

# HUMAN BIOLOGY

Seventeenth Edition

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## Chapter 10 Respiratory System

# 10.1 The Respiratory System 2

## The respiratory system.

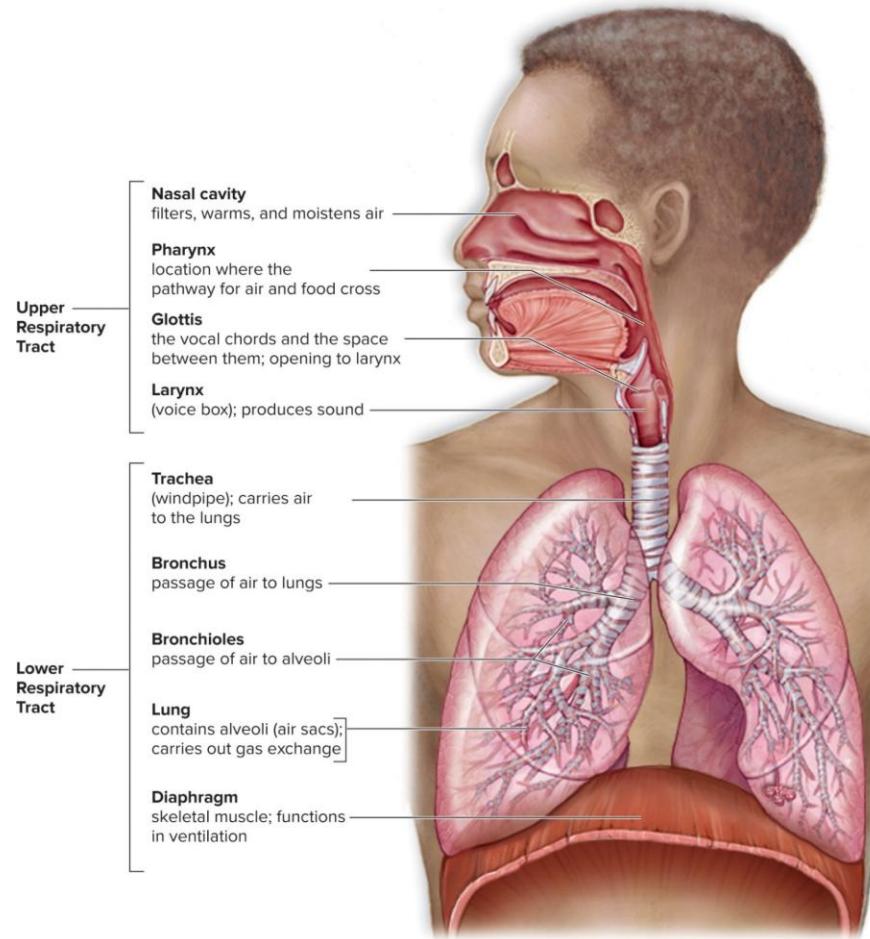
- Ensures that oxygen enters the body and carbon dioxide leaves the body.
- During **inspiration**, or inhalation, air moves from the atmosphere to the lungs through cavities and tubes.
- During **expiration**, or exhalation, air moves from the lungs to the atmosphere via the same structures.

# 10.1 The Respiratory System <sub>1</sub>

## Learning Outcomes:

- Summarize the role of the respiratory system in homeostasis.
- Distinguish between inspiration and expiration.
- Identify the structures of the human respiratory system.

# The Human Respiratory Tract (Figure 10.1)



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# 10.1 The Respiratory System 3

The **respiratory system**, concluded.

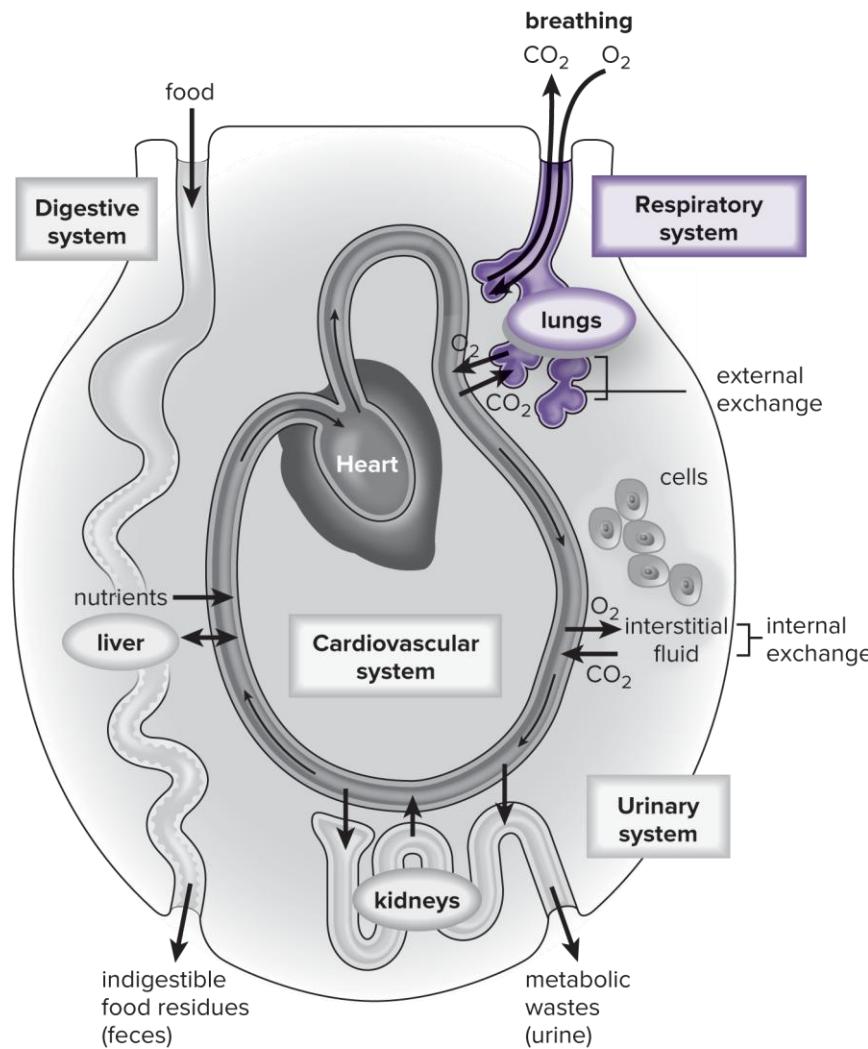
- **Ventilation** (breathing)—inspiration and expiration.
- Depends on the cardiovascular system to transport oxygen from the lungs to the tissues and carbon dioxide from the tissues to the lungs.
- During cellular respiration, cells use up oxygen and produce carbon dioxide.

# The Respiratory System and Homeostasis

Ways the respiratory system works with the cardiovascular system to maintain homeostasis:

- External respiration, the exchange of gases (oxygen and carbon dioxide) between air and the blood.
- Transport of gases to and from the lungs and the tissues.
- Internal respiration, the exchange of gases between the blood and tissue fluid.

# The Respiratory System and Homeostasis (Figure 10.2)



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# Check Your Progress 10.1

Trace the path of air from the nasal cavities to the lungs.

Explain how the flow of air differs during inspiration and expiration.

Describe the function(s) of the respiratory system.

# 10.2 The Upper Respiratory Tract <sub>1</sub>

## Learning Outcomes:

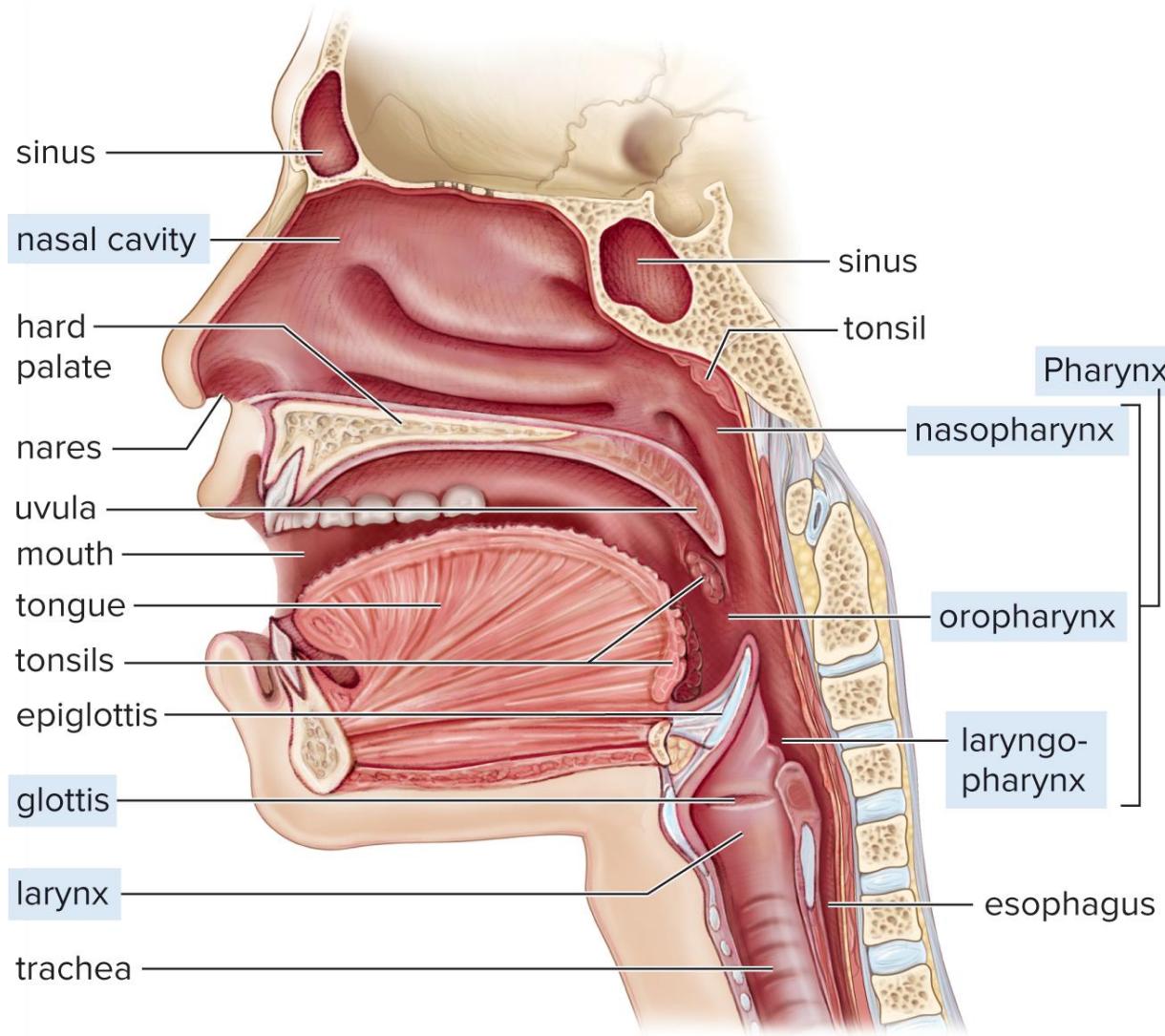
- Summarize the role of the nose, pharynx, and larynx in respiration.
- Identify the structures of the upper respiratory system and provide their function.
- Explain how sound is produced by the larynx.

# 10.2 The Upper Respiratory Tract <sub>2</sub>

**The upper respiratory tract includes:**

- The **nasal cavities**.
- The **pharynx**.
- The **larynx**.

# The Upper Respiratory Tract (Figure 10.3)



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# The Nose <sub>1</sub>

The **nose** opens at the **nares** (nostrils), which lead to the **nasal cavities**.

- The nasal cavities are separated from each other by a **septum** composed of bone and cartilage.
- **Hairs** filter the air and trap small particles so they don't enter air passages.

# The Nose 2

Nasal cavities, continued.

Lined with mucous membrane.

- The mucus helps trap particles and move them to the pharynx, where they can be swallowed or expectorated.

Under the mucous layer is the **submucosa**, which contains lots of capillaries that help warm and moisten the incoming air.

- The abundance of capillaries makes us susceptible to nosebleeds.

# The Nose 3

Nasal cavities, continued.

Contain odor receptors.

Tear glands in the eye drain into the nasal cavities by way of tear ducts.

- Crying causes a runny nose.

The nasal cavities also connect with the **sinuses** of the skull.

- Fluid may accumulate in these sinuses, causing an increase in pressure, sinus headache.

# The Nose 4

Nasal cavities, concluded.

Air in the nasal cavities passes into the **nasopharynx**, the upper portion of the pharynx.

**Auditory tubes (eustachian tubes)** connect the nasopharynx to the middle ear.

- When air pressure inside the middle ears equalizes with the air pressure in the nasopharynx, the auditory tube openings may create a “popping” sensation.

# The Pharynx

The **pharynx** (throat)—funnel-shaped cavity that connects the nasal and oral cavities to the larynx.

- Has three portions: **nasopharynx**, **oropharynx**, and **laryngopharynx**.

**Tonsils**—made of lymphoid tissue at the junction of the oral cavity and pharynx.

- Provide defense against inhaled pathogens.

# The Larynx <sub>1</sub>

## The larynx.

- Cartilaginous structure between the pharynx and the trachea.
- The Adam's apple (laryngeal prominence) is located at the front of the neck.

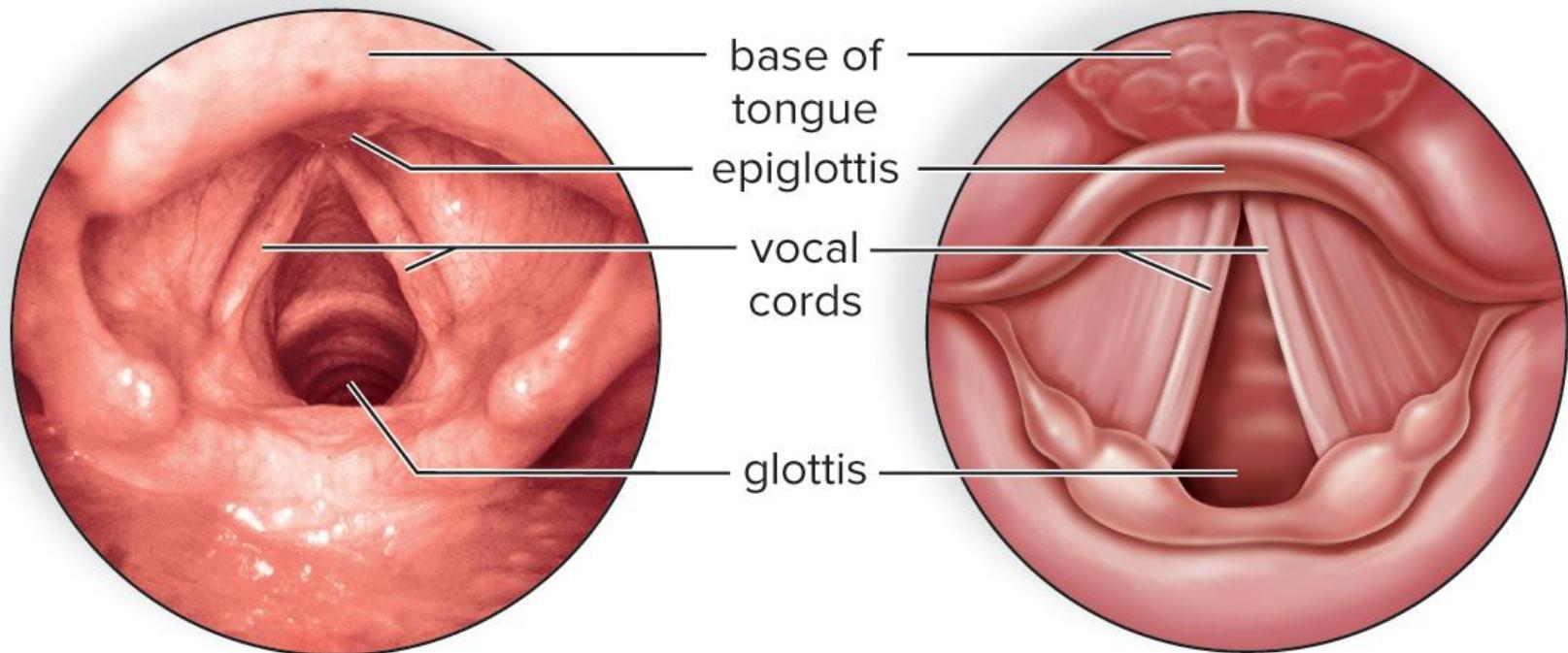
# The Larynx 2

## The larynx, continued.

Houses the **vocal cords**—mucosal folds supported by elastic ligaments.

- The slit between the vocal cords is called the **glottis**.
- When air passes through the glottis, the vocal cords vibrate, producing sound.
- The greater the tension in the vocal cords, the higher the pitch.
- When the glottis is wider, the pitch is lower.
- Loudness depends on the degree to which the vocal cords vibrate.

# The Vocal Cords (Figure 10.5)



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# The Larynx 3

## The larynx, concluded.

- When food is swallowed, the larynx moves upward against the **epiglottis**—a flap of tissue that prevents food from passing into the larynx.

# Check Your Progress 10.2

Describe the function of each of the structures of the upper respiratory tract.

Name and briefly describe the body systems that have connections with the pharynx.

Explain how sound is produced by the body.

# 10.3 The Lower Respiratory Tract <sup>1</sup>

## Learning Outcomes:

- Summarize the role of the trachea, bronchial tree, and lungs in respiration.
- Identify the structures of the lower respiratory tract and provide their function.
- Explain how the alveoli increase the efficiency of the respiratory system.

# 10.3 The Lower Respiratory Tract <sub>2</sub>

**The lower respiratory tract includes:**

- The **trachea**.
- The **bronchial tree**.
- The **lungs**.

# The Trachea 1

## The trachea.

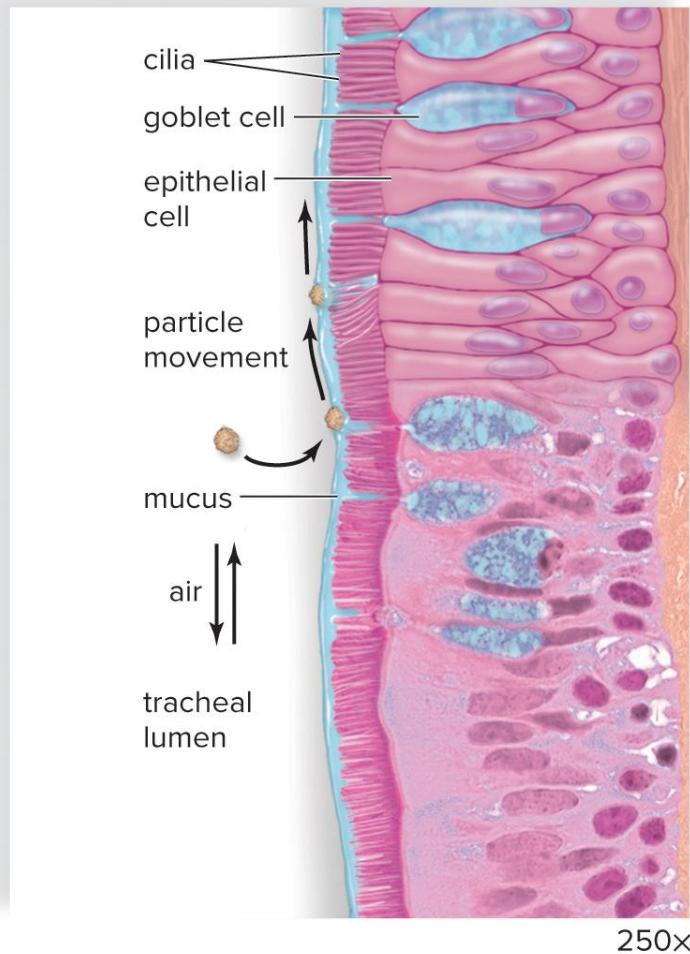
Commonly called the “windpipe.”

Connects the larynx to the **primary bronchi**.

Its walls are reinforced by C-shaped cartilaginous rings, which prevent the trachea from collapsing.

- The C shape allows the esophagus to expand into the trachea when swallowing.

# The Cells Lining the Trachea (Figure 10.6)



# The Trachea 2

## The trachea, continued.

Lined with pseudostratified ciliated columnar epithelium and goblet cells.

- The goblet cells produce mucus, which traps debris from the air as it passes through the trachea.
- The mucus is then swept away from the lungs and toward the pharynx by the cilia.
  - Smoking damages the cilia, causing smoker's cough.

**Tracheostomy**—a breathing tube inserted into the trachea.

# The Bronchial Tree <sub>1</sub>

## The bronchial tree.

Two **primary bronchi** (*sing.*, bronchus) lead from the trachea into the lungs.

The primary bronchi branch into **secondary bronchi**, which continue to branch until they are small **bronchioles** about 1 mm in diameter.

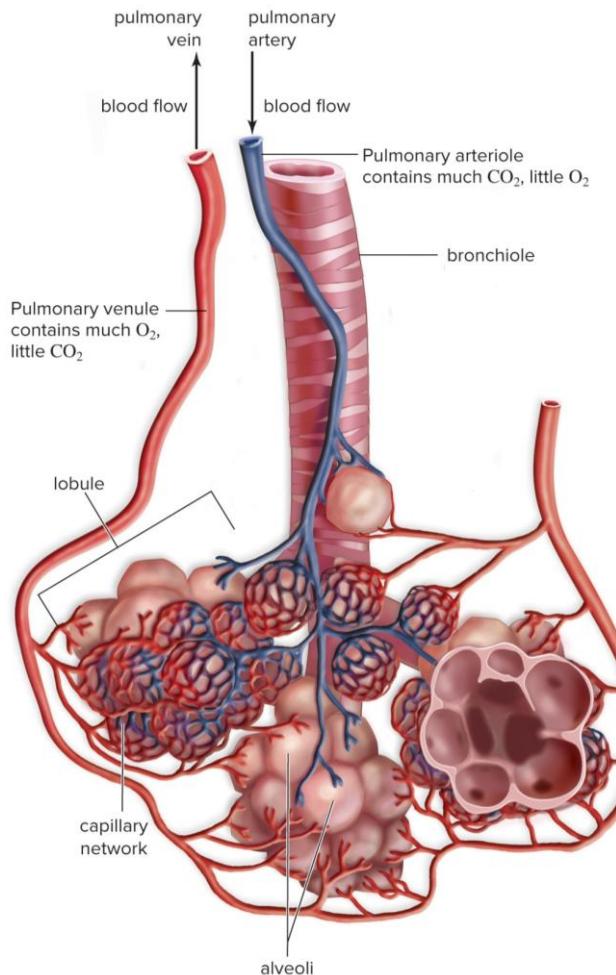
- Bronchi have cartilage like the trachea, but as they get smaller, the cartilage disappears.

# The Bronchial Tree <sub>2</sub>

## The bronchial tree, continued.

- During an asthma attack, the smooth muscle of the bronchioles contracts, constricting it and causing wheezing.
- Each bronchiole leads to an elongated space enclosed by many air sacs called **alveoli** (*sing.*, alveolus).

# Alveoli and Pulmonary Circulation (Figure 10.7)



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# The Lungs 1

## The lungs.

- Made up of the secondary bronchi, bronchioles, and alveoli.
- The right lung has three lobes while the left lung has two lobes (to make room for the heart).
- Each lobe is divided into lobules.
- Each lung is enclosed by **pleurae** (*sing.*, pleura)—two layers of serous membrane that produce **serous fluid**.

# The Lungs 2

## The lungs, continued.

The pleural fluid has surface tension, which adheres the parietal and visceral pleurae.

- Surface tension is due to hydrogen bonds between water molecules.
- Because of surface tension, when the thoracic cavity enlarges, the parietal pleura “pulls” the visceral pleura, and therefore the lungs, outward.
  - This increases the size of the lungs.

**Pleurisy**—inflammation of the pleurae; painful.

# The Alveoli <sub>1</sub>

## Alveoli.

- The lungs have about 300 million alveoli.
- Each alveolar sac is surrounded by blood capillaries.
- The walls of the sac and the capillaries are both made of simple squamous epithelium.
- Gas exchange occurs between air in the alveoli and blood in the capillaries.

# The Alveoli 2

## Alveoli, continued.

Oxygen diffuses across the alveolar wall and enters the bloodstream, and carbon dioxide diffuses from the blood into the alveoli.

The alveoli are lined with **surfactant**, a film of lipoprotein that lowers the surface tension of water and prevents the alveoli from closing.

- **Infant respiratory distress syndrome**—when premature infants don't make enough surfactant; the alveoli collapse.

# Check Your Progress 10.3

Briefly describe the functions of the organs of the lower respiratory system.

Trace the movement of gas in the organs of the lower respiratory system.

Explain why the alveoli have a high surface area.

# 10.4 Mechanism of Breathing <sup>1</sup>

## Learning Outcomes:

- Contrast the processes of inspiration and expiration during ventilation.
- Define the terms *tidal volume*, *vital capacity*, and *residual volume* in relation to ventilation.
- Summarize the purpose of the inspiratory and expiratory reserve volumes.

# 10.4 Mechanism of Breathing <sup>2</sup>

**Ventilation** (breathing), has two phases:

- **Inpiration** (inhalation) moves air into the lungs.
- **Expiration** (exhalation) moves air out of the lungs.

To understand ventilation, it is necessary to remember the following facts:

- Normally there is a continuous column of air from the pharynx to the alveoli of the lungs.

# 10.4 Mechanism of Breathing <sup>3</sup>

## Ventilation facts, continued.

The lungs lie within the sealed thoracic cavity.

- **Rib cage**—top and sides of the thoracic cavity.
- **Intercostal muscles**—between the ribs.
- **Diaphragm**—floor of the thoracic cavity.

The lungs adhere to the thoracic wall by way of the pleura.

- Space between the two pleurae is minimal and filled with **pleural fluid**.

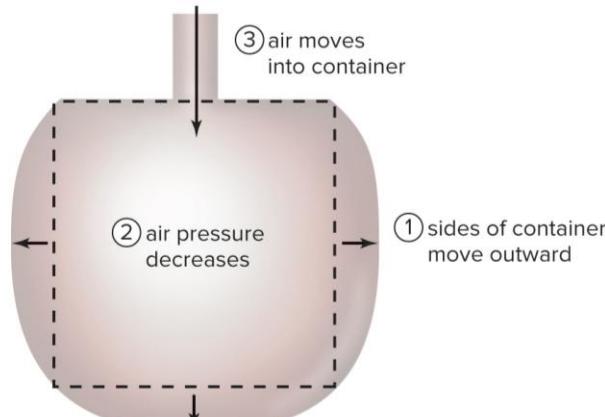
# 10.4 Mechanism of Breathing <sup>4</sup>

**Ventilation facts, concluded.**

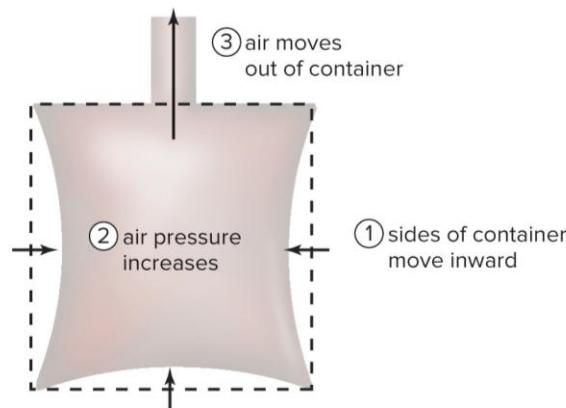
**Ventilation is governed by Boyle's Law.**

- At a constant temperature, the pressure of a given quantity of gas is inversely proportional to its volume.
  - This relationship controls inhalation and exhalation.

# The Relationship Between Air Pressure and Volume (Figure 10.8)



a. Inhalation



b. Exhalation

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# Inspiration <sub>1</sub>

## Inspiration.

The active phase of ventilation.

The diaphragm and the external intercostal muscles contract.

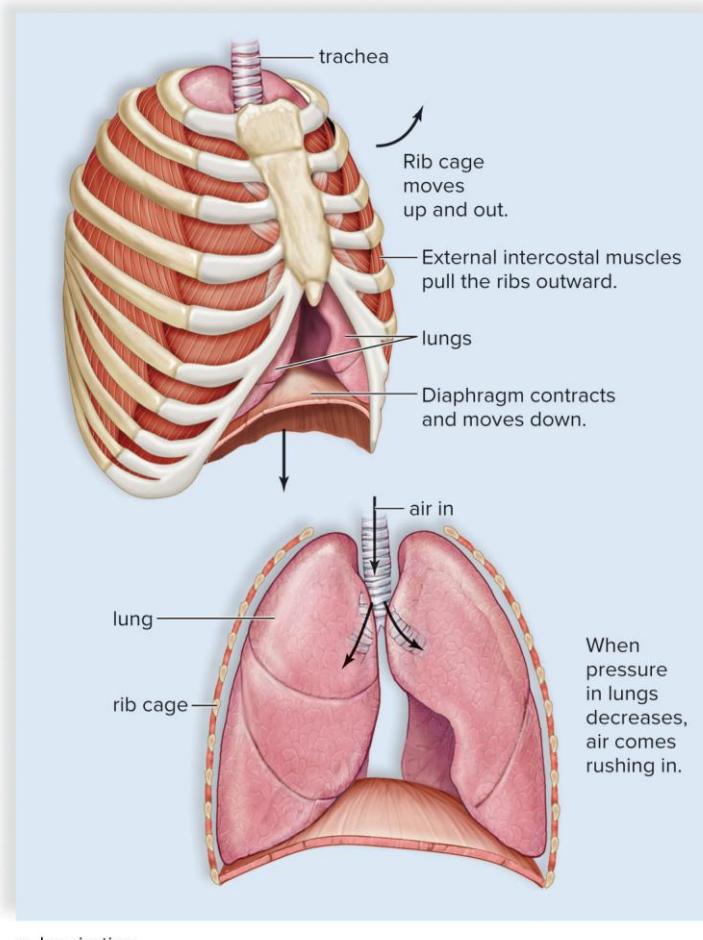
- In its relaxed state, the diaphragm is dome-shaped; during inspiration, it contracts and becomes flattened.
- Contraction of the external intercostal muscles causes the rib cage to move upward and outward.
- Both actions increase the size of the thoracic cage.

# Inspiration <sub>2</sub>

## Inspiration, continued.

- As the thoracic volume increases, the lungs increase in volume as well, because the lung adheres to the wall of the thoracic cavity.
- As the lung volume increases, the air pressure in the alveoli decreases.
- Alveolar pressure is now less than atmospheric pressure, so air flows from outside the body into the lungs.

# The Thoracic Cavity During Inspiration and Expiration (Figure 10.9a)



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# Expiration <sub>1</sub>

## Expiration.

- The passive phase of breathing; the diaphragm and external intercostal muscles relax.
- The rib cage returns to its resting position, moving down and inward.
- The lungs recoil, and the air pressure inside increases; air flows out.

# Expiration <sub>2</sub>

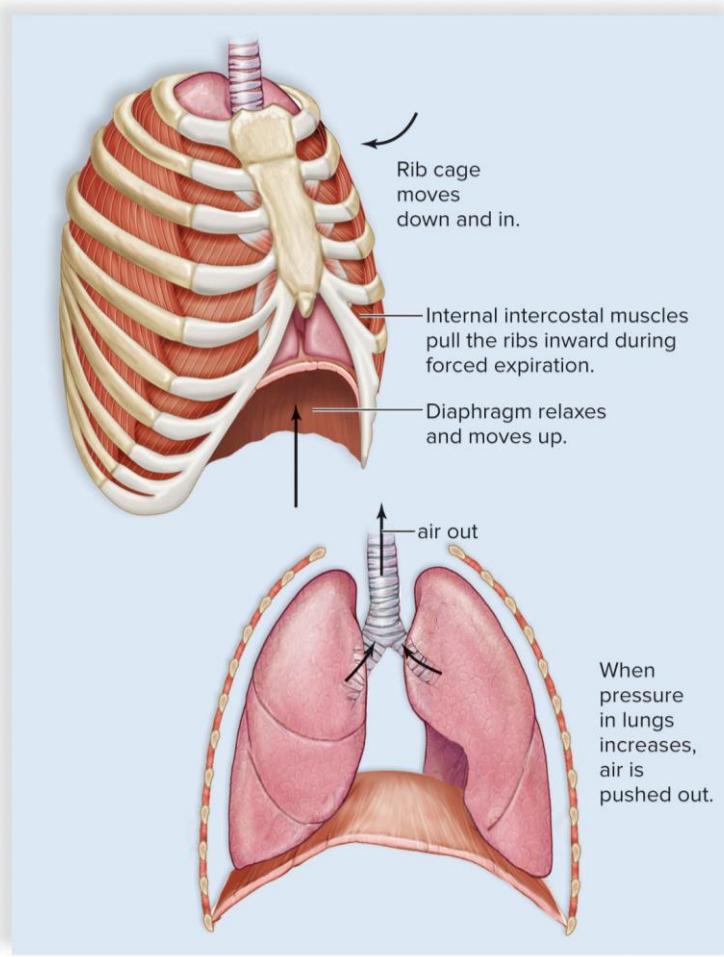
## Expiration, continued.

Surfactant keeps the alveoli from collapsing during expiration.

Also, as the lungs recoil, the pressure between the pleurae decreases, and this keeps the alveoli open.

- When, in an accident, the thoracic cavity is punctured (a “punctured lung”), air enters the space between the two pleurae, causing the lung to collapse.

# The Thoracic Cavity During Inspiration and Expiration (Figure 10.9b)



b. Expiration

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# Maximizing Inspiration and Expiration <sup>1</sup>

Breathing hard (maximum inspiratory effort) uses muscles of the back, chest, and neck.

- Increases the size of the thoracic cavity more than usual, allowing maximum expansion of the lungs.

# Maximizing Inspiration and Expiration <sup>2</sup>

Expiration can also be forced.

- That is, singing, blowing air.
- Contraction of the internal intercostal muscles forces the rib cage downward and inward.
- Also, when abdominal muscles contract, they push on the abdominal organs, which push upward against the diaphragm, forcing air out.

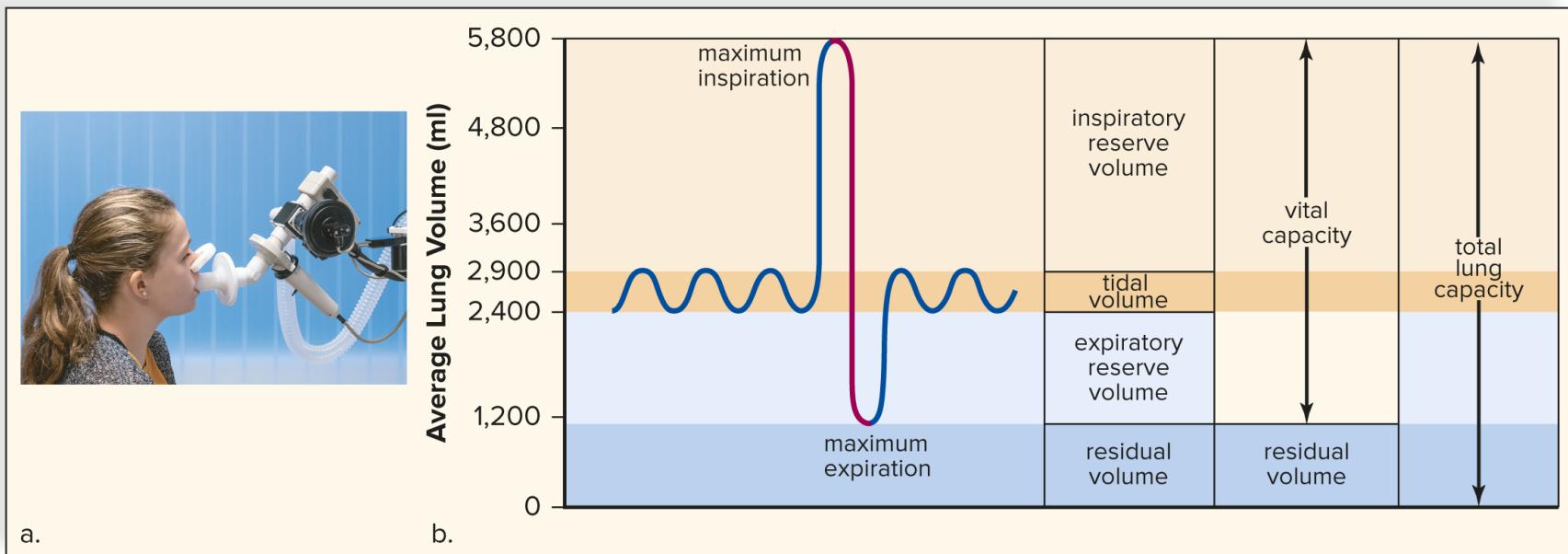
# Volumes of Air Exchanged During Ventilation <sub>1</sub>

**Tidal volume**—the amount of air that moves in and out with each normal breath.

**Vital capacity**—the maximum volume that can be moved in plus the maximum amount that can be moved out during one breath.

**Inspiratory and expiratory reserve volume**—the increased volume of air moving in or out of the body with forced inspiration and expiration.

# Measuring the Air Capacity of the Lungs (Figure 10.10)



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# Volumes of Air Exchanged During Ventilation 2

Vital capacity is the sum of tidal, inspiratory reserve, and expiratory reserve volumes.

Some inhaled air never reaches the lungs; it fills the nasal cavities, trachea, bronchi, and bronchioles.

- These passages are not used for gas exchange; they contain **dead air space**.

**Residual volume**—the air remaining in the lungs after exhalation.

# Check Your Progress 10.4

Explain how the volume of the thoracic cavity affects the pressure in the lungs.

Distinguish between the different volumes of air exchanged during ventilation.

Discuss what effect insufficient expiration might have on overall homeostasis.

# 10.5 Control of Ventilation <sub>1</sub>

## Learning Outcomes:

- Explain how the nervous system controls the process of breathing.
- Explain the role of chemoreceptors and pH levels in regulating breathing rate.

# 10.5 Control of Ventilation <sup>2</sup>

Breathing is controlled by nervous and chemical control mechanisms.

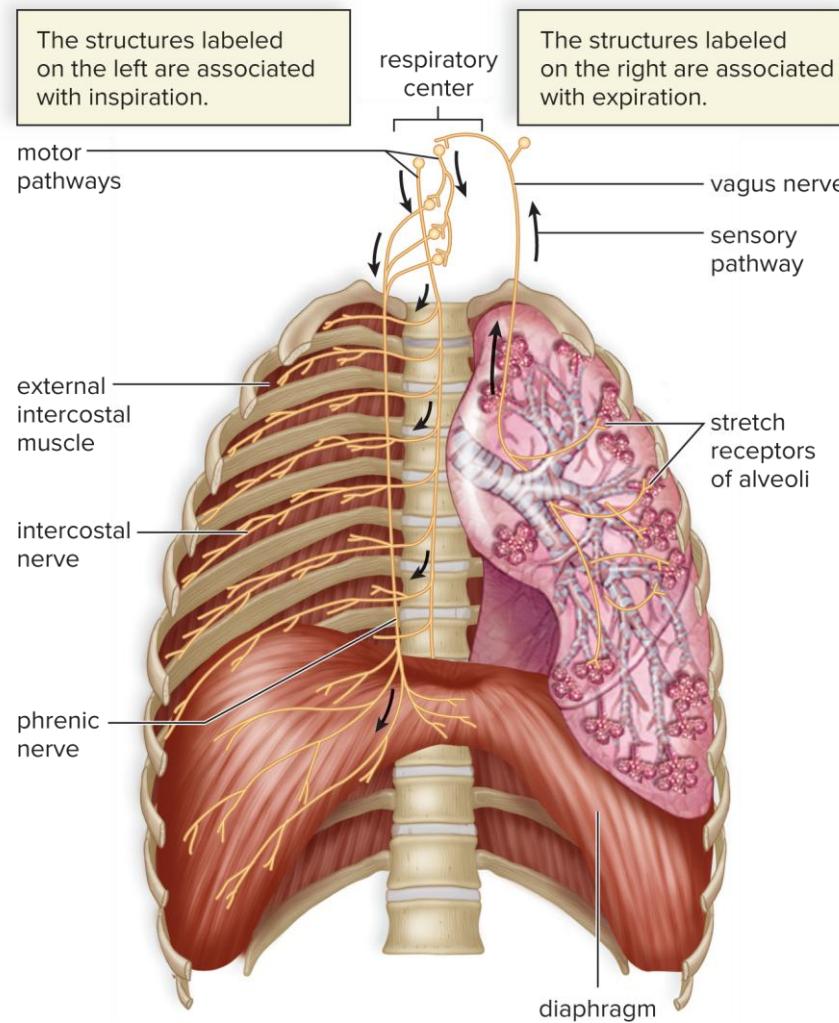
# Nervous Control of Breathing <sup>1</sup>

## Nervous control of breathing.

Respiratory control center in the brain automatically sends out nerve signals to the diaphragm and the external intercostal muscles of the rib cage, causing inspiration to occur.

- When the respiratory center stops sending nerve signals to the diaphragm and the rib cage, the muscles relax and expiration occurs.

# The Control of Breathing by the Respiratory Center (Figure 10.11)



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# Nervous Control of Breathing <sup>2</sup>

**Sudden infant death syndrome (SIDS) or crib death.**

- An infant under 1 year is put to bed seemingly healthy, and sometime while sleeping the child stops breathing.
- The cause of SIDS is not known, but vaccinations, vomiting, and infections have been ruled out as factors.
- Might be a miscommunication between the respiratory center of the brain and the lungs.

# Nervous Control of Breathing <sup>3</sup>

Nervous control of breathing, continued.

- Although the respiratory center automatically controls the rate and depth of breathing, it is influenced by the nervous system.
- Can voluntarily change our breathing pattern for speaking, singing, eating, swimming underwater.
- Following forced inspiration, stretch receptors in the airway walls initiate inhibitory nerve impulses that stop the respiratory center from sending out nerve signals and overstretching the lungs.

# Chemical Control of Breathing <sup>1</sup>

Chemical control of breathing.

Cells produce CO<sub>2</sub> during cellular respiration.

CO<sub>2</sub> then enters the blood, where it combines with water, forming an acid that breaks down and gives off hydrogen ions.

- These H<sup>+</sup> decrease the pH of the blood.

**Chemoreceptors**—sensory receptors that are sensitive to the chemical composition of body fluids.

# Chemical Control of Breathing <sup>2</sup>

Chemical control of breathing, continued.

Two sets of chemoreceptors sensitive to pH can cause breathing to speed up.

- One set is in the medulla oblongata of the brain stem.
- The other set is the **carotid bodies** of the carotid arteries, and **aortic bodies** of the aorta.
  - These chemoreceptors mostly respond to carbon dioxide levels of the blood.

# Chemical Control of Breathing <sup>3</sup>

Chemical control of breathing, concluded.

When blood pH decreases, the respiratory center increases the rate and depth of breathing to remove CO<sub>2</sub> from the blood.

- This increases the pH, so the breathing rate returns to normal.

When you hold your breath, CO<sub>2</sub> begins accumulating in the blood, decreasing the pH.

- The respiratory center, stimulated by the chemoreceptors, is able to override a voluntary inhibition of respiration, forcing breathing.

# Check Your Progress 10.5

Explain why chemoreceptors are important for the regulation of ventilation.

Describe the importance of the respiratory control center in the brain.

Discuss why it's not possible to hold your breath for more than a few minutes.

# 10.6 Gas Exchange in the Body <sup>1</sup>

## Learning Outcomes:

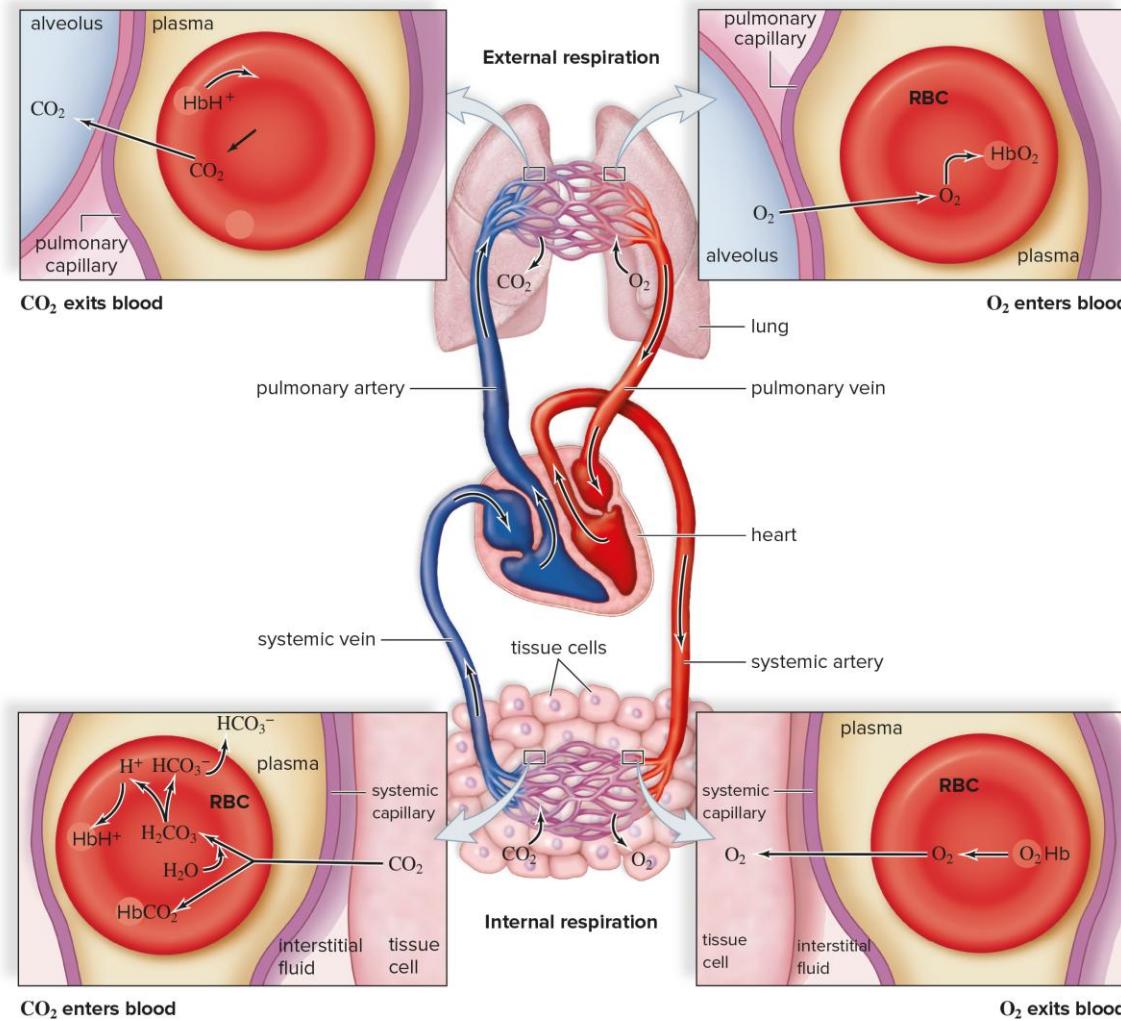
- Distinguish between external and internal respiration.
- Summarize the chemical processes involved in external and internal respiration.
- Identify the role of carbonic anhydrase and carbaminohemoglobin in respiration.

# 10.6 Gas Exchange in the Body <sup>2</sup>

## Gas exchange in the body.

- Oxygen is needed to produce ATP, so must be supplied to all the cells, and the carbon dioxide produced must be removed from the body.
- Respiration includes the exchange of gases not only in the lungs but also in the tissues.
- The principles of diffusion govern whether O<sub>2</sub> or CO<sub>2</sub> enters or leaves the blood.

# Movement of Gases During External and Internal Respiration (Figure 10.12)



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# 10.6 Gas Exchange in the Body <sup>3</sup>

Gas exchange in the body, continued.

- Gases exert pressure, and the amount of pressure each gas exerts is called its partial pressure, symbolized as  $P_{CO_2}$  or  $P_{O_2}$ .
- If the partial pressure of a gas differs across a membrane, it will diffuse from higher to lower partial pressure.

# External Respiration <sub>1</sub>

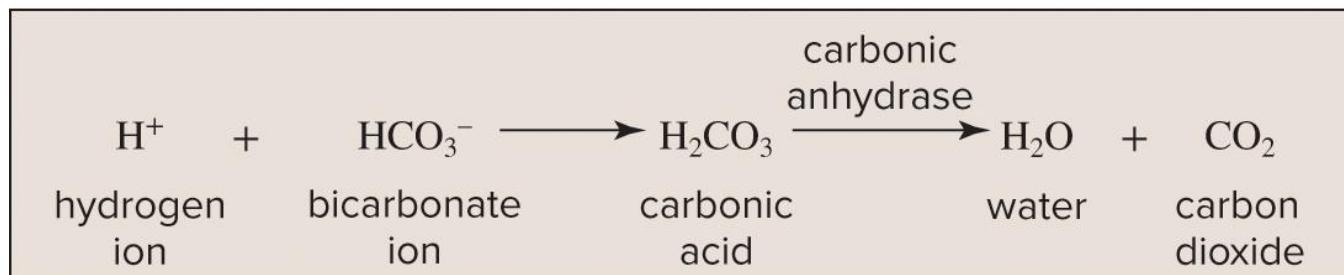
## External respiration.

- Exchange of gases between the lung alveoli and the blood capillaries.
- $P_{CO_2}$  is higher in the lung capillaries than the air; thus,  $CO_2$  diffuses out of the blood into the lungs.
- The partial pressure pattern for  $O_2$  is just the opposite, so  $O_2$  diffuses from the alveolar air into the red blood cells in the pulmonary capillaries.

# External Respiration <sub>2</sub>

## External respiration, continued.

- Most of the CO<sub>2</sub> is carried in plasma as **bicarbonate ions** (HCO<sub>3</sub><sup>-</sup>).
- In the low-P<sub>CO<sub>2</sub></sub> environment of the lungs, this reaction proceeds to the right:



# External Respiration 3

## External respiration, continued.

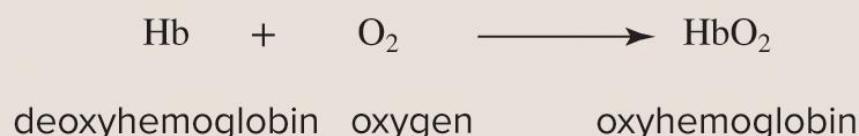
- **Carbonic anhydrase**—the enzyme that speeds the breakdown of carbonic acid ( $\text{H}_2\text{CO}_3$ ) in red blood cells.
- **Hyperventilation** (breathing at a high rate) pushes the reaction to the right; blood has fewer hydrogen ions; **alkalosis** (high blood pH) occurs.
- **Hypoventilation** (breathing at a low rate) pushes the reaction to the left; **acidosis** (low blood pH) occurs.

# External Respiration 4

## External respiration, concluded.

Pulmonary capillary blood is low in oxygen, and alveolar air has a higher partial pressure of oxygen.

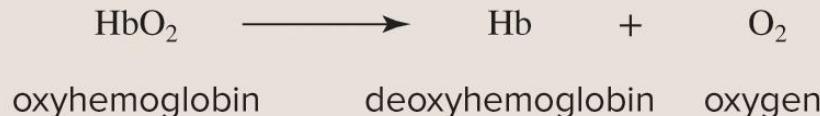
- Therefore,  $O_2$  diffuses *into plasma and then into red blood cells in the lungs.*
- Hemoglobin takes up oxygen and becomes **oxyhemoglobin ( $HbO_2$ )**.



# Internal Respiration <sub>1</sub>

## Internal respiration.

- Exchange of gases between the blood in systemic capillaries and the tissue cells.
- Blood entering systemic capillaries is bright red because red blood cells contain oxyhemoglobin.
- After  $\text{HbO}_2$  gives up  $\text{O}_2$ , it diffuses out of the blood into the tissues.



# Internal Respiration <sub>2</sub>

## Internal respiration, continued.

*Oxygen diffuses out of the blood into the tissues* because the  $P_{O_2}$  of interstitial fluid is lower than that of blood.

- The lower  $P_{O_2}$  is due to cells continuously using up oxygen during cellular respiration.

*Carbon dioxide diffuses into the blood from the tissues* because the  $P_{O_2}$  of interstitial fluid is higher than that of blood.

- Carbon dioxide is produced during cellular respiration and collects in interstitial fluid.

# Check Your Progress 10.6

Describe the differences between external respiration and internal respiration.

Describe how hemoglobin functions in the transport of both oxygen and carbon dioxide.

Detail the influence of  $P_{O_2}$  on both external and internal respiration.

# 10.7 Disorders of the Respiratory System

## Learning Outcomes:

- Identify the symptoms and causes of selected upper respiratory tract infections.
- Identify the symptoms and causes of selected lower respiratory tract disorders.
- Summarize how smoking is related to cancer and emphysema.

# Upper Respiratory Tract Infections <sub>1</sub>

## **Upper respiratory tract infections.**

- Can spread from the nose, nasal cavities, pharynx, and larynx, to the sinuses, middle ears.
- The upper respiratory tract is susceptible to viral and bacterial infections because it is responsible for filtering out pathogens and other materials in the air.

# **Upper Respiratory Tract Infections** 2

**Upper respiratory tract infections**, continued.

**Viral infections**—viruses that cause “colds.”

- Sneezing, runny nose, mild fever.

**Sinusitis**—blockage of sinuses.

**Tonsillitis**—inflammation of the tonsils.

- **Tonsillectomy**—surgical removal of the tonsils.

**Laryngitis**—infection of the larynx; leads to voice loss.

# Lower Respiratory Tract Disorders <sup>1</sup>

Lower respiratory tract disorders.

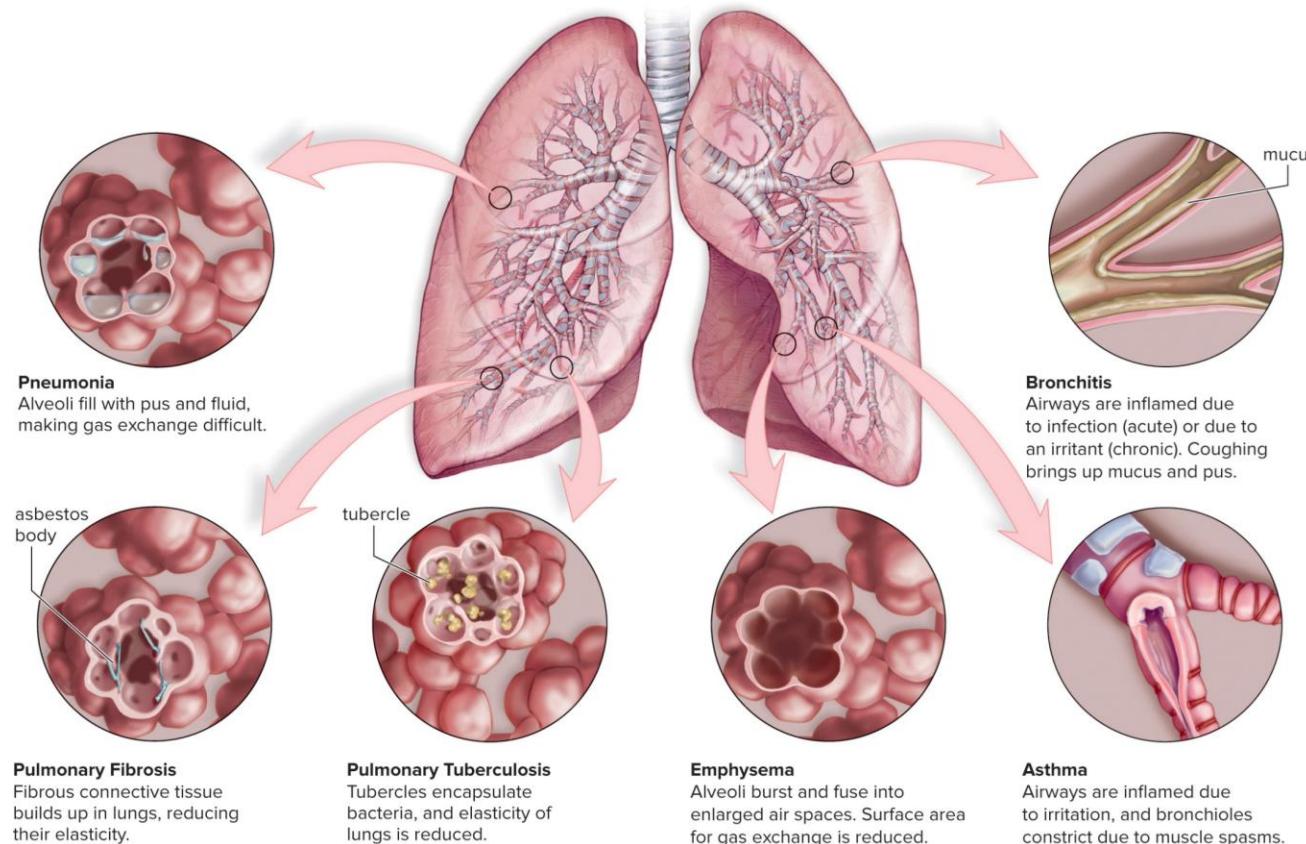
- Include **infections, restrictive pulmonary disorders, obstructive pulmonary disorders, and lung cancer.**

# Lower Respiratory Tract Disorders 2

## Lower respiratory infections.

- **Acute bronchitis**—infection of the primary and secondary bronchi.
- **Pneumonia**—bacterial or viral infection; the bronchi and alveoli fill with thick fluid.
- **Tuberculosis**—bacterial infection that leads to tubercles (encapsulated bacteria).

# Some Diseases and Disorders of the Respiratory System (Figure 10.13)



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# Lower Respiratory Tract Disorders 3

## **Restrictive pulmonary disorders.**

Vital capacity is reduced; lungs have lost elasticity.

That is, **pulmonary fibrosis**—fibrous connective tissue builds up in the lungs, usually because of inhaled particles like sand, coal dust, asbestos, fiberglass.

- Lungs cannot inflate properly.
- Can lead to cancer.

# Lower Respiratory Tract Disorders <sup>4</sup>

## Obstructive pulmonary disorders.

- Air does not flow freely in the airways.
- That is, **chronic bronchitis, emphysema, and asthma** are collectively referred to as **chronic obstructive pulmonary disease (COPD)** because they tend to recur.

# Lower Respiratory Tract Disorders <sup>5</sup>

## **Obstructive pulmonary disorders**, continued.

**Chronic bronchitis**—airways are inflamed and filled with mucus.

- Bronchi undergo degenerative changes, including the loss of cilia.
- Smoking is the most frequent cause.
- Exposure to other pollutants can also cause it.

# Lower Respiratory Tract Disorders <sub>6</sub>

## **Obstructive pulmonary disorders, continued.**

### **Emphysema.**

- Chronic and incurable.
- Alveoli are distended and their walls are damaged.
- Surface area for gas exchange is reduced, so less oxygen reaches the heart and the brain.
- Most often caused by smoking.
- Elastic recoil of the lungs is reduced, so not only are the airways narrowed but the driving force behind expiration is also reduced.

# Lower Respiratory Tract Disorders ,

## Obstructive pulmonary disorders, continued.

### Emphysema, continued.

- Lack of oxygen to the brain can make the person feel depressed, sluggish, and irritable.
- Severe emphysema may be treated by lung transplantation or **lung volume reduction surgery (LVRS)**.
  - A third of the most diseased lung tissue is removed, which enables the remaining tissue to function better.

# Lower Respiratory Tract Disorders 8

## Obstructive pulmonary disorders, concluded.

### Asthma.

- Symptoms: wheezing, breathlessness, and sometimes a cough and expectoration of mucus.
- When exposed to an irritant like pollen or tobacco smoke, the smooth muscle in the bronchioles spasms.
- Asthma is not curable, but it is treatable with special inhalers.

# Lower Respiratory Tract Disorders ,

## Lung cancer.

- More prevalent in men than in women.
- The first event in lung cancer is thickening of the lining of the bronchi.
- Then cilia are lost, making it impossible to prevent dust and dirt from settling in the lungs.
- Following this, cells with atypical nuclei appear in the lining.
- A tumor made of cells with atypical nuclei is considered cancer in situ (at one location).

# Lower Respiratory Tract Disorders <sup>10</sup>

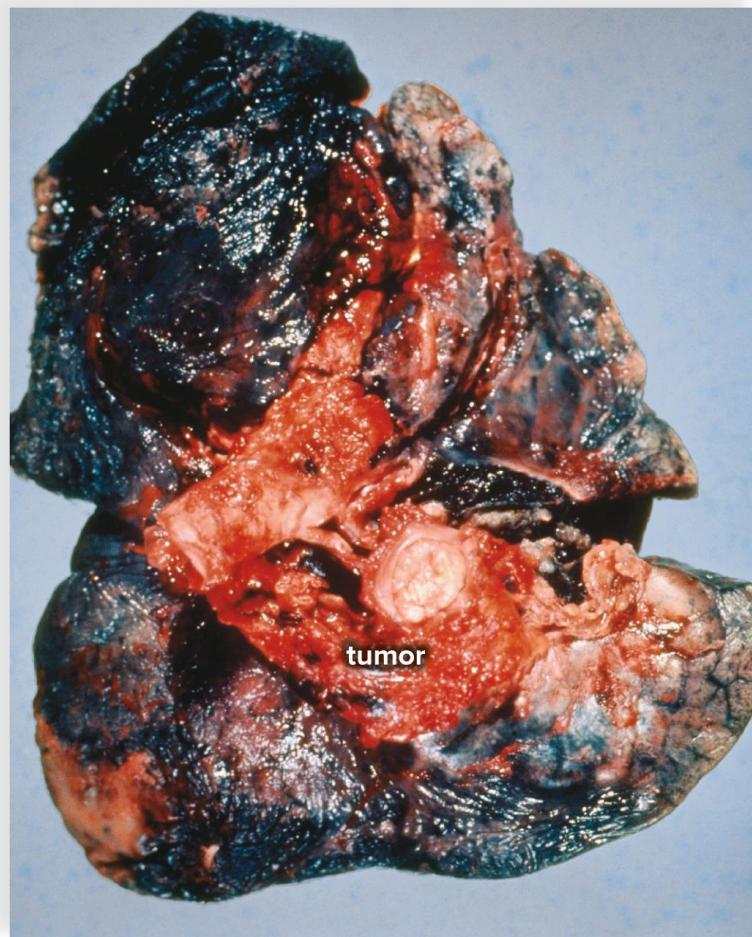
## Lung cancer, continued.

- The final step occurs when some of these cells break loose and penetrate other tissues (metastasis).
- The original tumor may grow until a bronchus is blocked, cutting off the supply of air to that lung.
- **Pneumonectomy** (removal of a lobe or the whole lung) needs to be performed before metastasis occurs.

# Effect of Smoking on a Human Lung (Figure 10.14)



a. Normal lung



b. Lung cancer