The Respiratory System

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Modified Key:

Dark Blue Text: Information present in original presentation.
Highlighted Text: Text read by the Doctor.
Red Text: Information stated by the Doctor, not present in original presentation file.
Blue Text: Additional information added for further comprehension.

Objectives (lecture + practical)

- 1. Identify the conduction part of the respiratory tract and analyze the function of each segment
- 2. Identify the transitional area separating the conduction from the respiratory part
- 3. Comment on the fine structures and function of the pulmonary alveoli and the blood-air barrier

Objectives (lecture + practical)

- 4. Describe the various units of the lung as seen by the surgeon, the histologist or the physiologist.

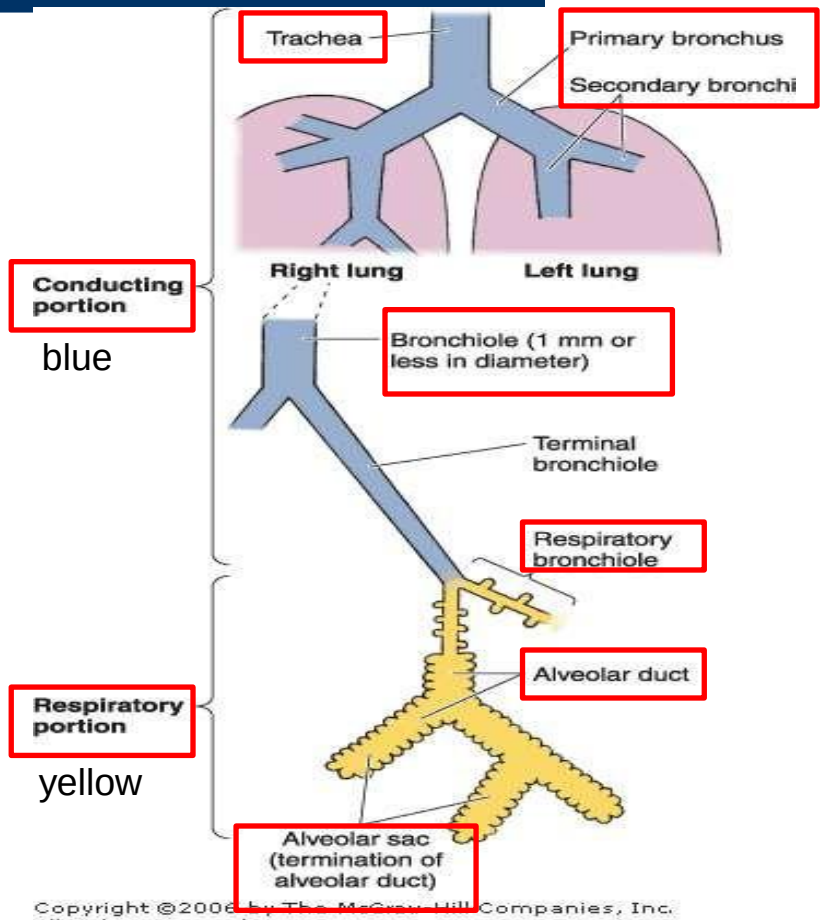
- 5. Solve the clinical problems
- E.g: Effect of smoking ?

The Respiratory System

Histologically, the respiratory tract can be divided into:

- **Conducting portion:**
- Provides passage of air
- No gaseous exchange occur through it

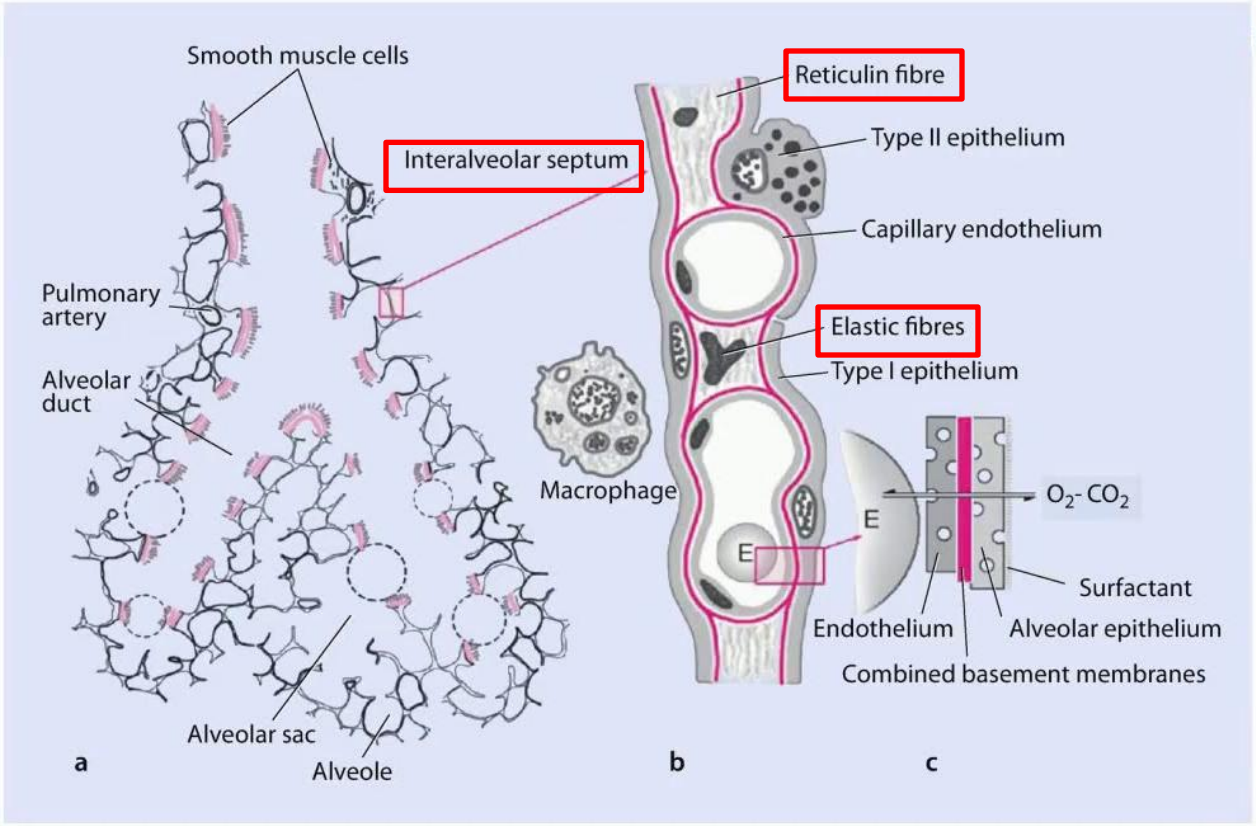
- **Respiratory portion** :
- Where gas exchange takes place



Doctor’s Notes:

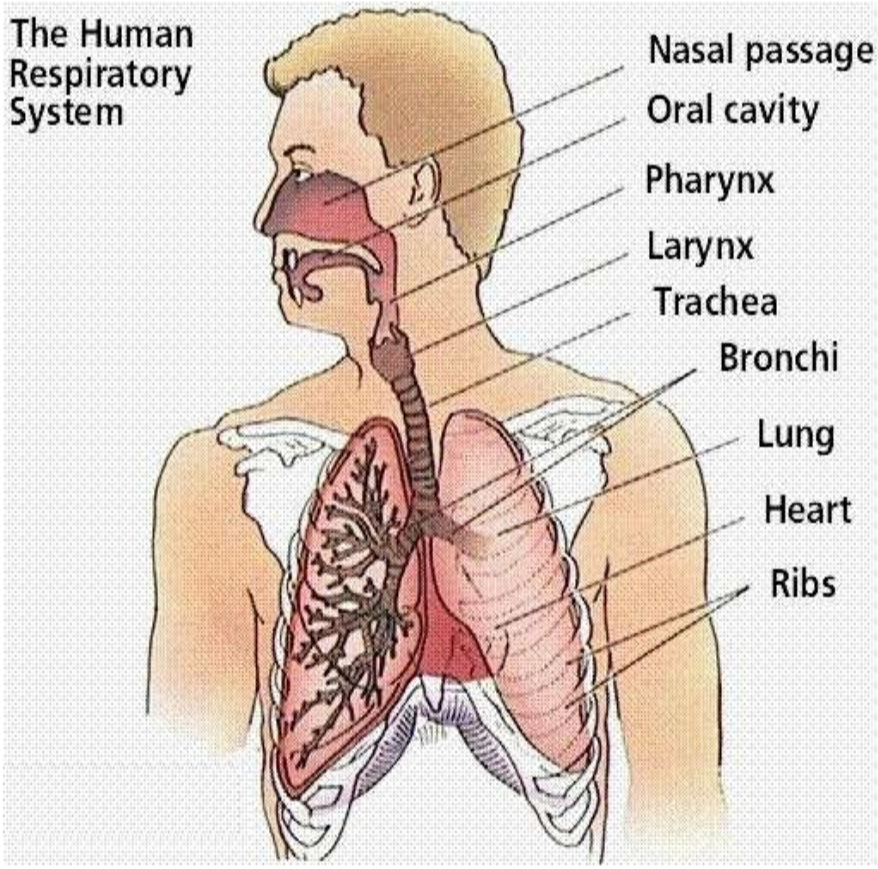
- The alveolar duct and sacs are all surrounded by alveoli where gas exchange takes place.
- The walls of alveoli have points of contact which each other which are called alveolar septa, the corners of which are filled with elastic and reticular tissue to allow distention and relaxation of lungs. We can also find a dense network of capillaries for gas exchange (lungs have the densest network of capillaries).

Extra picture to clarify the alveolar septum:



Conducting portion

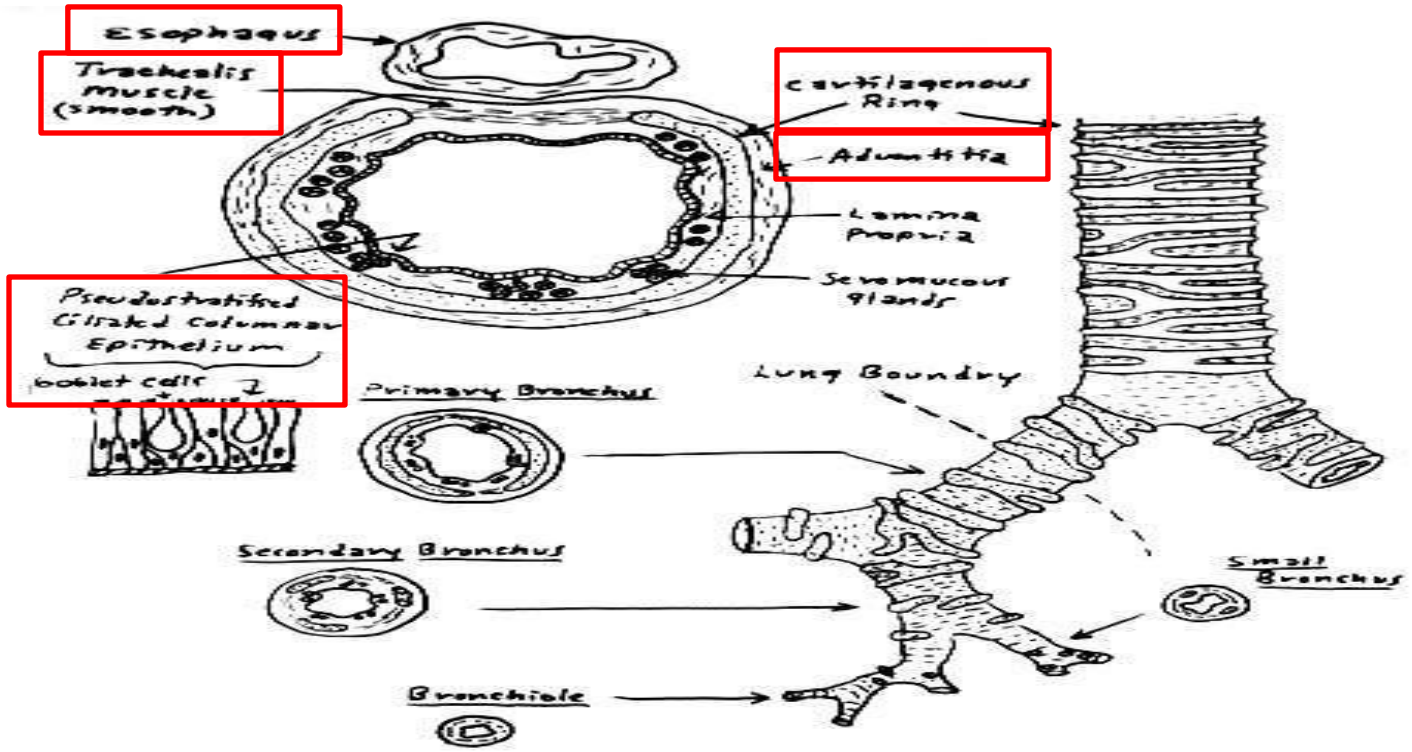
- **Nose**
- **Nasopharyngeal cavity**
- **Larynx**
- **Trachea**
- **Bronchi: (1ry,2ndry,3ry)**
- **Large Bronchioles**
- **Terminal bronchioles**



Doctor's Notes:

- An important difference between bronchi and bronchioles is the presence of hyaline cartilage; bronchi have hyaline cartilage while bronchioles have SMOOTH MUSCLES and no hyaline cartilage.
- Therefore, asthma involves the bronchioles, NOT the bronchi since cartilage helps keep it open. The narrow lumen causes wheezing within the bronchioles.

Conducting portion



Doctor's Notes:

- The previous slide presents a cross section through the trachea. Just to revise some GI for comparison purposes, its lining epithelium was simple columnar epithelium (without goblet cells in the stomach, with goblets cells in the small intestine). Also, the layers of the esophagus are:

1. Mucosa
2. Submucosa
3. Muscular layer
4. Adventitia/serosa

Doctor's Notes:

- On the other hand, the respiratory tract is lined by pseudostratified ciliated columnar epithelium with goblet cells up until the bronchioles which are lined by simple ciliated cuboidal/columnar epithelium. Also, the trachea is formed by:

1. Mucosa
2. Submucosa
3. Supportive layer (hyaline cartilage)
4. Connective tissue

- Another important difference between the GIT and the RT is the location of glands: in the GI, it is mainly within the mucosa (lamina propria), while in the RT, it is mainly in the submucosa (some can be found within the lamina propria, though).
- We can notice, also, that the trachea is surrounded by c-shaped cartilage.
- Why do we have cartilage? To hold the trachea open.
- Why is it c-shaped? Because posterior to it is the esophagus which has peristaltic movement. If the cartilage were a full circle, it would press on the esophagus and prevent proper propagation of the food bolus.
- Of course, we won't leave the remaining part of that layer empty. We can find a smooth muscle called the trachealis muscle which allows for peristaltic movement in the esophagus.

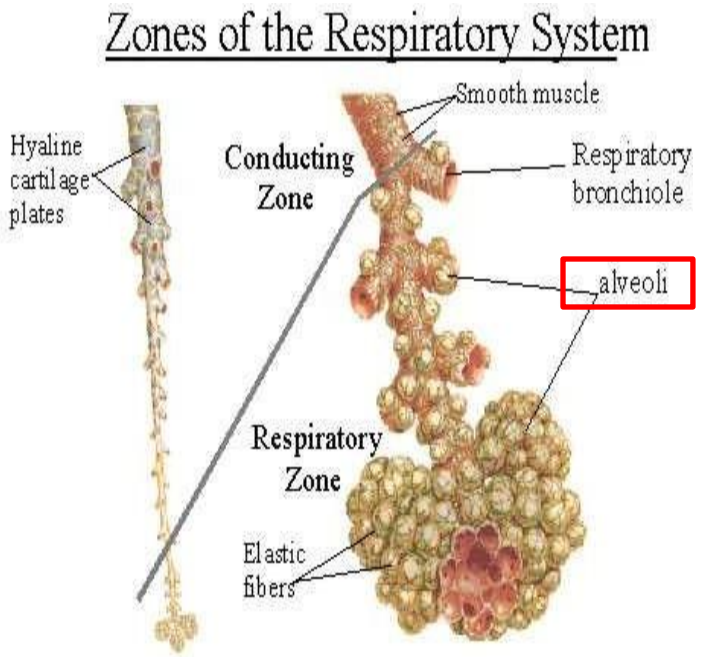
Conducting portion

- Major function of the conducting portion is to condition the inspired air
- Before it enters the lungs, inspired air is **cleansed, moistened, and warmed**
- Mucosa of the conducting portion is lined with a specialized **respiratory epithelium** **where cilia assists in pushing foreign material outside the body.**
- Numerous mucous and serous glands as well as a rich superficial vascular network in the lamina propria.

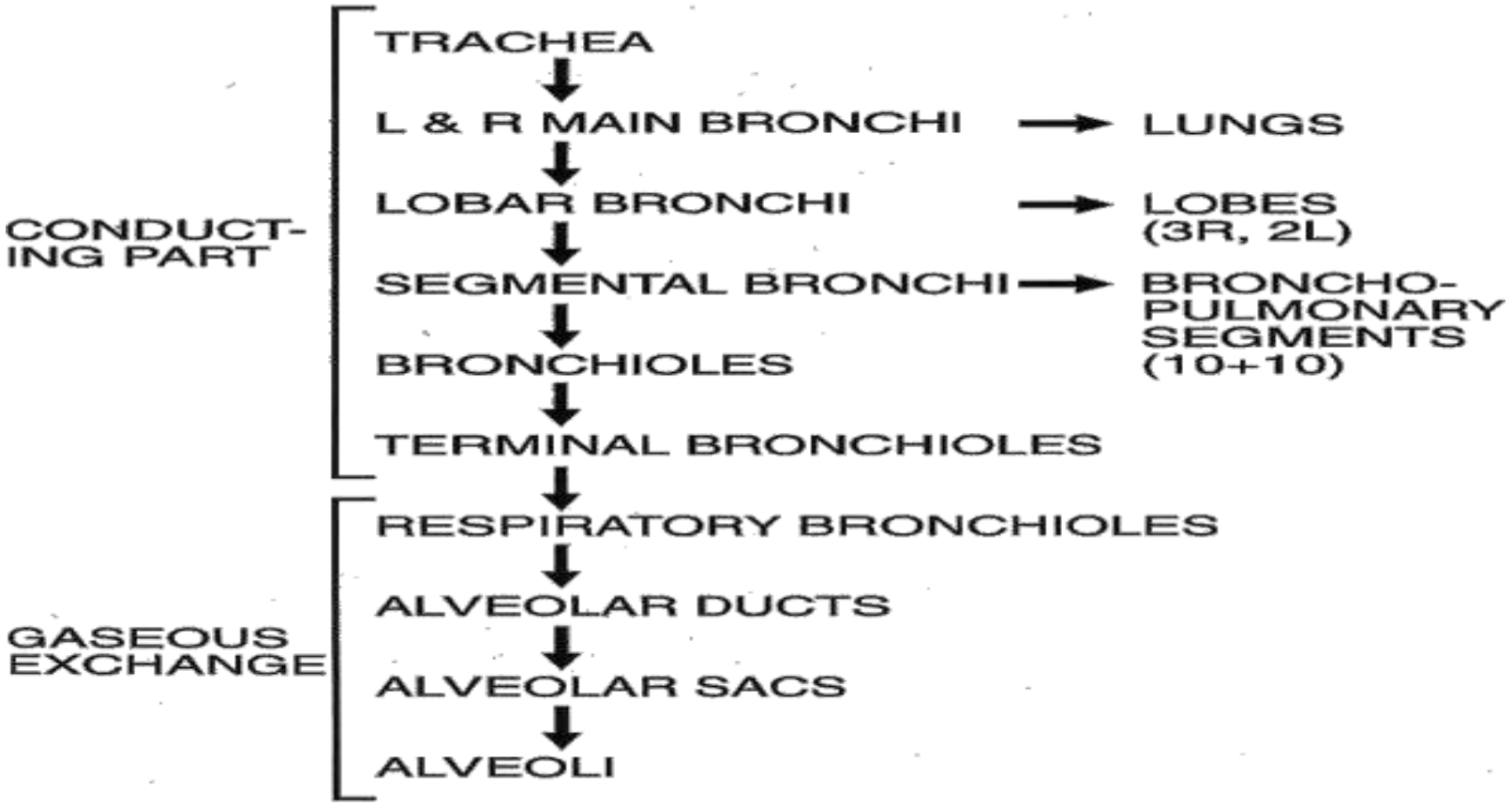
Respiratory portion

- Consisting of :
- **Respiratory bronchioles** (region of transition)

- **Alveolar ducts**
- **Alveolar sacs always at the end of ducts**
- **Alveoli** : main sites for the principal function of the lungs
- the exchange of O_2 and CO_2 between inspired air and blood.



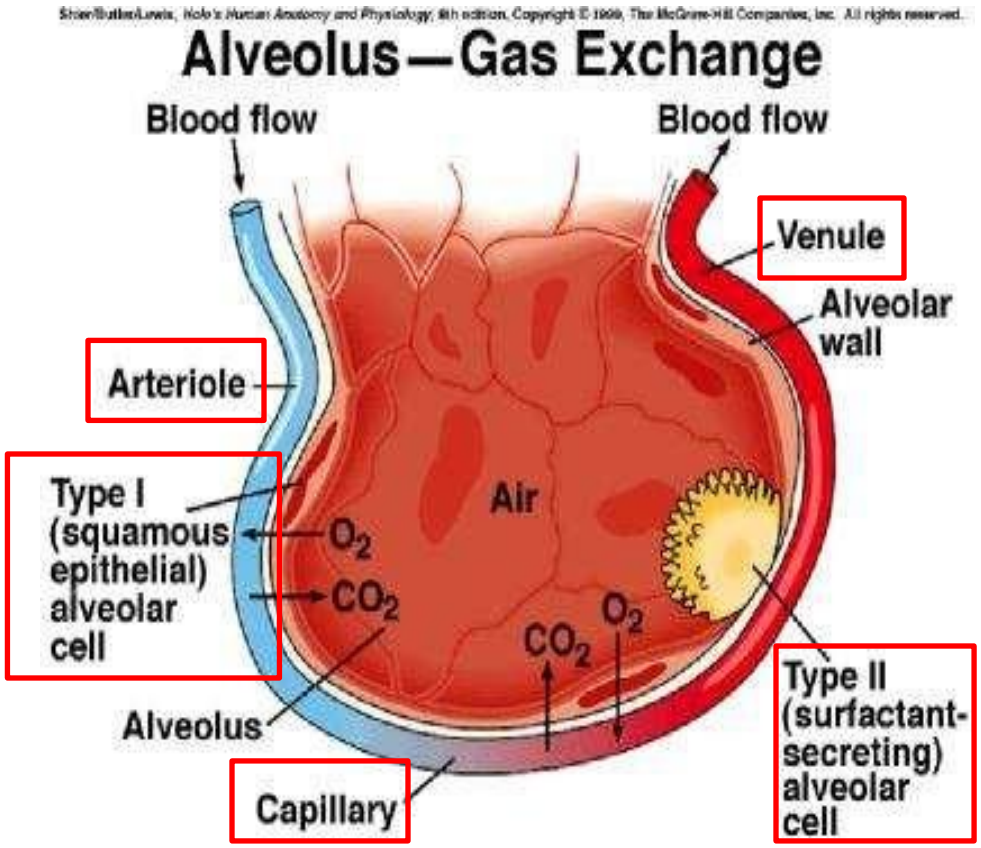
Respiratory tract



Gas exchange

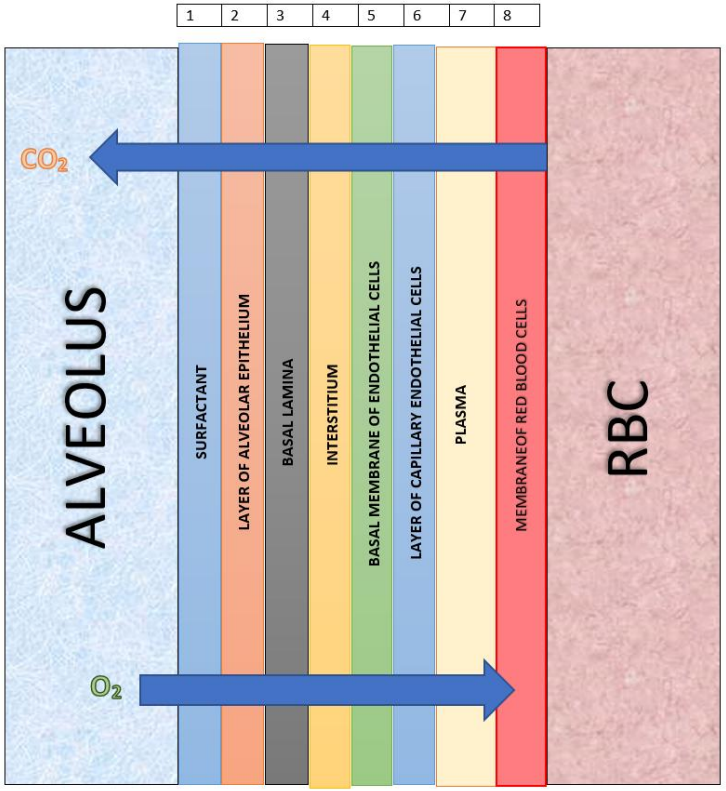
- The exchange of gases (O2 & CO2) between the alveoli & the blood occurs by passive diffusion

- When blood first arrives at the pulmonary capillary at its arteriole end, the partial pressures of carbon dioxide and oxygen are:
  PCO2 = 45 mm Hg
  PO2 = 40 mm Hg



Doctor's Notes:

- In the previous slide, we can see the alveolus and its wall comprised of simple squamous epithelium (type 1 cells), similar to the surrounding capillaries (to maximize gas exchange).
- The simple squamous epithelium also has a thin, fused basement membrane. Both of these form what is called the respiratory membrane (a part of the alveolar septum) across which gas exchange occurs. It is actually more complex than just these, check this diagram to the right.
- Wherever we find an alveolar wall/respiratory membrane and capillaries together, gas exchange occurs there.



Doctor's Notes:

- We can also notice another type of cell within the alveoli, type 2 alveolar cell, which makes up 3% of the total cells of the walls of alveoli while 97% is made up by the simple squamous epithelial cells.
- Type 2 cells play an important role in secreting the surfactant, a crucial molecule to decrease surface tension within the alveoli; it must be present in proper quantities within a newborn to allow lungs and alveoli to fill with air. If it is present in insufficient amounts, it causes RDS, respiratory distress syndrome, and the newborn must be placed within an incubator to provide them with oxygen since they can't breathe on their own.
- During pregnancy, the fetus doesn't breathe. However, during the end of the 8^{th} month and the 9^{th} month, type 2 cells start secreting surfactants to prepare alveoli for gas exchange.
- Immediately after birth, a baby is slapped on the back to stimulate, through the skin, the respiratory center in the medulla oblongata. Neural impulses are produced and propagated through the phrenic nerve to the diaphragm which contracts and initiates respiration, indicated by a baby's first cry.

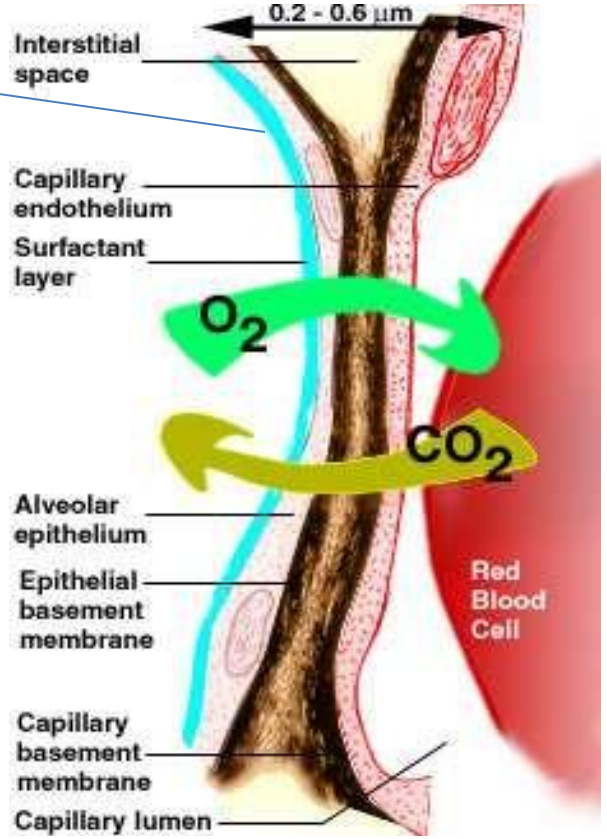
Gas exchange

- In the alveoli
- PO2 = 105 mmHg
- PCO2 = 45 mmHg

Surfactant membrane; formed when surfactant is present in sufficient amounts

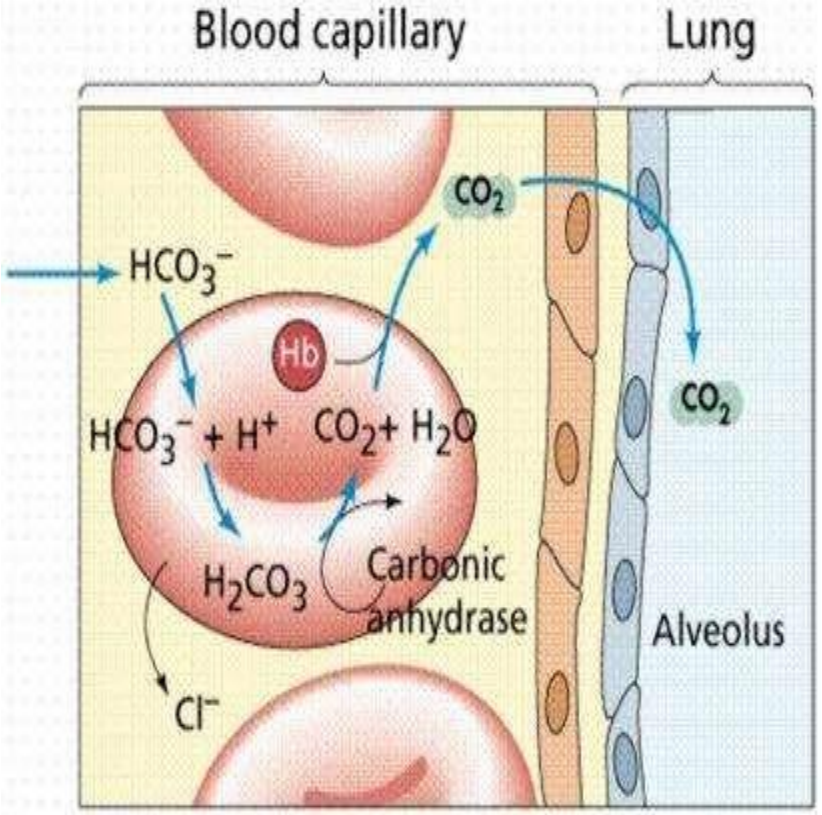
- O2 is taken up by RBCs and CO2 is released due to difference in pressure

- After the net diffusion of oxygen PO2 in the venous end equals **95-100mmHG**
- Oxygen is then taken by tissue cells for metabolic activity (tissue PO2 = 40-45 mmHg, same as arterioles and capillaries in lungs before exchange)



Carbon-dioxide in the blood

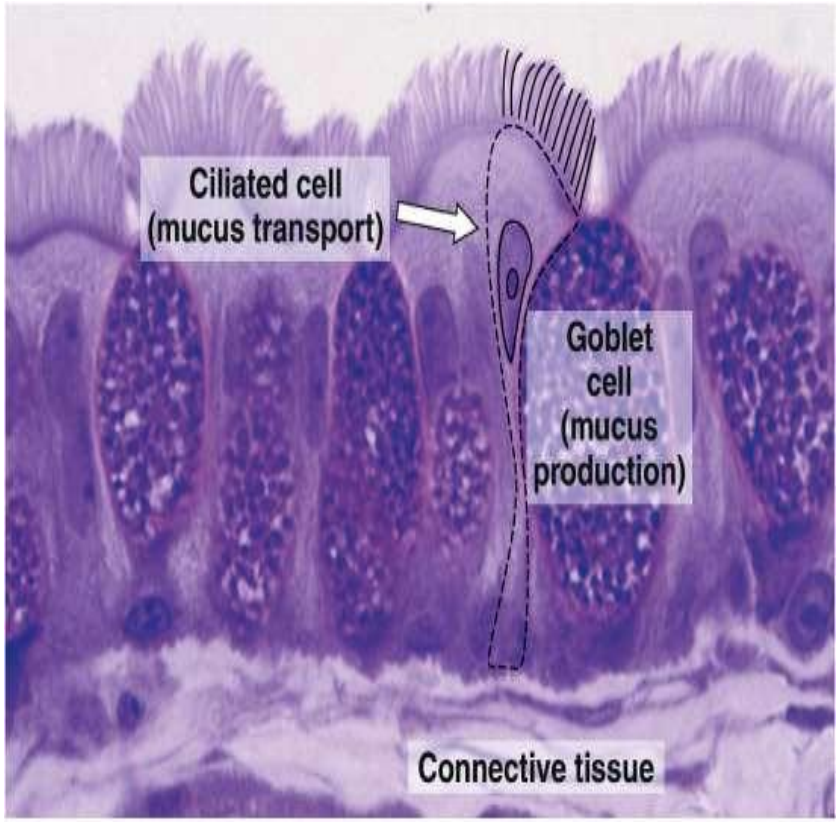
- 7% dissolved in plasma
- 23% combine with hemoglobin to form **carbaminohemglobin**
- 70% converted to protons by **carbonic anhydrase** and combines to hemoglobin (reversible reaction)



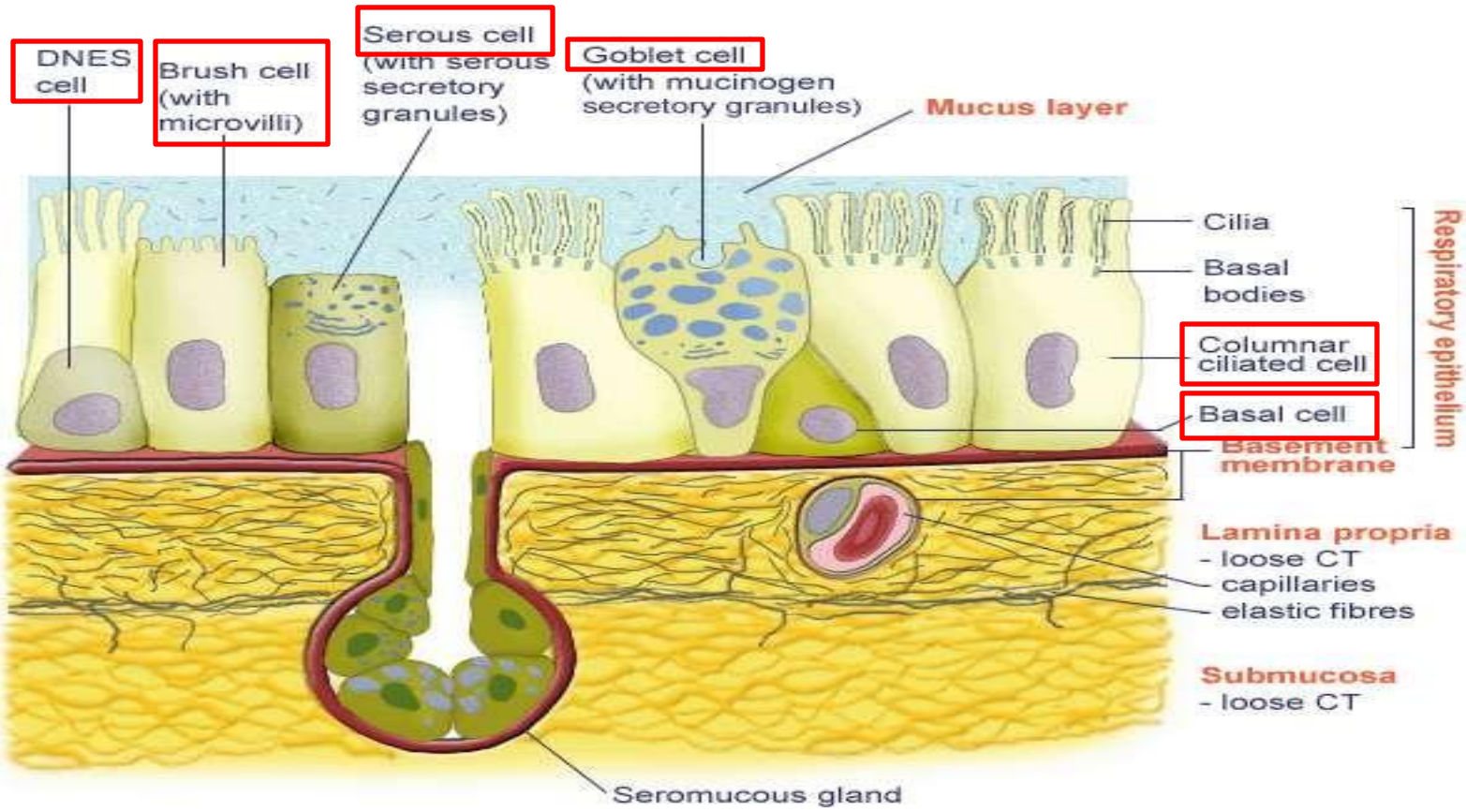
Respiratory Epithelium

Respiratory Epithelium

- Lined mostly with ciliated **pseudostratified ciliated columnar epithelium**
- Contains 5 types of cells
- All of them resting on basement membrane
- but not all of them reach the surface
- Under the light microscope, we can only see the pseudostratified columnar epithelium and goblet cells; other cell types are ultrastructural and require electron microscopy.

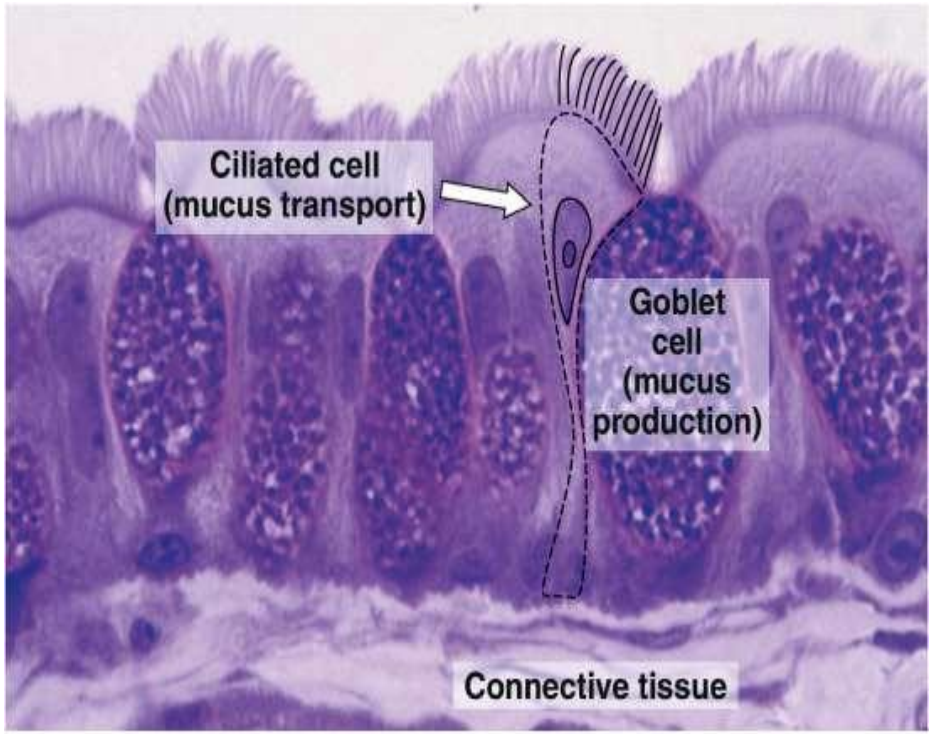


Respiratory epithelium cells

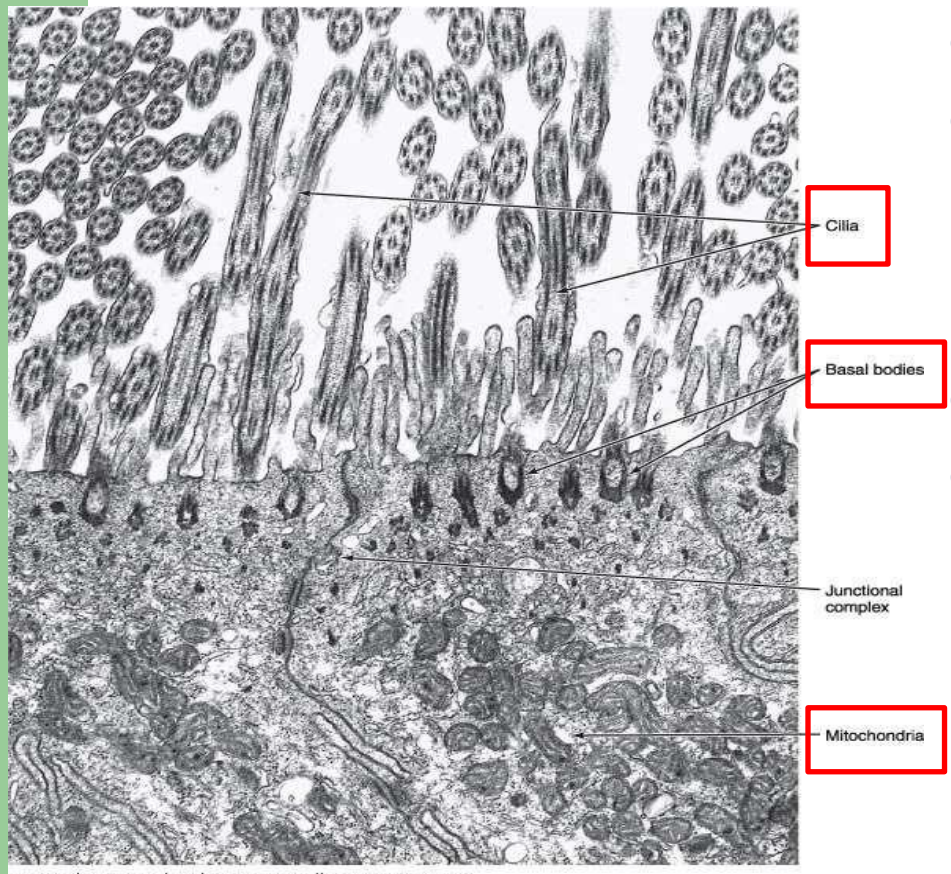


Ciliated columnar cells

- Most abundant type
- Each cell has about 300 cilia on its apical surface



Ciliated columnar cells

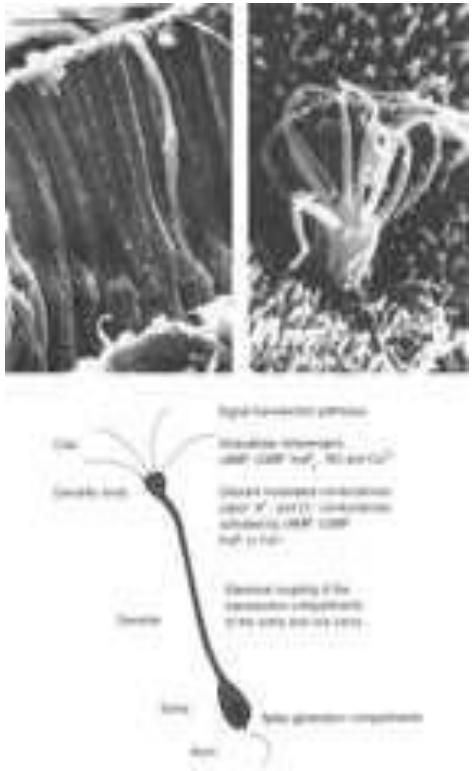


- **Basal bodies**:
- Where cilia is inserted in the apical part of the cell

- **Apical mitochondria**
- supply adenosine triphosphate (ATP) for ciliary beating**.**

Cilliary movements

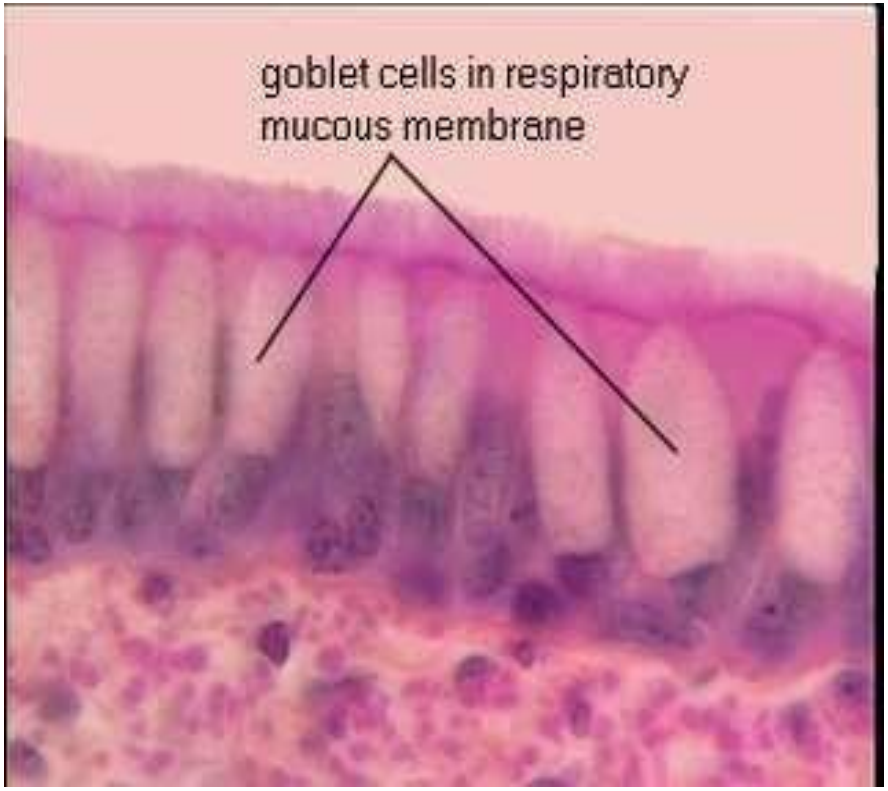
- **Dynein,** a protein normally participates in the unidirectional ciliary movement (towards the outside)
- **Nicotin** prevents formation of dynein, which leads to improper movement of cilia.
- **Immotile cilia syndrome** (**Kartagner syndrome) (any infection becomes chronic)**
- caused by immobility of cilia and flagella
- induced, in some cases, by deficiency of **dynein**
- causes infertility in men (tails of sperms become immotile) and chronic respiratory tract infections in both sexes



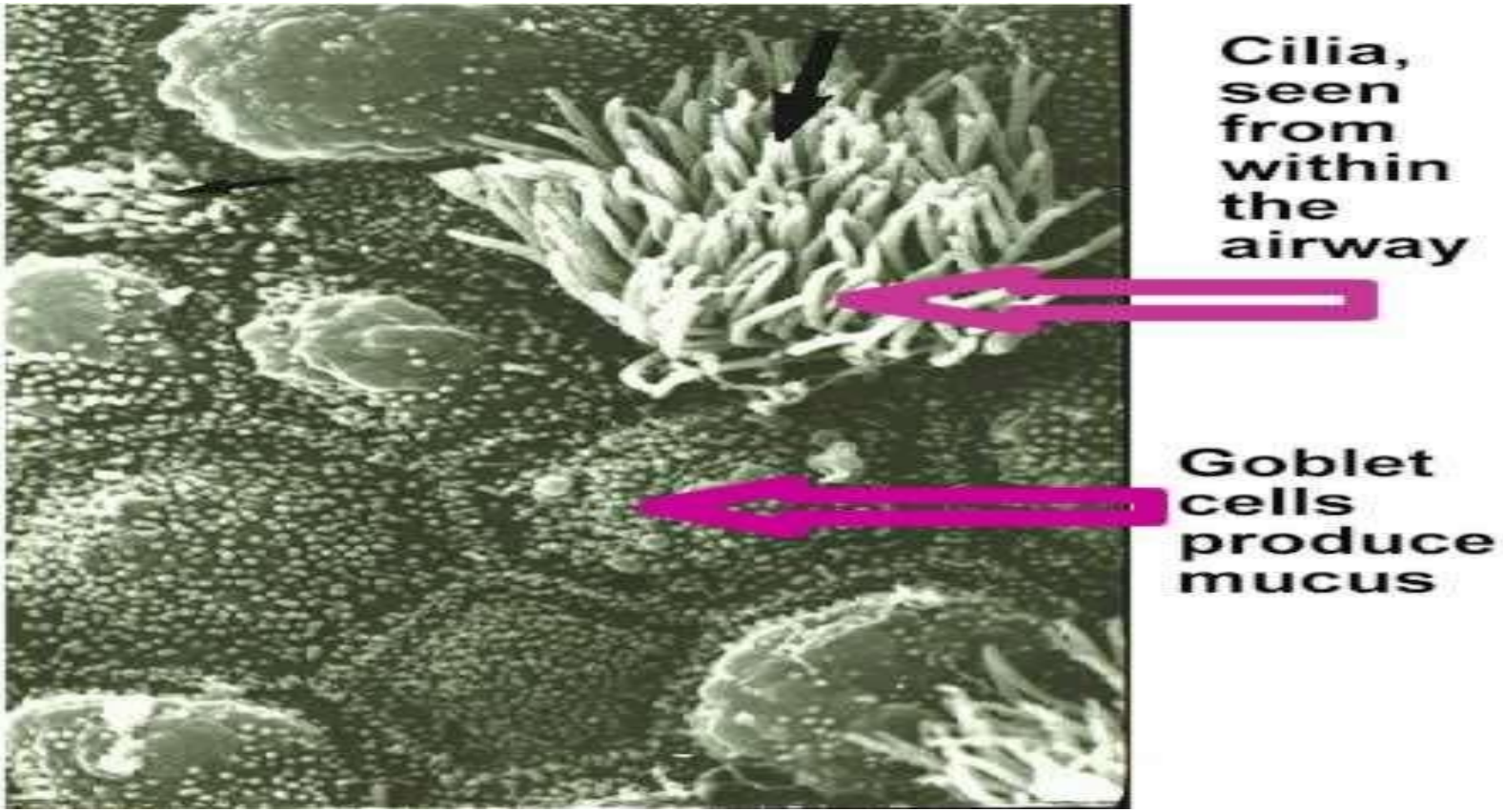
Mucous goblet cells

Apical mucous droplets to trap foreign bodies

Composed of **glycoproteins** and contains **polysaccharides.**

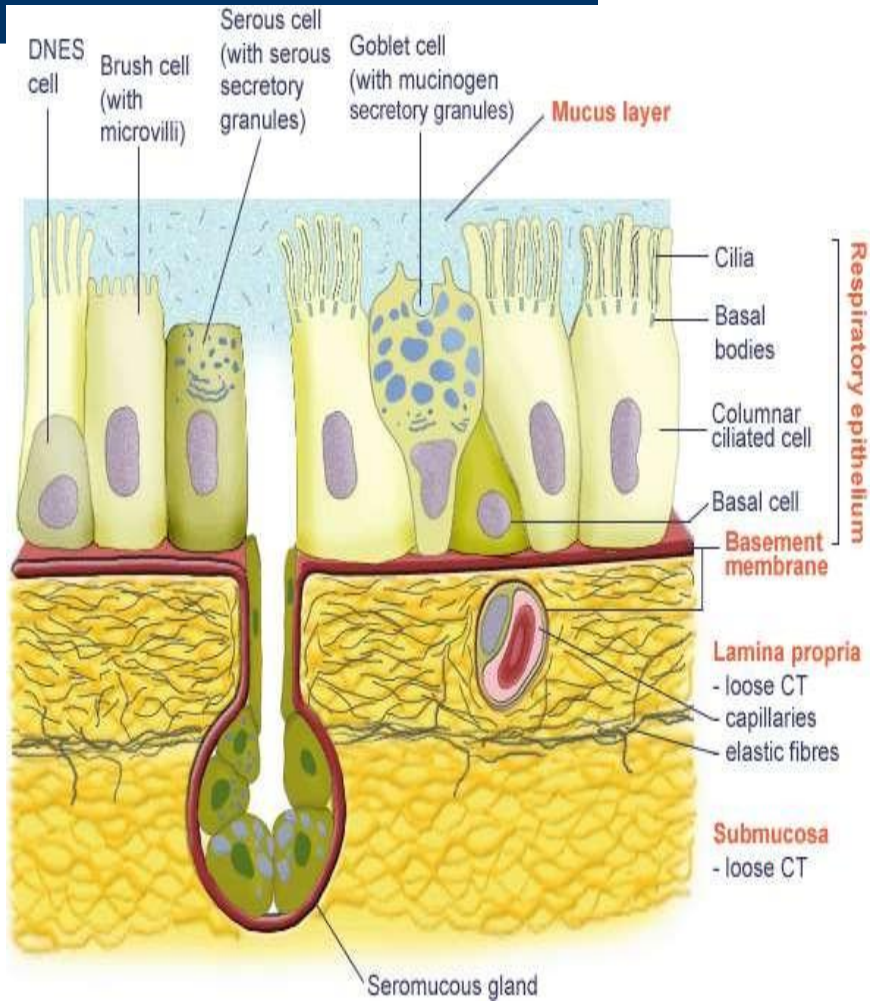


Respiratory epithelium



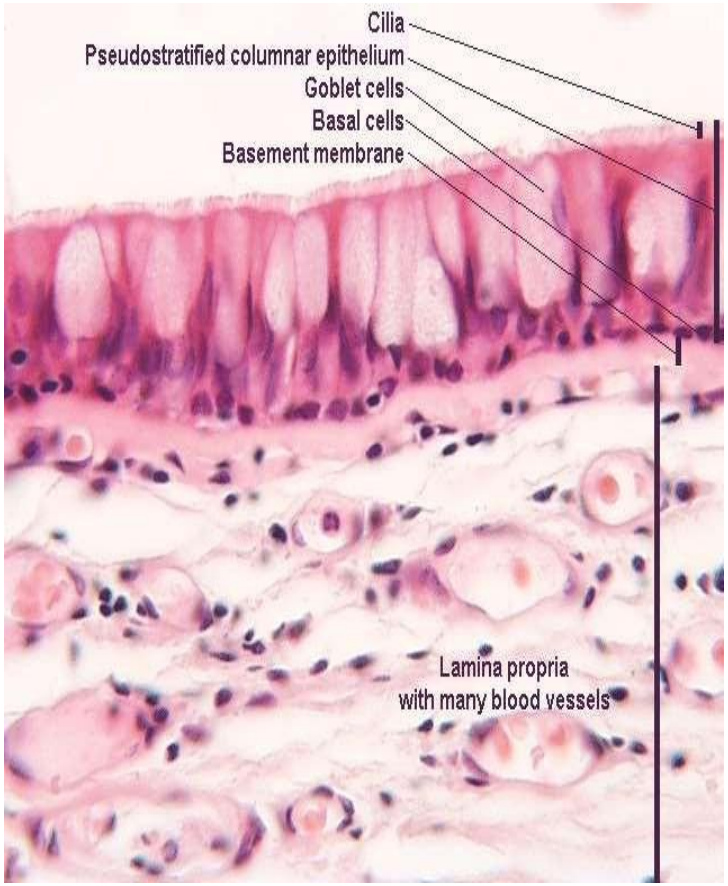
Brush cells

- Numerous microvilli on their apical surface
- Sensory receptors (afferent nerve endings on their basal surfaces)



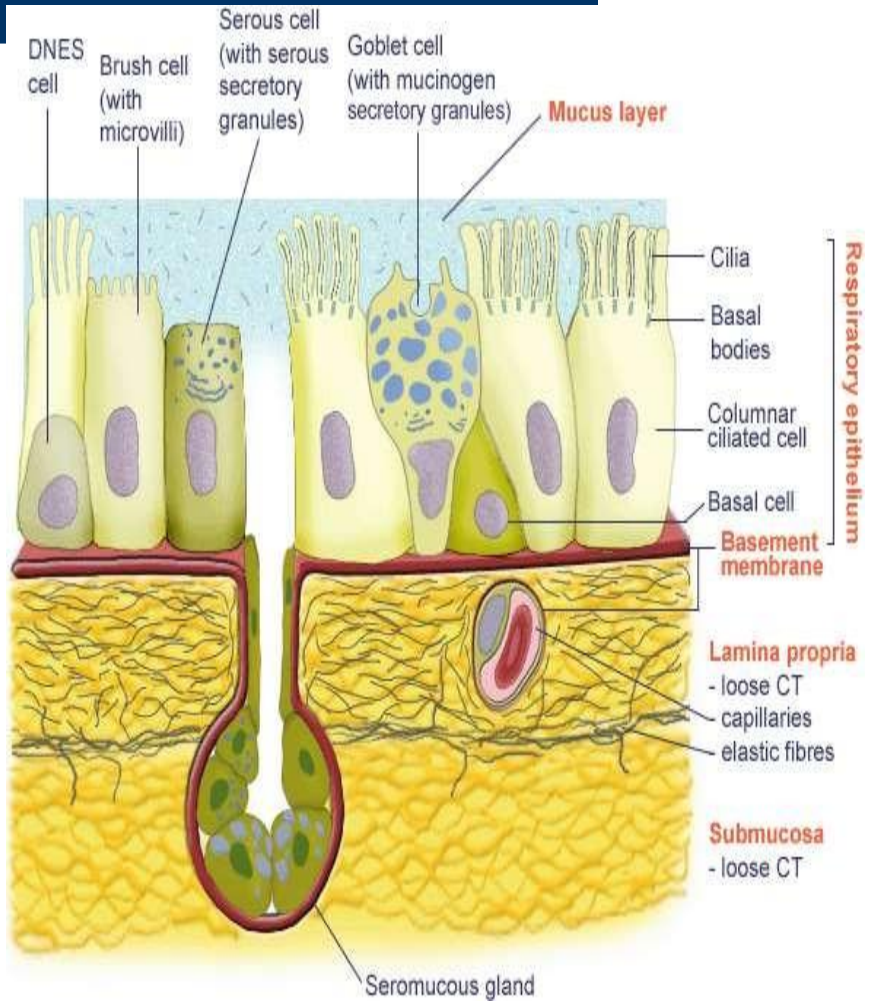
Basal (short) cells

- Small rounded cells
- Believed to be mitotic generative stem cells
- Differentiate into the other cell types (**reserve cells**)



Small granule cell

- Cells of the **DNES** (diffuse neuroendocrine system)
- Regulates locally the excretions or secretions of mucous and serous glands in the respiratory tract
- Also called **Kulchitsky Cells**



Layers of the respiratory tube

- 1. **Mucosa :**

  a. ***epithelium*** resting on a thick basment membrane and goblet cells

  b. lamina propria

  c. muscularis mucosa (smooth muscle)

2. **Submucosa:** that houses mucous and seromucous glands unlike the GI as we said in slide 12

Layers of the respiratory tube

- 3. **Supportive layer**:

  smooth muscle and *cartilage*

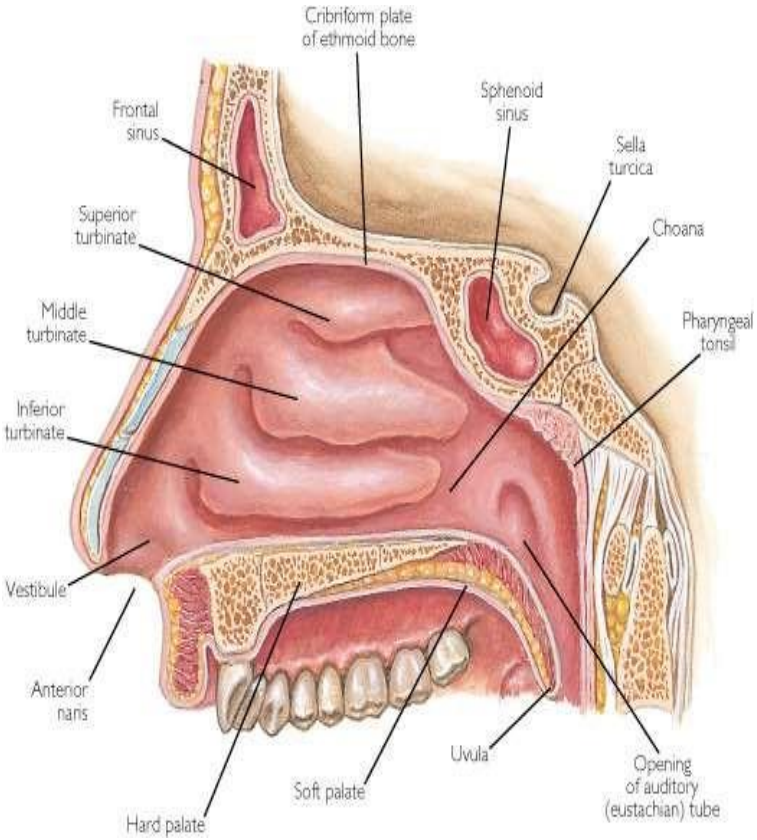
  4. **Adventitia:**

  connective tissue coverings.

Nasal Cavity

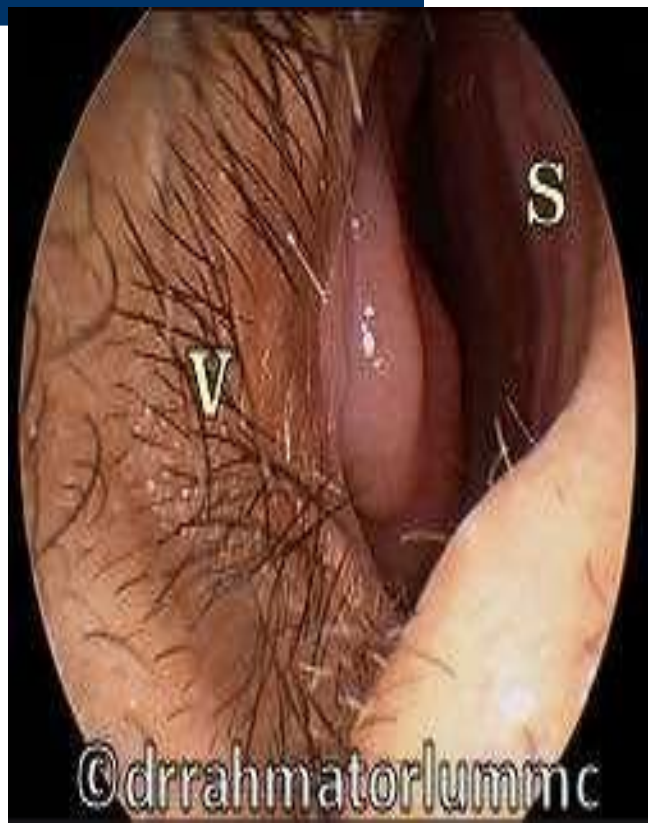
Nasal Cavity

- Subdivided into
- The **vestibule** **(anterior part)**
- The **respiratory area** **(lateral +medial/septal walls)**
- **Olfactory region** **in the roof, above the superior concha**



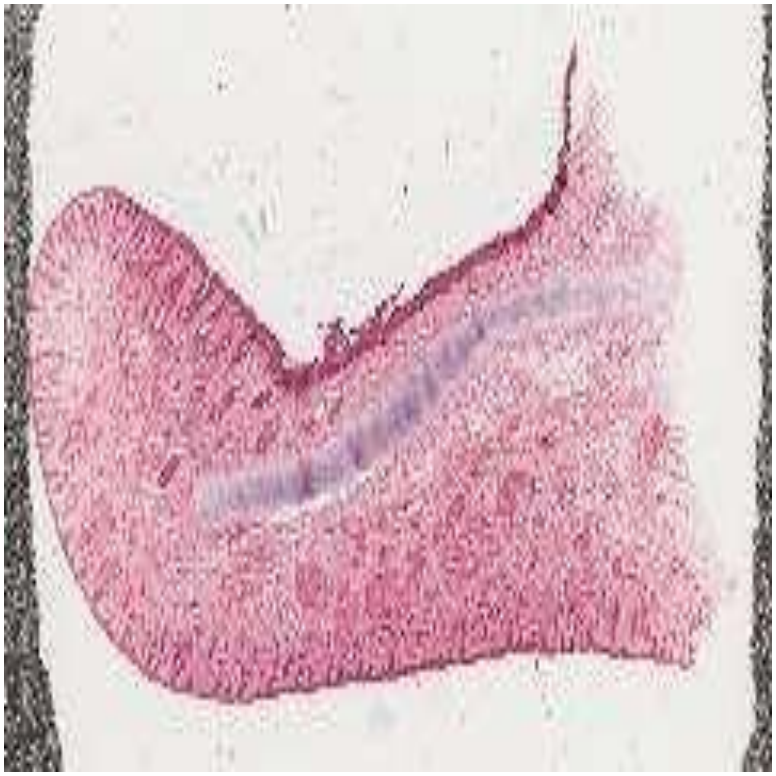
The vestibule

- Most anterior and dilated portion of the nasal cavity
- Lined by skin
- Contains sebaceous and sweat gland
- Thick short hairs, or **vibrissae**
- Trap and filters out large particles from the inspired air



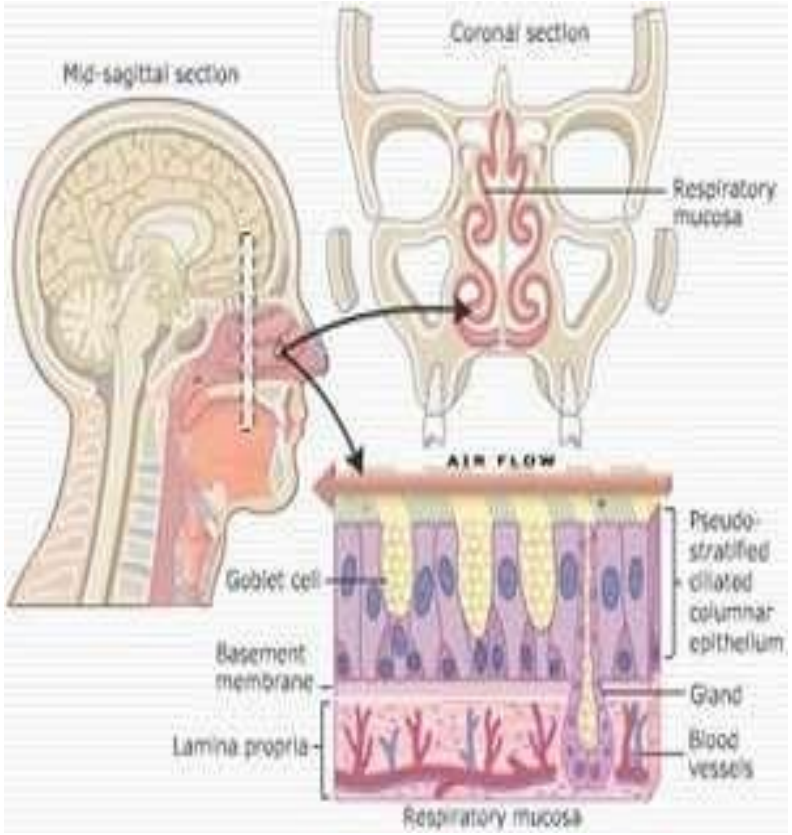
The vestibule

- Epithelium loses its keratinized nature and undergoes a **transition** into typical respiratory epithelium **before** entering the nasal fossae



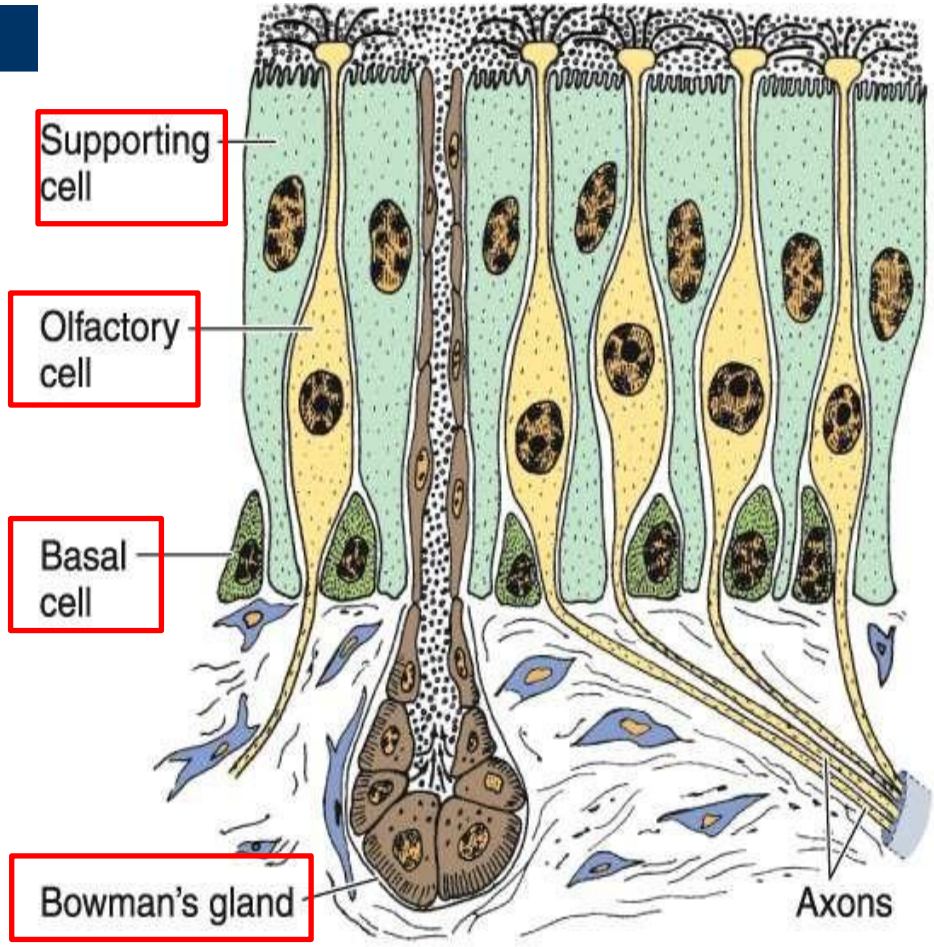
The respiratory area

- Covered with pseudo-stratified columnar and goblet cells
- The sub. Epithelial connective tissue is rich with blood vessels and seromucous glands.



Olfactory region

- Present in the roof and upper parts of the nasal cavity
- Covered by **olfactory mucosa**
- Which contains:
- **Olfactory epithelium**
- **Corium (lamina propria)**
- **Bowman's gland which produces secretions to dissolve material on the surface.**



Olfactory epithelium

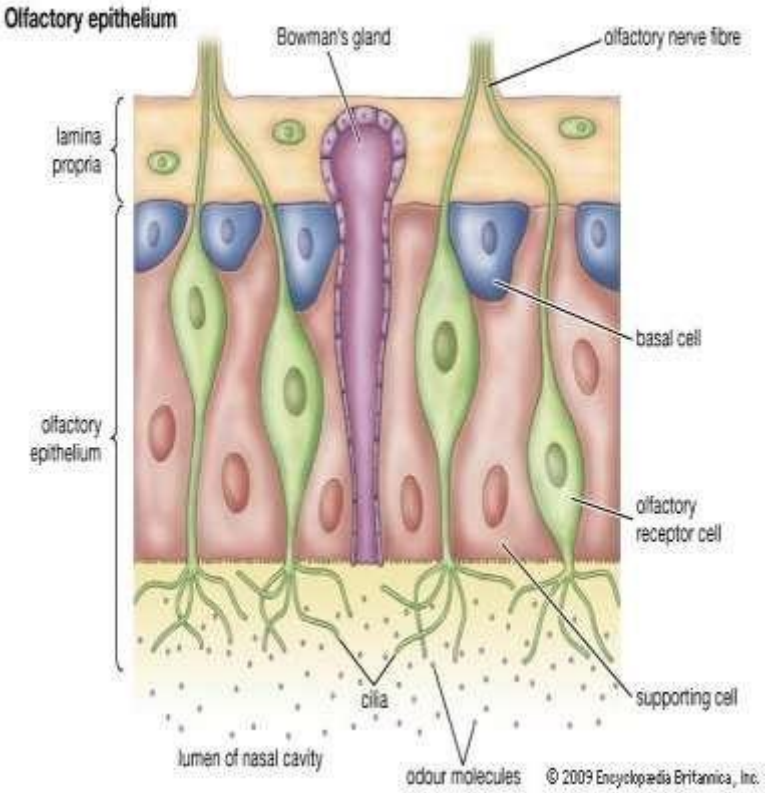
- It is a pseudostratified columnar epithelium composed of three types of cells:

1. supporting (sustinacular) columnar cells

- broad, cylindrical apexes and narrower bases
- microvilli submerged in a fluid layer
- contain a light yellow pigment

2. basal cells : single layer at the base of the epithelium

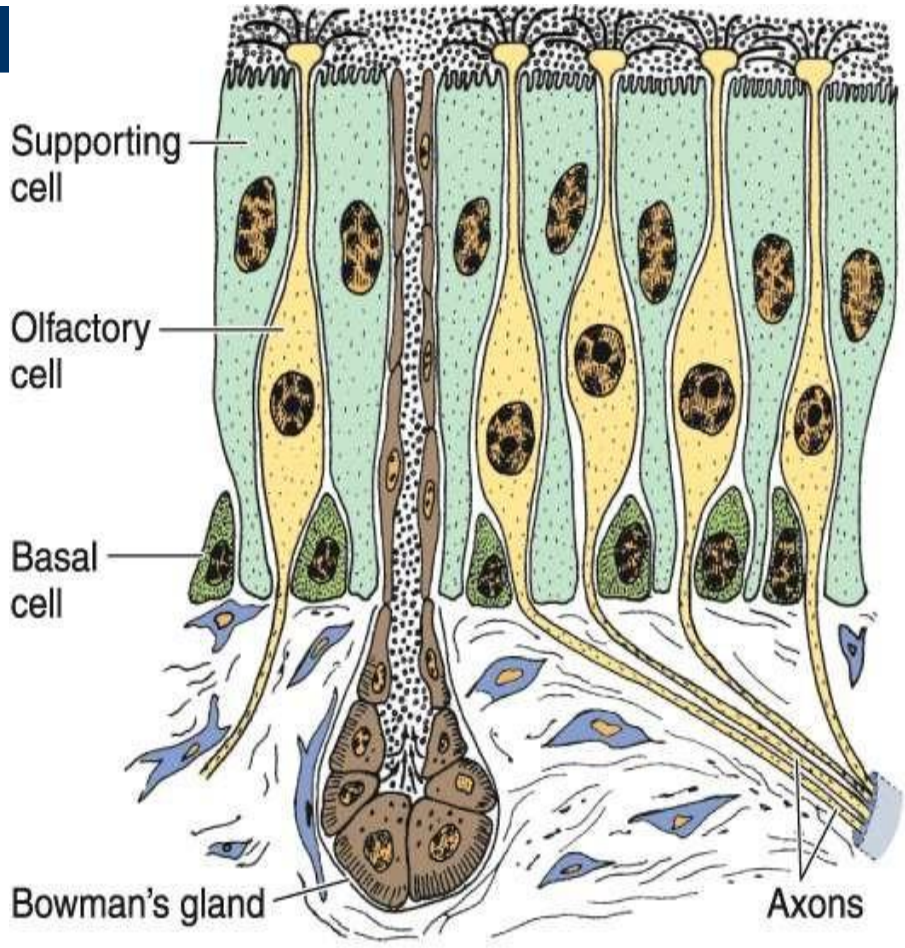
- spherical or cone shaped



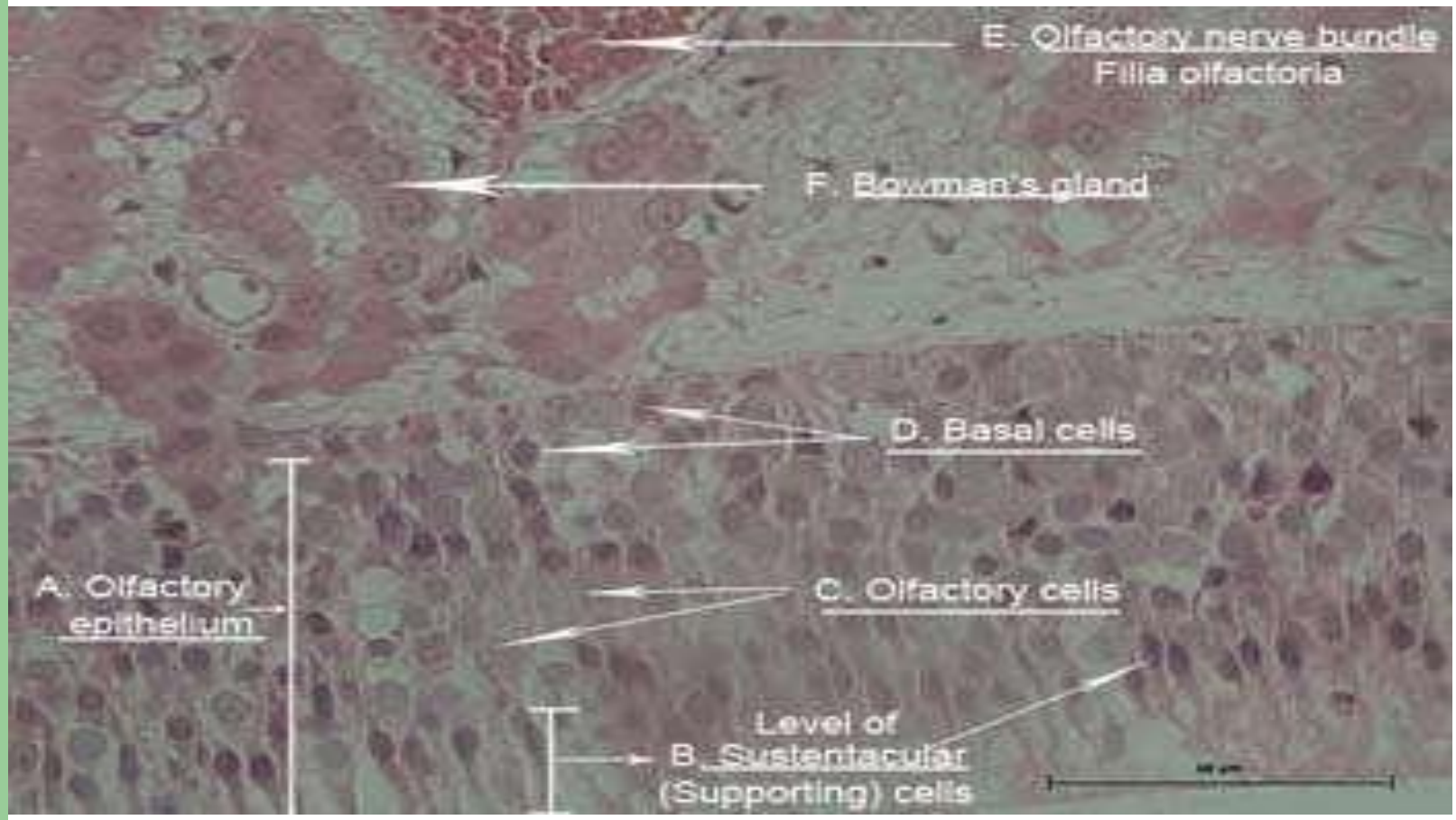
Olfactory epithelium

3. **olfactory cells**: bipolar neurons

- Their nuclei lie below the nuclei of the supporting cells
- From one pole, cilia (nonmotile) rise from their apexes (dendrites)
- Respond to odoriferous substances by generating a receptor potential (neural impulse)
- From the other pole, afferent axons/olfactory filaments of these bipolar neurons unite in small bundles, and synapse with the olfactory lobe.



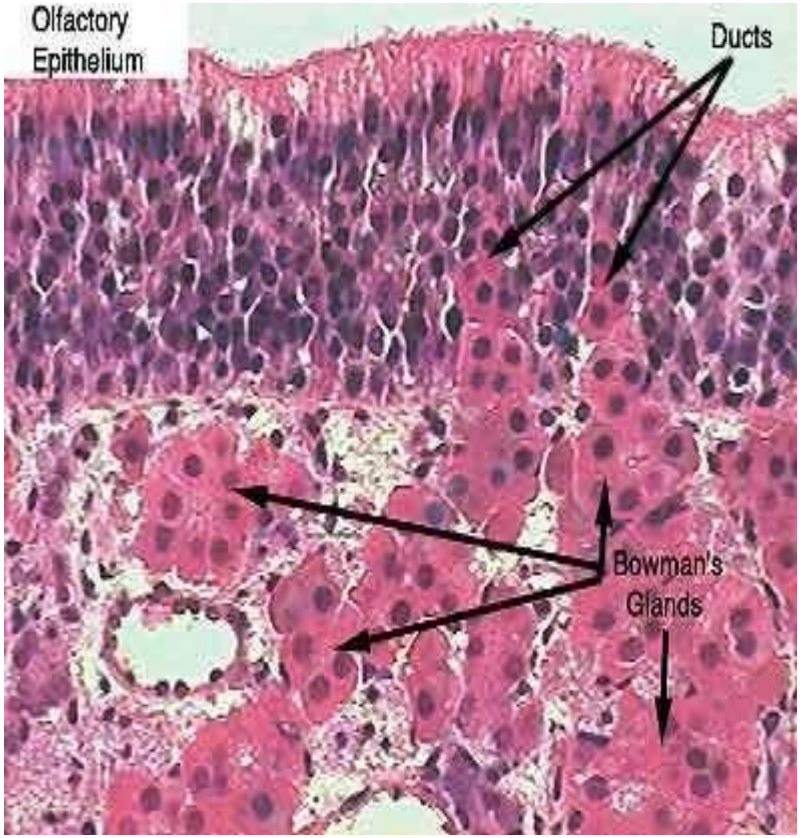
Olfactory epithelium



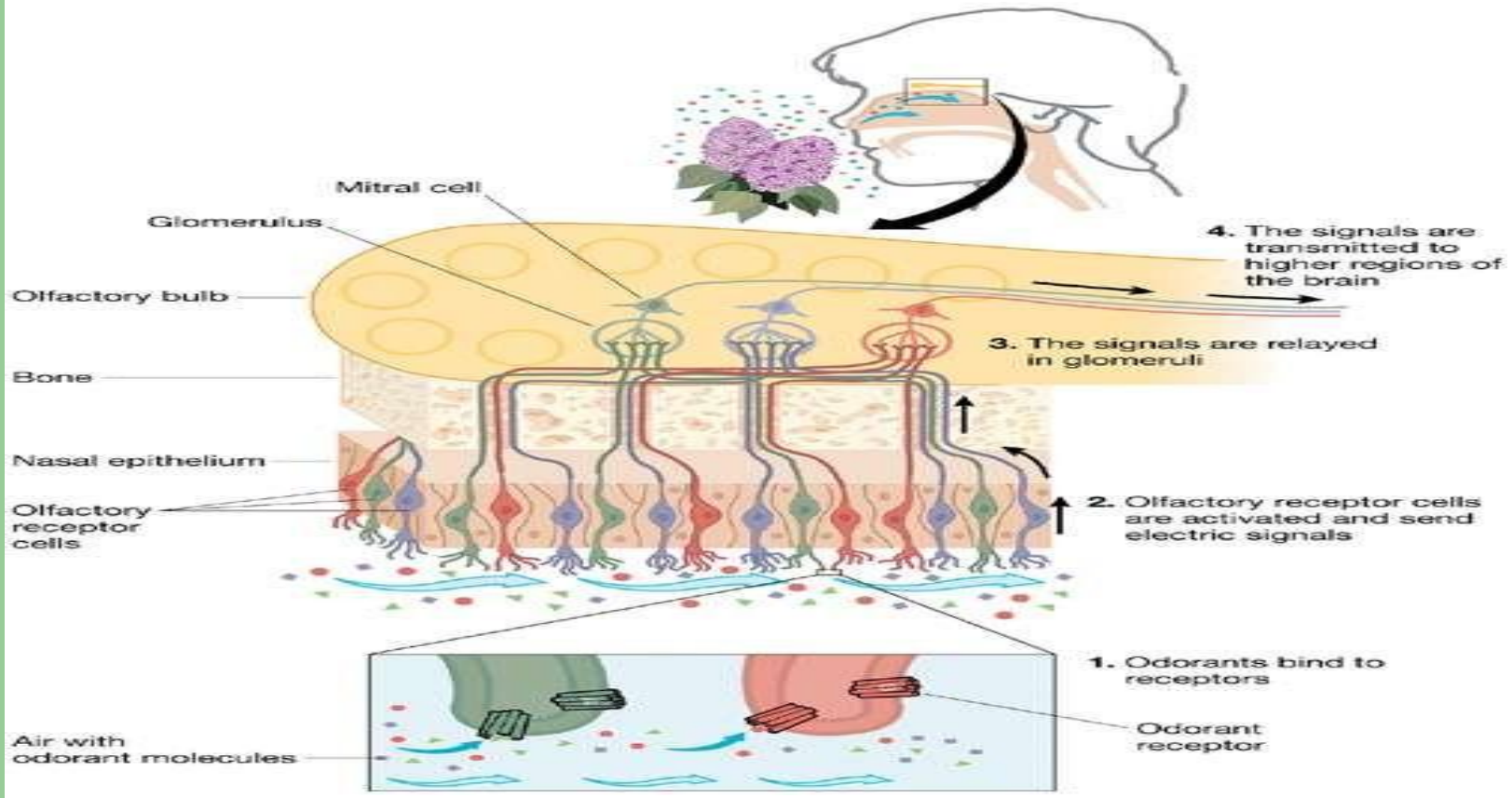
Olfactory cells

lamina propria

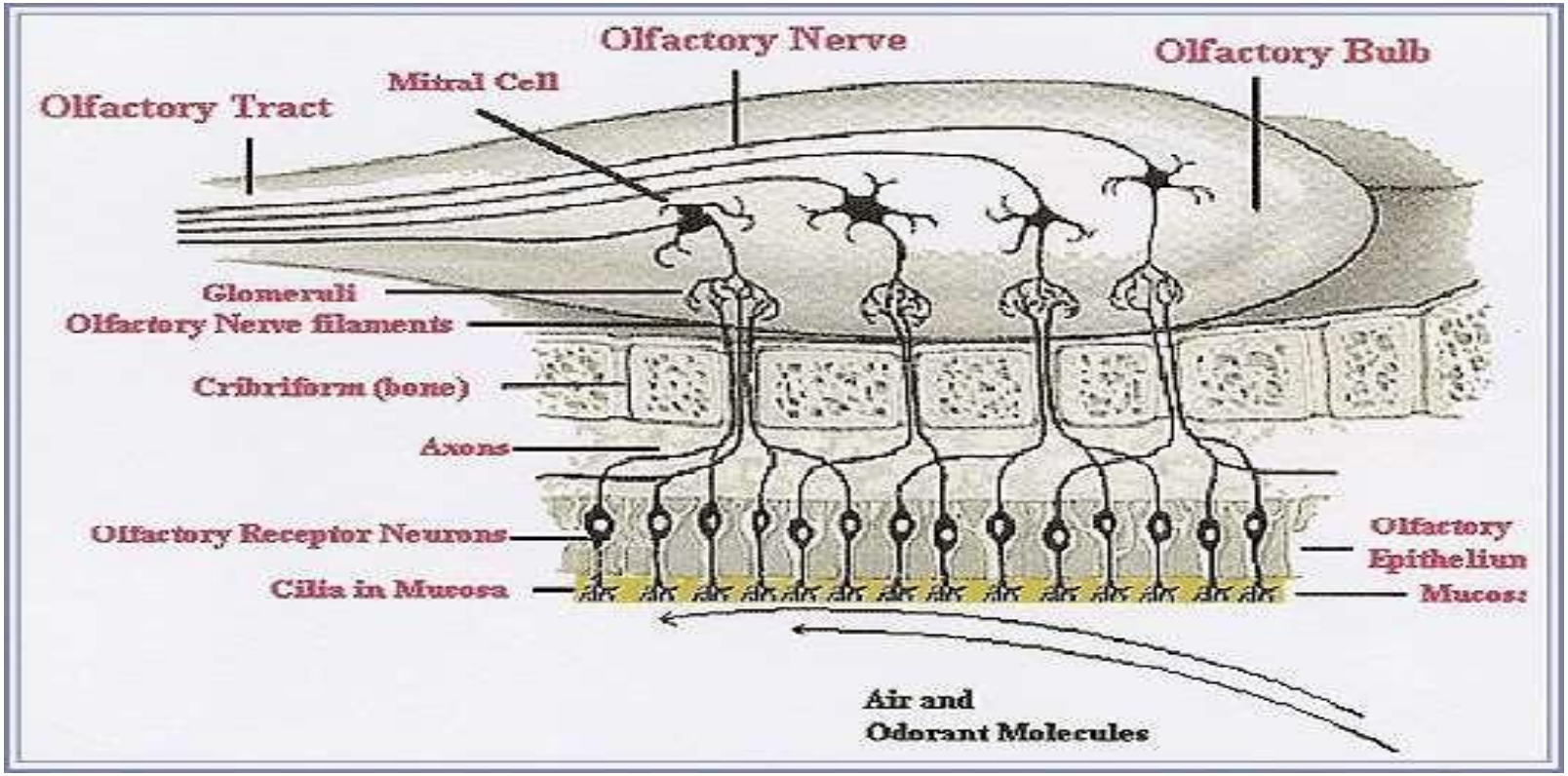
- **Corium** (lamina propria) is rich in blood vessles.
- Contains **Bowman's gland** that secrets watery mucous
- Facilitating the access of new odoriferous substances.



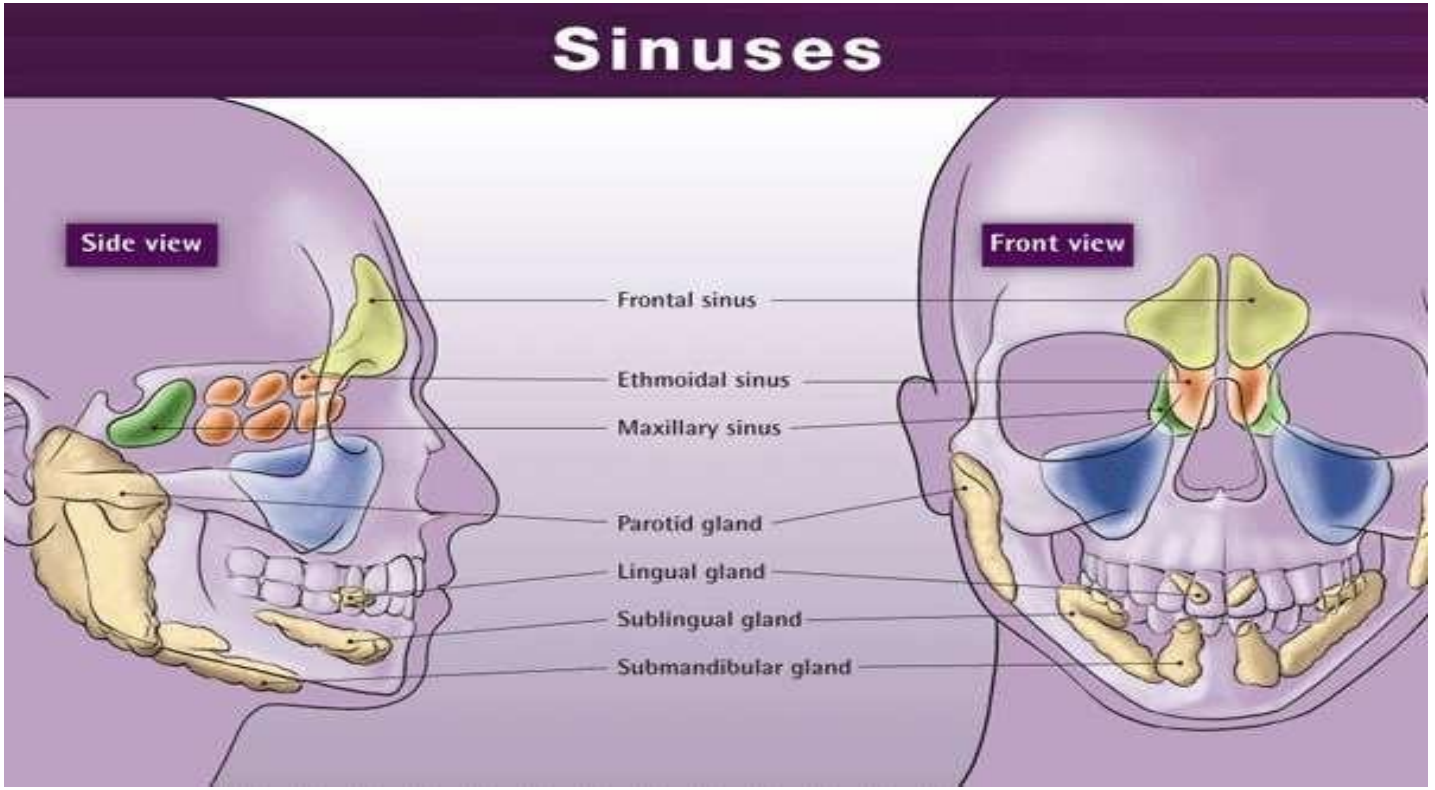
Olfaction


Mitral cell
Glomerulus
Olfactory bulb
Bone
Nasal epithelium
Olfactory receptor cells
Air with odorant molecules
4. The signals are transmitted to higher regions of the brain
3. The signals are relayed in glomeruli
2. Olfactory receptor cells are activated and send electric signals
1. Odorants bind to receptors
Odorant receptor

Olfaction

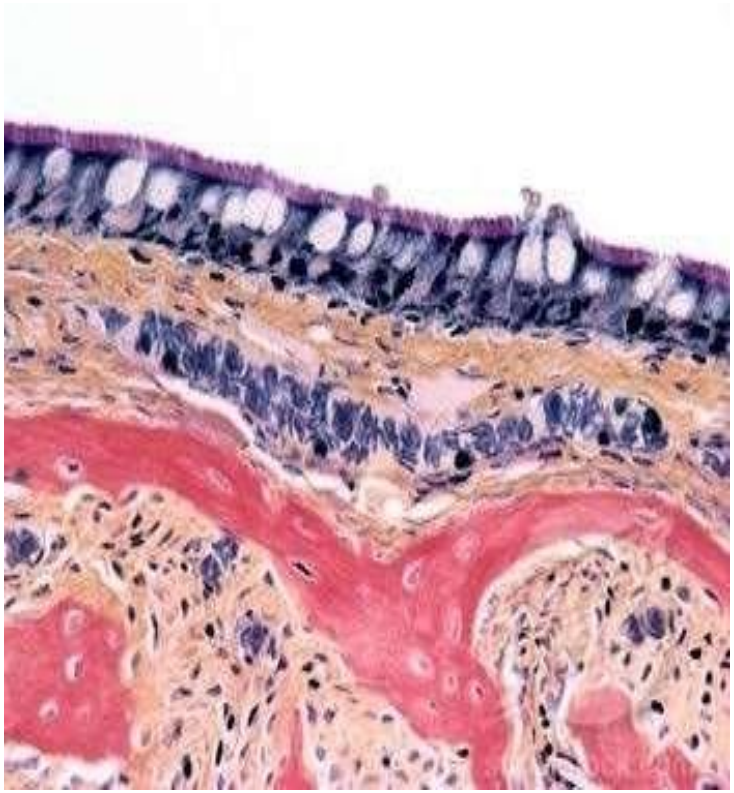

Olfactory Nerve
Olfactory Bulb
Mitral Cell
Olfactory Tract
Glomeruli
Olfactory Nerve filaments
Cribriform (bone)
Axons
Olfactory Receptor Neurons
Olfactory Epithelium
Cilia in Mucosa
Mucos
Air and
Odorant Molecules

Nasal Sinuses



Nasal Sinuses

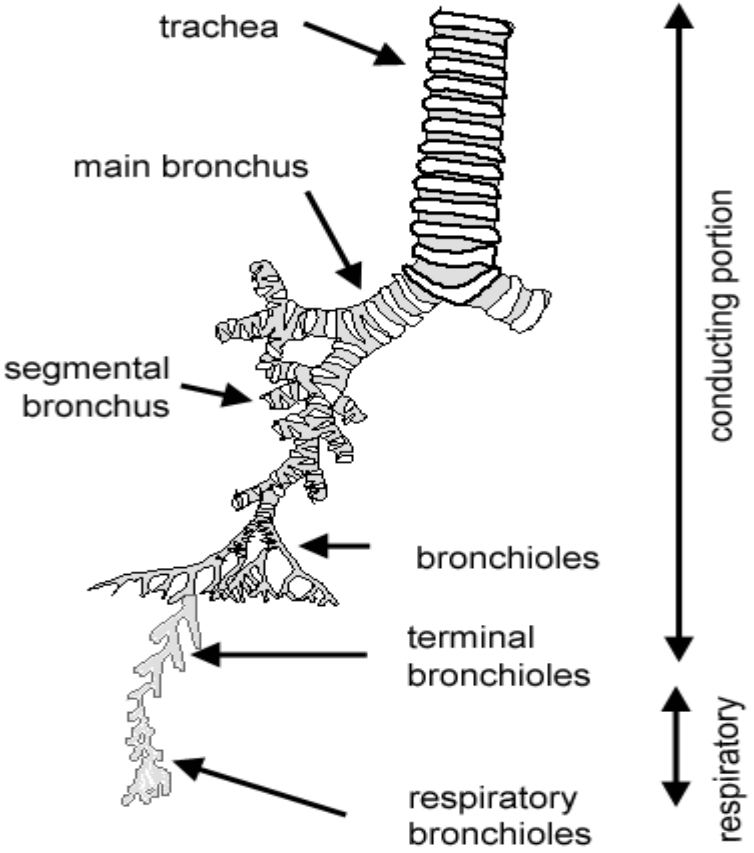
- lined with a thinner respiratory epithelium
- Contains few goblet cells
- The lamina propria contains only a few small glands
- Continuous with the underlying periosteum



The Bronchial Tree

Structural changes in the bronchial tree

- The trachea extends from the level of C6 to T4 (bifurcation point) (can reach T6 with deep inspiration)
- Trachea branches into main bronchi and then terminal and respiratory bronchioles, each having distinct histology.
- Only The trachea and the 1ry (main) bronchus are extra-pulmonary
- We have **three** lobar(2ndry) bronchus in the right and **two** in the left lung



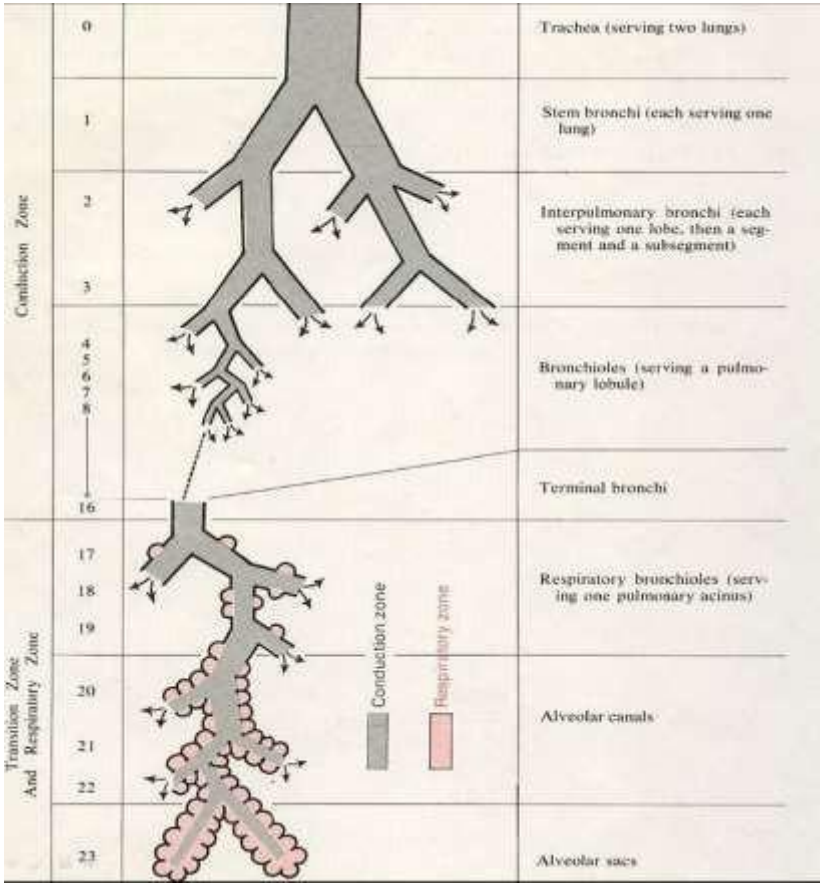
Doctor's Notes:

- Regarding structure of bronchi (primary, secondary and tertiary), all have cartilage.
- However, in primary bronchi, it is present as circular pieces surrounding the lumen.
- In secondary bronchi (inside the lungs now), we have cartilage but less than the primary bronchi, and they are present as diffuse pieces.
- In tertiary bronchi, we have cartilage as well but they are present diffusely in much less amounts than the secondary bronchi.

- We usually have 10 tertiary bronchi in each lung, called bronchopulmonary segments. This is important clinically as, nowadays, segments are removed (segmentectomy) rather than lobes (lobectomy).

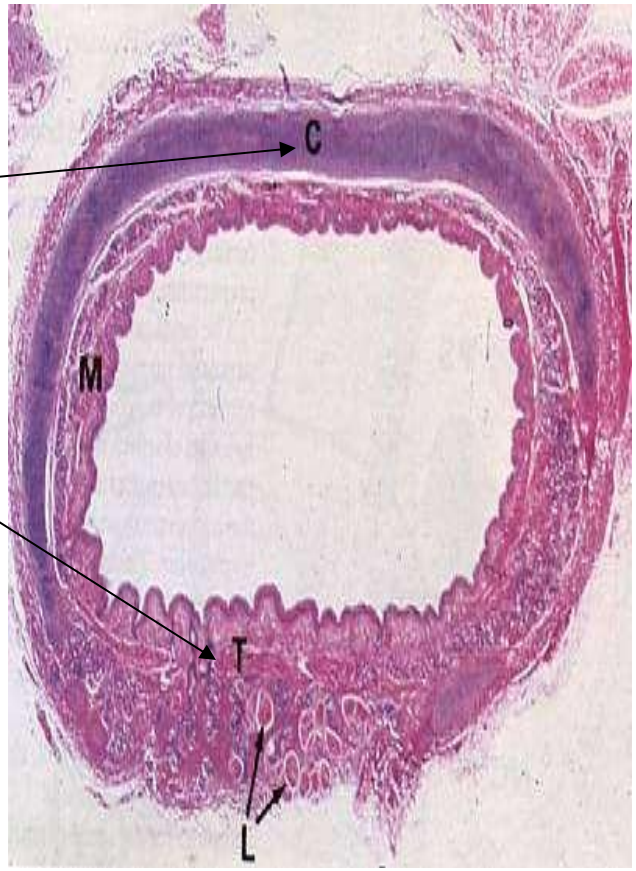
Structural changes in the bronchial tree

- Segmental (tertiary) bronchus is almost 5mm or less in diameter
- Each bronchiole enters a pulmonary lobule
- Each large bronchiole (1 mm) gives 5-7 terminal ones
- Terminal bronchioles (0.5 mm) contain **clara cells** (no cilia) and **neuroepithelial bodies** (chemoreceptor)



Trachea

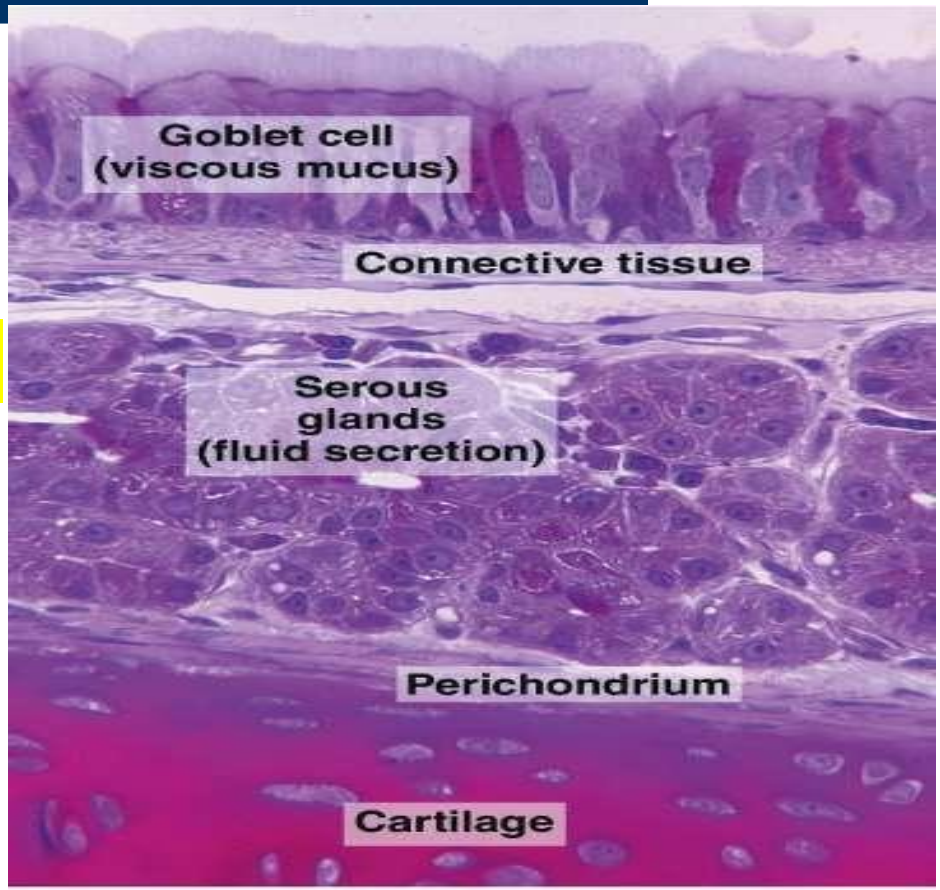
- lined with a typical respiratory mucosa
- **C**-shaped rings of hyaline cartilage that keep the tracheal lumen open (in the lamina propria)
- Fibroelastic ligament and bundle of smooth muscle **(Trachealis)** bind to the perichondrium and close the rings **posteriorly**
- Some longitudinal muscles may be found behind the trachealis



Trachea

- Numerous seromucous glands in the submucosa that produce a more fluid mucus

- Contain the same 5 types of cells in the mucosa



Trachea

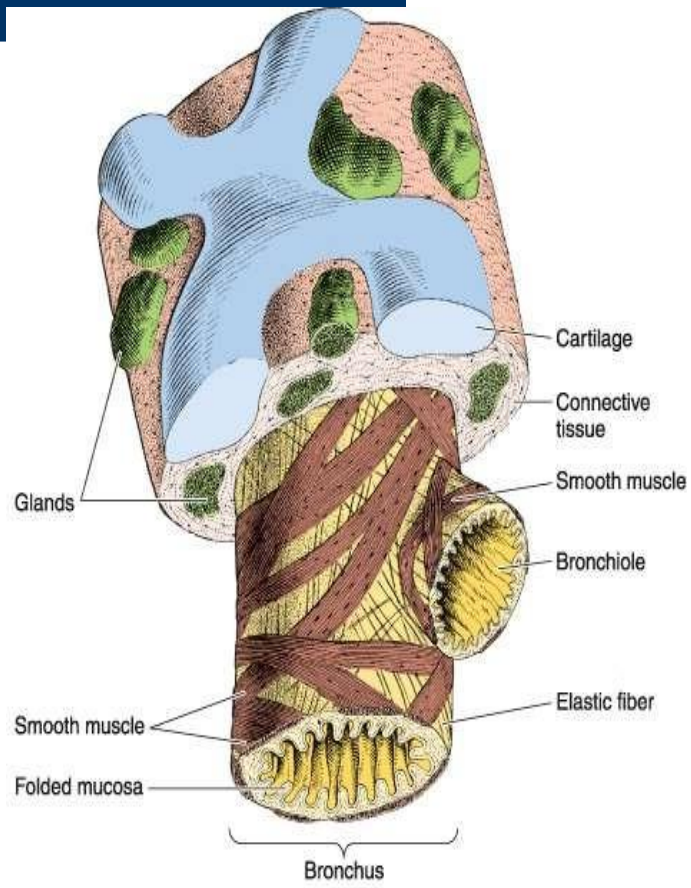
- The ligament prevents overdistention of the lumen
- The muscle allows regulation of the lumen
- Contraction of the Trachealis muscle and the resultant narrowing of the tracheal lumen are involved in the **cough reflex**

Bronchi

- Divided into:

- **Extrapulmonary (primary bronchus) (more cartilage) :**
- Resembles trachea in structure

- **Intrapulmonary (2ndry and tertiary) :**
- They have complete circular muscular layer
- Cartilaginous plates instead of rings



Doctor's Notes:

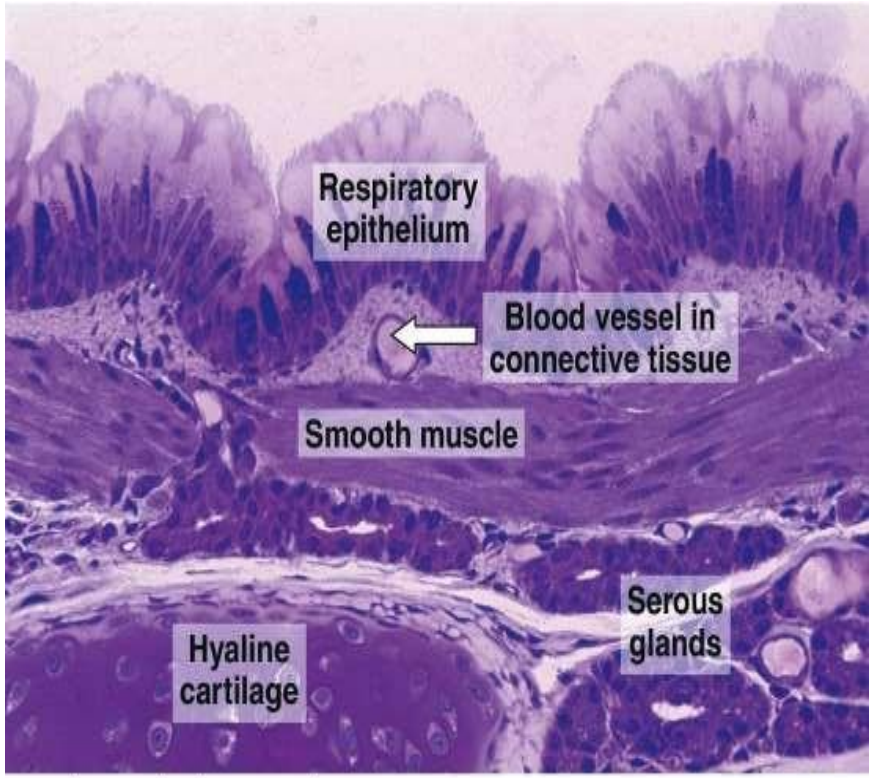
- The further distal we go in bronchi, we have:

1. Less cartilage
2. Less goblet cells
3. More smooth muscles

- When cartilage is completely absent and smooth muscles are abundant, we reach the bronchioles (where we have asthma. No asthma in all bronchi since we have cartilage). (IMPORTANT)

Differnces between the trachea and bronchi

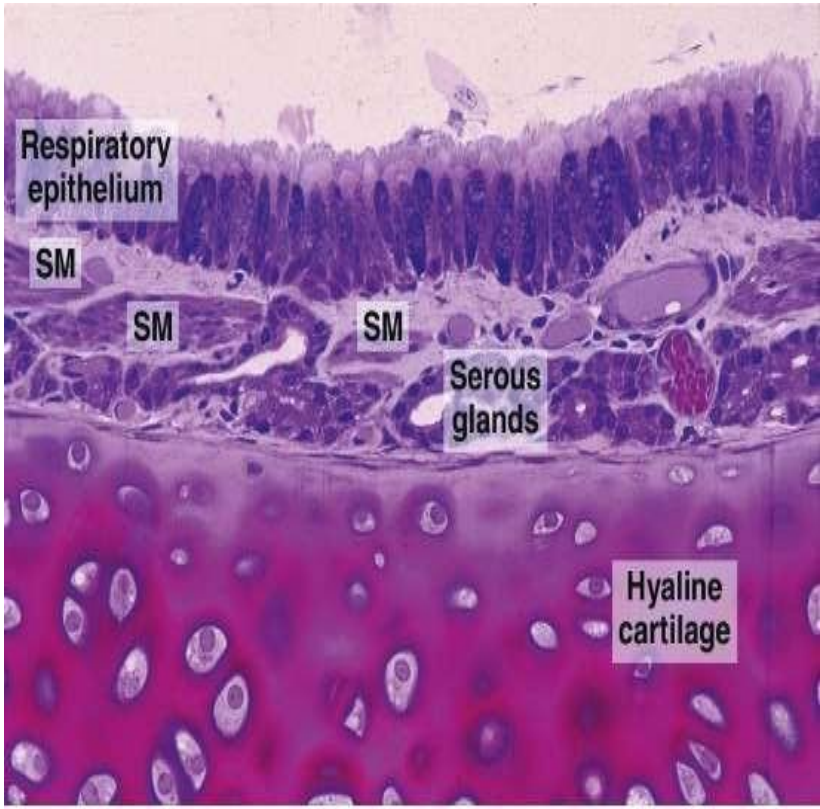
- 1. narrower lumen (small bronchus 5mm or less)
- 2. irregular bronchial cartilage Plates/pieces
- 3. smooth muscle layer consisting of **spirally arranged bundles** between the lamina p. and submucosa
- Contraction of this muscle layer is responsible for the folded appearance of the bronchial mucosa



Differnces between the trachea and bronchi

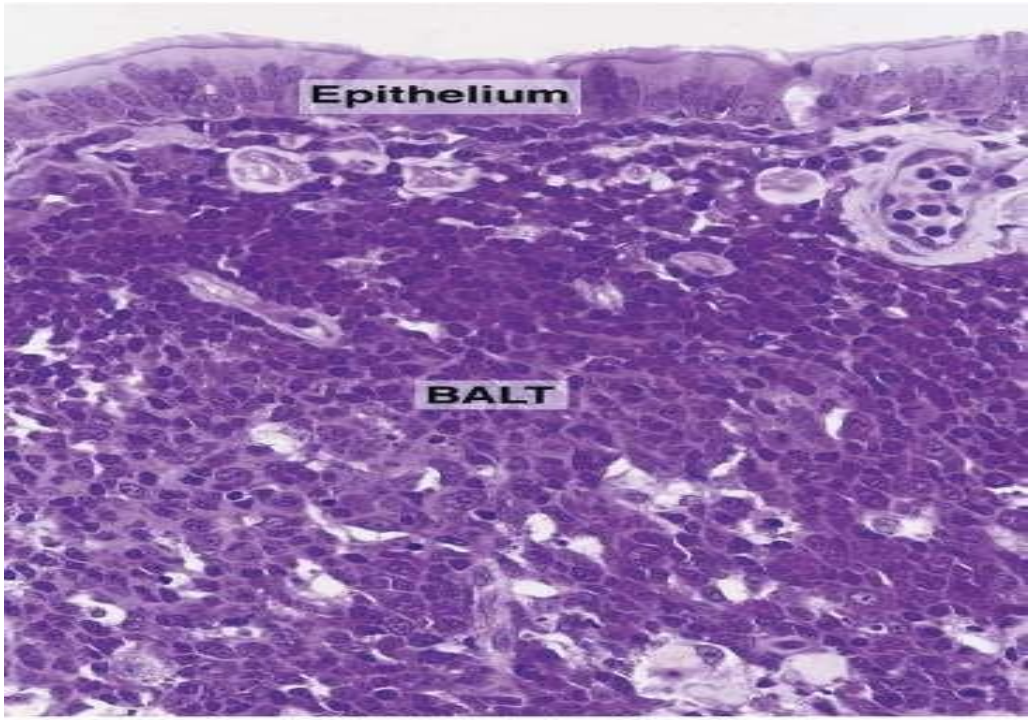
- 4. lamina propria is rich in elastic fibers and contains an abundance of mucous and serous glands

- 5. respiratory epithelium with fewer goblet cells



Differnces between the trachea and bronchi

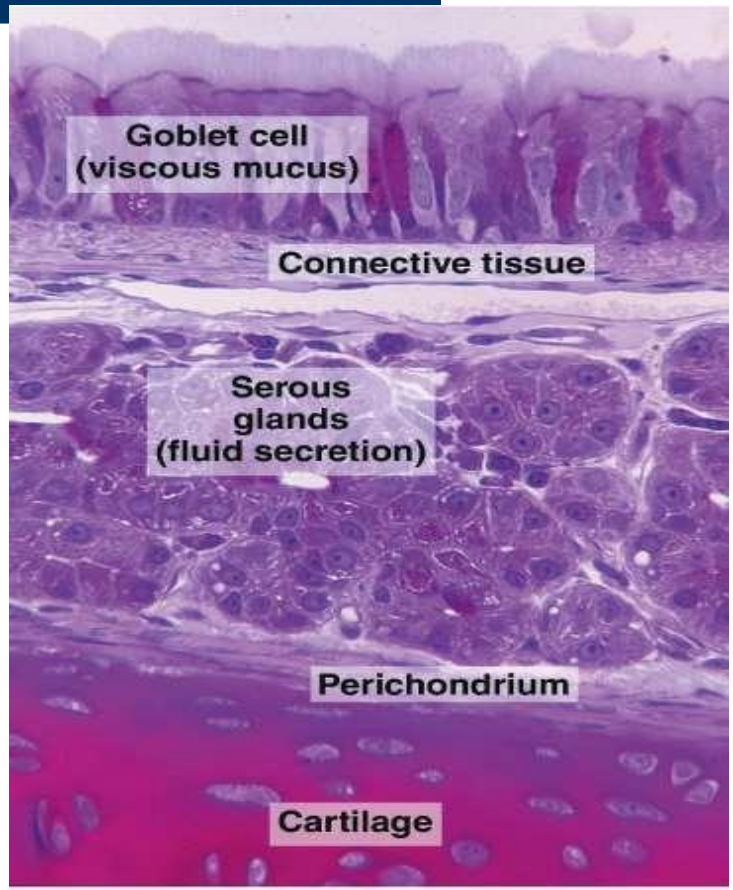
- 6. Numerous lymphocytes and Lymphatic nodules (BALT) are present (infiltrated by the adventitia)
- Note, however, that lymphocytes are present all along the RT.



Structural changes in the conducting portion of the respiratory tract

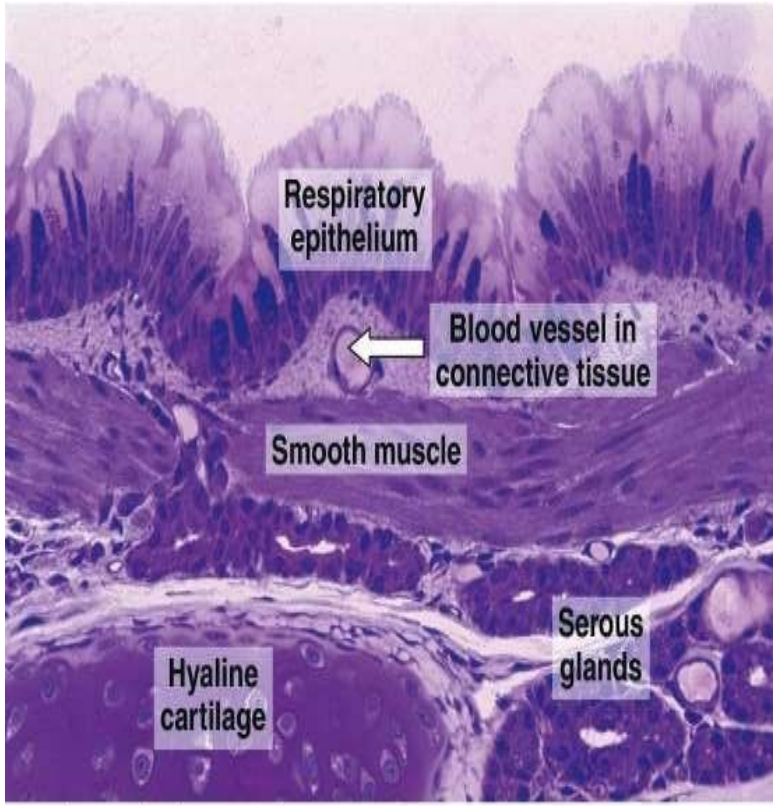
Extra-pulmonary bronchi (no lung tissue under microscope)

- **Pseudostratified ciliated columnar epithelium with goblet cells.**
- Prominent basement membrane.
- Relatively thin lamina propria (elastic layer at base)
- Submucosa with **seromucous glands**
- "C" shaped hyaline **cartilage rings** w/ smooth muscle between ends of cartilage



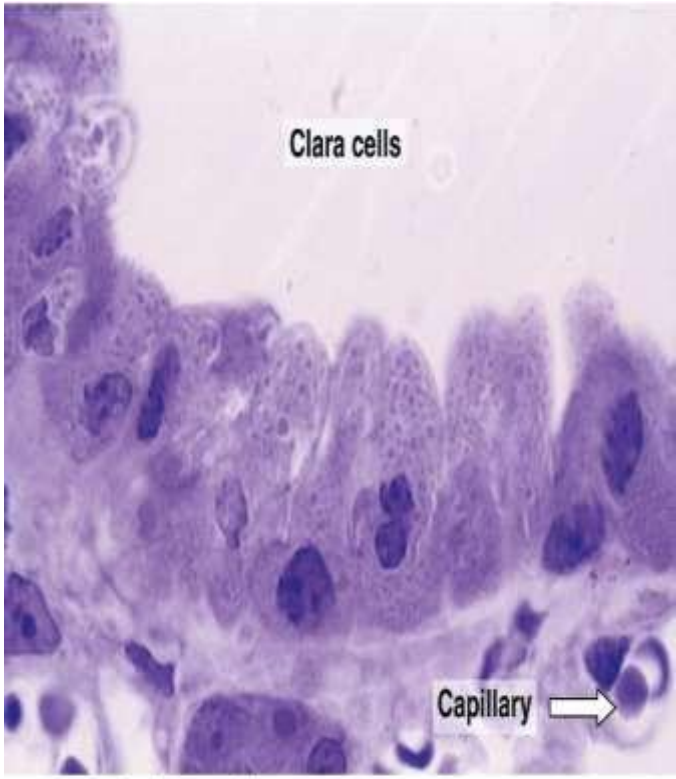
Intrapulmonary bronchi (we find lung tissue under microscope)

- **Pseudostratified ciliated columnar** changing to **ciliated simple columnar** in smaller branches. **Goblet cells** at all levels.
- Below lamina propria are interlacing **spirals** of **smooth muscle**
- Seromucous glands decrease as bronchi get smaller.
- **Plates of cartilage** gradually disappear



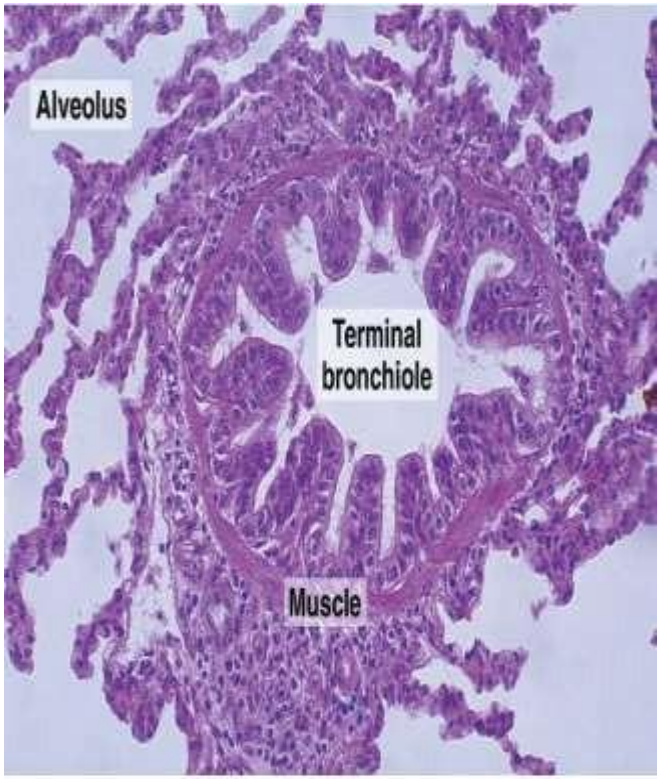
Bronchioles (1 mm or less)

- **Ciliated columnar to ciliated cuboidal**
- **Goblet cells decrease and Clara cells** appear
- Spirals of **smooth muscle** relatively heavier (more abundant) than elsewhere (gradually decrease in amount)
- **No** seromucous glands
- **No** cartilage (important difference from bronchi)



Respiratory bronchioles (respiratory= simple squamous epithelium + no cartilage + no goblet cells + no glands. We see alveoli under the microscope)

- **Cuboidal epithelium with some cilia**. Clara cells and **no goblet cells.**
- Thin supporting wall of C.T. and an incomplete layer of smooth muscle.
- **Outpocketings of alveoli**, numbers increase at lower levels.



Bronchioles

- **Clara cells**
- Simple cuboidal cells devoid of cilia, which are hypothesized to play a role in surfactant synthesis
- secrete proteins that protect the bronchiolar lining against oxidative pollutants and inflammation.

Clara cells contain:

- **Neuroepithelial bodies**
- contain secretory granules and receive cholinergic nerve endings
- **chemoreceptors** that react to changes in gas composition within the airway

Elastic Fibers

- Longitudinal elastic fibers are present in all the segments of the bronchial system (in the L.propria)
- The smaller the bronchiole the higher proportions of elastic fibers (highest at the end of RT)
- The more the inflation and deflation, the more elastic fibers we have, including the alveolar septa which also have reticular fibers.

Thank You