Functions of the respiratory system

The respiratory system helps in:

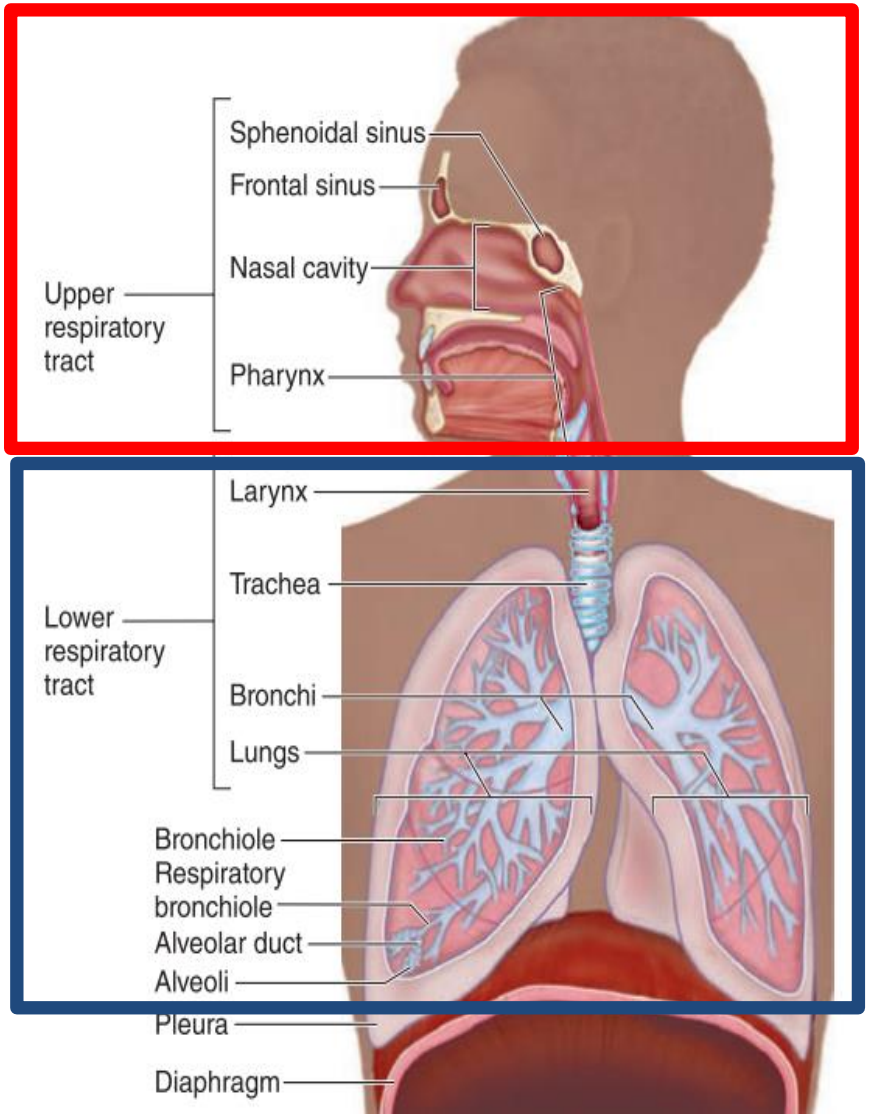
1. **Breathing:** It facilitates the exchange of gases between the air and the blood.
2. **Vibration of the Vocal Cords:** Producing sounds involved in speaking.
3. **Olfaction or Smelling**.
4. **Defence:** Its passages are lined with hair, cilia and mucous to help trap foreign substances.
5. **Regulation:** Regulation of blood pressure (activation of **angiotensin I** to **angiotensin II** by **ACE** in the lung) and the control of blood pH and regulation of water and heat.

Divisions of the respiratory system

The respiratory system divided anatomically into:

1. The upper respiratory tract consists of the parts **outside the chest cavity**: nose, nasal cavities, and pharynx.

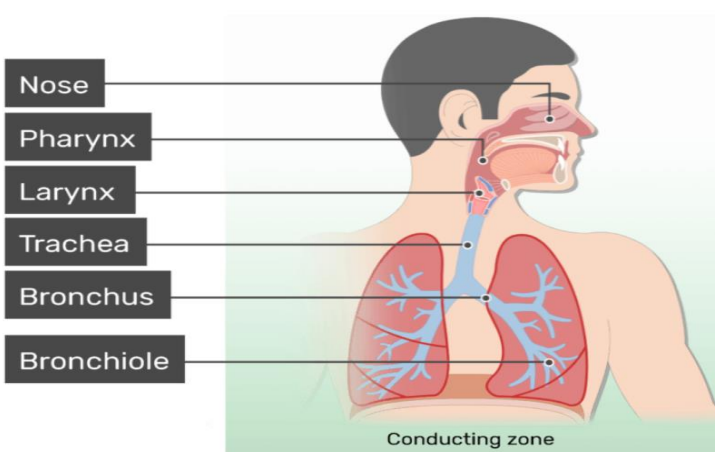
2. The lower respiratory tract consists of the parts found **within the chest cavity**: larynx, trachea and the lungs which include the bronchial tubes and alveoli.

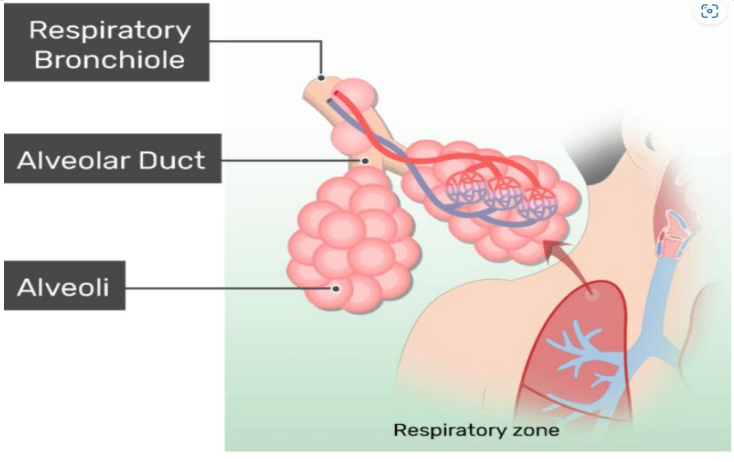


Divisions of the respiratory system

The respiratory system can be divided histologically and functionally into: conducting and respiratory zones

Criteria	Conducting zone	Respiratory zone
Components	Nasal cavities, Nasopharynx, larynx, trachea, bronchi, bronchioles, and terminal bronchioles.	Respiratory bronchioles, alveolar ducts, and alveoli.
Function	1. Conducts air to respiratory zone. 2. Humidifies, warms and filters air from harmful substances.	Exchange of gases between air and blood.



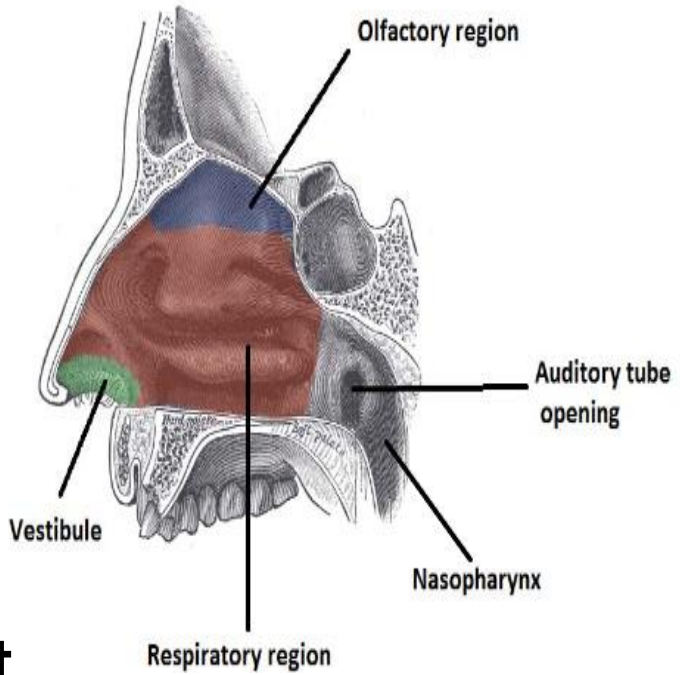


Nasal cavities: 1.The external, dilated vestibule

The left and right nasal cavities each have two parts:

1. The external, dilated vestibule:

Skin of the nose enters the **nares (nostrils)** partway into the vestibule and includes sweat glands, sebaceous glands, and coarse, moist hairs called **vibrissae**, which filter out particulate material from inspired air.



Nasal cavities: 2. The internal nasal cavity

2. The internal nasal cavity.

The nasal cavities lie within the skull as two chambers separated by the **nasal septum**.

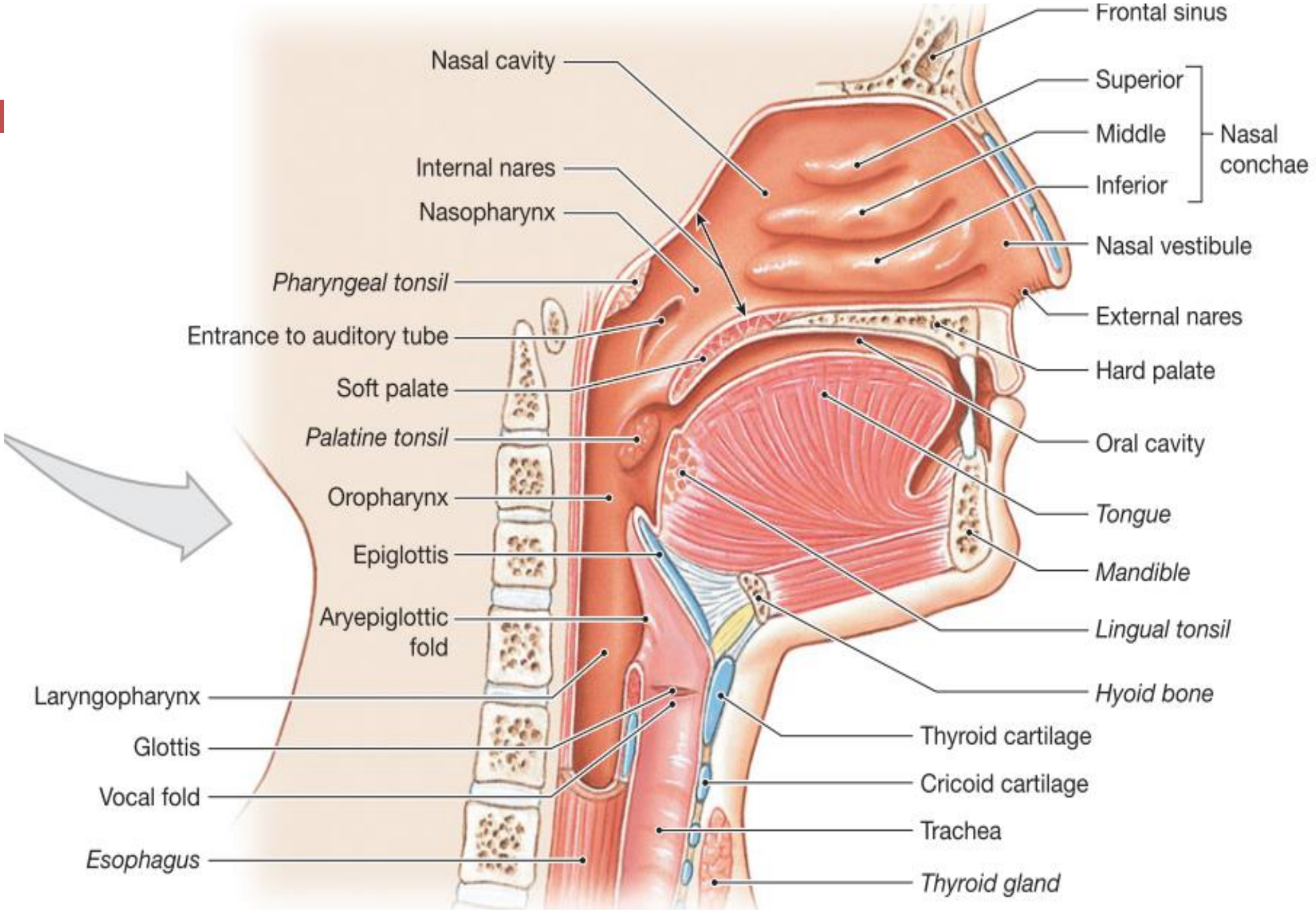
Extending from each lateral wall are three bony shelf-like projections called **conchae**, or **turbinate bones**. **The conchae increase the surface area of the nasal mucosa.**

The nasal cavity walls are covered by **mucosa (mucous membrane)** which consists of:

A. Epithelial layer (middle and inferior conchae is covered by **respiratory epithelium**; the **roof of the nasal cavities and the superior conchae** are covered with **olfactory epithelium)**.

B. Lamina propria is a connective tissue with important roles in conditioning inhaled air. A complex vasculature with loops of capillaries near the epithelial surface carries blood and releases heat to warm that air.

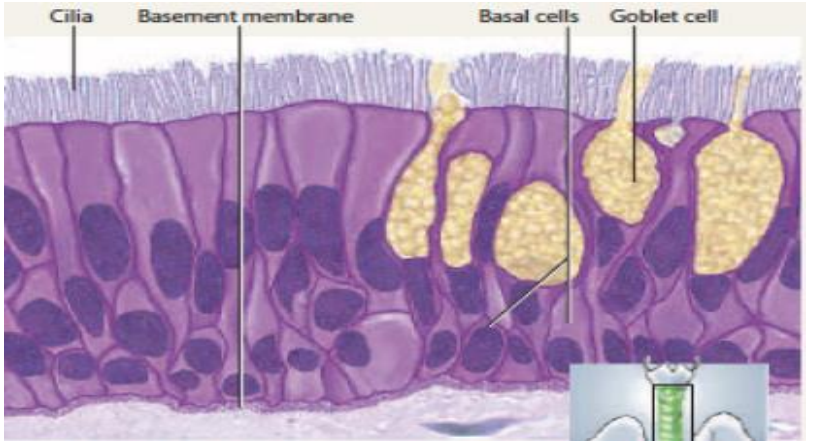
The air is humidified by water secreted from **small seromucous glands**. The thin mucus layer produced by these glands and **goblet cells** serves to trap foreign particles that are then removed. The secretions also contain immunoglobulin A (IgA) from plasma cells in the lamina propria.


Frontal sinus
Nasal cavity
Superior
Middle
Inferior
Nasal conchae
Internal nares
Nasopharynx
Nasal vestibule
Pharyngeal tonsil
External nares
Entrance to auditory tube
Hard palate
Soft palate
Oral cavity
Palatine tonsil
Tongue
Oropharynx
Mandible
Epiglottis
Lingual tonsil
Aryepiglottic fold
Hyoid bone
Laryngopharynx
Thyroid cartilage
Glottis
Cricoid cartilage
Vocal fold
Trachea
Esophagus
Thyroid gland

The respiratory epithelium

Most of the nasal cavities and conducting portion of the system is lined with mucosa having ciliated pseudostratified columnar epithelium commonly known as respiratory epithelium.

This epithelium has **five major cell types**, all of which contact a thick basement membrane



1. Ciliated columnar cells are the most abundant, each with 250-300 **cilia** on its apical surface.

2. Goblet cells are also numerous and predominate in some areas with basal nuclei and apical domains filled with granules of **mucin glycoproteins**.

3. Basal cells give rise to the other epithelial cell types.

The respiratory epithelium

4. Small granule cells (or Kulchitsky cells) they represent only about 3% of the cells in respiratory epithelium. They possess numerous dense core granules 100-300 nm in diameter. Like enteroendocrine cells of the gut, they are part of the **diffuse neuroendocrine system (DNES)**

5. Brush cells are a much less numerous, columnar cell type, in which a small apical surface has **microvilli**. Brush cells are **chemosensory receptors** resembling gustatory cells, with similar signal transduction components and synaptic contact with afferent nerve endings on their basal surfaces.

Olfactory Epithelium

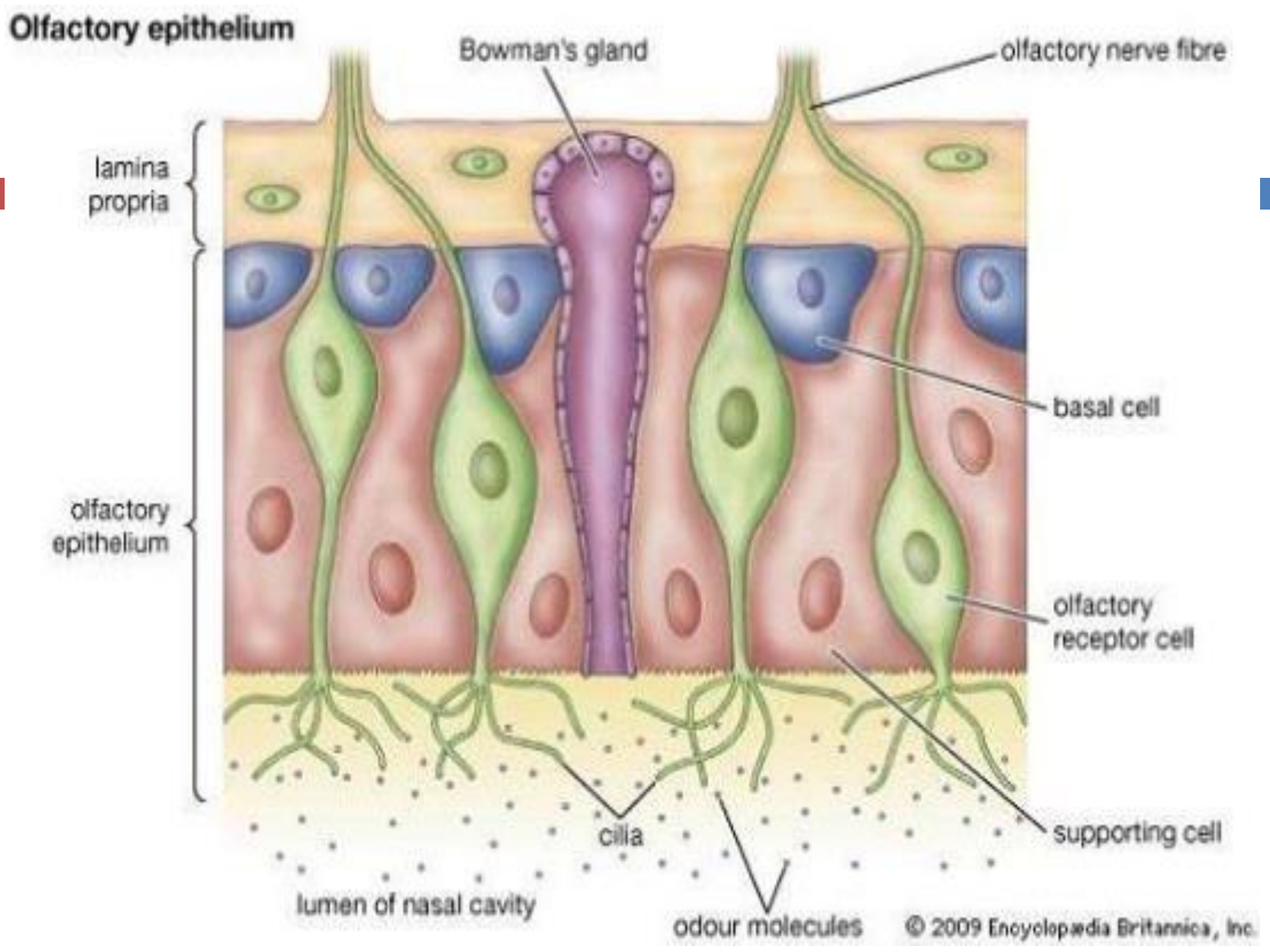
The roof of the nasal cavities and the superior conchae are covered with specialized **olfactory epithelium** has three major cell types:

1. Olfactory neurons are **bipolar neurons** present throughout this epithelium. The apex of each olfactory cell has dendrite with long **non-motile cilia** which provide a large surface for transmembrane **chemoreceptors**. The axons leave the epithelium and unite in the lamina propria as very small nerves that then pass to the brain. There they form the olfactory nerve (**cranial nerve I)** and synapse with neurons in the olfactory bulb of the brain.

2. Supporting cells are columnar, with apical **microvilli**, they help maintain olfactory function and survival of Olfactory neurons .

3. Basal cells are small, spherical, or cone-shaped cells near the basal lamina. These are the stem cells for the other two types, replacing the olfactory neurons every 2-3 months and supporting cells.

The lamina propria of the olfactory epithelium possesses large serous glands, the **olfactory glands (Bowman's glands**), which produce a constant flow of fluid surrounding the olfactory cilia and facilitating the access of new odoriferous substances.


Olfactory epithelium
Bowman's gland
olfactory nerve fibre
lamina propria
olfactory epithelium
basal cell
olfactory receptor cell
supporting cell
cilia
lumen of nasal cavity
odour molecules
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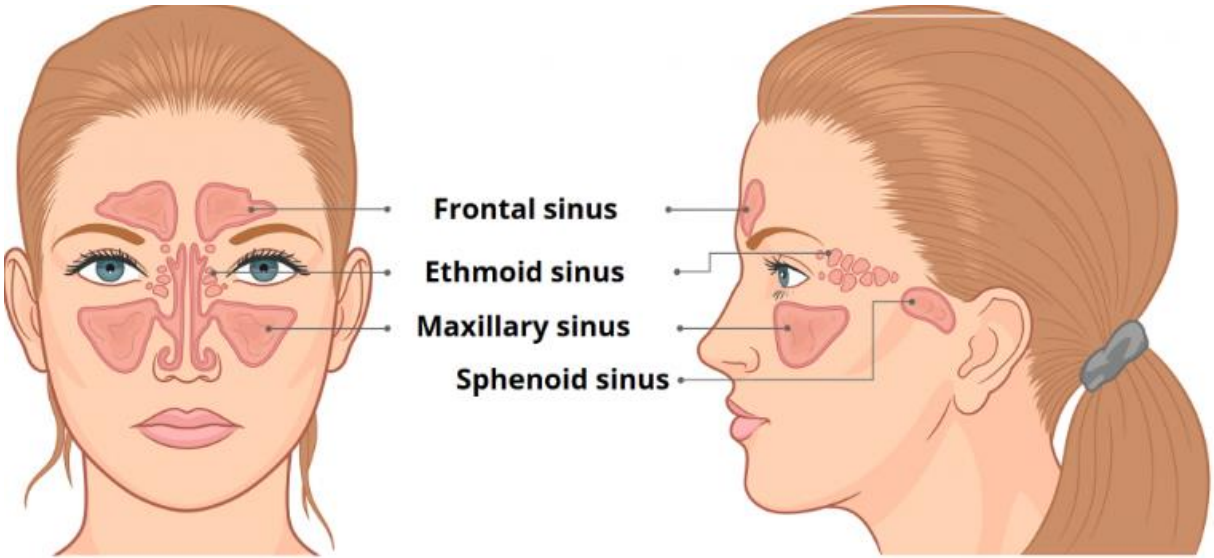
Paranasal sinuses

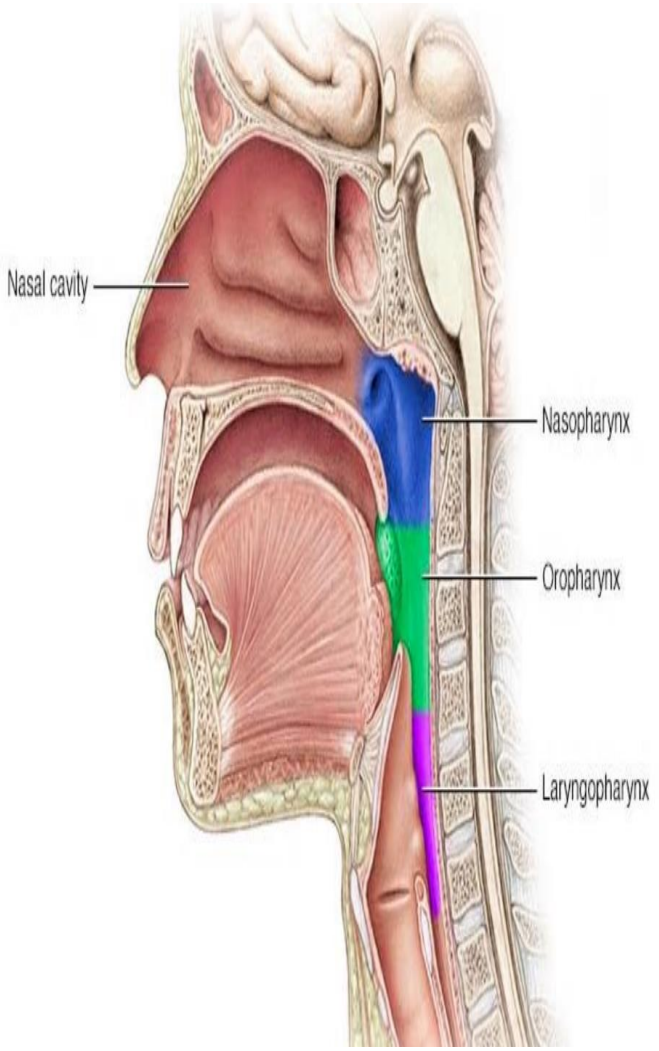
The paranasal sinuses are air cavities in the maxillae, frontal, sphenoid, and ethmoid bones. They are lined with thinner **respiratory epithelium** having **fewer goblet cells**. The lamina propria contains only a few small glands. The functions of the paranasal sinuses are to lighten the skull and provide resonance (more vibrating air) for the voice.



The nasopharynx

The nasopharynx lining is **respiratory epithelium**, and its mucosa contains **adenoid or pharyngeal tonsil**, a lymph nodule that contains macrophages.

The nasopharynx is **a passageway for air only**, but the remainder of the pharynx serves as both an air and food passageway, although not for both at the same time.



The larynx

The larynx is a short passage (4 cm × 4 cm) for air between the pharynx and the trachea. It is often called the **voice box**, a name that indicates its other functions, which is speaking.

The larynx is lined by **respiratory epithelium** **(except vocal cords and the lingual surface of epiglottis).**

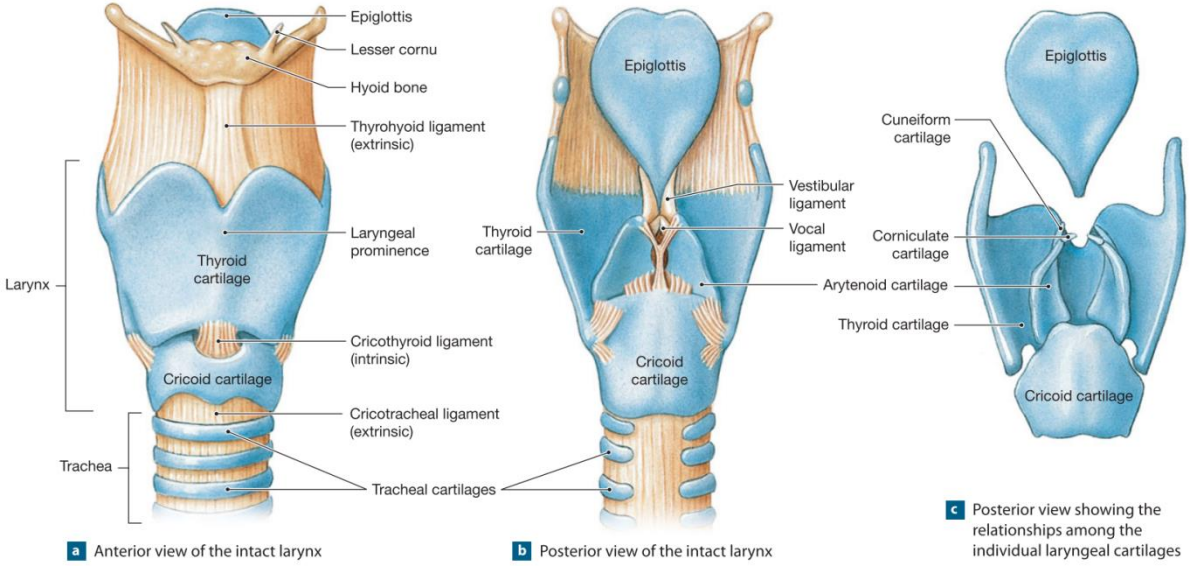
Air passages must be kept open at all times, and so the larynx is made of **cartilages connected by ligaments**.

Cartilage is a firm yet flexible tissue that prevents collapse of the larynx.

Cartilages of the Larynx

The larynx consists of three large cartilages: **1.** Thyroid cartilage, **2.** The cricoid cartilage **3.** The epiglottis.

- The largest cartilage of the larynx is the **thyroid cartilage**, which you can feel on the anterior surface of your neck.
- The thyroid and cricoid cartilages are **hyaline cartilages.**



The epiglottis

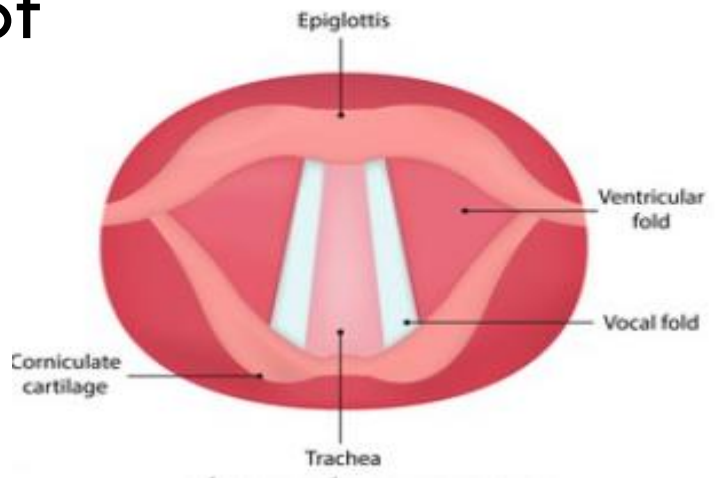
The **epiglottis:** it is a flattened structure projecting from the upper rim of the larynx.

Function of epiglottis: it serves to prevent swallowed food or fluid from entering the larynx. During swallowing, the larynx is elevated, and the epiglottis closes over the top to prevent the entry of saliva or food into the larynx.

The lingual surface of epiglottis has **stratified squamous epithelium**; at variable points on its **laryngeal surface**, this epithelium undergoes a transition to **ciliated pseudostratified columnar (respiratory epithelium)**.

Vestibular folds

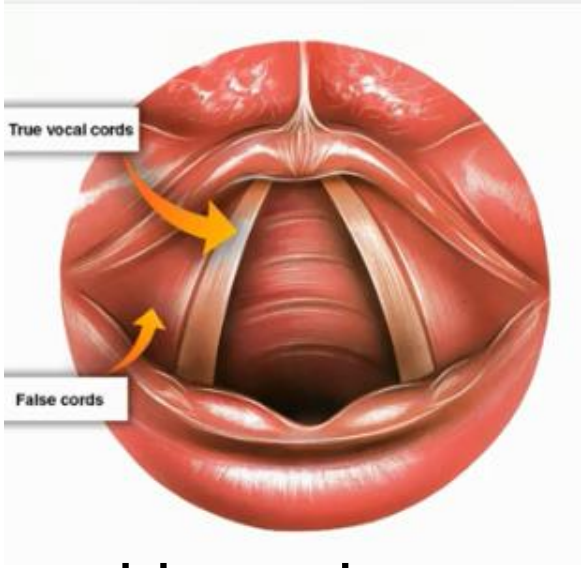
Below the epiglottis and vestibule of the larynx, the mucosa projects bilaterally into the lumen with **two pairs of folds** separated by a narrow space or **ventricle**.



1. The upper pair, the immovable **vestibular folds**, is partly covered with typical **respiratory epithelium.** They are fixed folds, which act to **provide protection to the larynx.**

Vocal Cords

2. The lower pair of folds, the vocal cords, have features important for phonation or sound production and each is covered with **non-keratinized stratified squamous epithelium** that protects the mucosa from **abrasion and desiccation** from rapid air movement.

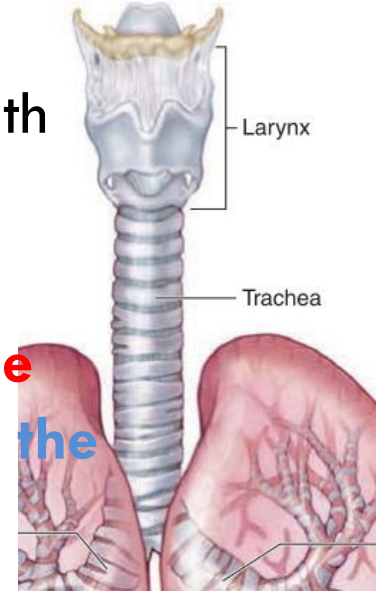


✓The free edge of each vocal fold is supported by a dense regular bundle of elastic connective tissue called the **vocal ligament**.

✓Deep to the mucosa are large bundles of striated fibers comprising the **vocalis muscle** that allow each vocal fold to be moved.

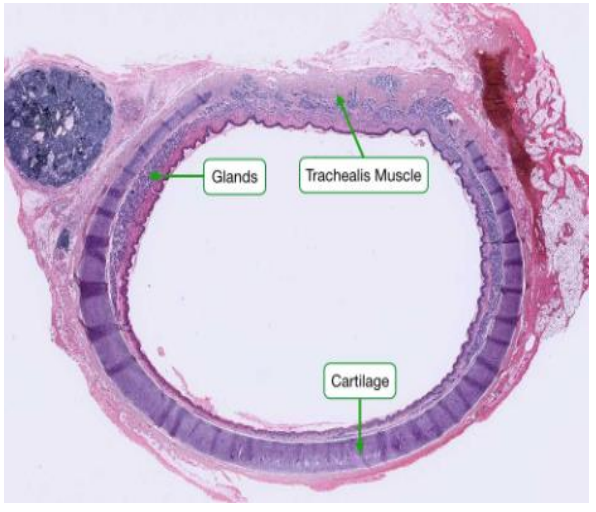
The trachea

The trachea "windpipe," is about 10 to 12 cm long and extends from the larynx to the primary bronchi. It is lined with **respiratory epithelium** and its lamina propria contains numerous **seromucous glands** producing **watery mucus**.



The wall of the trachea contains **C-shaped pieces of hyaline cartilage** between the submucosa and adventitia **reinforces the wall and keeps the tracheal lumen open**.

The open ends of the cartilage rings are on the posterior surface, against the esophagus, and are bridged by **a bundle of smooth muscle called the trachealis muscle. The trachealis muscle** relaxes during swallowing to facilitate the passage of food permit the expansion of the esophagus when food is swallowed.



The bronchial tree

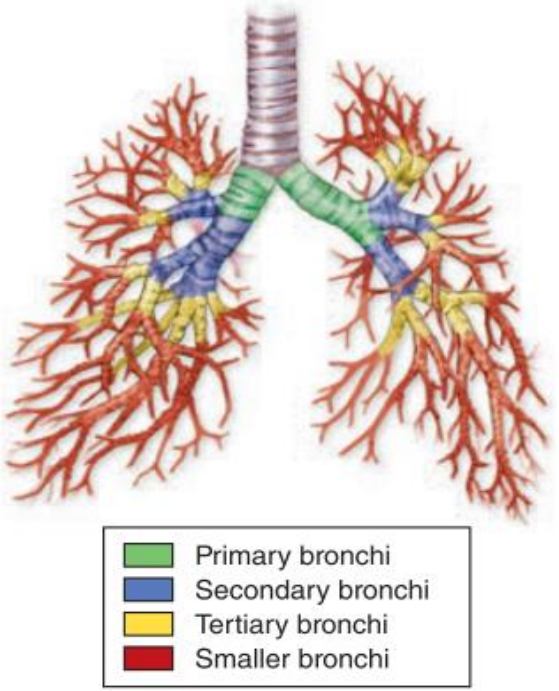
The trachea divides into **two primary bronchi** that enter each lung at the **hilum**, along with arteries, veins, and lymphatic vessels.

The right primary bronchus has a larger diameter than the left, and it descends toward the lung at a steeper angle. **For these reasons foreign objects that enter the trachea usually become lodged in the right bronchus rather than the left.**

Within the lungs, each primary bronchus branches into **secondary (lobar) bronchi** leading to the lobes of each lung (three right, two left).

These **secondary** bronchi again divide, forming **tertiary (segmental) bronchi.**

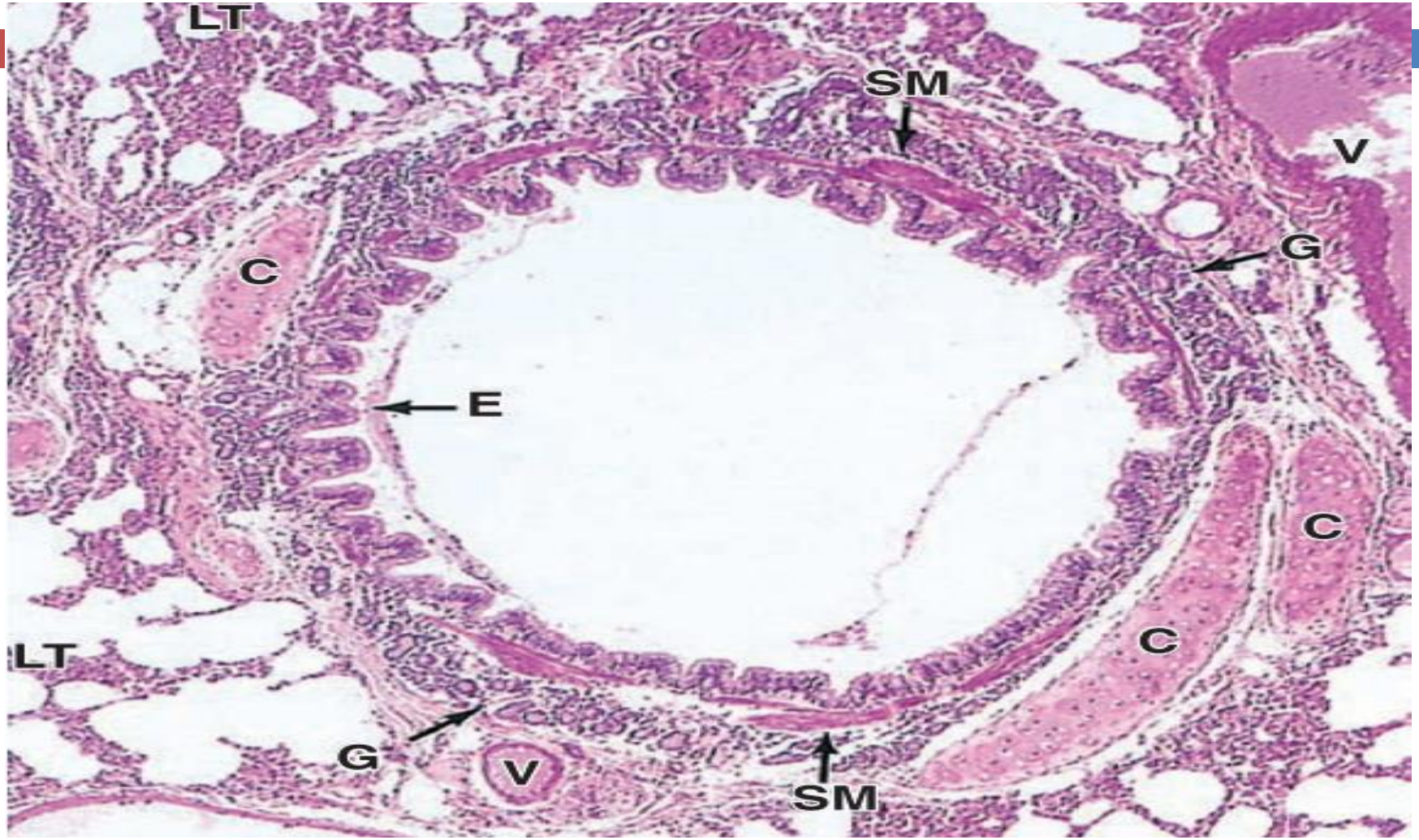
The **tertiary** bronchi give rise to smaller and smaller bronchi, whose terminal branches are called **bronchioles**. Each bronchiole enters a pulmonary lobule, where it branches to form **five to seven terminal bronchioles.**



Bronchi

Each primary bronchus branches repeatedly, with each branch becoming progressively smaller until it reaches a diameter of **1-2 mm**. In the **mucosa**: **The epithelial lining** of bronchi is mainly **pseudostratified ciliated columnar cells with a few goblet cells**. **The lamina propria** contains the bundles of spirally arranged **smooth muscle and elastic fibers**. In the primary bronchi most **cartilage rings completely encircle the lumen**, but as the bronchial diameter decreases, cartilage rings are gradually replaced with smaller isolated plates of hyaline cartilage. **The adventitia** it is a connective tissue containing blood vessels and nerves.

A cross section of a large bronchus



epithelium (E), smooth muscle (SM), Hyaline cartilage (C), seromucous glands (G), arteries and veins (V), lung tissue (LT)

Bronchioles

Bronchioles have diameters of **1 mm or less**, **they lack both mucosal glands and cartilage**, but they have **smooth muscle**.

In the larger bronchioles, the epithelium is still **ciliated pseudostratified columnar**, but this become **ciliated simple columnar or simple cuboidal epithelium** in the **smallest terminal bronchiole**.

The ciliated epithelial lining of bronchioles begins the **mucociliary apparatus or escalator**, important in clearing debris and mucus by moving it upward along the bronchial tree and trachea.

The cuboidal epithelium of terminal bronchioles

The cuboidal epithelium of terminal bronchioles consists largely of:

1. Club cells or bronchiolar exocrine cells (previously called Clara cells), with non-ciliated, dome-shaped apical ends containing secretory granules.

These exocrine cells have various functions, including the following:

A. Secretion of surfactant lipoproteins and mucins in the fluid layer on the epithelial surface. The surfactant prevents luminal adhesion.

B. Detoxification of inhaled chemical compounds by enzymes of the SER.

C. Secretion of antimicrobial peptides and cytokines for local immune defence.

2. Chemosensory brush cells.

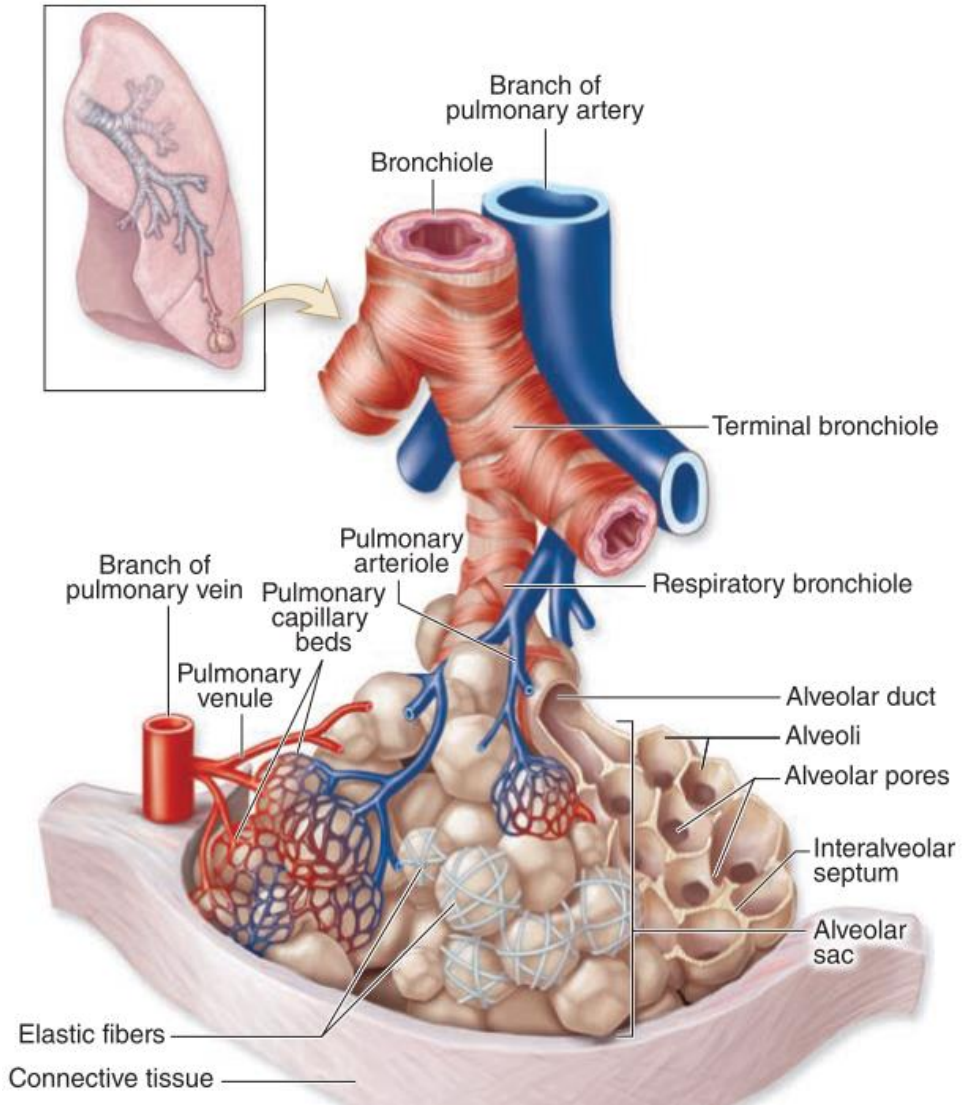
3. Small granule cells (DNES).

4. Stem cells.

Bronchioles

The respiratory bronchioles

- Each terminal bronchiole subdivides into **two or more respiratory bronchioles**, which always include saclike **alveoli** and represent, therefore, the first-part of this system's respiratory region.
- Smooth muscle and elastic connective tissue comprise the lamina propria.



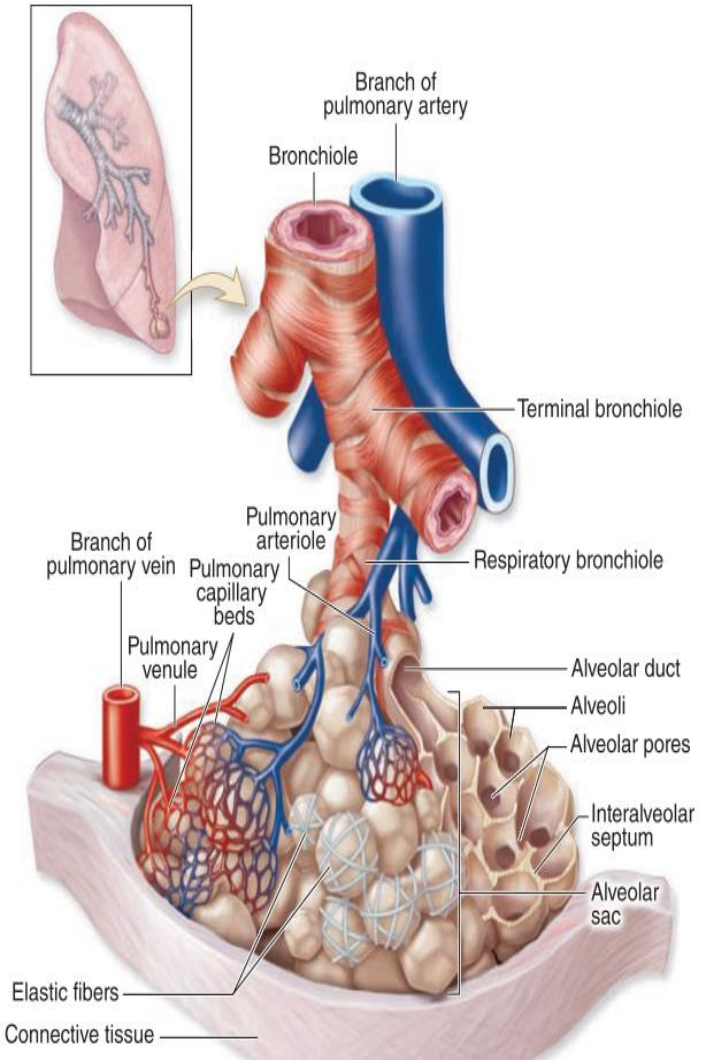
Alveolar ducts

The respiratory bronchioles branch into tubes called **alveolar ducts**, which are completely lined by the **openings of alveoli**.

Both the alveolar ducts and the alveoli themselves are lined with **squamous cells**.

In the thin lamina propria, a strand of smooth muscle cells surrounds each alveolar opening and a network of elastic and collagen fibers supports both the duct and its alveoli.

Larger clusters of alveoli called **alveolar sacs** form the ends of alveolar ducts distally and occur occasionally along their length.



The alveoli and blood-air barrier

Alveoli are saclike evaginations, each about **200 µm** in diameter, from the respiratory bronchioles, alveolar ducts, and alveolar sacs. Each lung contains approximately **200 million** alveoli, with a total internal surface area of **75 m2**. Alveoli are responsible for the spongy structure of the lungs.

The blood-air barrier: Air in the alveoli is separated from capillary blood by **three components** called the **respiratory membrane** or **blood-air barrier**:

1. The thin cells lining the alveolus.
2. The fused basal laminae of these cells and the endothelial cells of capillaries.
3. The thin capillary endothelial cells.

The alveolar structure

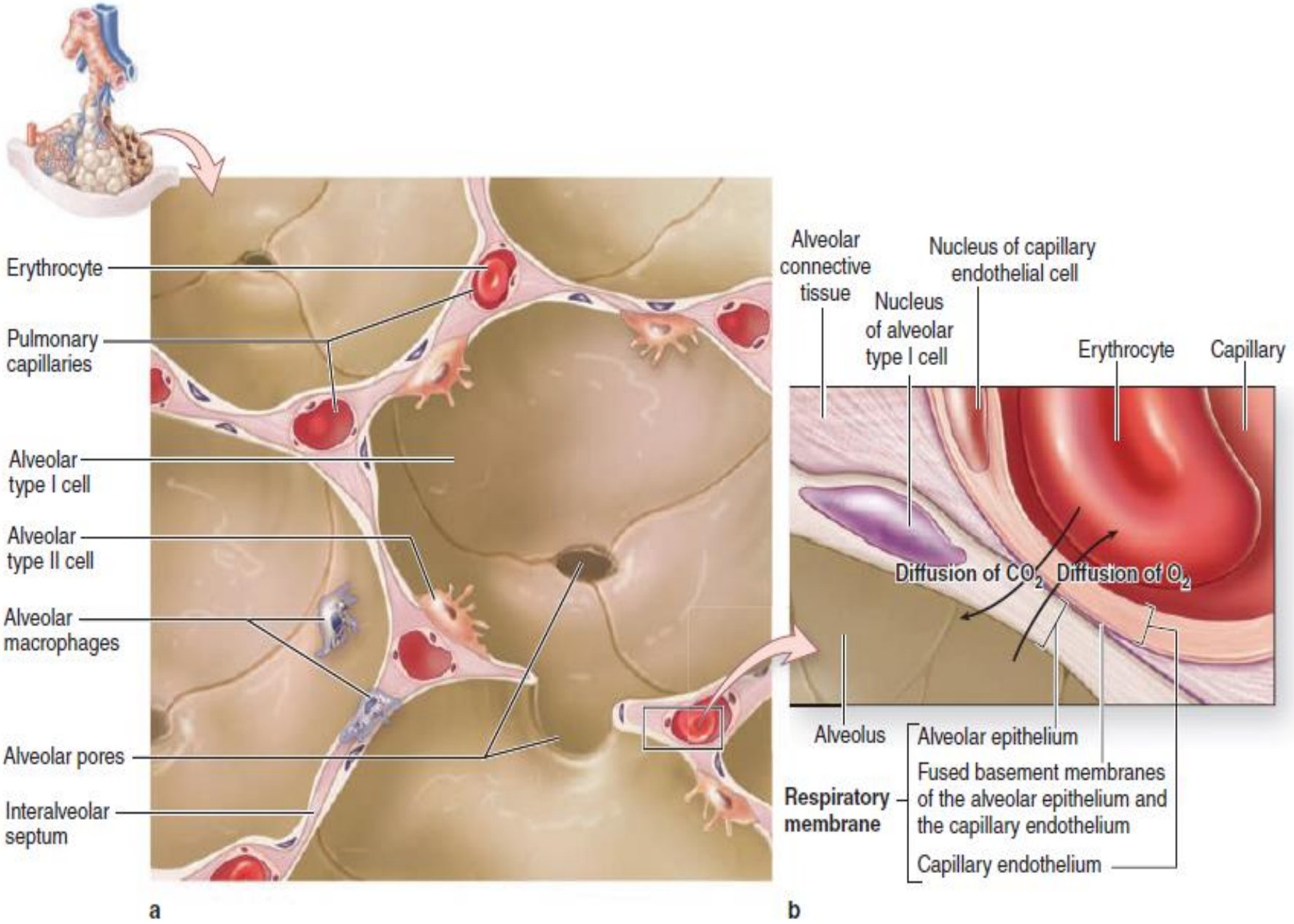
The alveolar epithelium consists primarily of **simple squamous epithelium.**

The alveolar epithelial cells consists of:

1. Pneumocyte type I cells, or **type I alveolar cells:** They make up about 95% of the alveolar lining and are responsible for gas exchange.

2. Pneumocyte type II cells, or **type II alveolar cells**, are cuboidal cells, scattered among the **type I cells**. These large cells produce an oily secretion containing a mixture of phospholipids. termed **surfactant**, **coats the inner surface of each alveolus and reduces surface tension in the fluid coating the alveolar surface. Without surfactant the alveoli would collapse.**

3. Roaming alveolar macrophages (dust cells) phagocytizing any particulate matter that has eluded the respiratory defenses and reached the alveolar surfaces.


Erythrocyte
Pulmonary capillaries
Alveolar type I cell
Alveolar type II cell
Alveolar macrophages
Alveolar pores
Interalveolar septum
a
Alveolar connective tissue
Nucleus of capillary endothelial cell
Nucleus of alveolar type I cell
Erythrocyte
Capillary
Diffusion of CO_2
Diffusion of O_2
Alveolus
Alveolar epithelium
Fused basement membranes of the alveolar epithelium and the capillary endothelium
Respiratory membrane
Capillary endothelium
b