

Respiratory System Histology

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Conducting Portion

- **Upper Airway: bone, cartilage, and fibrous tissue lined by stratified squamous and ciliated pseudostratified columnar epithelia**
 - Nasal Cavity
 - Pharynx
 - Nasopharynx
 - Oropharynx
 - Larynx
 - Epiglottis: elastic cartilage
 - Vocal cords: striated skeletal muscle / elastic fibers
- **Lower Airway: lined by respiratory epithelium**
 - Trachea: 15 to 20 C-shaped cartilages with smooth muscle
 - Bronchi
 - Extrapulmonary / primary bronchi: begin at the bifurcation of trachea and lead to lungs: extensions of the trachea
 - Intrapulmonary/secondary and tertiary bronchi: begin at lung hilum. Smooth muscle and hyaline cartilage plates
 - Bronchioles: no cartilage and Clara cells
 - Terminal bronchioles: increased Clara cells

Functions:

- Transports
- Warms
- Humidifies
- Filters

Respiratory Epithelium

- The typical respiratory epithelium consists of

5 cell types:

1. Ciliated cells;

2. Goblet cells;

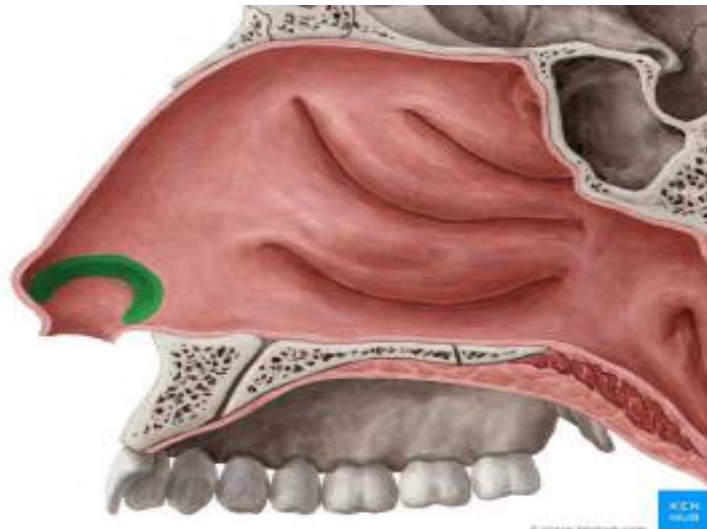
3. Brush cells (have short blunt microvilli);

4. Small granule cells (contain secretory granules);

5. Basal cells (stem cells).

Nasal vestibule

Entering the nares, or nostrils, the nasal vestibule is lined by **keratinized stratified squamous epithelium** – a continuation of the cutaneous lining from the external nose. It is also equipped with modified hairs, called **vibrissae** that filter out larger particles from inspired air. The membrane transitions from keratinized stratified squamous epithelium to **pseudostratified columnar ciliated epithelium with goblet cells** (also called respiratory epithelium) at a point known as the **limen nasi**.



Nasal cavity

Floor and walls of nasal cavity

The respiratory epithelium covers the floor, medial and lateral walls (just below the superior concha) of the nasal cavity to the choana (posterior boundary of the nasal cavity). Additionally, there are **seromucous glands** dispersed throughout the mucous membranes. Their secretions aid in respiration by moistening the inspired air and trapping unwanted particles. The trapped particles are propelled by the cilia to the pharynx where they can be expelled orally, or swallowed and digested.

Nasal cavity

The **roof of the nasal cavity** in the region of the cribriform plate of the ethmoid bone, the superior concha and the superior aspect of the nasal septum (composed of the perpendicular plate of the ethmoid bone) are covered with **pseudostratified columnar epithelium without goblet cells and motile cilia** (olfactory epithelium).

Nasal cavity

Although it is rather abrupt, the transition from respiratory to olfactory epithelium can be noted grossly by the change in colour (from pink respiratory to yellow olfactory epithelium) and histologically by the change in cell types and morphology. The columnar cells in the olfactory epithelium are generally taller than those in the respiratory epithelium.

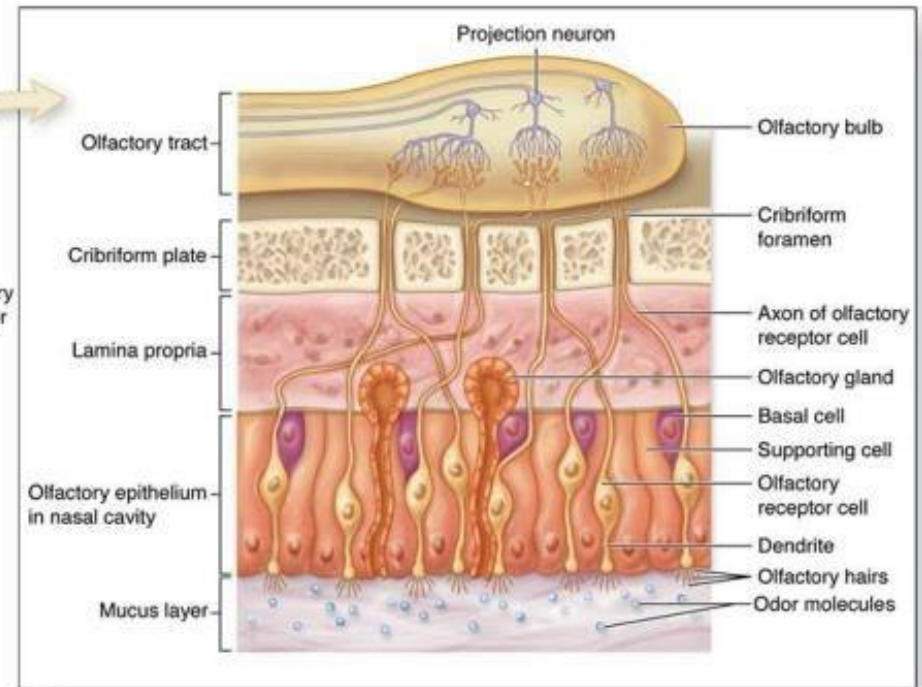
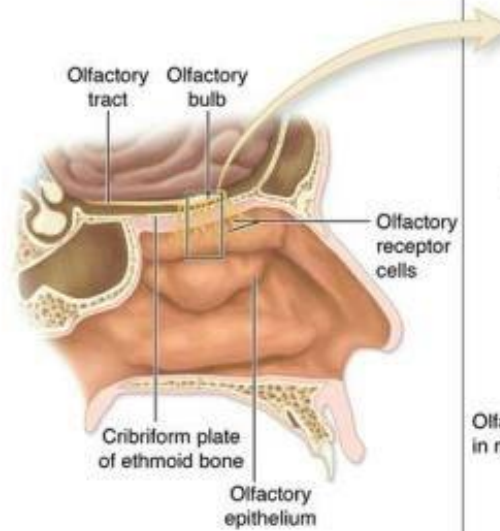
Nasal cavity

Cell types:

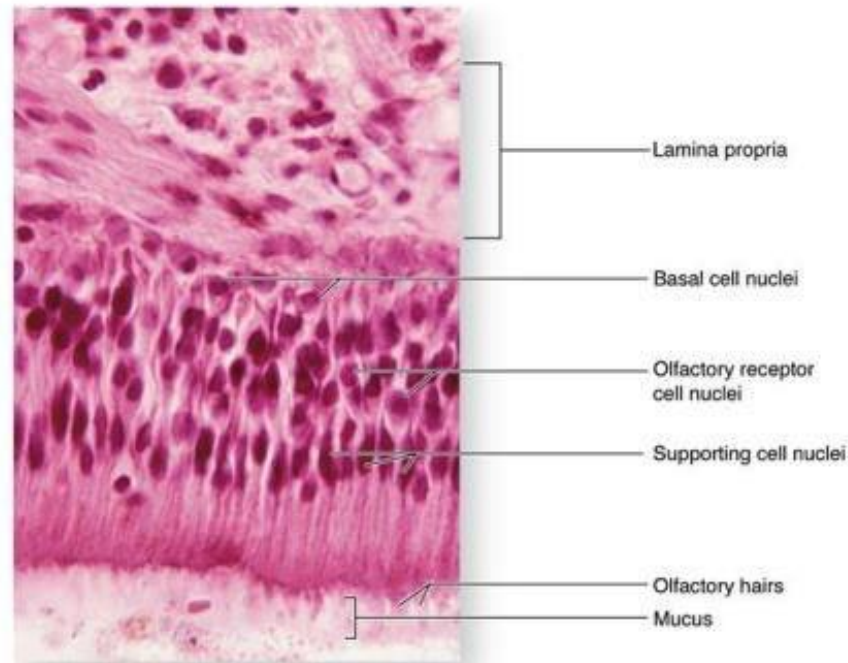
There are several cell types found in the epithelium that make olfaction possible. Air is first directed towards the olfactory epithelium by the turbinates (bones in the conchae that support the mucosa).

In the lamina propria, **Bowman's glands** (also called **olfactory glands**) produce serous secretions that dissolve odiferous particles so that they can interact with the olfactory cilia. The olfactory cilia are short hair-like projections that extend into the mucous lining to detect and transmit odors through the olfactory nerve cells.

Olfactory Epithelium



a



b

Nasal cavity

Cell types:

Sustentacular (supportive) cells distributed throughout the epithelium are interspersed with olfactory nerve cells and basal cells proximal to the cribriform plate of the ethmoid bone. The cell shapes are hard to distinguish; so the position and shape of the nuclei are used to distinguish the cell types.

- * The nuclei of the **basal cells** are spherical and proximal to the cribriform plate of the ethmoid bone.

- * The nuclei of **sustentacular cells** are more elongated and distal to the cribriform plate of the ethmoid bone.

- * The nuclei of the **olfactory nerve cells** are seen between those of the basal and sustentacular cells.

Nasal cavity

The mucosa of the paranasal sinuses is also respiratory epithelium. The only difference is that the epithelium is thinner and has fewer goblet cells and serous and mucous glands. The paranasal sinuses are typically devoid of lymphoid tissue.

Pharynx

The epithelium of the pharyngeal portion of the conducting zone changes with respect to each pharyngeal segment. In the **nasopharynx**, the epithelium is continuous with that of the nasal cavity. The cilia here continues to wharf foreign particles through the pharynx to be swallowed.

In the **oropharynx** and **laryngopharynx**, the epithelium transitions to **non-keratinized stratified squamous epithelium**. This durable epithelium is better suited to accommodate friction associated with swallowing food. Additionally, lymphatic aggregates (distributed throughout the mucosa) act as a first contact point for the immune system to sort through particles entering the body (Waldeyer's Ring).

Waldeyer's Ring

(The ring acts as a first line of defense against microbes that enter the body via the nasal and oral routes)

Pharyngeal tonsils (Adenoids): In the roof of the nasopharynx
Covered with respiratory epithelium

Tubal tonsils: In the roof of the nasopharynx
Covered with respiratory epithelium

Palatine tonsils: In the oropharynx
Covered with stratified non-keratinized squamous epithelium

Lingual tonsils: At the posterior one-third of the tongue
Covered by stratified non-keratinized squamous epithelium

MALT: Mucosa-associated lymphoid tissue found in mucosa of the gut (GALT) and bronchus (BALT), as well as in every mucosal lining of the body

Clinical relations: Adenoiditis, tonsillitis

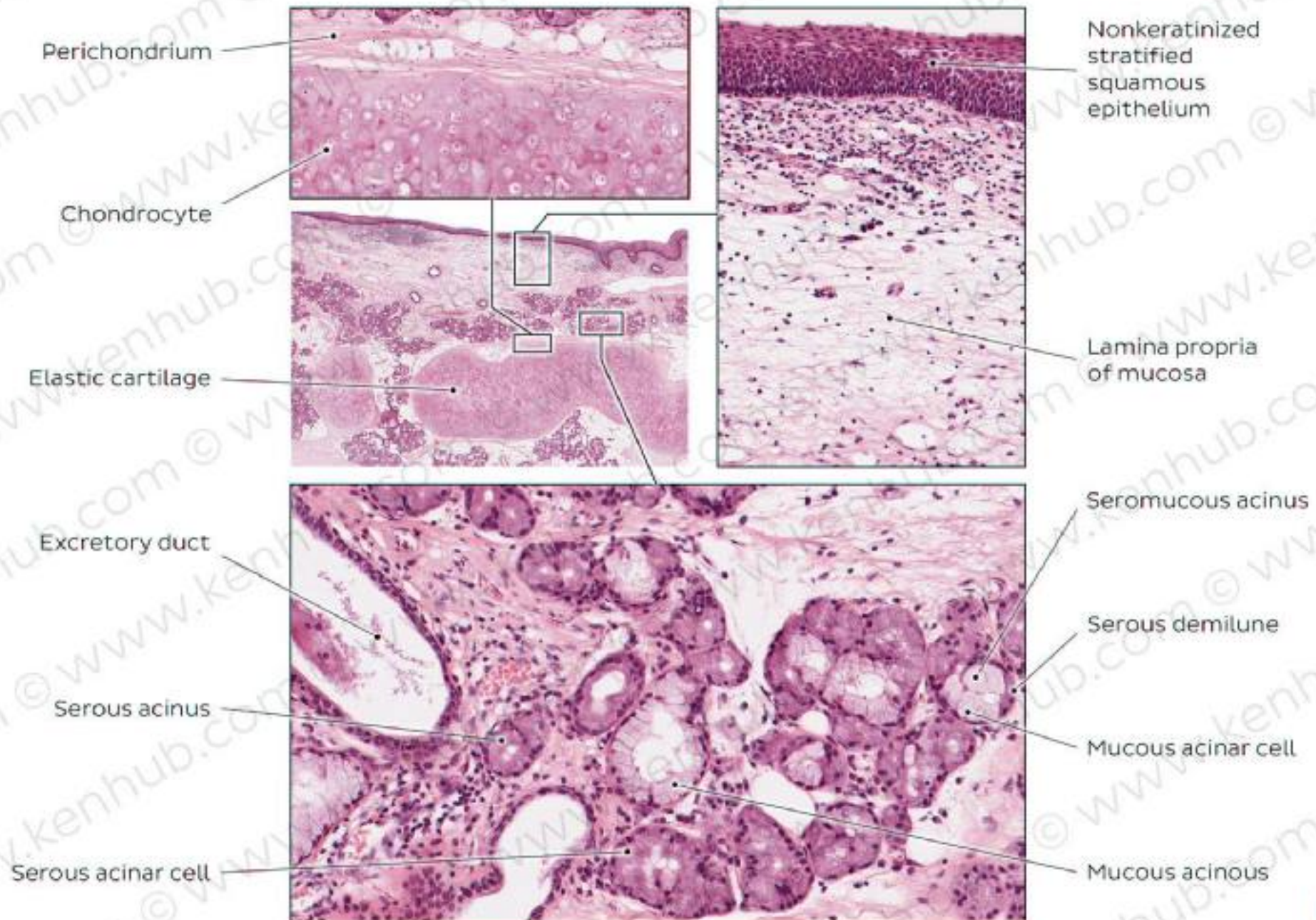
Epiglottis

The epiglottis is a cartilaginous structure located cranial to the larynx. It projects posteriosuperiorly to separate the pharynx from the larynx and prevents food from entering the lower airway during swallowing.

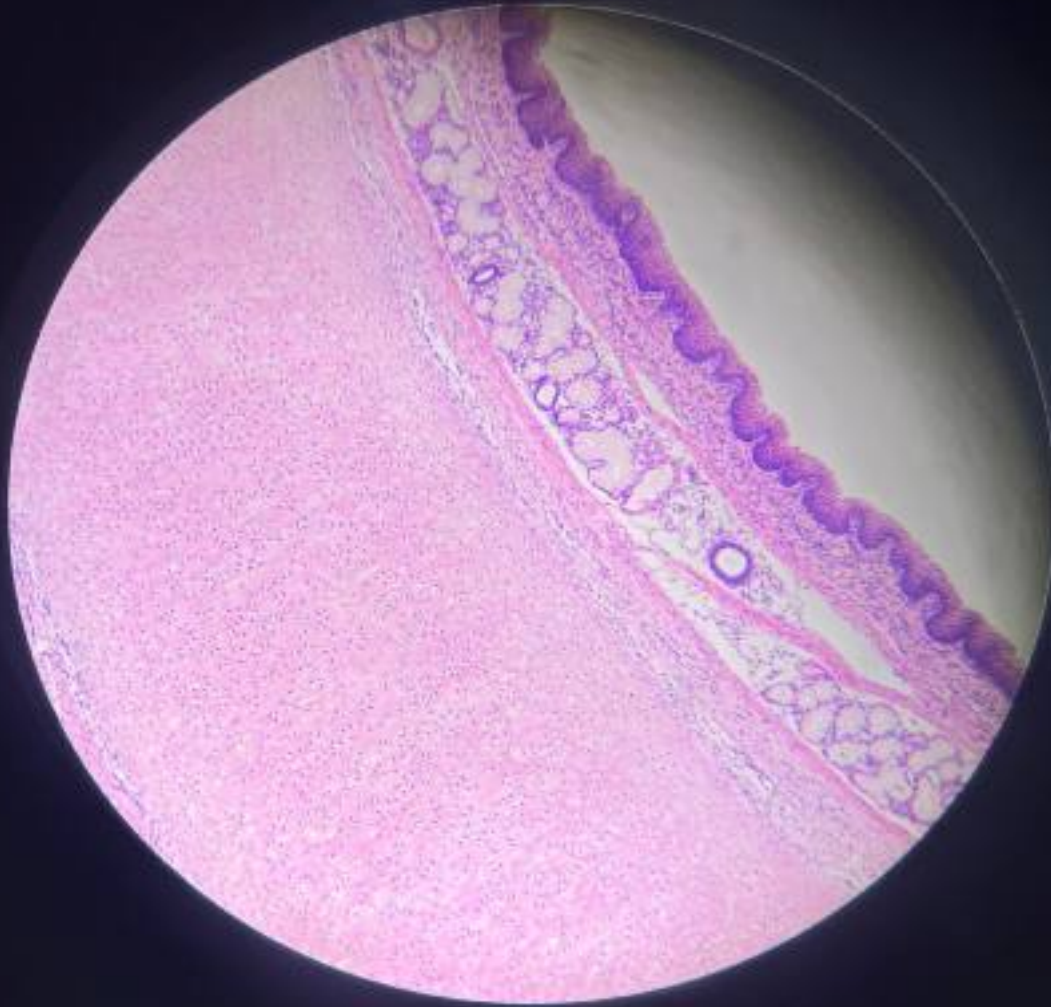
The mucosa of the **lingual surface** of the epiglottis (as well as half of the laryngeal surface) is continuous with that of the laryngopharynx. It is lined with **stratified squamous non keratinized epithelium** (lingual mucosa); the other half of its **laryngeal surface** is lined by **pseudostratified ciliated columnar epithelium**. Deep within the lamina propria of the mucosa are seromucous glands.

Elastic cartilage in the center of the epiglottis provides scaffolding for the overlying mucosa. Both surfaces of the epiglottis are equipped with diffuse lymphoid tissue and taste buds.

Epiglottis



Epiglottis



larynx

The larynx is composed of three large unpaired cartilages (cricoid, thyroid, and epiglottis) and three paired smaller cartilages (arytenoid, corniculate, and cuneiform), making a total of nine individual cartilages. The thyroid cartilage is the largest of the laryngeal cartilages and is composed of **hyaline cartilage** (the cricoid & arytenoid too, the rest are elastic). It forms the anterior and lateral portions of the larynx and has no posterior component. The broad flat right and left halves (laminae) of the cartilage fuse anteriorly in the midline to form a V-shaped anterior projection called the laryngeal prominence (commonly called the “Adam’s apple”).

larynx

The **mucosa** of the larynx forms two pairs of folds, false and true vocal cords, which extend into the lumen of the larynx. The laryngeal epithelium corresponding to the **mechanically exposed areas** consists of **stratified squamous nonkeratinized epithelium** (true vocal cords). the epithelium is **ciliated columnar pseudostratified** with a rich population of goblet cells. Except in the true vocal cords, lamina propria consists of rather loose connective tissue and contains groups of small, branched tubuloalveolar glands.

larynx

For the two pairs of folds within the larynx, the upper folds are the **vestibular folds (or false vocal cords)** , and the lower folds are the **actual vocal folds, (or true vocal cords)** .

Between the folds on each side are narrow spaces simply called **ventricles**.

Each true vocal cord will need relatively large muscles in order to move the vocal cords for speech.

These muscles, called the **vocalis muscles** are stained darker within the vocal folds.

larynx

The false vocal folds are covered by **respiratory epithelium**, while the true vocal folds are covered by **stratified squamous epithelium**. The false vocal folds are not responsible for sound production, but rather for resonance.

The ventricular folds, located just above the vocal cords, are sometimes termed false vocal cords **because they are not involved in voice production**

True vocal cords are **responsible for vocal sounds**. The true vocal cords contain **more elastic fibers**. The true vocal cords also have an opening between them to form the **glottis**. When an individual swallows, the false vocal cords close the glottis to prevent food and liquid from entering the trachea.

larynx

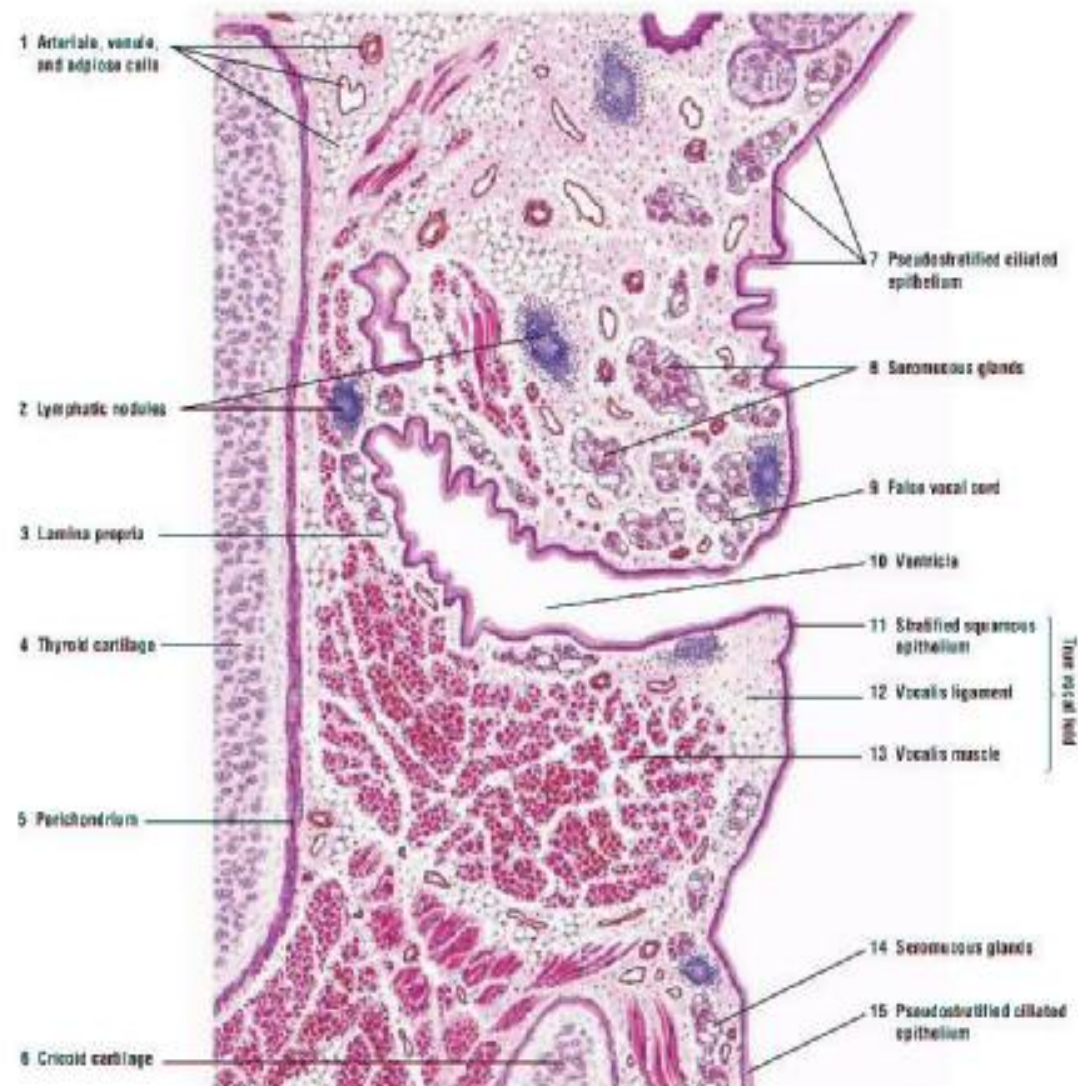
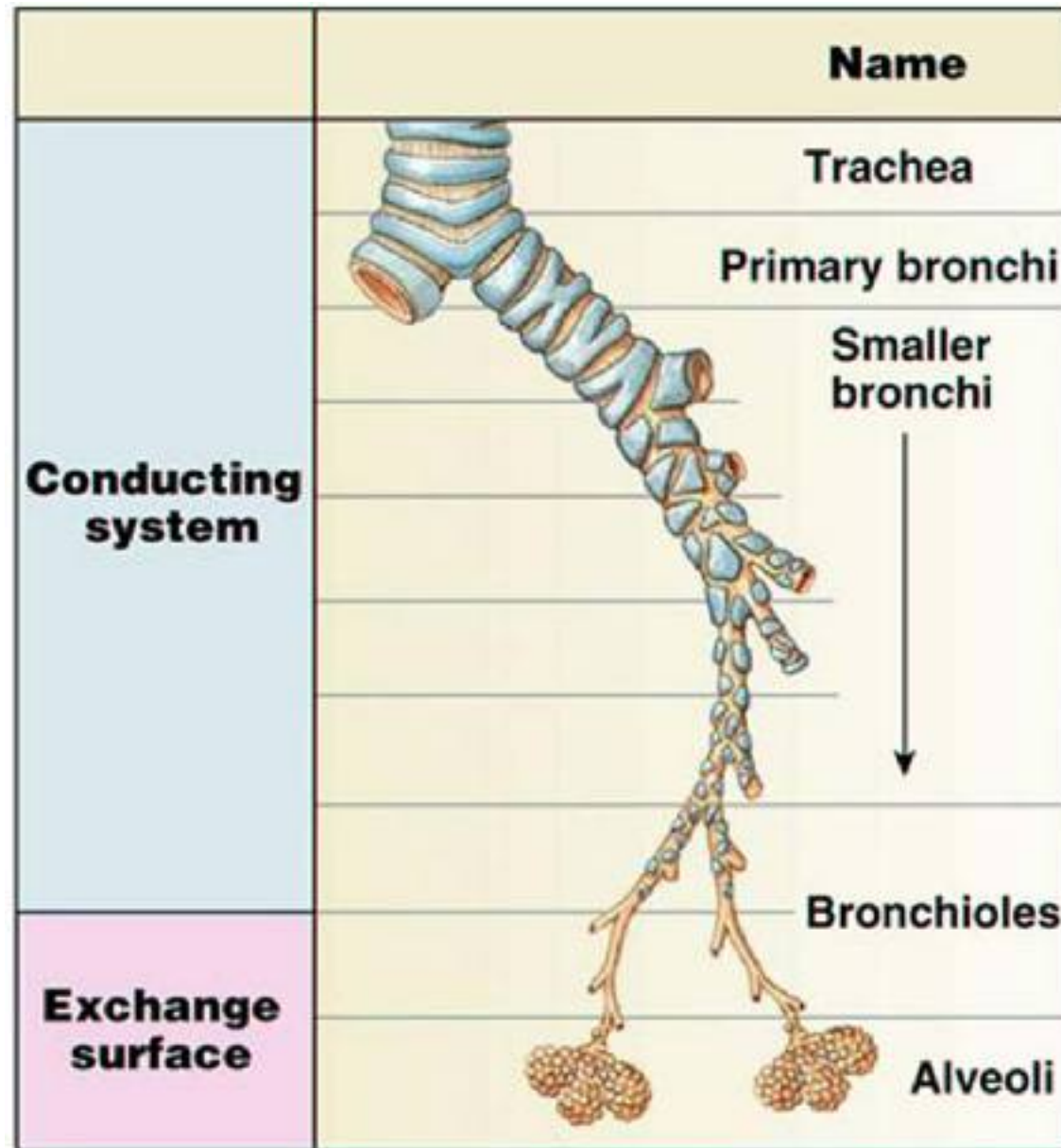


FIGURE 15.5 ■ Frontal section of larynx. Stain: hematoxylin and eosin. Low magnification.

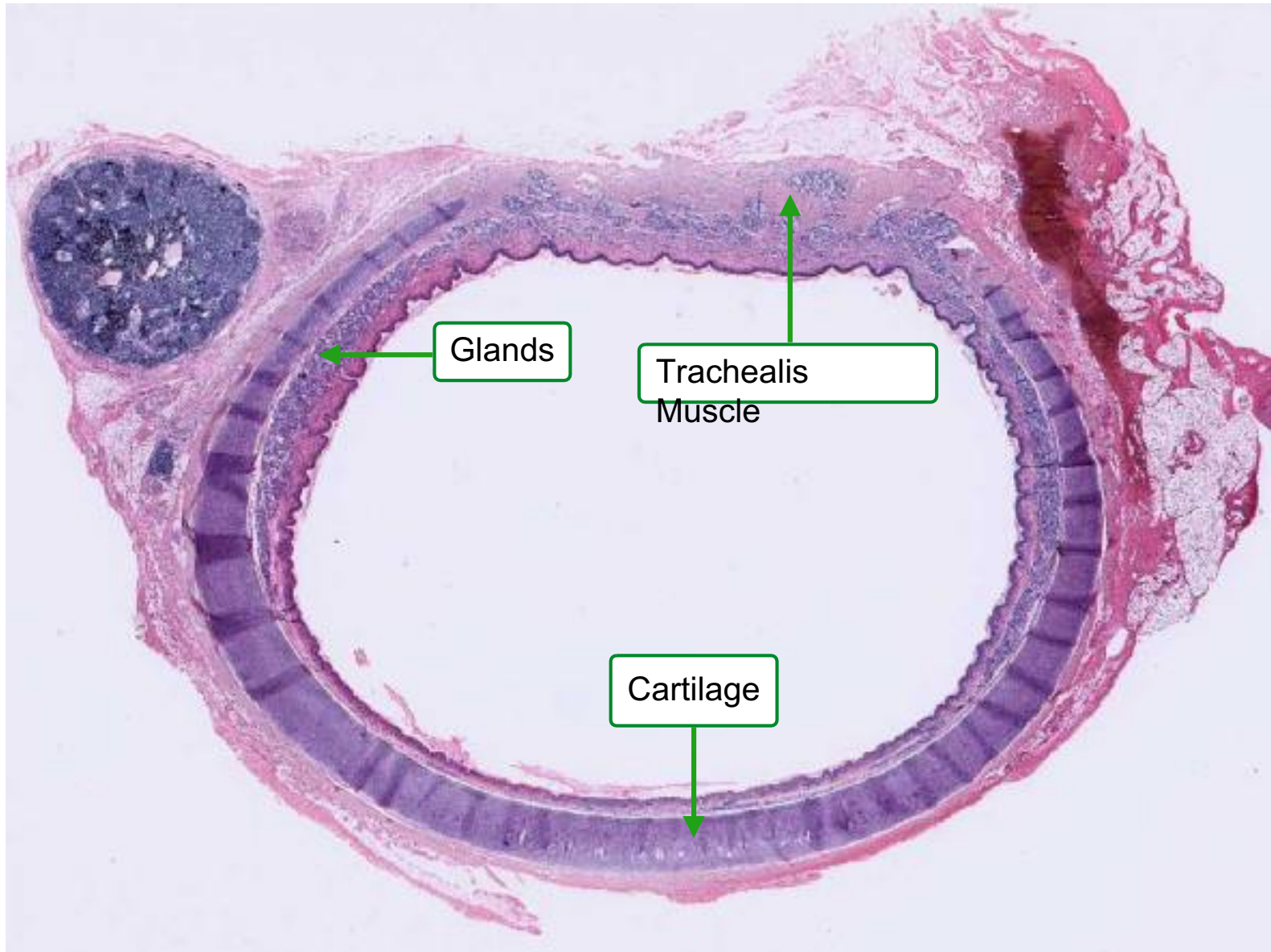
The respiratory system comprises conducting and gas exchange segments.



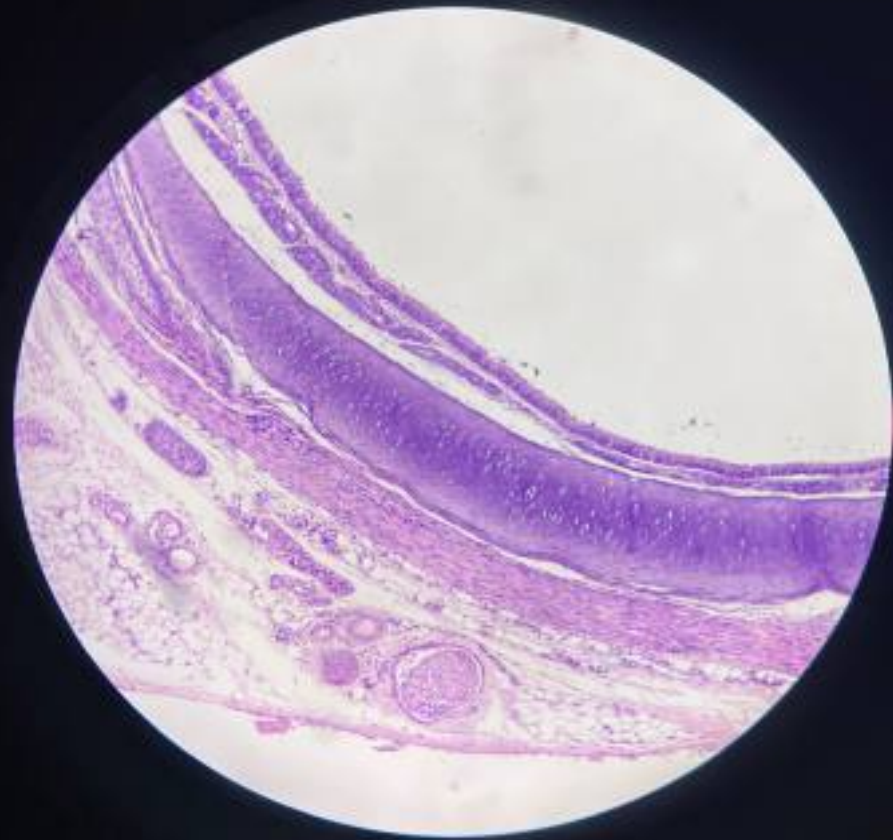
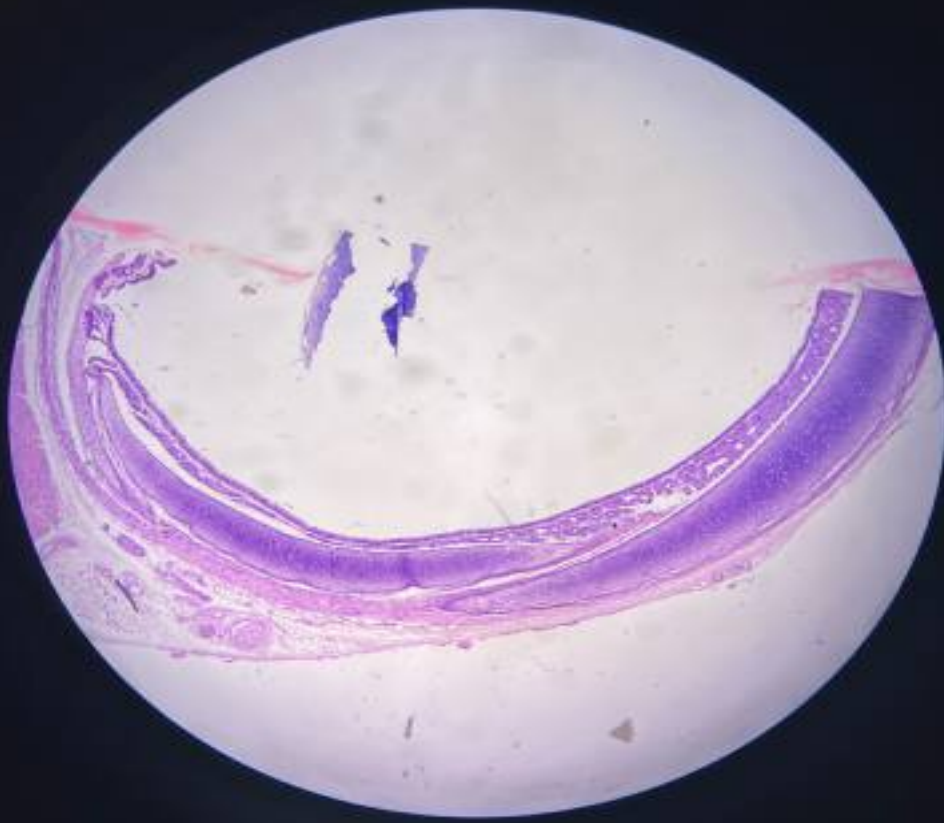
Conducting portion: Lower Airway

- Trachea: connects larynx to primary bronchi
 - Mucosa: respiratory epithelium = ciliated pseudostratified columnar epithelium and lamina propria
 - Ciliated cells, goblet cells, basal cells, and neuroendocrine cells
 - Submucosa: dense connective tissue and seromucous glands
 - Hyaline cartilage: C-shaped; some smooth muscle (trachealis) to stabilize opening
 - Adventitia: connective tissue that covers cartilage

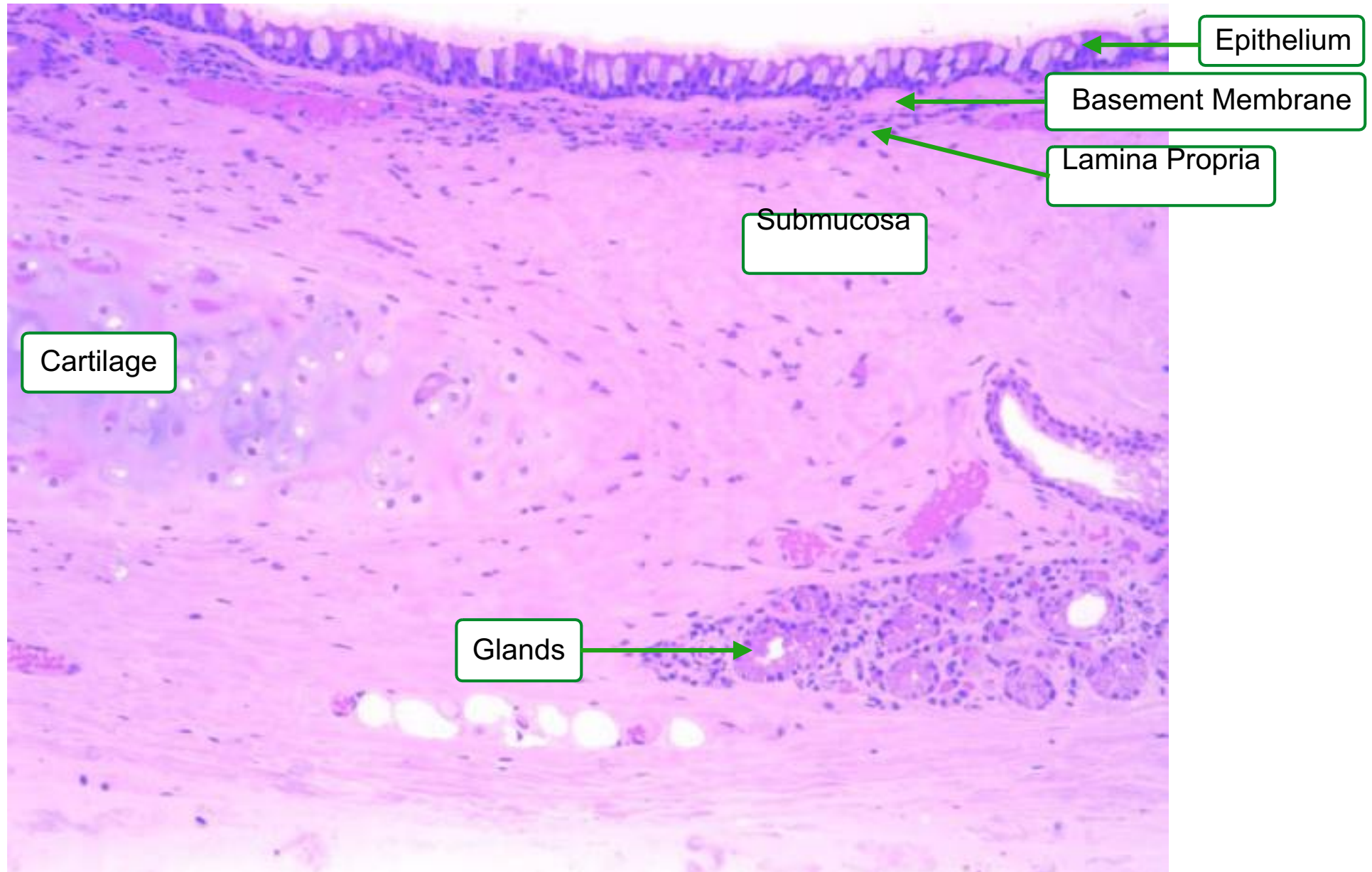
The trachea connects the larynx to primary bronchi and contains cartilage rings.



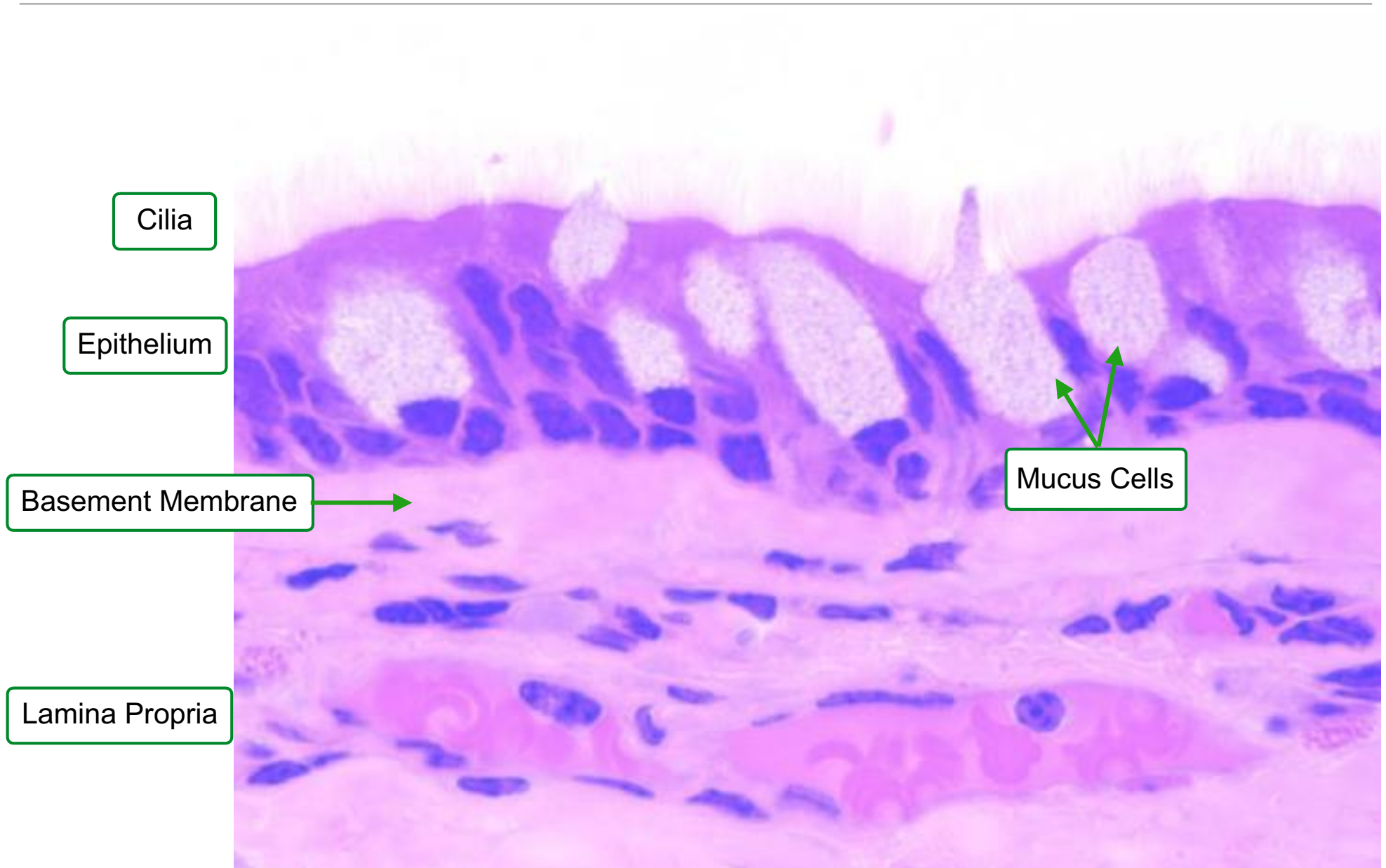
Respiratory Epithelium of the Trachea



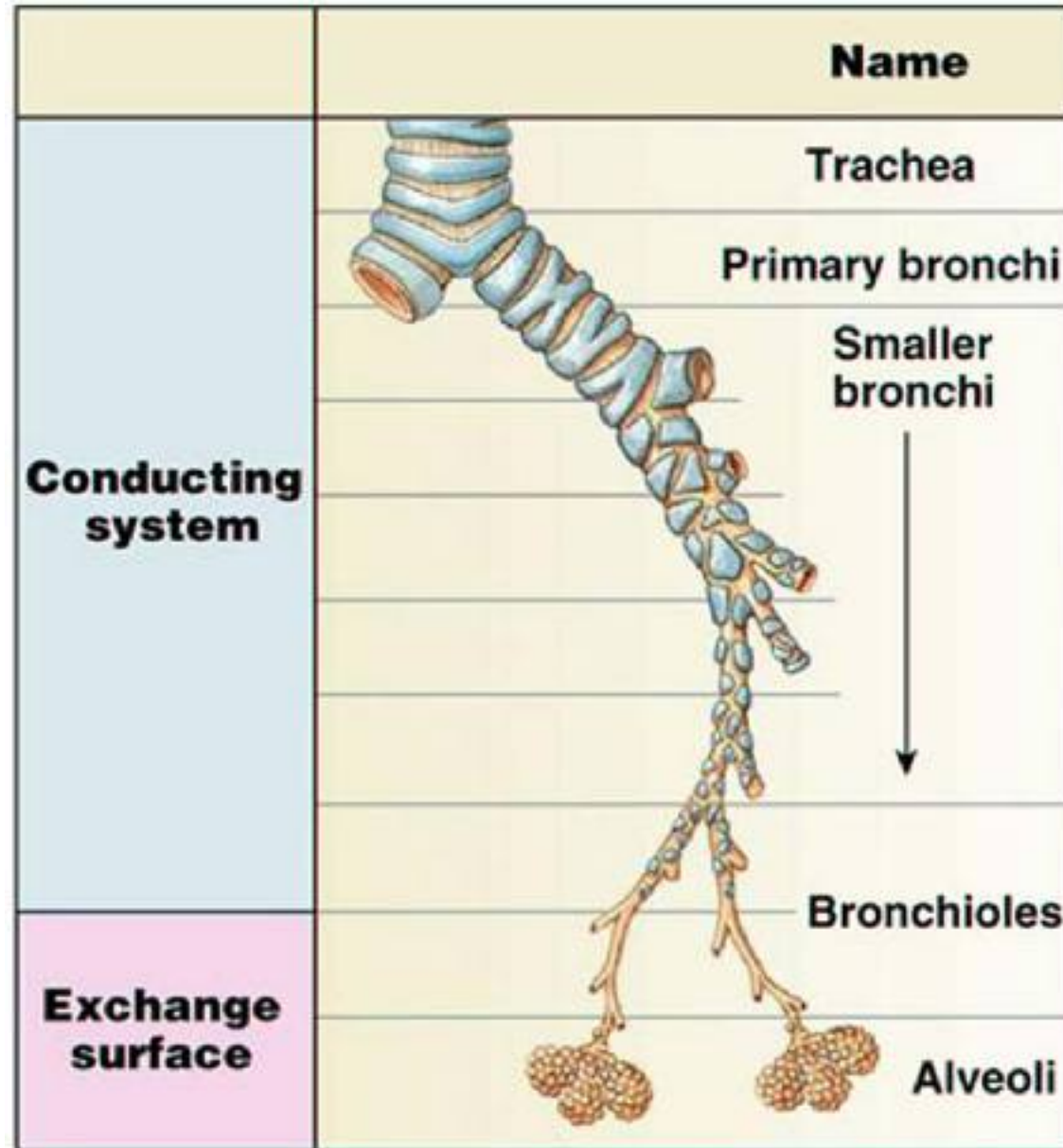
The wall of the trachea contains ciliated, pseudostratified epithelium, cartilage and glands.



The mucosal layer of the respiratory tract consist of epithelia, basement membrane and lamina propria.



The respiratory system comprises conducting and gas exchange segments.



Conducting portion: Lower Airway

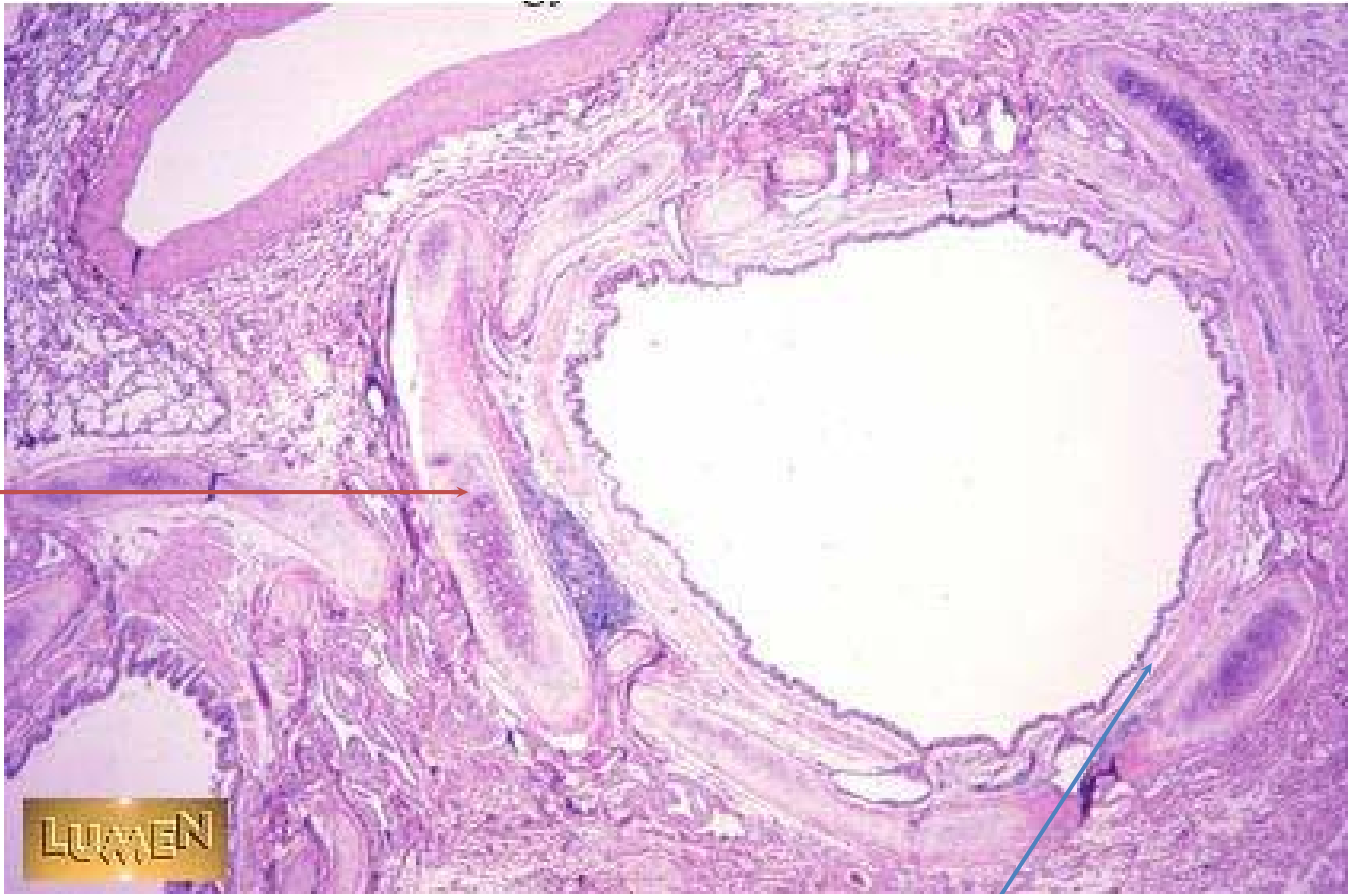
- Main / Primary Bronchi (extrapulmonary bronchi)
- Similar structure to trachea
- Right is wider and more vertical than the left

Conducting portion: Lower Airway

- Secondary /Tertiary (Intrapulmonary)
Bronchi
 - Mucosa: respiratory epithelium as seen in trachea and primary bronchi
 - Smooth muscle band between submucosa and mucosa
 - Innervated by the sympathetic and parasympathetic systems
 - Submucosa: seromucous glands
 - Hyaline cartilage plates
 - Adventitia

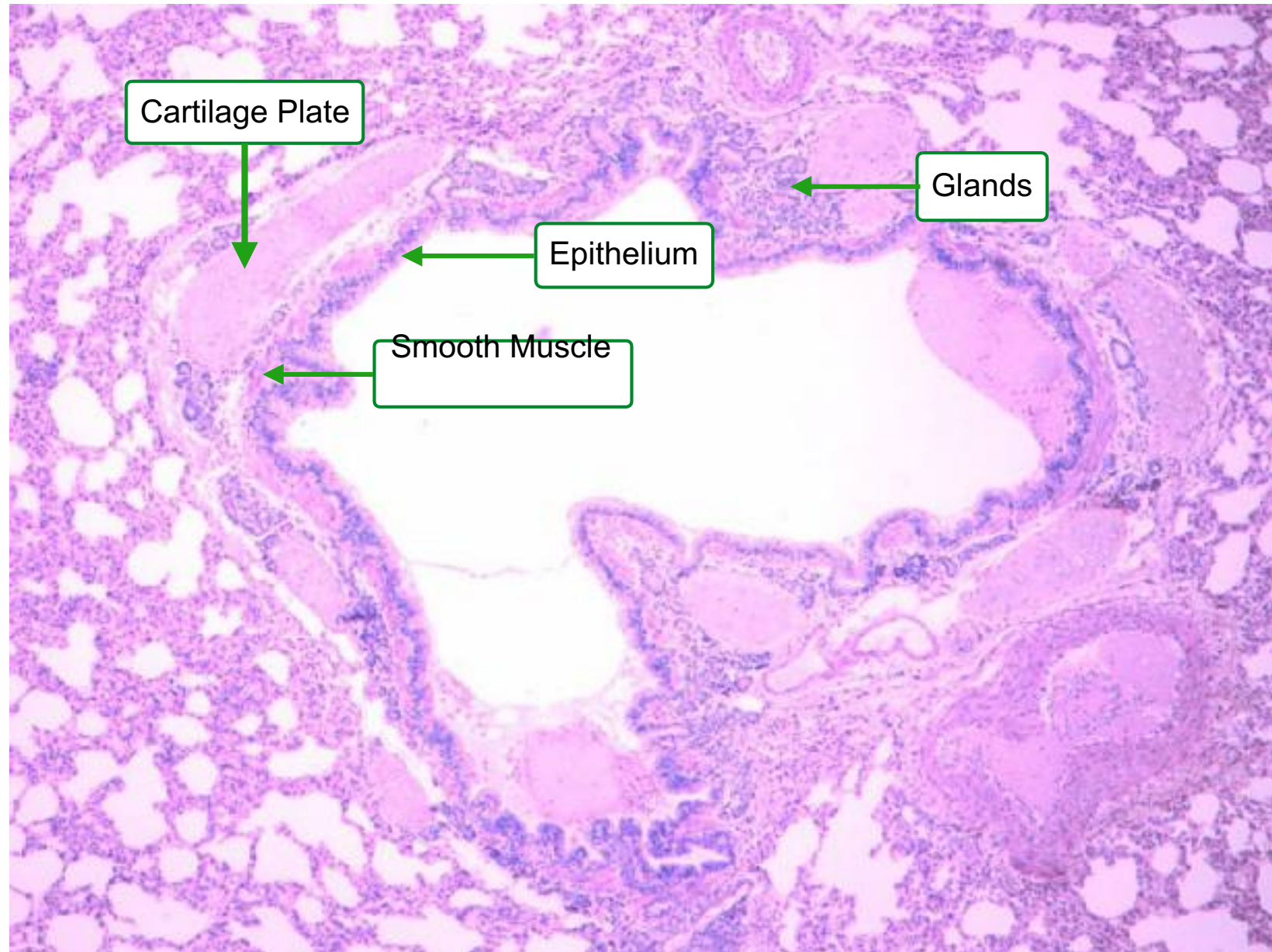
Bronchus, secondary

Hyaline
Cartilage
Plates



Smooth muscle band

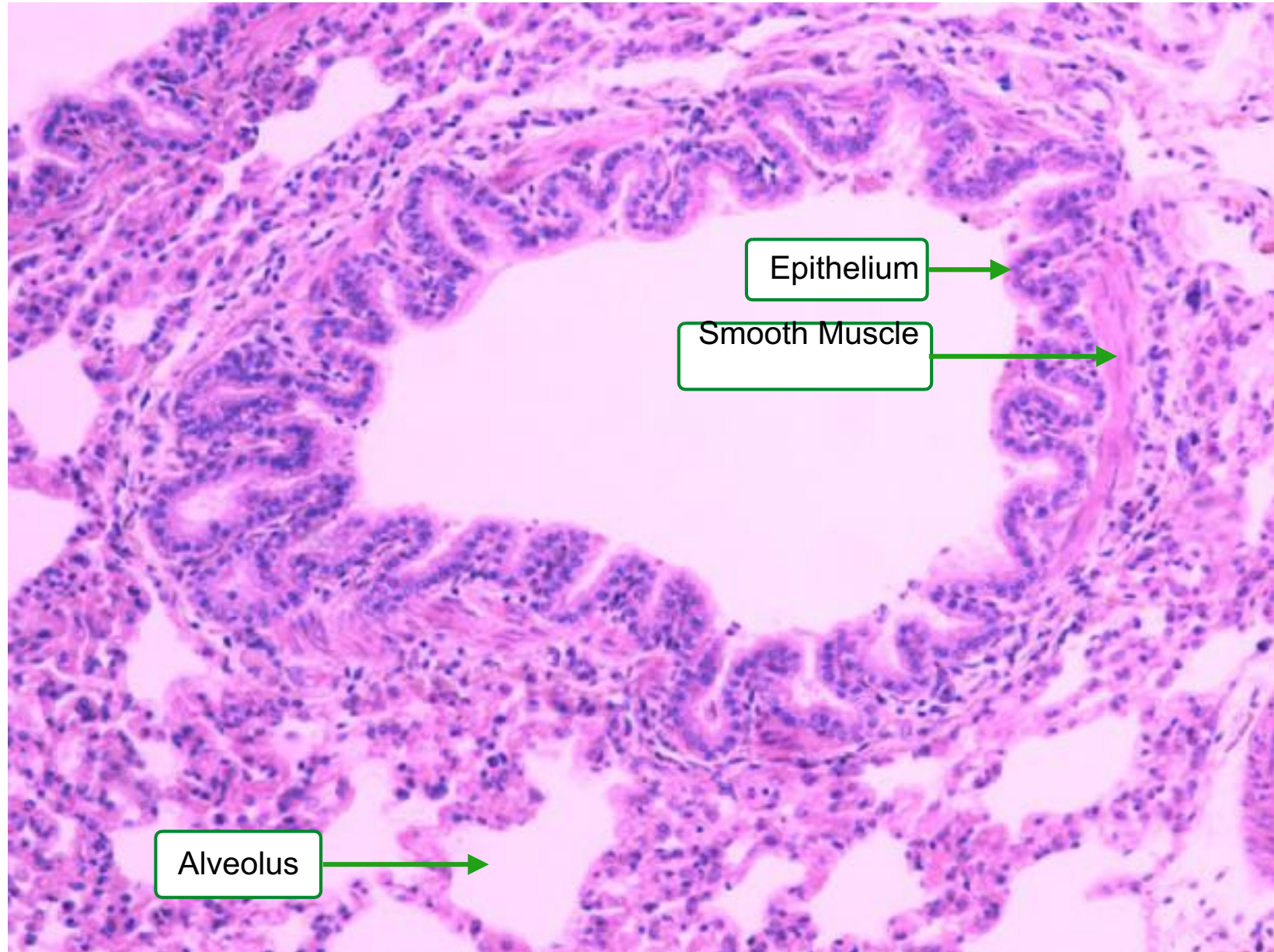
Bronchi contain pseudostratified epithelium and cartilage plates.

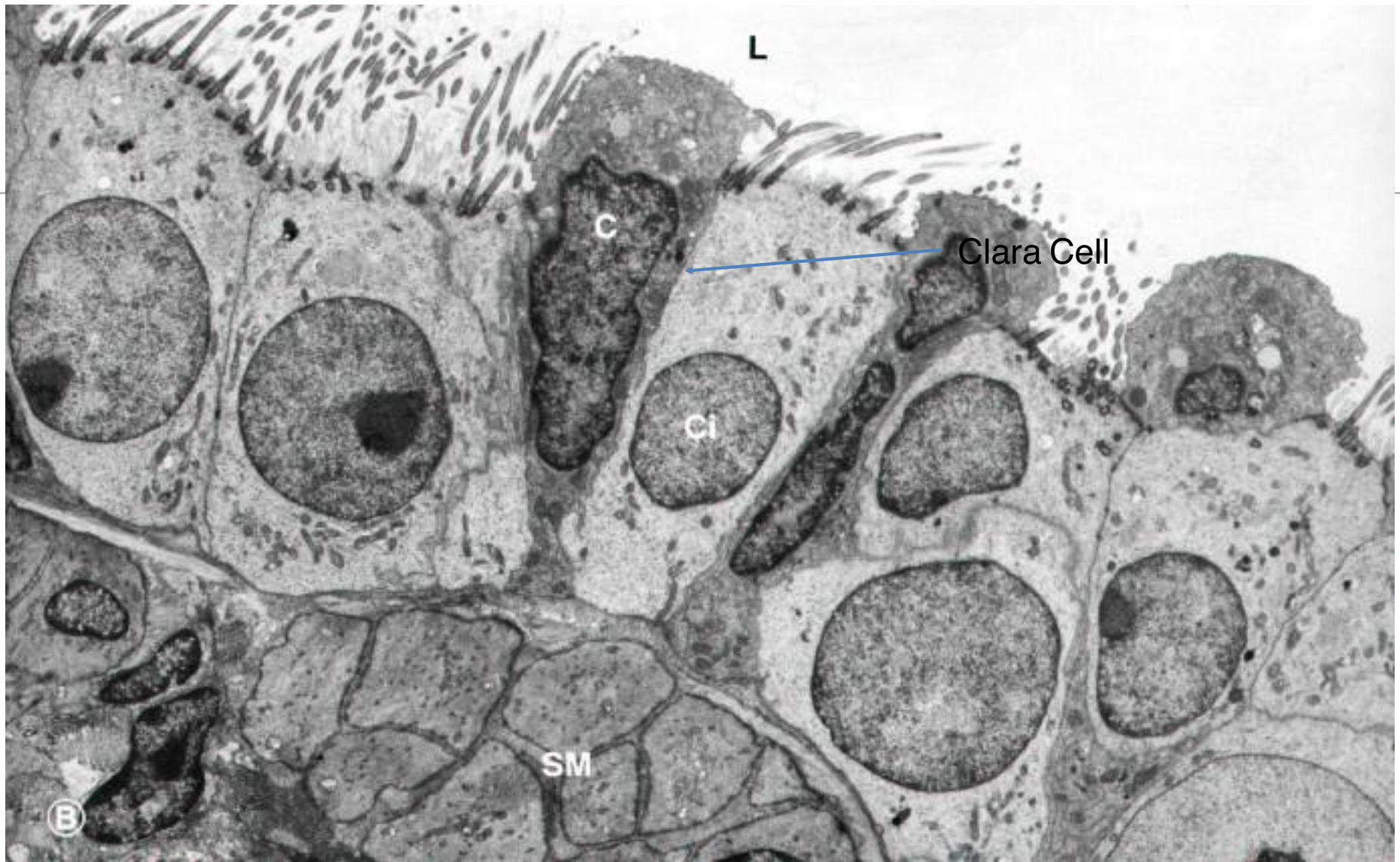


Conducting portion: Bronchioles

- Mucosa: lined by respiratory epithelium with Clara cells replacing goblet cells
 - Dome shaped cells without cilia secrete glycosaminoglycans and secretory proteins
 - Clara cells increase as bronchioles give rise to terminal bronchioles
 - Epithelium gradually become mostly clara cells with cuboidal rather than ciliated epithelium as the terminal bronchioles near the respiratory bronchioles
- Smooth muscle layer
- No cartilage
- Adventitia

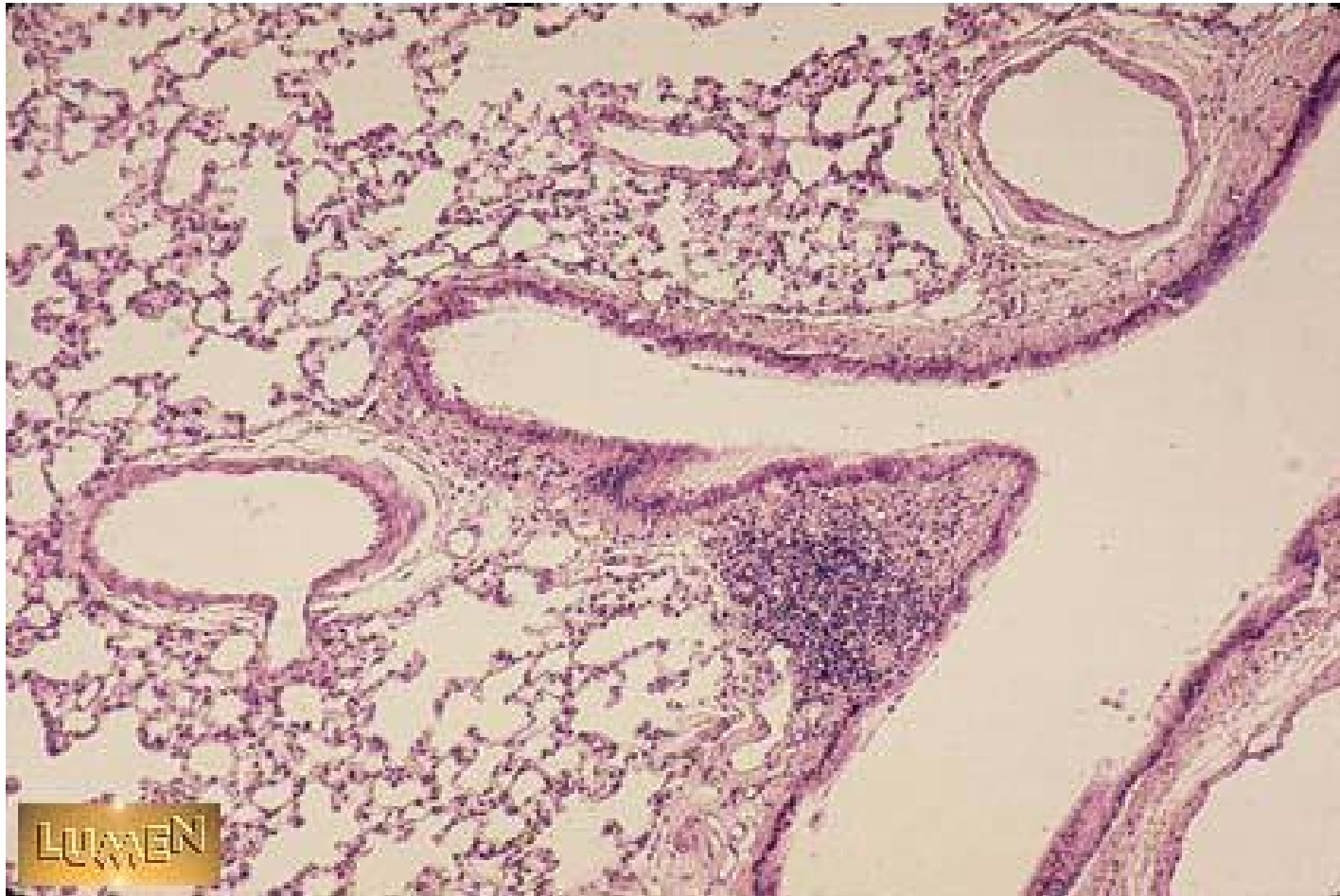
Bronchioles contain simple columnar epithelium and lack cartilage plates.



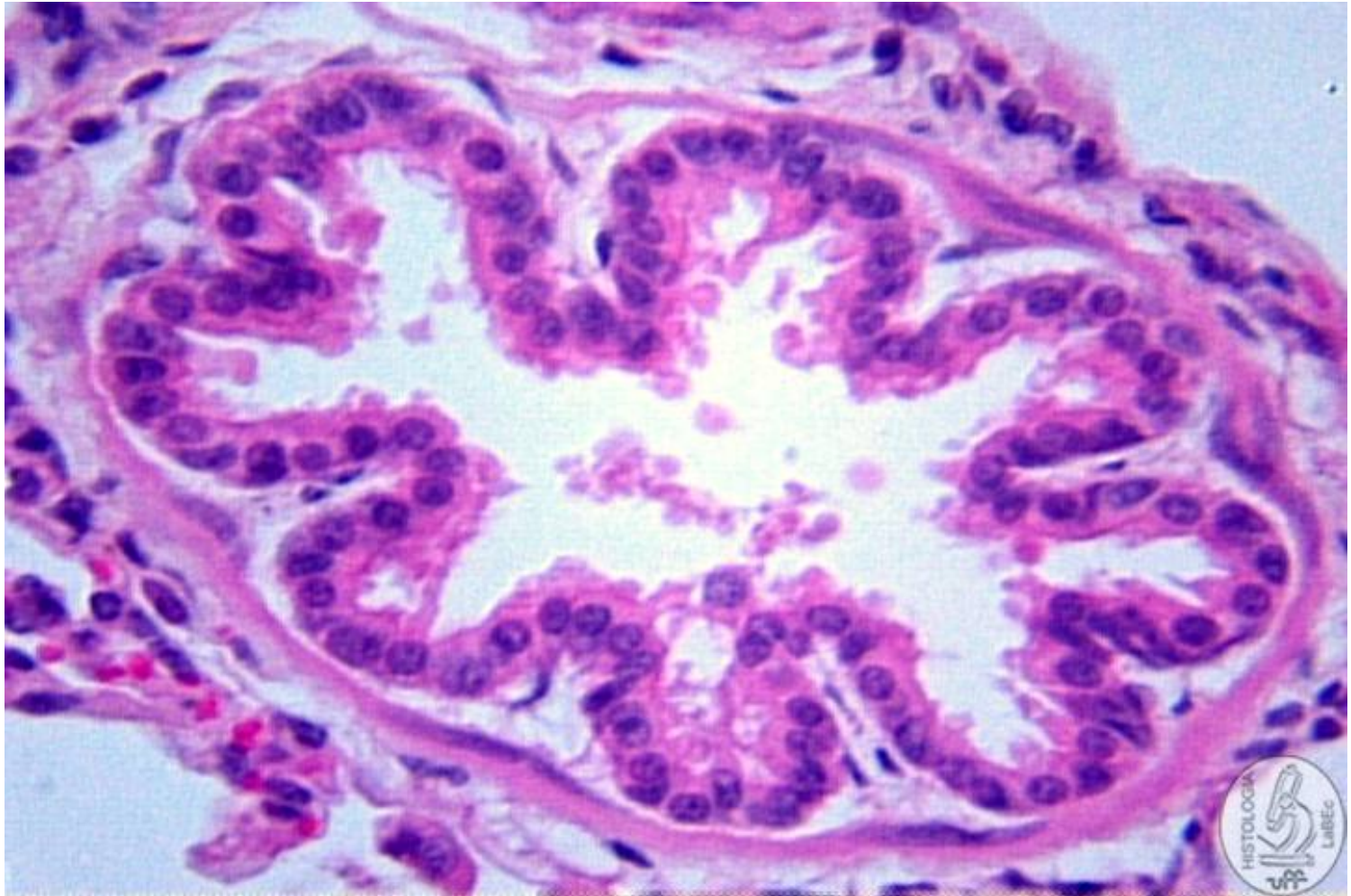


Electron micrograph (EM) of the respiratory mucosa. You can see the ciliated cells with interspersed Clara cells.

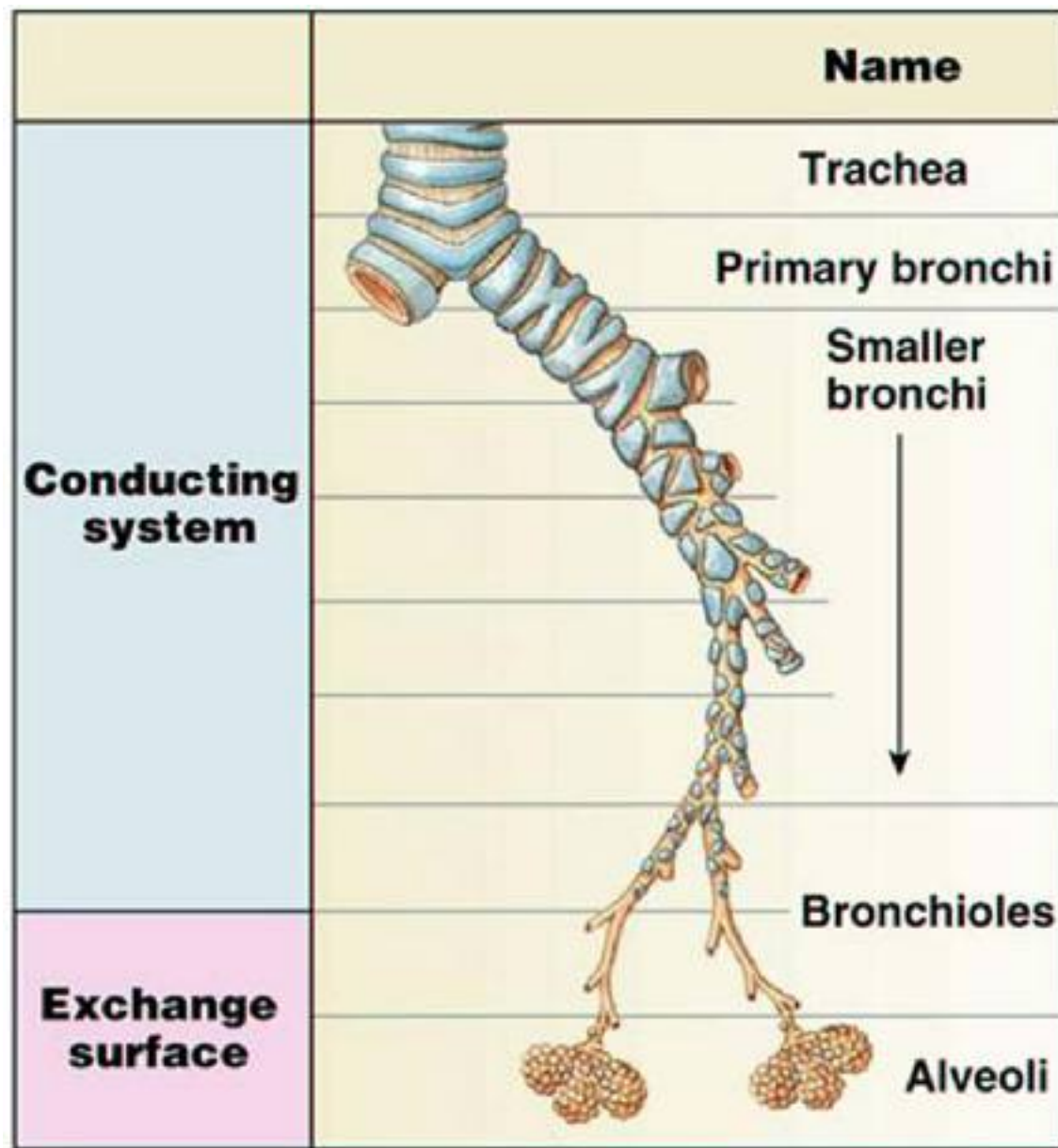
Bronchiole



Terminal bronchiole



Respiratory bronchioles and alveoli compose the gas exchange portion of the lung.



Respiratory portion

- Respiratory bronchioles: tubes between alveoli
- Alveolar ducts/alveolar sacs: arise from respiratory bronchioles but have more alveoli and terminate as blind pouches
- Alveoli: Thin-walled pouches lined by type I / type II pneumocytes

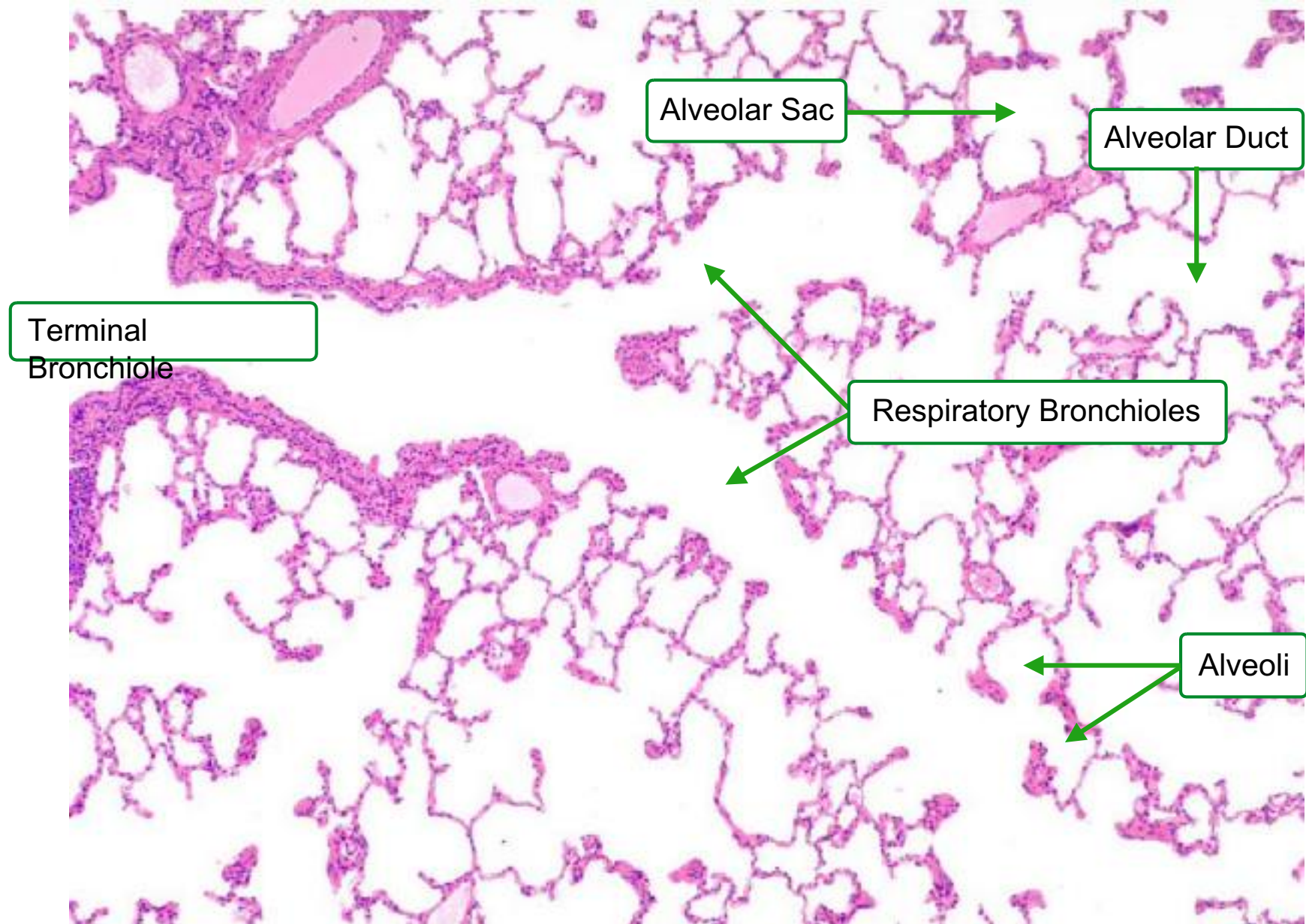
Function:

- Gas Exchange

Respiratory Portion: Respiratory Bronchioles

- Tertiary bronchioles give rise to respiratory bronchioles
- First airways to function in gas exchange
- Lined by cuboidal cells and connect to alveoli and alveolar ducts

The gas exchange portion comprises respiratory bronchioles, alveolar ducts and sacs and alveoli.

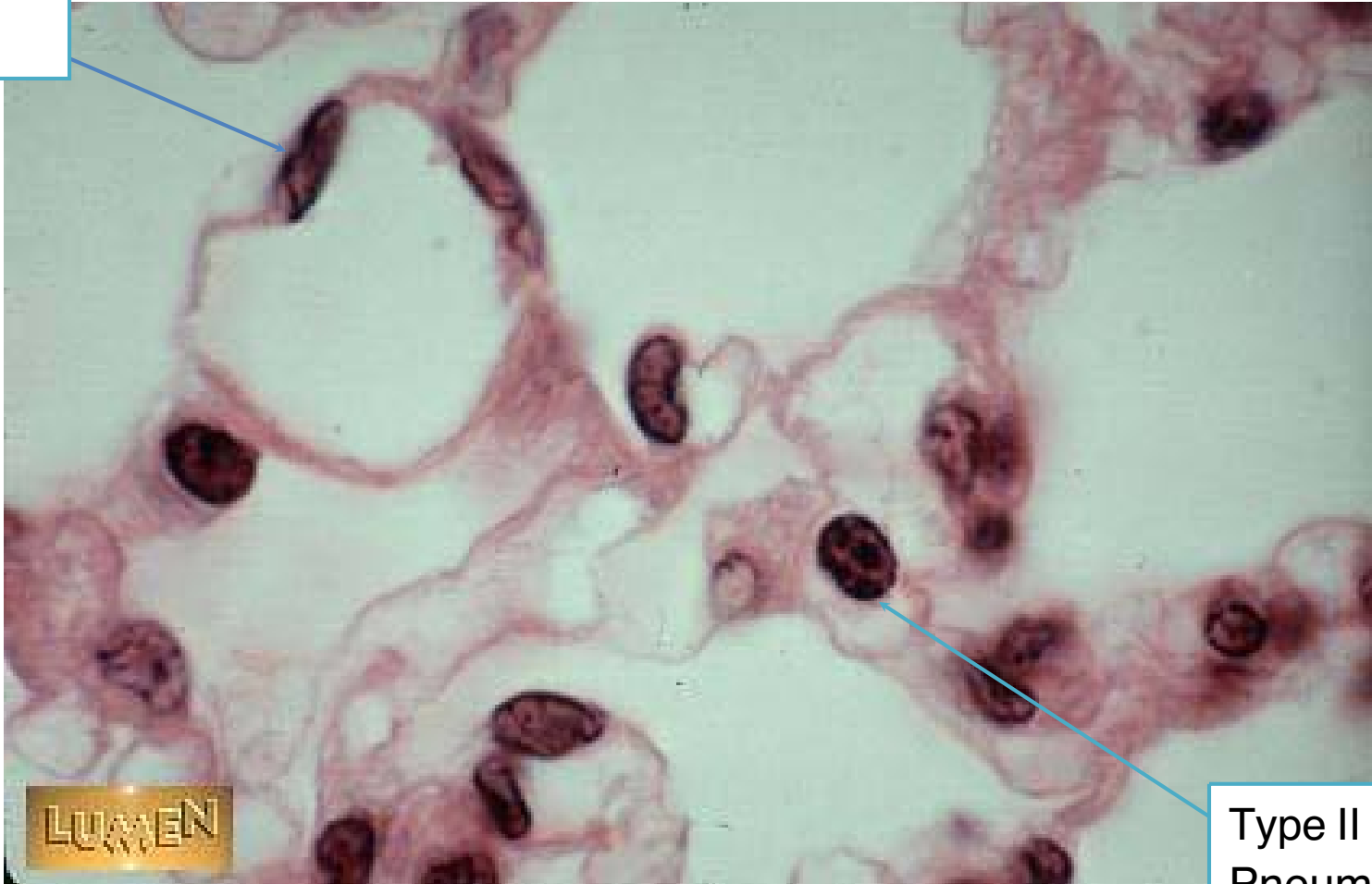


Respiratory Portion: Alveolar ducts and alveoli

- Ducts are lined by squamous alveolar cells (type I pneumocytes) with knobs of cuboidal cells
 - Each duct functions as a corridor to connect several alveoli
- Alveoli
 - 95%-97% Type I pneumocytes: flat dark oval nucleus and thin cytoplasm
 - Small percentage of Type II pneumocytes: can divide and replace type I cells – large polygonal cells at corner of alveoli. Secrete components of pulmonary surfactant.
 - Lined by septa = blood-air barrier for gas exchange formed by delicate connective tissue and capillaries
 - Alveolar macrophages: dust cells, located in septa, often contain phagocytized material

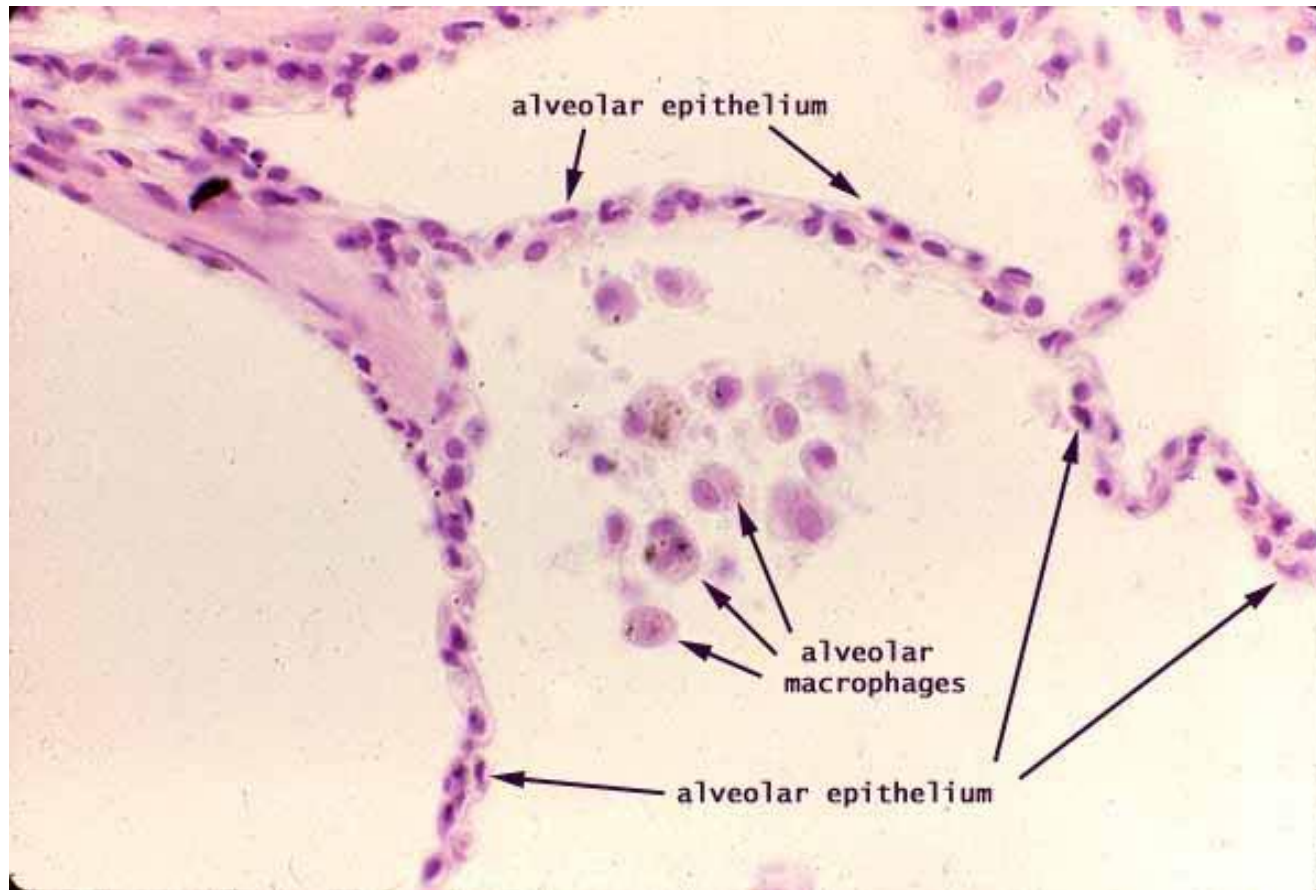
Alveolar spaces - Septa

Type I
Pneumocytes

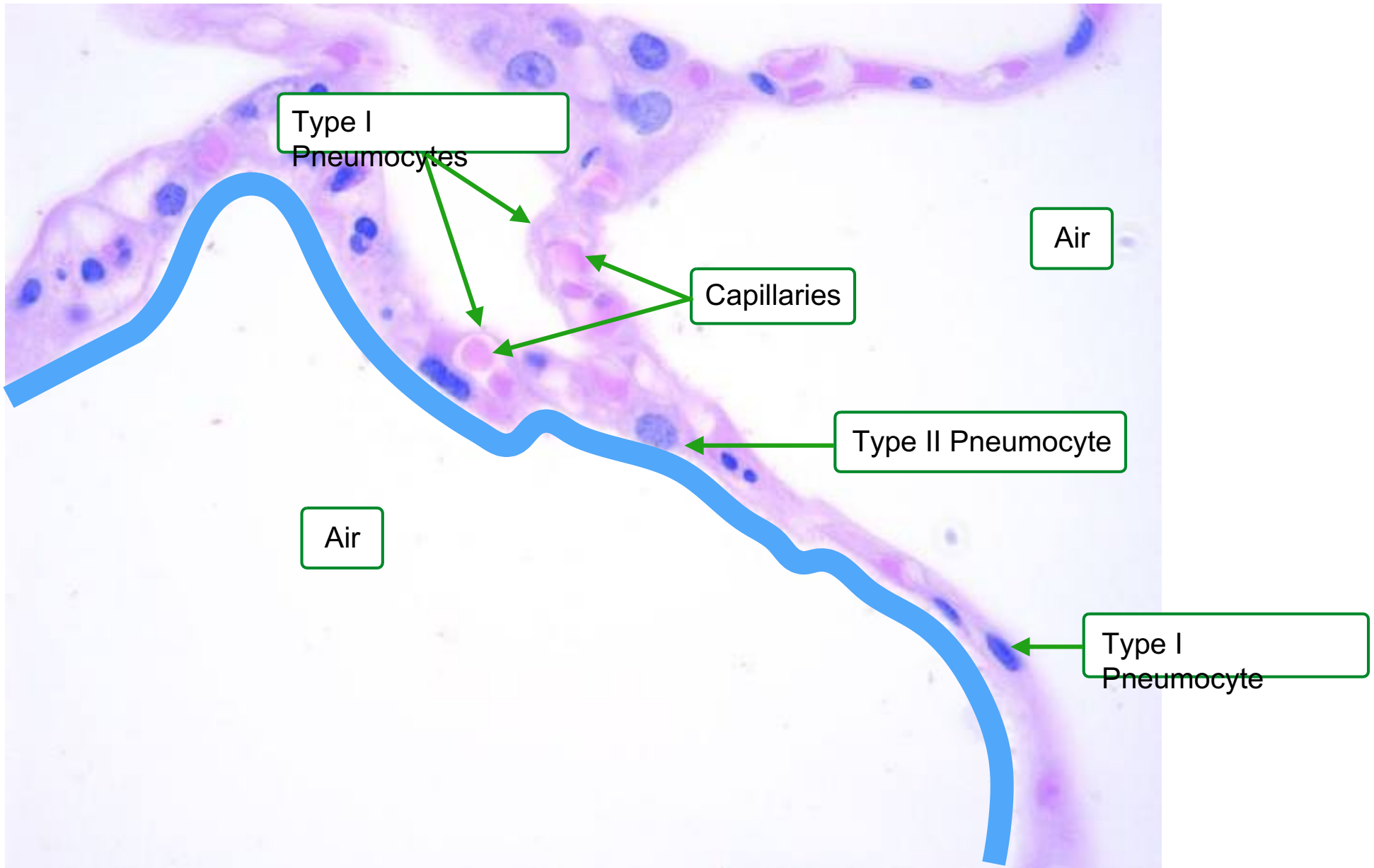


Type II
Pneumocyte

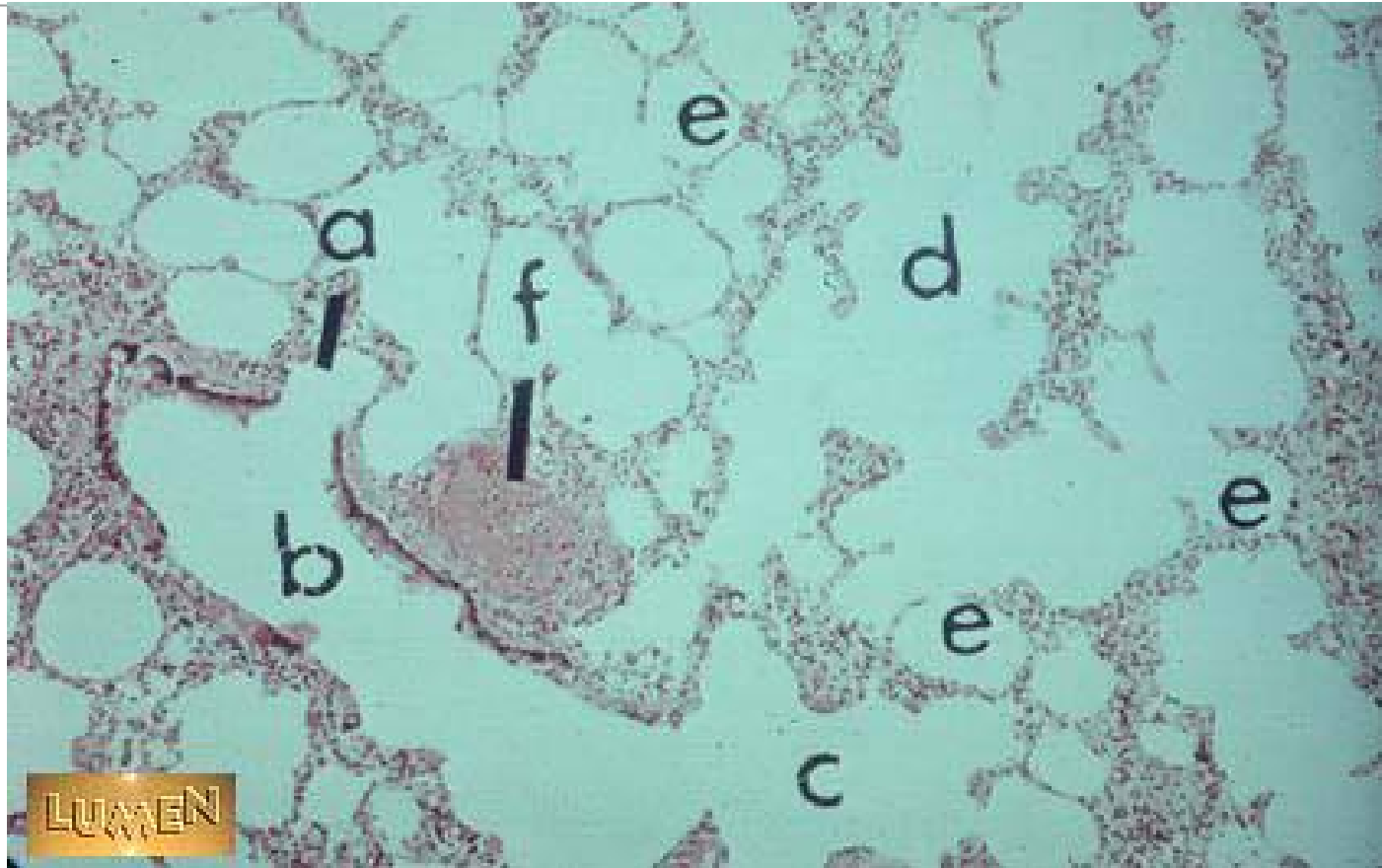
Alveolar Macrophages



Walls of alveoli consist of pneumocytes, capillaries and connective tissue.

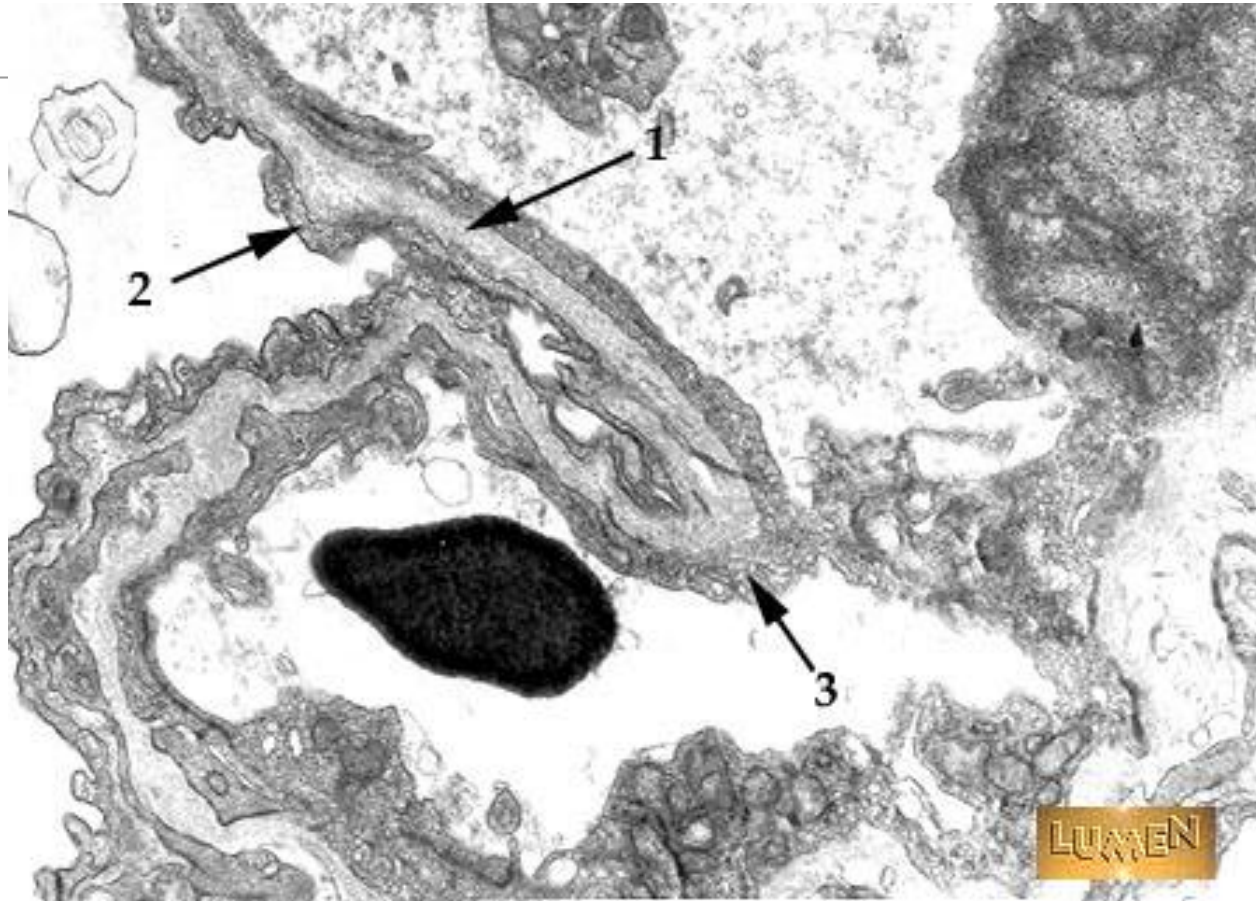


Respiratory bronchioles, alveolar ducts, and alveoli



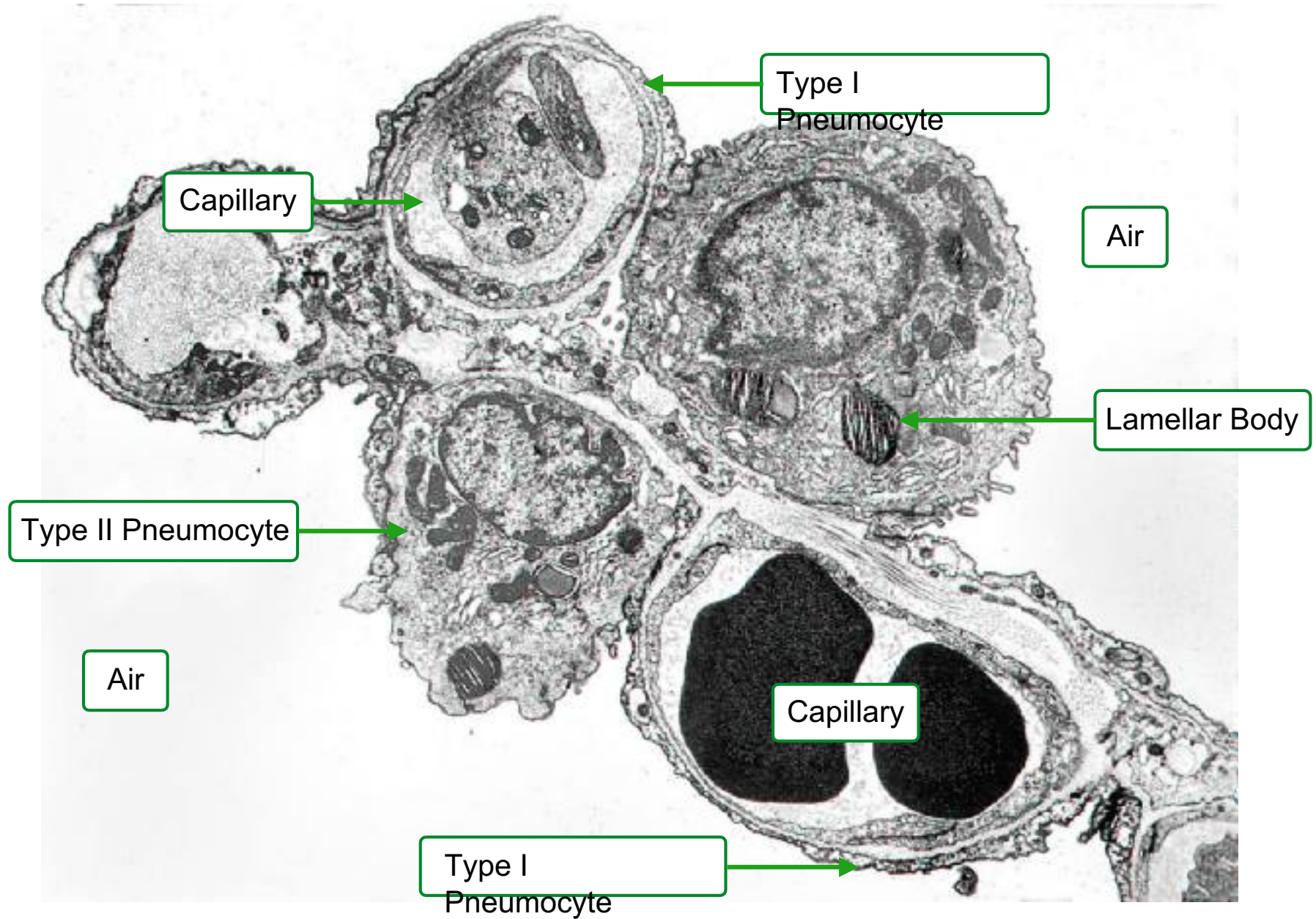
- b = respiratory bronchiole with alveolus (a) in its wall. Most of the wall of the bronchiole has a definite line of dark along it, signifying a cuboidal epithelium d & c = alveolar duct. Its wall consists almost entirely of alveoli, which have only a simple squamous lining, too flat to be visible here.
- e = alveoli (the smallest respiratory units)
- f = blood vessel (branch of pulmonary artery still)

Illustrative EM

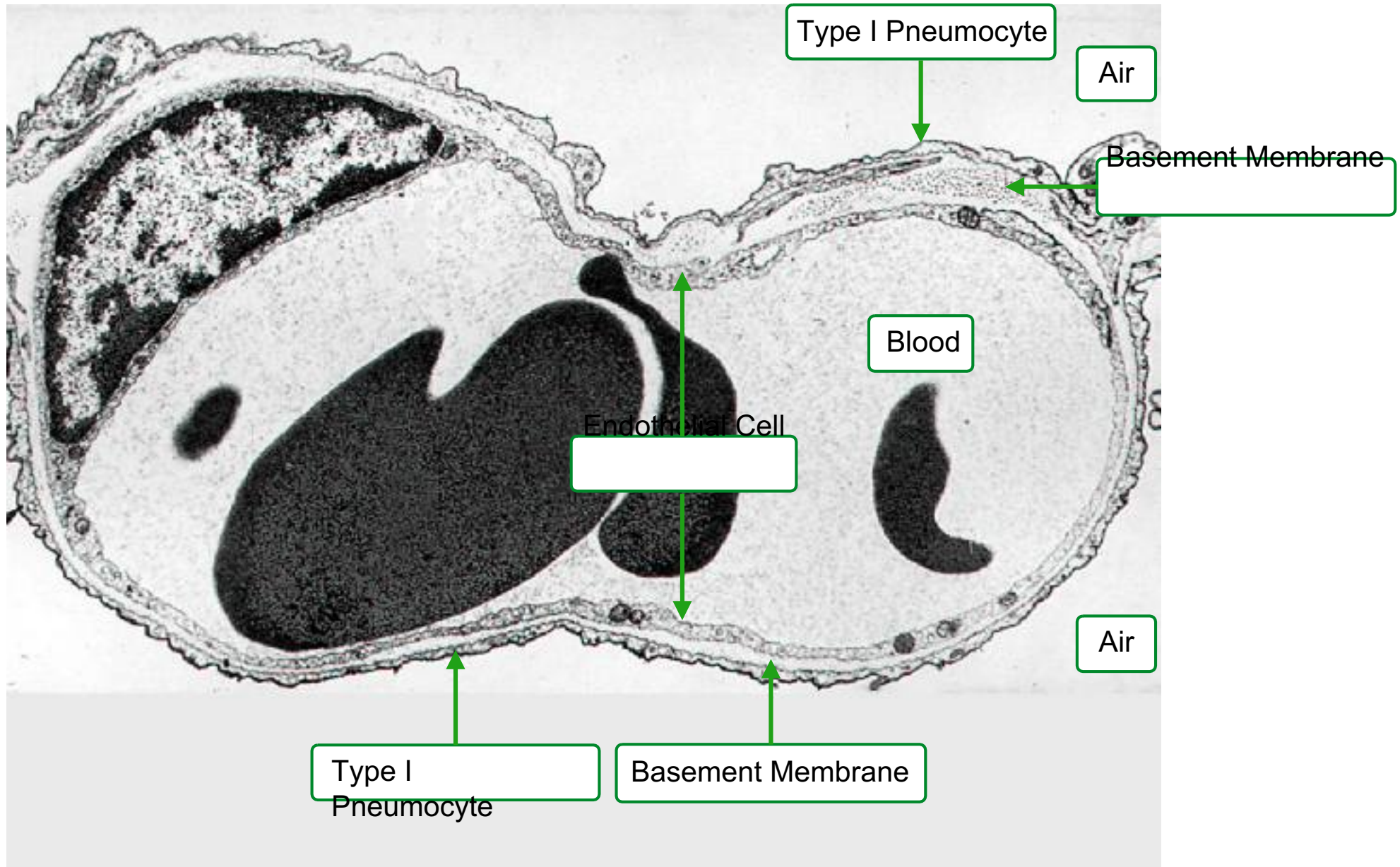


EM showing basal lamina (1) between squamous alveolar epithelium (2 = Type I cell) and capillary endothelium (3). The nucleus at upper right belongs to the endothelial cell lining the capillary. The dark structure is a red blood cell. The capillary plus the alveolar linings on both sides constitute the *inter alveolar septum* that lies between two alveolar spaces.

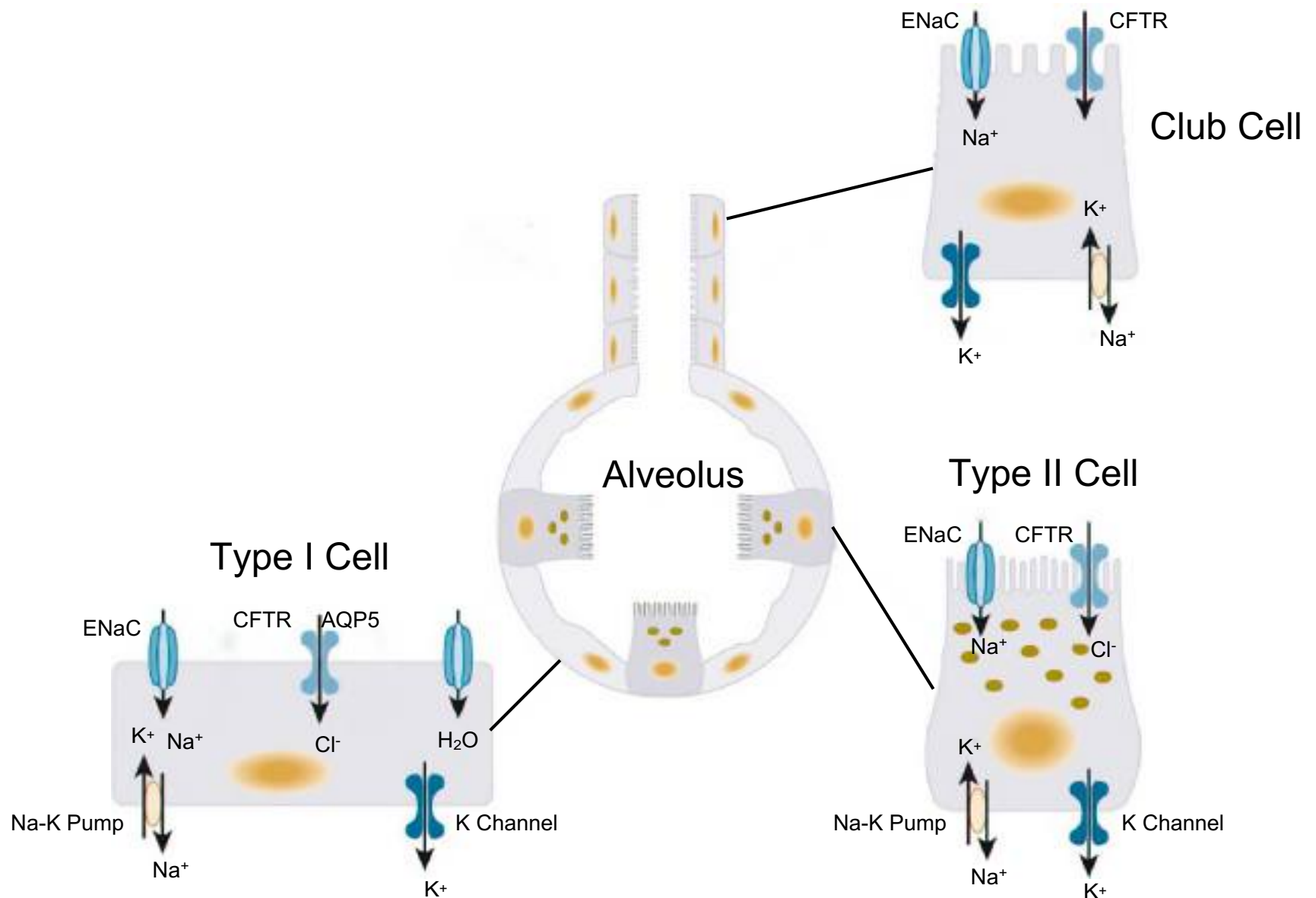
Type I pneumocytes are squamous and surround capillaries; type II pneumocytes are cuboidal.



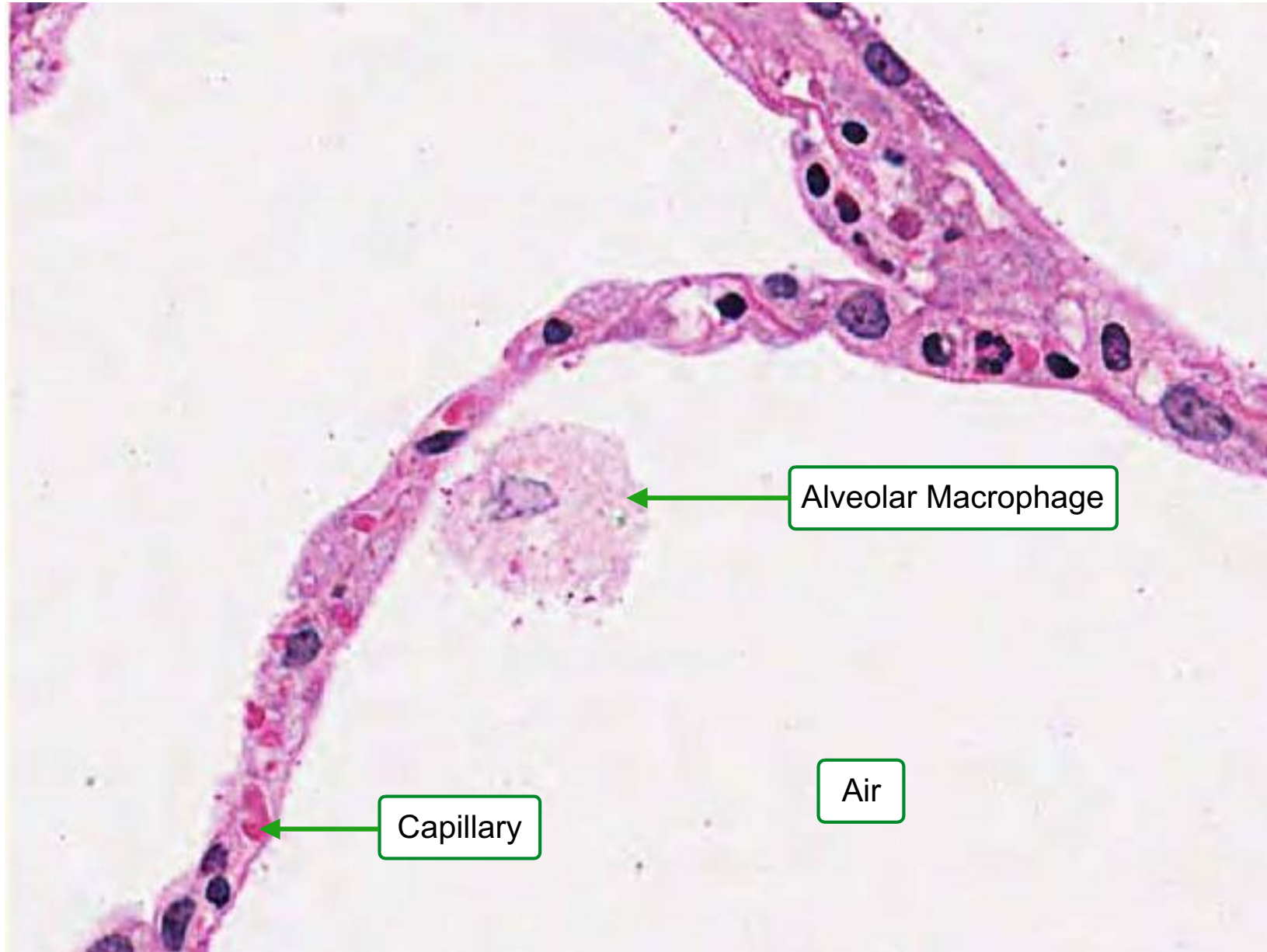
The gas exchange barrier comprises type I pneumocyte, basement membrane and endothelium.



Type I and type II pneumocytes absorb fluid from the lumen via vectorial transport of sodium and chloride.

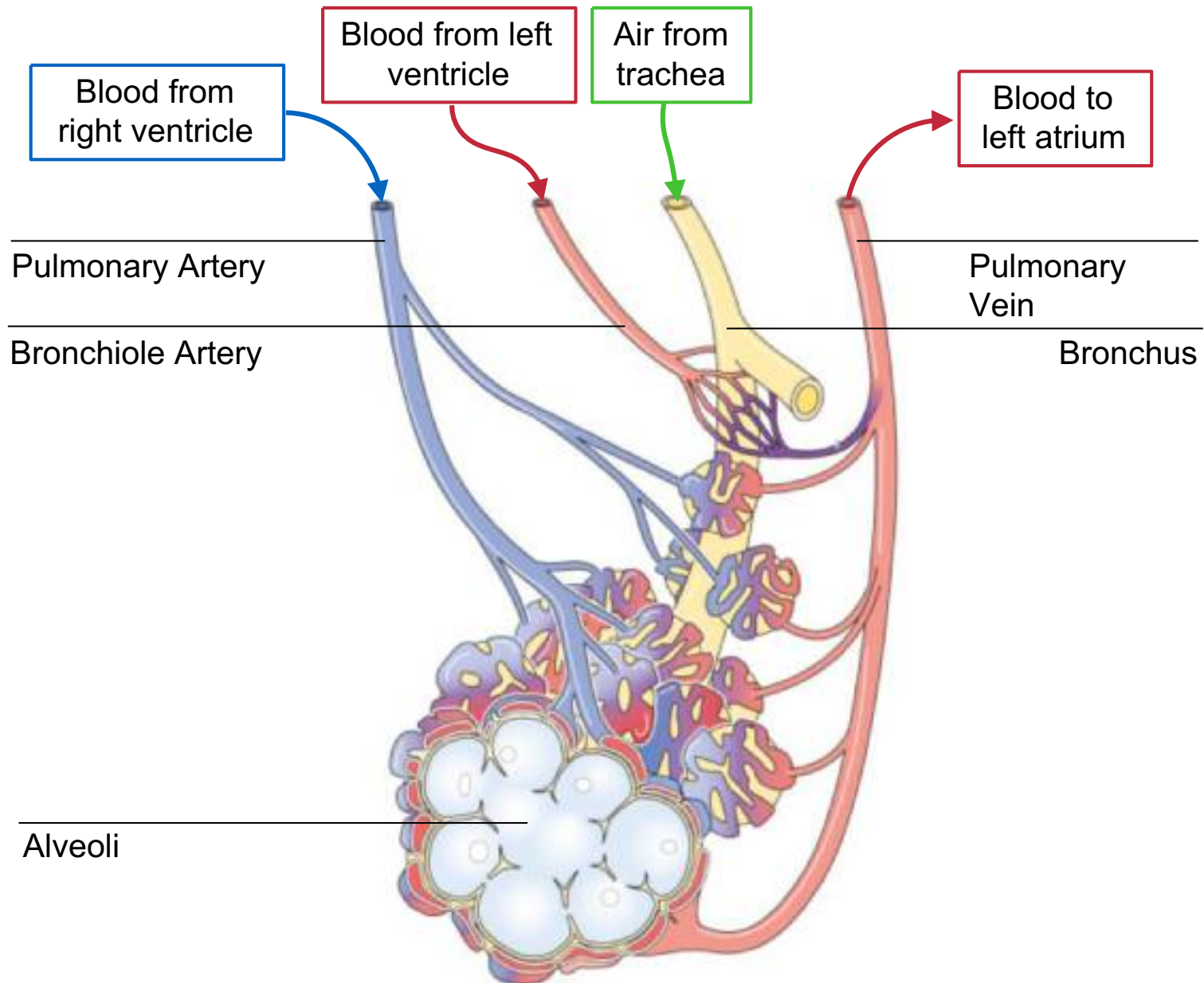


Alveolar macrophages (dust cells) reside in the airway and engulf particles and microorganisms.



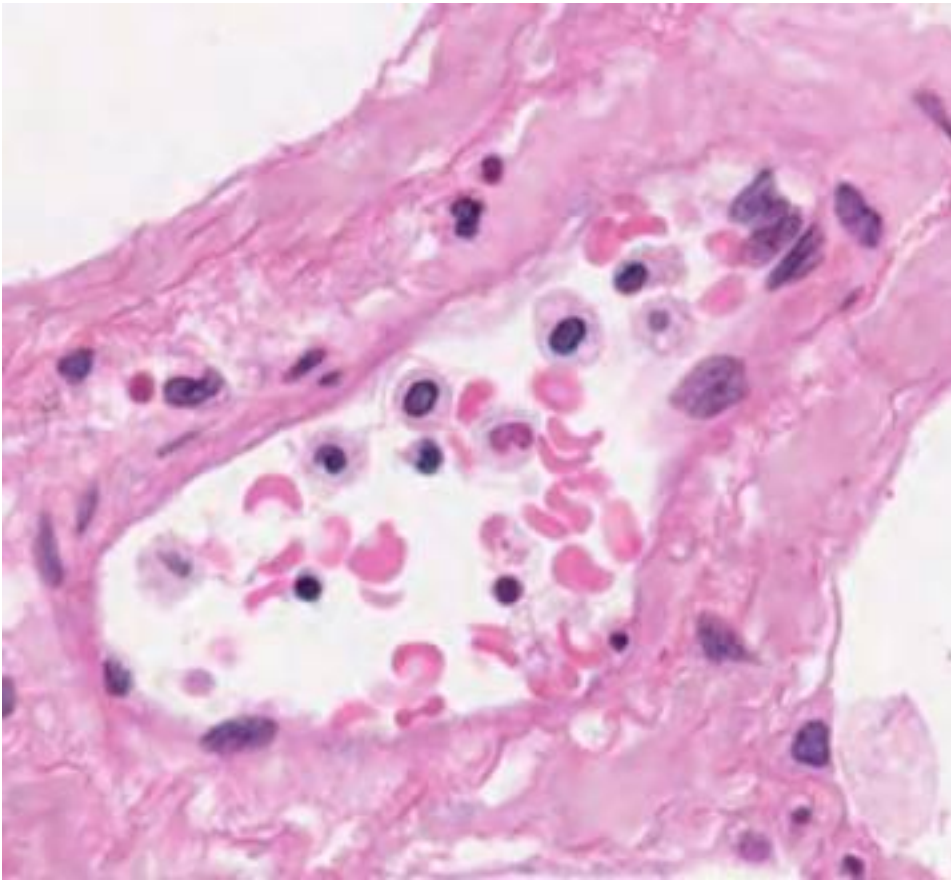
Pulmonary Circulation

Pulmonary system delivers deoxygenated blood and bronchial system delivers oxygenated blood.

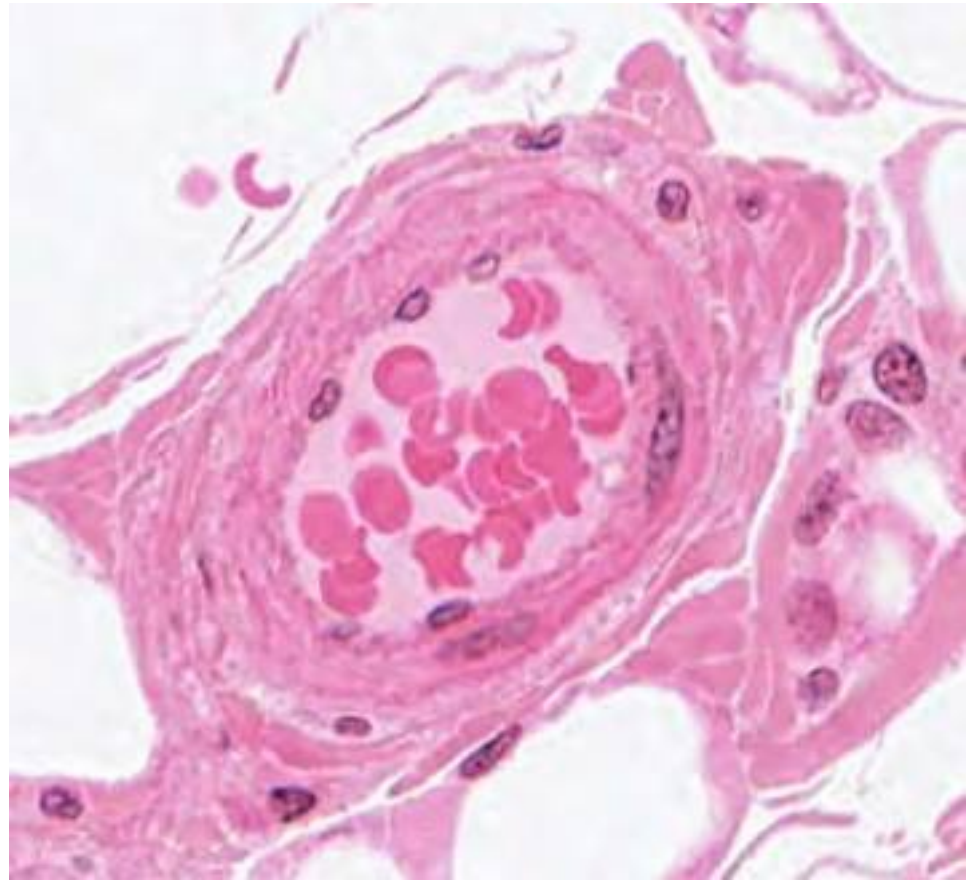


Pulmonary arterioles have thinner walls and generate less resistance than typical arterioles.

Pulmonary Arteriole

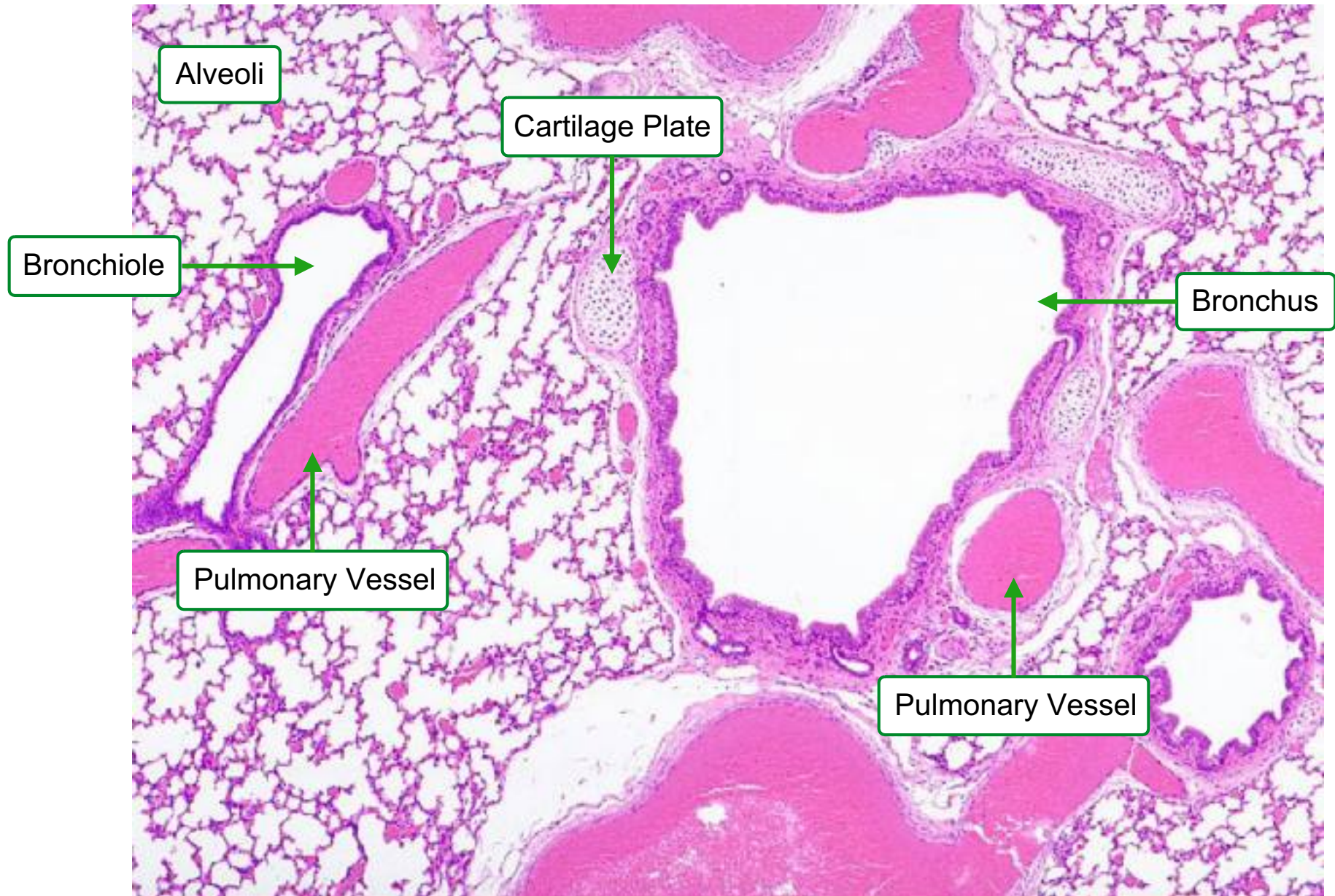


Typical Arteriole

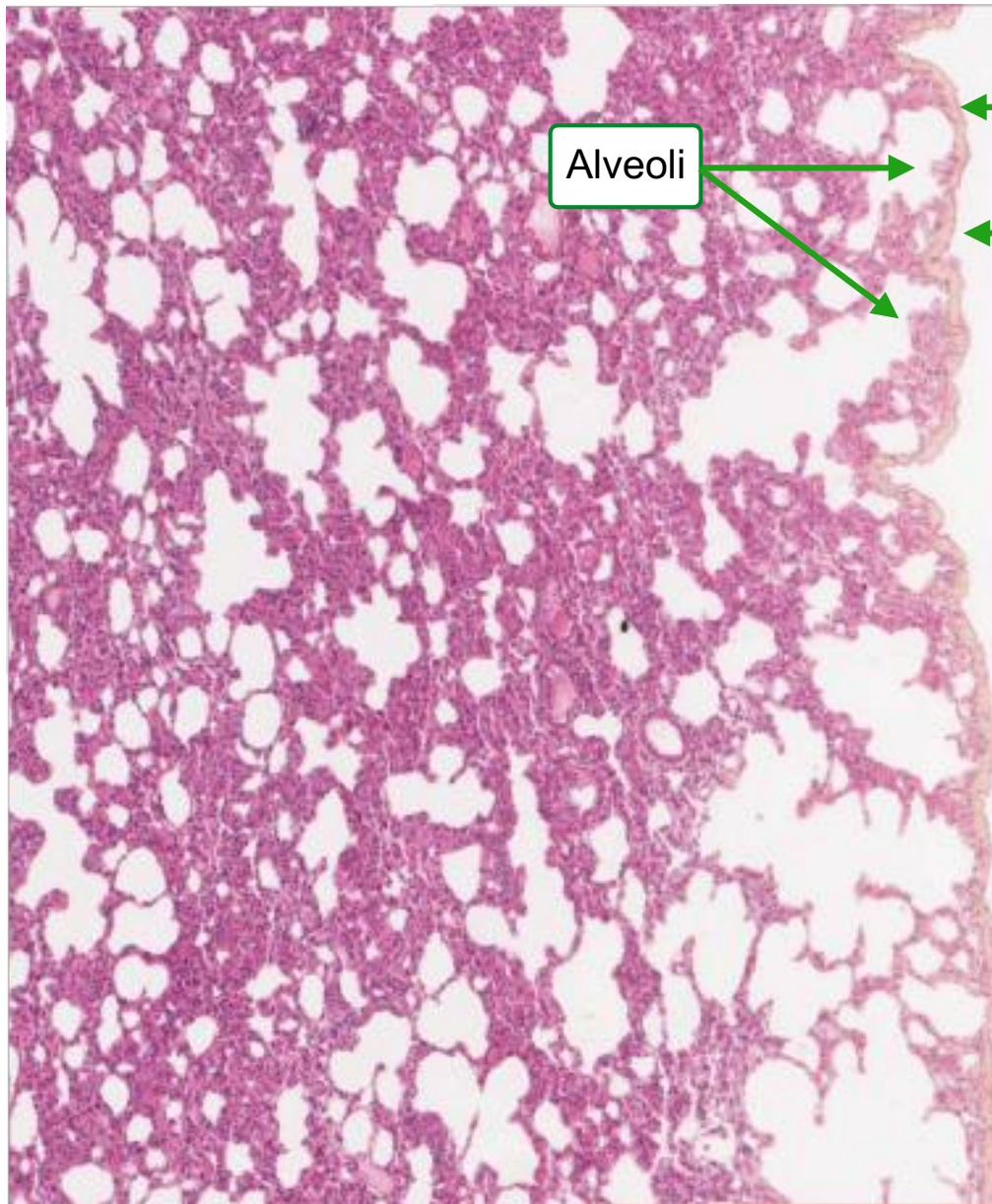


Structural arrangement of airways

Lung section reveals bronchus, bronchioles, alveoli and pulmonary vessels.



Composition and structure of alveoli determine compliance of lung.



Alveoli

Pleural Surface

Intrapleural Fluid

Lung Volume Change

Compliance

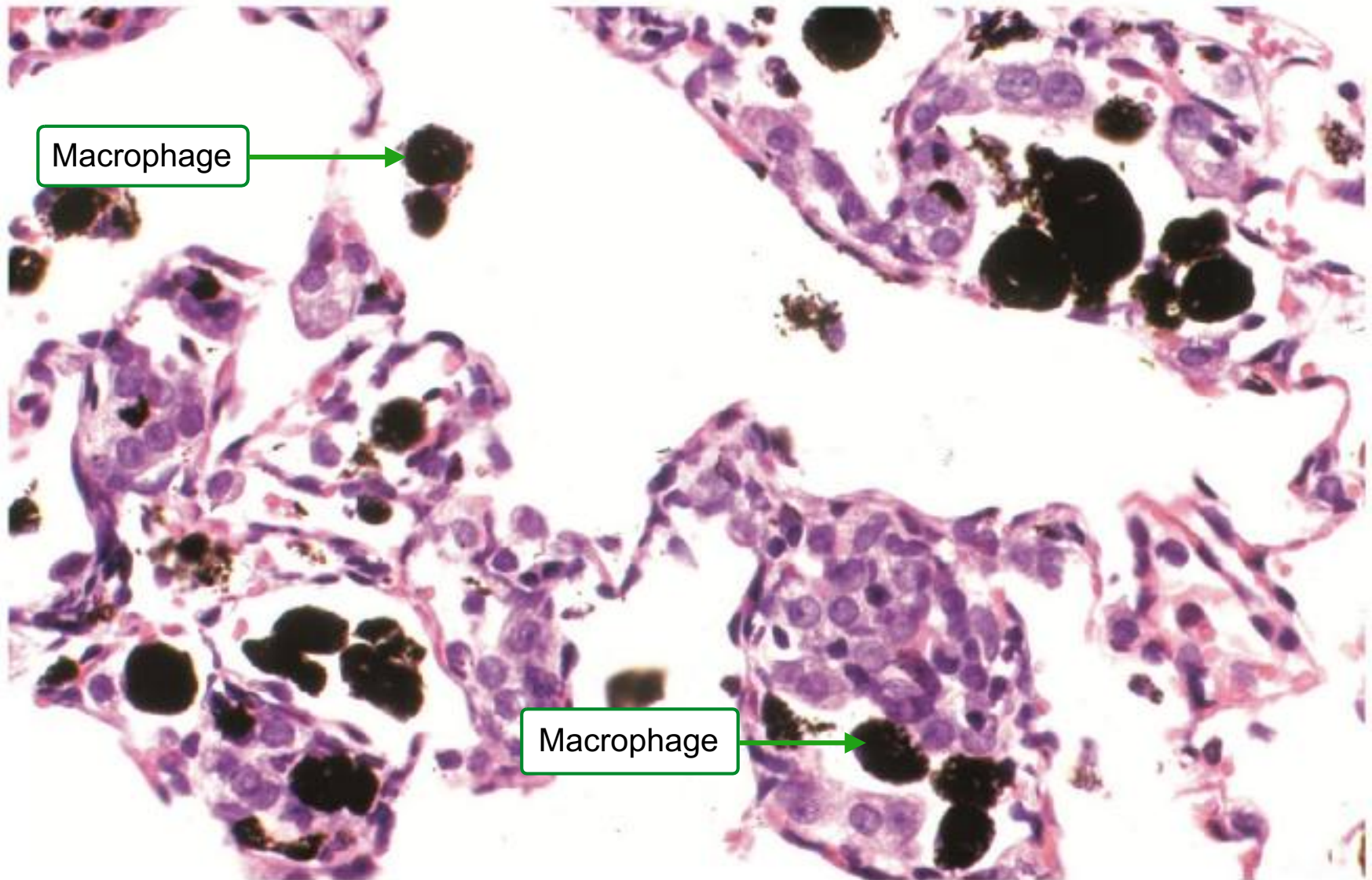
$$C = \frac{\Delta V}{\Delta P}$$

Intrapleural Pressure Change

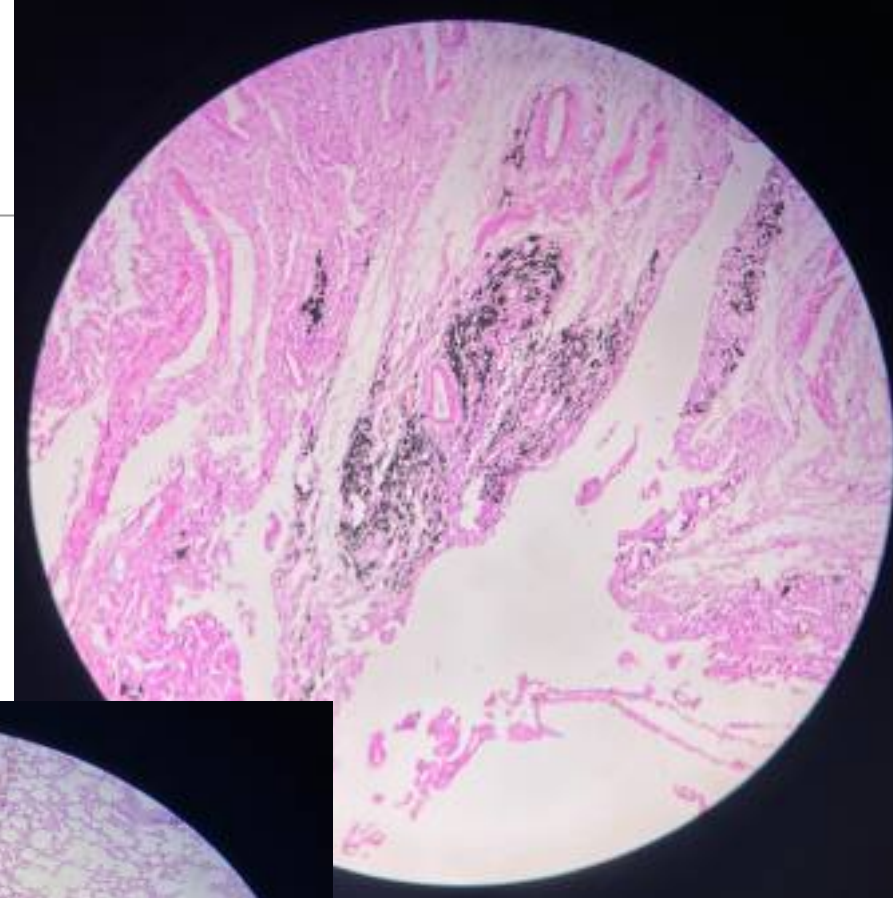
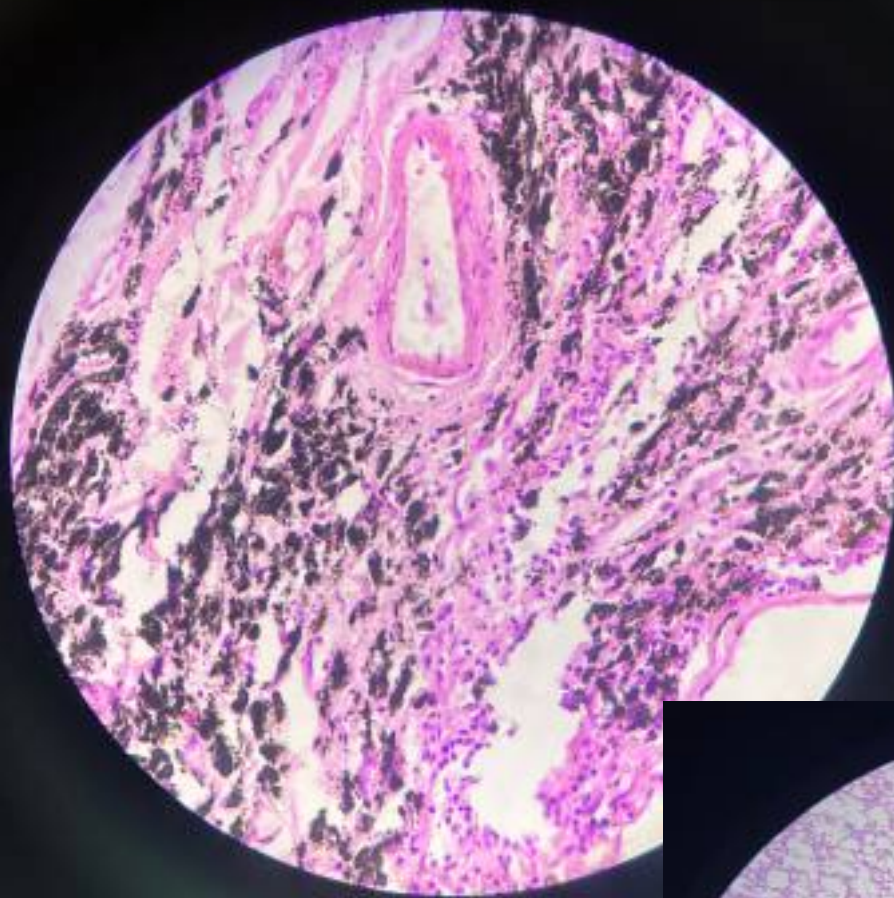
Factors that Affect Compliance

- Alveolar surface tension
- Alveolar elastic fibers
- Alveolar collagen fibers

Macrophages engulf inhaled foreign particles.



Smoker's Lung



Normal Lung

