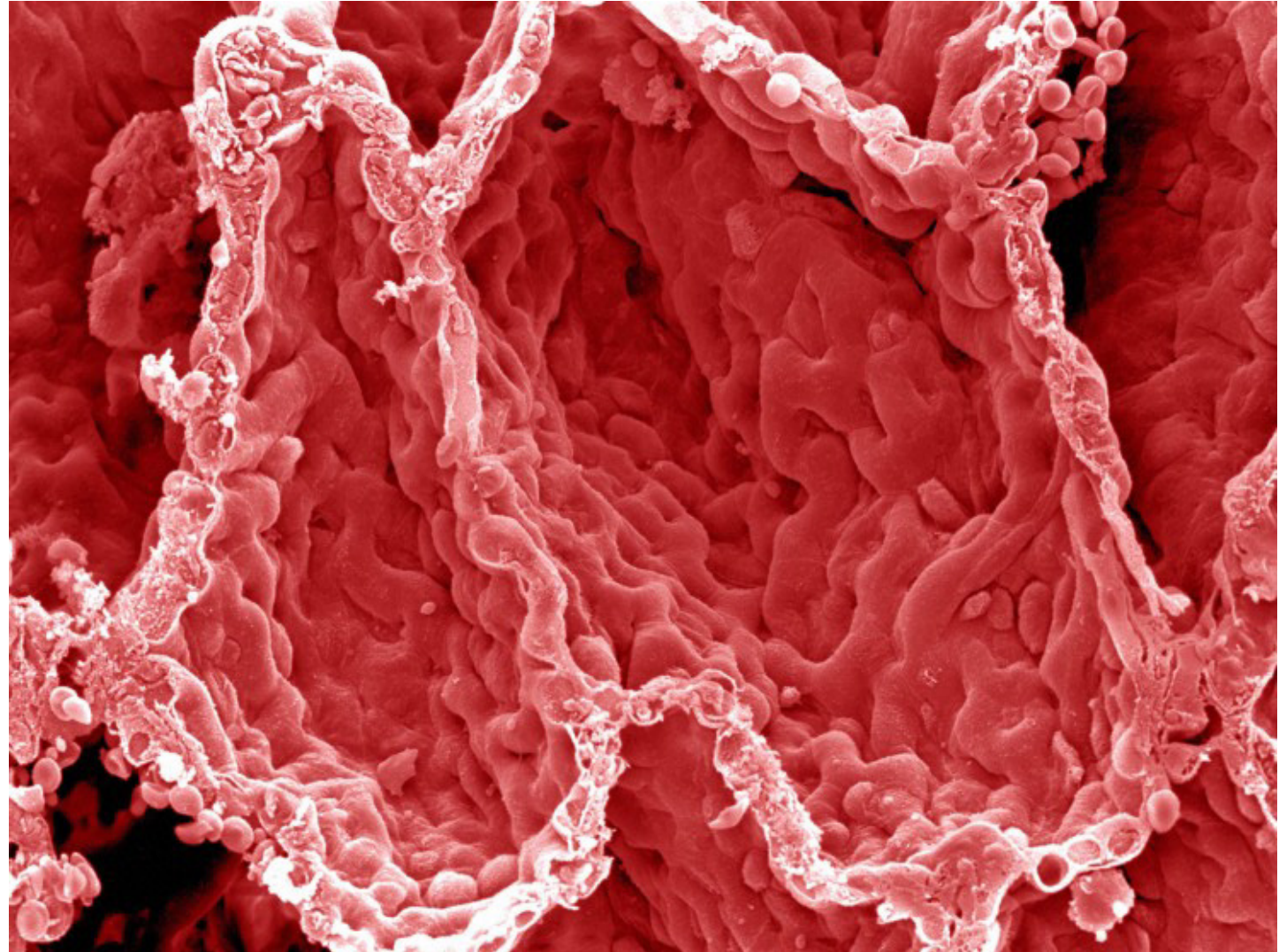


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Respiratory System



SEM of alveoli in lung.

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Introduction

The respiratory system consists of two functional divisions with distinct structural elements that reflect their unique roles in the process of respiration:

1. The **conducting airways** serve to clean, warm, moisten, and conduct air. This portion is composed of the nose, pharynx, larynx, trachea, bronchi, and bronchioles (terminal). In general, this portion is lined by respiratory epithelium (pseudostratified ciliated columnar epithelium).
 - **Extrapulmonary air conduits** are located outside of the lungs and begin with the nose, pharynx and larynx. The trachea is continuous with the larynx above and the two primary bronchi below.
 - **Intrapulmonary air conduits** are located within the lung and extend from the intralobar bronchi to the terminal bronchioles. When the bronchi enter the lung, the C-shaped cartilages that characterize the trachea and primary bronchi are replaced by irregular plates of cartilage that completely surround the cylindrical muscular airway tube. Cartilage disappears in the terminal bronchioles. The terminal bronchioles initially have a ciliated columnar epithelium that soon transitions to a low cuboidal epithelium.
2. The **respiratory airways** facilitate gas exchange (have alveoli). These are located entirely within the lung and are represented by respiratory bronchioles, alveolar ducts, alveolar sacs, and alveoli. The epithelium of the respiratory airways quickly transitions from a low, simple cuboidal epithelium to simple squamous epithelium.

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Learning Objectives

1. Describe the components of the nasal cavity and their functions in conditioning air.
2. Explain the structural features of the larynx and their roles in producing phonation.
3. Describe the key structural changes to the airway along the lower respiratory tract (trachea through alveoli).
4. Describe the structure/function relationship of the epithelial lining of the respiratory tract and how it changes from the trachea to the alveolus.
5. Identify the characteristic microscopic structural and cellular components of defined elements of the respiratory system from the trachea to the alveolus.
6. Identify the structural components of the nasal cavity, including the organization of the respiratory mucosa.
7. Describe the components of olfactory mucosa and explain their functions in producing the sense of smell.

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Learning Objectives (cont.)

- 8. Identify the structural features of the larynx, comparing and contrasting the true and false vocal folds.
- 9. Describe the structure and functions of the conducting portion of the respiratory system.
- 10. Recognize and describe respiratory epithelium and the functional significance of its structural features.
- 11. Describe and identify the structures of the larynx, trachea, and bronchial trees.
- 12. Explain the structure and functions of respiratory bronchioles, alveolar ducts, and alveoli.
- 13. Recognize and describe the functions of type I and type II pneumocytes and alveolar macrophages.
- 14. Recognize and describe the structural features of the alveolar septum or air-blood barrier.

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Keywords

Air-blood barrier
Alveolar duct
Alveolar sac
Alveoli
Bronchiole
Bronchus
Cartilage plate
Conchae (turbinates)
Dust cell (macrophage)
False vocal fold/cord
Larynx
Nasal cavity
Nasal septum

Olfactory epithelium
Respiratory bronchiole
Respiratory epithelium
Terminal bronchiole
Trachea
Tracheal ring
Trachealis muscle
True vocal fold/cord
Type I pneumocyte
Type II pneumocyte
Vocal ligament
Vocalis muscle

Lab 13 - Respiratory System

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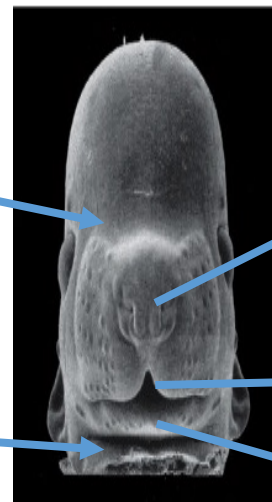
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Slide 130: Fetal Skull

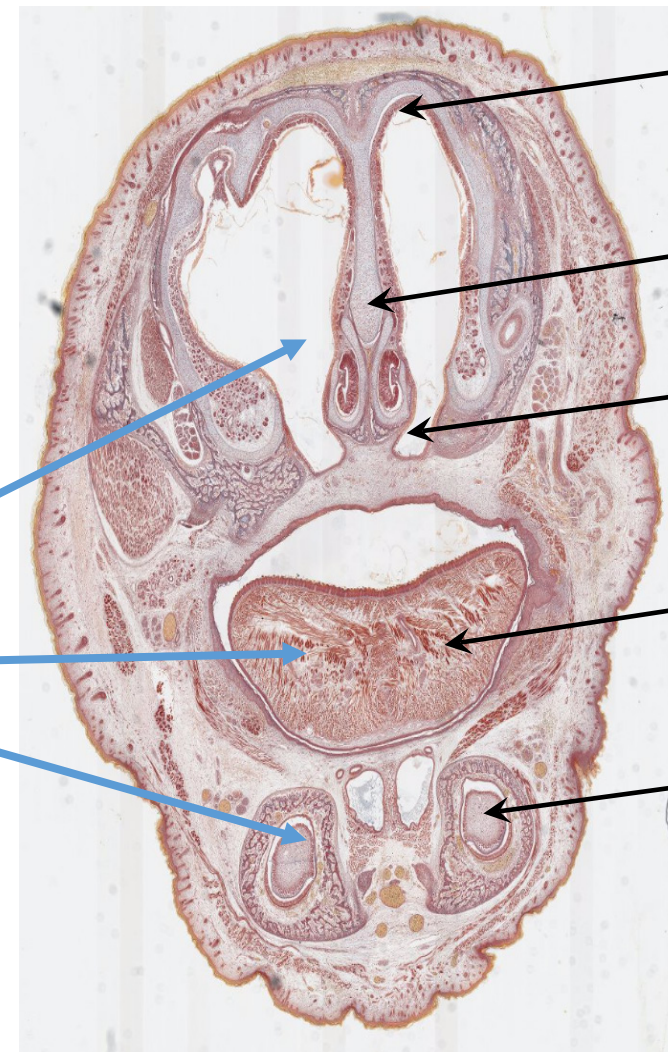
Slide Overview



Side View



Frontal View



look here for
**olfactory
epithelium**

cartilaginous **nasal
septum**

look here for
**respiratory
epithelium**

tongue in the
oral cavity

developing tooth

Slide 130 - Fetal Skull

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Slide 12a (464): Fetal Pig Head, H&E



olfactory epithelium

respiratory epithelium

pseudostratified ciliated
columnar epithelium

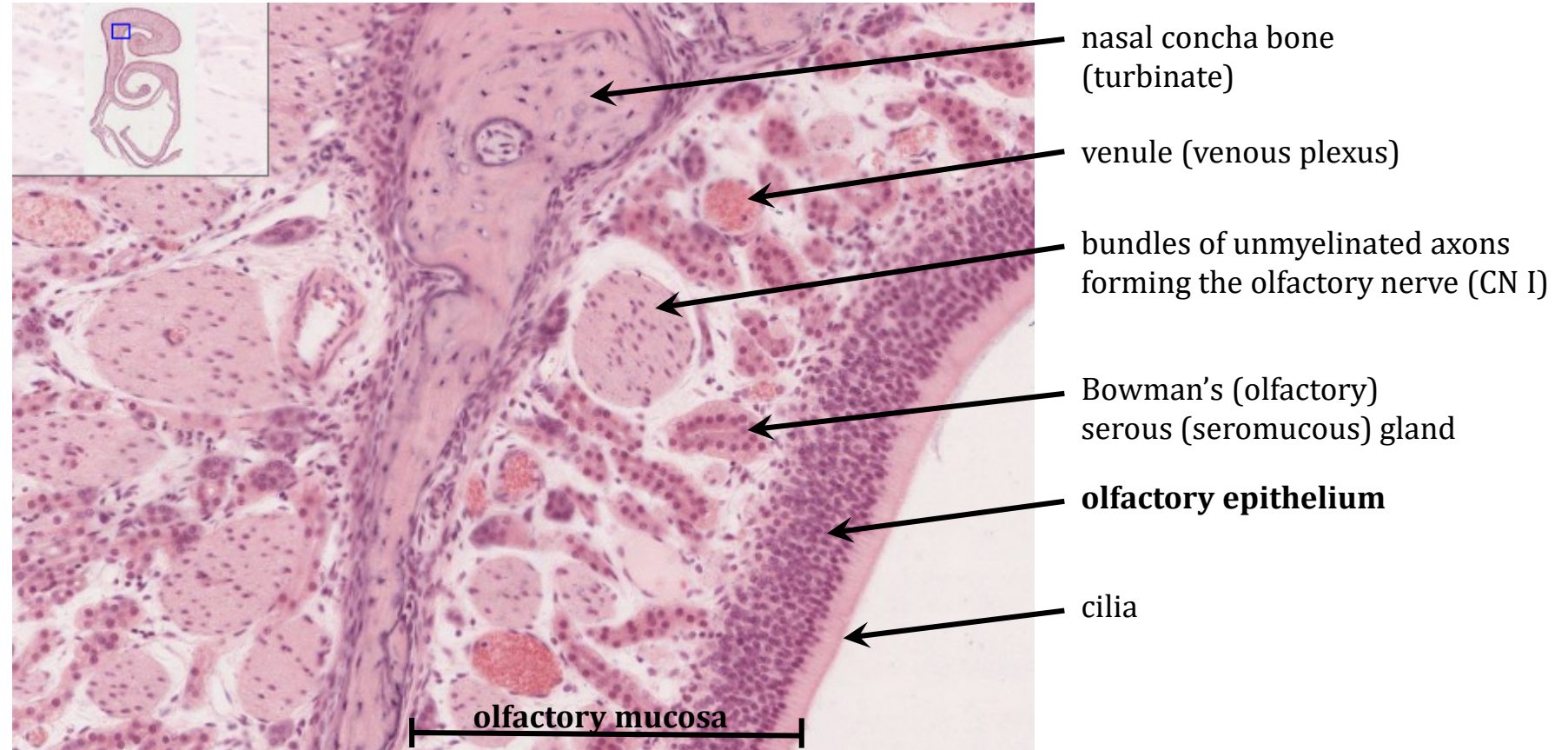
olfactory epithelium is specialized pseudostratified ciliated columnar epithelium located on the roof of the nasal cavity; it contains several cell types, including olfactory neurons, that facilitate the detection of odors

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Slide 64 (NW): Olfactory Epithelium, H&E



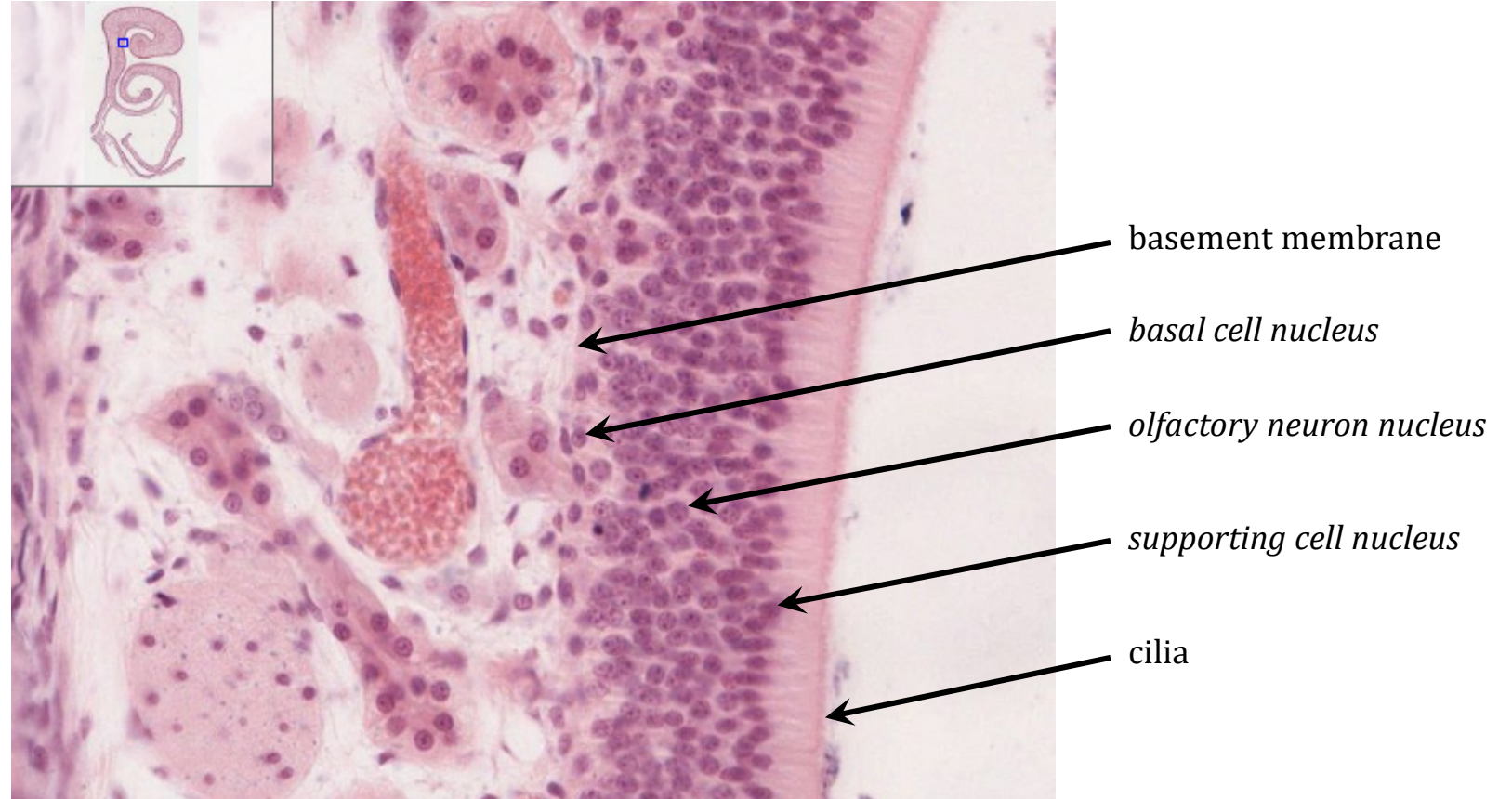
the *olfactory mucosa* – like all mucosa – consists of an *epithelial lining* and an underlying connective tissue *lamina propria*; the specialized **olfactory epithelium** contains neurons for olfaction (sense of smell); within the lamina propria, the extensive *venous plexus* permits effective heat exchange to warm incoming air; however, inflammatory conditions (e.g., allergies and infections) can cause engorgement and leakiness of the vessels, leading to swelling of the mucosa and obstruction of the air passageways

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Slide 64 (NW): Olfactory Epithelium, H&E



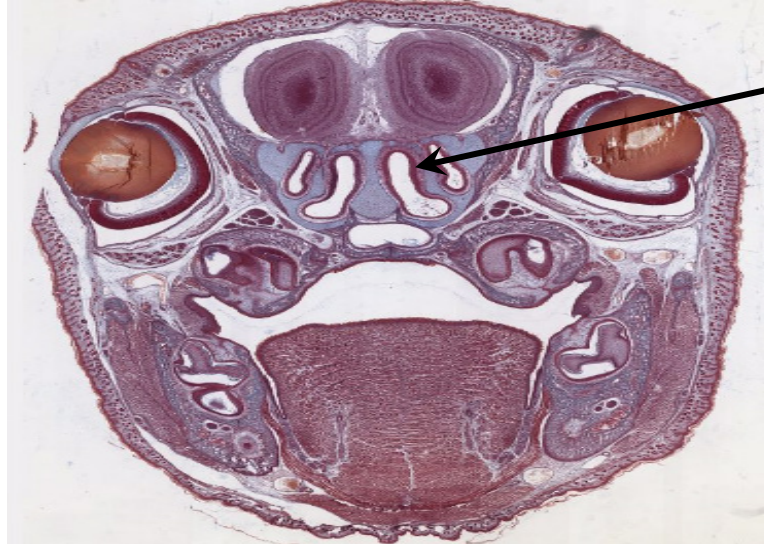
the **olfactory epithelium** is composed of three cell types: (1) the basally-located *basal cells* which serve as stem cells for the other two cell types, as olfactory neurons have a short lifespan (only about one month); (2) the *olfactory neurons* which span the depth of the epithelium but whose axons are generally located in the middle of the epithelium; and (3) the *supporting cells* which are pseudostratified columnar epithelial cells with apically-located nuclei and serve as support cells for the neurons and secrete the odor-binding proteins

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Slide 32 (NW): Osteogenesis



Additional Slides to Examine

look within the developing nasal cavity to find **olfactory epithelium** (and respiratory epithelium)

Slide 8a (464): Olfactory Epithelium



Slide 12a (464): Guinea Pig Head



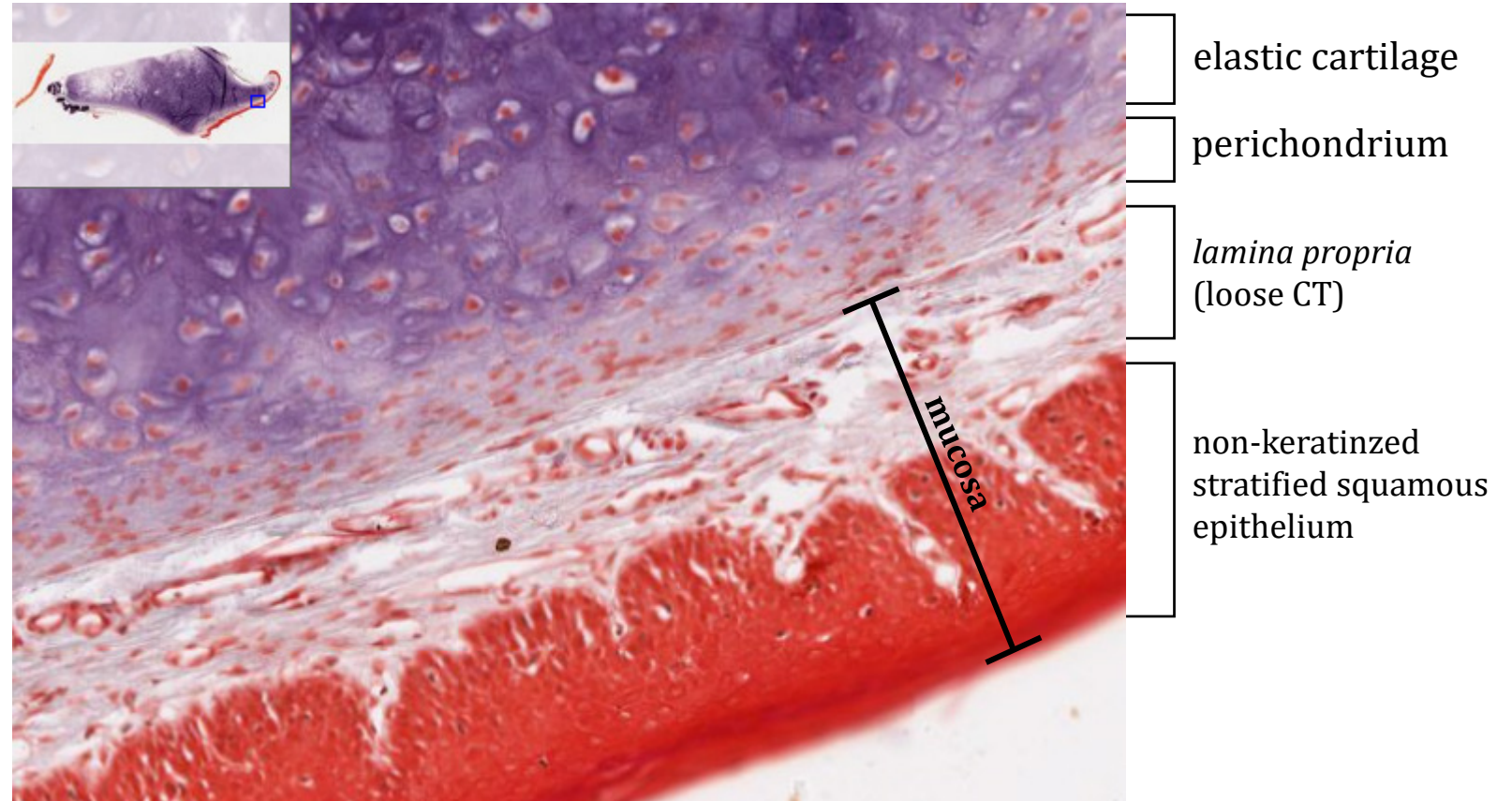
look within the developing nasal cavity to find **olfactory epithelium** (and respiratory epithelium)

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Slide 87: Epiglottis, Masson AF



the *epiglottis* is a large flap of elastic cartilage covered by mucosa that serves to close the entrance to the larynx; during swallowing, it closes off the entrance to the larynx so that swallowed food and liquid go into the esophagus instead of the larynx and ultimately the trachea and lungs

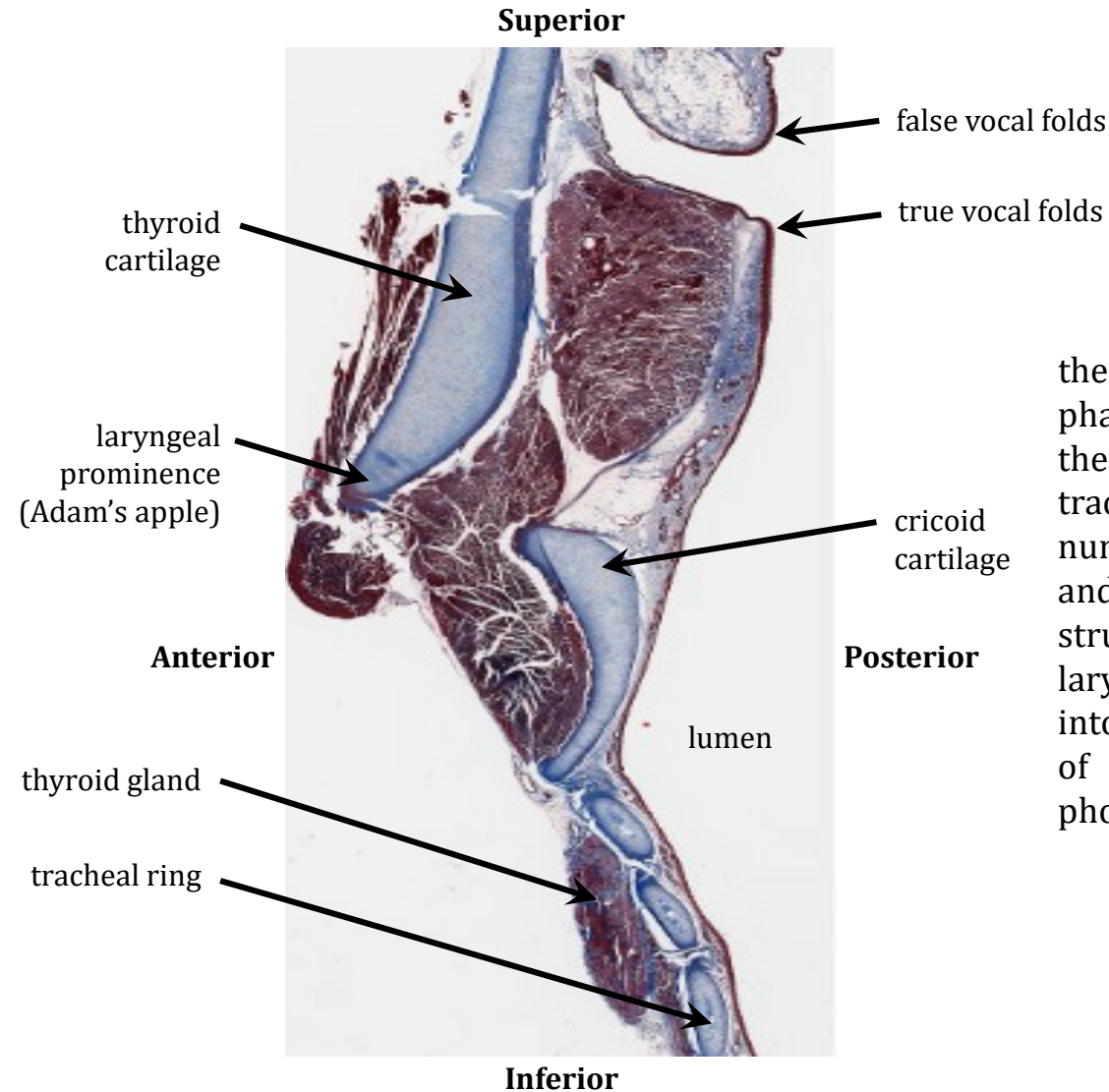
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Slide 7: Larynx (Monkey), Trichrome

Slide Overview



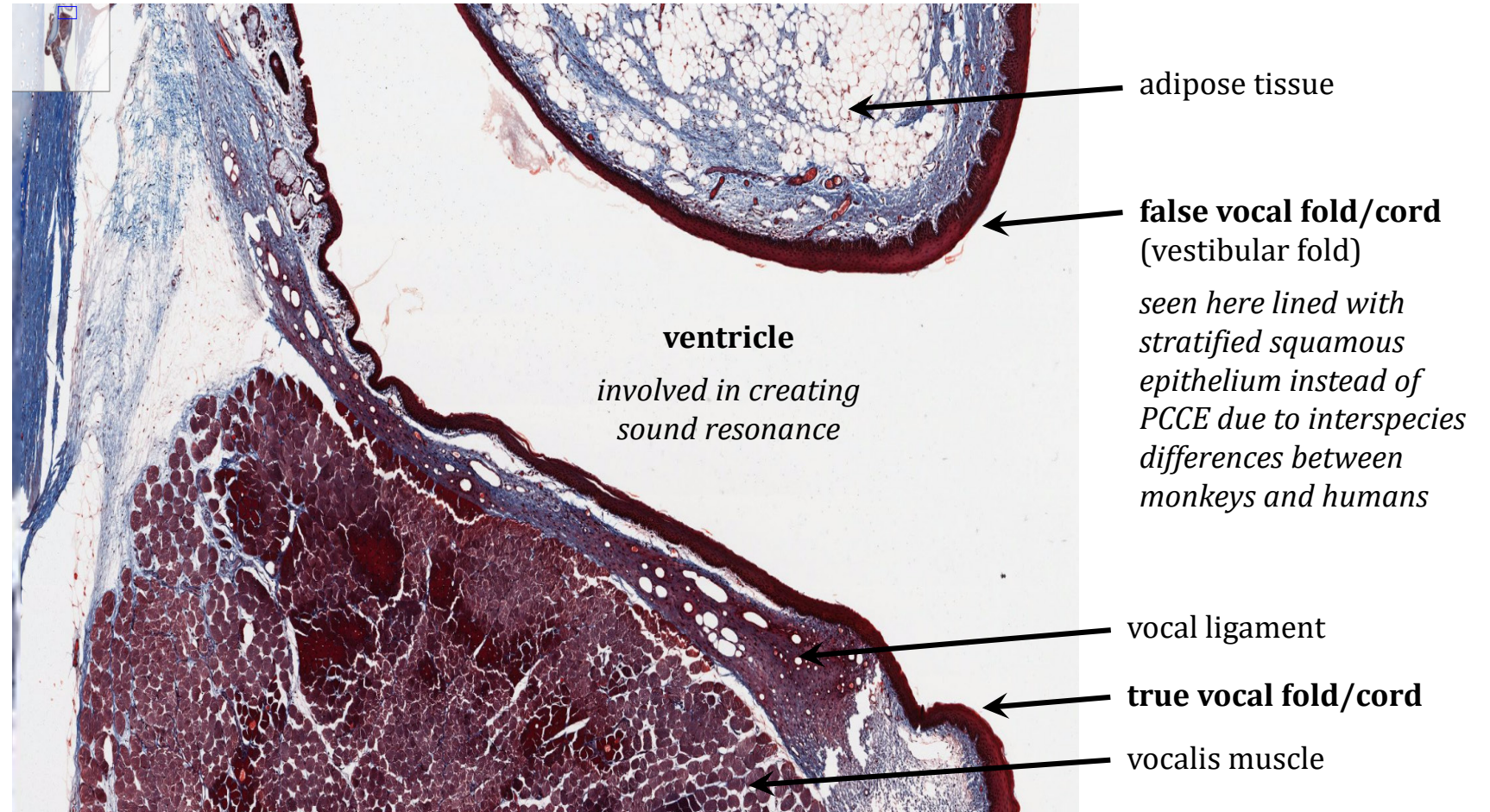
the **larynx** serves to conduct air from the pharynx to the trachea and is considered the entrance into the lower respiratory tract; it is composed of nine cartilages with numerous intrinsic and extrinsic muscles and ligaments; the complex arrangement of structures facilitates the functions of the larynx as both a valve to close off entrance into the lower airways during swallowing of food and liquids and as a source of phonation (sound production)

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Slide 7: Larynx (Monkey), Trichrome



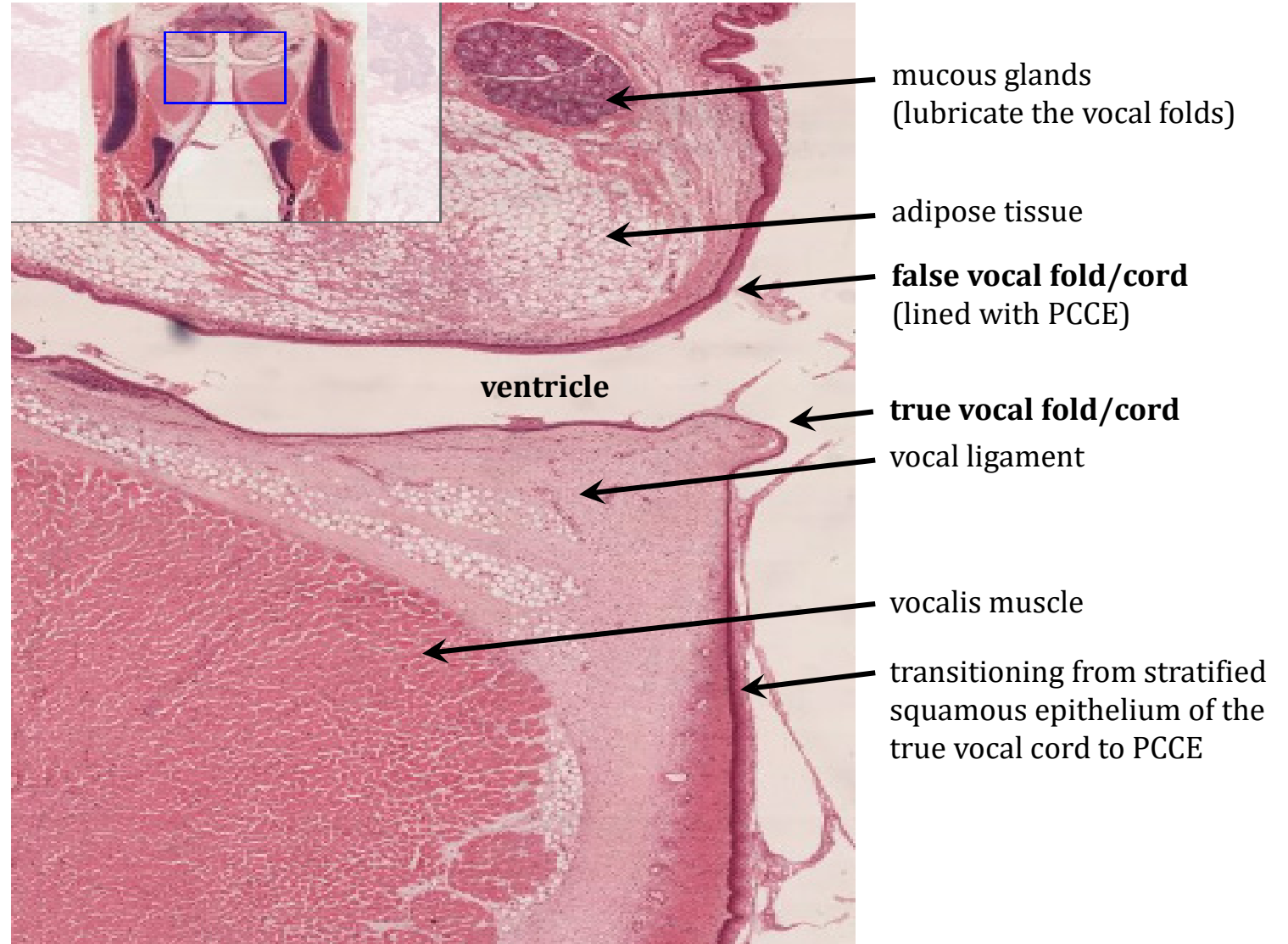
the **true vocal folds** are lined with stratified squamous epithelium and contain an underlying **vocal ligament** (dense elastic CT) and **vocalis muscle** (skeletal muscle) to enable their role in phonation (pitch); the **false vocal folds**, above the **ventricle** space, do not have underlying muscle so are not generally involved in phonation; they are usually lined by respiratory epithelium (PCCE), but in many adults – especially smokers – they are lined by stratified squamous epithelium instead (*metaplasia* is the term for a change from one tissue type to another)

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Slide 92 (NW): Larynx, H&E

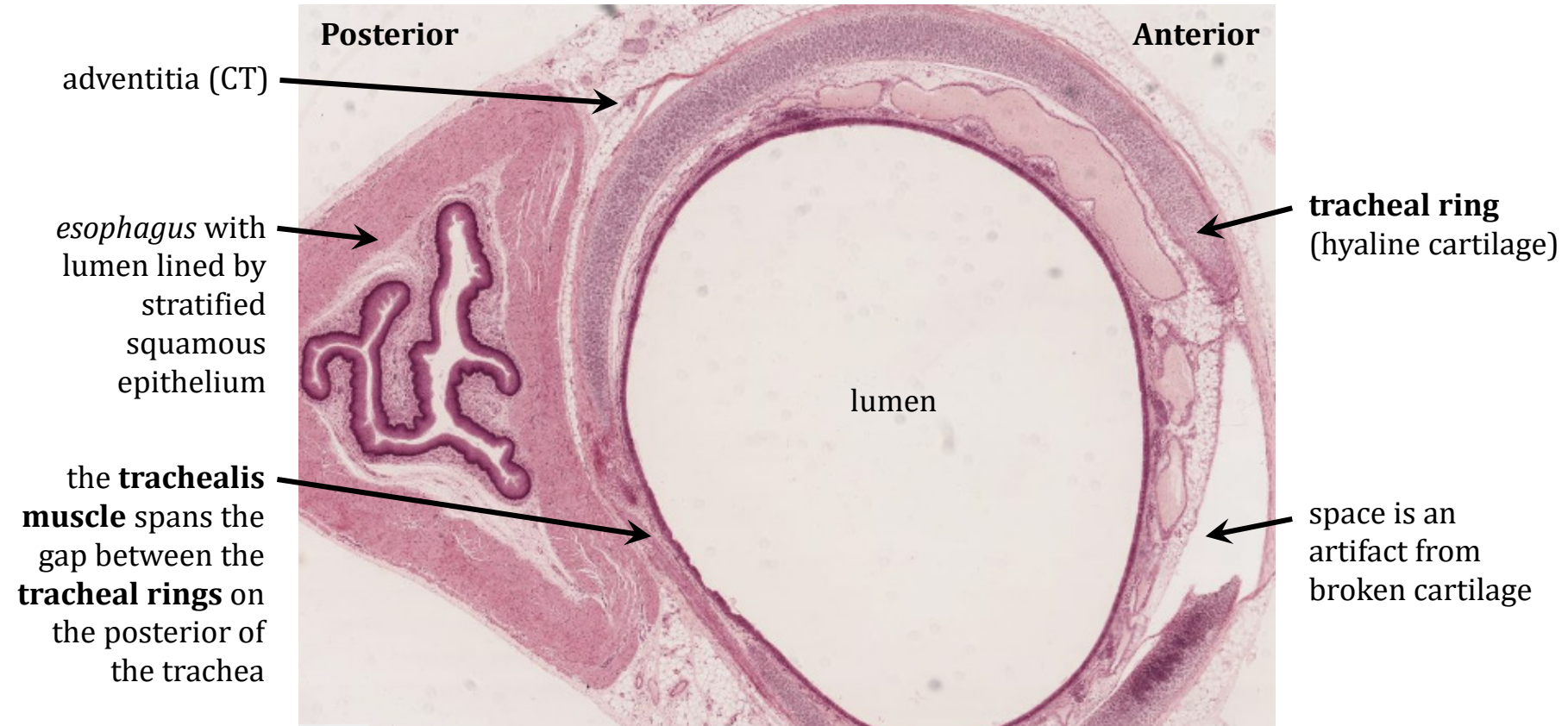


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Slide 93 (NW): Trachea, H&E



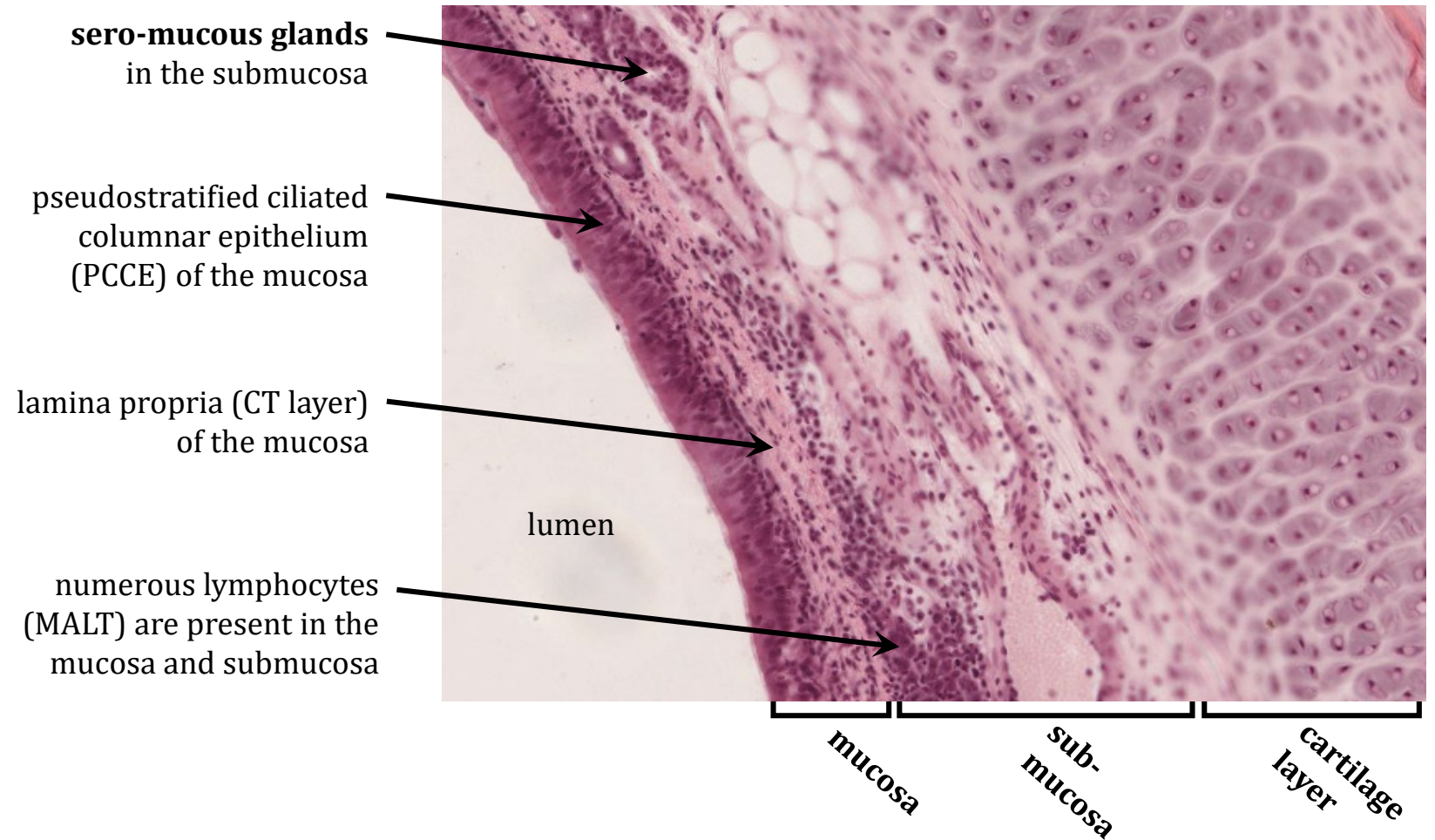
in adults, the **trachea** extends about 4in (10cm) from the larynx to the sternal angle in the thorax where it bifurcates into the two primary bronchi (each going to a lung); it has a supporting framework of 16-20 C-shaped hyaline cartilage **tracheal rings** which provide structural support to the trachea and prevent collapse due to the pressure changes associated with breathing, especially exhalation; the rings are open at the posterior wall of the trachea adjacent to the esophagus, with the gap between the rings being bridged by bundles of smooth muscle (trachealis m.) and elastic fibers

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Slide 93 (NW): Trachea, H&E



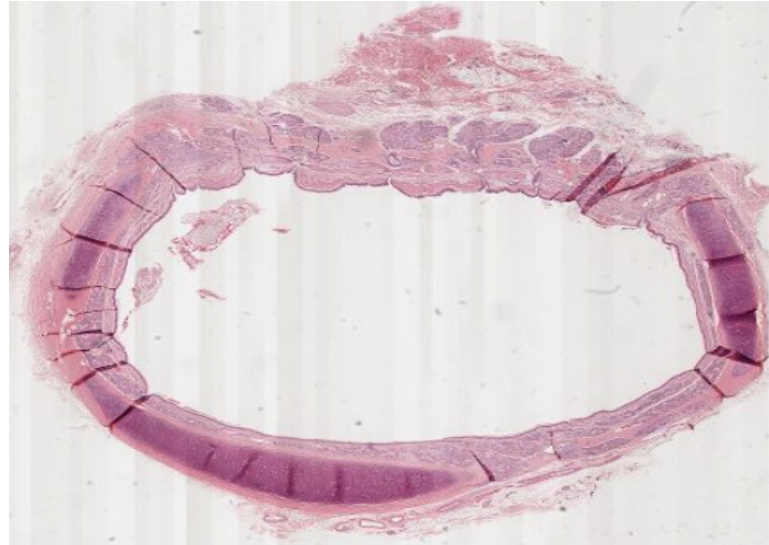
the **trachea** comprises four layers: the inner *mucosa*, *submucosa*, *cartilage layer*, and outer *adventitia* which is the CT layer that binds the trachea to surrounding structures (e.g., the esophagus)

Lab 13 – Respiratory System

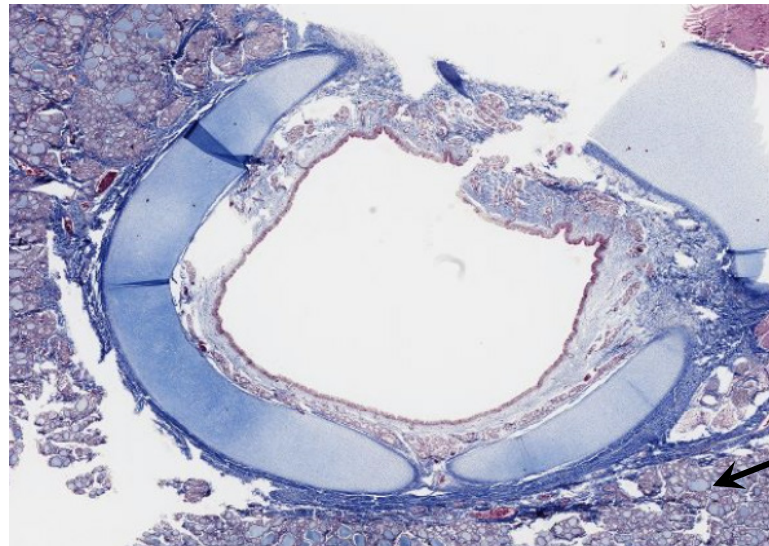
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Slide 140: Trachea, H&E



Slide 2: Thyroid and Trachea, Trichrome



Additional Slides of Trachea to Examine

Slide 60 (464): Trachea



look here to see good examples of tracheal **sero-mucous glands** extending to the lumen

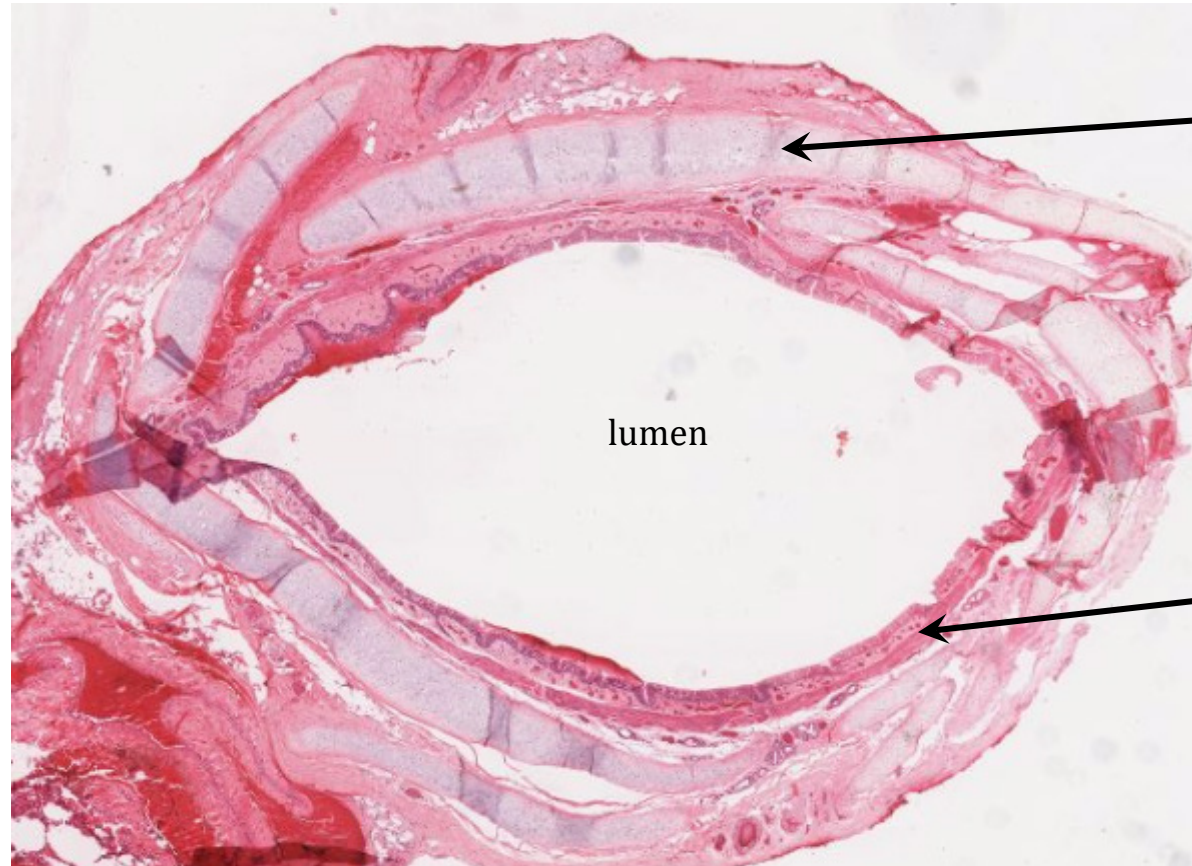
look here to see the *thyroid gland* adjacent to the trachea; it is characterized by the presence of large, colloid-filled follicles

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Slide 97 (NW): Lung and Bronchus, H&E



cartilage plates are discontinuous unlike the rings of cartilage present in the trachea

notice that there are many "fold" artifacts on this slide

*muscularis
circular layer of smooth muscle between mucosa and submucosa*

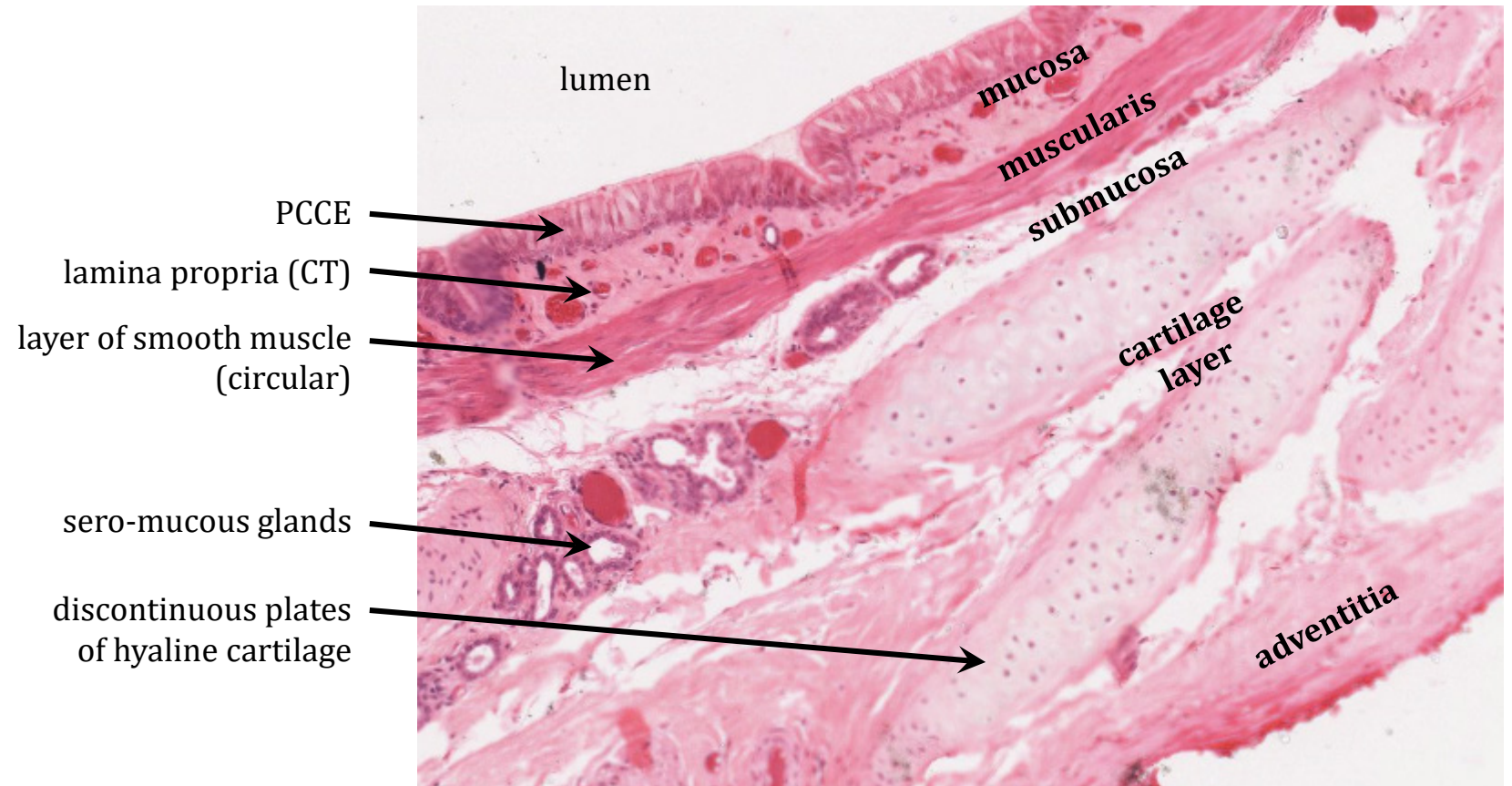
the **primary bronchi** (left and right) result from the bifurcation of the trachea; they conduct air into each lung where they branch into smaller **secondary (lobar) bronchi** conducting air into lobes of the lungs where they branch into smaller **tertiary (segmental) bronchi** going to individual *bronchopulmonary segments* (8 in left lung and 10 in right lung); all bronchi have *cartilage plates* (instead of the rings of the trachea) and a *muscularis*

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Slide 97 (NW): Lung and Bronchus, H&E



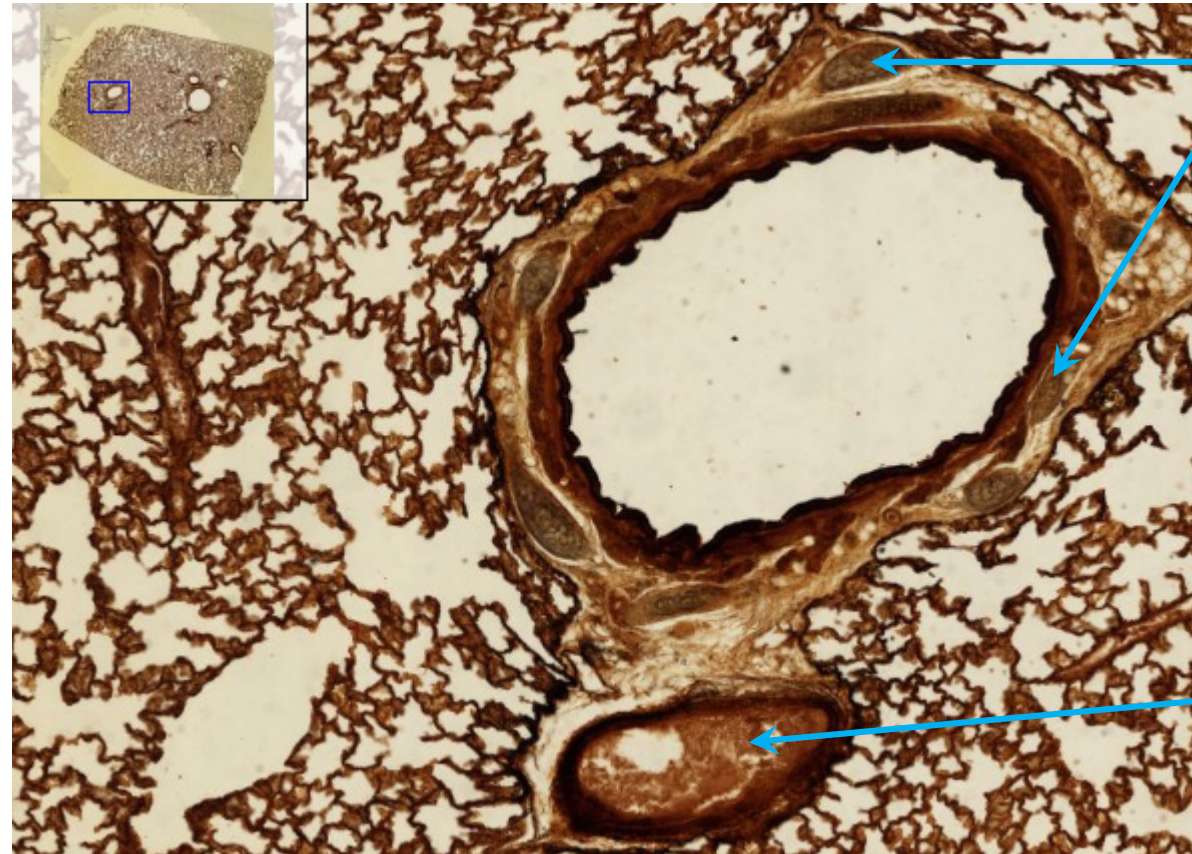
bronchi comprise five layers: the inner *mucosa*, *muscularis*, *submucosa*, *cartilage layer*, and outer *adventitia* which connects the bronchi to surrounding structures of the lung parenchyma; the muscularis layer permits regulation of the lumen diameter; as bronchi branch and become smaller, the height of the epithelium decreases and the amount of cartilage in the wall decreases until it ceases to be present and the airways become classified as *bronchioles*

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Slide 10a (464): Lung



cartilage plates distinguish this as still being a bronchus; however, the size of the plates continues to decrease in size as the bronchi branch and travel deeper into the lung

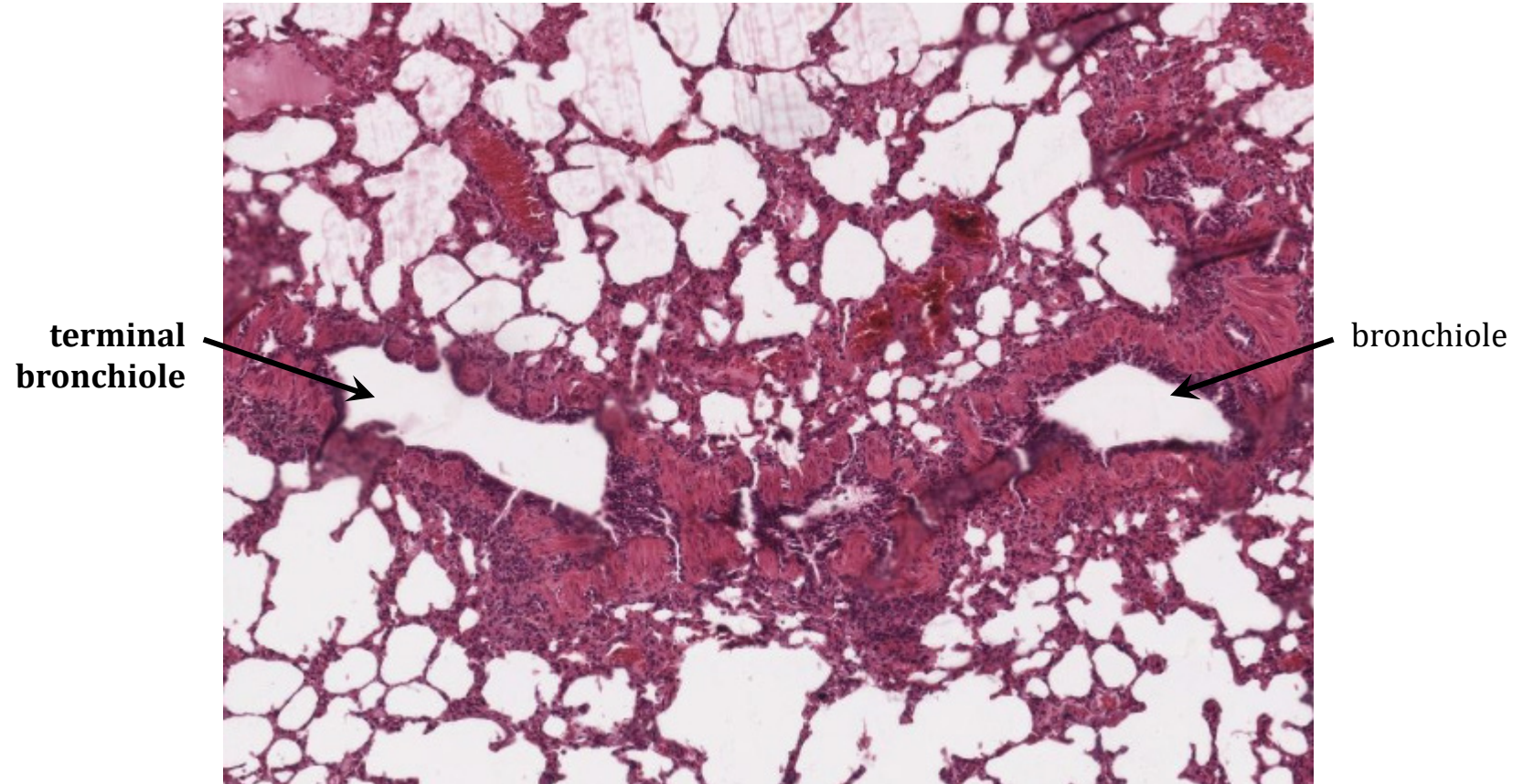
branch of pulmonary artery

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Slide 98 (NW): Lung, H&E



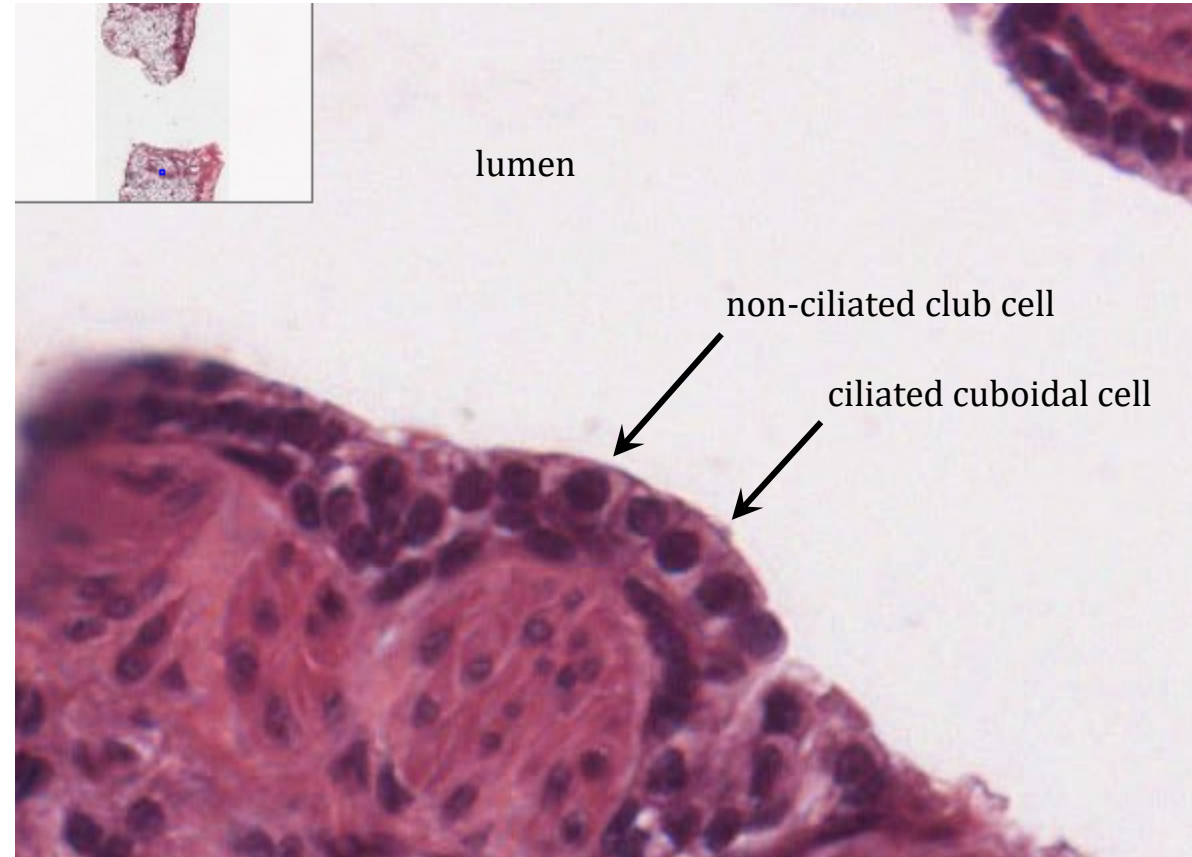
bronchioles supply air to individual lobules of bronchopulmonary segments; they lack cartilage plates and exocrine glands in their walls and generally have an overall diameter of less than 1mm; the epithelium continues to reduce in height from ciliated columnar to ciliated cuboidal, with an increasing number of *club cells*; **terminal bronchioles** are the final segment of the conducting airway system (no gas exchange occurs)

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Slide 98 (NW): Lung, H&E



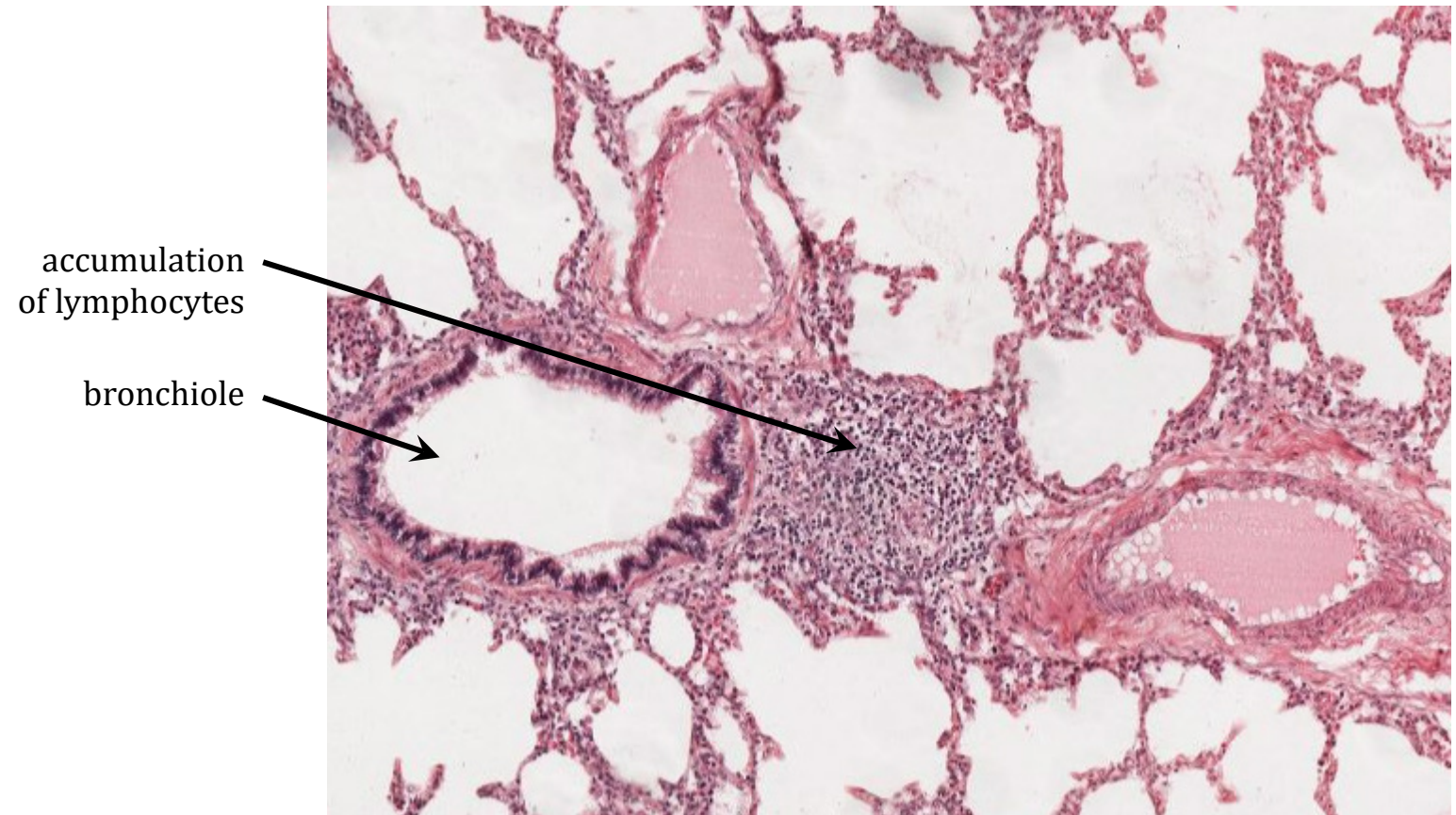
terminal bronchioles are the final segment of the conducting airway system (no gas exchange occurs); they have a ciliated cuboidal epithelium lacking goblet cells but with non-ciliated *club cells* that secrete a surfactant-like product to prevent adhesion of the wall; although they may be the most numerous cells present, club cells can be difficult to identify on routine slides and are better appreciated in electron micrographs; they are often seen with a bulging apical surface, similar in appearance to the umbrella cells of transitional epithelium

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Slide 97: Lung, H&E



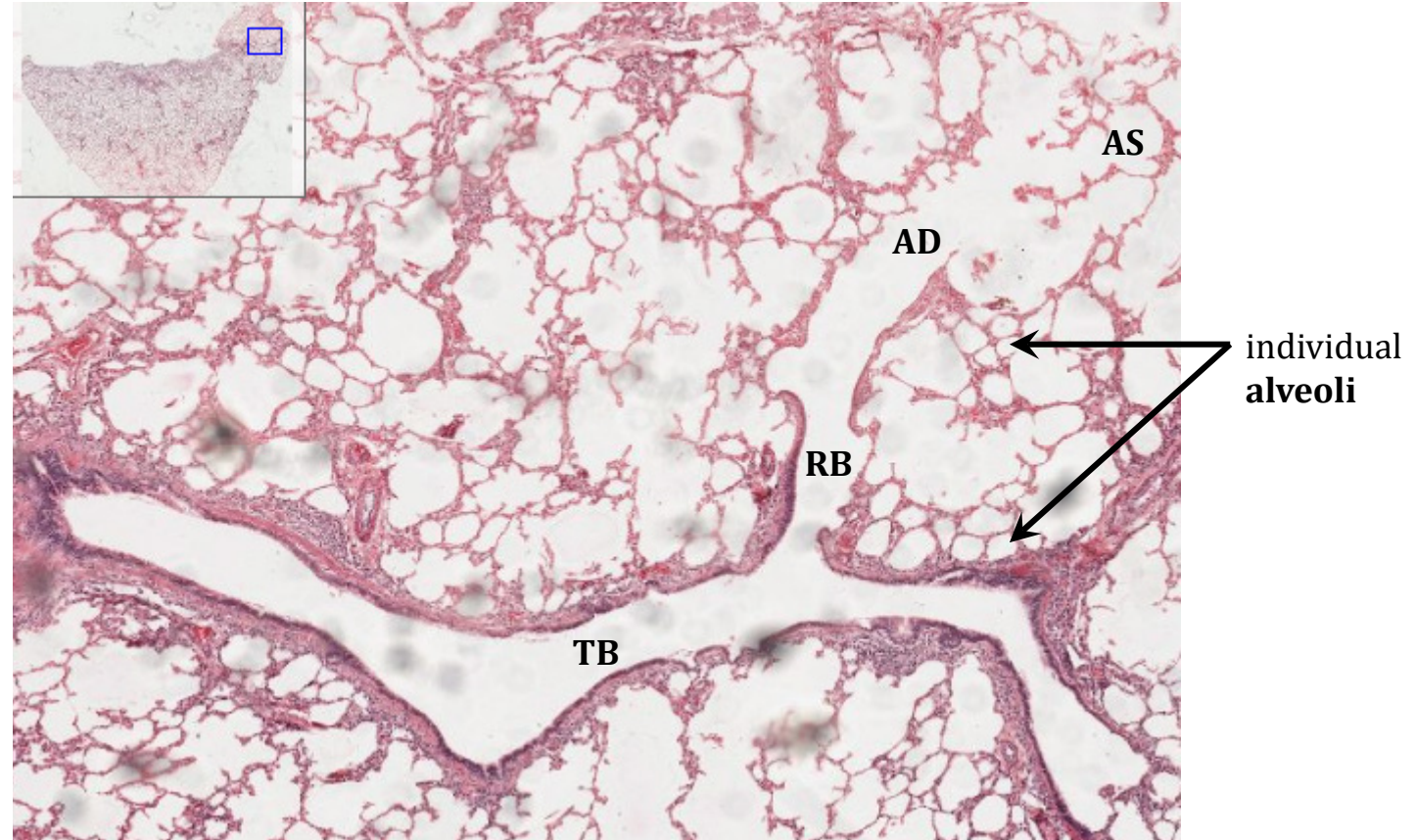
large accumulations of lymphocytes (lymphatic nodules) are often seen associated with the bronchi and bronchioles; these accumulations of cells are collectively known as *BALT* (*bronchus-associated lymphatic tissue*)

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Slide 97: Lung, H&E



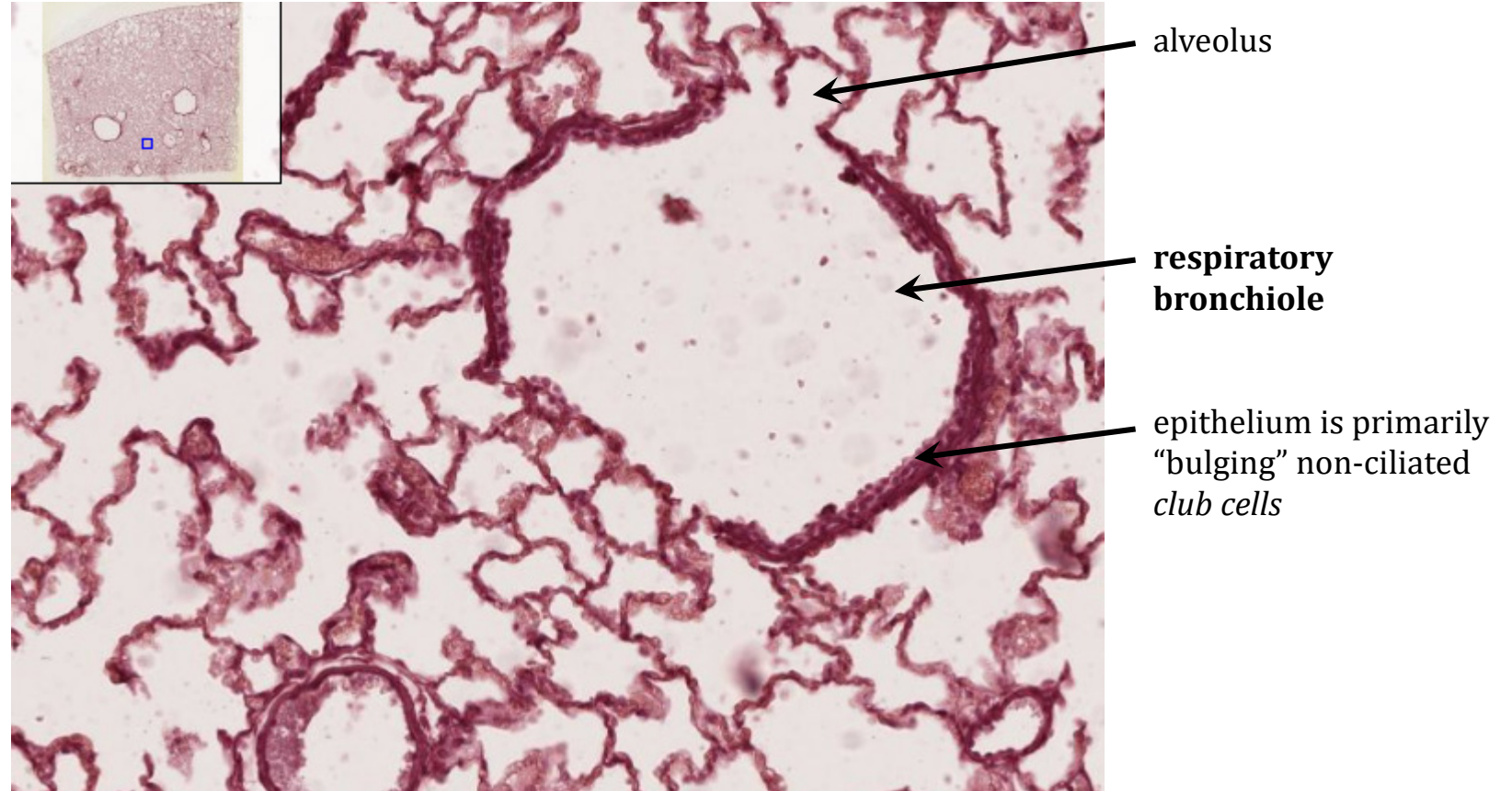
terminal bronchioles (**TB**) branch into **respiratory bronchioles (RB)** which are the first part of the respiratory airways (gas exchange occurs) as alveoli become present along the walls; respiratory bronchioles then branch into **alveolar ducts (AD)** in which the walls are composed primarily of alveoli; alveolar ducts lead into cul-de-sacs of alveoli known as **alveolar sacs (AS)** which have an acinar configuration of alveoli opening into a common shared air space

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Slide 61 (464): Lung, H&E



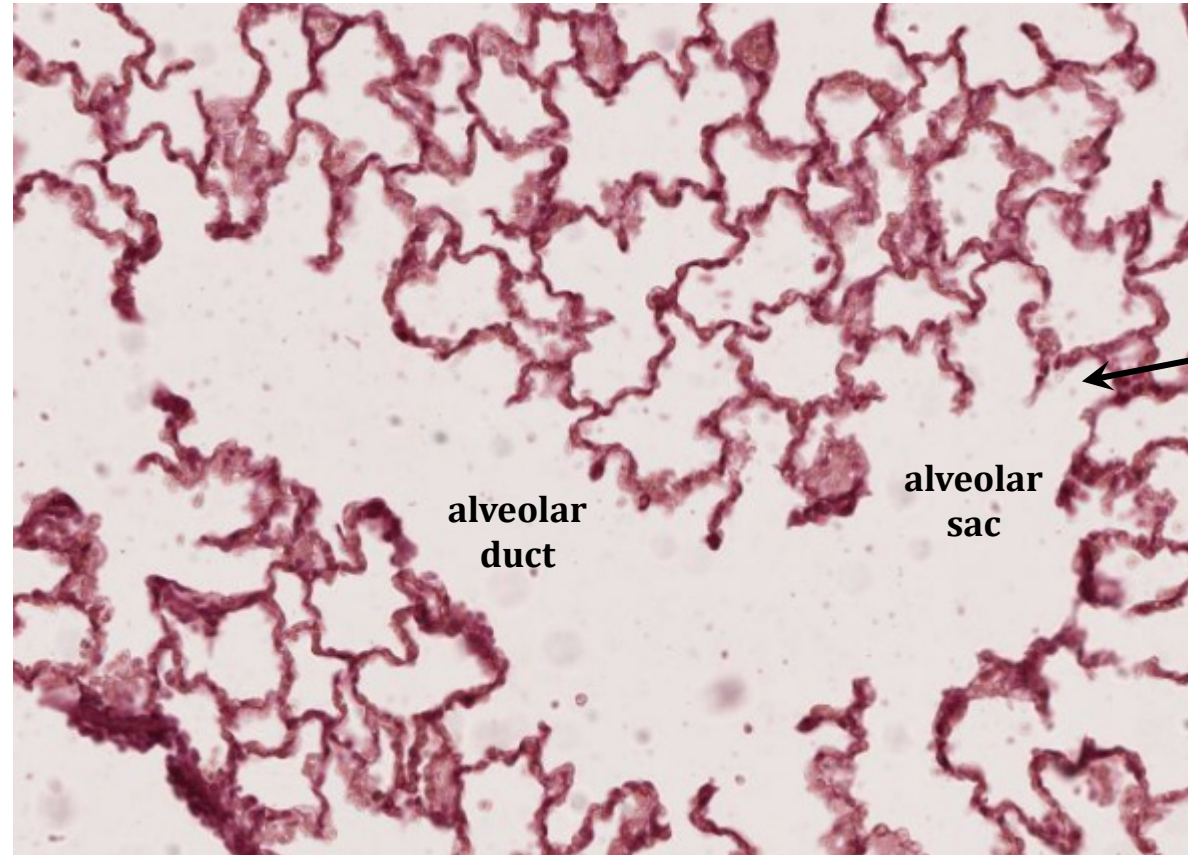
respiratory bronchioles are the first segment of the respiratory airway system (gas exchange occurs); they resemble terminal bronchioles and continue to serve to conduct air; however, respiratory bronchioles have scattered alveoli along their walls permitting gas exchange to occur, thus they are classified as part of the respiratory airway system; their epithelium is cuboidal and is predominated by *club cells*

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Slide 61 (464): Lung, H&E



alveolus

alveolar
duct

alveolar
sac

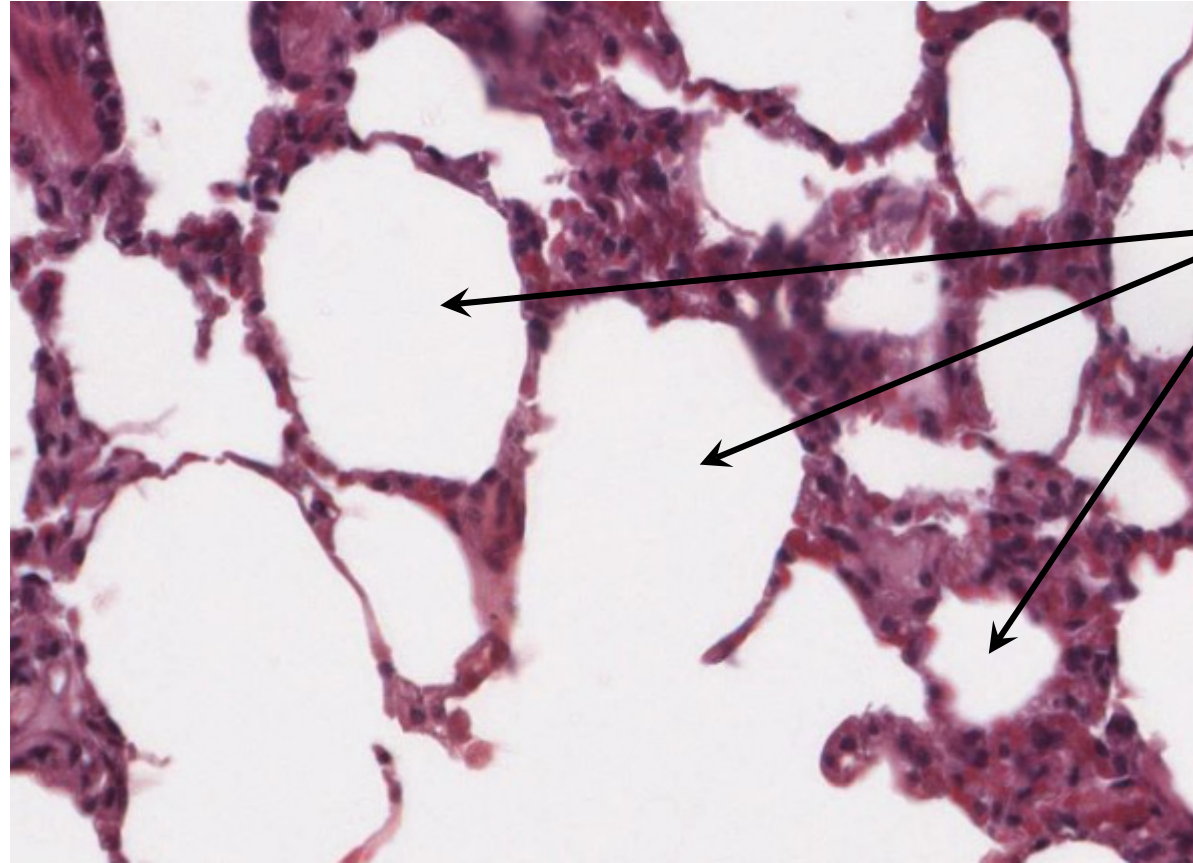
alveolar ducts are elongated airways with walls composed almost entirely of alveoli; small “knobs” of smooth muscle may be seen in the walls of the duct at the entrance of the alveoli; the ducts lead to **alveolar sacs** which are common air spaces (cul-de-sacs) surrounded by a cluster of **alveoli**

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Slide 98 (NW): Lung, H&E



alveoli

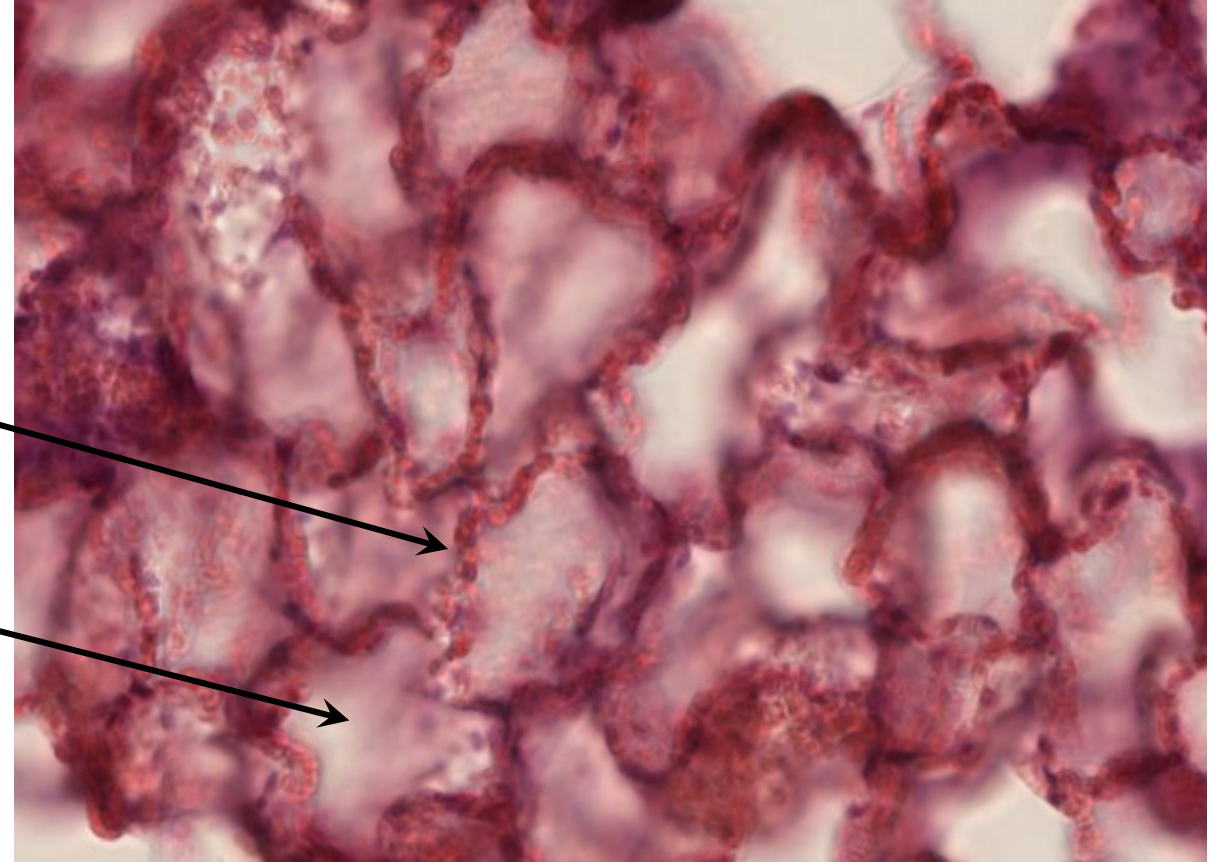
alveoli are the terminal air spaces of the respiratory system and compose the majority of the lung parenchyma (~250 million alveoli in each adult lung with a total combined surface area of 800ft²); alveoli consist of thin-walled epithelium surrounded by capillaries, allowing gas exchange to occur; despite possible appearances due to sectioning, the alveolar air space is not completely enclosed and is continuous with either a respiratory bronchiole, alveolar duct, or alveolar sac

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Slide 62 (464): Thick Lung Section, H&E



red blood cells
in capillaries
surrounding
alveoli

alveolus

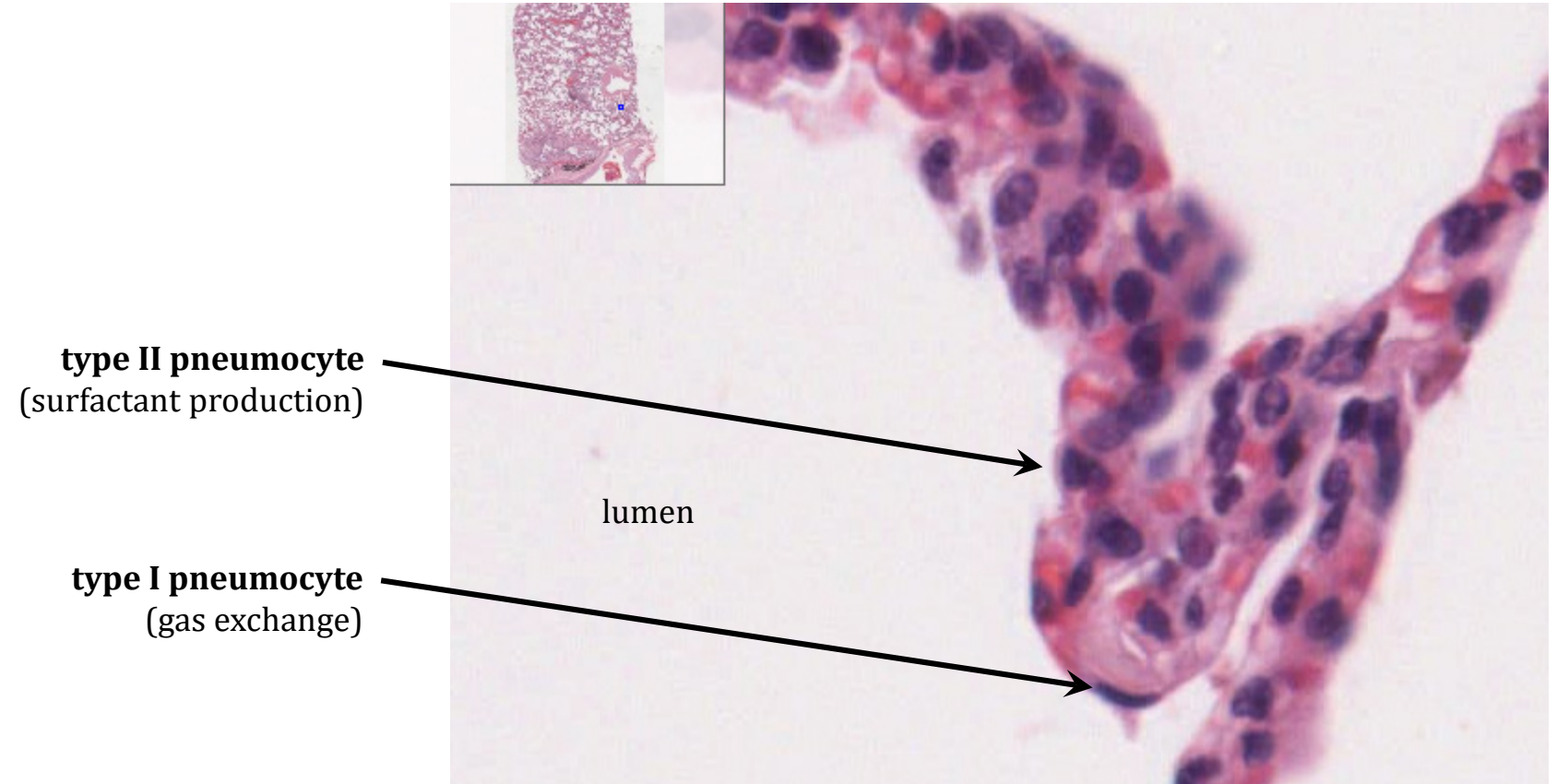
this slide shows a thick sectioning of the lung, permitting easy visualization of the extensive capillary network surrounding alveoli; under normal conditions, red blood cells transit through alveoli capillaries in about 0.75 seconds, becoming fully oxygenated within 0.25 seconds

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Slide 94 (NW): Lung, H&E



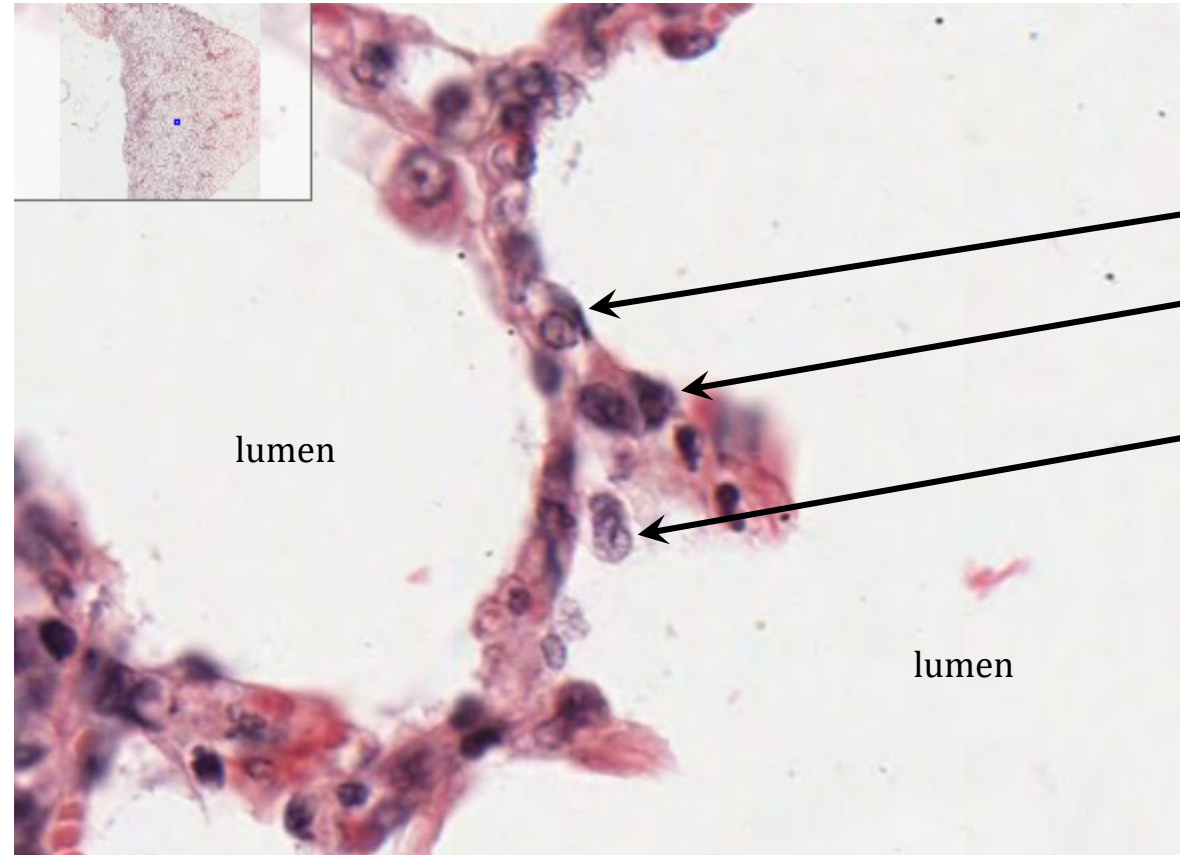
the walls of alveoli consist of two types of epithelial cells: **type I pneumocytes** are extremely thin squamous epithelial cells, with elongated nuclei which can be difficult to locate due to sectioning; while type I pneumocytes amount to less than half the total number of cells of the wall, they compose 95% of the wall surface area; **type II pneumocytes** have a more cuboidal appearance, generally seen bulging into the alveolar lumen; they are more abundant than type I pneumocytes but compose only 5% of the wall surface area

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Slide 97: Lung, H&E



type I pneumocyte

type II pneumocyte

dust cell
(alveolar macrophage)

easily identified when in the alveolar air space but more difficult when located in the alveolar septum, unless engulfed debris is seen in the cytoplasm

also commonly seen in alveoli are **dust cells (alveolar macrophages)**; they may be present in the *alveolar septum* (the tissue between adjacent alveolar air spaces) or within the lumen of the alveolar air space itself; they function to remove inhaled debris from the alveolus and cellular debris from within the septum; macrophages that have engulfed material may travel up through the airways in order to be coughed out or swallowed, or they may remain within the septal tissue (perhaps for the remainder of an individual's life)

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b. Intrapulmonary

i. Bronchi

ii. Terminal bronchiole

2. Respiratory Airways

a. Respiratory bronchiole

b. Alveolar duct and sac

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1. **Pulmonary Arteries**

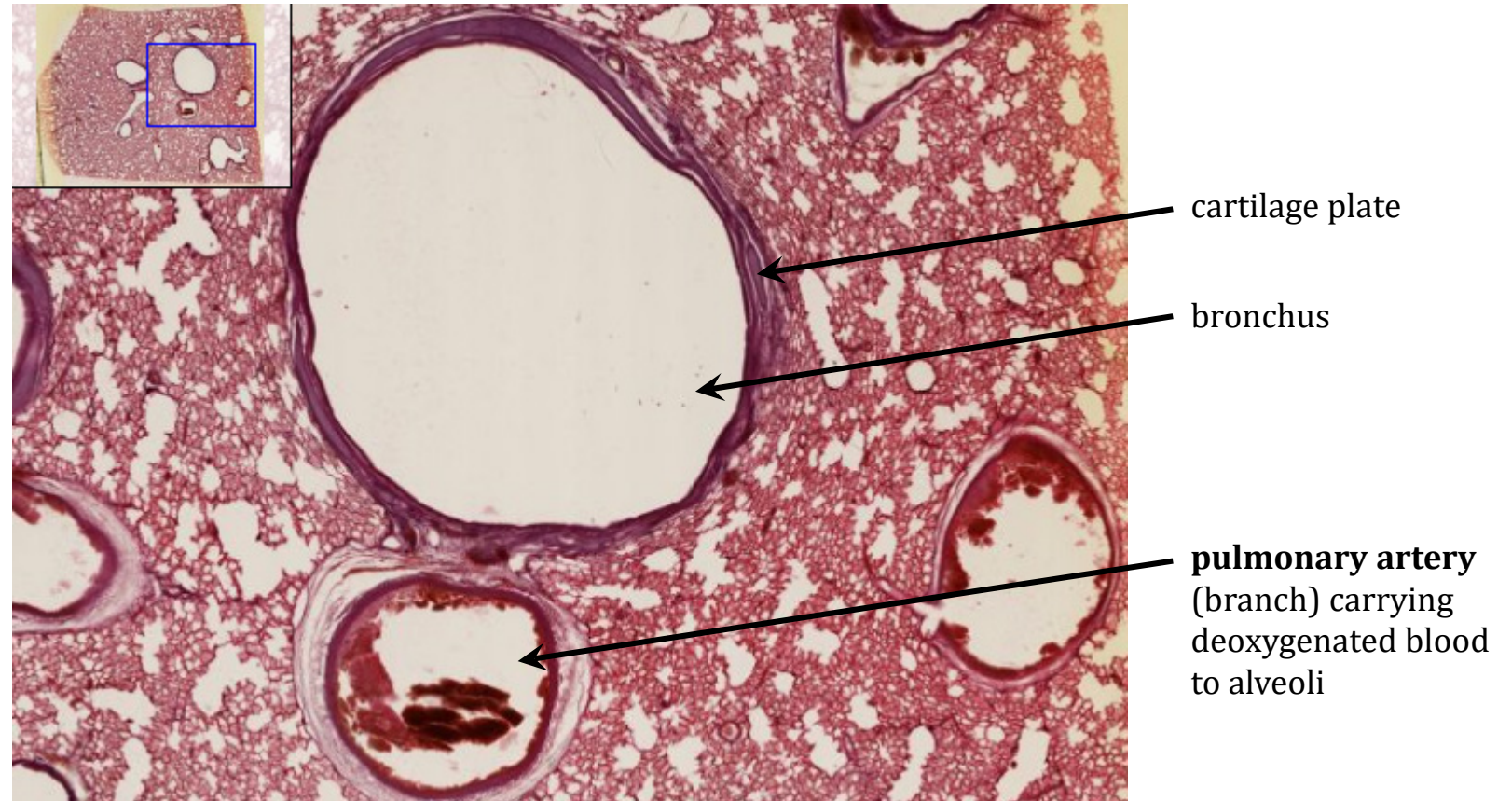
2. Pulmonary Veins

3. Bronchial Arteries

C. Pleura

V. Summary

Slide 62 (464): Thick Lung Section, H&E



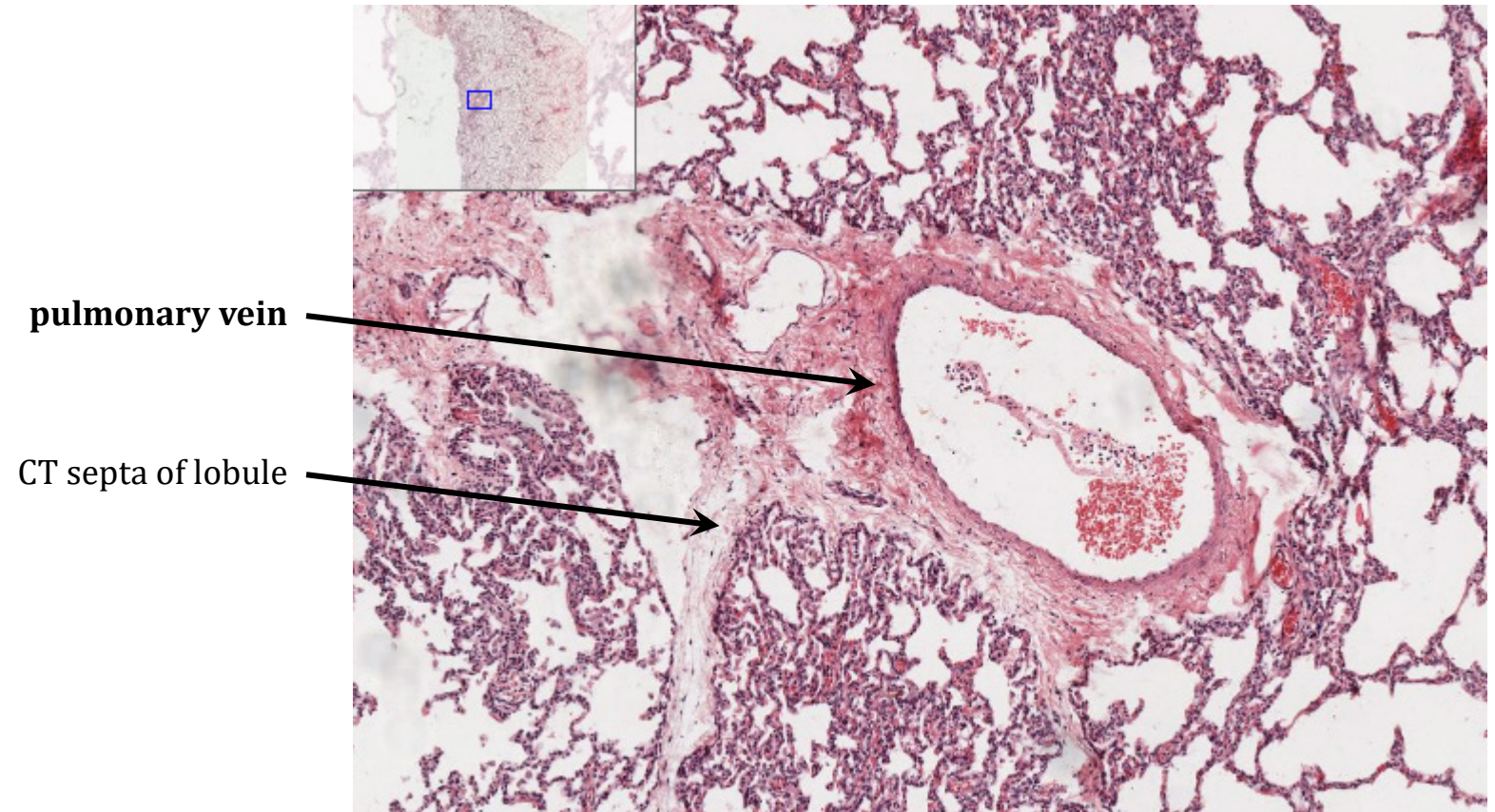
the lungs have two systems of arterial blood supply: the **pulmonary arteries** coming from the right ventricle of the heart and carrying deoxygenated blood, and the **bronchial arteries** generally branching from the thoracic aorta and carrying oxygenated blood; the pulmonary arteries are large but experience far less pressure than in the systemic circulation, so are much thinner-walled than arteries found elsewhere; they are generally seen running with bronchi and bronchioles

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Slide 97: Lung, H&E



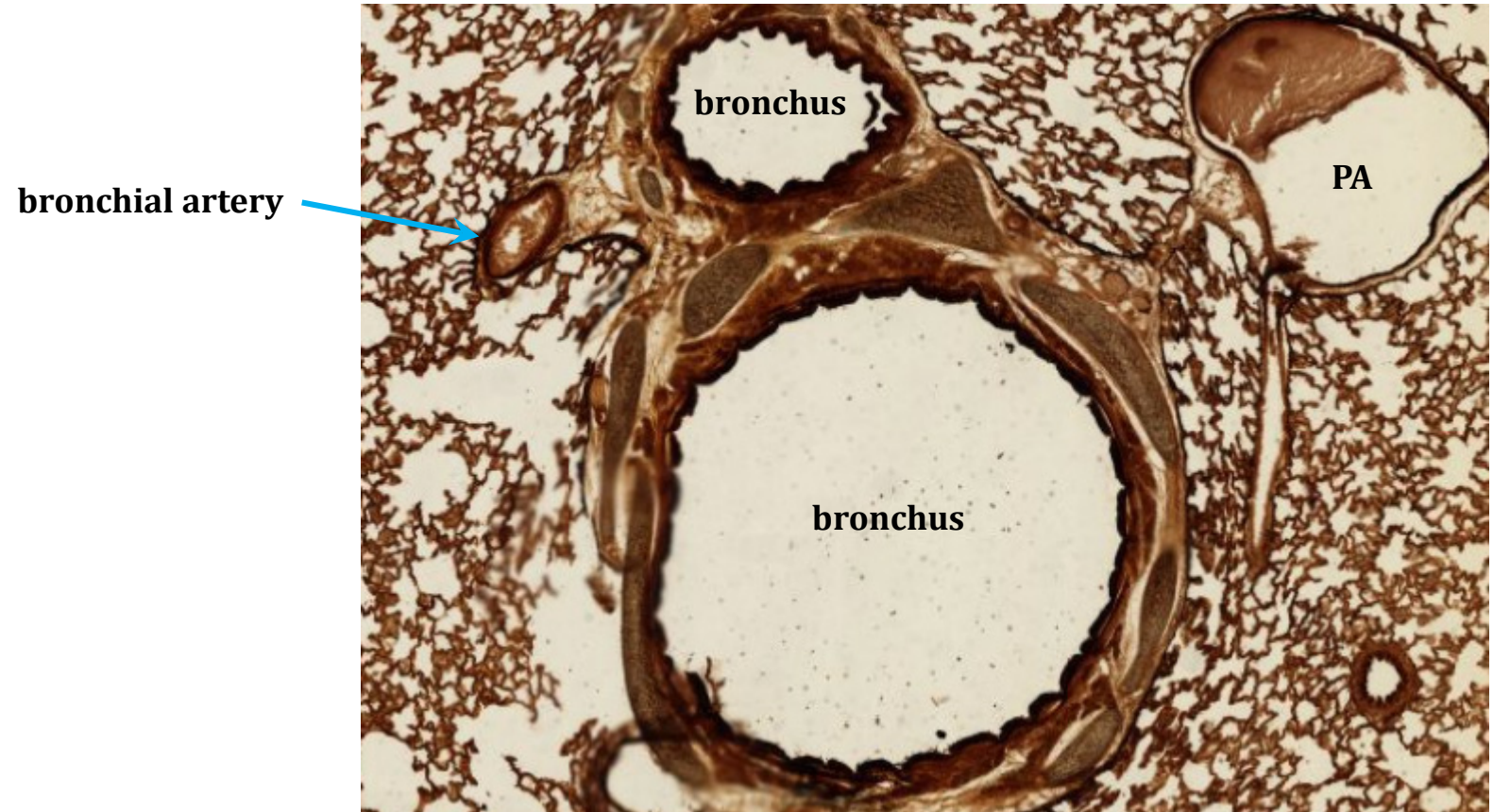
pulmonary veins carry the oxygenated blood from the alveoli (and most of the blood from the bronchial arteries) back to the left side of the heart; the veins are thin-walled like the pulmonary arteries, but they are found at the periphery of the lobules and do not travel with the bronchi or bronchioles

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Slide 10a (464): Lung



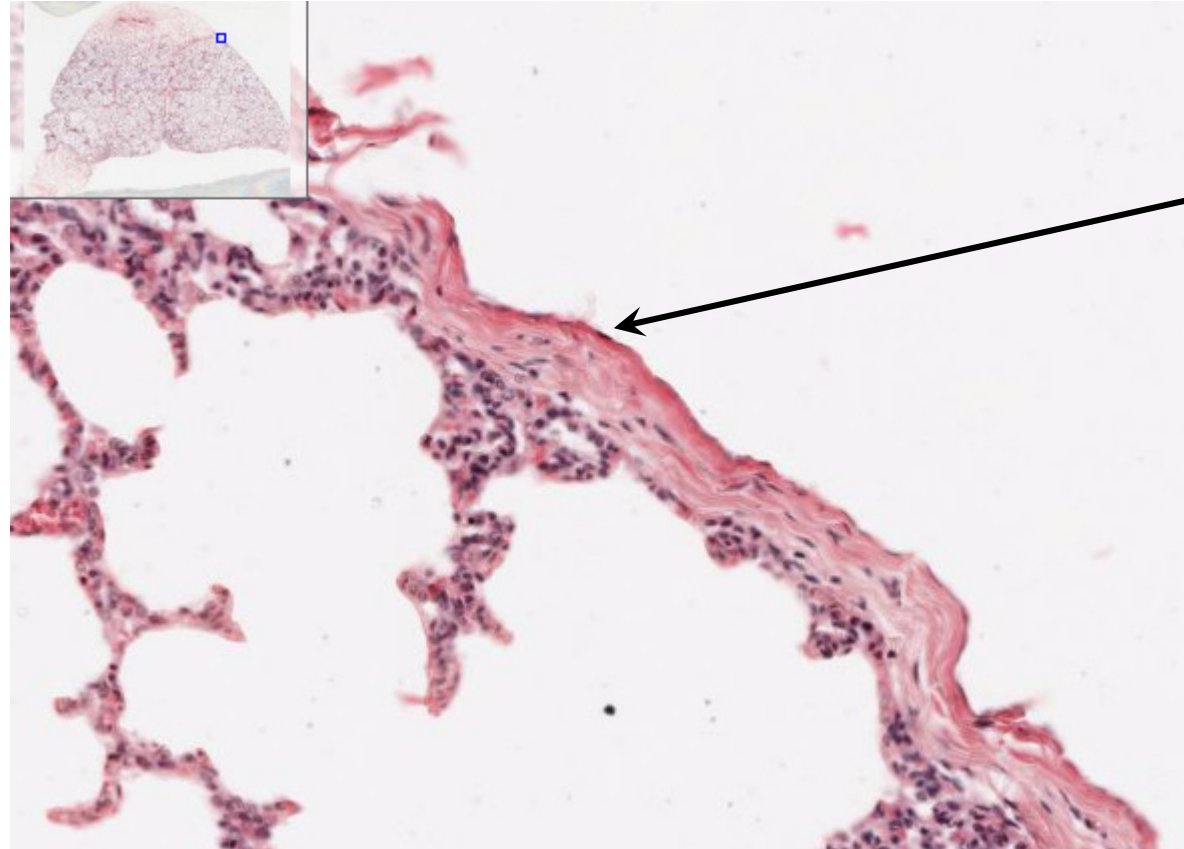
bronchial arteries are generally branches of the thoracic aorta that carry oxygenated blood to the tissues of the lung (e.g., the walls of the bronchi and bronchioles); most of the blood that reaches the lungs by the bronchial arteries drains via the pulmonary veins back to the heart; bronchial arteries have the appearance of normal systemic circulation vessels and are normally seen adjacent to the bronchi and bronchioles

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Slide 97 (low): Lung, H&E



visceral pleura of the lung with outer surface lined by flattened **mesothelium** (simple squamous epithelium) and underlying connective tissue

the **pleura** of the lungs, like the pericardium of the heart, is an a *serosa* (serous membrane) consisting of a *visceral layer* (lining the lung surface) and a *parietal layer* (lining the thoracic wall); between the two layers is a potential space filled with serous pleural fluid produced by the mesothelial cells

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Compare and Contrast Respiratory Structures

Structures	Compare and Contrast (Similarities? Differences?)
Olfactory vs. Respiratory epithelium	
Trachea vs. Bronchus	
Pulmonary artery vs. Bronchial artery	
Terminal bronchiole vs. Respiratory bronchiole	
False vs. True vocal folds	
Type I pneumocyte vs. Type II pneumocyte	