

The Respiratory System



Respiration

- **Breathing:** movement of air into and out of the lungs
- **External respiration:** O_2 and CO_2 exchange between the lungs and the blood
- **Transport:** O_2 and CO_2 in the blood
- **Internal respiration:** O_2 and CO_2 exchange between systemic blood vessels and tissues
- **Cellular respiration:** oxygen use to produce ATP, carbon dioxide as waste

Respiratory system

Circulatory system

UPPER RESPIRATORY TRACT

Nose
Passageway for air

Mouth Passageway
for food and air

Epiglottis
Covers larynx
during swallowing

Nasal cavity
Filters, warms, and
moistens air

Pharynx (Throat)
Common passageway
for air, food, and liquid

Larynx (Voice box)
Production of sound

LOWER RESPIRATORY TRACT

Pleural membranes
Cover the lungs and line
the chest cavity

Lung
Organ of gas
exchange

Intercostal muscle
Moves ribs during
respiration

Rib

Diaphragm
Skeletal muscle
of respiration

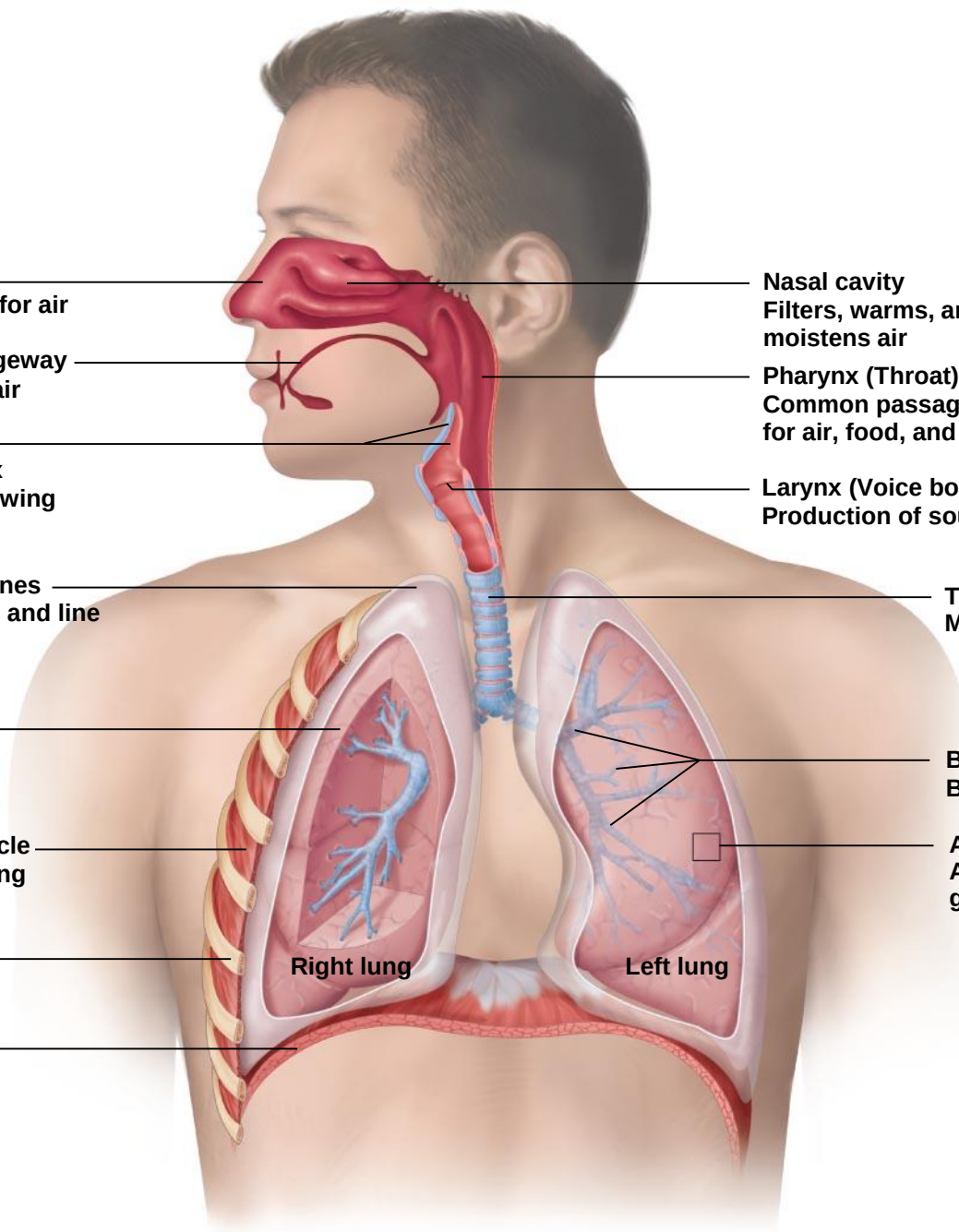
Trachea (Windpipe)
Main airway

Bronchi
Branching airways

Alveoli
Air sacs for
gas exchange

Right lung

Left lung



Upper Respiratory Tract

- Functions
 - Acts as passageway for respiration
 - Has receptors for smell
 - Filters larger foreign material from incoming air, inhaled microorganisms are entrapped in mucus
 - Moistens and warms incoming air
 - Has resonating chambers for voice

Sinuses

Nasal cavity

External nose

**Opening of the
auditory tube**

Nostril

Pharynx

Tongue

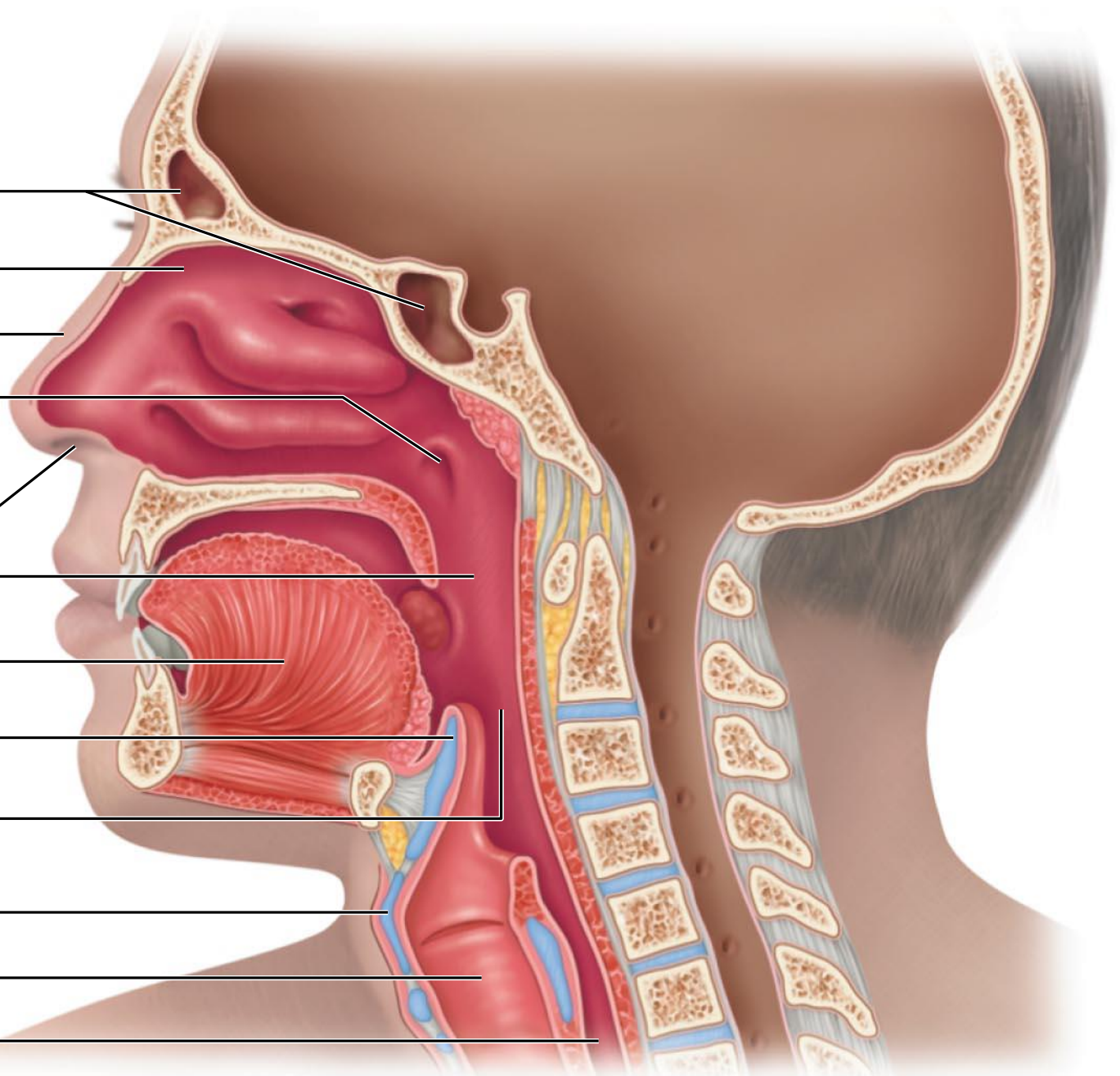
Epiglottis

Glottis

Larynx

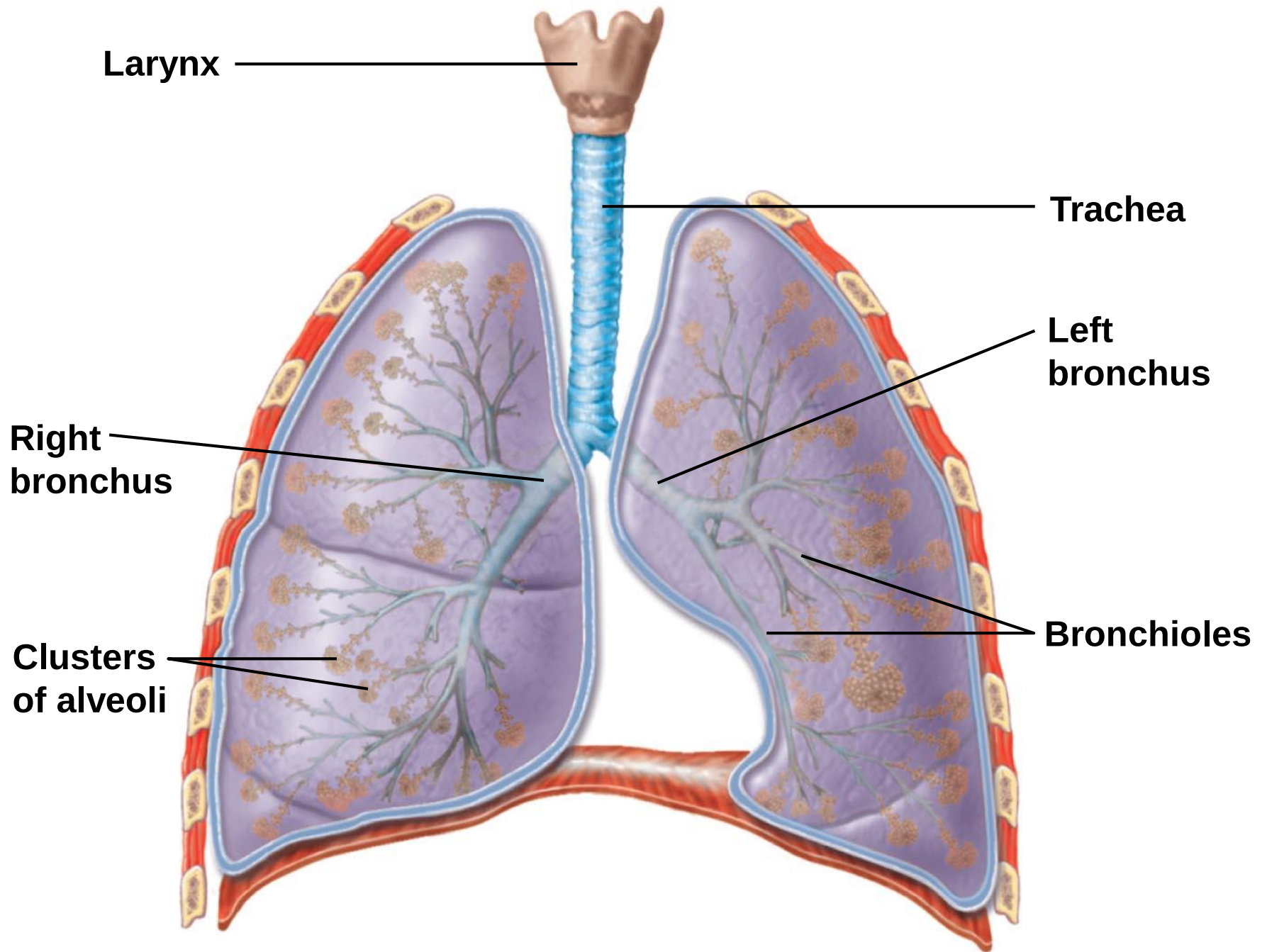
Trachea

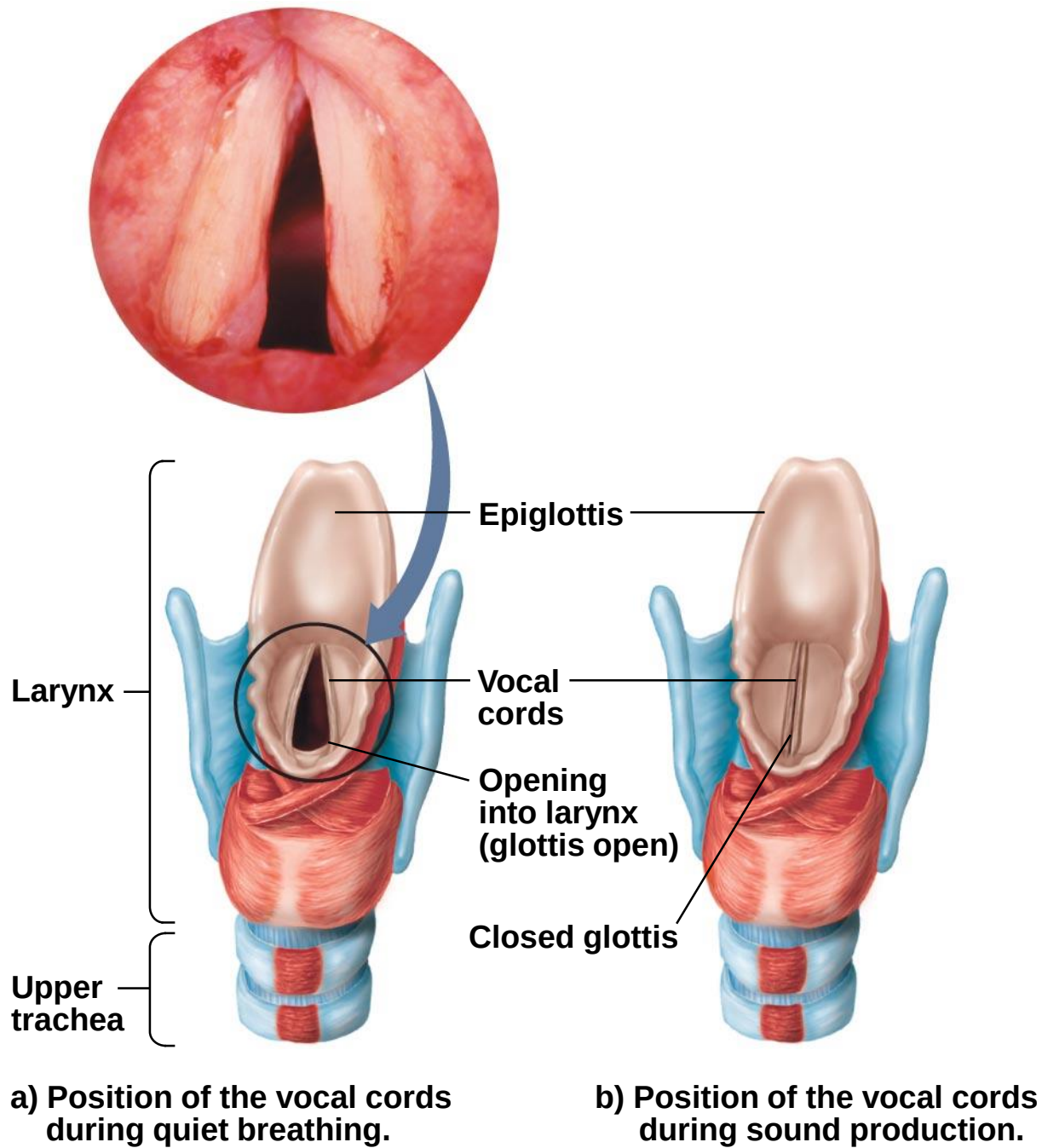
Esophagus



Lower Respiratory Tract

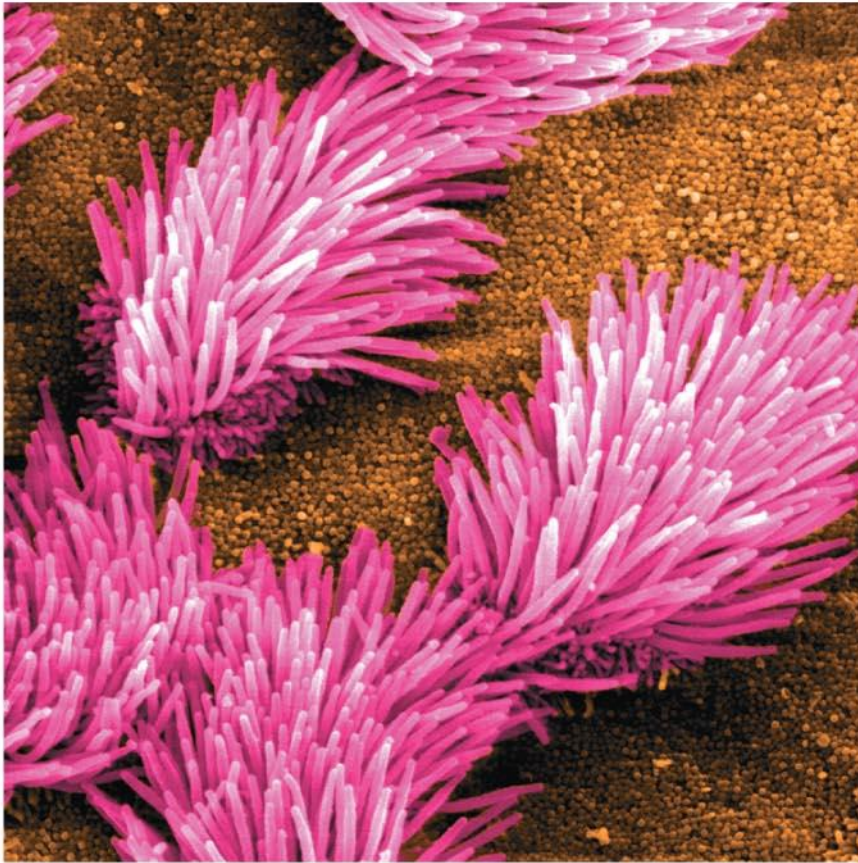
- Functions
 - **Larynx**
 - Maintains an open airway
 - Routes food and air appropriately
 - Assists in sound production
 - **Trachea**
 - transports air to and from lungs
 - **Bronchi**
 - branch into lungs
 - **Lungs**
 - transport air to alveoli for gas exchange



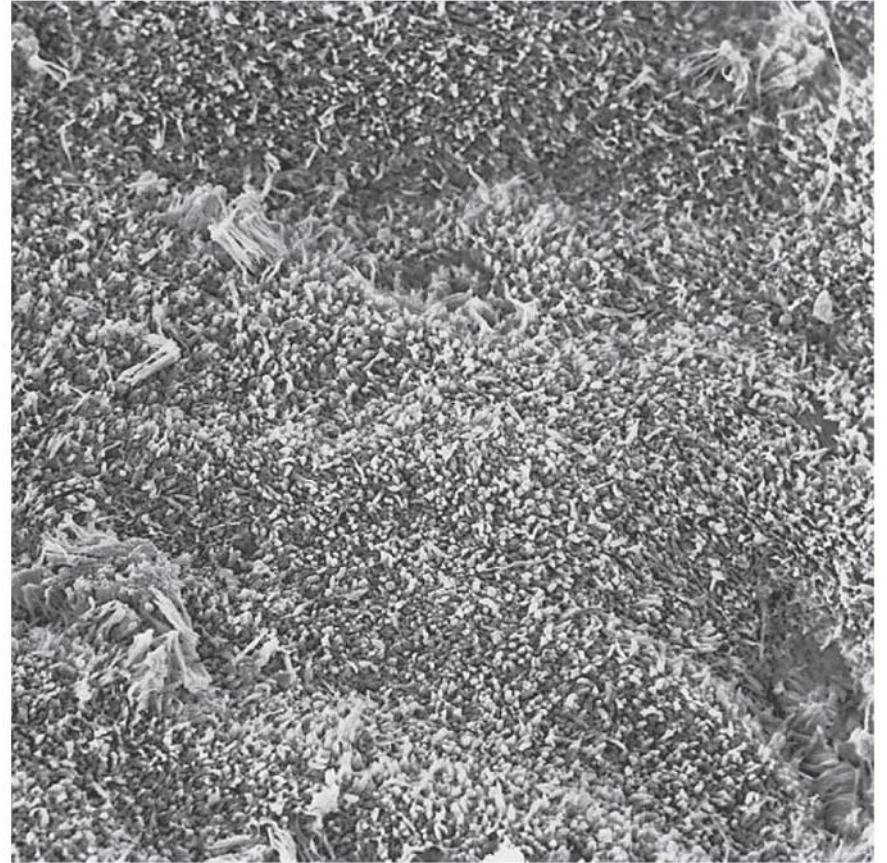


Defenses of the Respiratory Tract

- **Mucus** – entraps microorganisms
- **Cilia** – push microorganisms and mucus up and out of respiratory tract
 - Smoking – damages cilia, impairs this defense
- **Cough reflex**



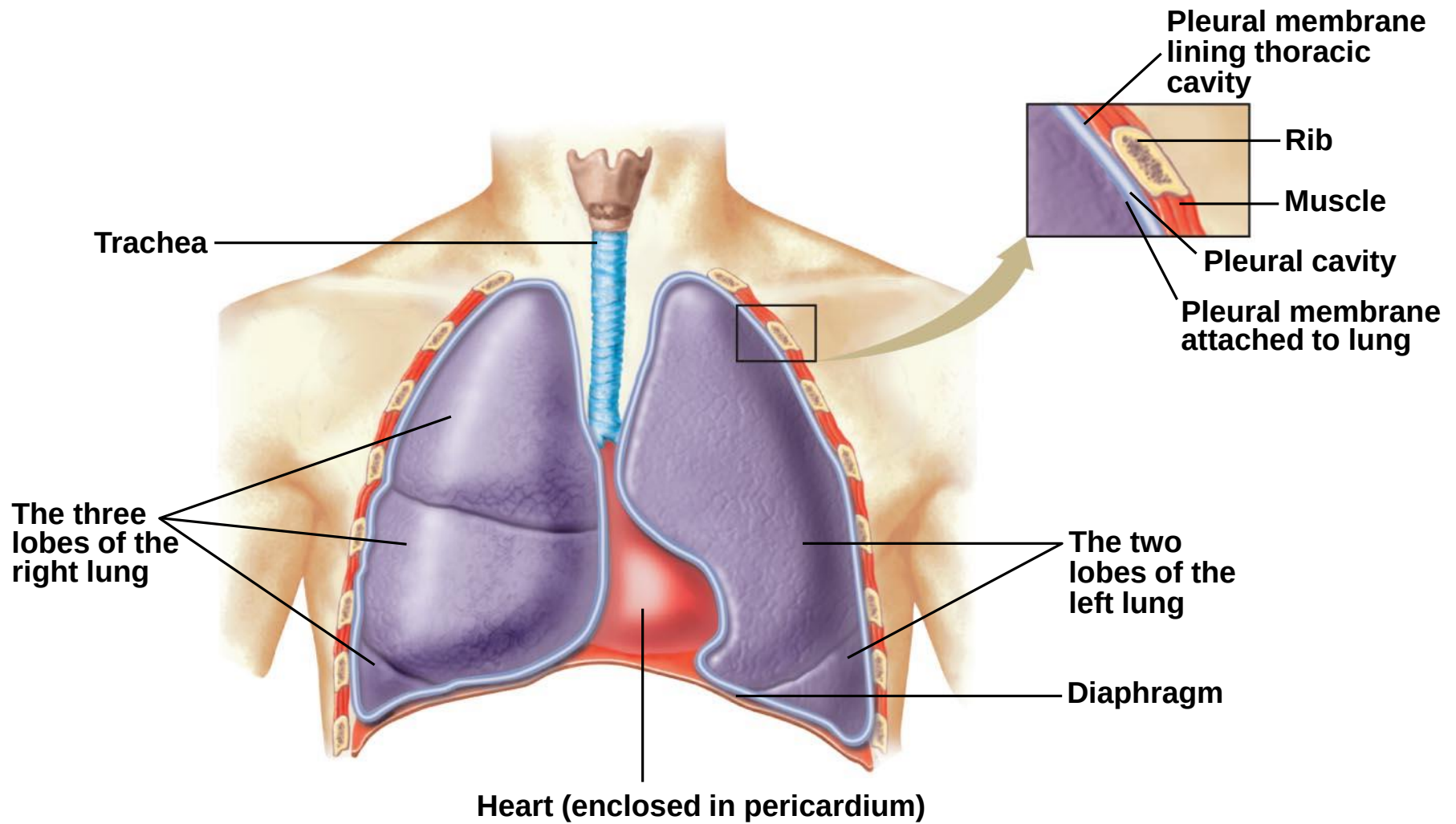
a) Healthy airway.



b) Smoker's airway.

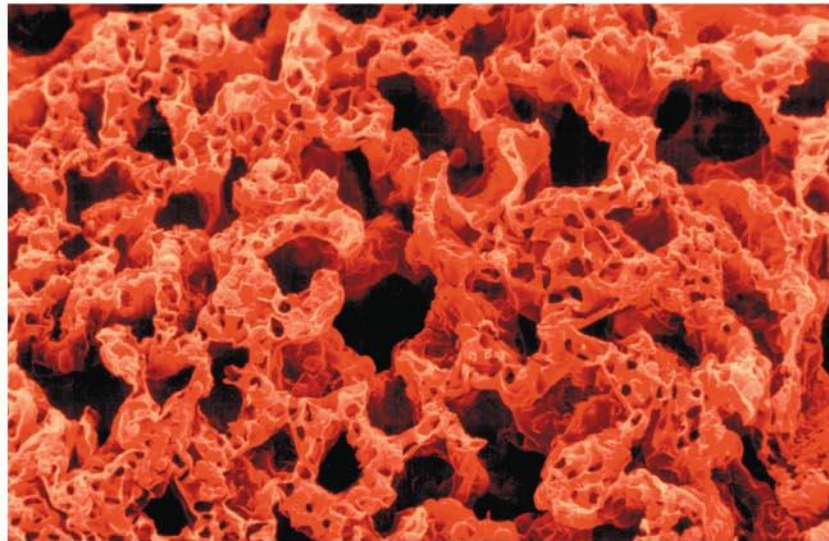
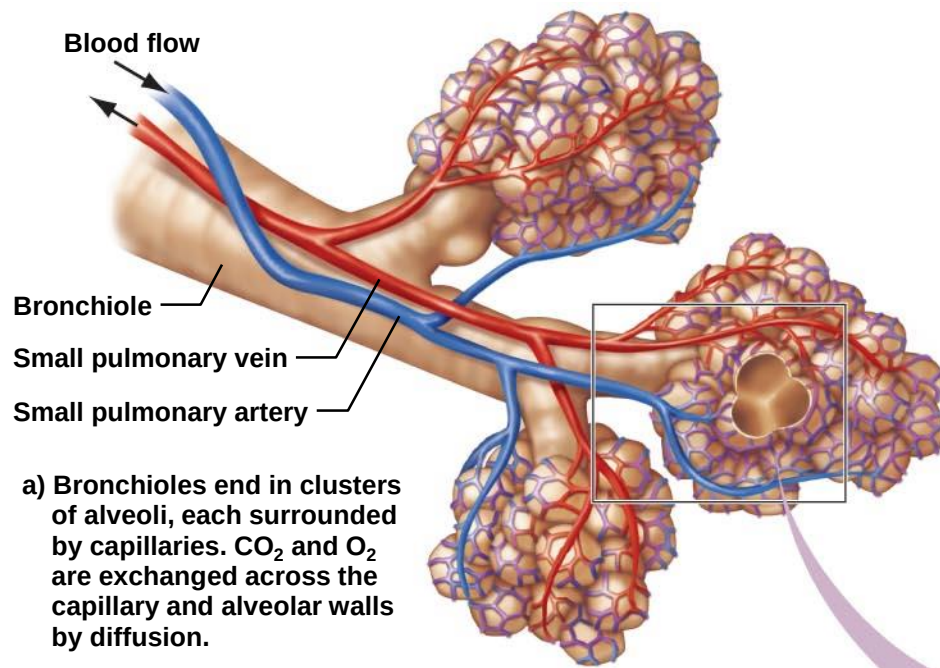
The Lungs Are Organs of Gas Exchange

- Located within thoracic cavity
- Surrounded by pleural membranes
- Bronchioles terminate in clusters of alveoli
- Alveoli
 - Tiny air-filled sacs
 - Gas exchange occurs here
- Pulmonary capillaries in alveolar walls – bring blood and air into close contact

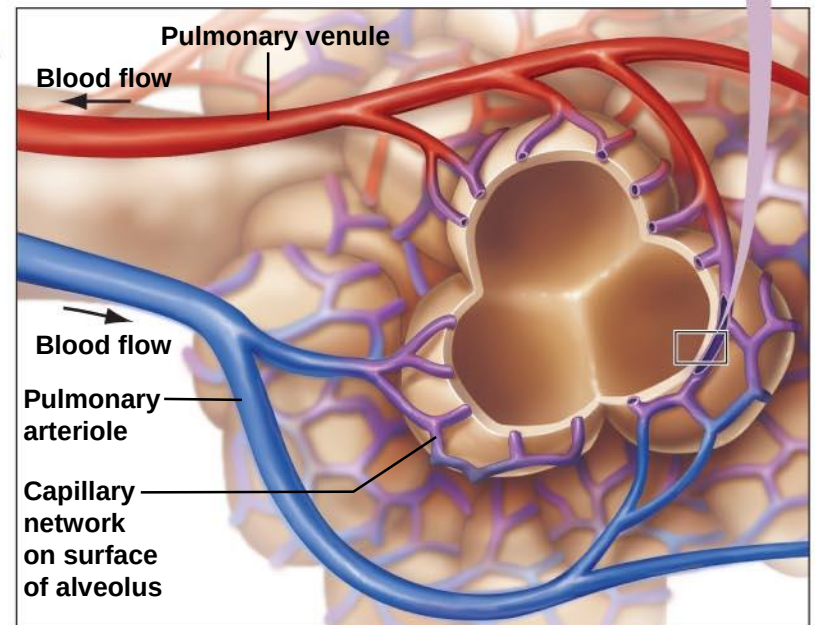
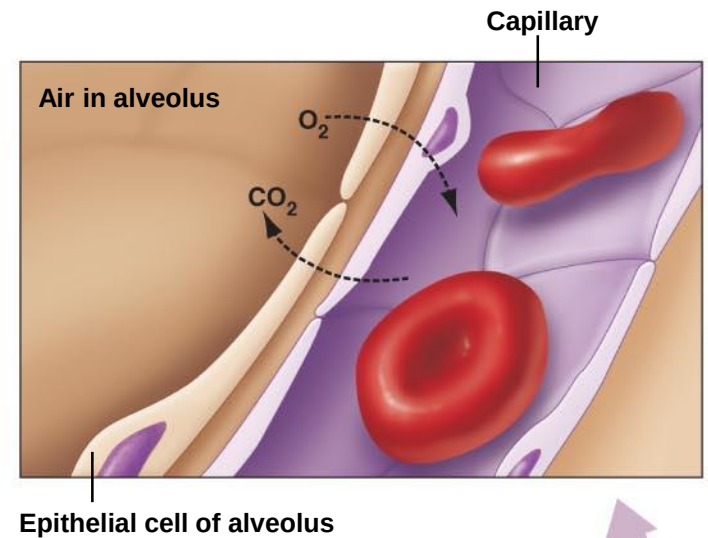


The Lungs Are Organs of Gas Exchange

- Pulmonary capillaries in alveolar walls – bring blood and air into close contact

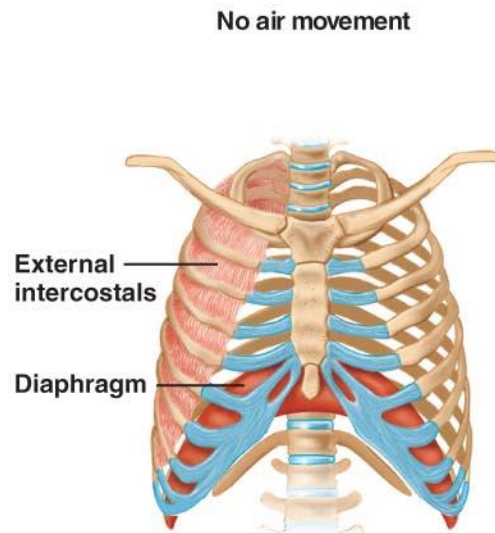


b) Photo of the surface of alveoli covered with capillaries.



The Process of Breathing Involves a Pressure Gradient

- Inspiration/expiration: air in/air out cycle
 1. Relaxed state
 - Diaphragm and intercostal muscles relaxed



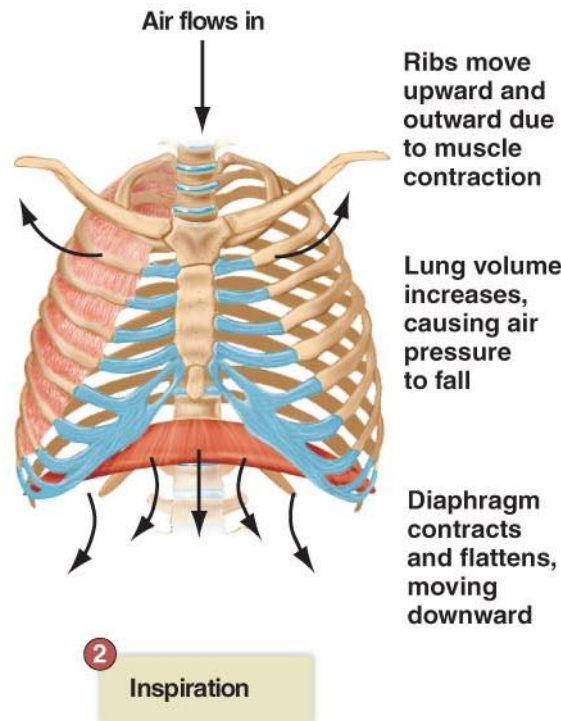
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Relaxed state

The Process of Breathing Involves a Pressure Gradient

2. Inspiration (inhale)

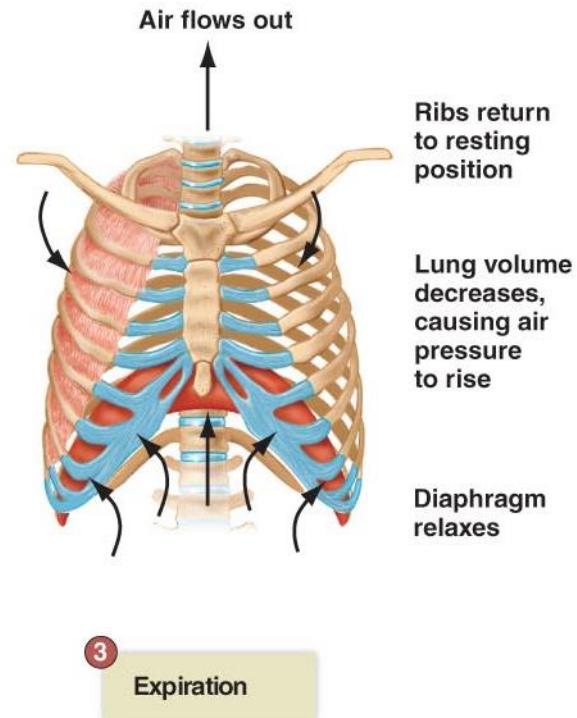
- Diaphragm contracts, pulling muscle down; intercostal muscles contract, elevating chest wall and expanding volume of chest, lowering pressure in lungs, pulling in air



The Process of Breathing Involves a Pressure Gradient

3. Expiration (exhale)

- Muscles relax; diaphragm resumes dome shape; intercostal muscles allow chest to lower, resulting in increase of pressure in chest and expulsion of air



Lung Volumes and Vital Capacity

Measure Lung Function

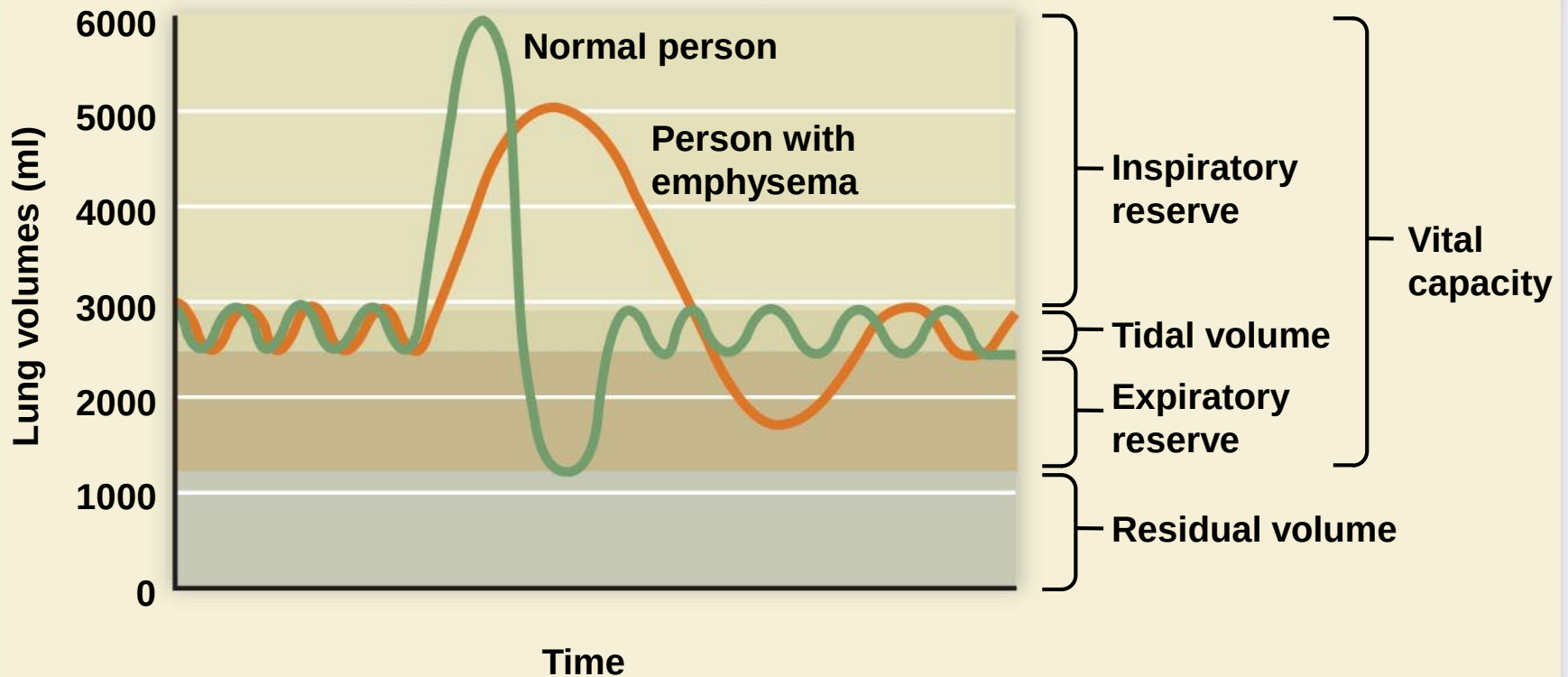
- **Tidal volume**
 - Volume of air inhaled and exhaled in a single breath
- **Dead space volume**
 - Volume of air that remains in the airways and does not participate in gas exchange
- **Vital capacity**
 - Maximal volume that can be exhaled after maximal inhalation

Lung Volumes and Vital Capacity

Measure Lung Function

- **Inspiratory reserve volume**
 - Volume of air that can be inhaled beyond the tidal volume
- **Expiratory reserve volume**
 - Volume of air that can be forcibly exhaled beyond the tidal volume
- **Residual volume**
 - Volume of air remaining in the lungs, even after a forceful maximal expiration
- Measured by **spirometer**

a) A recording of lung capacity. After several normal breaths, the person inhales and then exhales maximally. The volumes indicated by the green line are for a normal person. The orange line is typical of a patient with emphysema.



Gas Exchange and Transport Occur Passively: Partial Pressure

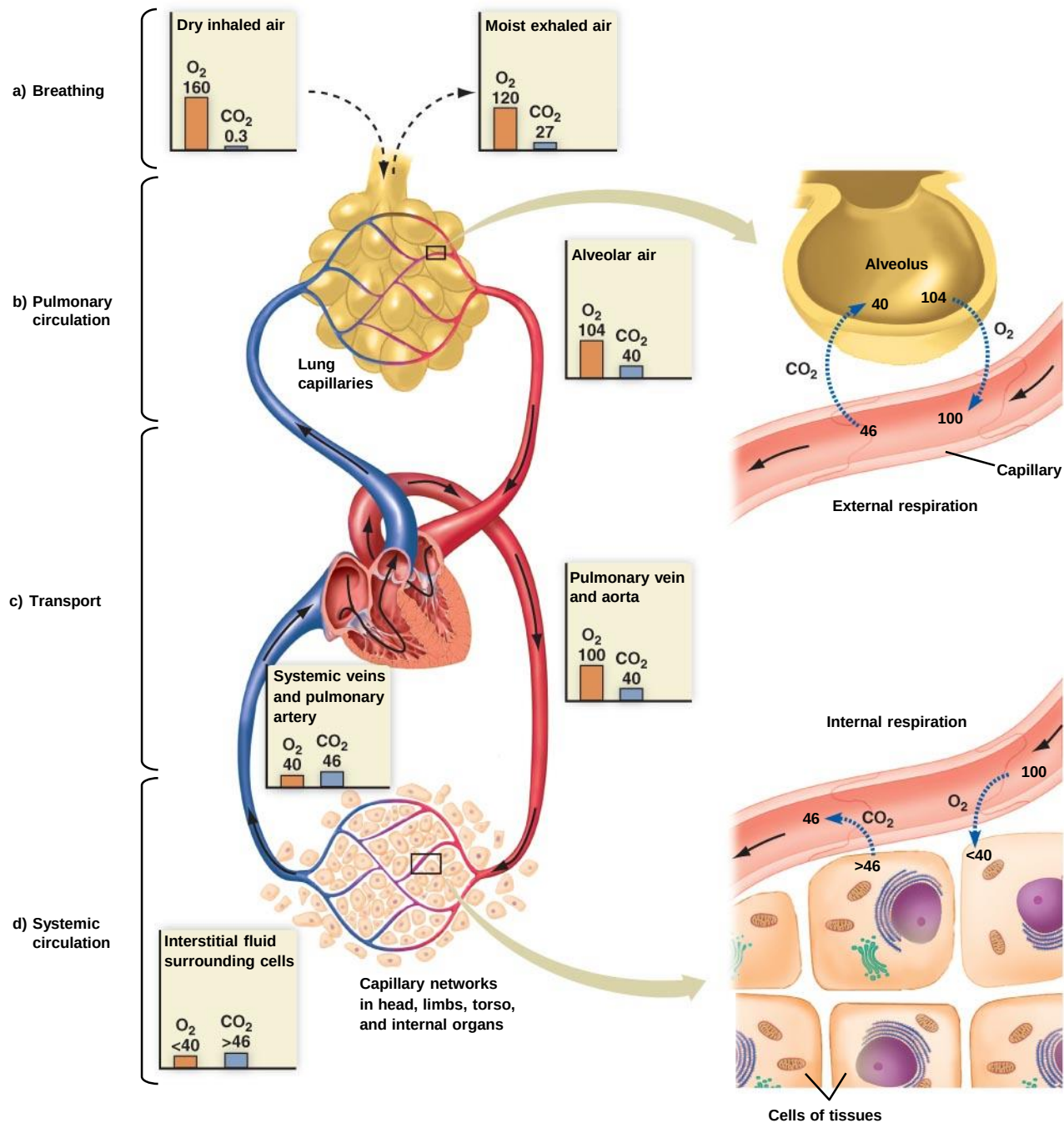
- **Partial Pressure:** The pressure exerted by one particular gas in a mixture of gases
- Partial pressure of a gas is proportional to its percentage of the total gas composition
- **A gas always diffuses down its partial pressure gradient, from higher to lower partial pressure**

External Respiration: Exchange of Gases Between Air and Blood (in lungs)

- O_2 diffuses from alveoli (P_{O_2} : 104 mmHg) into blood (P_{O_2} : 40 mmHg), down its partial pressure gradient
- CO_2 diffuses from blood (P_{CO_2} : 46 mmHg) into alveoli (P_{CO_2} : 40 mmHg), down its partial pressure gradient

Internal Respiration: The Exchange of Gases with Tissue Fluids (in body tissues)

- O_2 diffuses down its pressure gradient from capillaries to interstitial fluid and then to cells
- CO_2 diffuses down its pressure gradient from cells to interstitial fluid to capillaries



Hemoglobin Transports Most O₂

- 98% of O₂ in blood is carried bound to hemoglobin molecules in red blood cells

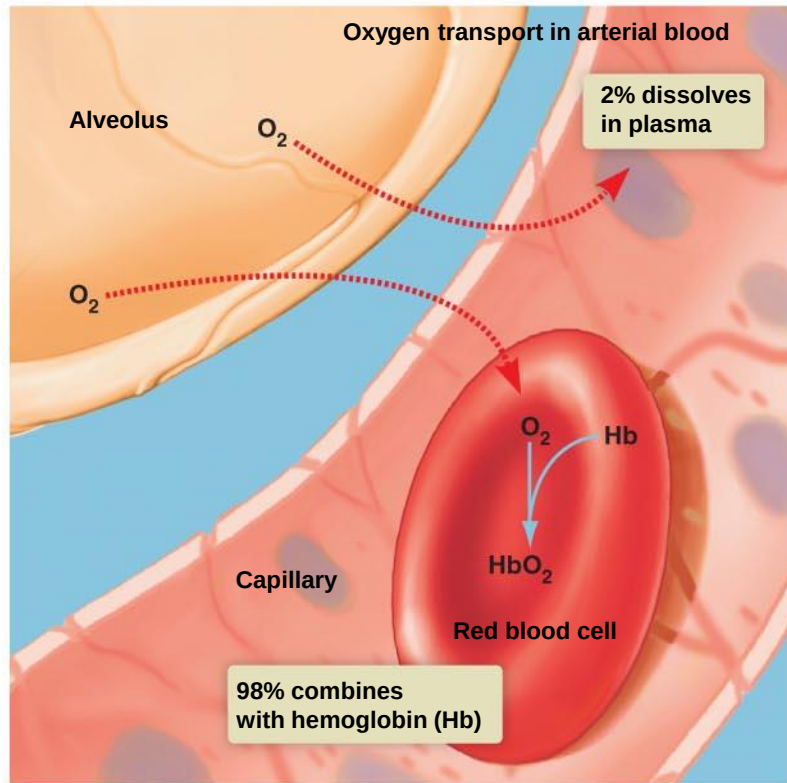


hemoglobin + oxygen → oxyhemoglobin

- 2% of O₂ is dissolved in plasma

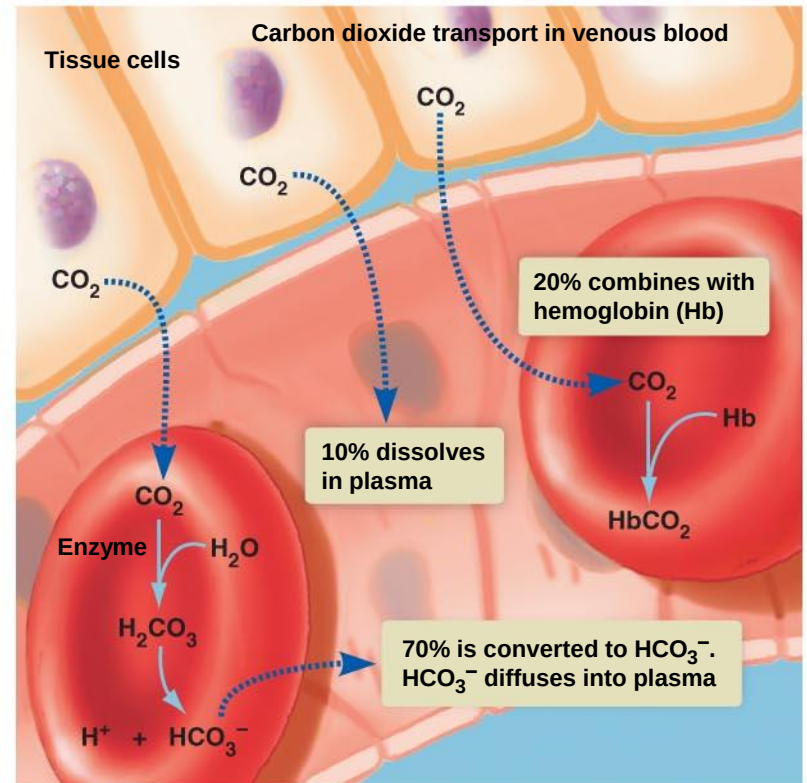
Most CO₂ Is Transported in Plasma as Bicarbonate

- 70% of CO₂ is converted to and transported in the plasma as bicarbonate
- 10% of CO₂ is dissolved in plasma
- 20% of CO₂ binds to hemoglobin for transport



a) Approximately 98% of all the O_2 transported to the tissues by arterial blood is bound to hemoglobin (Hb) within red blood cells.

Blood is transported from lungs to tissue



b) Most of the CO_2 transported to the lungs by venous blood is converted to bicarbonate (HCO_3^-) within red blood cells and then carried in plasma as dissolved HCO_3^- . The rest is either dissolved in plasma as CO_2 or transported within the red blood cells bound to hemoglobin.

The Nervous System Regulates Breathing

- Respiratory center is located in the medulla oblongata (brain stem)
 - Establishes basic breathing pattern
 - Neurons in medulla generate impulses every 4 – 5 seconds
 - Stimulates intercostal muscles and diaphragm

Chemical Receptors Monitor CO_2 , H^+ , and O_2 levels

- Monitoring of CO_2 levels
 - Receptors in medulla oblongata monitor CO_2 levels indirectly
 - $\uparrow P_{\text{CO}_2}$ in arterial blood will cause $\uparrow$ in H^+ in cerebrospinal fluid, which will signal medulla oblongata to $\uparrow$ respiratory rate
 - This is the primary regulator of respiration under normal conditions

Chemical Receptors Monitor CO_2 , H^+ , and O_2 levels

- Monitoring P_{O_2}
 - Aortic and carotid bodies monitor P_{O_2}
 - Become activated if P_{O_2} falls by at least 20%
 - Will increase rate and depth of breathing in response to sufficiently lowered arterial P_{O_2}
- The rate and depth of normal breathing is determined by the need to get rid of CO_2 rather than the need to obtain O_2

We Can Exert Some Conscious Control

- Conscious control resides in the cerebral cortex
 - Able to modify breath to speak and sing
 - Able to hold breath temporarily, but can't override automatic controls located in medulla oblongata indefinitely

The respiratory center: establishes a regular pattern of breathing

1 Receptor cells near the respiratory center respond to changes in cerebrospinal fluid H^+ caused by increases in arterial CO_2 .

2 Receptor cells in the carotid and aortic bodies respond to large decreases in arterial O_2 .

3 Higher centers in the cortex can exert conscious control over respiration.

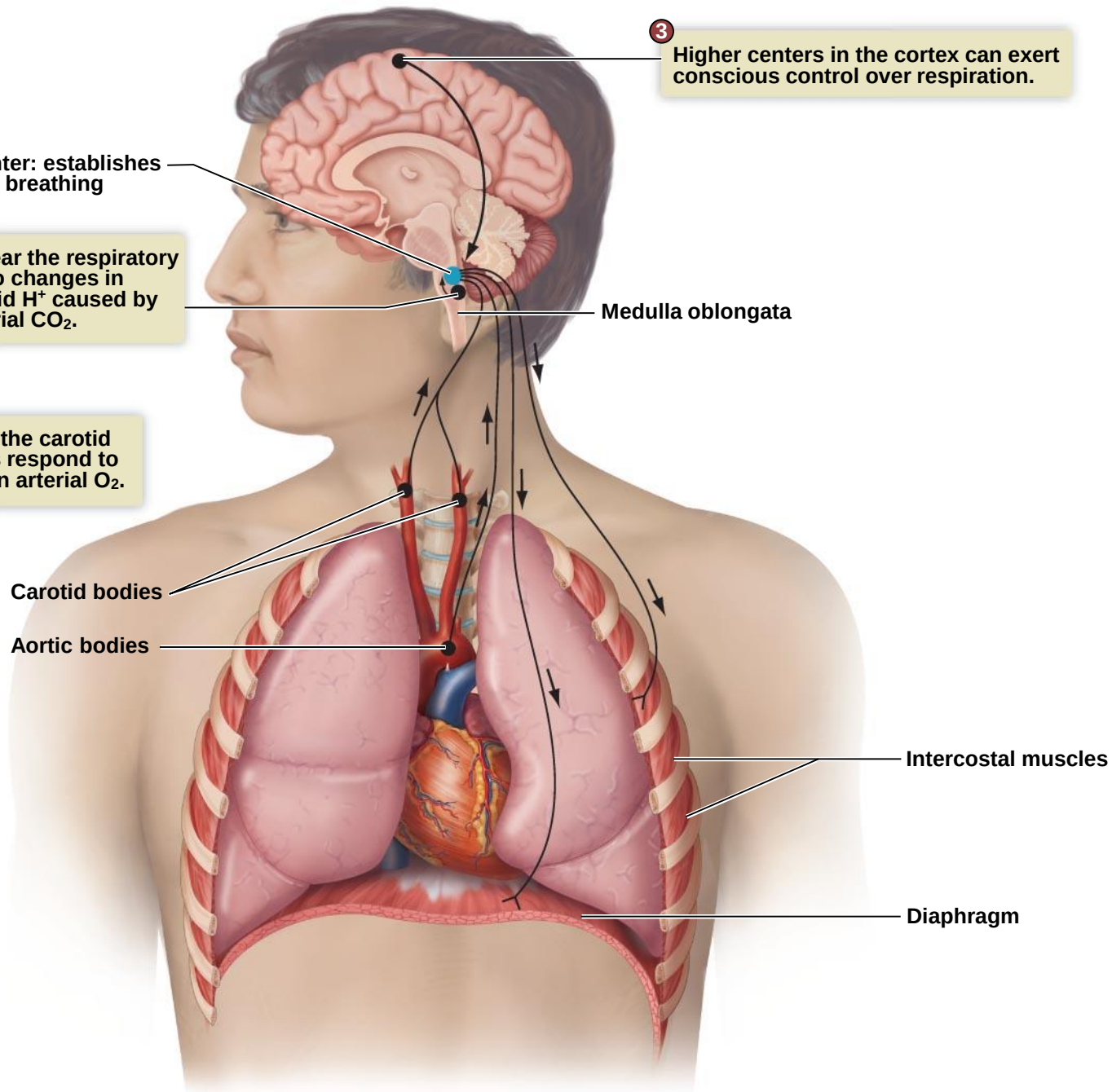
Medulla oblongata

Carotid bodies

Aortic bodies

Intercostal muscles

Diaphragm



Disorders of Respiratory System: Reduced Air Flow or Gas Exchange

- **Asthma:** spasmodic contraction of bronchi
 - Caused by episodic allergic responses
 - Controlled by bronchodilators and corticosteroids
- **Emphysema:** alveoli permanently impaired
 - Breathlessness due to decreased surface area for gas exchange
 - Most cases result from smoking

Disorders of Respiratory System: Reduced Air Flow or Gas Exchange

- **Bronchitis:** inflammation of bronchi
 - May be acute or chronic
 - Most cases related to smoking or air pollution
- **Cystic Fibrosis:** an inherited condition
 - Abnormally thick mucus in lungs impedes air flows
 - Frequent pulmonary infections
 - Other organ systems may be affected

Disorders of Respiratory System: Respiratory Infections

- Upper respiratory infections
 - **Colds and flu**
 - Caused by viruses
 - Antibiotics not effective
 - **Pneumonia:** infection of the lungs
 - May be caused by bacteria or viruses
 - One of the top 10 causes of death in the United States
 - Treatment depends on cause

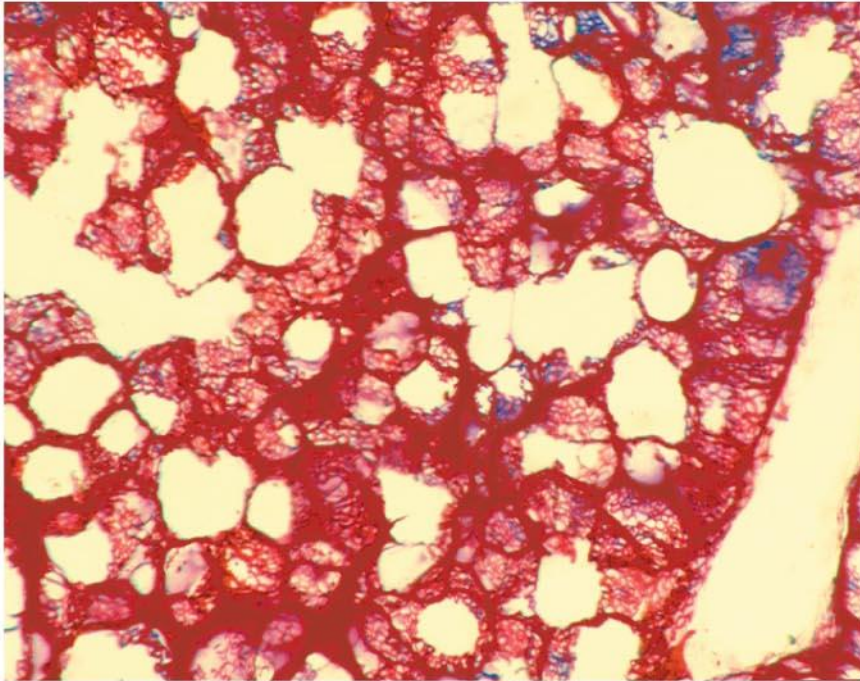
Disorders of Respiratory System: Respiratory Infections and Intoxications

- **Tuberculosis:** bacterial infection that scars the lungs
 - May be active infection with symptoms, or dormant infection that will reactivate later
 - Diagnosis: tuberculin skin test and chest X-ray
 - Treatment: antibiotics

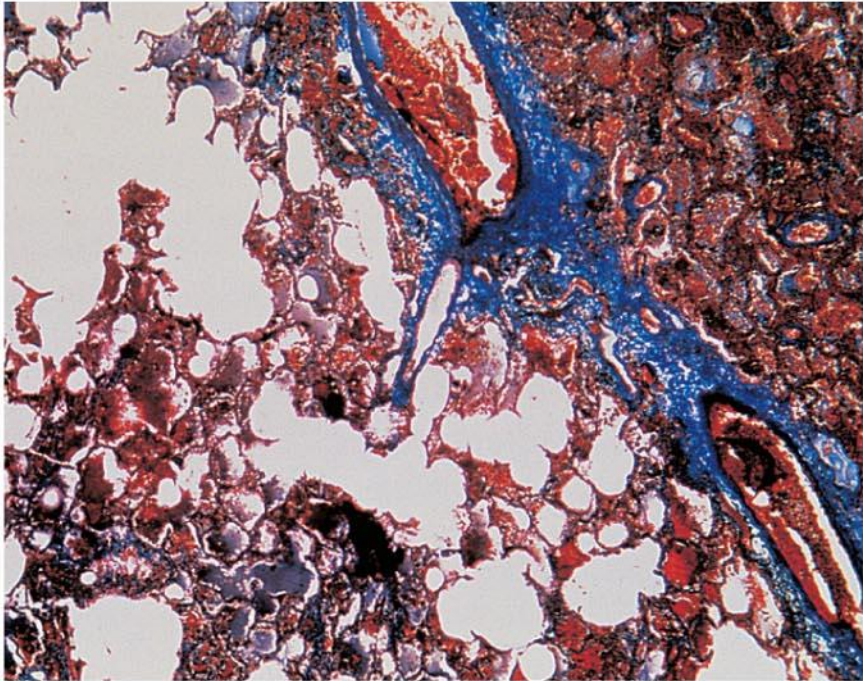
Disorders of Respiratory System:

Lung Cancer

- Cancer
 - uncontrolled growth of abnormal cells
- Impairs air flow, gas exchange, blood flow
- 1/3 of all U.S. cancer deaths
- Causes
 - **90%** of cases associated with smoking
 - Radon gas
 - Workplace chemicals such as asbestos



a) Normal lung.



b) Cancerous lung.

Pneumothorax and Atelectasis

- **Pneumothorax:** collapse of one or more lobes of the lungs
 - Most often due to penetrating wound
 - Inability to inflate the lung → poor gas exchange
 - Treatment: remove air from pleural cavity

Congestive Heart Failure Impairs Lung Function

- Congestive heart failure
 - heart becomes a less efficient pump
- Failure of left side of heart
 - Blood pressure increases within pulmonary capillaries
 - Fluid build-up occurs in pulmonary interstitial spaces and alveoli
 - Impaired gas exchange
- Treatment: improve pumping action of heart and remove fluid