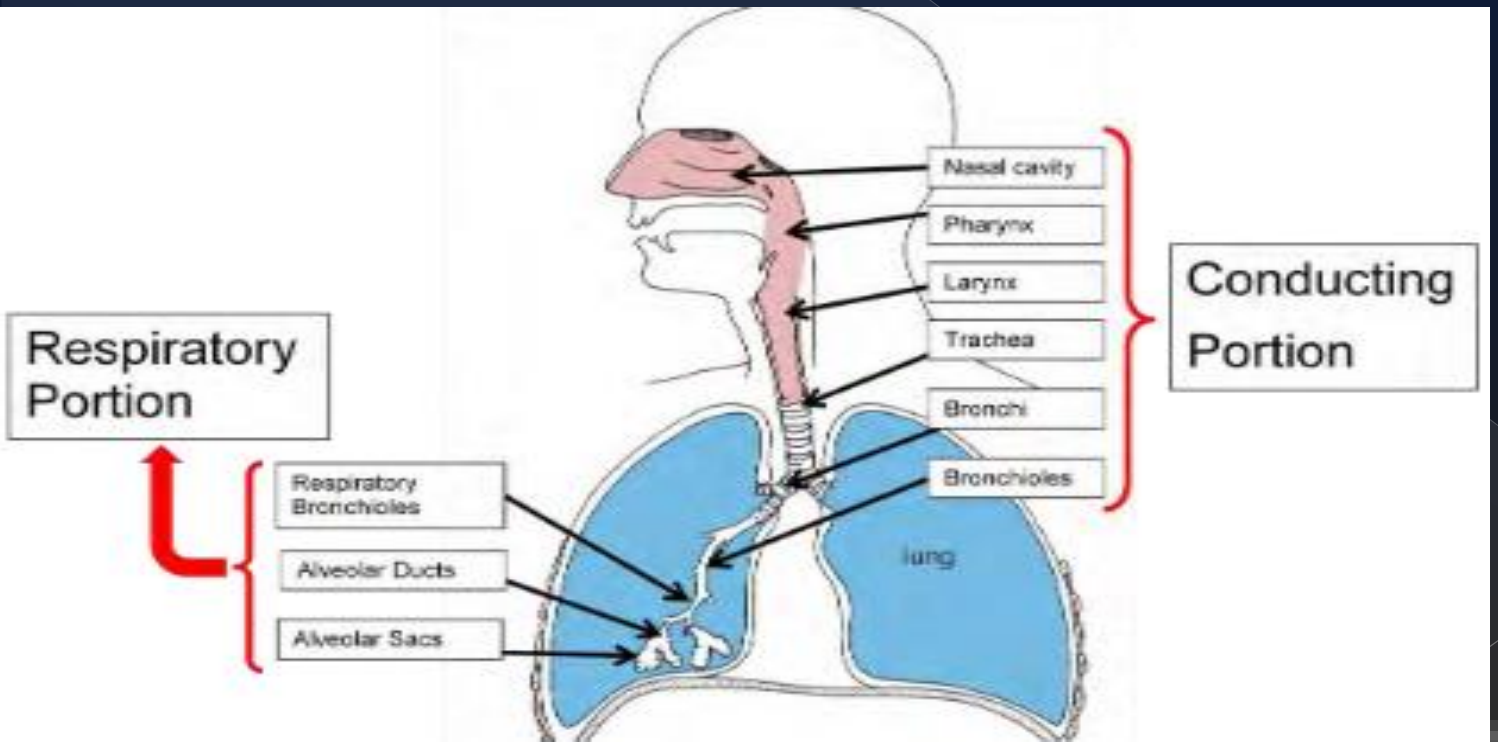
RESPIRATORY SYSTEM

Respiratory system - functions

Conducting portion - conducting, filtration /cleaning, moistening of the air, temperature regulation (warming)

- Reception of the odors
- Phonation

Respiratory portion - exchange of O_2 and CO_2



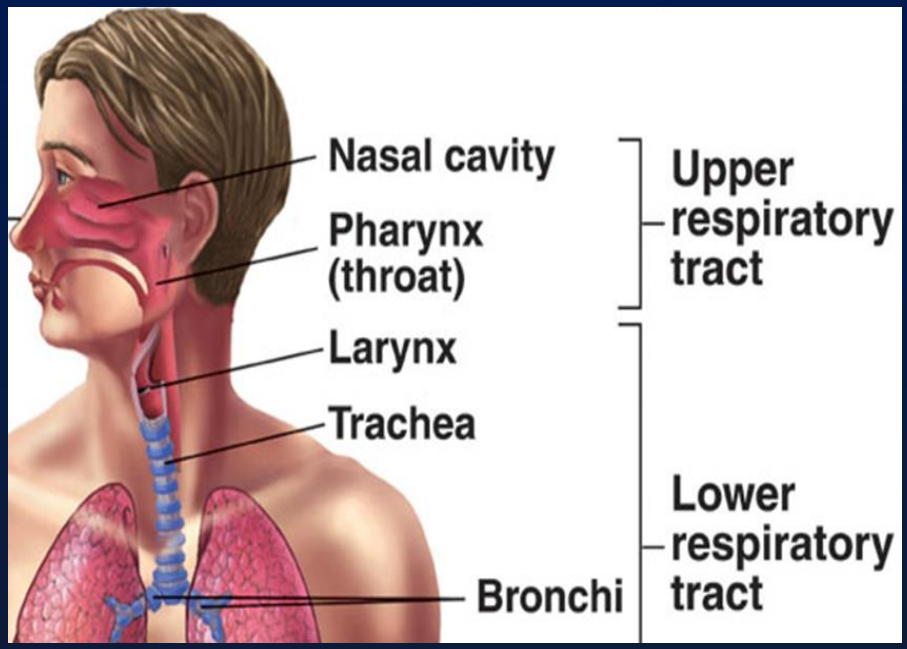
Conducting portion

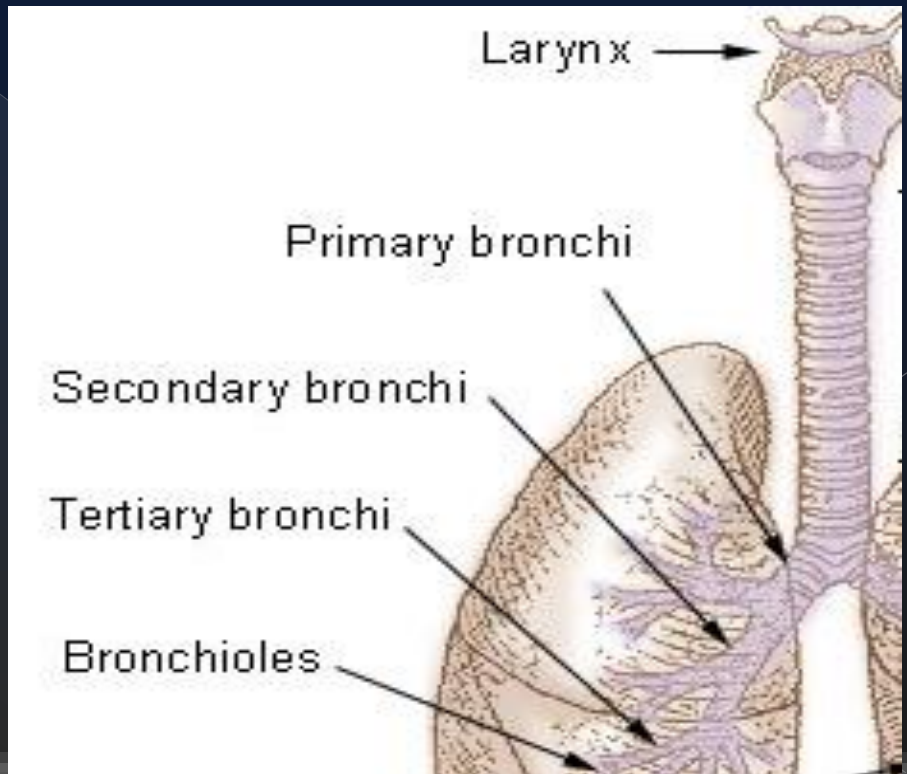
Extrapulmonary part – outside the lungs

- **nasal cavity**
- **pharynx**
- **larynx**
- **trachea**
- **primary bronchi**

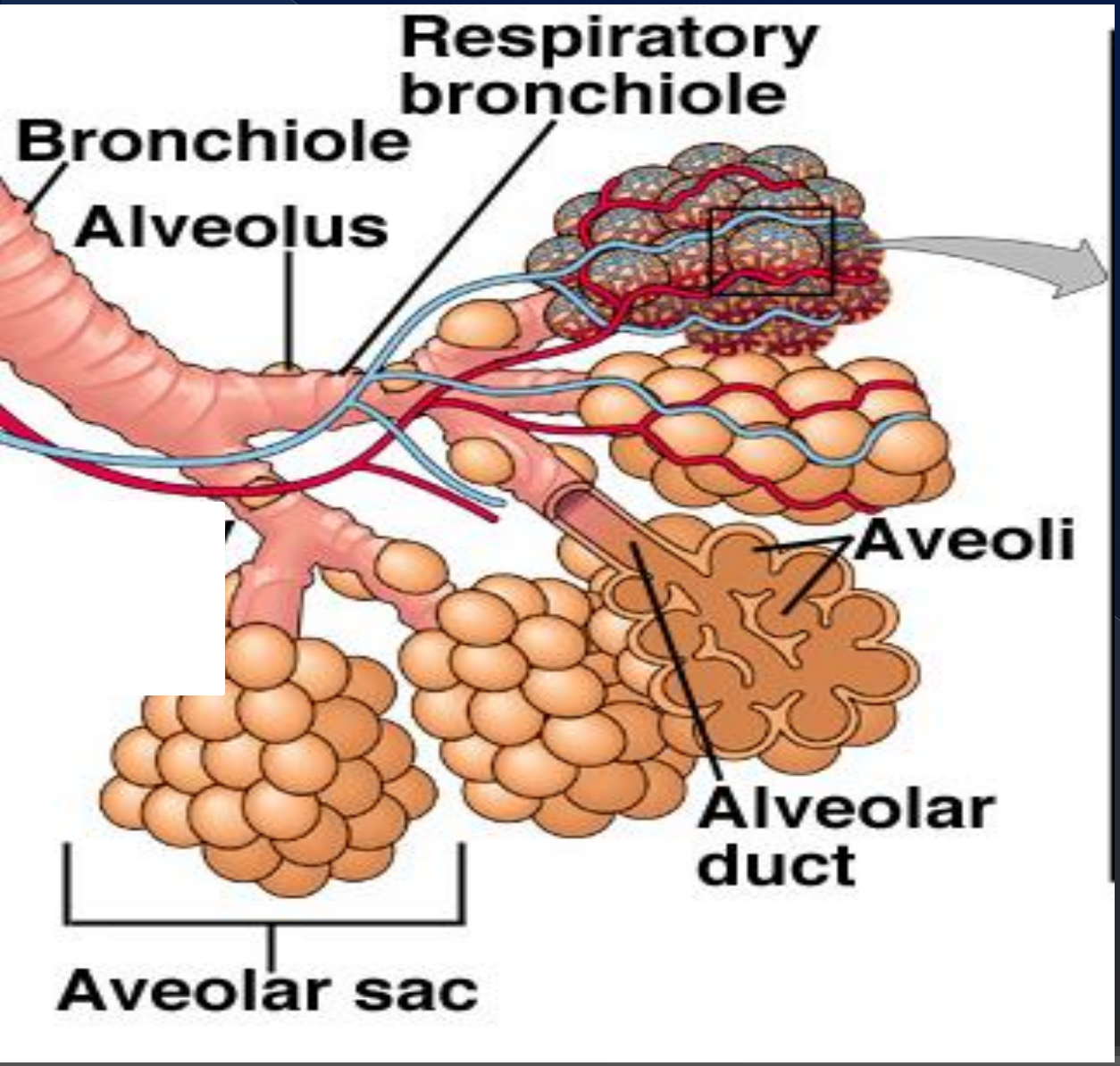
Intrapulmonary part – within lungs

- **secondary bronchi**
- **segmental (tertiary) bronchi**
- **bronchioles**
- **terminal bronchioles**



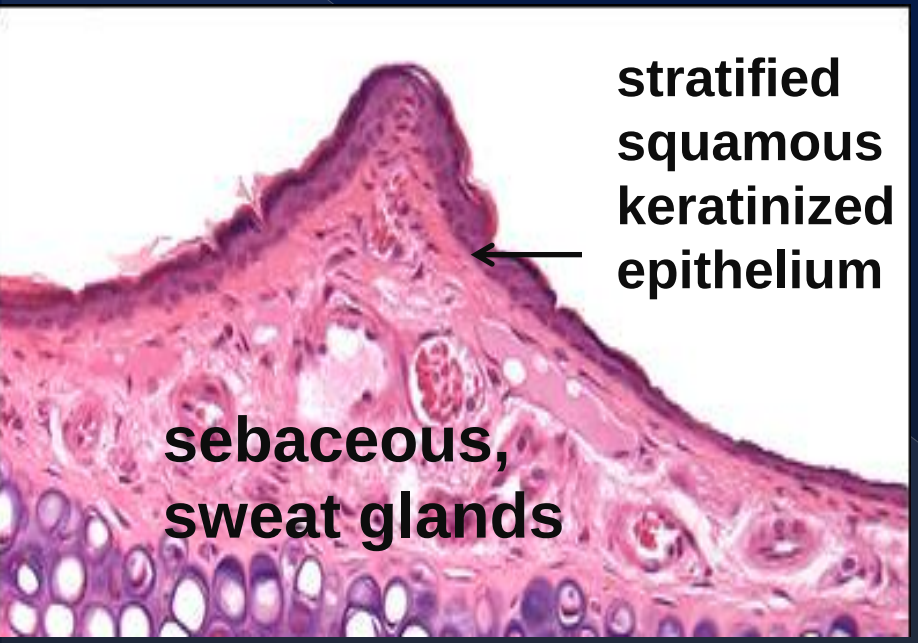


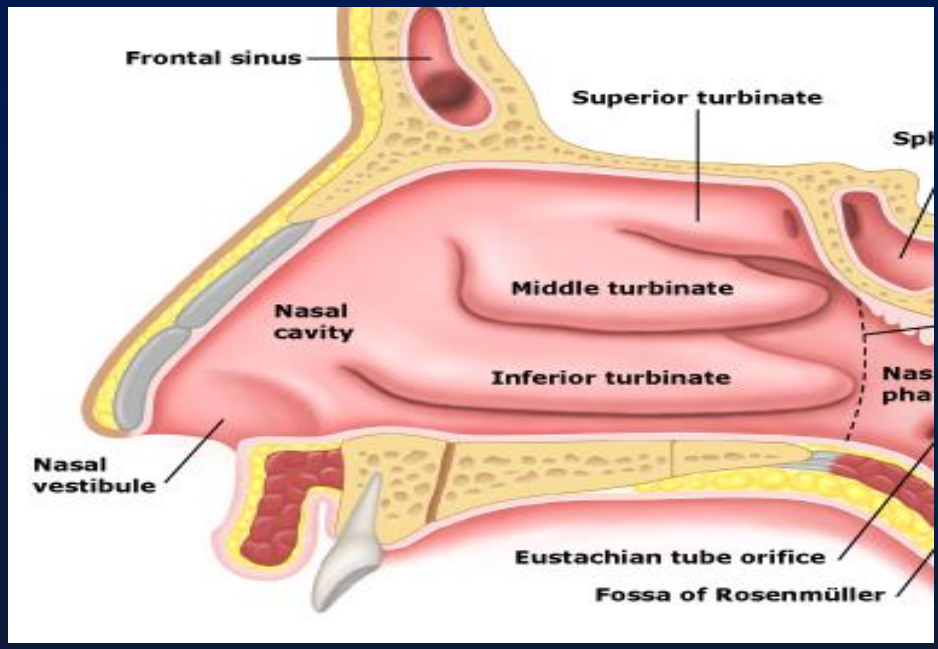
Respiratory portion (within the lungs) - exchange of O_2 and CO_2



- **respiratory bronchioles**
- **alveolar ducts**
- **alveolar sacs**
- **alveoli**

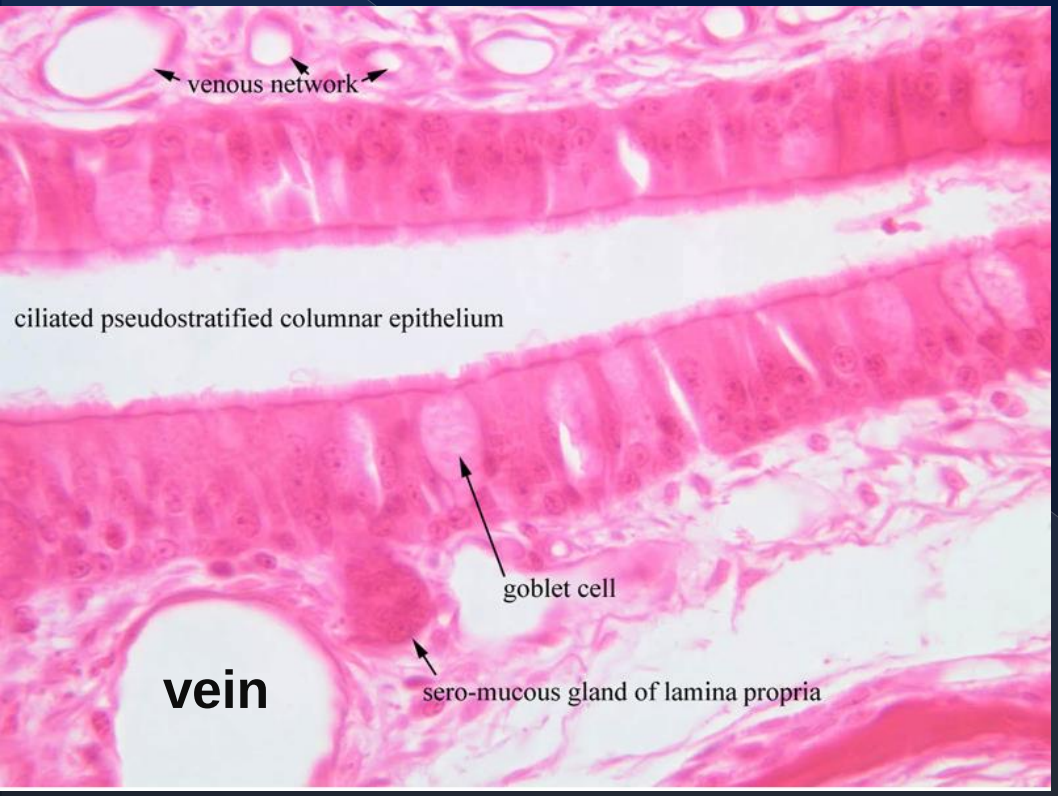
Nasal cavity - Anterior portion - Vestibule

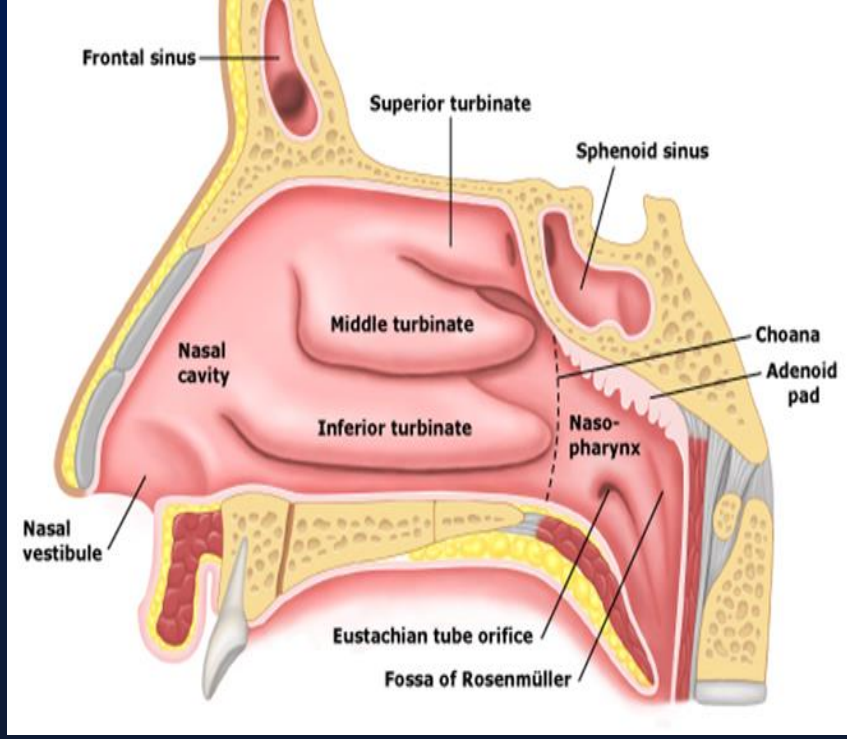




- thin skin - **stratified squamous keratinized epithelium**
- **sebaceous, sweat glands**
- **vibrissae** – stiff hairs

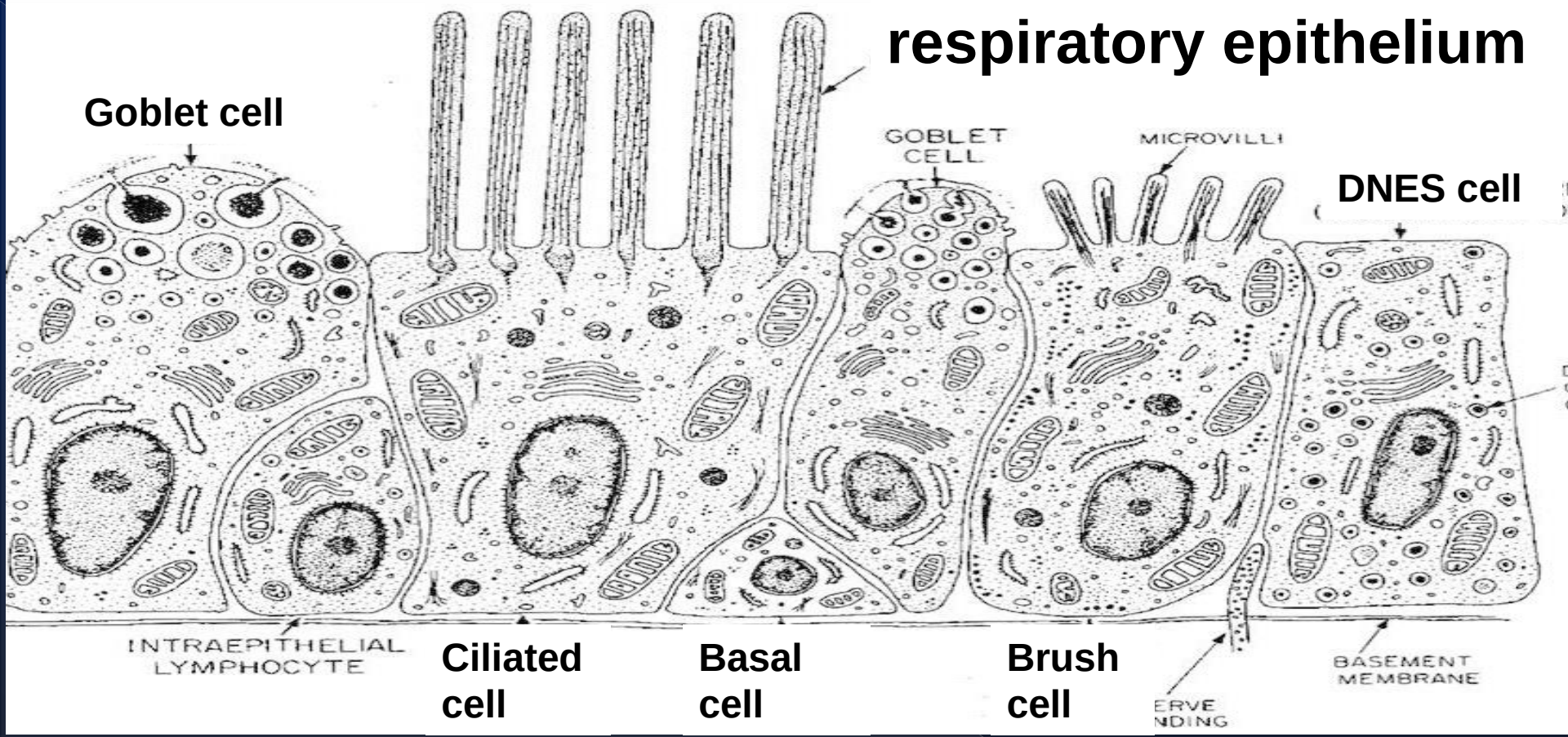
Nasal cavity - Posterior aspect





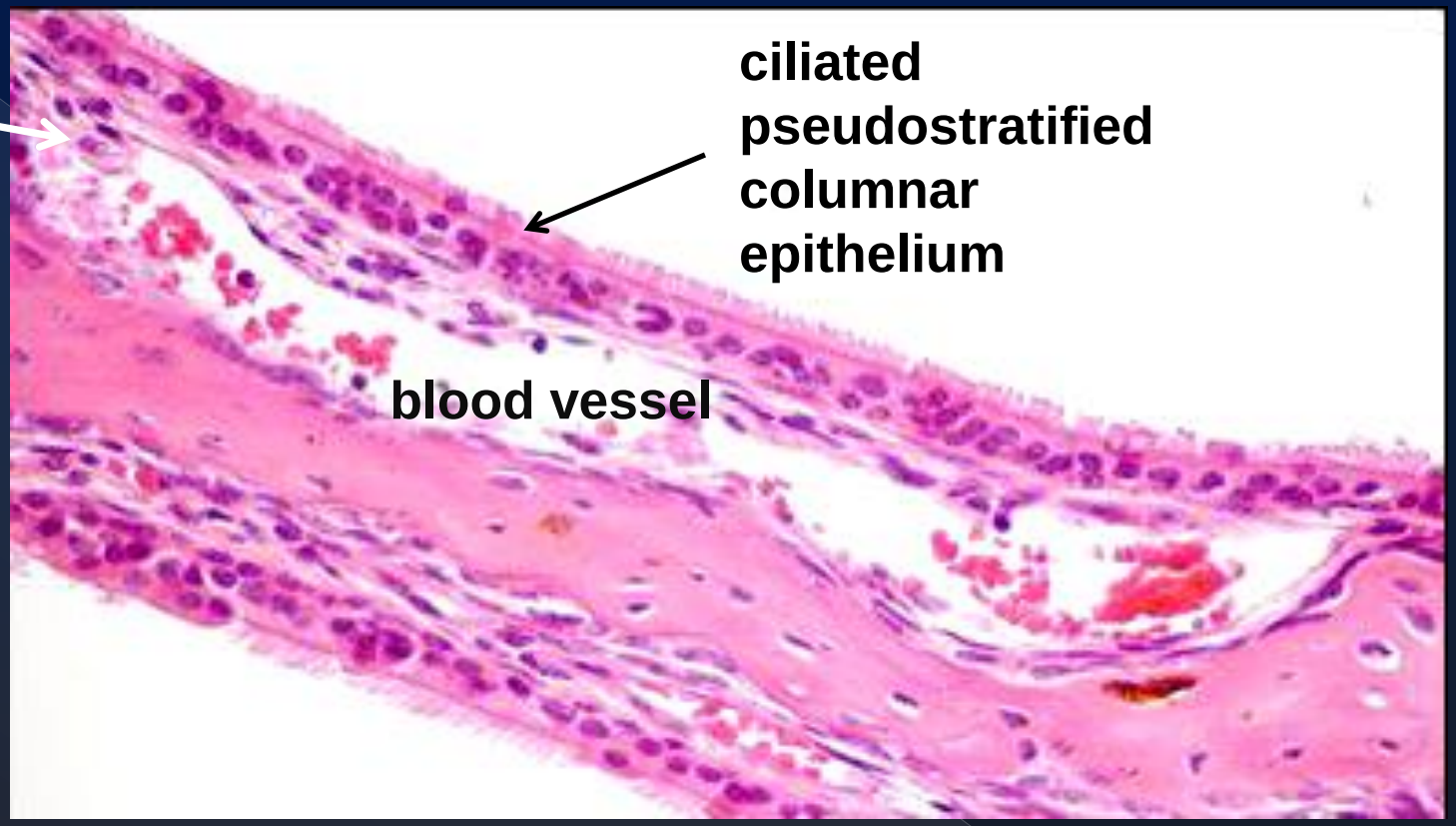
- pseudostratified ciliated columnar epithelium – respiratory epithelium
- Lamina propria

respiratory epithelium



1. **Ciliated columnar cells** (movement of mucus)
2. **Goblet cells** (mucus - moistening of epithelium, particles and pathogens are trapped in mucus)
3. **Brush cells** (receptors?)
4. **Basal cells** (stem cells)
5. **DNES cells** (hormones - regulation)

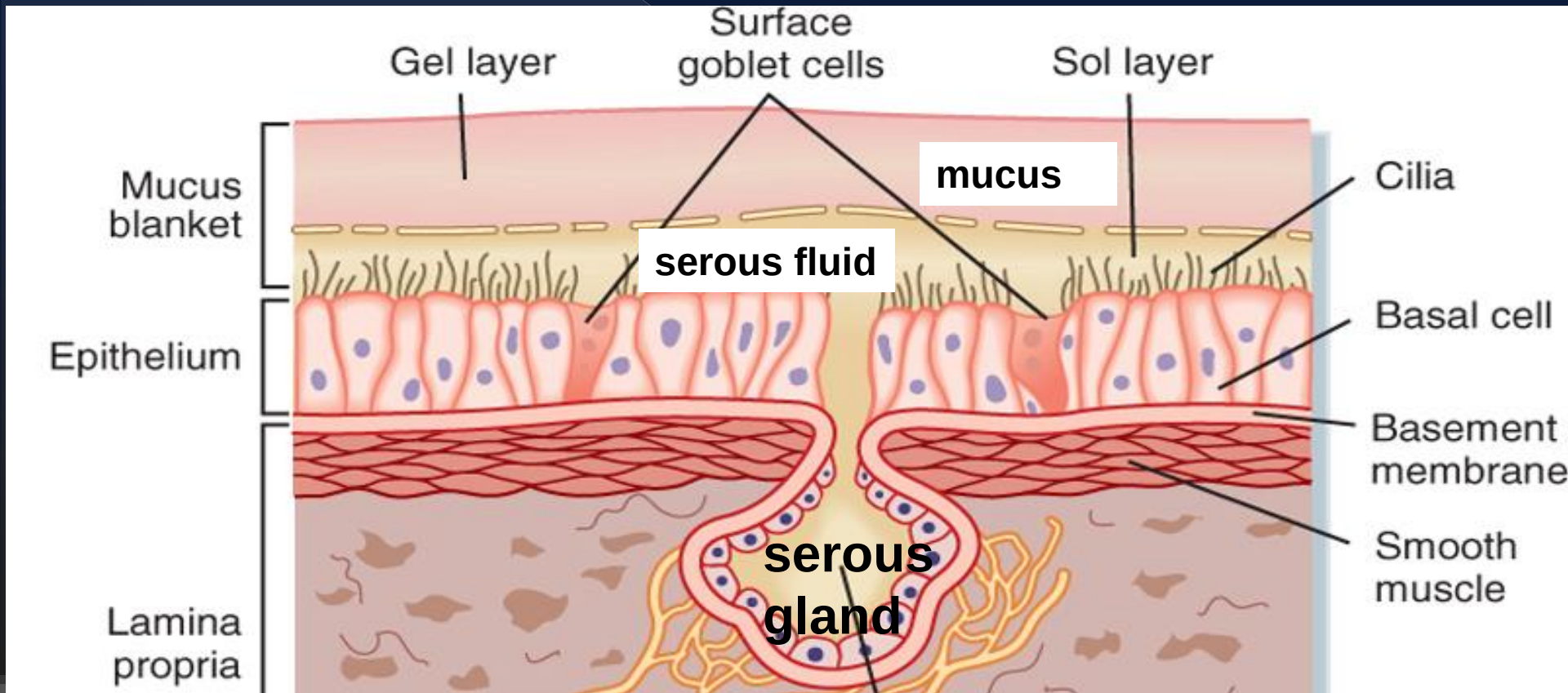
Nasal cavity – lamina propria



- richly vascularized connective tissue (**warming** of the air - heat is transferred between blood and air)
- seromucous glands, lymphoid tissue (NALT) - (protection against inhaled antigens)

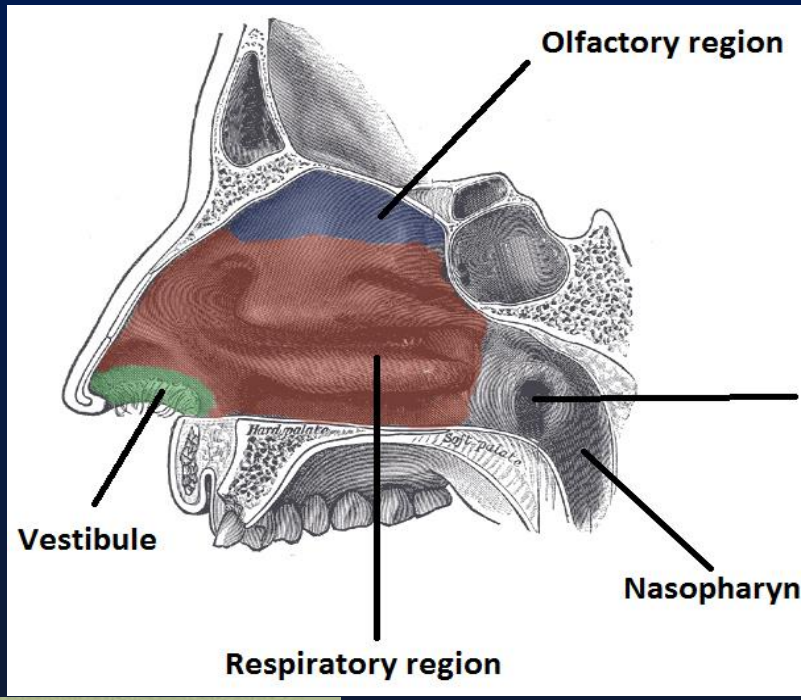
Nasal cavity – lamina propria

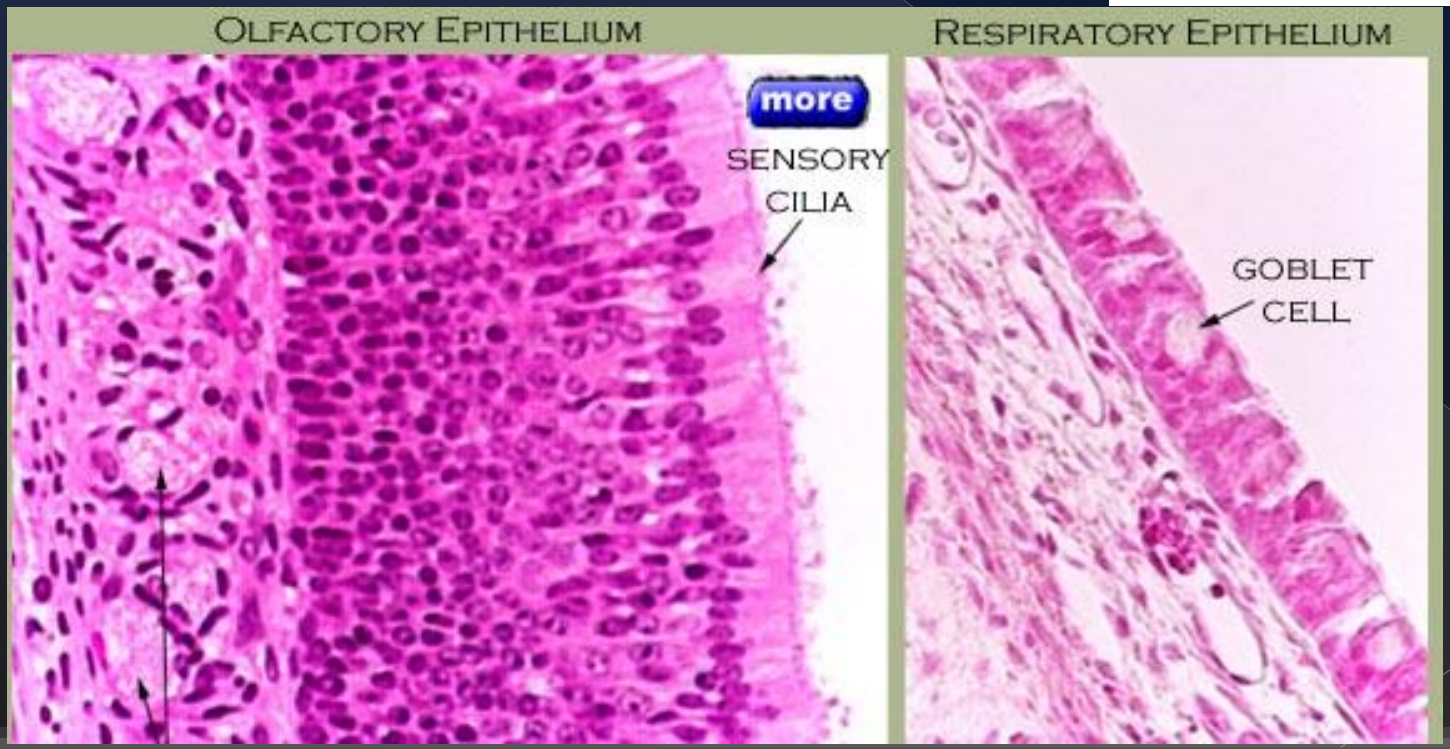
- **serous glands** – fluid - between the mucus and the apical membrane of epithelial cells - the movement of the cilia in serous fluid
- **mucous glands** – mucus - the particles trapped in mucus - eliminated from respiratory tract



Olfactory region - reception of odors

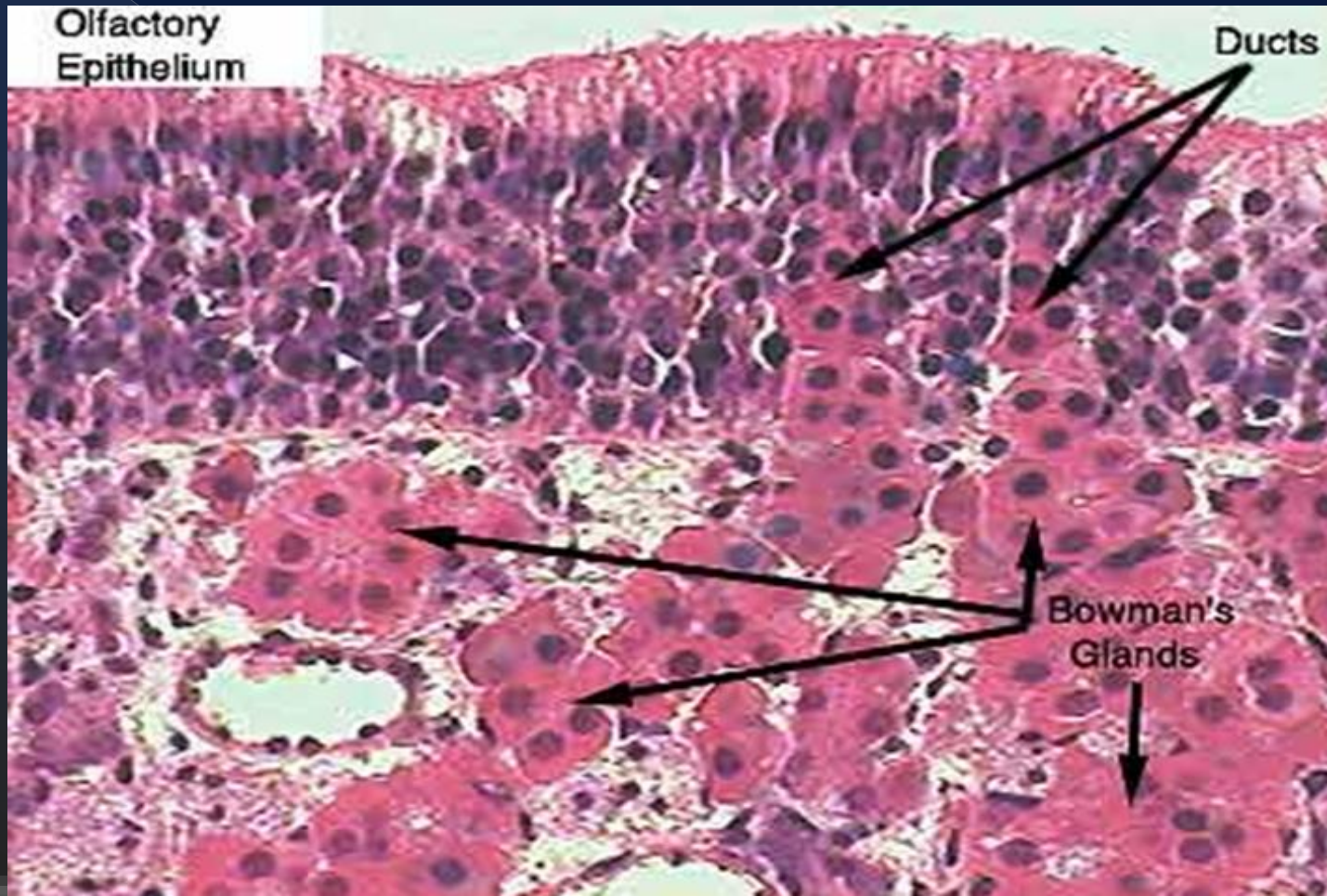
- the roof of the nasal cavity, the superior aspect of the nasal septum - **olfactory epithelium**





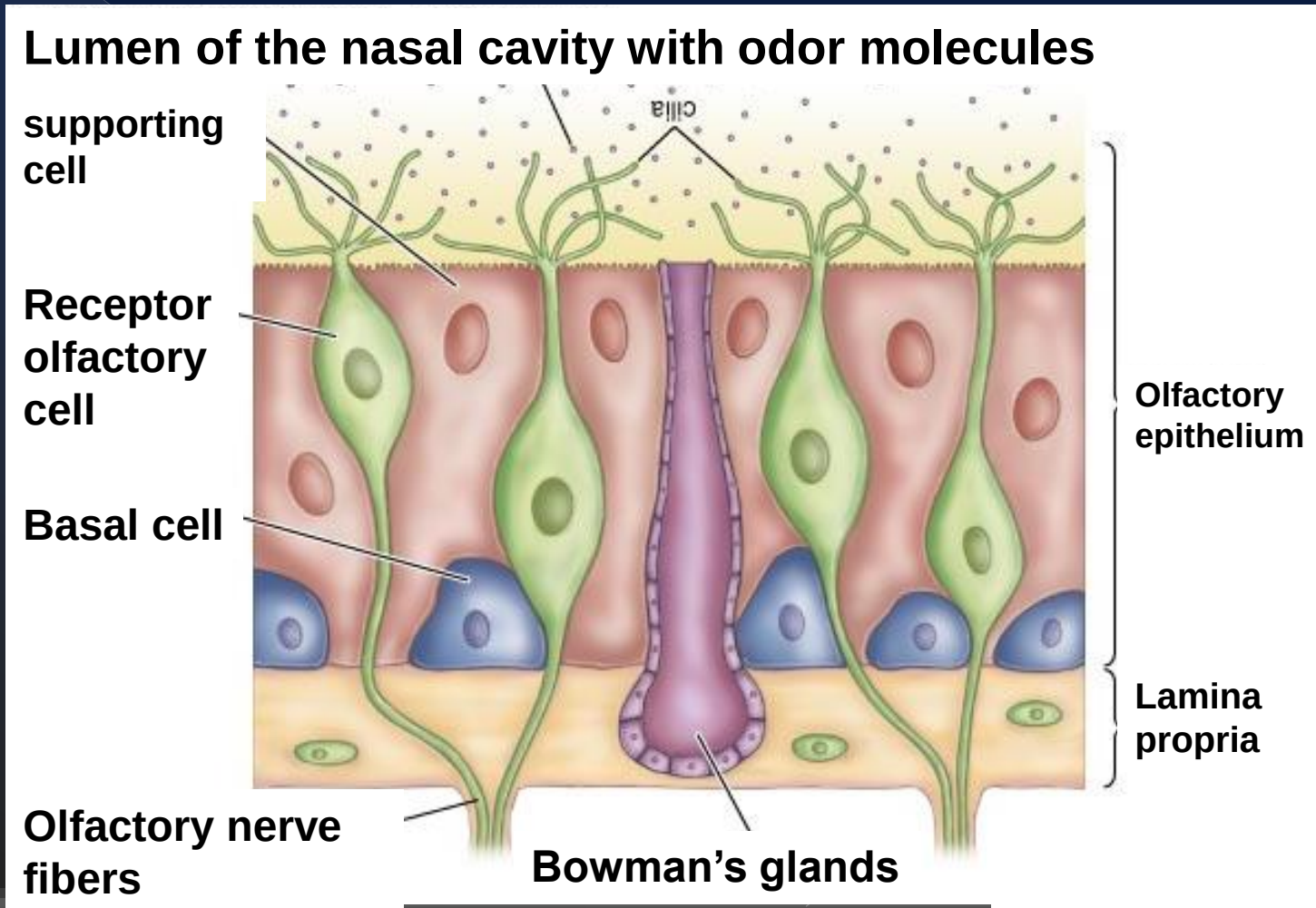
Olfactory region - the lamina propria

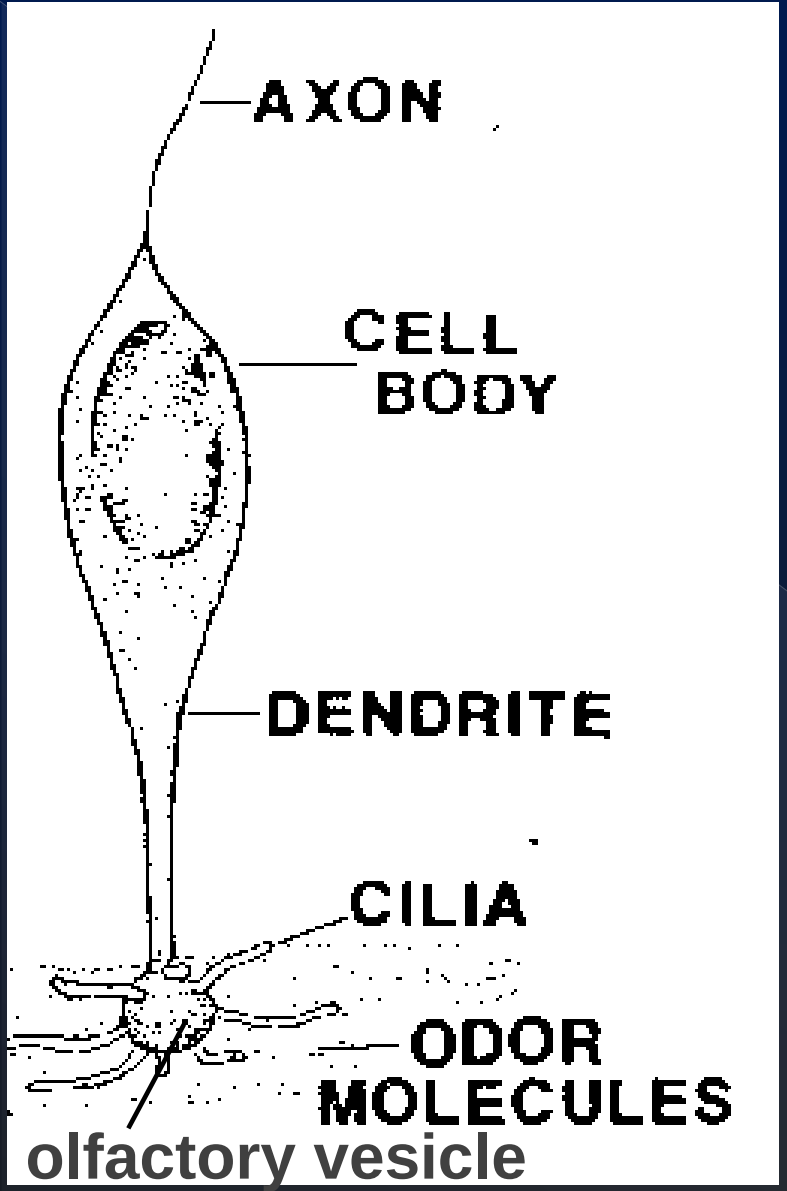
- **Bowman's glands** (lysozyme, IgA, secretions to moistening of the olfactory epithelium)
- axons of olfactory neurons of the **olfactory epithelium.**



Olfactory epithelium:

- **Receptor olfactory cells**
- **Sustentacular (**supporting cells, nourishment**)**
- **Basal cells (**stem cells)

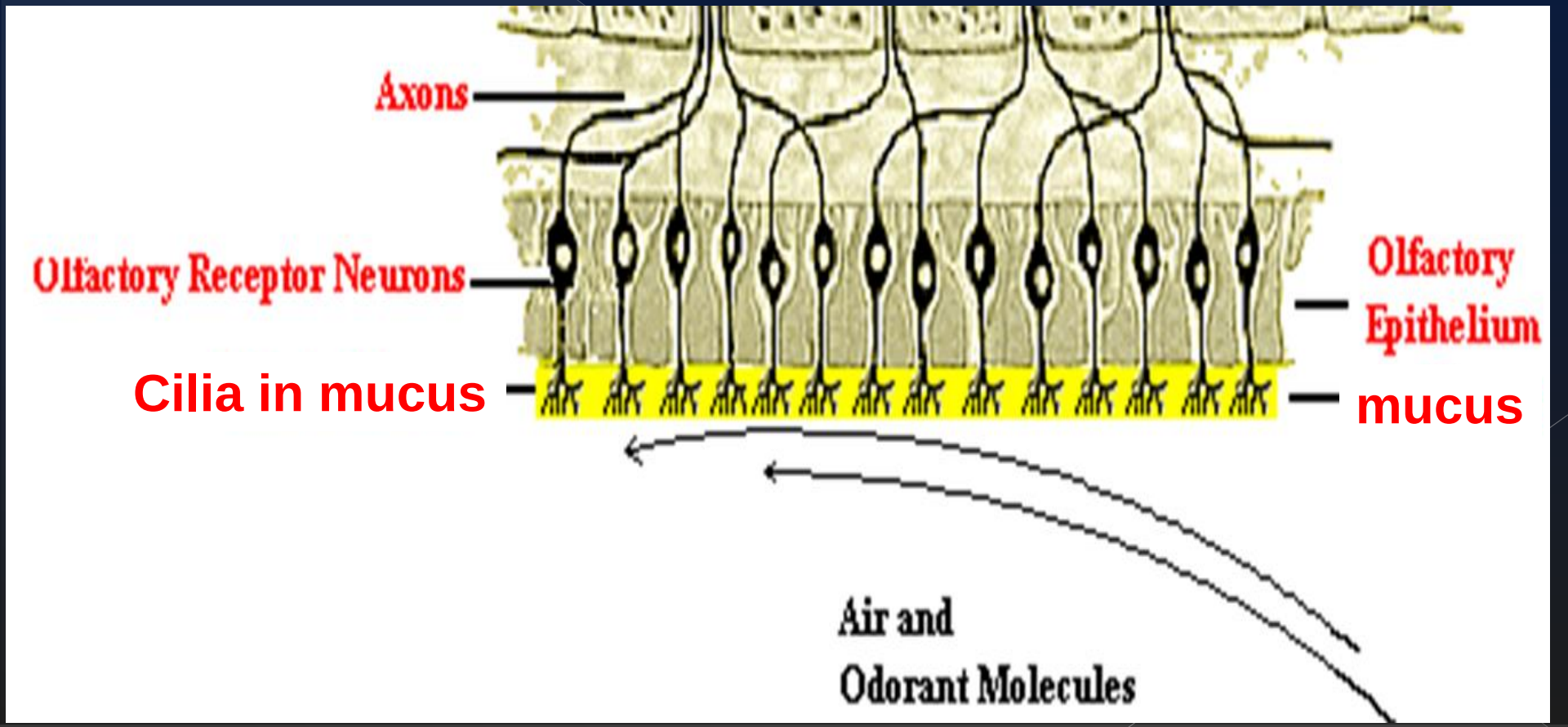




Olfactory cells - bipolar neurons

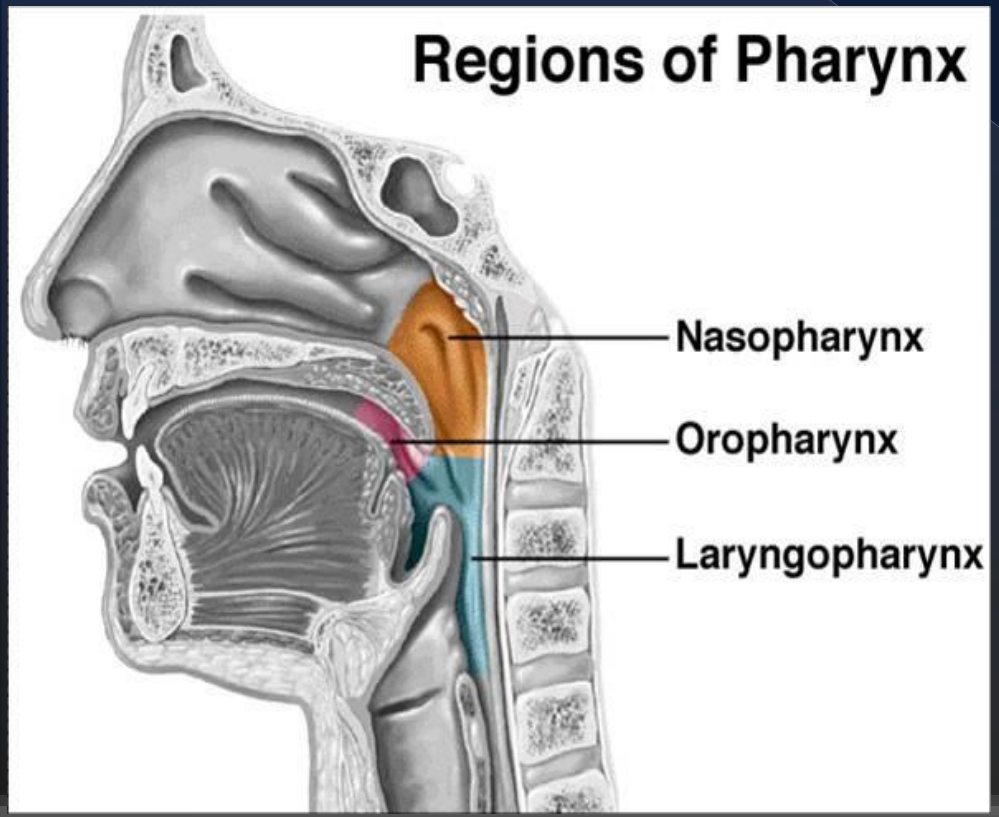
- dendrite - olfactory vesicle
- long, **nonmotile** olfactory **cilia** extend from the olfactory vesicle
- **axon** - penetrates the basal lamina and joins similar axons to form bundles of nerve fibers (in lamina propria).

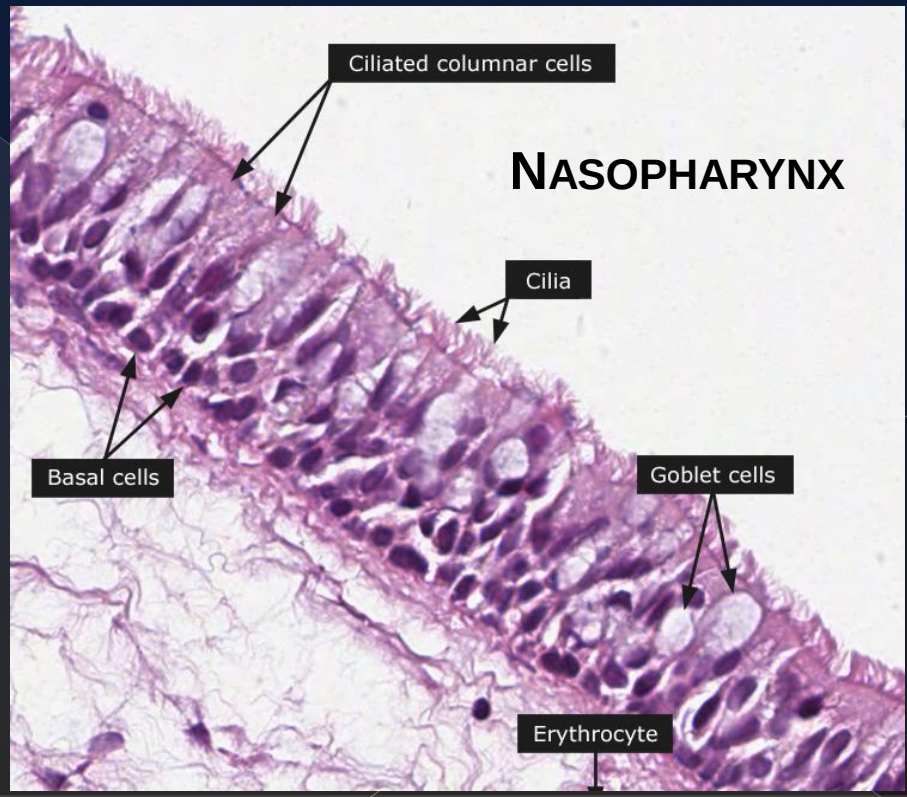
- dendrite - olfactory vesicle, projects above the surface of the epithelium - **cilia** lie on the surface of the epithelium.
- **axon** - penetrates the basal lamina and joins similar axons - bundles of nerve fibers (in lamina propria).



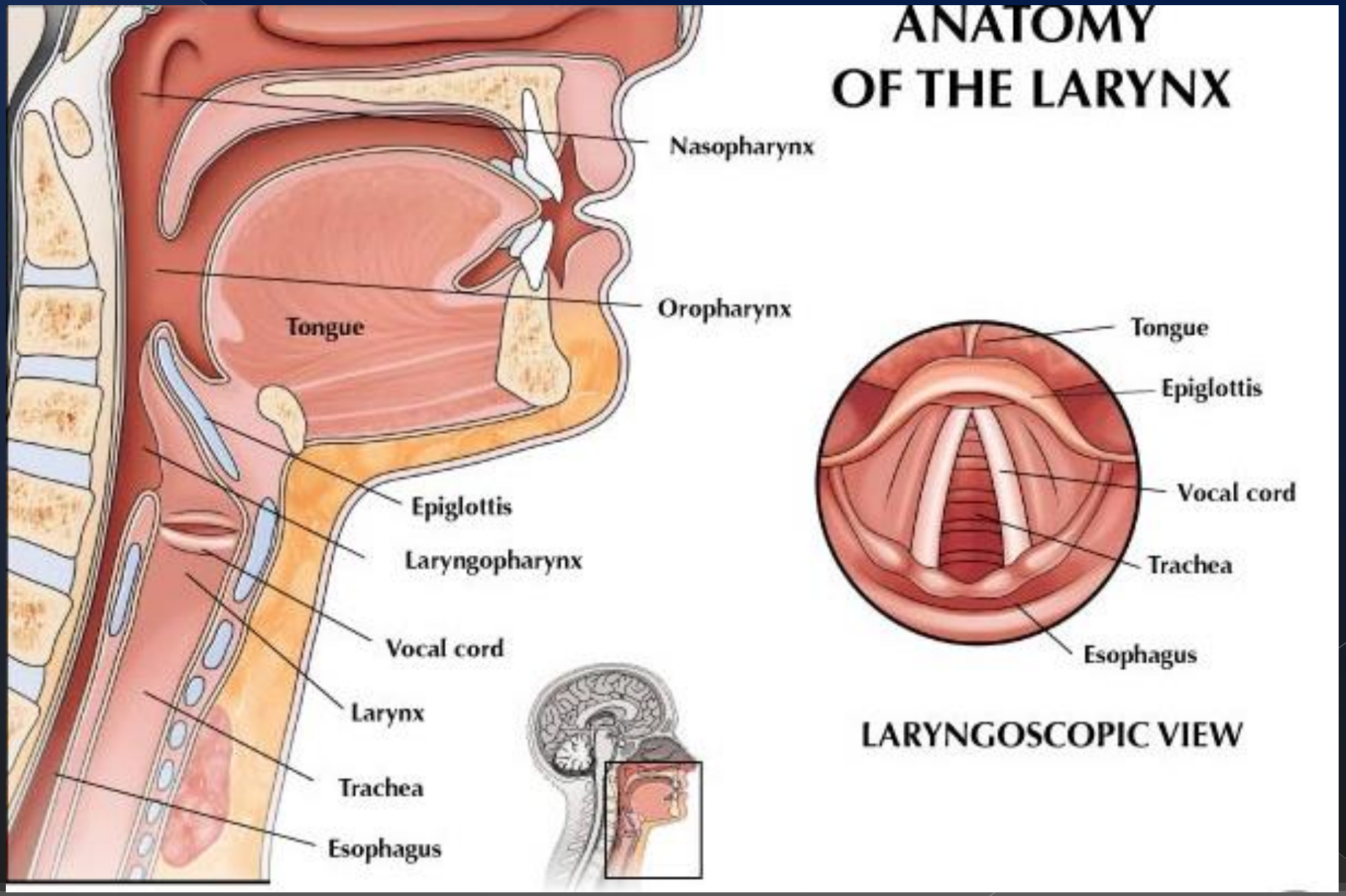
Pharynx - joints nasal cavity with larynx - filters, warms, and moistens air

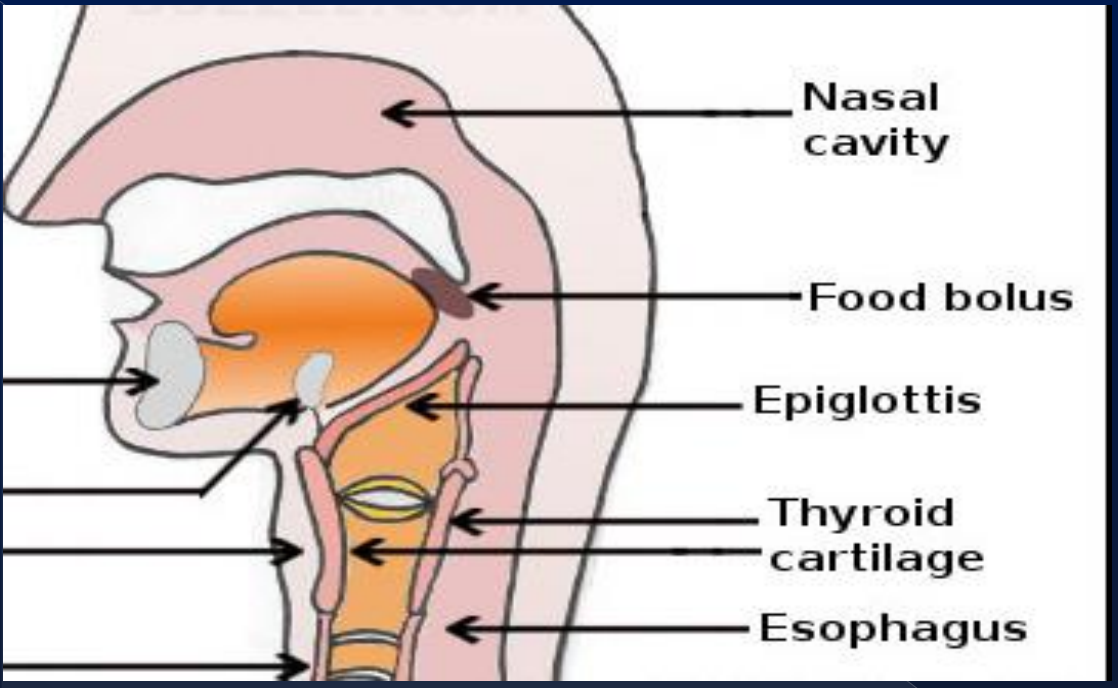
- **nasopharynx** - **respiratory epithelium**.
- **Oro-** and **laryngopharynx** - **nonkeratinized stratified squamous epithelium**,
- **lamina propria** - loose to dense connective tissue





larynx - voice box - phonation

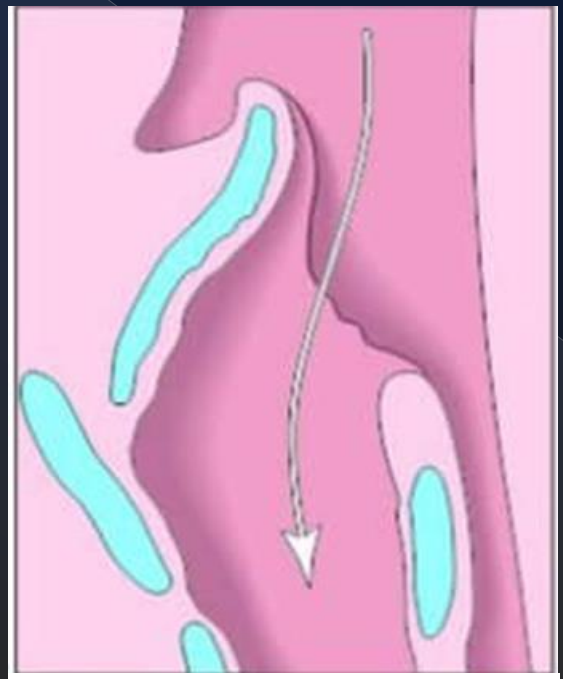




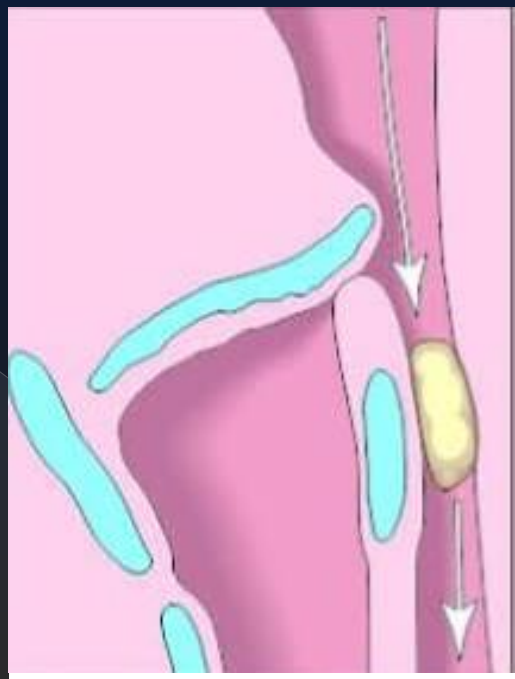
Larynx - the wall - hyaline cartilages and elastic cartilage **(epiglottis -** prevents the entry of food into the respiratory tract)

Epiglottis

- respiration - in vertical position
- swallowing - in horizontal position closes the aditus.

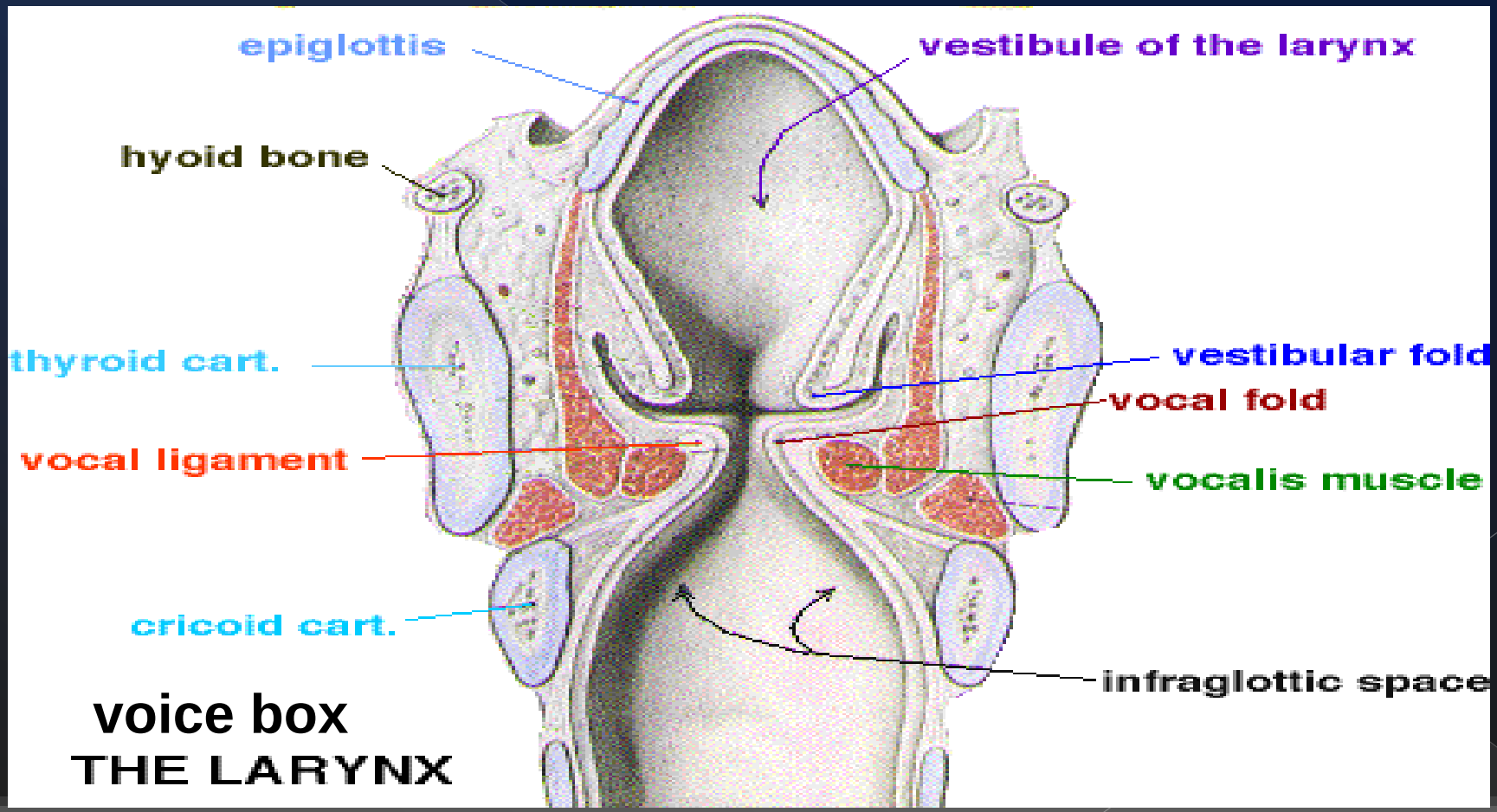


respiration

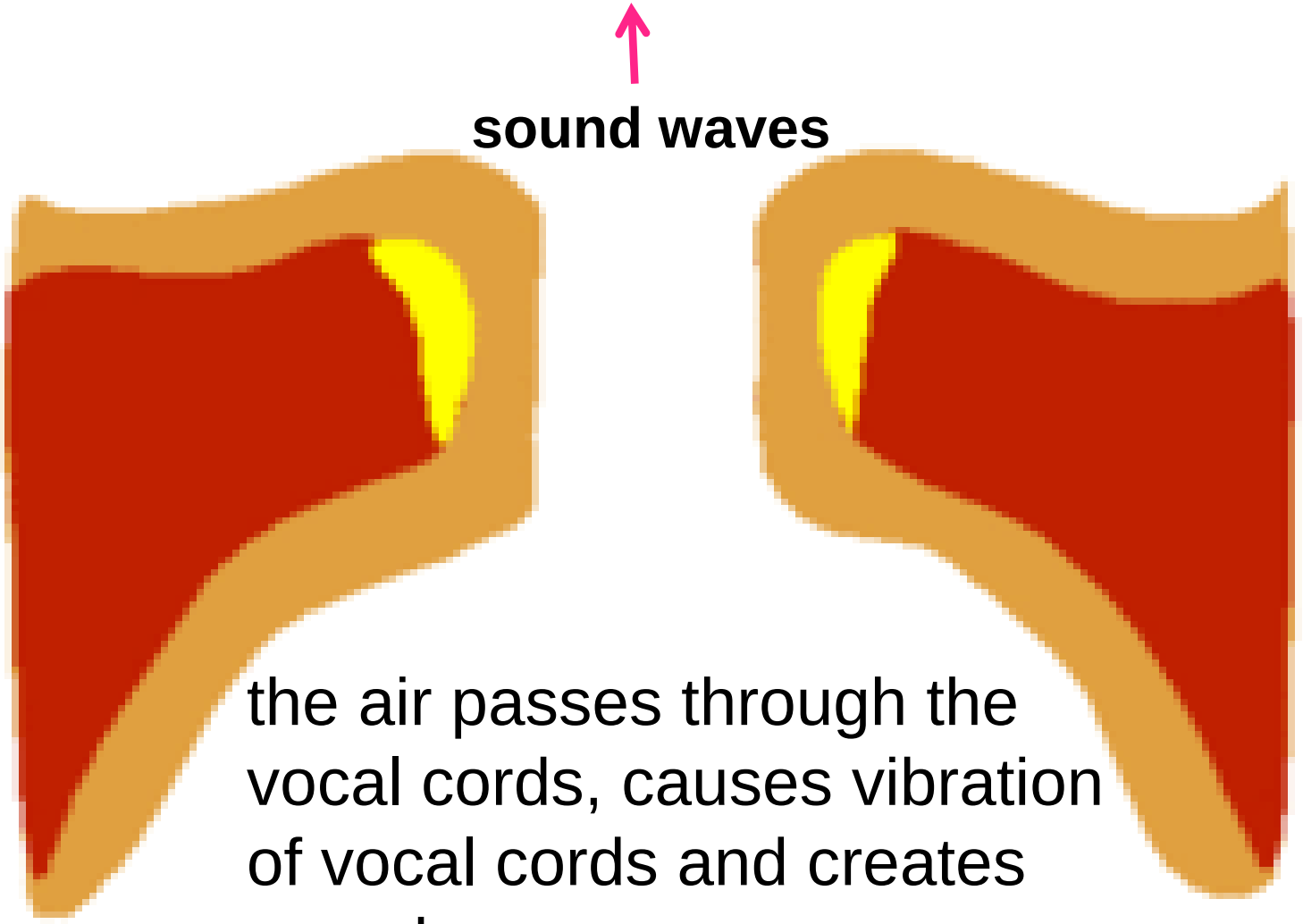


swallowing

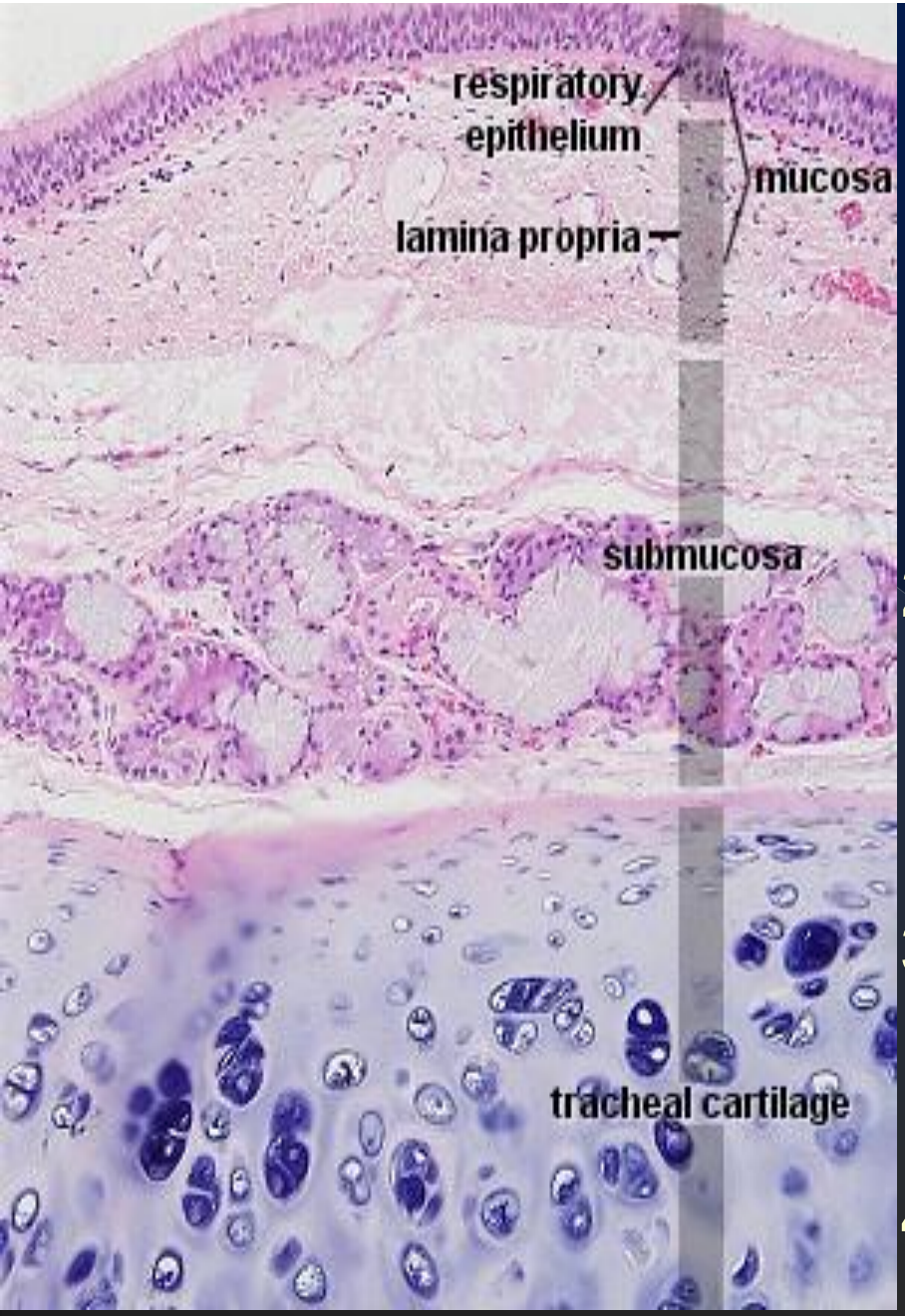
- **vestibular (false folds** - immovable) - respiratory epithelium
- **vocal folds** (vocal cords) – phonation - **stratified squamous nonkeratinized epithelium**. The lamina propria - dense, regular elastic connective tissue and **vocal muscles (striated muscles - voluntary muscle).**



The larynx - generates sound through the rhythmic opening and closing of the vocal folds (cords)



Trachea

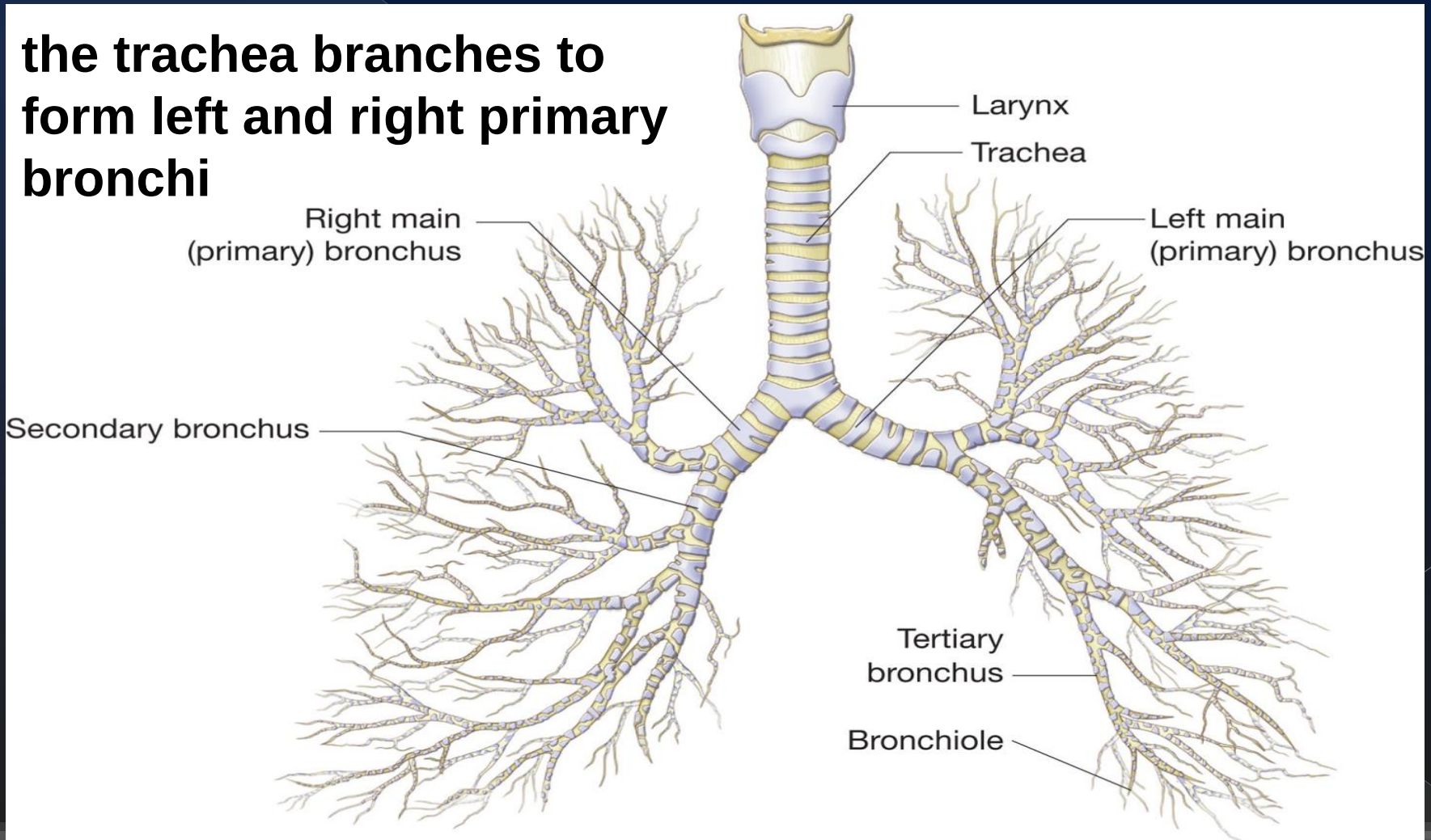


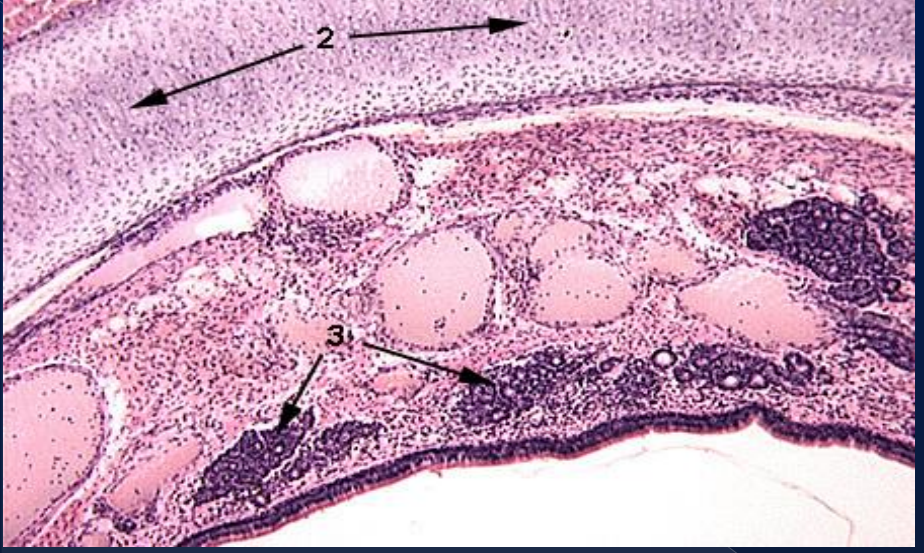
1. **Mucosa**
   - **respiratory epithelium**
   - **lamina propria** (loose connective tissue, mucous and seromucous glands, vessels, lymphoid tissue)
2. **Submucosa** (dense irregular connective tissue, glands, lymphoid elements, blood and lymph supply).
3. **Hyaline cartilage** – C-rings (cartilage rings - prevent the collapse of lumen)
4. **Adventitia** – loose connective tissue

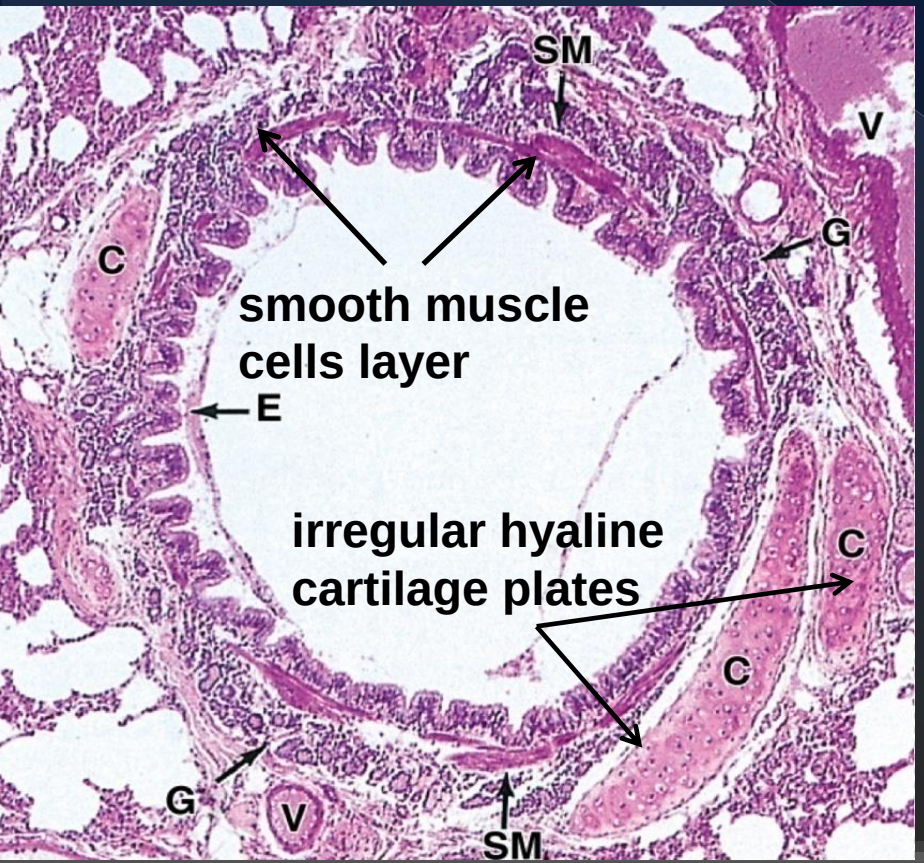
Bronchial tree - begins from the bifurcation of trachea**: left and right primary bronchi,**

- arborize 15 to 20 times before reaching the level of terminal bronchioles

the trachea branches to form left and right primary bronchi





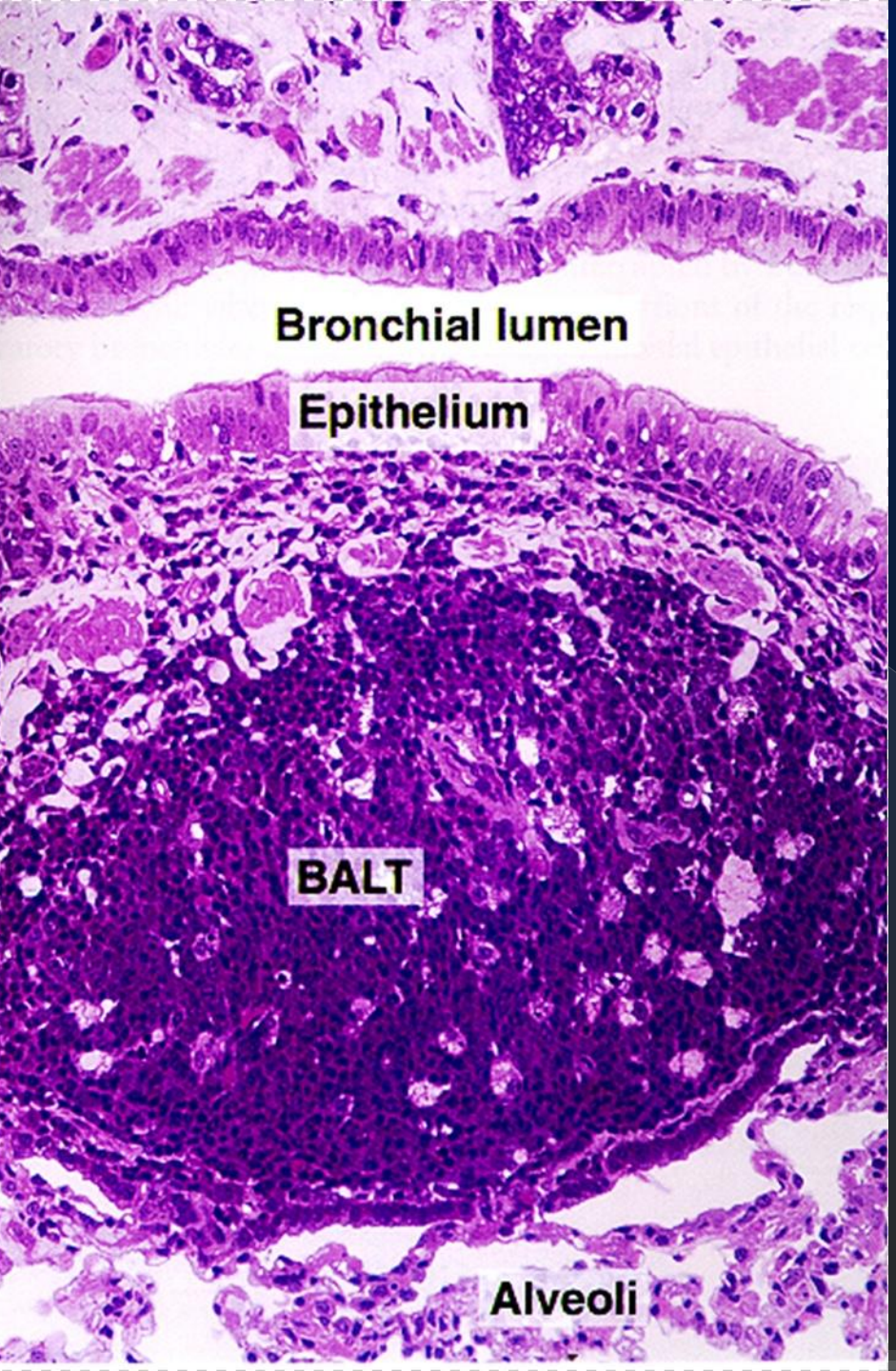


Primary bronchi

- similar to trachea (smaller in diameter, the wall is thinner).
- each primary bronchus enters the lung.

Secondary and tertiary bronchi

- irregular hyaline cartilage plates instead of C-rings
- between mucosa and submucosa - smooth muscle cells layer



Bronchus wall with bronchus – associated lymphoid tissue (BALT), a component of the mucosa-associated lymphoid tissue (MALT)

bronchioles - less than 1 mm of diameter

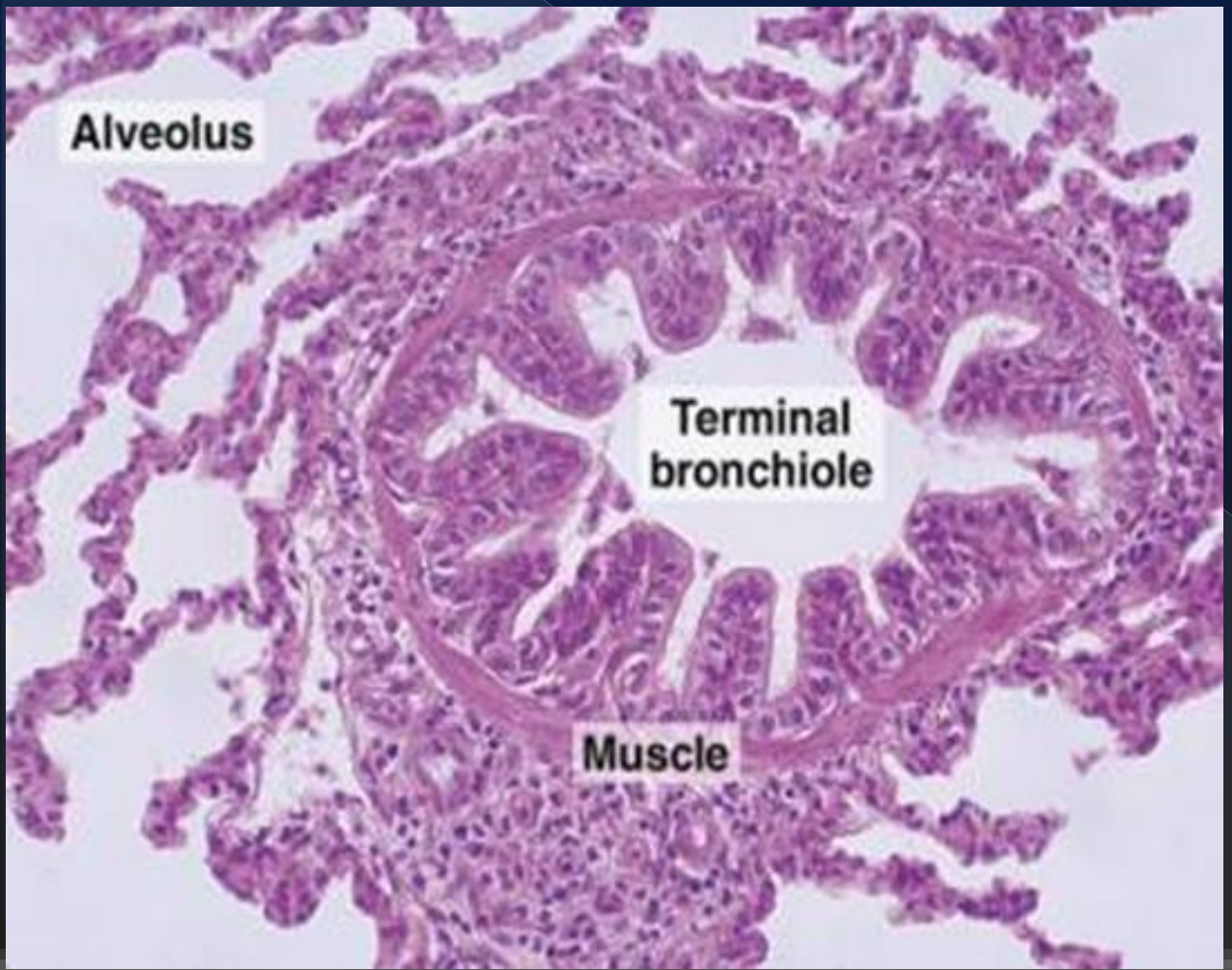
primary bronchioles

- **Epithelium** – from **ciliated simple columnar** (occasional goblet cells in larger bronchioles) to **simple cuboidal** (**Clara cells,** no goblet cells in smaller bronchioles).
- **Lamina propria -** connective tissue – **no glands**
- **Smooth muscle layers**

NO CARTILAGE!

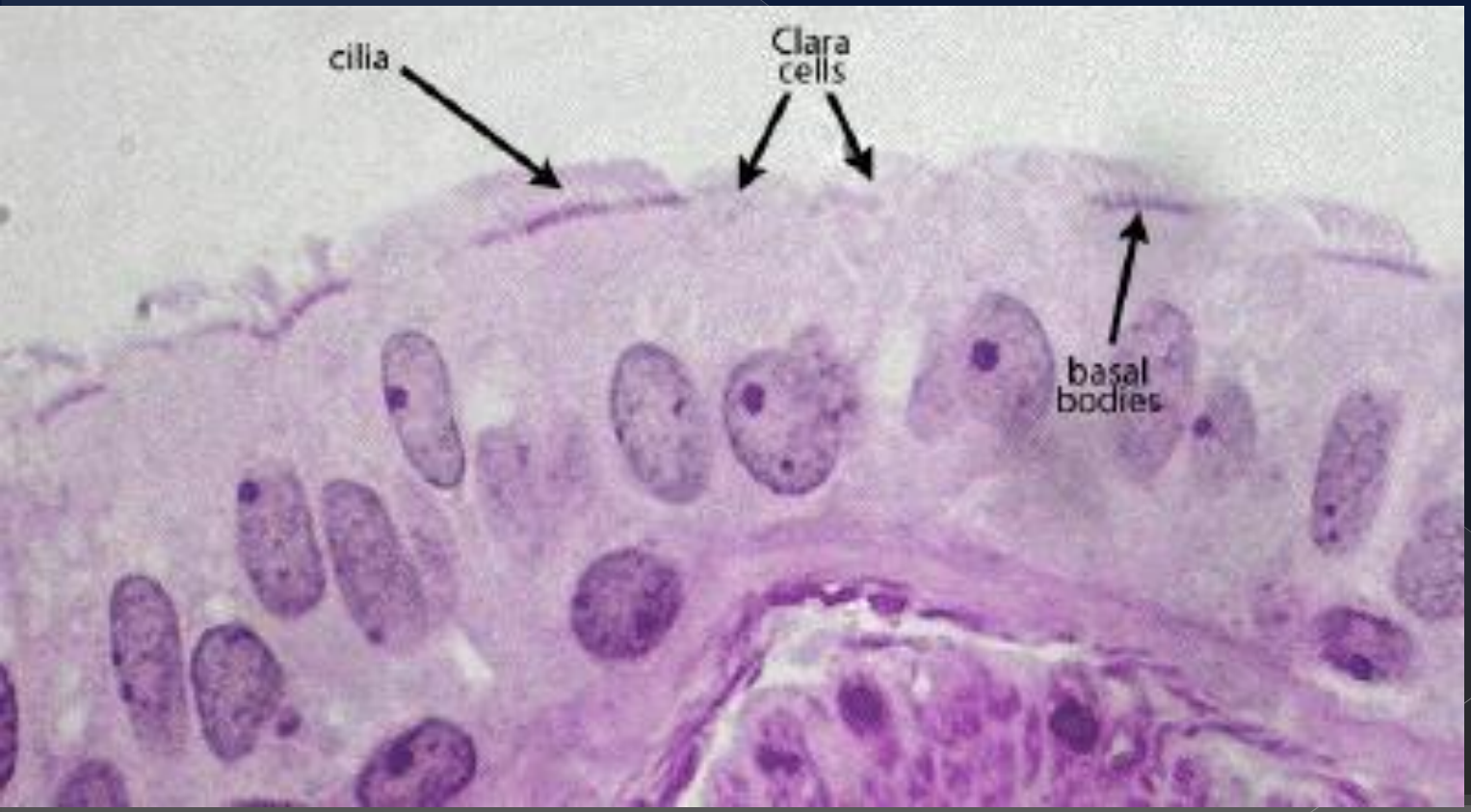
terminal bronchioles (0.5 mm) – the last part of conducting portion

- **simple cuboidal epithelium and Clara cells.**
- **smooth muscle cells**



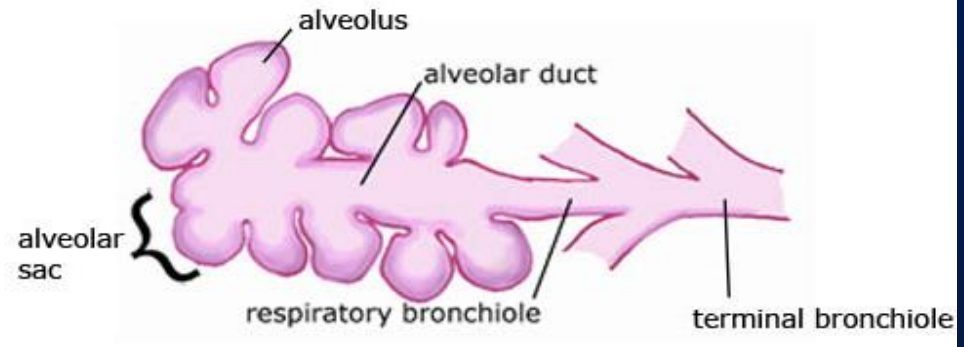
Clara cells - mainly in **terminal bronchioles**

- production of secretion and surfactant-like material - reduces the surface tension.
- degradation of toxins from inhaled air
- **stem cells** - regeneration of bronchiolar epithelium

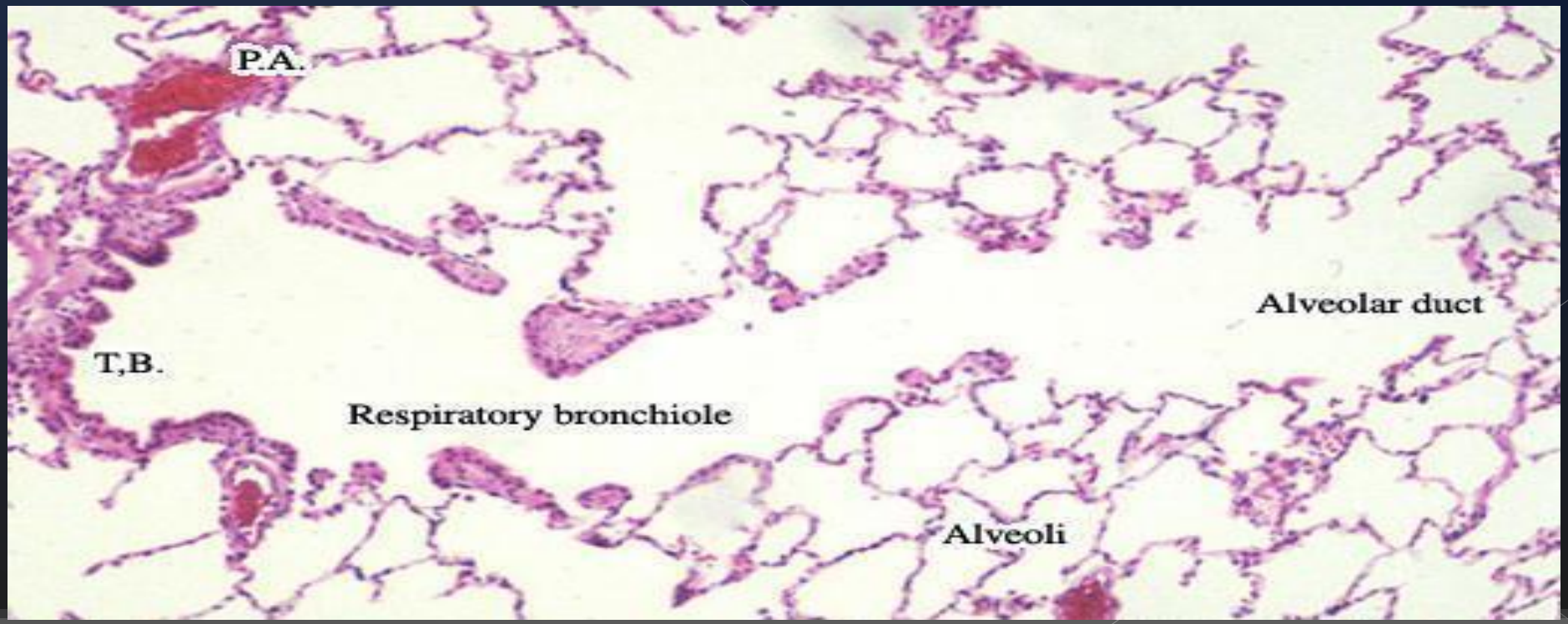


Respiratory bronchioles

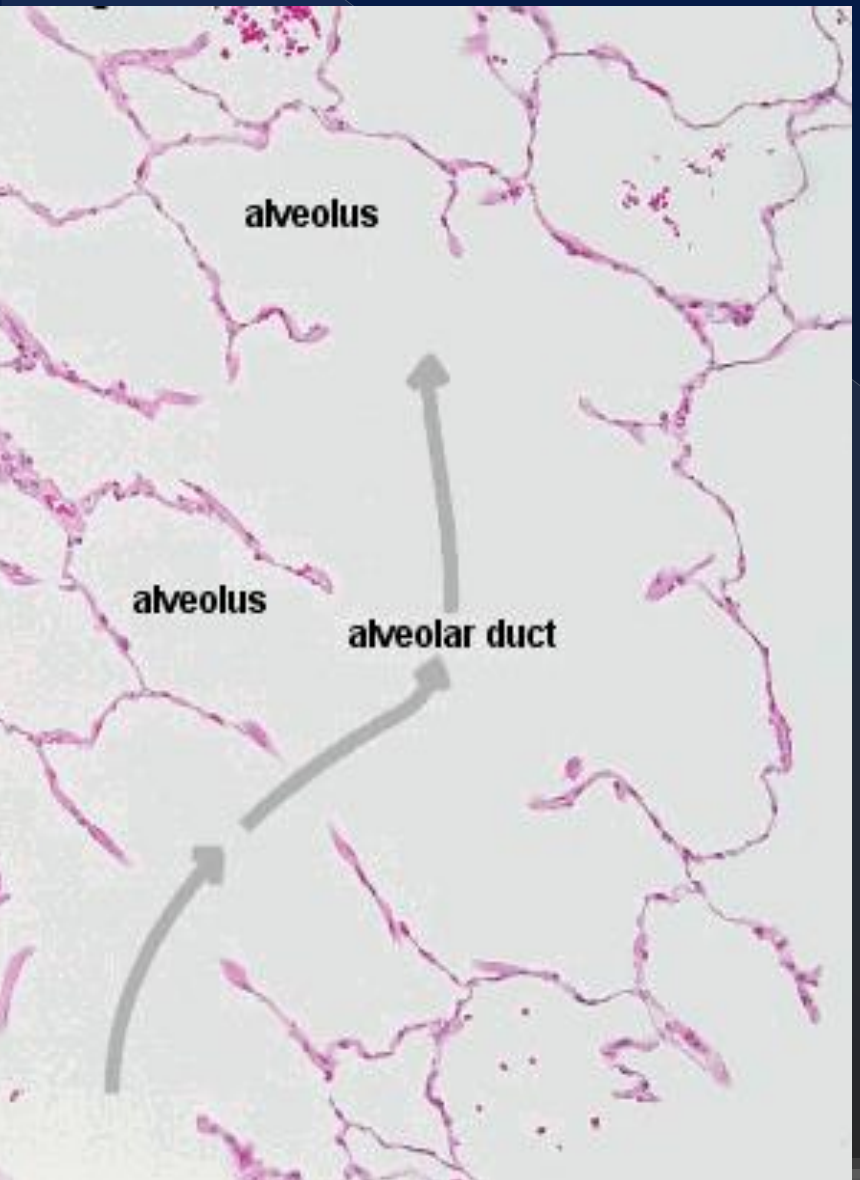
- the last part of bronchial tree and **first part of respiratory portion**



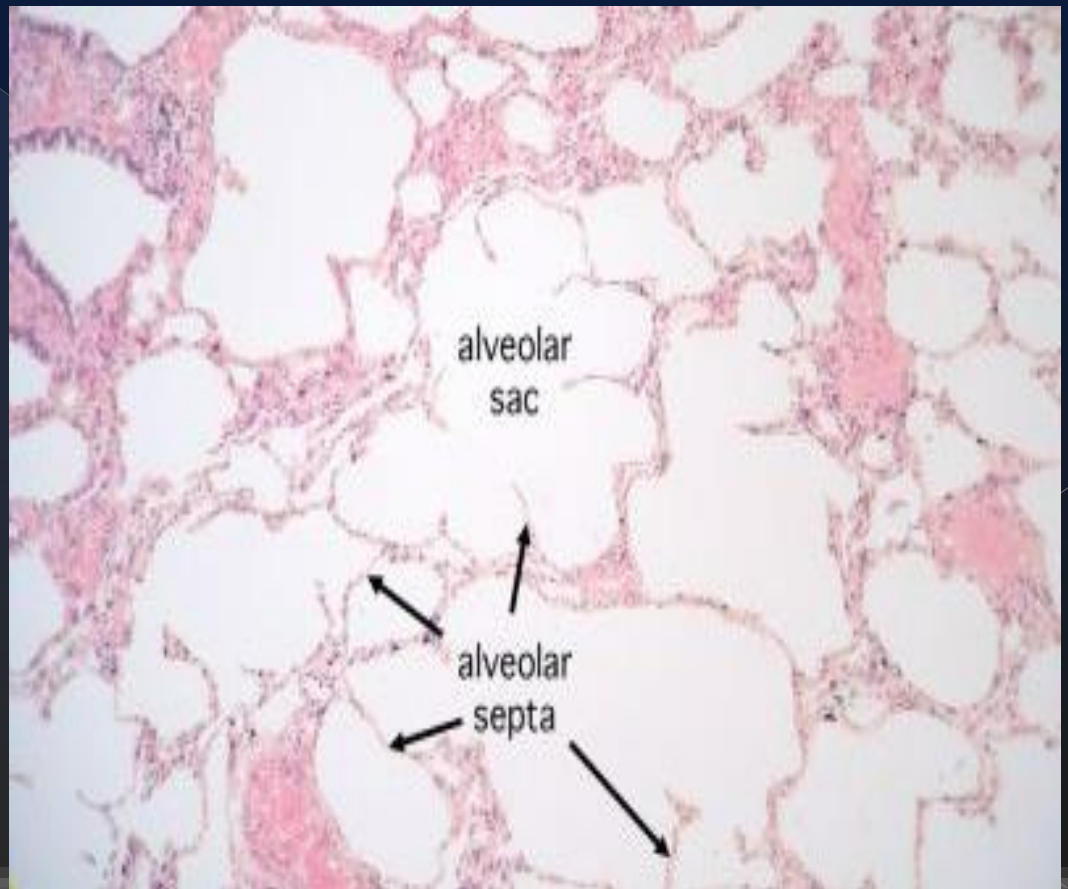
the wall - **simple cuboidal epithelium** interrupted by numerous **sac-like alveoli** - gas exchange



Alveolar ducts and **alveolar sacs** don't have their own walls (are formed by alveoli)

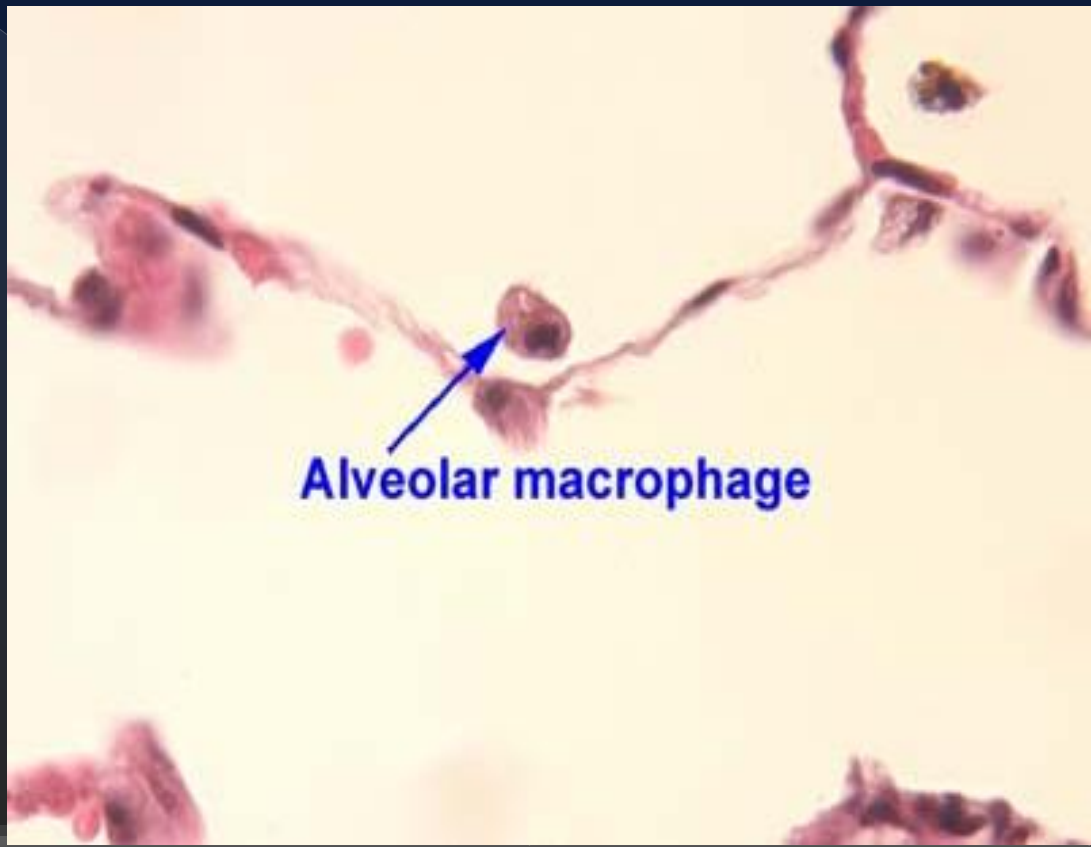


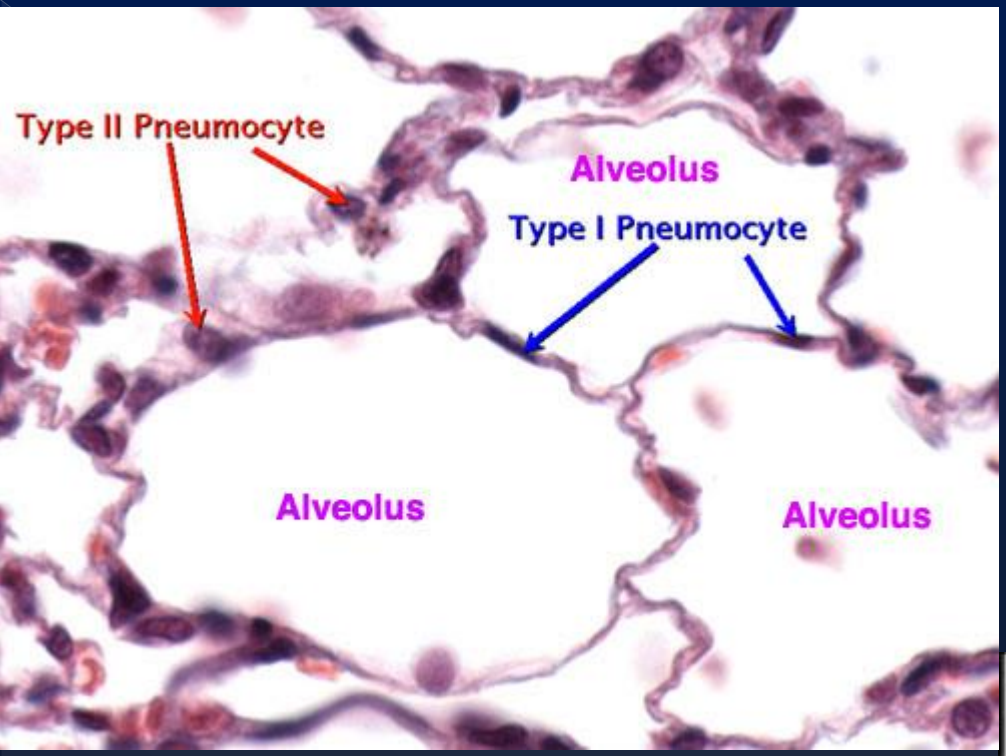
between alveoli – **interalveolar septa -** connective tissue



Alveolar Macrophages – Dust Cells

- in the lumen of alveoli and in the interalveolar septa
- macrophages can penetrate into the lumen of the alveoli and phagocytose dust particles, erythrocytes or bacteria.

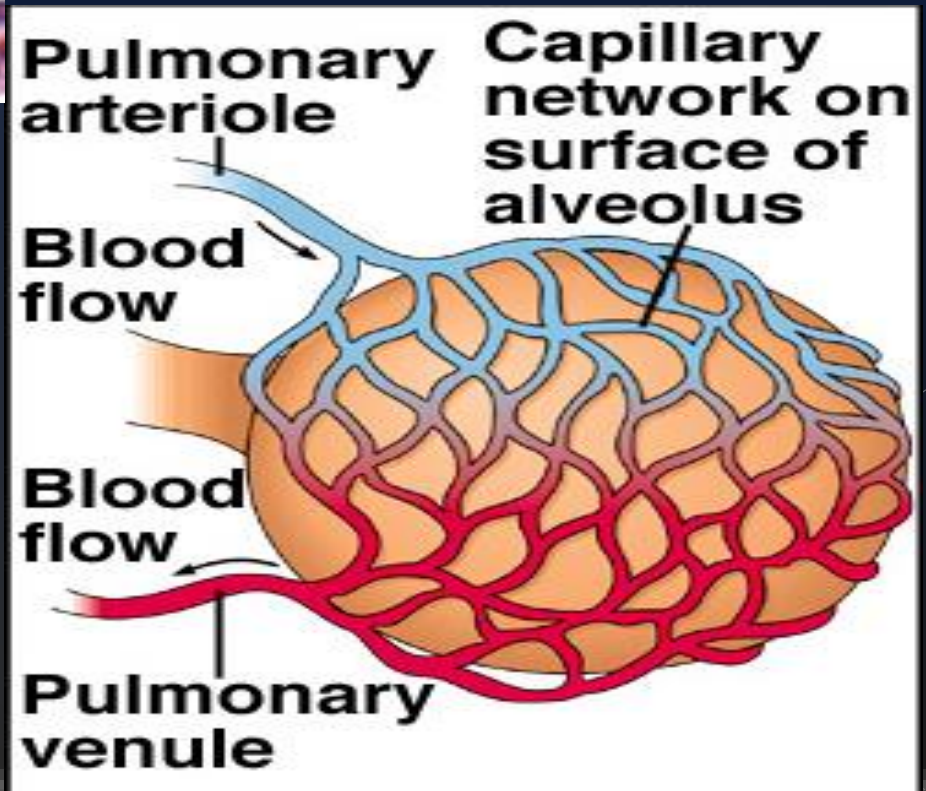




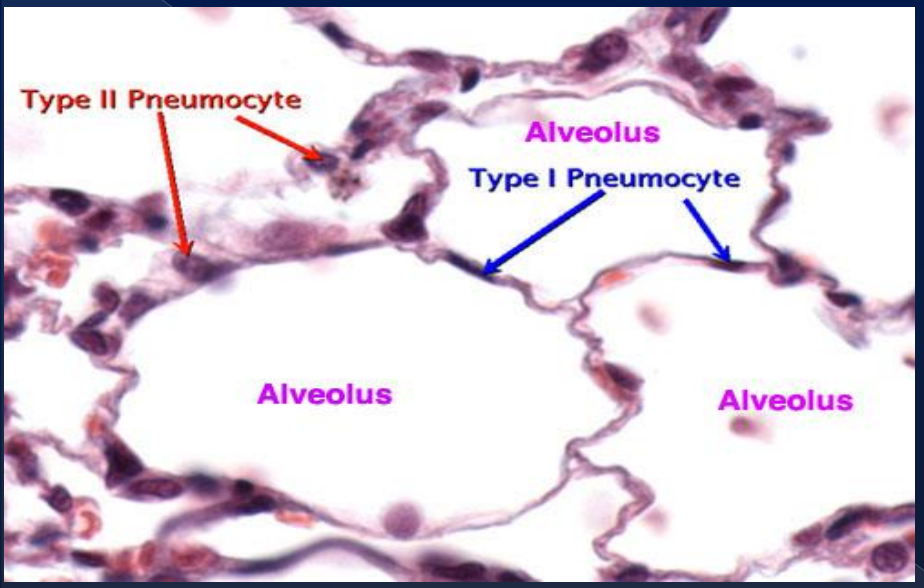
alveolus

- squamous **type I pneumocytes**
- cuboidal **type II pneumocytes.**
- **200 µm of diameter**

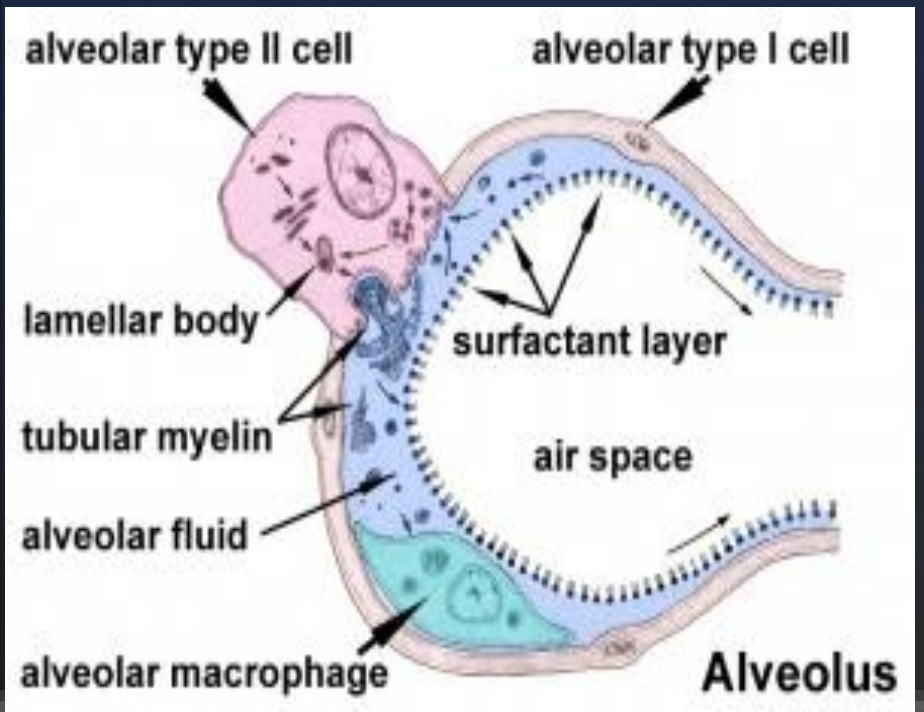
- each alveolus - surrounded by **capillary network.**



Type I Pneumocytes - squamous alveolar cells



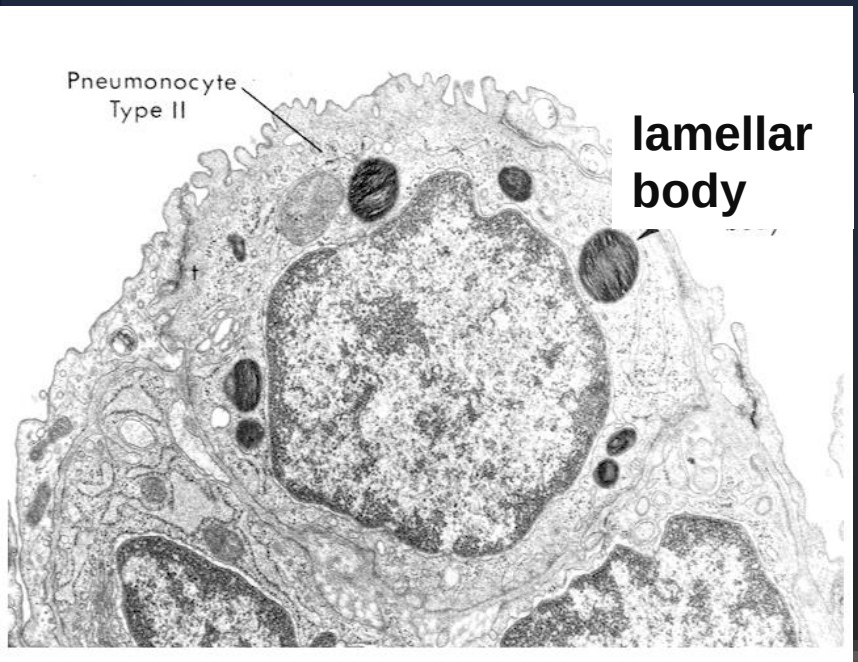
- 95% of the alveolar surface.
- extremely **attenuated** – this enables efficient exchange of gases.



The luminal surface of type I pneumocytes - lined by **surfactant (**produced by **type II pneumocytes**).

Type II Pneumocytes - cuboidal cells

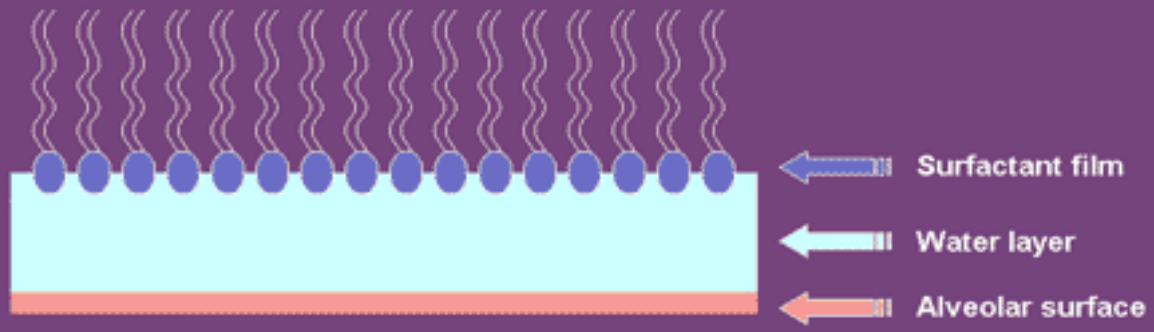
- 5% of alveolar surface, but are **more numerous than type I cells**.



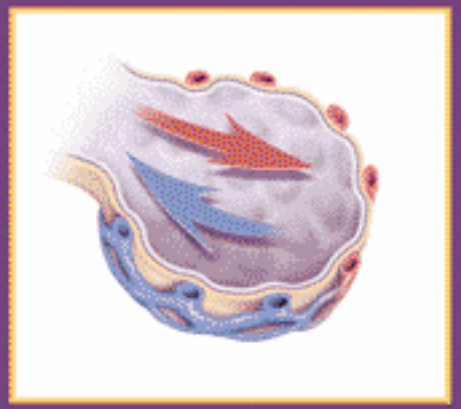
- **lamellar bodies** containing **surfactant**

- divide mitotically and can replace both types of alveolar cells (**stem cells**).

- **phospholipids** (water insoluble)
- surfactant **apoproteins** (water soluble)
- lipids cover water phase.



- Insufficient surfactant
  - Collapsed alveolus
  - Inadequate oxygen exchange



- Sufficient surfactant
  - Expanded alveolus
  - Adequate oxygen exchange

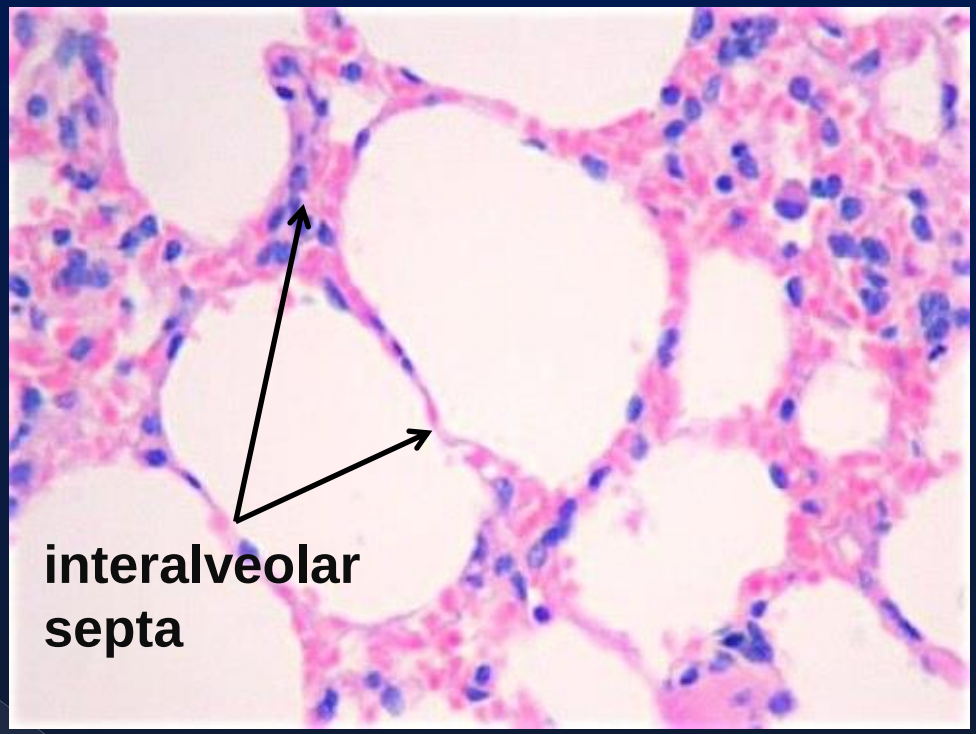
Surfactant

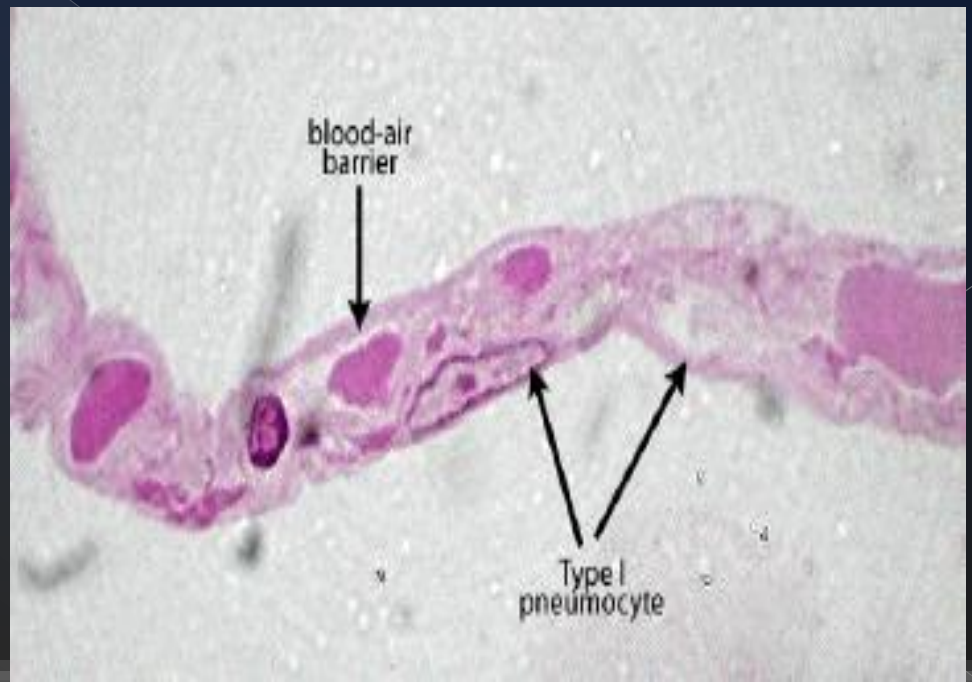
- acts as a detergent reducing **surface tension** of the alveolar cells
- prevents the collapse of alveoli

Interalveolar septum – region between 2 alveoli

- narrow - **continuous capillary** and its **basal lamina**
- or wider with connective tissue: fibers and cells

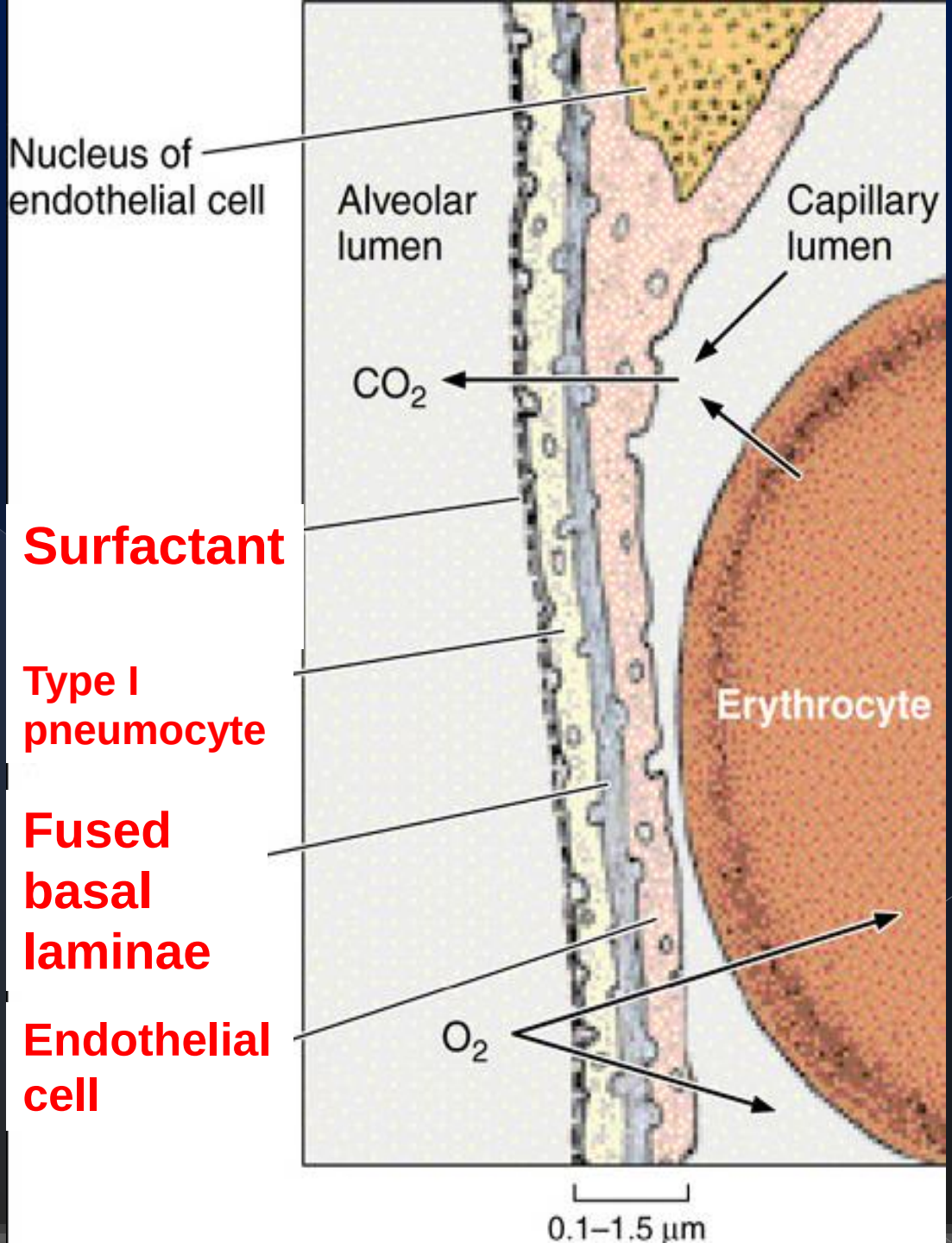
The narrowest regions of septum where gases can be exchanged - **blood-gas barrier**.





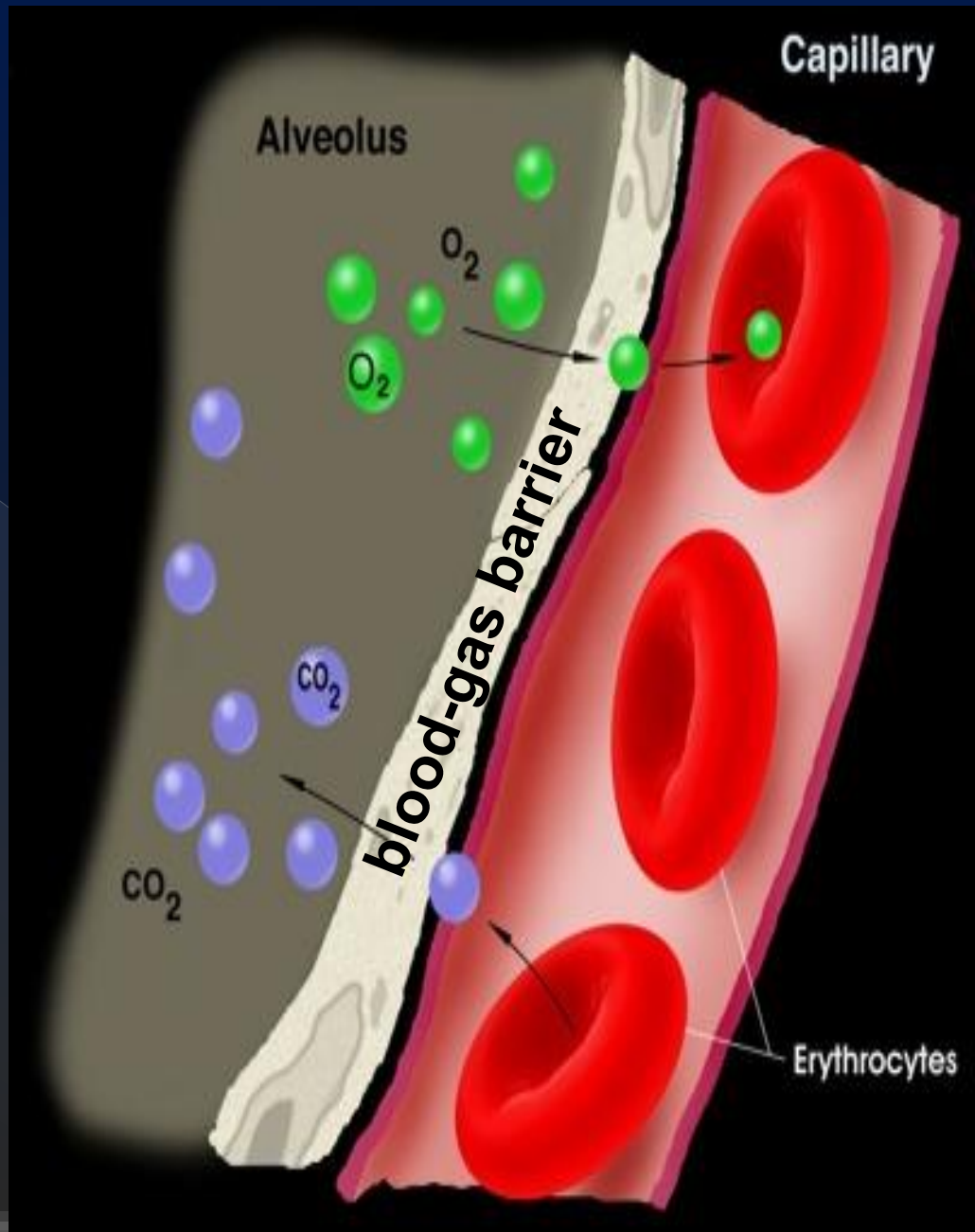
Blood- Gas Barrier

1. Surfactant
2. Type I pneumocyte
3. Fused basal laminae of type I pneumocyte and endothelial cell
4. Endothelial cell

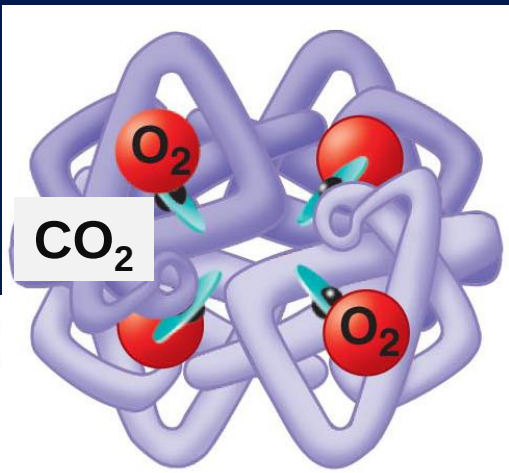


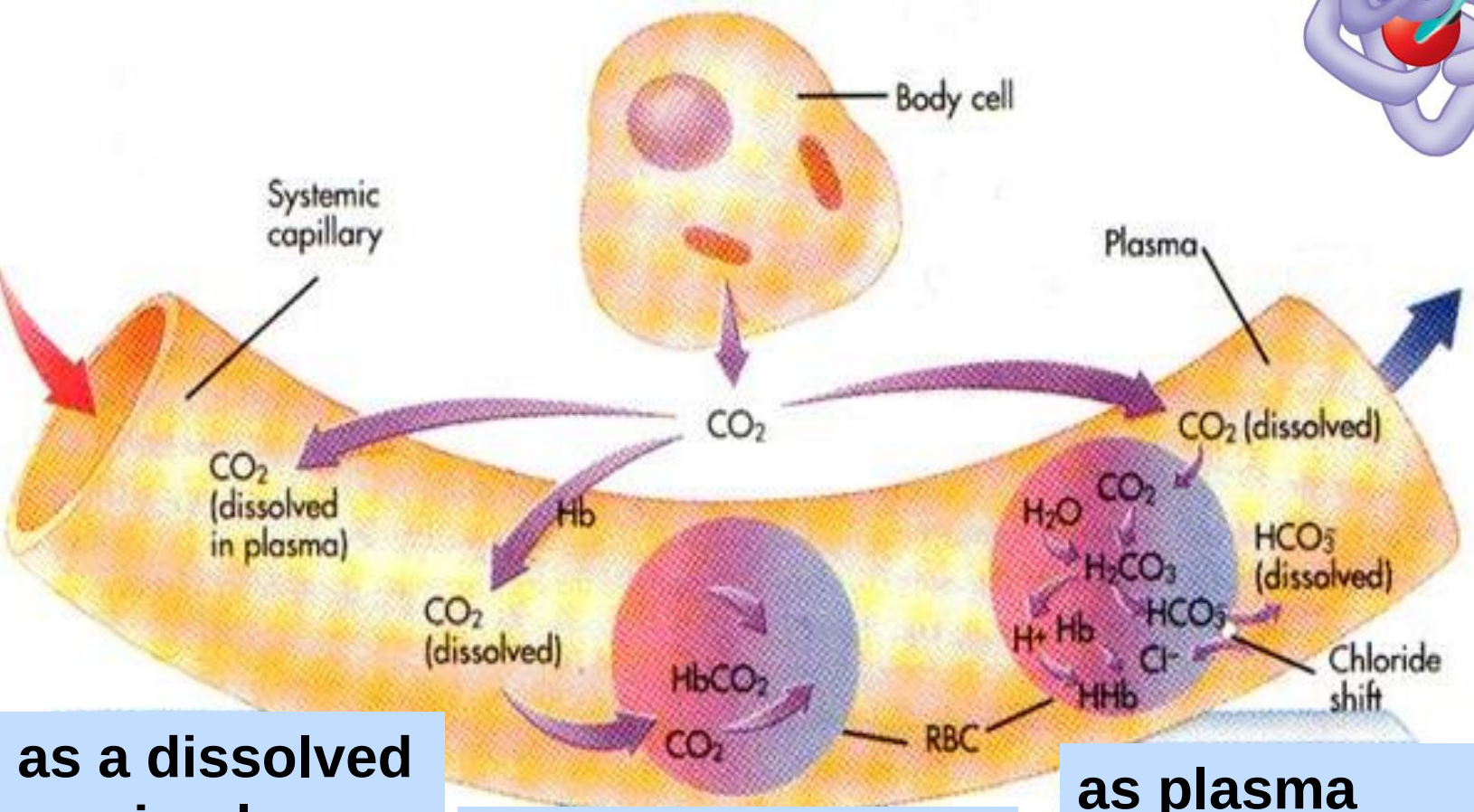
Exchange of gases through blood-gas barrier

- **Oxygen** (from alveolus) and **CO_2** (from the blood) diffuse (passive diffusion) through the blood-gas barrier - oxygen binds to the heme of erythrocyte hemoglobin **– oxyhemoglobin**



Transport of CO_2

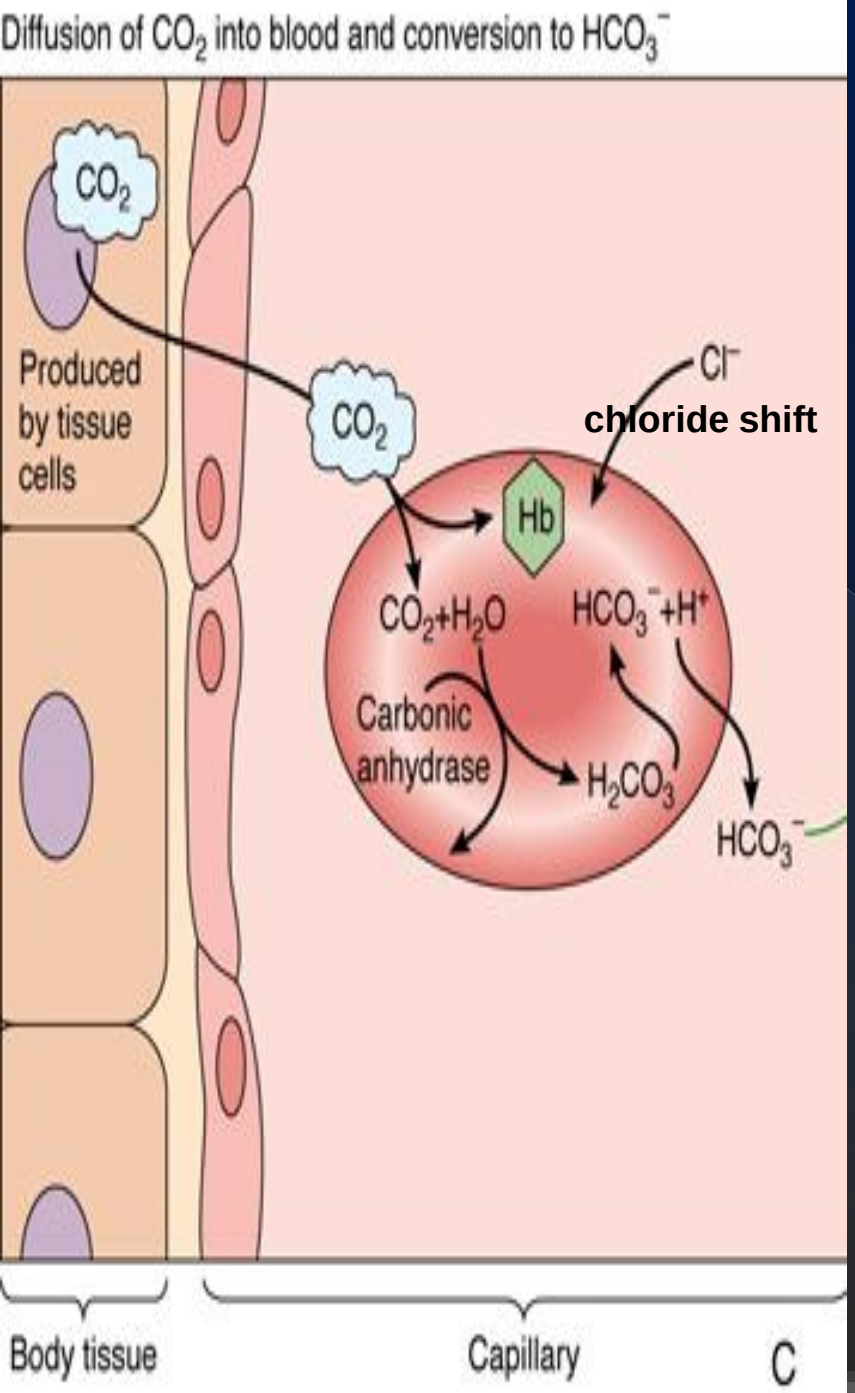




as a dissolved gas in plasma (10%)

bound to hemoglobin (20%) - **carbaminohemoglobin**

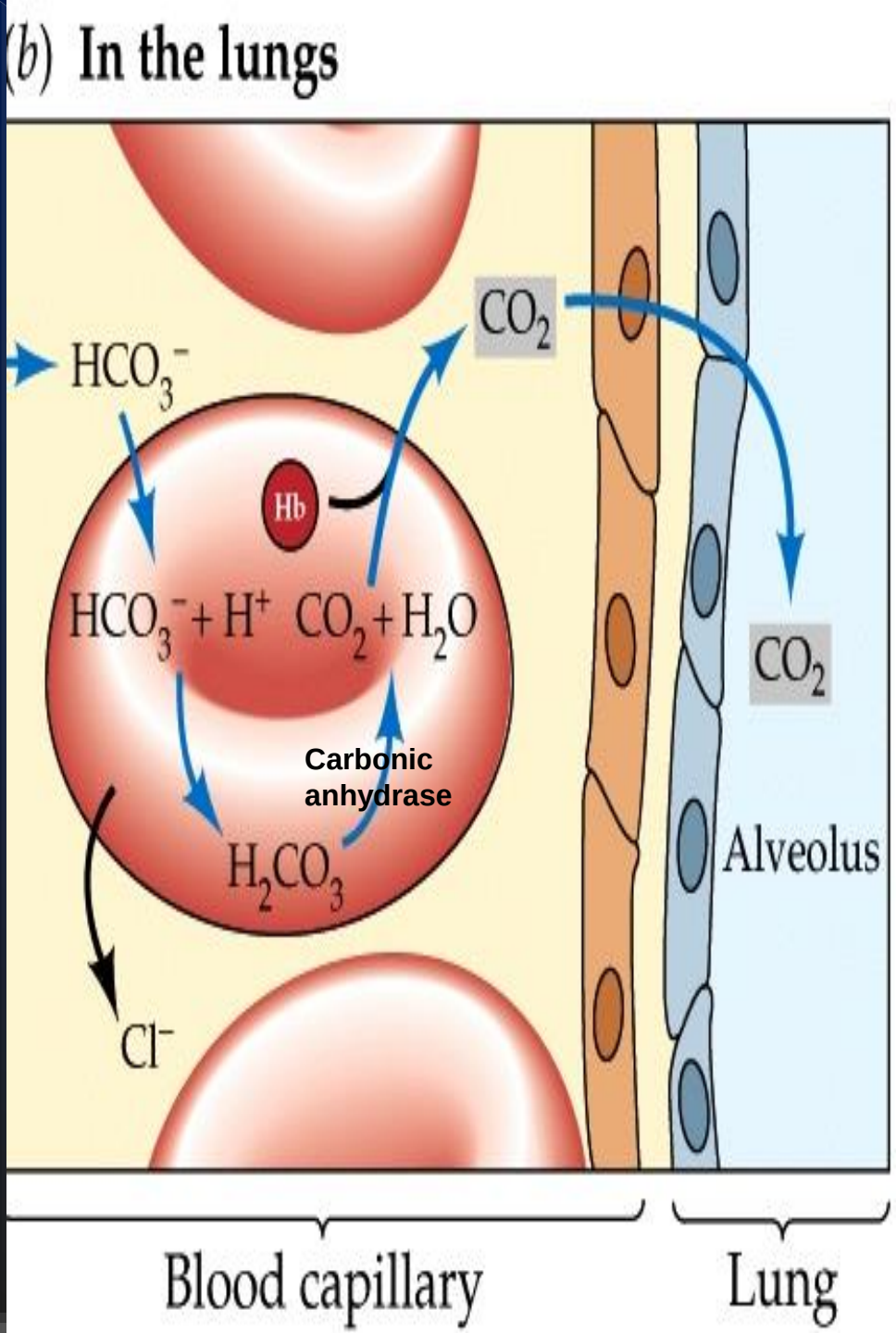
as plasma bicarbonate ions (70%)



1. CO_2 from plasma diffuses into the erythrocytes.

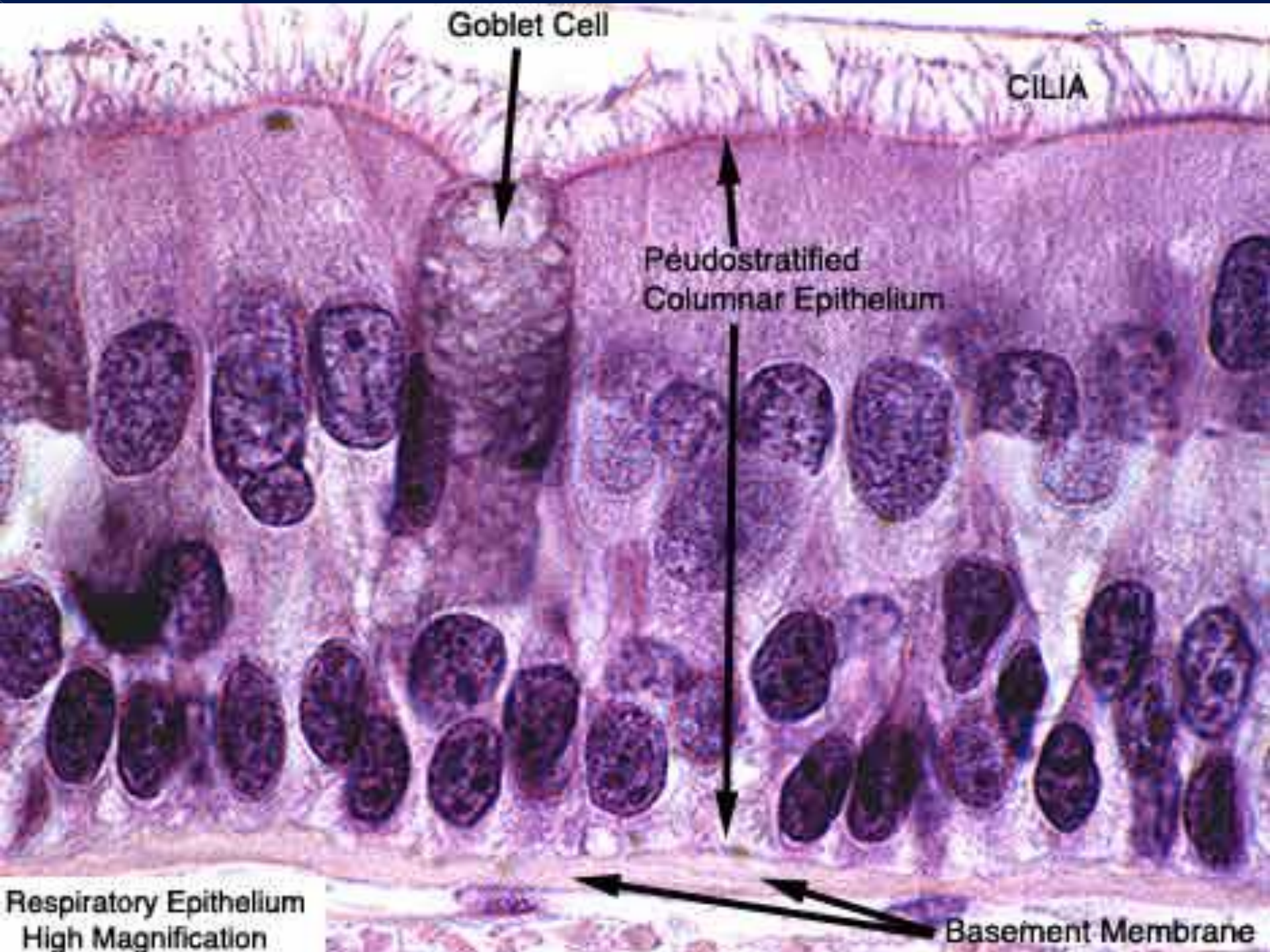
2. Within the erythrocyte

- $CO_2 + H_2O$ = carbonic acid **(carbonic anhydrase)**
- H_2CO_3 dissociates into hydrogen ion (H^+) and bicarbonate ion (HCO_3^-).
- HCO_3^- leaves the erythrocyte to enter the plasma.
- chloride ion (Cl^-) enters the erythrocyte (to maintain ionic equilibrium) - the **chloride shift.**



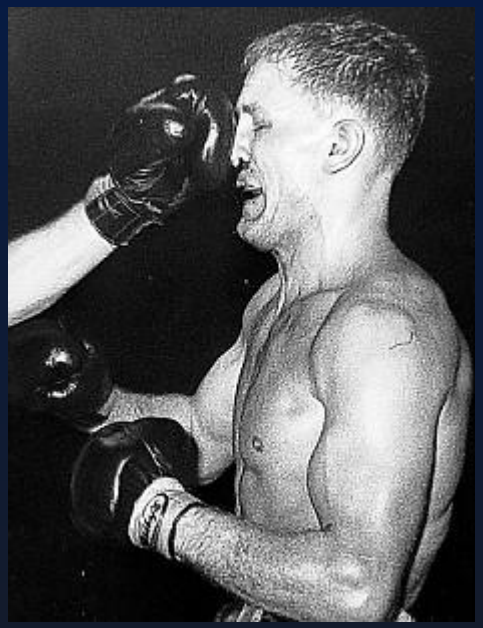
In the lungs

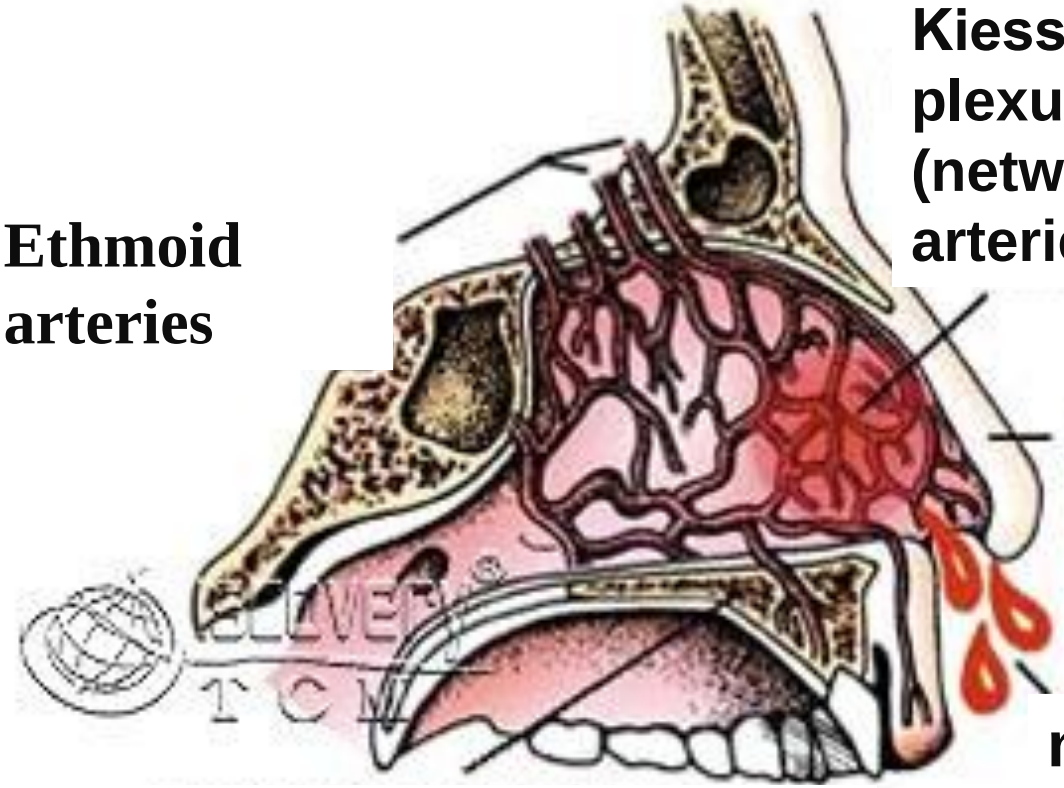
- HCO_3^- enters the erythrocytes (Cl^- from the cell into the plasma - **chloride shift**).
- HCO_3^- and H^+ within the erythrocyte combine to form carbonic acid.
- Carbonic anhydrase catalyzes the cleavage of carbonic acid to form water and CO_2.
- The carbon dioxide - diffuses into the alveoli and out of the body with the next exhalation.



Respiratory Epithelium
High Magnification

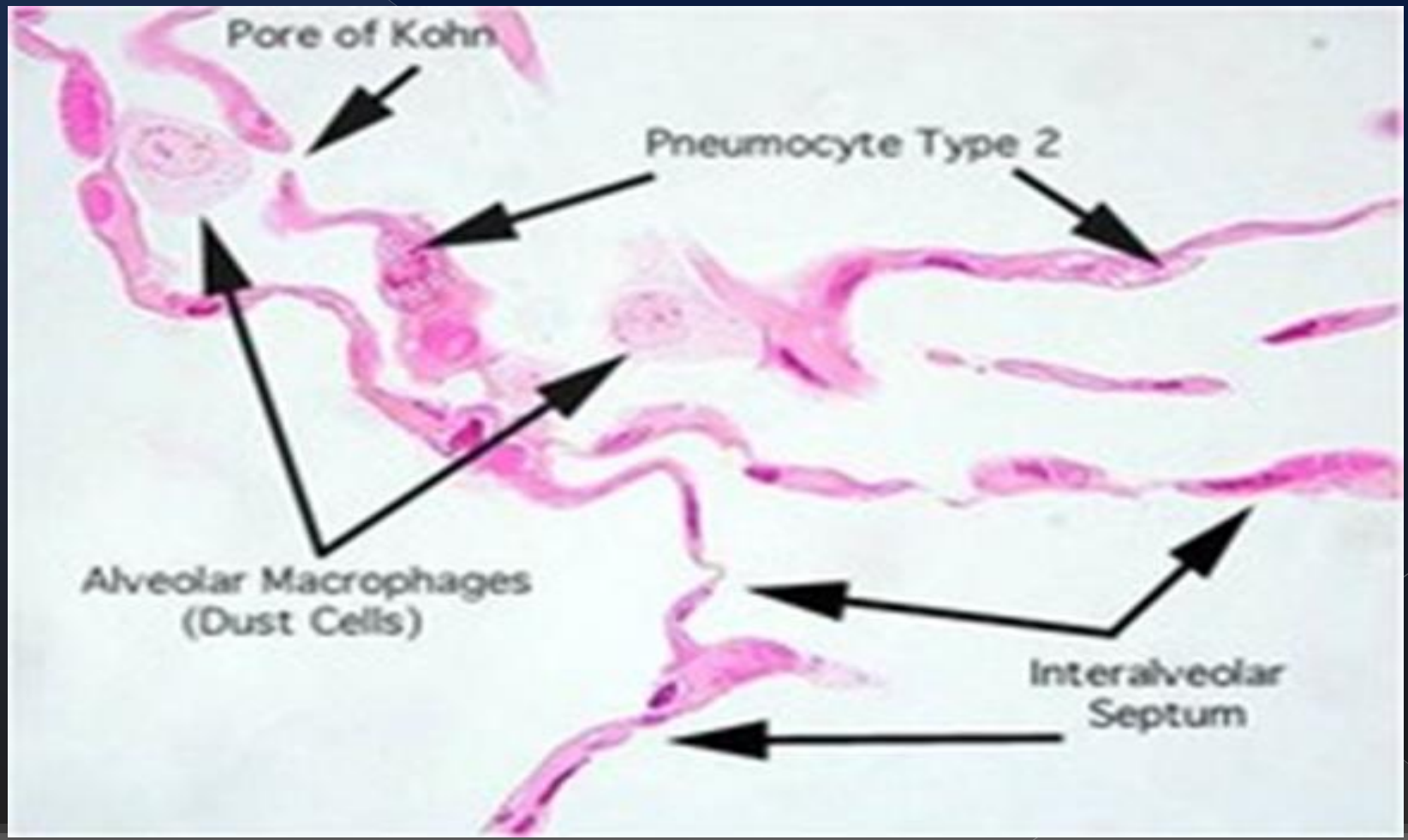
- in anteroinferior region of nasal septum – Kiesselbach's area (plexus) - four arteries form anastomosis - a vascular plexus - the site from which nasal bleeding occurs





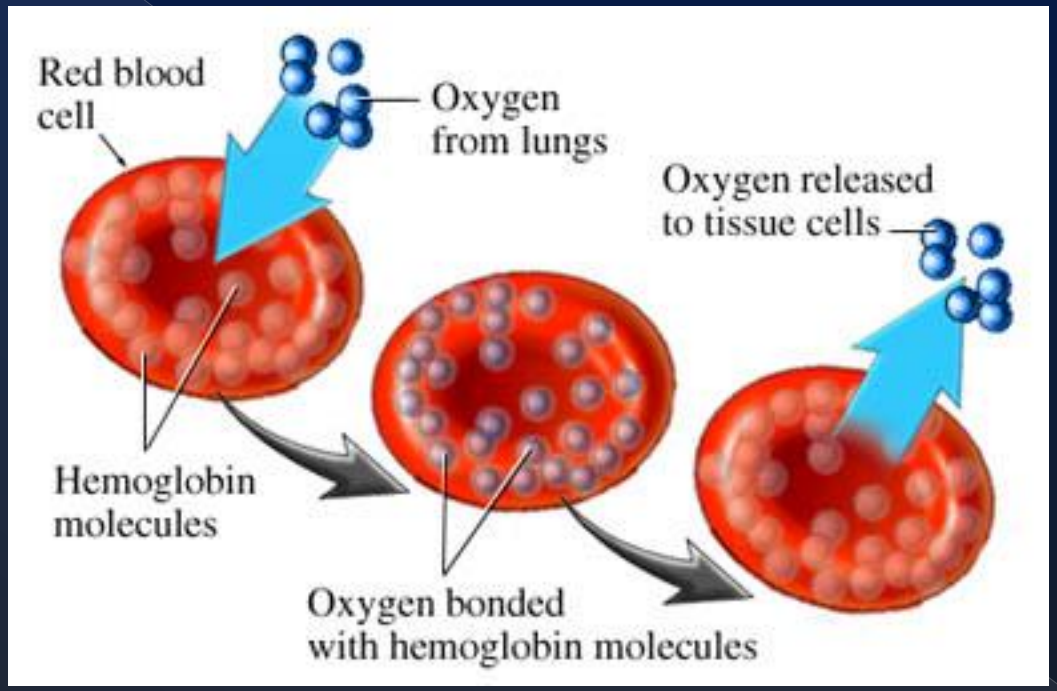
- blunt trauma, usually a sharp blow to the face

- alveoli communicate with each other through **alveolar pores (pores of Kohn)** - equilibrate air pressure within **pulmonary segment** (a part of lung supplied by tertiary bronchus).



vibrissae – stiff hairs - prevent the entering of large dust particles into the nasal cavity

low temperature, high pH, and increased oxygen pressure in the capillaries of the lungs

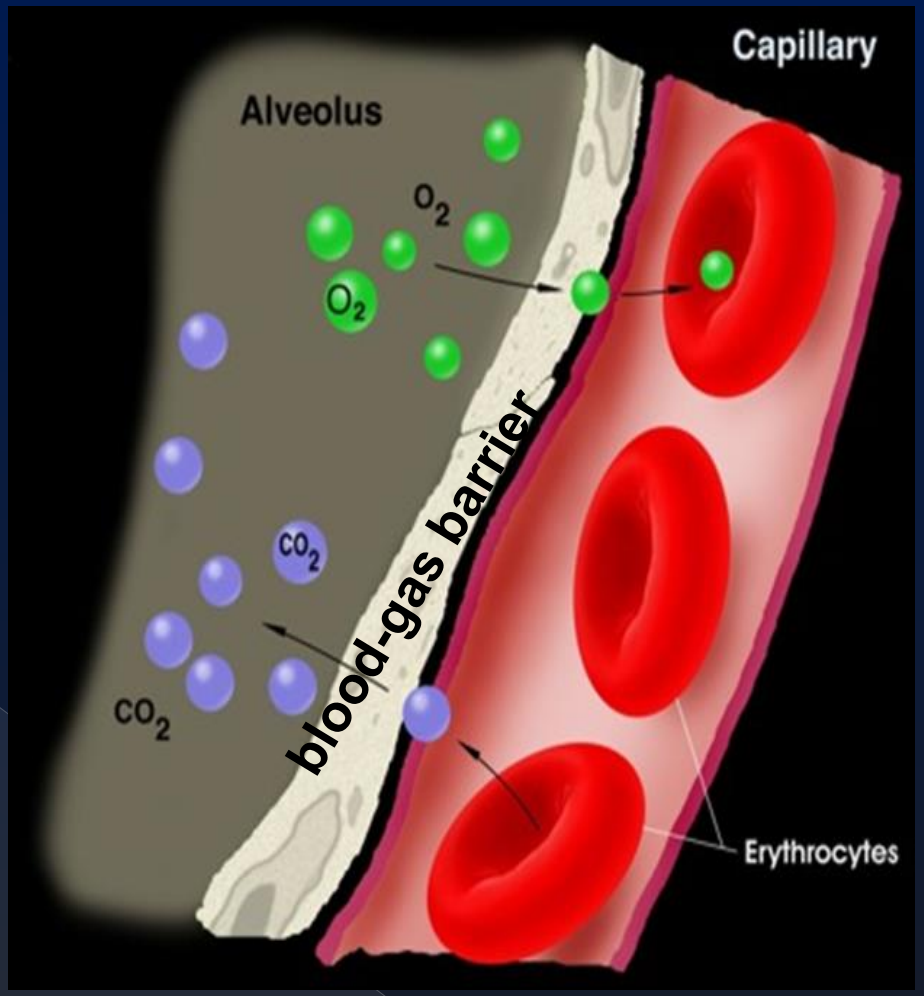


high temperature, low pH, and lower oxygen pressure in the tissues

About 98.5% of the oxygen is transported in form of oxyhemoglobin

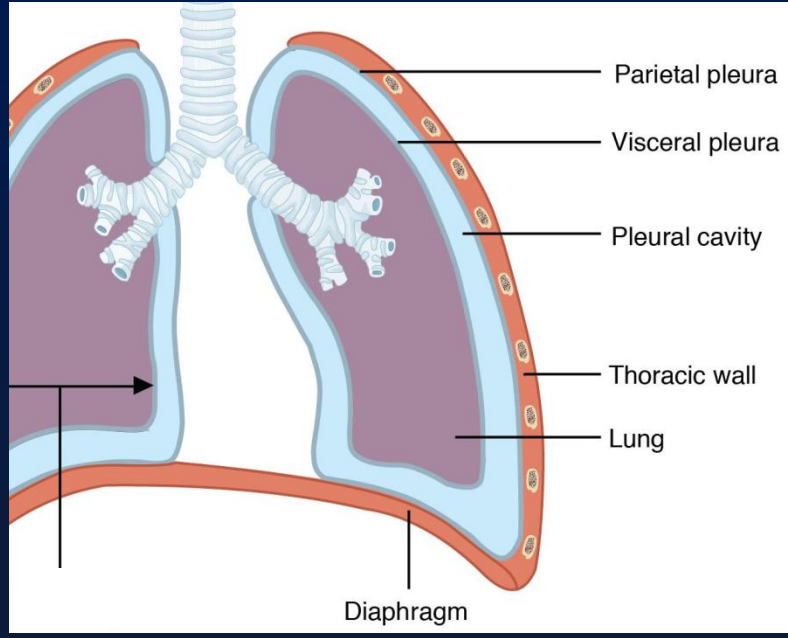
- approximately 200 ml of CO_2 is formed by the cells of the body per minute

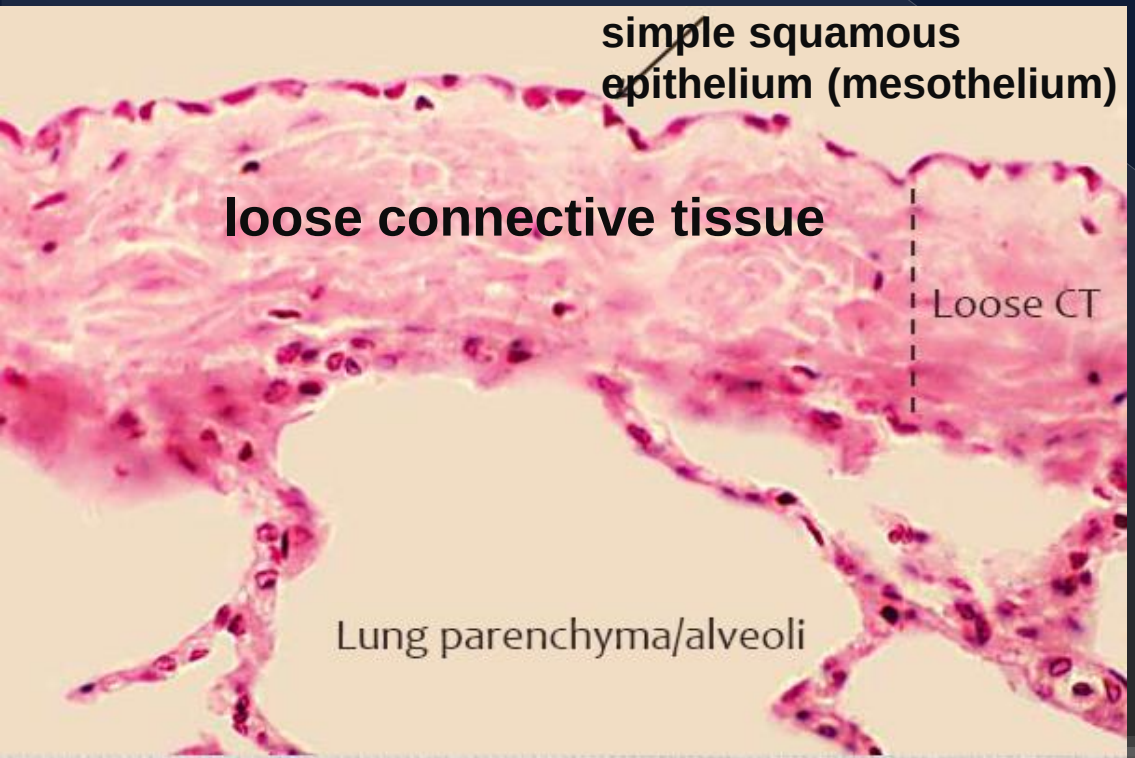
- CO_2 leaves the blood diffuses through the blood-gas barrier into the lumina of the alveolus (passive diffusion)
- CO_2 exits the alveolus as the CO_2 rich air during exhalation



Pleura

- the serous membrane investing the lungs (visceral pleura) and lining the walls of the thoracic cavity (parietal pleura)

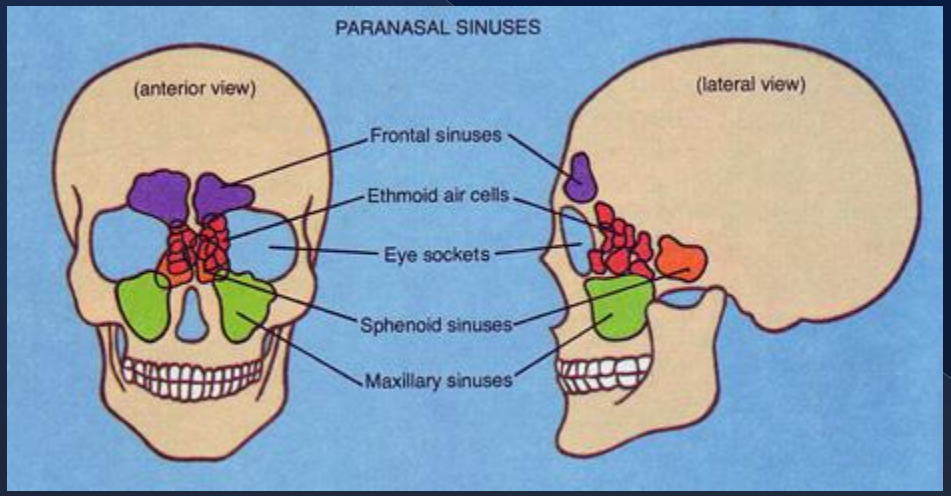


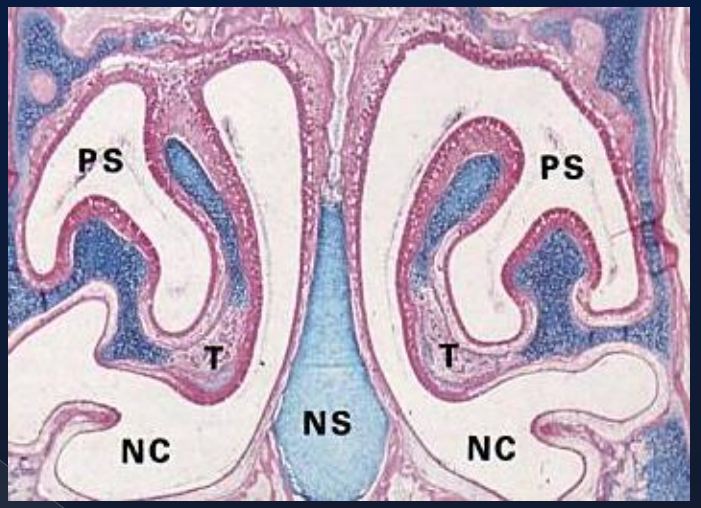


- simple squamous epithelium (mesothelium)
- loose connective tissue

PARANASAL SINUSES – 4 pairs: frontal, ethmoid, sphenoid and maxillary

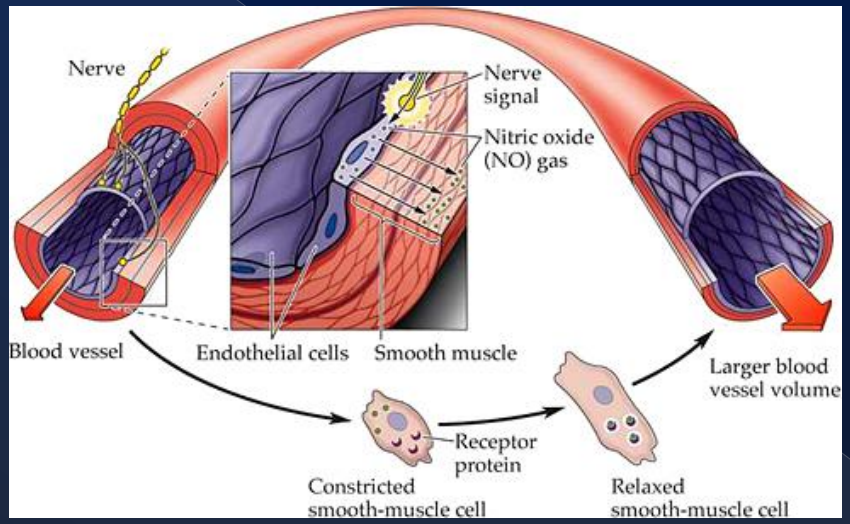
Spaces in bones , communicating with nasal cavity, whose lamina propria is fused with periosteum (mucoperiosteum) and similar to nasal cavity lamina propria.

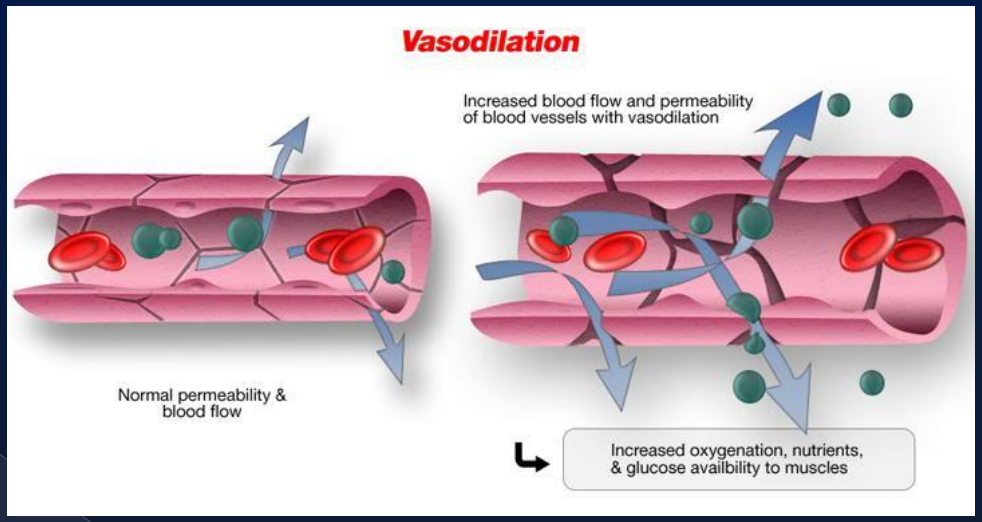




Decreasing the relative weight of the front of the skull
Increasing resonance of the voice.
Insulating sensitive structures like dental roots and eyes from rapid temperature fluctuations in the nasal cavity.
Humidifying and heating of inhaled air
Regulation of intranasal and serum gas pressures
Immunological defense
Despite these various proposals, the paranasal sinuses may not serve any biological function

Nitric Oxide





Hemoglobin also has two types of binding sites for nitric oxide (NO), a neurotransmitter that, when released by endothelial cells of blood vessels, causes relaxation of the vascular smooth muscle cells with a resultant dilation of the blood vessels. *H*emoglobin nitrosylated by nitric oxide produced by blood vessels of the lung, ferries NO to arterioles and metarterioles of the tissues, where NO is released and causes vasodilation. In this fashion, hemoglobin not only contributes to the modulation of blood pressure, but also facilitates the more efficient exchange of O_2 for CO_2. Moreover, once O_2 leaves hemoglobin to oxygenate the tissues, NO takes its place and is transported into the lungs, where it is released into the alveoli to be exhaled along with CO_2.