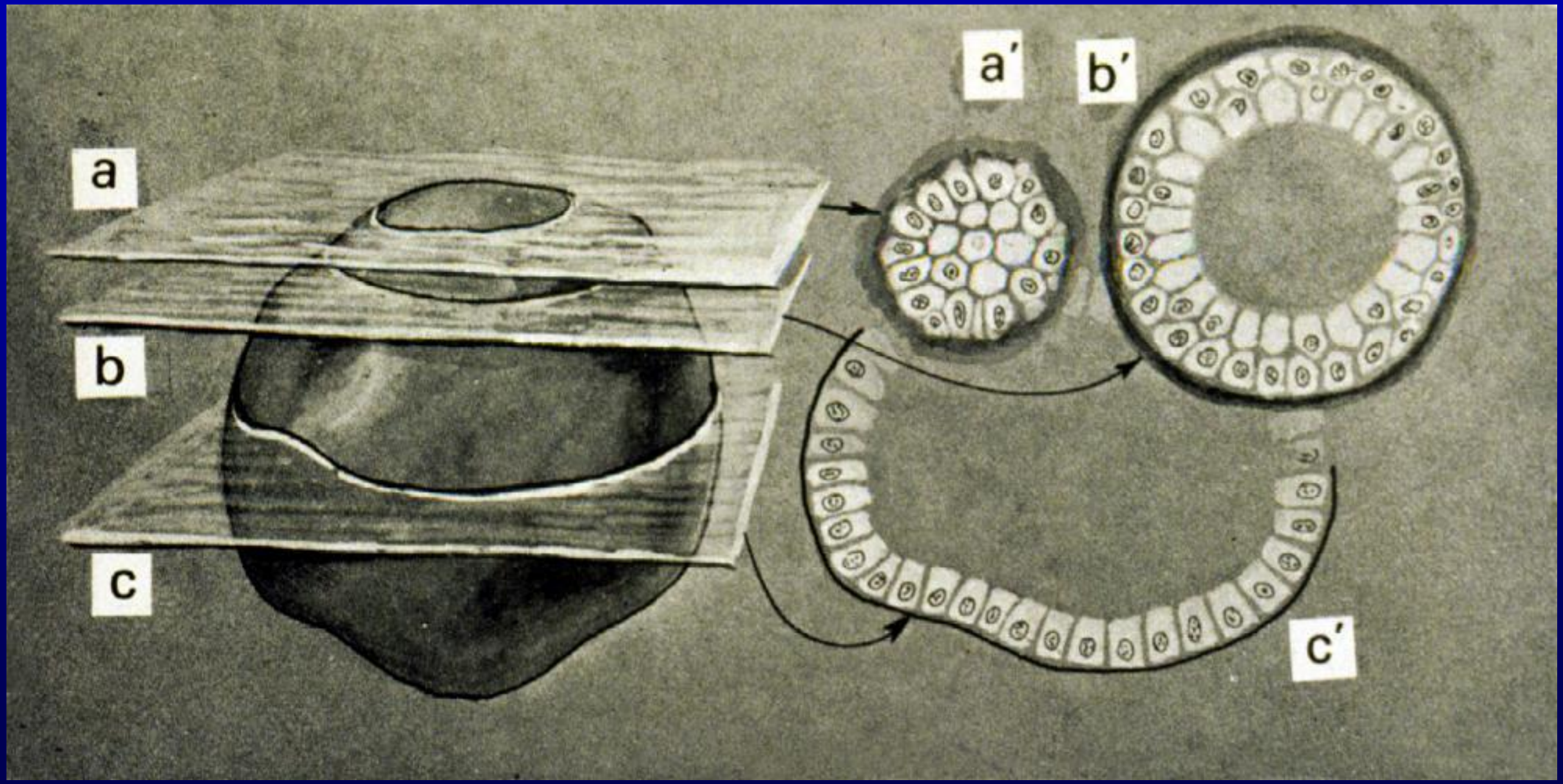


Fig. I-7. Cutting a sheet, thicker than the slice. The particular sheet shown here is a simple, columnar epithelium. One can observe that the number of layers appears to change with the direction of cutting. At the right, one notices that it will depend on the level of cutting whether cells appear to have a nucleus or not.

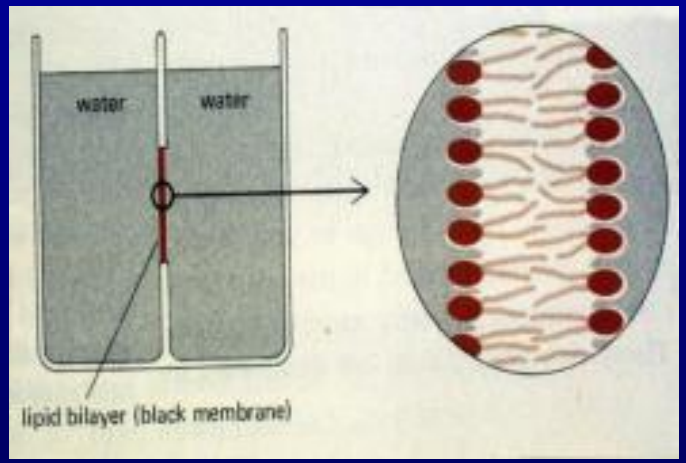
Section Orientation

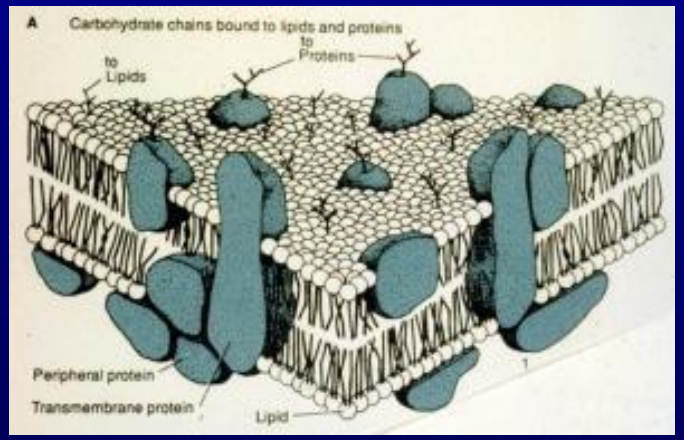
Plane of section can make it look as if there are more layers of cells than there are, but it can never make it look like there are less than the actual number.

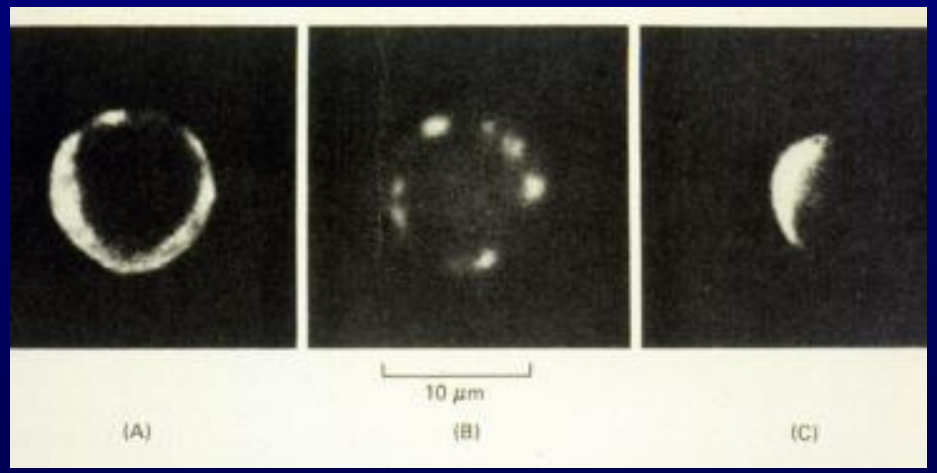


Next time

Membrane and Receptors







Many illustrations in these VIBS Histology YouTube videos were modified from the following books and sources: Many thanks to original sources!

- Bruce Alberts, et al. 1983. Molecular Biology of the Cell. Garland Publishing, Inc., New York, NY.
- Bruce Alberts, et al. 1994. Molecular Biology of the Cell. Garland Publishing, Inc., New York, NY.
- William J. Banks, 1981. Applied Veterinary Histology. Williams and Wilkins, Los Angeles, CA.
- Hans Elias, et al. 1978. Histology and Human Microanatomy. John Wiley and Sons, New York, NY.
- Don W. Fawcett. 1986. Bloom and Fawcett. A textbook of histology. W. B. Saunders Company, Philadelphia, PA.
- Don W. Fawcett. 1994. Bloom and Fawcett. A textbook of histology. Chapman and Hall, New York, NY.
- Arthur W. Ham and David H. Cormack. 1979. Histology. J. S. Lippincott Company, Philadelphia, PA.
- Luis C. Junqueira, et al. 1983. Basic Histology. Lange Medical Publications, Los Altos, CA.
- L. Carlos Junqueira, et al. 1995. Basic Histology. Appleton and Lange, Norwalk, CT.
- L.L. Langley, et al. 1974. Dynamic Anatomy and Physiology. McGraw-Hill Book Company, New York, NY.
- W.W. Tuttle and Byron A. Schottelius. 1969. Textbook of Physiology. The C. V. Mosby Company, St. Louis, MO.
- Leon Weiss. 1977. Histology Cell and Tissue Biology. Elsevier Biomedical, New York, NY.
- Leon Weiss and Roy O. Greep. 1977. Histology. McGraw-Hill Book Company, New York, NY.
- Nature (http://www.nature.com), Vol. 414:88,2001.
- A.L. Mescher 2013 Junqueira's Basis Histology text and atlas, 13th ed. McGraw
- Internet images and videos on biological presentations