

The Respiratory system

Function: exchange of O₂ and CO₂ between air and blood.

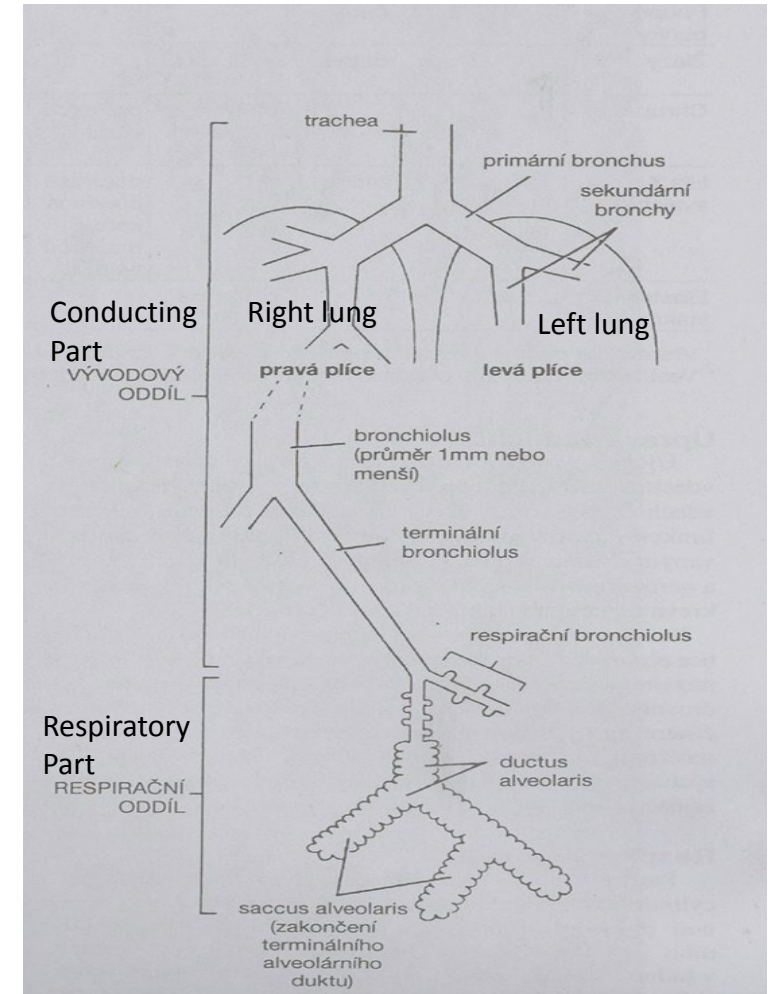
The respiratory system has two parts:

Conducting part - it is a system of tubes that are used to conduct air.

Nasal cavities, pharynx, larynx, trachea, bronchi, bronchioles and terminal bronchioles.

Respiratory part - alveoli protrude in the wall of the respiratory tube.

Respiratory bronchioles, alveolar duct and alveoli.

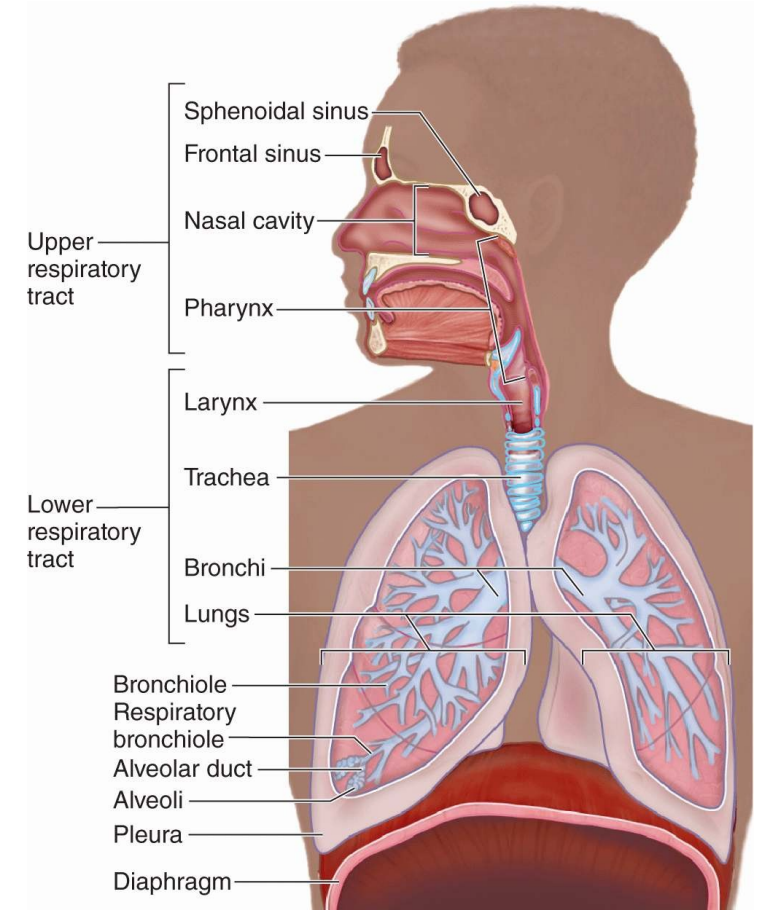
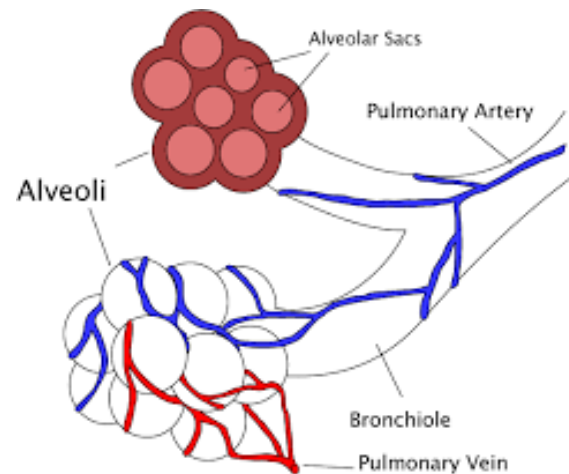


The Respiratory system

In medicine the respiratory system is divided into upper and lower respiratory tracts. The dividing line between them is the upper part of the larynx, or vocal cord.

Part of the airway contains cartilage in the wall, which prevents the tube from collapsing during inhalation. Due to the presence of cartilage, the respiratory tube is "always open".

Alveoli are the main site of gas exchange. They are saclike, with thin vascularized walls



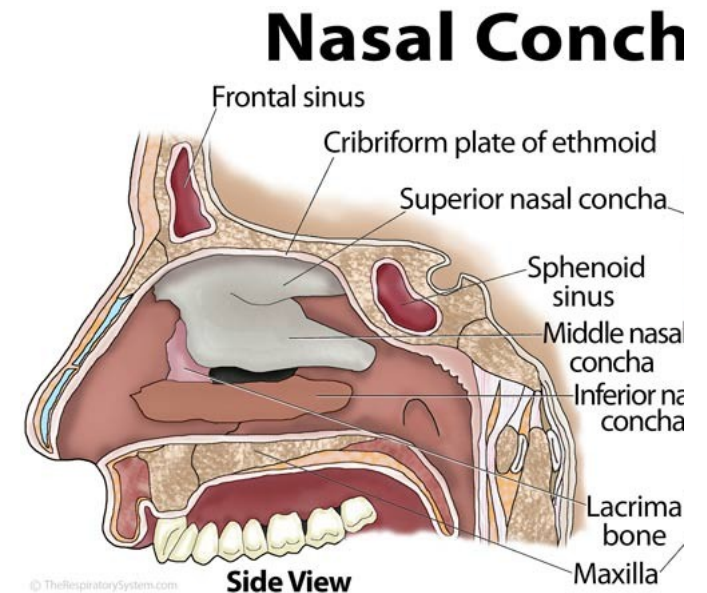
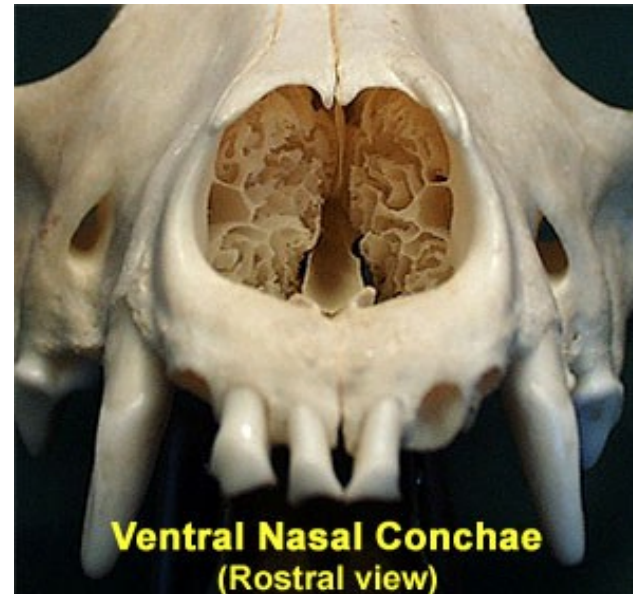
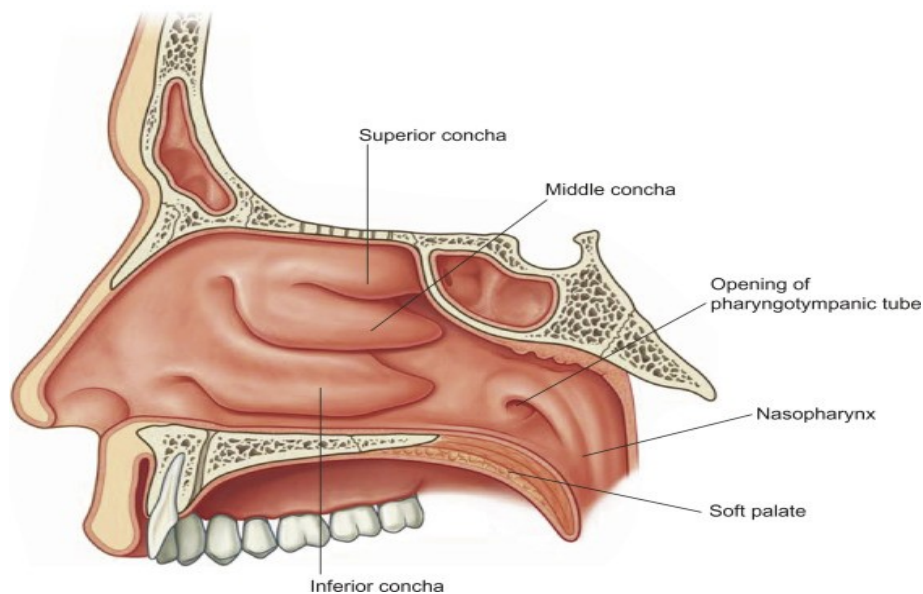
Parts of the Respiratory system

Nasal cavity:

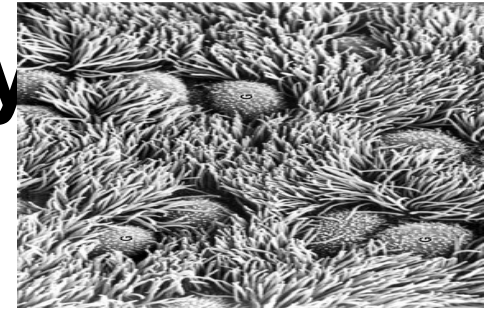
consists of two parts: the **vestibule** and the **internal nasal cavity**.

Epithelium: vestibule **stratified squamous**, cavity - **pseudostratified columnar**. In the skull part of nasal cavity there are **turbinate bones, or conchae** (inferior, middle and superior).

Conchae and the inner space of the nasal cavity are covered by vascularized mucosa - the air is heated here.



Epithelium in the nasal cavity



Ciliated and Goblet cells

Respiratory epithelium has a five cell types:

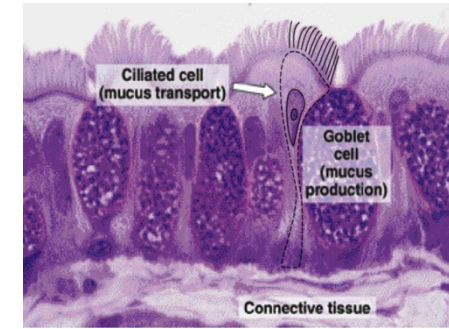
Ciliated columnar cells - a lot of mitochondria that produce energy

Goblet cells - they produce mucus

Brush cells - have microvilli and chemosensory function

Small granular cells – neuroendocrine function

Basal cells - stem cells, formation of new epithelial cells



Olfactory epithelium is located at the roof of nasal cavity and at the superior conchae.

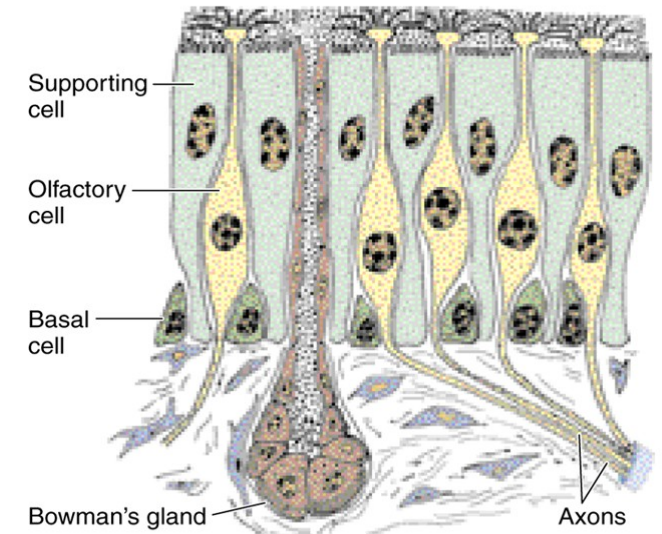
Three major cell types:

Olfactory cells – are bipolar neurons.

- Receptors are located on long non-motile cilia.
- Axons extending from the basal ends of these cells.

Supporting cells - create an optimal environment for the olfactory cells

Basal cells - stem cells for the other two types



Parts of the Respiratory system

Pharynx: consists of two parts:

nasopharynx (respiratory epithelium)

oropharynx (stratified epithelium)

there is an auditory tube opening (middle ear cavity – nasopharynx)

Larynx:

the wall consist of hyaline cartilage. The epiglottis is made of elastic cartilage (does not calcify and is still flexible even in old age)

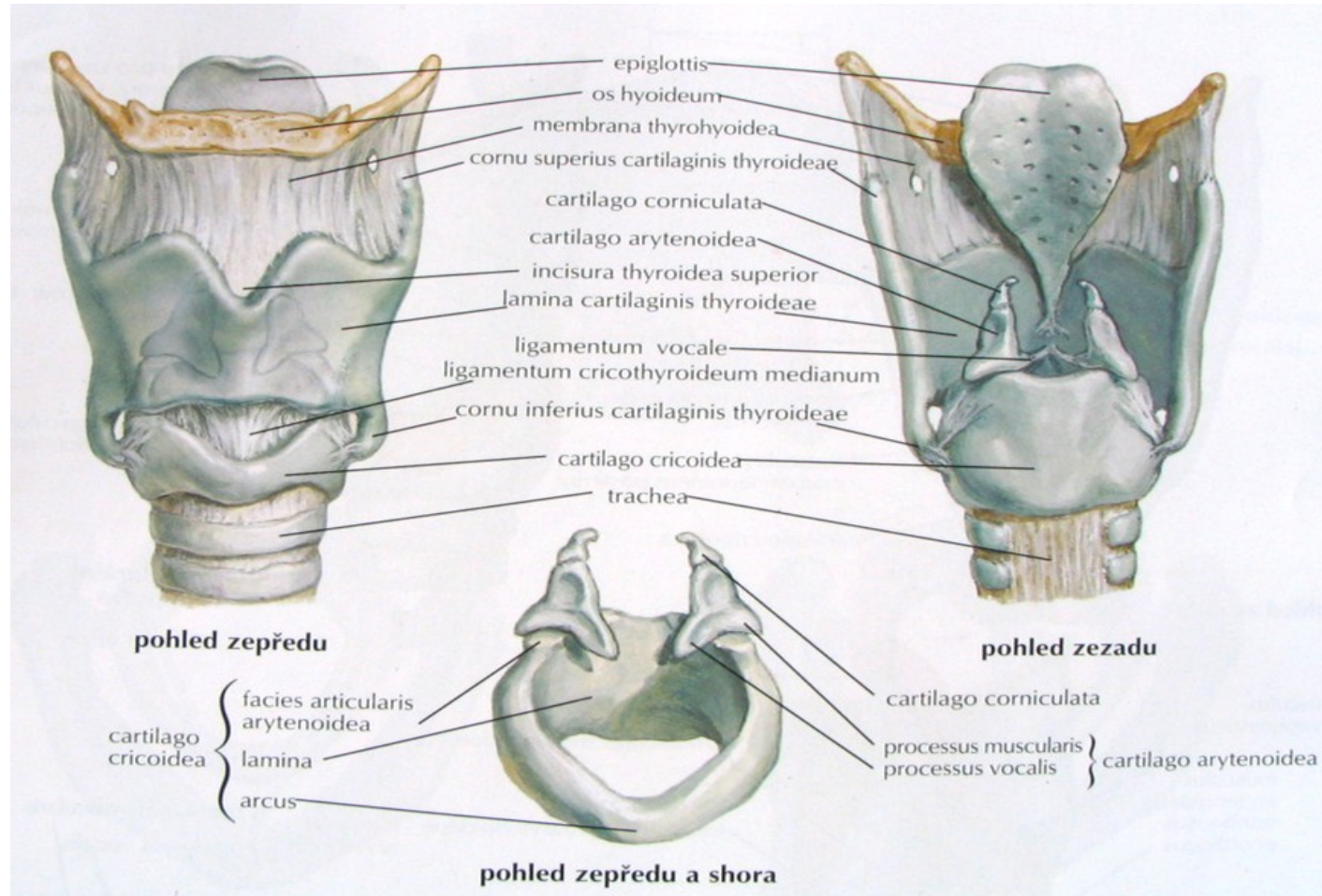
Vocal cords: in the larynx there are vocal folds attached to cartilage. The basis of the cords is elastic connective tissue and the vocal cord muscle. There is a **stratified squamous nonkeratinized epithelium** on the surface of the vocal cords. During phonation (voice production), the vocal folds come closer together and the air stream vibrates them. That's how sound is created.

Cartilage of the larynx

The vocal ligaments are between the processus vocalis and the back side of the thyroid cartilage

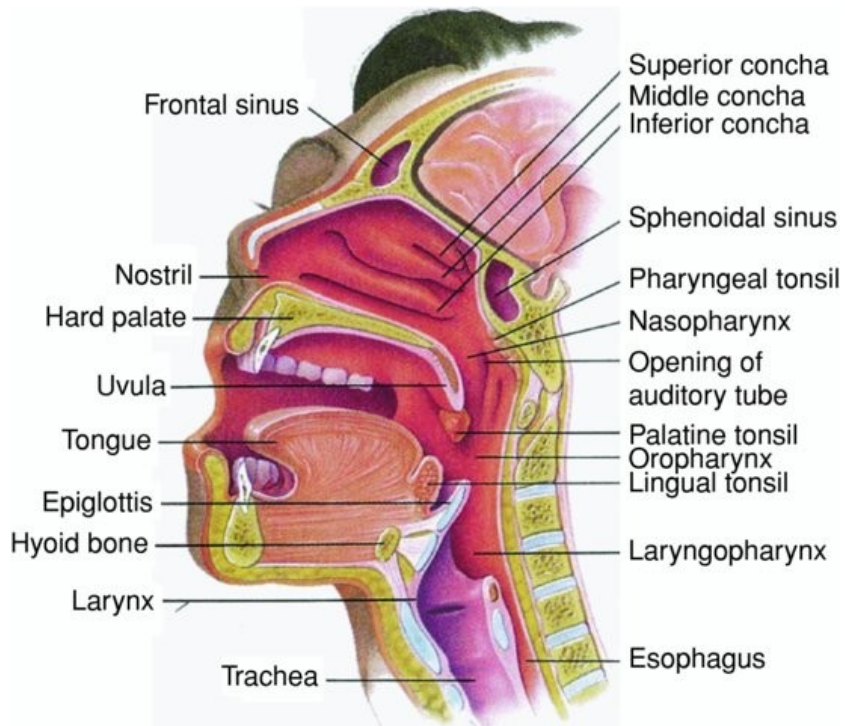
Front View

Back side



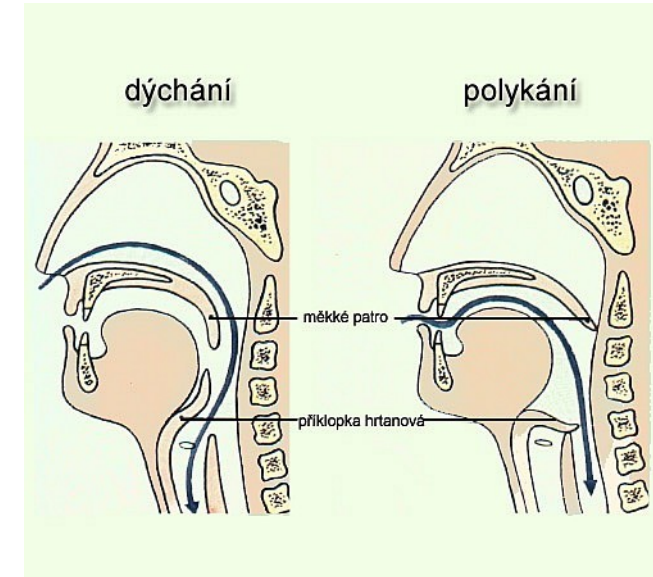
Front and top view

Parts of the Respiratory system



breathing

swallowing



During swallowing, the epiglottis reflexively closes the airway and the food goes into the esophagus.

When breathing when not swallowing, the airways are still open

Parts of the Respiratory system

Trachea:

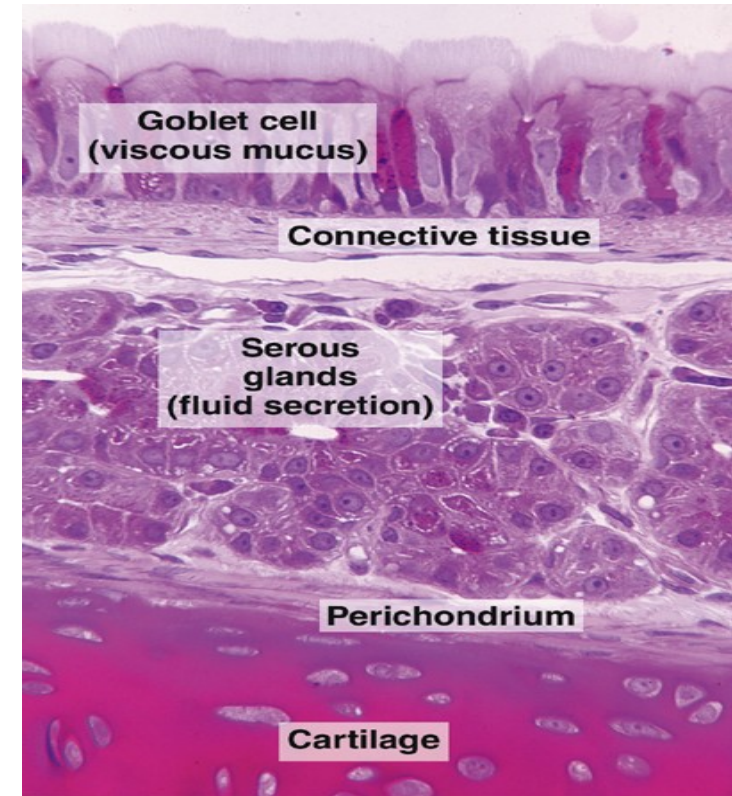
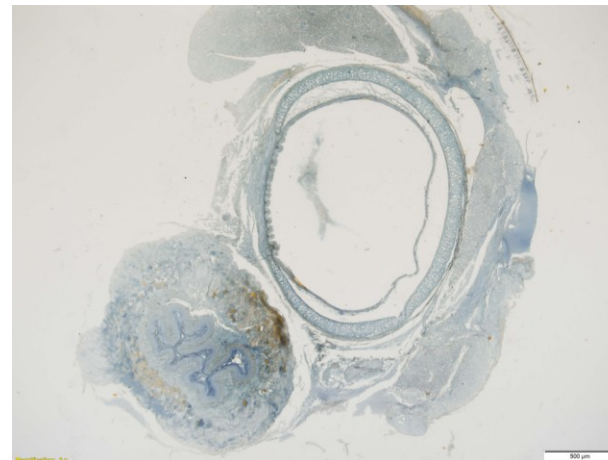
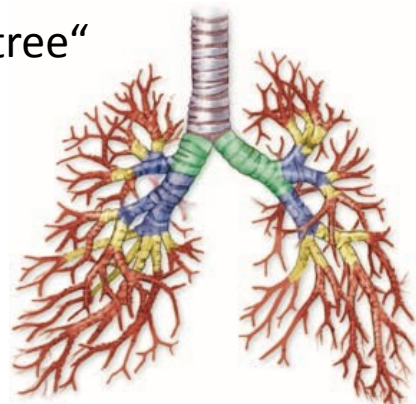
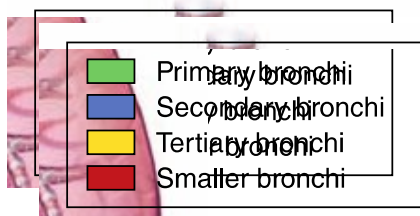
A tube approximately 10 cm long, composed of 12 incompletely closed C-shaped rings of hyaline cartilage.

The free end is filled with connective tissue and muscle and is near the esophagus.

Seromucinous glands are found in the lamina propria under the epithelium.

There is pseudostratified columnar epithelium, only at the point of bifurcation is stratified

„branching of the bronchial tree“



Tracheal wall

Trachea and esophagus, hamster

Parts of the Respiratory system

Bronchi: are a continuation of the trachea, it gradually branches about 10 times, the amount of cartilage decreases towards the lungs, on the contrary, elastic fibers and smooth muscles increase. Seromucinous glands and MALT are present.

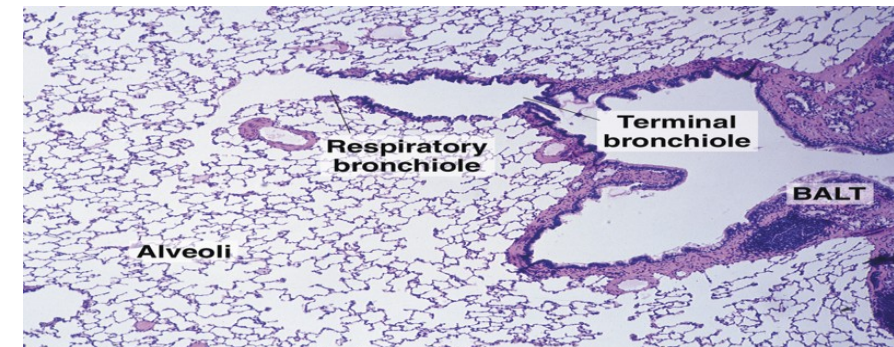
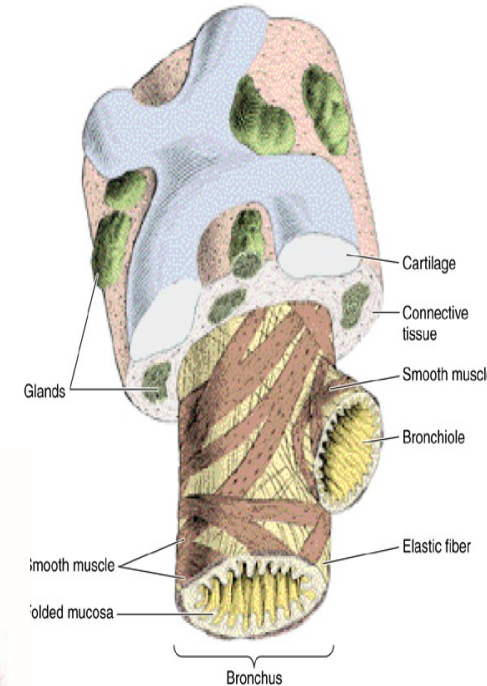
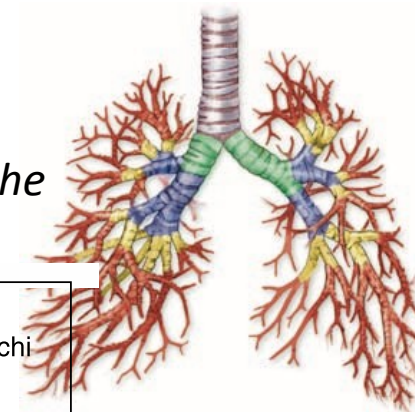
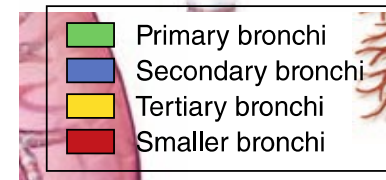
Bronchioles: it is a continuation of the branching of the bronchial tree.

Mucous glands and cartilage are not present.

The epithelium gradually decreases from simple columnar to simple cuboidal.

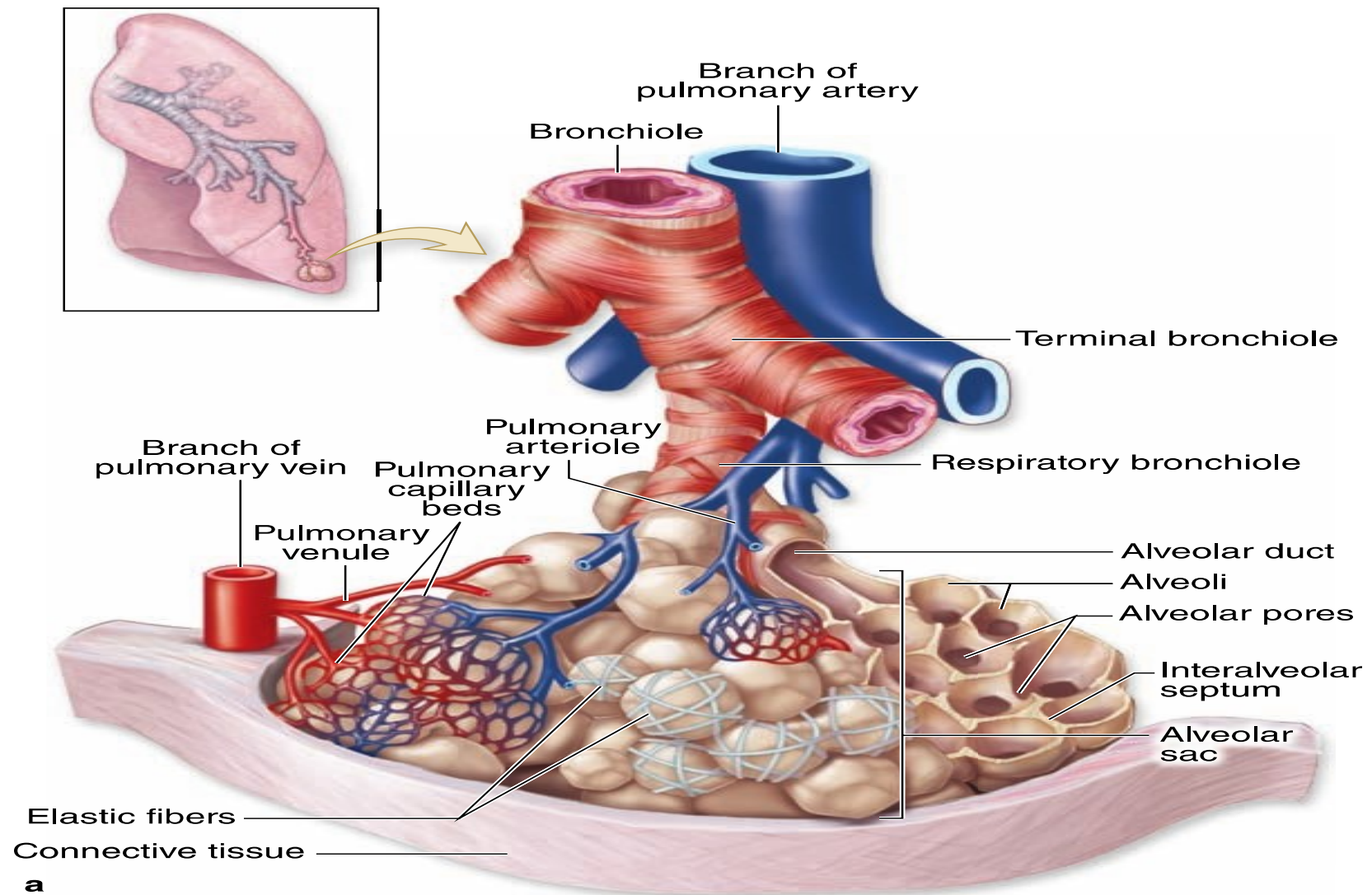
↳ *Clara cells cuboid cells, secretory function in bronchioles, they produce surfactant components, antimicrobial peptides and detoxification enzymes to degrade pollutants from the air*

„branching of the bronchial tree“



Important:

presence of cartilage: bronchi (YES) x bronchioles (NO)



Relative position and localization of capillaries and alveoli

Parts of the Respiratory system

Alveoli: saclike evaginations about 200 μm in diameter in the respiratory part of the system. Between the alveoli are thin septa of elastic connective tissue, which contain many capillaries. Alveoli are interconnected by pores.

On the inner surface of the alveoli are the following cells:

- **Pneumocytes type I:** extremely attenuated cells, few organelles, gas exchange takes place through their cytoplasm. they cover 95% of the inner surface of the alveoli.
- **Pneumocytes II:** cuboidal cells, produce pulmonary surfactant. During intrauterine development, they differentiate in the 6th month.
- **Alveolar macrophages:** they phagocytose dust and damaged erythrocytes that can penetrate into the alveoli. In microscopic sections they are dark, due to phagocytic material.

Fused basal laminae

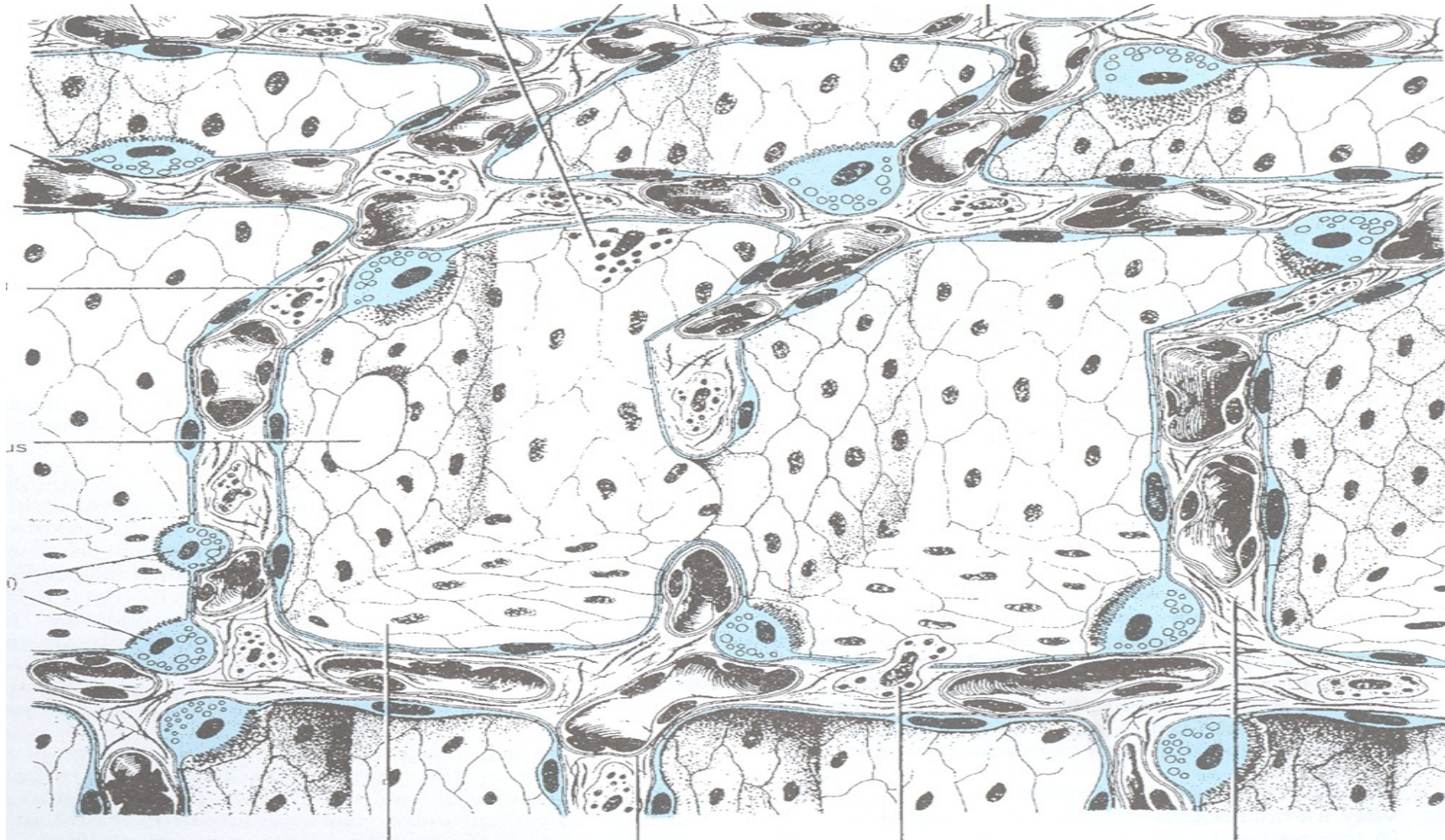
Alveolar macrophages:

Capillary

Porus

Pneumocytes II:

Elastic fibers



Pneumocytes type I:

Alveolar
septum

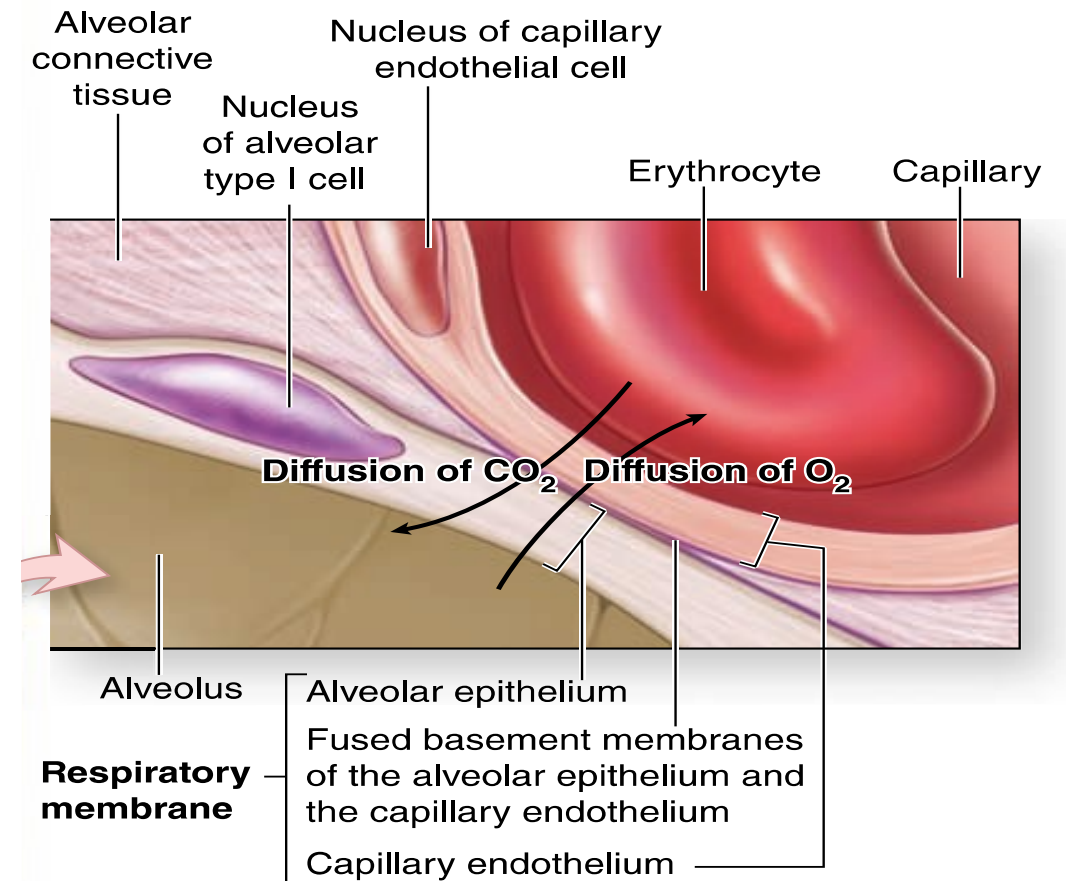
The Respiratory system

Blood-air barrier: layers that separate air and blood in the alveoli

One layer of pneumocytes I – fused basal laminae - capillary endothelial cells

Pulmonary surfactant:

- Is composed of phospholipids and proteins, helps breathing, decreases surface tension between air and epithelium.
- It helps keep the alveoli open.
- In premature babies, pneumocytes II are not yet developed and surfactant is not formed. Children need breathing support machines.



The Respiratory system

Pleura, pleural membranes: The pleura consists of 1 layer of mesothelial cells and connective tissue with collagen and elastic fibers

The outer surface of the lungs is covered by the visceral pleura and the inner surface of the chest cavity is covered by the parietal pleura.

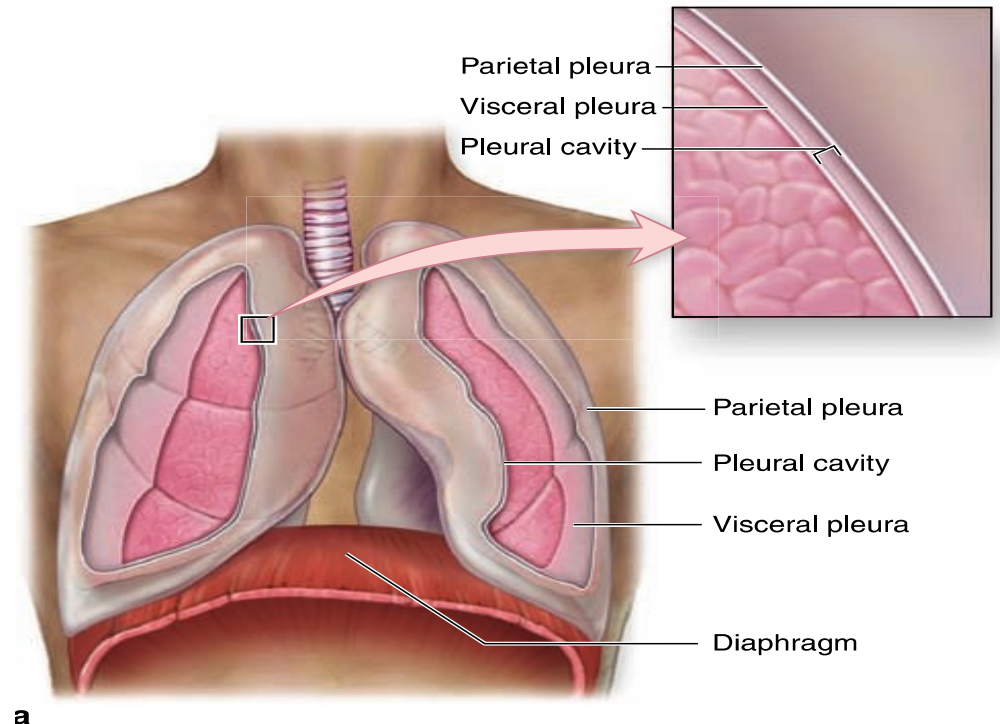
Between the two pleurae is a pleural cavity with a small amount of fluid. During inflammation, this amount of fluid can increase - pleural effusion.

Respiratory movements:

Inhalation is an active process, thanks to muscle contraction. The intercostal muscles and the diaphragm contract and thus the volume of the chest cavity increases.

During exhalation, the elastic fibers in the lungs contract and the muscles relax, the volume of the chest decreases.

inhalation - active, exhalation - passive



Features of the upper respiratory tract, larynx, trachea

Region	Epithelium	Glands	Musculoskeletal Support	Other Features and Major Functions
Vestibules of nasal cavities	Stratified squamous, keratinized to nonkeratinized	Sebaceous and sweat glands	Hyaline cartilage	Vibrissae (stiff hairs) and moisture both filter and humidify air
Most areas of nasal cavities	Respiratory	Seromucous glands	Bone and hyaline cartilage	Rich vasculature and glands warm, humidify, and clean air
Superior areas of nasal cavities	Olfactory, with bipolar neurons	Serous (Bowman) glands	Bone (ethmoid)	Solubilize and detect odorant molecules in air
Nasopharynx and posterior oropharynx	Respiratory and stratified squamous	Seromucous glands	Bone and skeletal muscle	Conduct air to larynx; pharyngeal and palatine tonsils
Larynx	Respiratory and stratified squamous	Mucous glands, smaller seromucous glands	Elastic and hyaline cartilage, ligaments, skeletal muscle	Site for phonation; epiglottis closes while swallowing
Trachea	Respiratory	Mainly mucous glands, some serous or mixed glands	C-shaped rings of hyaline cartilage, with smooth (trachealis) muscle in posterior opening of each	Conduct air to primary bronchi entering lungs; some MALT

and intrapulmonary branches of the bronchial tree

Region of Airway	Epithelium	Muscle and Skeletal Support	Other Features and Major Functions
Bronchi	Respiratory	Prominent spiral bands of smooth muscle; irregular hyaline cartilage plates	Repeated branching; conduct air deeper into lungs
Bronchioles	Simple ciliated cuboidal to columnar, with Clara cells	Prominent circular layer of smooth muscle; no cartilage	Conduct air; important in bronchoconstriction and bronchodilation
Terminal bronchioles	Simple cuboidal, ciliated and Clara cells	Thin, incomplete circular layer of smooth muscle; no cartilage	Conduct air to respiratory portions of lungs; Clara cells with several protective functions
Respiratory bronchioles	Simple cuboidal, ciliated and Clara cells, with scattered alveoli	Fewer smooth muscle fibers, mostly around alveolar openings	Conduct air deeper, with some gas exchange and protective Clara cells
Alveolar ducts and sacs	Simple cuboidal between many alveoli	Bands of smooth muscle around alveolar openings	Conduct air, with much gas exchange
Alveoli	Types I and II alveolar cells (pneumocytes)	None (but with network of elastic and reticular fibers)	Sites of all gas exchange; surfactant from type II pneumocytes; dust cells

The Urinary system

The paired kidneys and ureters, the bladder and the uterus

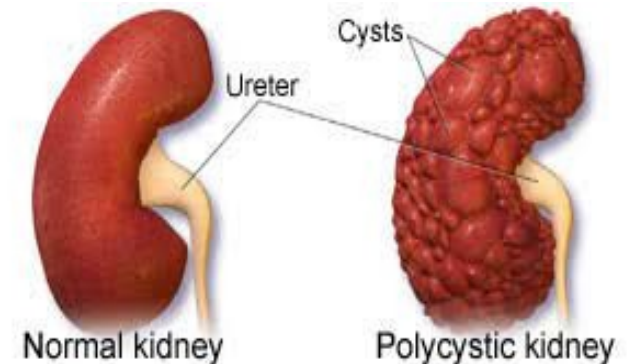
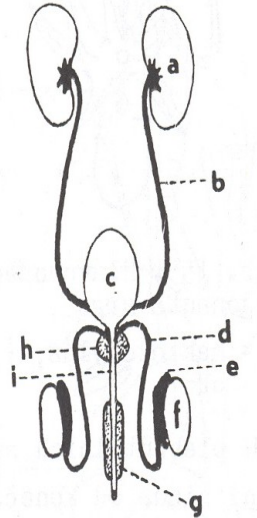
Function:

- excretion of metabolic waste, excess water and electrolytes. maintaining homeostasis in the organism.
- excretion of biologically active substances, drugs
- secretion of erythropoietin, which stimulates the production of erythrocytes in the bone marrow
- renin converts angiotensinogen to angiotensin I and thus regulates blood pressure

*Polycystic kidney disease:
a hereditary kidney disease in which a large number of fluid-filled cysts form in the cortex. Healthy kidney tissue is reduced and organ failure may occur.*

Male urogenital system

- a – kidney
- b – ureter
- c – bladder
- d – vas deferens
- e,f – testes, epididymis
- g – corpus cavernosum
- h – prostate
- i – uterus



Parts of the Urinary system

Kidneys: size 12 x 6 cm, covered by a fibrous capsule.

During an autopsy, the capsule can be easily removed, but in the case of a patient with kidney disease, the capsule firmly adheres to the surface of the kidney and cannot be removed.

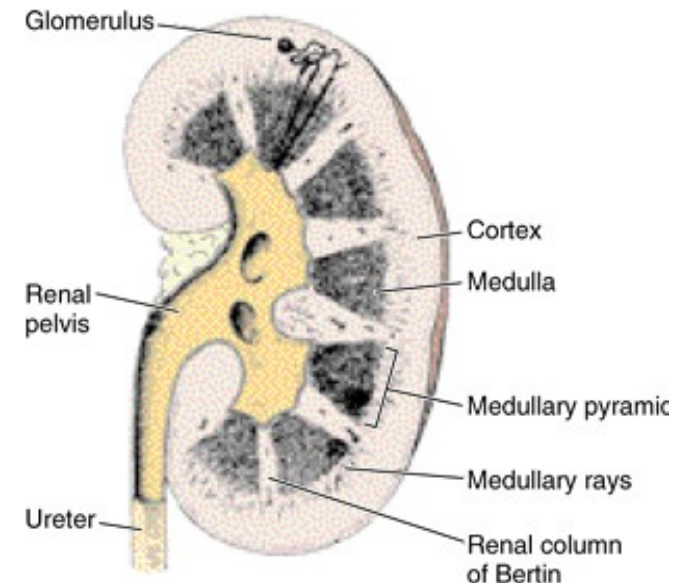
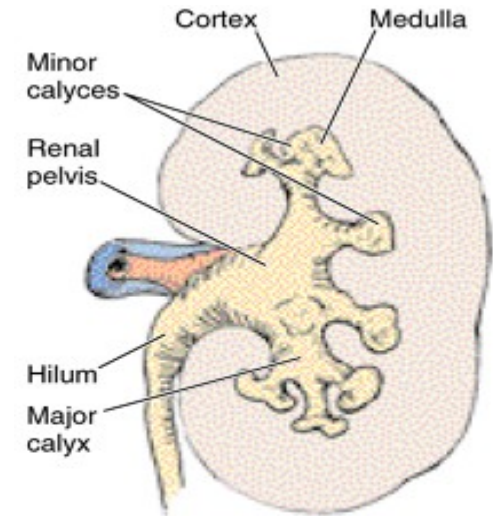
The hilum - the artery enters and the vein and ureter exit.

The ureter expands in the kidney into the renal pelvis, which is followed by the renal calyces.

Parenchyma is composed of:

Cortex: is located on the outside of the kidney and also forms the „columnae renales“. Contains renal corpuscles (part of nephron).

Medulla: the medulla contains mainly tubules and ducts, it is located in the renal pyramids and in the medullary rays (ducts and tubules extending from the medulla into the cortex).



Nephron

Is the basic structural and functional unit of the kidney.

There are approximately 1-4 million of nephrons in one kidney

Nephron consists of the renal corpuscle and the tubules.

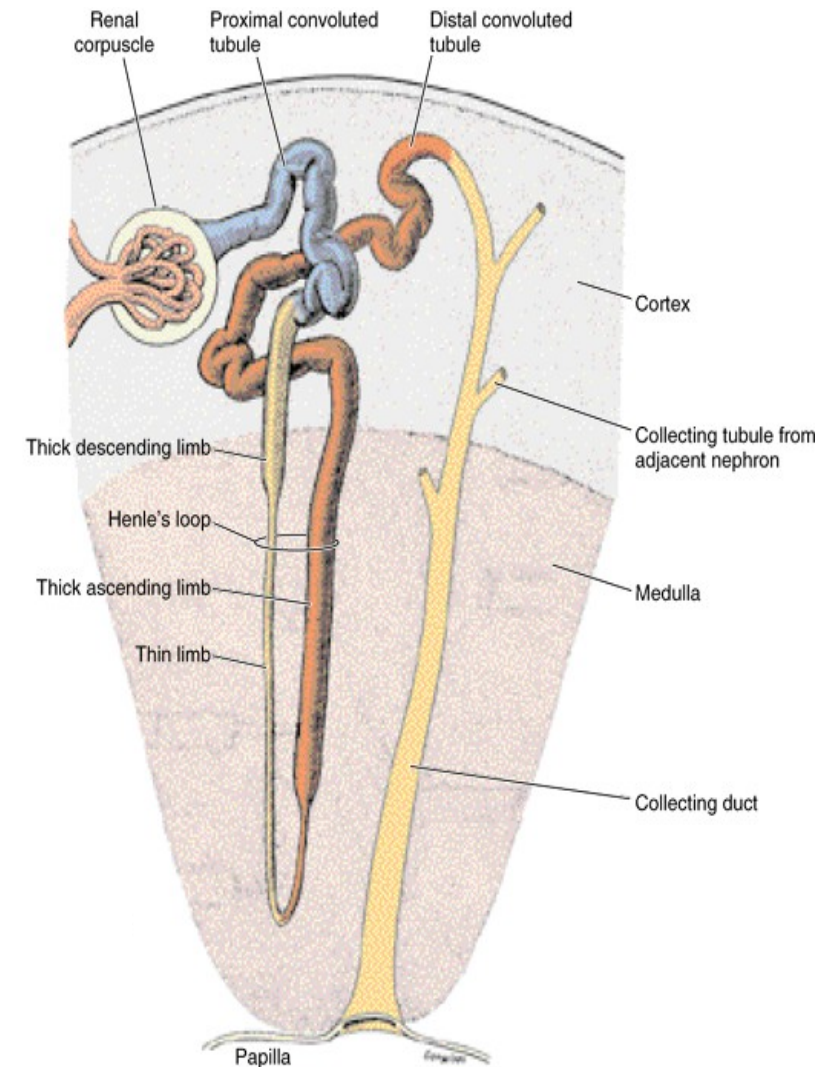
The tubule contains a single-layered epithelium and has 3 parts.

Main parts of nephron:

- Renal corpuscle
- Proximal tubule
- Loop of Henle (a thin descending and ascending limb, thick limb)
- Distal tubule
- Connecting tubule – short part connecting nephron to collecting duct

Collecting tubule -

it is not part of an individual nephron. Several nephrons open into one collecting duct. It continues to the renal papilla and the renal calyx



Nephron

Types of nephrons:

Cortical - located completely in the cortex

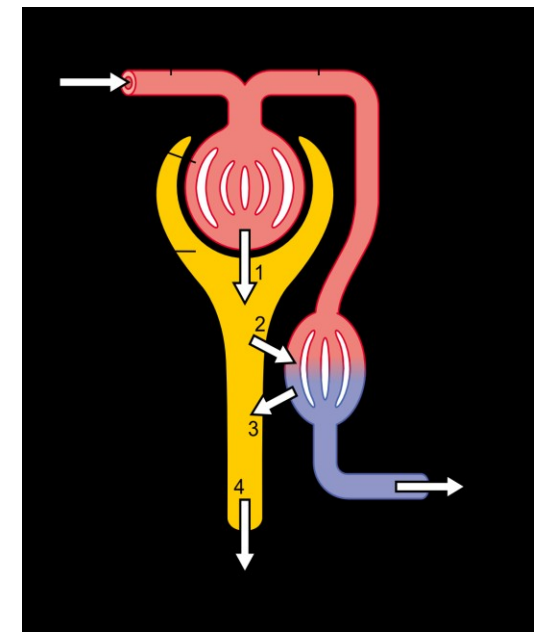
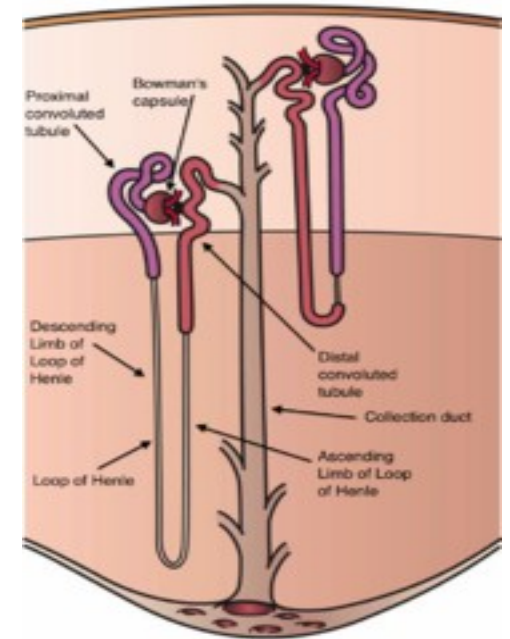
Juxtamedullary - located near the medulla and have long loops of Henle

Which processes take place in the kidneys?

Filtration: water and dissolved substances from the blood pass through the vessel wall of the capillaries in the glomerulus into the urinary space in the nephron.

Secretion: substances from the interstitium and capillaries around the tubules pass through the epithelium of the tubules into the lumen

Reabsorption (resorption): substances from the lumen of the tubules pass into the interstitium and capillaries around the tubules



Parts of the nephron

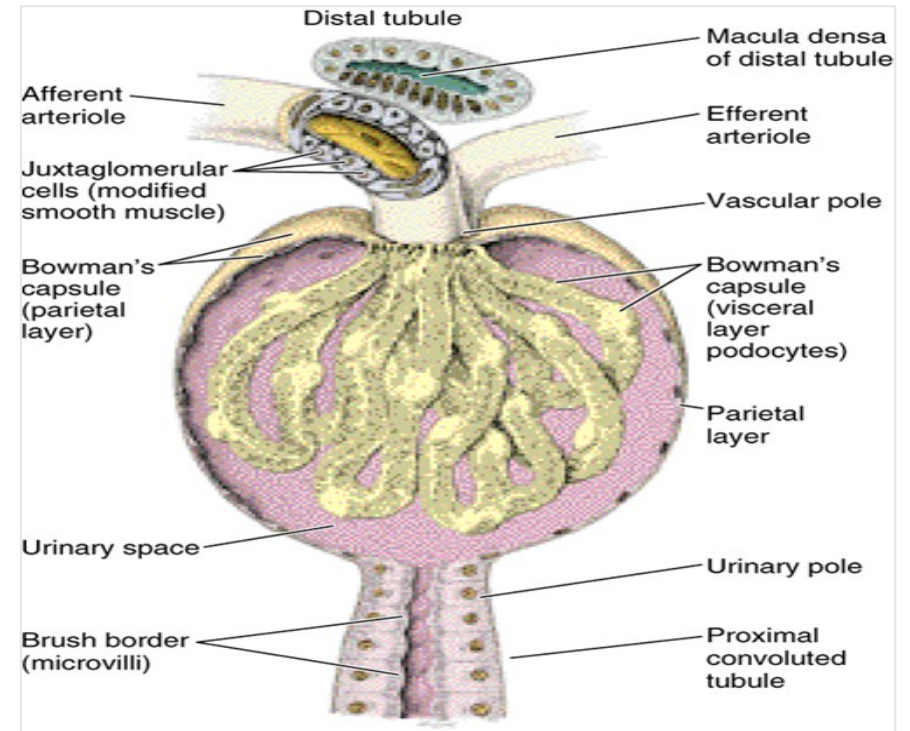
Vascular pole - afferent arteriole enters, efferent leaves
Tubular pole – here the proximal tubule begins.

Renal corpuscles:

Glomerulus (capillaries inside the body)

Bowman capsule:

- Visceral layer - it is formed by **podocytes** that closely surround the endothelial cells of the capillaries.
- Parietal layer - simple squamous epithelium with basal lamina externally



Urinary space – primary urine accumulates here. It is produced approx. 120 l/day

Parts of the nephron

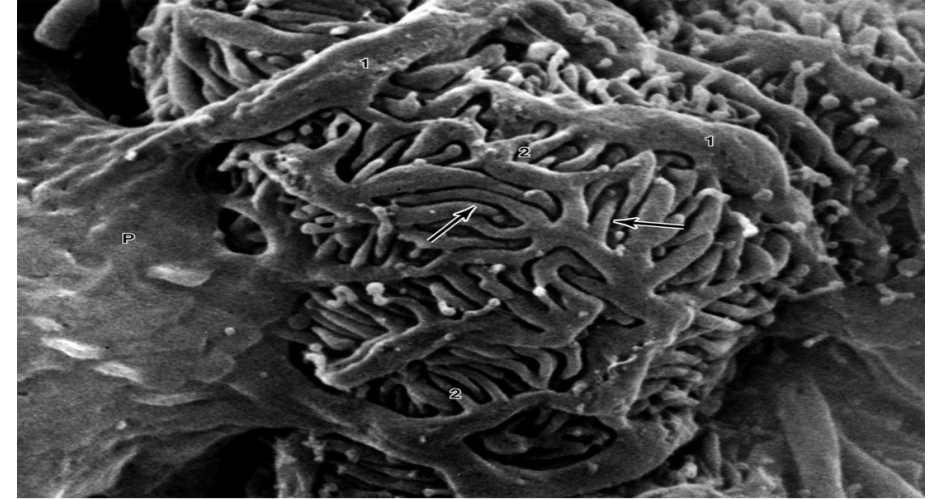
Podocytes:

They have primary and secondary processes (called pedicels) that are in direct contact with the basal lamina of capillaries.

Between the pedicles there are filter slits with a width of 20-30 nm. These slits are covered by a slit membrane.

The slit membrane is made up of proteins, glycoproteins and proteoglycans, which are bound in the pedicels membrane and protrude into the cleft space.

There is a high content of the special protein nephrin.

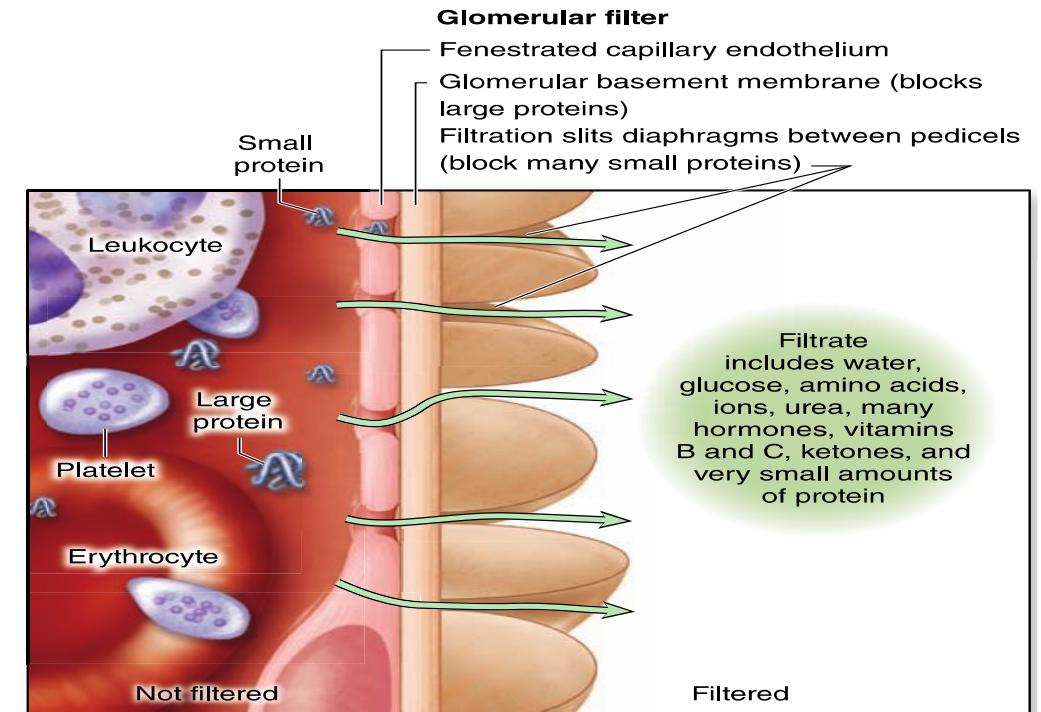
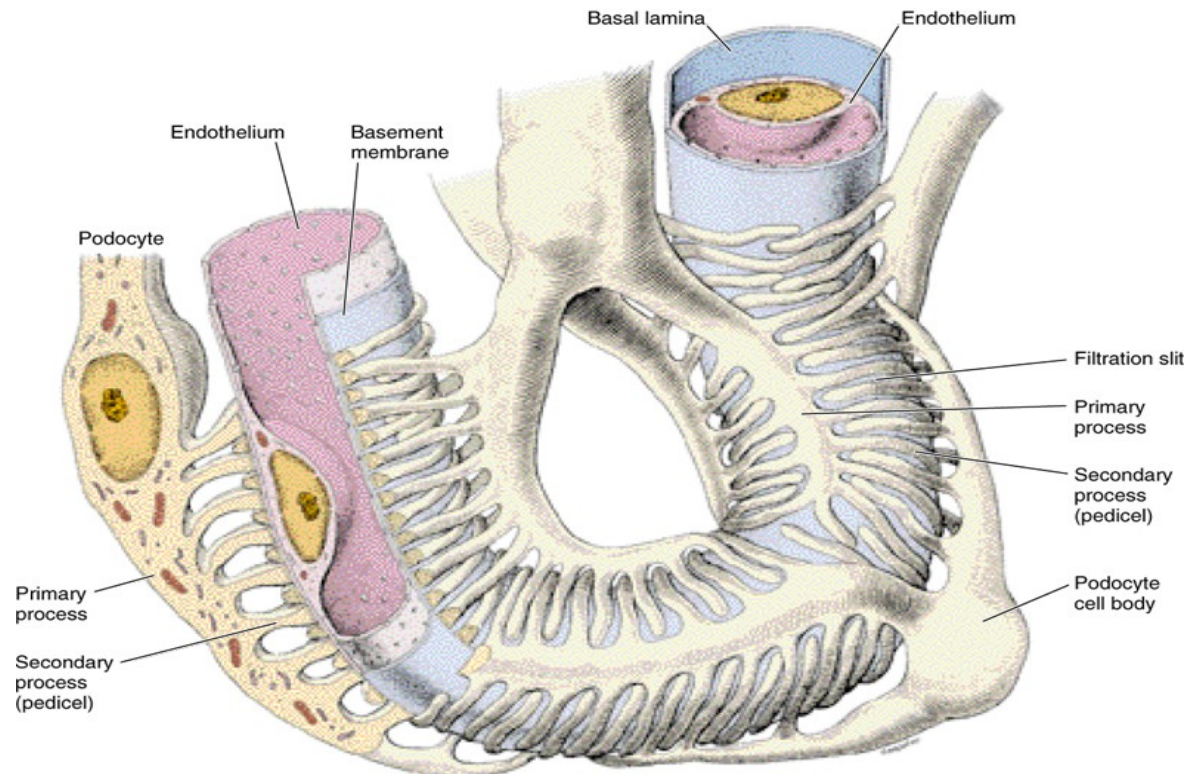


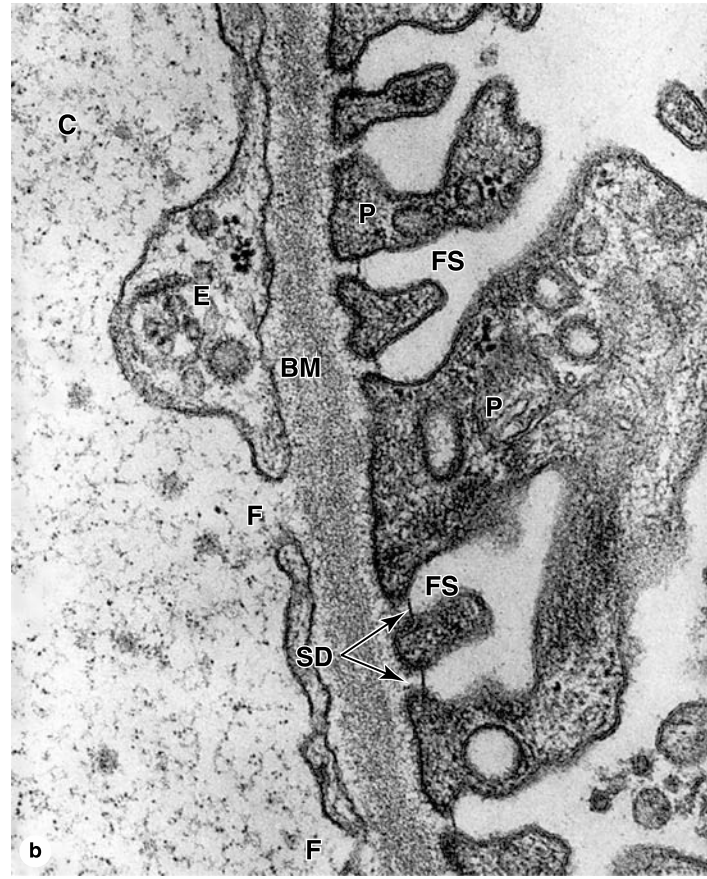
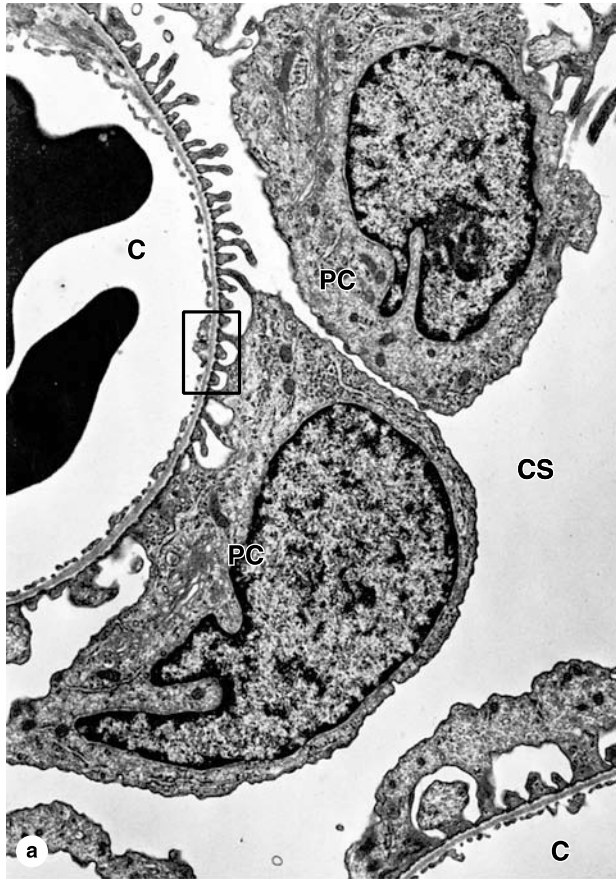
Scanning electron microscope image of podocytes and their pedicles

Parts of the nephron

Filtration barrier between blood and primary urine:

- The fenestration of the capillary endothelium - blocks blood cells
- Fused basal laminae (one from endothelium, the other from podocytes) - blocks large proteins
- Slit membrane (diaphragms) between pedicels - blocks small proteins, organic anions





The glomerular filtration barrier consists of three layered components: the fenestrated **capillary endothelium**, the **glomerular basement membrane (GBM)**, and **filtration slit** diaphragms between pedicels. The major component of the filter is formed by fusion of the basal laminae of a podocyte and a capillary endothelial cell. **(a)** TEM shows cell bodies of two podocytes (**PC**) and the series of pedicels on the capillary (**C**) basement membrane separated by the filtration slit diaphragms. Around the capillaries and podocytes is the capsular space (**CS**) into which the filtrate enters. The enclosed area is shown in part **b**. X10,000.

(b) At higher magnification, both the fenestrations (**F**) in the endothelium (**E**) of the capillary (**C**) and the filtration slits (**FS**) separating the pedicels (**P**) are clearly seen on the two sides of the thick, fused basement membrane (**BM**). Thin slit diaphragms (**SD**) bridge the slits between pedicels. X45,750.

(c) Diagram shows the three parts of the glomerular filter and their major functions.

Transmission electron microscope (TEM) image of the filter barrier between podocyte pedicels and capillaries

Parts of the nephron

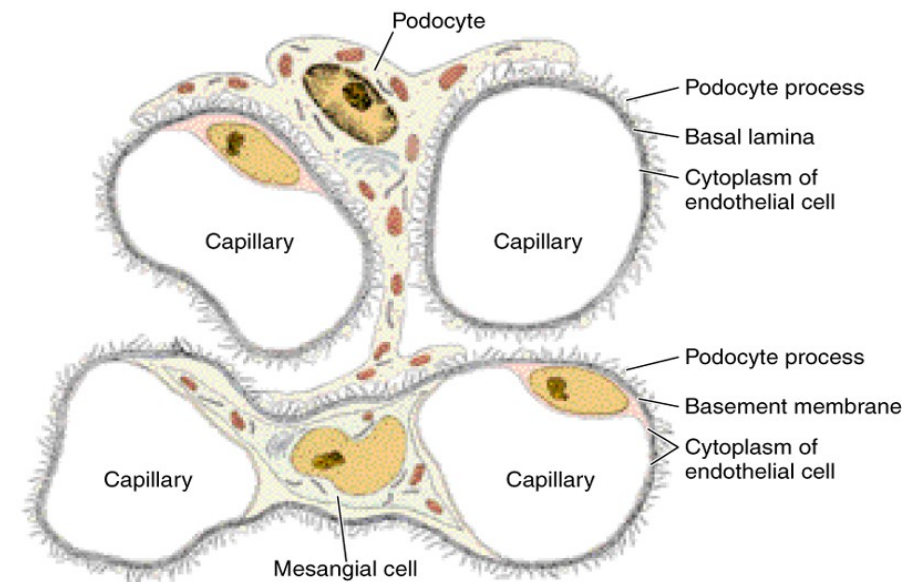
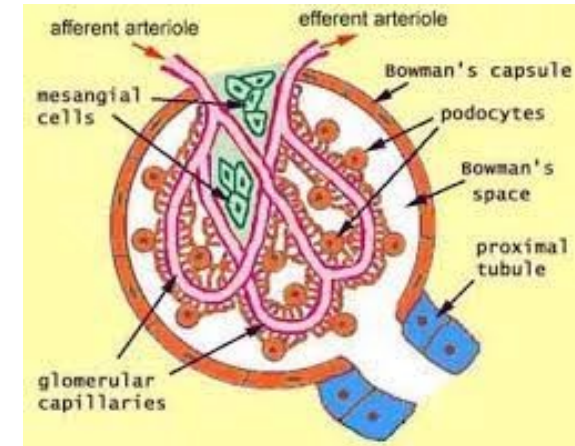
Mesangium: is the space between the capillaries and podocytes in the glomerulus.

There are mesangial cells:

- have the ability to contract
- have their own basal lamina.

Functions of the mesangium: regulation of blood pressure, phagocytosis, production of cytokines and other regulatory substances

Proteuria: *The primary filtrate (primary urine) under normal circumstances has a similar composition to blood plasma, but contains very few proteins. When the filter barrier is damaged (with diabetes mellitus or inflammation), even larger proteins pass through and are then present in the urine. A urine test with a diagnostic strip is often performed by a doctor.*



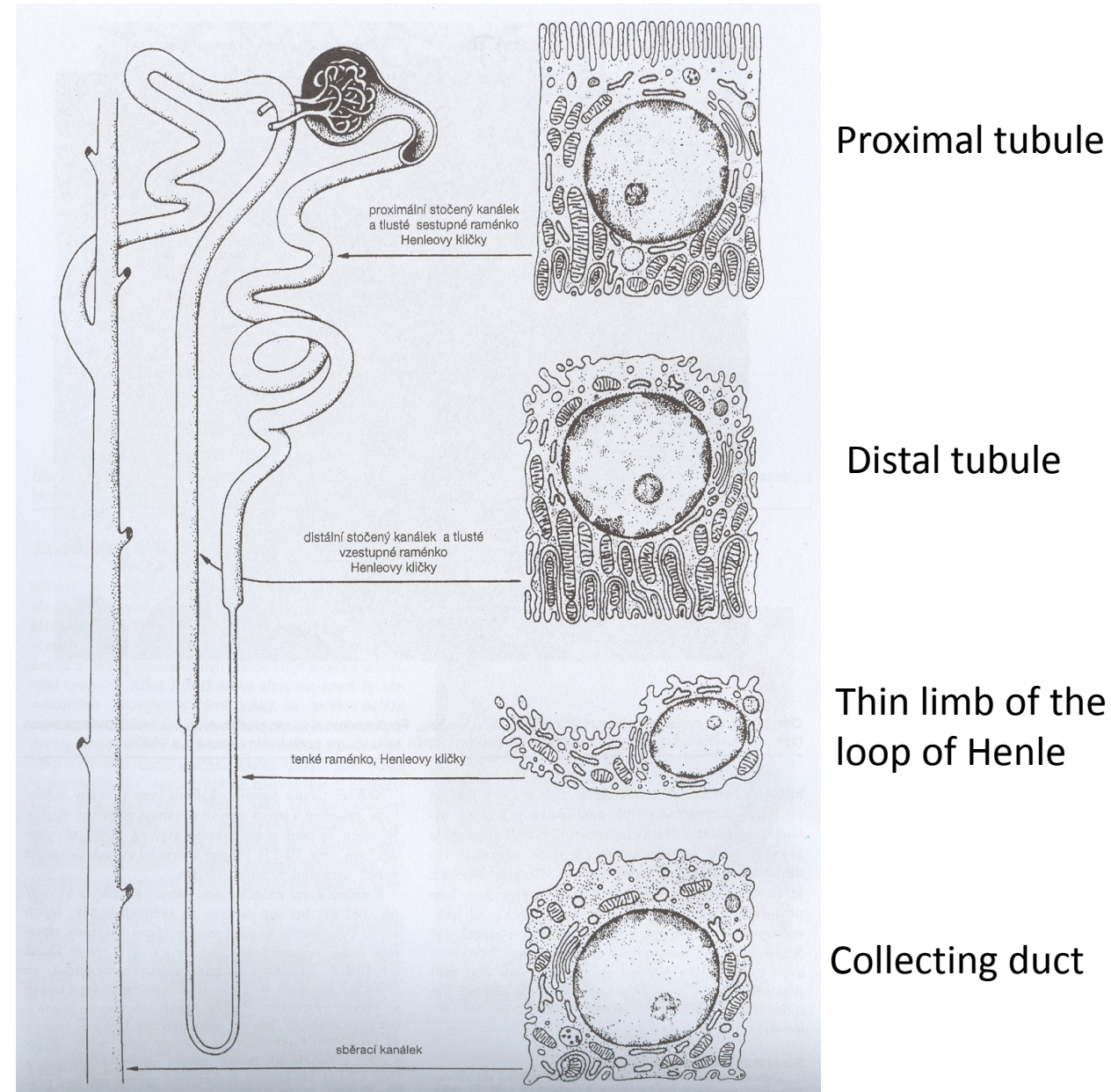
Parts of the nephron

Proximal tubule: the cells of the simple epithelium are cuboidal, large, not all nuclei are visible on cross-sections, many mitochondria, a brush border and invagination of the basement membrane (they increase the area).

Cells have many ion pumps (transmembrane ion transporters in the membranes) and transport vesicles in the cytoplasm.

Transport: reabsorption of water and organic nutrients takes place here, and organic cations and anions are secreted in the opposite direction.

The hydroxylation of vitamin D and its release into the blood takes place in the epithelium of the proximal tubule.



Parts of the nephron

Loop of Henle: consists of three parts: thin descending limb, thin ascending limb (both of simple squamous epithelia) and thick ascending limb (simple cuboidal epithelium).

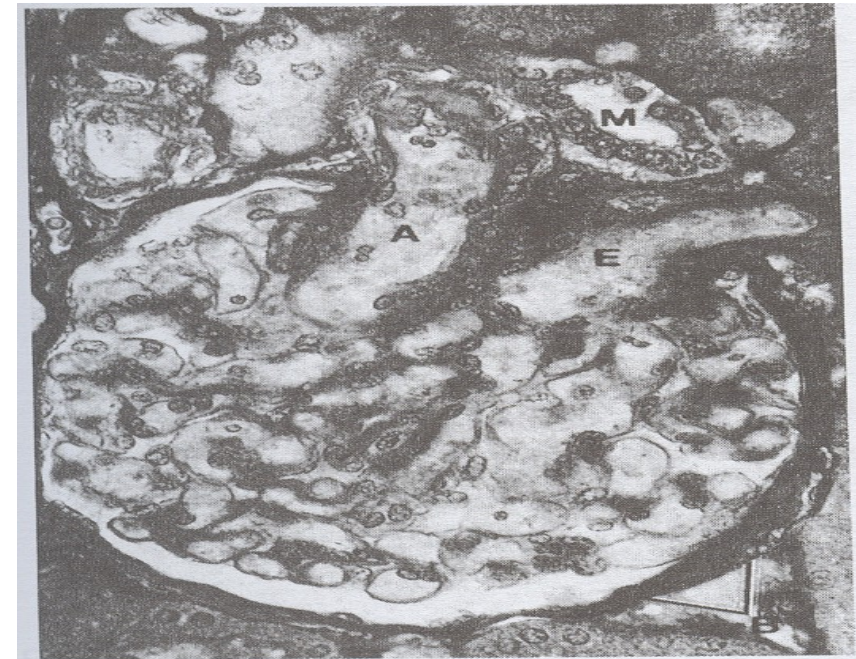
Passive and active reabsorption of electrolytes

Distal tubule: cells are smaller in the proximal tubule, there is no brush border, the lumen is large and clear, all nuclei are usually visible in cross section. Aldosterone-controlled reabsorption of sodium cations takes place here.

Macula densa: layer of epithelium in the distal tubule at the point of contact with arterioles at the vascular pole of the nephron.

Epithelial cells are columnar and darker and have a chemoreceptive function.

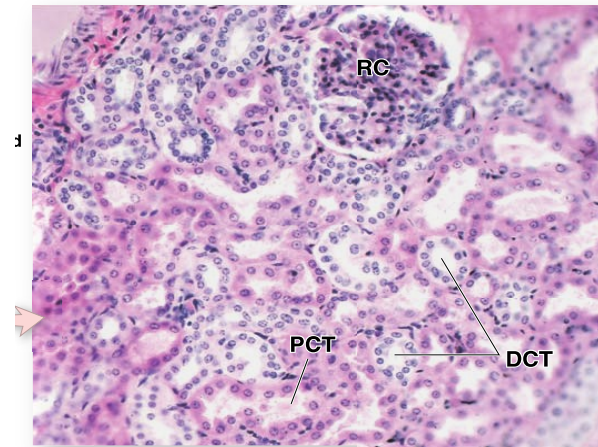
Muscle cells in the tunica media in the afferent arteriole at this site **produce renin**. The system is called the **juxtaglomerular apparatus** and regulates blood pressure and glomerular filtration.



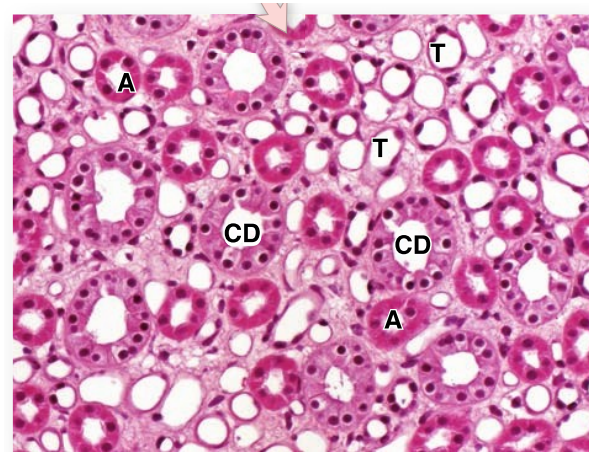
Parts of the nephron

Collecting ducts: cuboidal epithelium, cells have a basal invagination

Reabsorption takes place here via aquaporins.



(b) Renal cortex



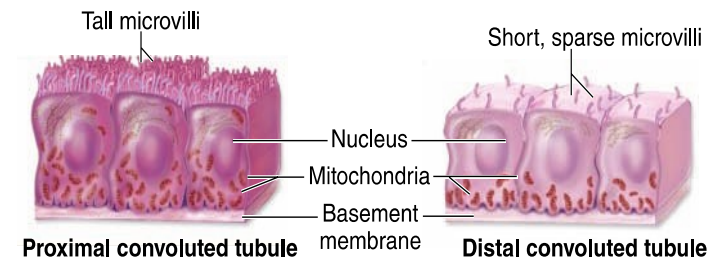
(d) Cross section of renal medulla

(b) A section of cortical tissue shows one renal corpuscle (**RC**), the wide, eosinophilic proximal convoluted tubules (**PCT**) with the smaller, less well-stained distal convoluted tubules (**DCT**). X160. H&E.

(c) Diagram shows the major structural differences between the cuboidal cells of proximal and distal tubules. Cells of both tubules have basal membrane invaginations associated with mitochondria.

(d) A cross section through a medullary pyramid shows the simple squamous epithelium of the thin descending and ascending limbs of loops of Henle (**T**) and its thick ascending limbs (**A**), as well as the pale columnar cells of collecting ducts (**CD**). Note also the homogeneous interstitium with capillaries smaller than the thin limbs. X160. Mallory trichrome.

Interstitial fibroblasts in the surrounding connective tissue in the cortex produce erythropoietin.



(c) Convoluted tubule epithelia

Blood circulation in the kidney

Blood circulation:

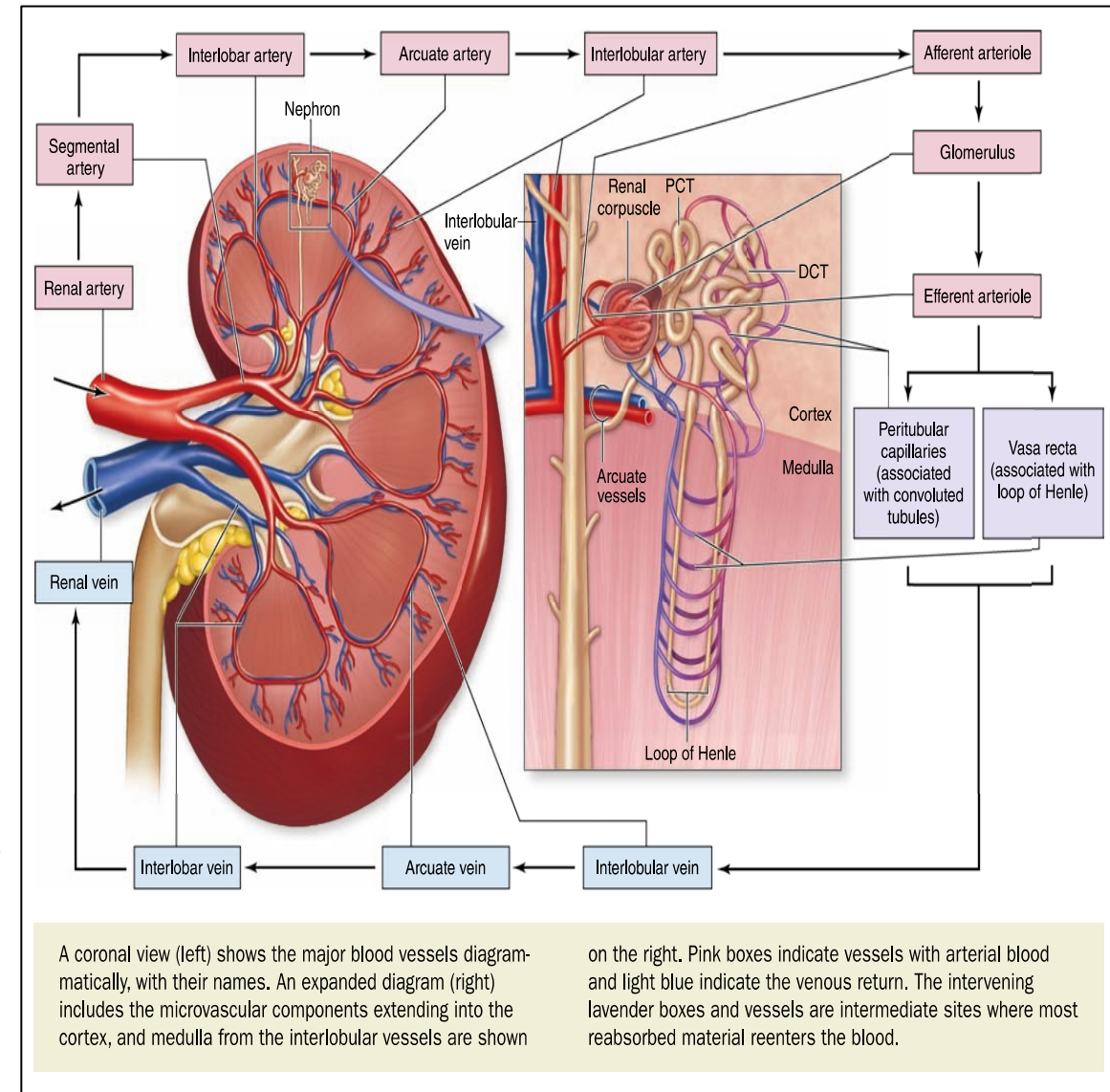
From the interlobular arteries arise the **afferent arteriole**, which form a plexus of capillary loops (glomerulus). Blood leaves the glomerulus via **efferent arterioles** (not veins!)

Efferent arterioles branch again to form another capillary network:

- peritubal capillaries (around the cortical tubules)
- *vasa recta* (around the loops of Henle and collecting ducts)

From this second capillary network, the blood is drained into the veins.

This arrangement is called **the arterial portal circulation** – it is especially in the kidneys.



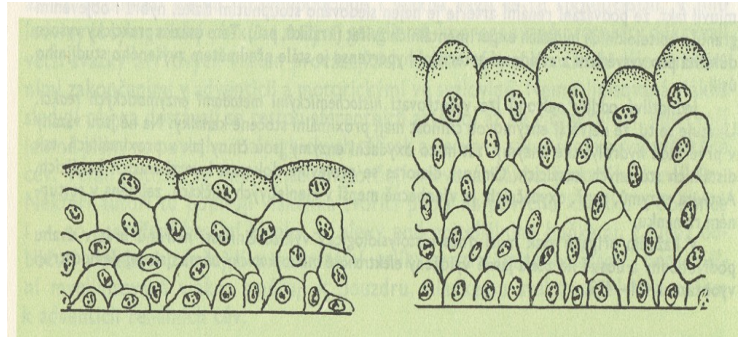
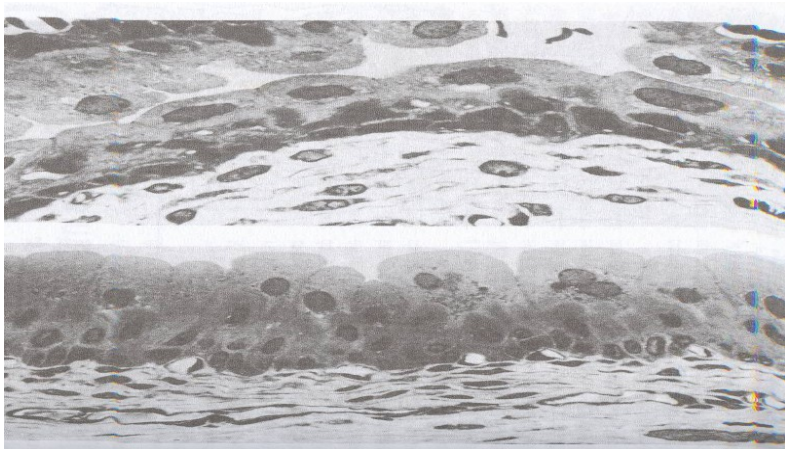
Ureters, Bladder, Urethra

The wall consists of three layers:

- Tunica mucosa – urothelium or transitional epithelium with umbrella cells - modified (uroplakin proteins) and thicker apical membrane that is in contact with urine. Under the epithelium is the lamina propria.
- Tunica muscularis – smooth muscle
- Adventitia – connective tissue

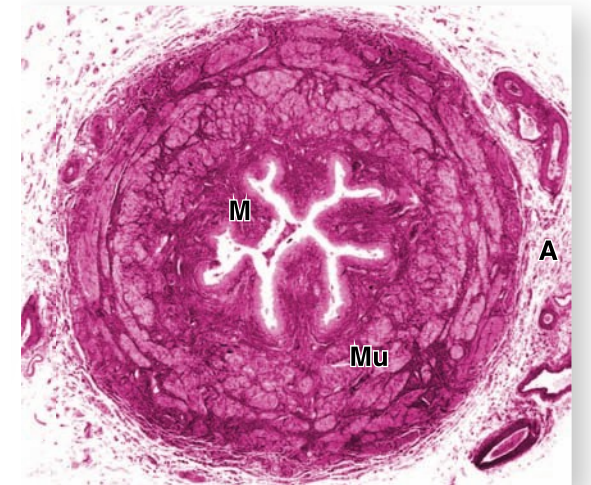
Ureter: the lumen in transverse section has large folds, urothelium

Bladder: tunica muscularis consists of three layers, urothelium



Bladder

Transitional epithelium in full or empty situation.



Ureter

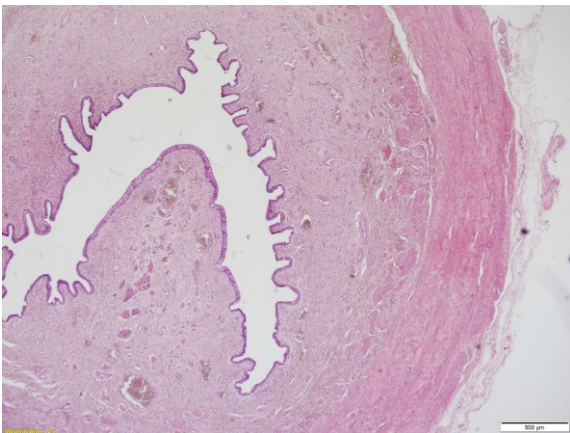
(b) Histologically the muscularis (Mu) is much thicker than the mucosa (M) and adventitia (A). X18. H&E.

Urethra:

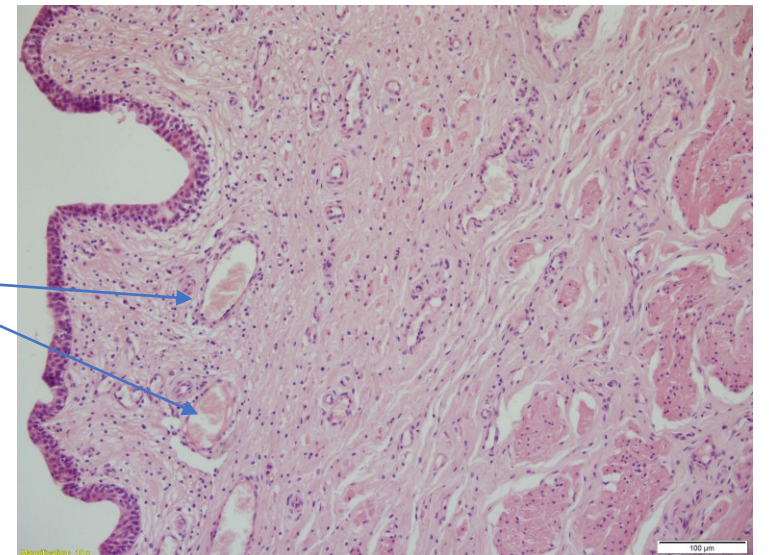
Male urethra is longer, the vas deferens opens into it. It consists of three segments:

- prostatic urethra - in the place of the prostate, it is lined with urothelium
- membranous urethra - passes through the external sphincter from striated muscle, stratified columnar epithelium
- spongy urethra – is enclosed within erectile tissue of the penis, stratified epithelium

Female urethra is shorter, urothelium initially and then stratified squamous. Bladder infections are more common in women than in men, because infection from the surface of the body can more easily penetrate the body through the shorter urethra.



Female urethra: thick layer of lamina propria in the mucosa with large blood vessels - venous plexus.



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