LECTURE PRESENTATIONS
For CAMPBELL BIOLOGY, NINTH EDITION
Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson

Chapter 42

Circulation and Gas Exchange

Lectures by
Erin Barley
Kathleen Fitzpatrick

© 2011 Pearson Education, Inc.

Overview: Trading Places

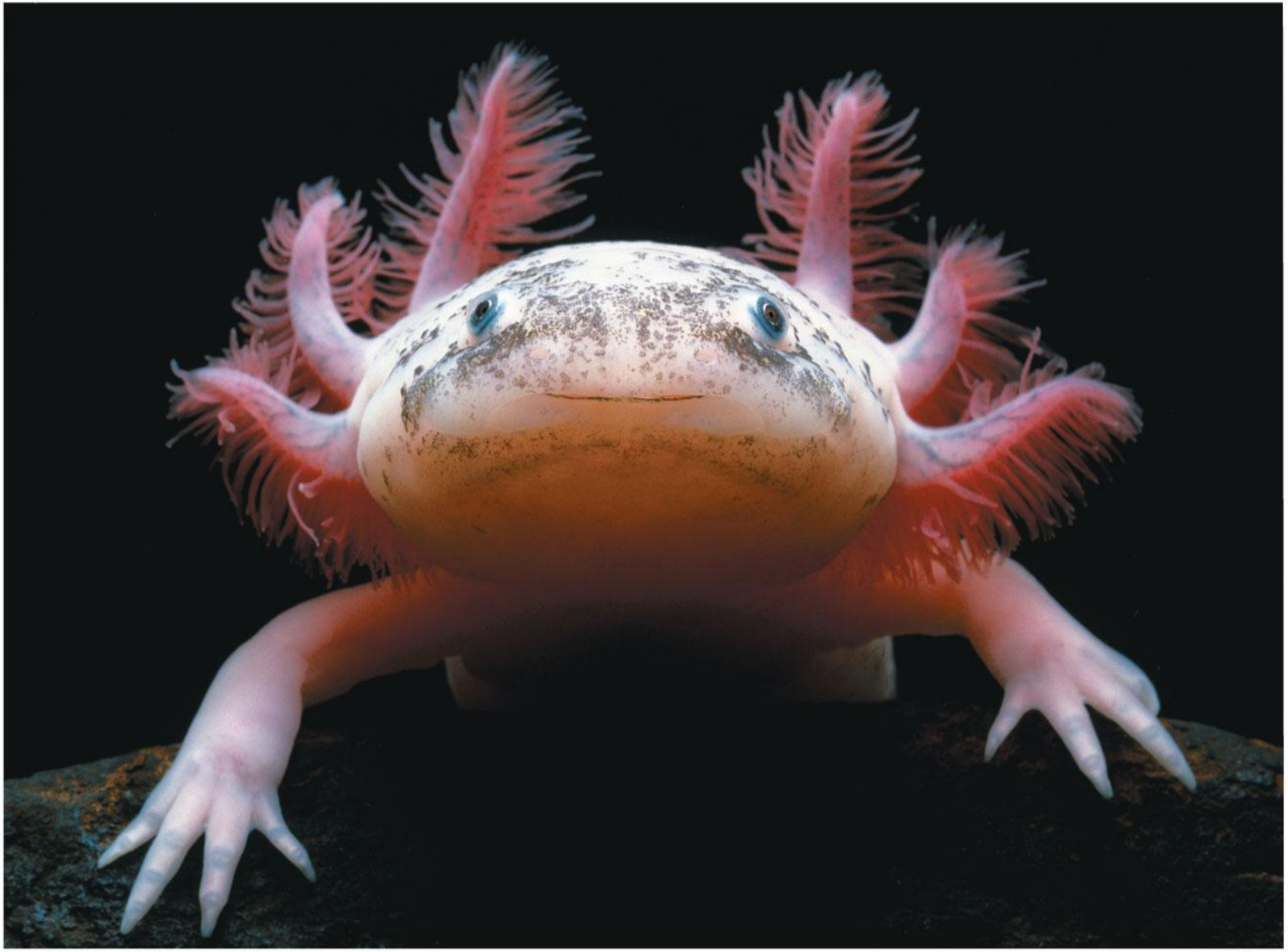
- Every organism must exchange materials with its environment
- Exchanges ultimately occur at the cellular level by crossing the plasma membrane
- In unicellular organisms, these exchanges occur directly with the environment

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

- For most cells making up multicellular organisms, direct exchange with the environment is not possible
- Gills are an example of a specialized exchange system in animals
  - O_2 diffuses from the water into blood vessels
  - CO_2 diffuses from blood into the water
- Internal transport and gas exchange are functionally related in most animals

STUDENT HUB Pearson
© 2011 Pearson Education, Inc.

Figure 42.1



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Concept 42.1: Circulatory systems link exchange surfaces with cells throughout the body

- Diffusion time is proportional to the square of the distance
- Diffusion is only efficient over small distances
- In small and/or thin animals, cells can exchange materials directly with the surrounding medium
- In most animals, cells exchange materials with the environment via a fluid-filled circulatory system

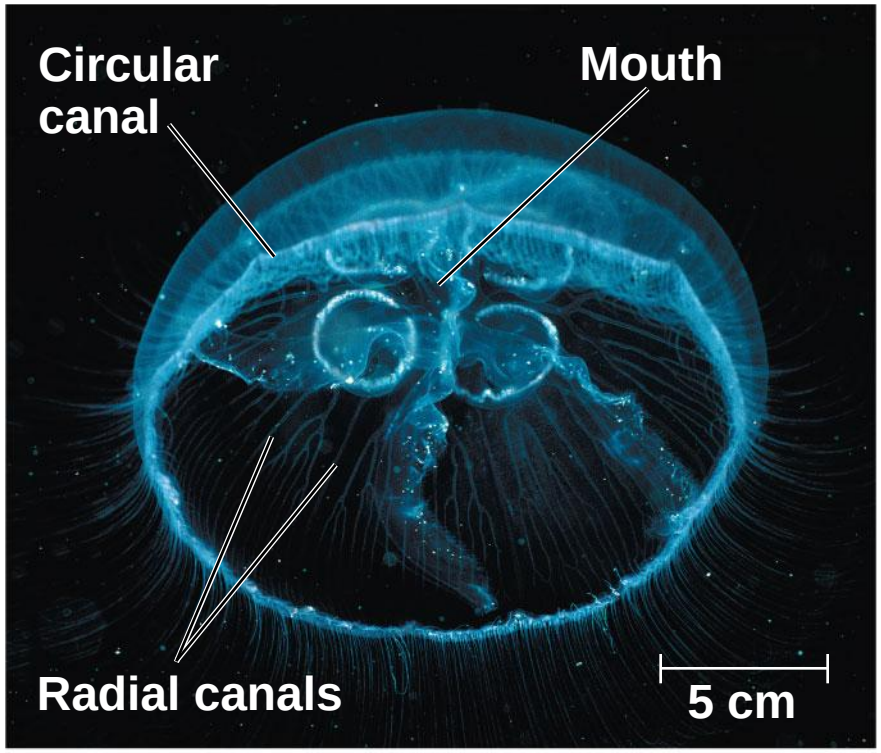
STUDENT HUB Pearson
© 2011 Pearson Education, Inc.

Gastrovascular Cavities

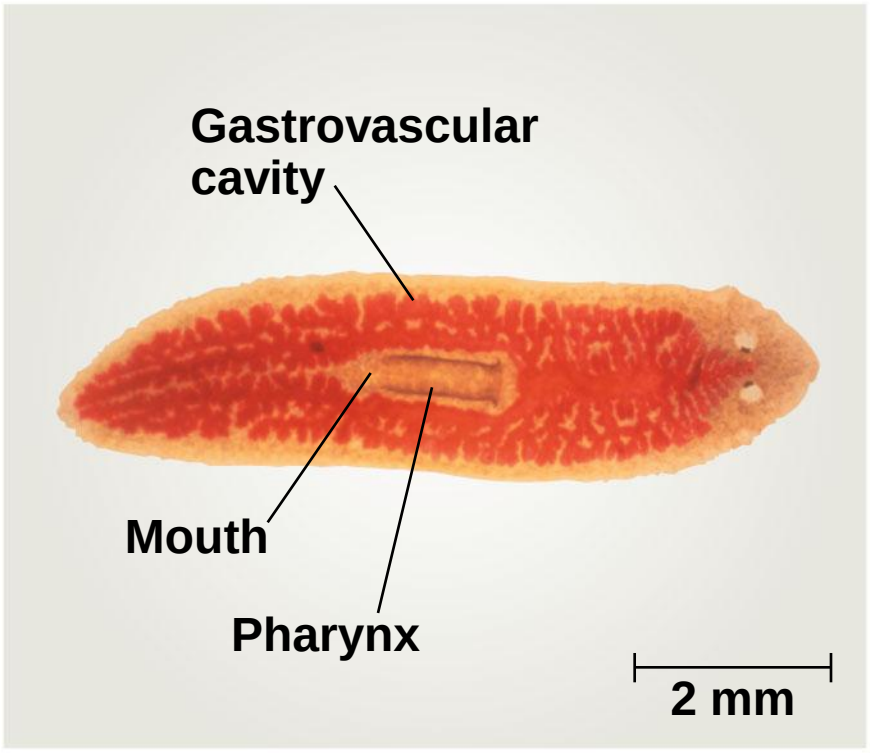
- Some animals lack a circulatory system
- Some cnidarians, such as jellies, have elaborate gastrovascular cavities
- A gastrovascular cavity functions in both digestion and distribution of substances throughout the body
- The body wall that encloses the gastrovascular cavity is only two cells thick
- Flatworms have a gastrovascular cavity and a large surface area to volume ratio

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Figure 42.2



(a) The moon jelly *Aurelia*, a cnidarian



(b) The planarian *Dugesia*, a flatworm

© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Evolutionary Variation in Circulatory Systems

- A circulatory system minimizes the diffusion distance in animals with many cell layers

STUDENT HUB Box
© 2011 Pearson Education, Inc.

General Properties of Circulatory Systems

- A circulatory system has
  - A circulatory fluid
  - A set of interconnecting vessels
  - A muscular pump, the **heart**
- The circulatory system connects the fluid that surrounds cells with the organs that exchange gases, absorb nutrients, and dispose of wastes
- Circulatory systems can be open or closed and vary in the number of circuits in the body

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Open and Closed Circulatory Systems

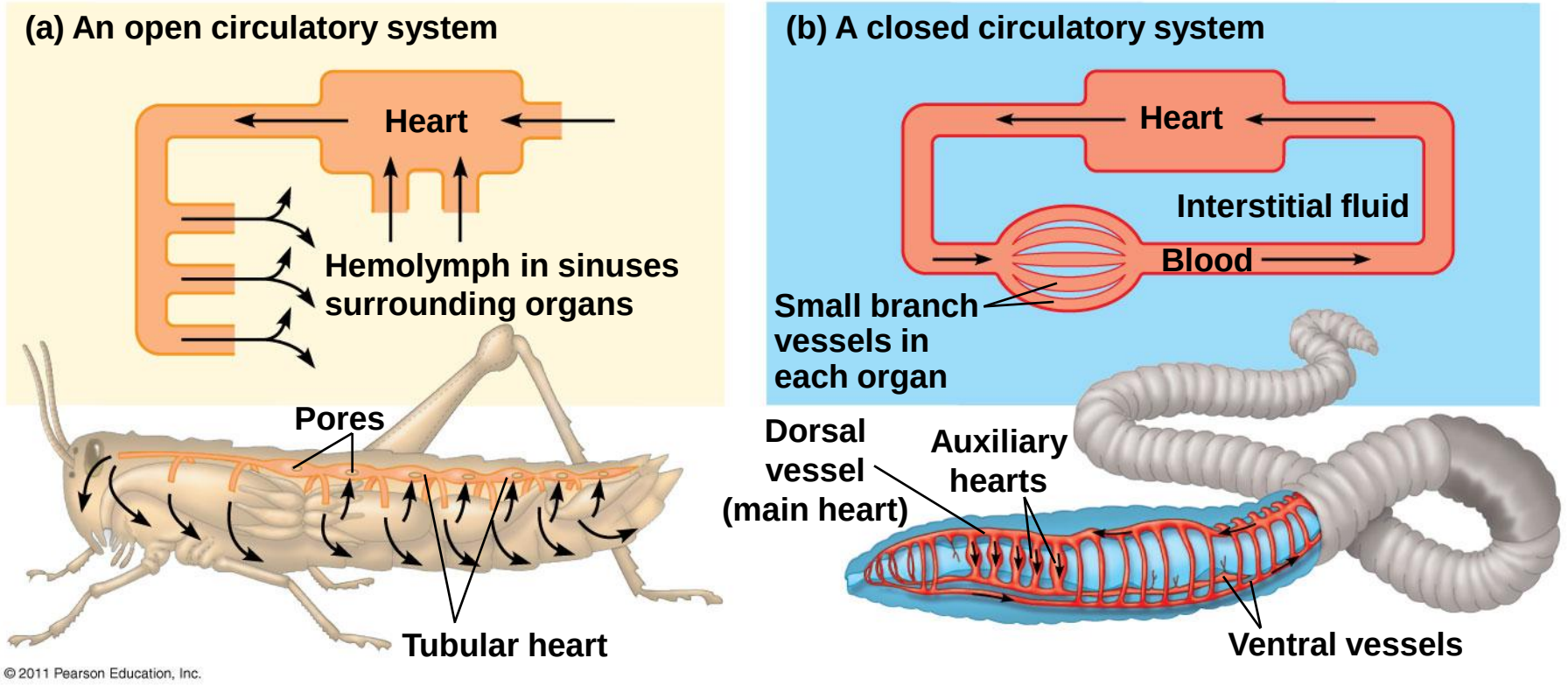
- In insects, other arthropods, and most molluscs, blood bathes the organs directly in an **open circulatory system**
- In an open circulatory system, there is no distinction between blood and interstitial fluid, and this general body fluid is called **hemolymph**

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

- In a **closed circulatory system**, **blood** is confined to vessels and is distinct from the interstitial fluid
- Closed systems are more efficient at transporting circulatory fluids to tissues and cells
- Annelids, cephalopods, and vertebrates have closed circulatory systems

STUDENT HUB Pearson
© 2011 Pearson Education, Inc.

Figure 42.3



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Organization of Vertebrate Circulatory Systems

- Humans and other vertebrates have a closed circulatory system called the **cardiovascular system**
- The three main types of blood vessels are arteries, veins, and capillaries
- Blood flow is one way in these vessels

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

- **Arteries** branch into **arterioles** and carry blood away from the heart to **capillaries**
- Networks of capillaries called **capillary beds** are the sites of chemical exchange between the blood and interstitial fluid
- **Venules** converge into **veins** and return blood from capillaries to the heart

STUDENT HUB Pearson
© 2011 Pearson Education, Inc.

- Arteries and veins are distinguished by the direction of blood flow, not by O_2 content
- Vertebrate hearts contain two or more chambers
- Blood enters through an **atrium** and is pumped out through a **ventricle**

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Single Circulation

- Bony fishes, rays, and sharks have single circulation with a two-chambered heart
- In **single circulation**, blood leaving the heart passes through two capillary beds before returning

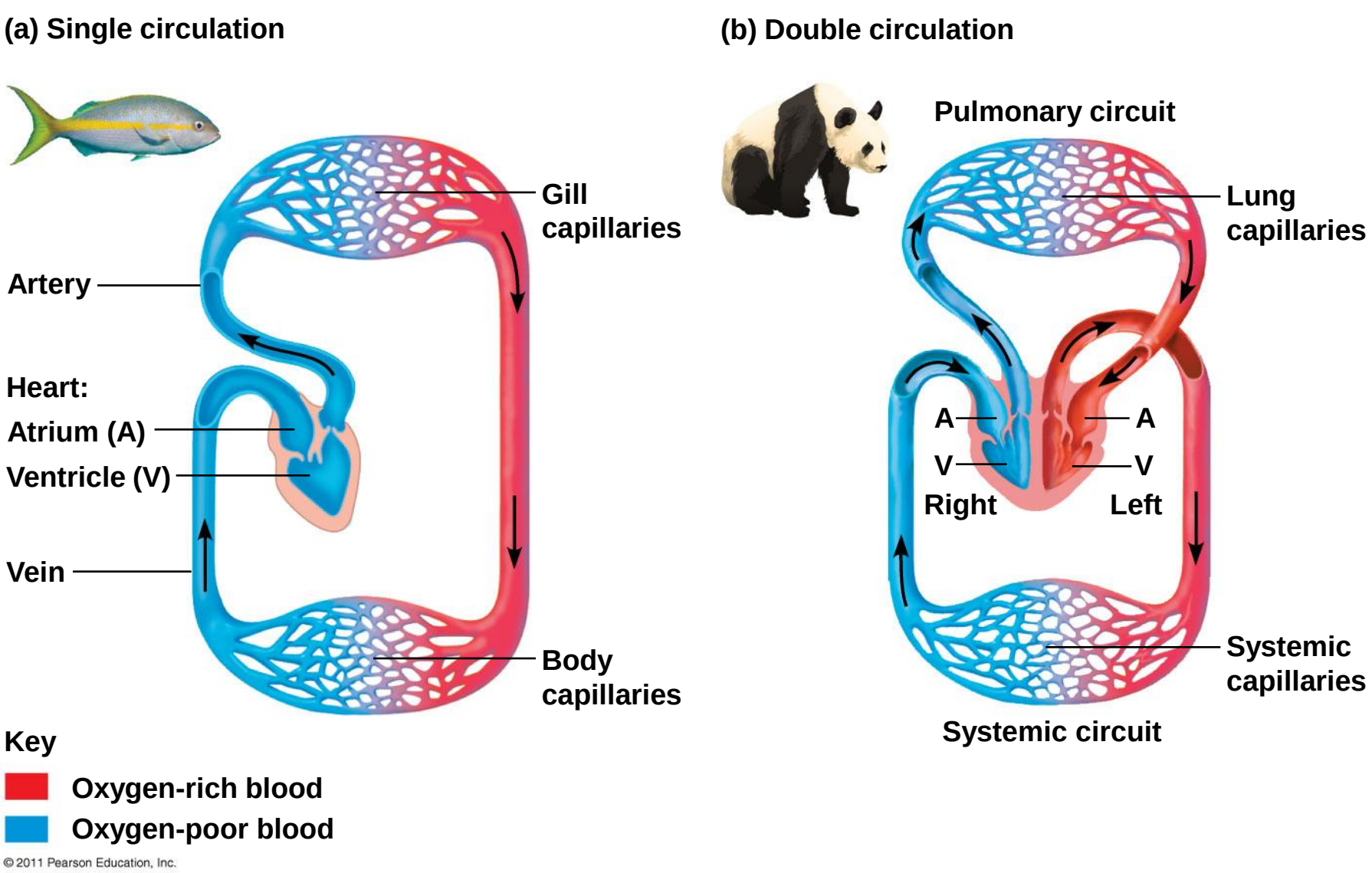
STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Double Circulation

- Amphibian, reptiles, and mammals have **double circulation**
- Oxygen-poor and oxygen-rich blood are pumped separately from the right and left sides of the heart

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Figure 42.4



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

- In reptiles and mammals, oxygen-poor blood flows through the **pulmonary circuit** to pick up oxygen through the lungs
- In amphibians, oxygen-poor blood flows through a **pulmocutaneous circuit** to pick up oxygen through the lungs and skin
- Oxygen-rich blood delivers oxygen through the **systemic circuit**
- Double circulation maintains higher blood pressure in the organs than does single circulation

STUDENT HUB Beta
© 2011 Pearson Education, Inc.

Adaptations of Double Circulatory Systems

- Hearts vary in different vertebrate groups

STUDENT HUB Demo
© 2011 Pearson Education, Inc.

Amphibians

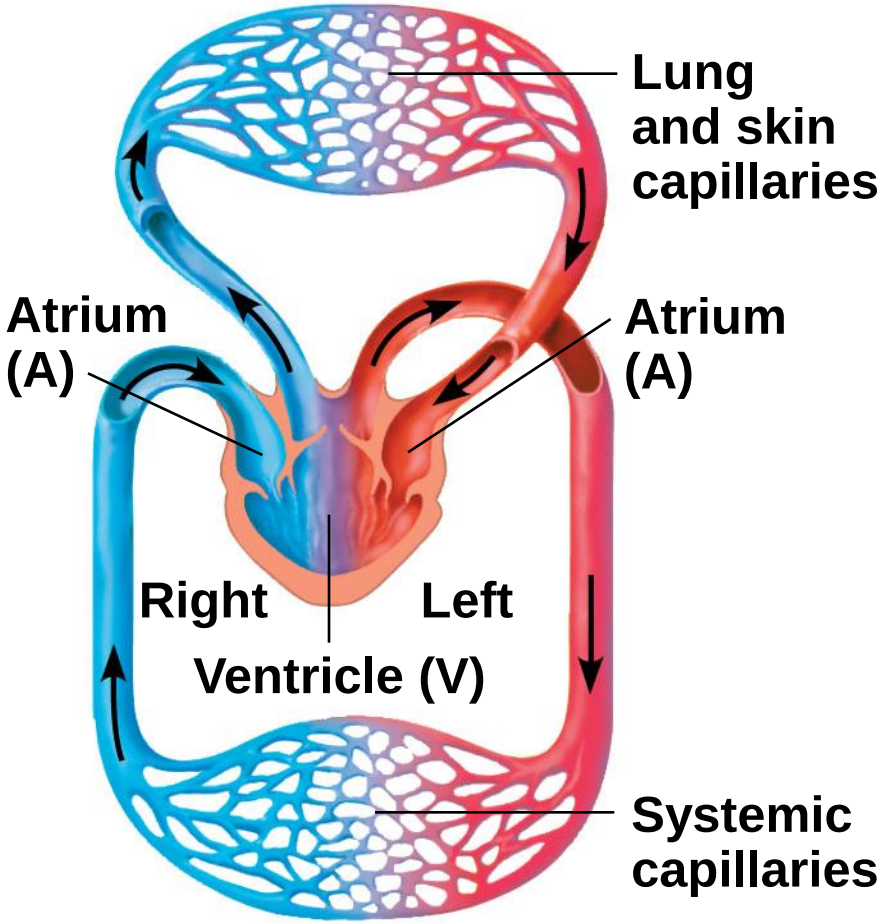
- Frogs and other amphibians have a three-chambered heart: two atria and one ventricle
- The ventricle pumps blood into a forked artery that splits the ventricle's output into the pulmocutaneous circuit and the systemic circuit
- When underwater, blood flow to the lungs is nearly shut off

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Figure 42.5a

Amphibians

Pulmocutaneous circuit



Systemic circuit

Key

- Oxygen-rich blood
- Oxygen-poor blood

© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

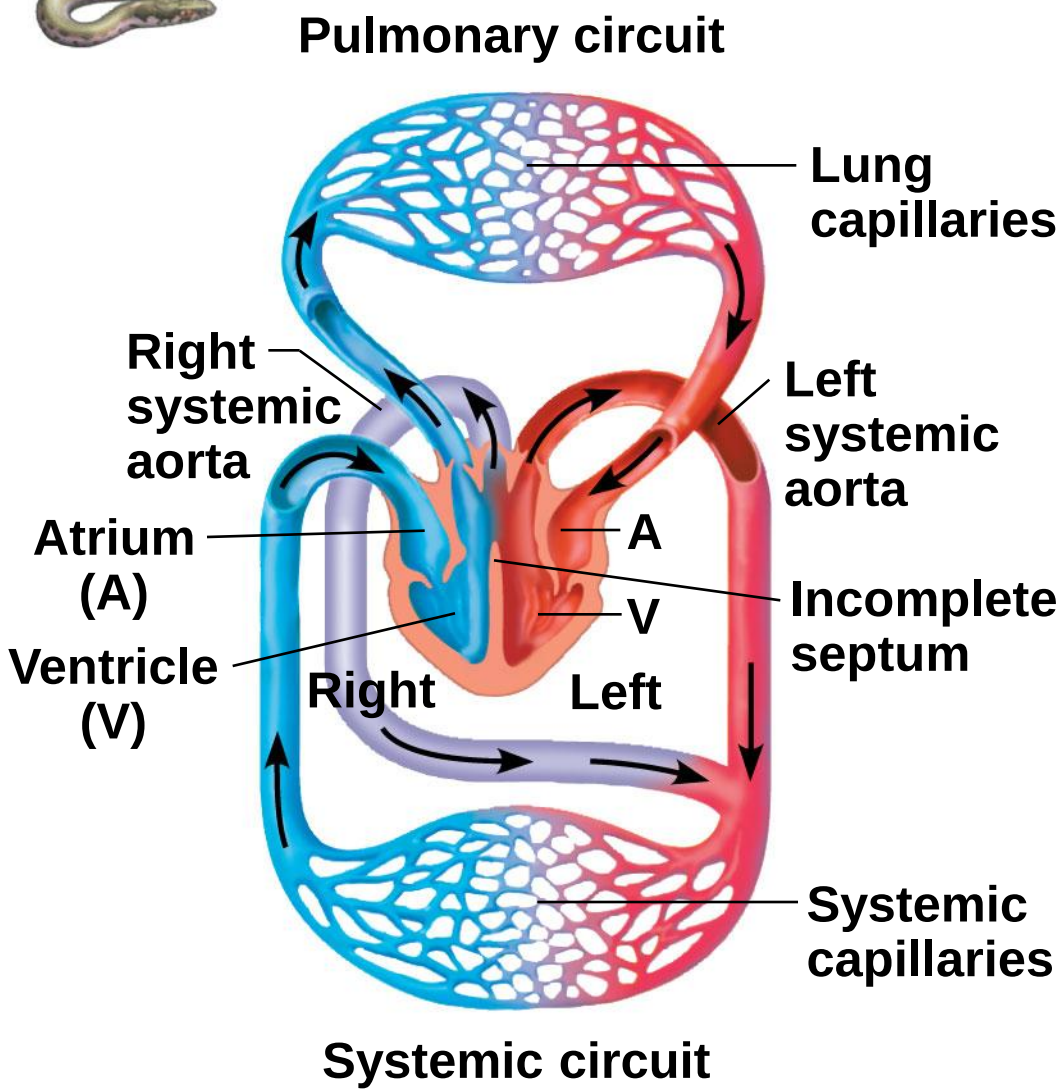
Reptiles (Except Birds)

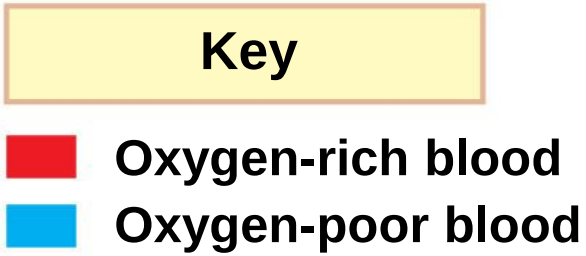
- Turtles, snakes, and lizards have a three-chambered heart: two atria and one ventricle
- In alligators, caimans, and other crocodilians a septum divides the ventricle
- Reptiles have double circulation, with a pulmonary circuit (lungs) and a systemic circuit

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Figure 42.5b

Reptiles (Except Birds)





© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Mammals and Birds

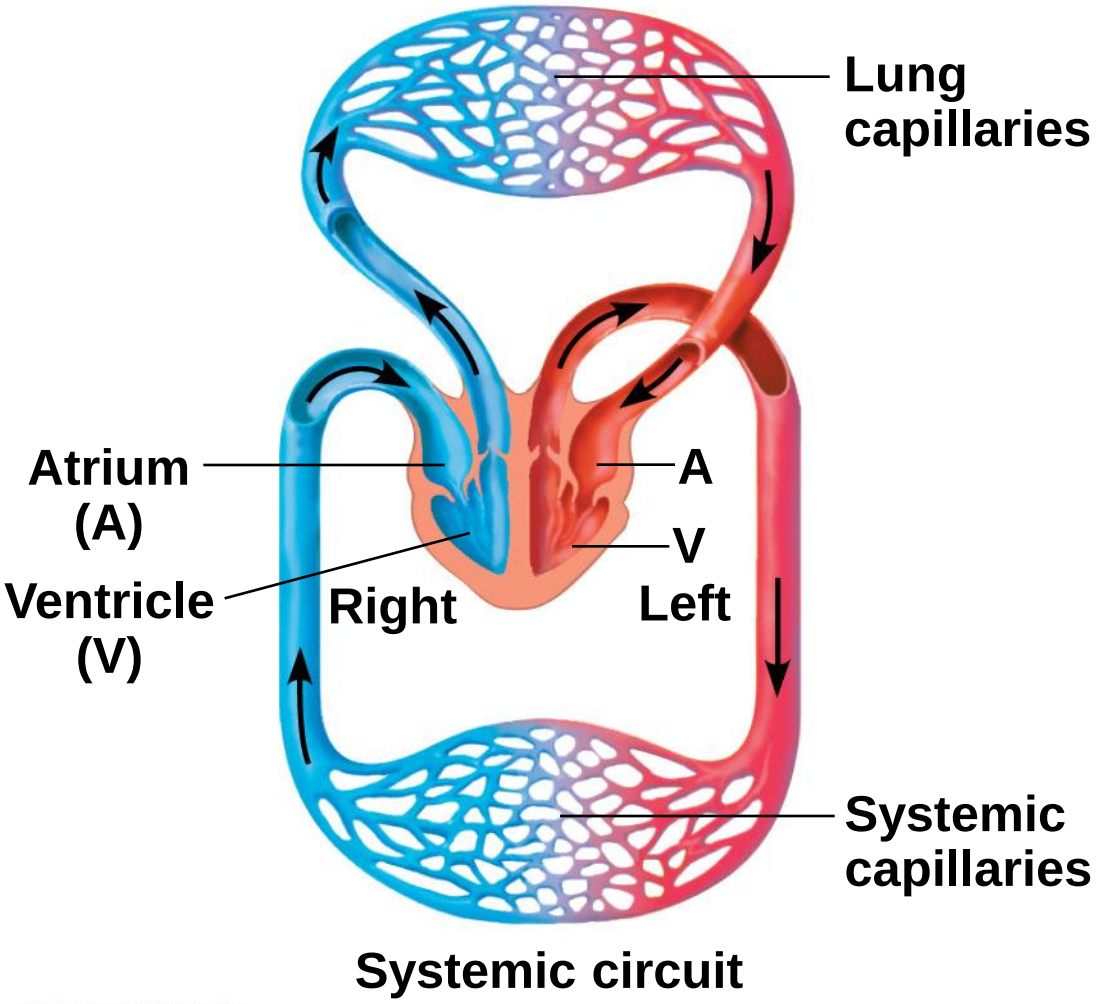
- Mammals and birds have a four-chambered heart with two atria and two ventricles
- The left side of the heart pumps and receives only oxygen-rich blood, while the right side receives and pumps only oxygen-poor blood
- Mammals and birds are endotherms and require more O_2 than ectotherms

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

Figure 42.5c

Mammals and Birds

Pulmonary circuit



Systemic circuit

© 2011 Pearson Education, Inc.

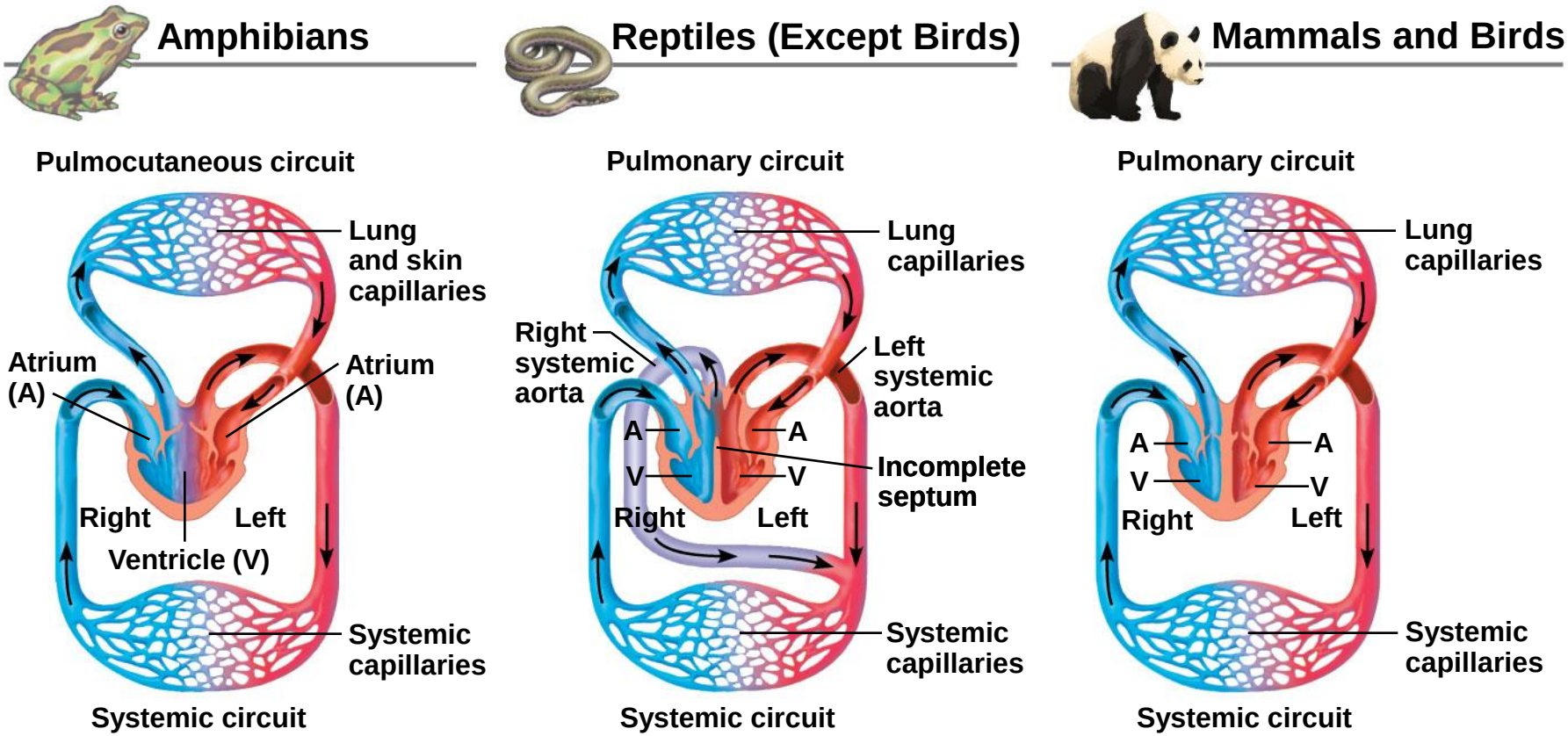
Key

Oxygen-rich blood

Oxygen-poor blood

STUDENTS-HUB.com

Figure 42.5



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Concept 42.2: Coordinated cycles of heart contraction drive double circulation in mammals

- The mammalian cardiovascular system meets the body's continuous demand for O_2

STUDENT HUB Pearson
© 2011 Pearson Education, Inc.

Mammalian Circulation

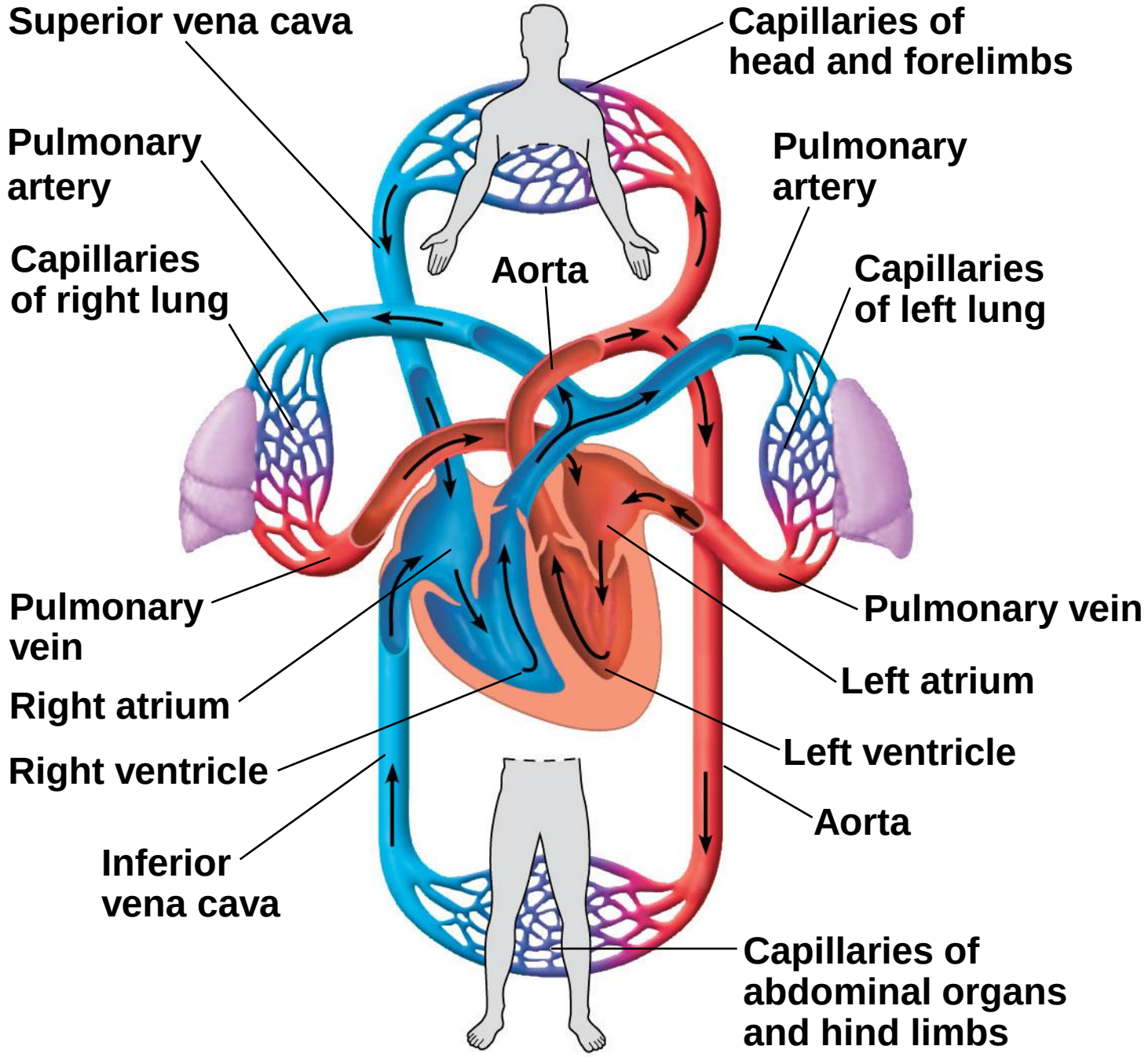
- Blood begins its flow with the right ventricle pumping blood to the lungs
- In the lungs, the blood loads O_2 and unloads CO_2
- Oxygen-rich blood from the lungs enters the heart at the left atrium and is pumped through the aorta to the body tissues by the left ventricle
- The aorta provides blood to the heart through the coronary arteries

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

- Blood returns to the heart through the superior vena cava (blood from head, neck, and forelimbs) and inferior vena cava (blood from trunk and hind limbs)
- The superior vena cava and inferior vena cava flow into the right atrium

STUDENT HUB Beta
© 2011 Pearson Education, Inc.

Figure 42.6



© 2011 Pearson Education, Inc.

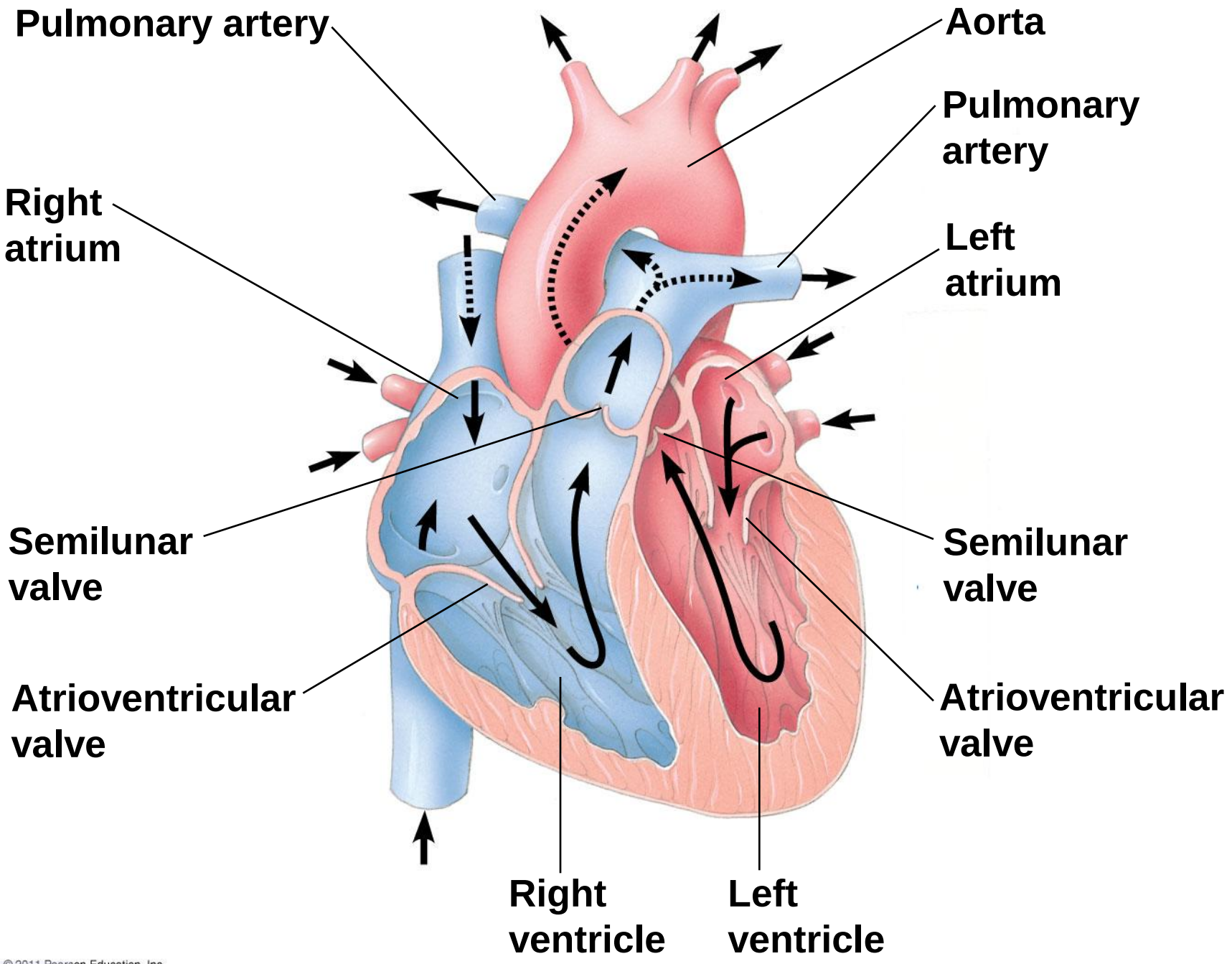
STUDENTS-HUB.com

The Mammalian Heart: *A Closer Look*

- A closer look at the mammalian heart provides a better understanding of double circulation

STUDENT HUB Demo
© 2011 Pearson Education, Inc.

Figure 42.7

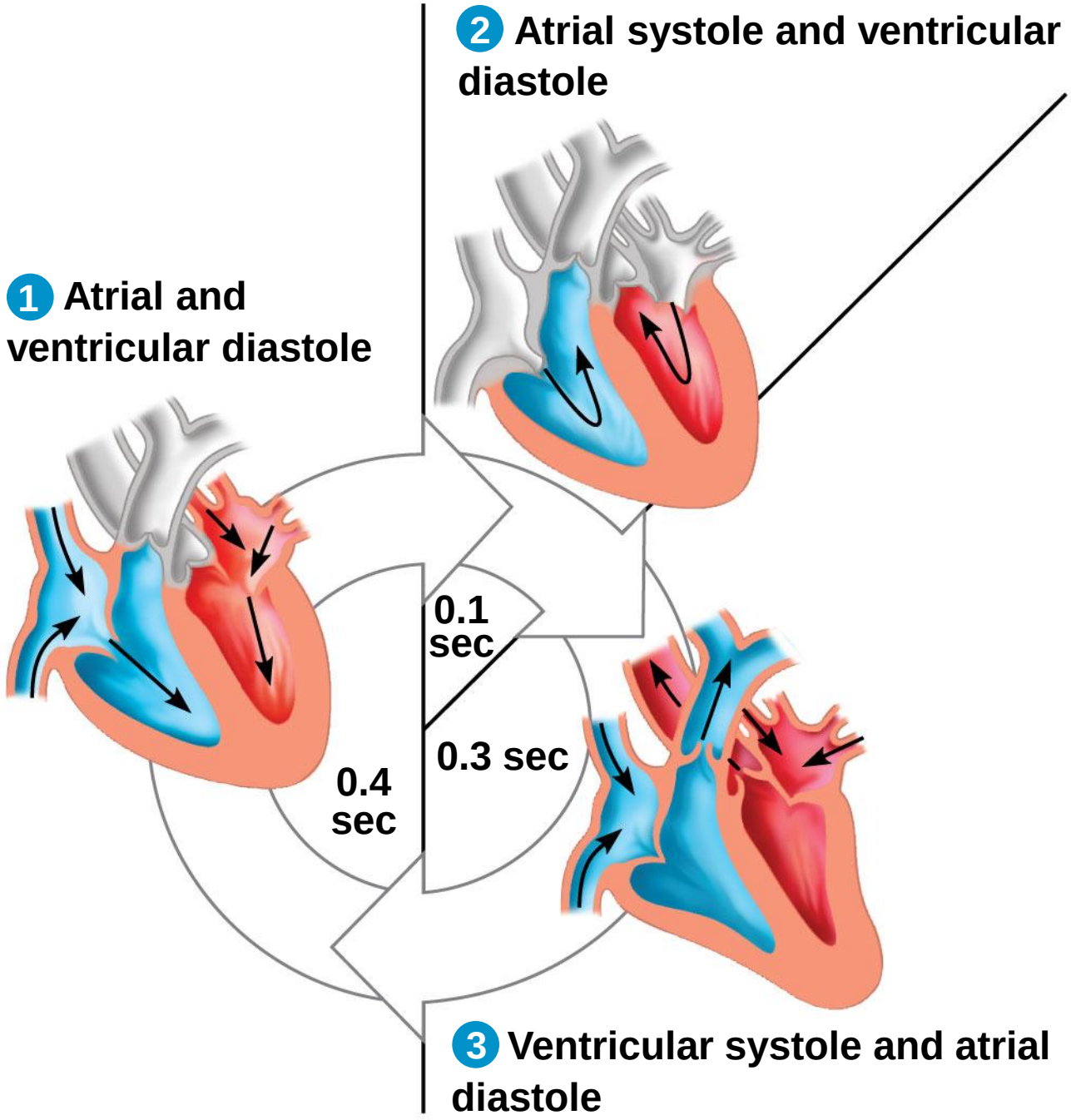


© 2011 Pearson Education, Inc.
STUDENTS-HUB.com

- The heart contracts and relaxes in a rhythmic cycle called the **cardiac cycle**
- The contraction, or pumping, phase is called **systole**
- The relaxation, or filling, phase is called **diastole**

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Figure 42.8-3



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

- The **heart rate**, also called the pulse, is the number of beats per minute
- The **stroke volume** is the amount of blood pumped in a single contraction
- The **cardiac output** is the volume of blood pumped into the systemic circulation per minute and depends on both the heart rate and stroke volume

STUDENT HUB Pearson
© 2011 Pearson Education, Inc.

- Four valves prevent backflow of blood in the heart
- The **atrioventricular (AV) valves** separate each atrium and ventricle
- The **semilunar valves** control blood flow to the aorta and the pulmonary artery

STUDENT HUB Box
© 2011 Pearson Education, Inc.

- The “lub-dup” sound of a heart beat is caused by the recoil of blood against the AV valves (lub) then against the semilunar (dup) valves
- Backflow of blood through a defective valve causes a **heart murmur**

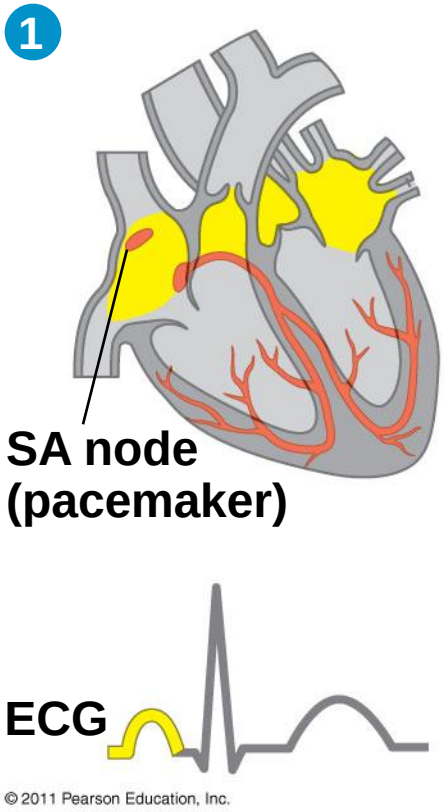
STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Maintaining the Heart's Rhythmic Beat

- Some cardiac muscle cells are self-excitable, meaning they contract without any signal from the nervous system
- The **sinoatrial (SA) node**, or pacemaker, sets the rate and timing at which cardiac muscle cells contract
- Impulses that travel during the cardiac cycle can be recorded as an **electrocardiogram** (**ECG** or **EKG**)

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

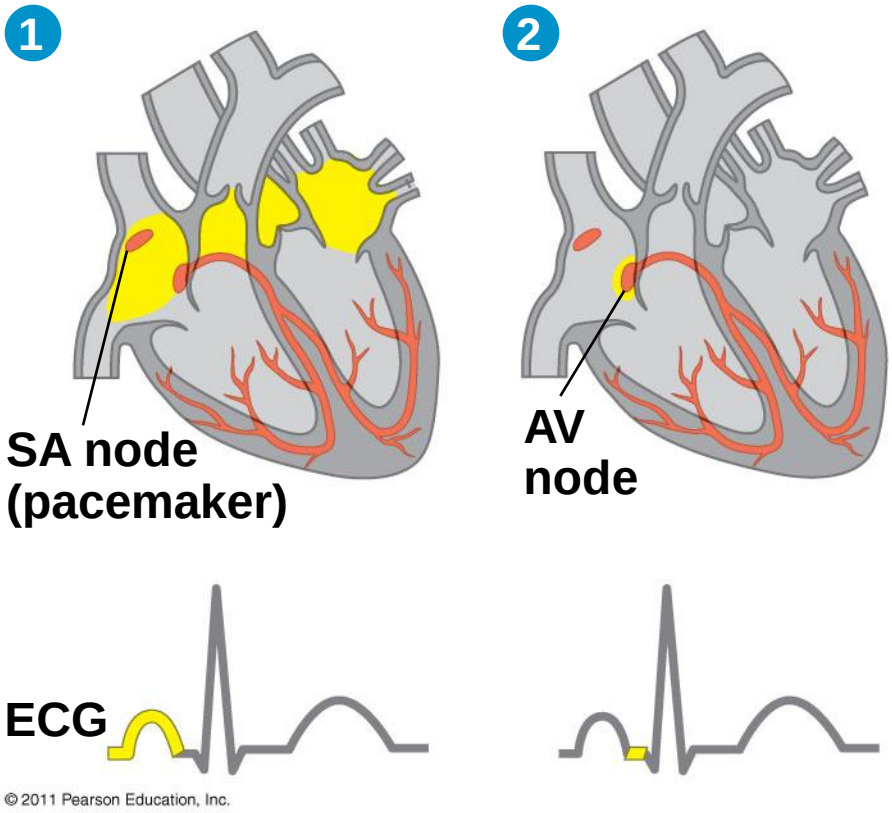
Figure 42.9-1



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

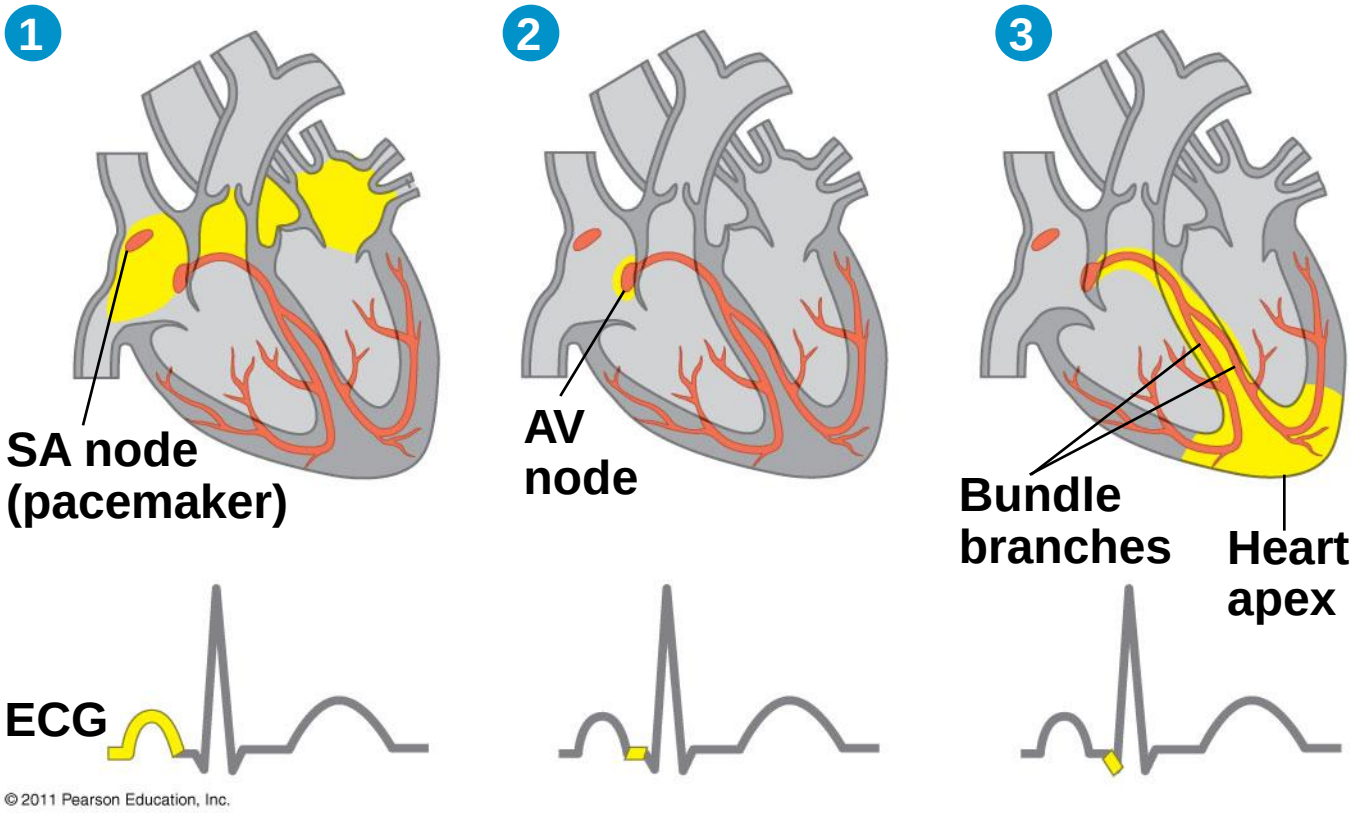
Figure 42.9-2



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

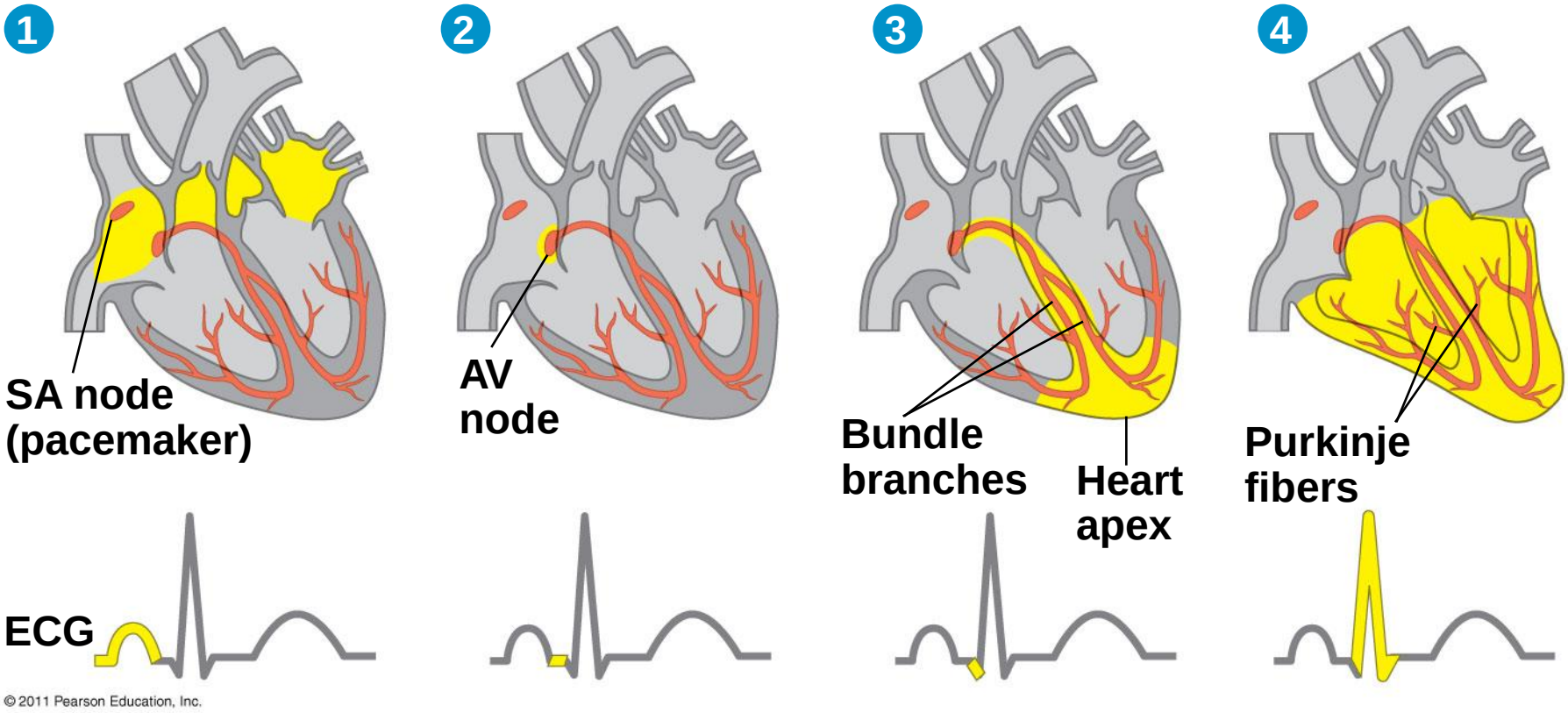
Figure 42.9-3



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Figure 42.9-4



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

- Impulses from the SA node travel to the **atrioventricular (AV) node**
- At the AV node, the impulses are delayed and then travel to the Purkinje fibers that make the ventricles contract

STUDENT HUB Demo
© 2011 Pearson Education, Inc.

- The pacemaker is regulated by two portions of the nervous system: the sympathetic and parasympathetic divisions
- The sympathetic division speeds up the pacemaker
- The parasympathetic division slows down the pacemaker
- The pacemaker is also regulated by hormones and temperature

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

Concept 42.3: Patterns of blood pressure and flow reflect the structure and arrangement of blood vessels

- The physical principles that govern movement of water in plumbing systems also influence the functioning of animal circulatory systems

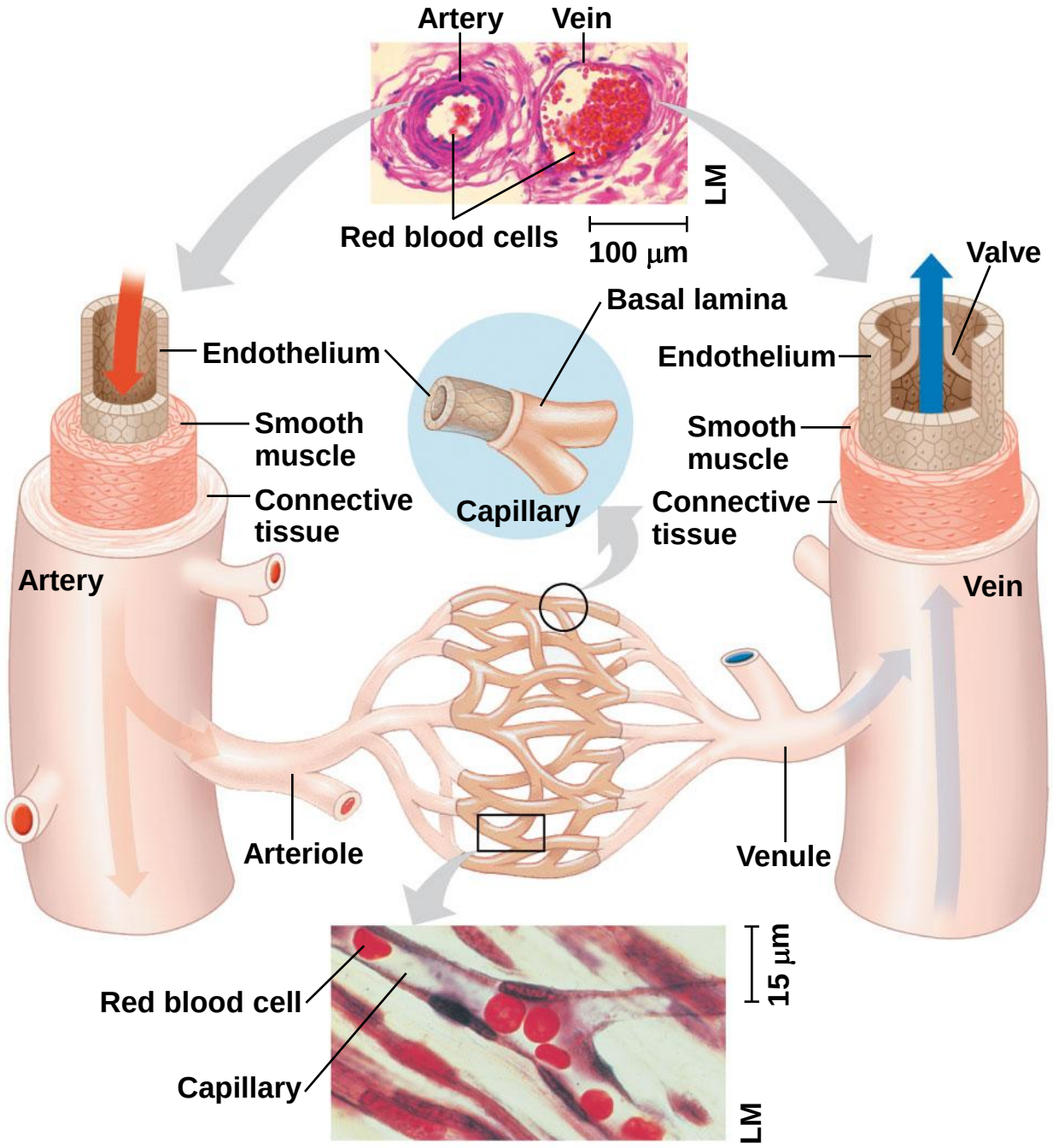
STUDENT HUB Demo
© 2011 Pearson Education, Inc.

Blood Vessel Structure and Function

- A vessel's cavity is called the central lumen
- The epithelial layer that lines blood vessels is called the **endothelium**
- The endothelium is smooth and minimizes resistance

STUDENT HUB Dem
© 2011 Pearson Education, Inc.

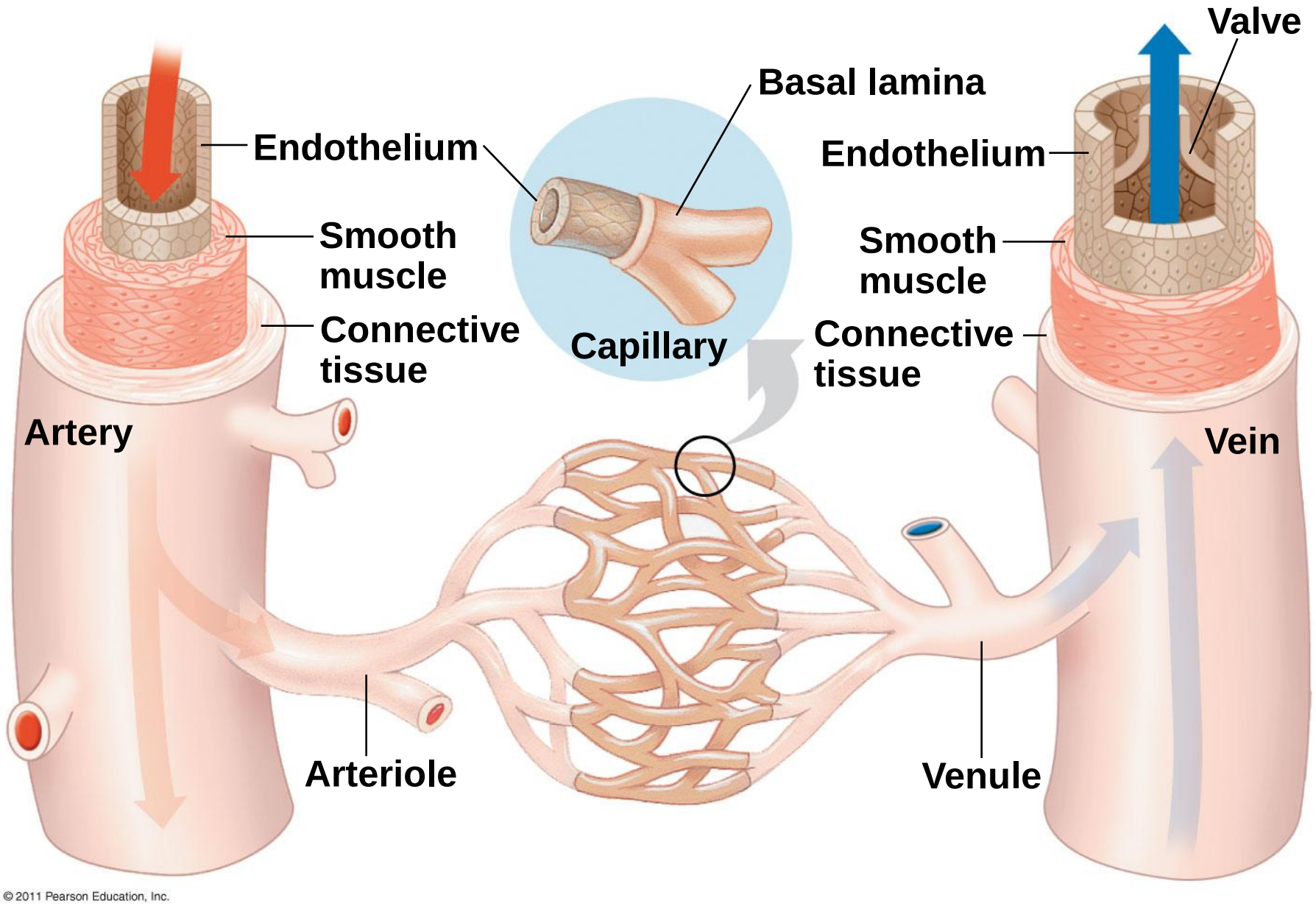
Figure 42.10



© 2011 Pearson Education, Inc.

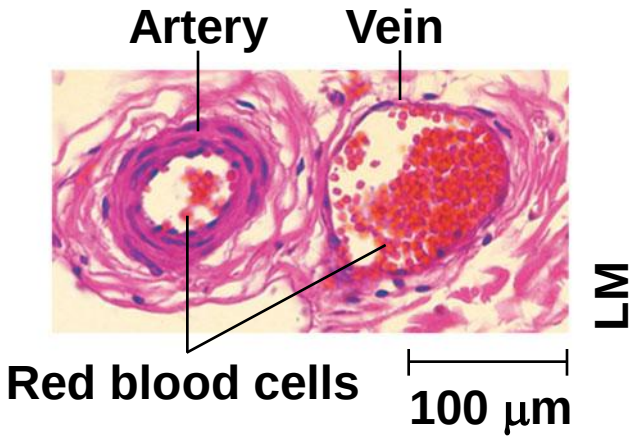
STUDENTS-HUB.com

Figure 42.10a



STUDENTS-HUB.com

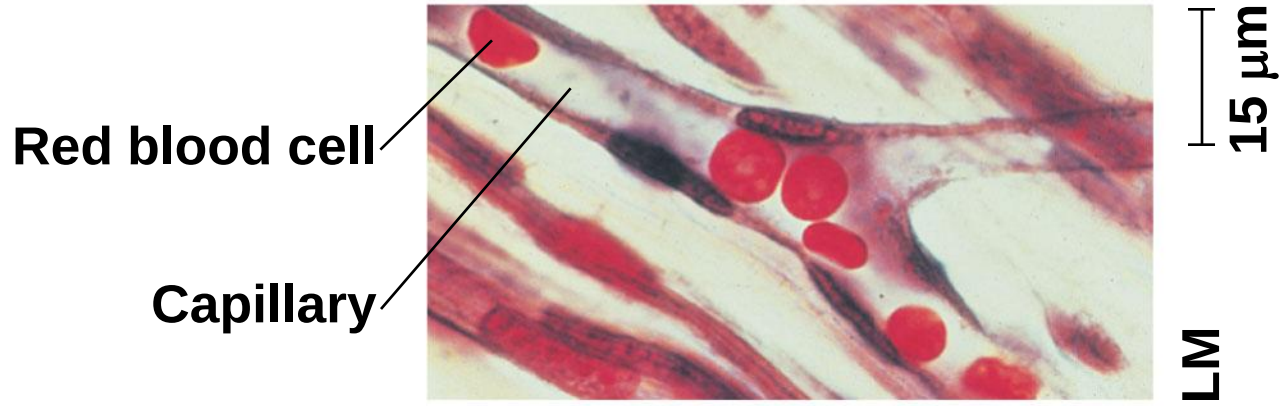
Figure 42.10b



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Figure 42.10c



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

- Capillaries have thin walls, the endothelium plus its basal lamina, to facilitate the exchange of materials
- Arteries and veins have an endothelium, smooth muscle, and connective tissue
- Arteries have thicker walls than veins to accommodate the high pressure of blood pumped from the heart
- In the thinner-walled veins, blood flows back to the heart mainly as a result of muscle action

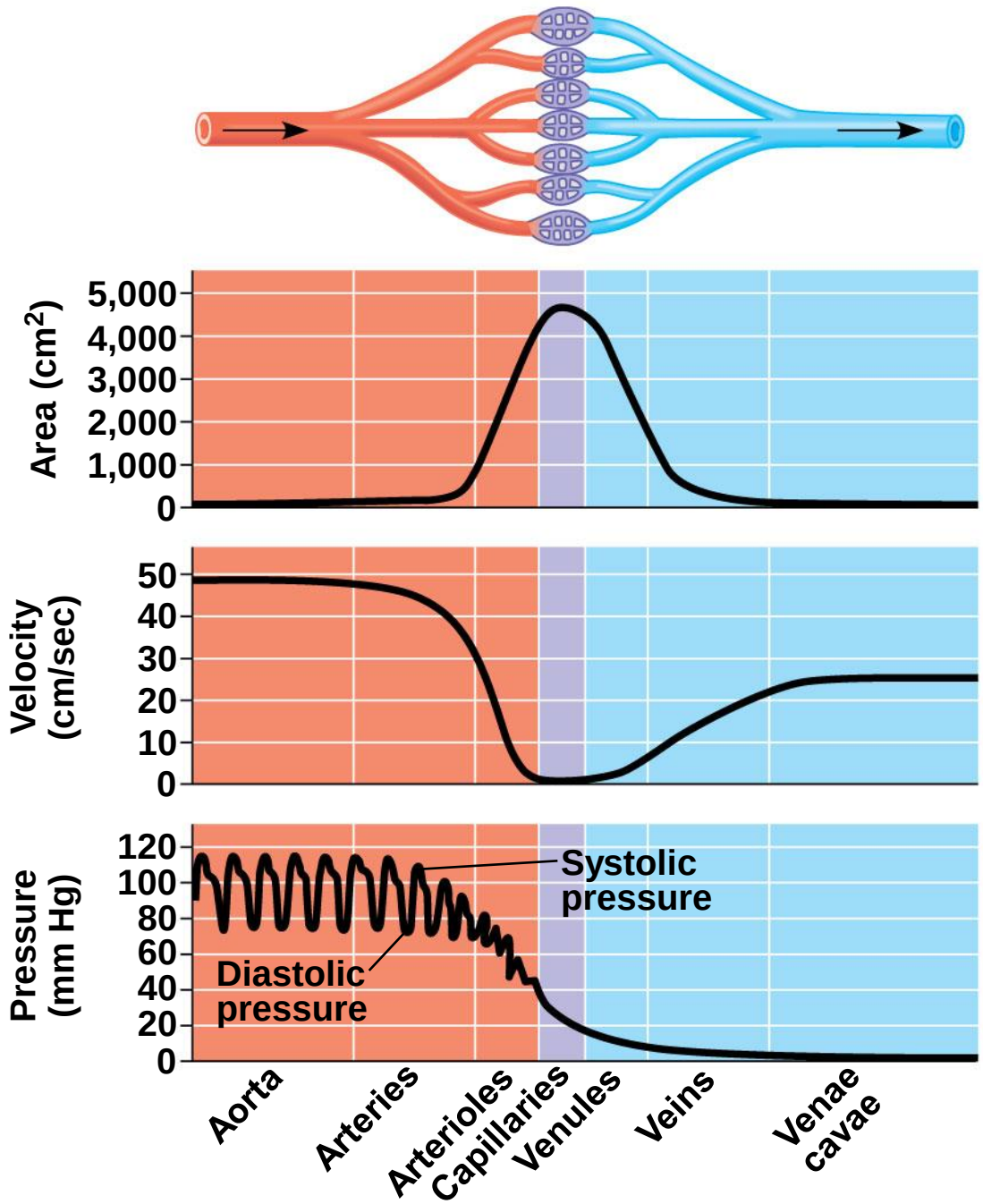
STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

Blood Flow Velocity

- Physical laws governing movement of fluids through pipes affect blood flow and blood pressure
- Velocity of blood flow is slowest in the capillary beds, as a result of the high resistance and large total cross-sectional area
- Blood flow in capillaries is necessarily slow for exchange of materials

STUDENT HUB Dem
© 2011 Pearson Education, Inc.

Figure 42.11



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Blood Pressure

- Blood flows from areas of higher pressure to areas of lower pressure
- Blood pressure is the pressure that blood exerts against the wall of a vessel
- In rigid vessels blood pressure is maintained; less rigid vessels deform and blood pressure is lost

STUDENT HUB Beta
© 2011 Pearson Education, Inc.

Changes in Blood Pressure During the Cardiac Cycle

- **Systolic pressure** is the pressure in the arteries during ventricular systole; it is the highest pressure in the arteries
- **Diastolic pressure** is the pressure in the arteries during diastole; it is lower than systolic pressure
- A **pulse** is the rhythmic bulging of artery walls with each heartbeat

STUDENT HUB Demo
© 2011 Pearson Education, Inc.

Regulation of Blood Pressure

- Blood pressure is determined by cardiac output and peripheral resistance due to constriction of arterioles
- **Vasoconstriction** is the contraction of smooth muscle in arteriole walls; it increases blood pressure
- **Vasodilation** is the relaxation of smooth muscles in the arterioles; it causes blood pressure to fall

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

- Vasoconstriction and vasodilation help maintain adequate blood flow as the body's demands change
- Nitric oxide is a major inducer of vasodilation
- The peptide endothelin is an important inducer of vasoconstriction

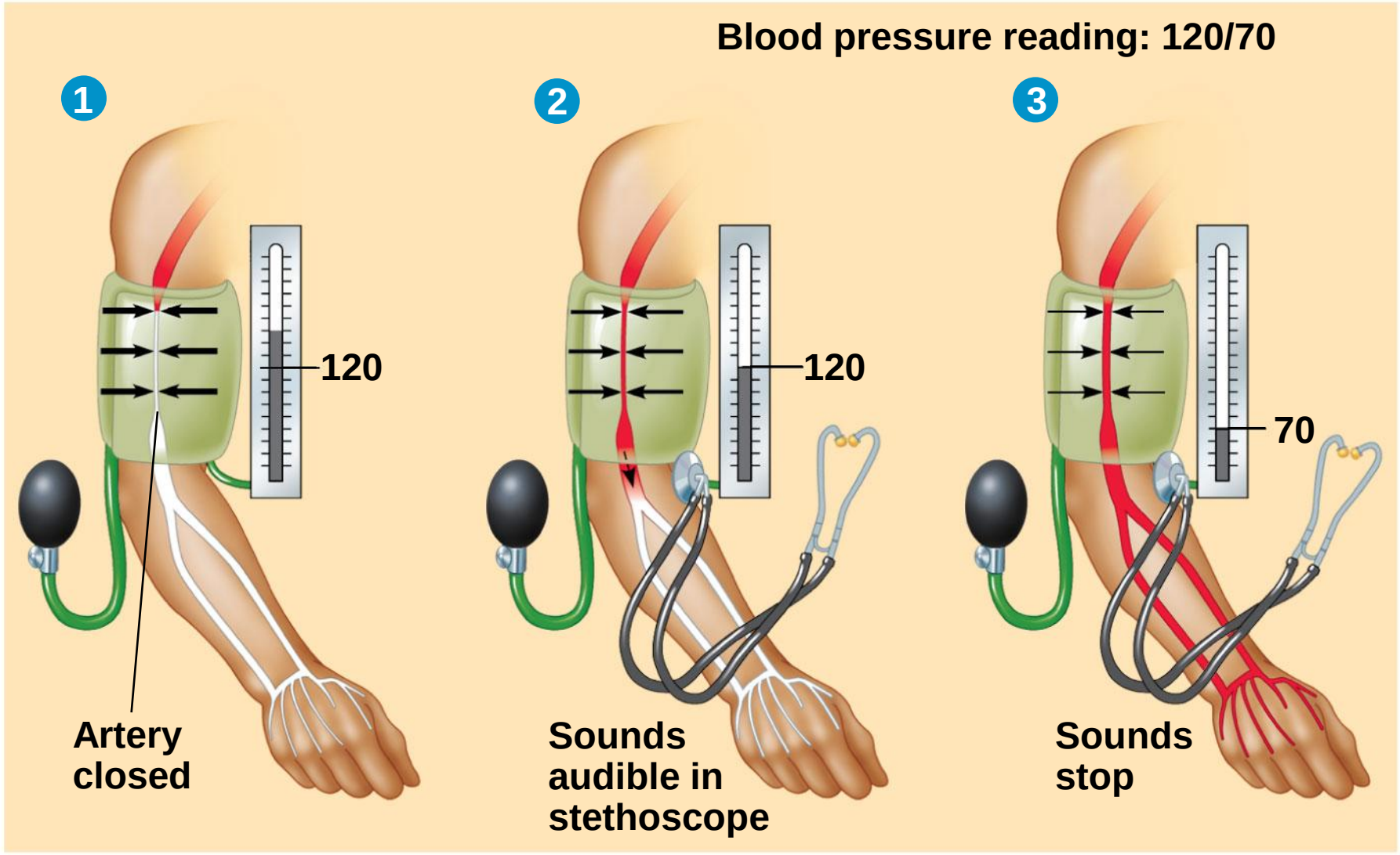
STUDENT HUB Pearson Education, Inc.
© 2011 Pearson Education, Inc.

Blood Pressure and Gravity

- Blood pressure is generally measured for an artery in the arm at the same height as the heart
- Blood pressure for a healthy 20-year-old at rest is 120 mm Hg at systole and 70 mm Hg at diastole

STUDENT HUB Beta
© 2011 Pearson Education, Inc.

Figure 42.12



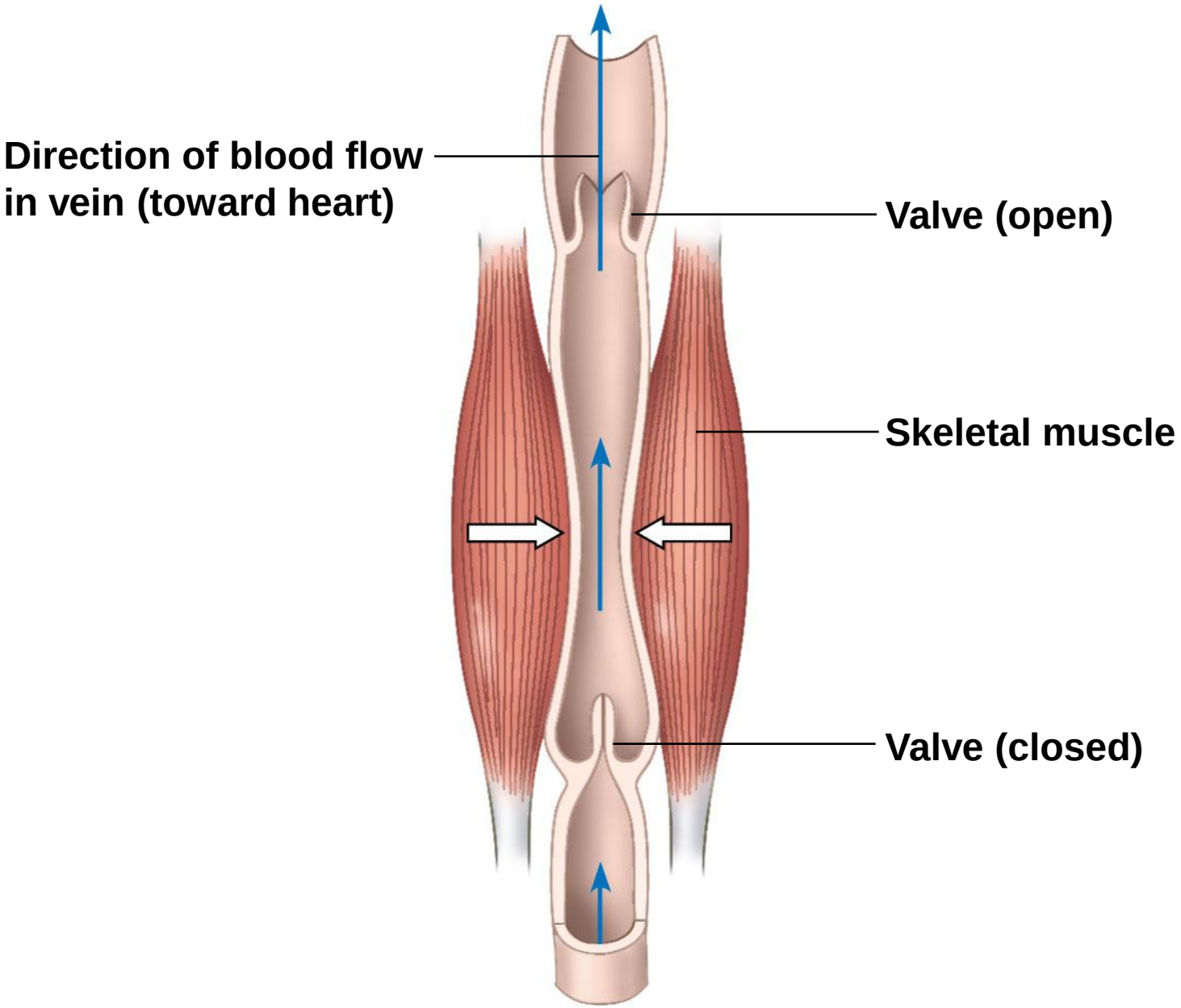
© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

- Fainting is caused by inadequate blood flow to the head
- Animals with longer necks require a higher systolic pressure to pump blood a greater distance against gravity
- Blood is moved through veins by smooth muscle contraction, skeletal muscle contraction, and expansion of the vena cava with inhalation
- One-way valves in veins prevent backflow of blood

STUDENT HUB Beta
© 2011 Pearson Education, Inc.

Figure 42.13



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Capillary Function

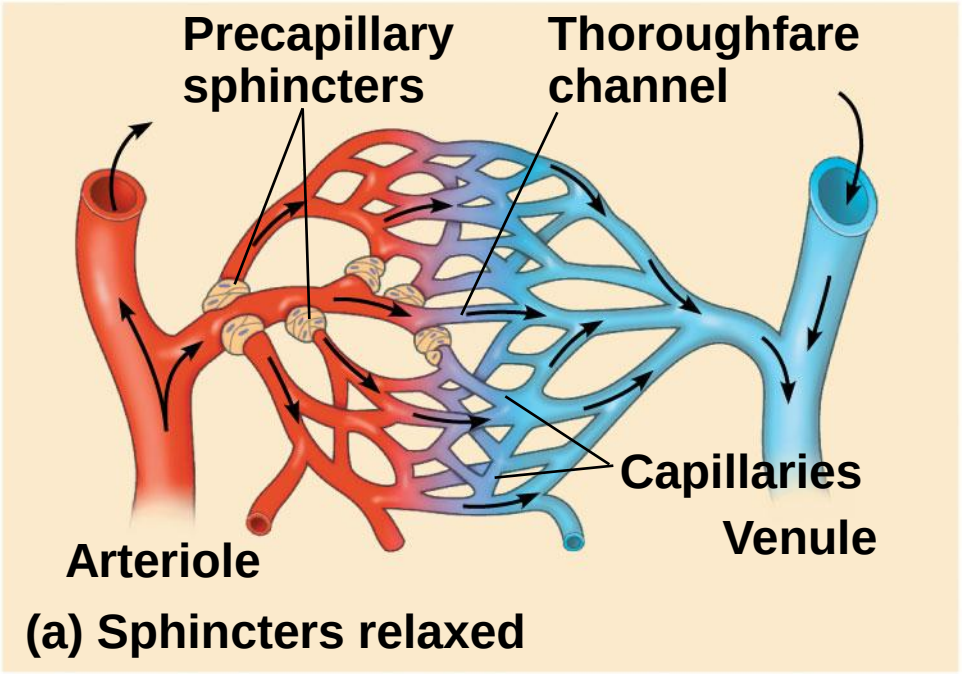
- Blood flows through only 5–10% of the body's capillaries at a time
- Capillaries in major organs are usually filled to capacity
- Blood supply varies in many other sites

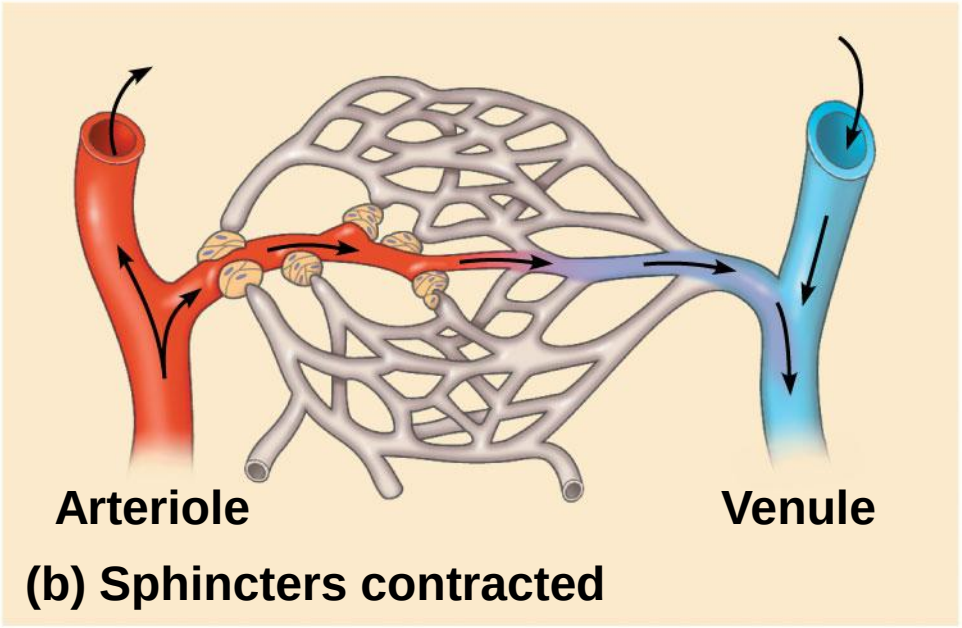
STUDENT HUB Dem
© 2011 Pearson Education, Inc.

- Two mechanisms regulate distribution of blood in capillary beds
  - Contraction of the smooth muscle layer in the wall of an arteriole constricts the vessel
  - Precapillary sphincters control flow of blood between arterioles and venules
- Blood flow is regulated by nerve impulses, hormones, and other chemicals

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Figure 42.14





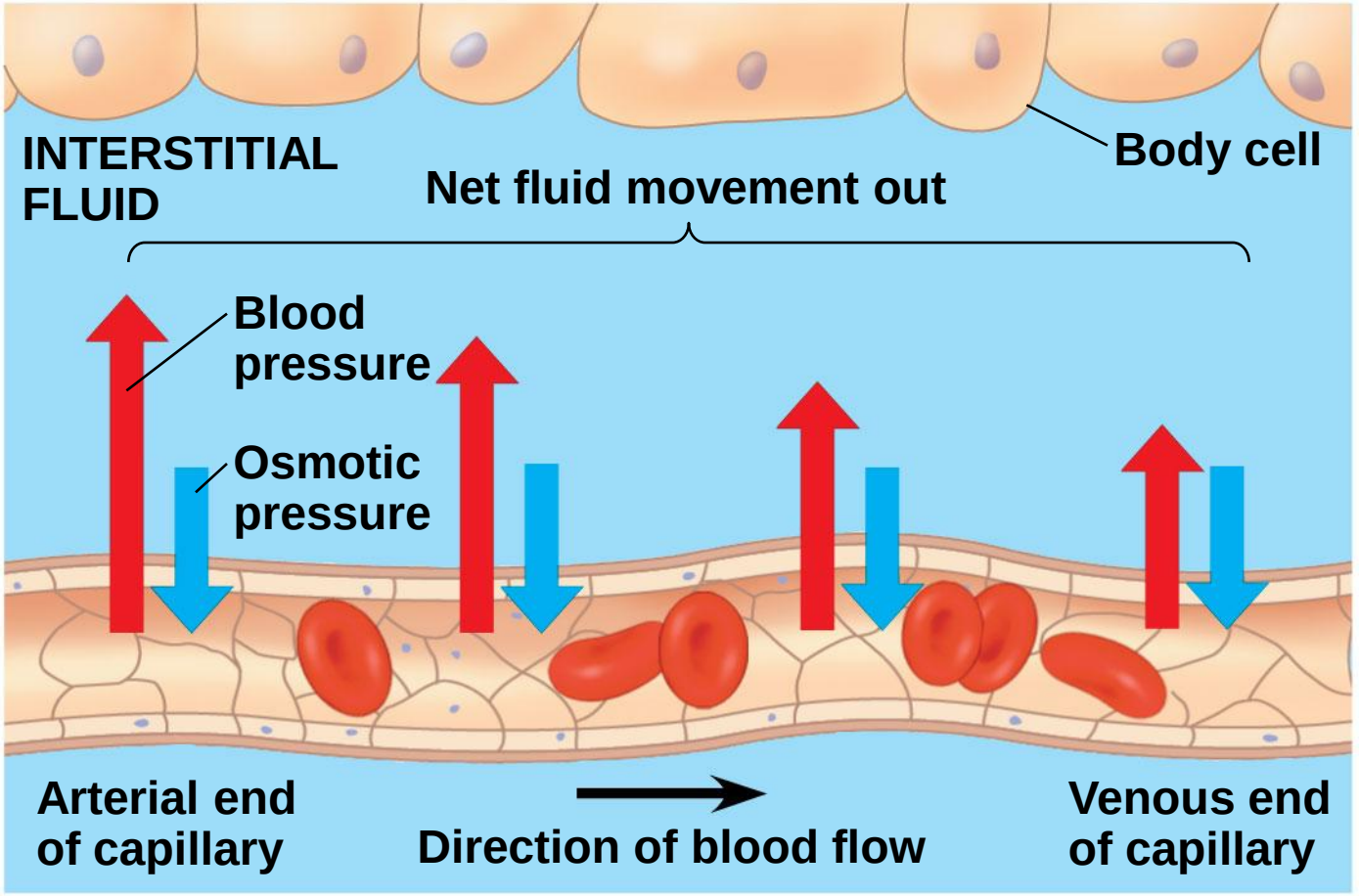
© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

- The exchange of substances between the blood and interstitial fluid takes place across the thin endothelial walls of the capillaries
- The difference between blood pressure and osmotic pressure drives fluids out of capillaries at the arteriole end and into capillaries at the venule end
- Most blood proteins and all blood cells are too large to pass through the endothelium

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Figure 42.15



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Fluid Return by the Lymphatic System

- The **lymphatic system** returns fluid that leaks out from the capillary beds
- Fluid, called **lymph**, reenters the circulation directly at the venous end of the capillary bed and indirectly through the lymphatic system
- The lymphatic system drains into veins in the neck
- Valves in lymph vessels prevent the backflow of fluid

STUDENT HUB Demo
© 2011 Pearson Education, Inc.

- **Lymph nodes** are organs that filter lymph and play an important role in the body's defense
- Edema is swelling caused by disruptions in the flow of lymph

STUDENT HUB Demo
© 2011 Pearson Education, Inc.

Concept 42.4: Blood components contribute to exchange, transport, and defense

- With open circulation, the fluid that is pumped comes into direct contact with all cells
- The closed circulatory systems of vertebrates contain blood, a specialized connective tissue

STUDENT HUB Pearson
© 2011 Pearson Education, Inc.

Blood Composition and Function

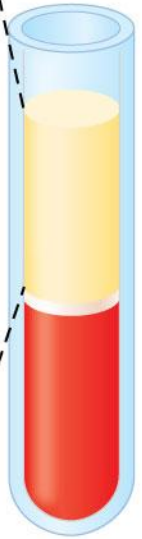
- Blood consists of several kinds of cells suspended in a liquid matrix called **plasma**
- The cellular elements occupy about 45% of the volume of blood

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Figure 42.17a

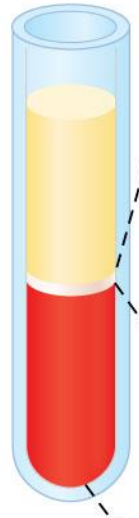
Plasma 55%	
Constituent	**Major functions**
Water	Solvent for carrying other substances
Ions (blood electrolytes) Sodium Potassium Calcium Magnesium Chloride Bicarbonate	Osmotic balance, pH buffering, and regulation of membrane permeablity
Plasma proteins Albumin Fibrinogen Immunoglobulins (antibodies)	Osmotic balance, pH buffering Clotting Defense
Substances transported by blood Nutrients Waste products Respiratory gases Hormones	

Separated blood elements



STUDENTS-HUB.com
Copyright © Pearson Education, Inc.

Figure 42.17b



Separated blood elements

Cellular elements 45%		
Cell type	**Number per μL (mm^3) of blood**	**Functions**
Leukocytes (white blood cells) Basophils Lymphocytes Eosinophils Neutrophils Monocytes	**5,000–10,000**	**Defense and immunity**
Platelets	**250,000–400,000**	**Blood clotting**
Erythrocytes (red blood cells)	**5–6 million**	**Transport of O_2 and some CO_2**

© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Cardiovascular Disease

- Cardiovascular diseases are disorders of the heart and the blood vessels
- Cardiovascular diseases account for more than half the deaths in the United States
- Cholesterol, a steroid, helps maintain membrane fluidity

STUDENT HUB Pro © 2011 Pearson Education, Inc.

- **Low-density lipoprotein (LDL)** delivers cholesterol to cells for membrane production
- **High-density lipoprotein (HDL)** scavenges cholesterol for return to the liver
- Risk for heart disease increases with a high LDL to HDL ratio
- Inflammation is also a factor in cardiovascular disease

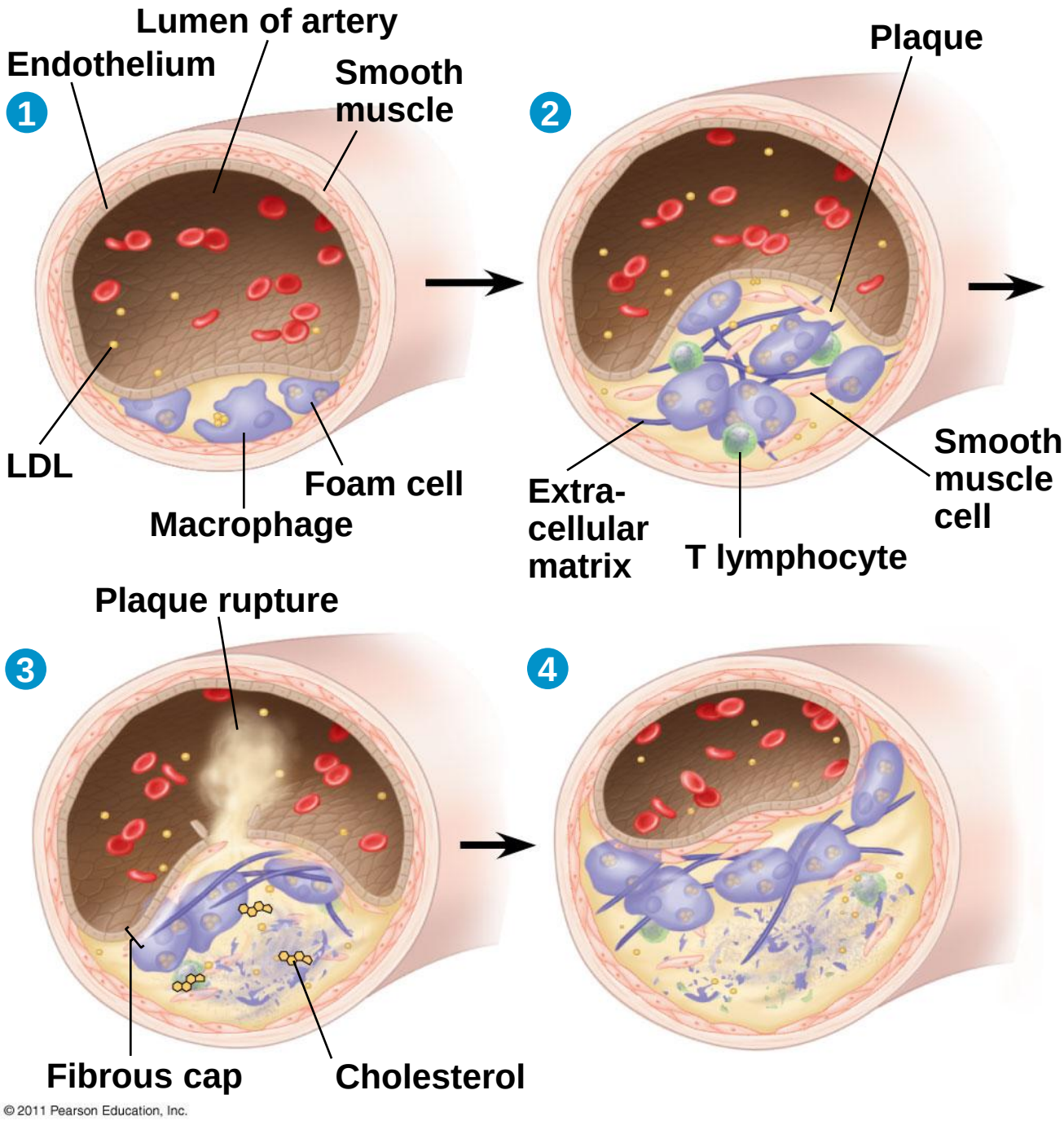
STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

Atherosclerosis, Heart Attacks, and Stroke

- One type of cardiovascular disease, **atherosclerosis**, is caused by the buildup of plaque deposits within arteries

STUDENT HUB Pearson
© 2011 Pearson Education, Inc.

Figure 42.20



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

- A **heart attack,** or myocardial infarction, is the death of cardiac muscle tissue resulting from blockage of one or more coronary arteries
- Coronary arteries supply oxygen-rich blood to the heart muscle
- A **stroke** is the death of nervous tissue in the brain, usually resulting from rupture or blockage of arteries in the head
- Angina pectoris is caused by partial blockage of the coronary arteries and results in chest pains

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

Concept 42.5: Gas exchange occurs across specialized respiratory surfaces

- **Gas exchange** supplies O_2 for cellular respiration and disposes of CO_2

STUDENT CD-ROM Part
© 2011 Pearson Education, Inc.

Partial Pressure Gradients in Gas Exchange

- A gas diffuses from a region of higher partial pressure to a region of lower partial pressure
- **Partial pressure** is the pressure exerted by a particular gas in a mixture of gases
- Gases diffuse down pressure gradients in the lungs and other organs as a result of differences in partial pressure

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

Respiratory Media

- Animals can use air or water as a source of O_2, or respiratory medium
- In a given volume, there is less O_2 available in water than in air
- Obtaining O_2 from water requires greater efficiency than air breathing

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

Respiratory Surfaces

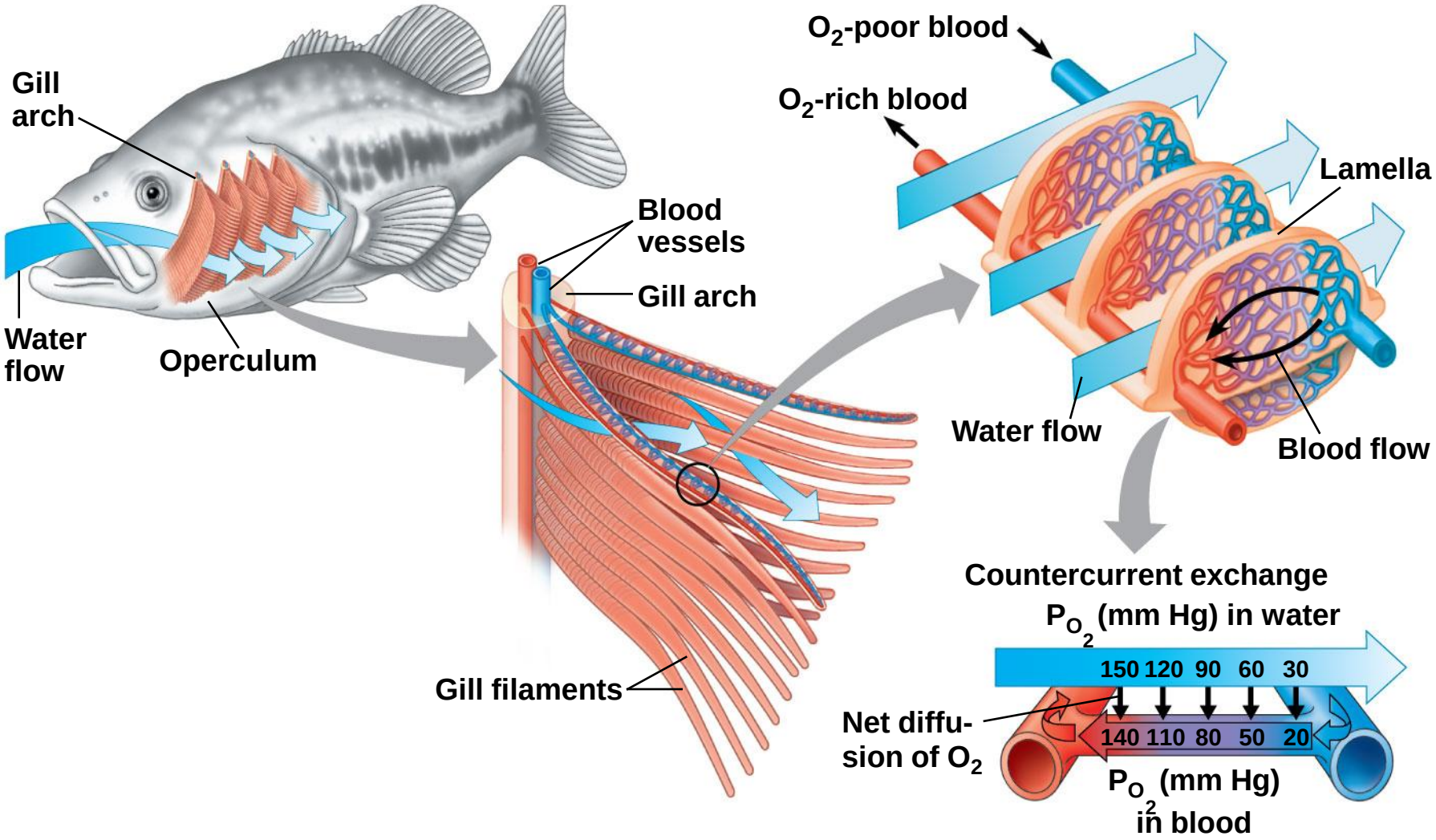
- Animals require large, moist respiratory surfaces for exchange of gases between their cells and the respiratory medium, either air or water
- Gas exchange across respiratory surfaces takes place by diffusion
- Respiratory surfaces vary by animal and can include the outer surface, skin, gills, tracheae, and lungs

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

- **Ventilation** moves the respiratory medium over the respiratory surface
- Aquatic animals move through water or move water over their gills for ventilation
- Fish gills use a **countercurrent exchange** system, where blood flows in the opposite direction to water passing over the gills; blood is always less saturated with O_2 than the water it meets

STUDENT HUB Beta
© 2011 Pearson Education, Inc.

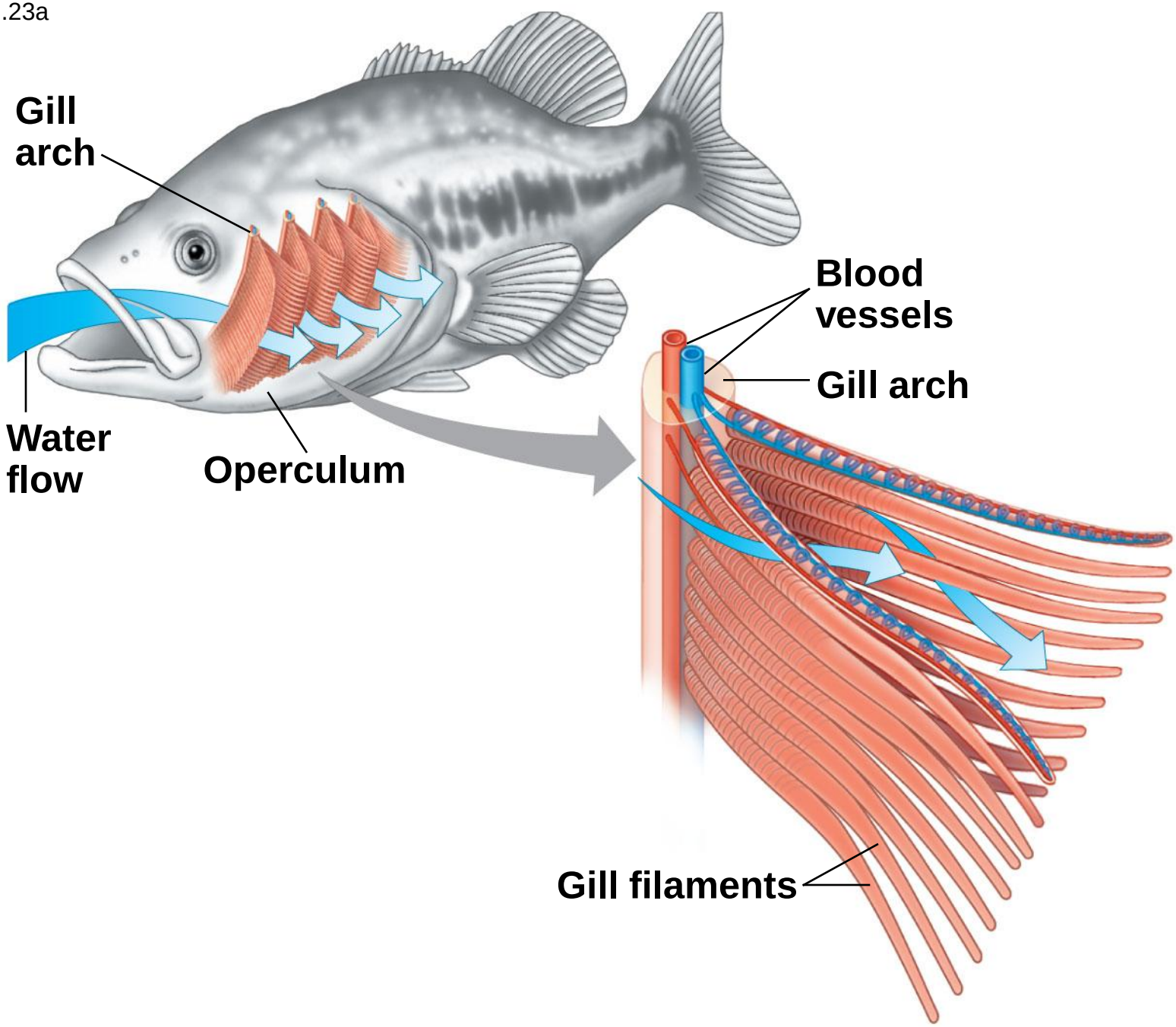
Figure 42.23



© 2011 Pearson Education, Inc.

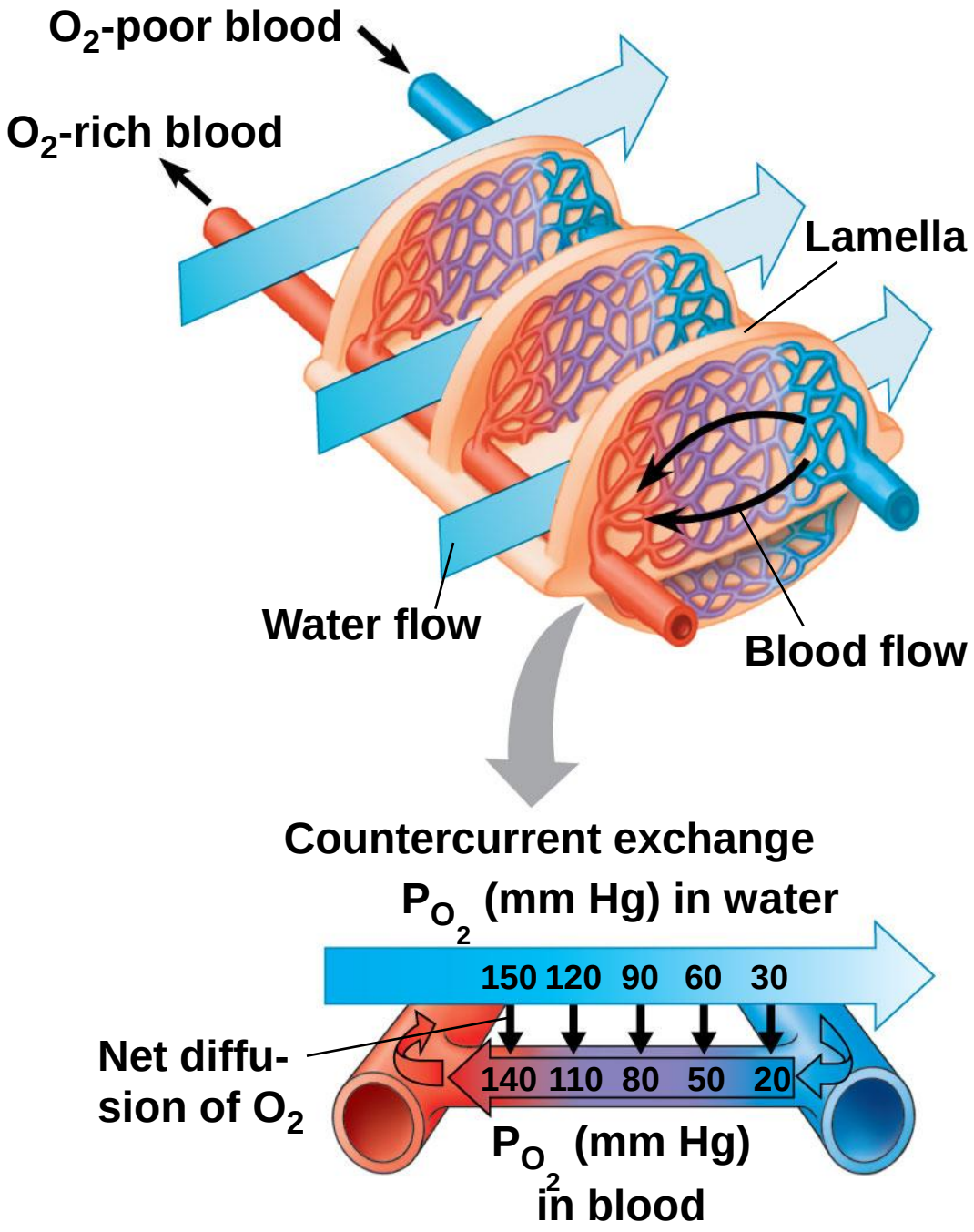
STUDENTS-HUB.com

Figure 42.23a



© 2011 Pearson Education, Inc.
STUDENTS-HUB.com

Figure 42.23b



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Lungs

- **Lungs** are an infolding of the body surface
- The circulatory system (open or closed) transports gases between the lungs and the rest of the body
- The size and complexity of lungs correlate with an animal's metabolic rate

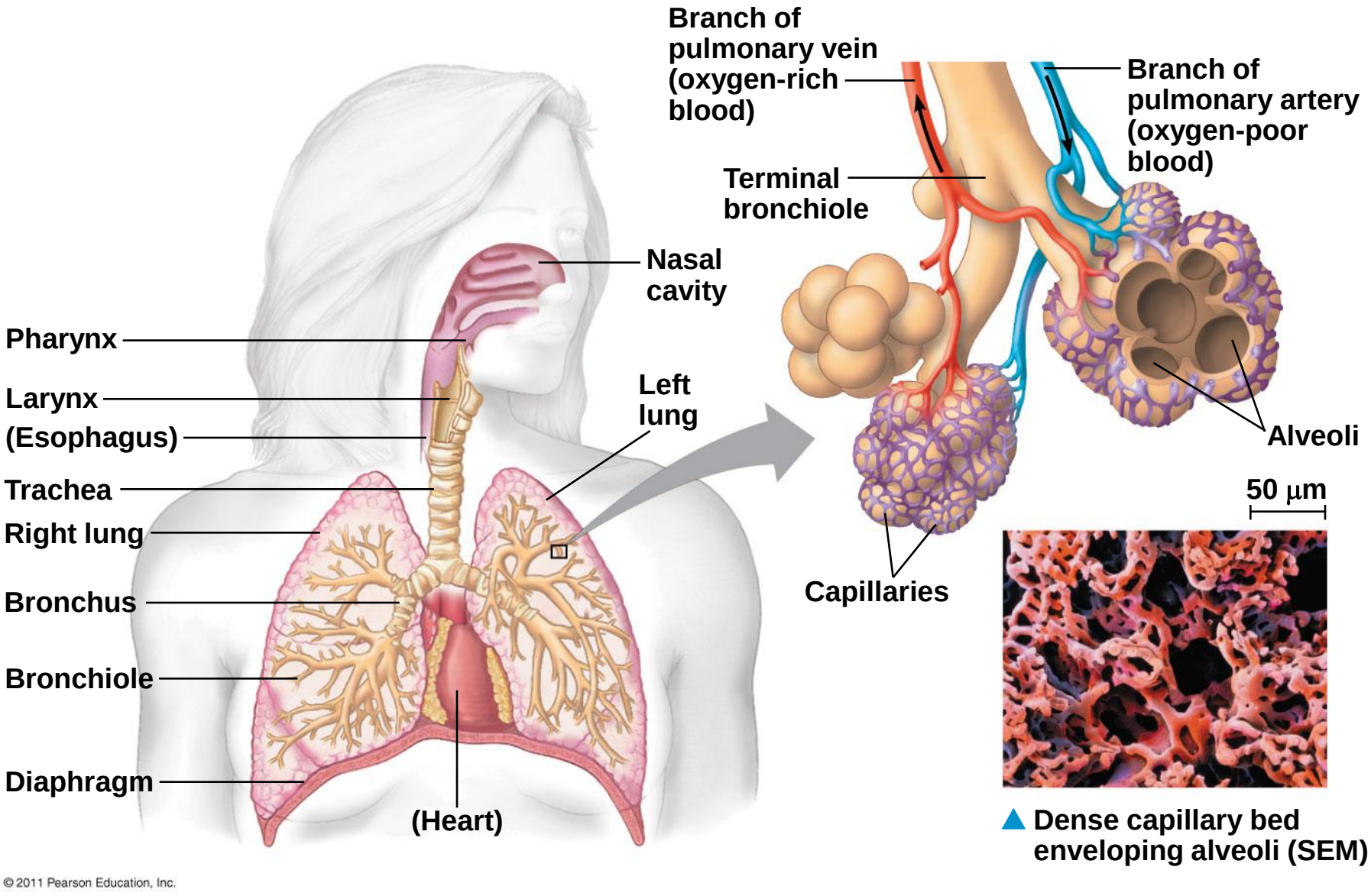
STUDENT HUB Demo
© 2011 Pearson Education, Inc.

Mammalian Respiratory Systems: A Closer Look

- A system of branching ducts conveys air to the lungs
- Air inhaled through the nostrils is warmed, humidified, and sampled for odors
- The pharynx directs air to the lungs and food to the stomach
- Swallowing tips the epiglottis over the glottis in the pharynx to prevent food from entering the **trachea**

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

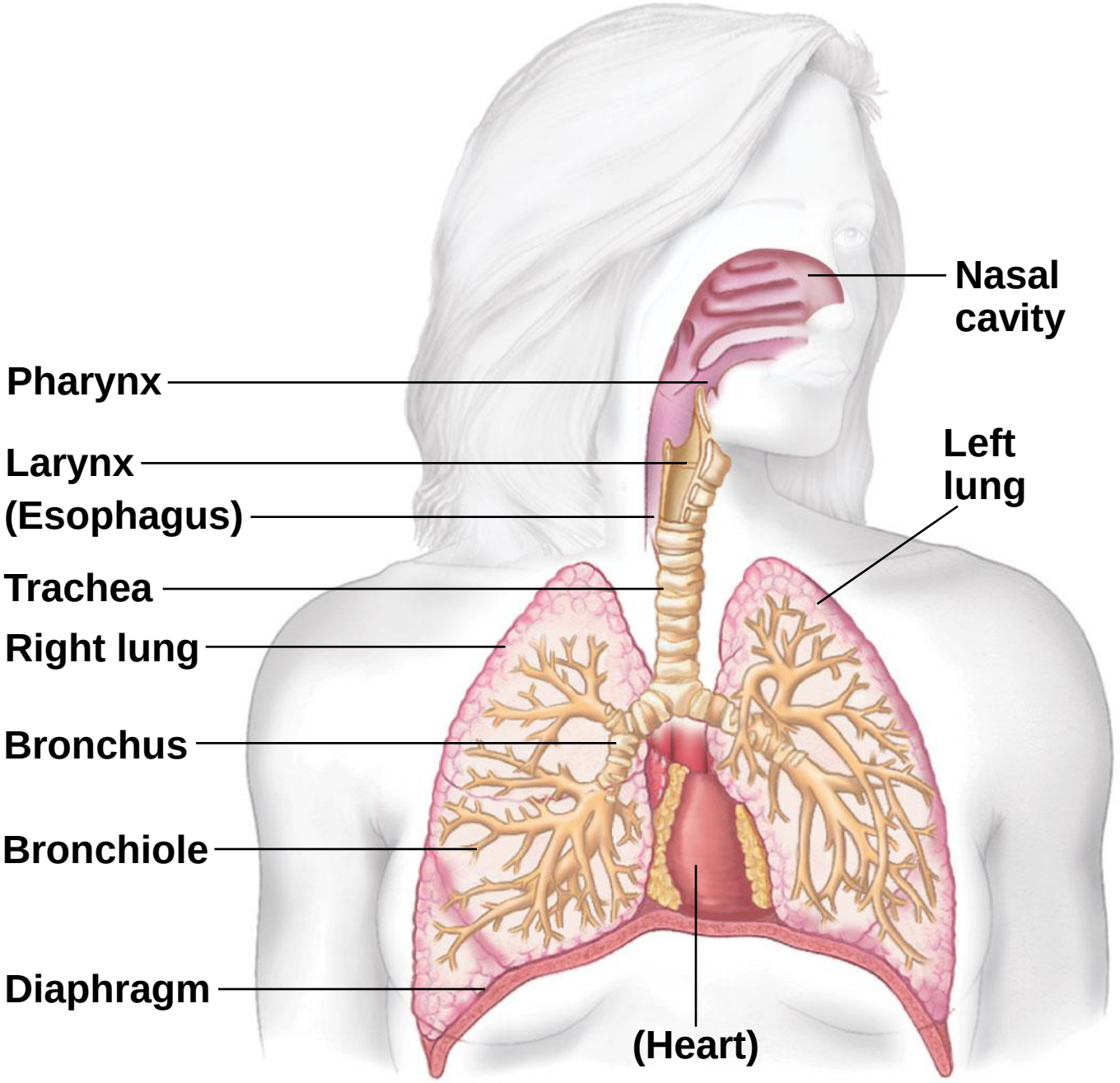
Figure 42.25



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

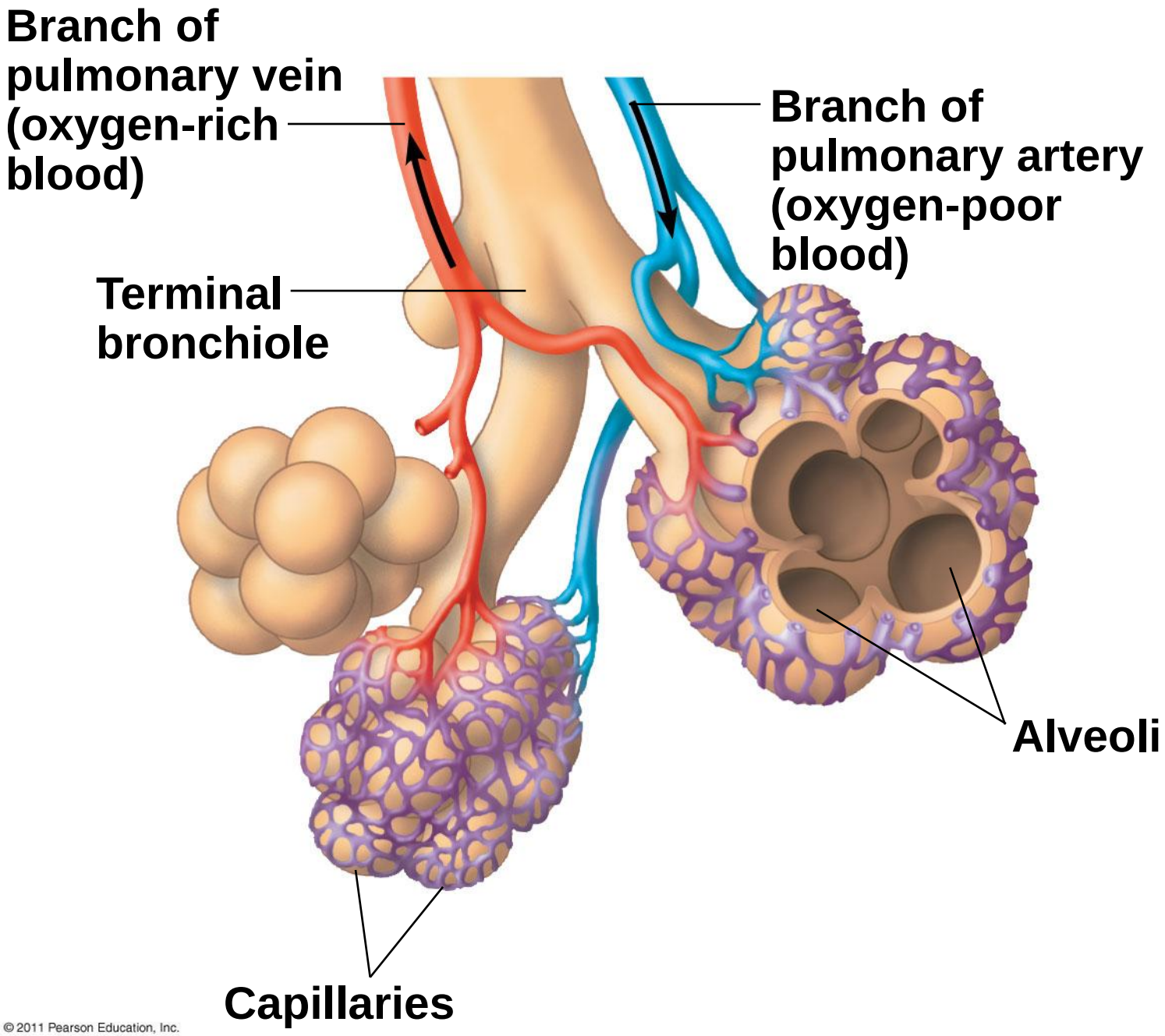
Figure 42.25a



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

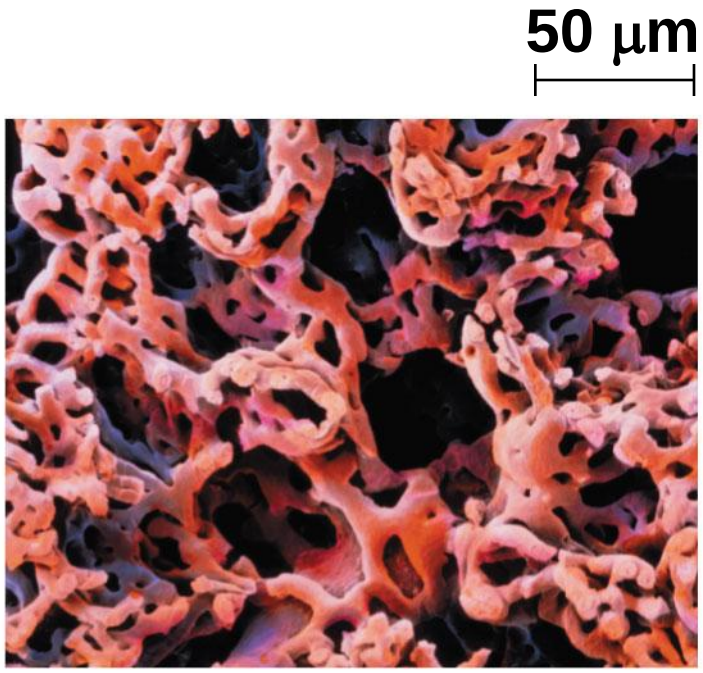
Figure 42.25b



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Figure 42.25c



▲ **Dense capillary bed enveloping alveoli (SEM)**

© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

- Air passes through the pharynx, **larynx**, trachea, **bronchi**, and **bronchioles** to the alveoli, where gas exchange occurs
- Exhaled air passes over the vocal cords in the larynx to create sounds
- Cilia and mucus line the epithelium of the air ducts and move particles up to the pharynx
- This “mucus escalator” cleans the respiratory system and allows particles to be swallowed into the esophagus

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

- Gas exchange takes place in **alveoli**, air sacs at the tips of bronchioles
- Oxygen diffuses through the moist film of the epithelium and into capillaries
- Carbon dioxide diffuses from the capillaries across the epithelium and into the air space

STUDENT HUB Beta
© 2011 Pearson Education, Inc.

- Alveoli lack cilia and are susceptible to contamination
- Secretions called **surfactants** coat the surface of the alveoli
- Preterm babies lack surfactant and are vulnerable to respiratory distress syndrome; treatment is provided by artificial surfactants

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

Concept 42.6: Breathing ventilates the lungs

- The process that ventilates the lungs is **breathing**, the alternate inhalation and exhalation of air

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

How an Amphibian Breathes

- An amphibian such as a frog ventilates its lungs by **positive pressure breathing**, which forces air down the trachea

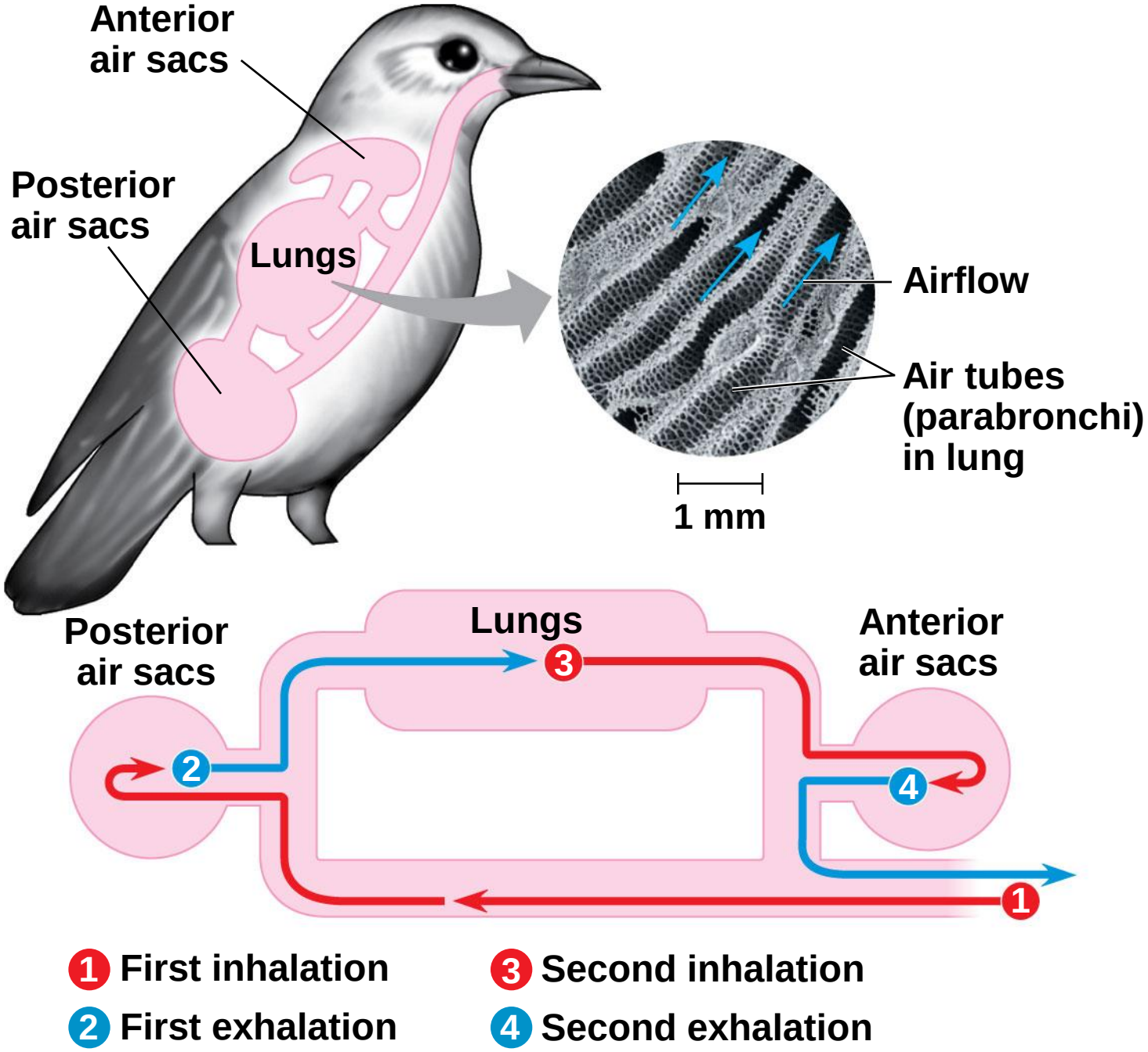
STUDENT HUB Pro
© 2011 Pearson Education, Inc.

How a Bird Breathes

- Birds have eight or nine air sacs that function as bellows that keep air flowing through the lungs
- Air passes through the lungs in one direction only
- Every exhalation completely renews the air in the lungs

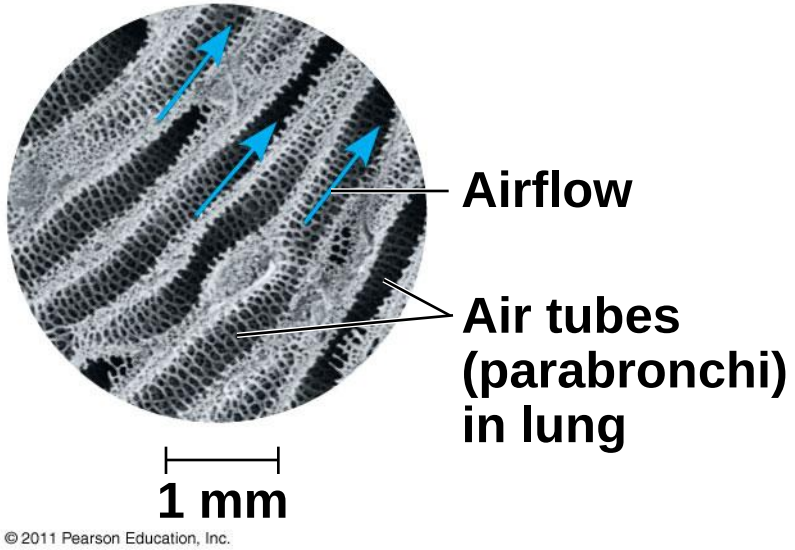
STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Figure 42.27



© 2011 Pearson Education, Inc.
STUDENTS-HUB.com

Figure 42.27a



© 2011 Pearson Education, Inc.

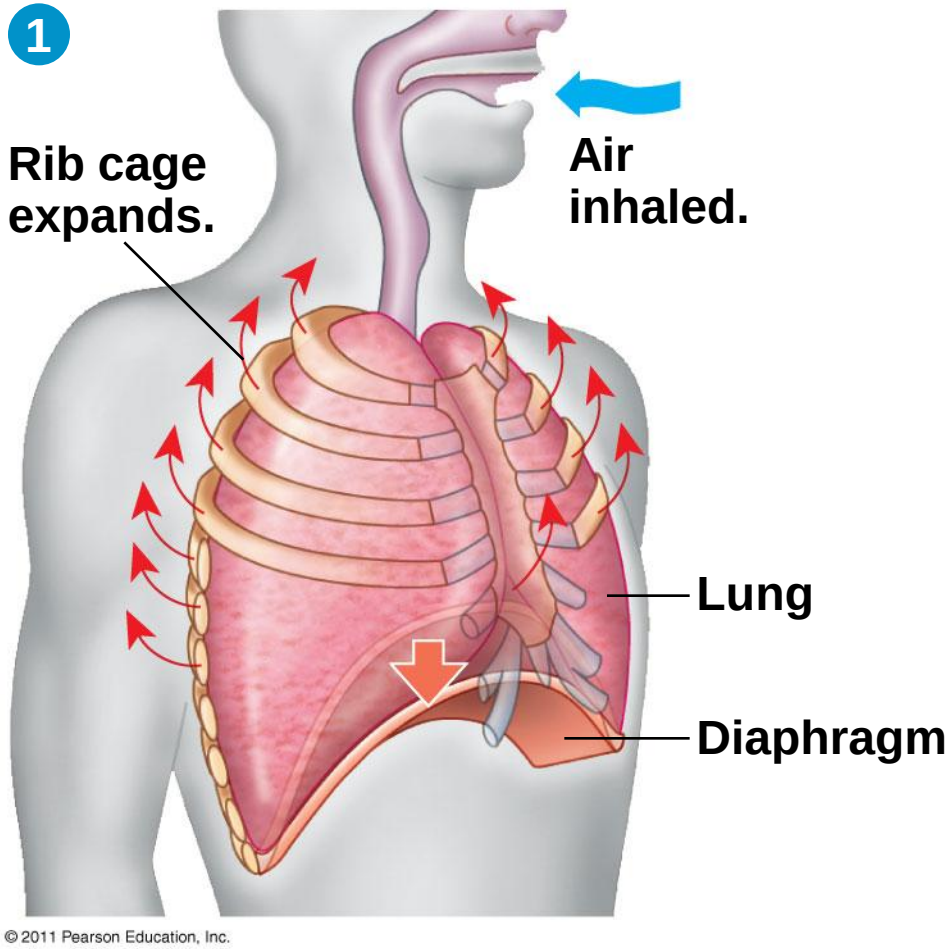
STUDENTS-HUB.com

How a Mammal Breathes

- Mammals ventilate their lungs by **negative pressure breathing**, which pulls air into the lungs
- Lung volume increases as the rib muscles and **diaphragm** contract
- The **tidal volume** is the volume of air inhaled with each breath

STUDENT HUB Pro
© 2011 Pearson Education, Inc.

Figure 42.28



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

- The maximum tidal volume is the **vital capacity**
- After exhalation, a **residual volume** of air remains in the lungs

STUDENT HUB Demo
© 2011 Pearson Education, Inc.

Control of Breathing in Humans

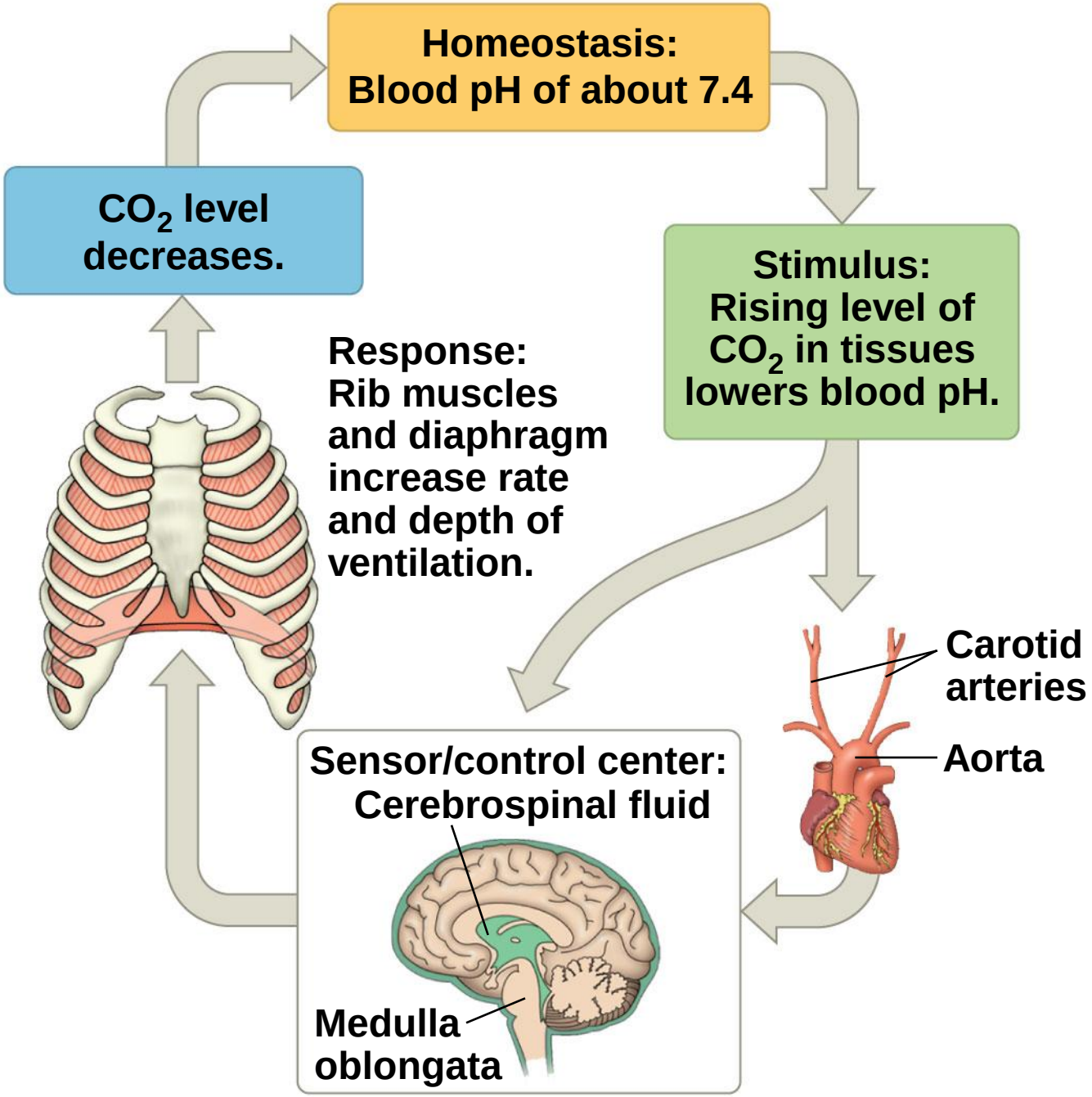
- In humans, the main **breathing control centers** are in two regions of the brain, the medulla oblongata and the pons
- The medulla regulates the rate and depth of breathing in response to pH changes in the cerebrospinal fluid
- The medulla adjusts breathing rate and depth to match metabolic demands
- The pons regulates the tempo

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

- Sensors in the aorta and carotid arteries monitor O_2 and CO_2 concentrations in the blood
- These sensors exert secondary control over breathing

STUDENT HUB Demo
© 2011 Pearson Education, Inc.

Figure 42.29



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Concept 42.7: Adaptations for gas exchange include pigments that bind and transport gases

- The metabolic demands of many organisms require that the blood transport large quantities of O_2 and CO_2

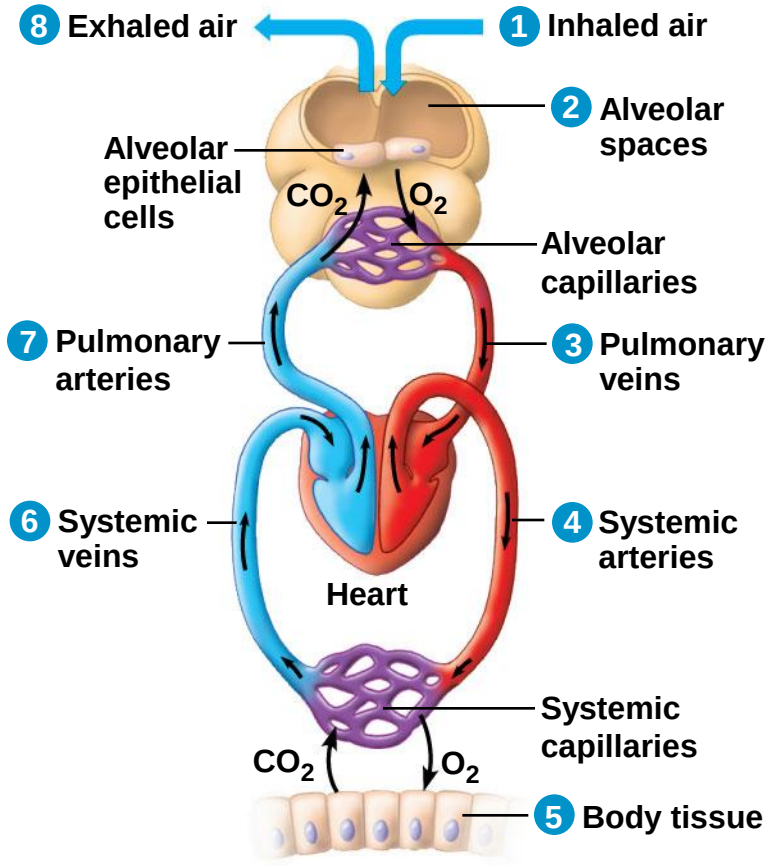
STUDENT HUB Pearson
© 2011 Pearson Education, Inc.

Coordination of Circulation and Gas Exchange

- Blood arriving in the lungs has a low partial pressure of O_2 and a high partial pressure of CO_2 relative to air in the alveoli
- In the alveoli, O_2 diffuses into the blood and CO_2 diffuses into the air
- In tissue capillaries, partial pressure gradients favor diffusion of O_2 into the interstitial fluids and CO_2 into the blood

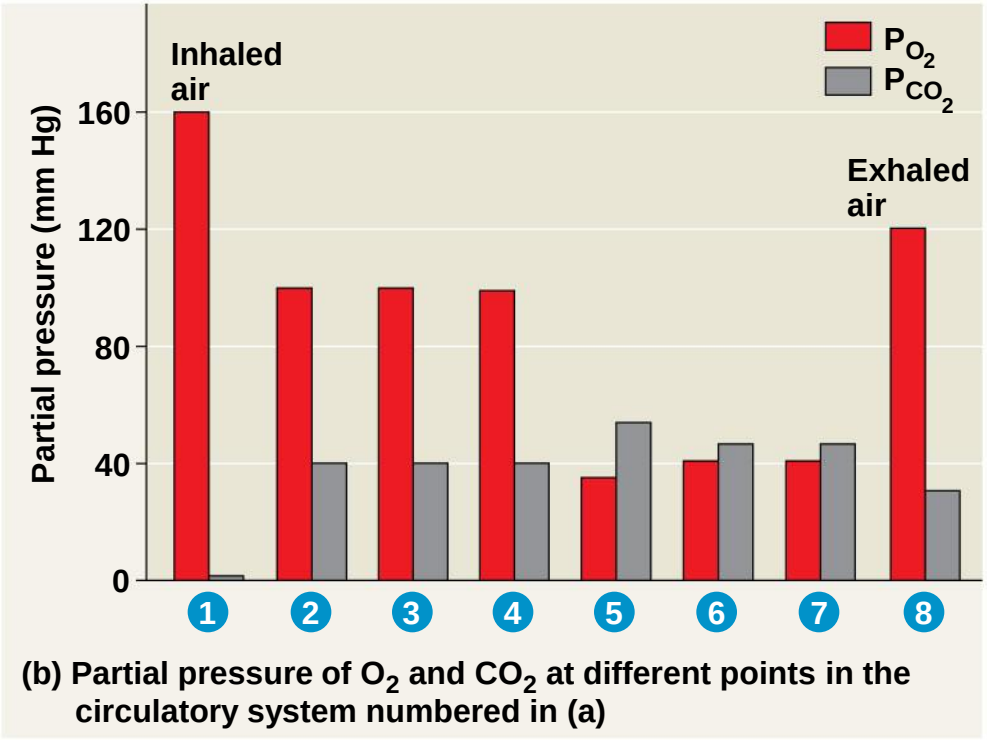
STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

Figure 42.30



(a) The path of respiratory gases in the circulatory system

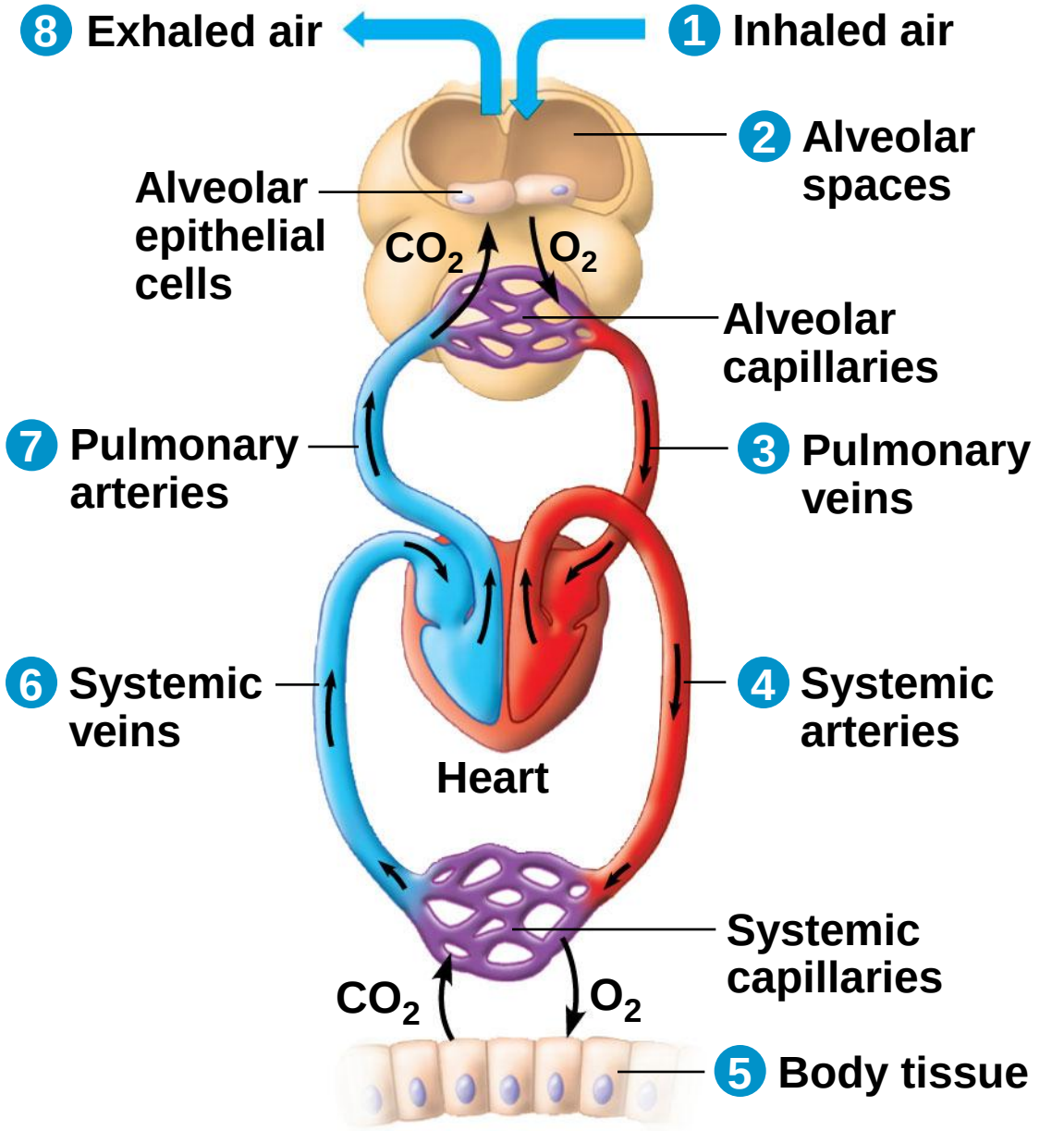
© 2011 Pearson Education, Inc.



(b) Partial pressure of O_2 and CO_2 at different points in the circulatory system numbered in (a)

STUDENTS-HUB.com

Figure 42.30a

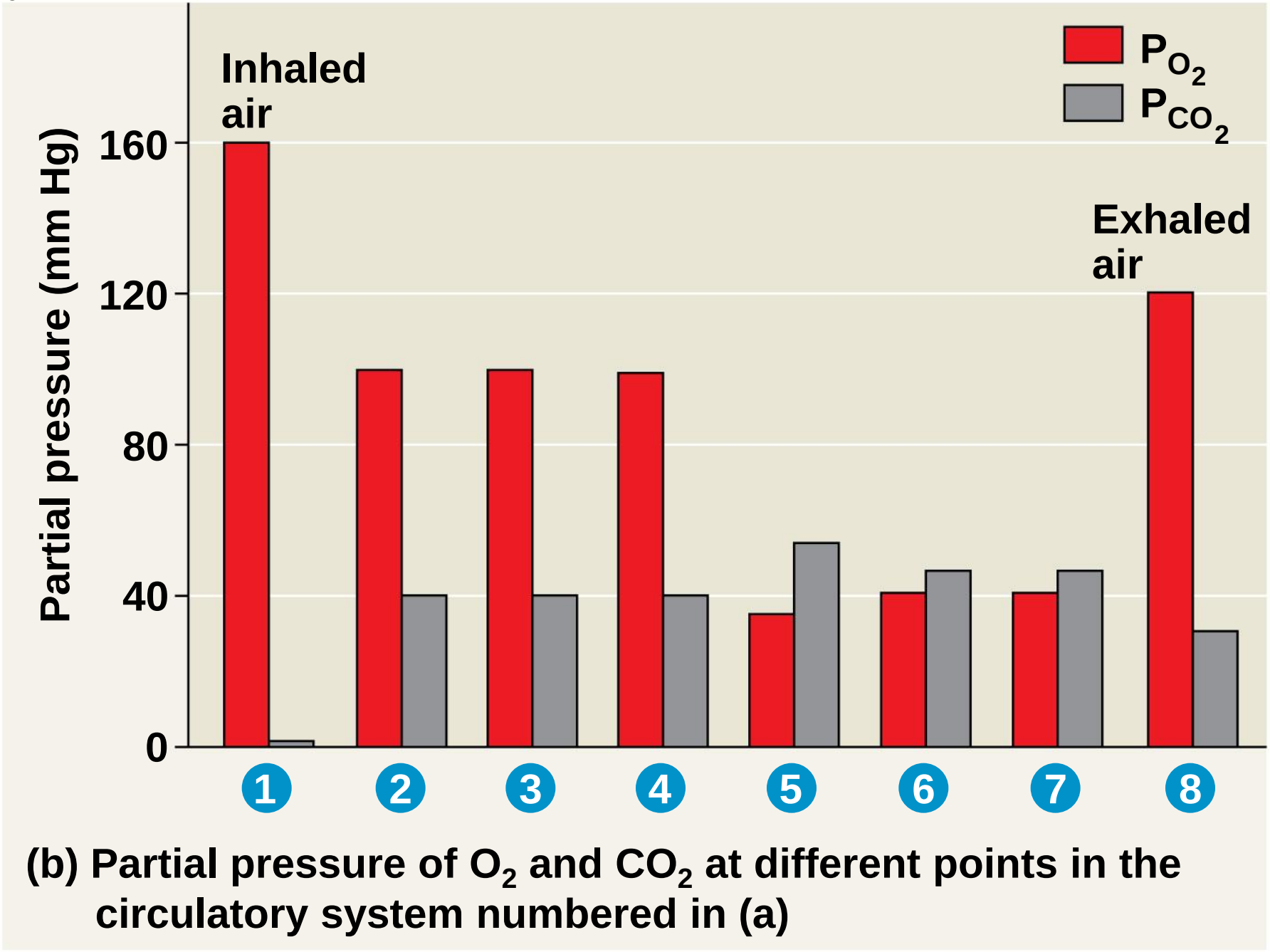


(a) The path of respiratory gases in the circulatory system

© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Figure 42.30b



(b) Partial pressure of O_2 and CO_2 at different points in the circulatory system numbered in (a)

STUDENTS-HUB.com
Pearson Education, Inc.

Respiratory Pigments

- **Respiratory pigments**, proteins that transport oxygen, greatly increase the amount of oxygen that blood can carry
- Arthropods and many molluscs have hemocyanin with copper as the oxygen-binding component
- Most vertebrates and some invertebrates use hemoglobin
- In vertebrates, hemoglobin is contained within erythrocytes

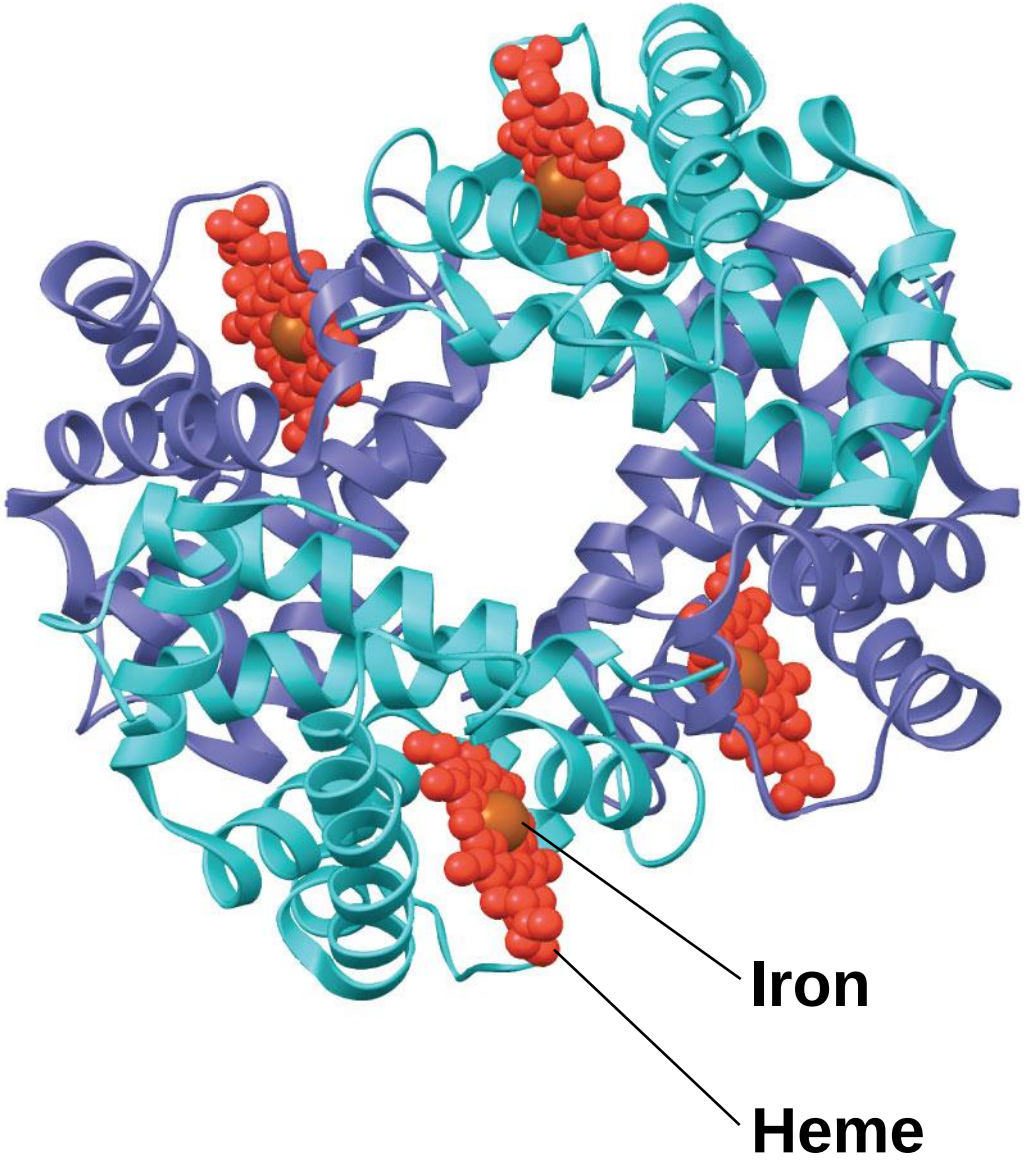
STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

Hemoglobin

- A single hemoglobin molecule can carry four molecules of O_2, one molecule for each iron-containing heme group
- The hemoglobin dissociation curve shows that a small change in the partial pressure of oxygen can result in a large change in delivery of O_2
- CO_2 produced during cellular respiration lowers blood pH and decreases the affinity of hemoglobin for O_2; this is called the **Bohr shift**

STUDENTS-HUB.com
© 2011 Pearson Education, Inc.

Figure 42.UN01

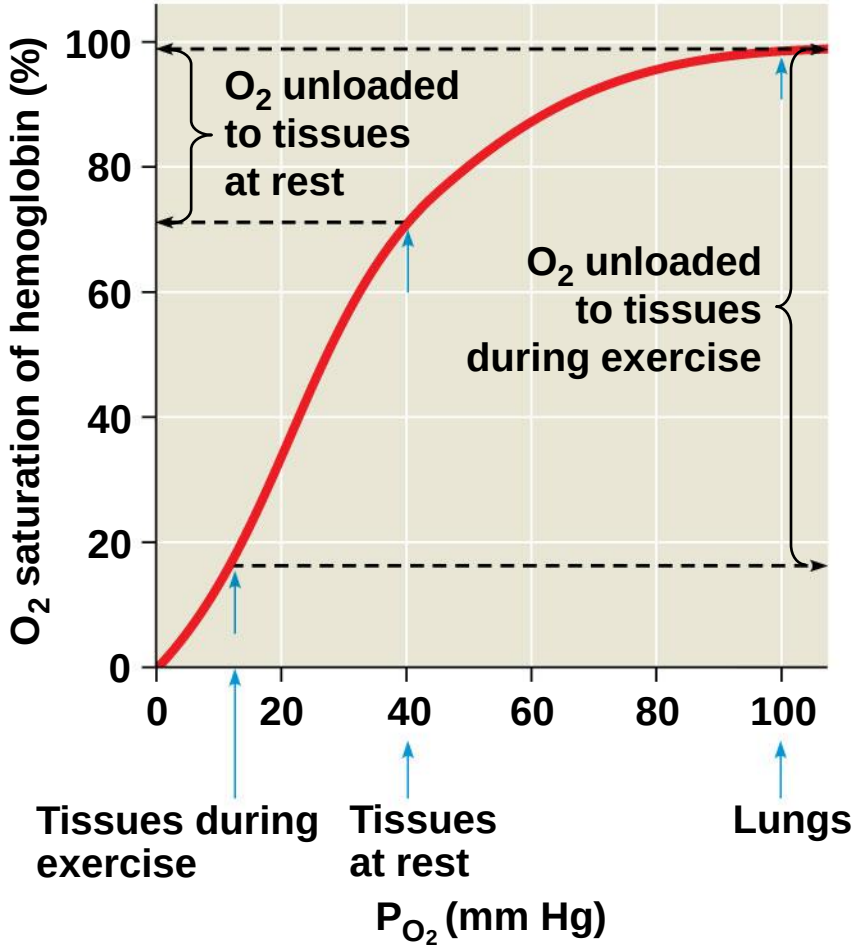


Hemoglobin

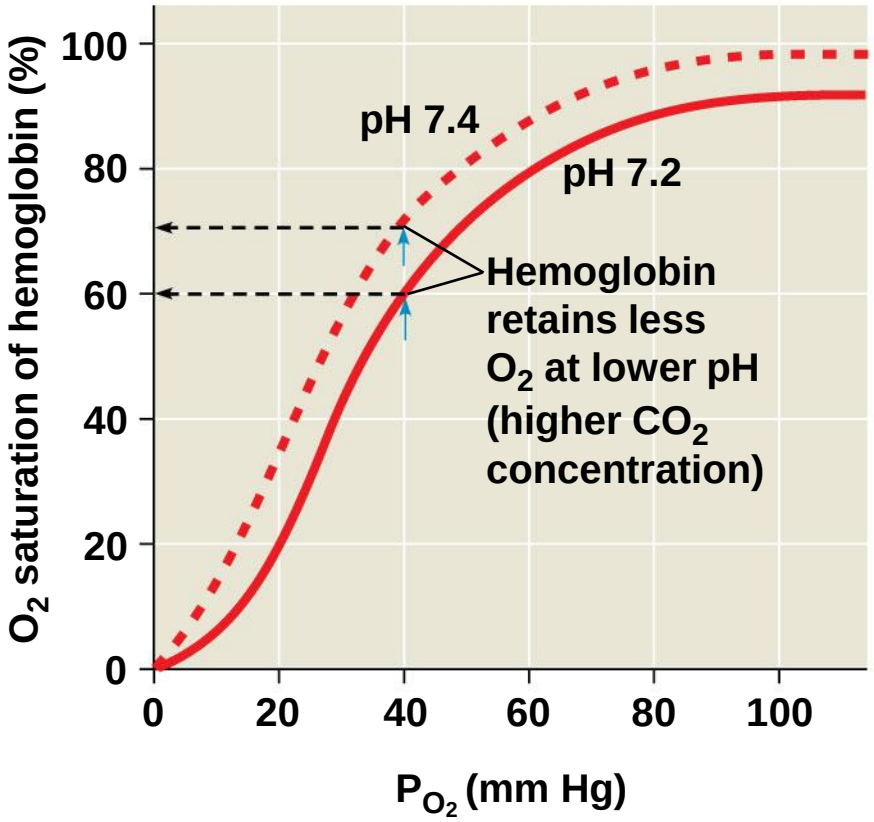
© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Figure 42.31



(a) P_{O_2} and hemoglobin dissociation at pH 7.4

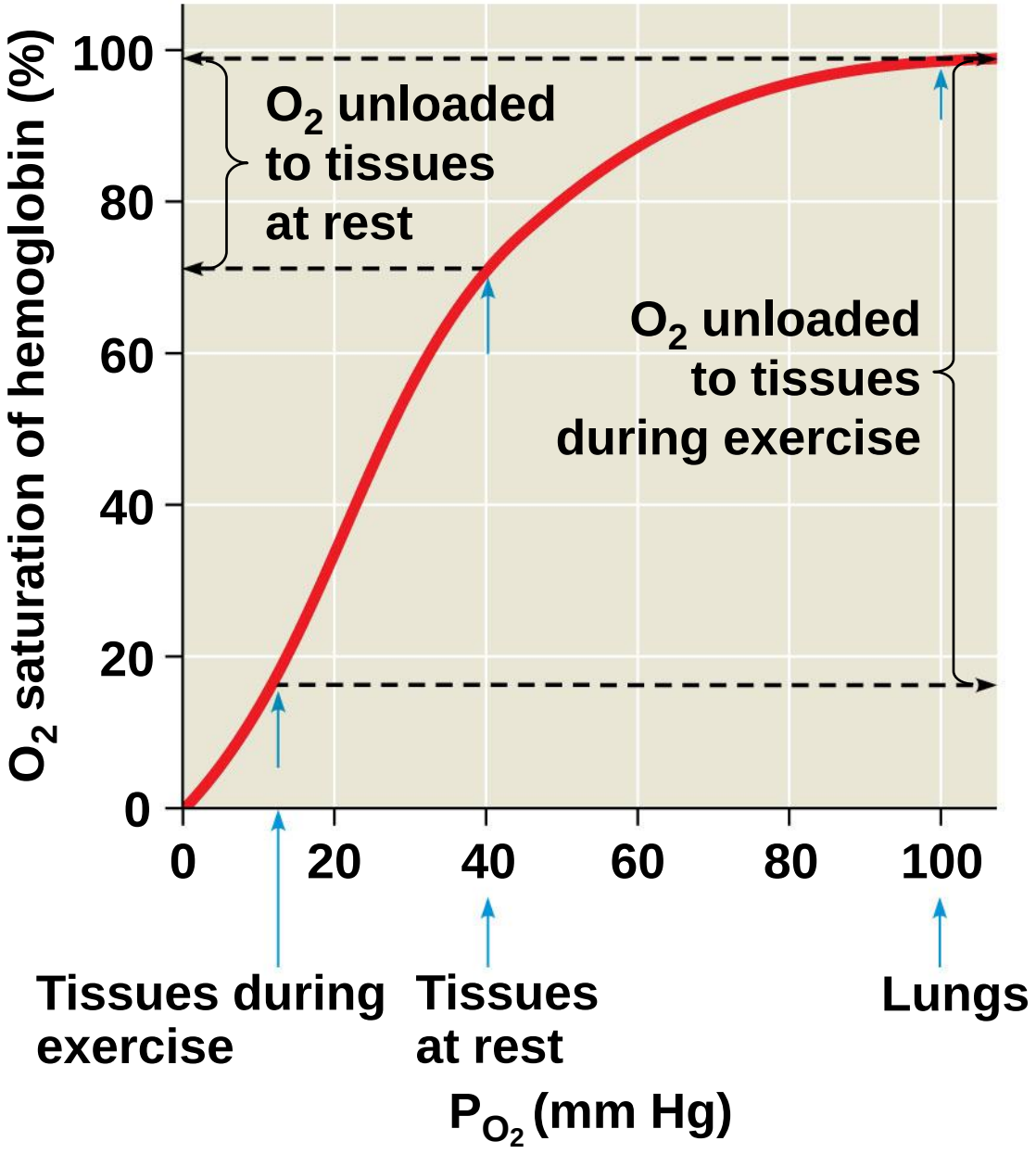


(b) pH and hemoglobin dissociation

© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Figure 42.31a

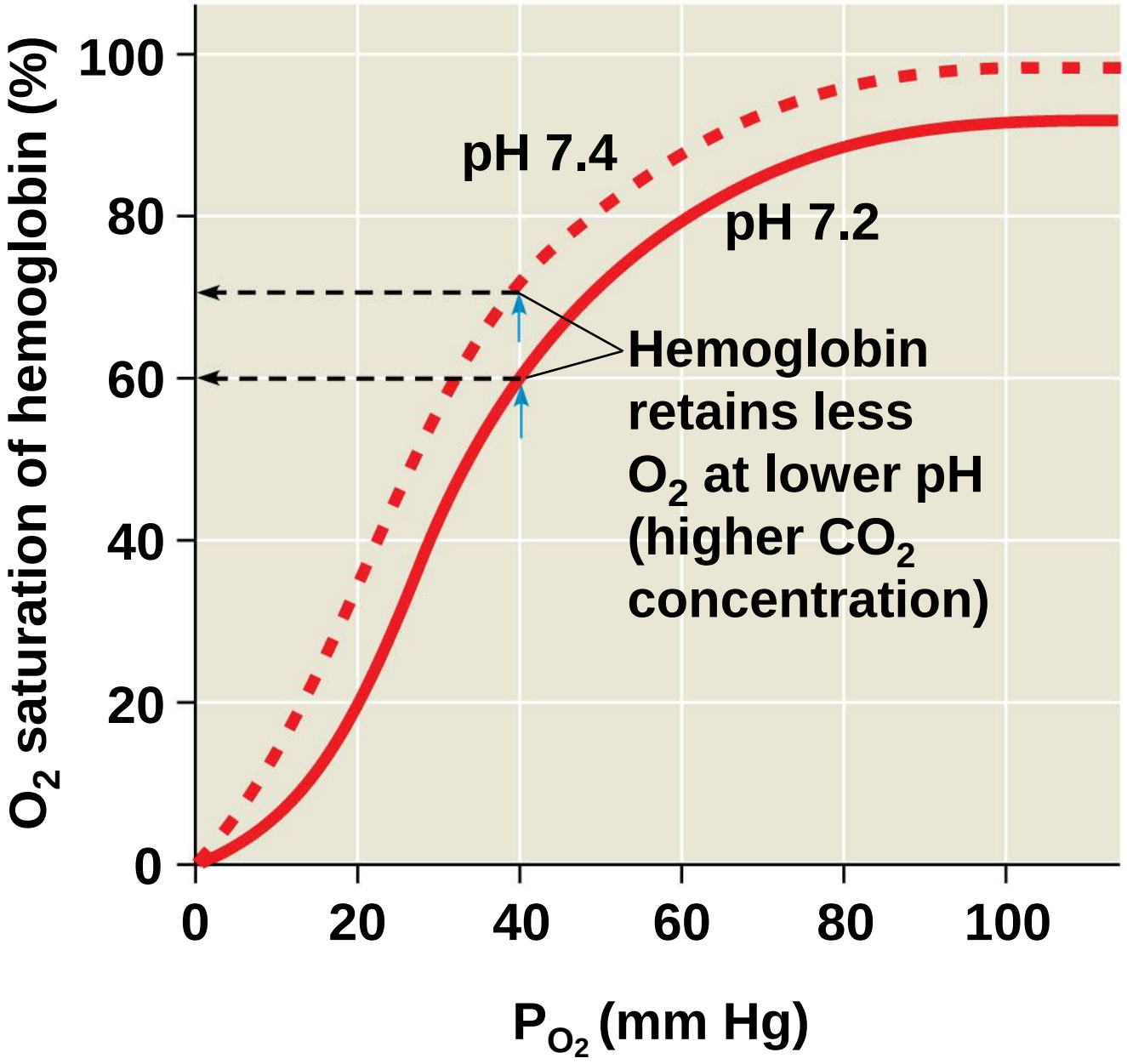


(a) P_{O_2} and hemoglobin dissociation at pH 7.4

© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Figure 42.31b



(b) pH and hemoglobin dissociation

© 2011 Pearson Education, Inc.

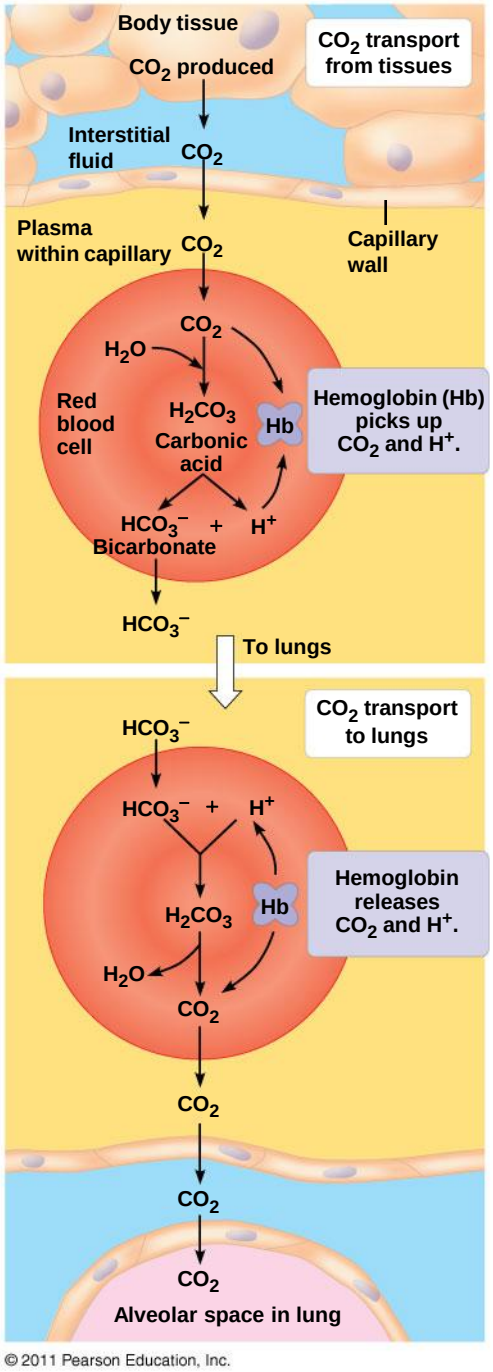
STUDENTS-HUB.com

Carbon Dioxide Transport

- Hemoglobin also helps transport CO_2 and assists in buffering the blood
- CO_2 from respiring cells diffuses into the blood and is transported in blood plasma, bound to hemoglobin, or as bicarbonate ions (HCO_3^-)

STUDENT HUB Box
© 2011 Pearson Education, Inc.

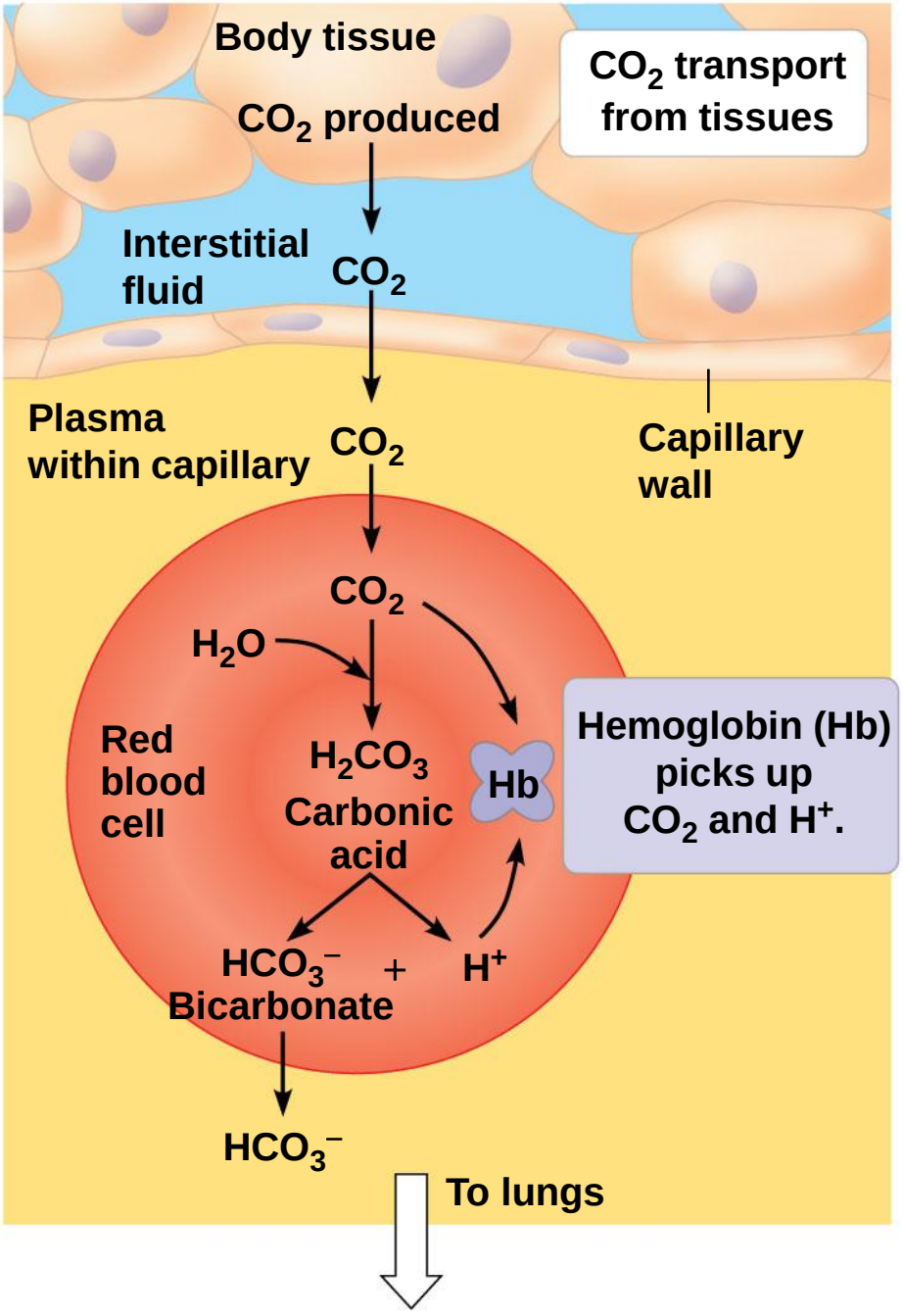
Figure 42.32



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

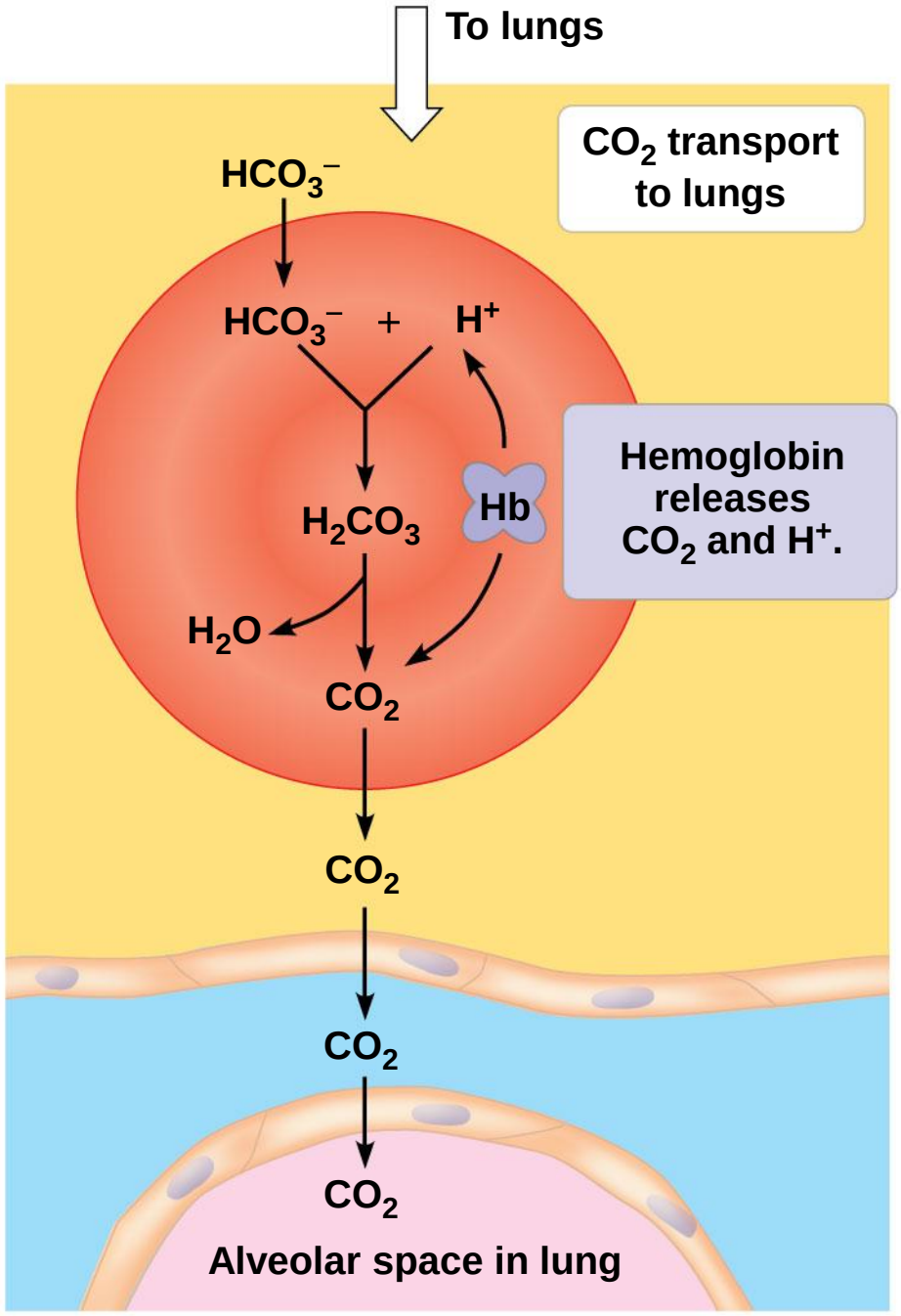
Figure 42.32a



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com

Figure 42.32b



© 2011 Pearson Education, Inc.

STUDENTS-HUB.com