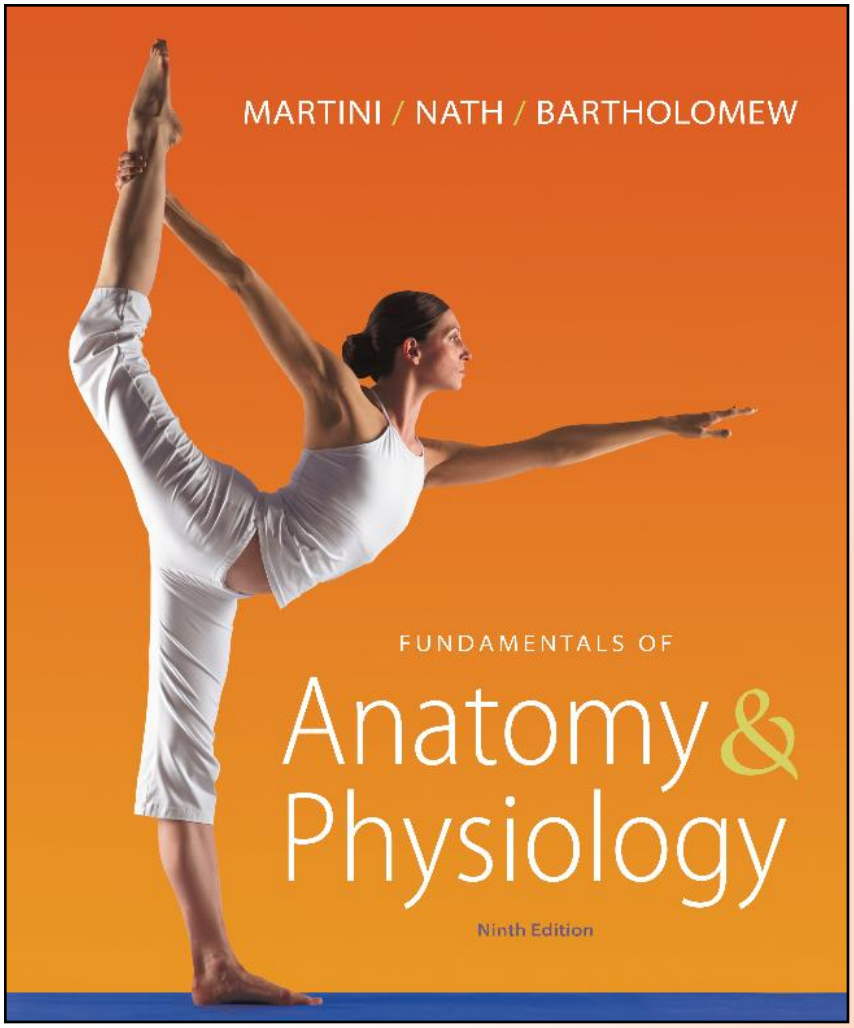


23

The Respiratory System

PowerPoint® Lecture Presentations prepared by Jason LaPres

Lone Star College—North Harris

An Introduction to the Respiratory System

- Learning Outcomes
  - **23-1** Describe the primary functions of the respiratory system, and explain how the delicate respiratory exchange surfaces are protected from pathogens, debris, and other hazards.
  - **23-2** Identify the organs of the upper respiratory system, and describe their functions.
  - **23-3** Describe the structure of the larynx, and discuss its roles in normal breathing and in the production of sound.

An Introduction to the Respiratory System

- Learning Outcomes
  - **23-4** Discuss the structure of the extrapulmonary airways.
  - **23-5** Describe the superficial anatomy of the lungs, the structure of a pulmonary lobule, and the functional anatomy of alveoli.
  - **23-6** Define and compare the processes of external respiration and internal respiration.

An Introduction to the Respiratory System

- Learning Outcomes
  - **23-7** Summarize the physical principles governing the movement of air into the lungs, and describe the origins and actions of the muscles responsible for respiratory movements.
  - **23-8** Summarize the physical principles governing the diffusion of gases into and out of the blood and body tissues.
  - **23-9** Describe the structure and function of hemoglobin, and the transport of oxygen and carbon dioxide in the blood.

An Introduction to the Respiratory System

- Learning Outcomes
  - **23-10** List the factors that influence respiration rate, and discuss reflex respiratory activity and the brain centers involved in the control of respiration.
  - **23-11** Describe age-related changes in the respiratory system.
  - **23-12** Give examples of interactions between the respiratory system and other organ systems studied so far.

An Introduction to the Respiratory System

- The Respiratory System
  - Cells produce energy
    - For maintenance, growth, defense, and division
    - Through mechanisms that use oxygen and produce carbon dioxide

An Introduction to the Respiratory System

- Oxygen
  - Is obtained from the air by diffusion across delicate exchange surfaces of lungs
  - Is carried to cells by the cardiovascular system, which also returns carbon dioxide to the lungs

23-1 Components of the Respiratory System

- Five Functions of the **Respiratory System**
  1. Provides extensive gas exchange surface area between air and circulating blood
  2. Moves air to and from exchange surfaces of lungs
  3. Protects respiratory surfaces from outside environment
  4. Produces sounds
  5. Participates in olfactory sense

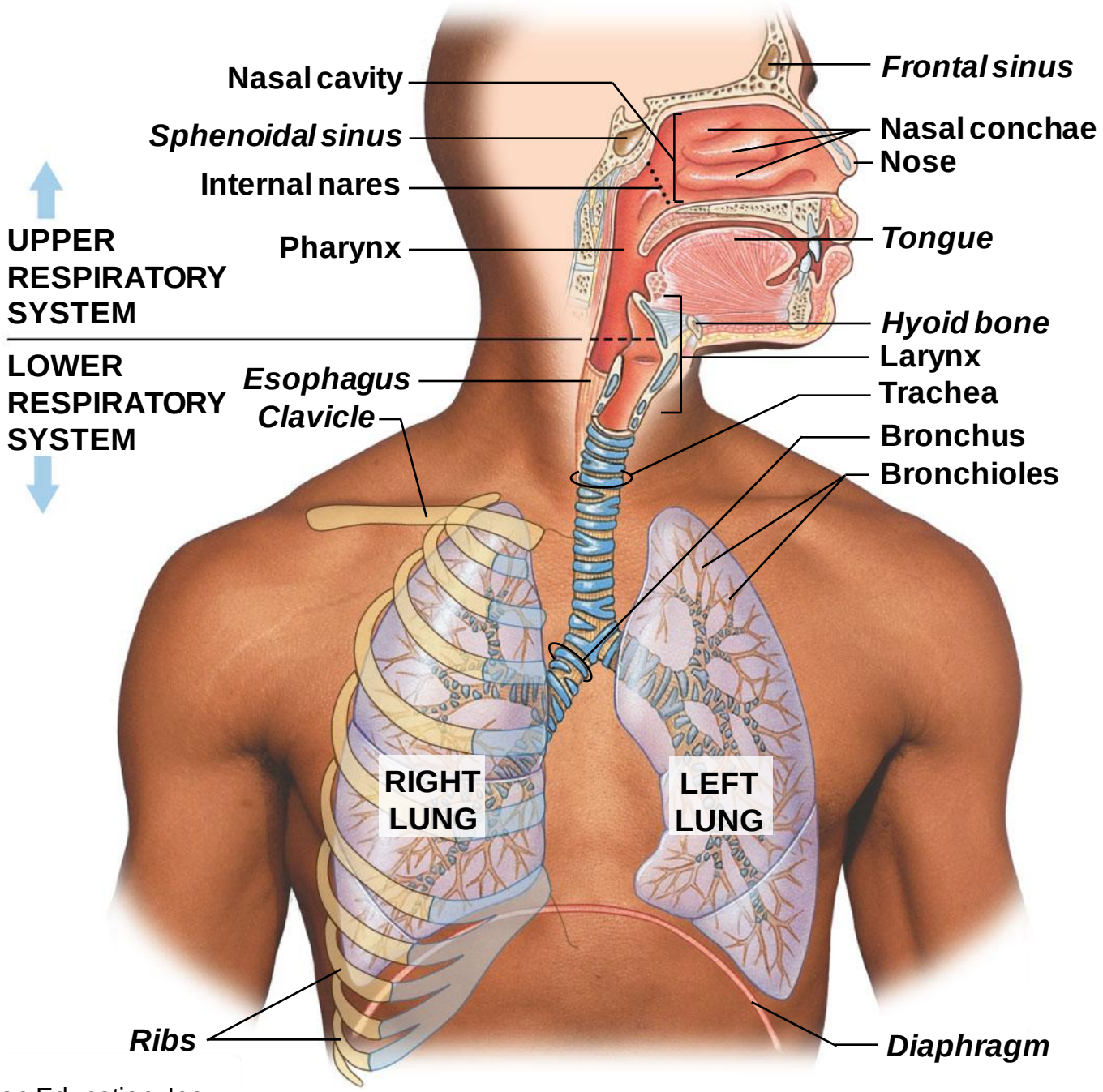
23-1 Components of the Respiratory System

- Organization of the Respiratory System
  - The respiratory system is divided into:
    - **Upper respiratory system** - above the larynx
    - **Lower respiratory system** - below the larynx

23-1 Components of the Respiratory System

- The **Respiratory Tract**
  - Consists of a *conducting portion*
    - From nasal cavity to terminal *bronchioles*
  - Consists of a *respiratory portion*
    - The respiratory bronchioles and alveoli
  - **Alveoli**
    - Are air-filled pockets within the lungs
      - Where all gas exchange takes place

Figure 23-1 The Components of the Respiratory System



23-1 Components of the Respiratory System

- The Respiratory Epithelium
  - For gases to exchange efficiently:
    - Alveoli walls must be very thin (<1 μm)
    - Surface area must be very great (about 35 times the surface area of the body)

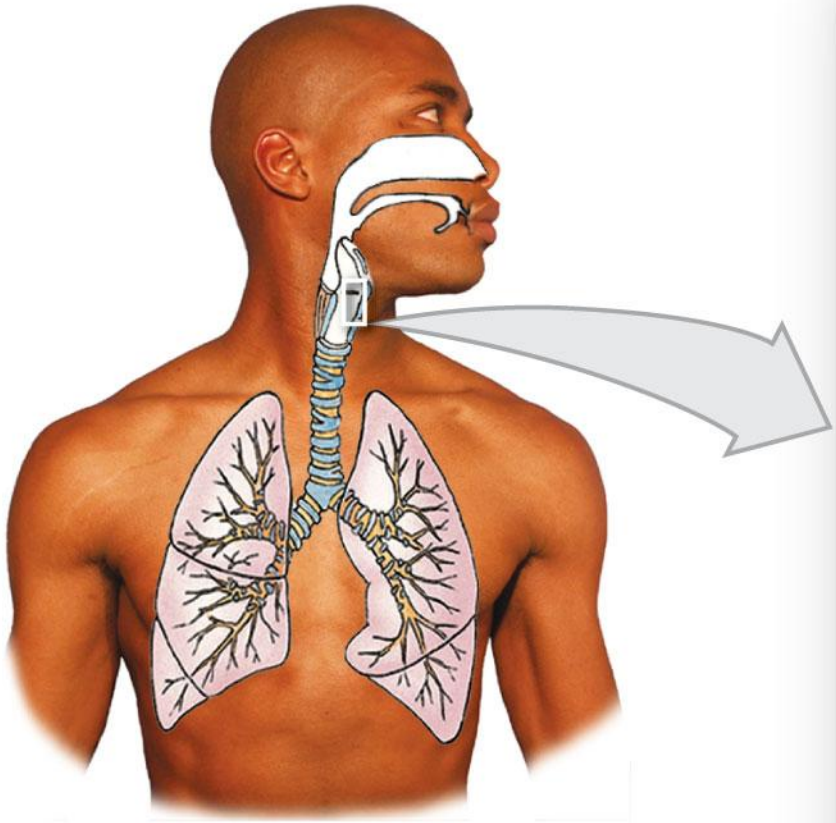
23-1 Components of the Respiratory System

- The **Respiratory Mucosa**
  - Consists of:
    - An epithelial layer
    - An areolar layer called the lamina propria
  - Lines the conducting portion of respiratory system

23-1 Components of the Respiratory System

- The **Lamina Propria**
  - Underlying layer of areolar tissue that supports the respiratory epithelium
  - In the upper respiratory system, trachea, and bronchi
    - It contains mucous glands that secrete onto epithelial surface
  - In the conducting portion of lower respiratory system
    - It contains smooth muscle cells that encircle lumen of bronchioles

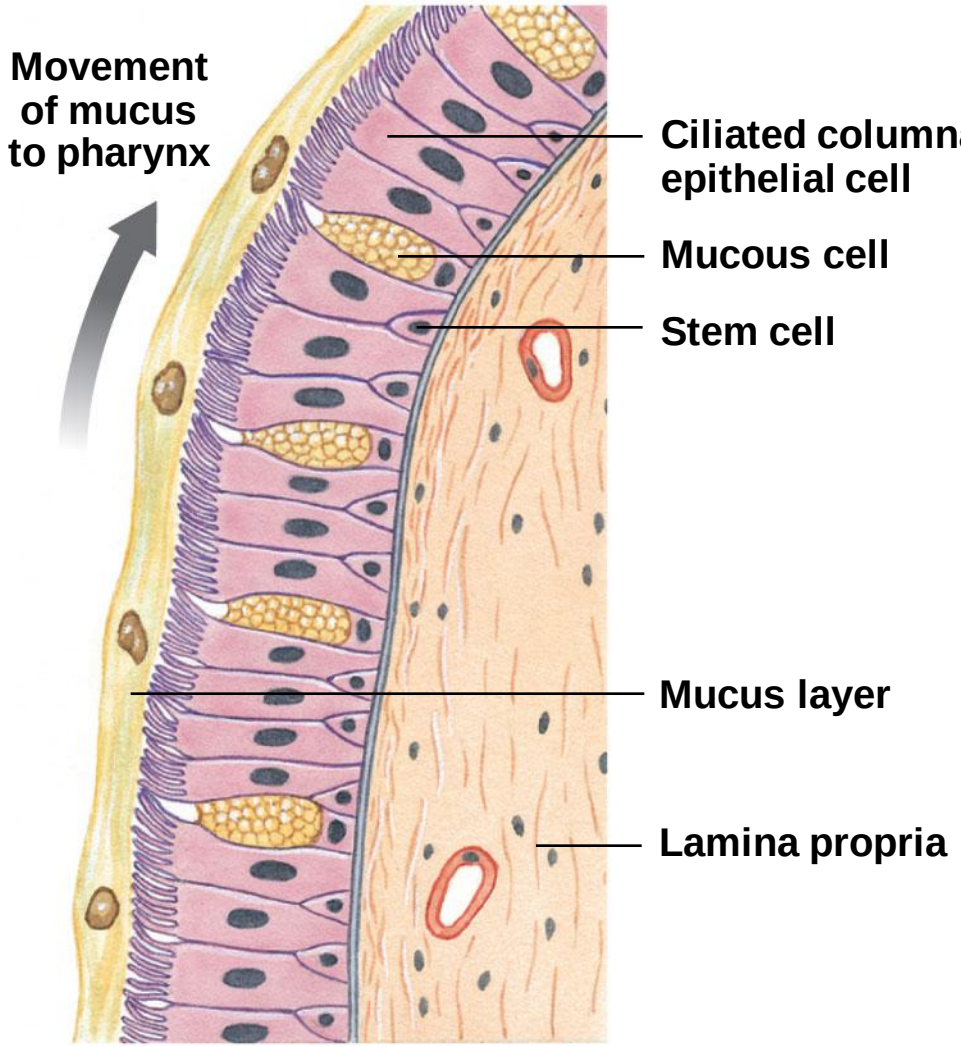
Figure 23-2a The Respiratory Epithelium of the Nasal Cavity and Conducting System



Superficial view SEM × 1647

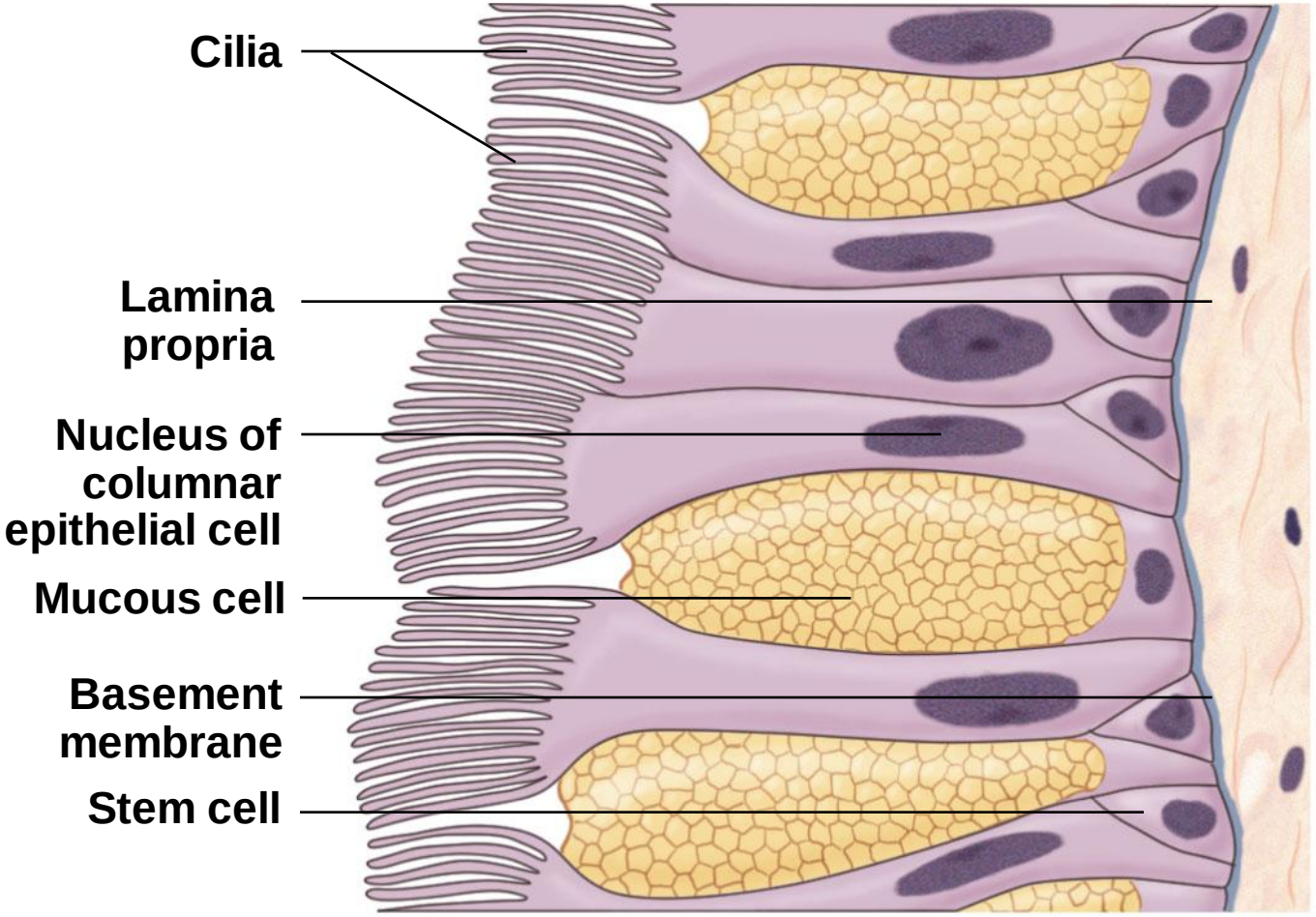
a A surface view of the epithelium. The cilia of the epithelial cells form a dense layer that resembles a shag carpet. The movement of these cilia propels mucus across the epithelial surface.

Figure 23-2b The Respiratory Epithelium of the Nasal Cavity and Conducting System



b **A diagrammatic view of the respiratory epithelium of the trachea, indicating the direction of mucus transport inferior to the pharynx.**

Figure 23-2c The Respiratory Epithelium of the Nasal Cavity and Conducting System



C **The sectional appearance of the respiratory epithelium, a pseudostratified ciliated columnar epithelium.**

23-1 Components of the Respiratory System

- Structure of Respiratory Epithelium
  - Pseudostratified ciliated columnar epithelium with numerous mucous cells
    - Nasal cavity and superior portion of the pharynx
  - Stratified squamous epithelium
    - Inferior portions of the pharynx
  - Pseudostratified ciliated columnar epithelium
    - Superior portion of the lower respiratory system
  - Cuboidal epithelium with scattered cilia
    - Smaller bronchioles

23-1 Components of the Respiratory System

- *Alveolar Epithelium*
  - Is a very delicate, simple squamous epithelium
  - Contains scattered and specialized cells
  - Lines exchange surfaces of alveoli

23-1 Components of the Respiratory System

- The **Respiratory Defense System**
  - Consists of a series of filtration mechanisms
  - Removes particles and pathogens

23-1 Components of the Respiratory System

- Components of the Respiratory Defense System
  - Mucous cells and mucous glands
    - Produce mucus that bathes exposed surfaces
  - Cilia
    - Sweep debris trapped in mucus toward the pharynx *(mucus escalator)*
  - Filtration in nasal cavity removes large particles
  - Alveolar macrophages engulf small particles that reach lungs

23-2 Upper Respiratory Tract

- The Nose
  - Air enters the respiratory system
    - Through nostrils or **external nares**
    - Into **nasal vestibule**
  - Nasal hairs
    - Are in nasal vestibule
    - Are the first particle filtration system

23-2 Upper Respiratory Tract

- The Nasal Cavity
  - The **nasal septum**
    - Divides nasal cavity into left and right
  - Superior portion of nasal cavity is the *olfactory region*
    - Provides sense of smell
  - Mucous secretions from *paranasal sinus* and tears
    - Clean and moisten the nasal cavity

23-2 Upper Respiratory Tract

- Air Flow
  - From vestibule to internal nares
    - Through **superior, middle,** and **inferior meatuses**
    - Meatuses are constricted passageways that produce air turbulence
      - Warm and humidify incoming air
      - Trap particles

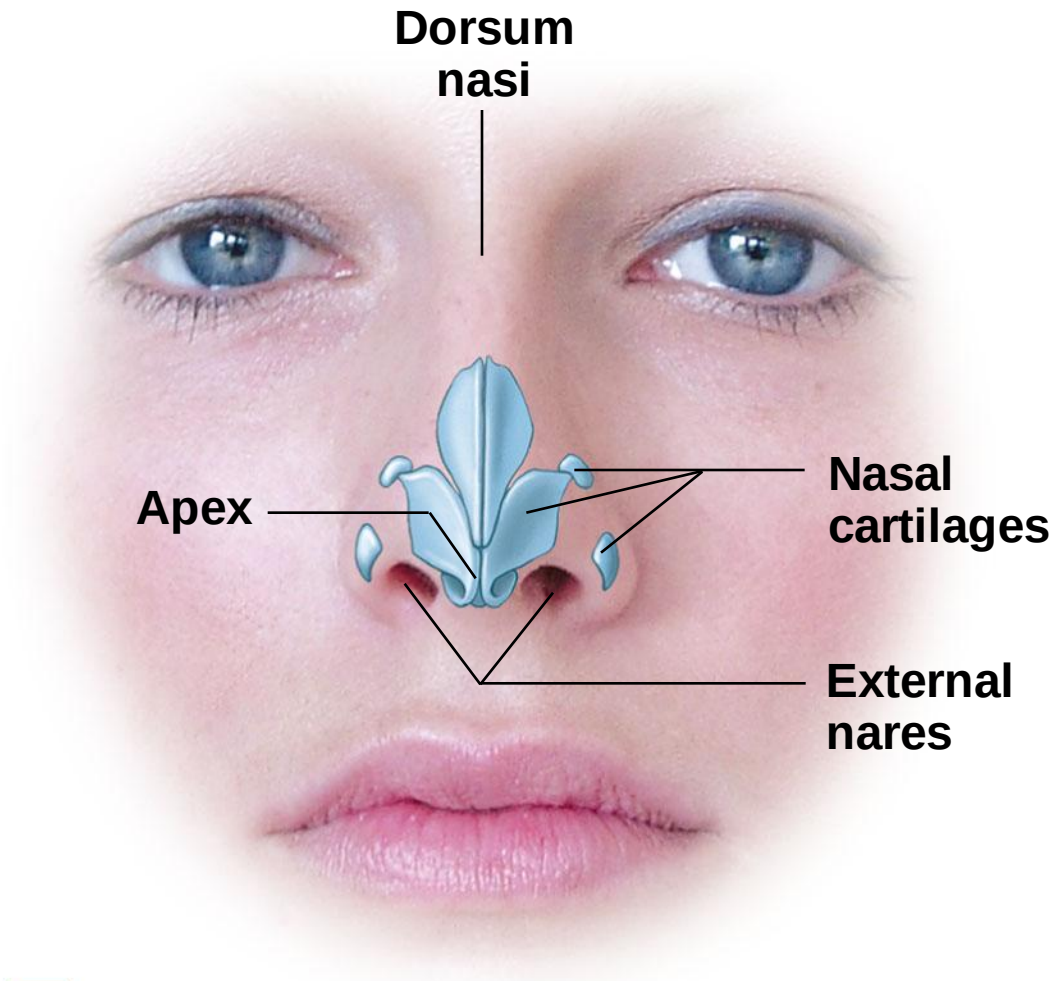
23-2 Upper Respiratory Tract

- The Palates
  - **Hard palate**
    - Forms floor of nasal cavity
    - Separates nasal and oral cavities
  - **Soft palate**
    - Extends posterior to hard palate
    - Divides superior *nasopharynx* from lower pharynx

23-2 Upper Respiratory Tract

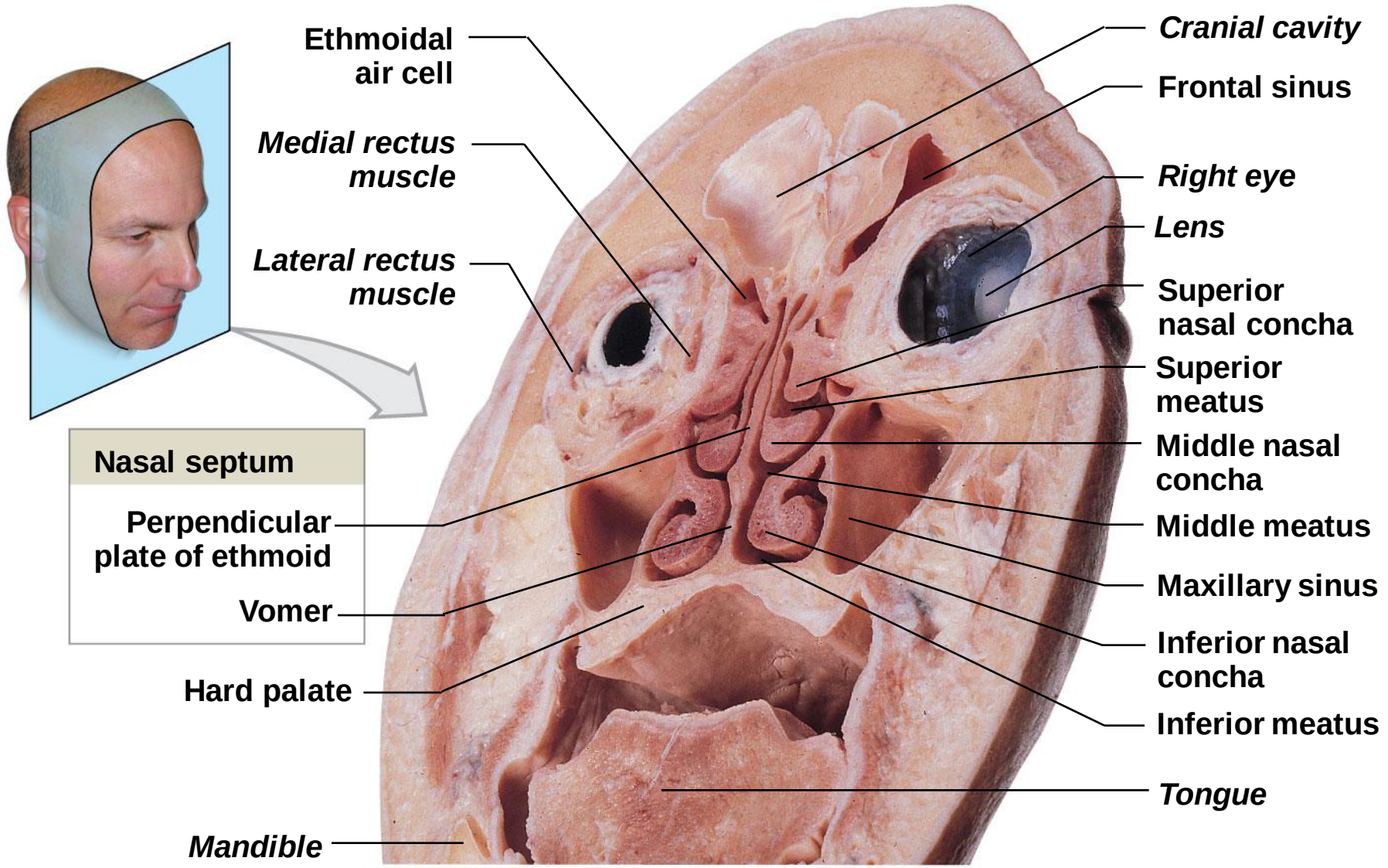
- Air Flow
  - Nasal cavity opens into nasopharynx through **internal nares**
- The Nasal Mucosa
  - Warms and humidifies inhaled air for arrival at lower respiratory organs
  - Breathing through mouth bypasses this important step

Figure 23-3a Structures of the Upper Respiratory System



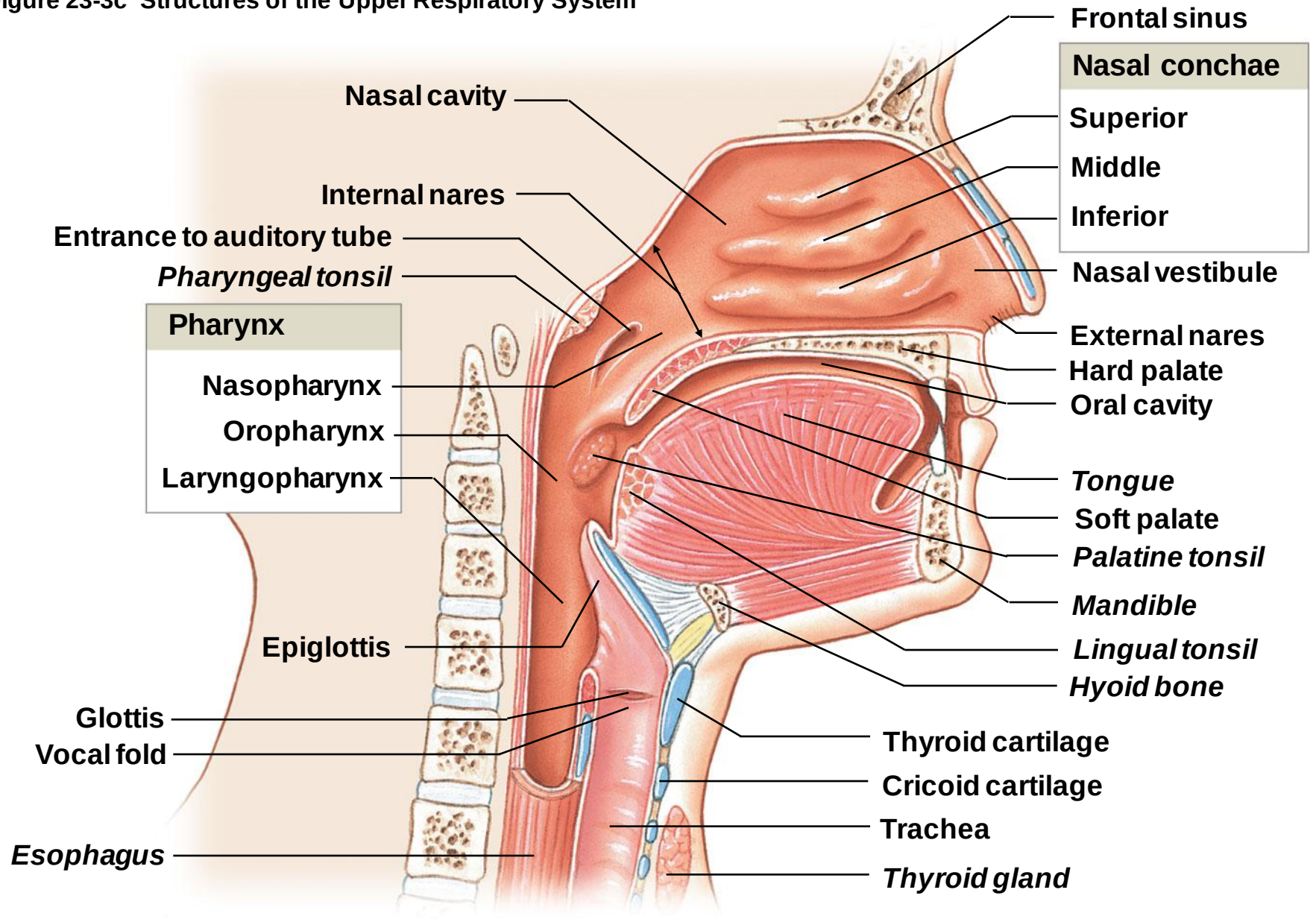
a The nasal cartilages and external landmarks on the nose

Figure 23-3b Structures of the Upper Respiratory System



b **A frontal section through the head, showing the meatuses and the maxillary sinuses and air cells of the ethmoidal labyrinth**

Figure 23-3c Structures of the Upper Respiratory System



C The nasal cavity and pharynx, as seen in sagittal section with the nasal septum removed

23-2 Upper Respiratory Tract

- The **Pharynx**
  - A chamber shared by digestive and respiratory systems
  - Extends from internal nares to entrances to larynx and esophagus
  - Divided into three parts
    1. The **nasopharynx**
    2. The **oropharynx**
    3. The **laryngopharynx**

23-2 Upper Respiratory Tract

- The **Nasopharynx**
  - Superior portion of pharynx
  - Contains pharyngeal tonsils and openings to left and right auditory tubes
- The **Oropharynx**
  - Middle portion of pharynx
  - Communicates with oral cavity
- The **Laryngopharynx**
  - Inferior portion of pharynx
  - Extends from hyoid bone to entrance of larynx and esophagus

23-3 The Larynx

- Air Flow
  - From the pharynx enters the **larynx**
    - A cartilaginous structure that surrounds the **glottis**, which is a narrow opening

23-3 The Larynx

- Cartilages of the Larynx
  - Three large, unpaired cartilages form the larynx
    1. **Thyroid cartilage**
    2. **Cricoid cartilage**
    3. **Epiglottis**

23-3 The Larynx

- The **Thyroid Cartilage**
  - Is hyaline cartilage
  - Forms anterior and lateral walls of larynx
  - Anterior surface called *laryngeal prominence*, or *Adam's apple*
  - Ligaments attach to hyoid bone, epiglottis, and laryngeal cartilages

23-3 The Larynx

- The **Cricoid Cartilage**
  - Is hyaline cartilage
  - Forms posterior portion of larynx
  - Ligaments attach to first tracheal cartilage
  - Articulates with *arytenoid cartilages*

23-3 The Larynx

- The **Epiglottis**
  - Composed of elastic cartilage
  - Ligaments attach to thyroid cartilage and hyoid bone

23-3 The Larynx

- Cartilage Functions
  - Thyroid and cricoid cartilages support and protect:
    - The glottis
    - The entrance to trachea
  - During swallowing:
    - The larynx is elevated
    - The epiglottis folds back over glottis
  - Prevents entry of food and liquids into respiratory tract

23-3 The Larynx

- The Larynx Contains Three Pairs of Smaller Hyaline Cartilages
  1. **Arytenoid cartilages**
  2. **Corniculate cartilages**
  3. **Cuneiform cartilages**

Figure 23-4a The Anatomy of the Larynx

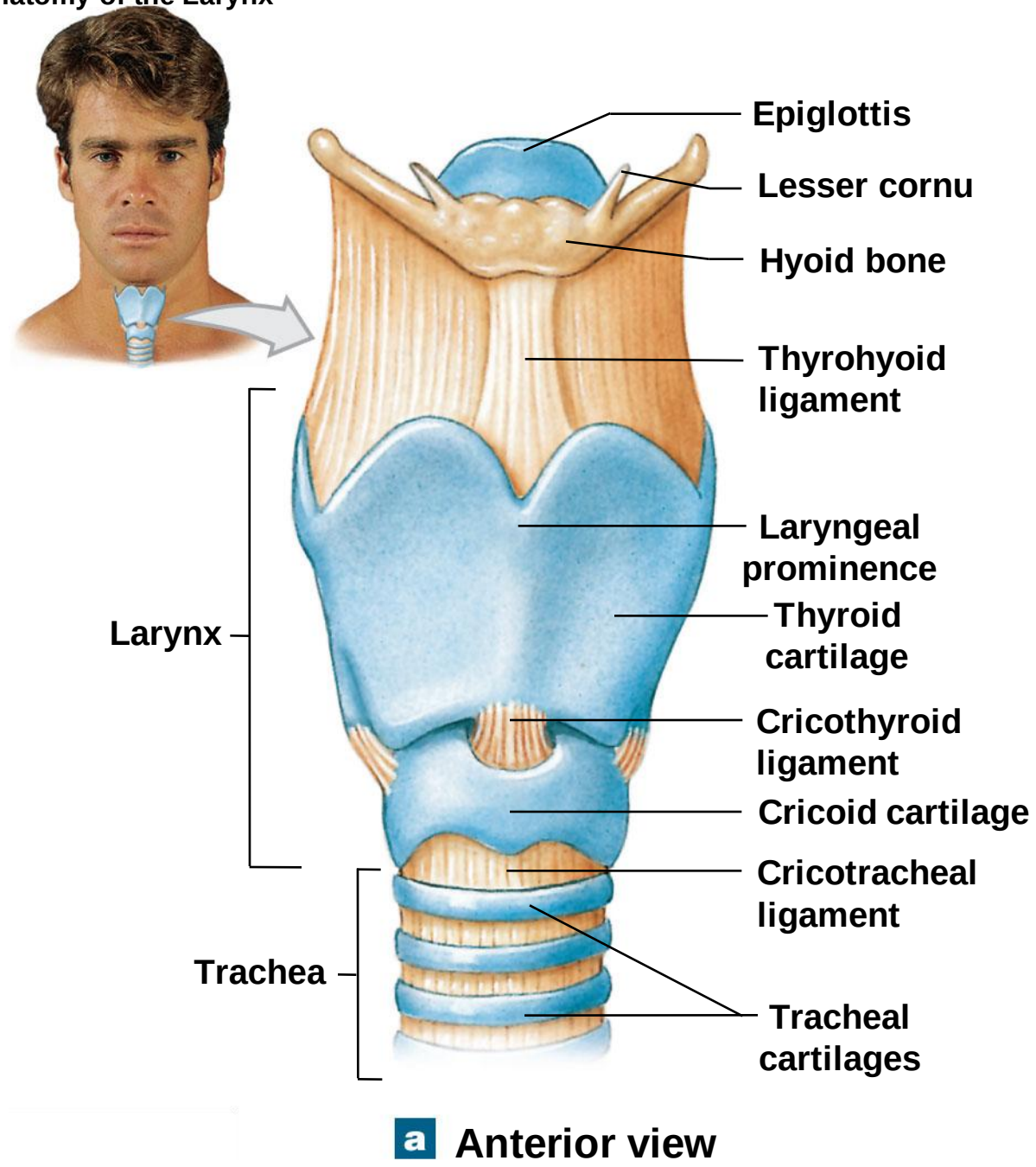


Figure 23-4b The Anatomy of the Larynx

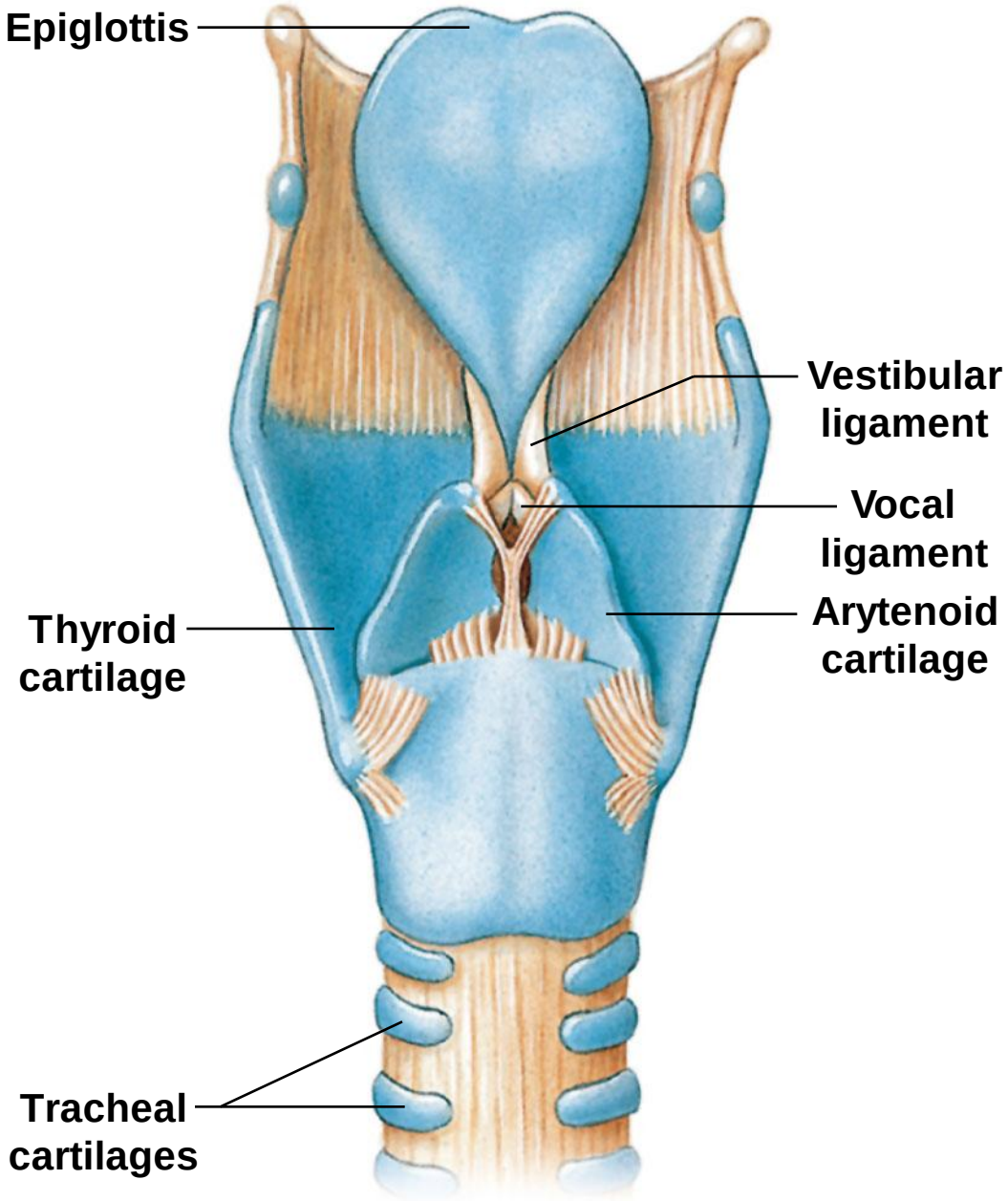
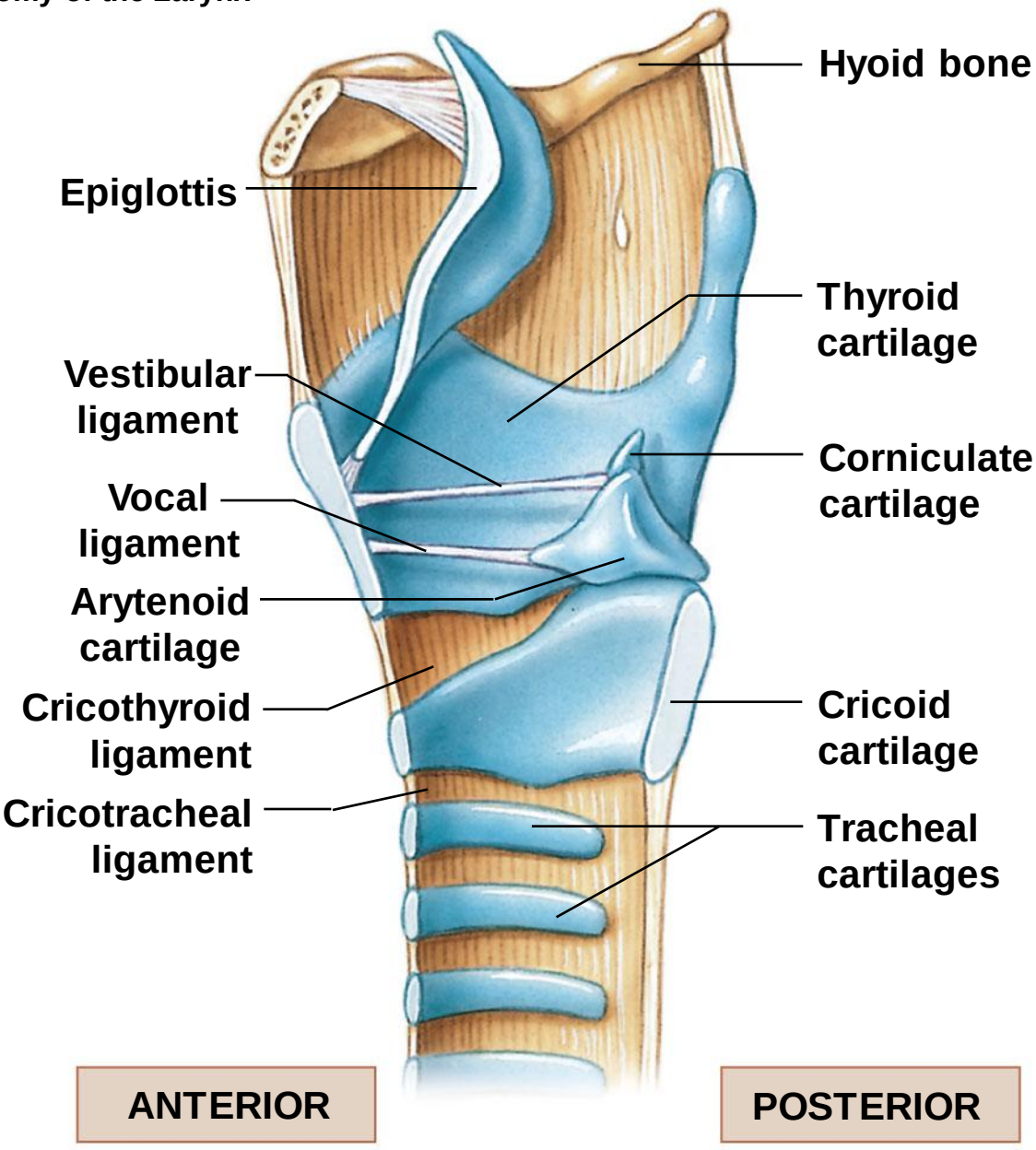


Figure 23-4c The Anatomy of the Larynx



C Sagittal section

23-3 The Larynx

- Cartilage Functions
  - Corniculate and arytenoid cartilages function in:
    - Opening and closing of glottis
    - Production of sound

23-3 The Larynx

- Ligaments of the Larynx
  - **Vestibular ligaments** and **vocal ligaments**
    - Extend between thyroid cartilage and arytenoid cartilages
    - Are covered by folds of laryngeal epithelium that project into glottis

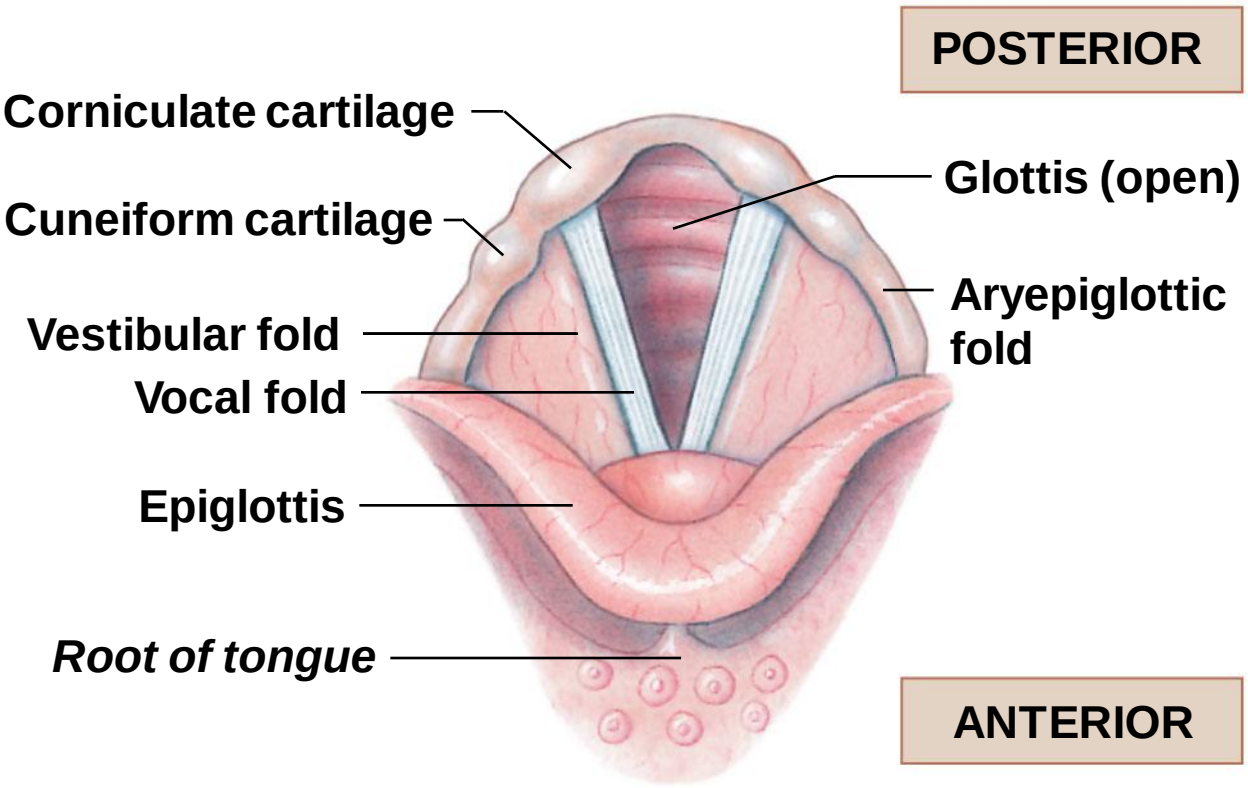
23-3 The Larynx

- The Vestibular Ligaments
  - Lie within **vestibular folds**
    - Which protect delicate **vocal folds**
- Sound Production
  - Air passing through glottis
    - Vibrates vocal folds
    - Produces sound waves

23-3 The Larynx

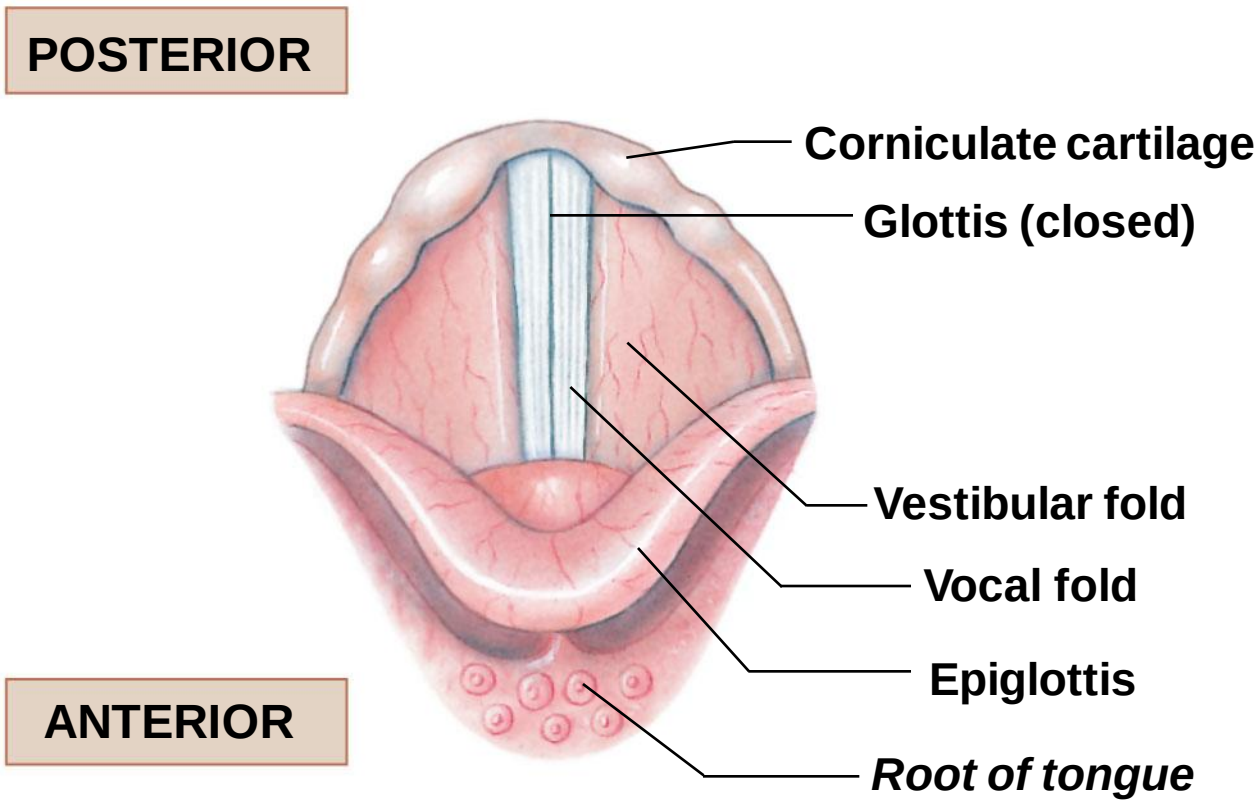
- Sound Production
  - Sound is varied by:
    - Tension on vocal folds
      - Vocal folds involved with sound are known as **vocal cords**
    - Voluntary muscles (position arytenoid cartilage relative to thyroid cartilage)
  - Speech is produced by:
    - *Phonation*
      - Sound production at the larynx
    - *Articulation*
      - Modification of sound by other structures

Figure 23-5a The Glottis and Surrounding Structures



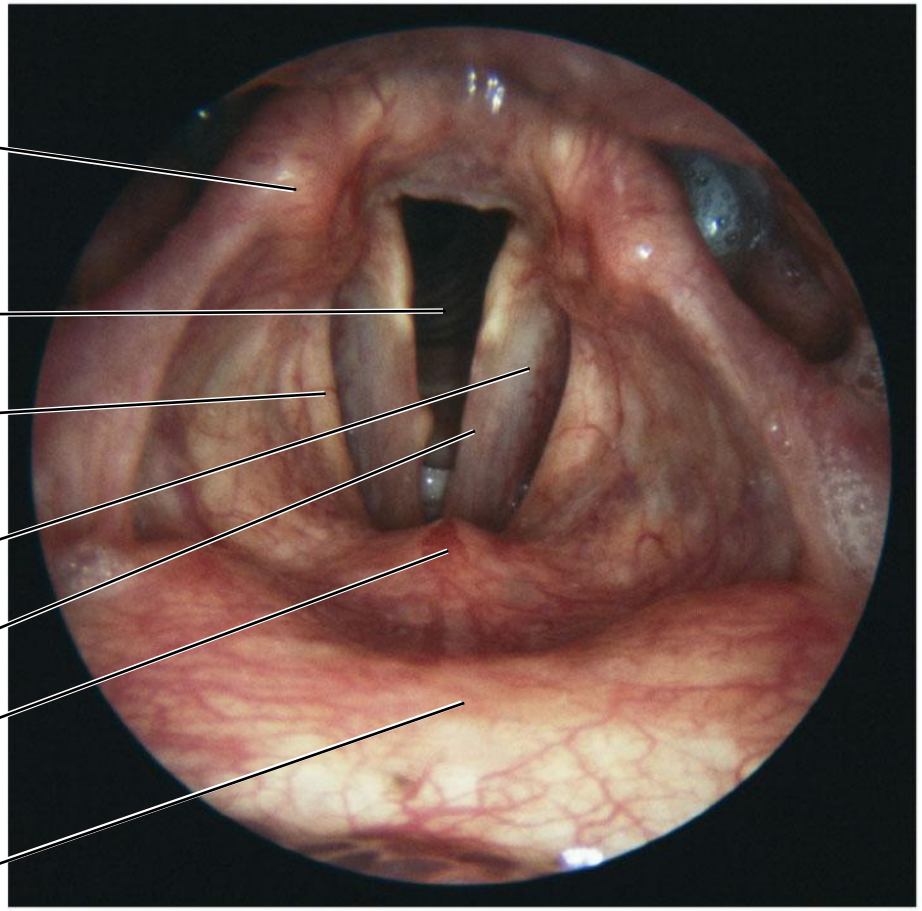
a Glottis in the open position.

Figure 23-5b The Glottis and Surrounding Structures



b Glottis in the closed position.

Figure 23-5c The Glottis and Surrounding Structures



c **This photograph is a representative laryngoscopic view. For this view the camera is positioned within the oro-pharynx, just superior to the larynx.**

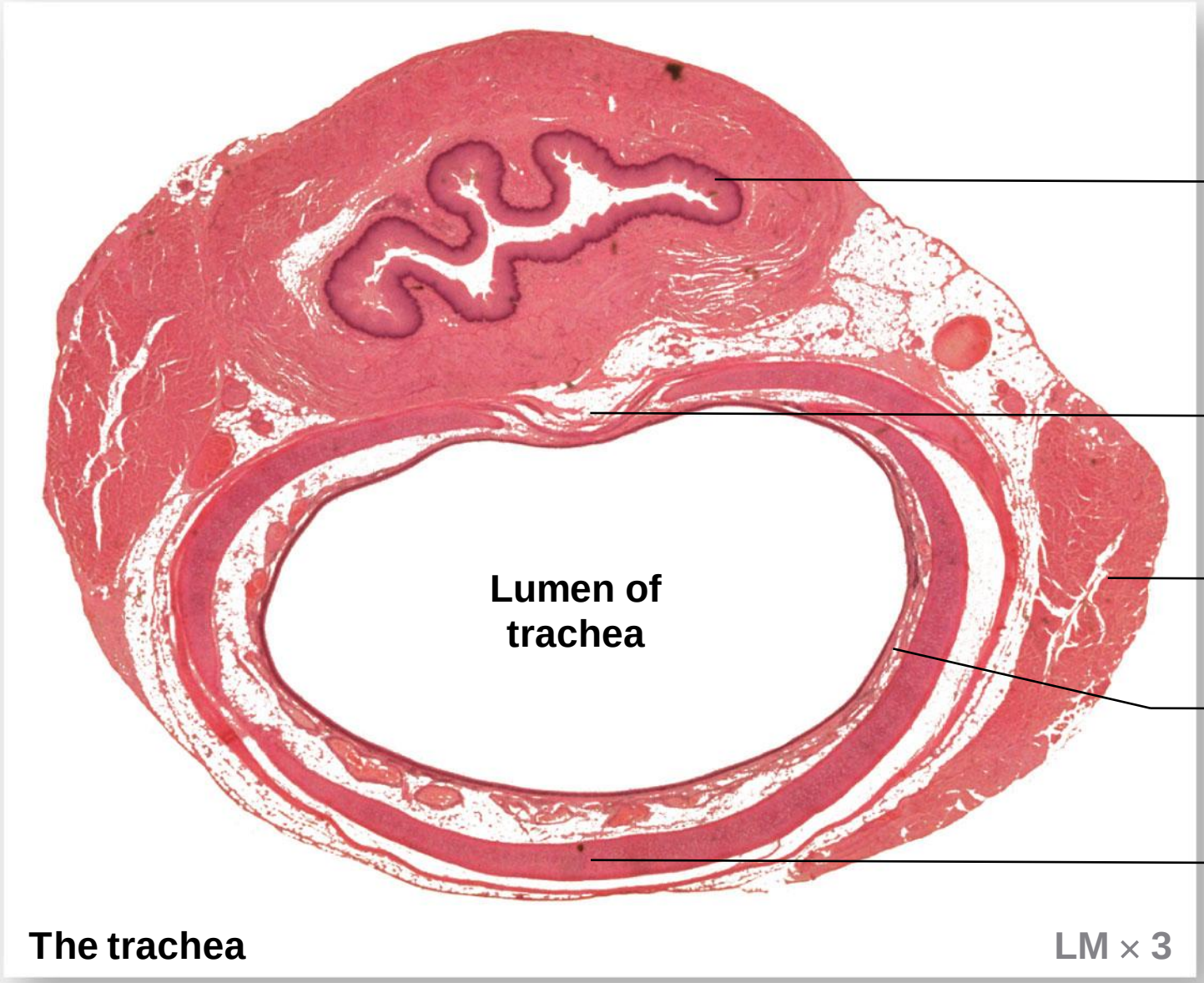
23-3 The Larynx

- The Laryngeal Musculature
  - The larynx is associated with:
    1. Muscles of neck and pharynx
    2. Intrinsic muscles
       - Control vocal folds
       - Open and close glottis

23-4 The Trachea

- The **Trachea**
  - Also called the windpipe
  - Extends from the cricoid cartilage into mediastinum
    - Where it branches into right and left pulmonary bronchi
  - The **submucosa**
    - Beneath mucosa of trachea
    - Contains mucous glands

Figure 23-6b The Anatomy of the Trachea



b A cross-sectional view

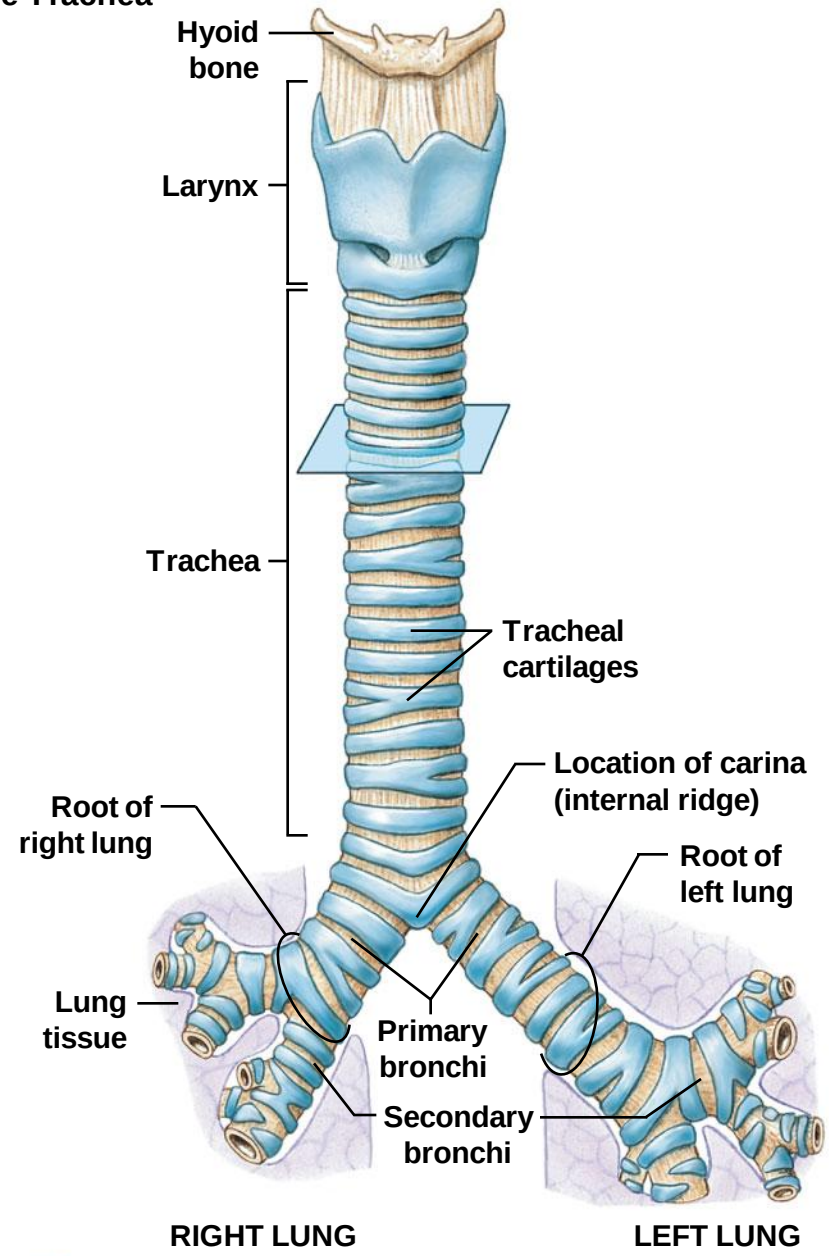
23-4 The Trachea

- The **Tracheal Cartilages**
  - 15–20 tracheal cartilages
    - Strengthen and protect airway
    - Discontinuous where trachea contacts esophagus
  - Ends of each tracheal cartilage are connected by:
    - An elastic ligament and **trachealis muscle**

23-4 The Trachea

- The Primary Bronchi
  - **Right** and **Left Primary Bronchi**
    - Separated by an internal ridge (the **carina**)
  - The Right Primary Bronchus
    - Is larger in diameter than the left
    - Descends at a steeper angle

Figure 23-6a The Anatomy of the Trachea



a A diagrammatic anterior view showing the plane of section for part (b)

23-4 The Trachea

- The Primary Bronchi
  - **Hilum**
    - Where pulmonary nerves, blood vessels, lymphatics enter lung
    - Anchored in meshwork of connective tissue
  - The **root** of the lung
    - Complex of connective tissues, nerves, and vessels in hilum
      - Anchored to the mediastinum

ANIMATION Respiration: Respiratory Tract

23-5 The Lungs

- The Lungs
  - Left and right lungs
    - Are in left and right pleural cavities
  - The base
    - Inferior portion of each lung rests on superior surface of diaphragm
  - **Lobes** of the lungs
    - Lungs have lobes separated by deep fissures

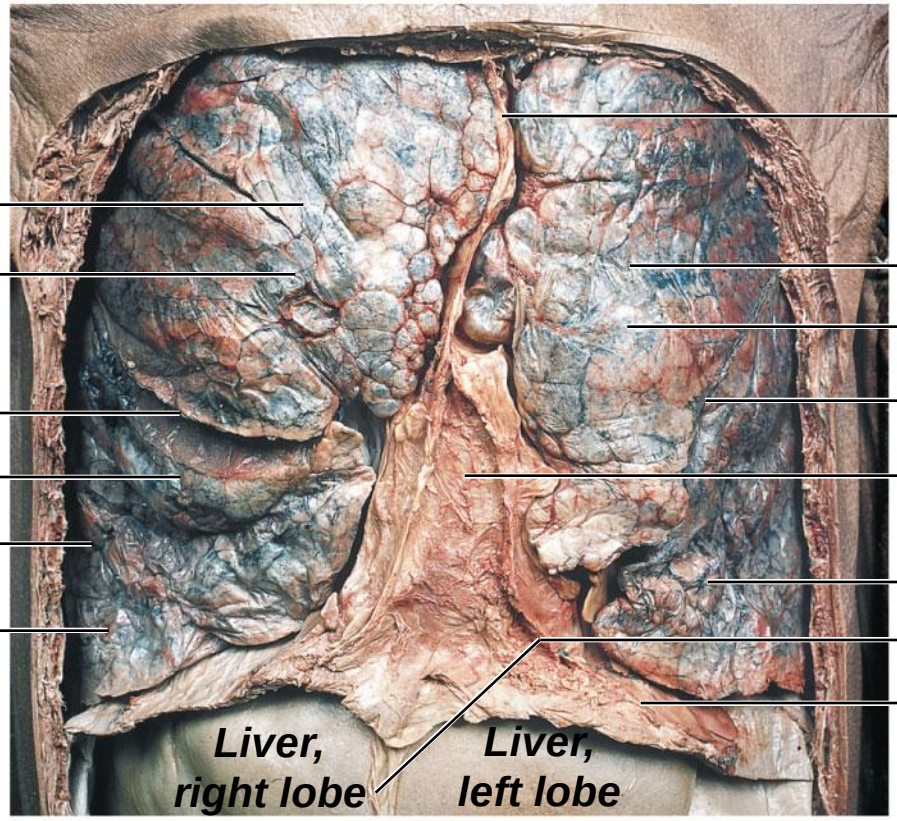
23-5 The Lungs

- Lobes and Surfaces of the Lungs
  - The right lung has three lobes
    - *Superior, middle,* and *inferior*
    - Separated by *horizontal* and *oblique fissures*
  - The left lung has two lobes
    - *Superior* and *inferior*
    - Separated by an *oblique fissure*

23-5 The Lungs

- Lung Shape
  - Right lung
    - Is wider
    - Is displaced upward by liver
  - Left lung
    - Is longer
    - Is displaced leftward by the heart forming the **cardiac notch**

Figure 23-7a The Gross Anatomy of the Lungs



a Thoracic cavity, anterior view

Figure 23-7b The Gross Anatomy of the Lungs

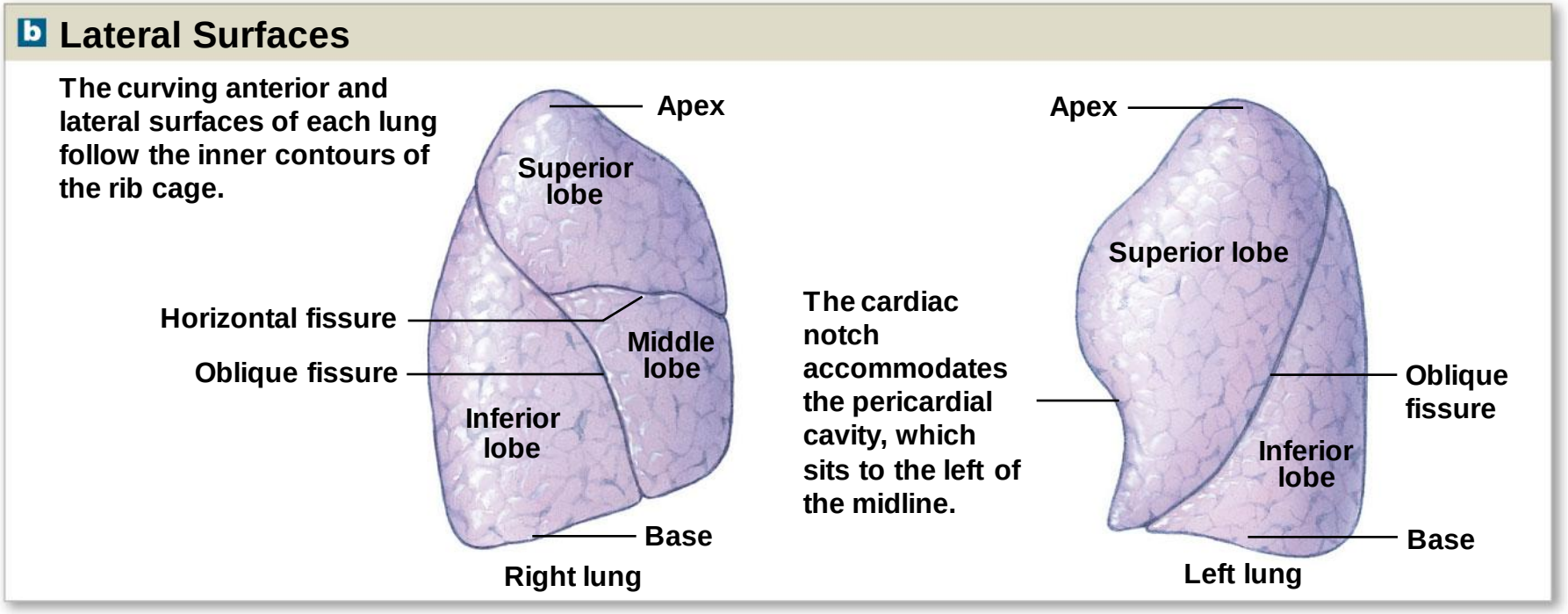


Figure 23-7c The Gross Anatomy of the Lungs

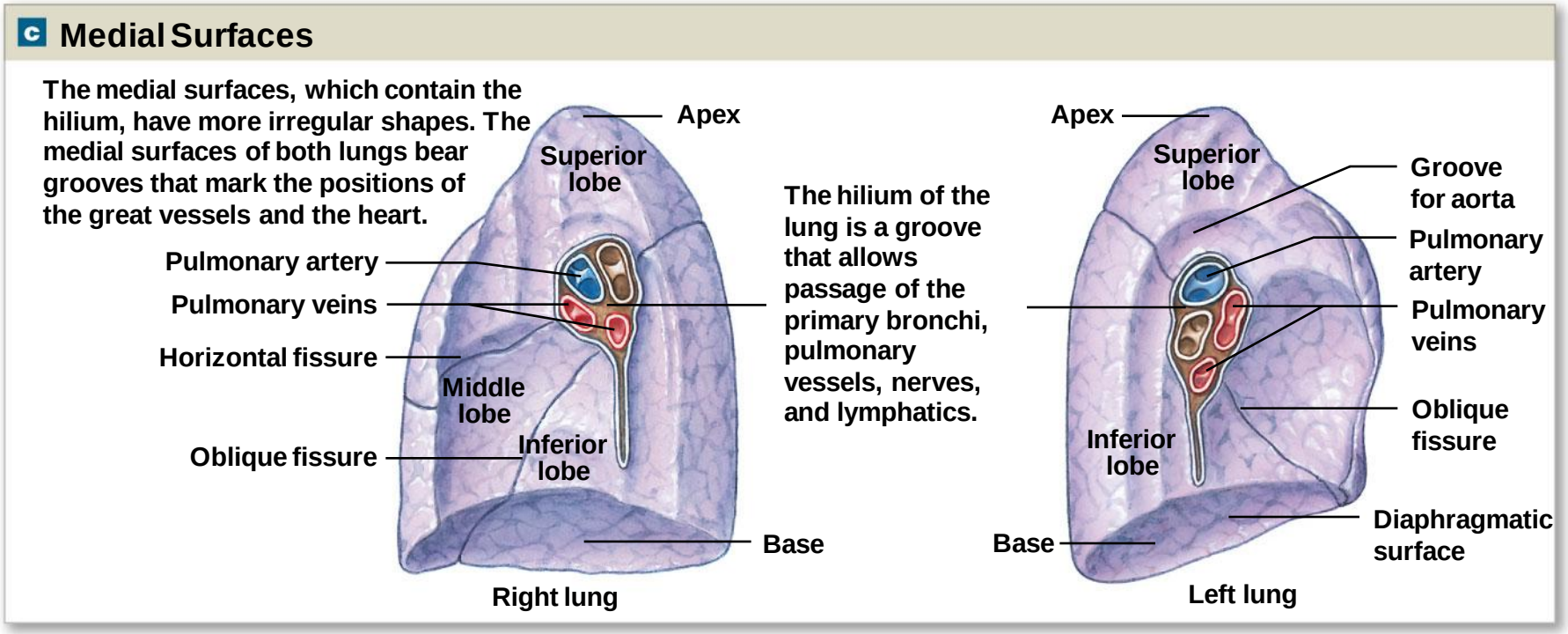
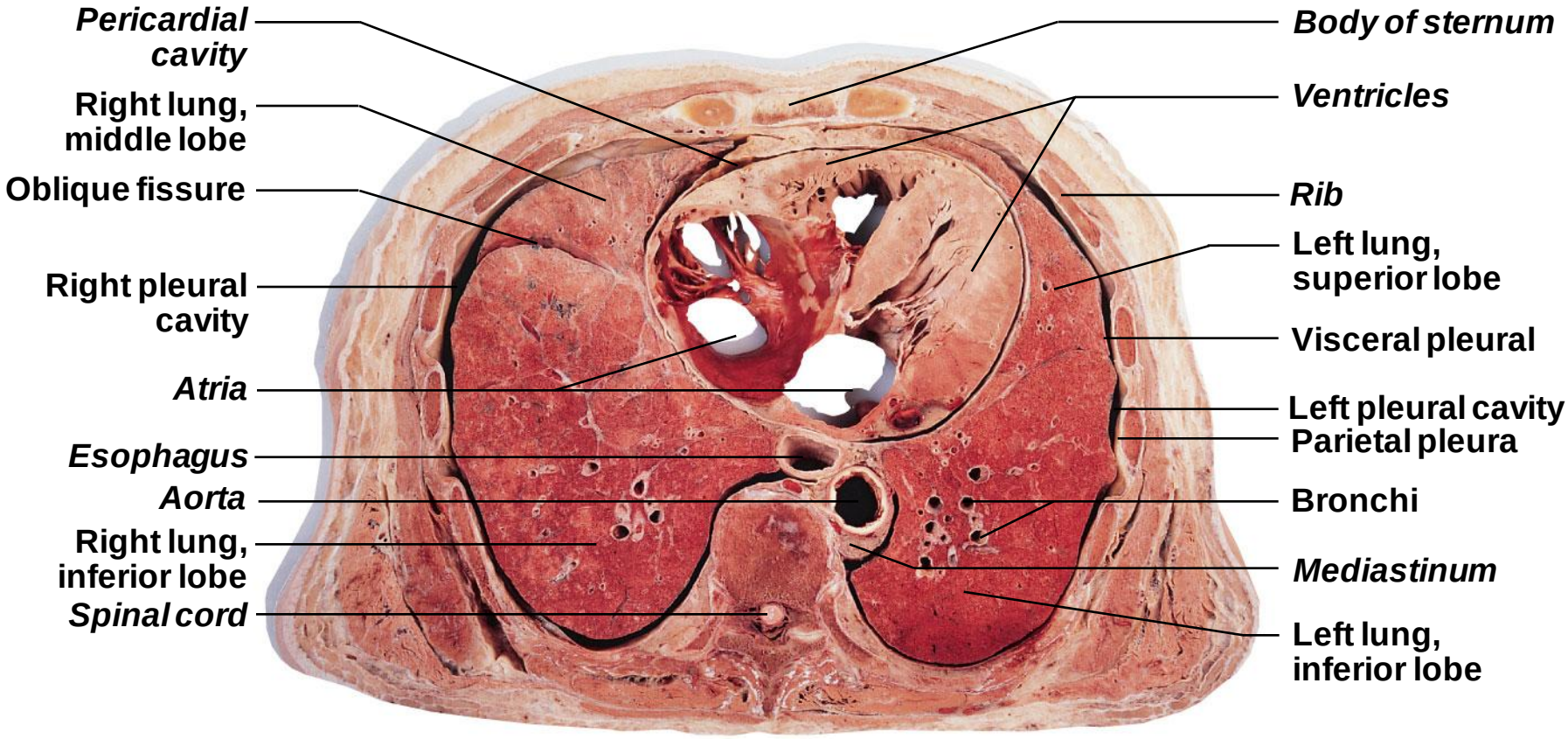


Figure 23-8 The Relationship between the Lungs and Heart



23-5 The Lungs

- The Bronchi
  - The **Bronchial Tree**
    - Is formed by the primary bronchi and their branches
  - *Extrapulmonary Bronchi*
    - The left and right bronchi branches outside the lungs
  - *Intrapulmonary Bronchi*
    - Branches within the lungs

23-5 The Lungs

- A Primary Bronchus
  - Branches to form **secondary bronchi** (*lobar bronchi*)
  - One secondary bronchus goes to each lobe
- Secondary Bronchi
  - Branch to form **tertiary bronchi** (*segmental bronchi)*
  - Each segmental bronchus
    - Supplies air to a single **bronchopulmonary segment**

23-5 The Lungs

- Bronchopulmonary Segments
  - The right lung has 10
  - The left lung has 8 or 9
- Bronchial Structure
  - The walls of primary, secondary, and tertiary bronchi
    - Contain progressively less cartilage and more smooth muscle
    - Increased smooth muscle tension affects airway constriction and resistance

23-5 The Lungs

- **Bronchitis**
  - Inflammation of bronchial walls
    - Causes constriction and breathing difficulty

23-5 The Lungs

- The **Bronchioles**
  - Each tertiary bronchus branches into multiple bronchioles
  - Bronchioles branch into **terminal bronchioles**
    - One tertiary bronchus forms about 6500 terminal bronchioles
- Bronchiole Structure
  - Bronchioles
    - Have no cartilage
    - Are dominated by smooth muscle

23-5 The Lungs

- Autonomic Control
  - Regulates smooth muscle
    - Controls diameter of bronchioles
    - Controls airflow and resistance in lungs

23-5 The Lungs

- **Bronchodilation**
  - Dilation of bronchial airways
  - Caused by sympathetic ANS activation
  - Reduces resistance
- **Bronchoconstriction**
  - Constricts bronchi
    - Caused by:
      - Parasympathetic ANS activation
      - Histamine release (allergic reactions)

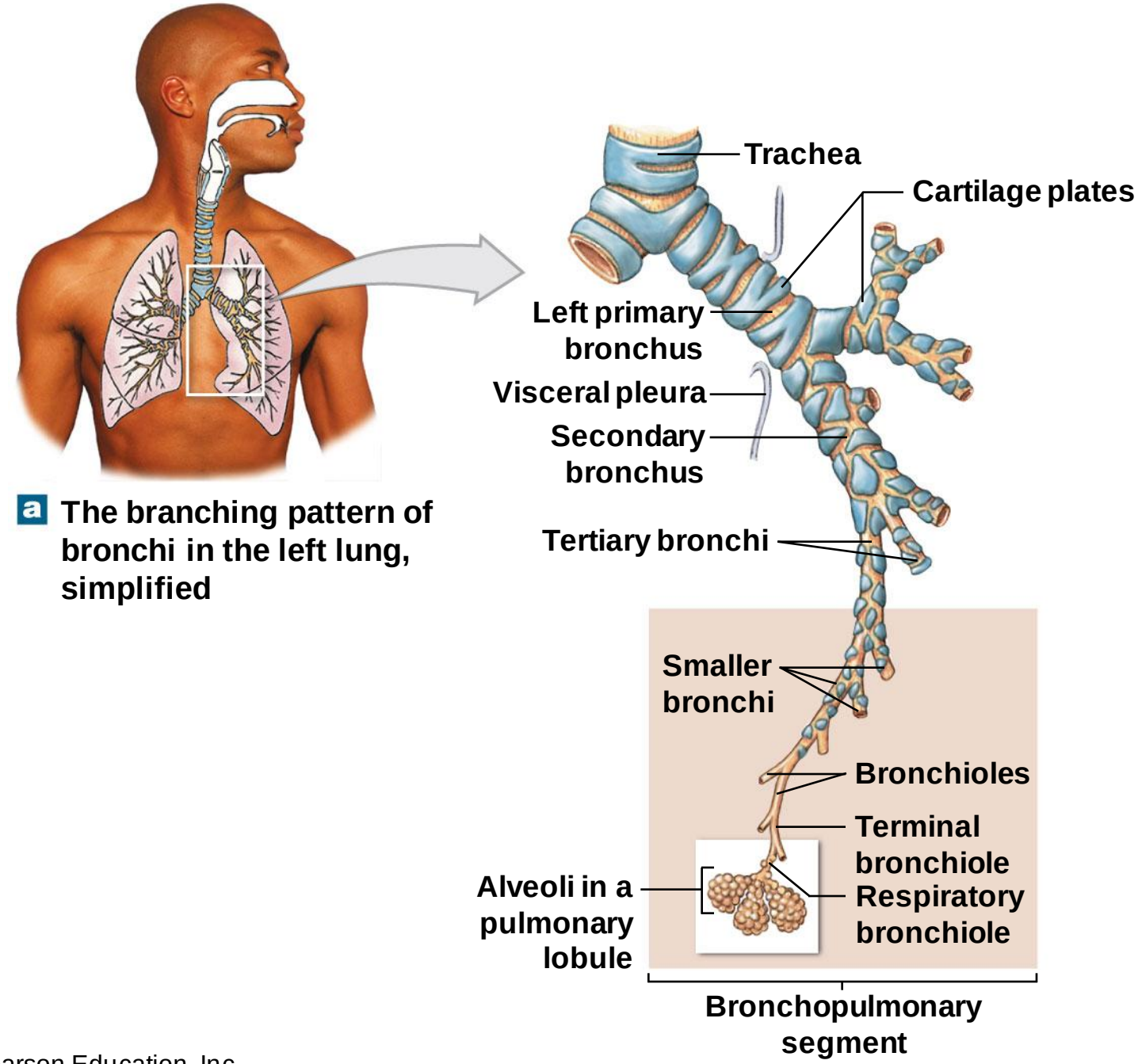
23-5 The Lungs

- **Asthma**
  - Excessive stimulation and bronchoconstriction
  - Stimulation severely restricts airflow

23-5 The Lungs

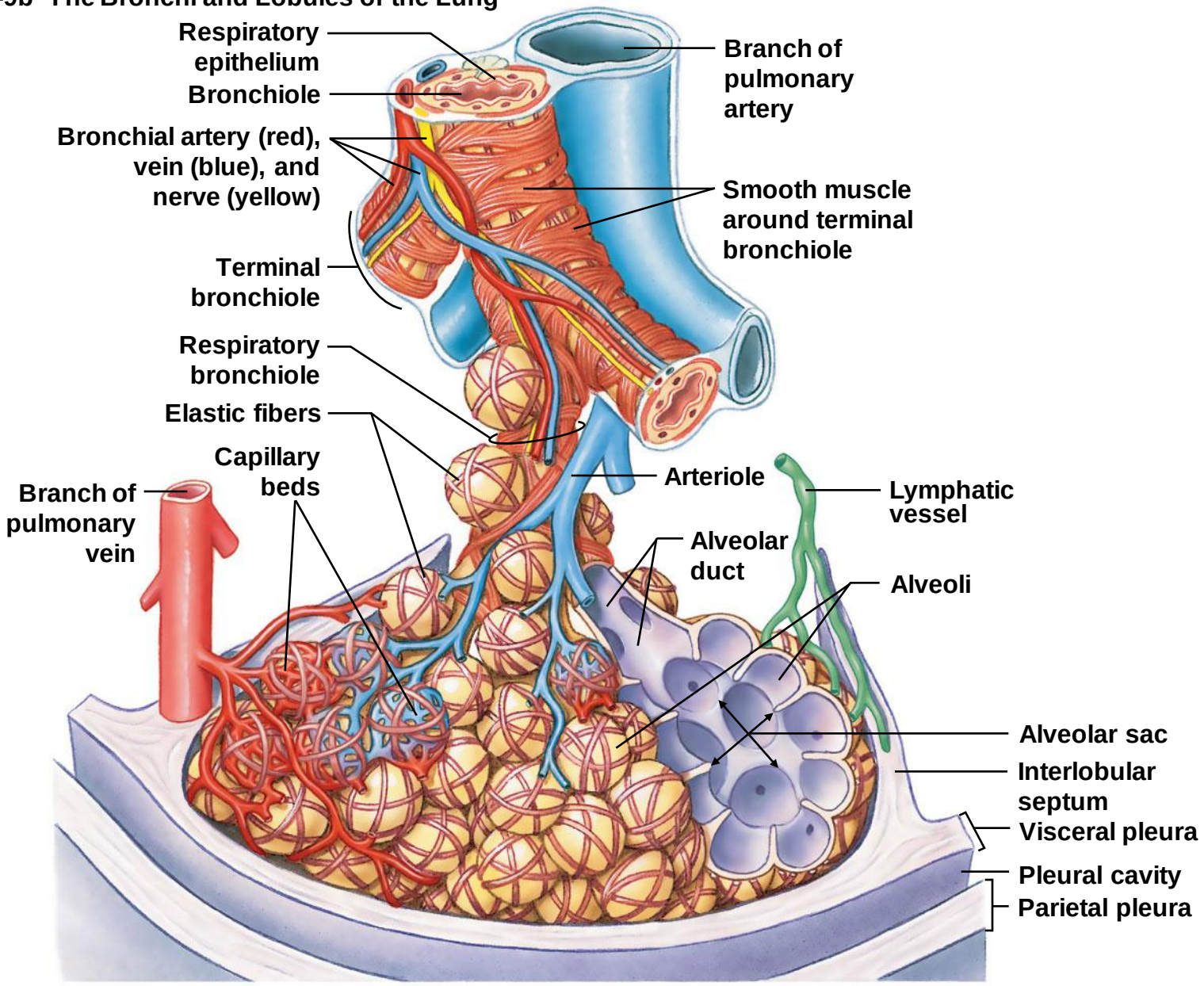
- Pulmonary Lobules
  - *Trabeculae*
    - Fibrous connective tissue partitions from root of lung
    - Contain supportive tissues and lymphatic vessels
    - Branch repeatedly
    - Divide lobes into increasingly smaller compartments
    - **Pulmonary lobules** are divided by the smallest trabecular partitions (**interlobular septa**)

Figure 23-9a The Bronchi and Lobules of the Lung



a The branching pattern of bronchi in the left lung, simplified

Figure 23-9b The Bronchi and Lobules of the Lung



b **The structure of a single pulmonary lobule, part of a bronchopulmonary segment**

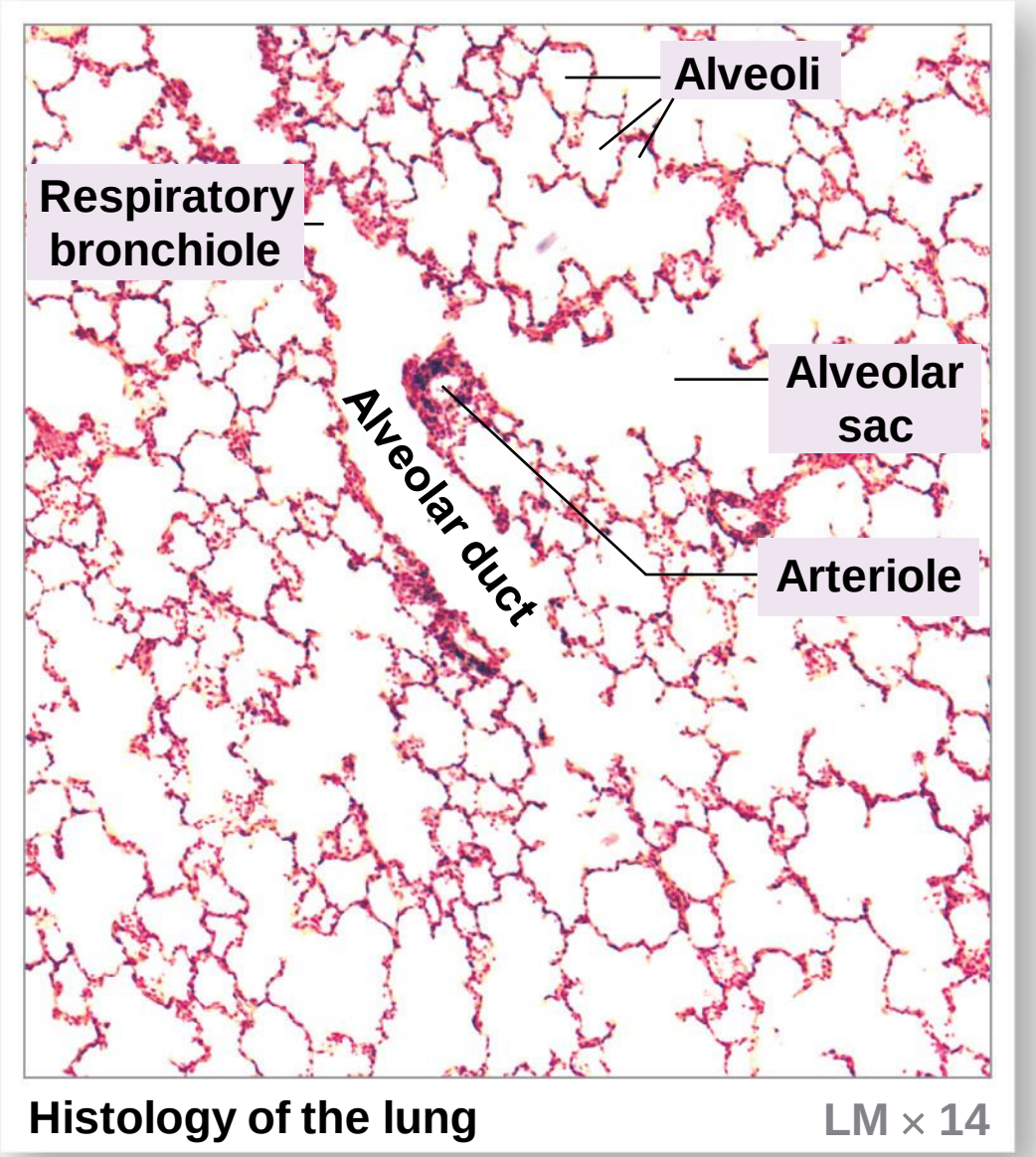
23-5 The Lungs

- Pulmonary Lobules
  - Each terminal bronchiole delivers air to a single pulmonary lobule
  - Each pulmonary lobule is supplied by pulmonary arteries and veins
  - Each terminal bronchiole branches to form several **respiratory bronchioles**, where gas exchange takes place

23-5 The Lungs

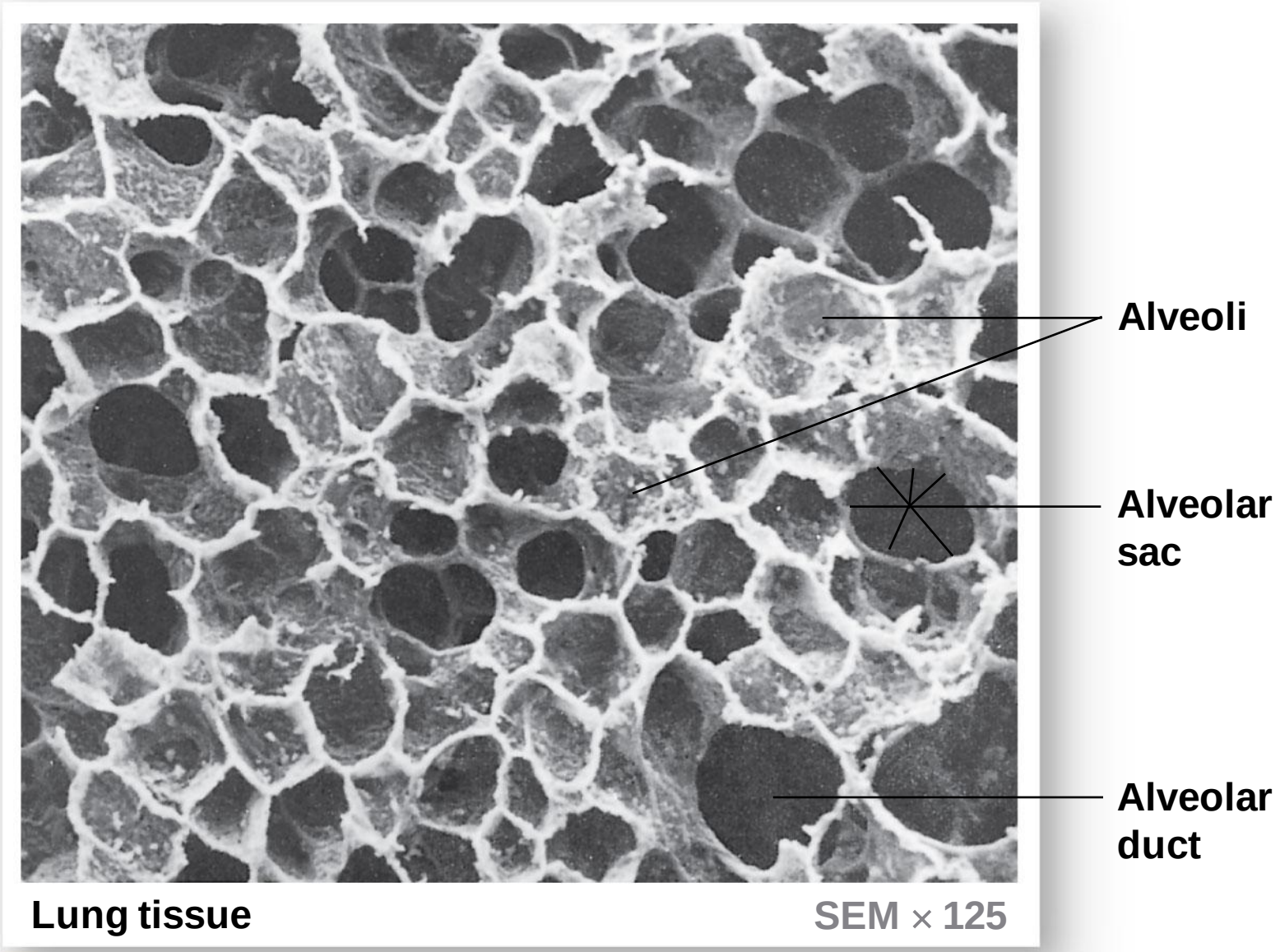
- Alveolar Ducts and Alveoli
  - Respiratory bronchioles are connected to alveoli along **alveolar ducts**
  - Alveolar ducts end at **alveolar sacs**
    - Common chambers connected to many individual alveoli
  - Each alveolus has an extensive network of capillaries
    - Surrounded by elastic fibers

Figure 23-10a Respiratory Tissue



a Low power micrograph of lung tissue

Figure 23-10b Respiratory Tissue



b **SEM of lung tissue showing the appearance and organization of the alveoli**

23-5 The Lungs

- Alveolar Epithelium
  - Consists of simple squamous epithelium
  - Consists of thin, delicate **pneumocytes type I**
  - Patrolled by **alveolar macrophages** (*dust cells*)
  - Contains **pneumocytes type II** (*septal cells*) that produce surfactant

23-5 The Lungs

- **Surfactant**
  - Is an oily secretion
  - Contains phospholipids and proteins
  - Coats alveolar surfaces and reduces surface tension

Figure 23-11a Alveolar Organization

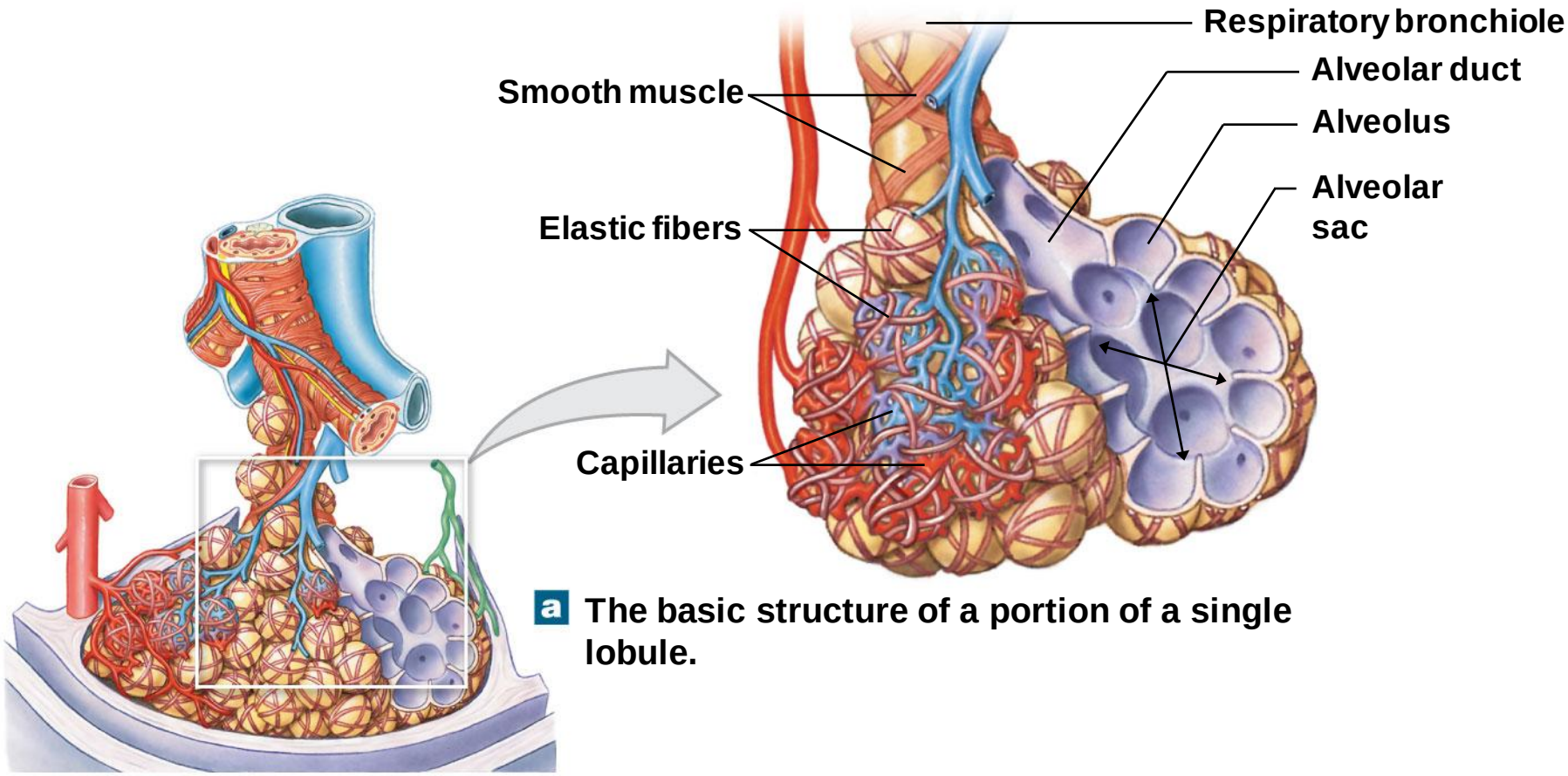
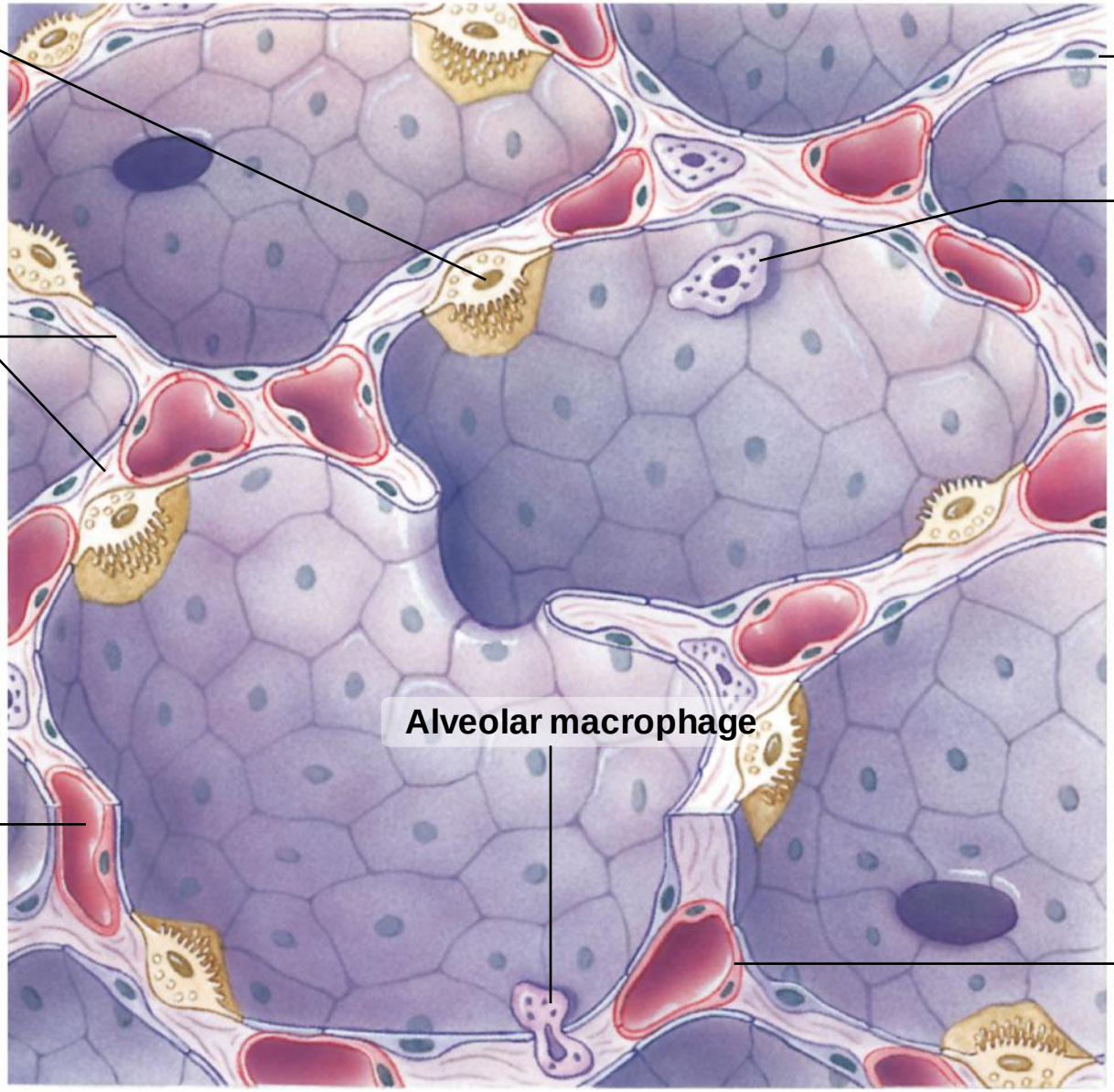


Figure 23-11b Alveolar Organization



b A diagrammatic view of alveolar structure. A single capillary may be involved in gas exchange with several alveoli simultaneously.

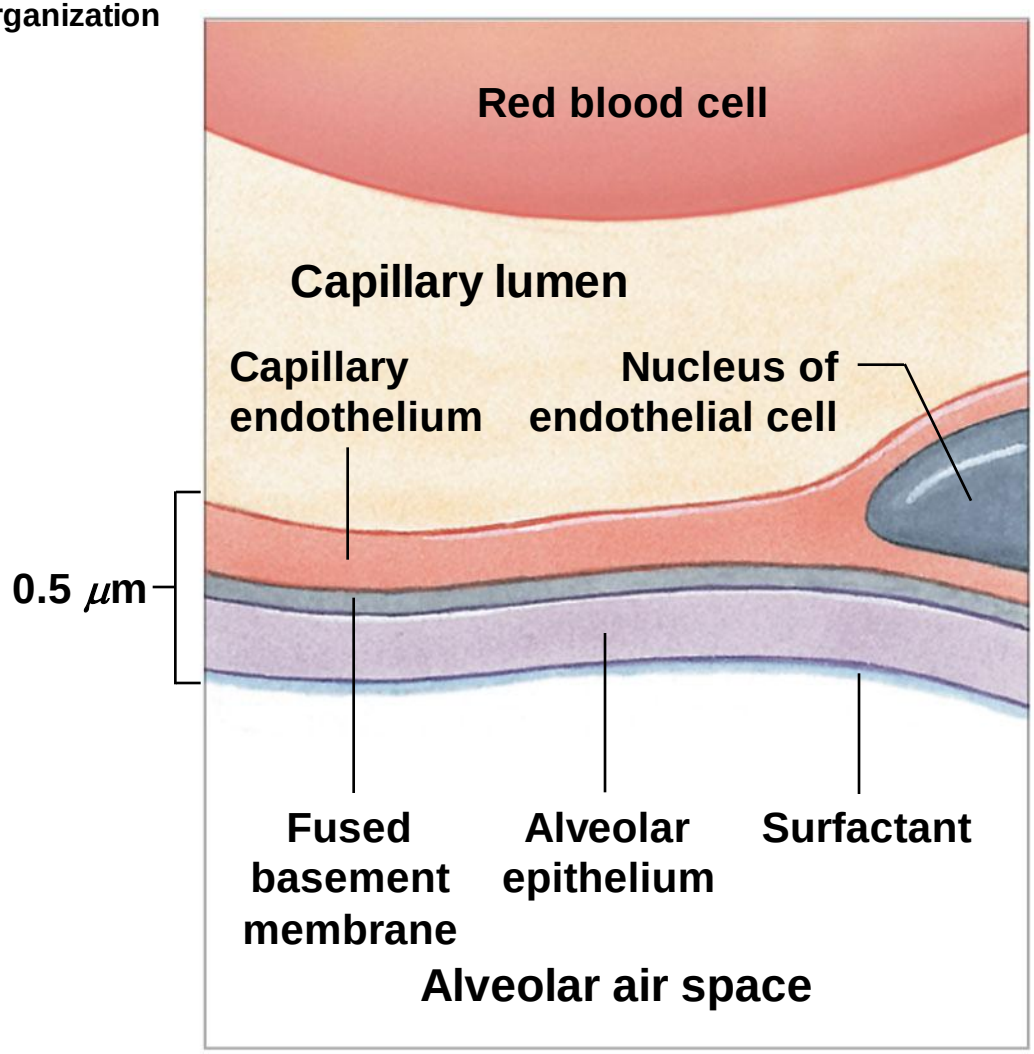
23-5 The Lungs

- *Respiratory Distress Syndrome*
  - Difficult respiration
    - Due to alveolar collapse
    - Caused when pneumocytes type II do not produce enough surfactant
- **Respiratory Membrane**
  - The thin membrane of alveoli where gas exchange takes place

23-5 The Lungs

- Three Layers of the Respiratory Membrane
  1. Squamous epithelial cells lining the alveolus
  2. Endothelial cells lining an adjacent capillary
  3. Fused basement membranes between the alveolar and endothelial cells

Figure 23-11c Alveolar Organization



c The respiratory membrane, which consists of an alveolar epithelial cell, a capillary endothelial cell, and their fused basement membranes.

23-5 The Lungs

- Diffusion
  - Across respiratory membrane is very rapid
    - Because distance is short
    - Gases (O_2 and CO_2) are lipid soluble
- Inflammation of Lobules
  - Also called **pneumonia**
    - Causes fluid to leak into alveoli
    - Compromises function of respiratory membrane

23-5 The Lungs

- Blood Supply to the Lungs
  - Respiratory exchange surfaces receive blood
    - From arteries of pulmonary circuit
  - A capillary network surrounds each alveolus
    - As part of the respiratory membrane
  - Blood from alveolar capillaries
    - Passes through pulmonary venules and veins
    - Returns to left atrium
    - Also site of *angiotensin-converting enzyme (ACE)*

23-5 The Lungs

- Blood Supply to the Lungs
  - Capillaries supplied by bronchial arteries
    - Provide oxygen and nutrients to tissues of conducting passageways of lung
  - Venous blood bypasses the systemic circuit and flows into pulmonary veins

23-5 The Lungs

- Blood Pressure
  - In pulmonary circuit is low (30 mm Hg)
  - Pulmonary vessels are easily blocked by blood clots, fat, or air bubbles
    - Causing **pulmonary embolism**

23-5 The Lungs

- The Pleural Cavities and Pleural Membranes
  - Two **pleural cavities**
    - Are separated by the mediastinum
  - Each pleural cavity:
    - Holds a lung
    - Is lined with a serous membrane (the pleura)

23-5 The Lungs

- The **Pleura**
  - Consists of two layers
    1. **Parietal pleura**
    2. **Visceral pleura**
  - **Pleural fluid**
    - Lubricates space between two layers

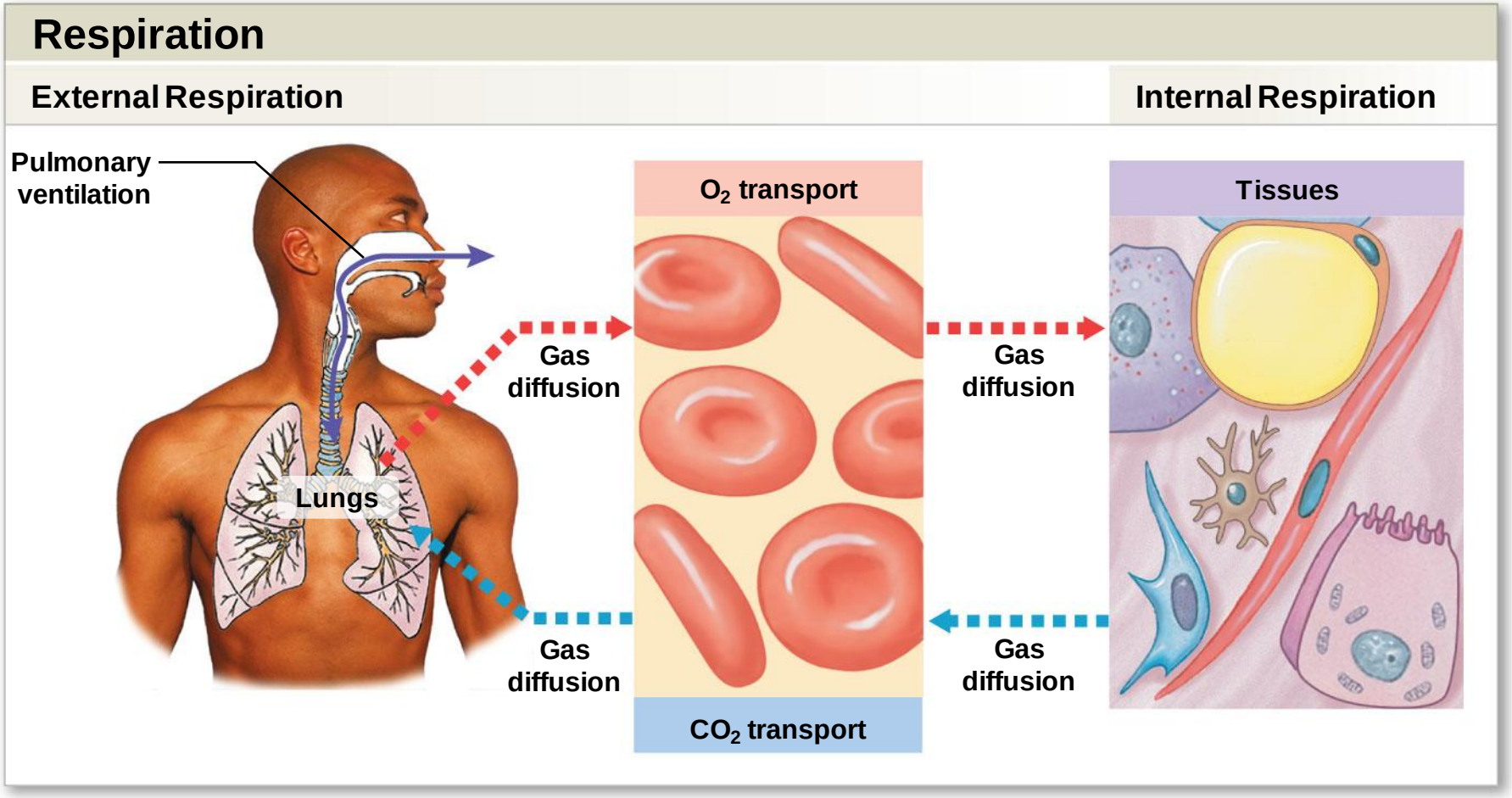
23-6 Introduction to Gas Exchange

- Respiration
  - Refers to two integrated processes
    1. **External respiration**
       - Includes all processes involved in exchanging O_2 and CO_2 with the environment
    2. **Internal respiration**
       - Result of *cellular respiration*
       - Involves the uptake of O_2 and production of CO_2 within individual cells

23-6 Introduction to Gas Exchange

- Three Processes of External Respiration
  1. *Pulmonary ventilation* (breathing)
  2. *Gas diffusion*
     - Across membranes and capillaries
  3. *Transport of O_2 and CO_2*
     - Between alveolar capillaries
     - Between capillary beds in other tissues

Figure 23-12 An Overview of the Key Steps in Respiration



23-6 Introduction to Gas Exchange

- Abnormal External Respiration Is Dangerous
  - **Hypoxia**
    - Low tissue oxygen levels
  - **Anoxia**
    - Complete lack of oxygen

23-7 Pulmonary Ventilation

- **Pulmonary Ventilation**
  - Is the physical movement of air in and out of respiratory tract
  - Provides *alveolar ventilation*
- The Movement of Air
  - **Atmospheric pressure**
    - The weight of air
      - Has several important physiological effects

23-7 Pulmonary Ventilation

- Gas Pressure and Volume
  - **Boyle's Law**
    - Defines the relationship between gas pressure and volume

$$P = 1/V$$

    - In a contained gas:
      - External pressure forces molecules closer together
      - Movement of gas molecules exerts pressure on container

Figure 23-13 Gas Pressure and Volume Relationships

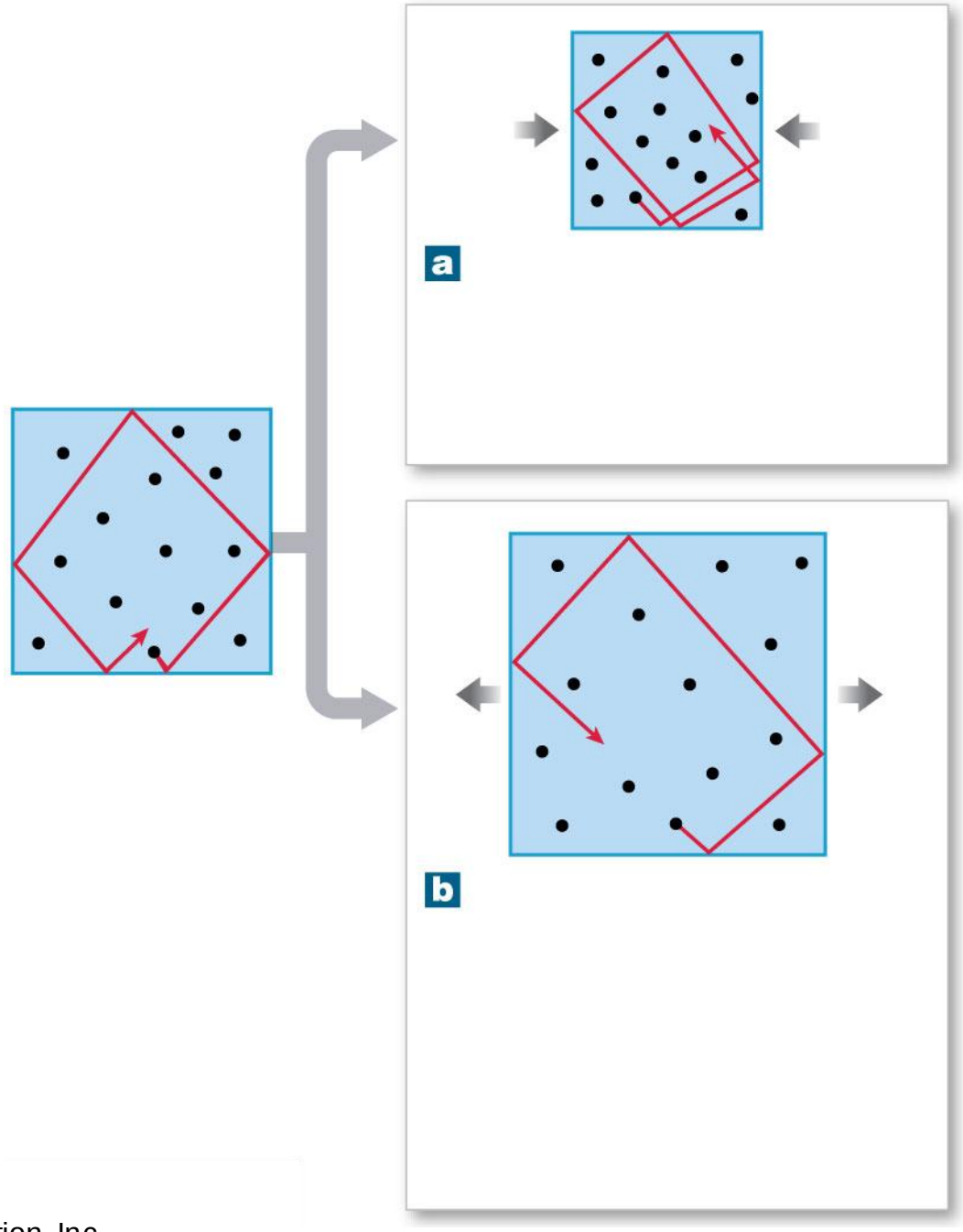


Figure 23-13a Gas Pressure and Volume Relationships

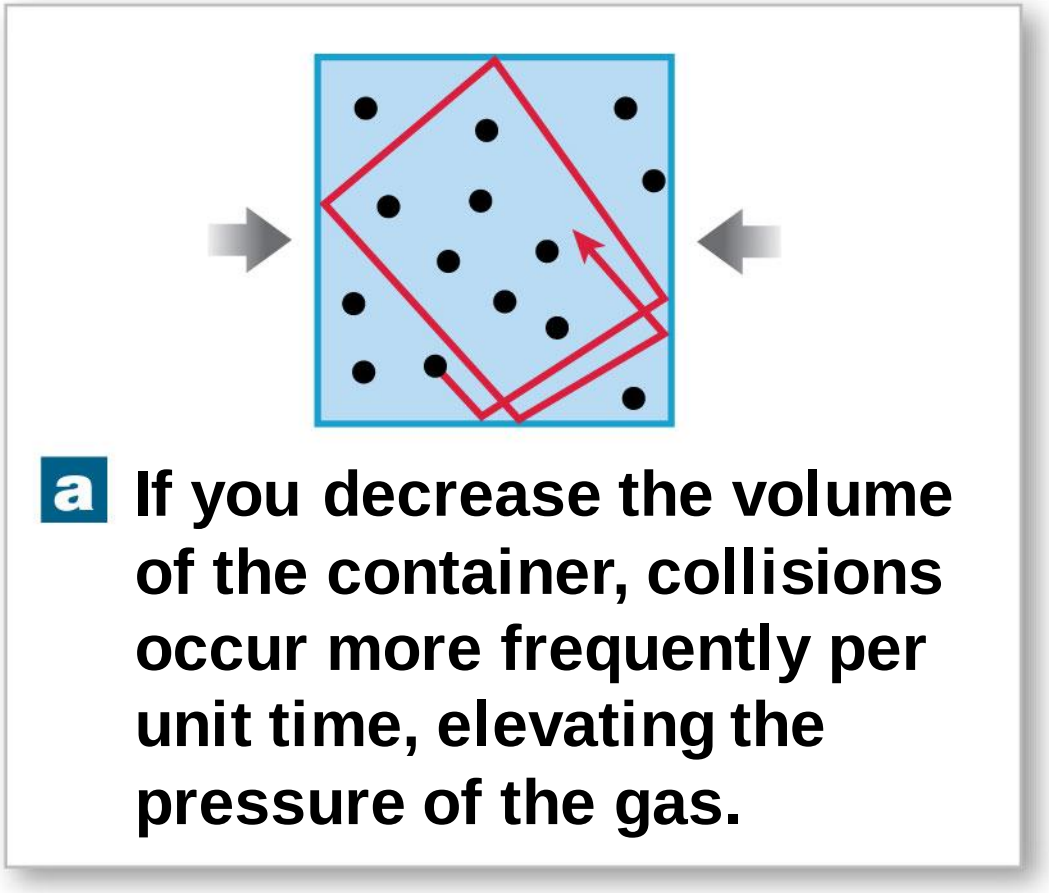
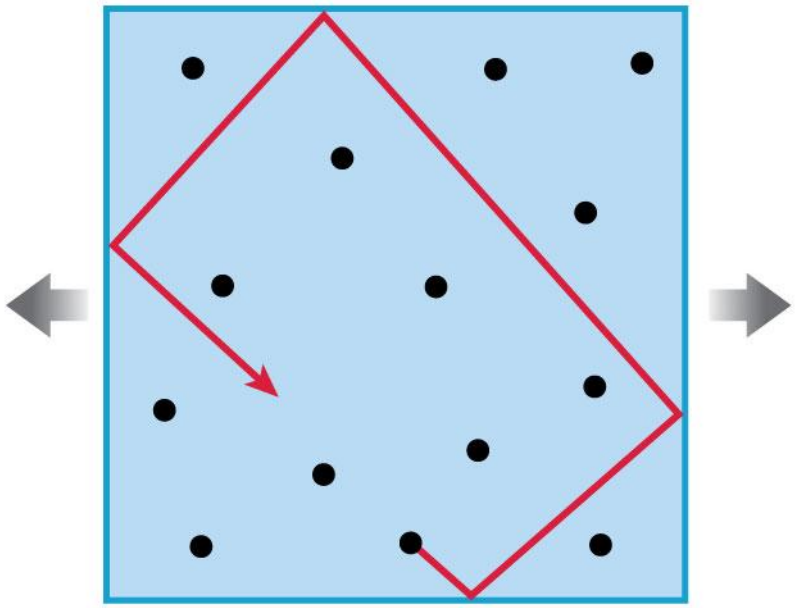


Figure 23-13b Gas Pressure and Volume Relationships



b If you increase the volume, fewer collisions occur per unit time, because it takes longer for a gas molecule to travel from one wall to another. As a result, the gas pressure inside the container declines.

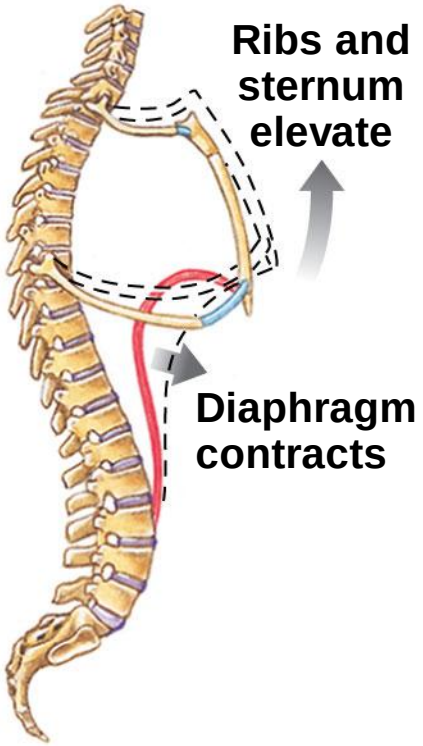
23-7 Pulmonary Ventilation

- Pressure and Airflow to the Lungs
  - Air flows from area of higher pressure to area of lower pressure
  - A Respiratory Cycle
    - Consists of:
      - An *inspiration* (inhalation)
      - An *expiration* (exhalation)

23-7 Pulmonary Ventilation

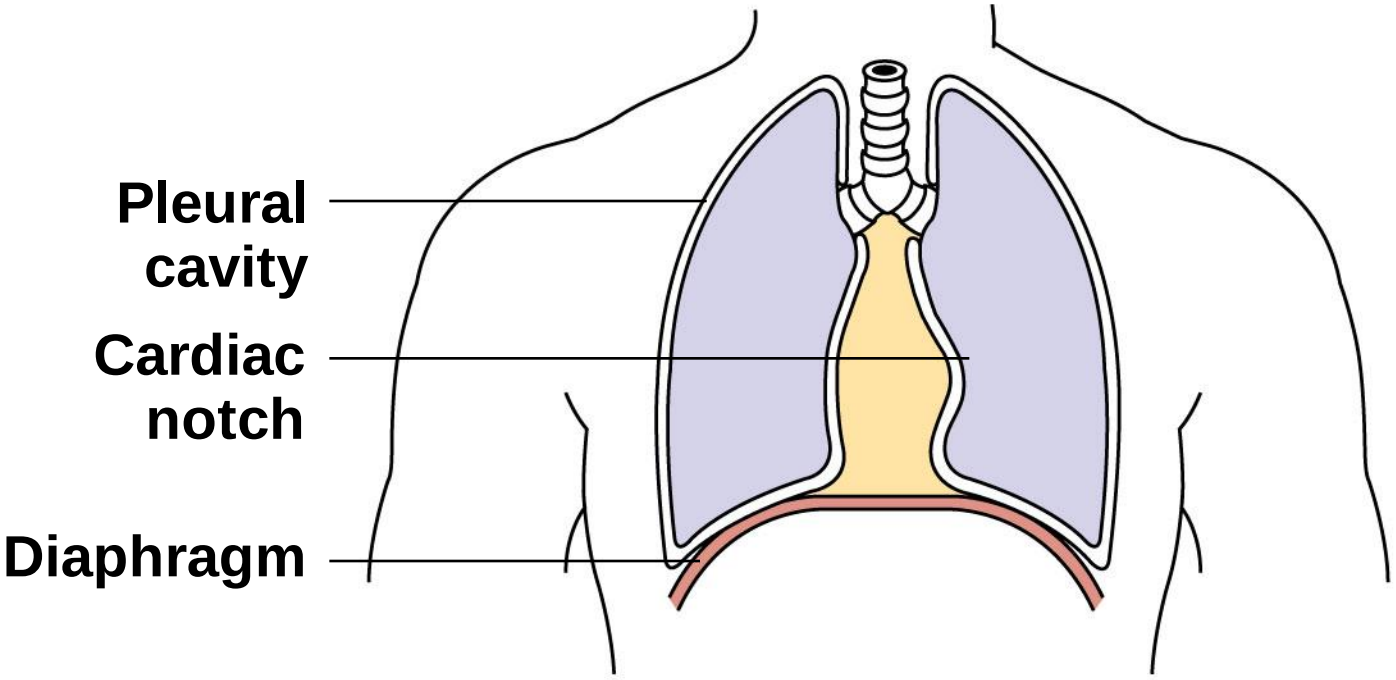
- Pulmonary Ventilation
  - Causes volume changes that create changes in pressure
  - Volume of thoracic cavity changes
    - With expansion or contraction of diaphragm or rib cage

Figure 23-14a Mechanisms of Pulmonary Ventilation



a As the rib cage is elevated or the diaphragm is depressed, the volume of the thoracic cavity increases.

Figure 23-14b Mechanisms of Pulmonary Ventilation

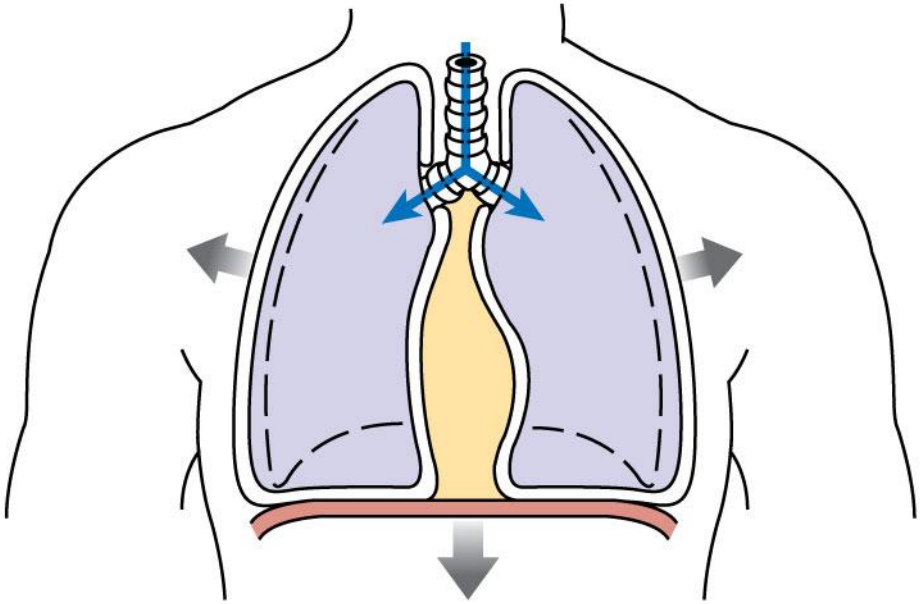


$P_{outside} = P_{inside}$

Pressure outside and inside are equal, so no air movement occurs

b At rest.

Figure 23-14c Mechanisms of Pulmonary Ventilation



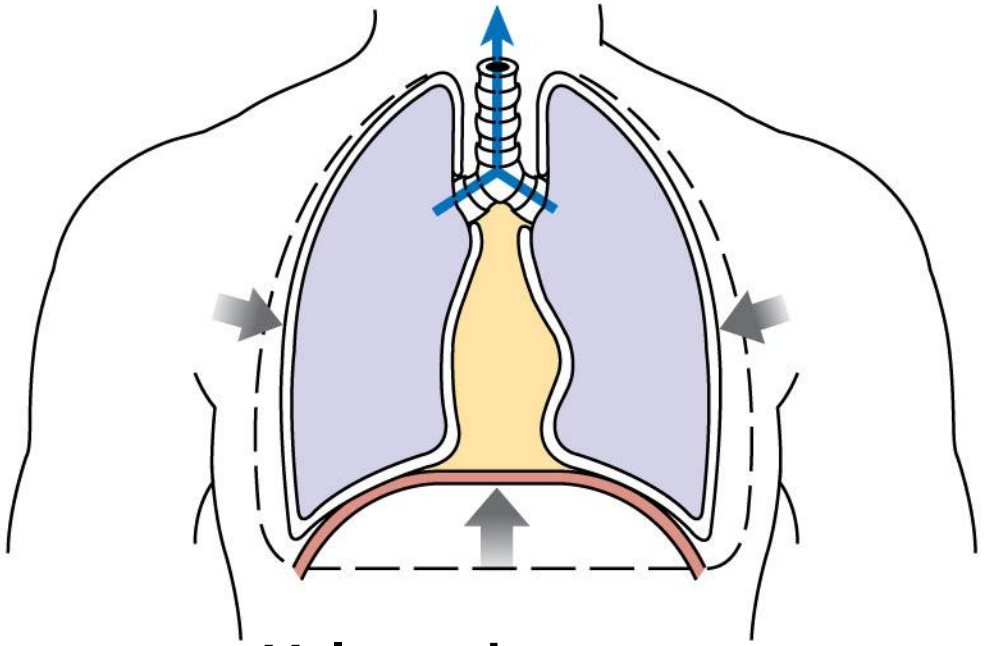
Volume increases

$P_{outside} > P_{inside}$

Pressure inside falls, so air flows in

c Inhalation. Elevation of the rib cage and contraction of the diaphragm increase the size of the thoracic cavity. Pressure within the thoracic cavity decreases, and air flows into the lungs.

Figure 23-14d Mechanisms of Pulmonary Ventilation



Volume decreases

$P_{outside} < P_{inside}$

Pressure inside rises, so air flows out

d Exhalation. When the rib cage returns to its original position and the diaphragm relaxes, the volume of the thoracic cavity decreases. Pressure rises, and air moves out of the lungs.

23-7 Pulmonary Ventilation

- **Compliance**
  - An indicator of expandability
  - Low compliance requires greater force
  - High compliance requires less force
  - Factors That Affect Compliance
    - *Connective tissue structure of the lungs*
    - *Level of surfactant production*
    - *Mobility of the thoracic cage*

23-7 Pulmonary Ventilation

- Pressure Changes during Inhalation and Exhalation
  - Can be measured inside or outside the lungs
  - Normal atmospheric pressure
    - 1 *atm* = 760 mm Hg

PLAY ANIMATION Respiration: Pressure Gradients

23-7 Pulmonary Ventilation

- The **Intrapulmonary Pressure**
  - Also called **intra-alveolar pressure**
  - Is relative to atmospheric pressure
  - In relaxed breathing, the difference between atmospheric pressure and intrapulmonary pressure is small
    - About –1 mm Hg on inhalation or +1 mm Hg on exhalation

23-7 Pulmonary Ventilation

- Maximum Intrapulmonary Pressure
  - Maximum straining, a dangerous activity, can increase range
    - From –30 mm Hg to +100 mm Hg

23-7 Pulmonary Ventilation

- The **Intrapleural Pressure**
  - Pressure in space between parietal and visceral pleura
  - Averages –4 mm Hg
  - Maximum of –18 mm Hg
  - Remains below atmospheric pressure throughout respiratory cycle

Table 23-1 The Four Most Common Methods of Reporting Gas Pressures

Table 23–1 The Four Most Common Methods of Reporting Gas Pressures

millimeters of mercury (mm Hg): This is the most common method of reporting blood pressure and gas pressures. Normal atmospheric pressure is approximately 760 mm Hg.
torr: This unit of measurement is preferred by many respiratory therapists; it is also commonly used in Europe and in some technical journals. One torr is equivalent to 1 mm Hg; in other words, normal atmospheric pressure is equal to 760 torr.
centimeters of water (cm H_2O): In a hospital setting, anesthetic gas pressures and oxygen pressures are commonly measured in centimeters of water. One cm H_2O is equivalent to 0.735 mm Hg; normal atmospheric pressure is 1033.6 cm H_2O.
pounds per square inch (psi): Pressures in compressed gas cylinders and other industrial applications are generally reported in psi. Normal atmospheric pressure at sea level is approximately 15 psi.

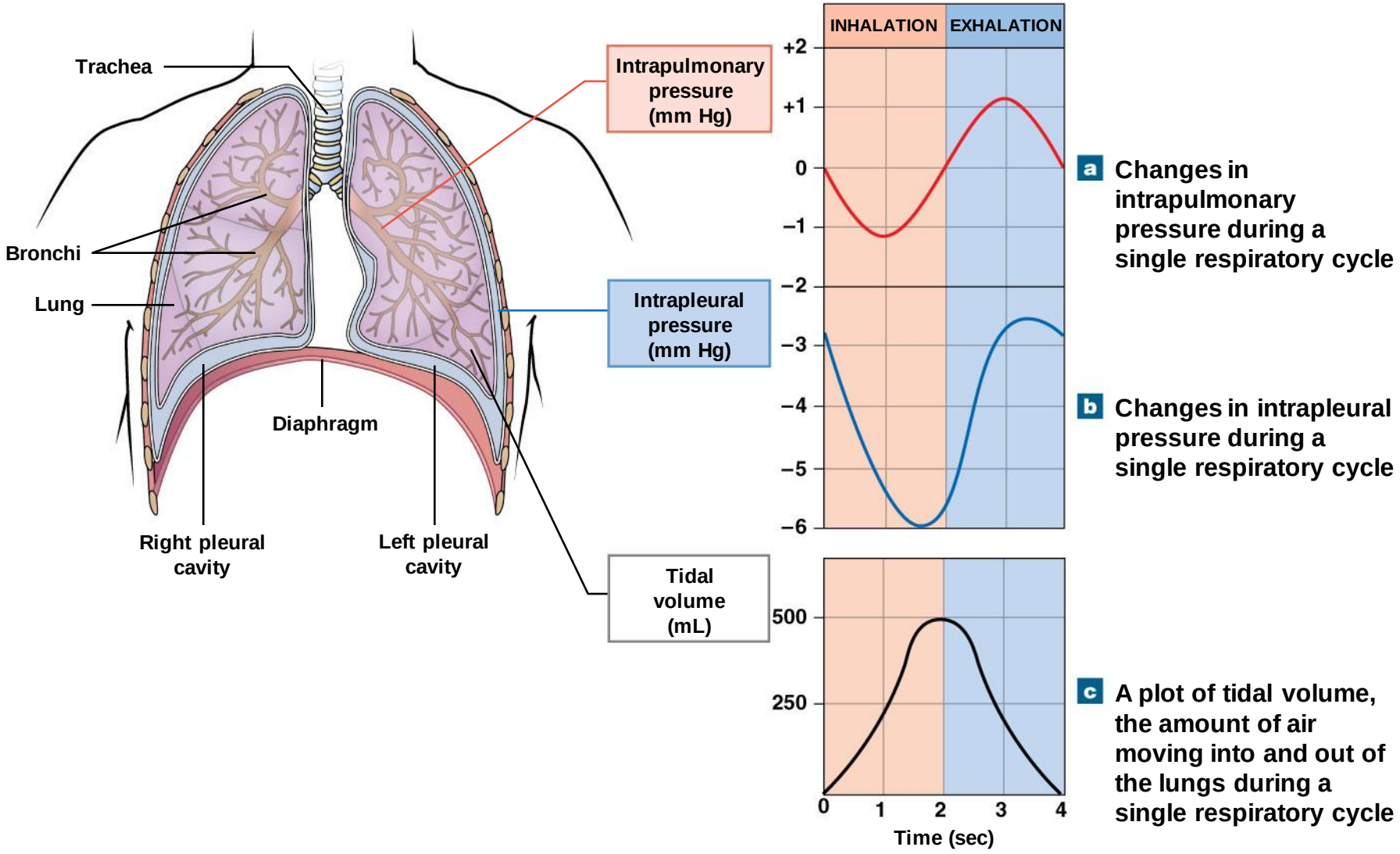
23-7 Pulmonary Ventilation

- The **Respiratory Cycle**
  - Cyclical changes in intrapleural pressure operate the respiratory pump
    - Which aids in venous return to heart
  - **Tidal Volume** (V_T)
    - Amount of air moved in and out of lungs in a single respiratory cycle

23-7 Pulmonary Ventilation

- Injury to the Chest Wall
  - **Pneumothorax** allows air into pleural cavity
  - **Atelectasis** (also called a collapsed lung) is a result of pneumothorax

Figure 23-15 Pressure and Volume Changes during Inhalation and Exhalation



a Changes in intrapulmonary pressure during a single respiratory cycle

b Changes in intrapleural pressure during a single respiratory cycle

c A plot of tidal volume, the amount of air moving into and out of the lungs during a single respiratory cycle

23-7 Pulmonary Ventilation

- The Respiratory Muscles
  - Most important are:
    - The *diaphragm*
    - *External intercostal muscles* of the ribs
    - **Accessory respiratory muscles**
      - Activated when respiration increases significantly

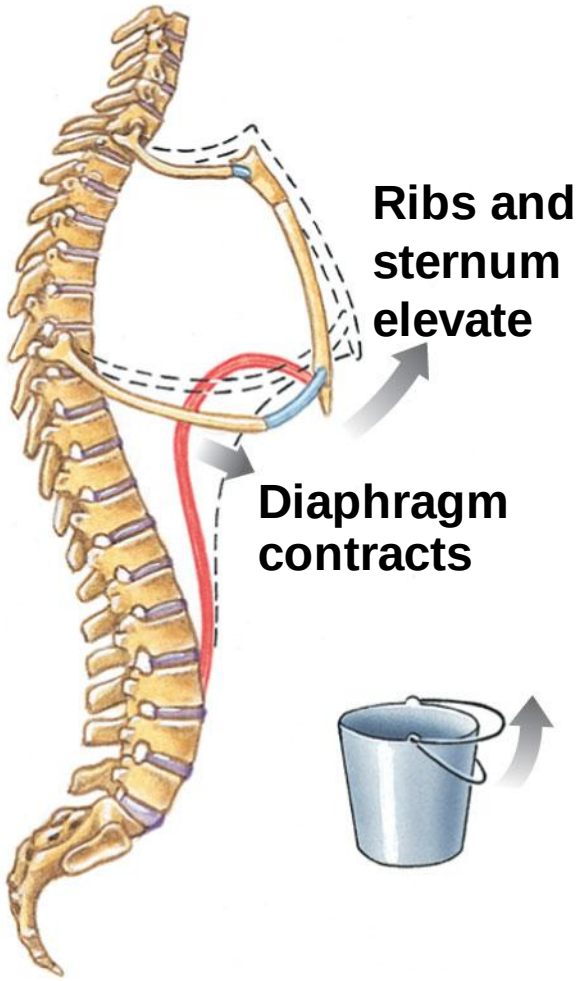
23-7 Pulmonary Ventilation

- The Mechanics of Breathing
  - Inhalation
    - Always active
  - Exhalation
    - Active or passive

23-7 Pulmonary Ventilation

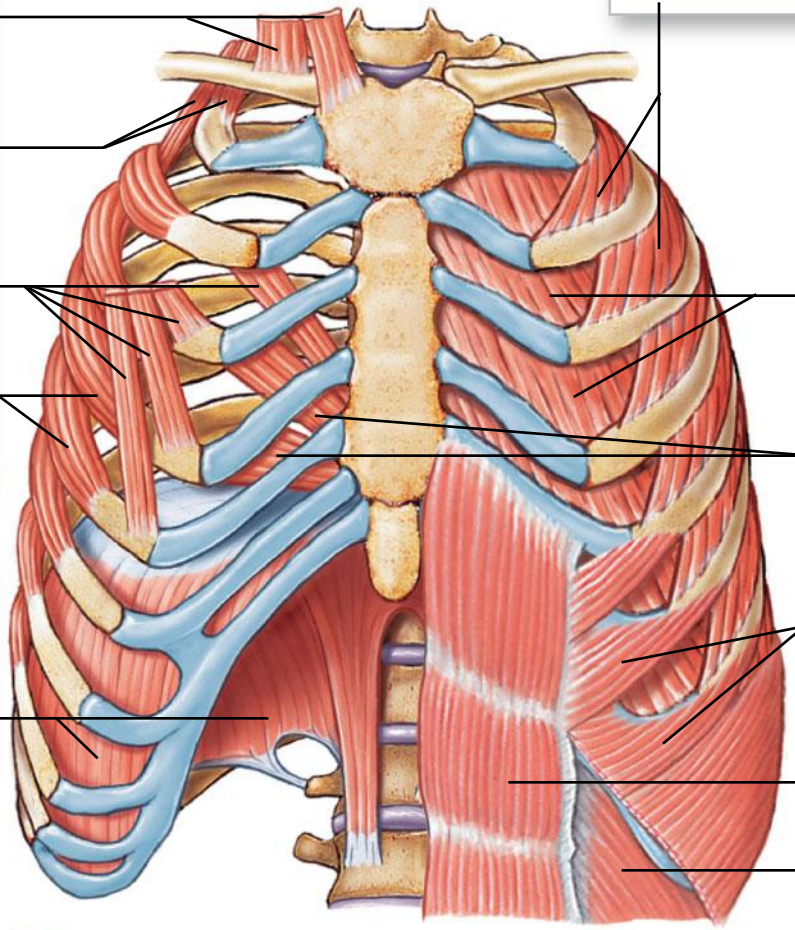
- Muscles Used in Inhalation
  - Diaphragm
    - Contraction draws air into lungs
    - 75% of normal air movement
  - External intercostal muscles
    - Assist inhalation
    - 25% of normal air movement
  - Accessory muscles assist in elevating ribs
    - Sternocleidomastoid
    - Serratus anterior
    - Pectoralis minor
    - Scalene muscles

Figure 23-16a The Respiratory Muscles



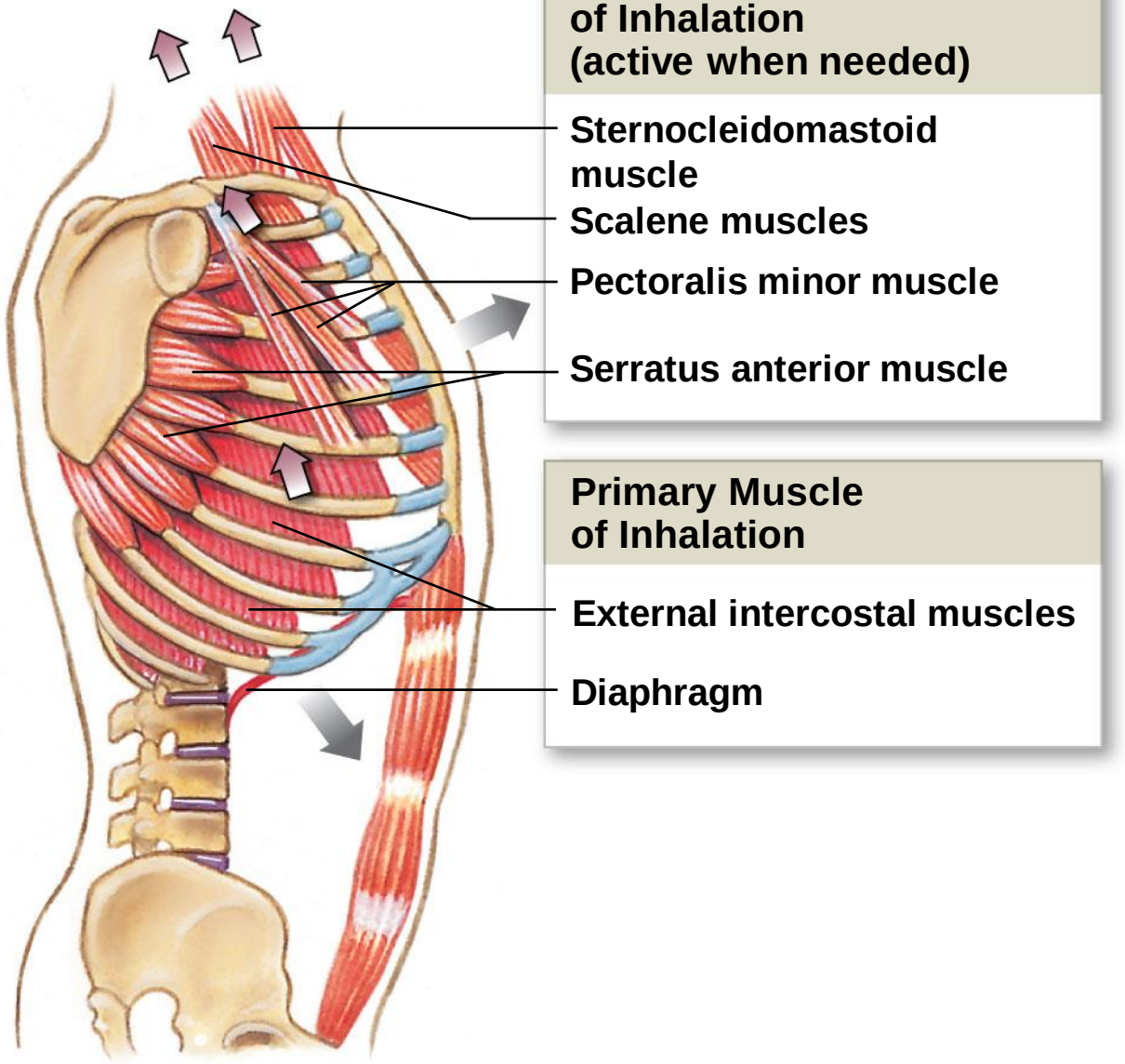
a **Movements of the ribs and diaphragm that increase the volume of the thoracic cavity. Diaphragmatic movements were also illustrated in *Figure 23–14*.**

Figure 23-16b The Respiratory Muscles



b An anterior view at rest (with no air movement), showing the primary and accessory respiratory muscles.

Figure 23-16c The Respiratory Muscles

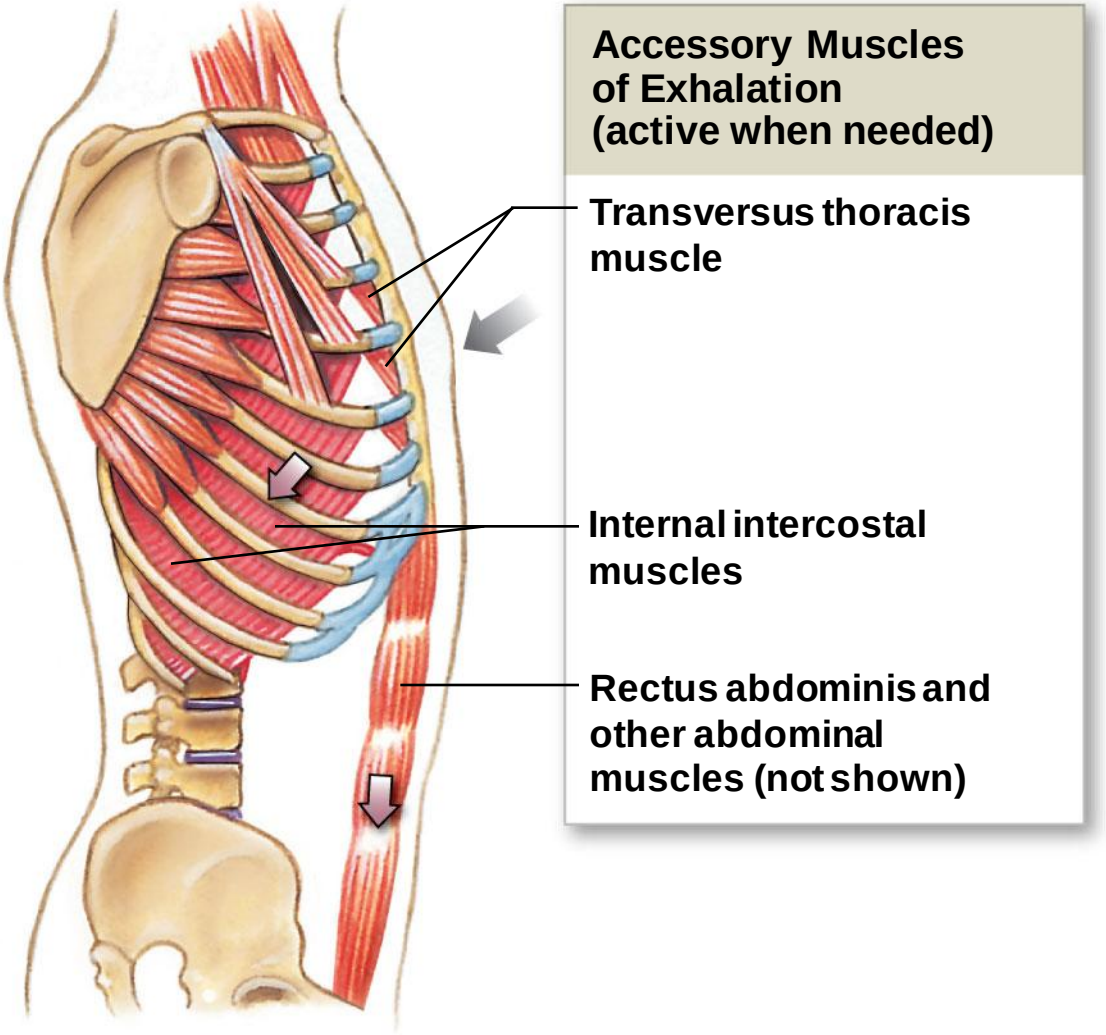


C **Inhalation. A lateral view during inhalation, showing the muscles that elevate the ribs.**

23-7 Pulmonary Ventilation

- Muscles Used in Exhalation
  - Internal intercostal and transversus thoracis muscles
    - Depress the ribs
  - Abdominal muscles
    - Compress the abdomen
    - Force diaphragm upward

Figure 23-16d The Respiratory Muscles



d **Exhalation. A lateral view during exhalation, showing the muscles that depress the ribs. The abdominal muscles that assist in exhalation are represented by a single muscle (the rectus abdominis).**

23-7 Pulmonary Ventilation

- Modes of Breathing
  - Respiratory movements are classified
    - By pattern of muscle activity
    - *Quiet breathing*
    - *Forced breathing*

23-7 Pulmonary Ventilation

- **Quiet Breathing (Eupnea)**
  - Involves active inhalation and passive exhalation
  - **Diaphragmatic breathing** or **deep breathing**
    - Is dominated by diaphragm
  - **Costal breathing** or **shallow breathing**
    - Is dominated by rib cage movements

23-7 Pulmonary Ventilation

- **Elastic Rebound**
  - When inhalation muscles relax
    - Elastic components of muscles and lungs recoil
    - Returning lungs and alveoli to original position

23-7 Pulmonary Ventilation

- **Forced Breathing (Hyperpnea)**
  - Involves active inhalation and exhalation
  - Assisted by accessory muscles
  - Maximum levels occur in exhaustion

23-7 Pulmonary Ventilation

- Respiratory Rates and Volumes
  - Respiratory system adapts to changing oxygen demands by varying:
    - The number of breaths per minute (**respiratory rate**)
    - The volume of air moved per breath (**tidal volume**)

23-7 Pulmonary Ventilation

- The **Respiratory Minute Volume** (V_E)
  - Amount of air moved per minute
  - Is calculated by:

    respiratory rate $\times$ tidal volume
  - Measures pulmonary ventilation

23-7 Pulmonary Ventilation

- **Alveolar Ventilation** (V_A)
  - Only a part of respiratory minute volume reaches alveolar exchange surfaces
  - Volume of air remaining in conducting passages is **anatomic dead space**
  - Alveolar ventilation is the amount of air reaching alveoli each minute
  - Calculated as:

$$(\text{tidal volume} - \text{anatomic dead space}) \times \text{respiratory rate}$$

23-7 Pulmonary Ventilation

- Alveolar Gas Content
  - Alveoli contain less O_2, more CO_2 than atmospheric air
    - Because air mixes with exhaled air

23-7 Pulmonary Ventilation

- Relationships among V_T, V_E, and V_A
  - Determined by respiratory rate and tidal volume
    - For a given respiratory rate:
      - Increasing tidal volume increases alveolar ventilation rate
    - For a given tidal volume:
      - Increasing respiratory rate increases alveolar ventilation

23-7 Pulmonary Ventilation

- Respiratory Performance and Volume Relationships
  - Total lung volume is divided into a series of *volumes* and *capacities* useful in diagnosing problems
  - Four Pulmonary Volumes
    1. **Resting tidal volume (V_t)**
    2. **Expiratory reserve volume (ERV)**
    3. **Residual volume**
    4. **Inspiratory reserve volume (IRV)**

23-7 Pulmonary Ventilation

- **Resting Tidal Volume (V_t)**
  - In a normal respiratory cycle
- **Expiratory Reserve Volume (ERV)**
  - After a normal exhalation
- **Residual Volume**
  - After maximal exhalation
  - **Minimal volume** (in a collapsed lung)
- **Inspiratory Reserve Volume (IRV)**
  - After a normal inspiration

23-7 Pulmonary Ventilation

- Four Calculated Respiratory Capacities

1. **Inspiratory capacity**
   - Tidal volume + inspiratory reserve volume
2. **Functional residual capacity (FRC)**
   - Expiratory reserve volume + residual volume
3. **Vital capacity**
   - Expiratory reserve volume + tidal volume + inspiratory reserve volume

23-7 Pulmonary Ventilation

- Four Calculated Respiratory Capacities
  4. **Total lung capacity**
     - Vital capacity + residual volume
- Pulmonary Function Tests
  - Measure rates and volumes of air movements

Figure 23-17 Pulmonary Volumes and Capacities

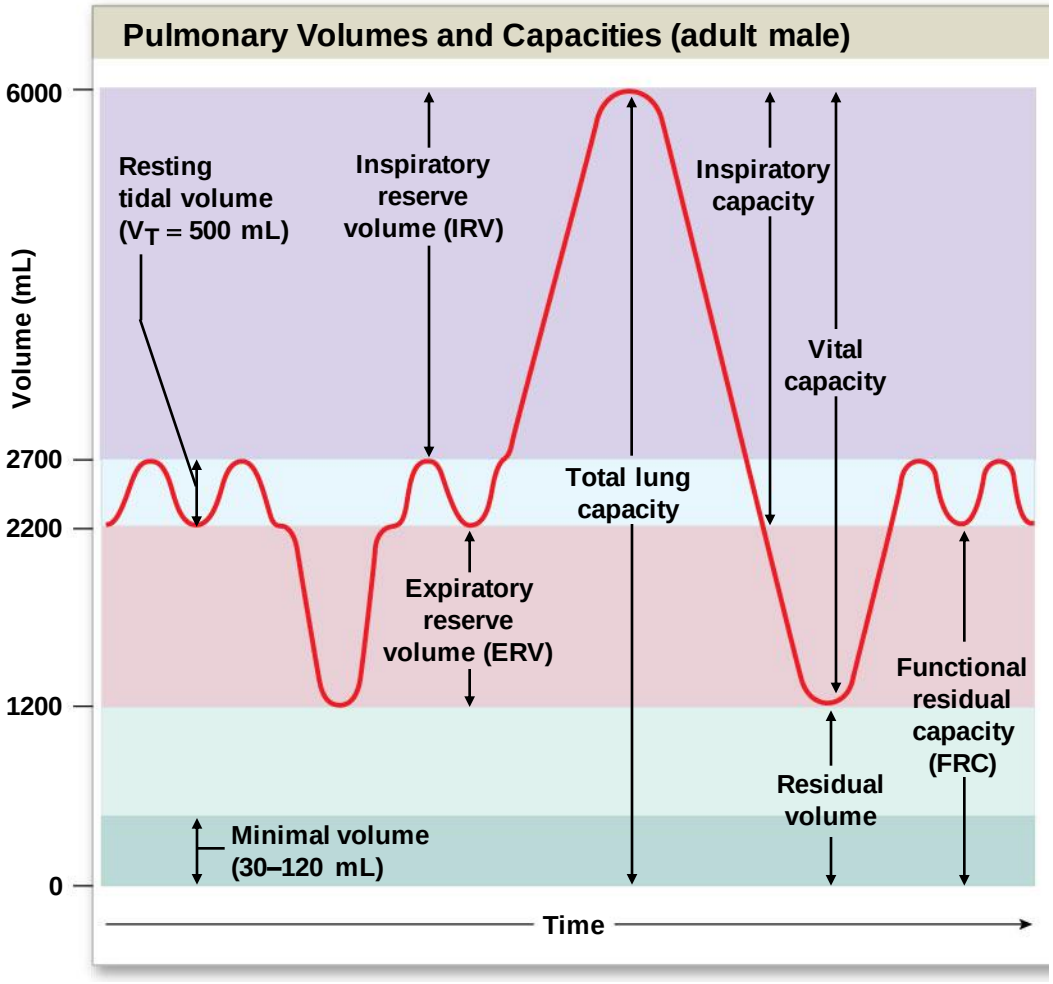
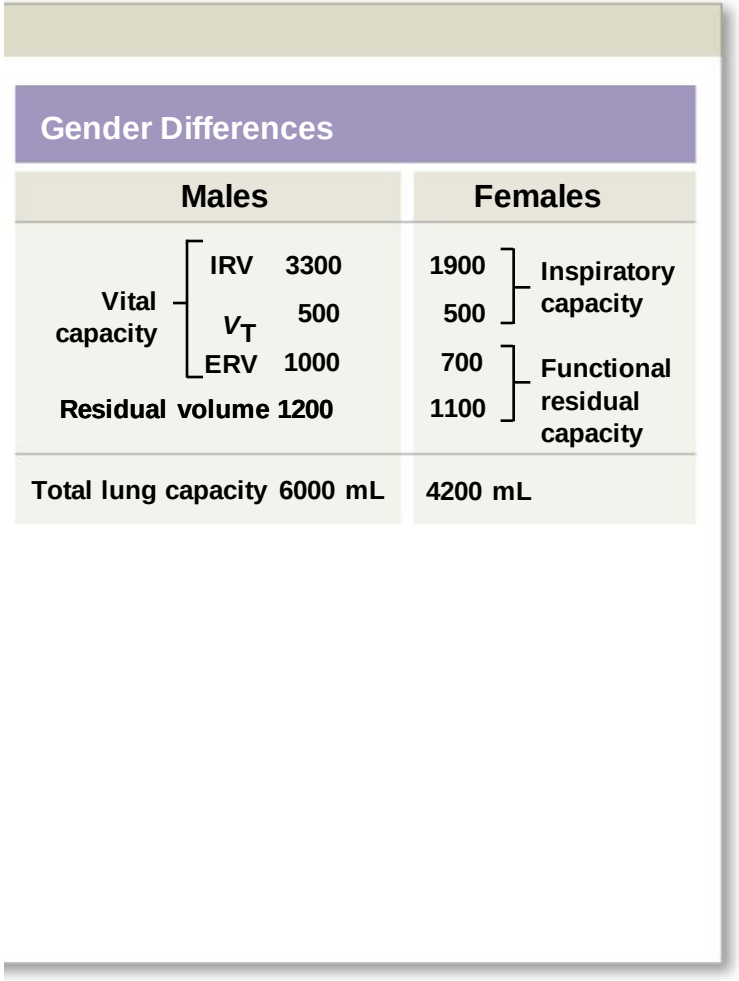


Figure 23-17 Pulmonary Volumes and Capacities



23-8 Gas Exchange

- Gas Exchange
  - Occurs between blood and alveolar air
  - Across the respiratory membrane
- Depends on:
  1. *Partial pressures* of the gases
  2. Diffusion of molecules between gas and liquid

23-8 Gas Exchange

- The Gas Laws
  - Diffusion occurs in response to concentration gradients
  - Rate of diffusion depends on physical principles, or *gas laws*
    - For example, Boyle's law

23-8 Gas Exchange

- **Dalton's Law** and **Partial Pressures**
  - Composition of Air
    - Nitrogen (N_2) is about 78.6%
    - Oxygen (O_2) is about 20.9%
    - Water vapor (H_2O) is about 0.5%
    - Carbon dioxide (CO_2) is about 0.04%

23-8 Gas Exchange

- Dalton's Law and Partial Pressures
  - Atmospheric pressure (760 mm Hg)
    - Produced by air molecules bumping into each other
  - Each gas contributes to the total pressure
    - In proportion to its number of molecules (Dalton's law)

23-8 Gas Exchange

- Partial Pressure
  - The pressure contributed by each gas in the atmosphere
  - All partial pressures together add up to 760 mm Hg

23-8 Gas Exchange

- Diffusion between Liquids and Gases
  - **Henry's Law**
    - When gas under pressure comes in contact with liquid
      - Gas dissolves in liquid until equilibrium is reached
    - At a given temperature
      - Amount of a gas in solution is proportional to partial pressure of that gas
    - The actual amount of a gas in solution (at given partial pressure and temperature)
      - Depends on the solubility of that gas in that particular liquid

Figure 23-18 Henry's Law and the Relationship between Solubility and Pressure

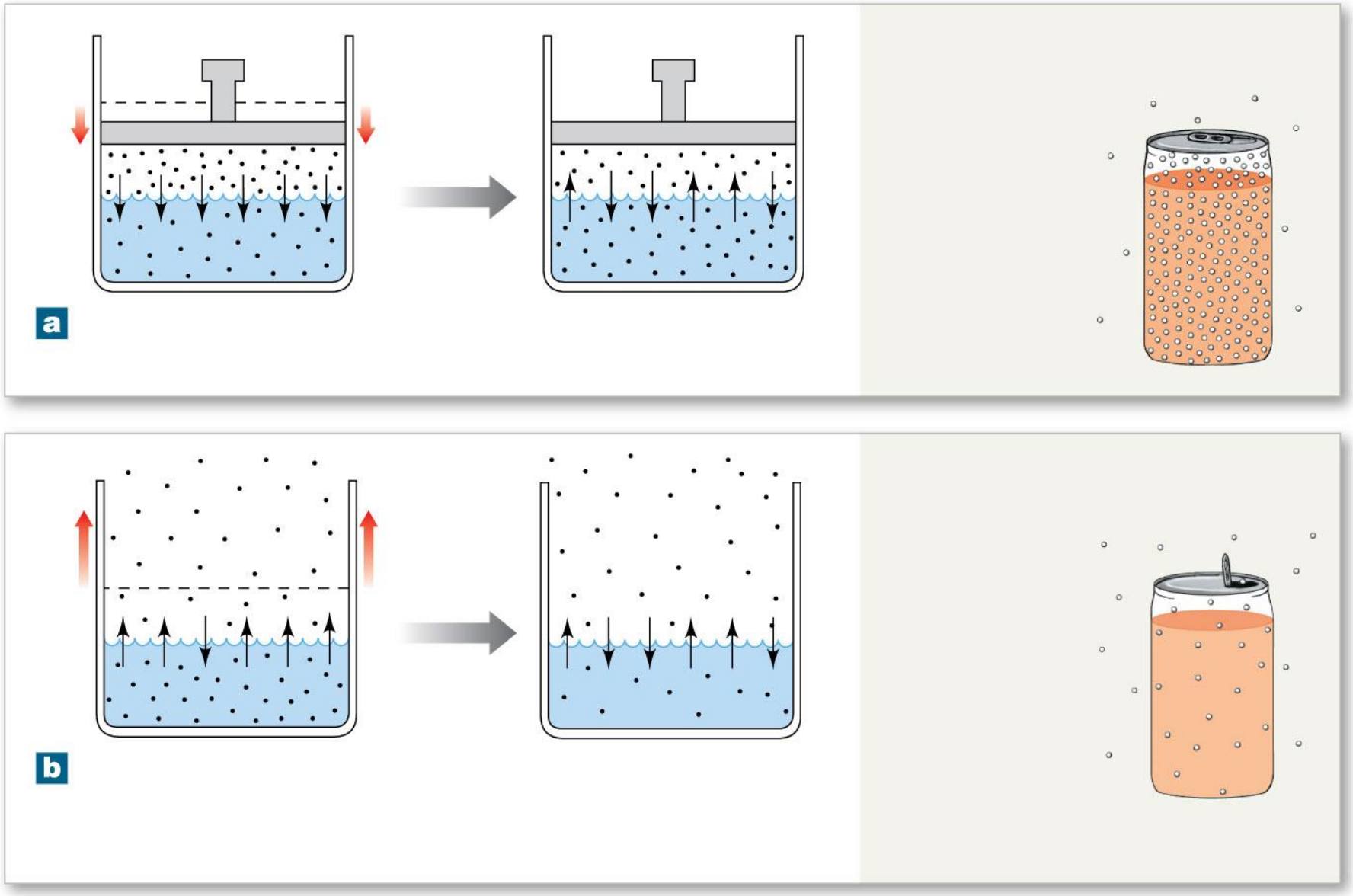
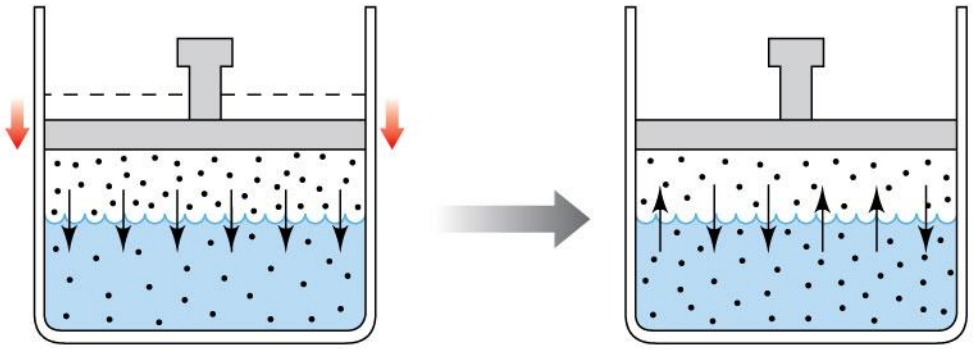


Figure 23-18a Henry's Law and the Relationship between Solubility and Pressure

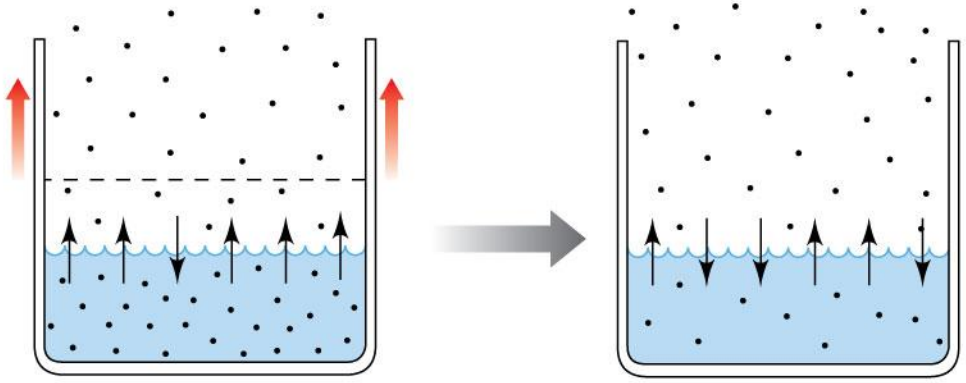


a **Increasing the pressure drives gas molecules into solution until an equilibrium is established.**

Example

Soda is put into the can under pressure, and the gas (carbon dioxide) is in solution at equilibrium.

Figure 23-18b Henry's Law and the Relationship between Solubility and Pressure



b When the gas pressure decreases, dissolved gas molecules leave the solution until a new equilibrium is reached.

Example
Opening the can of soda relieves the pressure, and bubbles form as the dissolved gas leaves the solution.

23-8 Gas Exchange

- Solubility in Body Fluids
  - CO_2 is very soluble
  - O_2 is less soluble
  - N_2 has very low solubility

23-8 Gas Exchange

- Normal Partial Pressures
  - In pulmonary vein plasma
    - P_{CO_2} = 40 mm Hg
    - P_{O_2} = 100 mm Hg
    - P_{N_2} = 573 mm Hg

Table 23-1 The Four Most Common Methods of Reporting Gas Pressures

Table 23–1 The Four Most Common Methods of Reporting Gas Pressures

millimeters of mercury (mm Hg): This is the most common method of reporting blood pressure and gas pressures. Normal atmospheric pressure is approximately 760 mm Hg.
torr: This unit of measurement is preferred by many respiratory therapists; it is also commonly used in Europe and in some technical journals. One torr is equivalent to 1 mm Hg; in other words, normal atmospheric pressure is equal to 760 torr.
centimeters of water (cm H_2O): In a hospital setting, anesthetic gas pressures and oxygen pressures are commonly measured in centimeters of water. One cm H_2O is equivalent to 0.735 mm Hg; normal atmospheric pressure is 1033.6 cm H_2O.
pounds per square inch (psi): Pressures in compressed gas cylinders and other industrial applications are generally reported in psi. Normal atmospheric pressure at sea level is approximately 15 psi.

23-8 Gas Exchange

- Diffusion and Respiratory Function
  - Direction and rate of diffusion of gases across the respiratory membrane
    - Determine different partial pressures and solubilities

23-8 Gas Exchange

- Five Reasons for Efficiency of Gas Exchange
  1. Substantial differences in partial pressure across the respiratory membrane
  2. Distances involved in gas exchange are short
  3. O_2 and CO_2 are lipid soluble
  4. Total surface area is large
  5. Blood flow and airflow are coordinated

23-8 Gas Exchange

- Partial Pressures in Alveolar Air and Alveolar Capillaries
  - Blood arriving in pulmonary arteries has:
    - Low P_{O_2}
    - High P_{CO_2}
  - The concentration gradient causes:
    - O_2 to enter blood
    - CO_2 to leave blood
  - Rapid exchange allows blood and alveolar air to reach equilibrium

23-8 Gas Exchange

- Partial Pressures in the Systemic Circuit
  - Oxygenated blood mixes with deoxygenated blood from conducting passageways
  - Lowers the P_{O_2} of blood entering systemic circuit (drops to about 95 mm Hg)

23-8 Gas Exchange

- Partial Pressures in the Systemic Circuit
  - Interstitial Fluid
    - P_{O_2} 40 mm Hg
    - P_{CO_2} 45 mm Hg
  - Concentration gradient in peripheral capillaries is opposite of lungs
    - CO_2 diffuses into blood
    - O_2 diffuses out of blood

Figure 23-19a An Overview of Respiratory Processes and Partial Pressures in Respiration

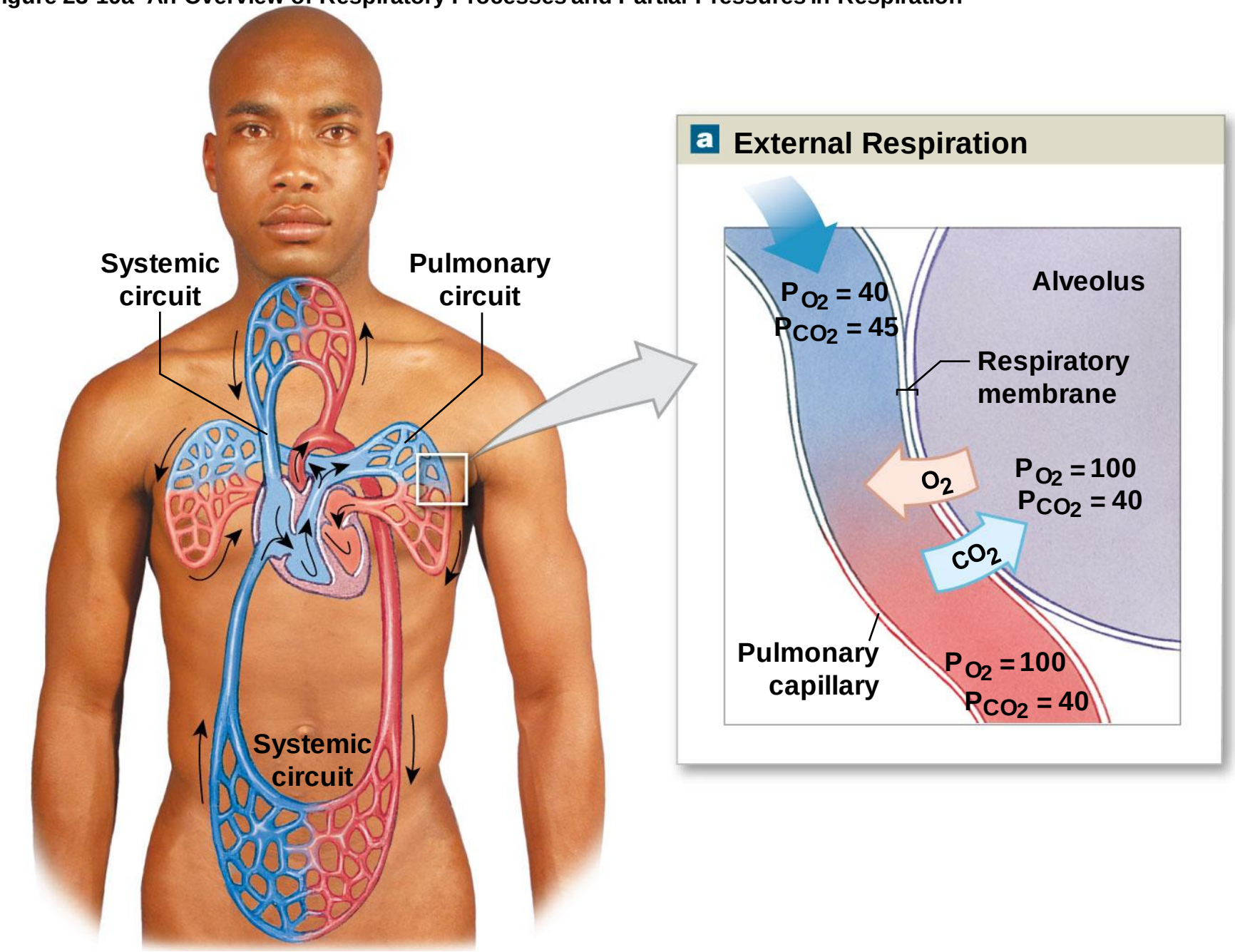
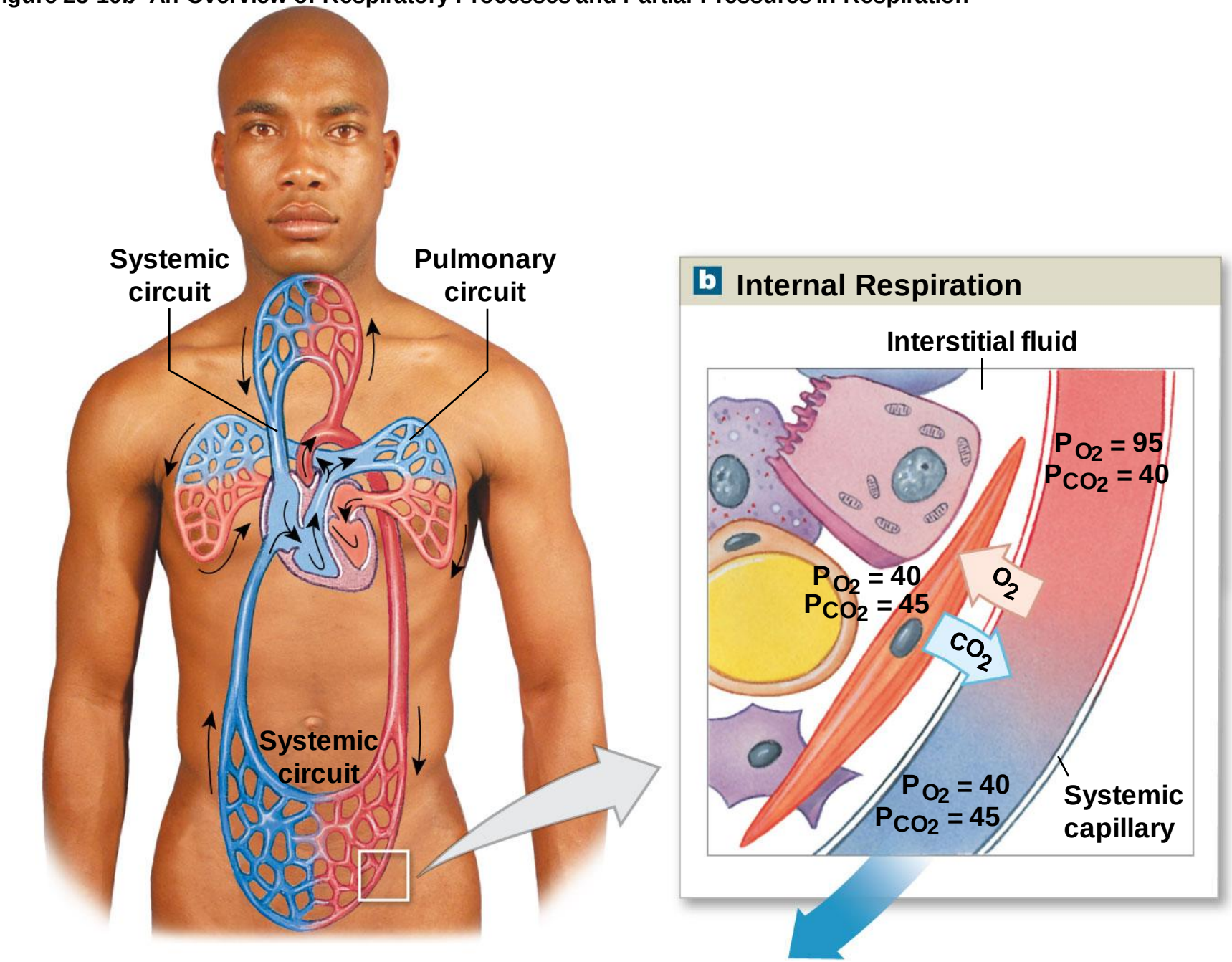


Figure 23-19b An Overview of Respiratory Processes and Partial Pressures in Respiration



23-9 Gas Transport

- Gas Pickup and Delivery
  - Blood plasma cannot transport enough O_2 or CO_2 to meet physiological needs
  - Red Blood Cells (RBCs)
    - Transport O_2 to, and CO_2 from, peripheral tissues
    - Remove O_2 and CO_2 from plasma, allowing gases to diffuse into blood

23-9 Gas Transport

- Oxygen Transport
  - O_2 binds to iron ions in hemoglobin (Hb) molecules
    - In a reversible reaction
    - New molecule is called **oxyhemoglobin (HbO_2)**
  - Each RBC has about 280 million Hb molecules
    - Each binds four oxygen molecules

23-9 Gas Transport

- **Hemoglobin Saturation**
  - The percentage of heme units in a hemoglobin molecule that contain bound oxygen
- Environmental Factors Affecting Hemoglobin
  - P_{O_2} of blood
  - Blood pH
  - Temperature
  - Metabolic activity within RBCs

23-9 Gas Transport

- **Oxygen–Hemoglobin Saturation Curve**
  - A graph relating the saturation of hemoglobin to partial pressure of oxygen
    - Higher P_{O_2} results in greater Hb saturation
  - Curve rather than a straight line because Hb changes shape each time a molecule of O_2 is bound
    - Each O_2 bound makes next O_2 binding easier
    - Allows Hb to bind O_2 when O_2 levels are low

23-9 Gas Transport

- Oxygen Reserves
  - O_2 diffuses
    - From peripheral capillaries (high P_{O_2})
    - Into interstitial fluid (low P_{O_2})
  - Amount of O_2 released depends on interstitial P_{O_2}
  - Up to 3/4 may be reserved by RBCs

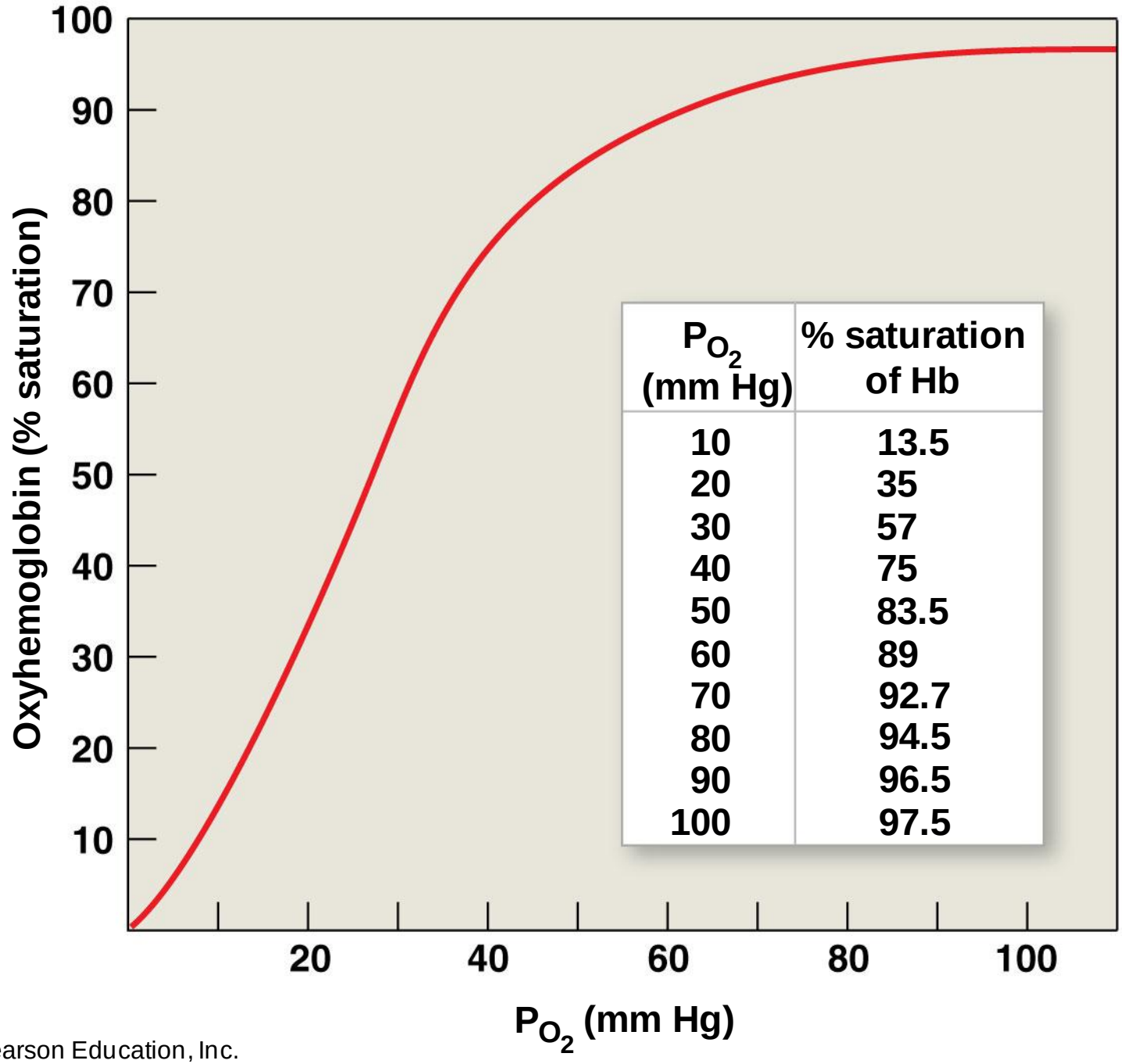
23-9 Gas Transport

- Carbon Monoxide
  - CO from burning fuels
    - Binds strongly to hemoglobin
    - Takes the place of O_2
    - Can result in **carbon monoxide poisoning**

23-9 Gas Transport

- The Oxygen–Hemoglobin Saturation Curve
  - Is standardized for normal blood (pH 7.4, 37°C)
  - When pH drops or temperature rises:
    - More oxygen is released
    - Curve shifts to right
  - When pH rises or temperature drops:
    - Less oxygen is released
    - Curve shifts to left

Figure 23-20 An Oxygen-Hemoglobin Saturation Curve

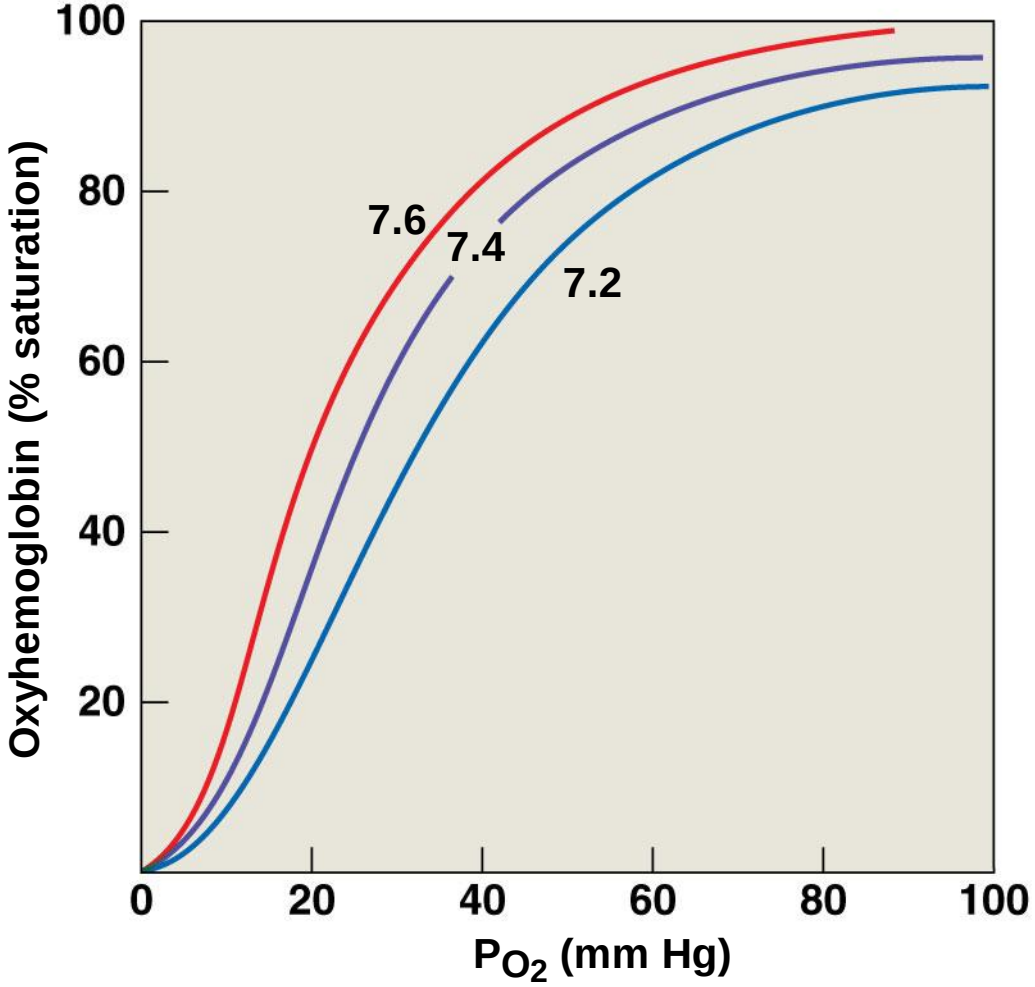


P_{O_2} (mm Hg)	% saturation of Hb
10	13.5
20	35
30	57
40	75
50	83.5
60	89
70	92.7
80	94.5
90	96.5
100	97.5

23-9 Gas Transport

- Hemoglobin and pH
  - **Bohr effect** is the result of pH on hemoglobin-saturation curve
  - Caused by CO_2
    - CO_2 diffuses into RBC
    - An enzyme, called **carbonic anhydrase**, catalyzes reaction with H_2O
    - Produces carbonic acid (H_2CO_3)
      - Dissociates into hydrogen ion (H^+) and bicarbonate ion (HCO_3^-)
      - Hydrogen ions diffuse out of RBC, lowering pH

Figure 23-21a The Effects of pH and Temperature on Hemoglobin Saturation

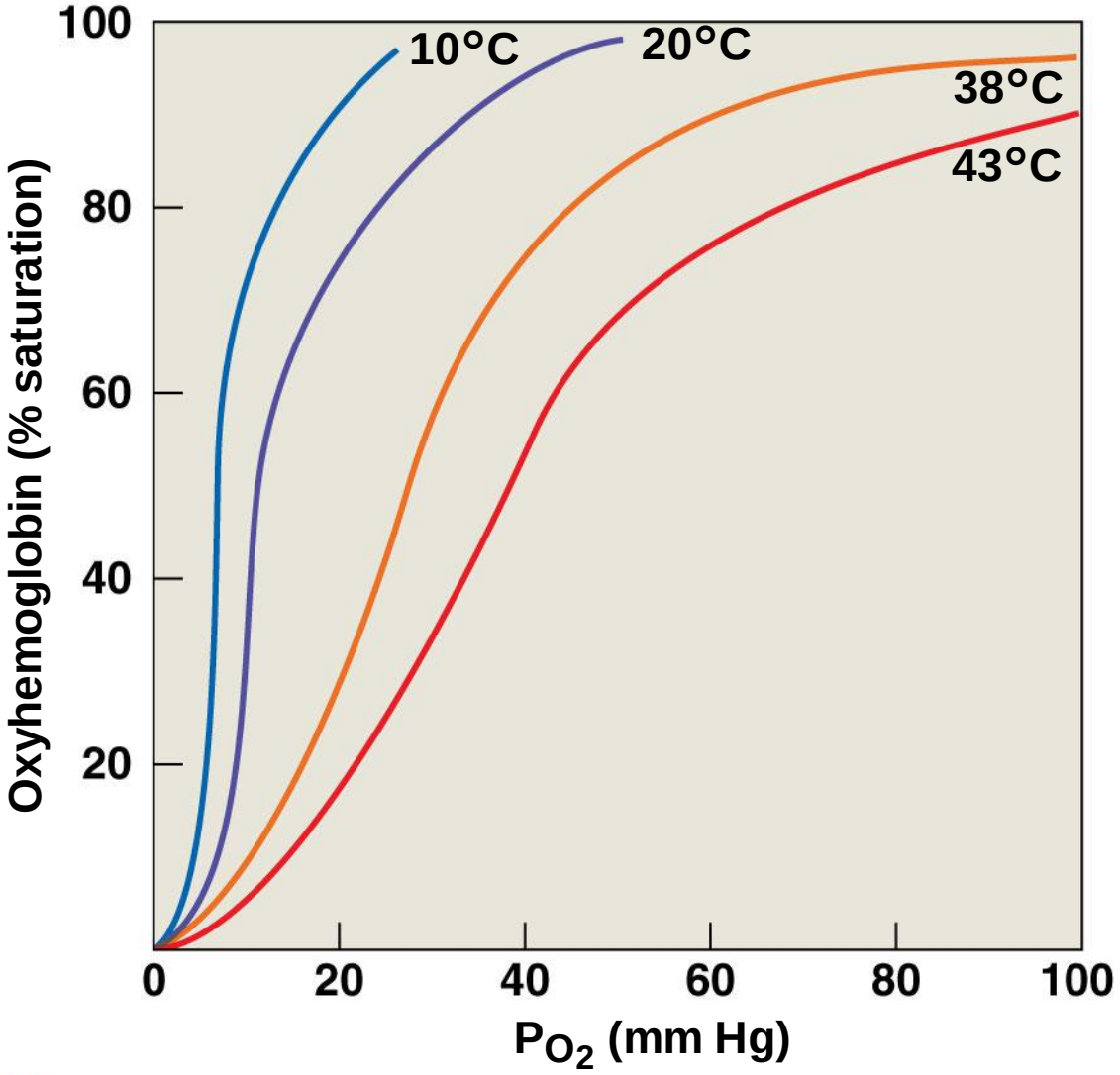


a **Effect of pH. When the pH drops below normal levels, more oxygen is released; the oxygen–hemoglobin saturation curve shifts to the right. When the pH increases, less oxygen is released; the curve shifts to the left.**

23-9 Gas Transport

- Hemoglobin and Temperature
  - Temperature increase = hemoglobin releases more oxygen
  - Temperature decrease = hemoglobin holds oxygen more tightly
    - Temperature effects are significant only in active tissues that are generating large amounts of heat
      - For example, active skeletal muscles

Figure 23-21b The Effects of pH and Temperature on Hemoglobin Saturation



b **Effect of temperature. When the temperature rises, more oxygen is released; the oxygen–hemoglobin saturation curve shifts to the right.**

23-9 Gas Transport

- Hemoglobin and BPG
  - **2,3-bisphosphoglycerate (BPG)**
    - RBCs generate ATP by glycolysis
      - Forming lactic acid and BPG
    - BPG directly affects O_2 binding and release
      - More BPG, more oxygen released

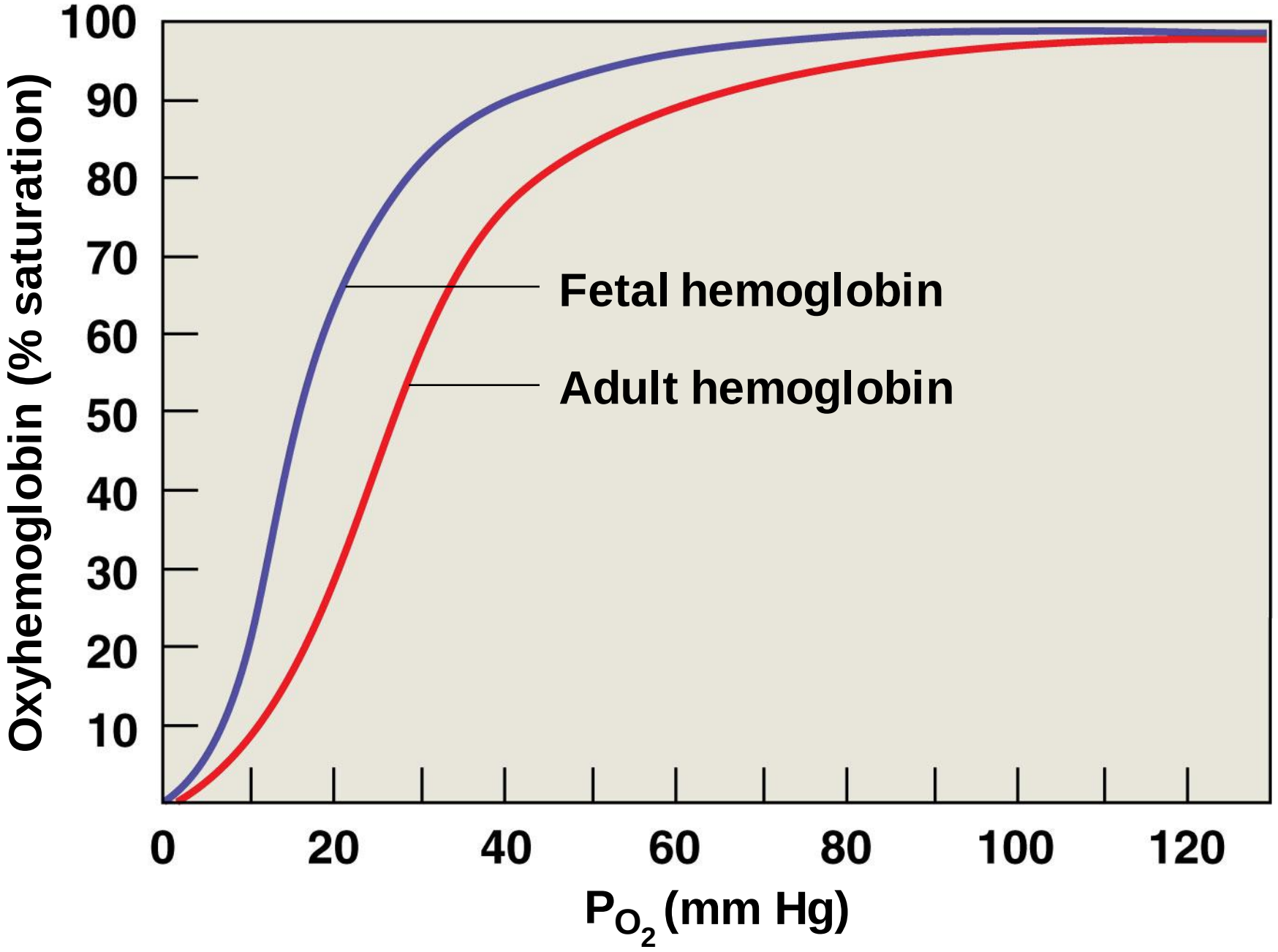
23-9 Gas Transport

- BPG Levels
  - BPG levels rise:
    - When pH increases
    - When stimulated by certain hormones
  - If BPG levels are too low:
    - Hemoglobin will not release oxygen

23-9 Gas Transport

- **Fetal Hemoglobin**
  - The structure of fetal hemoglobin
    - Differs from that of adult Hb
  - At the same P_{O_2}:
    - Fetal Hb binds more O_2 than adult Hb
    - Which allows fetus to take O_2 from maternal blood

Figure 23-22 A Functional Comparison of Fetal and Adult Hemoglobin



23-9 Gas Transport

- Carbon Dioxide Transport (CO_2)
  - Is generated as a by-product of aerobic metabolism (cellular respiration)
  - CO_2 in the bloodstream can be carried three ways
    1. Converted to carbonic acid
    2. Bound to hemoglobin within red blood cells
    3. Dissolved in plasma

23-9 Gas Transport

- Carbonic Acid Formation
  - 70% is transported as carbonic acid (H_2CO_3)
    - Which dissociates into H^+ and bicarbonate (HCO_3^-)
      - Hydrogen ions bind to hemoglobin
      - Bicarbonate Ions
        - Move into plasma by an exchange mechanism (the **chloride shift**) that takes in Cl^- ions without using ATP

23-9 Gas Transport

- CO_2 Binding to Hemoglobin
  - 23% is bound to amino groups of globular proteins in Hb molecule
    - Forming **carbaminohemoglobin**
- Transport in Plasma
  - 7% is transported as CO_2 dissolved in plasma

Figure 23-23 Carbon Dioxide Transport in Blood

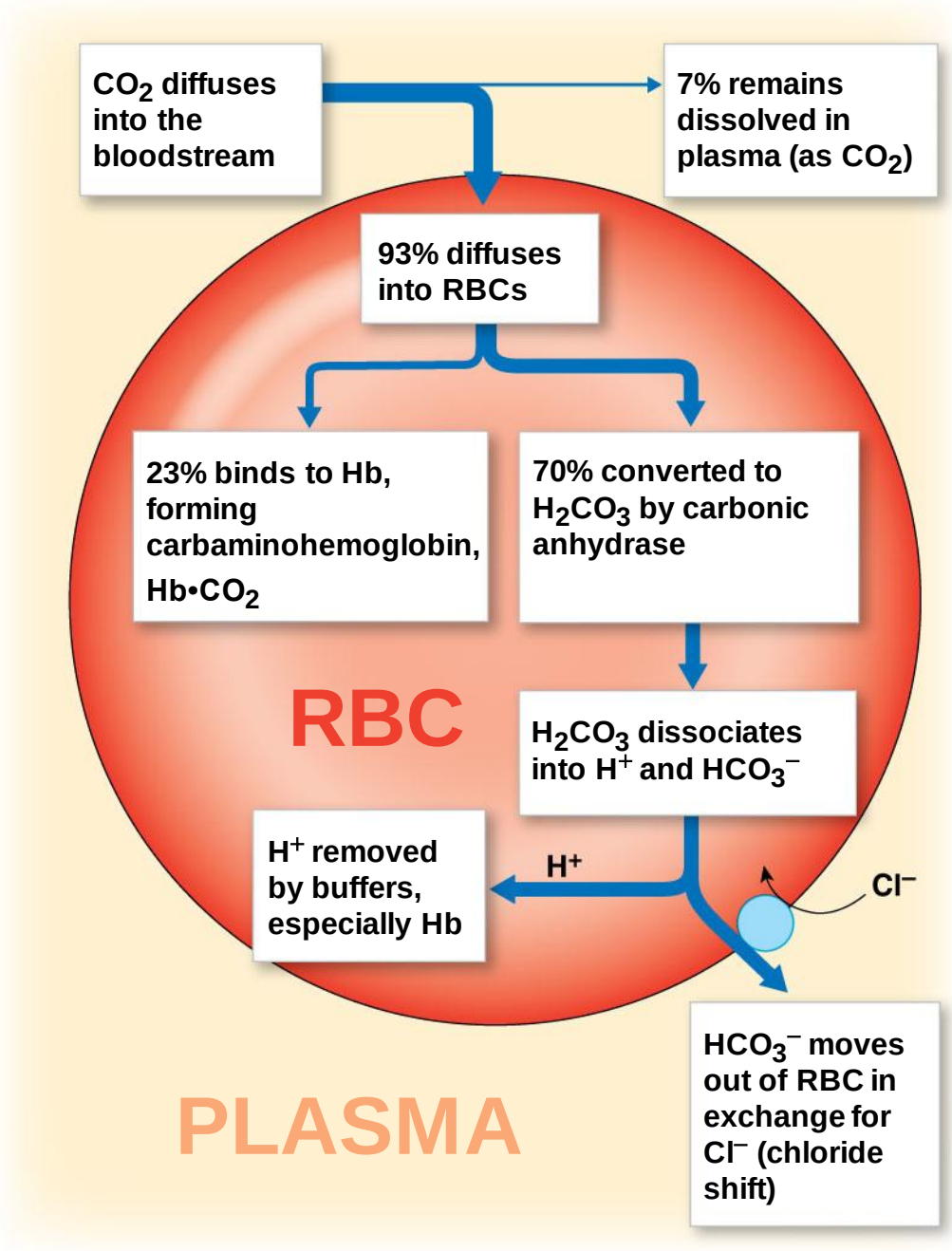


Figure 23-24 A Summary of the Primary Gas Transport Mechanisms

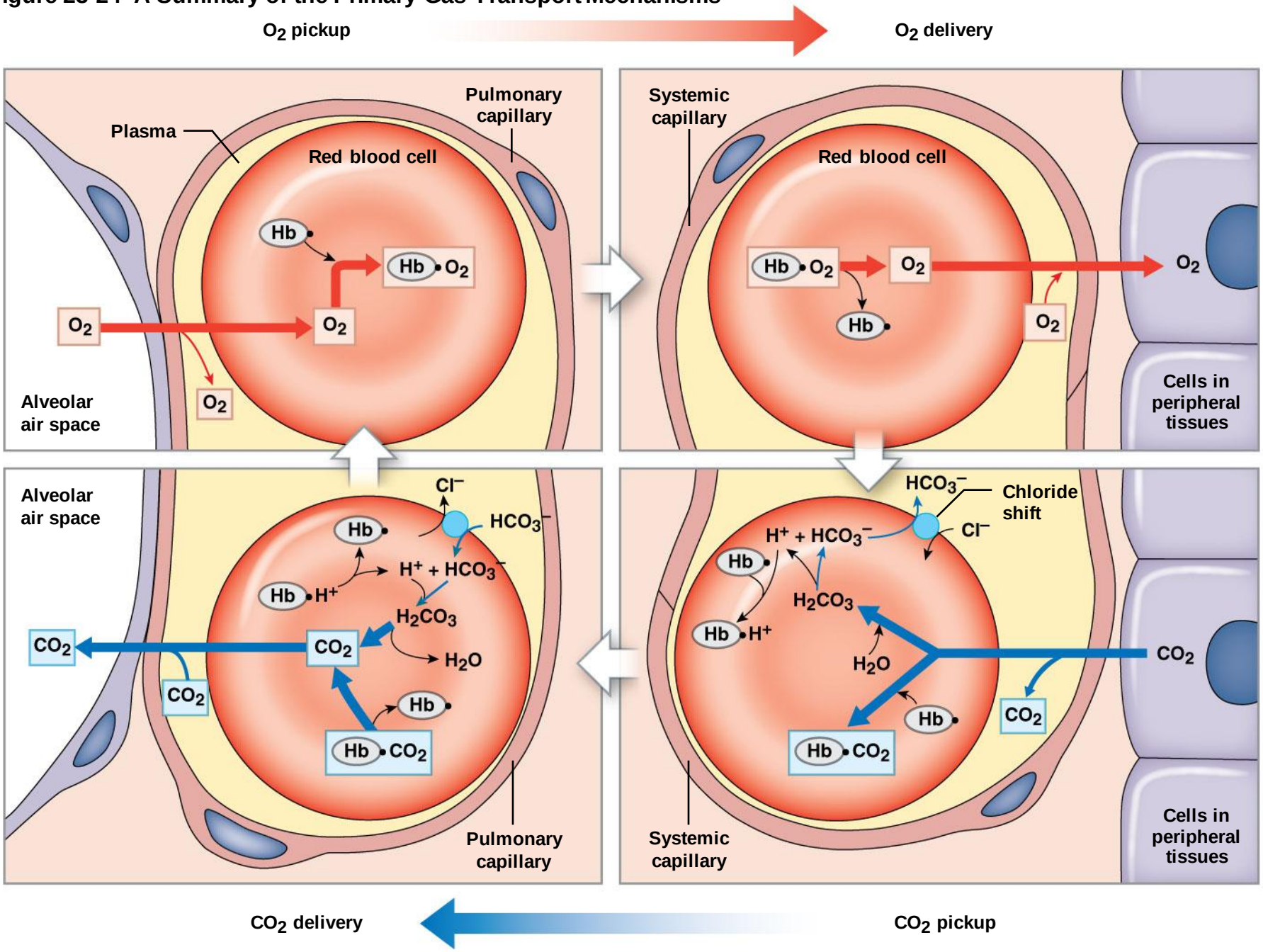


Figure 23-24 A Summary of the Primary Gas Transport Mechanisms

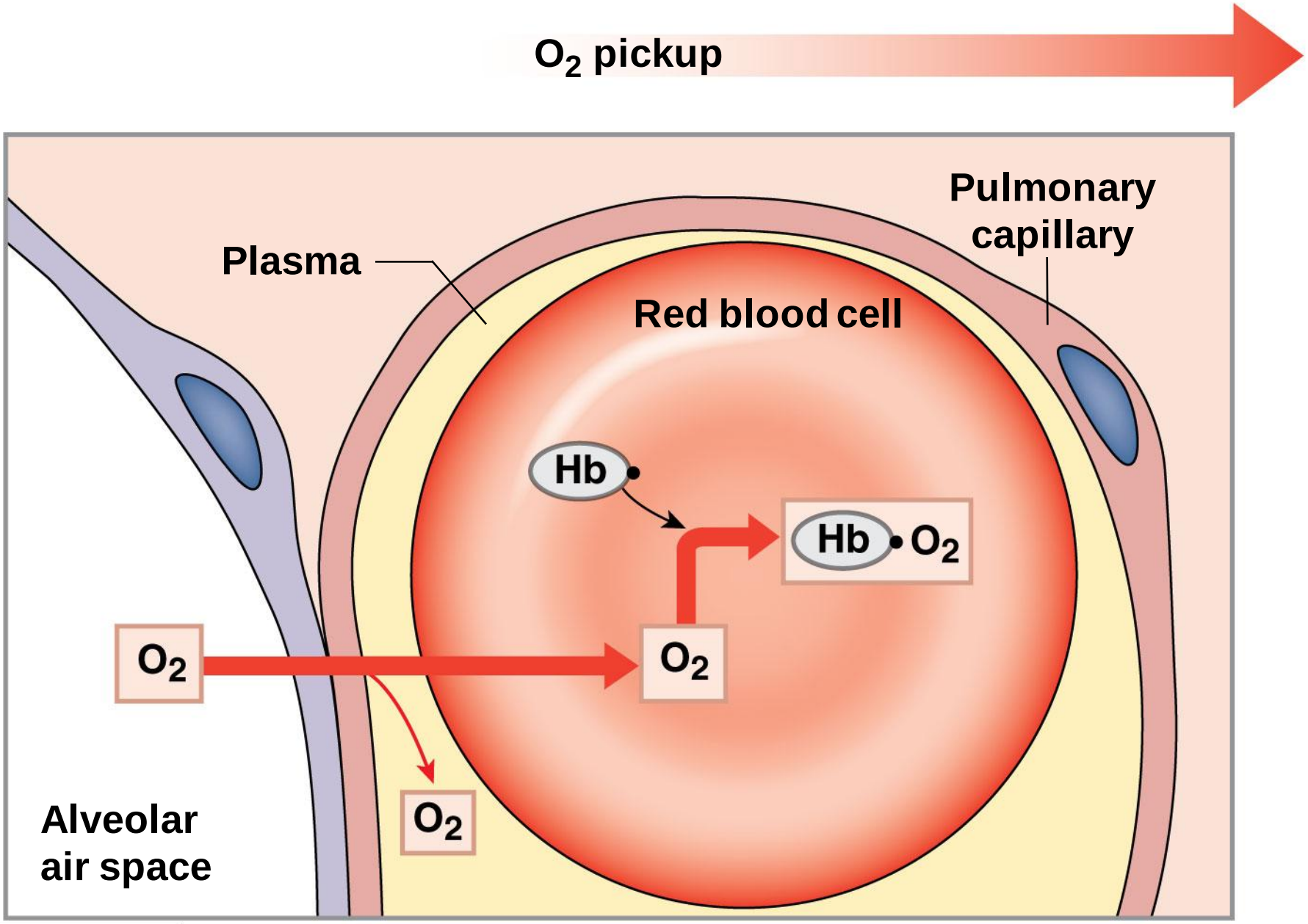


Figure 23-24 A Summary of the Primary Gas Transport Mechanisms

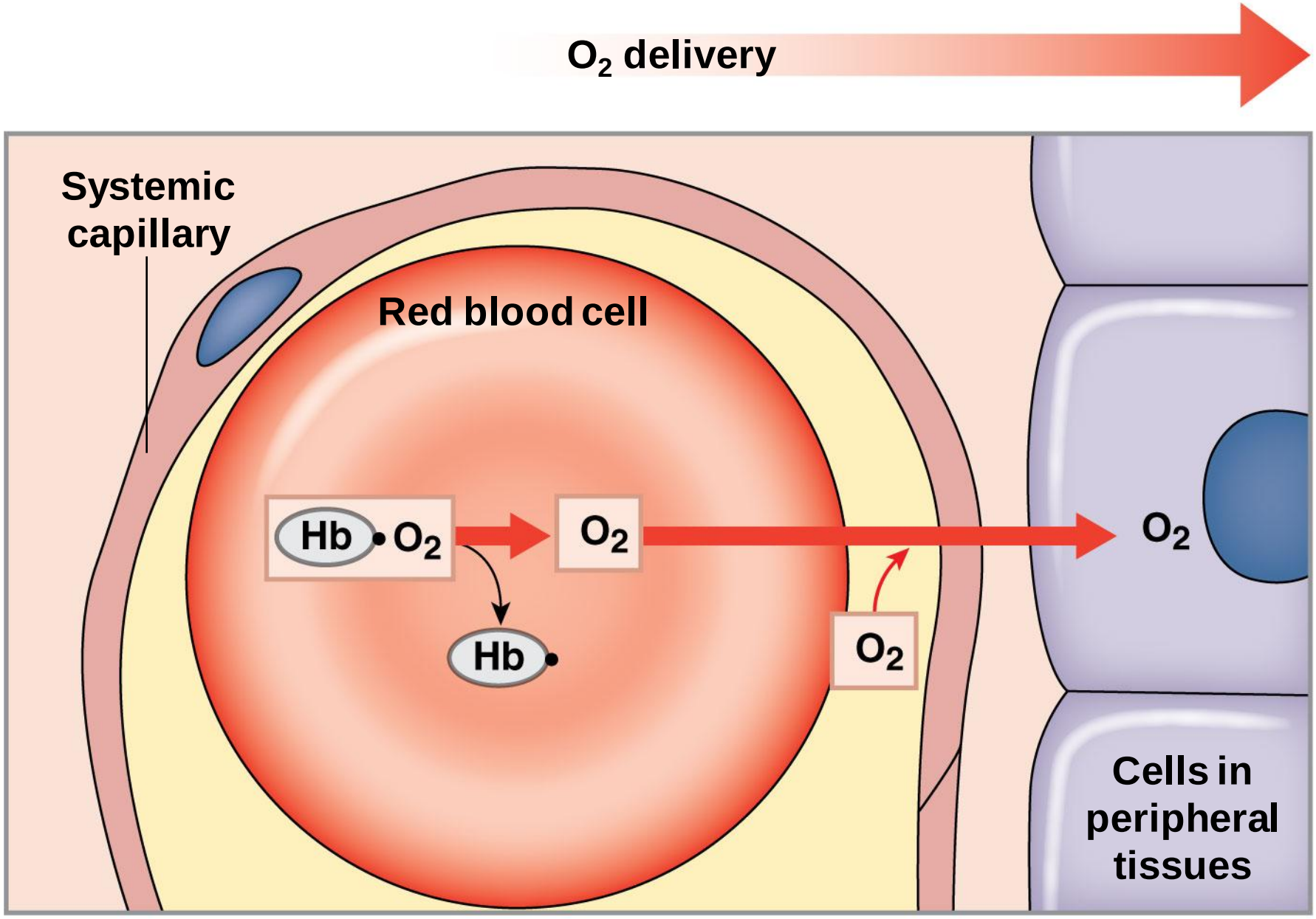


Figure 23-24 A Summary of the Primary Gas Transport Mechanisms

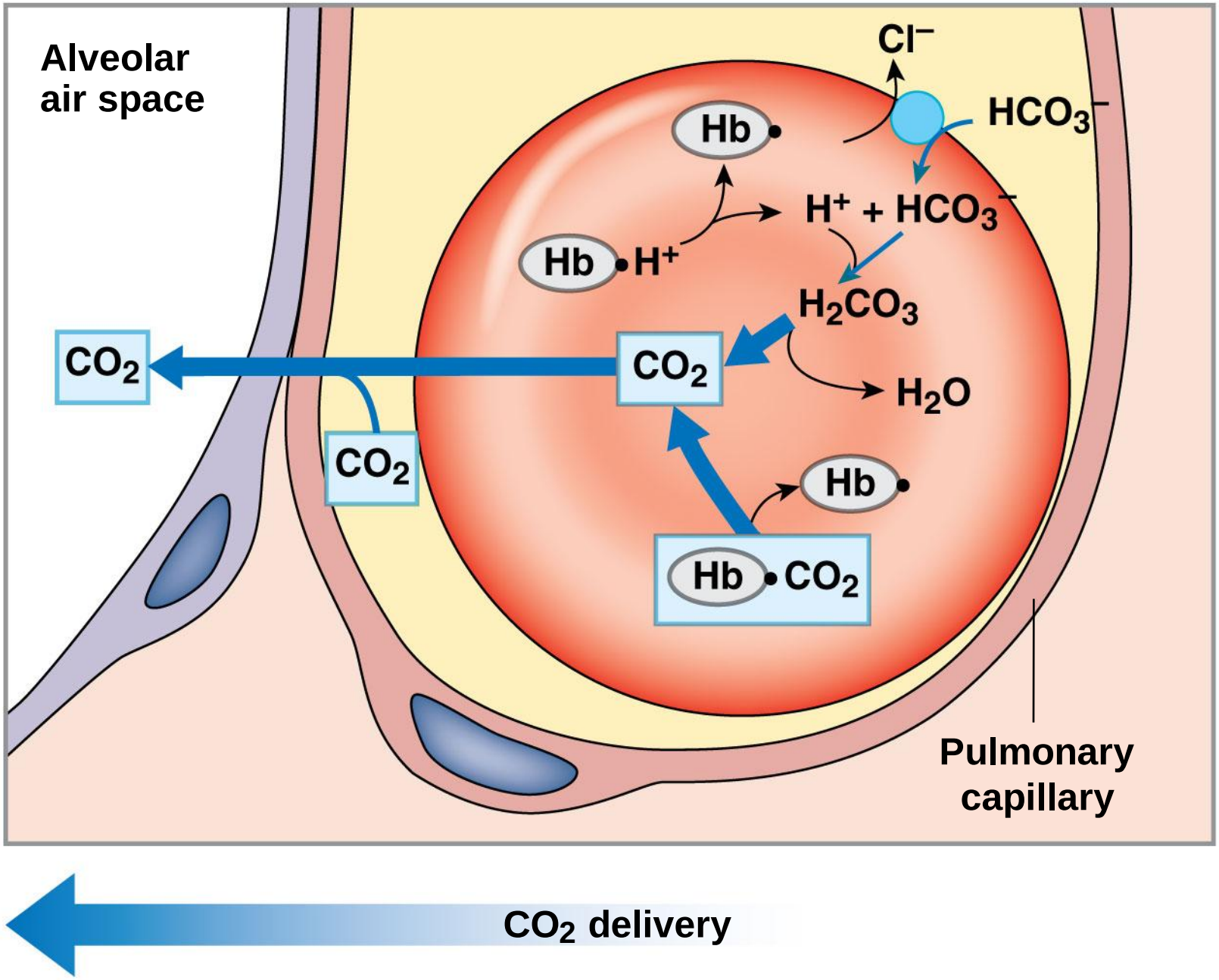
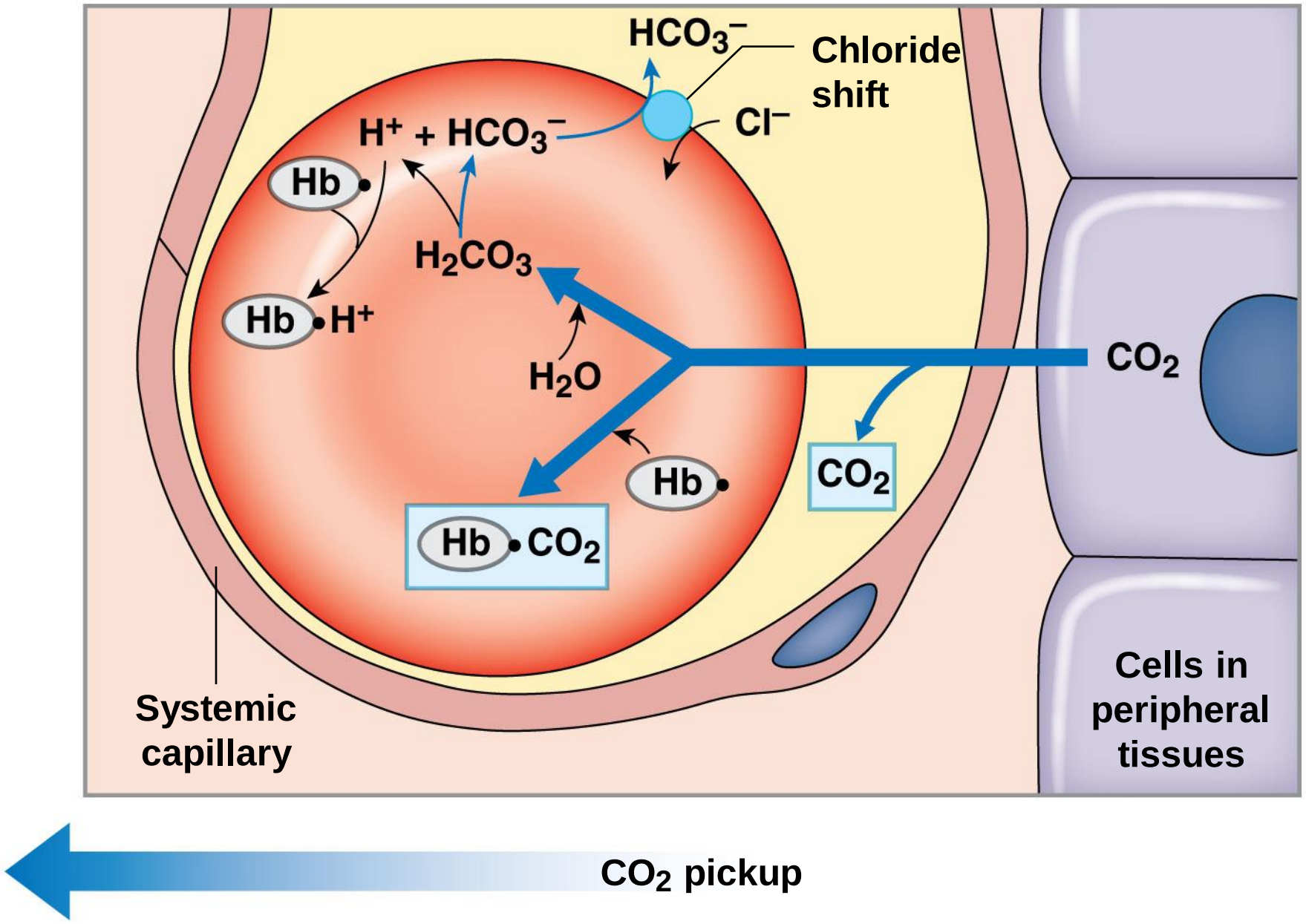


Figure 23-24 A Summary of the Primary Gas Transport Mechanisms



23-10 Control of Respiration

- Peripheral and Alveolar Capillaries
  - Maintain balance during gas diffusion by:
    1. Changes in blood flow and oxygen delivery
    2. Changes in depth and rate of respiration

23-10 Control of Respiration

- Local Regulation of Gas Transport and Alveolar Function
  - Rising P_{CO_2} levels
    - Relax smooth muscle in arterioles and capillaries
    - Increase blood flow
  - Coordination of *lung perfusion* and *alveolar ventilation*
    - Shifting blood flow
  - P_{CO_2} levels
    - Control bronchoconstriction and bronchodilation

23-10 Control of Respiration

- The Respiratory Centers of the Brain
  - When oxygen demand rises:
    - Cardiac output and respiratory rates increase under neural control
      - Have both voluntary and involuntary components

23-10 Control of Respiration

- The Respiratory Centers of the Brain
  - Voluntary centers in cerebral cortex affect:
    - Respiratory centers of pons and medulla oblongata
    - Motor neurons that control respiratory muscles
  - The **Respiratory Centers**
    - Three pairs of nuclei in the reticular formation of medulla oblongata and pons
    - Regulate respiratory muscles
    - In response to sensory information via *respiratory reflexes*

23-10 Control of Respiration

- Respiratory Centers of the Medulla Oblongata
  - Set the pace of respiration
  - Can be divided into two groups
    1. *Dorsal respiratory group (DRG)*
    2. *Ventral respiratory group (VRG)*

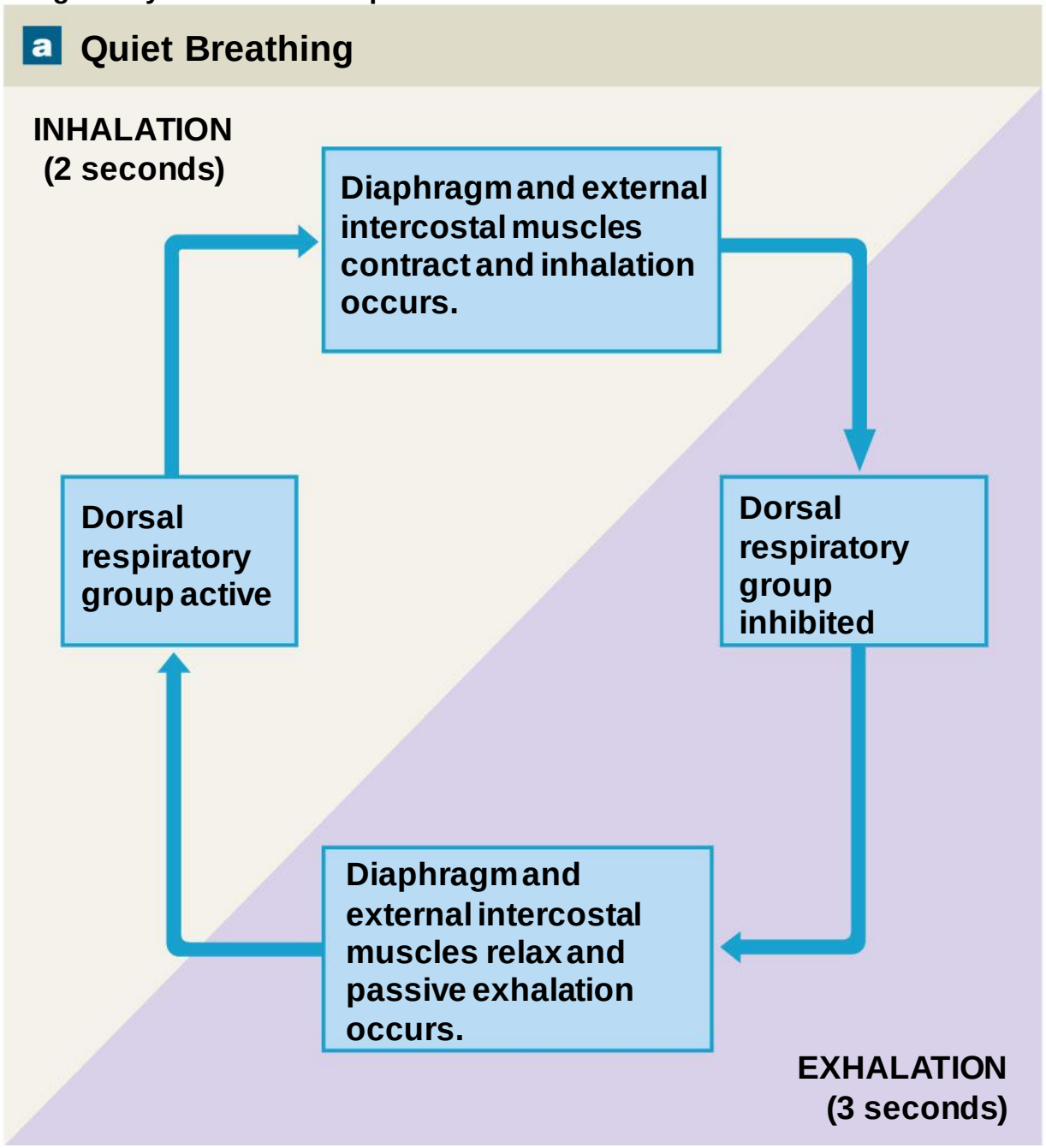
23-10 Control of Respiration

- Dorsal Respiratory Group (DRG)
  - *Inspiratory center*
  - Functions in quiet and forced breathing
- Ventral Respiratory Group (VRG)
  - *Inspiratory* and *expiratory center*
  - Functions only in forced breathing

23-10 Control of Respiration

- Quiet Breathing
  - Brief activity in the DRG
    - Stimulates inspiratory muscles
  - DRG neurons become inactive
    - Allowing passive exhalation

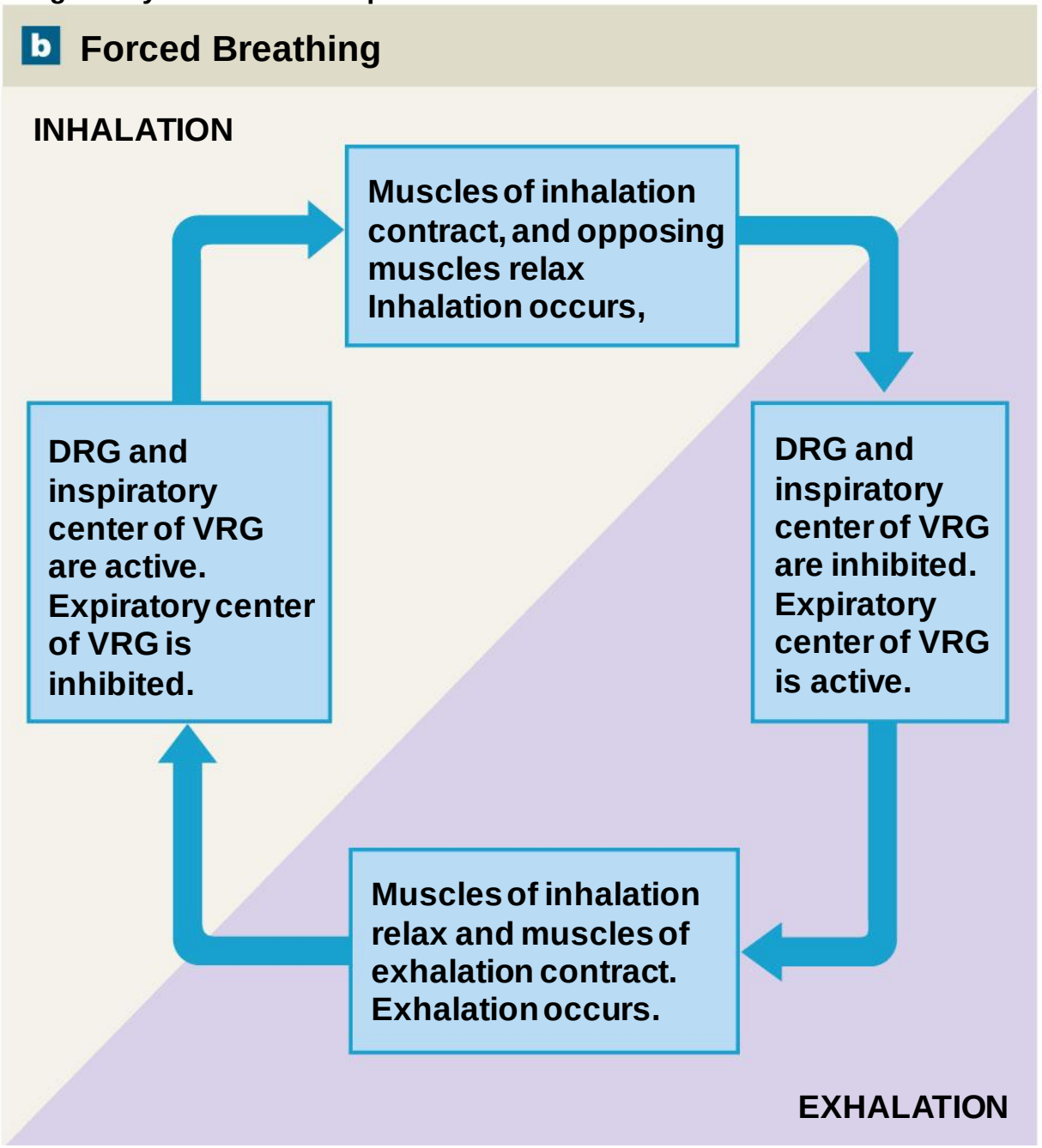
Figure 23-25a Basic Regulatory Patterns of Respiration



23-10 Control of Respiration

- Forced Breathing
  - Increased activity in DRG
    - Stimulates VRG
    - Which activates accessory inspiratory muscles
  - After inhalation
    - Expiratory center neurons stimulate active exhalation

Figure 23-25b Basic Regulatory Patterns of Respiration



23-10 Control of Respiration

- The Apneustic and Pneumotaxic Centers of the Pons
  - Paired nuclei that adjust output of respiratory rhythmicity centers
    - Regulating respiratory rate and depth of respiration
  - Apneustic Center
    - Provides continuous stimulation to its DRG center
  - Pneumotaxic Centers
    - Inhibit the apneustic centers
    - Promote passive or active exhalation

23-10 Control of Respiration

- Respiratory Centers and Reflex Controls
  - Interactions between VRG and DRG
    - Establish basic pace and depth of respiration
  - The pneumotaxic center
    - Modifies the pace

Figure 23-26 Control of Respiration

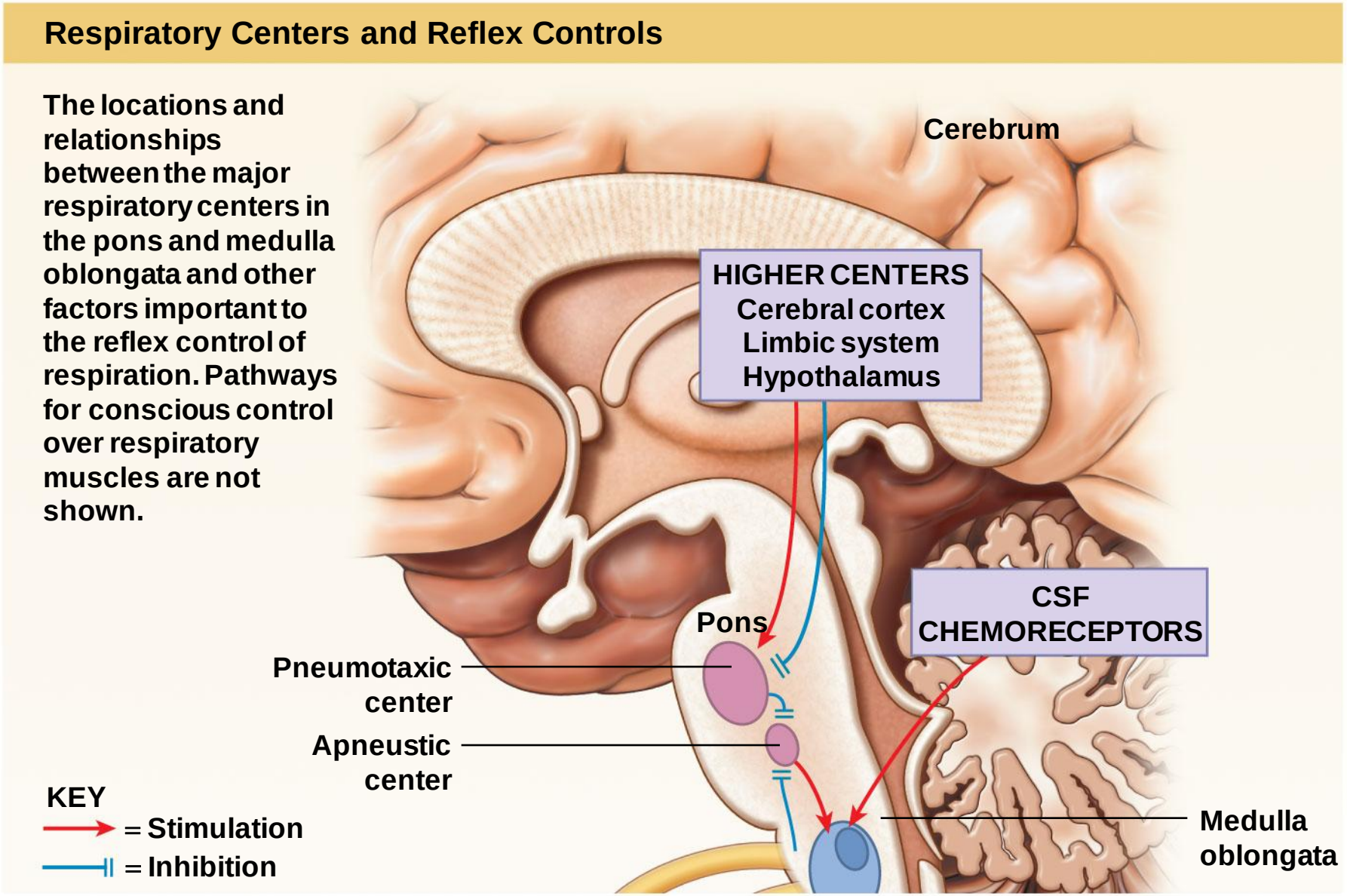
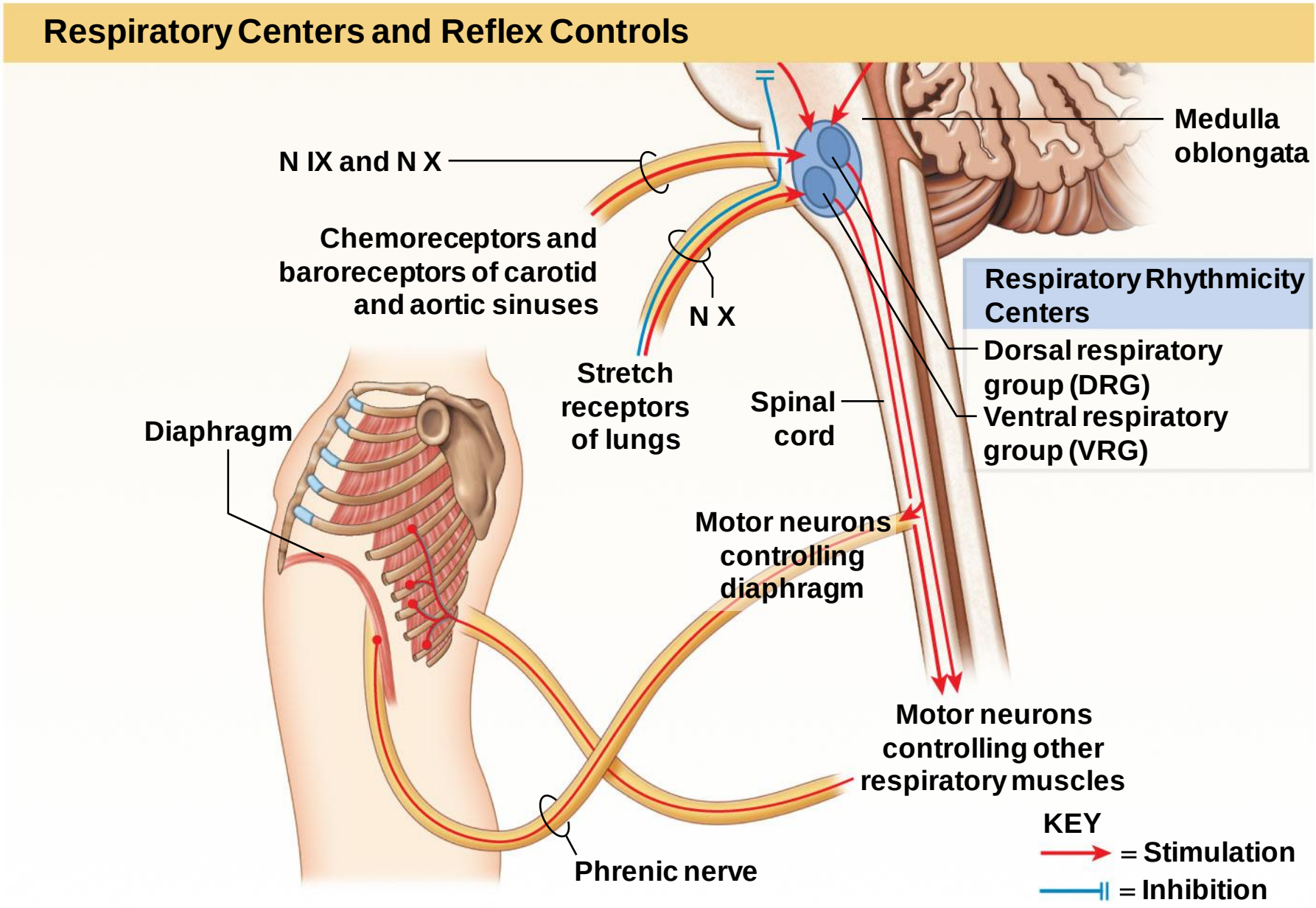


Figure 23-26 Control of Respiration



23-10 Control of Respiration

- **Sudden Infant Death Syndrome (SIDS)**
  - Disrupts normal respiratory reflex pattern
  - May result from connection problems between pacemaker complex and respiratory centers

23-10 Control of Respiration

- Respiratory Reflexes
  - Chemoreceptors are sensitive to P_{CO_2}, P_{O_2}, or pH of blood or cerebrospinal fluid
  - Baroreceptors in aortic or carotid sinuses are sensitive to changes in blood pressure
  - Stretch receptors respond to changes in lung volume
  - Irritating physical or chemical stimuli in nasal cavity, larynx, or bronchial tree
  - Other sensations including pain, changes in body temperature, abnormal visceral sensations

23-10 Control of Respiration

- The Chemoreceptor Reflexes
  - Respiratory centers are strongly influenced by chemoreceptor input from:
    - Glossopharyngeal nerve (N IX)
    - Vagus nerve (N X)
    - *Central chemoreceptors* that monitor cerebrospinal fluid

23-10 Control of Respiration

- The Chemoreceptor Reflexes
  - The glossopharyngeal nerve
    - From carotid bodies
    - Stimulated by changes in blood pH or P_{O_2}
  - The vagus nerve
    - From aortic bodies
    - Stimulated by changes in blood pH or P_{O_2}

23-10 Control of Respiration

- The Chemoreceptor Reflexes
  - Central chemoreceptors that monitor cerebrospinal fluid
    - Are on ventrolateral surface of medulla oblongata
    - Respond to P_{CO_2} and pH of CSF

23-10 Control of Respiration

- Chemoreceptor Stimulation
  - Leads to increased depth and rate of respiration
  - Is subject to adaptation
    - Decreased sensitivity due to chronic stimulation

23-10 Control of Respiration

- **Hypercapnia**
  - An increase in arterial P_{CO_2}
  - Stimulates chemoreceptors in the medulla oblongata
    - To restore homeostasis

23-10 Control of Respiration

- Hypercapnia and **Hypocapnia**
  - **Hypoventilation** is a common cause of hypercapnia
  - Abnormally low respiration rate
    - Allows CO_2 buildup in blood
  - Excessive ventilation, **hyperventilation**, results in abnormally low P_{CO_2} (hypocapnia)
    - Stimulates chemoreceptors to decrease respiratory rate

Figure 23-27a The Chemoreceptor Response to Changes in P_{CO_2}

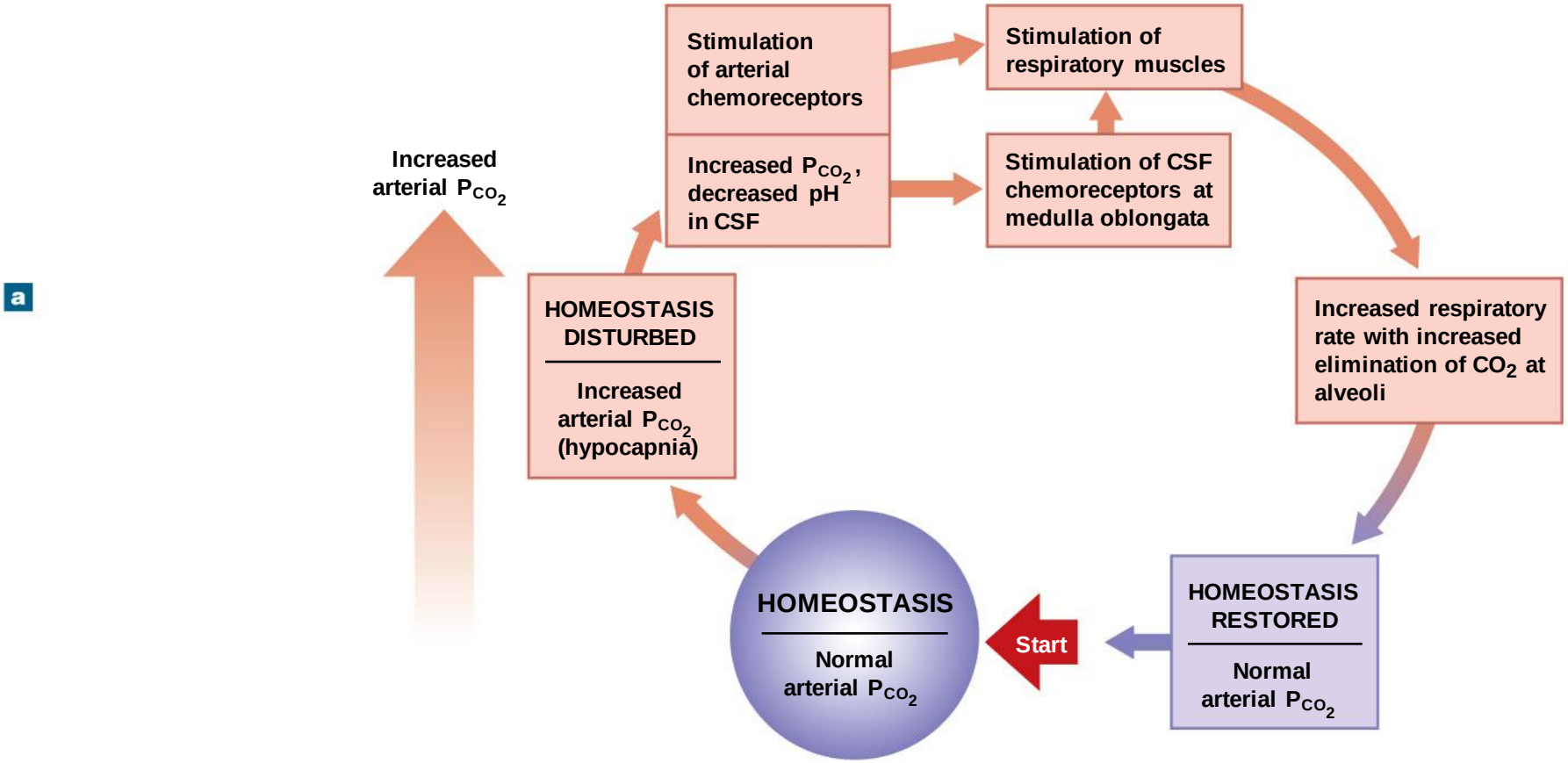
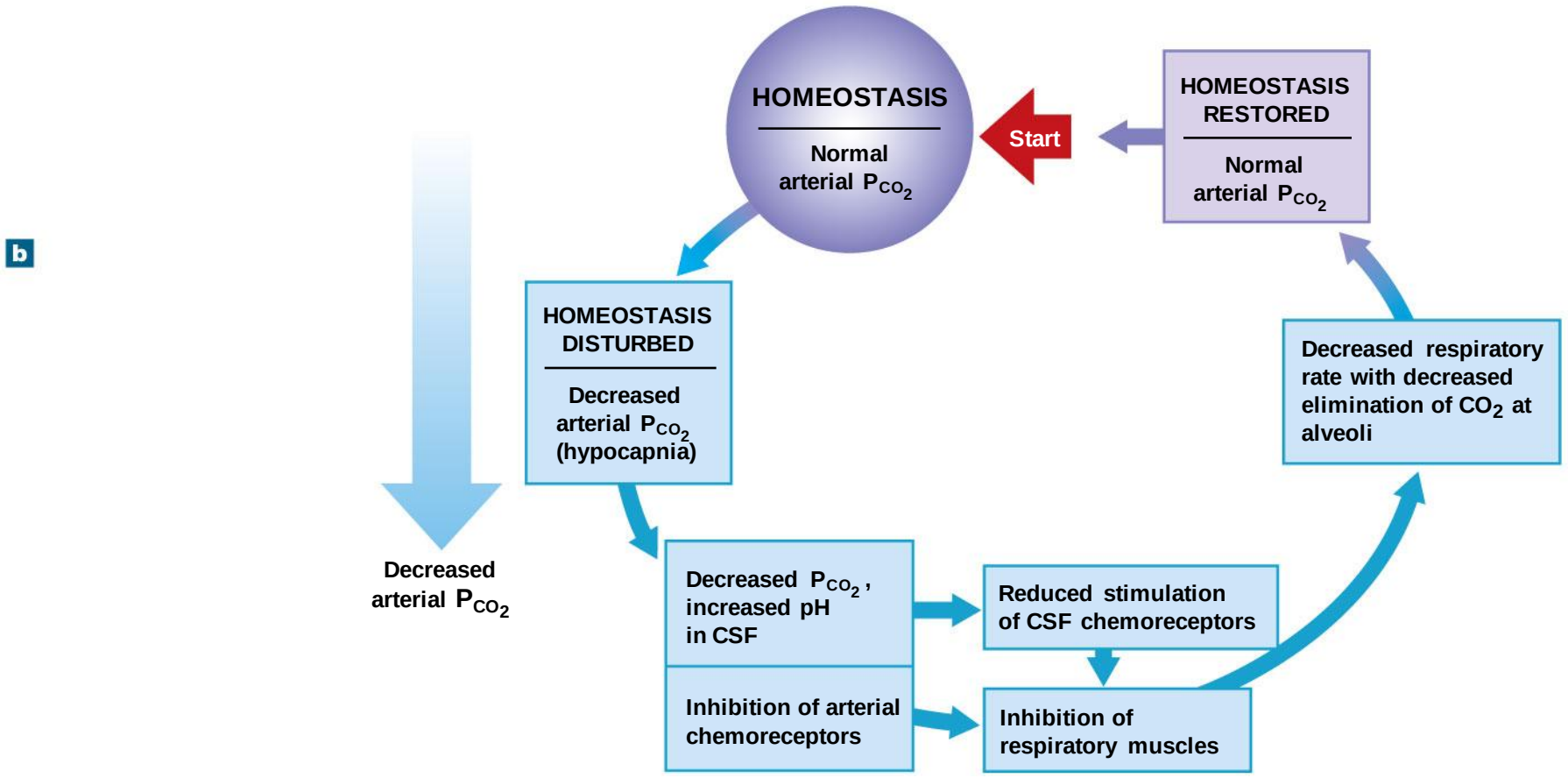


Figure 23-27b The Chemoreceptor Response to Changes in P_{CO_2}



23-10 Control of Respiration

- The Baroreceptor Reflexes
  - Carotid and aortic baroreceptor stimulation
    - Affects blood pressure and respiratory centers
  - When blood pressure falls:
    - Respiration increases
  - When blood pressure increases:
    - Respiration decreases

23-10 Control of Respiration

- The **Hering–Breuer Reflexes**
  - Two baroreceptor reflexes involved in forced breathing
    1. **Inflation reflex**
       - Prevents overexpansion of lungs
    2. **Deflation reflex**
       - Inhibits expiratory centers
       - Stimulates inspiratory centers during lung deflation

23-10 Control of Respiration

- Protective Reflexes
  - Triggered by receptors in epithelium of respiratory tract when lungs are exposed to:
    - Toxic vapors
    - Chemical irritants
    - Mechanical stimulation
  - Cause sneezing, coughing, and laryngeal spasm

23-10 Control of Respiration

- **Apnea**
  - A period of suspended respiration
  - Normally followed by explosive exhalation to clear airways
    - Sneezing and coughing
- Laryngeal Spasm
  - Temporarily closes airway
    - To prevent foreign substances from entering

23-10 Control of Respiration

- Voluntary Control of Respiration
  - Strong emotions can stimulate respiratory centers in hypothalamus
  - Emotional stress can activate sympathetic or parasympathetic division of ANS
    - Causing bronchodilation or bronchoconstriction
  - Anticipation of strenuous exercise can increase respiratory rate and cardiac output by sympathetic stimulation

23-10 Control of Respiration

- Changes in the Respiratory System at Birth
  - Before birth
    - Pulmonary vessels are collapsed
    - Lungs contain no air
  - During delivery
    - Placental connection is lost
    - Blood P_{O_2} falls
    - P_{CO_2} rises

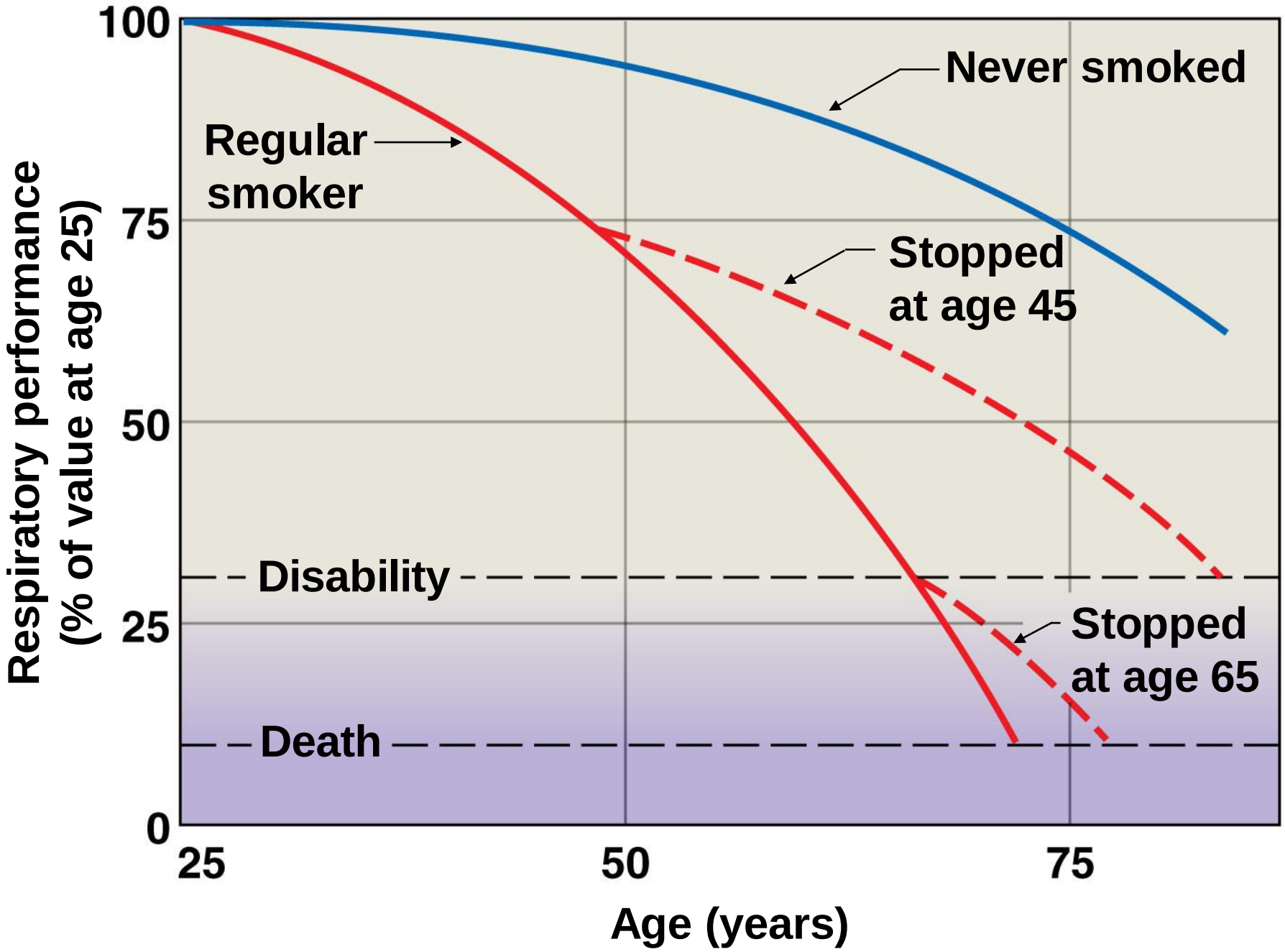
23-10 Control of Respiration

- Changes in the Respiratory System at Birth
  - At birth
    - Newborn overcomes force of surface tension to inflate bronchial tree and alveoli and take first breath
  - Large drop in pressure at first breath
    - Pulls blood into pulmonary circulation
    - Closing foramen ovale and ductus arteriosus
    - Redirecting fetal blood circulation patterns
  - Subsequent breaths fully inflate alveoli

23-11 Effects of Aging on the Respiratory System

- Three Effects of Aging on the Respiratory System
  1. Elastic tissues deteriorate
     - Altering lung compliance and lowering vital capacity
  2. Arthritic changes
     - Restrict chest movements
     - Limit respiratory minute volume
  3. Emphysema
     - Affects individuals over age 50
     - Depending on exposure to respiratory irritants (e.g., cigarette smoke)

Figure 23-28 Decline in Respiratory Performance with Age and Smoking



23-12 Respiratory System Integration

- Respiratory Activity
  - Maintaining homeostatic O_2 and CO_2 levels in peripheral tissues requires coordination between several systems
    - Particularly the respiratory and cardiovascular systems

23-12 Respiratory System Integration

- Coordination of Respiratory and Cardiovascular Systems
  - Improves efficiency of gas exchange by controlling lung perfusion
  - Increases respiratory drive through chemoreceptor stimulation
  - Raises cardiac output and blood flow through baroreceptor stimulation

Figure 23-29 System Integrator: The Respiratory System