

# THE RESPIRATORY SYSTEM:

- 1-The respiratory system includes the **lungs** and a branching system of tubes that link the sites of gas exchange with the external environment.
- 2-Air is moved through the lungs by a ventilating mechanism, consisting of the thoracic cage, intercostal muscles, diaphragm, and elastic components of the lung tissue.
- 3-The respiratory system is divided anatomically into structures of the upper and lower respiratory tracts.

4-these structures make up the system's **conducting portion**, which consists of the nasal cavities, nasopharynx, larynx, trachea, bronchi, bronchioles, and terminal bronchioles; and a **respiratory portion**, consisting of respiratory bronchioles, alveolar ducts, and alveoli.

**5-Alveoli** are saclike structures that make up the greater part of the lungs. They are the main sites for the principal function of the lungs—the exchange of O<sub>2</sub> and CO<sub>2</sub> between inspired air and blood.

# **RESPIRATORY EPITHELIUM.**

Most of the conducting portion is lined with ciliated pseudostratified columnar epithelium known as **respiratory epithelium** . This epithelium has at least five cell types, all of which touch the thick basement membrane:

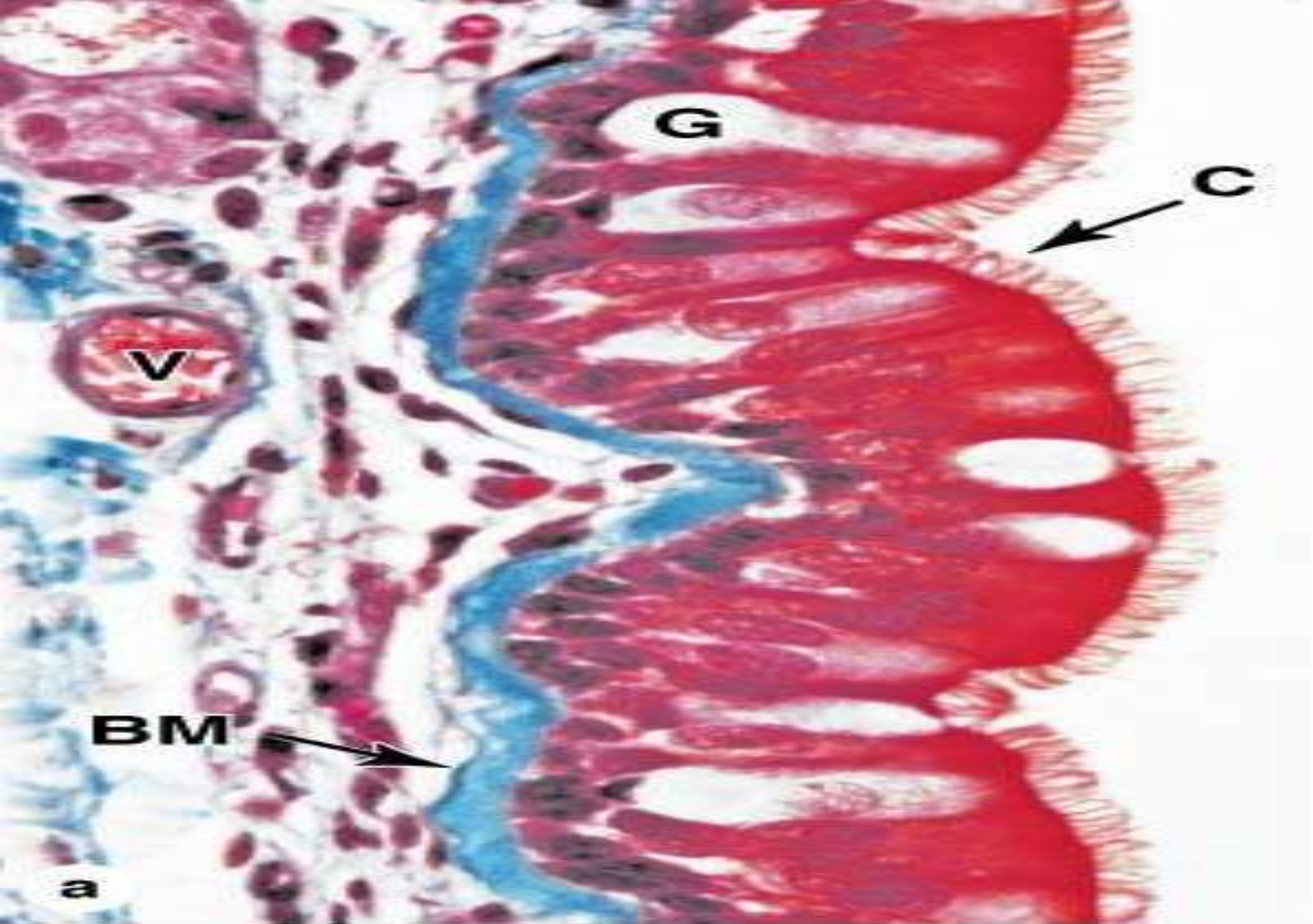
**1-Ciliated columnar cells** are the most abundant, each with about 300 cilia on its apical surface .

**2-Goblet cells** are also abundant in some areas of the respiratory epithelium , filled in their apical portions with granules of mucin glycoproteins.

**3-Brush cells** are a much more sparsely scattered and less easily found, columnar cell type, which has a small apical surface bearing a tuft of many short, blunt microvilli . receptors.

**4-Small granule cells** are also difficult to distinguish in routine preparations, but possess numerous dense core granules . Like brush cells, they represent about 3% of the total cells and are part of the diffuse neuroendocrine system .

**5-Basal cells**, small rounded cells on the basement membrane and not extending to the luminal surface, are stem cells that give rise to the other cell types.



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# NASAL CAVITIES:

- 1-The left and right nasal cavity each has two components: the external **vestibule** and the internal **nasal cavities (or fossae)**. The vestibule is the most anterior and dilated portion of each nasal cavity.
- 2- Skin of the nose enters the **nares** (nostrils) partway up the vestibule and has sweat glands, sebaceous glands, and short coarse **vibrissae** (hairs) that filter out particulate material from the inspired air.
- 3-Within the vestibule, the epithelium loses its keratinized nature and undergoes a transition into typical respiratory epithelium before entering the nasal fossae.
- 4-The nasal cavities lie within the skull as two cavernous chambers separated by the osseous **nasal septum**. Extending from each lateral wall are three bony shelf like **projections** called **conchae**.

5-The middle and inferior conchae are covered with respiratory epithelium; the superior conchae are covered with a specialized **olfactory epithelium**.

6-The narrow passages between the conchae improve the conditioning of the inspired air by increasing the surface area of moist, warm respiratory epithelium and by slowing and increasing turbulence in the airflow. **The result is increased contact between air streams and the mucous layer.**

7-Within the lamina propria of the **conchae are large venous plexuses known as swell bodies**. Every 20–30 minutes, the swell bodies on one side become temporarily engorged with blood, resulting in distension of the conchal mucosa and a concomitant decrease in the flow of air. **During this time, most of the air is directed through the other nasal fossa**, allowing the engorged respiratory mucosa to recover from dehydration.



## **Smell (Olfaction):**

1-The olfactory chemoreceptors are located in the **olfactory epithelium**, a specialized region of the mucous membrane covering the superior conchae at the roof of the nasal cavity.

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

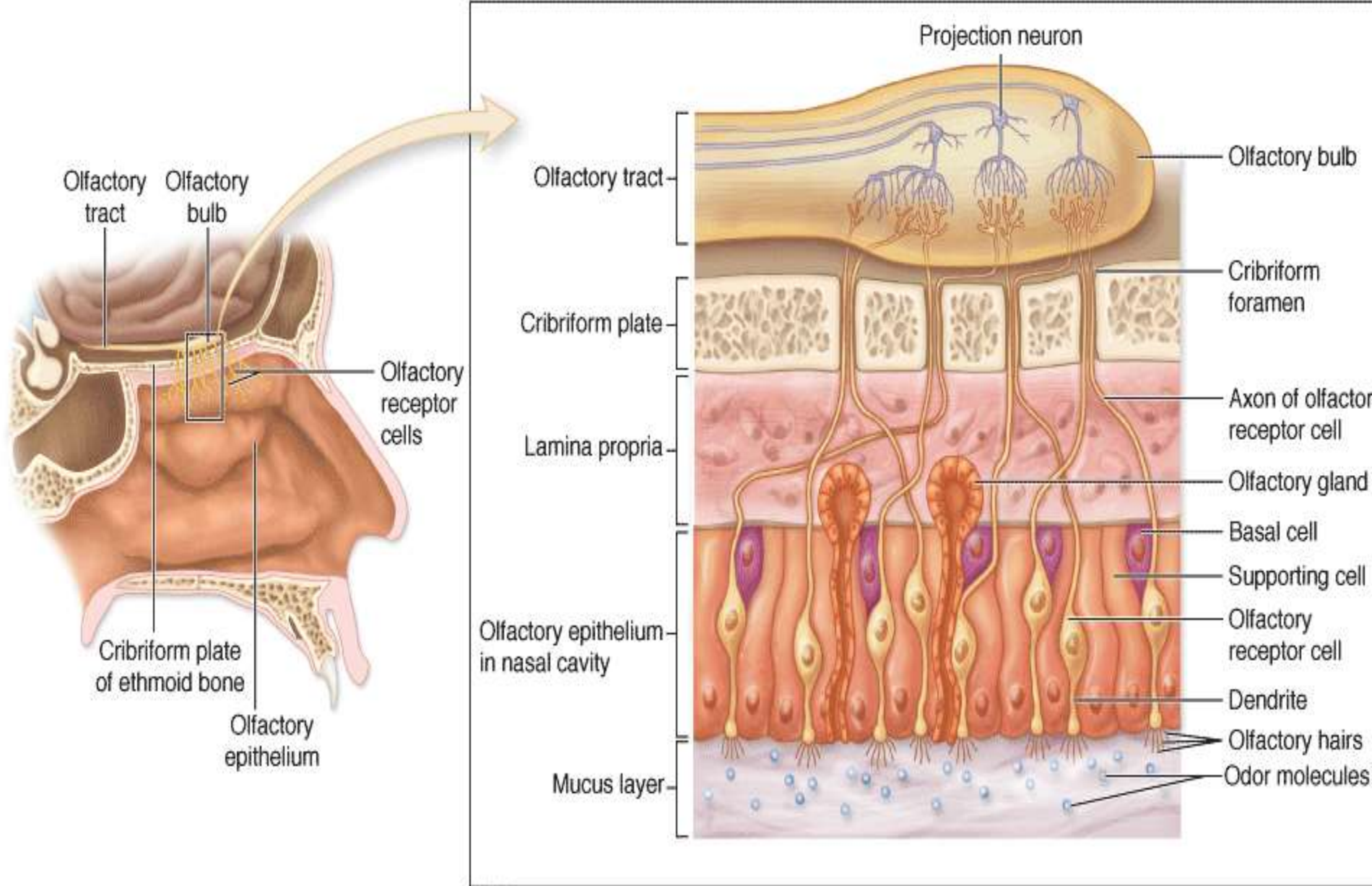
**i)Basal cells** are small, spherical or cone-shaped and form a layer at the basal lamina. They are the stem cells for the other two types.

**ii)Supporting cells** are columnar, with broad, cylindrical apices and narrower bases. On their free surface are microvilli submerged in a fluid layer.

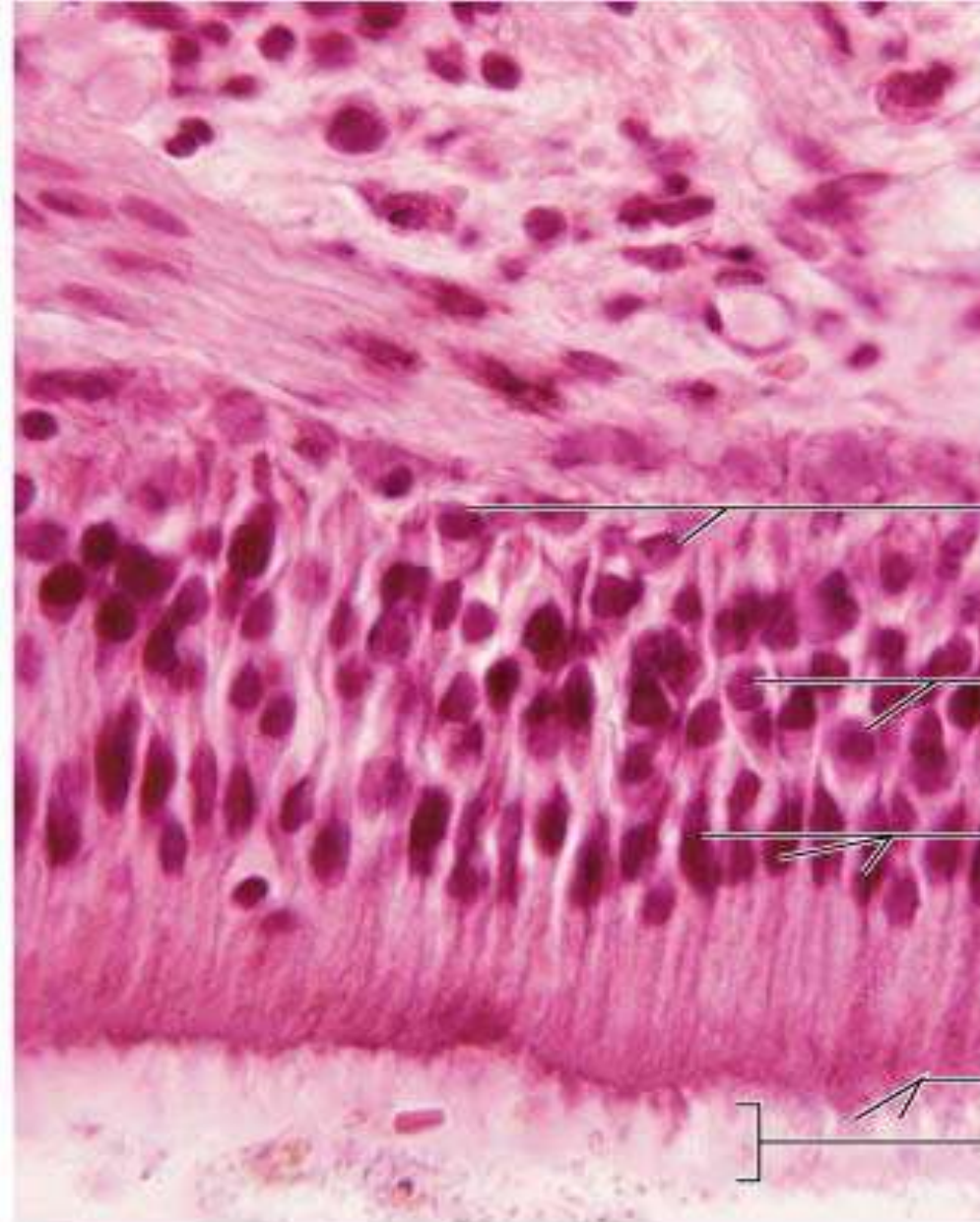


**iii) Olfactory neurons** are bipolar neurons present throughout this epithelium.

**a)** They are distinguished from supporting cells by the position of their nuclei, which lie between those of the supporting cells and the basal cells. **b)** The dendrite end of each olfactory neuron is the apical (luminal) pole of the cell and has a knoblike swelling with about a dozen basal bodies. **c)** From the basal bodies emerge long non motile cilia with defective axonemes but a considerable surface area for membrane chemoreceptors. **d)** These receptors respond to odoriferous substances by generating an action potential along the (basal) axons of these neurons, **e)** There they form cranial nerve I, the olfactory nerve, and eventually synapse with other neurons in the olfactory bulb.



a



Lamina propria

Basal cell nuclei

Olfactory receptor  
cell nuclei

Supporting cell nuclei

Olfactory hairs

Mucus

**b**

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# SINUSES & NASOPHARYNX:

- i)* **The paranasal sinuses** are bilateral cavities in the frontal, maxillary, ethmoid, and sphenoid bones of the skull . They are lined with a thinner respiratory epithelium with fewer goblet cells.
- ii)* **The lamina propria** contains only a few small glands and is continuous with the underlying periosteum.
- iii)* **The paranasal sinuses** communicate with the nasal cavities through small openings and mucus produced in the sinuses is moved into the nasal passages by the activity of the ciliated epithelial cells.

# LARYNX:

1-The **larynx** is a rigid, short (4 cm x 4 cm) passage for air between the pharynx and the trachea . Its wall is reinforced by hyaline cartilage (in the thyroid, cricoid, and the inferior arytenoid cartilages) and smaller elastic cartilages (in the epiglottis, cuneiform, corniculate, and the superior arytenoid cartilages), all connected by ligaments.

2-In addition to maintaining an open airway, movements of these cartilages by skeletal muscles participate in sound production during phonation and the epiglottis serves as a valve to prevent swallowed food or fluid from entering the trachea.



3-The **epiglottis**, which projects from the upper rim of the larynx, extends into the pharynx and has lingual and laryngeal surfaces. The entire lingual surface and the apical portion of the laryngeal surface are covered with stratified squamous epithelium.

4-At variable points on the laryngeal surface of the epiglottis the epithelium undergoes a transition to ciliated pseudostratified columnar epithelium. Mixed mucous and serous glands are found in the lamina propria beneath the epithelium.

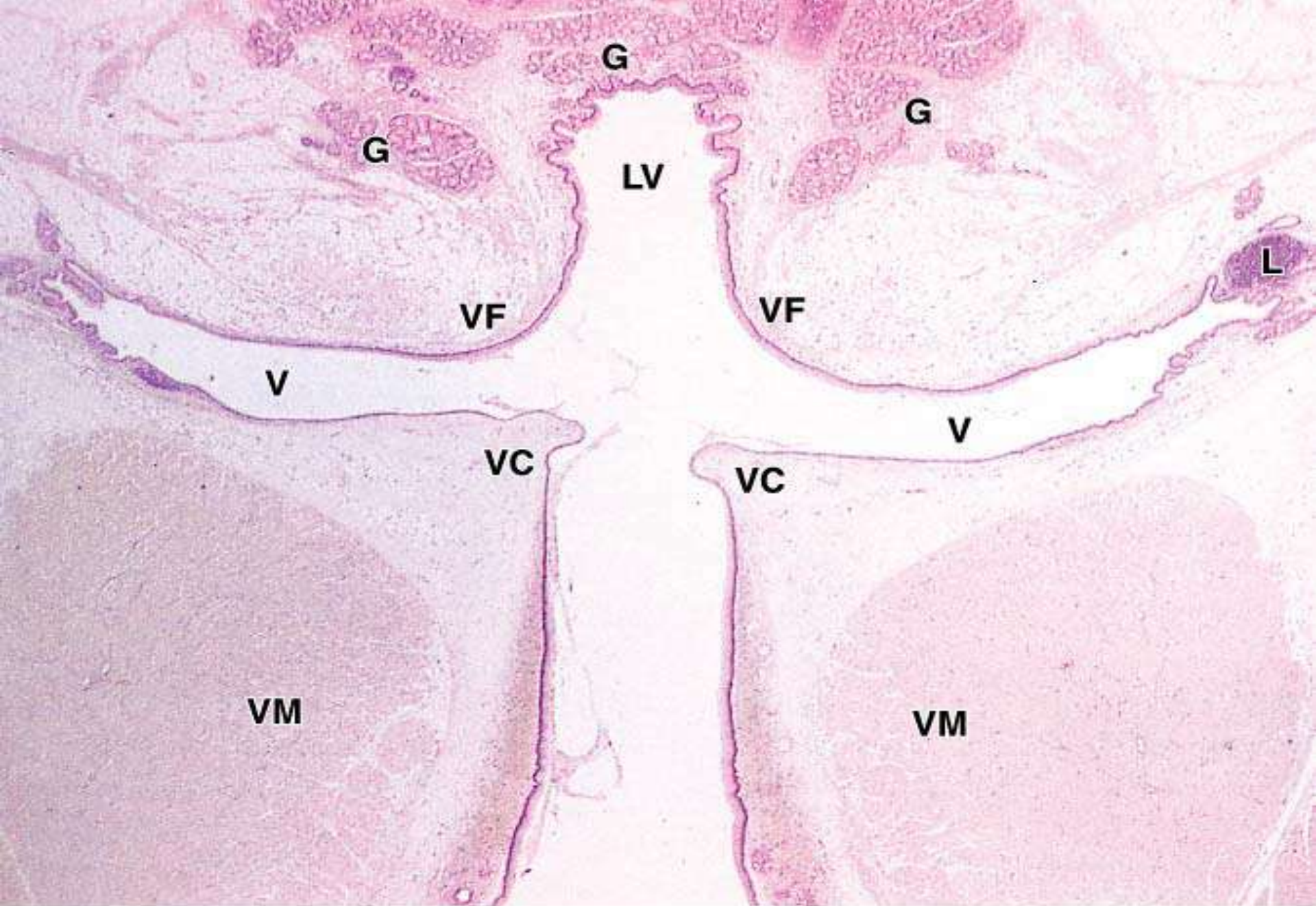
**5-Below the epiglottis**, the mucosa of the larynx extends two pairs of folds bilaterally into the **lumen**.

*i)*The upper pair, the **vestibular folds** or **false vocal cords**, is partly covered with typical respiratory epithelium beneath which lie numerous seromucous glands.

*ii)*The lower pair of folds constitutes the **vocal folds** or **vocal cords**. These are covered with stratified squamous epithelium and contain bundles of parallel elastic fibers (vocal ligament) and large bundles of striated **vocalis muscles**.

*iii)*The muscles regulate the tension of each vocal fold and its ligaments. As expelled air is forced between the folds, variable tension in these vocal cords produces different sounds.

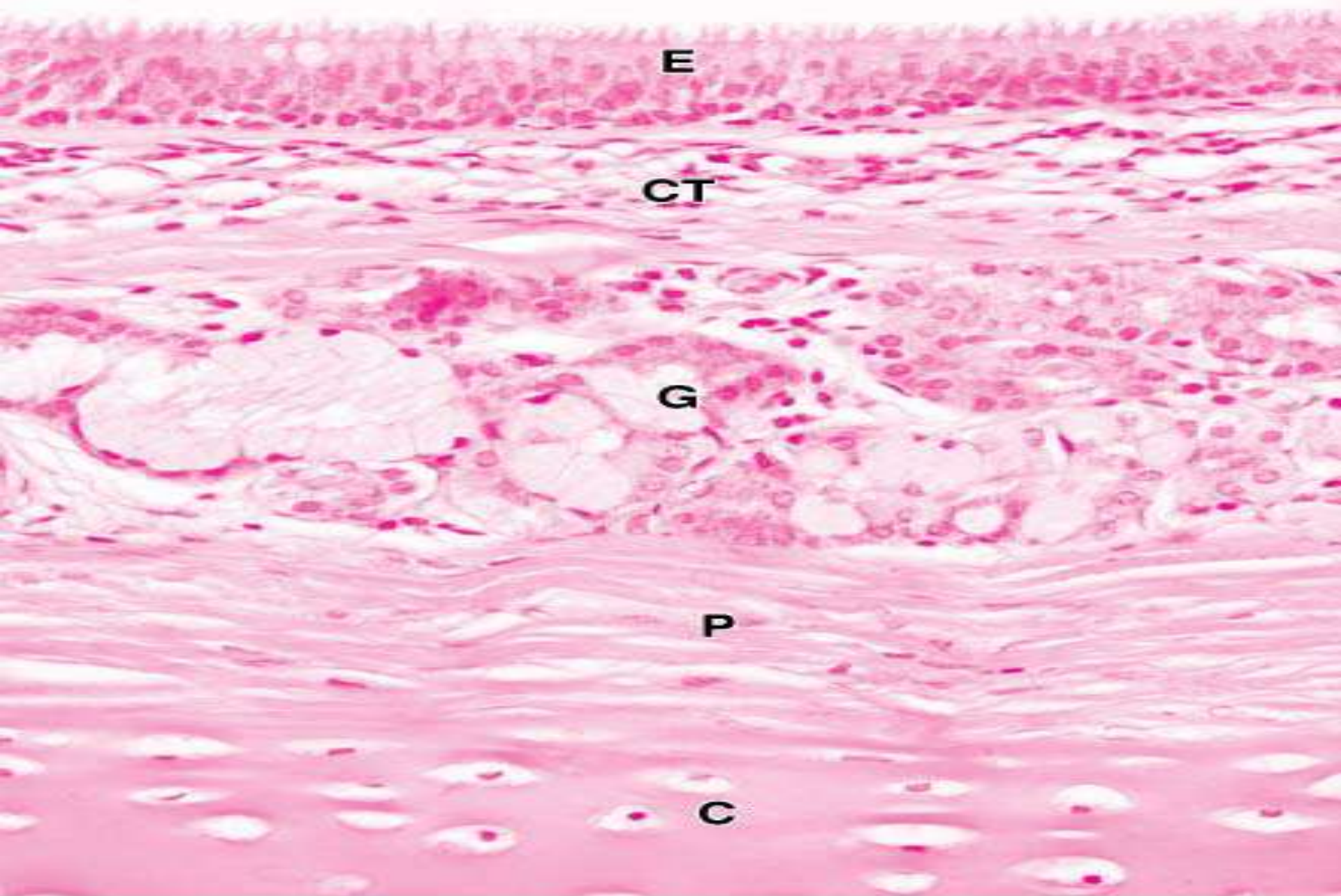




# TRACHEA:

1-The **trachea** is lined with a typical respiratory mucosa. In the lamina propria numerous seromucous glands produce watery mucus and in the submucosa 16–20 C-shaped rings of hyaline cartilage keep the tracheal lumen open . 2-The open ends of the cartilage rings are on the posterior surface, against the esophagus, and are bridged by a bundle of smooth muscle (**trachealis muscle**) and a sheet of fibroelastic tissue attached to the perichondrium. 3-The trachea relaxes during swallowing to facilitate the passage of food by allowing the esophagus to bulge into the lumen of the trachea, with the elastic layer preventing excessive distention of the lumen. 4- In the cough reflex the muscle contracts to narrow the tracheal lumen and provide for increased velocity of the expelled air and better loosening of material in the air passage.





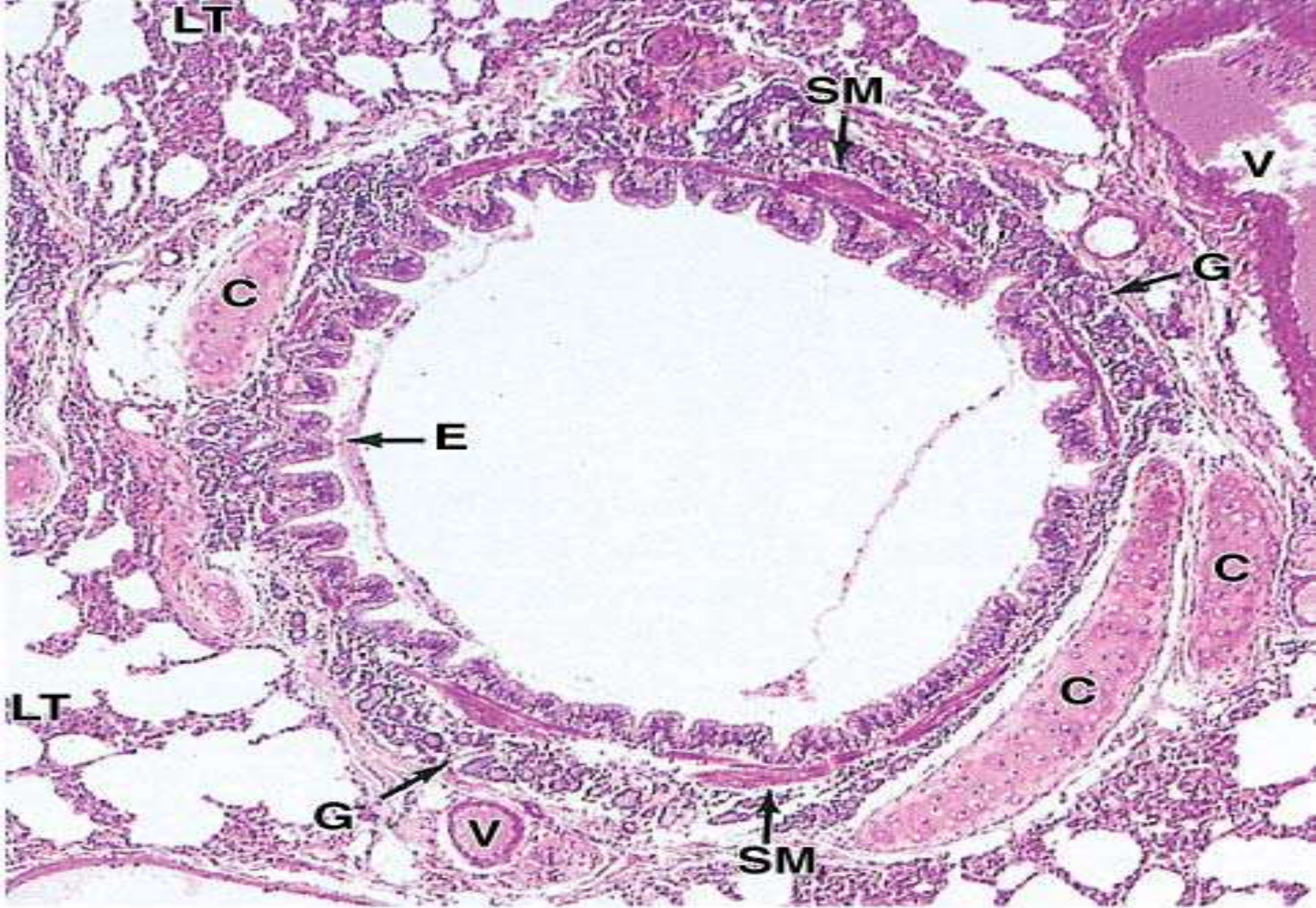
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# Bronchi:

- i)* The mucosa of the larger bronchi is structurally similar to the tracheal mucosa except for the organization of cartilage and smooth muscle.
- ii)* In the primary bronchi most cartilage rings completely encircle the lumen, but as the bronchial diameter decreases, cartilage rings are gradually replaced with isolated plates of hyaline cartilage.
- iii)* Abundant mucous and serous glands are also present, with ducts opening into the bronchial lumen.
- iv)* In the bronchial lamina propria is a layer of crisscrossing bundles of spirally arranged smooth muscle, which become more prominent in the smaller bronchial branches.





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**v)** Contraction of this muscle layer is responsible for the folded appearance of the bronchial mucosa observed in histologic section.

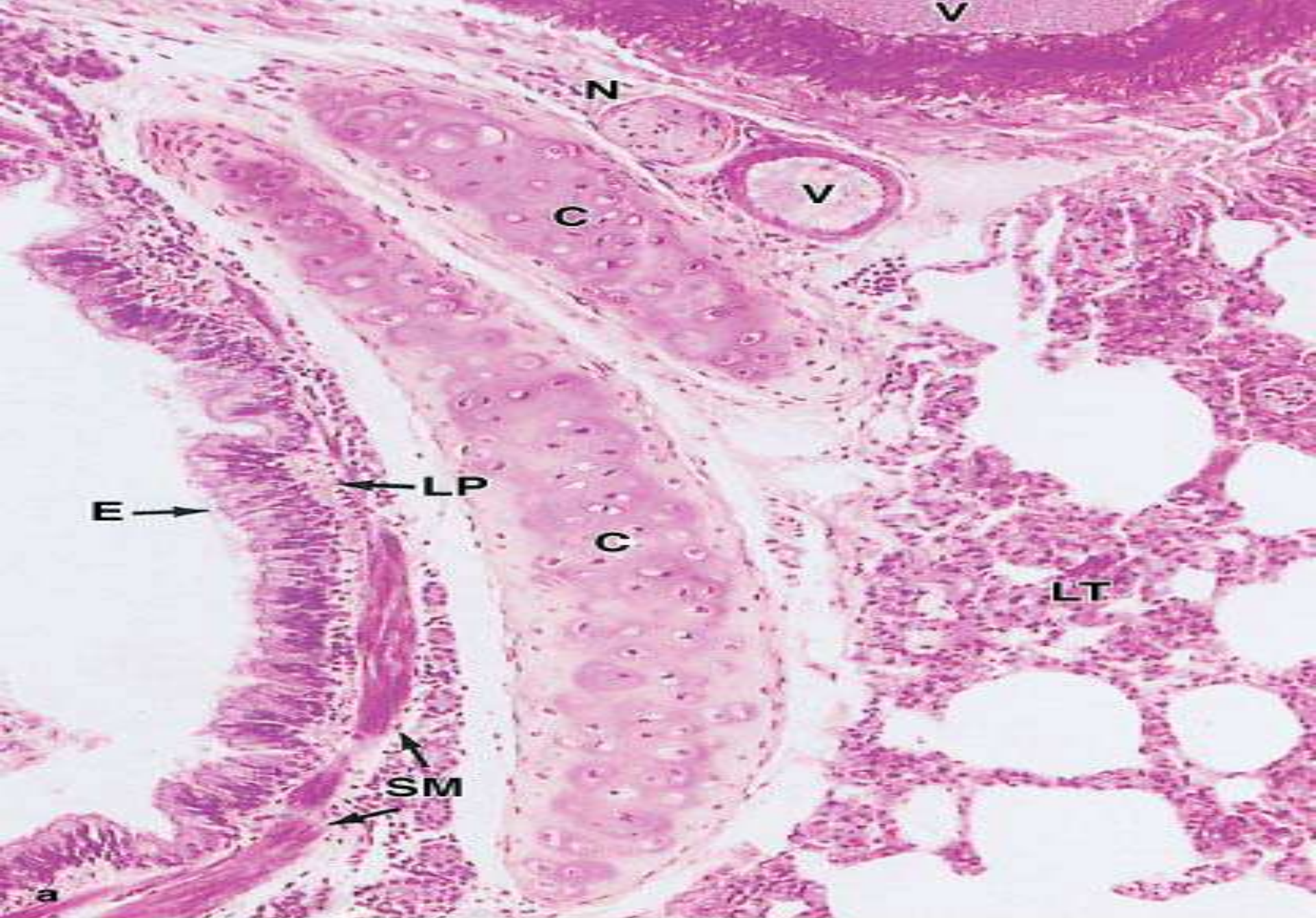
**vi)** The lamina propria also contains elastic fibers and abundant mucous and serous glands whose ducts open into the bronchial lumen.

**vii)** Numerous lymphocytes are found both within the lamina propria and among the epithelial cells.

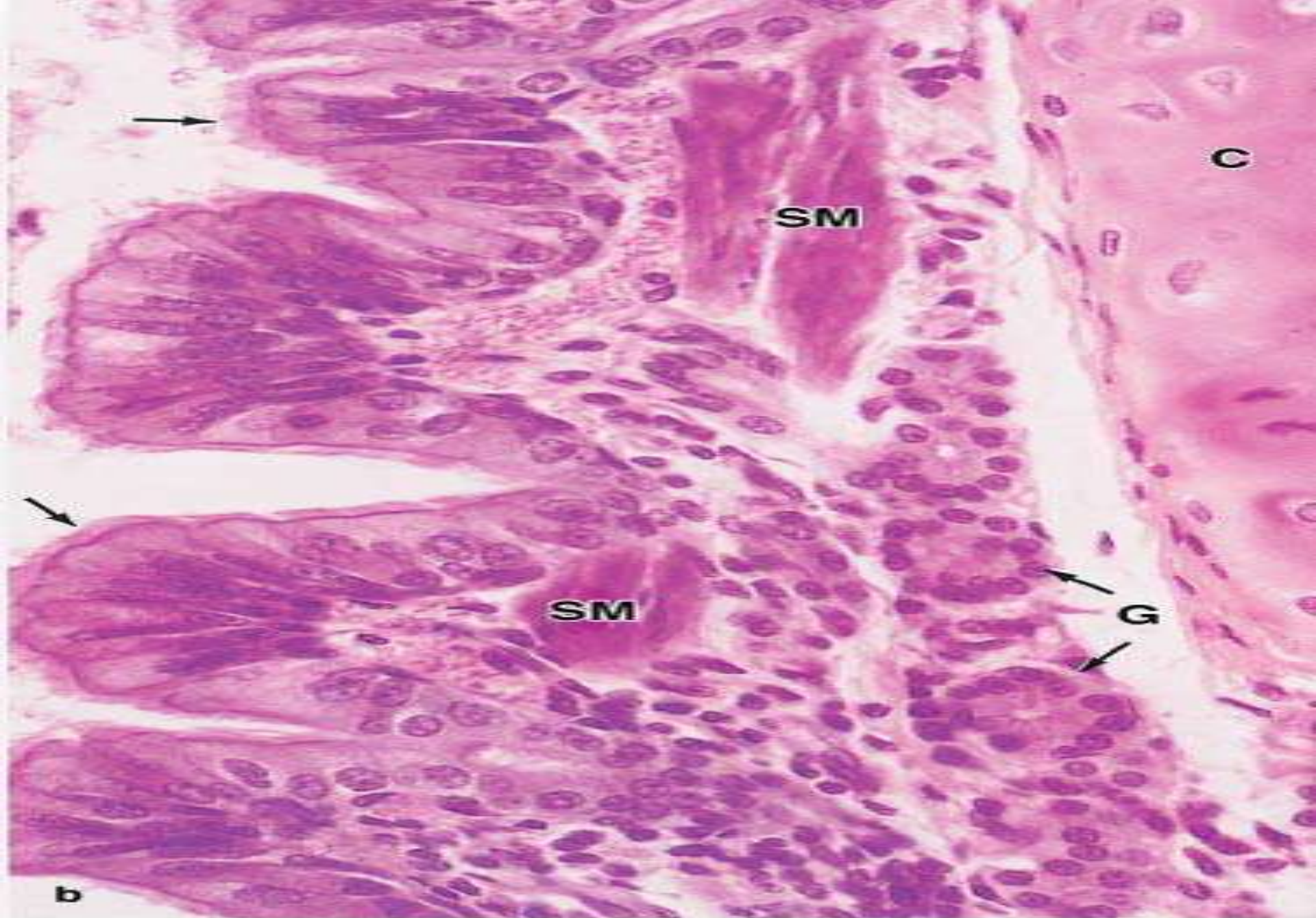
Lymphatic nodules are present and are particularly numerous at the branching points of the bronchial tree.

**viii)** Elastic fibers, smooth muscle, become relatively more abundant as bronchi become smaller and cartilage and other connective tissue are reduced.









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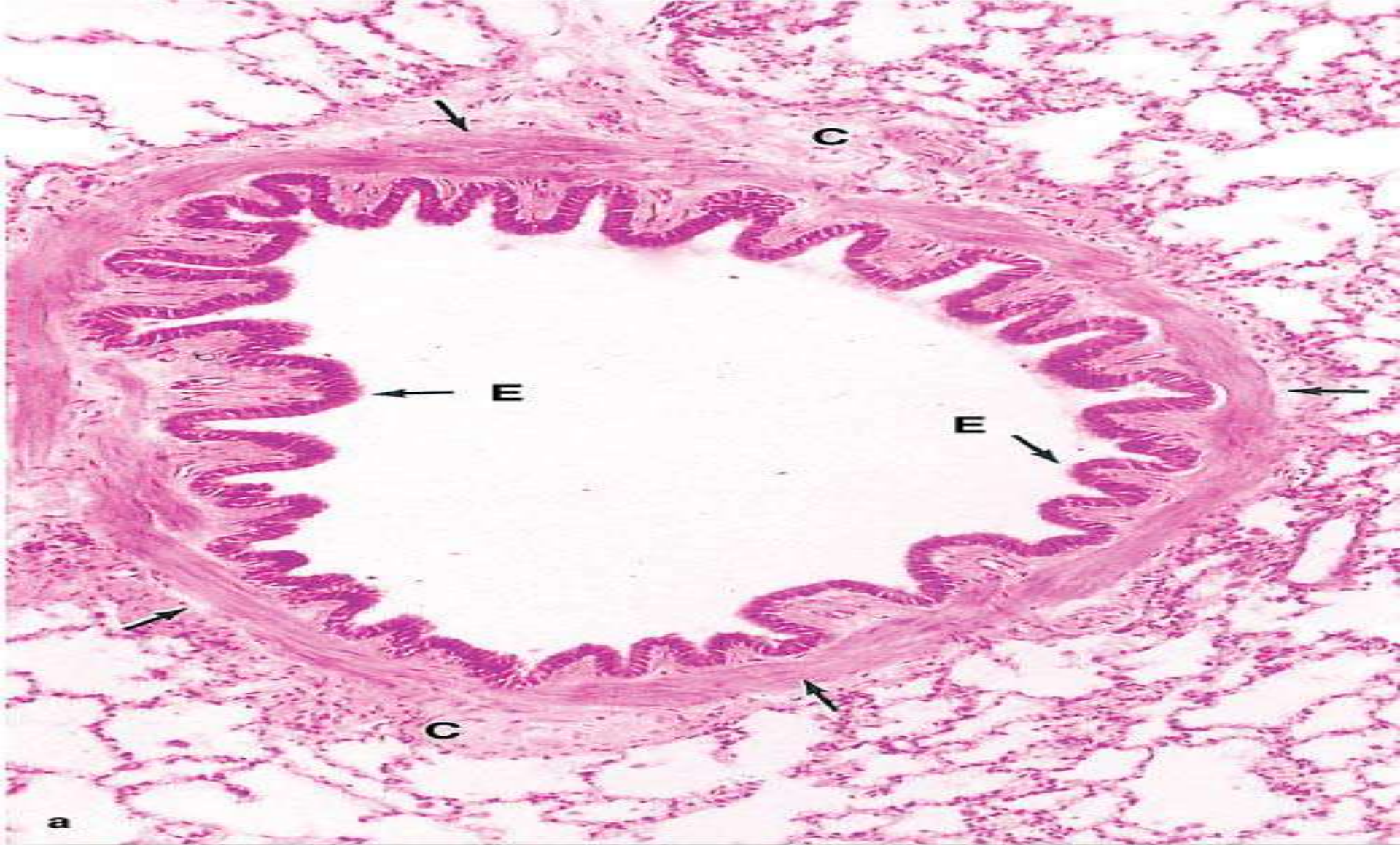
# **Bronchioles:**

1-Bronchioles are the intralobular airways with diameters of 5 mm or less, formed after about the tenth generation of branching, and have neither cartilage nor glands in their mucosa .

2-In the larger bronchioles, the epithelium is still ciliated pseudostratified columnar, but this decreases in height and complexity to become ciliated simple columnar or cuboidal epithelium in the smaller terminal bronchioles.

3-Goblet cells disappear during this transition, but the epithelium of terminal bronchioles instead contains other numerous columnar cells:

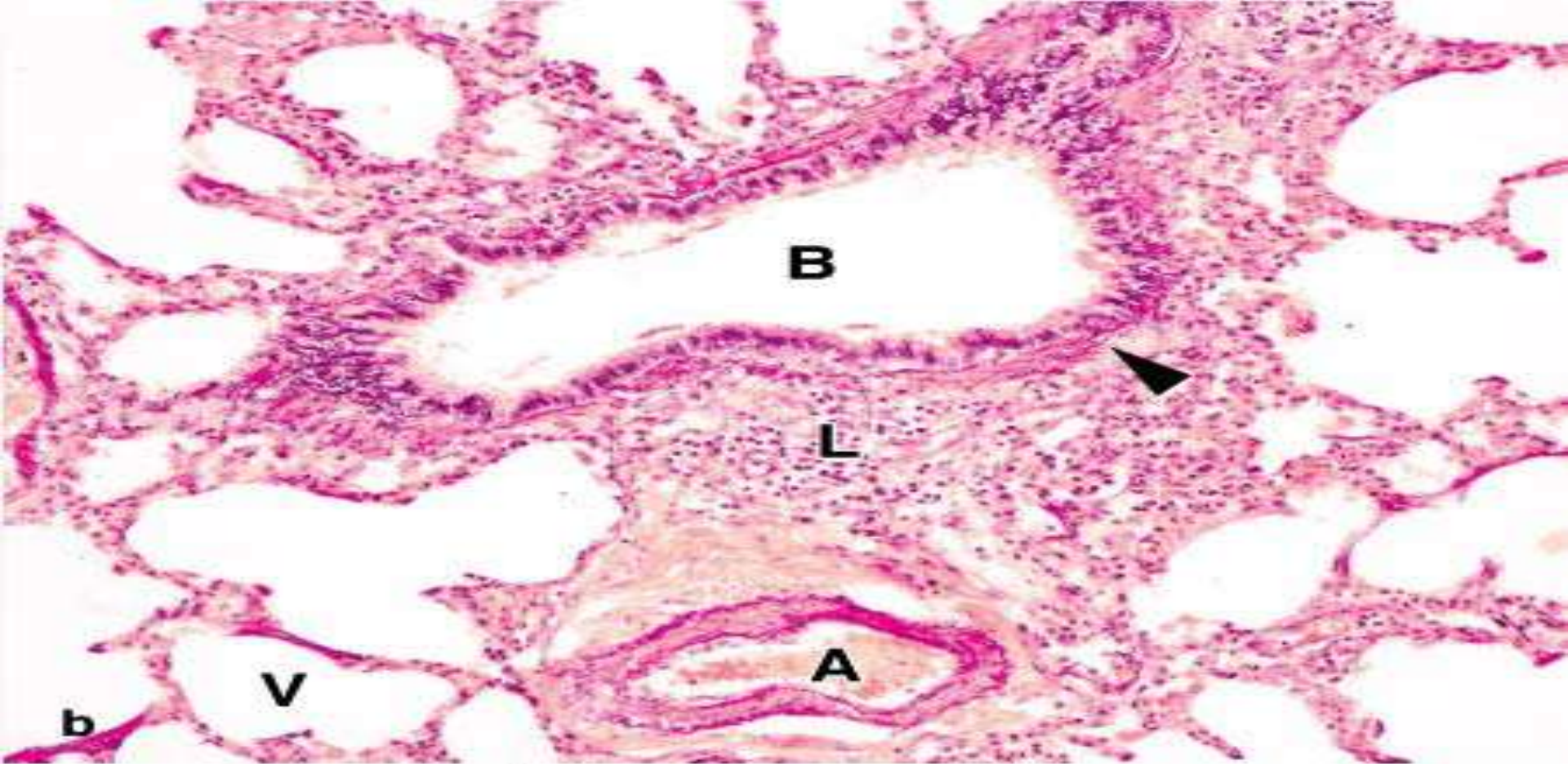




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A large bronchiole has the characteristically folded respiratory epithelium (E) and prominent smooth muscle (arrows), but is supported only by fibrous connective tissue (C) with no glands.





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### Staining for elastic fibers

reveals the high elastic content of the smooth muscle (arrowhead) associated with the muscle of a smaller bronchiole (B) in which the epithelium is simple columnar. Darkly stained elastic fibers are also present in the tunica media of a large arteriole (A) nearby and to a lesser extent in the accompanying venule (V). The connective tissue includes many lymphocytes (L) .





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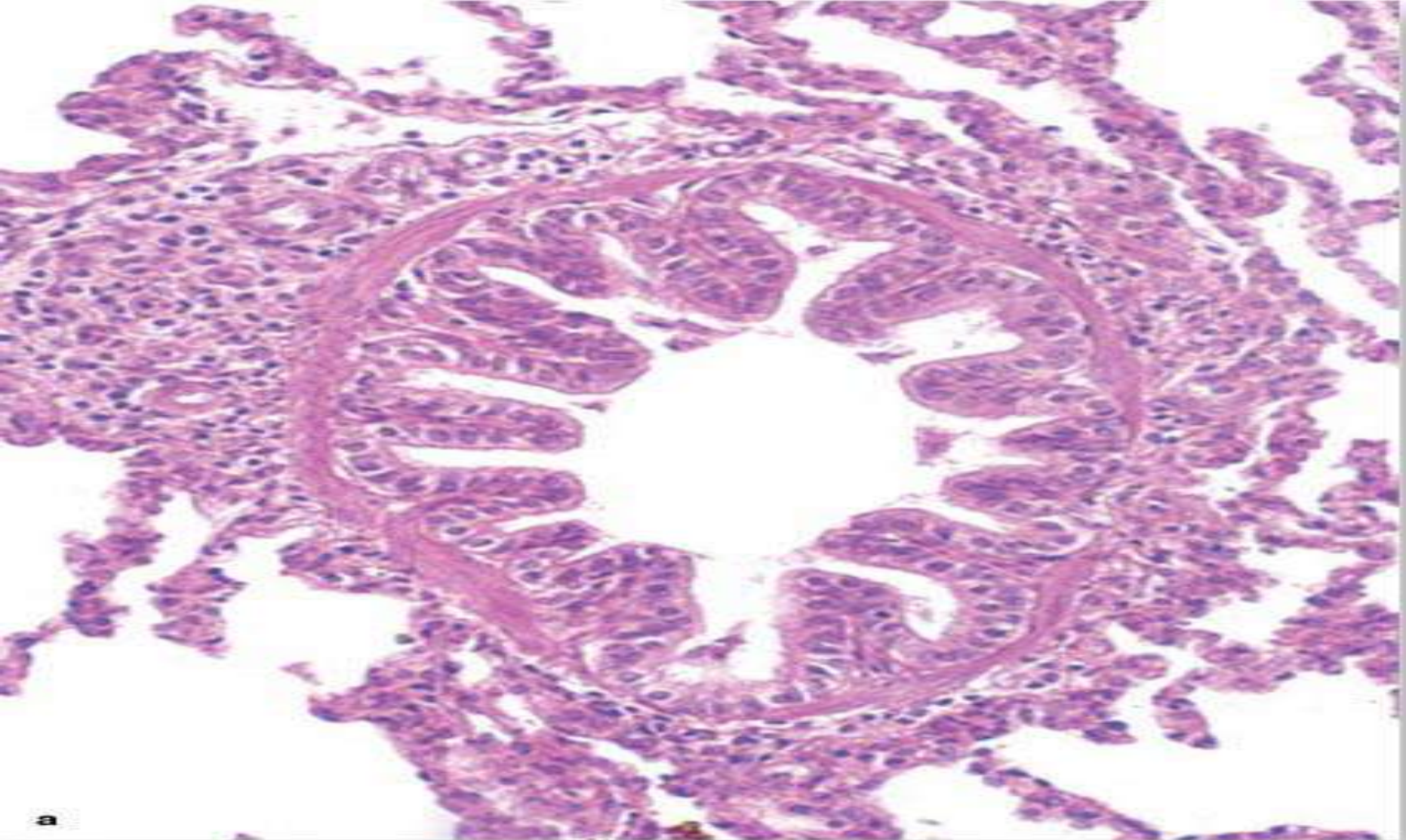
In very small bronchioles the epithelium (E) is reduced to simple low columnar and the several layers of smooth muscle cells (arrows) comprise a high proportion of the wall.

*i)* the **exocrine bronchiolar cells**, commonly called **Clara cells**. These mitotically active cells secrete surfactant components and have various important defensive roles.

*ii)* Scattered **neuroendocrine cells** are also present, producing serotonin and other peptides that help control the tone of the local smooth muscle.

*iii)* Groups of similar cells, called **neuroepithelial bodies**, occur in some bronchioles and at higher levels in the bronchial tree. These are innervated by autonomic and sensory fibers and some of the cells appear to function as chemosensory receptors in monitoring air O<sub>2</sub> levels. **Epithelial stem cells** are also present in these groups of cells.

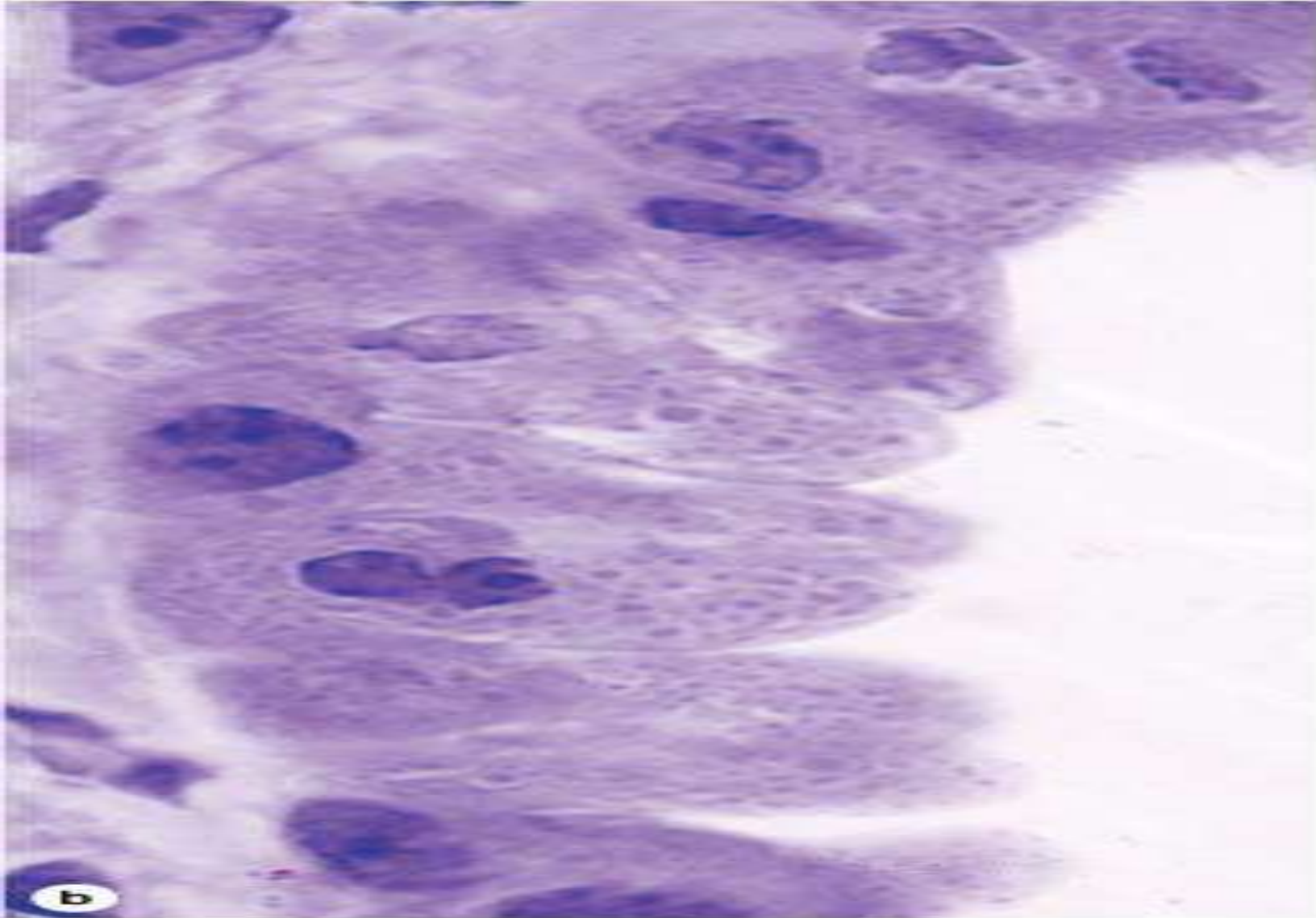




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Cross-section shows that a terminal bronchiole has only one or two layers of smooth muscle cells. The epithelium contains ciliated cuboidal cells and many low columnar nonciliated cells.





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The nonciliated Clara cells with bulging domes of apical cytoplasm contain granules, as seen better in a plastic section.

# **Respiratory Bronchioles:**

1-Each **terminal bronchiole** subdivides into two or more respiratory bronchioles that serve as regions of transition between the conducting and respiratory portions of the respiratory system .

2- The respiratory **bronchiolar mucosa** is structurally identical to that of the terminal bronchioles, except that their walls are interrupted by the openings to saclike alveoli where gas exchange occurs.

3-Portions of the respiratory bronchioles are lined with **ciliated cuboidal epithelial cells** and Clara cells, but at the rim of the alveolar openings the bronchiolar epithelium becomes continuous with the **squamous alveolar lining cells (type I alveolar cells)**.

4-Proceeding distally along these bronchioles, **the alveoli increase in number, and the distance between them is reduced**. Between alveoli the bronchiolar epithelium consists **of ciliated cuboidal epithelium, although cilia may be absent** in more distal portions.

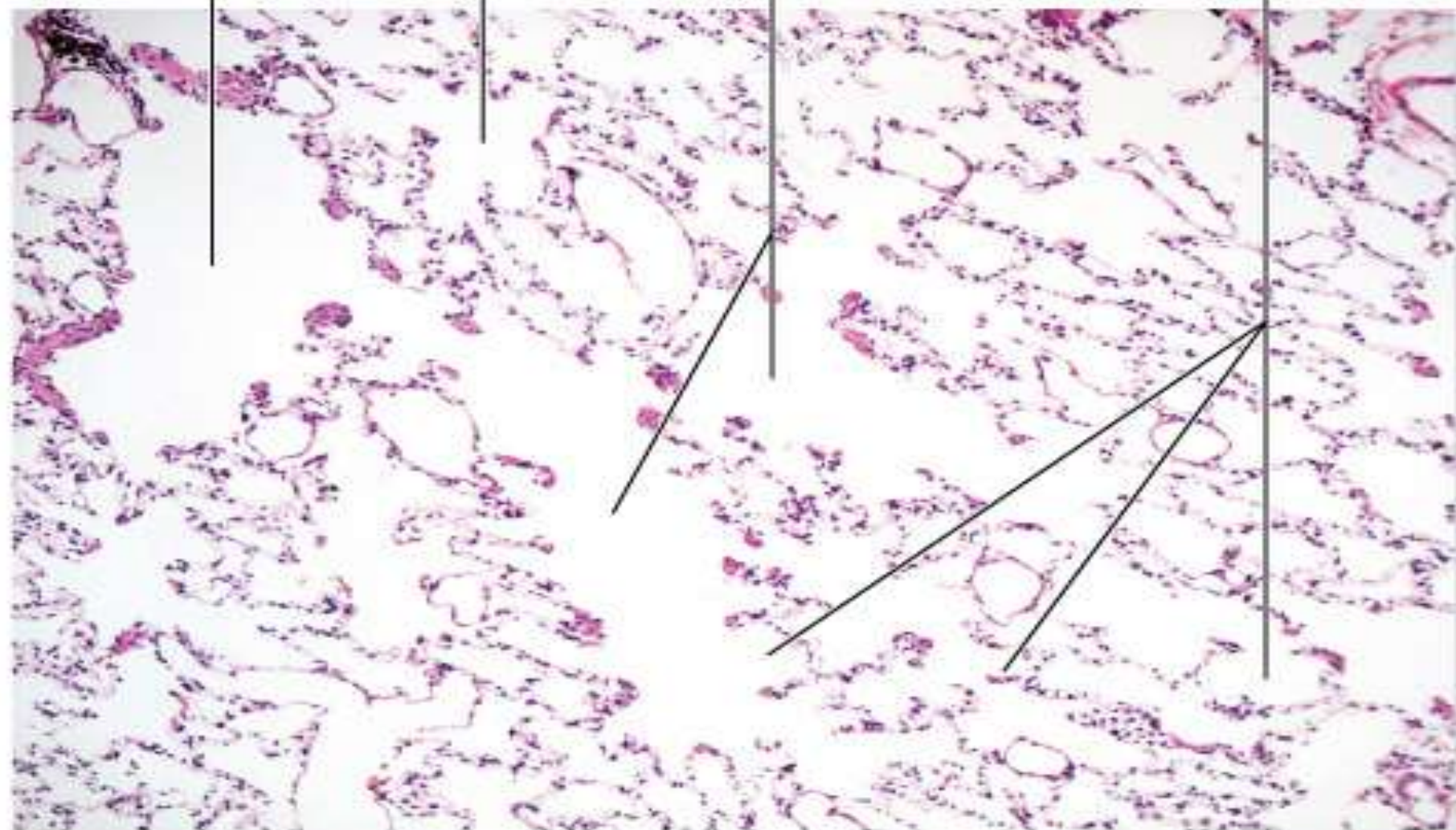
5-Smooth muscle and elastic connective tissue lie beneath the epithelium of respiratory bronchioles.

Respiratory  
bronchiole

Alveolar  
sac

Alveolar ducts

Alveoli



**b**

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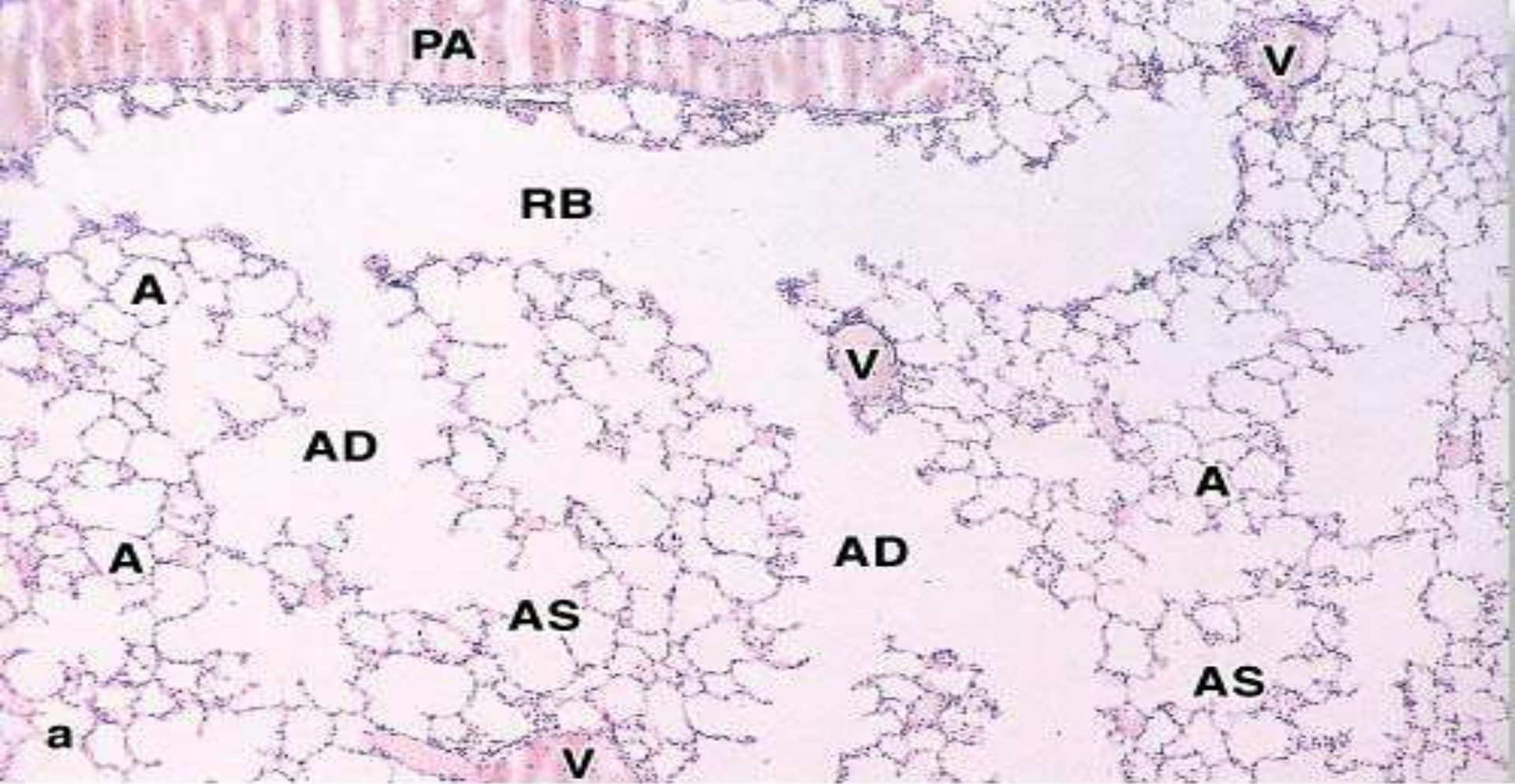
# Alveolar Ducts:

- 1-**Proceeding** distally along the respiratory bronchioles, **the number of alveolar openings in the bronchiolar wall slowly increases. Respiratory bronchioles branch into tubes called **alveolar ducts** that are completely lined by the openings of alveoli.**
- 2- **Both the alveolar ducts and the alveoli are lined with extremely attenuated squamous alveolar cells.**
- 3- In the lamina propria **surrounding the rim of the alveoli is a thin network of smooth muscle cells, which disappears at the distal ends of alveolar ducts.**

**4-** A rich matrix of elastic and collagen fibers provides the only support of the duct and its alveoli.

**5-Alveolar ducts** open into atria of two or more **alveolar sacs** . Elastic and reticular fibers form a network encircling the openings of atria, alveolar sacs, and alveoli.

**6-The elastic fibers** enable the alveoli to expand with inspiration and to contract passively with expiration. The reticular fibers serve as a support that prevents overdistention and damage to the delicate capillaries and thin alveolar septa. **Both fibers contribute to the connective tissue housing** the network of capillaries around each alveolus.



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Typical section of lung tissue including many bronchioles, some of which are respiratory bronchioles (RB) and showing alveolar ducts (AD) and sacs (AS). Individual alveoli (A) all open to the sacs or ducts. The respiratory bronchiole runs along a thin-walled branch of the pulmonary artery (PA), which has a relatively thin wall, while branches of the pulmonary vein (V).



# **Alveoli:**

**a)** Alveoli are saclike evaginations (about 200  $\mu$ m in diameter) of the respiratory bronchioles, alveolar ducts, and alveolar sacs. Alveoli are responsible for the spongy structure of the lungs .

**b)** Structurally, alveoli resemble small pockets that are open on one side, similar to the honeycombs of a beehive. Within these cuplike structures,  $O_2$  and  $CO_2$  are exchanged between the air and the blood.

**c)** The structure of alveolar walls is specialized to enhance diffusion between the external and internal environments. Generally, each wall lies between two neighboring alveoli and is therefore called an **interalveolar septum**.

***d)*** These septa contain the cells and connective tissue, notably the elastic and collagen fibers, which is vascularized with the richest capillary network in the body .

***e)*** Air in the alveoli is separated from capillary blood by **three components** referred to collectively as the **respiratory membrane** or blood-air barrier:

***i)*** Surface lining and cytoplasm of the alveolar cells,

***ii)*** Fused basal laminae of the closely apposed alveolar cells and capillary endothelial cells, and

***iii)*** Cytoplasm of the endothelial cells.

*f)* Pores occur in the interalveolar septum and connect neighboring alveoli opening to different bronchioles. These pores equalize air pressure in the alveoli .

*g)* **Type I alveolar cells** (also called type I pneumocytes or squamous alveolar cells) are extremely attenuated cells that line the alveolar surfaces.

*i)* These cells are so thin.

*ii)* The cytoplasm in the thin portion contains **pinocytotic vesicles**,

*iii)* In addition to desmosomes, all type I epithelial cells have **occluding junctions** that prevent the leakage of tissue fluid into the alveolar air space .

*iv)* The main role of these cells is to provide a barrier of minimal thickness that is readily permeable to gases.

**h) Type II alveolar cells** (type II pneumocytes) are interspersed among the type I alveolar cells with which they have occluding and desmosomal junctions .

**i) Type II cells** are rounded cells that often occur in groups of two or three along the alveolar surface at points where the alveolar walls unite.

**ii) These cells rest** on the basement membrane and are part of the epithelium, with the same origin as the type I cells that line the alveolar walls.

**iii) They divide by mitosis** to replace their own population and also the type I population.

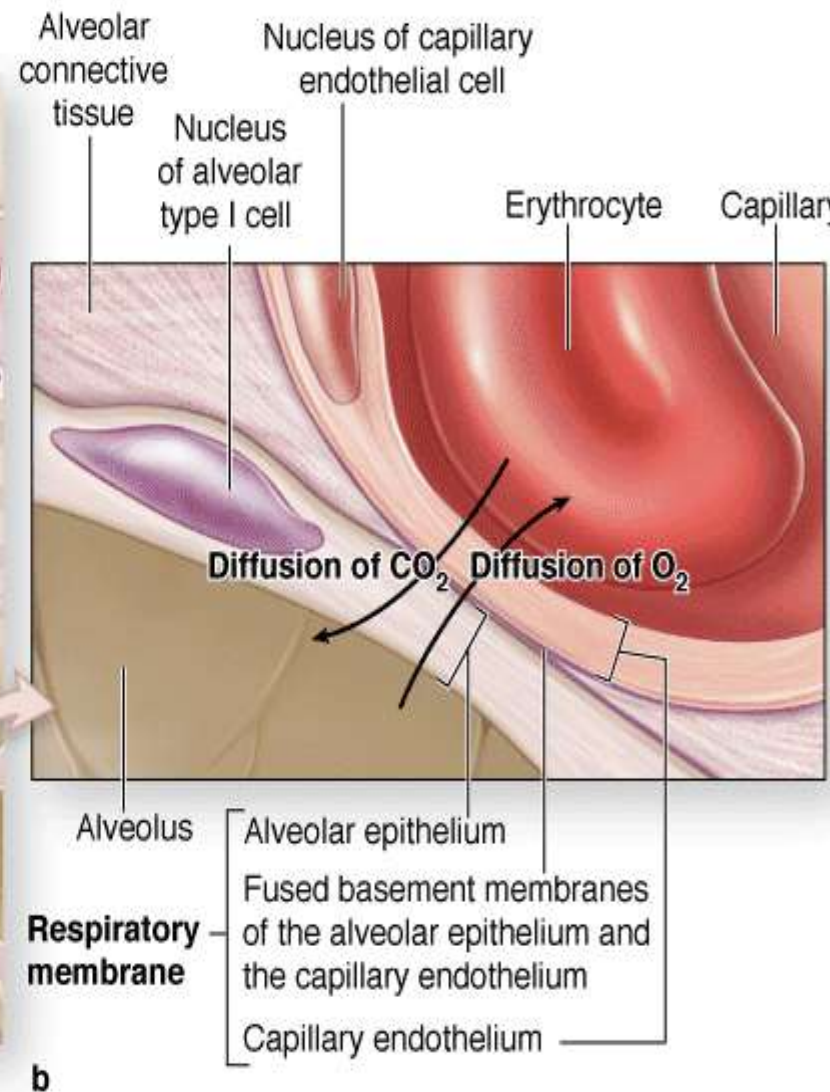
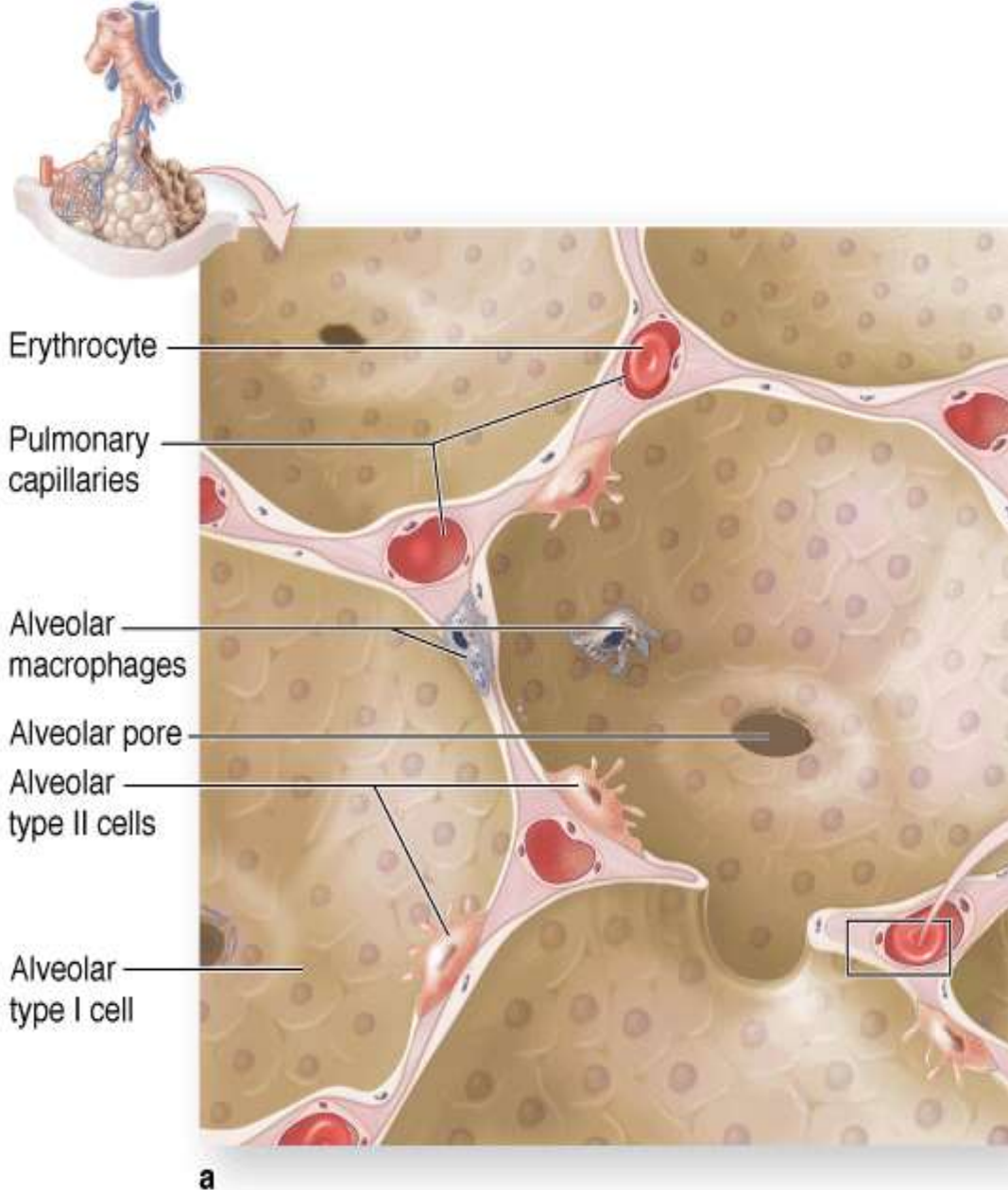
**v) In histologic sections, they exhibit a characteristic vesicular or foamy cytoplasm.** These vesicles are caused by the presence of **lamellar bodies** .

**I-Alveolar macrophages**, also called dust cells, are found in alveoli and in the interalveolar septum .

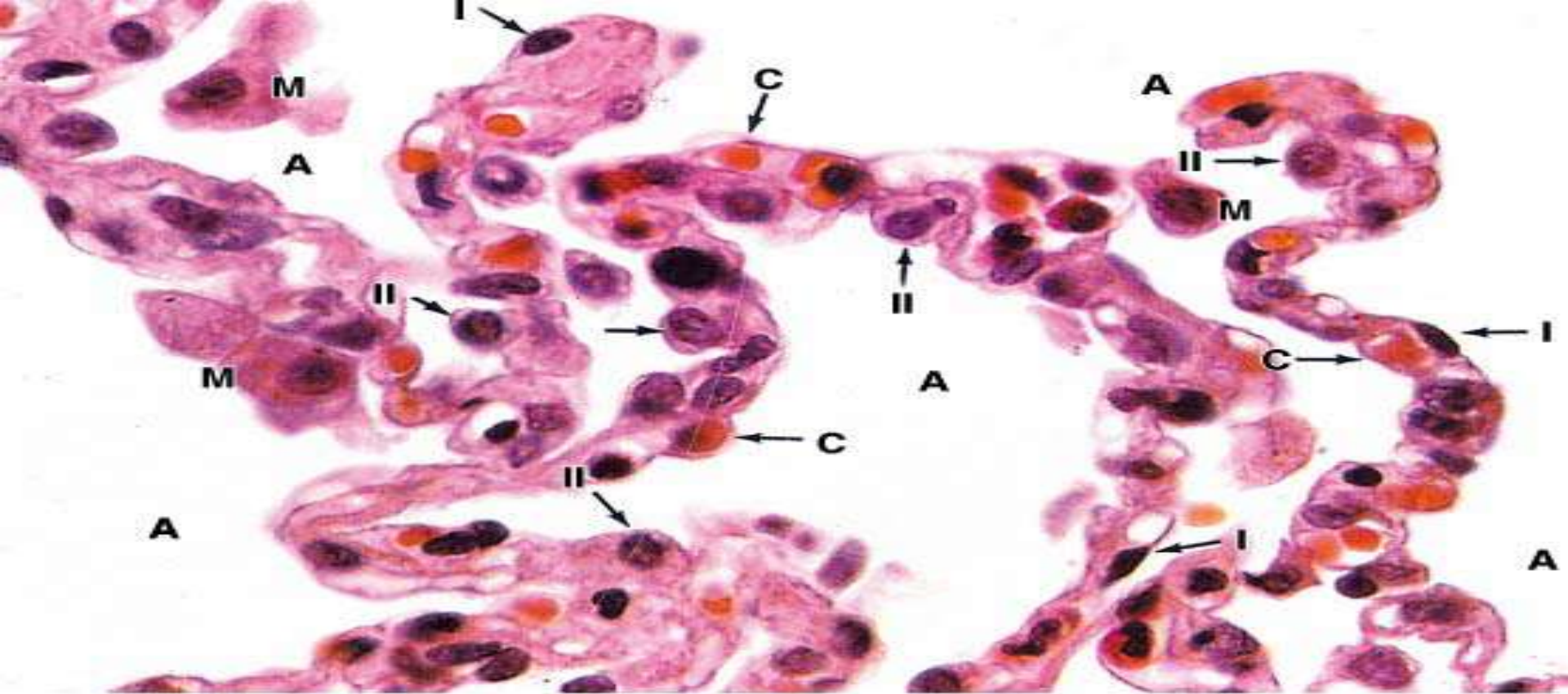
*i)* Tens of millions of **monocytes** migrate daily from the microvasculature into the lung tissue, where they phagocytose erythrocytes lost from damaged capillaries and air-borne particulate matter that has entered alveoli.

*ii)* Some debris within these cells was most likely passed from the alveolar lumen into the interstitium following the **pinocytotic** activity of type I alveolar cells.

*iii)* Active macrophages in lung are often slightly darker due to their content of dust and carbon from air and complexed iron (**hemosiderin**) from erythrocytes.





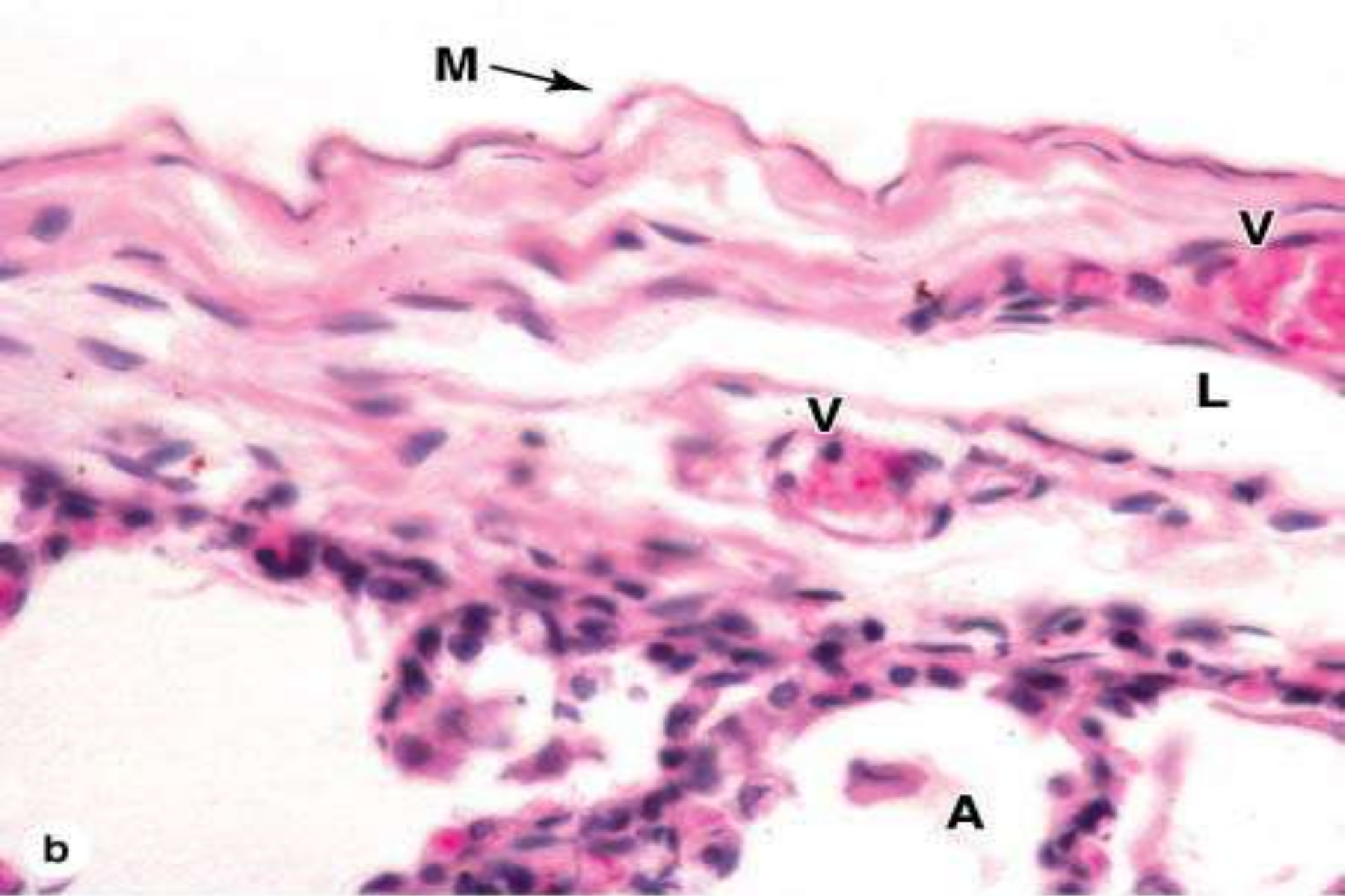


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The wall between alveoli (A) contains several cell types. As seen here the capillaries (C) contain erythrocytes and leukocytes. The alveoli are lined mainly by squamous type I alveolar cells (I), which line almost the entire alveolus surface and across which gas exchange occurs. Type II alveolar cells line a bit of each alveolus and are large rounded cells, often bulging into the alveolus (II). These type II cells have many functions of Clara cells, including production of surfactant. Also present are alveolar macrophages (M), sometimes called dust cells, which may be in the alveoli or in the interalveolar septa.

# PLEURA:

- 1-The lung's outer surface and the internal wall of the thoracic cavity are covered by a serous membrane called the **pleura** .
- 2-The membrane attached to lung tissue is called the **visceral pleura** and the membrane lining the thoracic walls is the **parietal pleura**.
- 3-The two layers are continuous at the hilum and are both composed of simple squamous mesothelial cells on a thin connective tissue layer containing collagen and elastic fibers.
- 4-The elastic fibers of the visceral pleura are continuous with those of the pulmonary parenchyma.
- 5-fluid that acts as a lubricant, facilitating the smooth sliding of one surface over the other during respiratory movements.



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