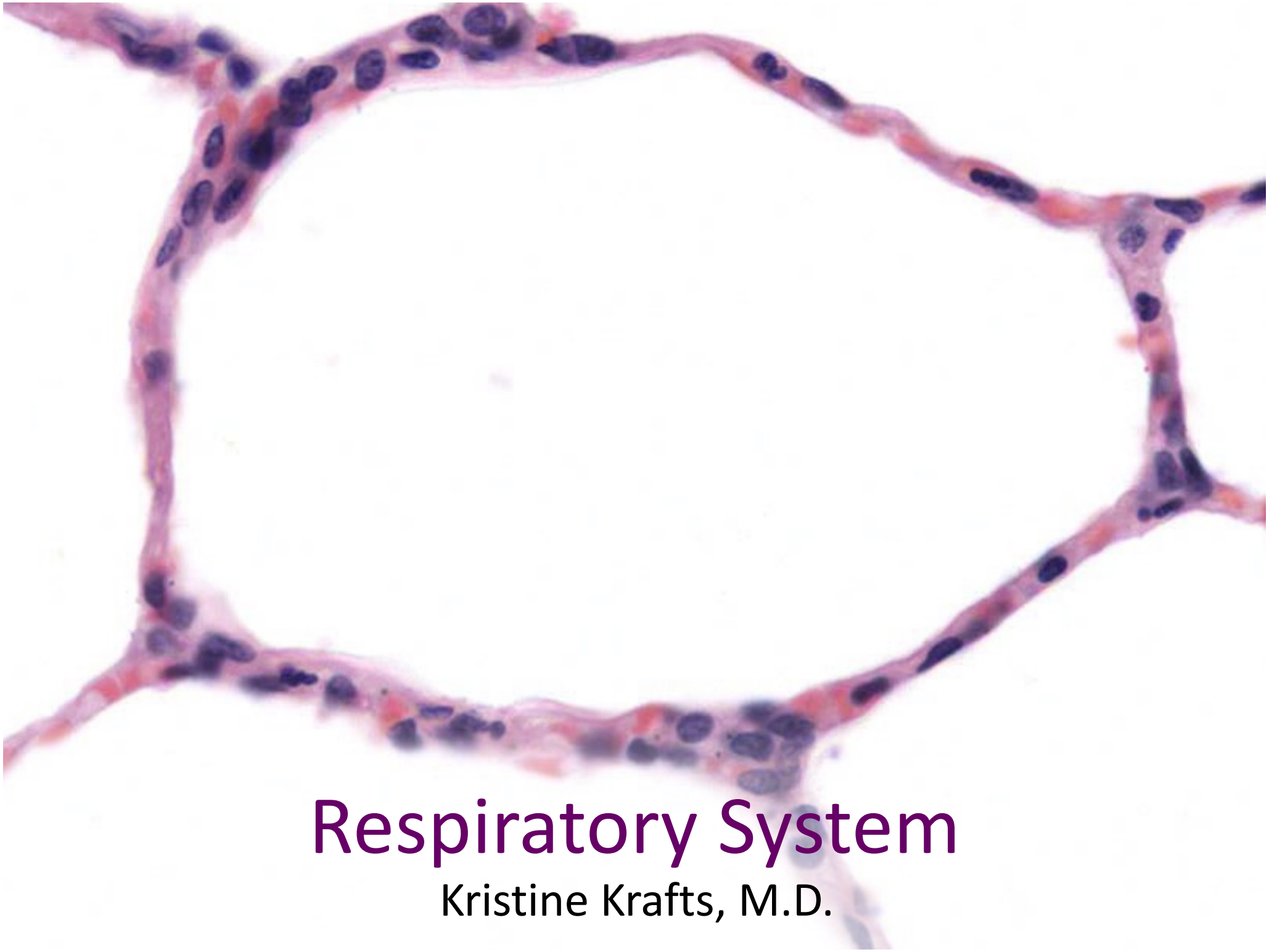


Respiratory System

Kristine Krafts, M.D.

Respiratory System Objectives

- Describe the components and functions of the conducting and respiratory portions of the respiratory system.
- Describe the embryologic steps in the development of the respiratory system.
- Describe and compare the characteristic microscopic features and functions of the different regions and airways of the respiratory system, including lining epithelium, glands, cartilage, smooth muscle and elastic fibers.

Respiratory System Lecture Outline

- Introduction
- Conducting portion
- Respiratory portion
- Pleura

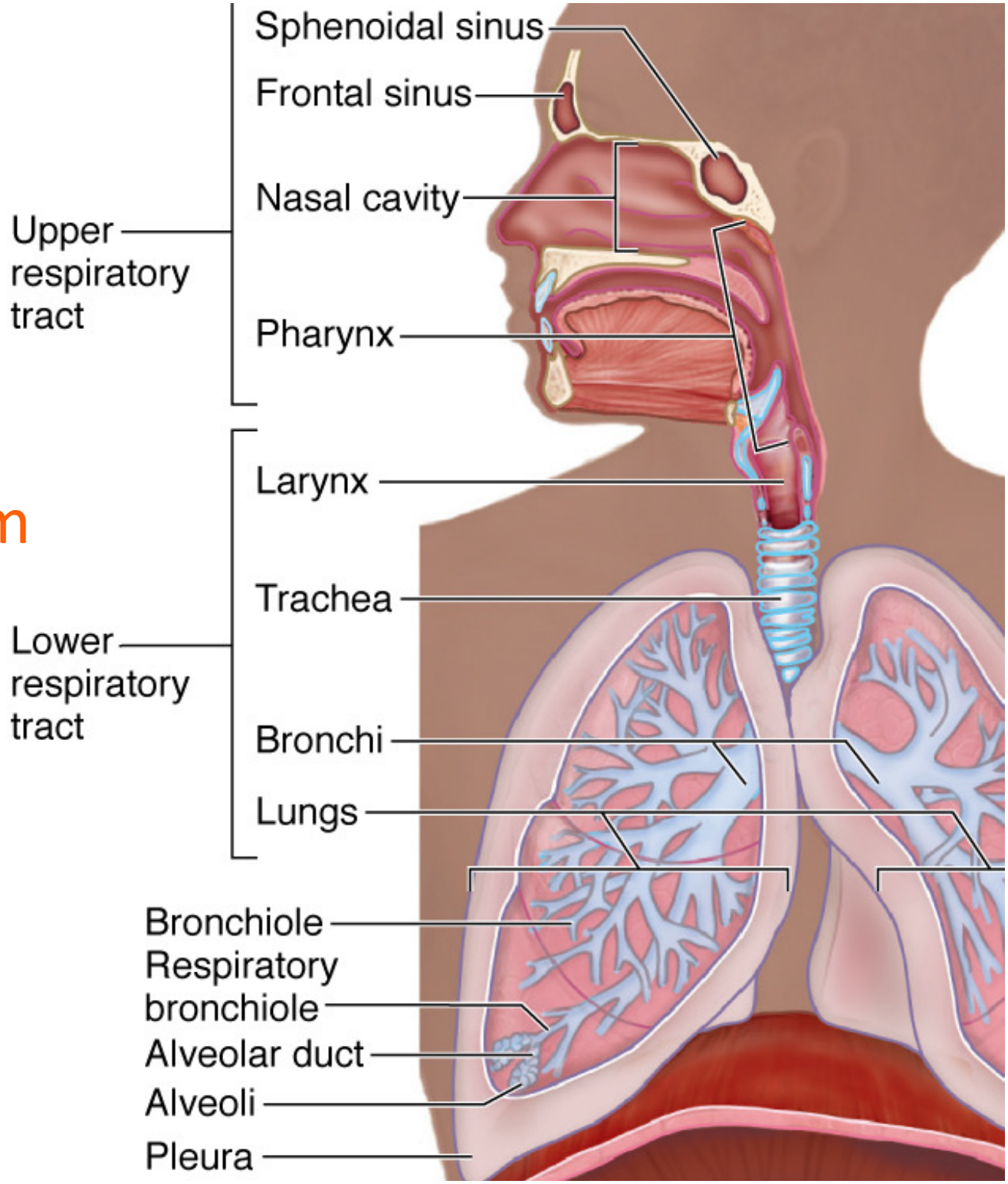
Respiratory System Lecture Outline

- Introduction
  - Anatomy
  - Embryology

Respiratory System Lecture Outline

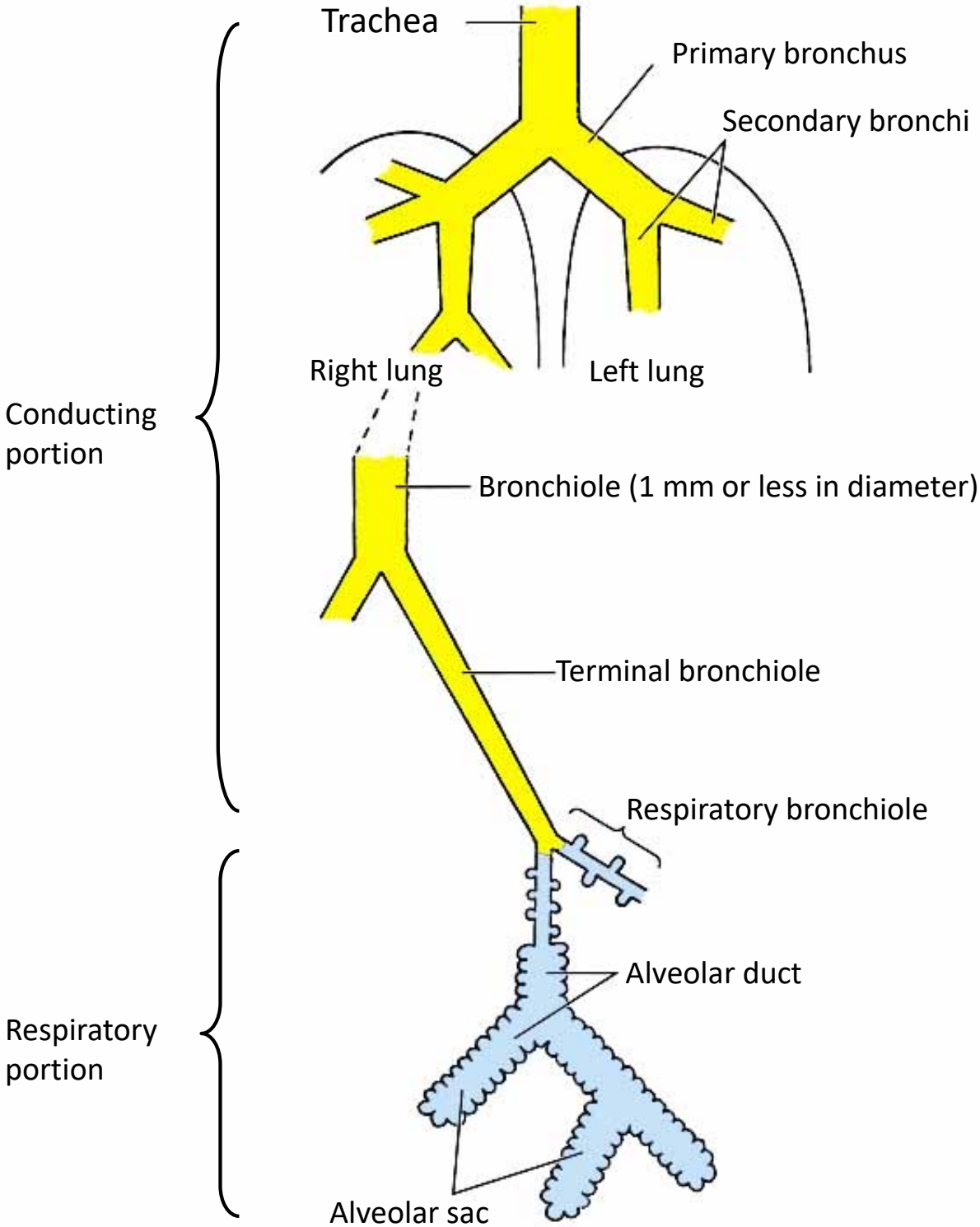
- Introduction
  - Anatomy

Anatomy of the respiratory system



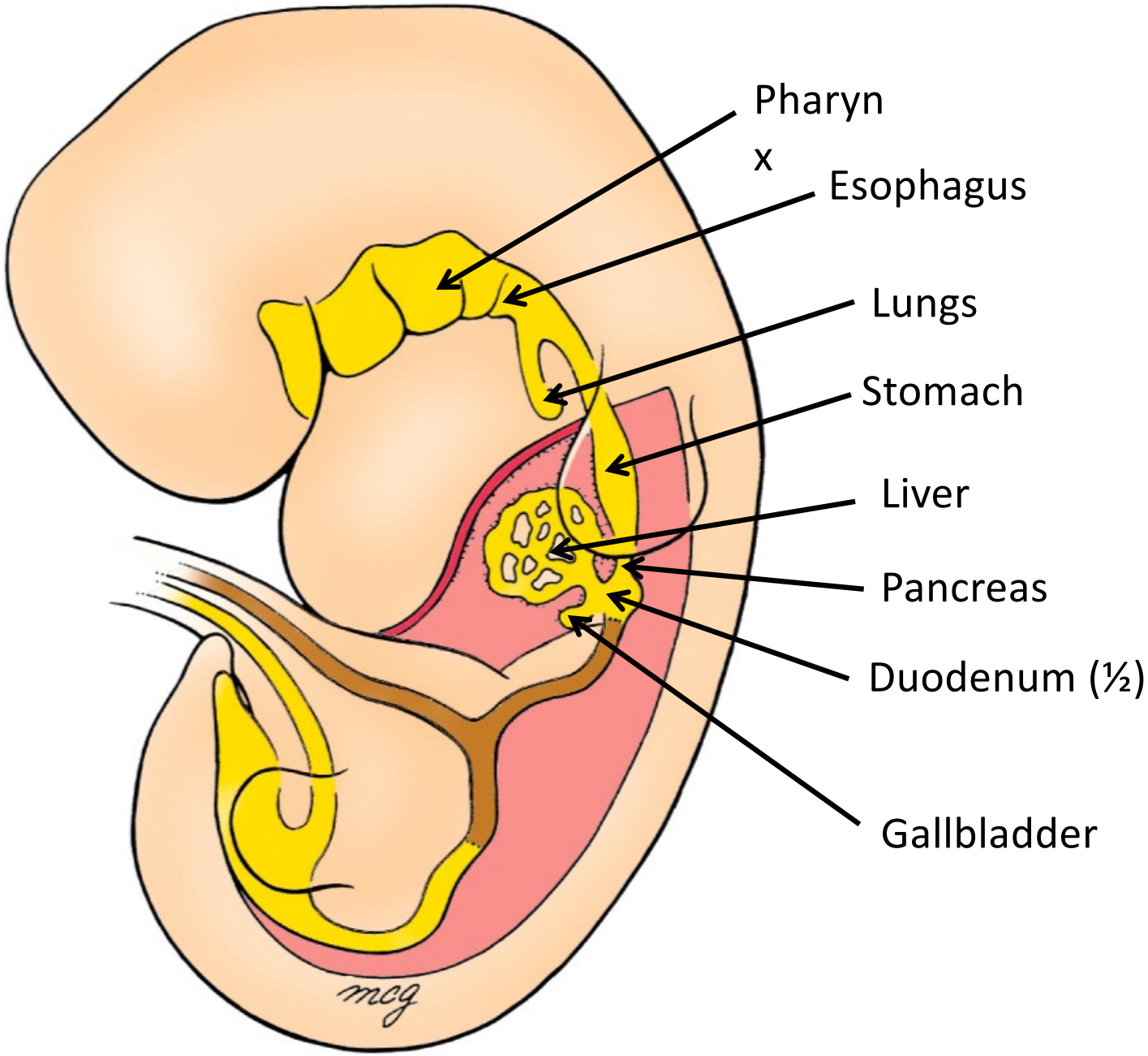
Two Functional Parts of the Respiratory Tract

- Conducting portion
  - Conduct air to and from alveoli
  - Condition the air (warm, humidify, filter)
- Respiratory portion
  - Gas exchange


Trachea
Primary bronchus
Secondary bronchi
Right lung
Left lung
Conducting portion
Bronchiole (1 mm or less in diameter)
Terminal bronchiole
Respiratory bronchiole
Alveolar duct
Respiratory portion
Alveolar sac

Respiratory System Lecture Outline

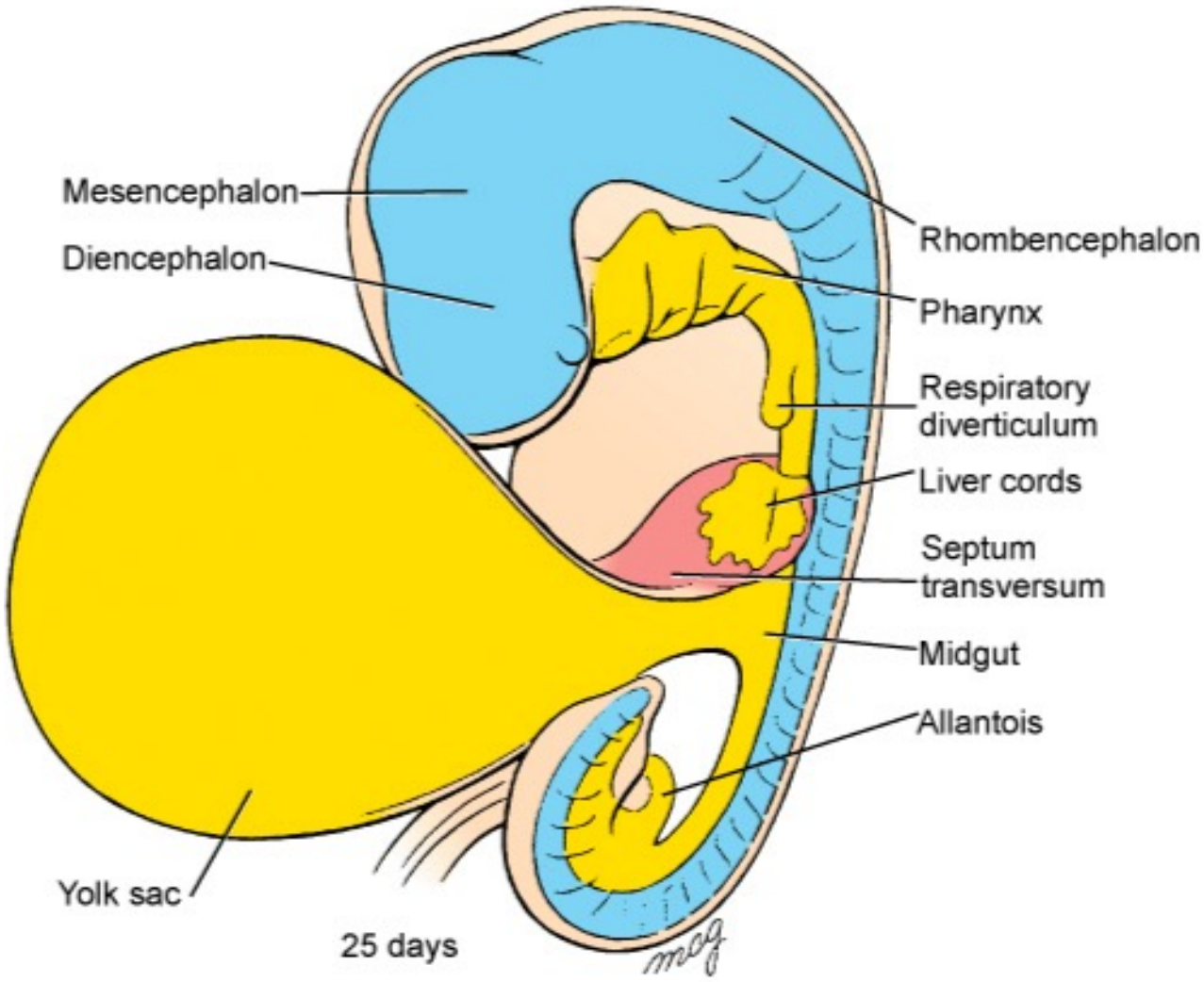
- Introduction
  - Anatomy
  - Embryology



Stuff that develops from the foregut

Endoderm gives rise to the epithelium and glands of the larynx, trachea, bronchi and the pulmonary epithelium.

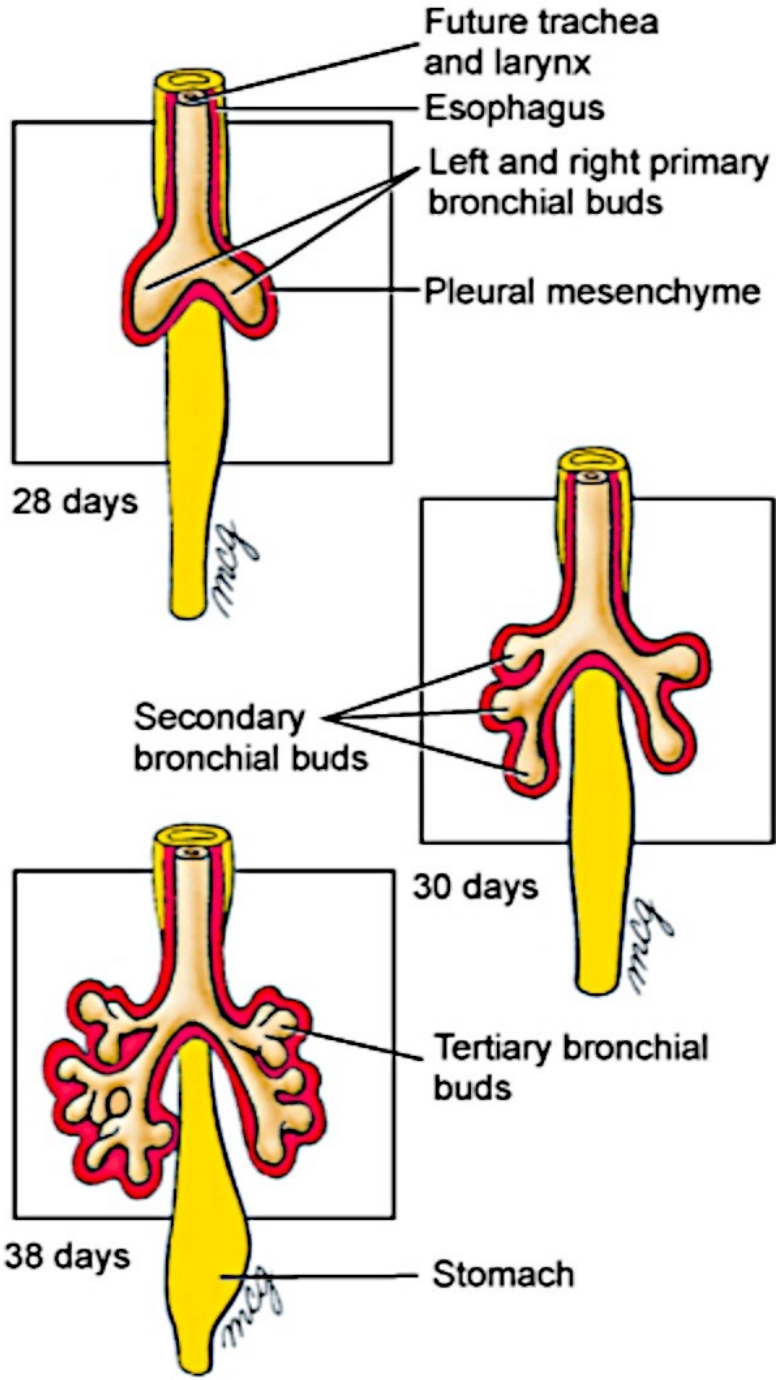
Mesoderm gives rise to the connective tissue, cartilage and smooth muscle of the respiratory tract.



Development of respiratory diverticulum (bud)

Development of bronchi and bronchioles

- The lung bud divides into two bronchial buds, which divide and form secondary and tertiary bronchi.
- As bronchi develop, the surrounding mesenchyme forms cartilage, smooth muscle, connective tissue and capillaries.



When can the baby breathe?

- By week 24, respiratory bronchioles are present and lungs are vascularized. Respiration is possible – but chances of survival outside placenta are slim.
- Weeks 24-26: terminal alveolar sacs develop and type II pneumocytes secrete surfactant (decreases surface tension)
- By week 26-28: there are enough alveolar sacs and surfactant to allow a prematurely born infant to survive without medical intervention.

Strange but true…

- 95% of mature alveoli develop after birth!
- The newborn infant has only 1/6 – 1/8 the number of alveoli as adults.
- Most alveolar growth is done by age 8.

Lungs at Birth

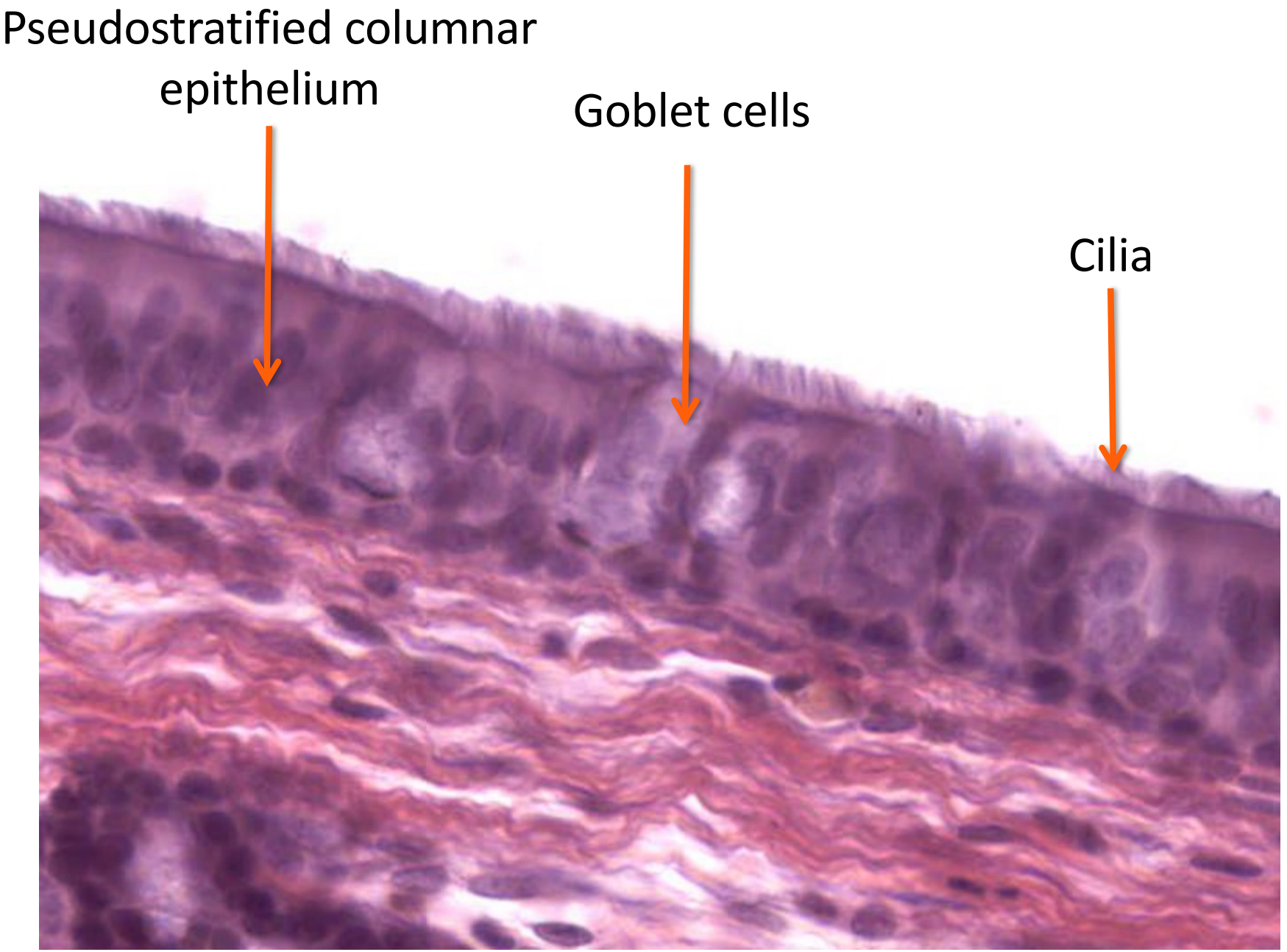
- At birth, the lungs are half-filled with amniotic fluid.
- This fluid is cleared through the mouth and nose by pressure on thorax during delivery. It also is reabsorbed into pulmonary blood vessels and lymphatics.

Respiratory System Lecture Outline

- Introduction
- Conducting portion
  - Nasal cavity
  - Larynx
  - Trachea
  - Bronchi
  - Bronchioles

Walls of the Conducting System

- The walls of the conducting system change in thickness and composition from region to region.
- Components include:
  - Epithelium (“respiratory epithelium”)
  - Lamina propria
  - Mucous and serous glands
  - Cartilage
  - Smooth muscle
  - Adventitia



Respiratory epithelium

Respiratory Epithelium Cell Types

- Ciliated columnar cells: most abundant cell type. Cilia beat in unison and move mucus and trapped particles to oropharynx, where it is swallowed or expectorated.
- Goblet cells: produce mucus.
- Basal cells: stem cells that replenish epithelium. Hard to see.
- Brush cells: Columnar cells. No cilia but have apical microvilli. Hard to see.
- Neuroendocrine cells: epithelial cells containing hormones. Hard to see.

Respiratory System Lecture Outline

- Introduction
- Conducting portion
  - Nasal cavity

Nasal Cavity

- Respiratory epithelium everywhere except at the top (which has specialized olfactory epithelium).
- Serous and mucous glands and numerous blood vessels in lamina propria.
- Nasal septum: midline structure consisting of bone and hyaline cartilage.
- Nasal fossa: chambers on each side of septum.

Respiratory System Lecture Outline

- Introduction
- Conducting portion
  - Nasal cavity
  - Larynx

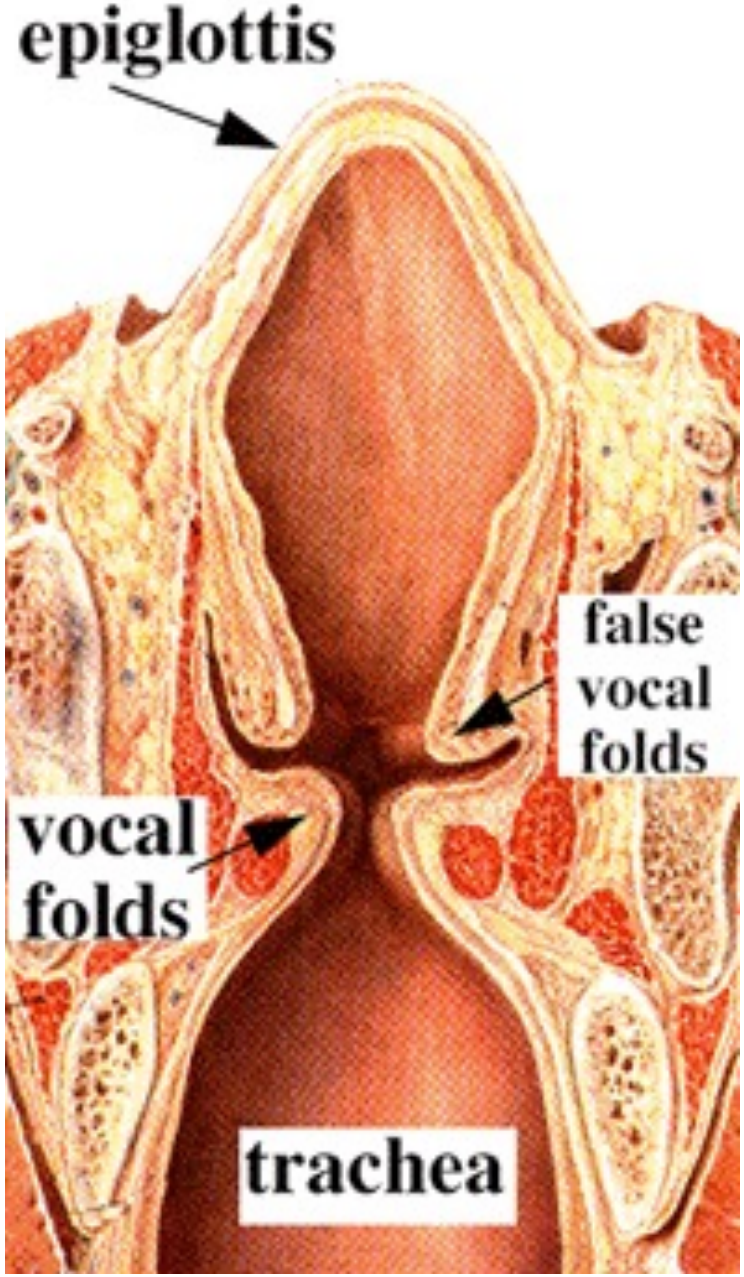
Epiglottis covers laryngeal opening during swallowing.

Core of elastic cartilage.

Superior surface: nonkeratinized stratified squamous epithelium.

Inferior surface: respiratory epithelium

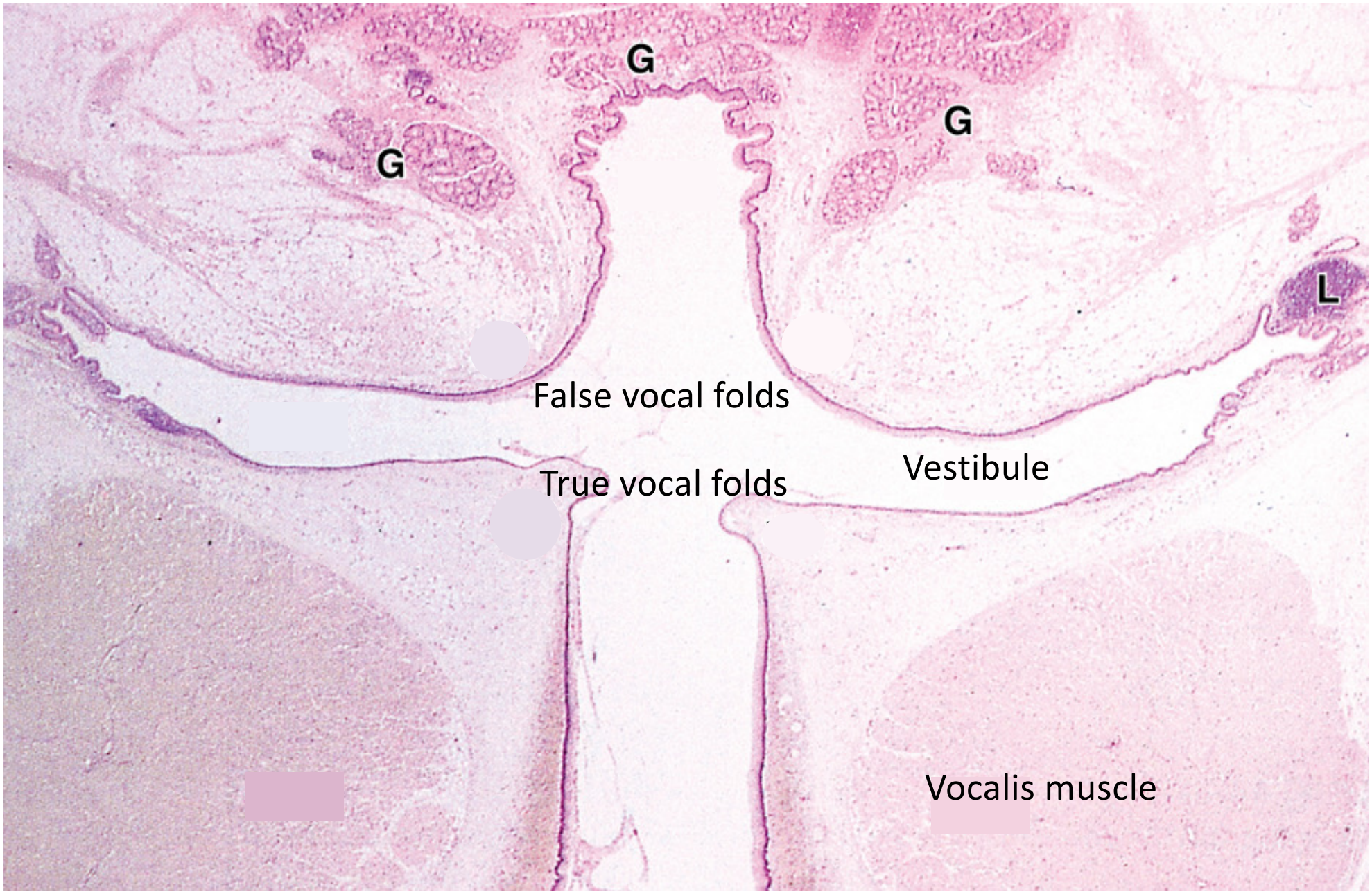
Vocal folds are covered by nonkeratinized stratified squamous epithelium



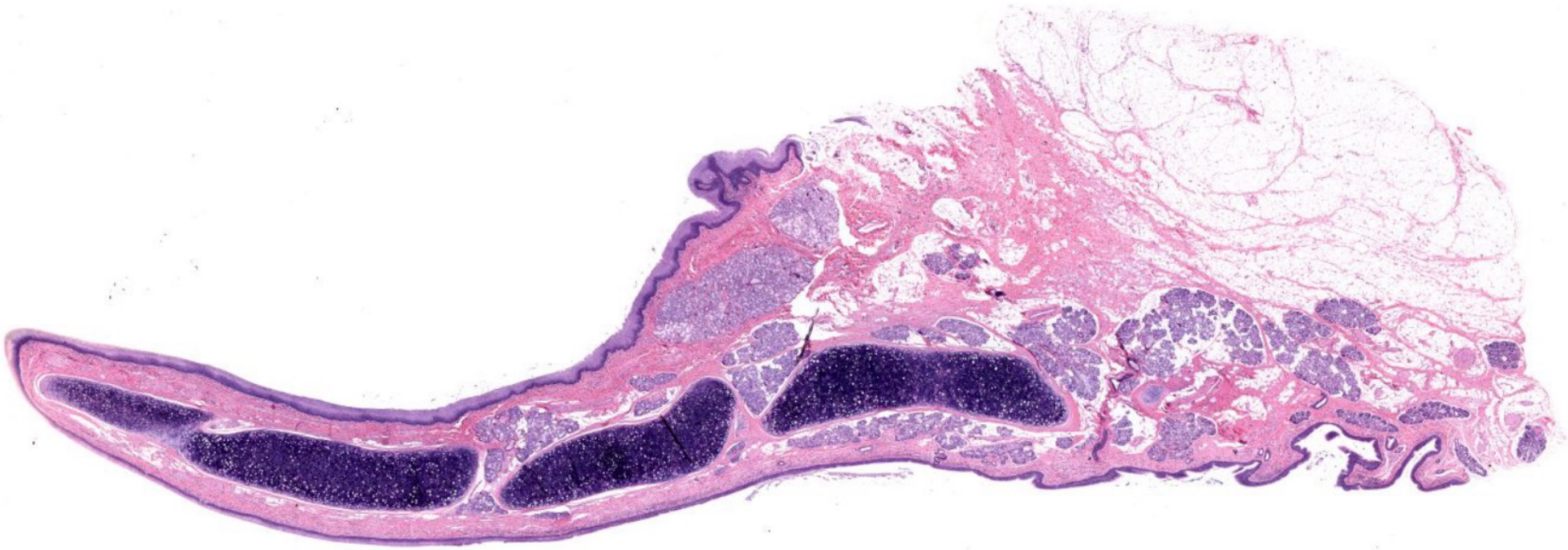
Laryngeal cartilages support the wall of the larynx and serve as attachments for vocalis muscles.

False vocal folds are covered by respiratory epithelium

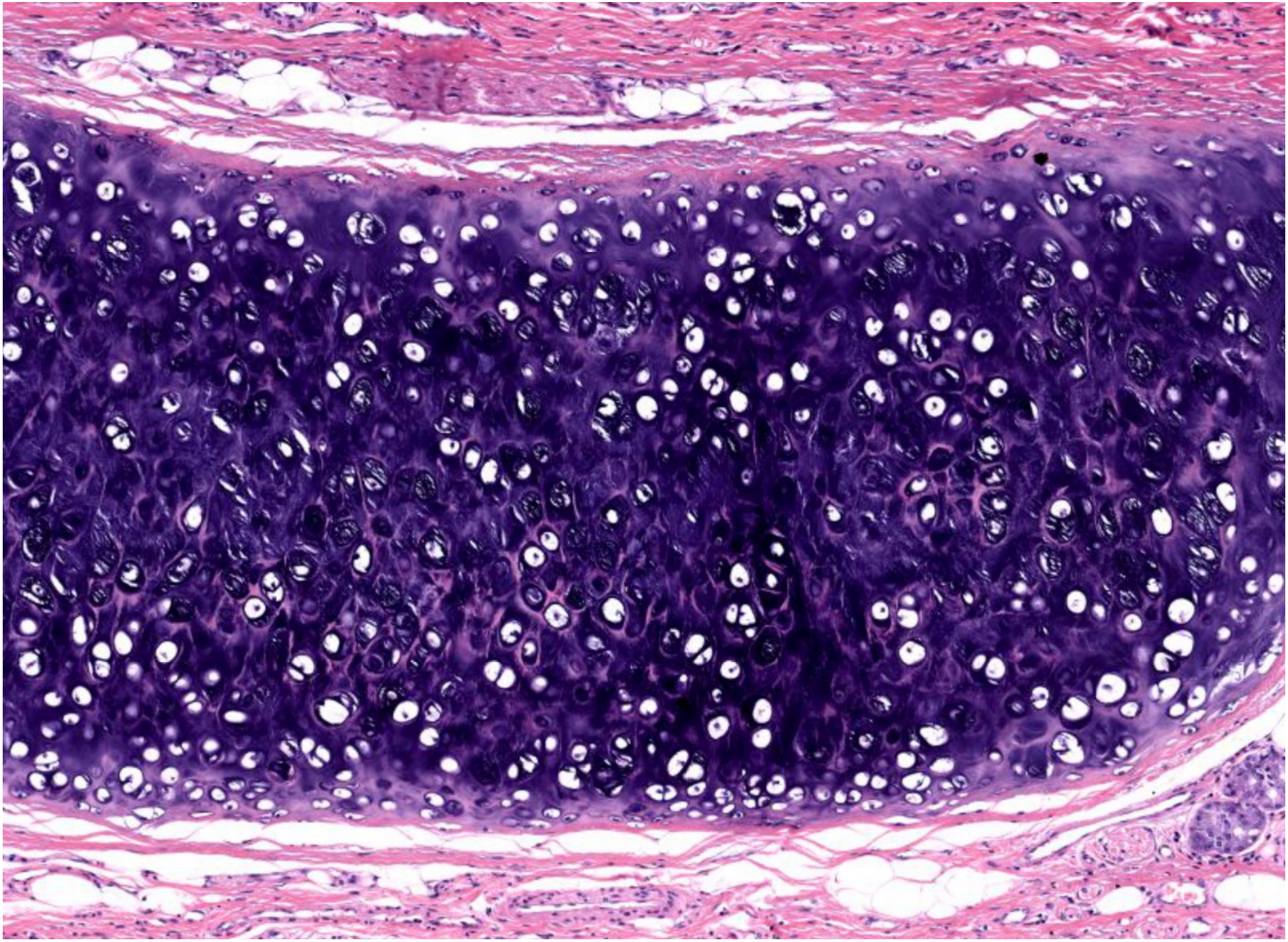
Larynx and epiglottis



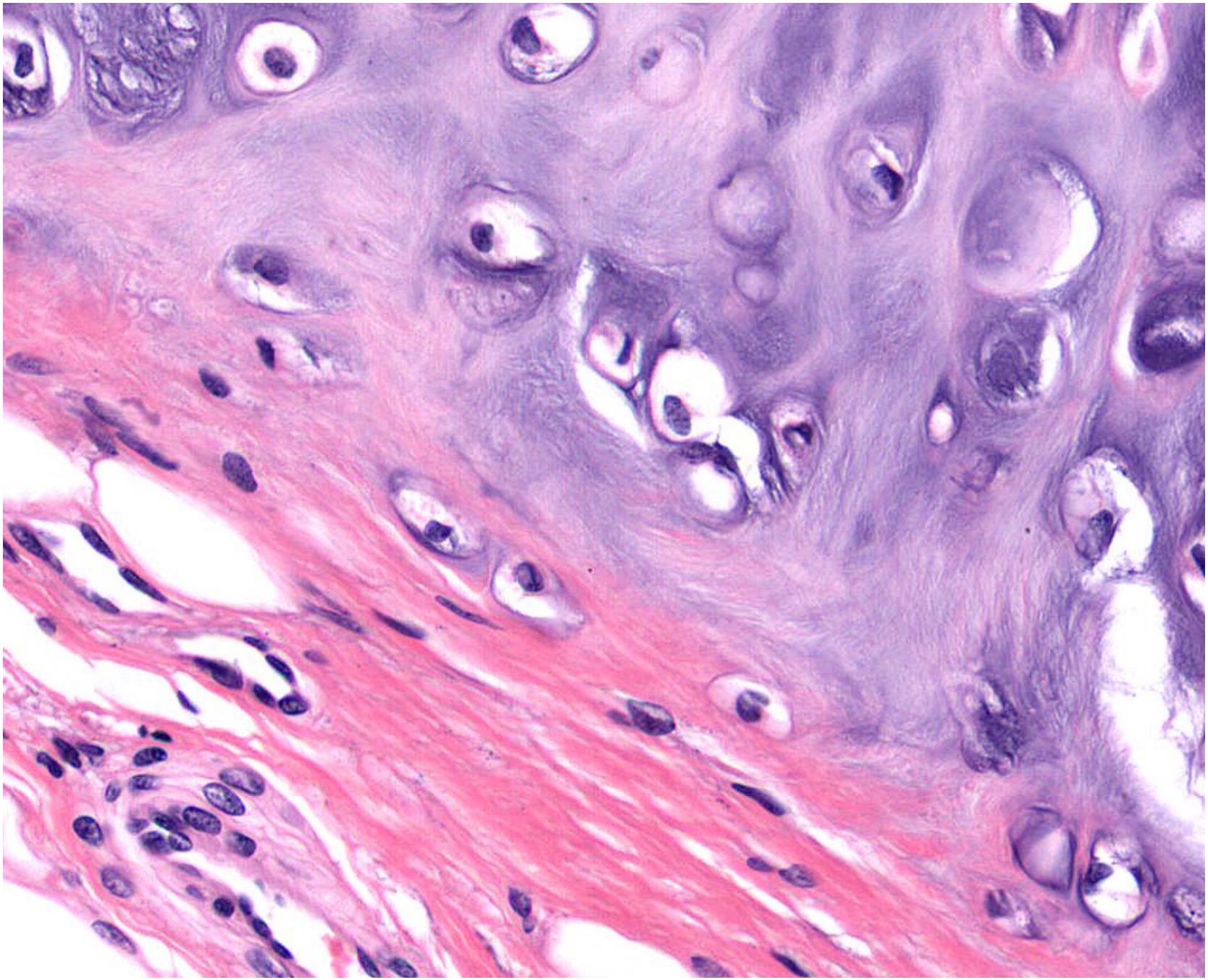
Larynx, coronal section



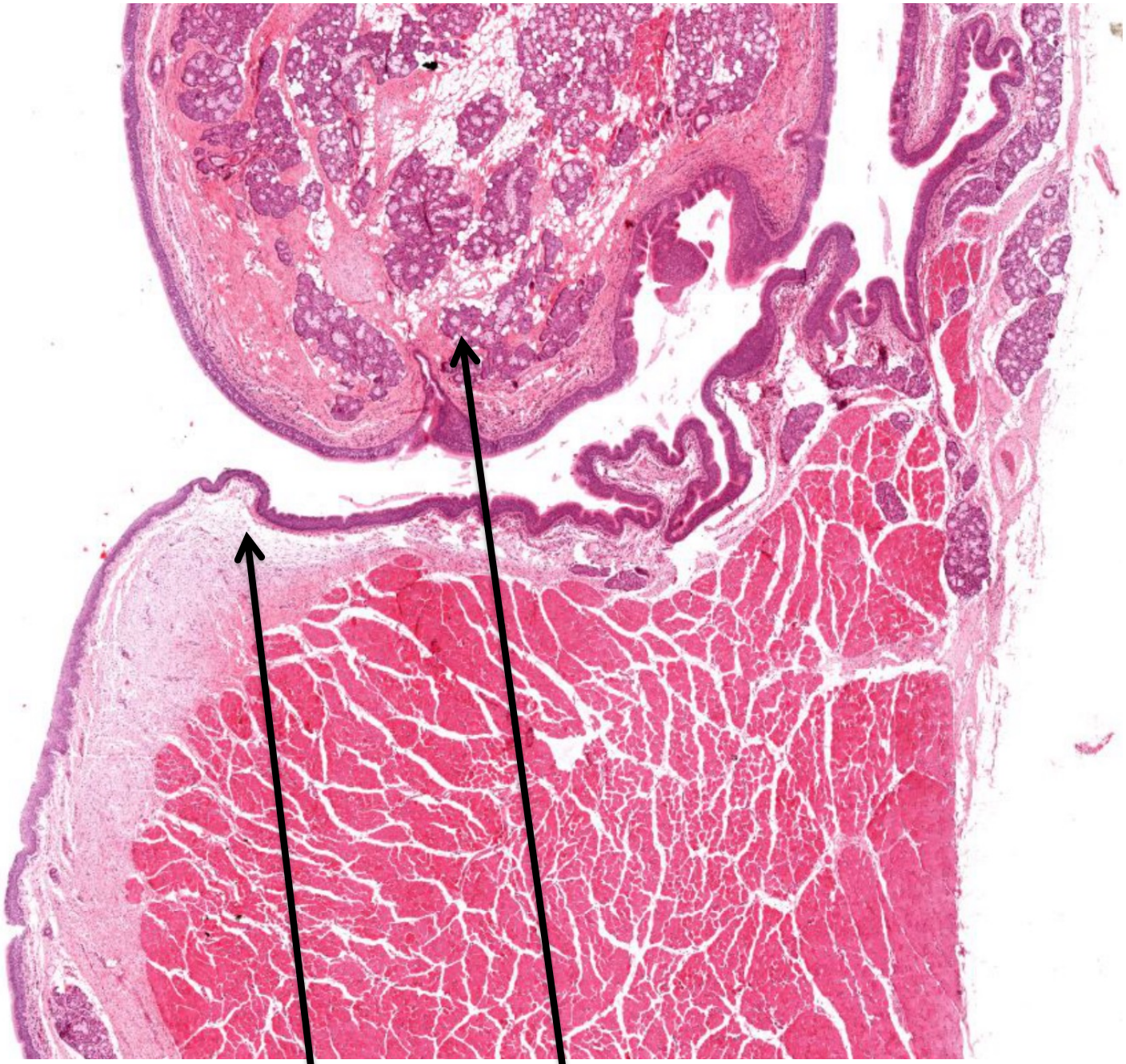
Epiglottis: super low-power view



Epiglottis: elastic cartilage



Epiglottis: elastic cartilage



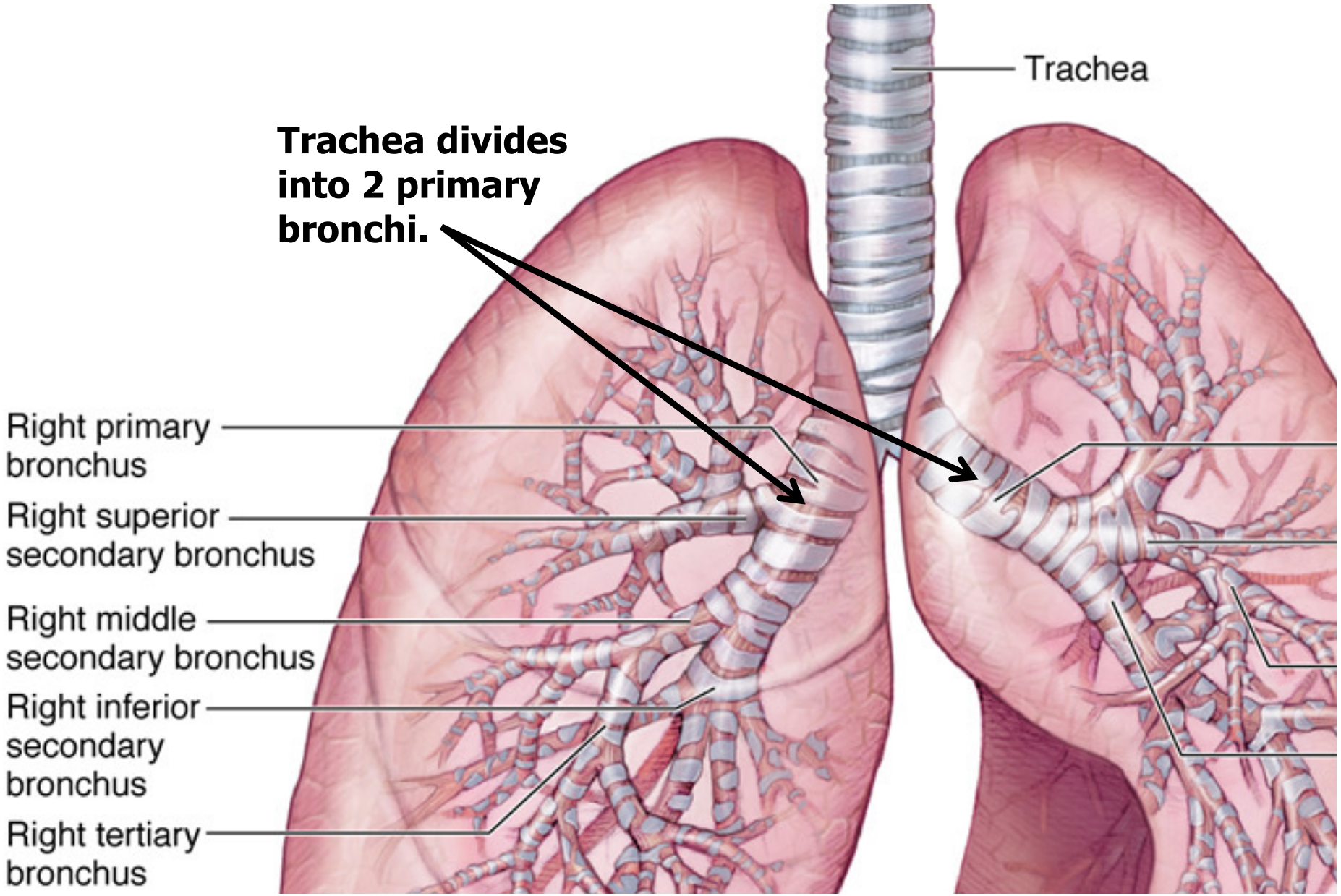
Larynx: true and false vocal cords

Respiratory System Lecture Outline

- Introduction
- Conducting portion
  - Nasal cavity
  - Larynx
  - Trachea

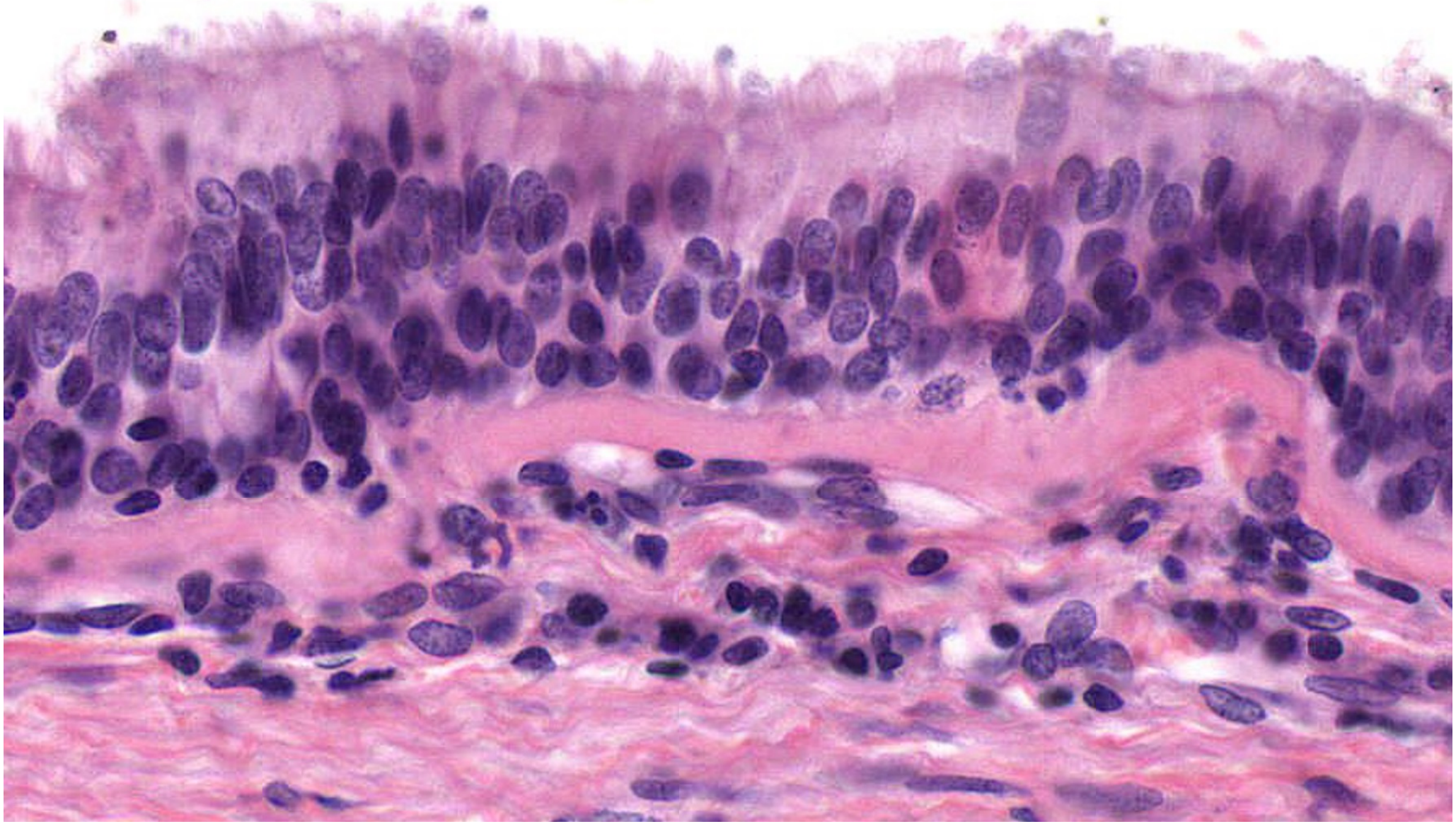
Trachea

- Extends from larynx and divides into two primary bronchi.
- Contains 16-20 C-shaped hyaline cartilage rings with the dorsal opening bridged by smooth muscle (trachealis muscle).
- Lined by respiratory epithelium.
- Seromucous glands in lamina propria and submucosa.

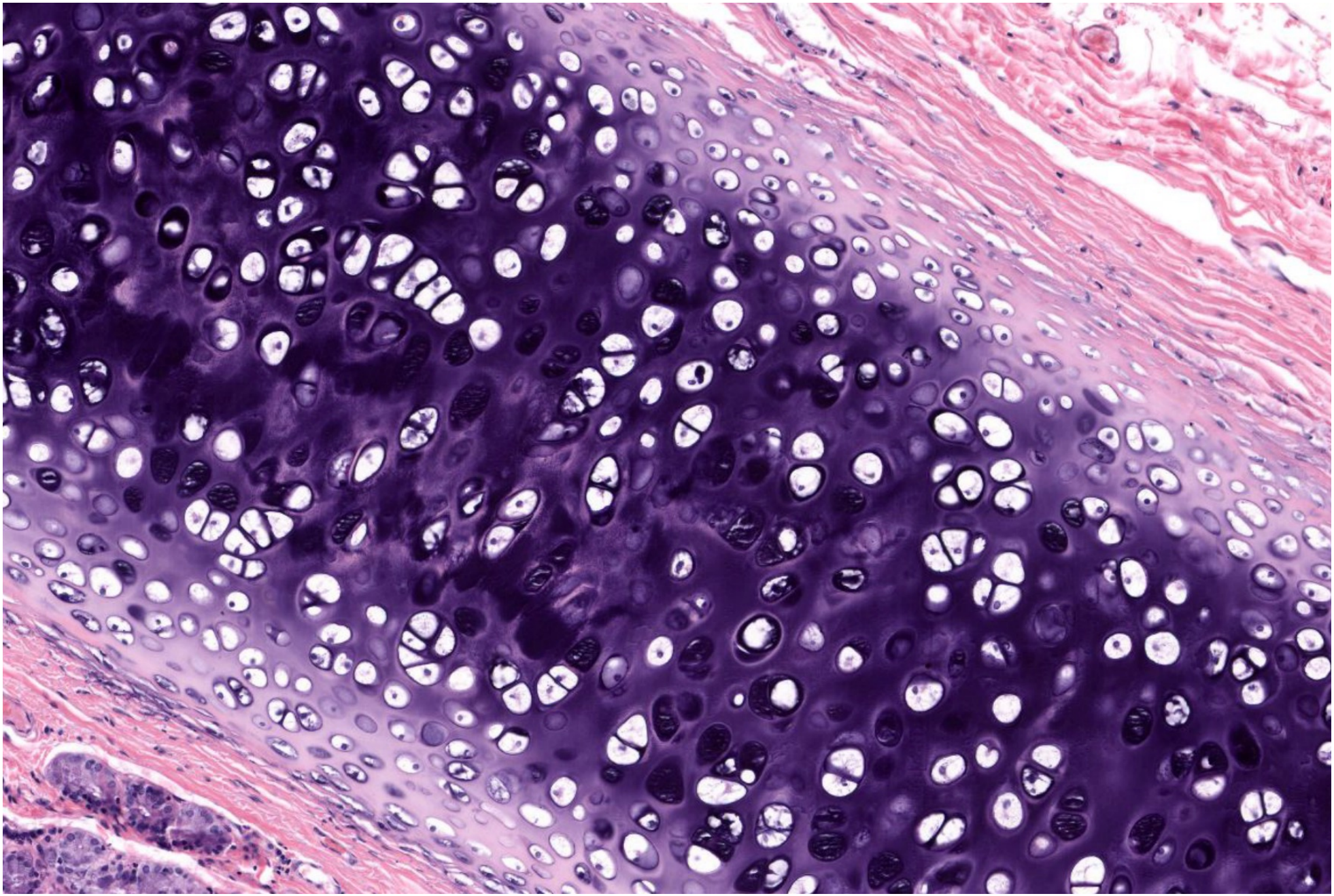

Trachea
Trachea divides into 2 primary bronchi.
Right primary bronchus
Right superior secondary bronchus
Right middle secondary bronchus
Right inferior secondary bronchus
Right tertiary bronchus

Trachea

Trachea: super low-power view



Trachea: respiratory epithelium



Trachea: hyaline cartilage

Respiratory System Lecture Outline

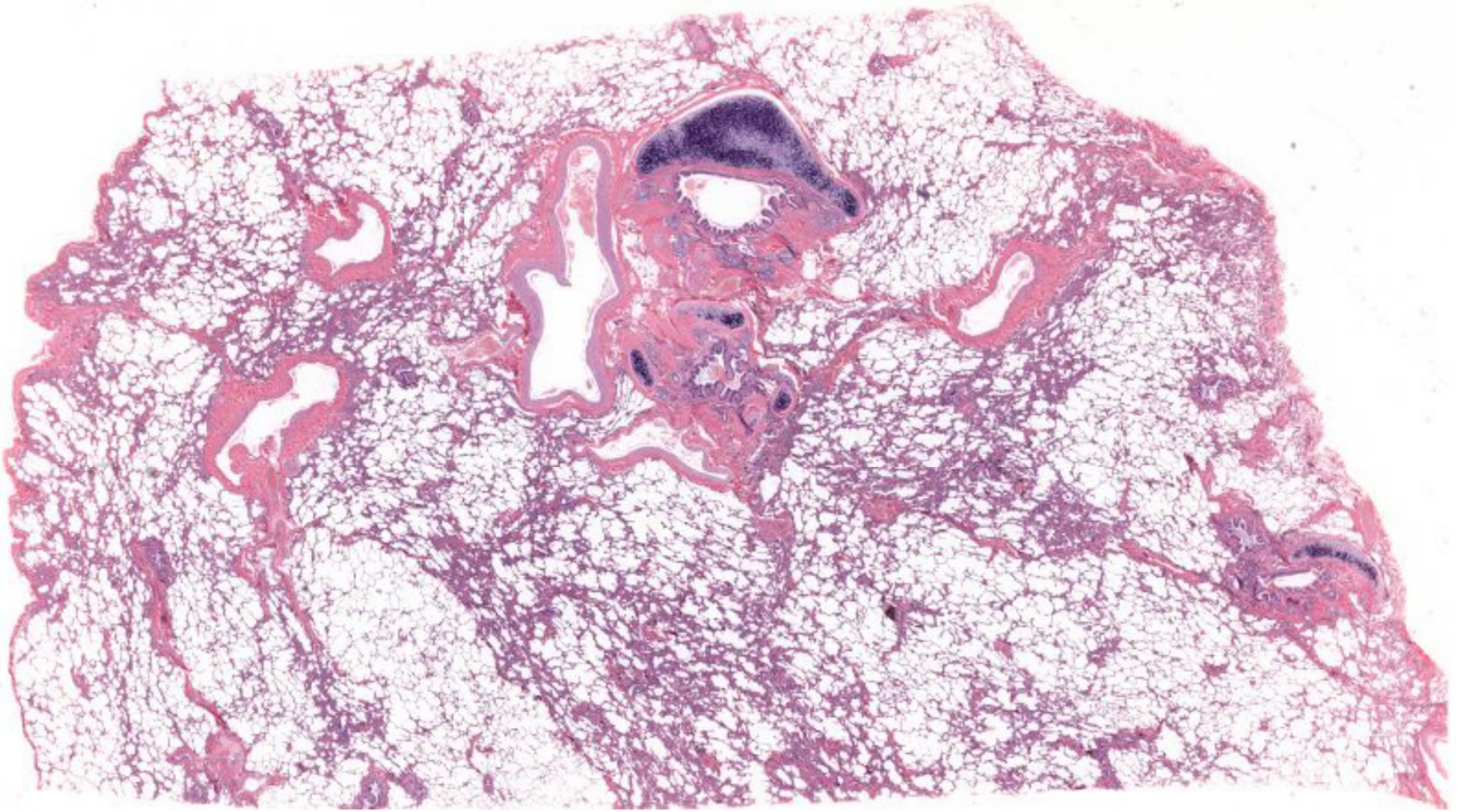
- Introduction
- Conducting portion
  - Nasal cavity
  - Larynx
  - Trachea
  - Bronchi

Bronchi

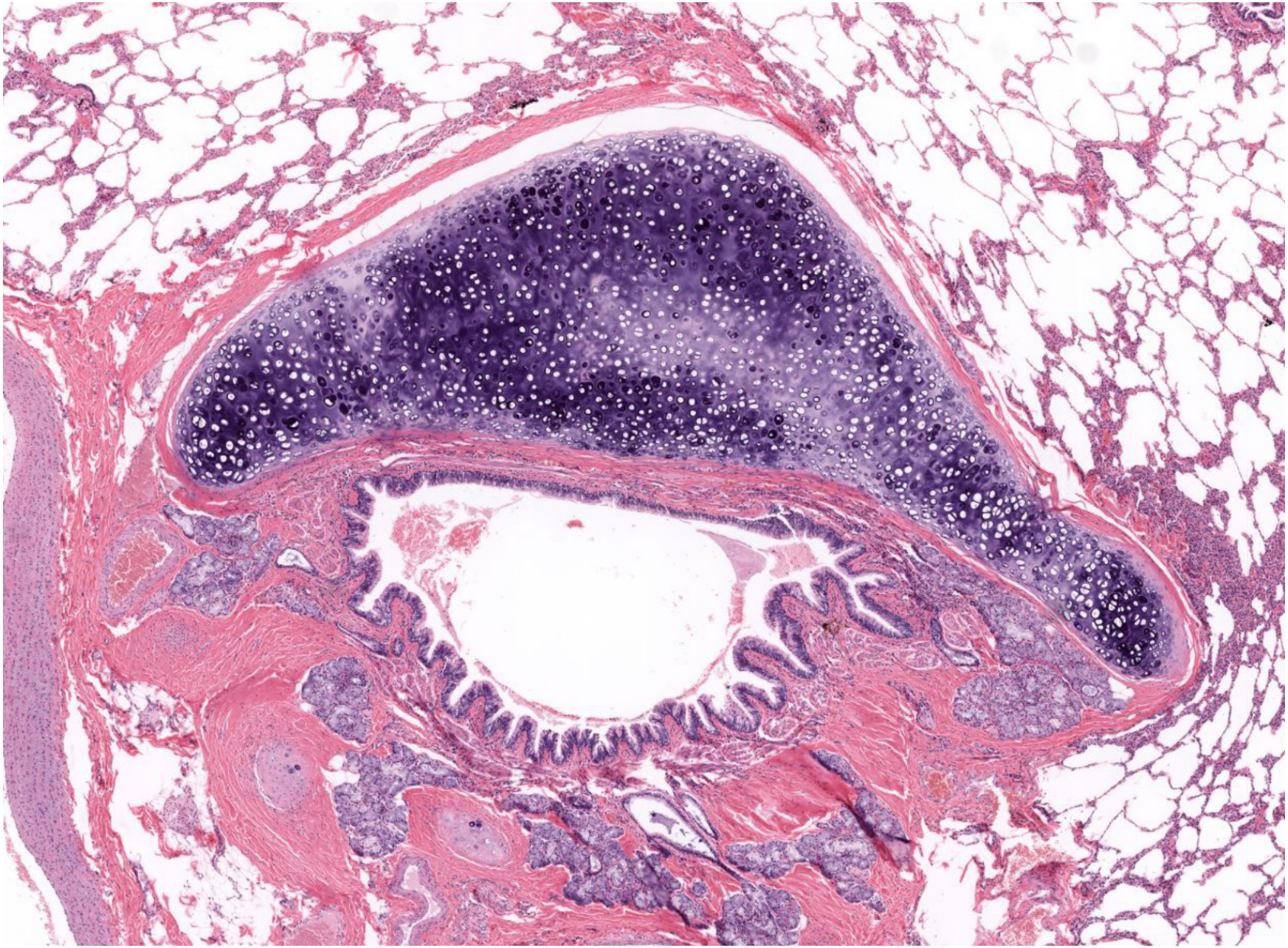
- Trachea divides into two primary bronchi, which divide into secondary bronchi.
- Secondary bronchi divide into tertiary bronchi, which supply bronchopulmonary segments.
- Tertiary bronchi divide into smaller bronchi, which divide into bronchioles.

Morphologic Changes as Bronchi Branch

- Bronchi undergo 9-12 branchings.
- As branching progresses:
  - Connective tissue decreases in thickness
  - Relative amount of smooth muscle and elastic tissue increases
  - Cartilage disappears (gone by bronchioles)

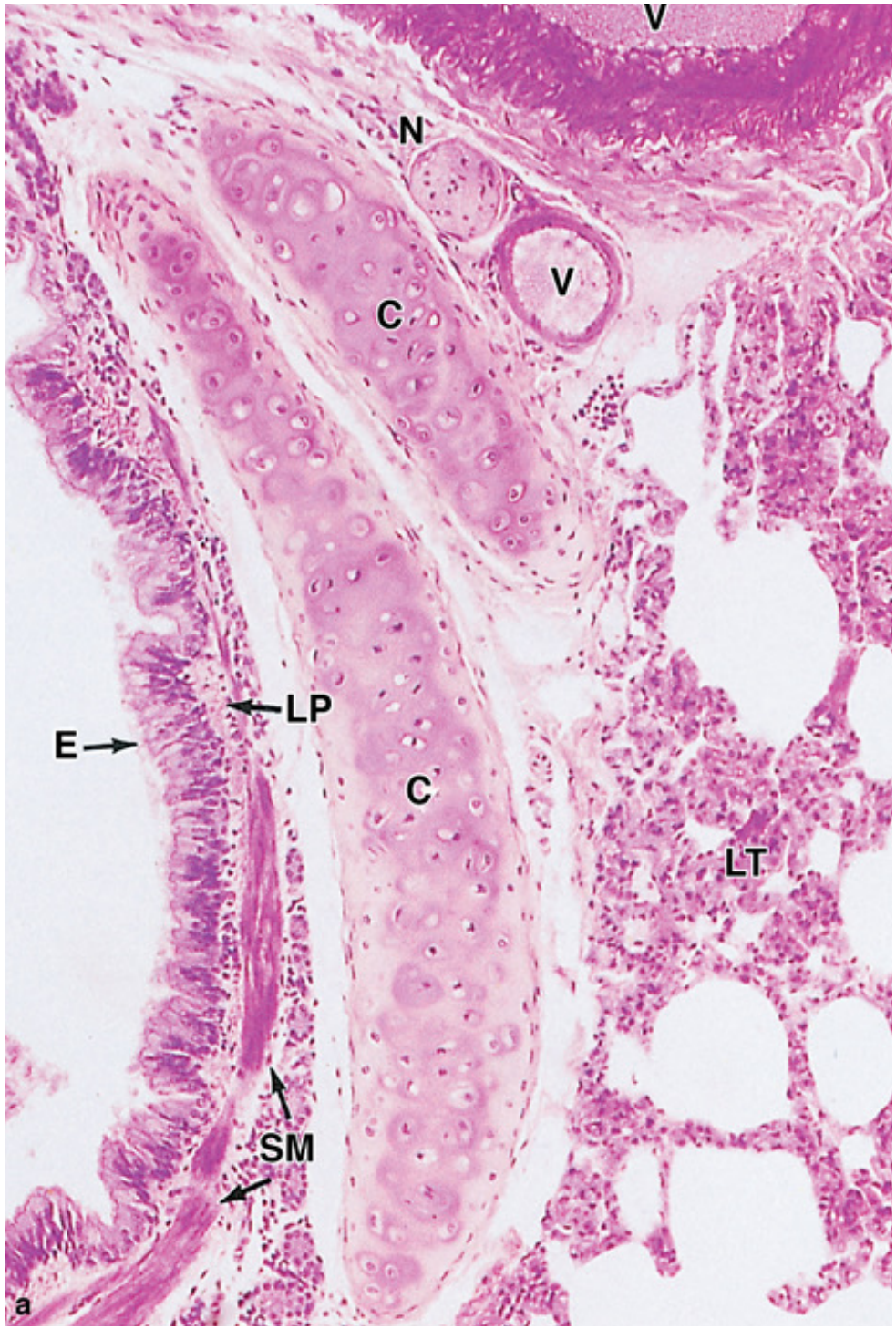


Lung super low-power view



Bronchus

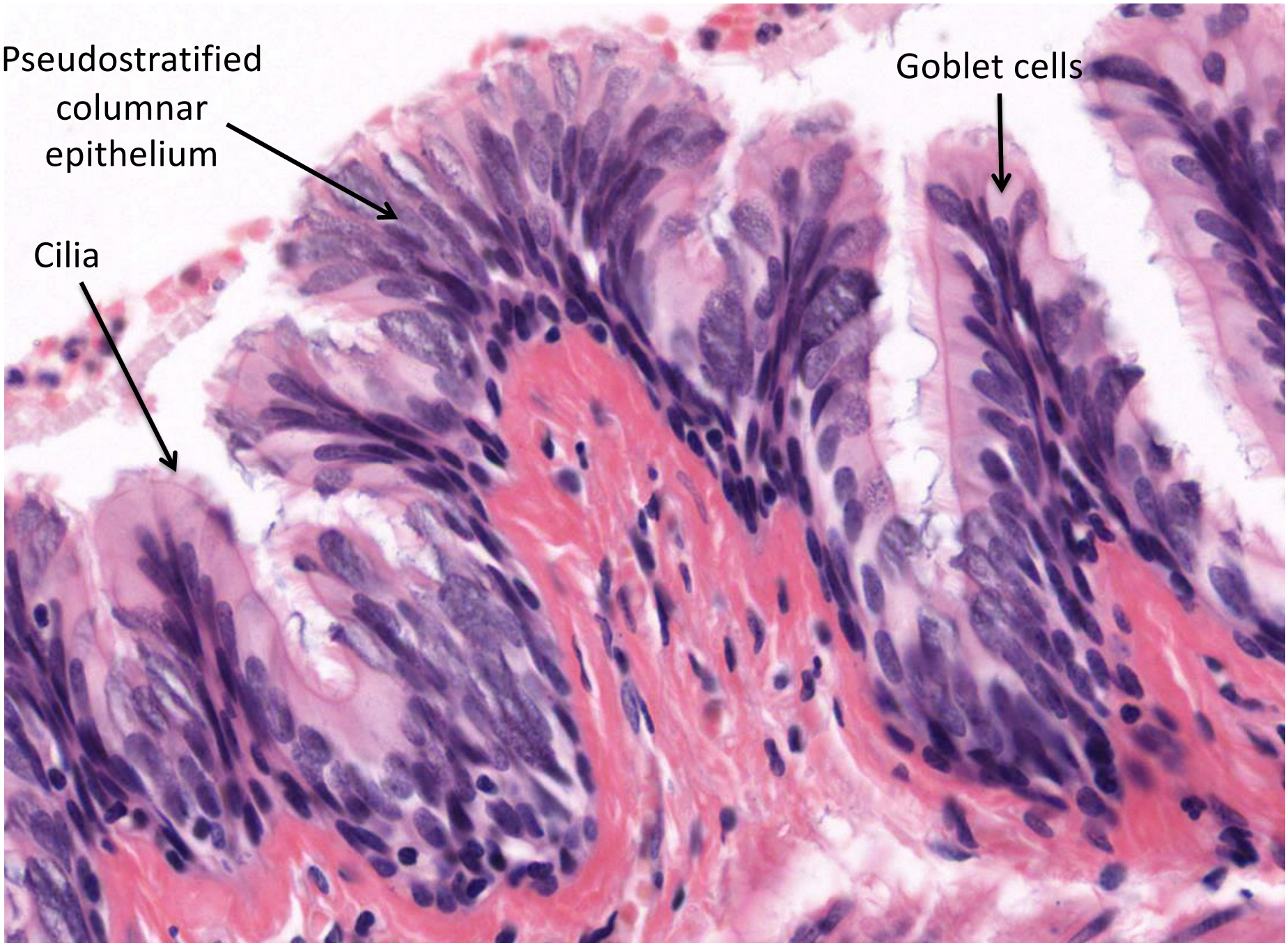
Bronchus



Wall of Bronchus

- Respiratory epithelium (E)
- Lamina propria (LP)
- Smooth muscle (SM)
- Hyaline cartilage (C)
- Nerves (N) and blood vessels (V)

Note the order of structures:
E → LP → SM → C



Bronchus: respiratory epithelium

Respiratory System Lecture Outline

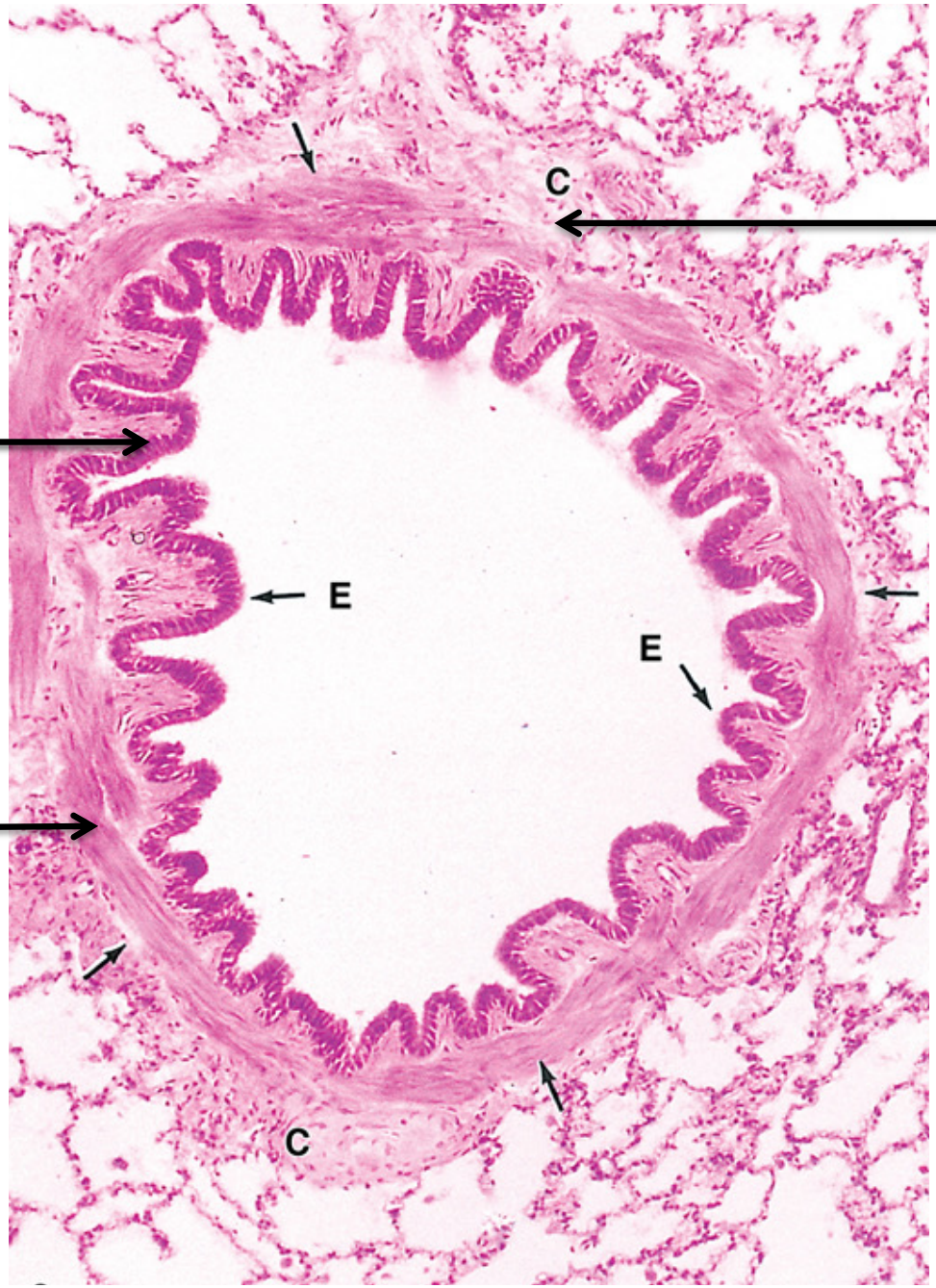
- Introduction
- Conducting portion
  - Nasal cavity
  - Larynx
  - Trachea
  - Bronchi
  - Bronchioles

Bronchioles

- NO glands or cartilage.
- Larger bronchioles have respiratory epithelium. Smaller bronchioles have low columnar epithelium.
- In asthma, the smooth muscle in the bronchioles constricts, causing difficulty breathing.

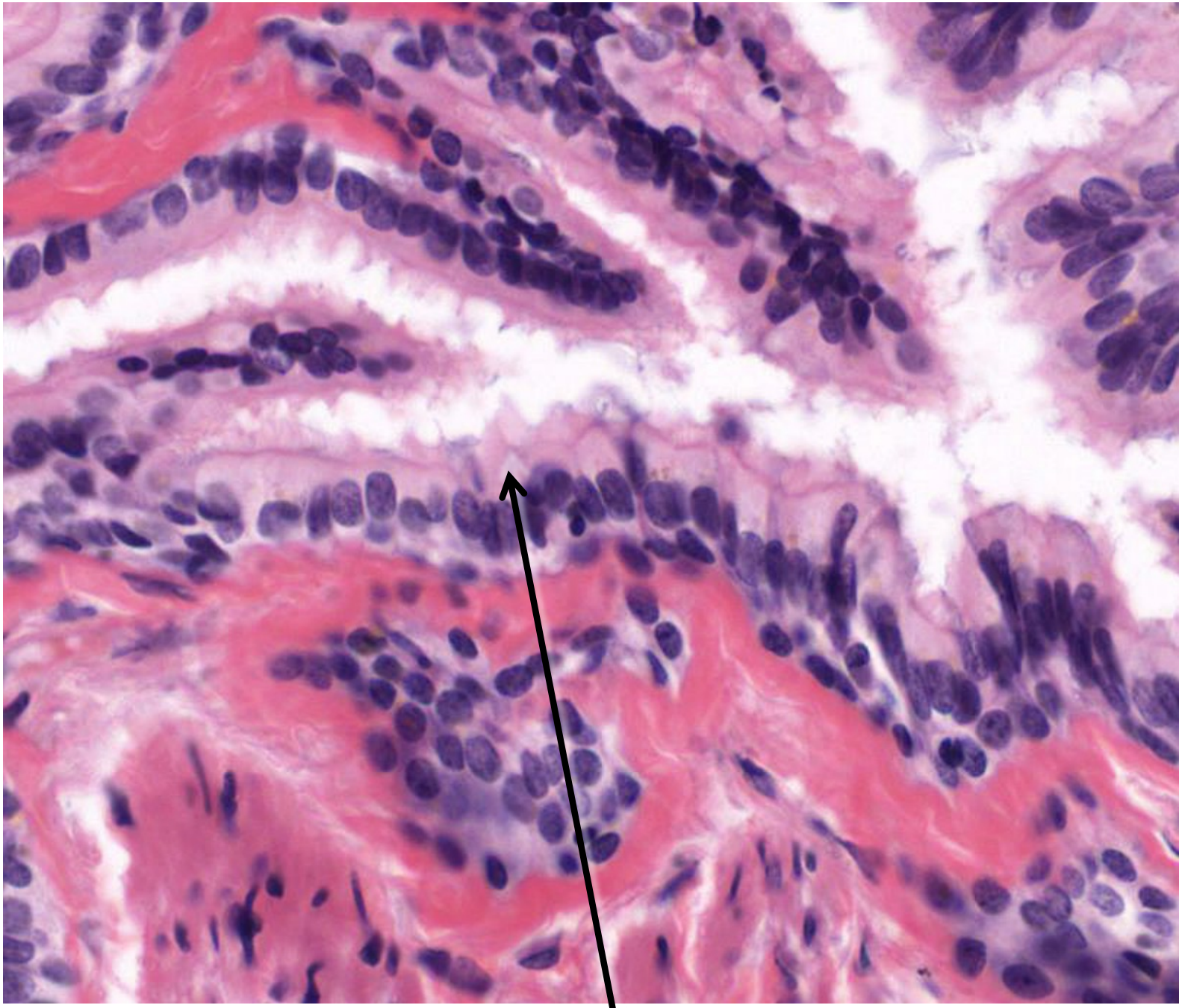
Respiratory epithelium is folded

Smooth muscle



Fibrous connective tissue is present but no cartilage or glands!

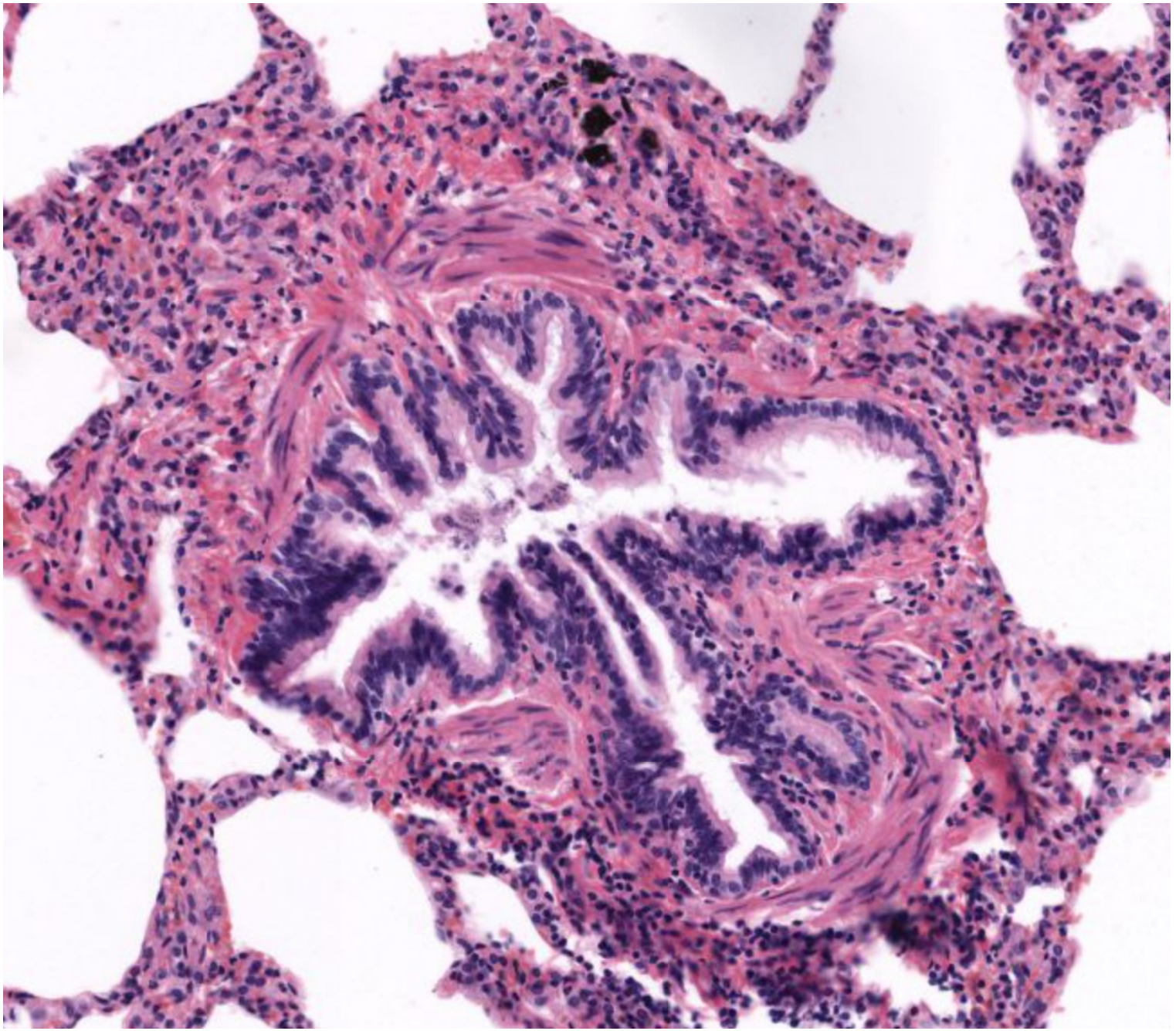
Bronchiole



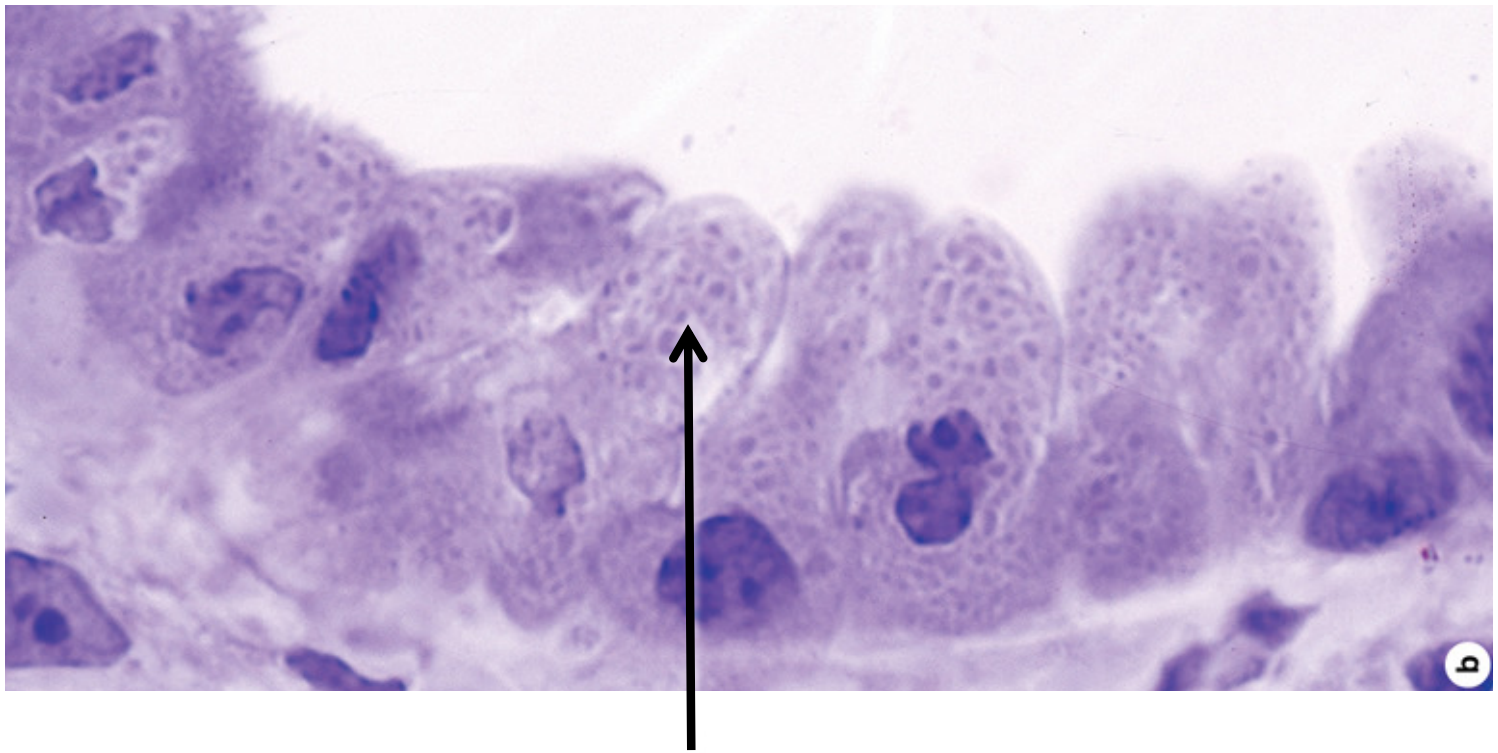
Smaller bronchioles have simple columnar epithelium

Terminal Bronchioles

- Simple cuboidal epithelium with cilia.
- Also: Clara cells (non-ciliated epithelial cells with secretory granules).
- No goblet cells.
- As you go down the respiratory tract, goblet cells are lost before cilia.



Terminal bronchiole



Clara cells

Is there anything they don't do?

Make surfactant components, break down mucus, detoxify harmful substances, transfer IgA, fight bacteria…

Respiratory System Lecture Outline

- Introduction
- Conducting portion
- Respiratory portion
  - Respiratory bronchioles
  - Alveoli

Respiratory System Lecture Outline

- Introduction
- Conducting portion
- Respiratory portion
  - Respiratory bronchioles

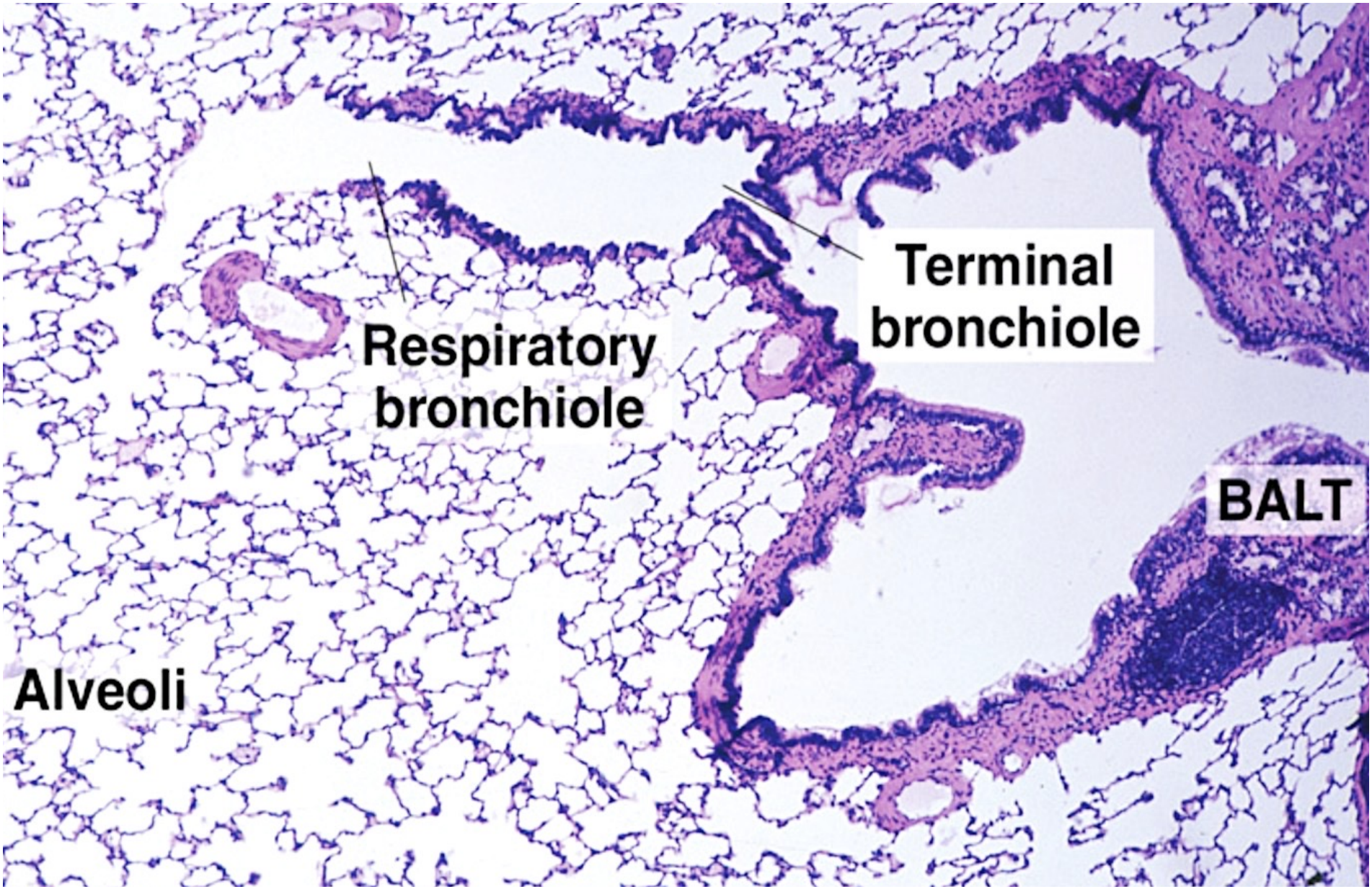
Airways Preceding Alveoli

Respiratory bronchioles

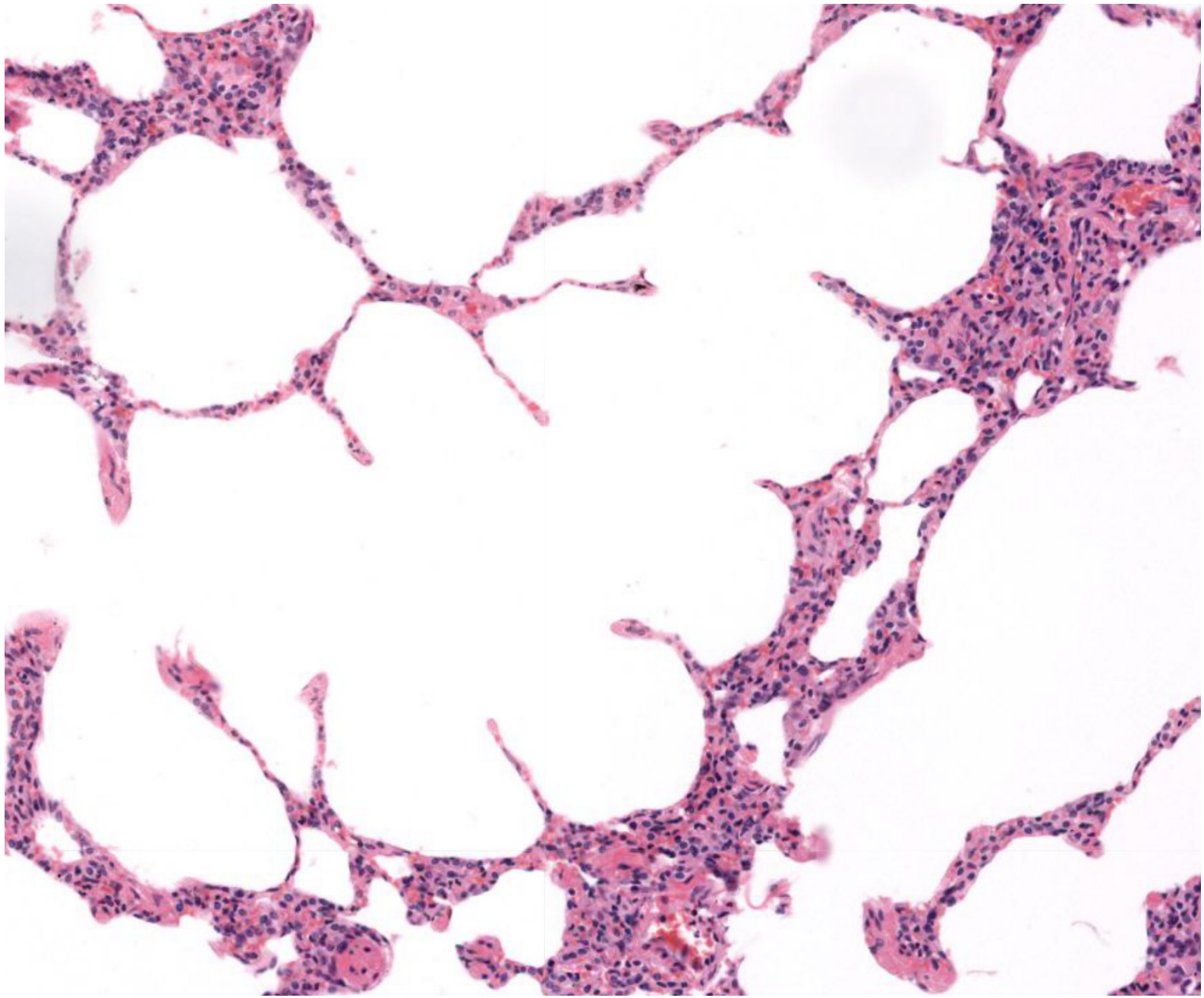
- As you go distally along the respiratory bronchioles, alveoli increase in number.
- Cilia are gone by the end of the respiratory bronchiole.

Alveolar ducts

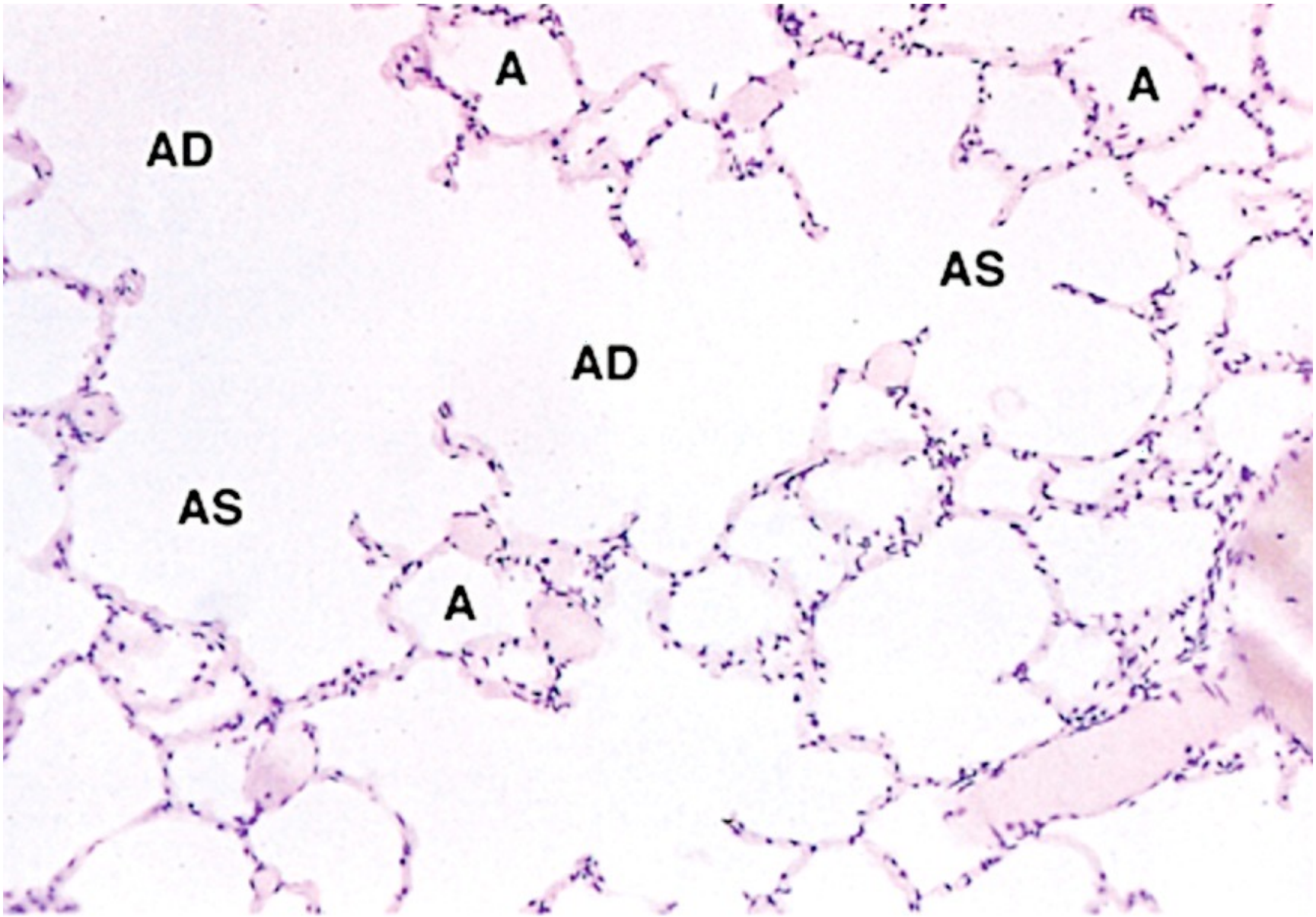
- Back-to-back alveolar openings along wall
- Smooth muscle between alveolar openings looks like knobs



Respiratory bronchiole



Alveolar duct



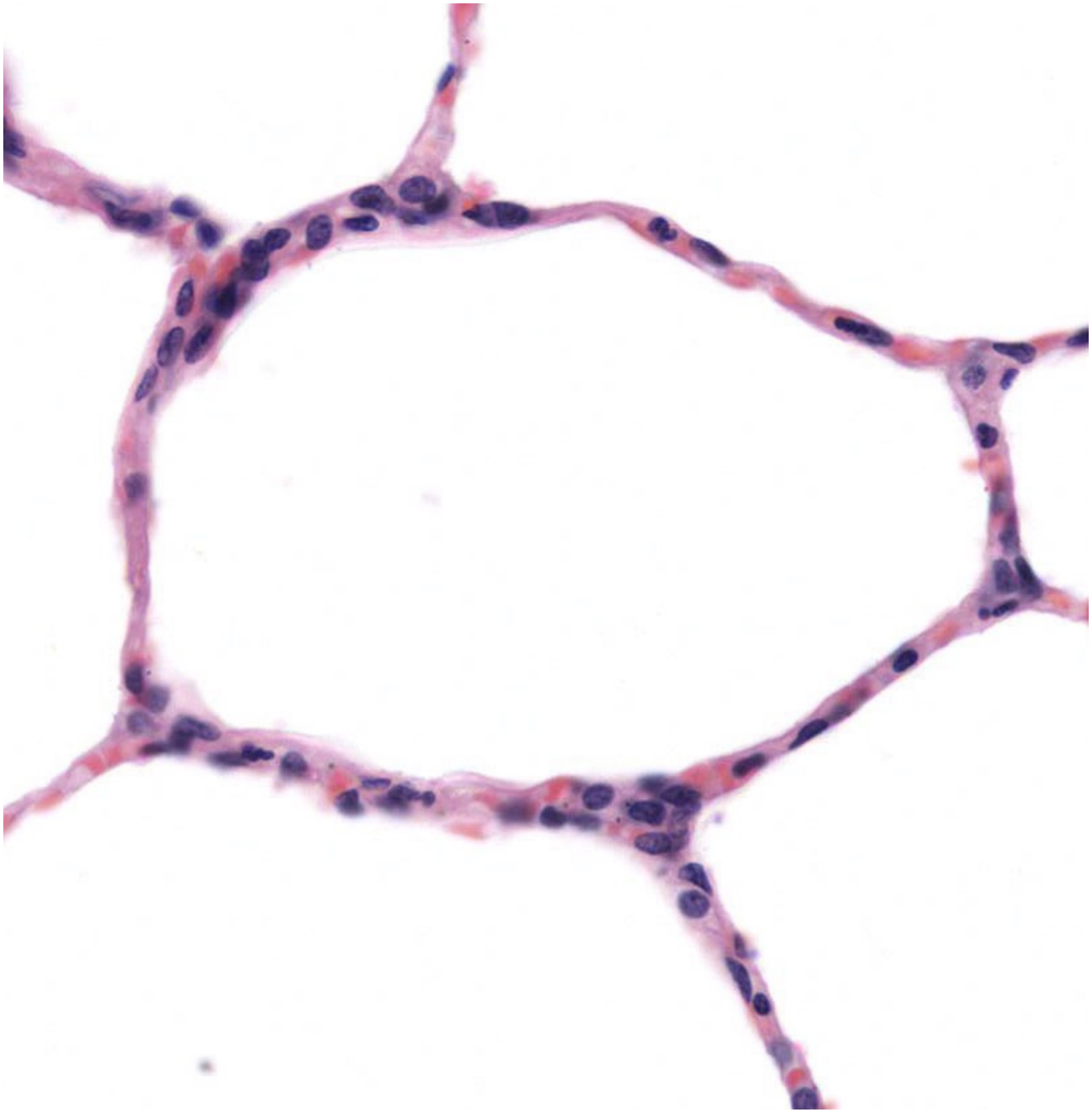
Alveolar duct (AD), alveolar sac (AS) and alveolus (A)

Respiratory System Lecture Outline

- Introduction
- Conducting portion
- Respiratory portion
  - Respiratory bronchioles
  - Alveoli

Alveoli

- Sac-like structures with super-thin walls so O_2 and CO_2 can diffuse between air and blood.
- Separated by interalveolar septae, which contain capillaries.
- Cells lining interalveolar septae:
  - Type I cells (thin, flat squamous cells)
  - Type II cells (pneumocytes): produce surfactant
  - Alveolar macrophages (dust cells)



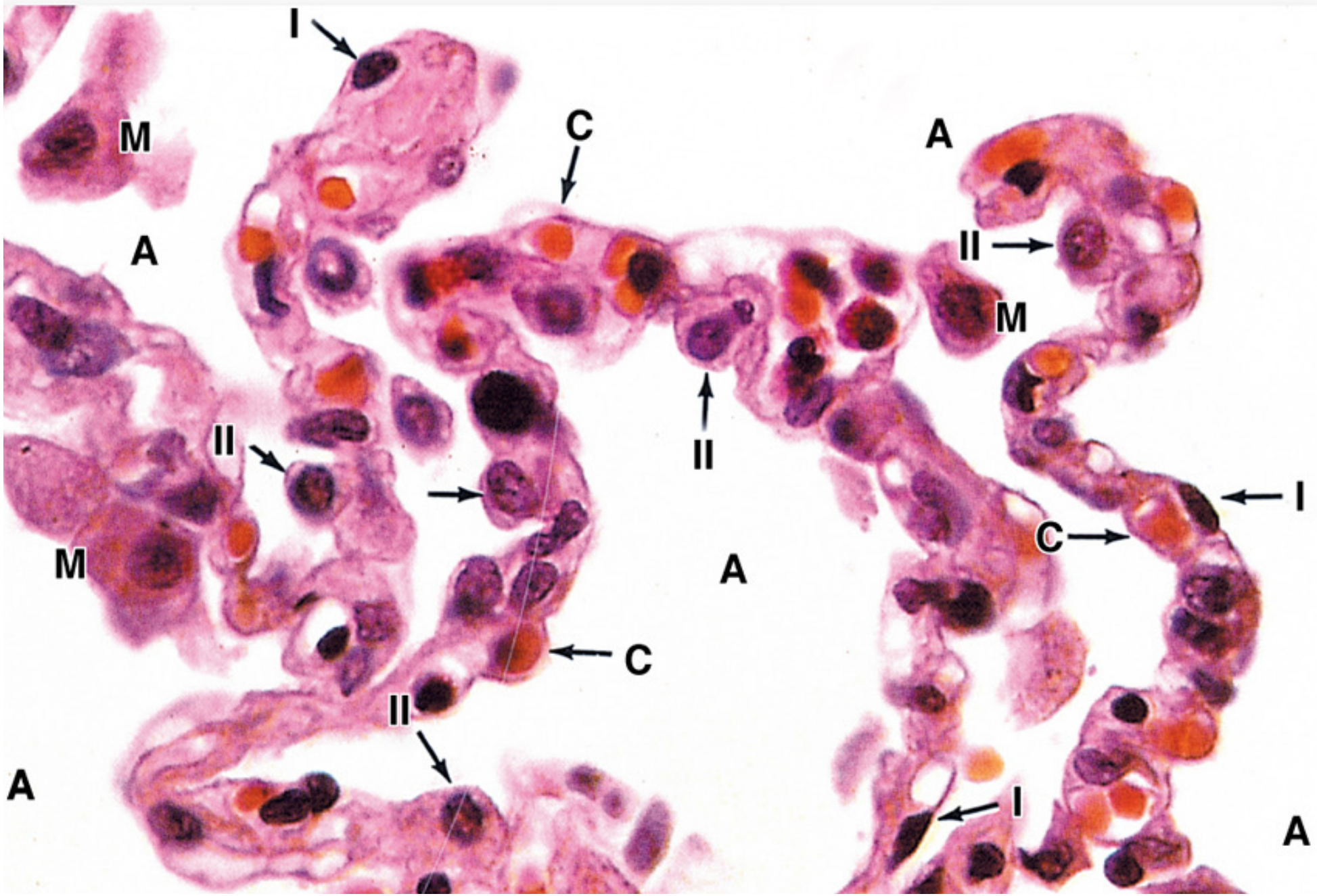
Alveolus

Type I Cells

- Cover 95% of alveolar surface
- Simple squamous cells with thin cytoplasm
- Blood-air barrier includes (from air to blood):
  - Type I cells
  - Fused basal laminae of type I cells and capillary endothelial cells
  - Capillary endothelial cells

Type II Cells (Pneumocytes)

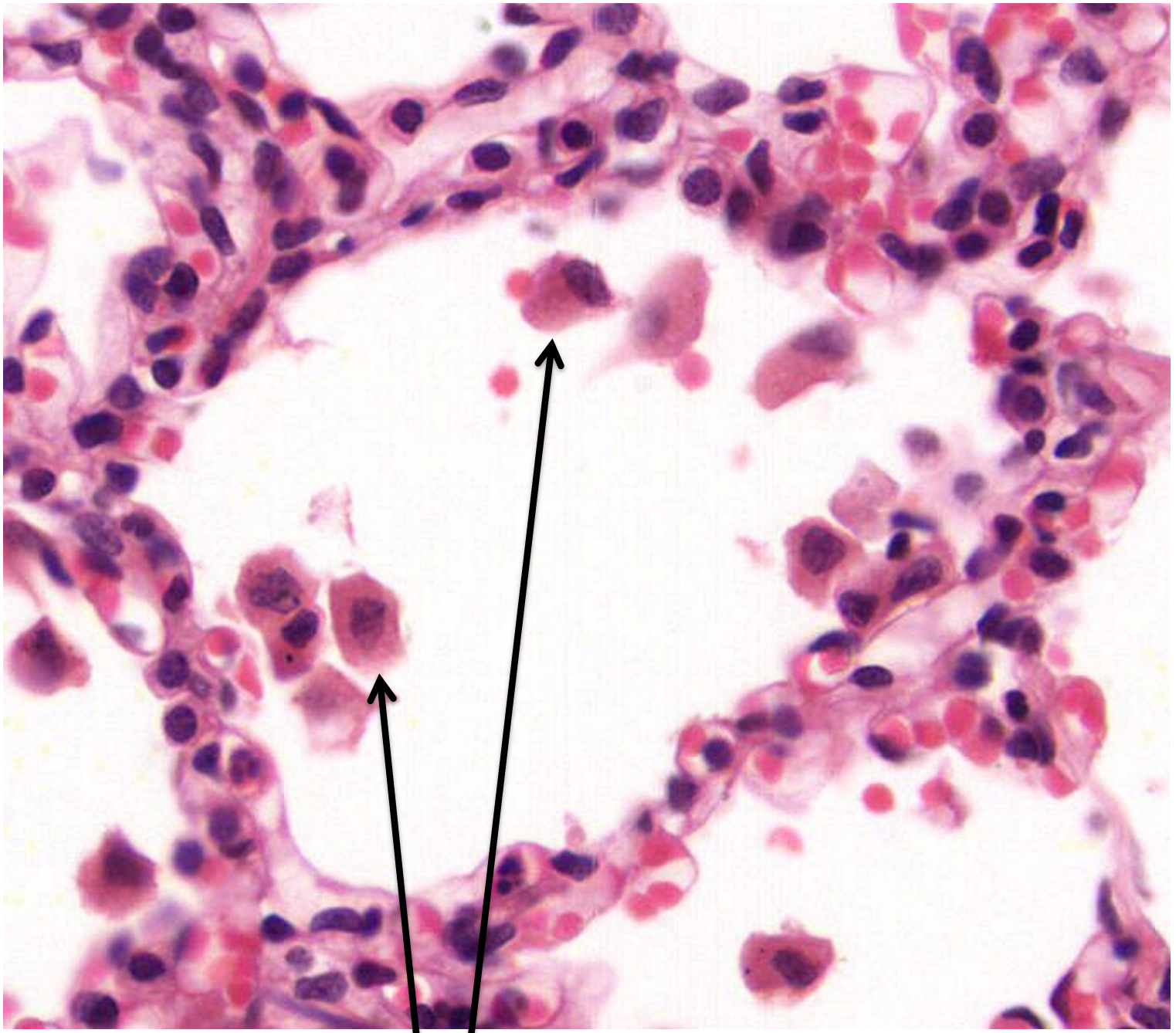
- Cover 5% of alveolar surface.
- Large cuboidal cells with round nuclei.
- Typical secretory cell structure. Lamellar bodies in cytoplasm make and store surfactant.
- Surfactant decreases surface tension in alveoli and prevents collapse of alveoli during expiration.



Alveoli lined by type I and II cells

Alveolar Macrophages (Dust Cells)

- Found on surface of alveoli, within alveoli and in interstitial connective tissue.
- Remove debris and particles that escape mucus and cilia in conducting portion of respiratory tract



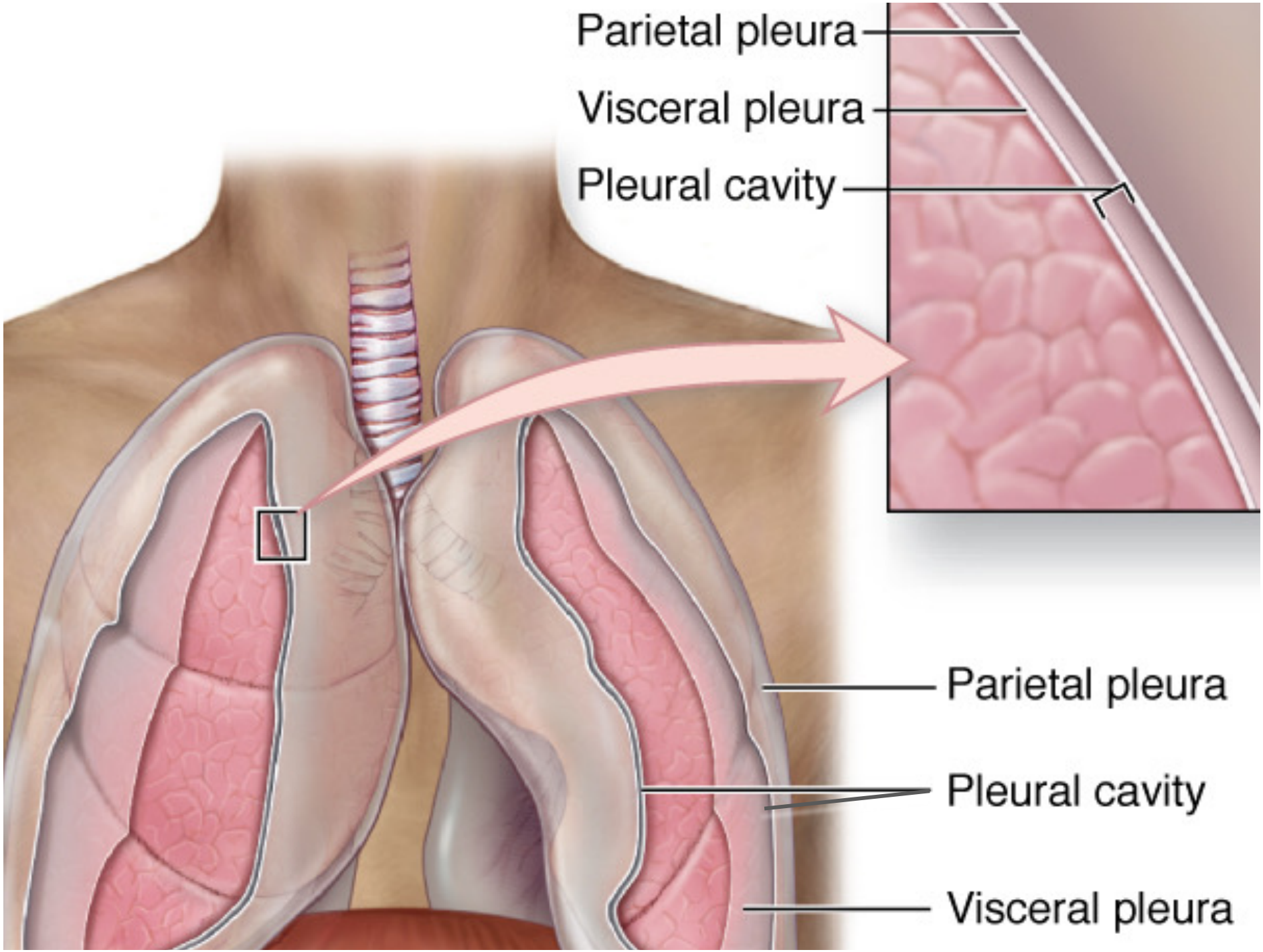
Macrophages (dust cells)

Respiratory System Lecture Outline

- Introduction
- Conducting portion
- Respiratory portion
- Pleura

Parietal and Visceral Pleura

- The outer surface of the lung and the inner surface of the thoracic cavity are covered by the pleura, which is a serous membrane (serosa).
- Parietal pleura lines the thoracic cavity; visceral pleura covers the lungs.
- Serous membranes consist of simple squamous epithelial cells called mesothelium plus a thin layer of connective tissue.
- The pleural cavity contains serous fluid made by the pleura.


Parietal pleura
Visceral pleura
Pleural cavity
Parietal pleura
Pleural cavity
Visceral pleura

Respiratory System Lecture Outline

- Introduction
- Conducting portion
- Respiratory portion
- Pleura