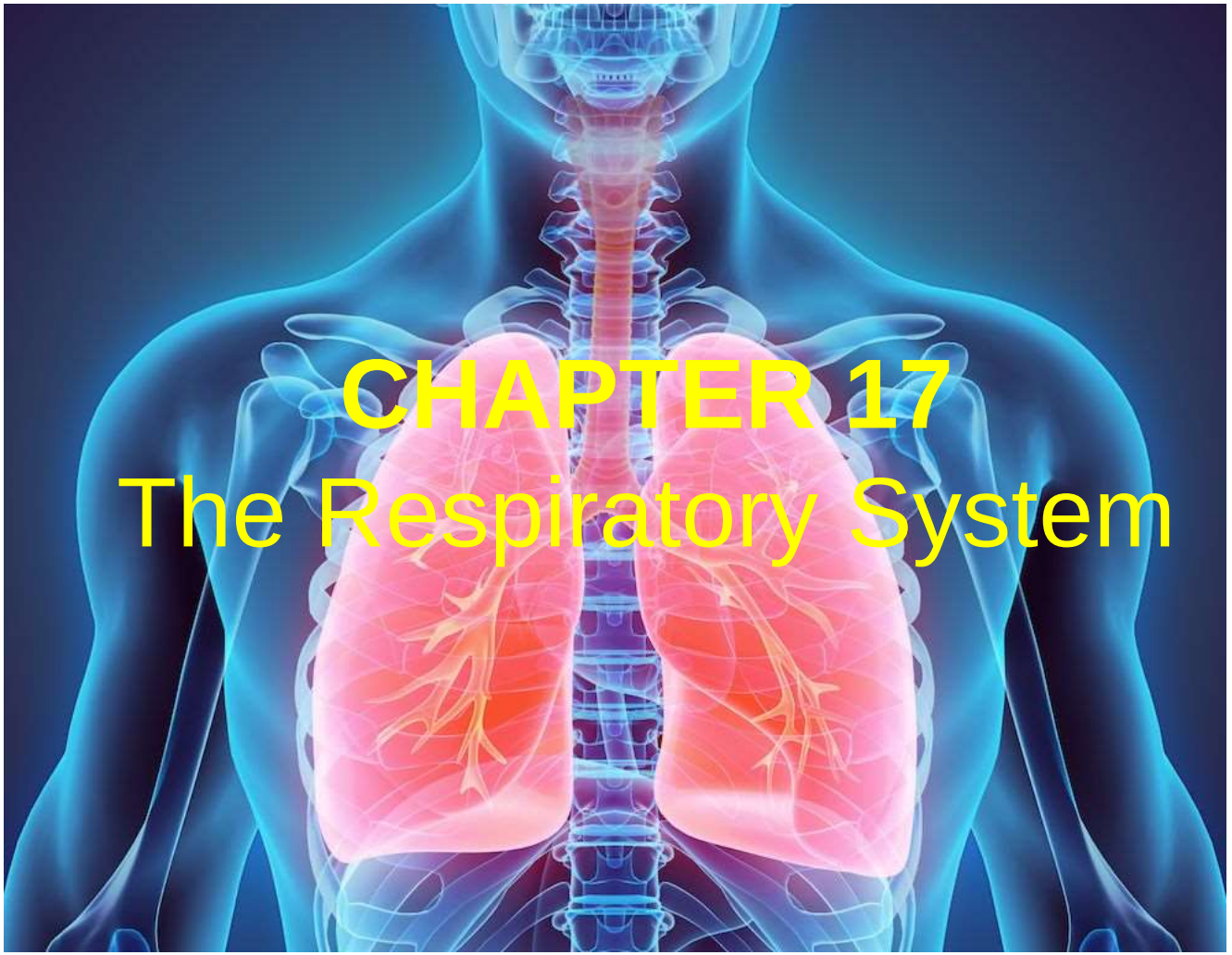

CHAPTER 17
The Respiratory System

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Introduction

- Principal function associated with the respiratory system is gas exchange.
- The respiratory system also participates in:

1. regulating blood pH
2. contains receptors for the sense of smell
3. filters inhaled air
4. produces sounds
5. rids the body of small amounts of water and heat in exhaled air

- Otorhinolaryngology
- Pulmonologist

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Respiratory System Anatomy

- The upper respiratory system
  - Nose
  - Nasal Cavity
  - Pharynx (throat)
- The lower respiratory system
  - Larynx (voice box)
  - Trachea (windpipe)
  - Bronchi
  - Lungs
- Functionally, the respiratory system also consists of two parts.
  - Conducting zone
  - Respiratory zone

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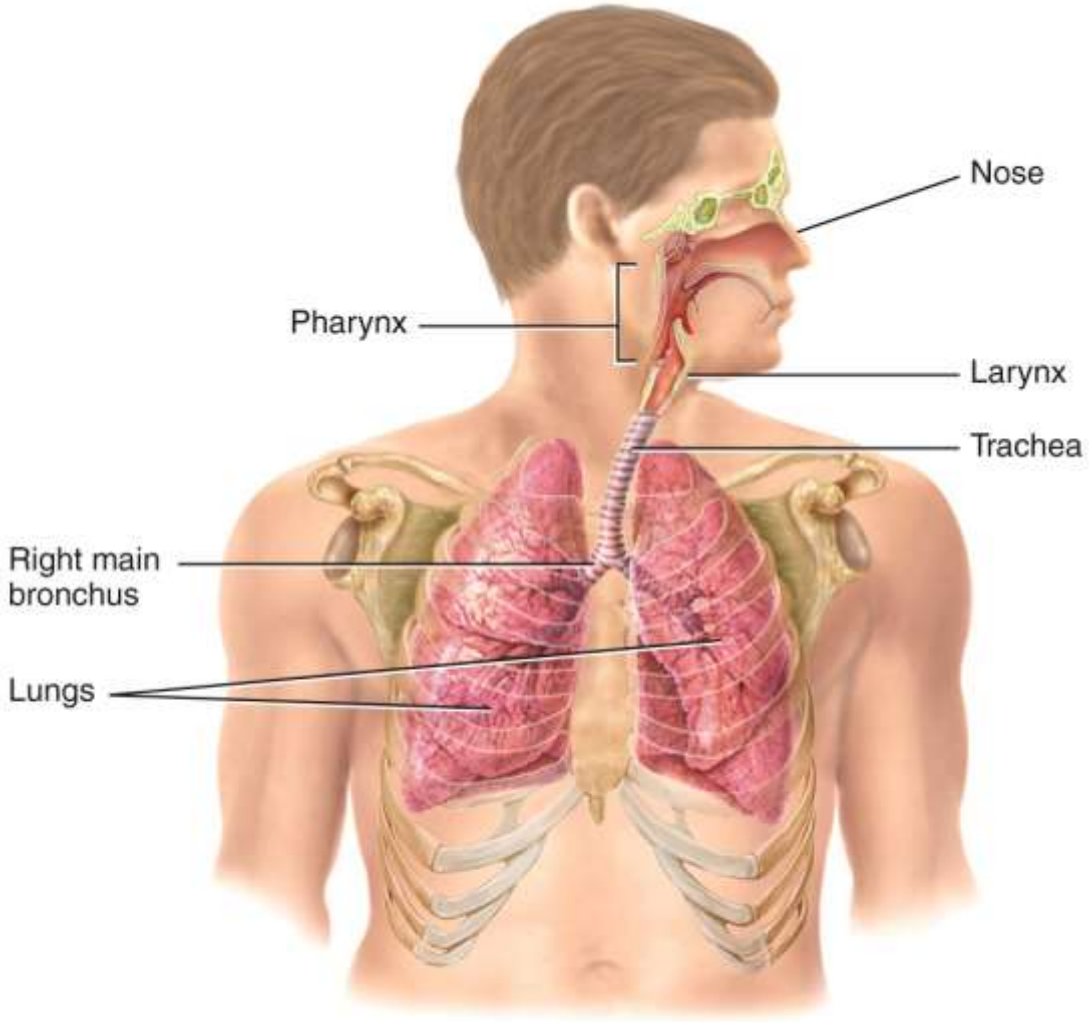
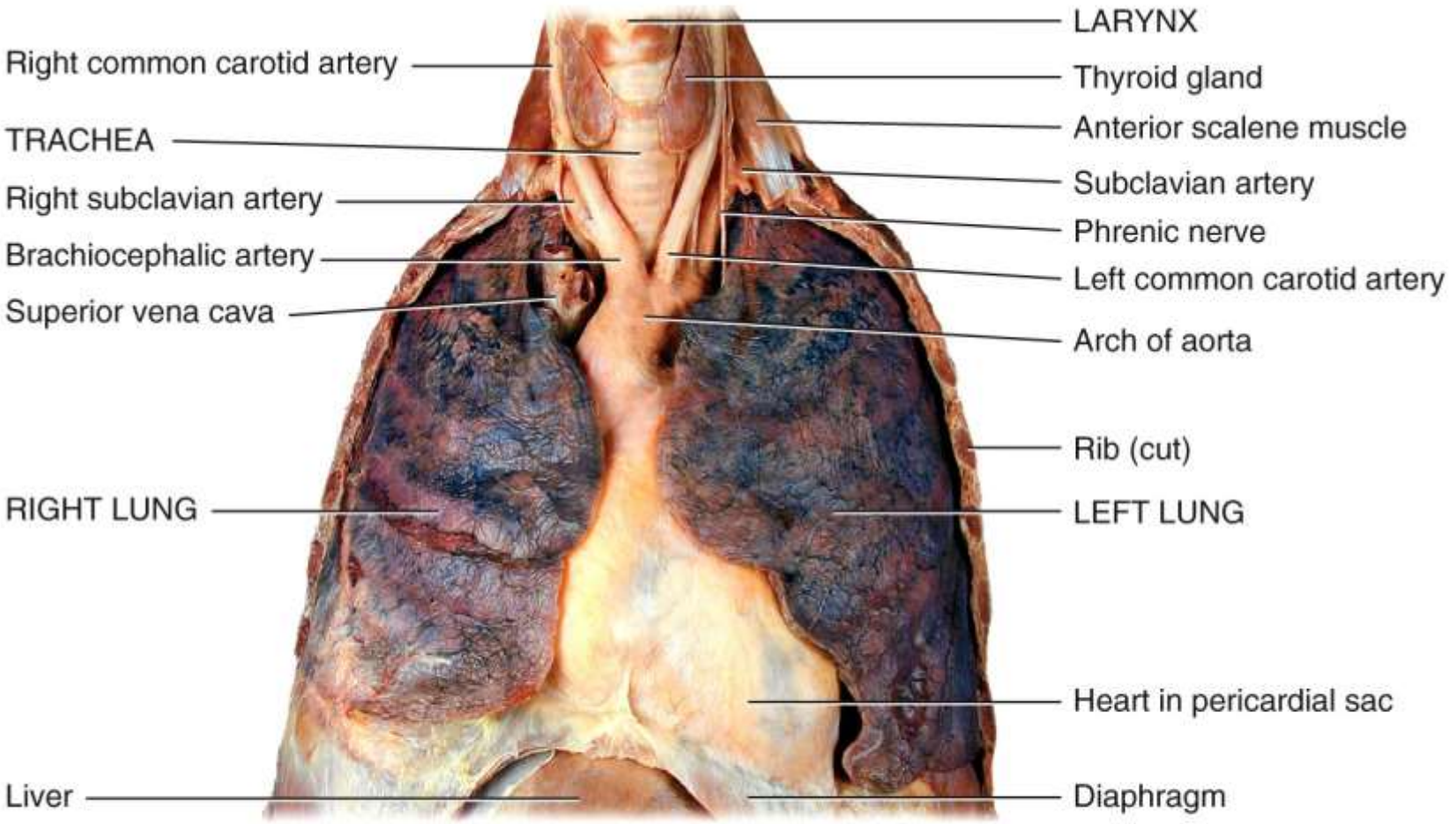
Respiratory System Anatomy



(a) Anterior view showing organs of respiration

Respiratory System Anatomy



(b) Anterior view of lungs and heart after removal of the anterolateral thoracic wall and pleura

Dissection Shawn Miller, Photograph Mark Nielsen

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Respiratory System Anatomy

Anatomy Overview:

- Respiratory Organs

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Nose

- The nose is divided into external and internal portions.
- External nose
  - Skin and muscle-covered portion of the nose
  - Bordered inferiorly by the maxillary bones
  - Superiorly by the nasal bones
- Cartilaginous framework of the external nose
  1. Unpaired septal nasal cartilage
  2. Paired major alar cartilages
  3. Minor alar cartilages

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Nose

- External nares *or nostrils*
- Nasal vestibules
- Internal nose
  - Internal nares or choanae
- Clinical connections
  - ***Rhinoplasty:*** can be done to reduce or increase nose size,change the shape, narrow the nostril span, or alter the angle between the nose and the upper lip
  - ***Deviated septum:*** is a condition in which the nasal septum -- the bone and cartilage that divide the nasal cavity of the nose in half -- is significantly off center, or crooked, making breathing difficult

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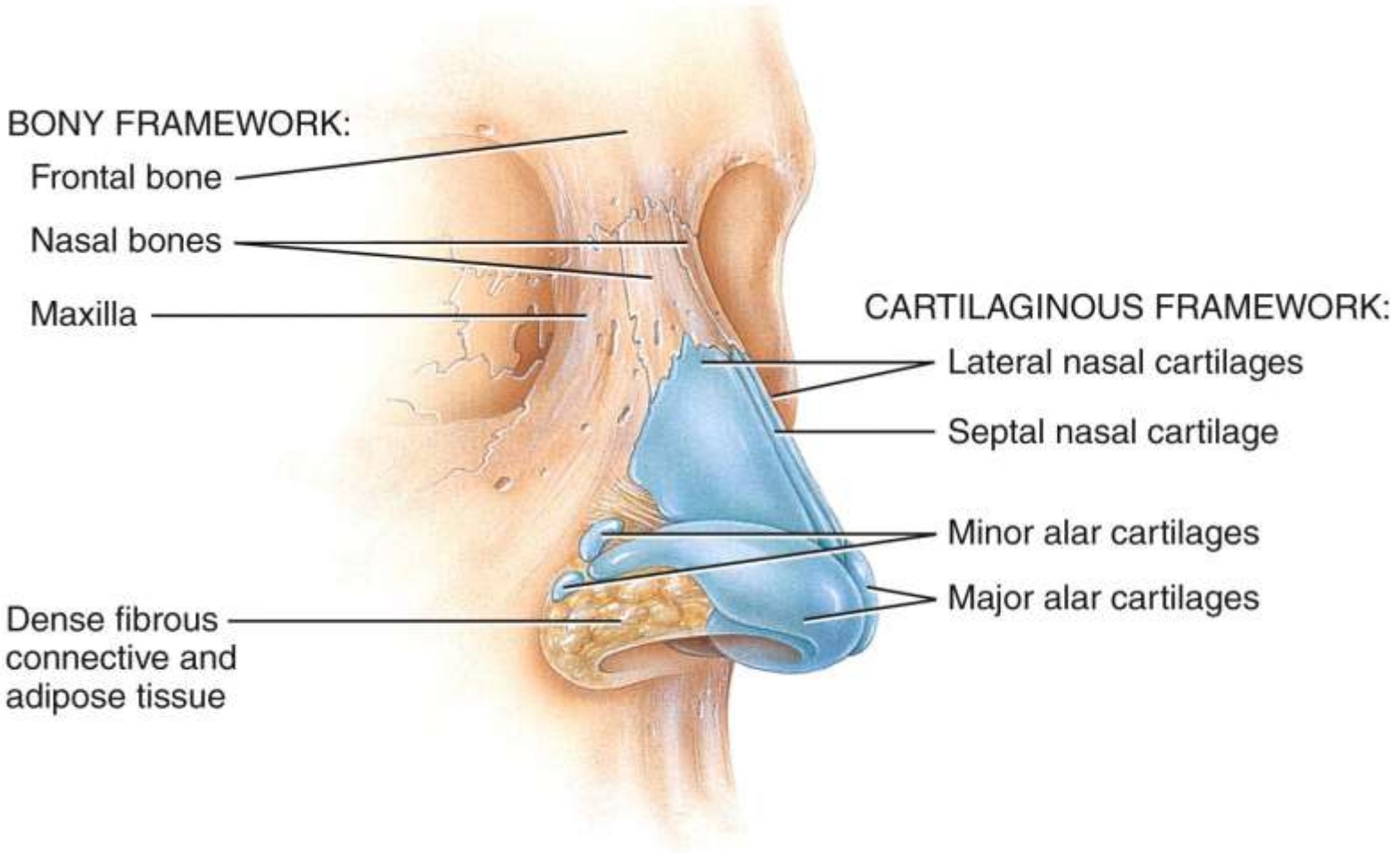
Nose



(a) Anterolateral view of nose showing cartilaginous and bony frameworks

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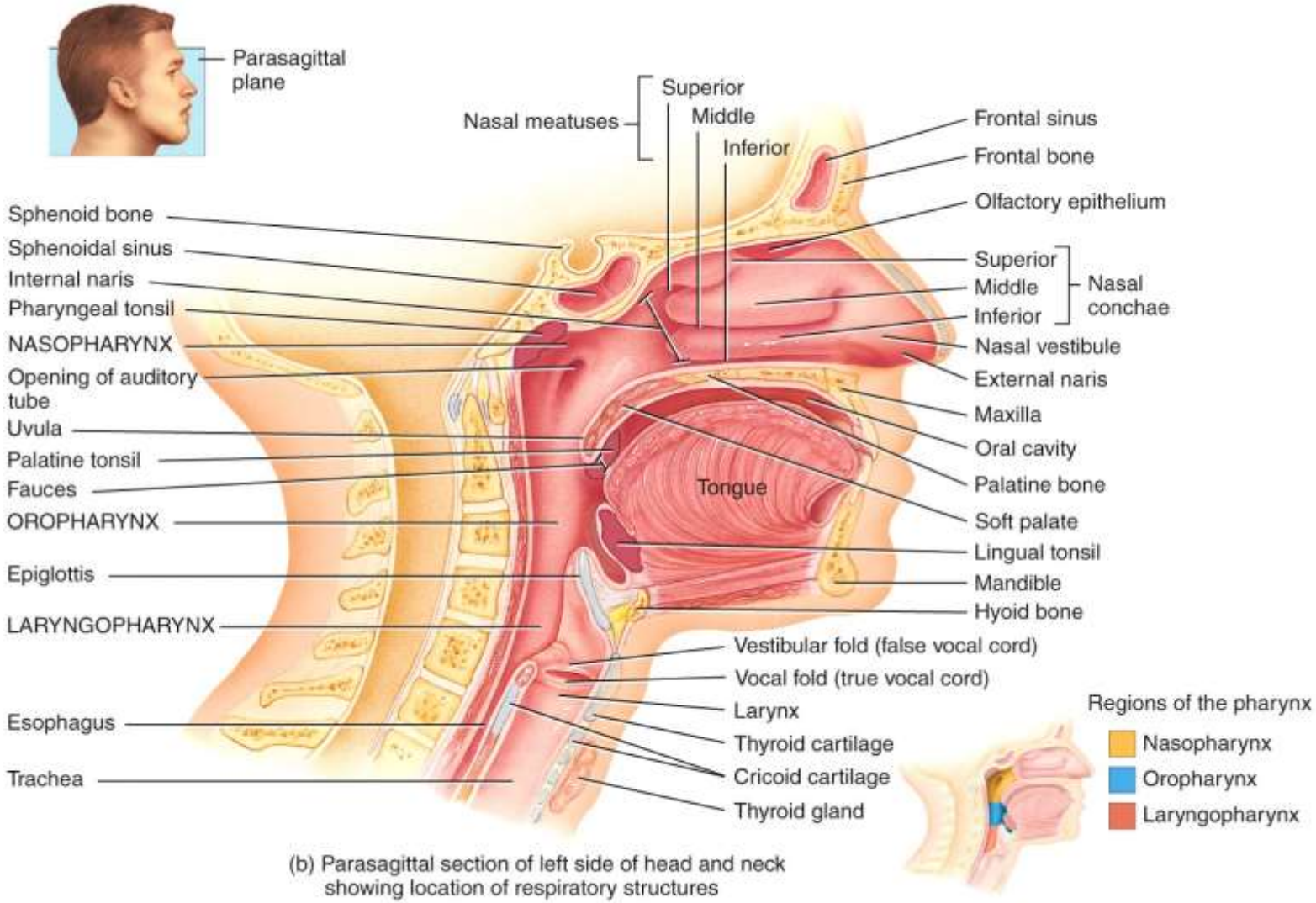
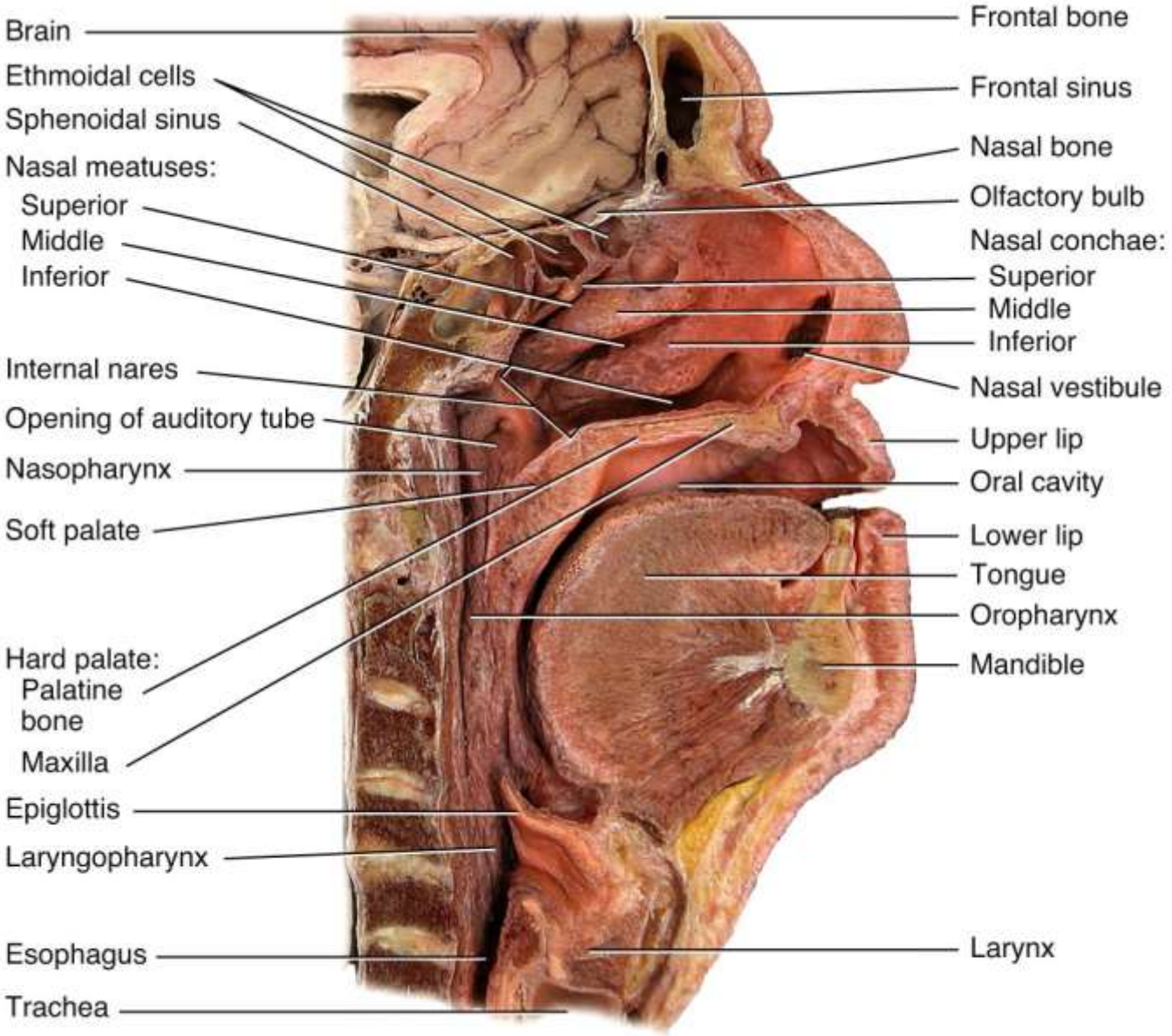
Nose



(b) Parasagittal section of left side of head and neck showing location of respiratory structures



(c) Parasagittal section

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Paranasal Sinuses

- Nasal cavity is divided by an intermediate nasal septum into right and left halves.
- The nasal septum is formed by the septal nasal cartilage, attaches to the vomer and perpendicular plate of the ethmoid bone.

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Conchae

- Subdivides each side of the nasal cavity into a series of groove-like passageways
  - Superior meatus
  - Middle meatus
  - Inferior meatus
- Olfactory epithelium and respiratory epithelium
- Resonance

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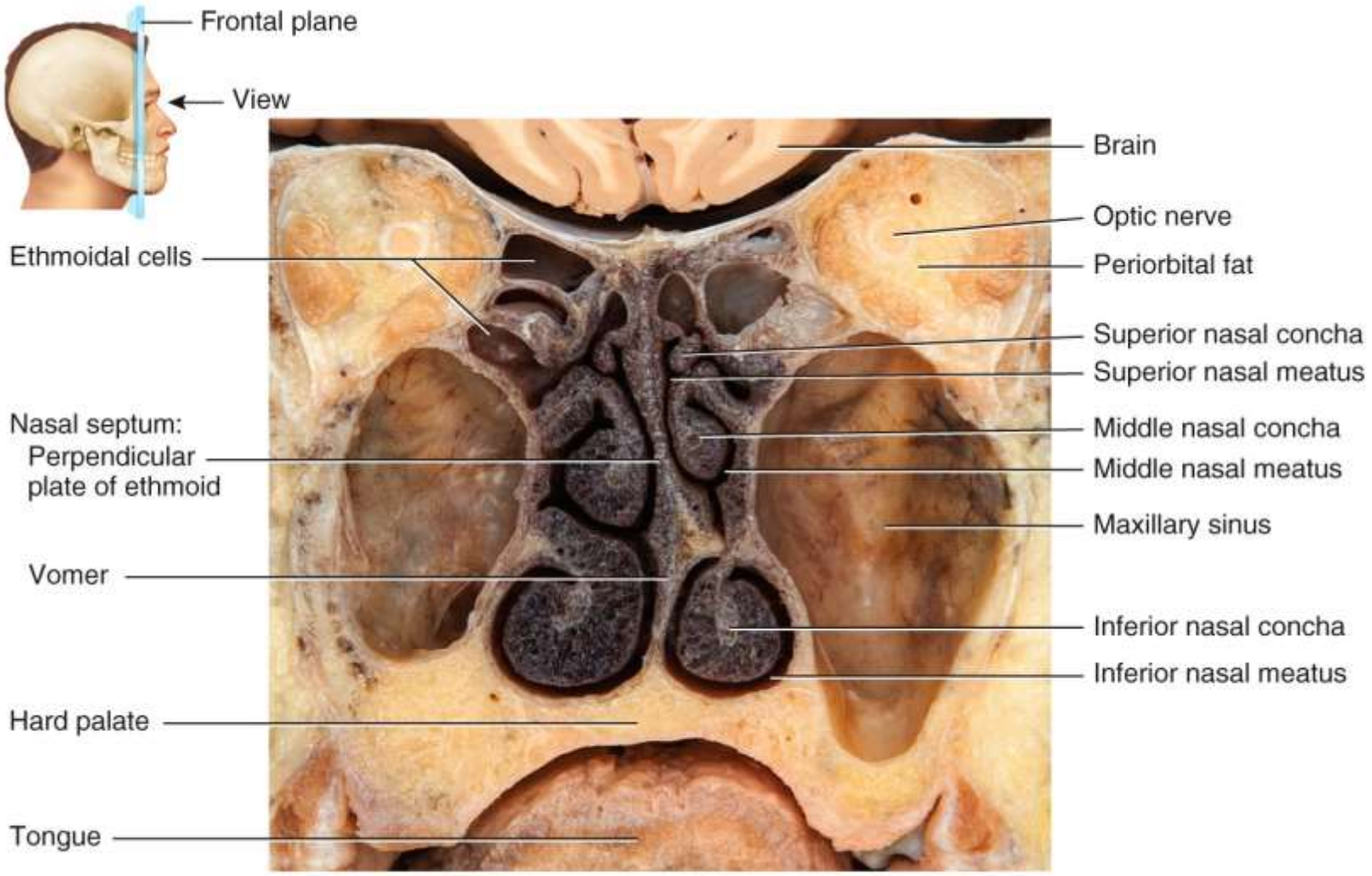
Concha



(d) Frontal section showing conchae

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Pharynx

- Functions of the pharynx (throat)
  - Passageway for air and food
  - Provides a resonating chamber for speech sounds
  - Houses the tonsils
- The pharynx can be divided into three anatomical regions:
  - Nasopharynx contains pharyngeal tonsil or adenoid
  - Oropharynx contains palantine and lingual tonsils
  - Laryngopharynx
- Muscles of pharynx are innervated by cranial nerves IX and X.

- **Clinical Connections:**
  - *Coryza:* catarrhal inflammation of the mucous membrane in the nose, caused especially by a cold or by hay fever.
  - *Seasonal influenza:* is characterized by a sudden onset of fever, cough (usually dry), headache, muscle and joint pain, severe malaise (feeling unwell), sore throat and a runny nose. The cough can be severe and can last 2 or more weeks

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Larynx

- Voice box connects the laryngopharynx with the trachea.
- The wall of the larynx is composed of nine pieces of cartilage.
  - Three occur singly (thyroid cartilage, epiglottis, and cricoid cartilage)
  - Three occur in pairs (arytenoid, cuneiform, and corniculate cartilages)
- The arytenoid cartilages are the true vocal cords.
- Thyroid cartilage (Adam's apple)
- Thyrohyoid membrane
- Epiglottis
- Glottis
- Rima glottidis

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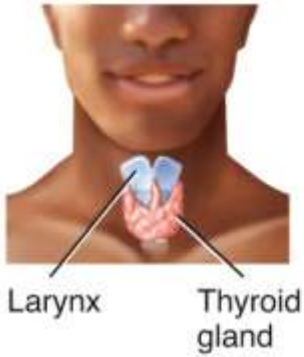
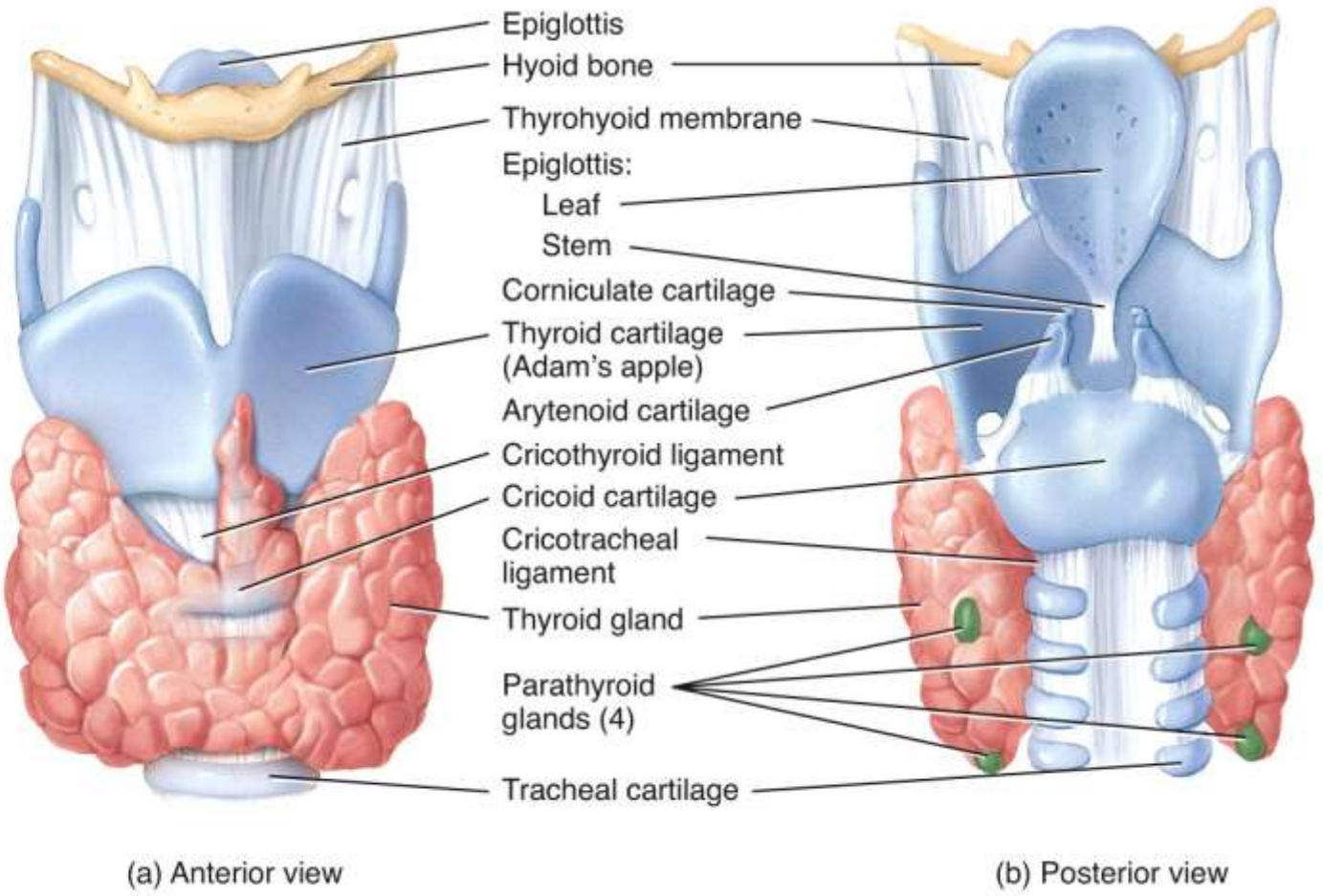
Larynx





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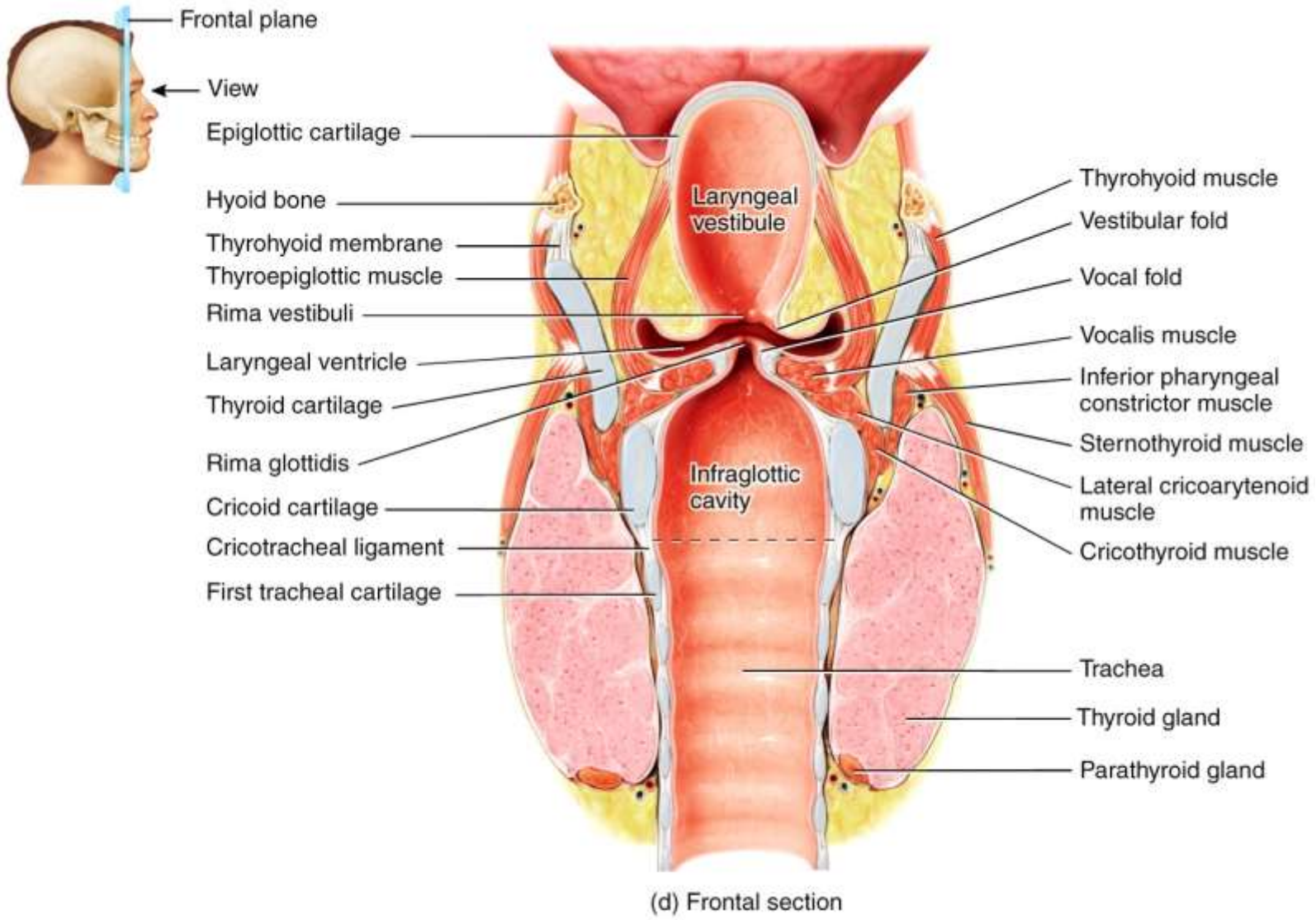
Larynx



(d) Frontal section

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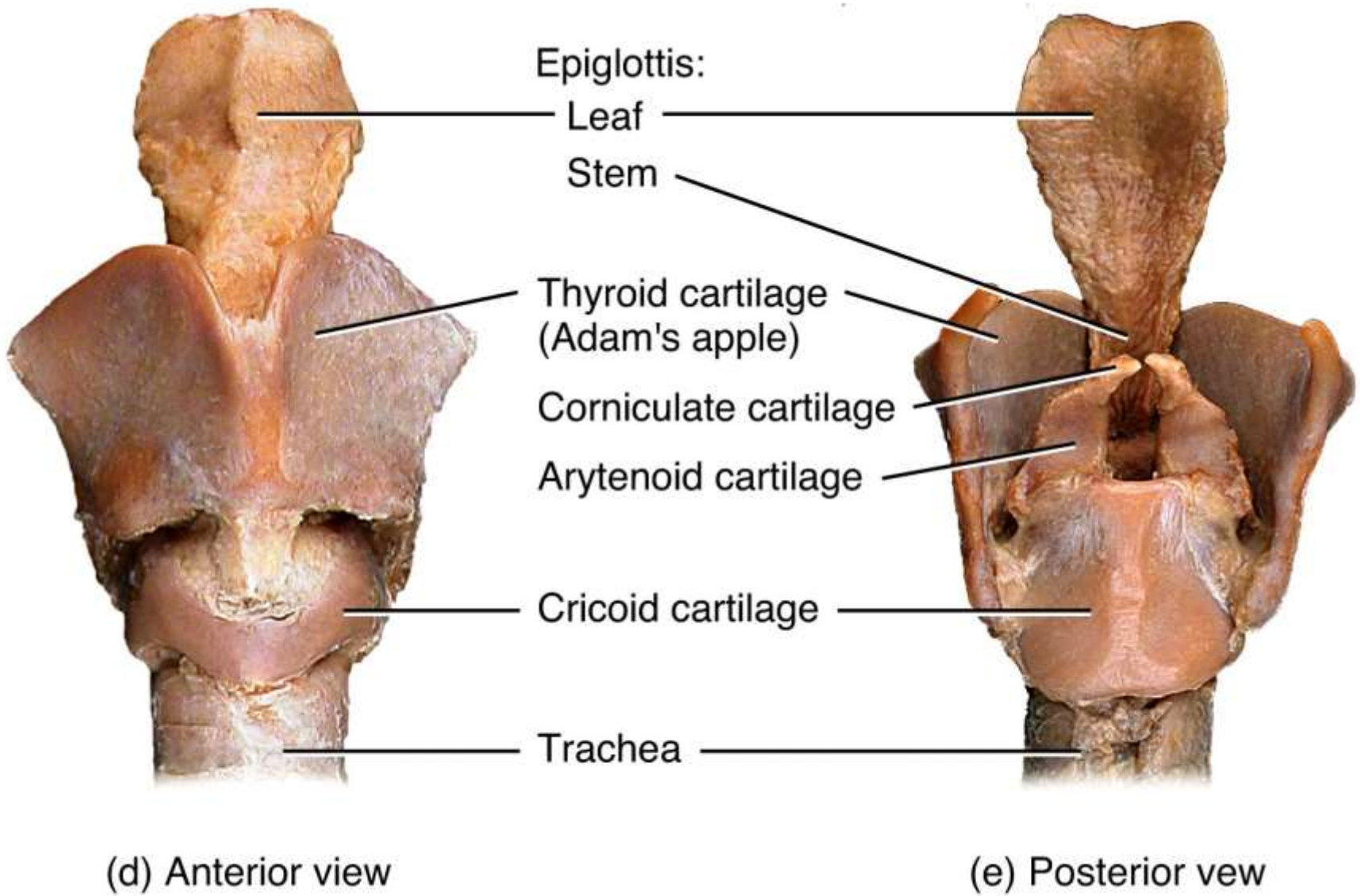

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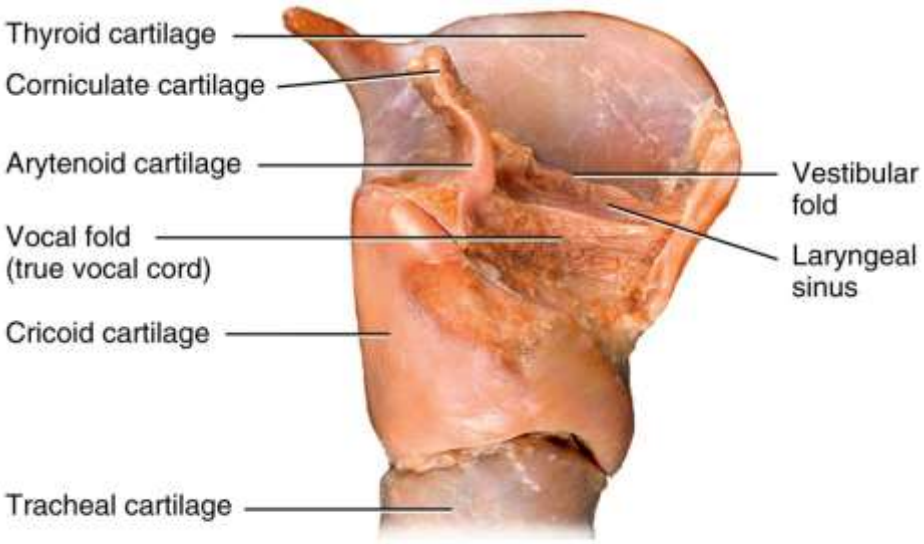

(f) Lateral view

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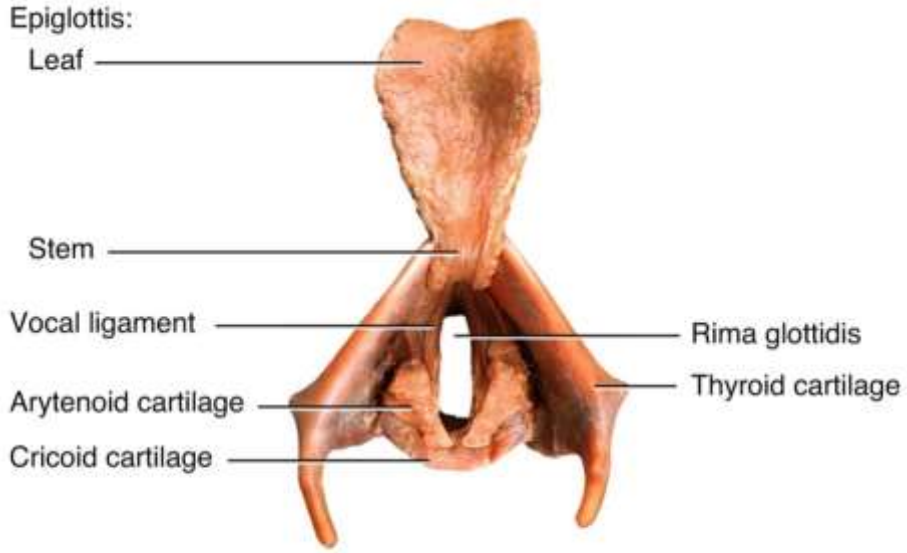

(g) Superior view

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To remember:

Cricoid cartilage
Thyroid cartilage
Arytenoid cartilages
True vocal chords vs false vocal chords
Rima glottidis
Laryngeal vestibule
Laryngeal ventricle
Infraglottic cavity

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Larynx Cartilage

- Cricoid cartilage
- Thyroid cartilage
- Arytenoid cartilages
- Clinical Connections
  - Laryngitis
  - Cancer of the Larynx

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The Structures of Voice Production

- Membrane of the larynx forms two pair of folds.
  - A **s**uperior pair called the vestibular folds (fal**s**e vocal cords)
  - An inferior pair called simply the vocal folds (true vocal cords)
- Laryngeal ventricle (sinus)

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The Structures of Voice Production

- Air passing through the larynx vibrates the folds and produces sound.
- The variation in the pitch of the sound is related to the tension in the vocal folds.

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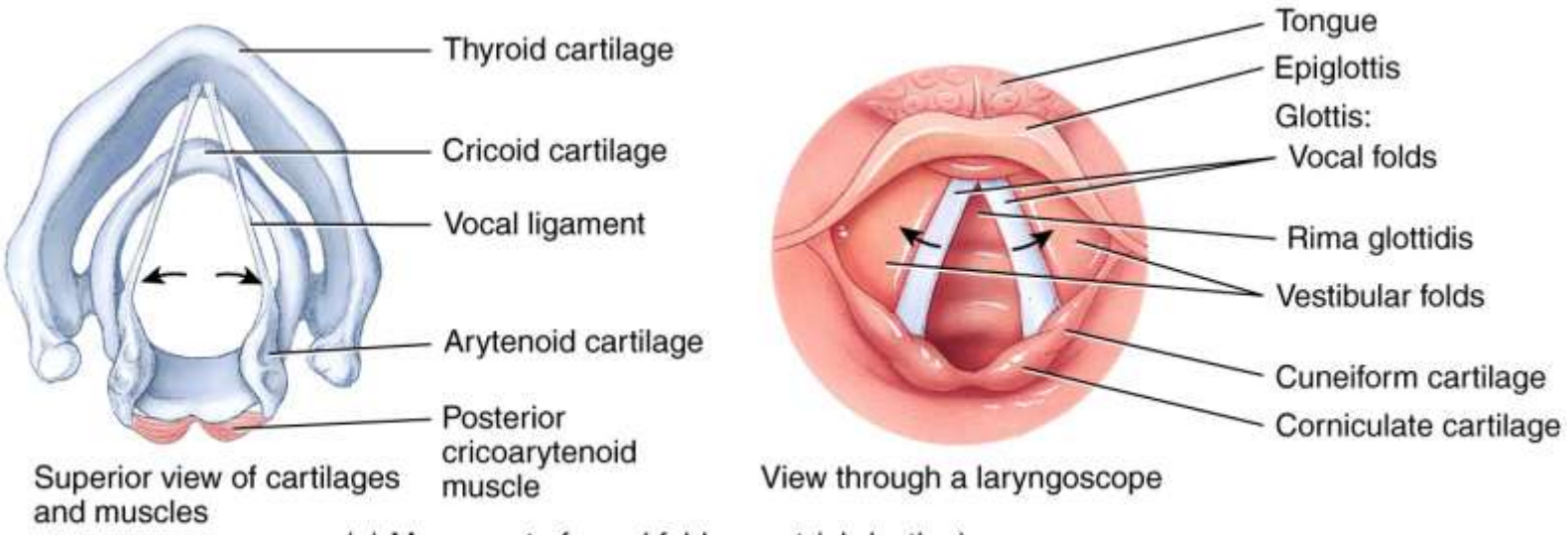
The Structures of Voice Production



Trachea

- Windpipe is a tubular passageway for air.
- Extends from the larynx to the superior border of T5 then divides into right and left main bronchi
- The layers of the tracheal wall, from deep to superficial
  - Mucosa
  - Submucosa
  - Fibromusculocartilaginous layer
  - Adventitia
- Trachealis muscle
- The solid C-shaped cartilage rings provide a semi-rigid support so that the tracheal wall does not collapse inward and obstruct the air passageway.

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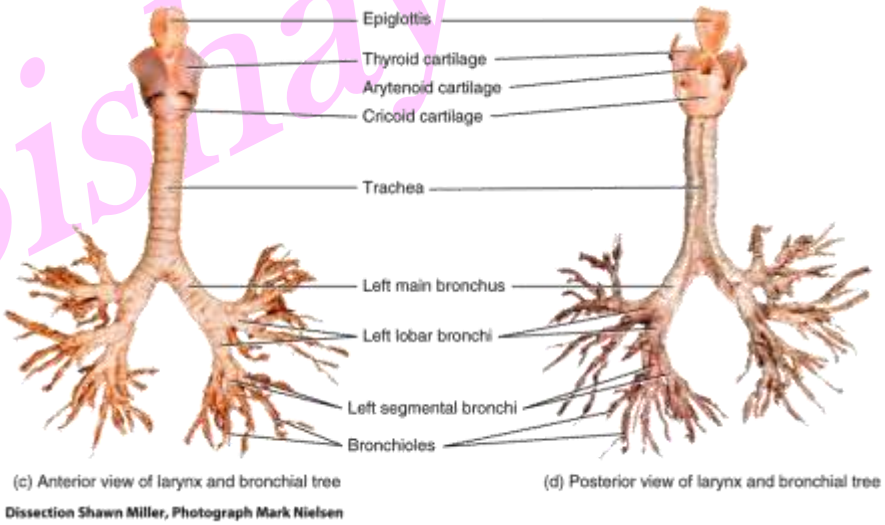
Trachea

The smooth muscle and glands of the trachea are innervated by cranial nerve X.

Clinical Connection

Tracheotomy: an incision in the windpipe made to relieve an obstruction to breathing

Intubation: is the process of inserting a tube, called an endotracheal tube (ET), through the mouth and then into the airway. This is done so that a patient can be placed on a ventilator to assist with breathing during anesthesia, sedation, or severe illness.



(c) Anterior view of larynx and bronchial tree

(d) Posterior view of larynx and bronchial tree

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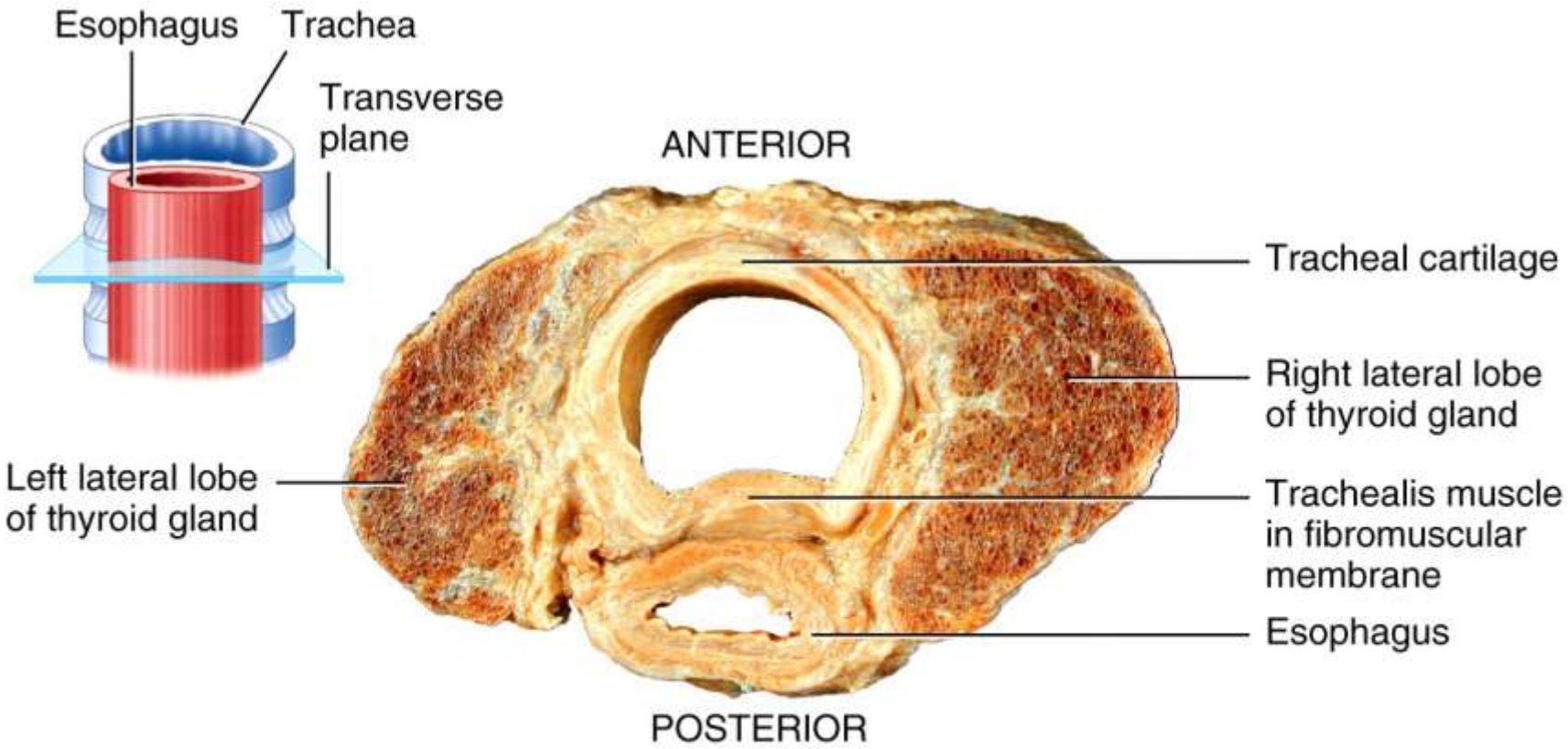
Trachea



Superior view of transverse section of thyroid gland, trachea, and esophagus

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Bronchi

- Located at the superior border of T5
- Trachea divides into a right main (primary) bronchus and a left main (primary) bronchus.
- Carina
- The bronchi divide to form the lobar (secondary) bronchi, one for each lobe of the lung.
- Lobar branch into segmental (tertiary) bronchi
- Segmental branch into bronchioles
- Bronchioles branch into terminal bronchioles
- Role of the Autonomic Nervous System in Respiratory System
- Clinical Connections
  - Asthma
  - Chronic Bronchitis

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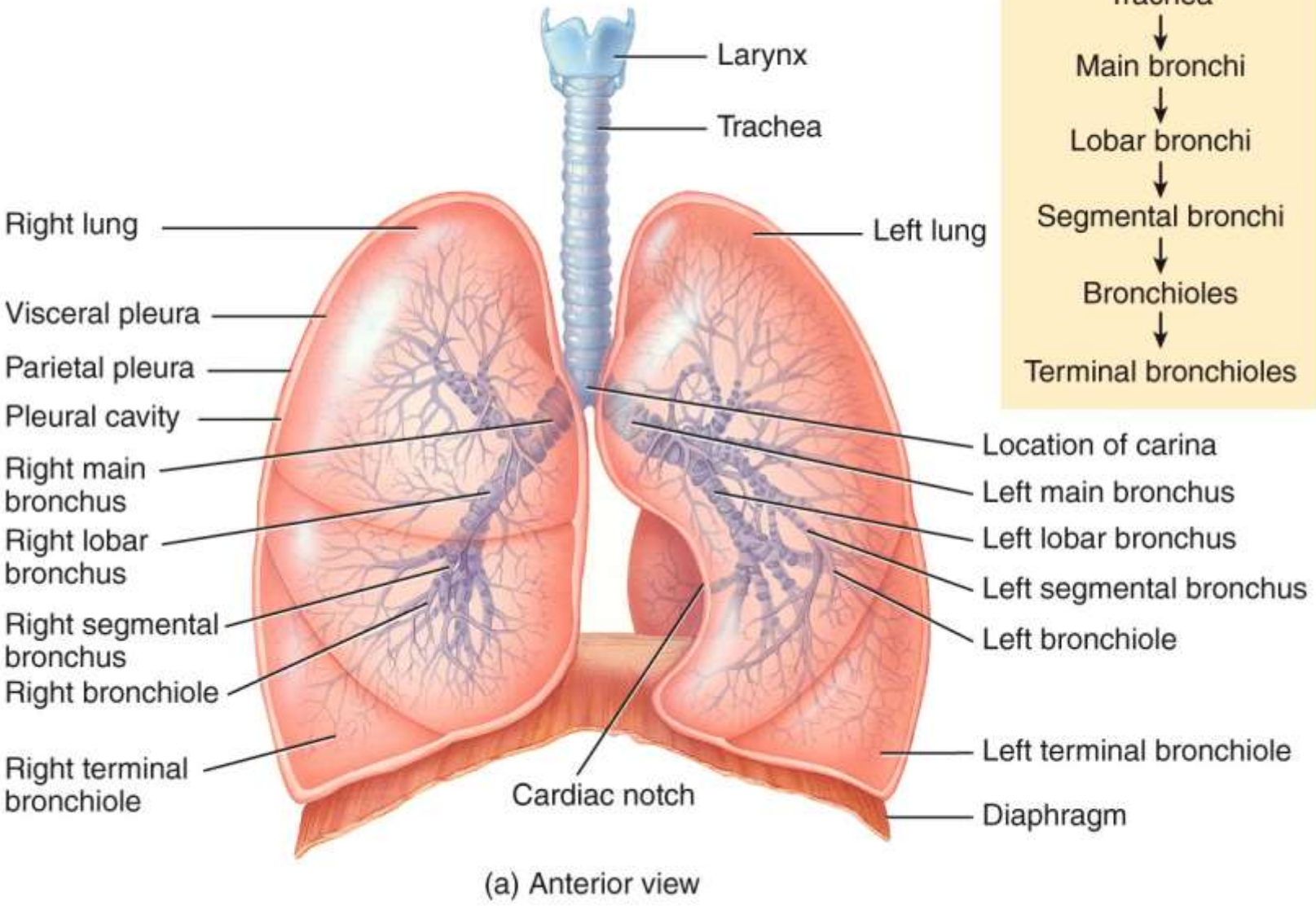
Bronchial Tree

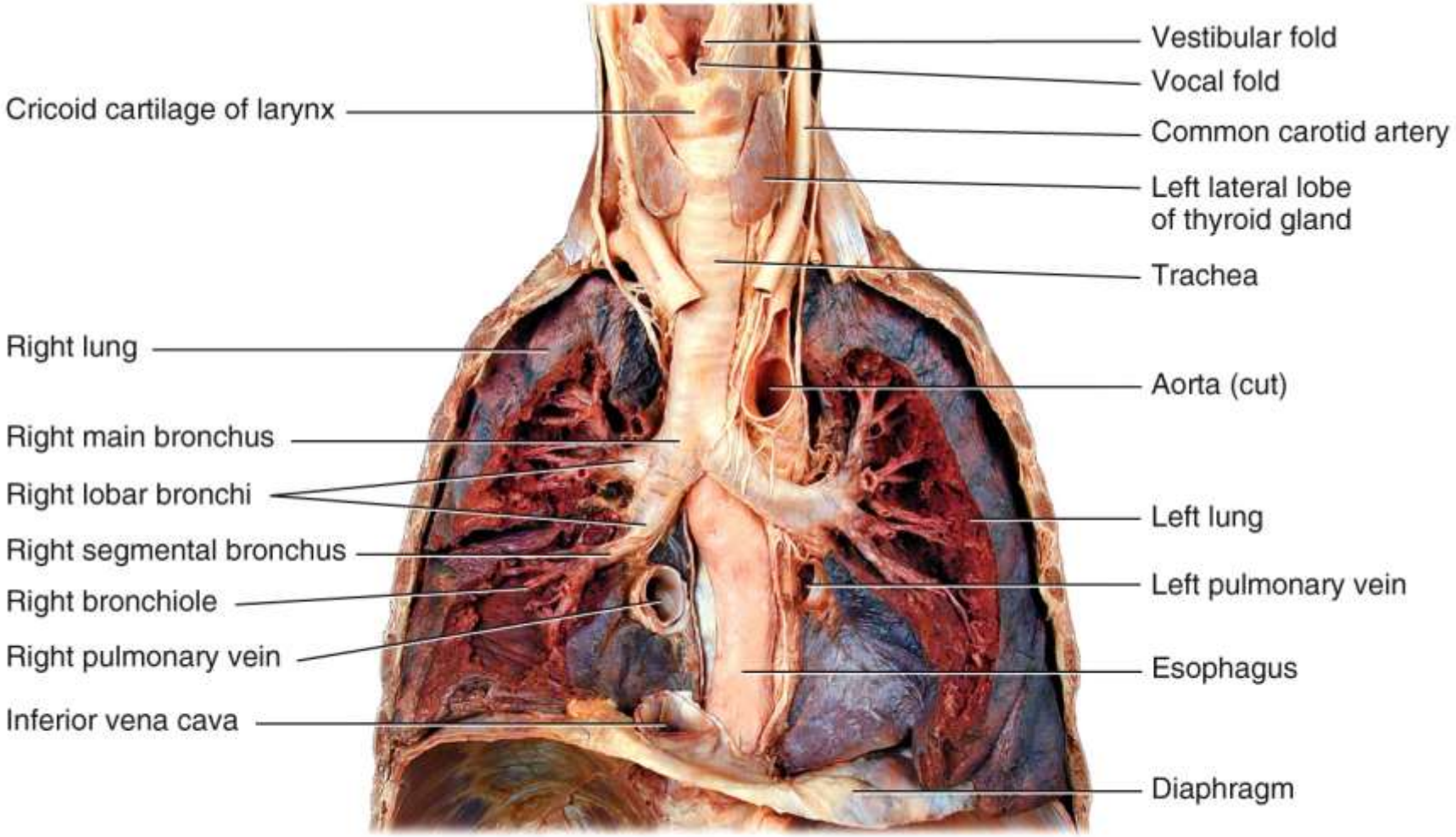


BRANCHING OF BRONCHIAL TREE

Trachea
↓
Main bronchi
↓
Lobar bronchi
↓
Segmental bronchi
↓
Bronchioles
↓
Terminal bronchioles

erved.

Bronchial Tree



(b) Anterior view of bronchial tree in lungs

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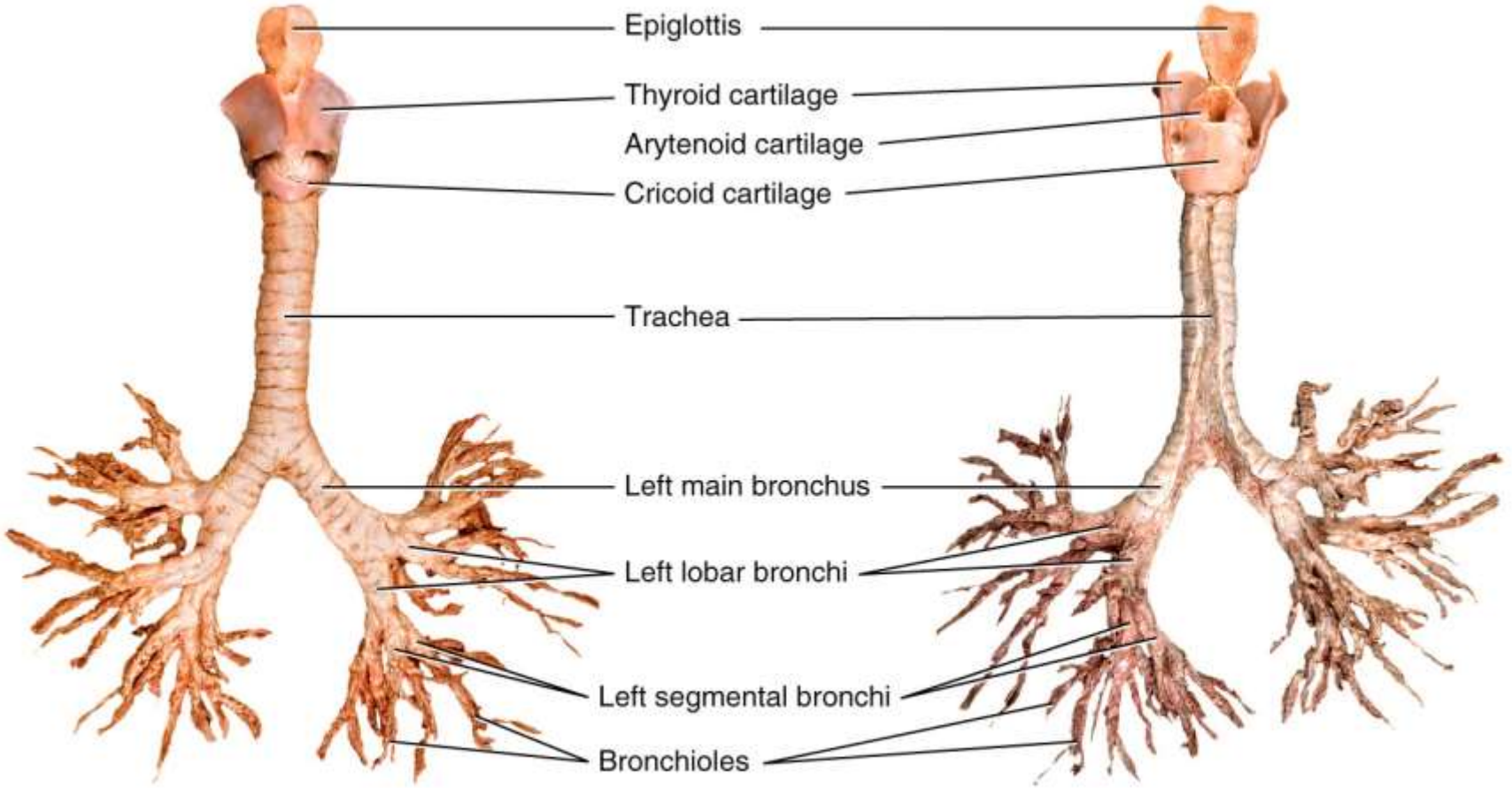
Bronchial Tree



(c) Anterior view of larynx and bronchial tree

(d) Posterior view of larynx and bronchial tree

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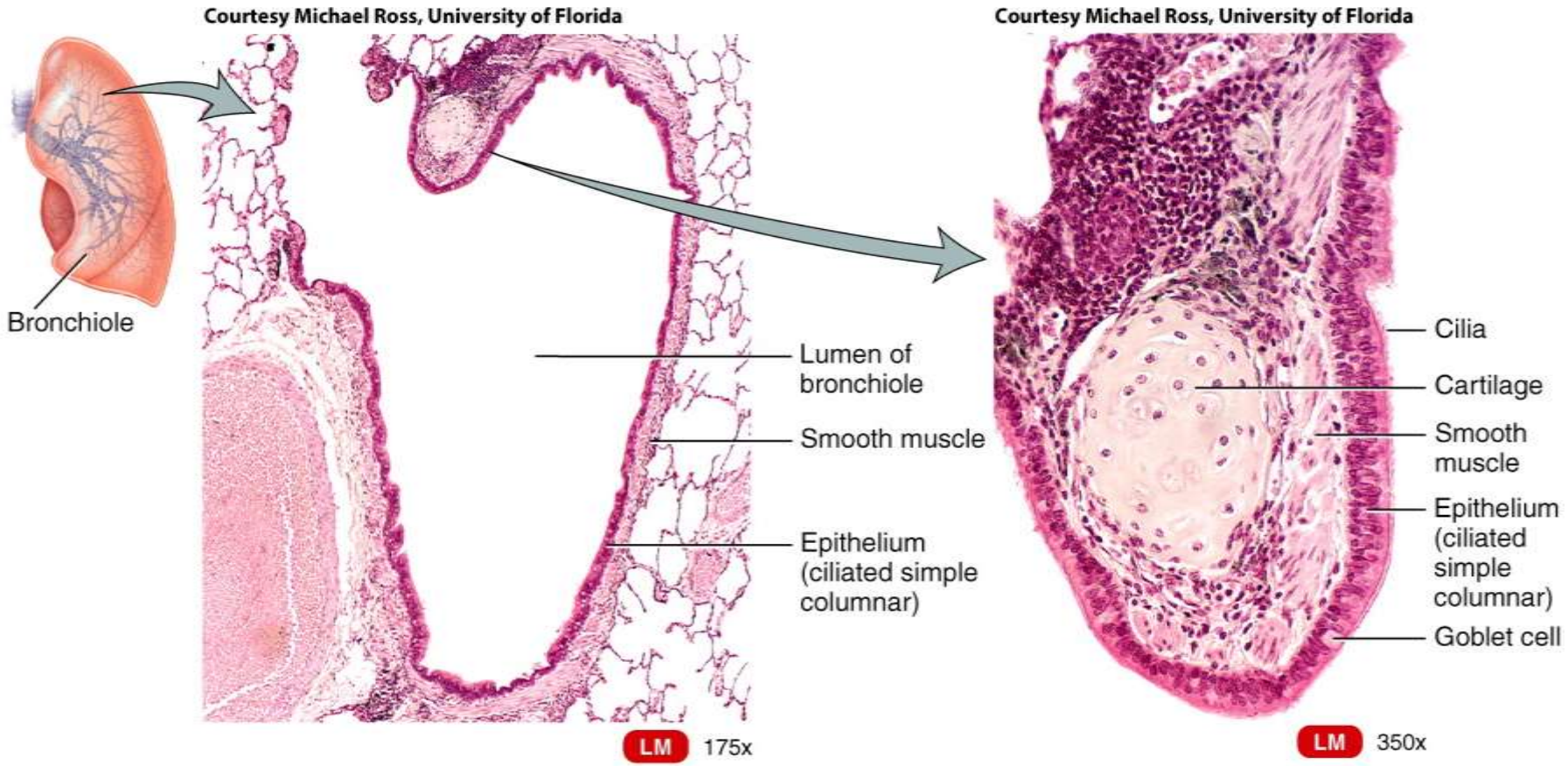
Histology of a Brochiole



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Lungs

- Mediastinum separates the thoracic cavity into two anatomically distinct chambers.
- Pleural membrane
  - Parietal pleura
  - Visceral pleura
- Pleural cavity
- Hilum
- Cardiac notch
- Clinical Connections
  - Pneumothorax
  - Hemothorax

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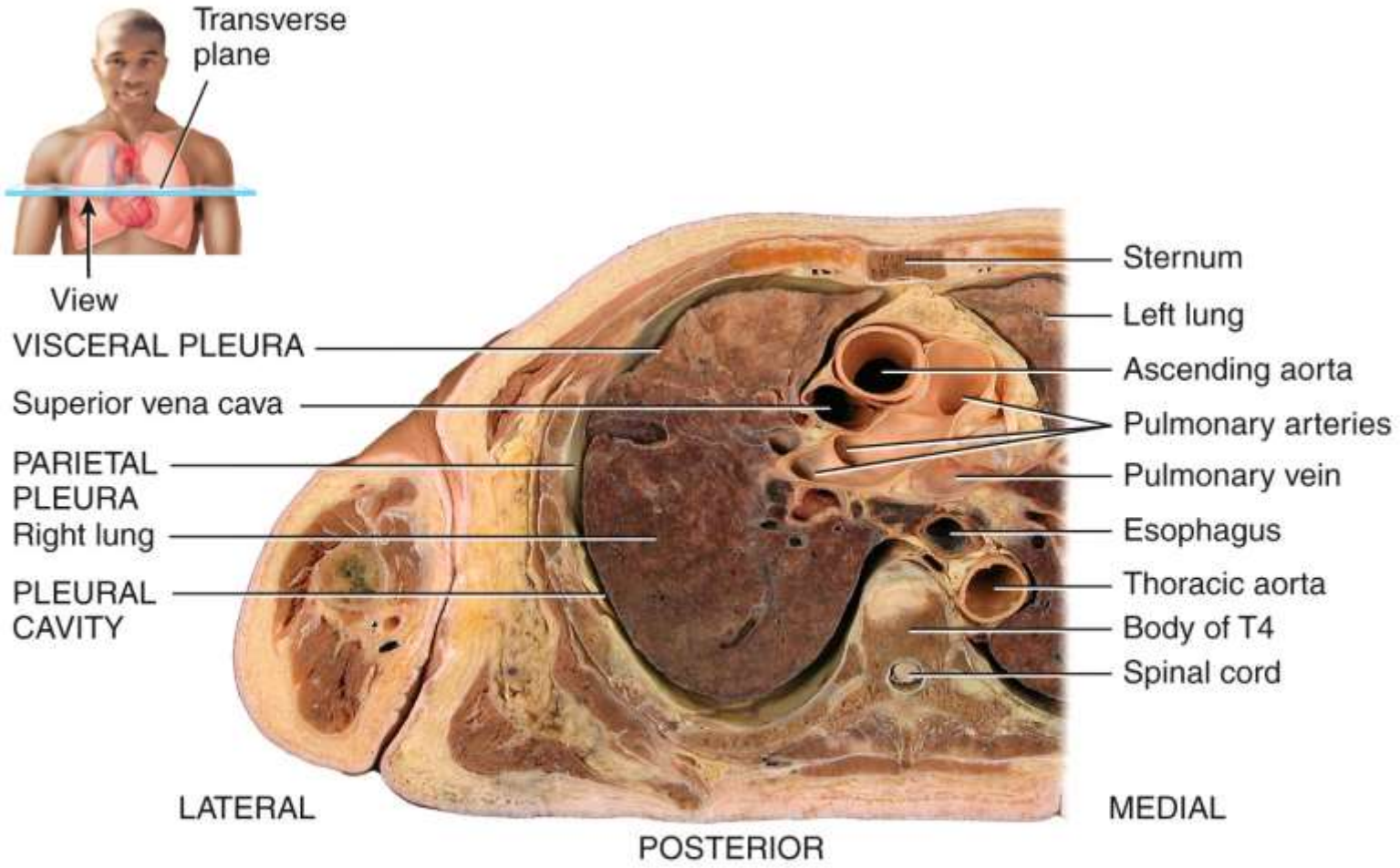
Lungs



Inferior view of a transverse section through the thoracic cavity showing the pleural cavity and pleural membranes

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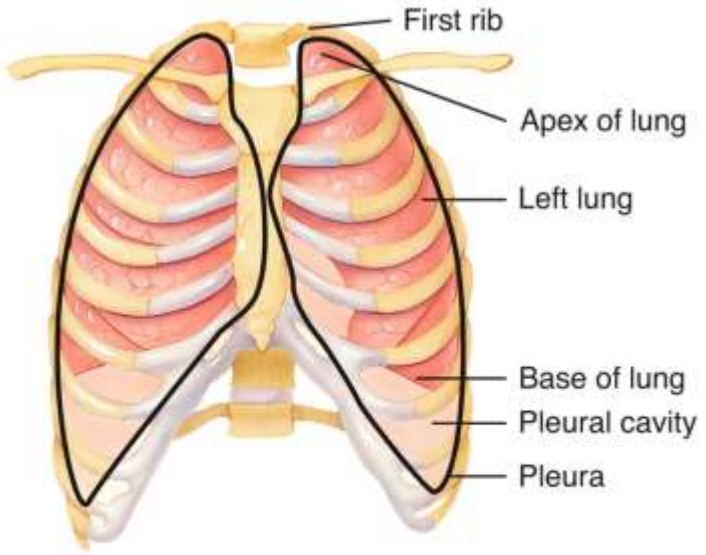
Lungs

Base

Apex

Costal surface

Hilum



(a) Anterior view of lungs and pleurae in thorax

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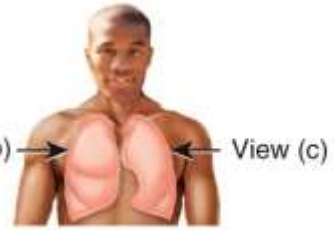
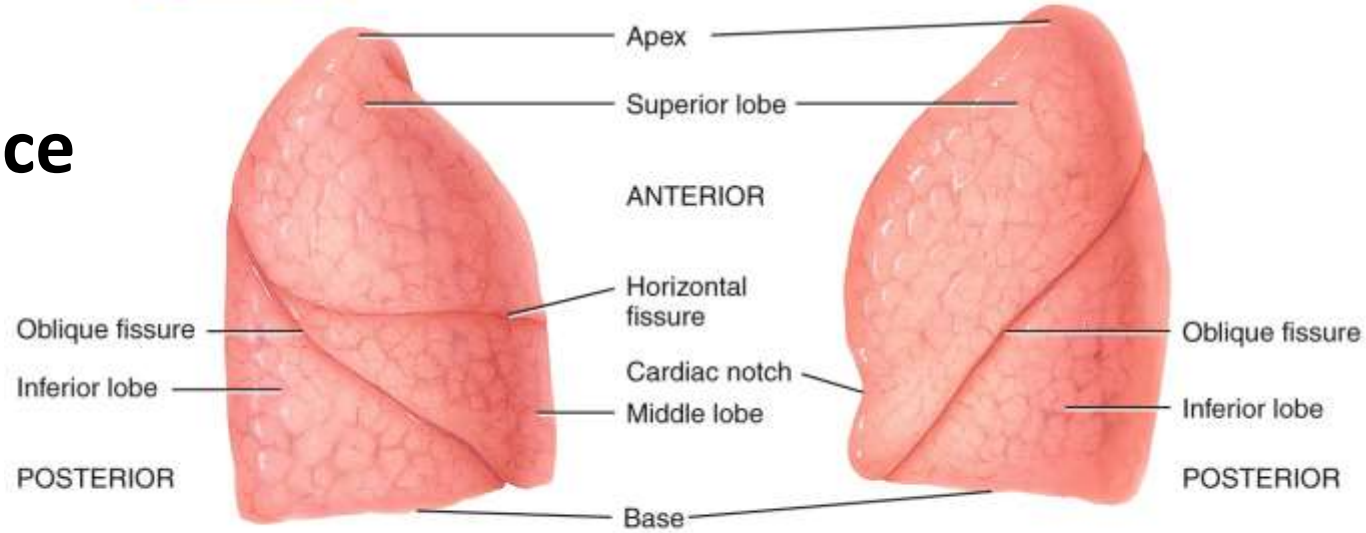
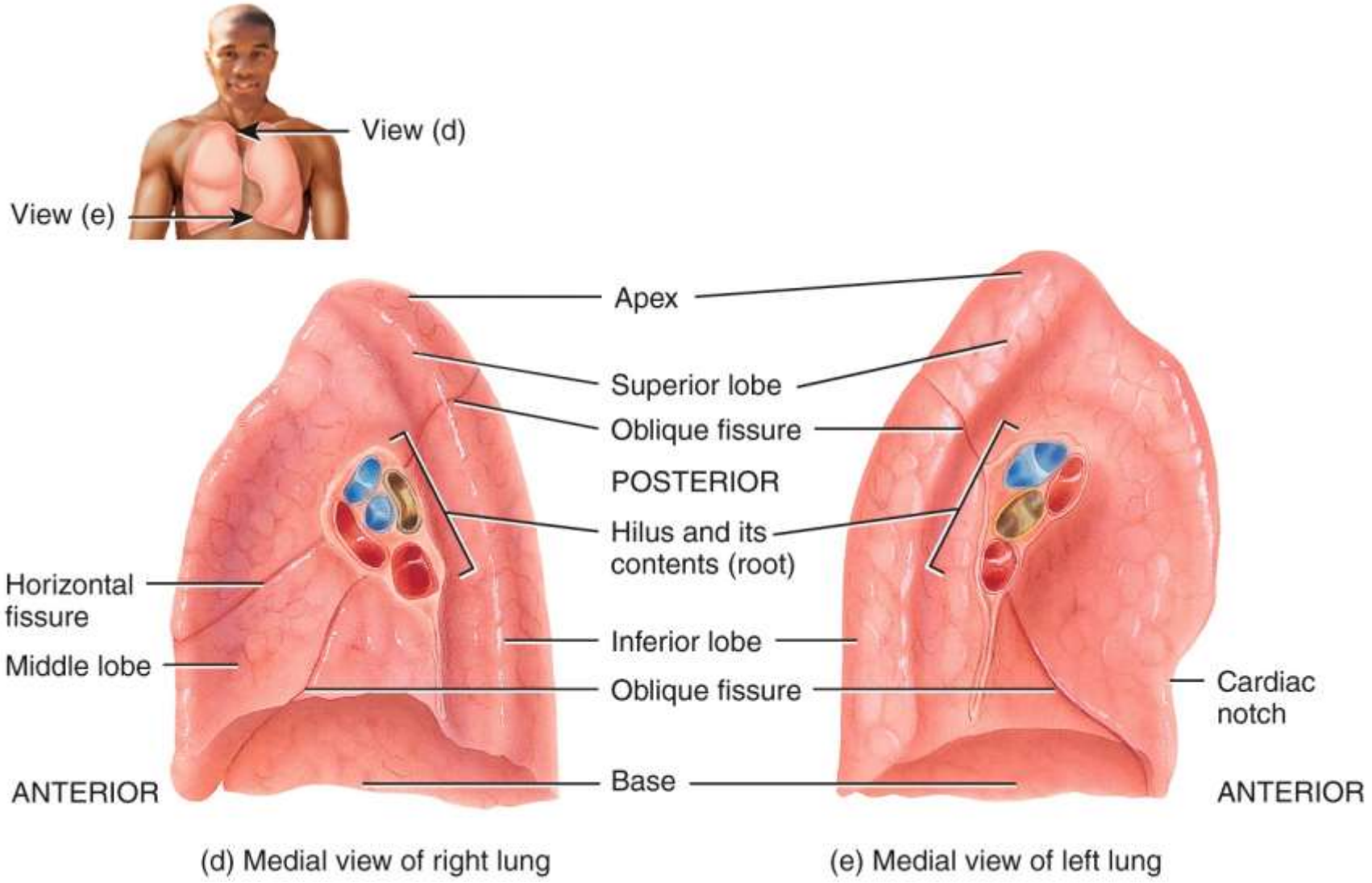




(b) Lateral view of right lung

(c) Lateral view of left lung

Lungs



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Lobes of the Lungs

- Both lungs have an oblique fissure.
- Right lung also has a horizontal fissure.
- Oblique fissure in the left lung separates superior lobe from inferior lobe.
- In the right lung, superior part of the oblique fissure separates superior lobe from inferior lobe and from the middle lobe.
- Right and left main bronchus
- Lobar bronchi
- Segmental bronchi
- Bronchopulmonary segment
  - lobules
  - terminal bronchioles
  - alveolar ducts

- Clinical Connection
  - Effects of Smoking on the Respiratory System

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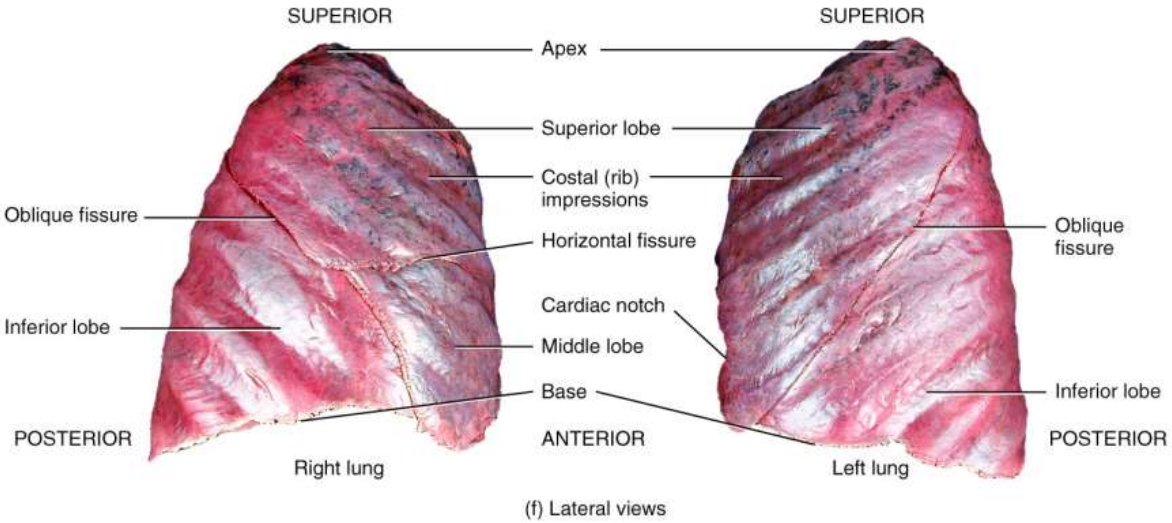
Lobes of the Lungs



(f) Lateral views

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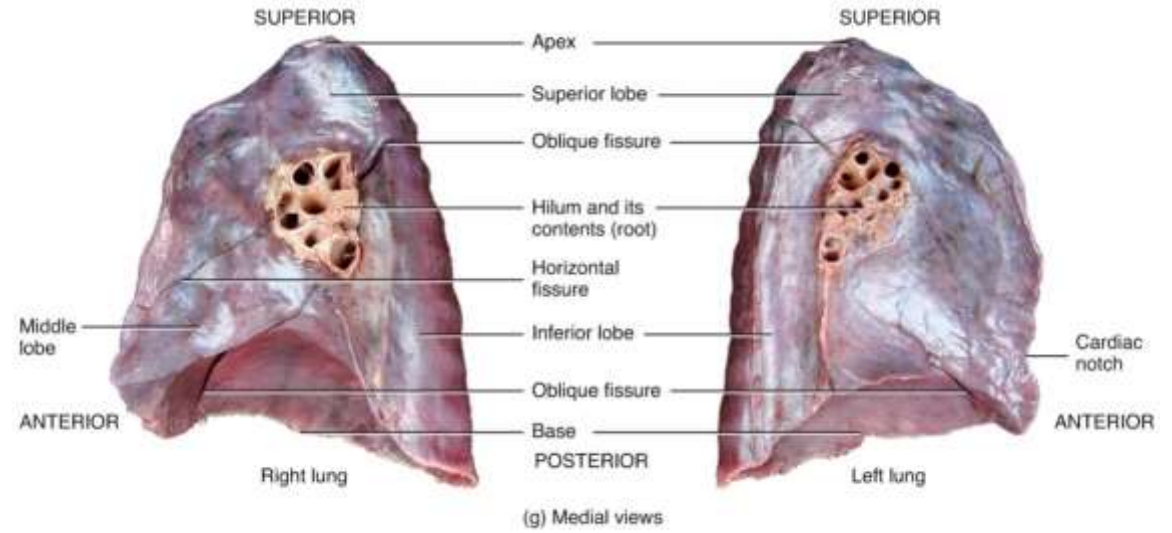

(g) Medial views

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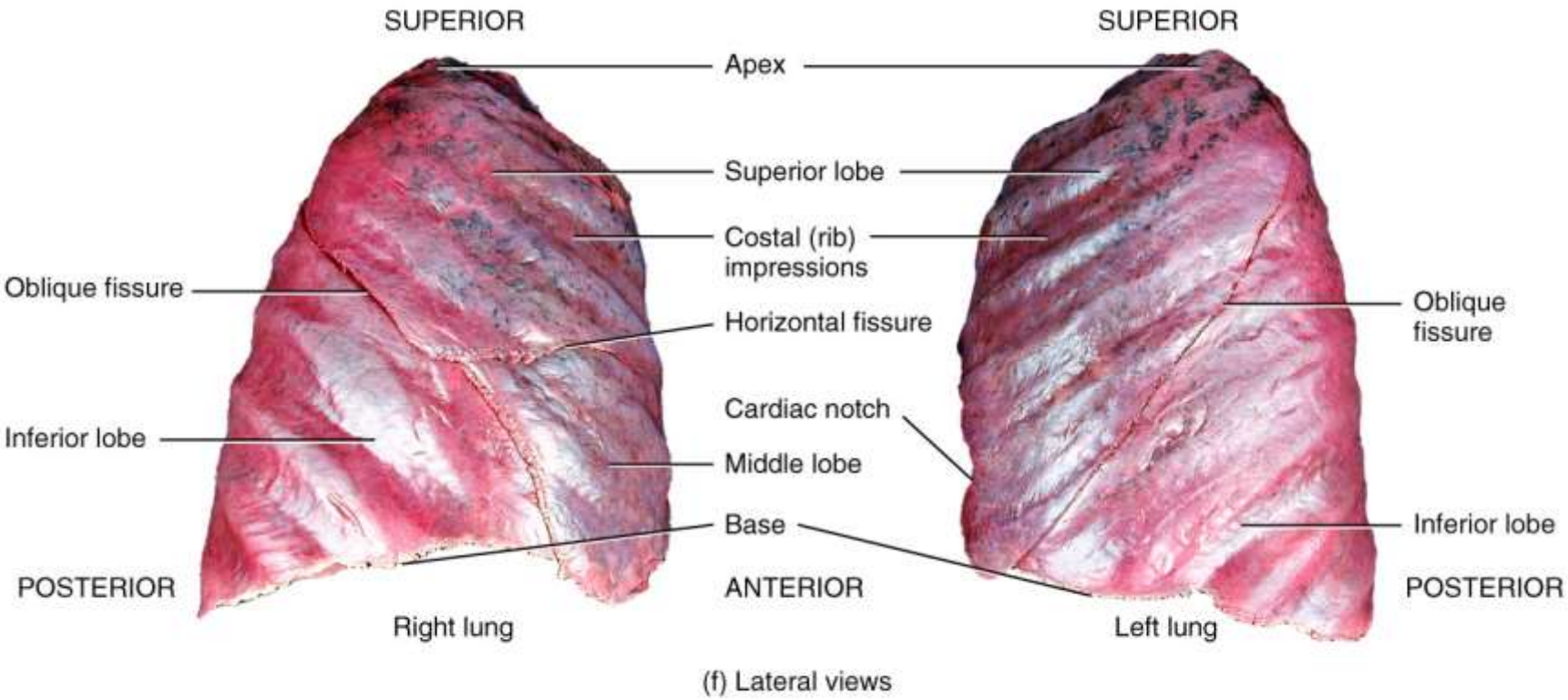
Lobes of the Lungs



(f) Lateral views

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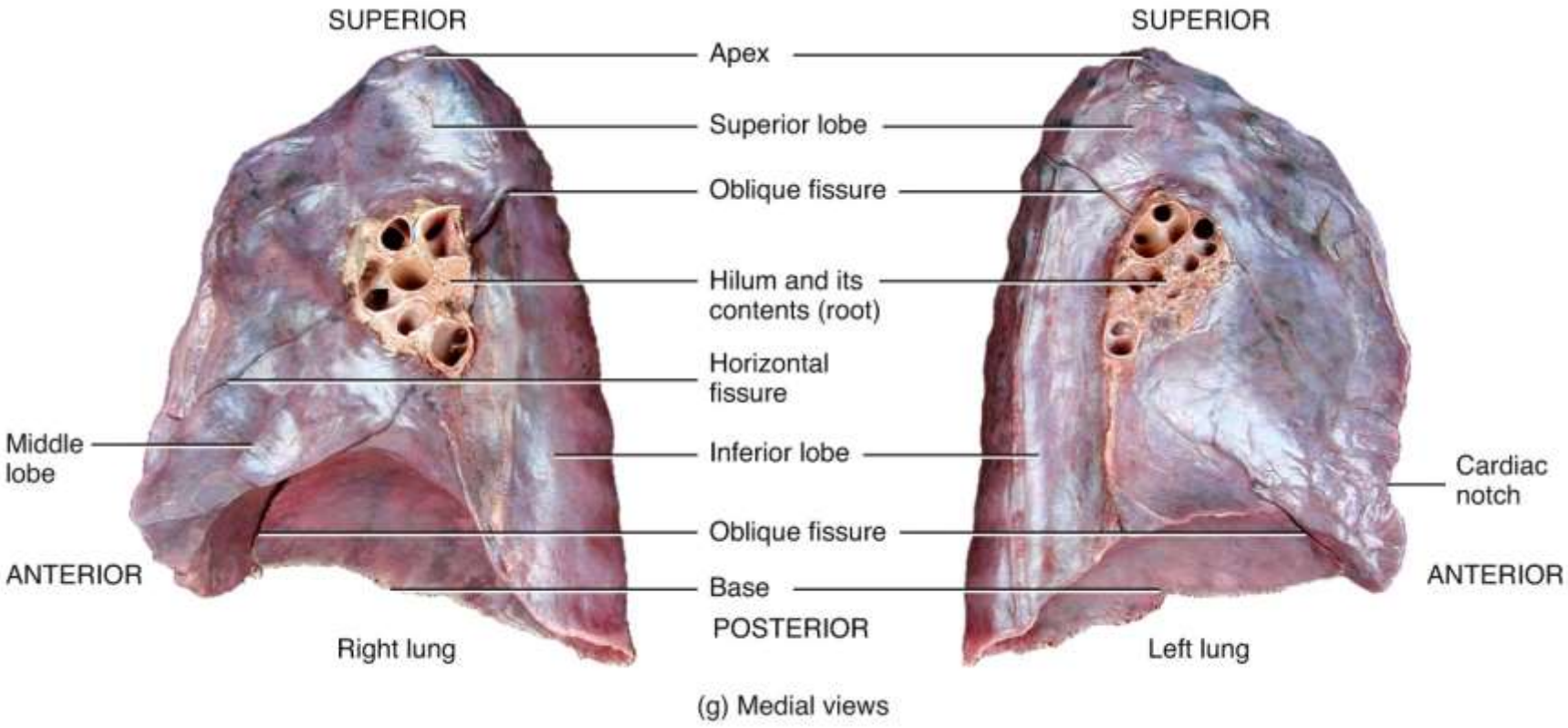
Lobes of the Lungs



(g) Medial views

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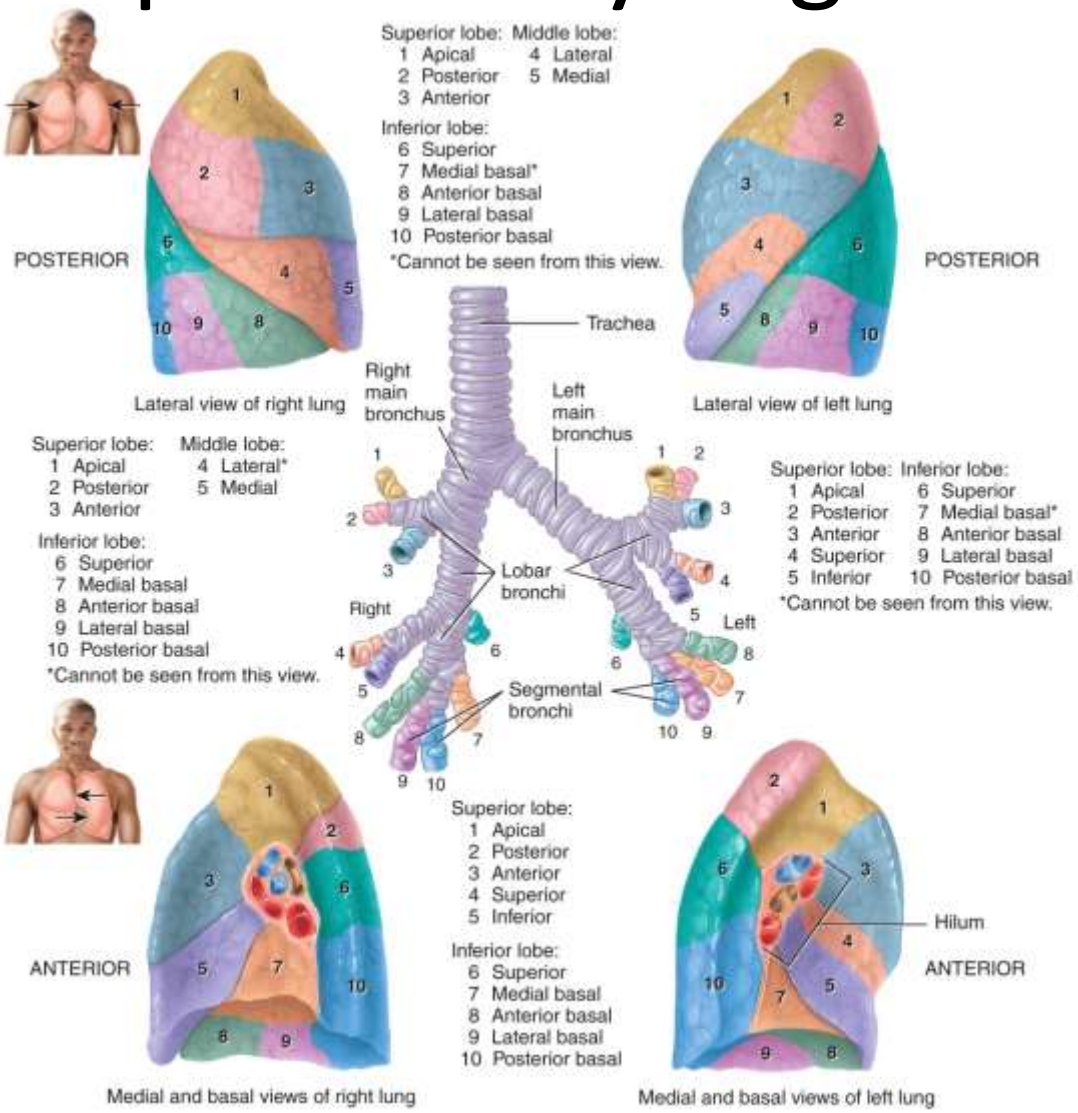
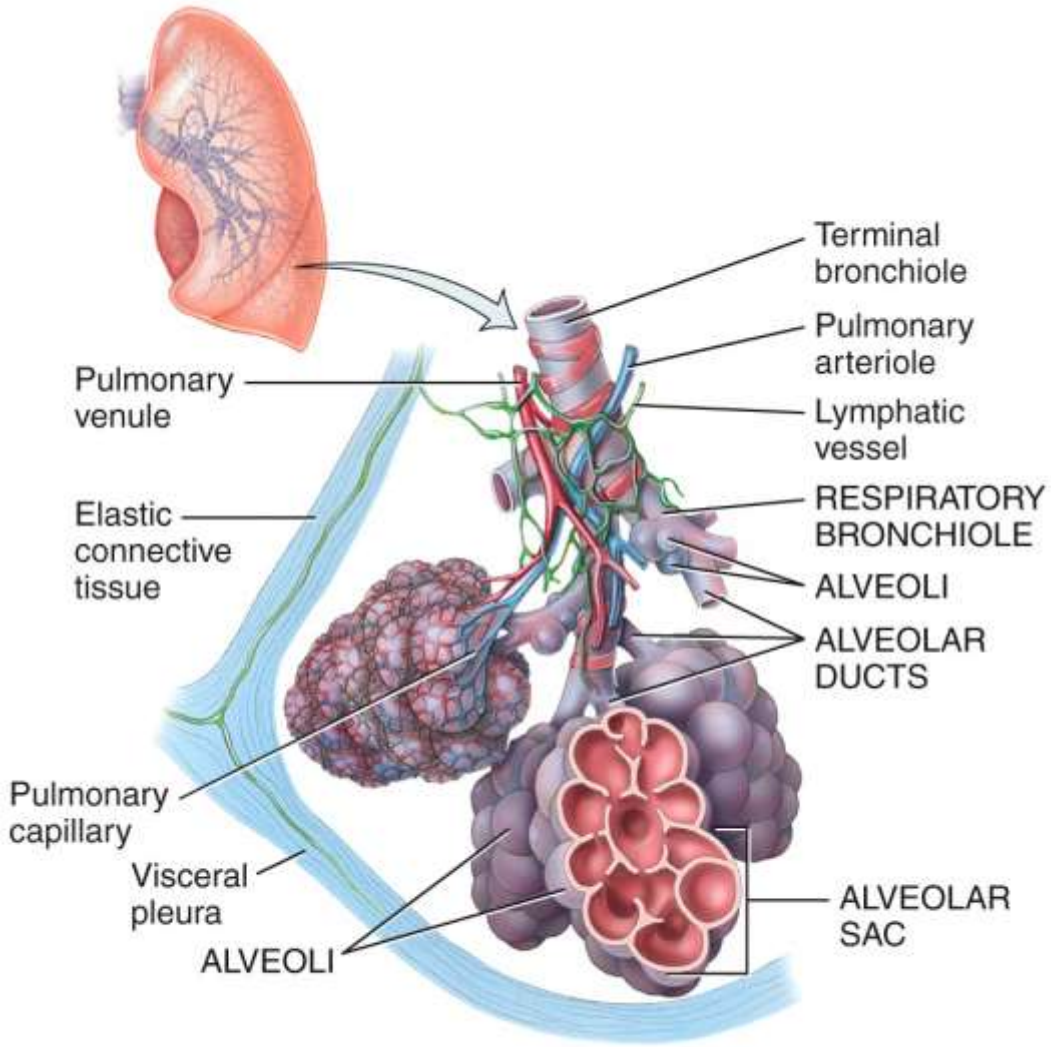
Bronchopulmonary Segments



Microscopic Anatomy of Lungs



(a) Diagram of a portion of a lobule of the lung

MICROSCOPIC AIRWAYS

Respiratory bronchioles

↓

Alveolar ducts

↓

Alveolar sacs

↓

Alveoli

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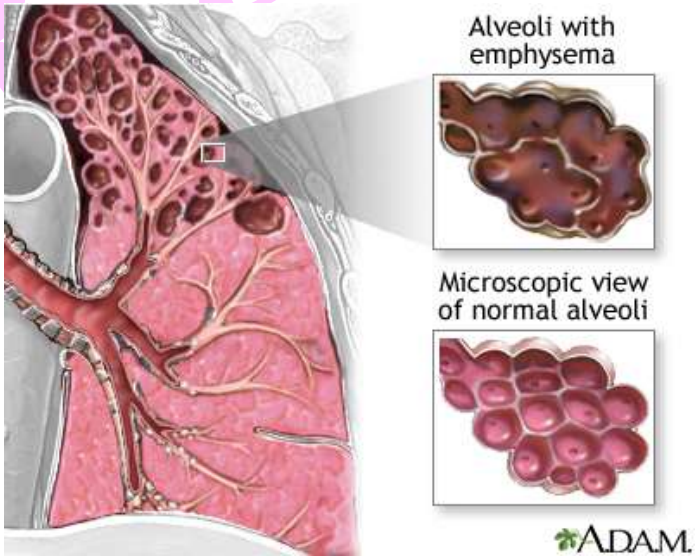
Alveoli

- Alveolar sac consists of two or more alveoli that share a common opening.
- Clinical Connections
  - **Emphysema:** is a lung condition that causes shortness of breath. In people with emphysema, the air sacs in the lungs (alveoli) are damaged. Over time, the inner walls of the air sacs weaken and rupture — creating larger air spaces instead of many small ones



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Respiratory Membrane

- Extending from the alveolar air space to blood plasma, the respiratory membrane consists of four layers.
  - A layer of alveolar cells and associated alveolar macrophages that constitutes the alveolar wall
  - Epithelial basement
  - Capillary basement
  - Endothelial cells of the capillary

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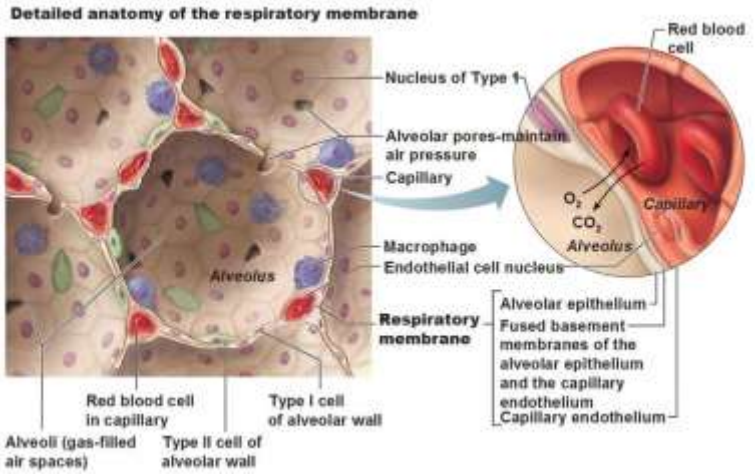

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Blood Supply and Patency

- **Blood supply to the lungs is via two sets of arteries:**
  - **Pulmonary arteries:** carries deoxygenated blood from the right ventricle to the lungs. The blood here passes through capillaries adjacent to alveoli and becomes oxygenated as part of the process of respiration. In contrast to the pulmonary arteries, the bronchial arteries supply nutrition to the lungs themselves
  - **Bronchial arteries:** supply the lungs with nutrition and oxygenated blood. Although there is much variation, there are usually two bronchial arteries that run to the left lung, and one to the right lung

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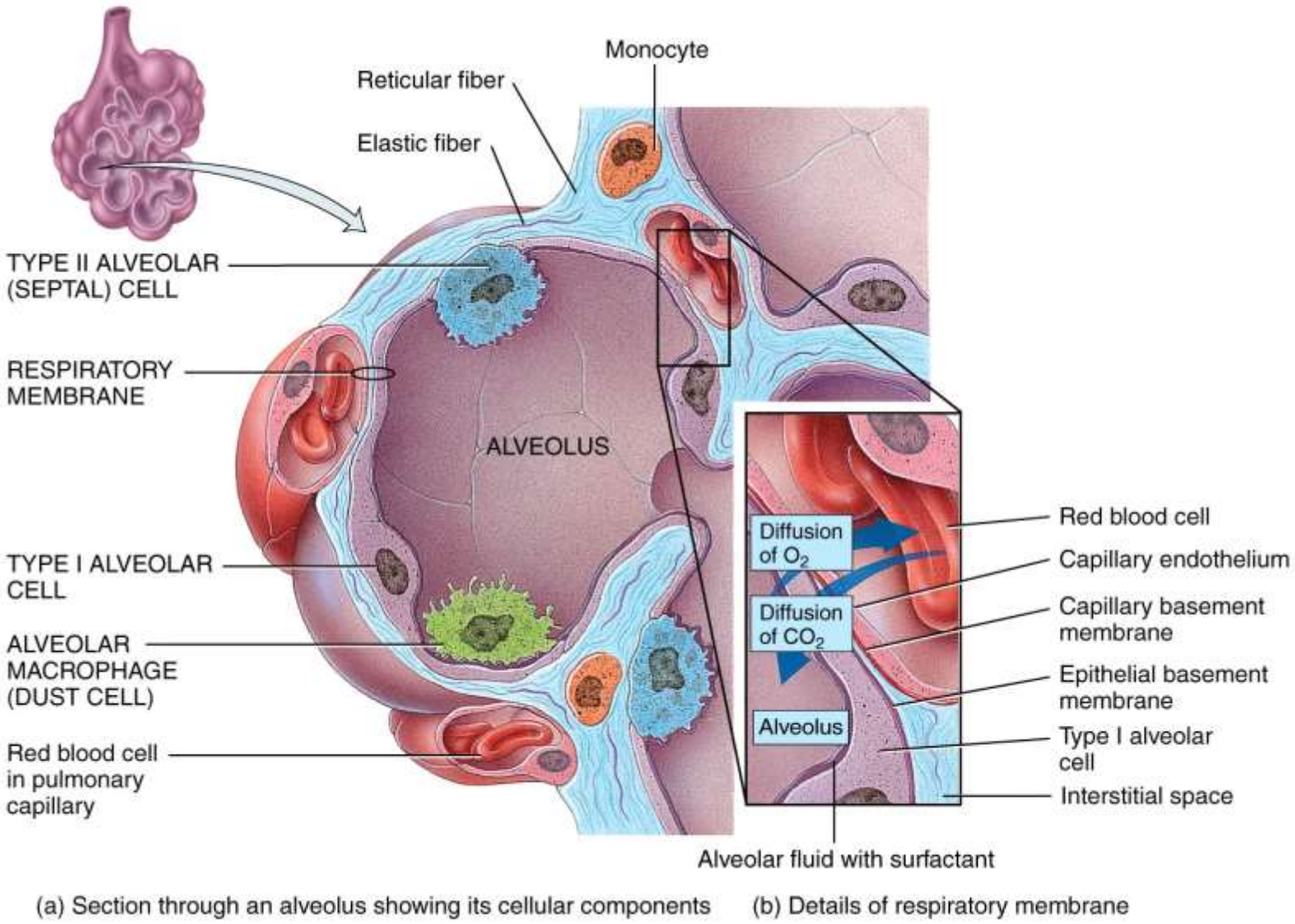
Alveoli



(a) Section through an alveolus showing its cellular components (b) Details of respiratory membrane

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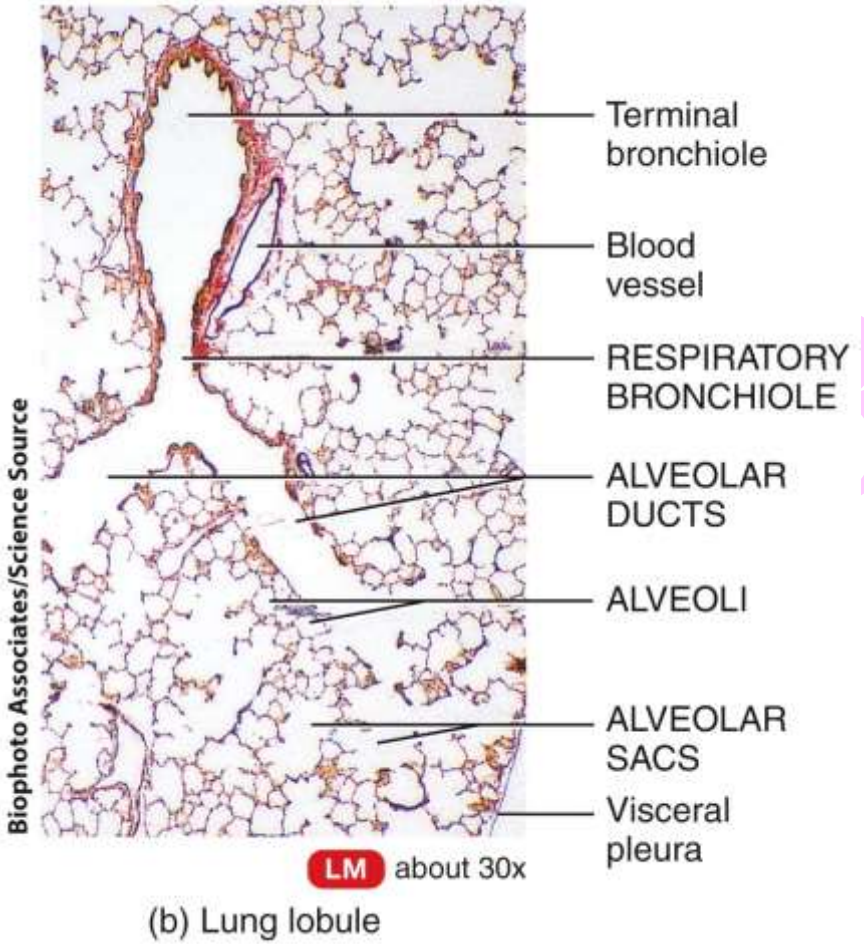
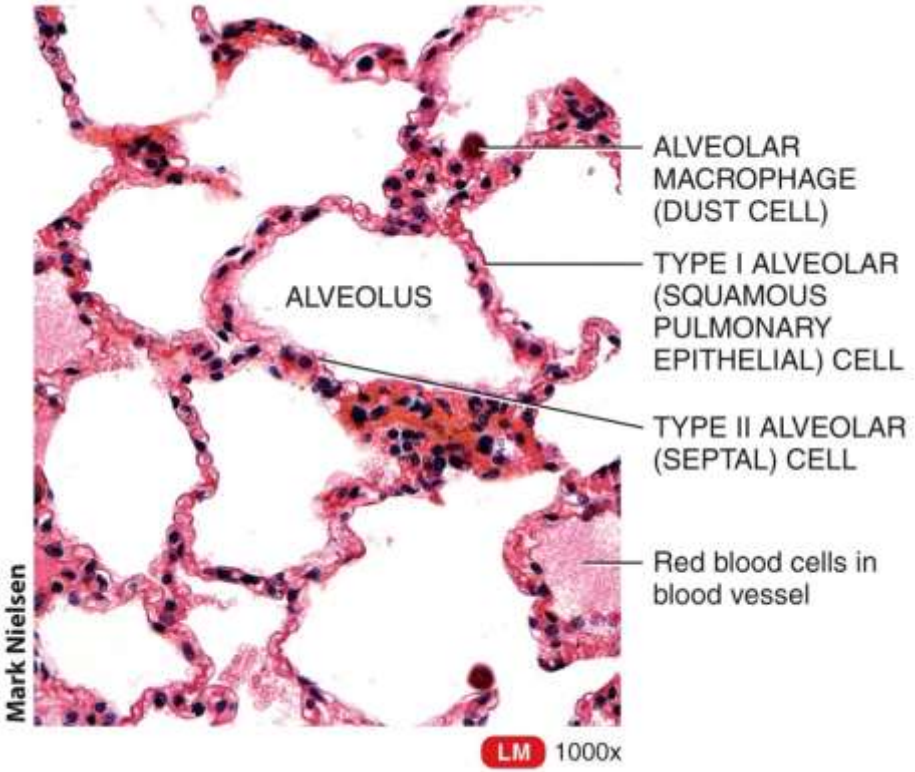
Microscopic Anatomy of Lungs



(b) Lung lobule



(c) Details of several alveoli

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Respiratory Tissues

Anatomy Overview:

- Respiratory Tissues

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Mechananics of Pulmonary Ventilation (Breathing)

- Respiration is the exchange of gases between the atmosphere, blood, and body cells, in 3 steps:
  - **Pulmonary ventilation:** is commonly referred to as breathing. It is the process of air flowing into the lungs during inspiration (inhalation) and out of the lungs during expiration (exhalation). Air flows because of pressure differences between the atmosphere and the gases inside the lungs
  - **External (pulmonary) respiration:** External respiration occurs in the lungs where oxygen diffuses into the blood and carbon dioxide diffuses into the alveolar air.
  - **Internal (tissue) respiration:** occurs in the metabolizing tissues, where oxygen diffuses out of the blood and carbon dioxide diffuses out of the cells

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Inhalation (Inspiration)

- Just before each inhalation, the air pressure inside the lungs is equal to the pressure of the atmosphere.
- For air to flow into the lungs, the pressure inside the alveoli must become lower than the atmospheric pressure.
- For inhalation to occur, the lungs must expand.
- The first step in expanding the alveoli of the lungs during normal quiet breathing involves contraction of the principal muscles of breathing.

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Exhalation (Expiration)

- Exhalation is also achieved by a pressure gradient, the gradient is however reversed.
- The pressure in the lungs is greater than the pressure of the atmosphere.
- Normal exhalation during quiet breathing depends on two factors:
  - The recoil of elastic fibers
  - The inward pull of surface tension
- Exhalation starts when the inspiratory muscles relax; the external intercostals relax; the ribs move inferiorly; the diaphragm relaxes.

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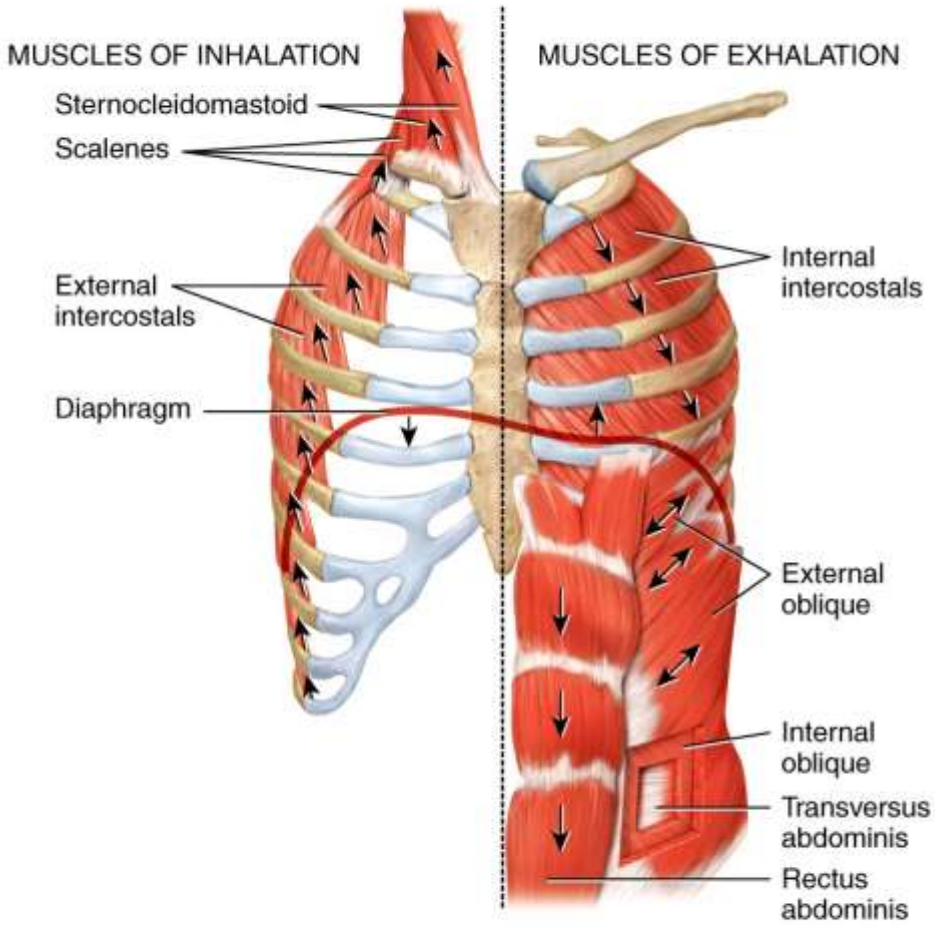
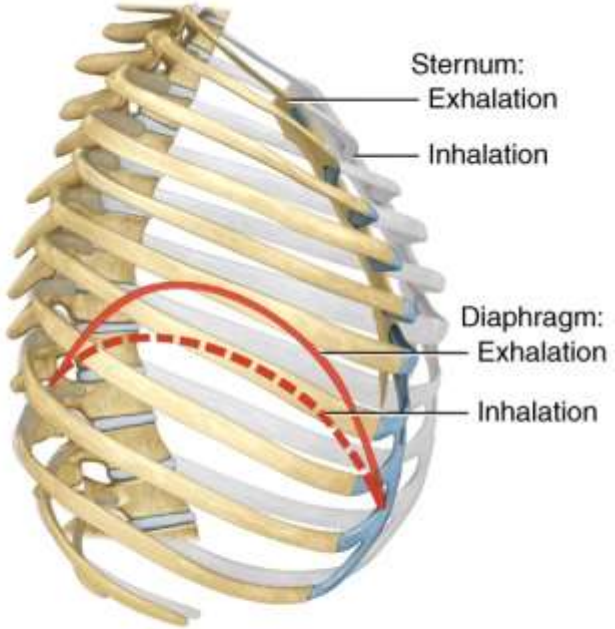
Muscles of Inhalation and Exhalation



(a) Muscles of inhalation (left); muscles of exhalation (right); arrows indicate the direction of muscle contraction



(b) Changes in size of thoracic cavity during inhalation and exhalation

(c) During inhalation, the lower ribs (7–10) move upward and outward like the handle on a bucket

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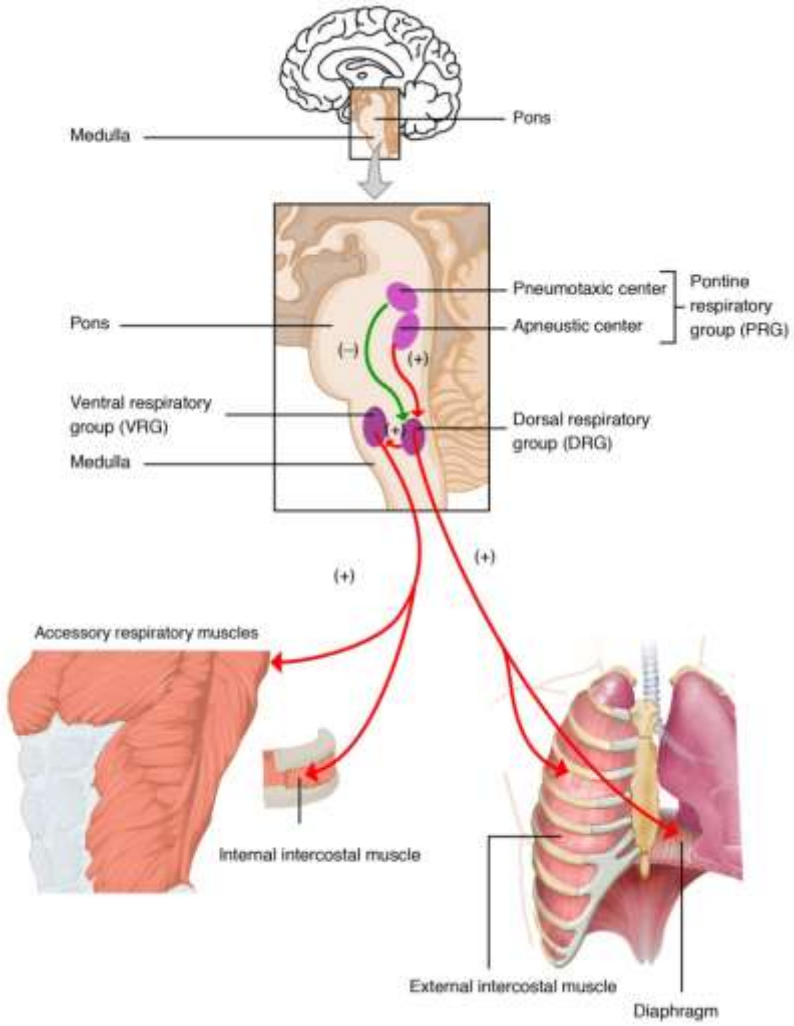
Respiratory Center

- Role of the respiratory center
- The area from which nerve impulses are sent to breathing muscles consists of clusters of neurons located bilaterally in the medulla oblongata and pons.
- The respiratory center is made up of three major respiratory groups of neurons, two in the medulla and one in the pons. In the medulla they are the dorsal respiratory group, and the ventral respiratory group
- The *medulla* which sends signals to the *muscles* involved in breathing, and the pons which controls the rate of breathing



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Medullary Respiratory Center

- The medullary respiratory center controls the basic rhythm of respiration; normal resting state is about 2 seconds of inhalation and 3 seconds of exhalation.
- During quiet normal breathing, neurons of the inspiratory area generate impulses that contract the diaphragm and intercostal muscles.
- The neurons of the expiratory area remain inactive during quiet breathing.

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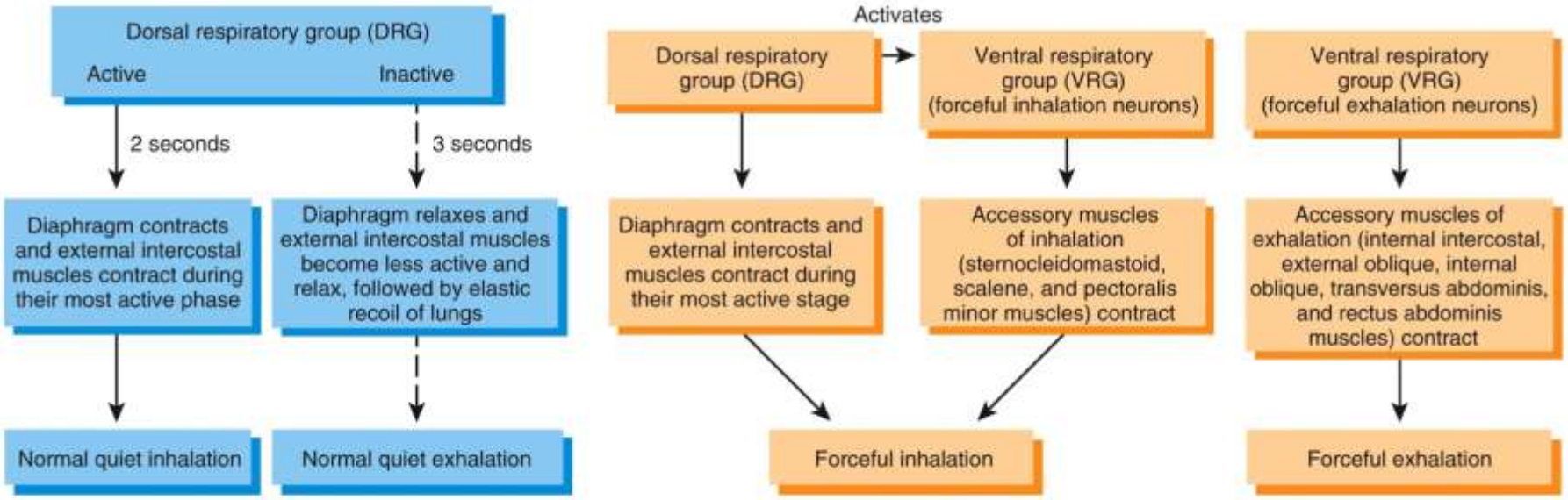
Medullary Respiratory Center



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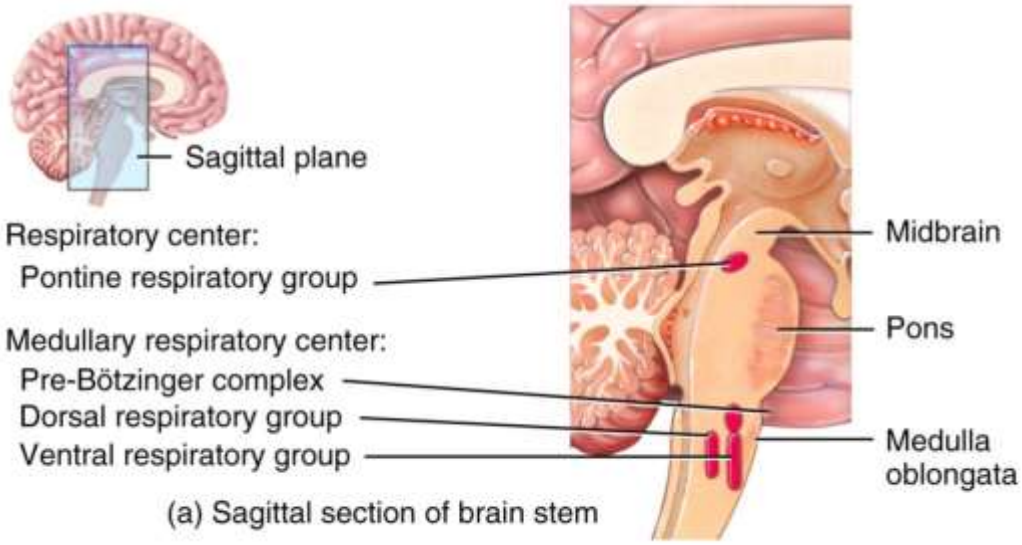
Pontine Respiratory Group

Formerly called the pneumotaxic area, the PRG in the upper pons transmits inhibitory impulses to the DRG in the medulla.

When the pontine group is more active, breathing rate is more rapid.



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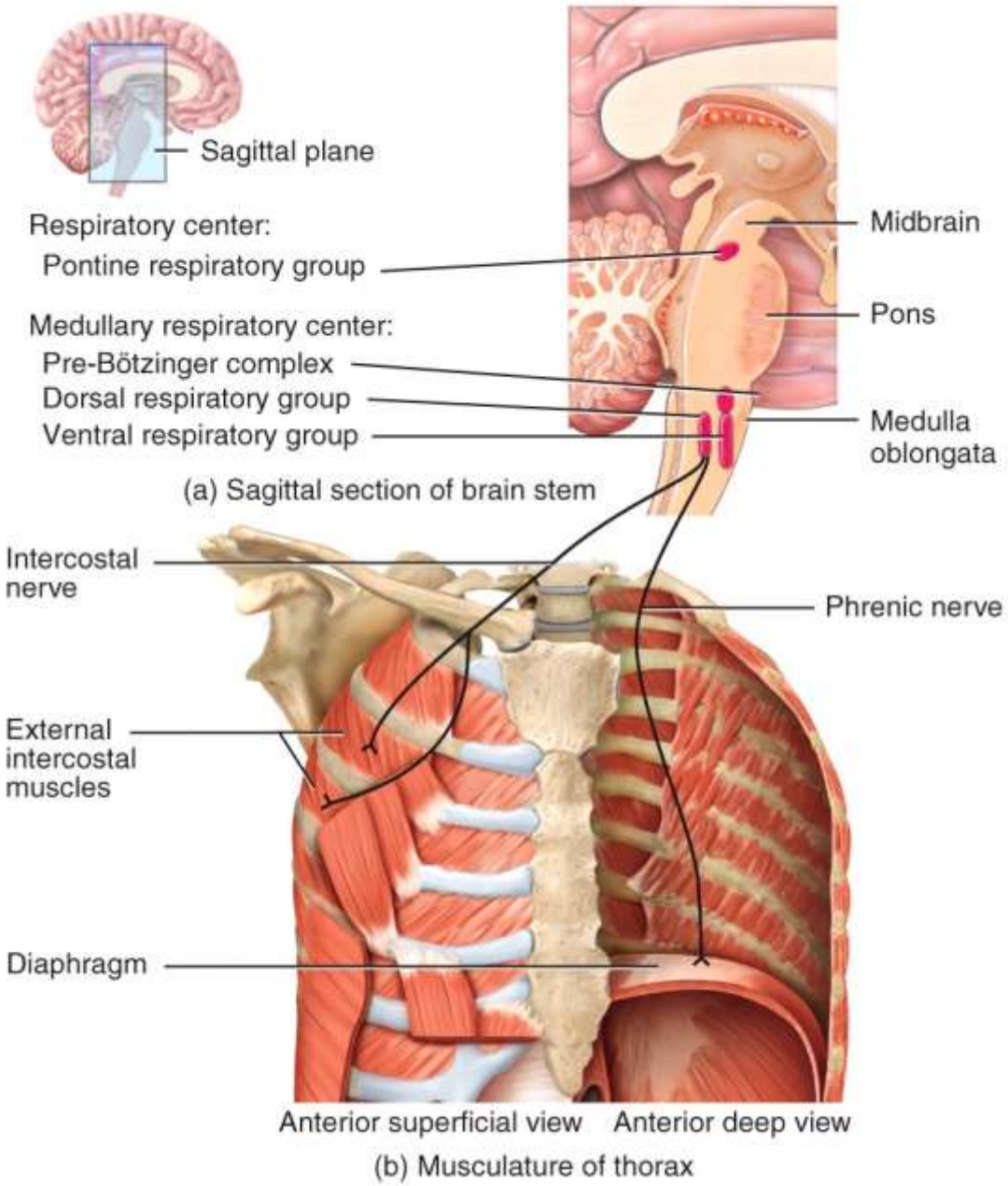
Pontine Respiratory Group



Cortical Influences on Breathing

- Because the cerebral cortex has connections with the respiratory center, we can voluntarily alter our pattern of breathing.
- Voluntary control enables us to prevent water or irritating gases from entering the lungs.
- Role of phrenic and intercostal nerves
- Nerve impulses from the hypothalamus and limbic system also stimulate the respiratory center, allowing emotional stimuli to alter respirations.

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Chemoreceptor Regulation of Breathing

- Chemoreceptors monitor levels of CO_2, H^+, and O_2 and provide input to the respiratory center.
- Central chemoreceptors are located in the medulla oblongata.
- Peripheral chemoreceptors are located in the aortic bodies and carotid bodies.
- The PNS is sensitive to changes in O_2, H^+, and CO_2 in the blood.
- Axons of sensory neurons from the aortic bodies are part of vagus (X) nerves, and those from the carotid bodies are part of the right and left glossopharyngeal (IX) nerves and vagus (X) nerves.

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Control of Respiration

Anatomy Overview:

- Structures that Control Respiration

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