13

The Respiratory System

Organs of the Respiratory System

1. Nose
2. Pharynx
3. Larynx
4. Trachea
5. Bronchi
6. Lungs — alveoli

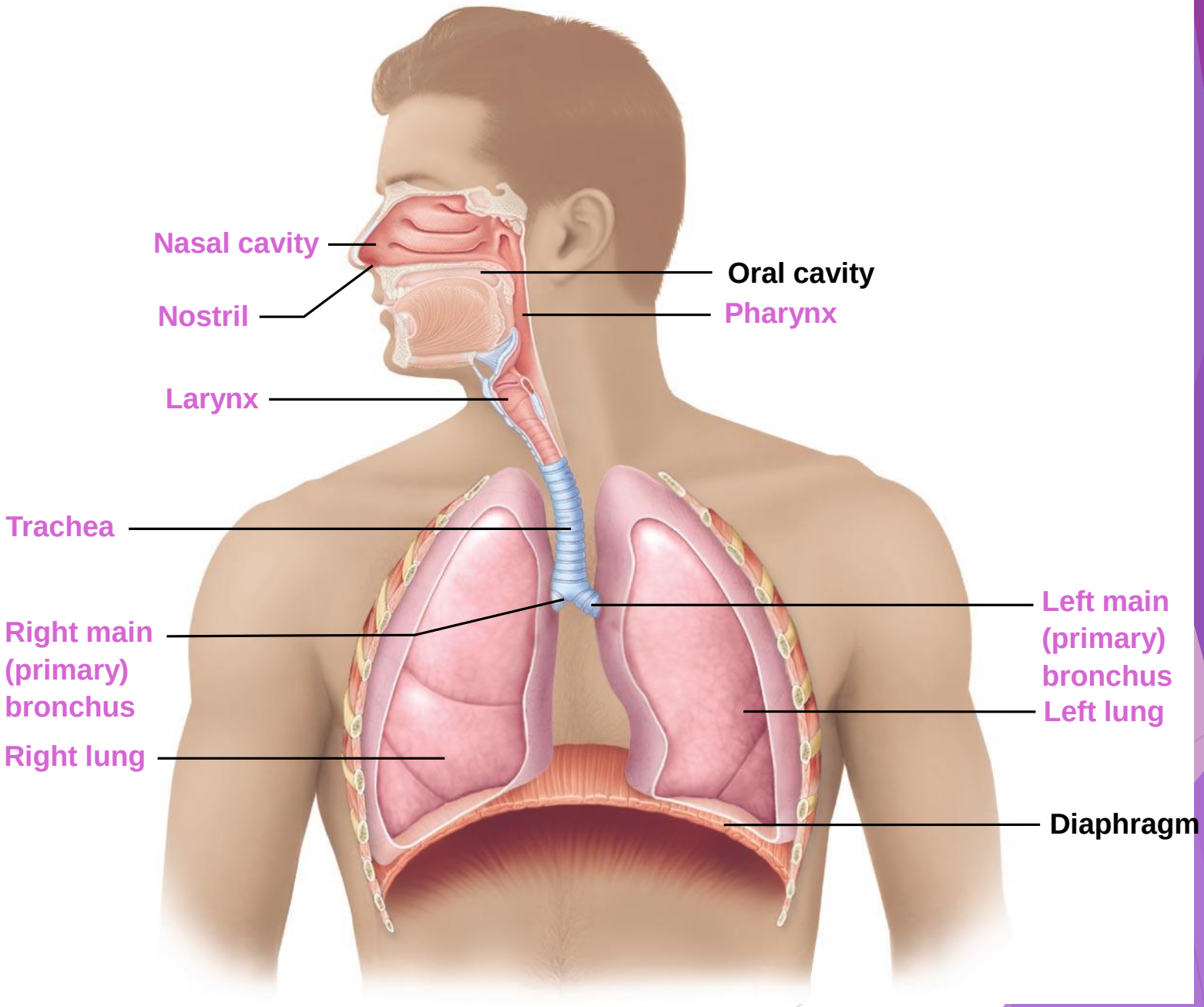

Nasal cavity
Nostril
Oral cavity
Pharynx
Larynx
Trachea
Right main (primary) bronchus
Right lung
Left main (primary) bronchus
Left lung
Diaphragm

Figure 13.1

General Introduction

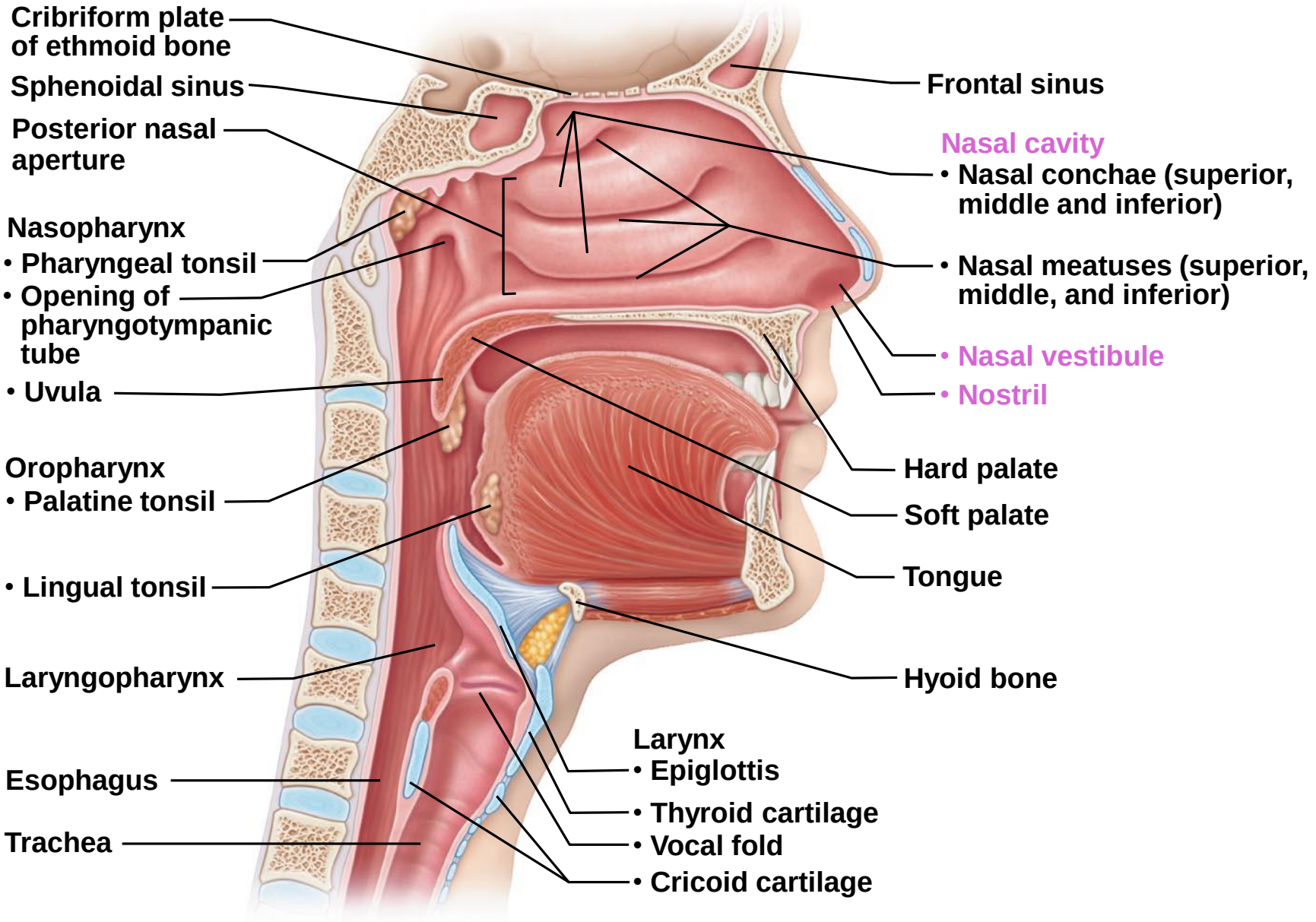
- https://www.youtube.com/watch?v=NRT1hOqniZ0
- https://www.youtube.com/watch?v=o2OcGgJbiUk
- Refer to PAL 3.0 cadaver; anatomical and histological sites located in study area of Chapter 13.

Functions of the Respiratory System

- Gas exchanges between the blood and external environment
  - Occurs in the alveoli of the lungs
- Passageways to the lungs **purify**, **humidify**, and **warm** the incoming air

1. The Nose

- Only externally visible part of the respiratory system
- Air enters the nose through the external nostrils (**nares**)
- Interior of the nose consists of a nasal cavity divided by a **nasal septum**



(b) Detailed anatomy of the upper respiratory tract

Figure 13.2b

Anatomy of the Nasal Cavity

- **Olfactory receptors** are located in the mucosa on the superior surface

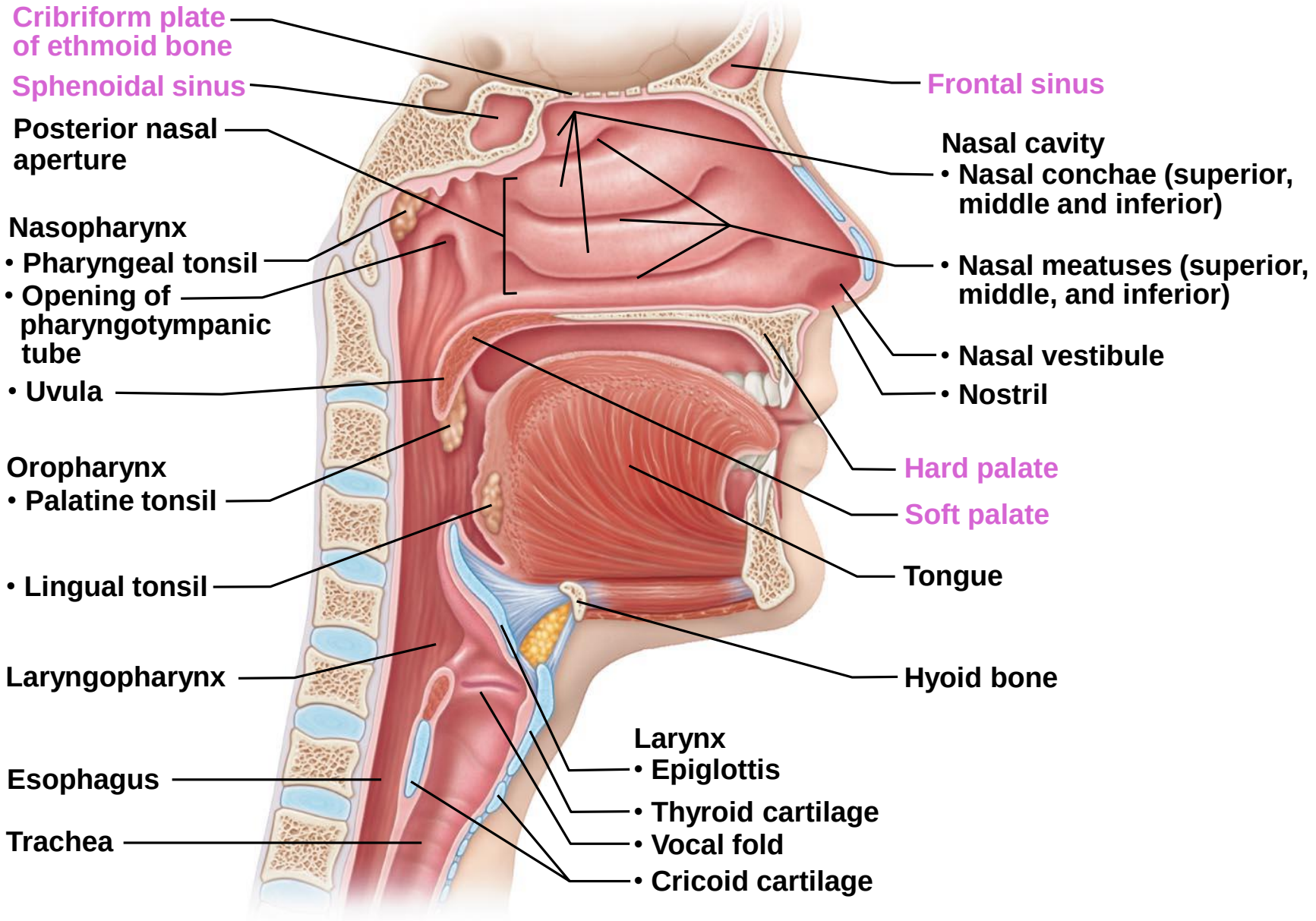
- The rest of the cavity is lined with respiratory mucosa that
  - **Moisten** air
  - **Trap incoming foreign particles**

Anatomy of the Nasal Cavity

- Lateral walls have projections called conchae
  - **Increase surface area**
  - **Increase air turbulence** within the nasal cavity
- The nasal cavity is separated from the oral cavity by the palate
  - Anterior hard palate (bone)
  - Posterior soft palate (muscle)

Paranasal Sinuses

- Cavities within bones surrounding the nasal cavity are called **sinuses**
- Sinuses are located in the following bones
  - **Frontal** bone
  - **Sphenoid** bone
  - **Ethmoid** bone
  - **Maxillary** bone



(b) Detailed anatomy of the upper respiratory tract

Figure 13.2b

Paranasal Sinuses

- Function of the sinuses
  - **Lighten** the skull
  - Act as resonance chambers for **speech**
  - Produce **mucus** that drains into the nasal cavity

2. Pharynx (Throat)

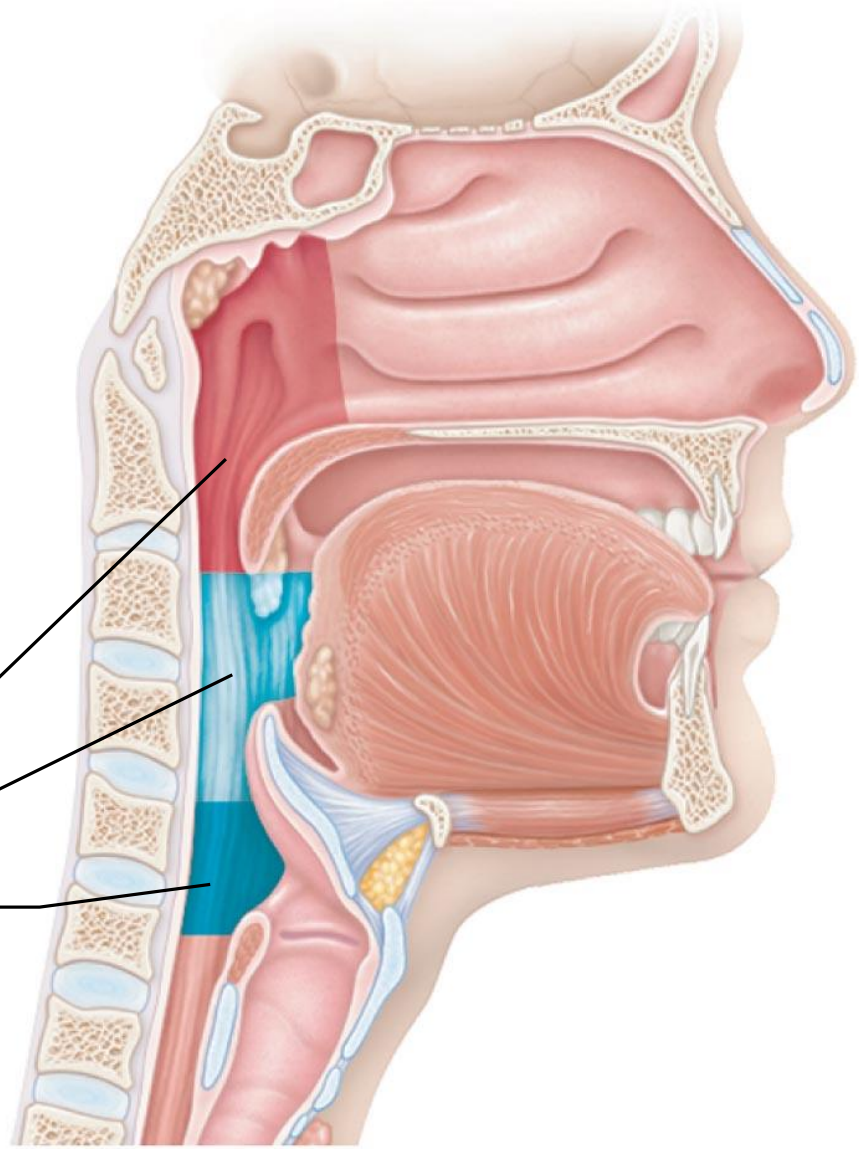
- Muscular passage from nasal cavity to larynx

- Three regions of the pharynx
  - **Nasopharynx** — superior region behind nasal cavity
  - **Oropharynx** — middle region behind mouth
  - **Laryngopharynx** — inferior region attached to larynx

- The oropharynx and laryngopharynx are common passageways for air and food

Pharynx

- Nasopharynx
- Oropharynx
- Laryngopharynx



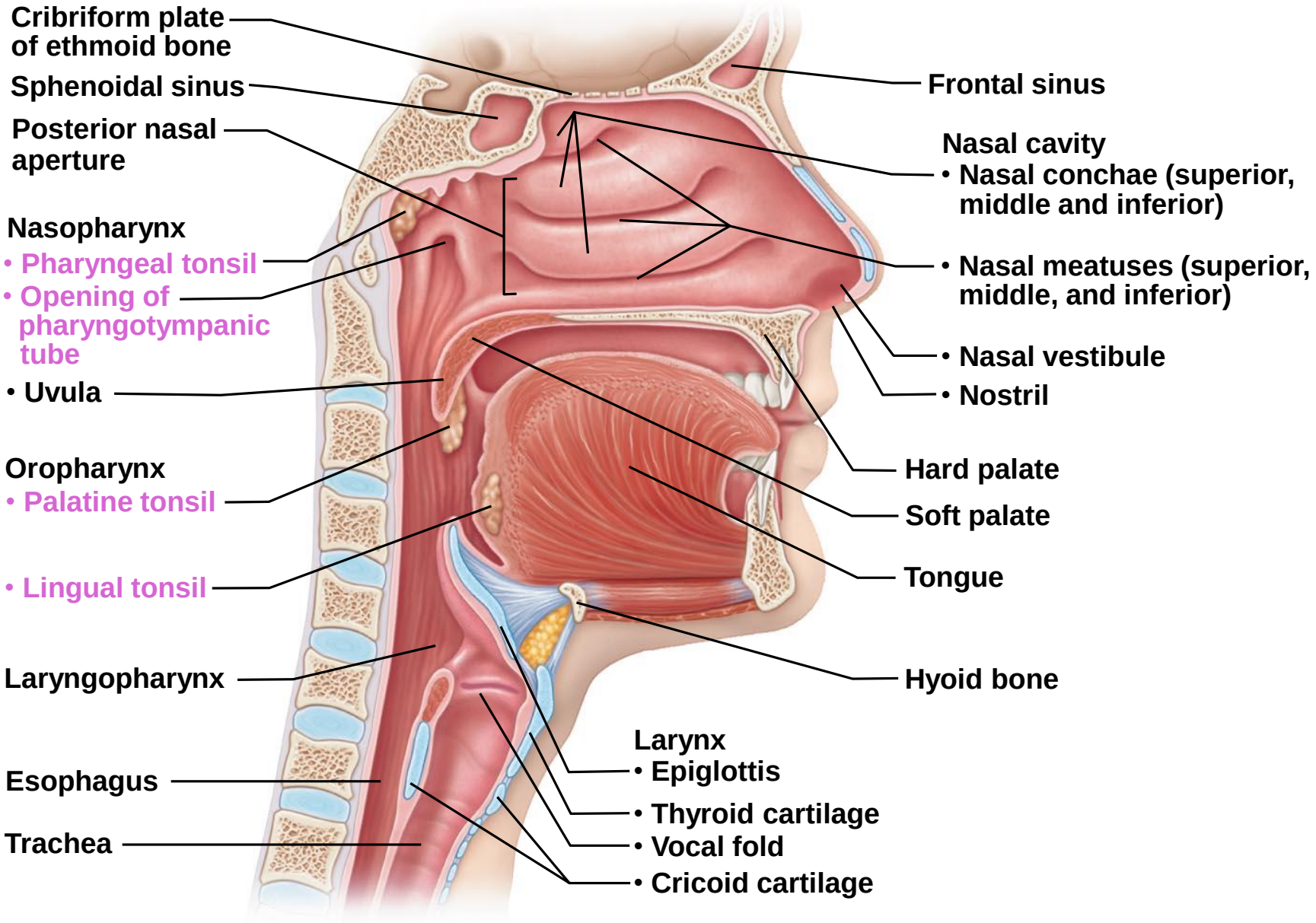
(a) Regions of the pharynx

Figure 13.2a

Structures of the Pharynx

- **Pharyngotympanic tubes** open into the nasopharynx

- Tonsils of the pharynx
  - **Pharyngeal** tonsil (adenoid) is located in the nasopharynx
  - **Palatine** tonsils are located in the oropharynx
  - **Lingual** tonsils are found at the base of the tongue



(b) Detailed anatomy of the upper respiratory tract

Figure 13.2b

3. Larynx (Voice Box)

- **Routes air** and food into proper channels
- Plays a role in **speech**
- Made of eight rigid hyaline cartilages and a spoon-shaped flap of elastic cartilage (**epiglottis**)

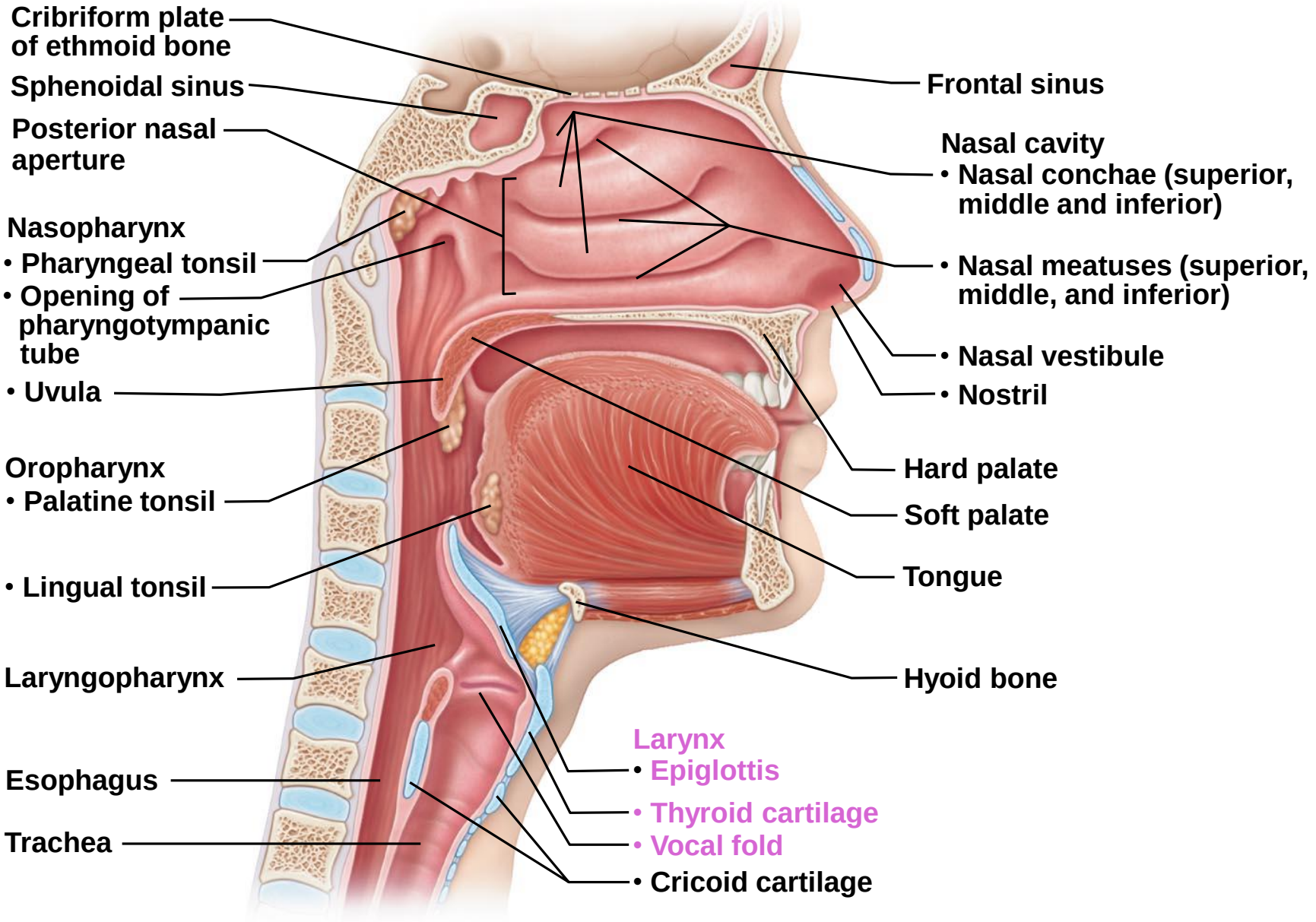
Structures of the Larynx

- **Thyroid** cartilage
  - Largest of the hyaline cartilages
  - Protrudes anteriorly (Adam's apple)

- **Epiglottis**
  - **Protects** the superior opening of the larynx
  - **Routes food** to the esophagus and **air** toward the trachea
  - When swallowing, the epiglottis rises and **forms a lid** over the opening of the larynx

Structures of the Larynx

- **Vocal folds** (true vocal cords)
  - Vibrate with expelled air to create sound (**speech**)
- **Glottis** — **opening** between vocal cords



(b) Detailed anatomy of the upper respiratory tract

Figure 13.2b

4. Trachea (Windpipe)

- Four-inch-long tube that connects larynx with bronchi
- Walls are reinforced with C-shaped hyaline cartilage
- Lined with ciliated mucosa
  - Beat continuously in the opposite direction of incoming air
  - **Expel mucus** loaded with dust and other debris away from lungs

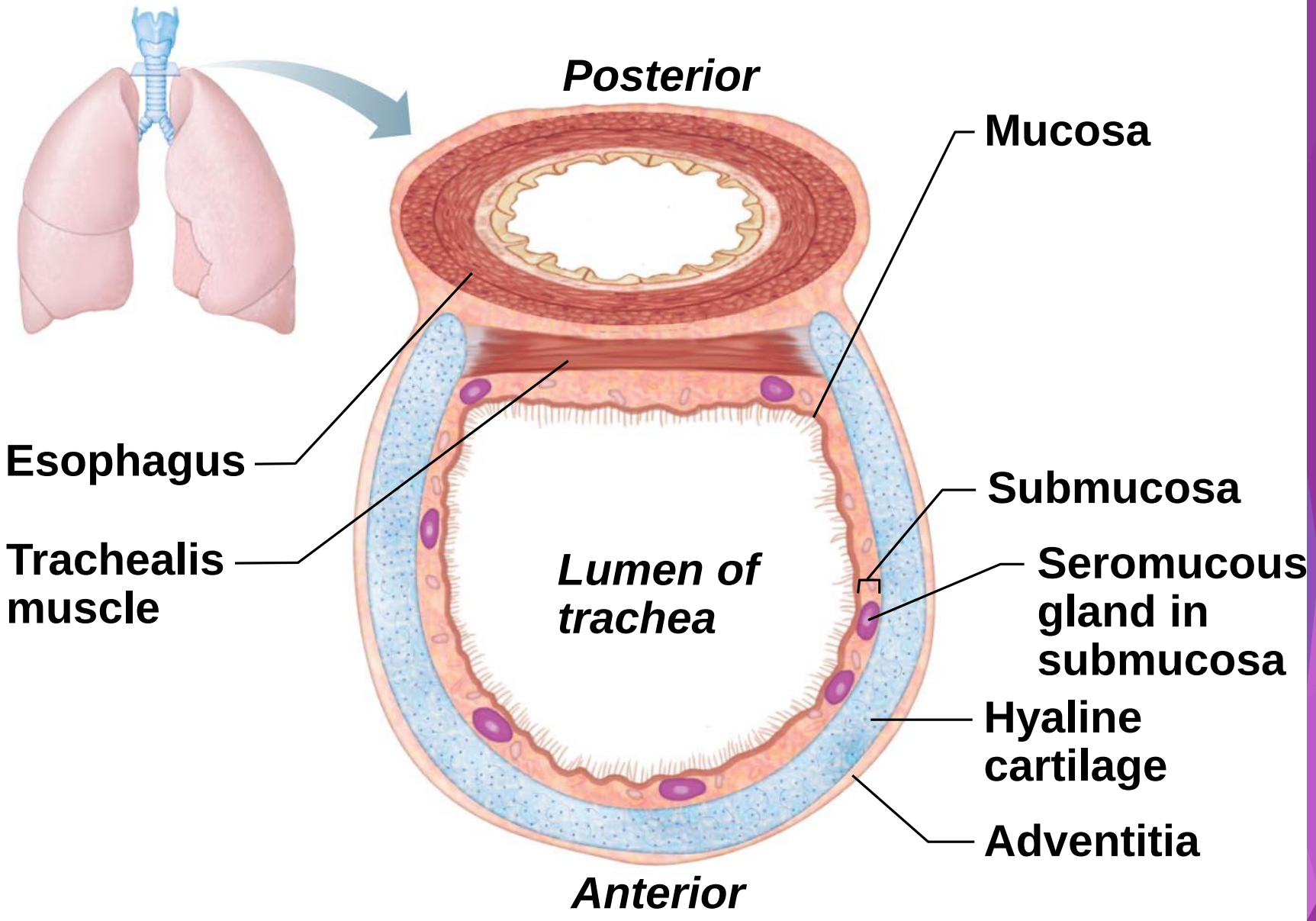
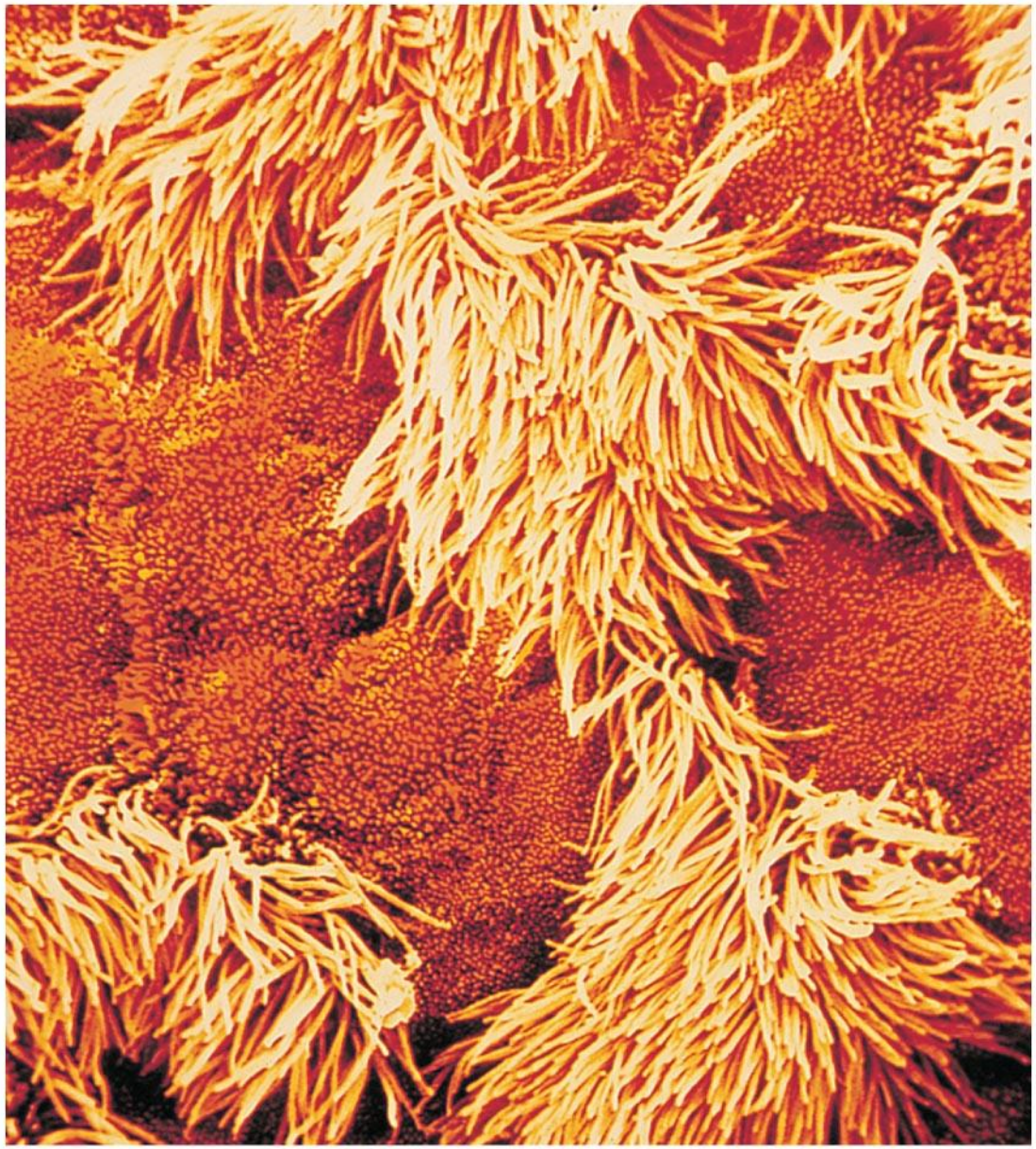

Posterior
Mucosa
Esophagus
Submucosa
Trachealis muscle
Lumen of trachea
Seromucous gland in submucosa
Hyaline cartilage
Adventitia
Anterior

Figure 13.3a

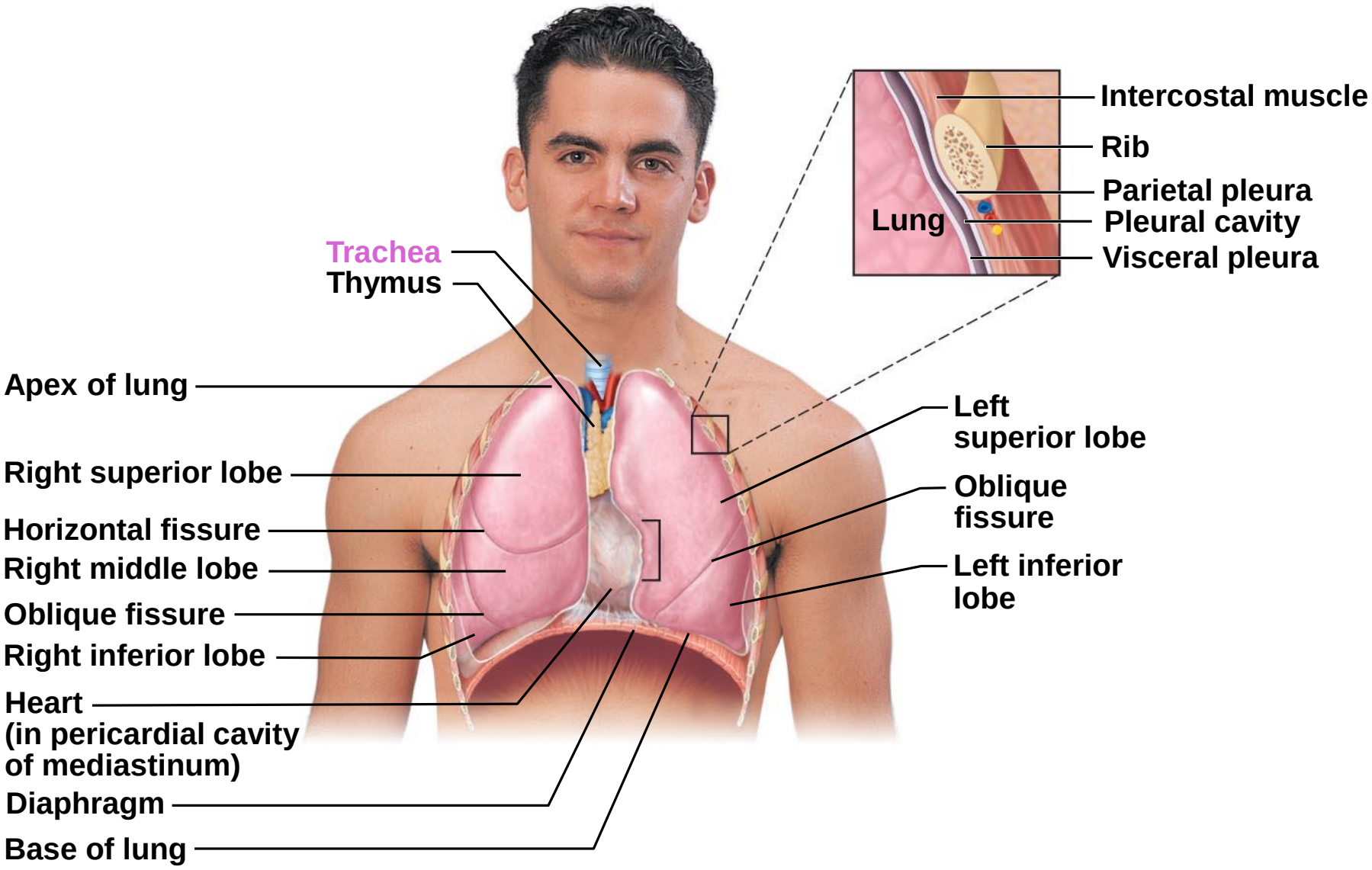


(b)

Figure 13.3b

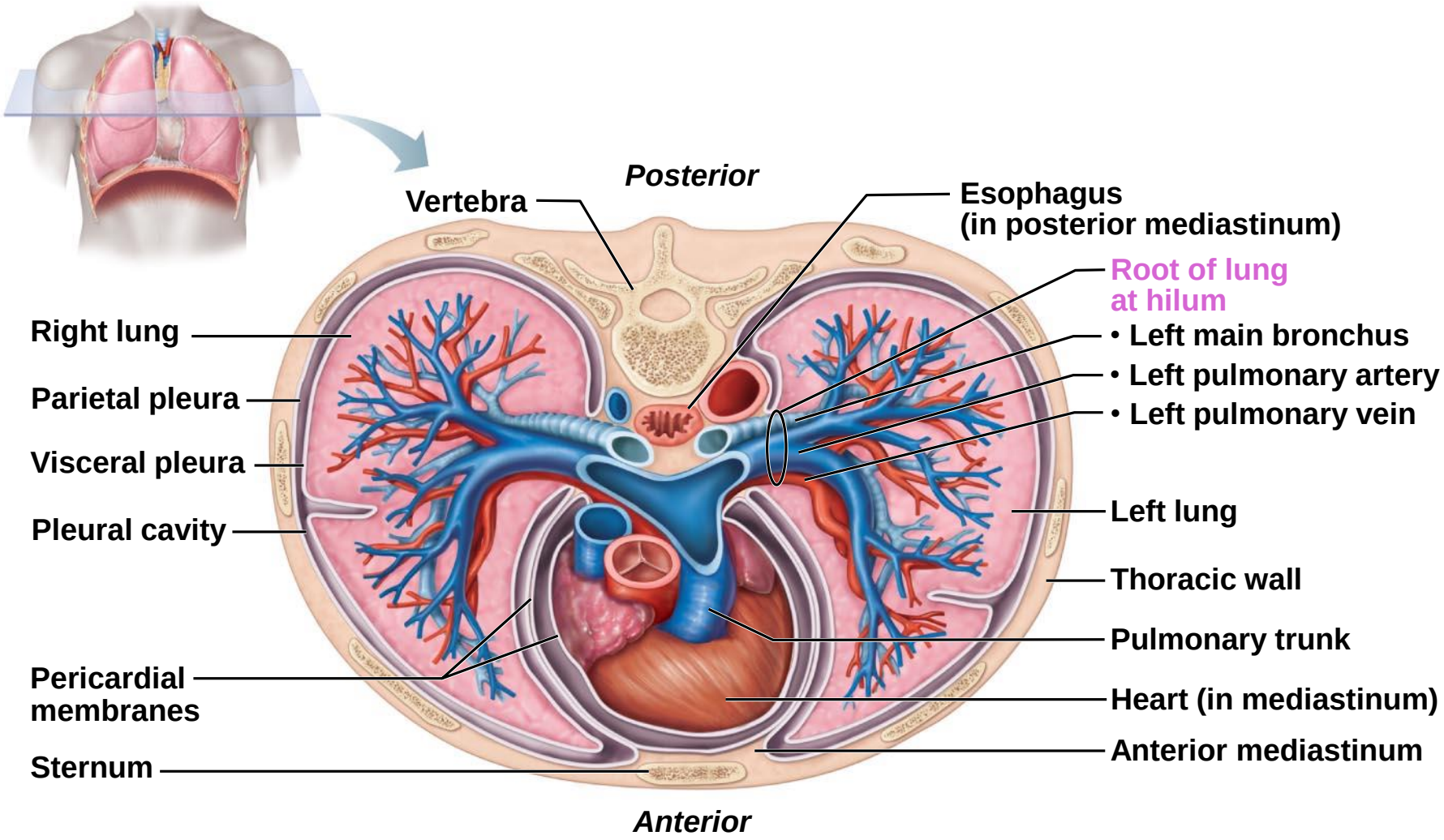
5. Main (Primary) Bronchi

- Formed by division of the trachea
- Enters the lung at the **hilum** (medial depression)
- Right bronchus is wider, shorter, and straighter than left
- Bronchi subdivide into smaller and smaller branches



(a) Anterior view. The lungs flank mediastinal structures laterally.

Figure 13.4a



(b) Transverse section through the thorax, viewed from above. Lungs, pleural membranes, and major organs in the mediastinum are shown.

Figure 13.4b

6. Lungs

- Occupy most of the thoracic cavity
  - Heart occupies central portion called **mediastinum**
- Apex is near the clavicle (superior portion)
- Base rests on the diaphragm (inferior portion)
- Each lung is divided into lobes by fissures
  - Left lung — two lobes
  - Right lung — three lobes
  - [Why?]

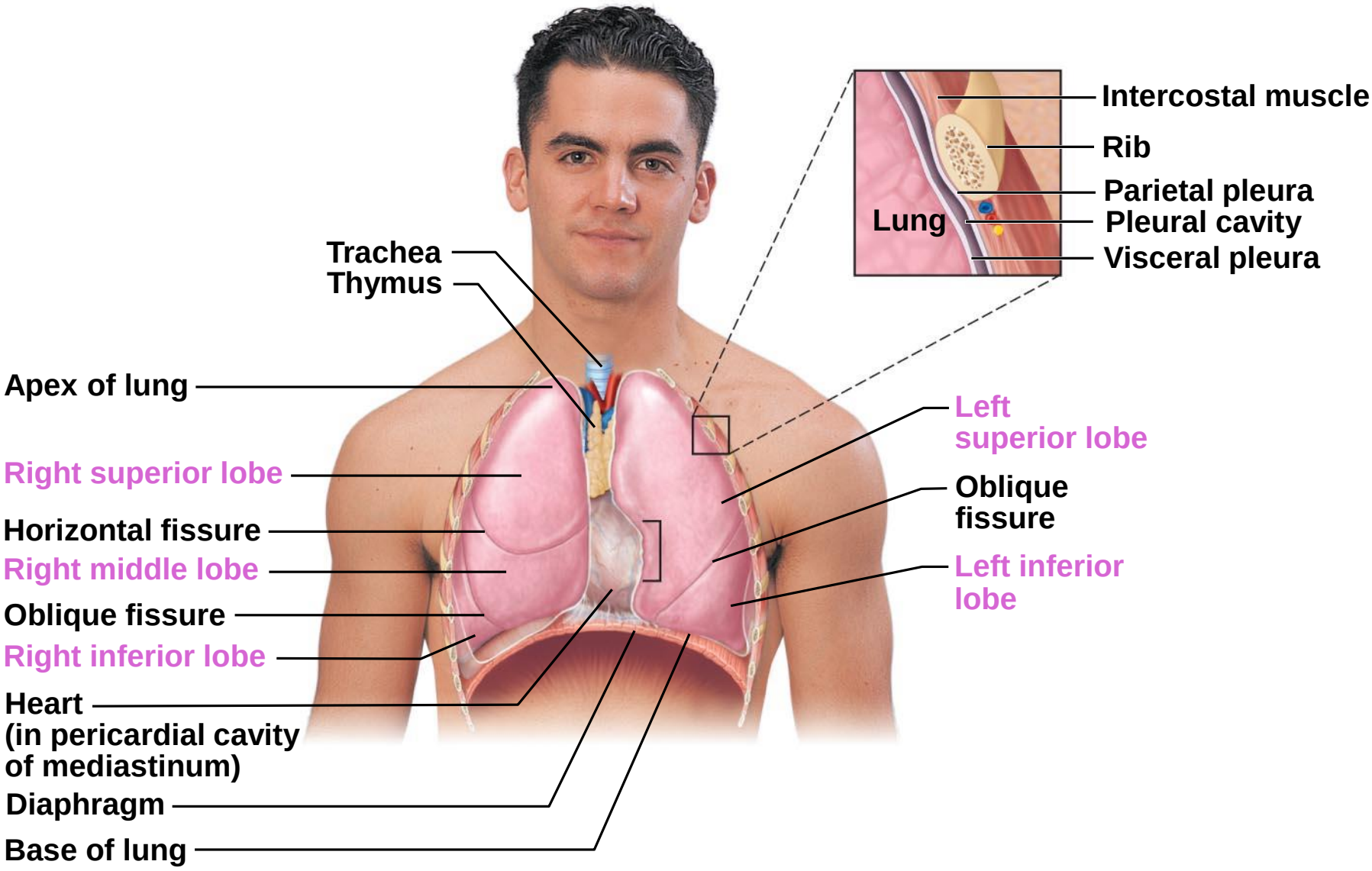


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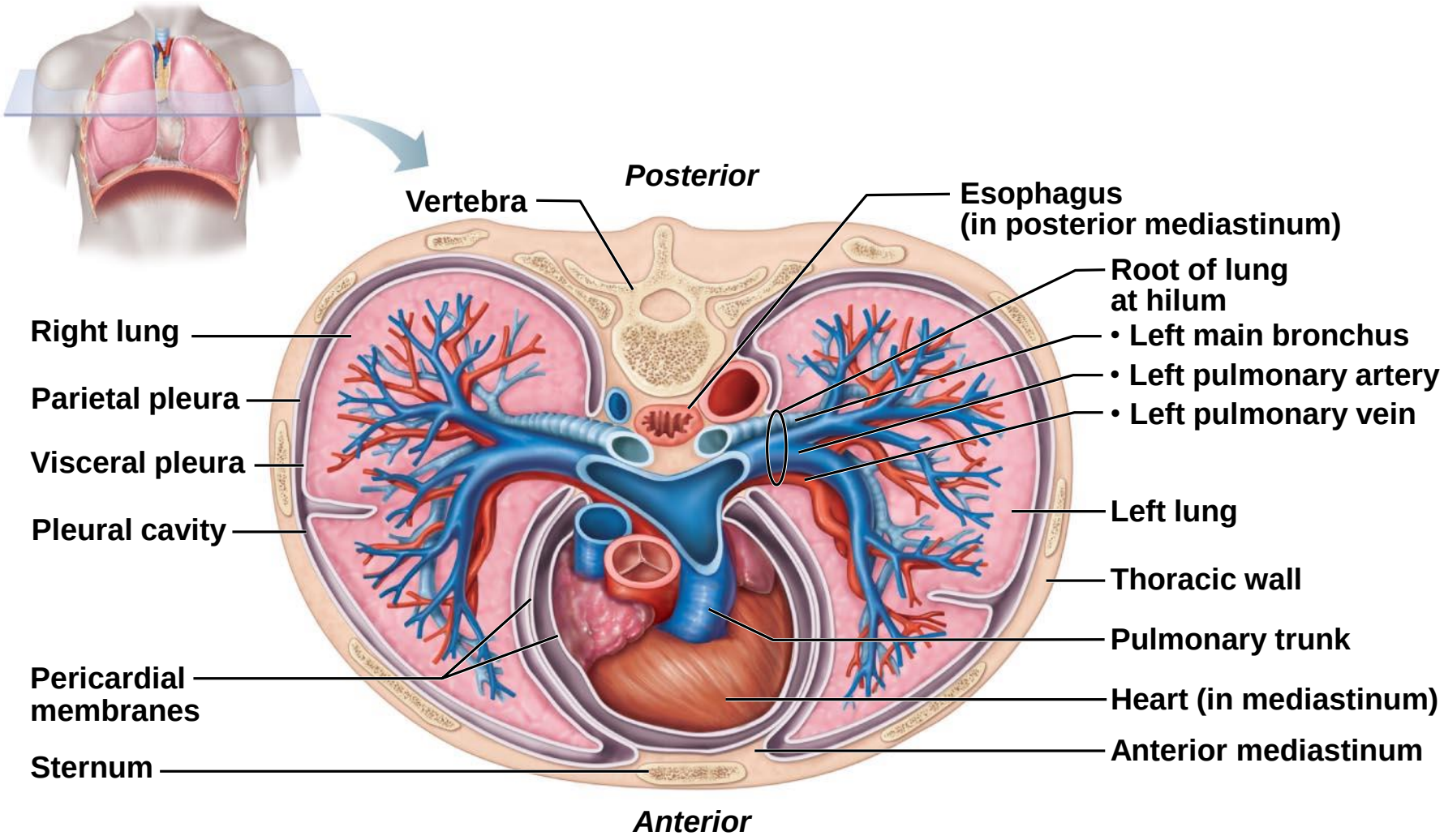
Figure 13.4a



(b) Transverse section through the thorax, viewed from above. Lungs, pleural membranes, and major organs in the mediastinum are shown.

Figure 13.4b

Coverings of the Lungs

- **Serosa** covers the outer surface of the lungs
  - **Pulmonary (visceral) pleura** covers the lung surface
  - **Parietal pleura** lines the walls of the thoracic cavity
- Pleural fluid fills the area between layers of pleura to allow **gliding**
- These two pleural layers resist being pulled apart

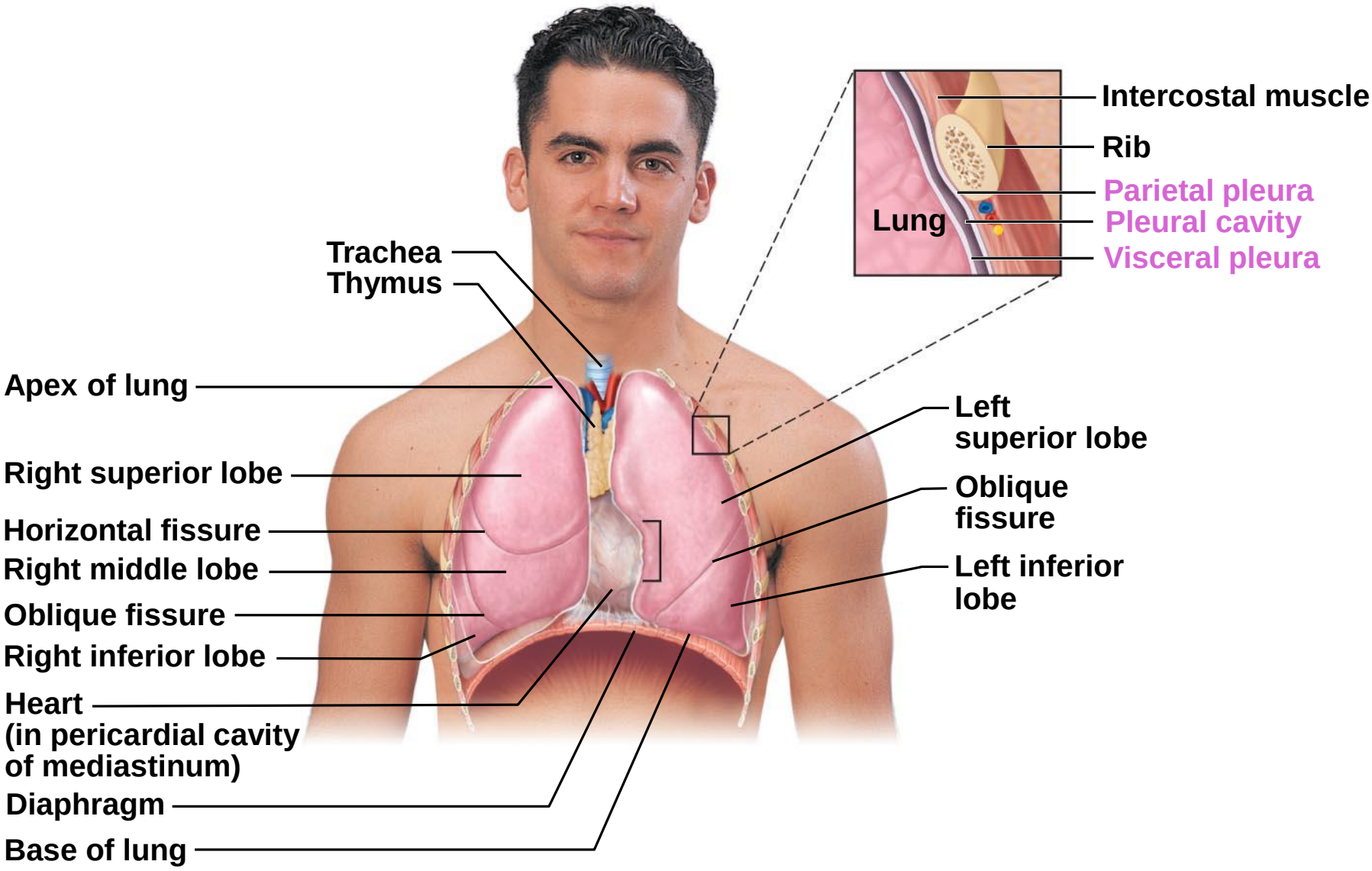


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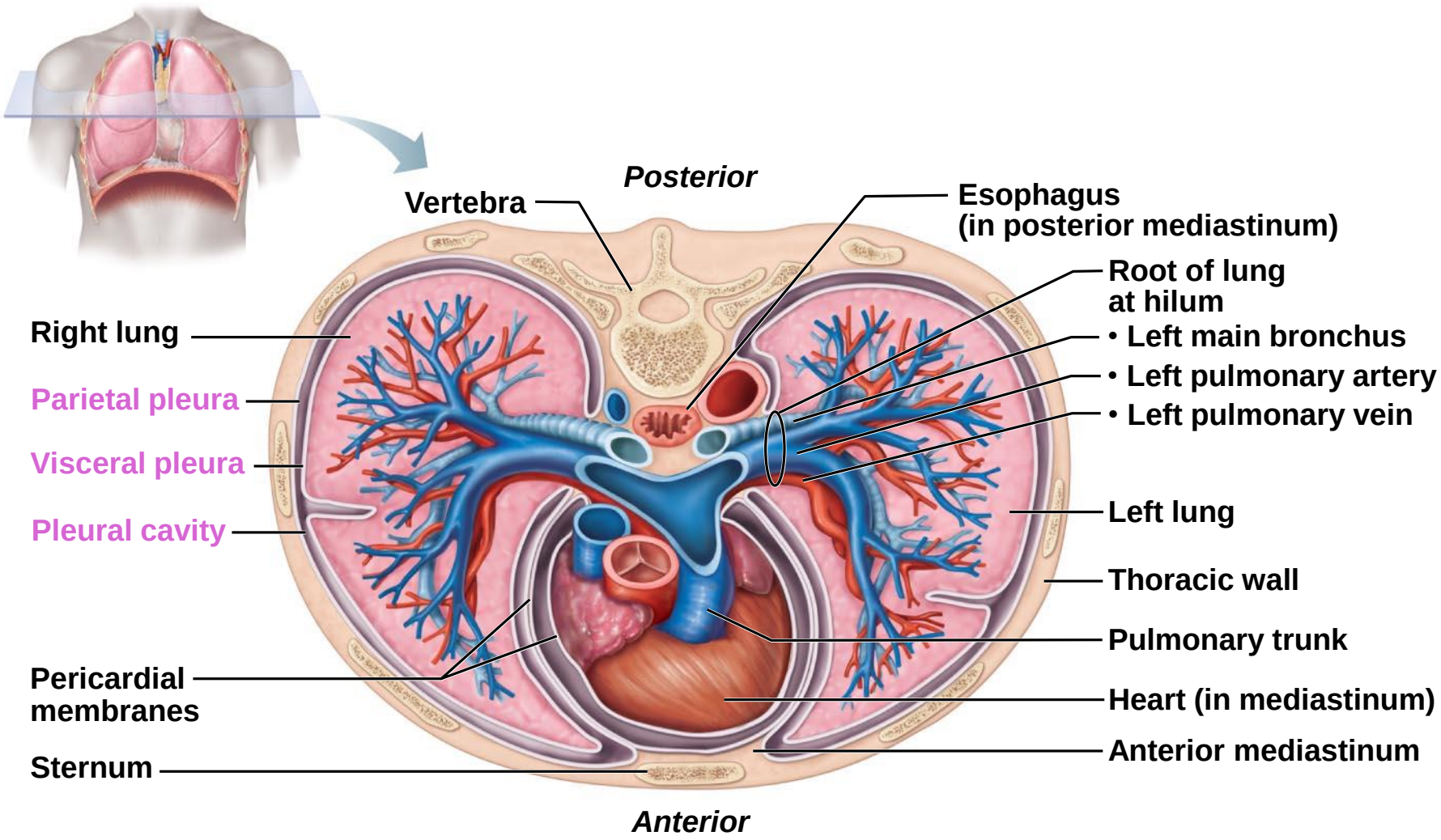
Figure 13.4a

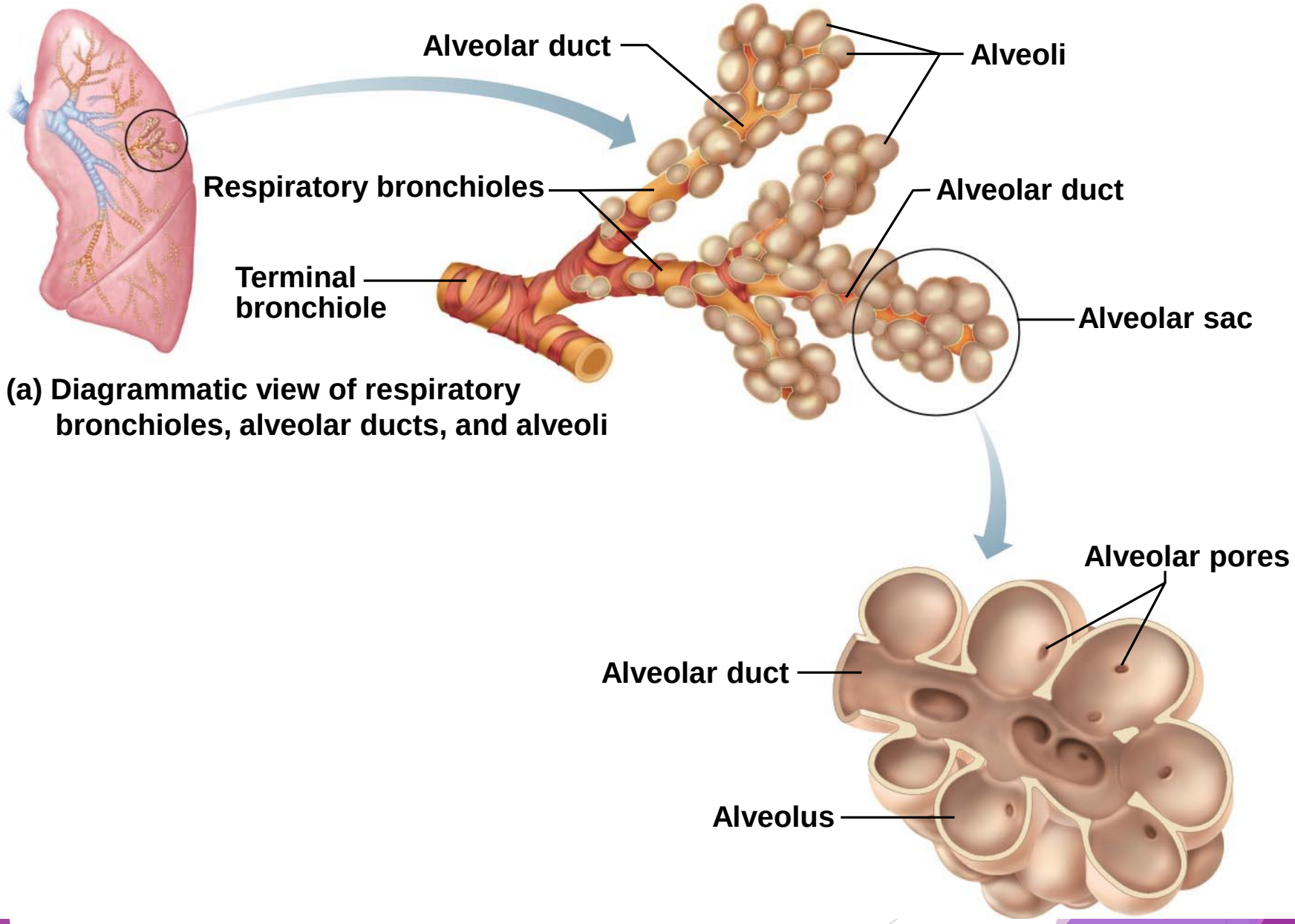


(b) Transverse section through the thorax, viewed from above. Lungs, pleural membranes, and major organs in the mediastinum are shown.

Figure 13.4b

Bronchial (Respiratory) Tree Divisions

- All but the smallest of these passageways have reinforcing cartilage in their walls
- (in order of air entering body)
  - Primary bronchi
  - Secondary bronchi
  - Tertiary bronchi
  - Bronchioles
  - Terminal bronchioles

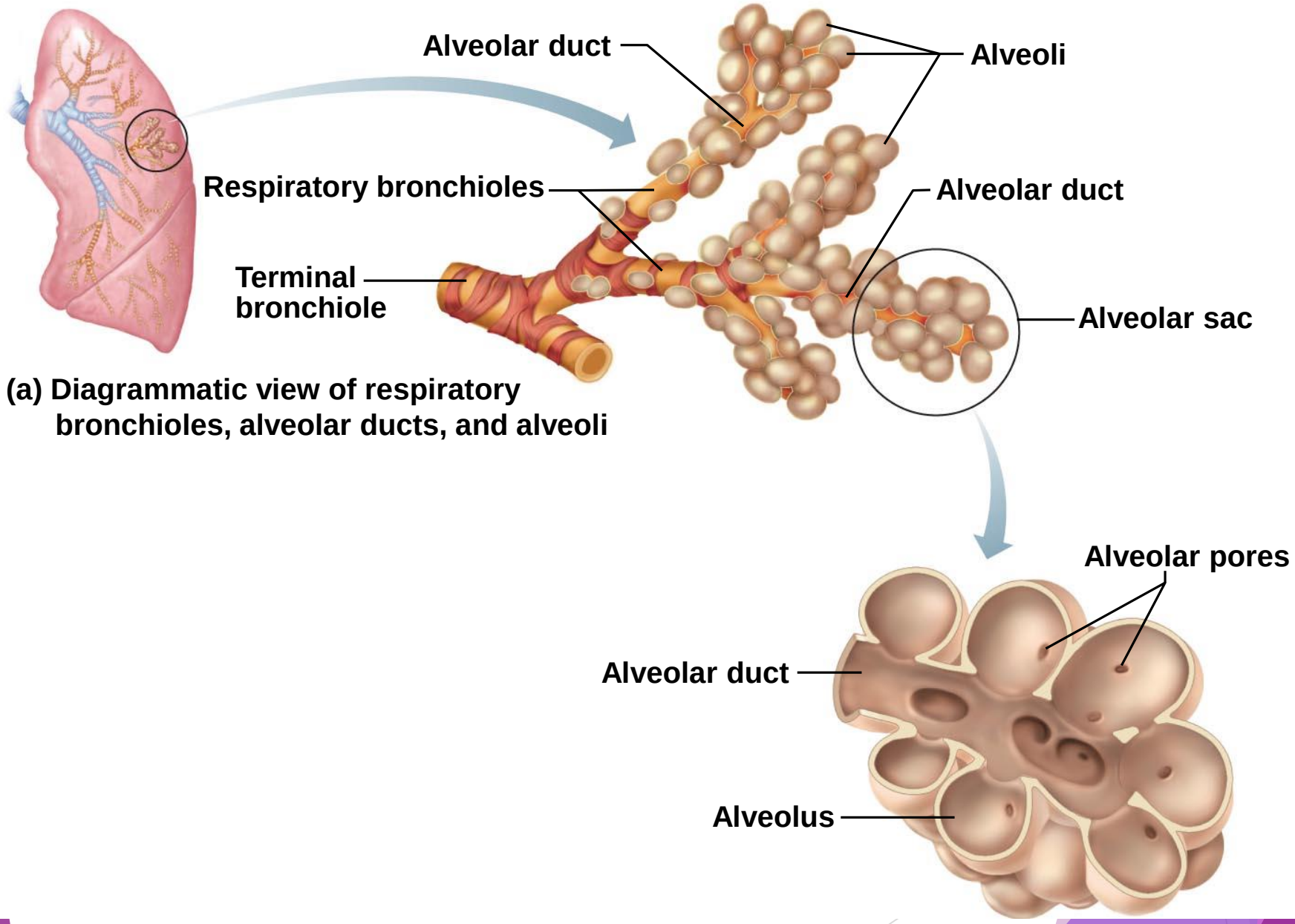


(a) Diagrammatic view of respiratory bronchioles, alveolar ducts, and alveoli

Figure 13.5a

Respiratory Zone

- Structures
  - Respiratory bronchioles
  - Alveolar ducts
  - Alveolar sacs
  - Alveoli (air sacs)
- Site of gas exchange = alveoli only



(a) Diagrammatic view of respiratory bronchioles, alveolar ducts, and alveoli

Figure 13.5a

(b) Scanning electron micrograph (SEM) of human lung tissue, showing the final divisions of the respiratory tree (225×)

Figure 13.5b

Workbook Page 256 #2

Workbook Page 258 #5

Respiratory Membrane (Air-Blood Barrier)

- Thin squamous epithelial layer lines alveolar walls
- Alveolar pores connect neighboring air sacs
- Pulmonary capillaries cover external surfaces of alveoli
- On one side of the membrane is air and on the other side is blood flowing past

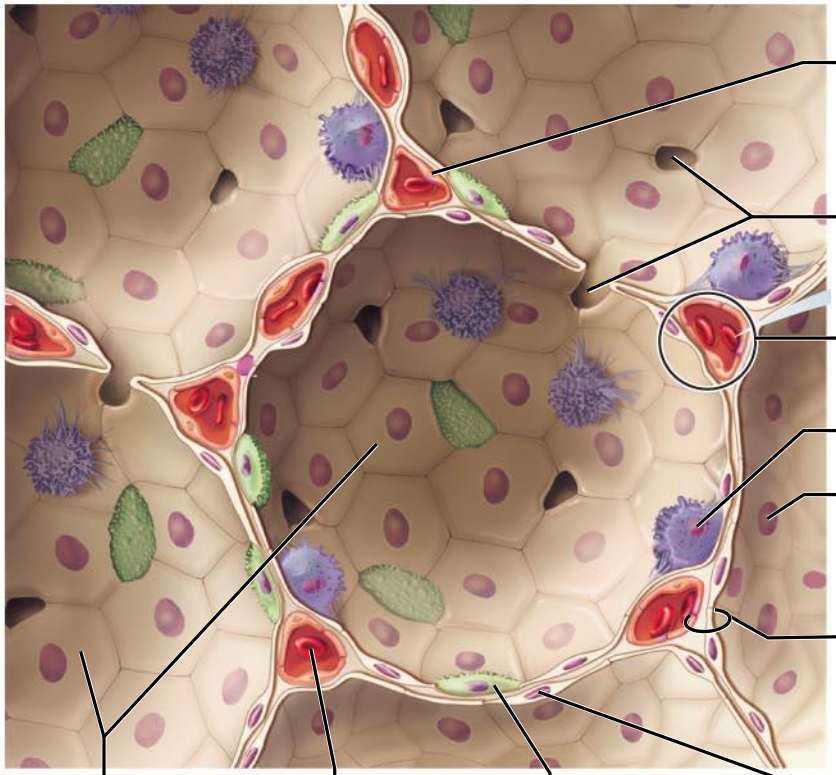


Figure 13.6 (1 of 2)

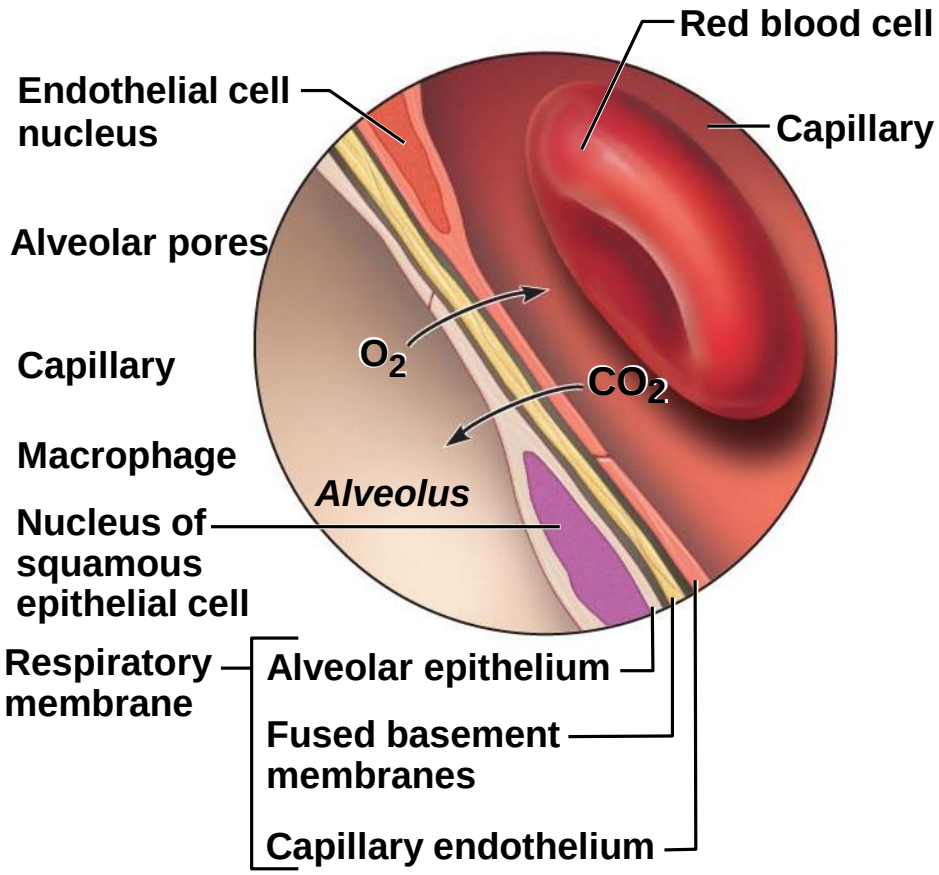


Figure 13.6 (2 of 2)

Gas Exchange

- Gas crosses the respiratory membrane by diffusion
  - Oxygen enters the blood
  - Carbon dioxide enters the alveoli
- Alveolar macrophages ("**dust cells**") add protection by picking up bacteria, carbon particles, and other debris
- **Surfactants** (a lipid molecule) coat gas-exposed alveolar surfaces

Four Events of Respiration

- (a) **Pulmonary ventilation** — moving air in and out of the lungs (commonly called *breathing*)
- (b) **External respiration** — gas exchange between pulmonary blood and alveoli
  - Oxygen is loaded into the blood
  - Carbon dioxide is unloaded from the blood

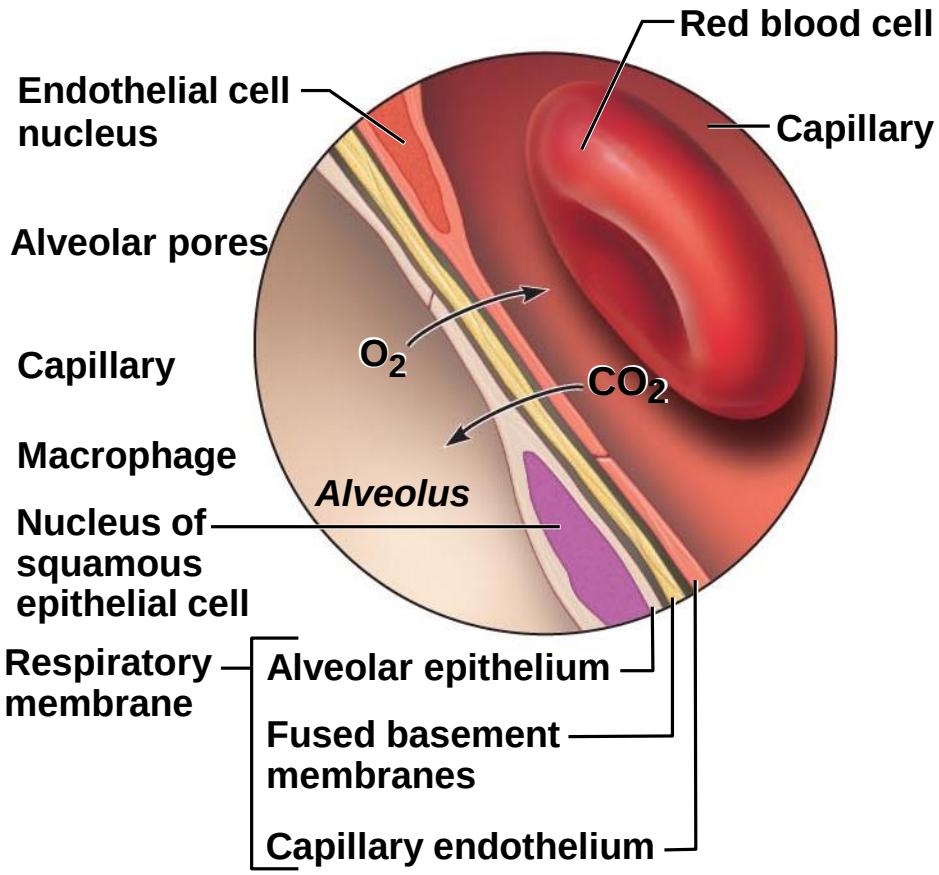


Figure 13.6 (2 of 2)

Four Events of Respiration

- (c) **Respiratory gas transport** — transport of oxygen and carbon dioxide via the bloodstream

- (d) **Internal respiration** — gas exchange between blood and tissue cells in systemic capillaries

Respiration & Gas Exchange

- https://www.youtube.com/watch?v=GjfD55C9v38

- https://www.youtube.com/watch?v=qDrV33rZlyA

(a) Mechanics of Breathing (Pulmonary Ventilation)

- Completely mechanical process that depends on volume changes in the thoracic cavity

- Volume changes lead to pressure changes, which lead to the flow of gases to equalize pressure

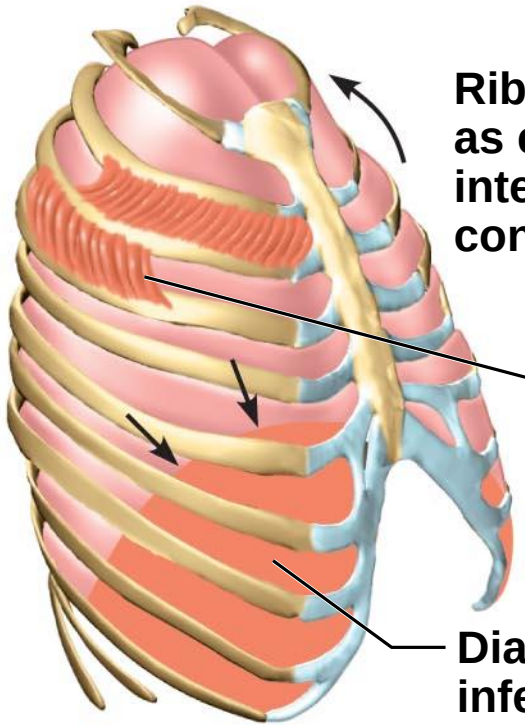
Mechanics of Breathing (Pulmonary Ventilation)

- Two phases
  - **Inspiration** = inhalation
    - Flow of air into lungs
  - **Expiration** = exhalation
    - Air leaving lungs

Inspiration

- Diaphragm and external intercostal muscles contract
- The size of the thoracic cavity increases
- External air is pulled into the lungs due to
  - Increase in intrapulmonary volume
  - Decrease in gas pressure

Changes in anterior-posterior and superior-inferior dimensions



Ribs elevated as external intercostals contract

External intercostal muscles

Diaphragm moves inferiorly during contraction

(a) Inspiration: Air (gases) flows into the lungs

Changes in lateral dimensions

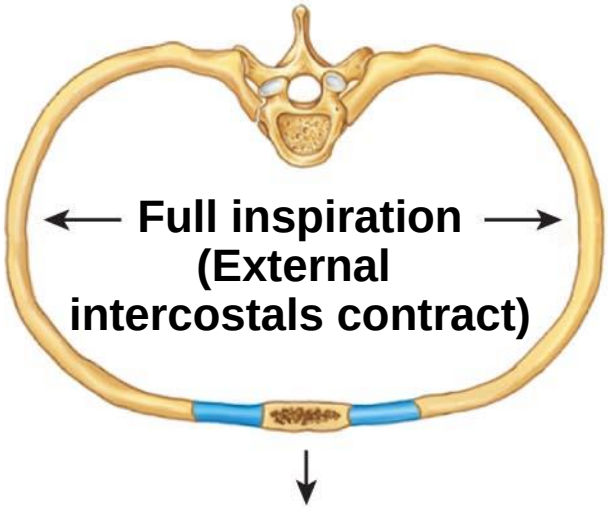


Figure 13.7a

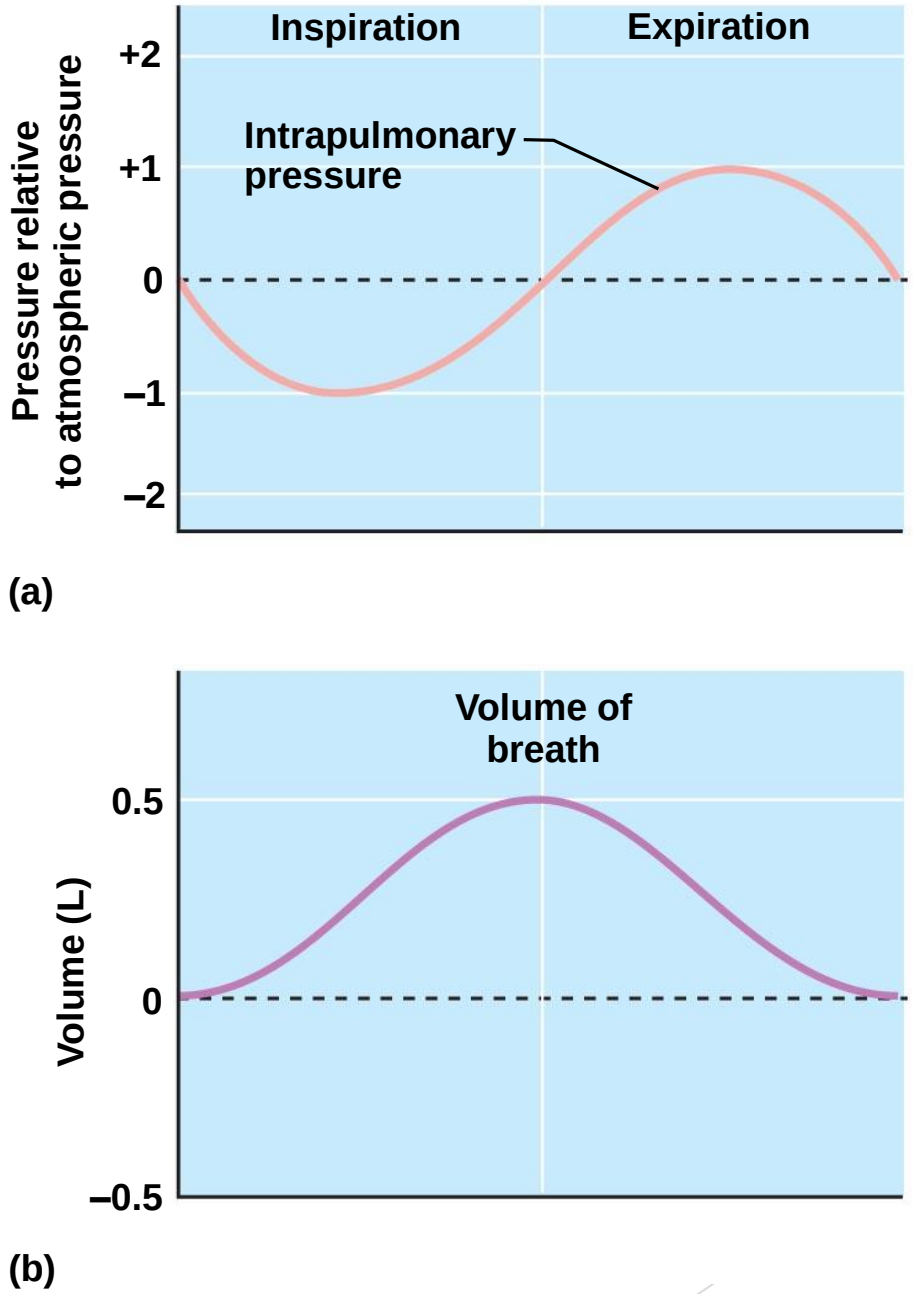
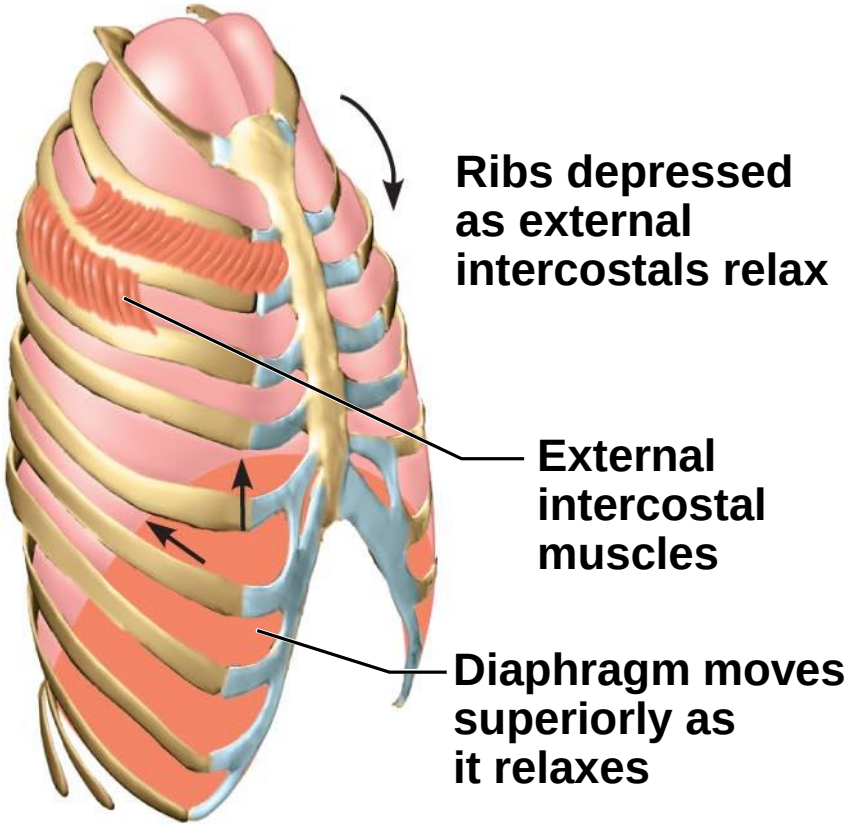

Inspiration
Expiration
Pressure relative to atmospheric pressure
+2
+1
0
–1
–2
Intrapulmonary pressure
(a)
Volume of breath
Volume (L)
0.5
0
–0.5
(b)

Figure 13.8

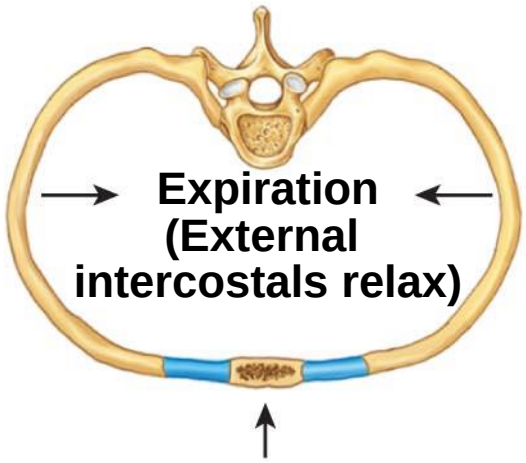
Expiration

- Largely a passive process which depends on natural lung elasticity
- As muscles relax, air is pushed out of the lungs due to
  - Decrease in intrapulmonary volume
  - Increase in gas pressure
- Forced expiration can occur mostly by contracting internal intercostal muscles to depress the rib cage

Changes in anterior-posterior and superior-inferior dimensions



Changes in lateral dimensions



(b) Expiration: Air (gases) flows out of the lungs

Figure 13.7b

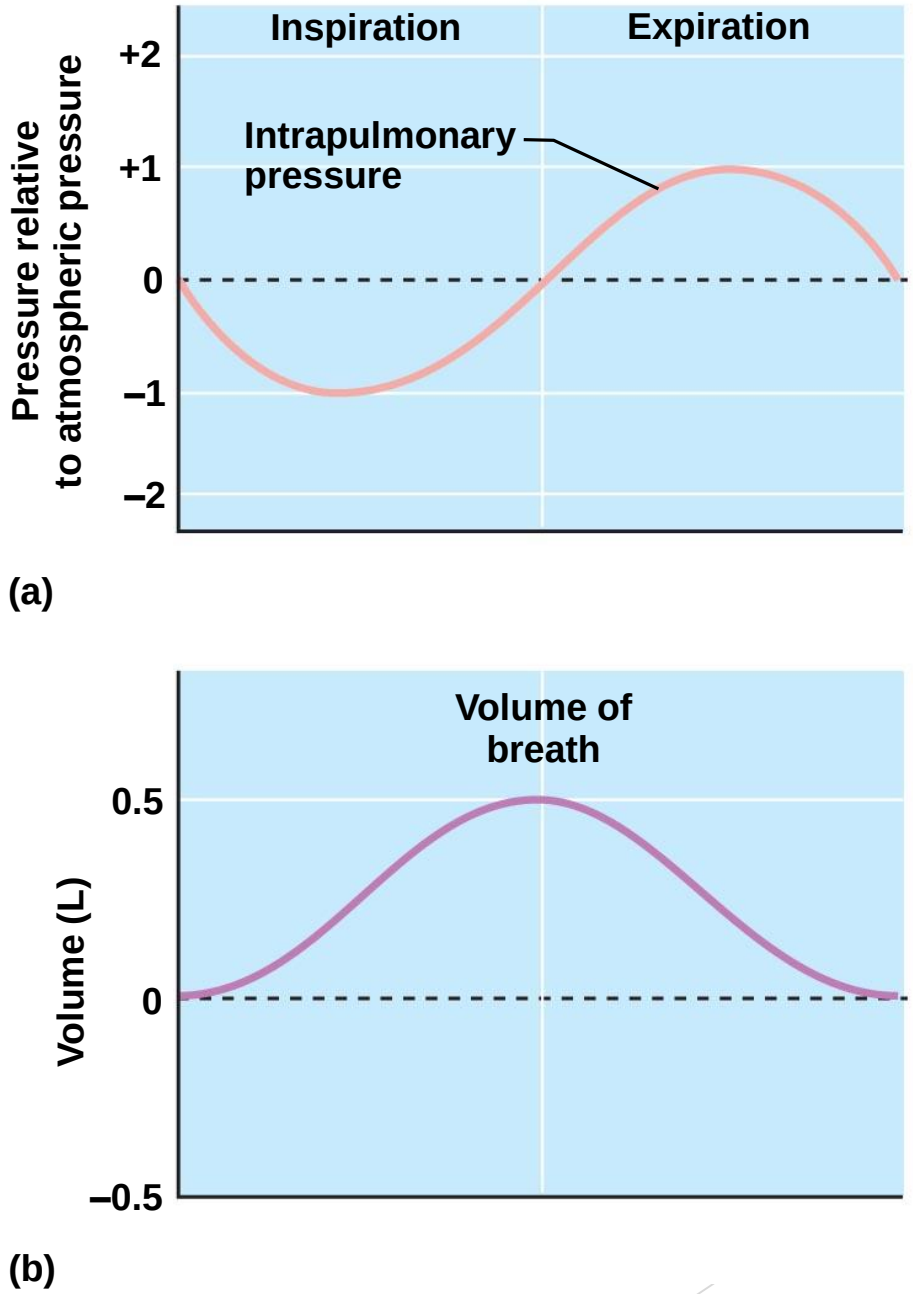

Inspiration
Expiration
Pressure relative to atmospheric pressure
+2
+1
0
–1
–2
Intrapulmonary pressure
(a)
Volume of breath
Volume (L)
0.5
0
–0.5
(b)

Figure 13.8

Workbook Page 264 #13

Pressure Differences in the Thoracic Cavity

- Normal pressure within the pleural space is always negative (**intrapleural pressure**)

- Differences in lung and pleural space pressures keep lungs from collapsing

Nonrespiratory Air (Gas) Movements

- Can be caused by reflexes or voluntary actions
- Examples:
  - Cough and sneeze — clears lungs of debris
  - Crying — emotionally induced mechanism
  - Laughing — similar to crying
  - Hiccup — sudden inspirations
  - Yawn — very deep inspiration

Workbook Page 264 #15

TERMS THAT REQUIRE YOUR ATTENTION

- Tidal volume (TV)
- Inspiratory reserve volume (IRV)
- Expiratory reserve volume (ERV)
- Residual volume
- Vital capacity
- Dead space volume
- Functional volume

Respiratory Volumes and Capacities

- Normal breathing moves about **500** mL of air with each breath
  - This respiratory volume is **tidal volume (TV)**
- Many factors that affect respiratory capacity
  - A person's size
  - Sex
  - Age
  - Physical condition

Respiratory Volumes and Capacities

- **Inspiratory reserve volume (IRV)**
  - Amount of air that can be taken in forcibly over the tidal volume
  - Usually around 3100 mL
- **Expiratory reserve volume (ERV)**
  - Amount of air that can be forcibly exhaled
  - Approximately 1200 mL

Respiratory Volumes and Capacities

- **Residual volume**
  - Air remaining in lung after expiration
  - About 1200 mL

Respiratory Volumes and Capacities

- **Vital capacity**
  - The total amount of exchangeable air
  - Vital capacity = TV + IRV + ERV
- **Dead space volume**
  - Air that remains in conducting zone and never reaches alveoli
  - About 150 mL

Respiratory Volumes and Capacities

- **Functional volume**
  - Air that actually reaches the respiratory zone
  - Usually about 350 mL

- Respiratory capacities are measured with a spirometer

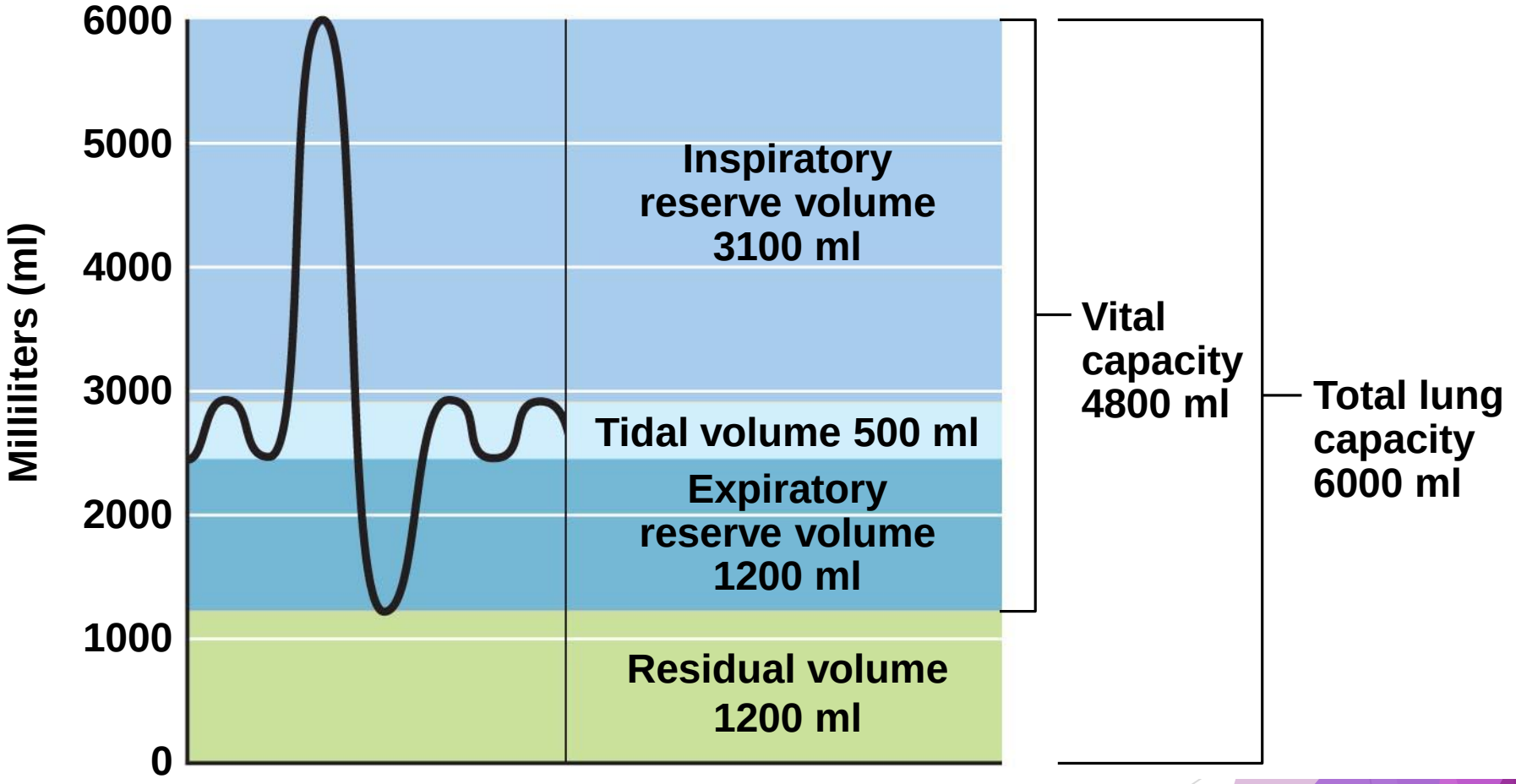

Milliliters (ml)
6000
5000
4000
3000
2000
1000
0
Inspiratory reserve volume 3100 ml
Tidal volume 500 ml
Expiratory reserve volume 1200 ml
Residual volume 1200 ml
Vital capacity 4800 ml
Total lung capacity 6000 ml

Figure 13.9

Workbook Page 265 #16

Respiratory Sounds

- Sounds are monitored with a stethoscope
- Two recognizable sounds can be heard with a stethoscope (it takes practice)
  - **Bronchial** sounds — produced by air rushing through large passageways such as the trachea and bronchi
  - **Vesicular breathing** sounds — soft sounds of air filling alveoli

External Respiration

- Oxygen loaded into the blood
  - The alveoli always have more oxygen than the blood
  - Oxygen moves by diffusion towards the area of lower concentration
  - Pulmonary capillary blood gains oxygen

External Respiration

- Carbon dioxide unloaded out of the blood
  - Blood returning from tissues has higher concentrations of carbon dioxide than air in the alveoli
  - Pulmonary capillary blood gives up carbon dioxide to be exhaled
- Blood leaving the lungs is oxygen-rich and carbon dioxide-poor

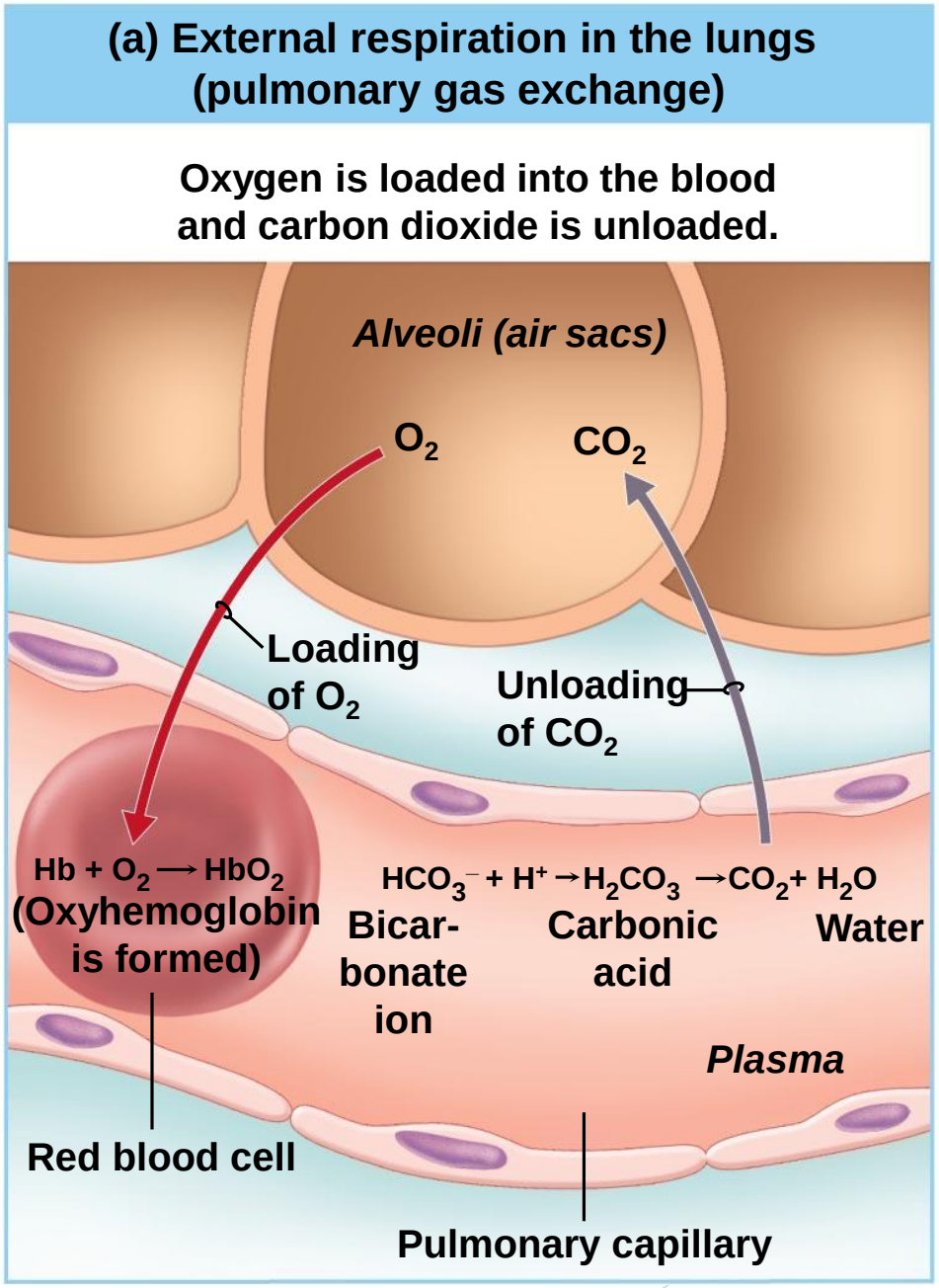


Figure 13.11a

Gas Transport in the Blood

- Oxygen transport in the blood
  - Most oxygen travels attached to hemoglobin and forms oxyhemoglobin (HbO_2)
  - A small dissolved amount is carried in the plasma

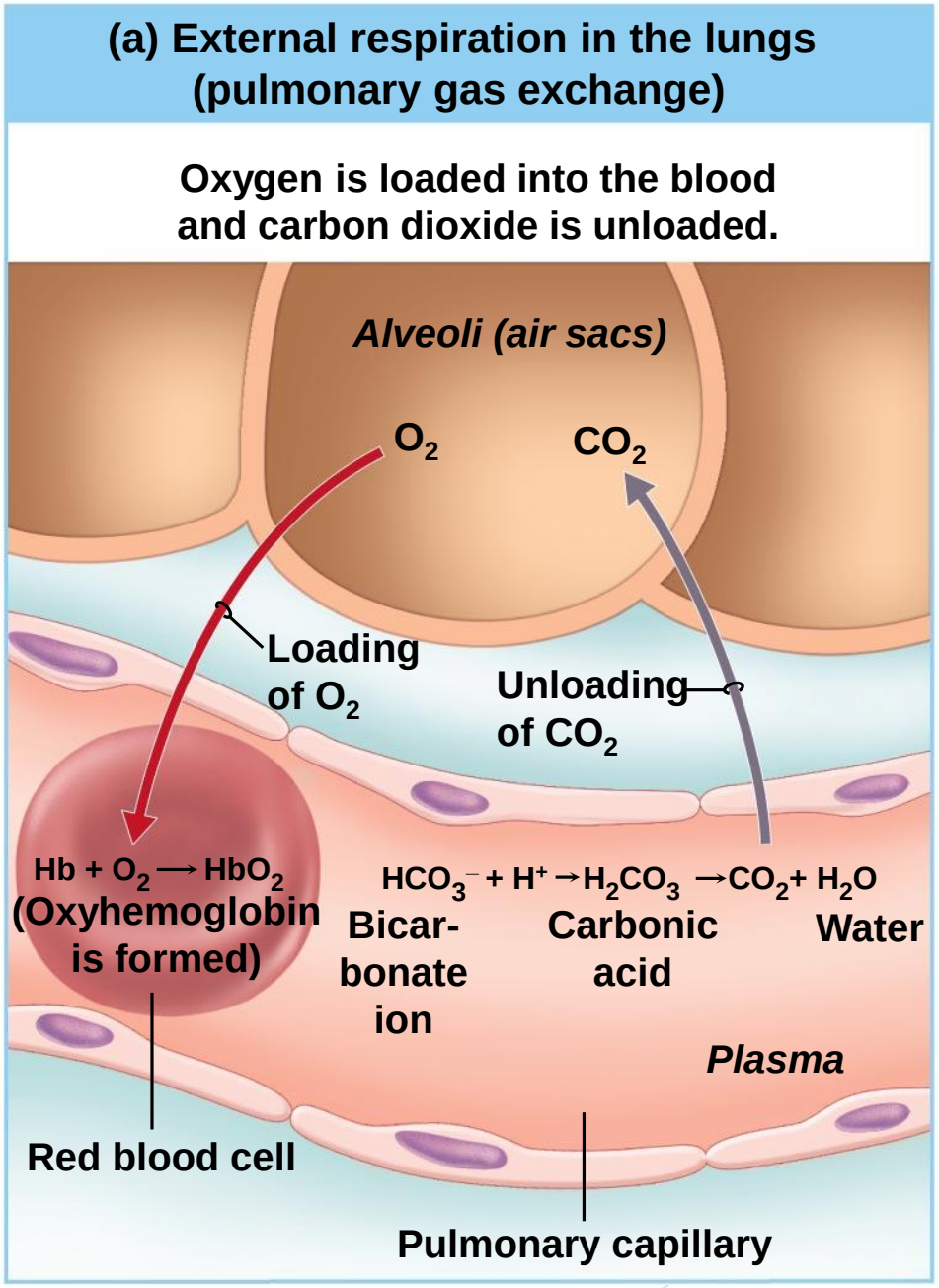


Figure 13.11a

Gas Transport in the Blood

- Carbon dioxide transport in the blood
  - Most is transported in the plasma as bicarbonate ion (HCO_3^-)
  - A small amount is carried inside red blood cells on hemoglobin, but at different binding sites than those of oxygen

Gas Transport in the Blood

- For carbon dioxide to diffuse out of blood into the alveoli, it must be released from its bicarbonate form:
  - Bicarbonate ions enter RBC
  - Combine with hydrogen ions
  - Form carbonic acid (H_2CO_3)
  - Carbonic acid splits to form water + CO_2
  - Carbon dioxide diffuses from blood into alveoli

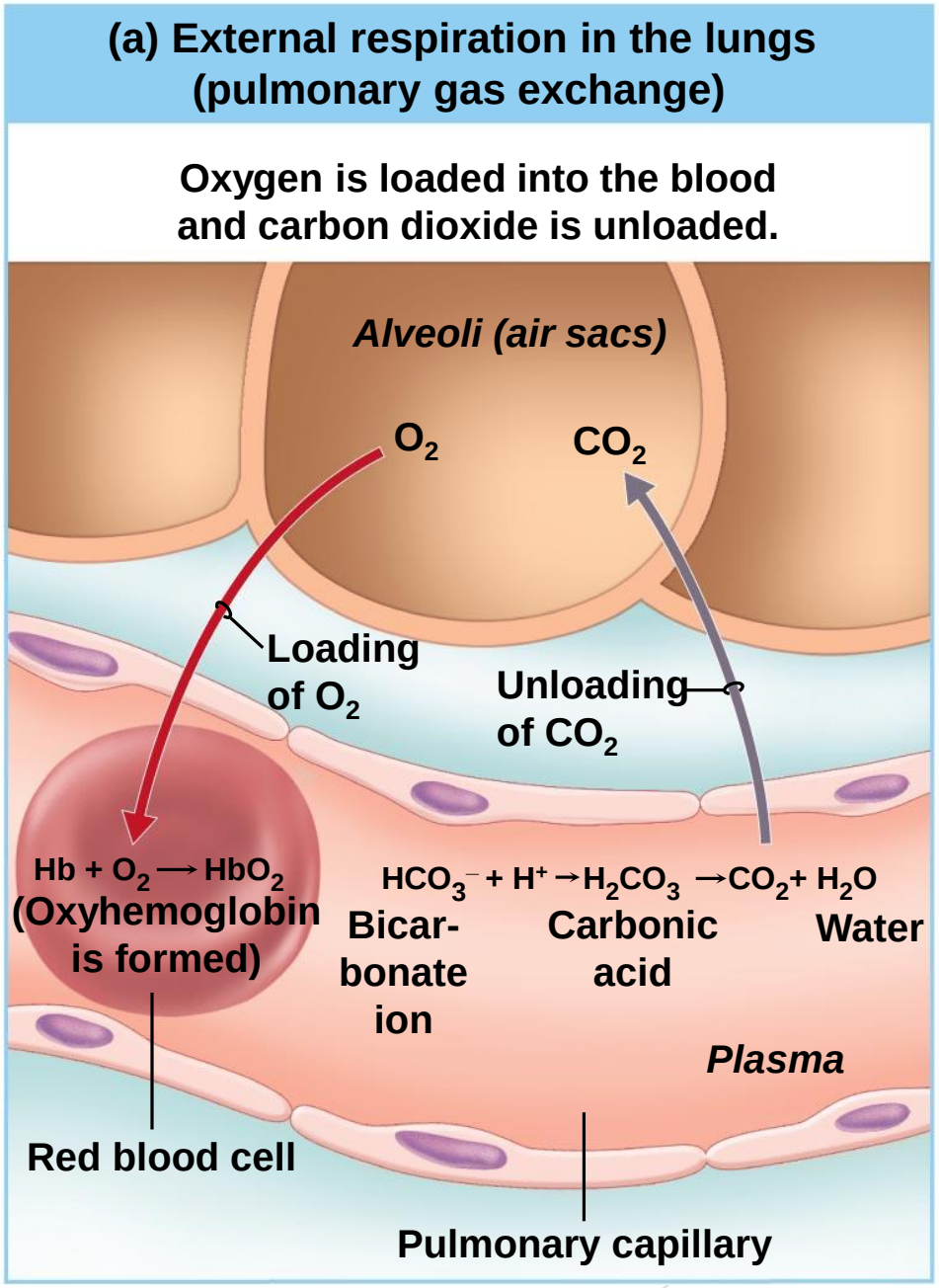


Figure 13.11a

Internal Respiration

- Exchange of gases between blood and body cells
- An opposite reaction to what occurs in the lungs
  - Carbon dioxide diffuses out of tissue to blood (called *loading*)
  - Oxygen diffuses from blood into tissue (called *unloading*)

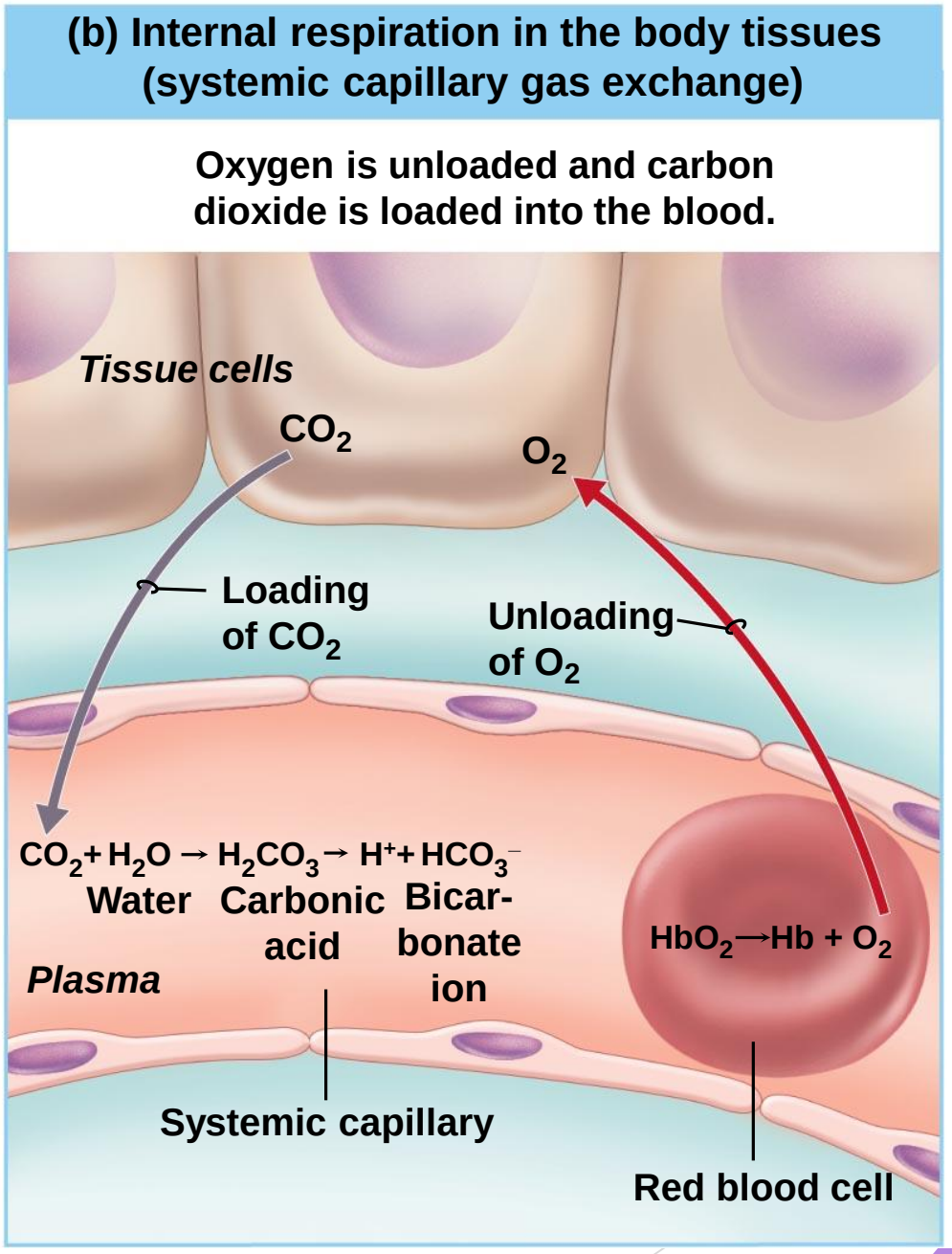


Figure 13.11b

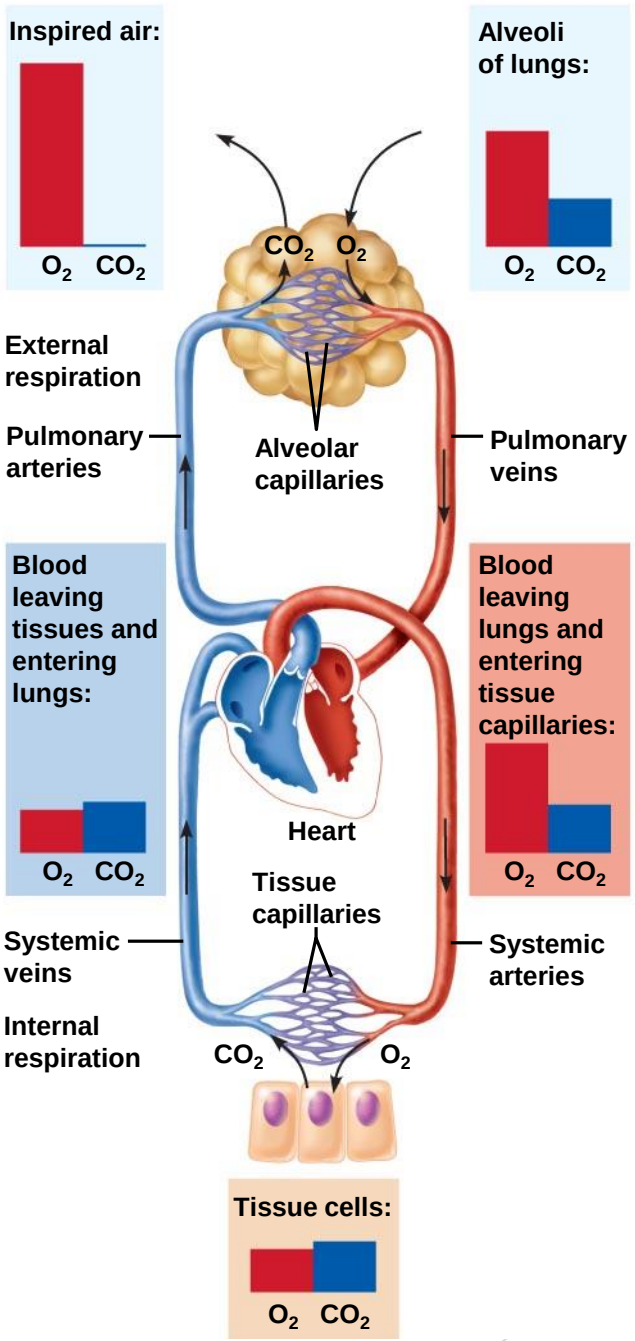

Inspired air:
O_2 CO_2
Alveoli of lungs:
O_2 CO_2
CO_2 O_2
External respiration
Pulmonary arteries
Alveolar capillaries
Pulmonary veins
Blood leaving tissues and entering lungs:
O_2 CO_2
Blood leaving lungs and entering tissue capillaries:
O_2 CO_2
Heart
Tissue capillaries
Systemic veins
Systemic arteries
Internal respiration
CO_2 O_2
Tissue cells:
O_2 CO_2

Figure 13.10

Workbook Page 266 #18

Neural Regulation of Respiration

- Activity of respiratory muscles is transmitted to and from the brain by phrenic and intercostal nerves
- Neural centers that control rate and depth are located in the medulla and pons
  - **Medulla** — sets basic rhythm of breathing and contains a pacemaker called the self-exciting inspiratory center
  - **Pons** — appears to smooth out respiratory rate

Neural Regulation of Respiration

- **Eupnea**
  - Normal respiratory rate
  - 12 to 15 respirations per minute
- **Hyperpnea**
  - Increased respiratory rate often due to extra oxygen needs

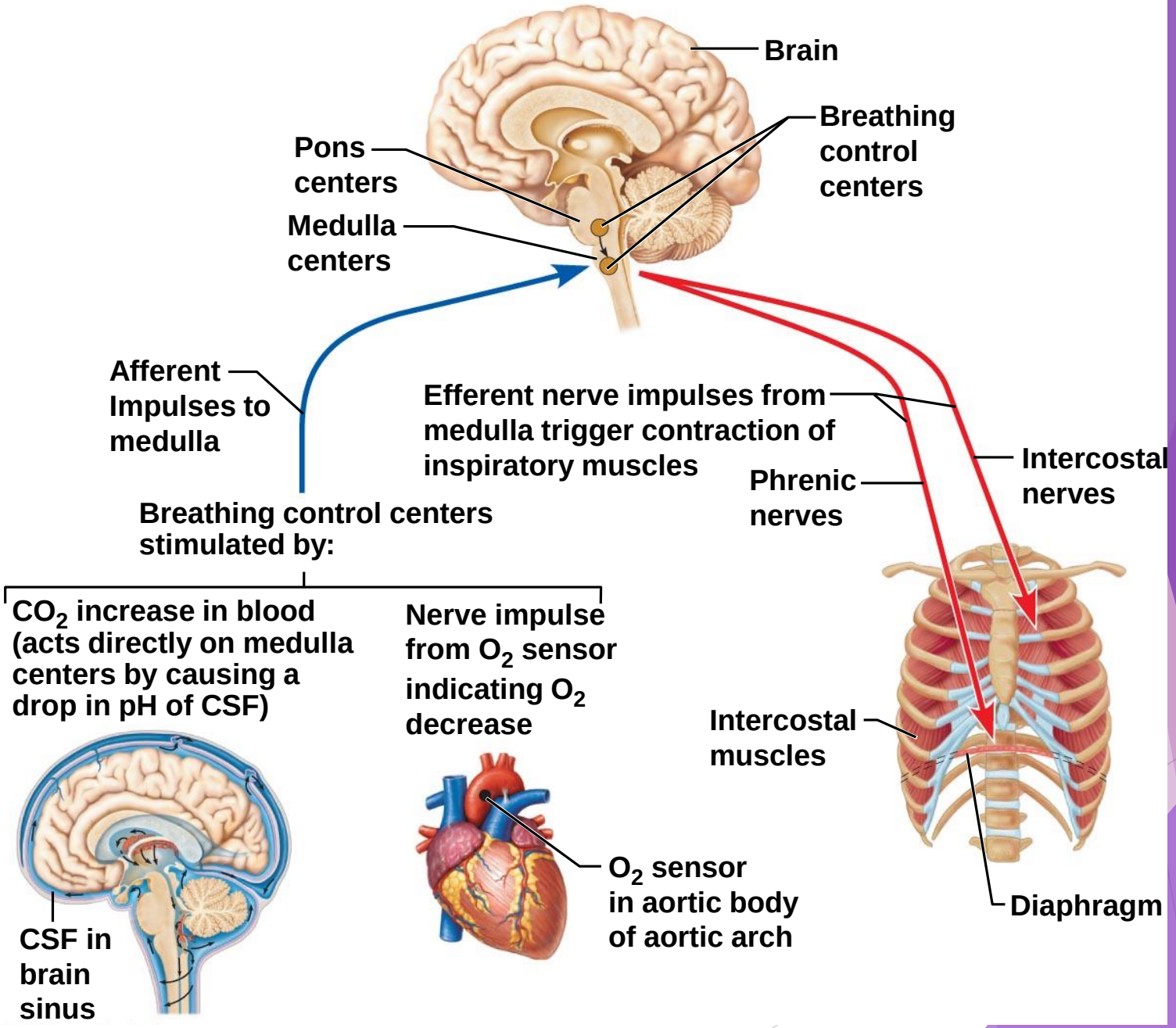

Brain
Breathing control centers
Pons centers
Medulla centers
Afferent Impulses to medulla
Efferent nerve impulses from medulla trigger contraction of inspiratory muscles
Phrenic nerves
Intercostal nerves
Breathing control centers stimulated by:
CO_2 increase in blood (acts directly on medulla centers by causing a drop in pH of CSF)
Nerve impulse from O_2 sensor indicating O_2 decrease
Intercostal muscles
CSF in brain sinus
O_2 sensor in aortic body of aortic arch
Diaphragm

Figure 13.12

Non-Neural Factors Influencing Respiratory Rate and Depth

- (a) Physical factors
  - Increased body temperature
  - Exercise
  - Talking
  - Coughing
- (b) Volition (conscious control)
- (c) Emotional factors

Non-Neural Factors Influencing Respiratory Rate and Depth

- (d_1) Chemical factors: CO_2 levels
  - The body's need to rid itself of CO_2 is the most important stimulus
  - Increased levels of carbon dioxide (and thus, a decreased or acidic pH) in the blood increase the rate and depth of breathing
  - Changes in carbon dioxide act directly on the medulla oblongata

Non-Neural Factors Influencing Respiratory Rate and Depth

- (d_2) Chemical factors: oxygen levels
  - Changes in oxygen concentration in the blood are detected by chemoreceptors in the aorta and common carotid artery
  - Information is sent to the medulla

Hyperventilation and Hypoventilation

- **Hyperventilation**
  - Results from increased CO_2 in the blood (acidosis)
  - Breathing becomes deeper and more rapid
  - Blows off more CO_2 to restore normal blood pH

Hyperventilation and Hypoventilation

- **Hypoventilation**
  - Results when blood becomes alkaline (alkalosis)
  - Extremely slow or shallow breathing
  - Allows CO_2 to accumulate in the blood

Respiratory Disorders: Chronic Obstructive Pulmonary Disease (COPD)

- Exemplified by chronic bronchitis and emphysema
- Major causes of death and disability in the United States

Respiratory Disorders: Chronic Obstructive Pulmonary Disease (COPD)

- Features of these diseases
  - Patients almost always have a history of smoking
  - Labored breathing (dyspnea) becomes progressively more severe
  - Coughing and frequent pulmonary infections are common
  - Most victims are hypoxic, retain carbon dioxide, and have respiratory acidosis
  - Those infected will ultimately develop respiratory failure

Respiratory Disorders: Chronic Bronchitis xxxxxx

- Mucosa of the lower respiratory passages becomes severely inflamed
- Mucus production increases
- Pooled mucus impairs ventilation and gas exchange
- Risk of lung infection increases
- Pneumonia is common
- Called “blue bloaters” due to hypoxia and cyanosis

Respiratory Disorders: Emphysema

- Alveoli enlarge as adjacent chambers break through
- Chronic inflammation promotes lung fibrosis
- Airways collapse during expiration
- Patients use a large amount of energy to exhale
- Overinflation of the lungs leads to a permanently expanded barrel chest
- Cyanosis appears late in the disease; sufferers are often called “pink puffers”

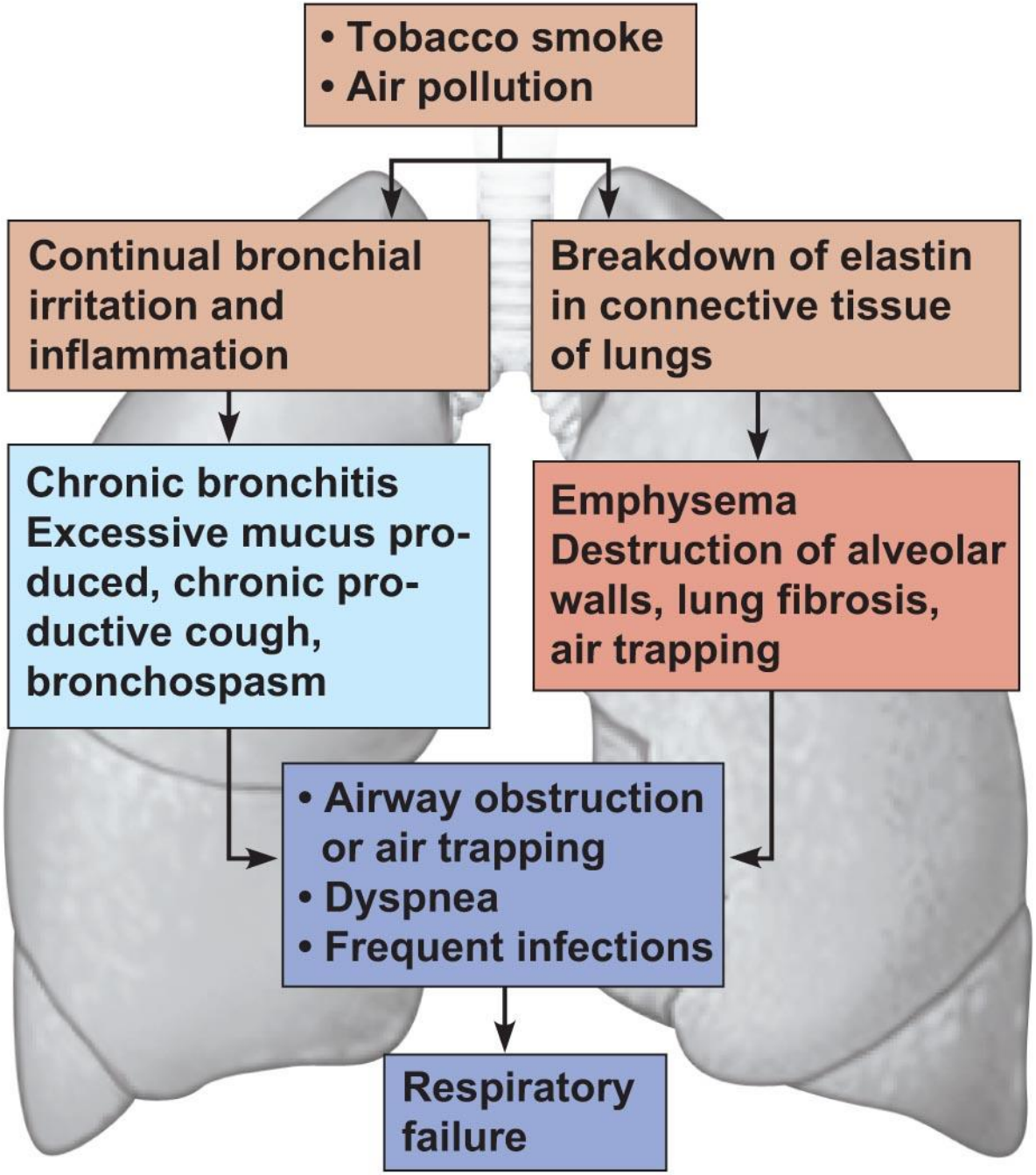

• Tobacco smoke
• Air pollution
Continual bronchial irritation and inflammation
Breakdown of elastin in connective tissue of lungs
Chronic bronchitis
Excessive mucus produced, chronic productive cough, bronchospasm
Emphysema
Destruction of alveolar walls, lung fibrosis, air trapping
• Airway obstruction or air trapping
• Dyspnea
• Frequent infections
Respiratory failure

Figure 13.13

Lung Cancer

- Accounts for one-third of all cancer deaths in the United States
- Increased incidence is associated with smoking
- Three common types
  - Squamous cell carcinoma
  - Adenocarcinoma
  - Small cell carcinoma

Developmental Aspects of the Respiratory System

- Lungs are filled with fluid in the fetus
- Lungs are not fully inflated with air until two weeks after birth
- Surfactant is a fatty molecule made by alveolar cells
  - Lowers alveolar surface tension so that lungs do not collapse between breaths
  - Not present until late in fetal development and may not be present in premature babies
  - Appears around 28 to 30 weeks of pregnancy

Developmental Aspects of the Respiratory System

- Homeostatic imbalance
  - Infant respiratory distress syndrome (IRDS)—surfactant production is inadequate
  - Cystic fibrosis—oversecretion of thick mucus clogs the respiratory system

Developmental Aspects of the Respiratory System

- Respiratory rate changes throughout life
  - Newborns: 40 to 80 respirations per minute
  - Infants: 30 respirations per minute
  - Age 5: 25 respirations per minute
  - Adults: 12 to 18 respirations per minute
  - Rate often increases somewhat with old age

Developmental Aspects of the Respiratory System

- Sudden Infant Death Syndrome (SIDS)
  - Apparently healthy infant stops breathing and dies during sleep
  - Some cases are thought to be a problem of the neural respiratory control center
  - One third of cases appear to be due to heart rhythm abnormalities
  - Recent research shows a genetic component

Developmental Aspects of the Respiratory System

- Asthma
  - Chronic inflamed hypersensitive bronchiole passages
  - Response to irritants with dyspnea, coughing, and wheezing

Developmental Aspects of the Respiratory System

- Aging effects
  - Elasticity of lungs decreases
  - Vital capacity decreases
  - Blood oxygen levels decrease
  - Stimulating effects of carbon dioxide decrease
  - Elderly are often hypoxic and exhibit sleep apnea
  - More risks of respiratory tract infection