Chapter 42

Circulation and Gas Exchange

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

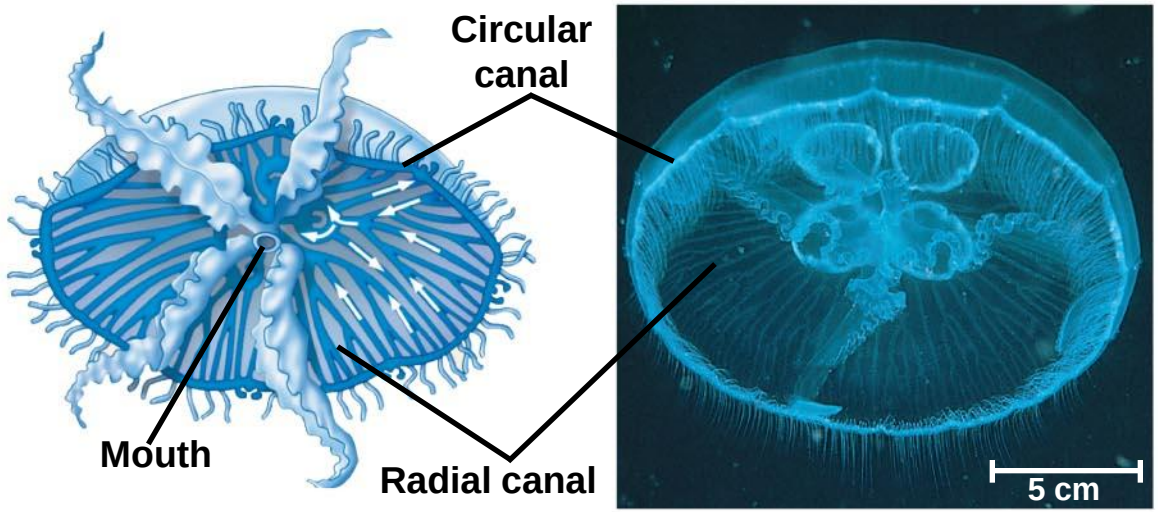
Key concepts

Deliver O_2 and nutrients, remove CO_2 and wastes.

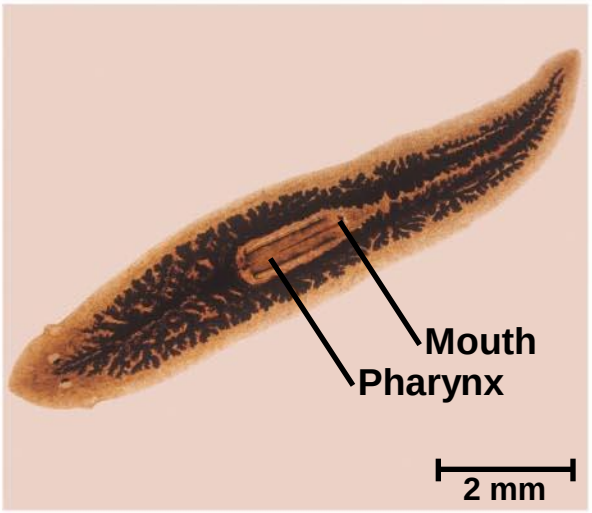
Fig. 42-1

Fig. 42-2

Gastrovascular Cavities



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

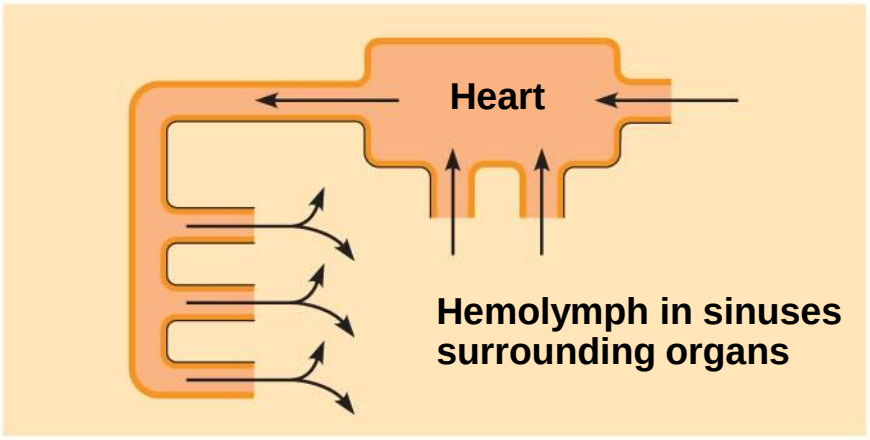


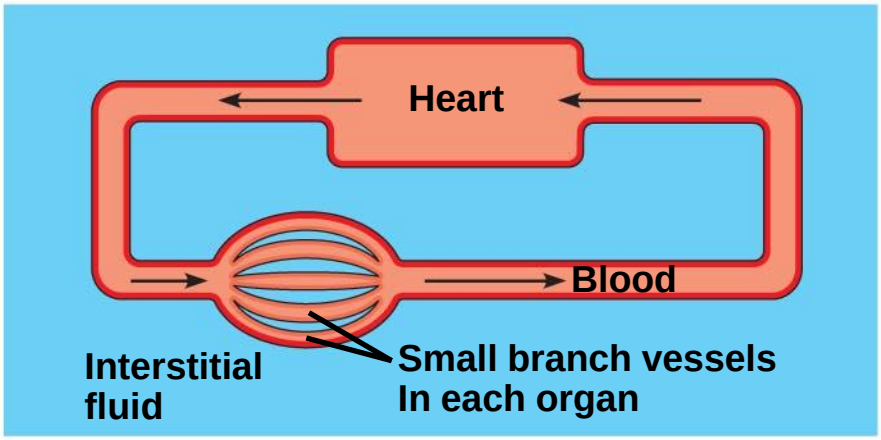
(b) The planarian *Dugesia*, a flatworm

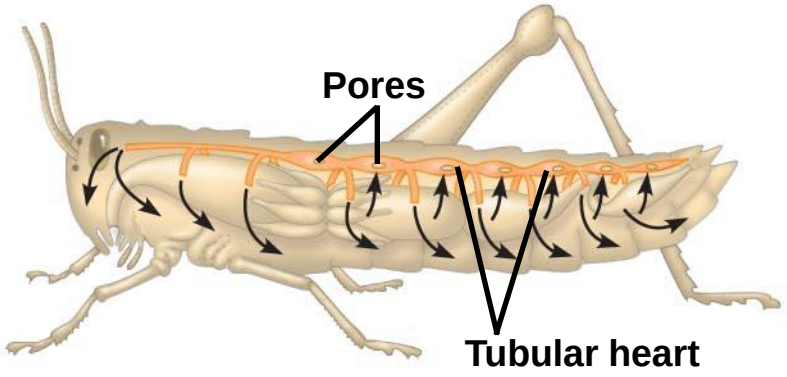
Open and Closed Circulatory Systems

- More complex animals have either open or closed circulatory systems
- Both systems have three basic components:
  - A circulatory fluid (blood or hemolymph)
  - A set of tubes (blood vessels)
  - A muscular pump (the **heart**)

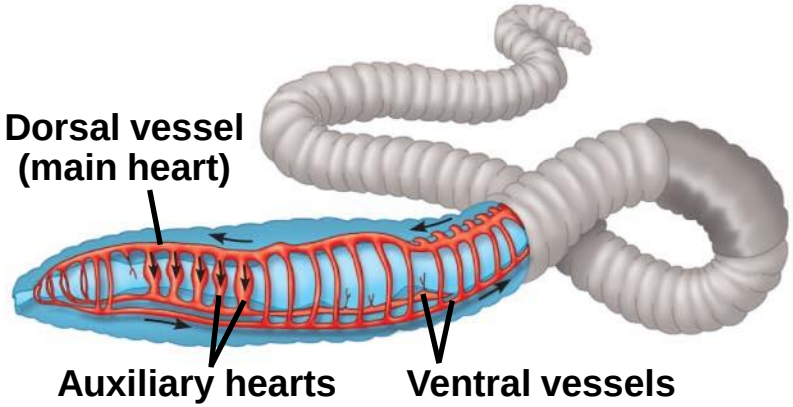
Fig. 42-3







(a) An open circulatory system



(b) A closed circulatory system

Organization of Vertebrate Circulatory Systems

- Humans and other vertebrates have a closed circulatory system, often called the **cardiovascular system**
- The three main types of blood vessels are arteries, veins, and capillaries

Fig. 42-4

Single Circulation

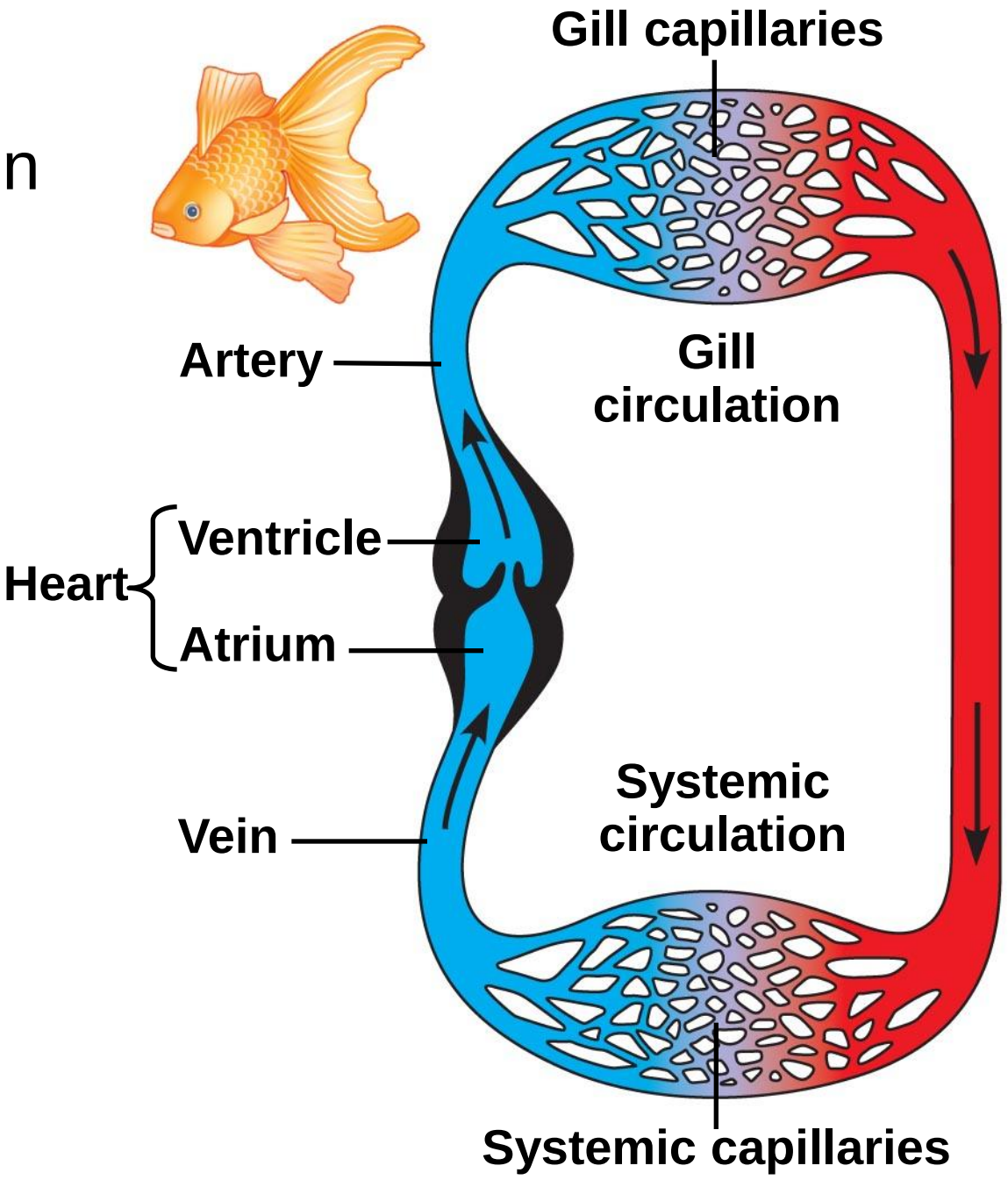


Fig. 42-5

Double Circulation

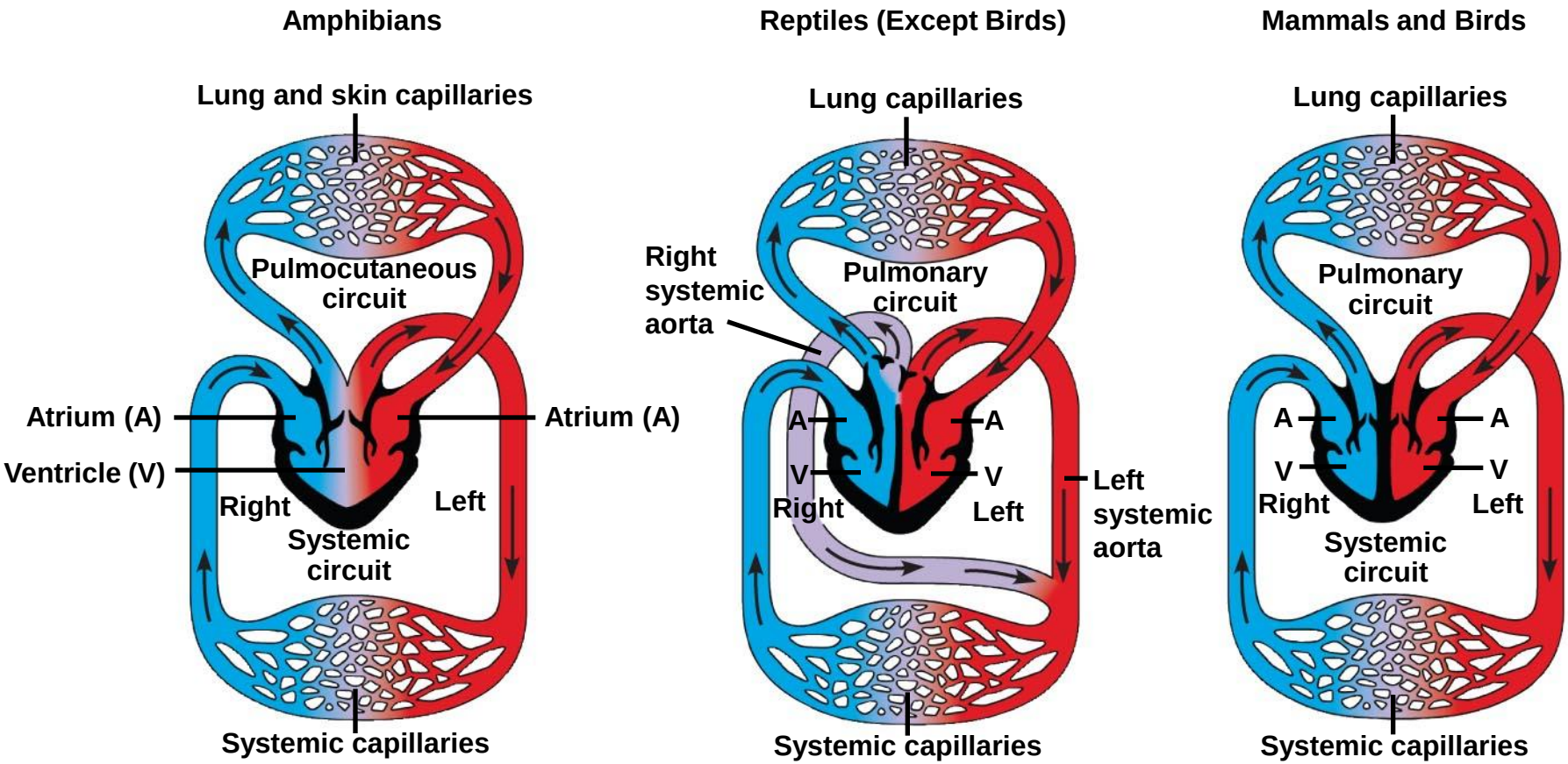


Fig. 42-6

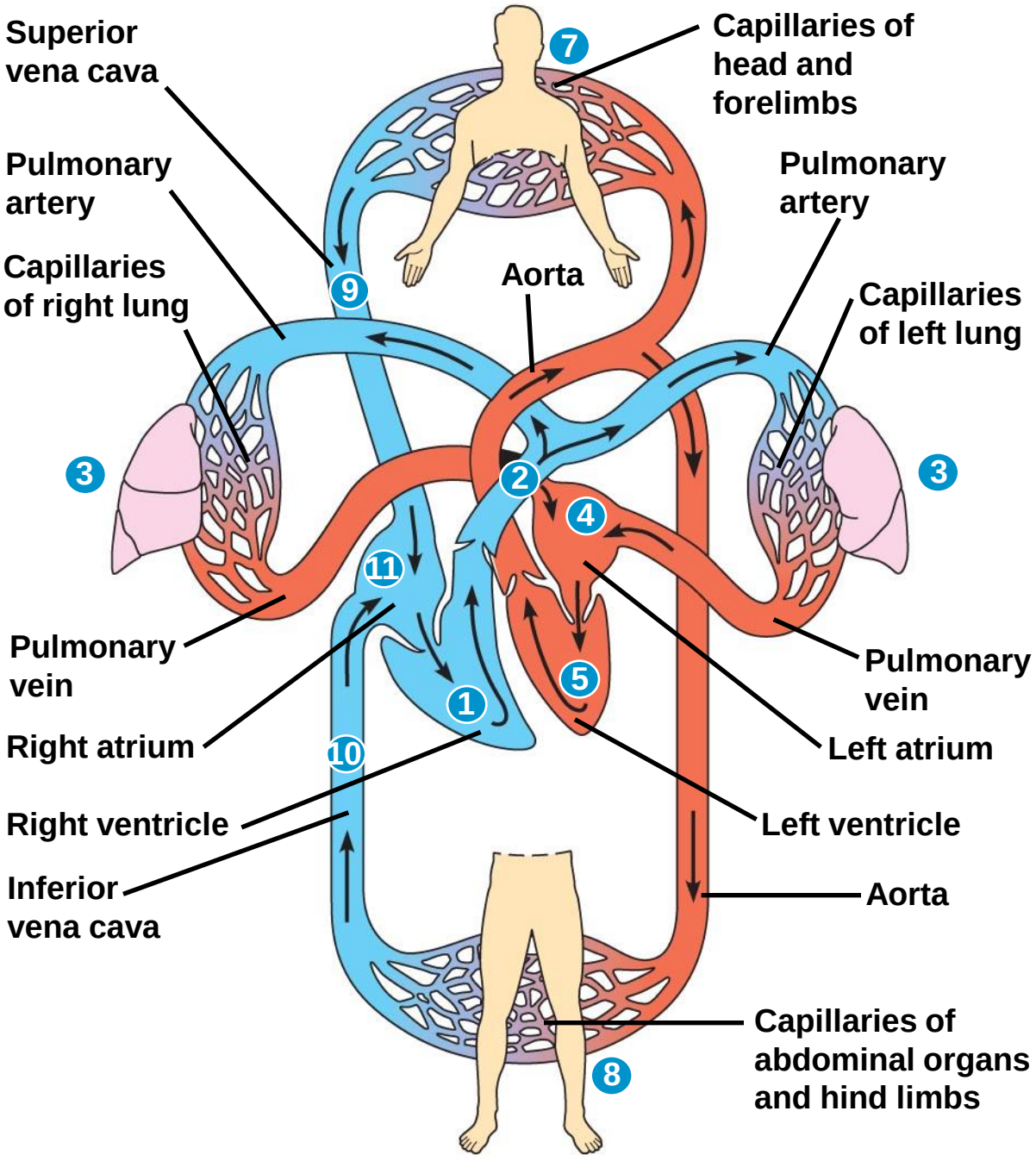
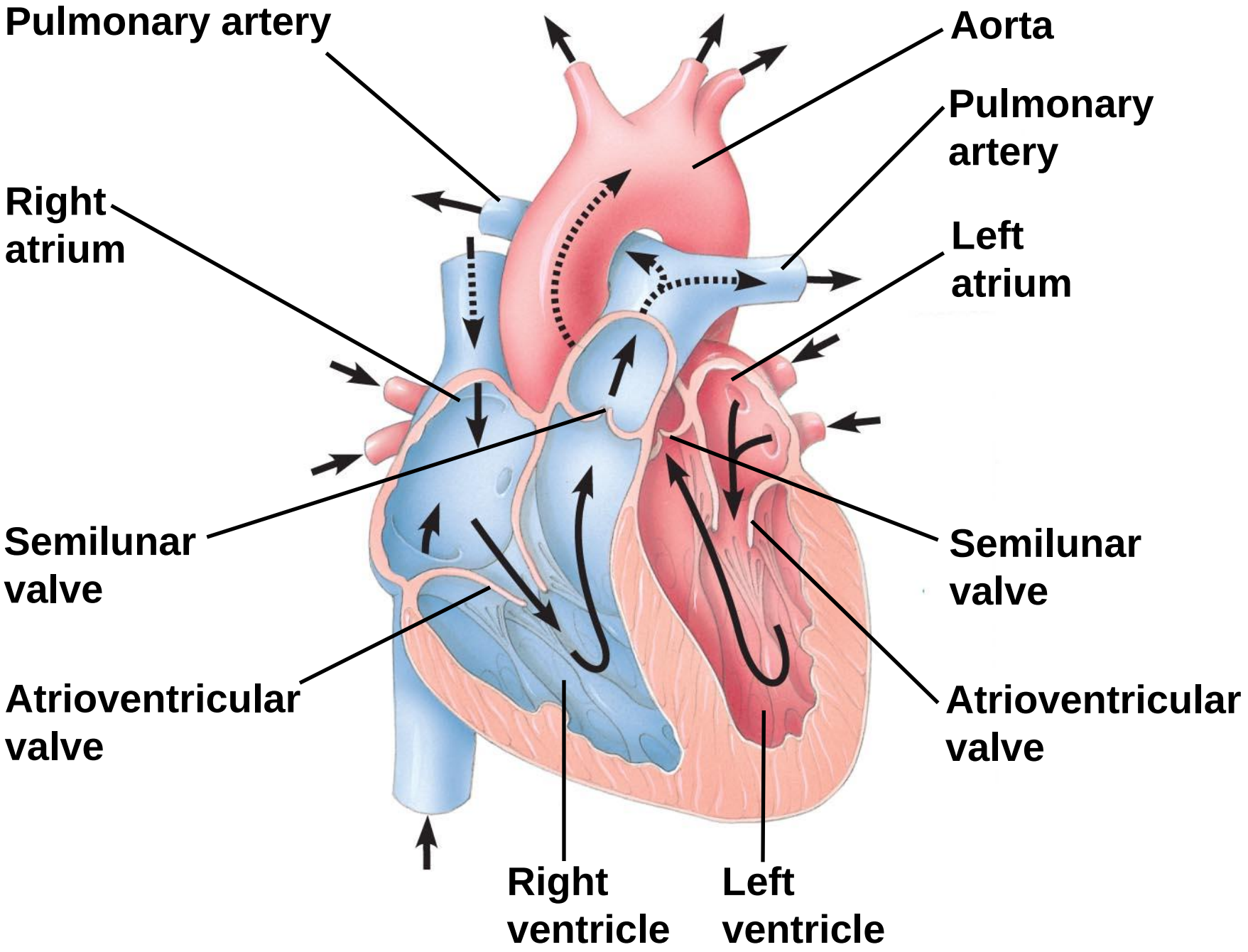
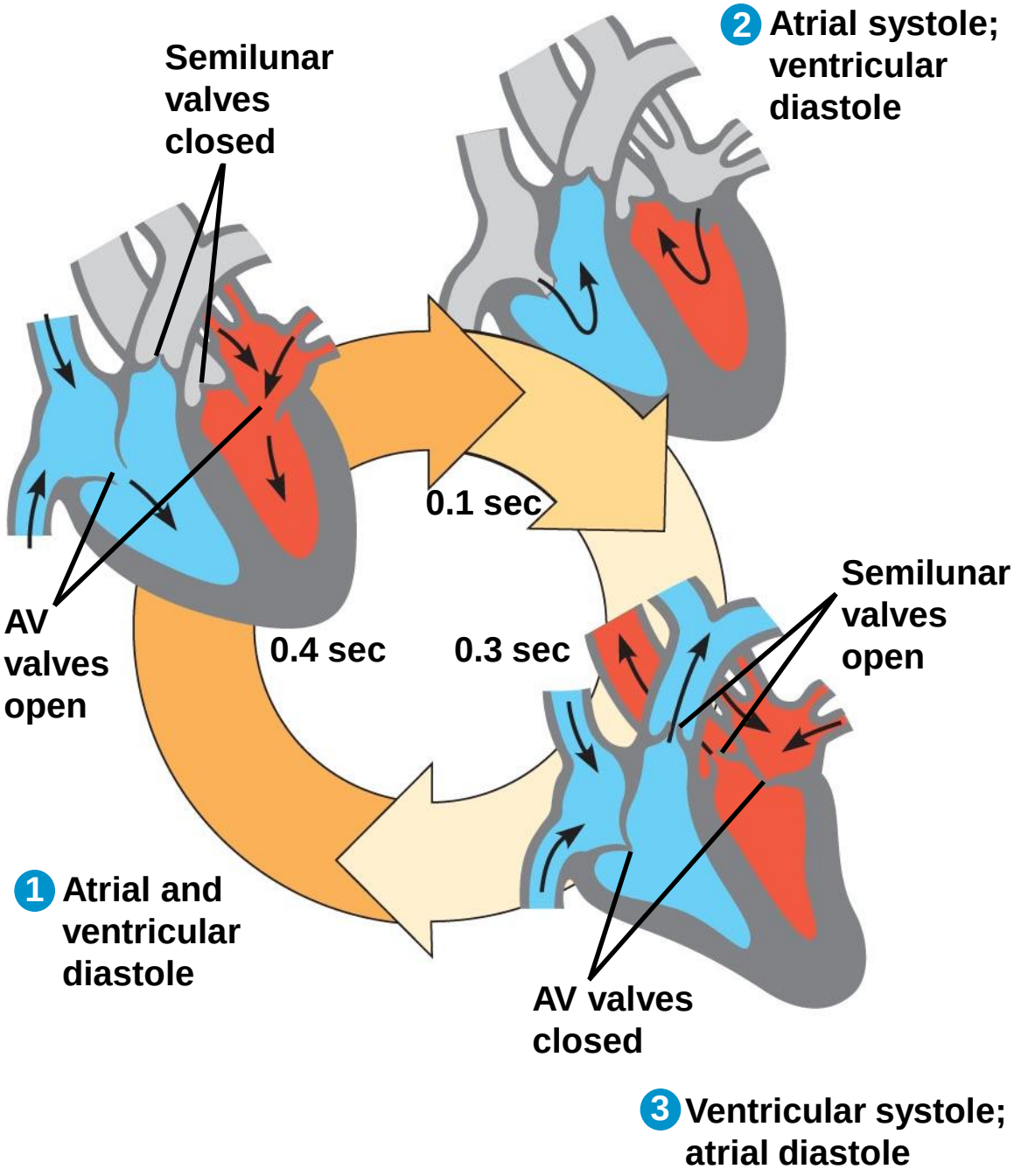


Fig. 42-7



- 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**

Fig. 42-8



- The **heart rate**, also called the pulse, is the number of beats per minute 72/min
- The **stroke volume** is the amount of blood pumped in a single contraction 75 ml
- 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 5 L/min

Fig. 42-9-5

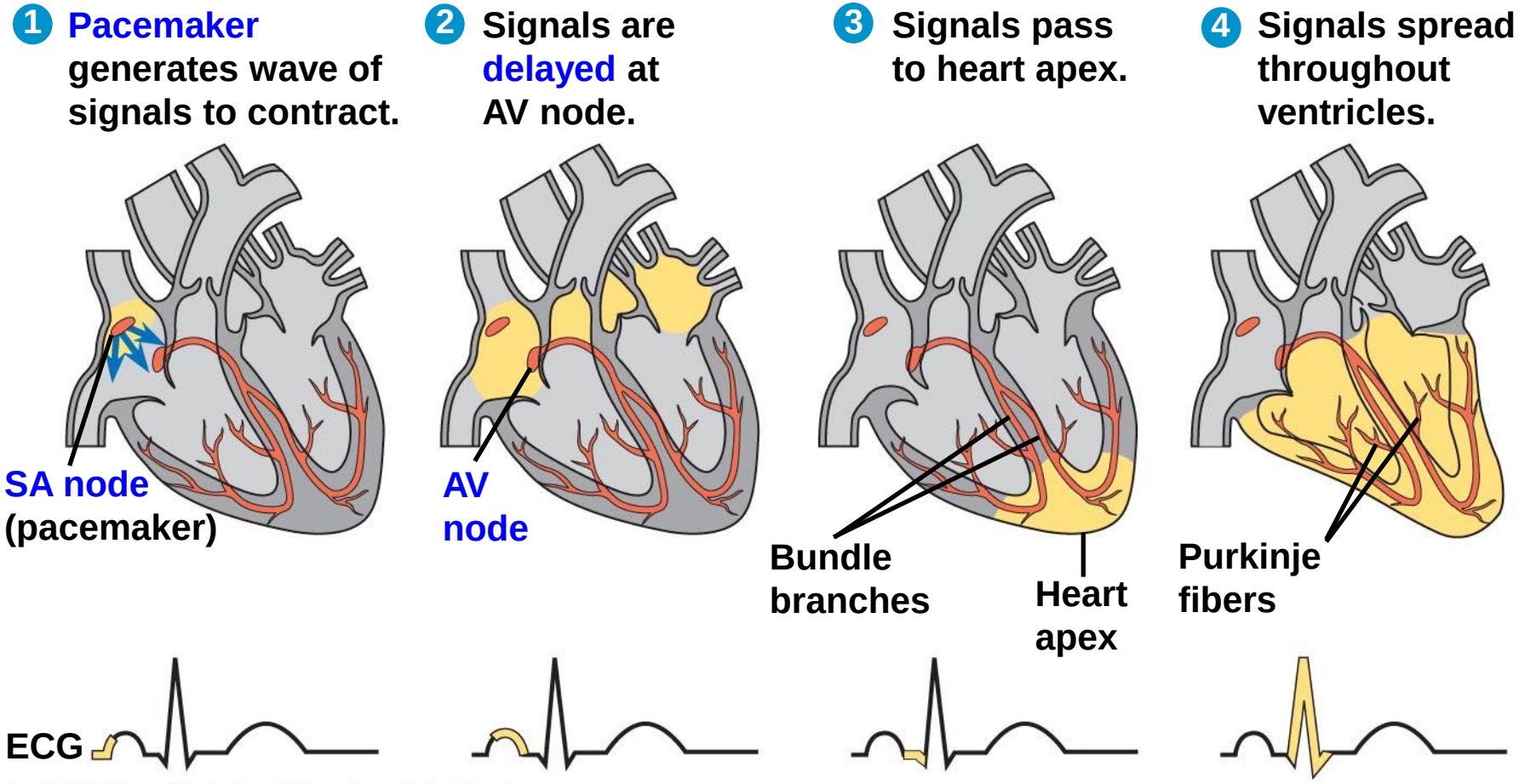


Fig. 42-10

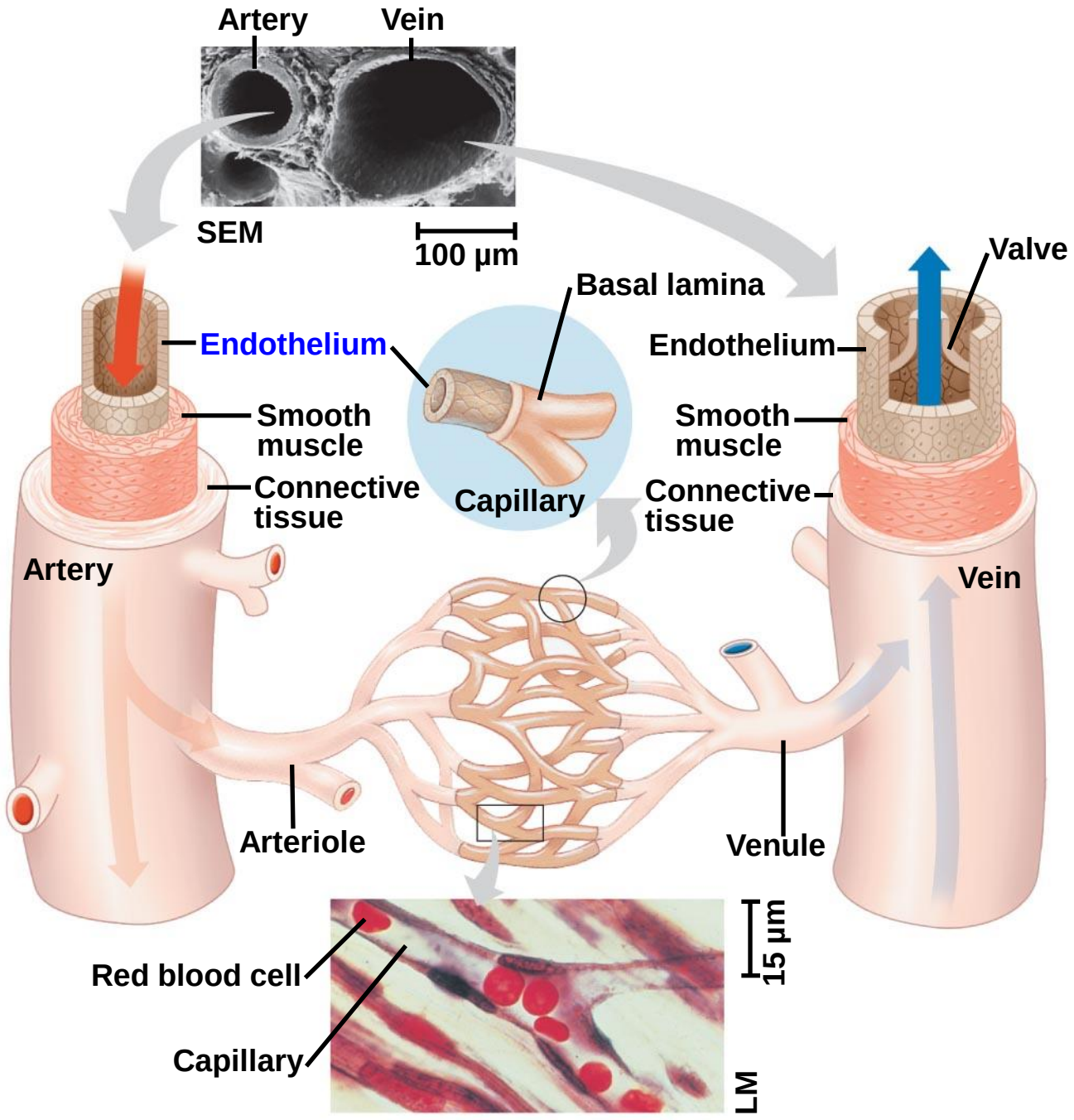
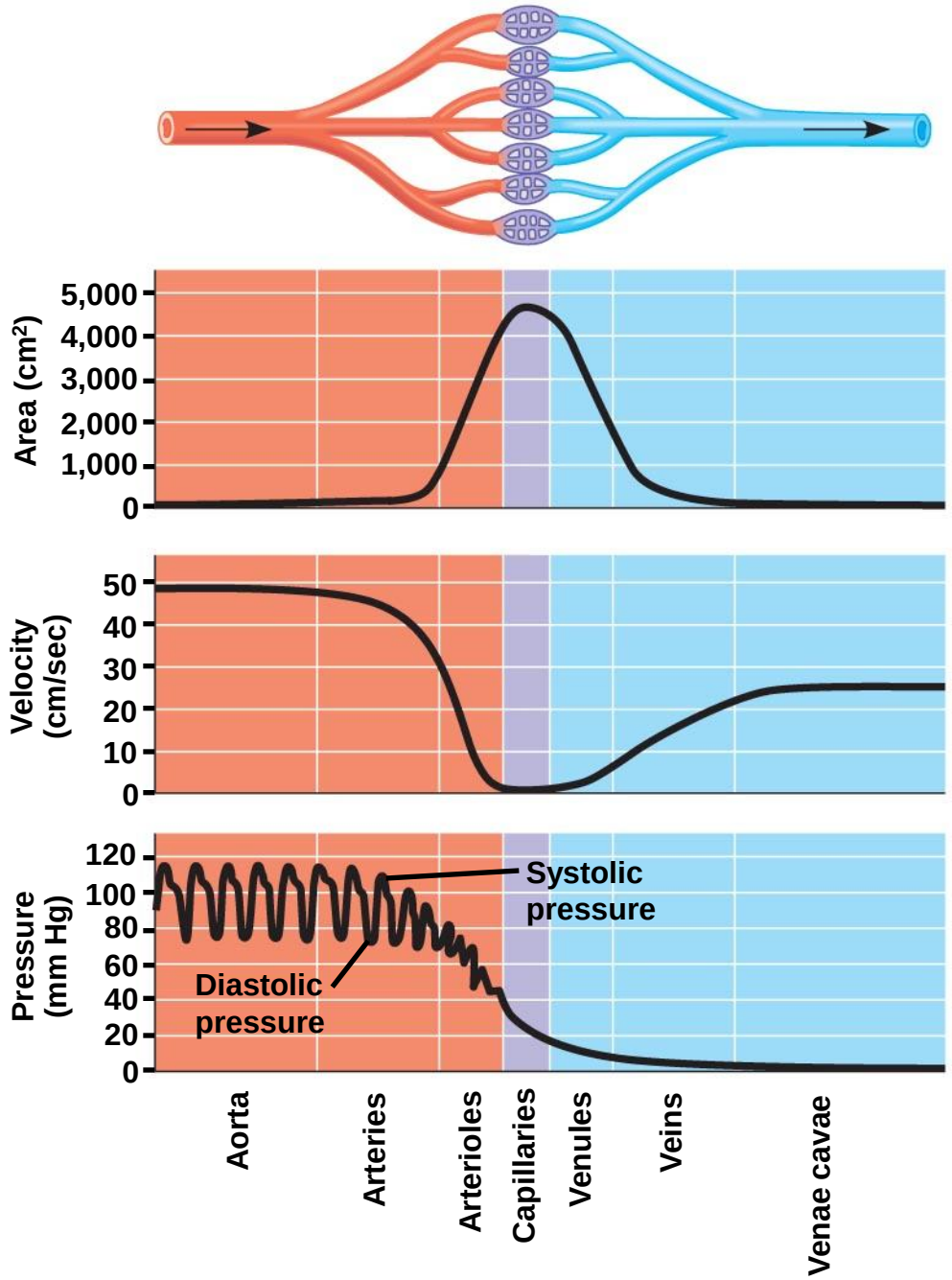


Fig. 42-11



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

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

Fig. 42-12

RESULTS

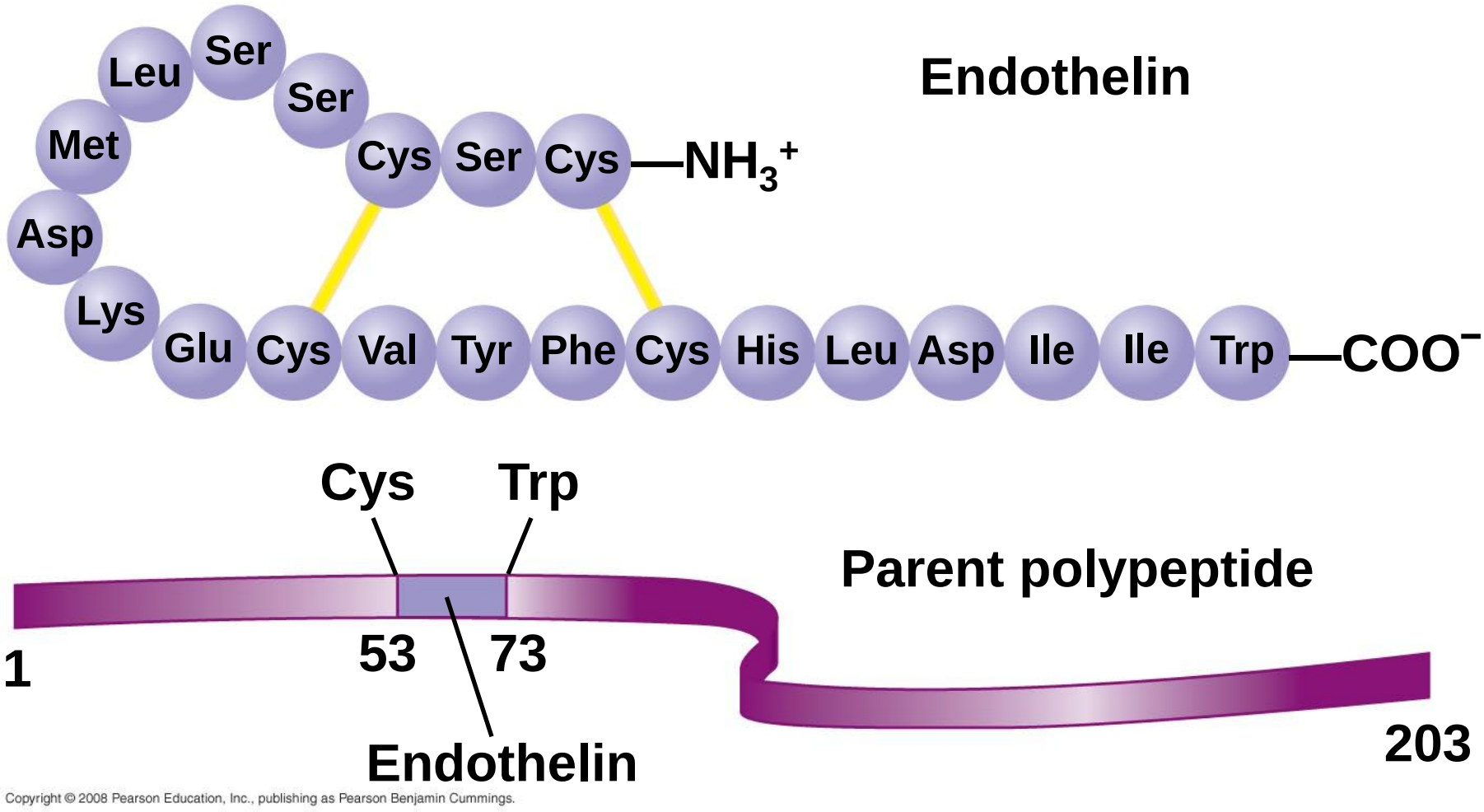


Fig. 42-13-3

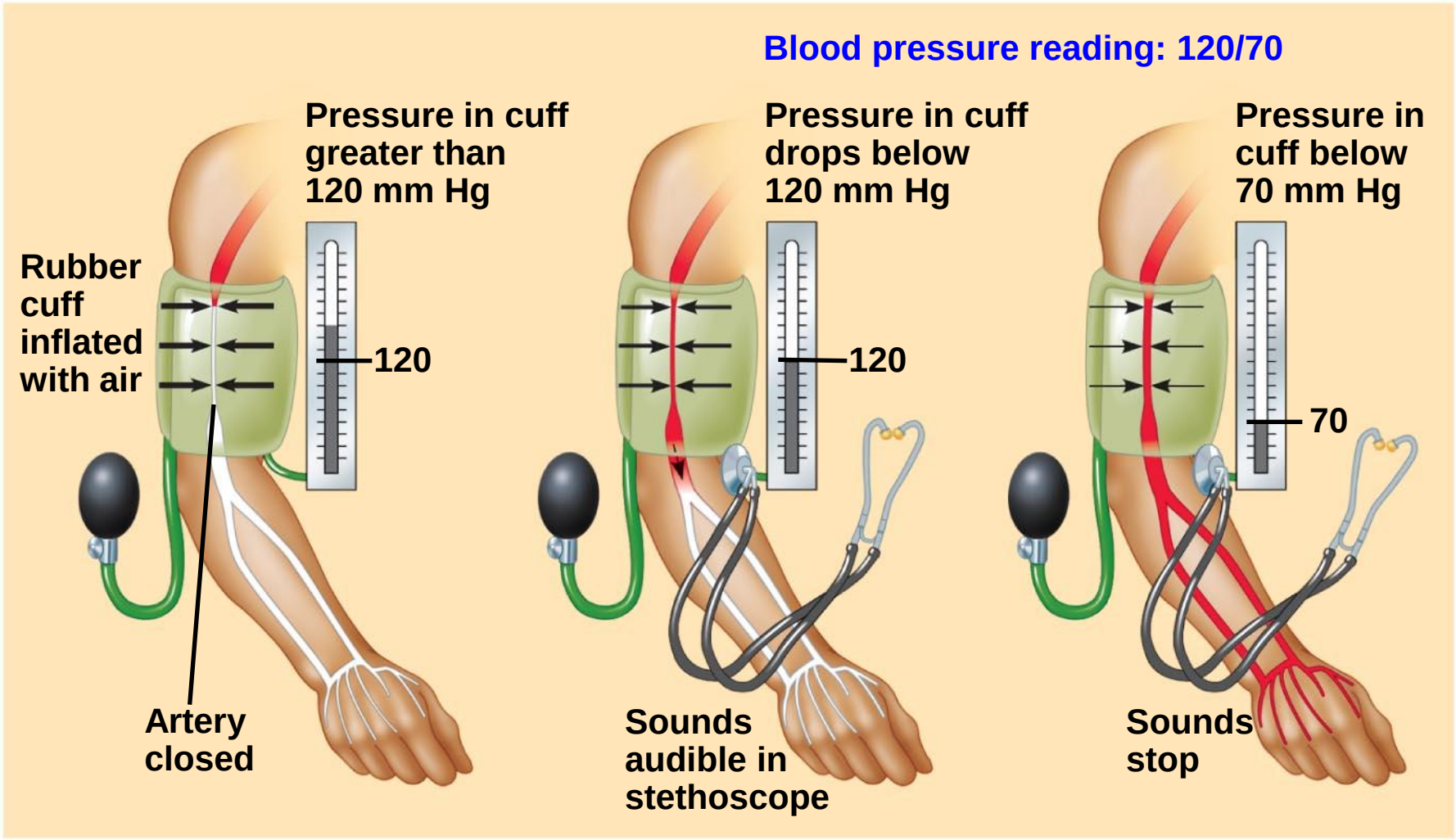


Fig. 42-14

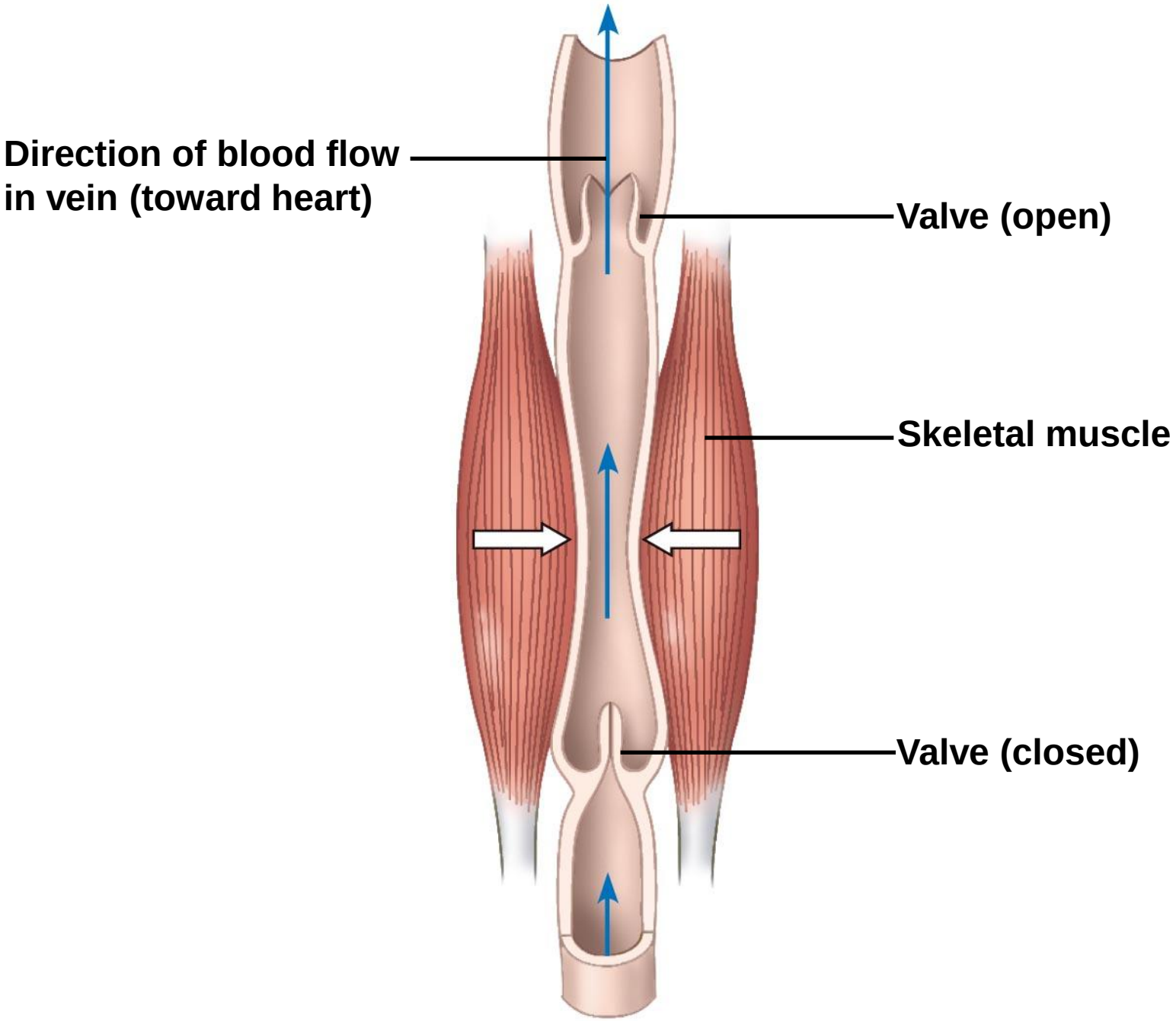


Fig. 42-15

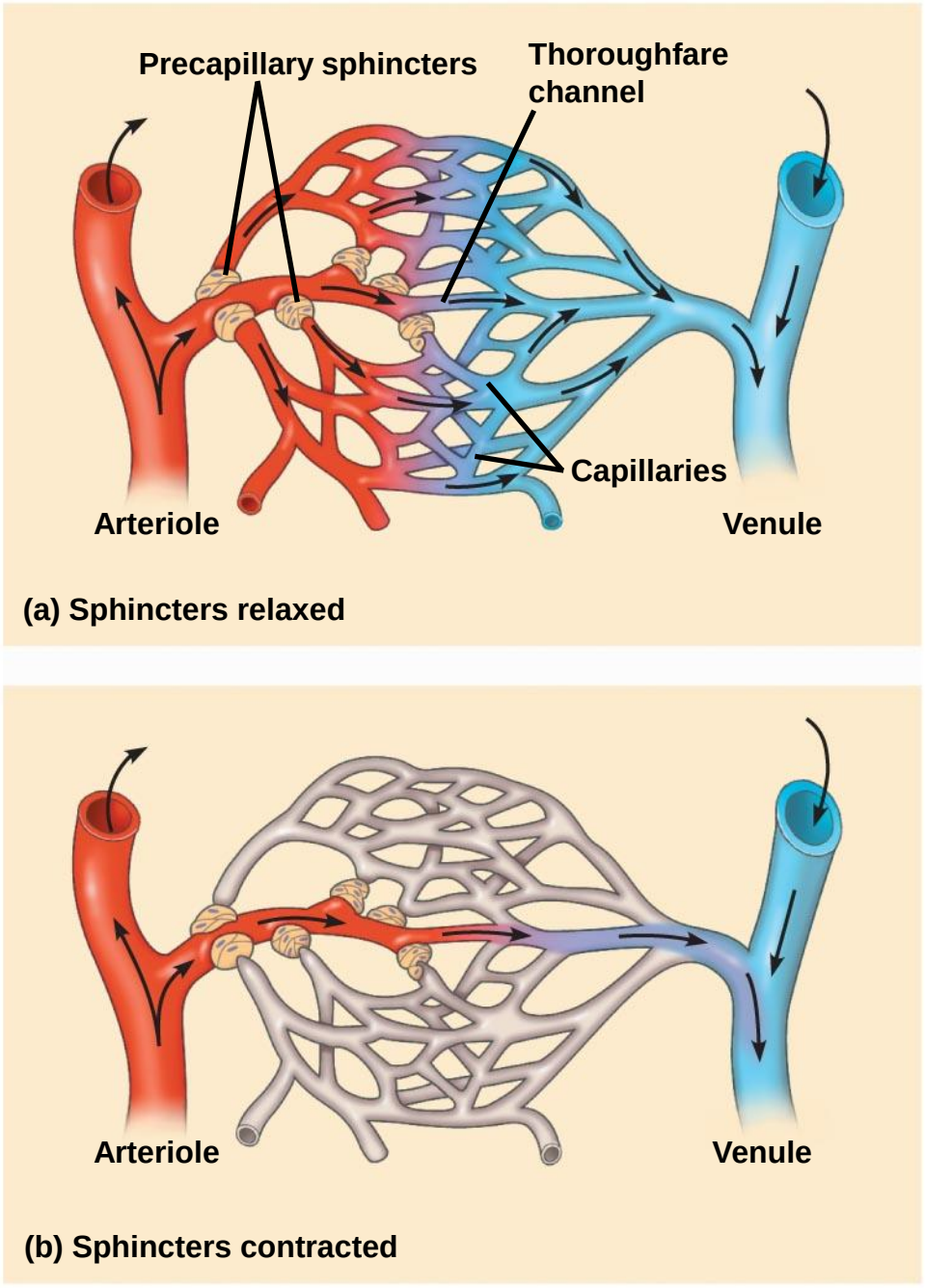
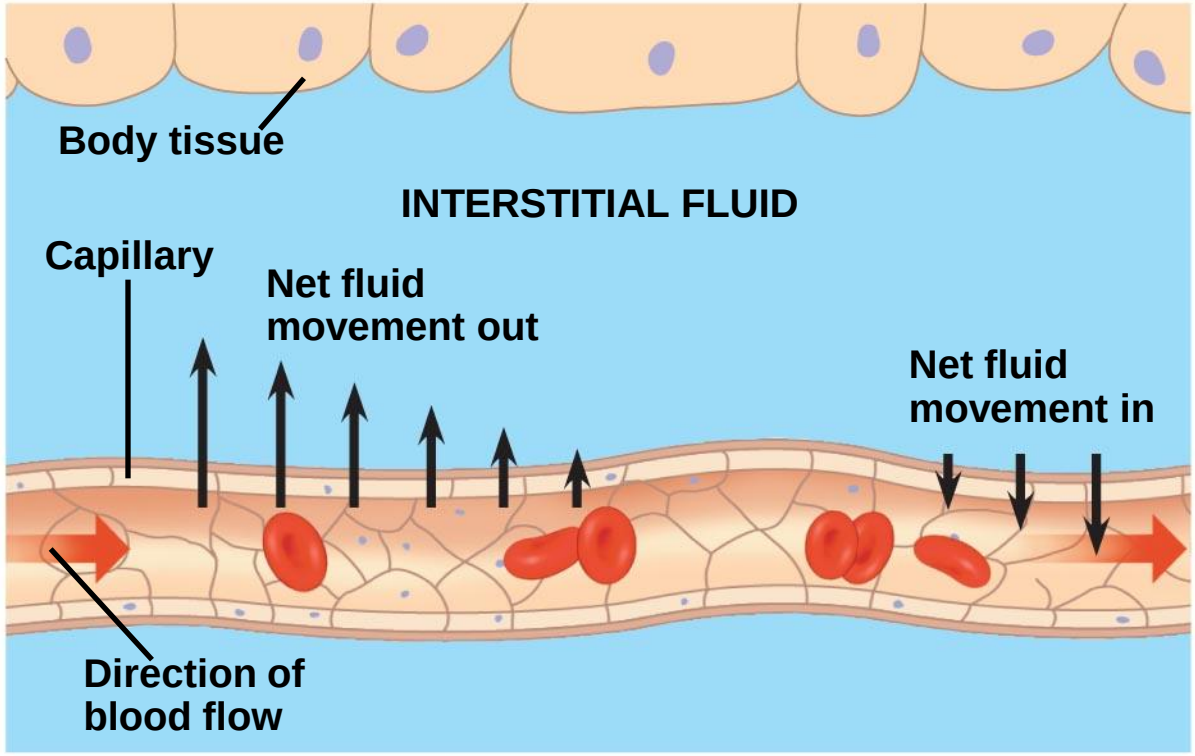
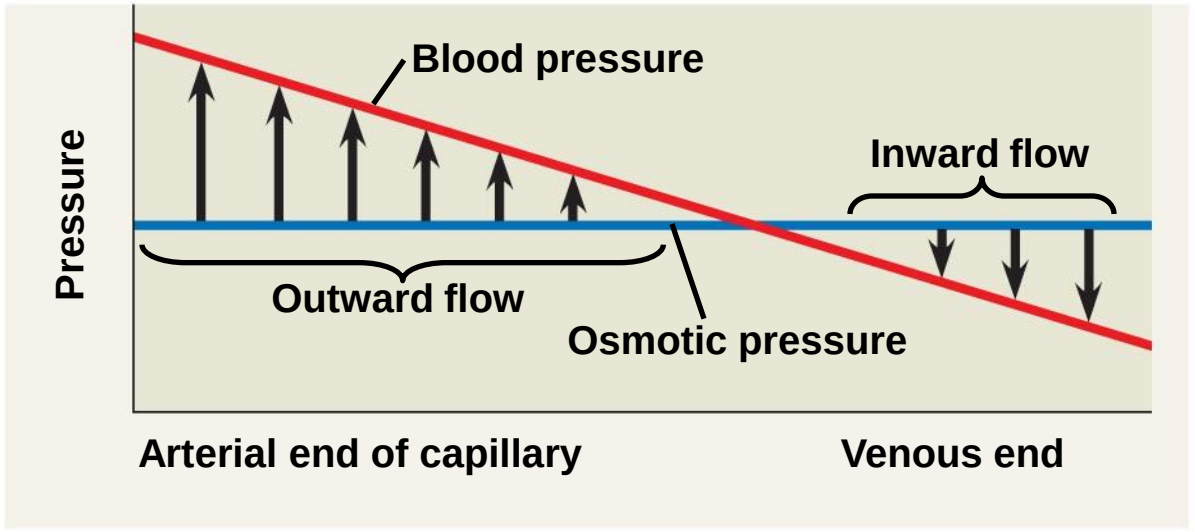


Fig. 42-16





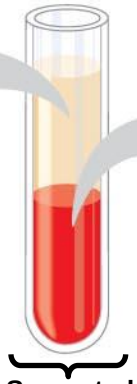
Fluid Return by the Lymphatic System

- The **lymphatic system** returns fluid that leaks out in the capillary beds
- This system aids in body defense

Fig. 42-17

Plasma 55%

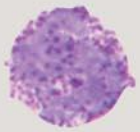
Constituent	Major functions
Water (90%)	Solvent for carrying other substances
Ions (blood electrolytes)	
Sodium, Potassium, Calcium, Magnesium, Chloride, Bicarbonate	Osmotic balance, pH buffering, and regulation of membrane permeability
Plasma proteins	
Albumin	Osmotic balance, pH buffering
Fibrinogen	Clotting
Immunoglobulins (antibodies)	Defense
Substances transported by blood	
Nutrients (such as glucose, fatty acids, vitamins)	
Waste products of metabolism	
Respiratory gases (O_2 and CO_2)	
Hormones	



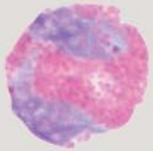
Separated blood elements

Cellular elements 45%

Cell type	Number per µL (mm^3) of blood	Functions
Erythrocytes (red blood cells)	5–6 million	Transport oxygen and help transport carbon dioxide
Leukocytes (white blood cells)	5,000–10,000	Defense and immunity
Platelets	250,000–400,000	Blood clotting



Basophil



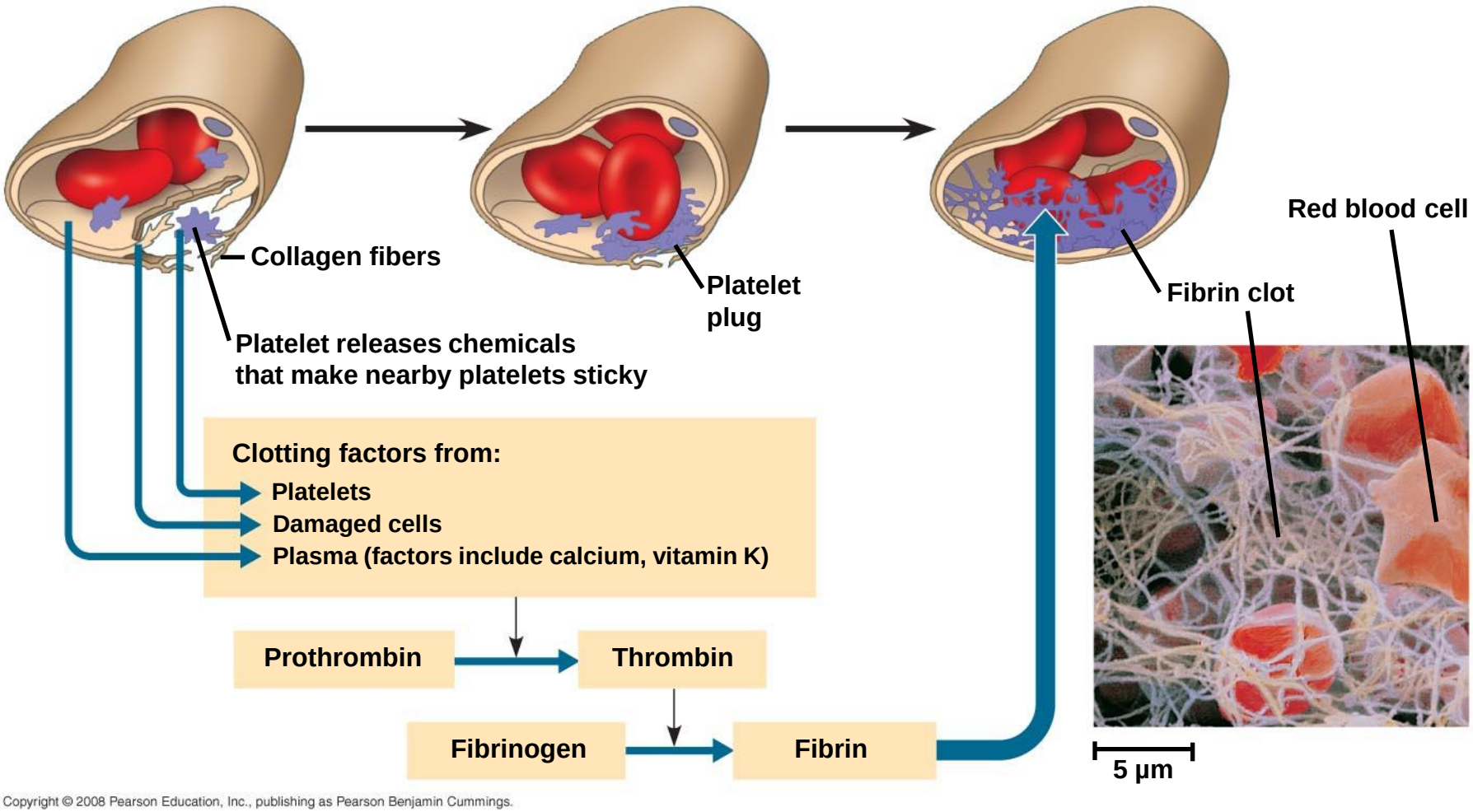
Eosinophil

Lymphocyte

Neutrophil

Monocyte

Fig. 42-18-4



A blood clot formed within a blood vessel is called a **thrombus** and can block blood flow

Stem Cells and the Replacement of Cellular Elements

- The cellular elements of blood wear out and are replaced constantly throughout a person's life
- Erythrocytes, leukocytes, and platelets all develop from a common source of **stem cells** in the red marrow of bones
- The hormone **erythropoietin (EPO)** stimulates erythrocyte production when oxygen delivery is low

Fig. 42-19

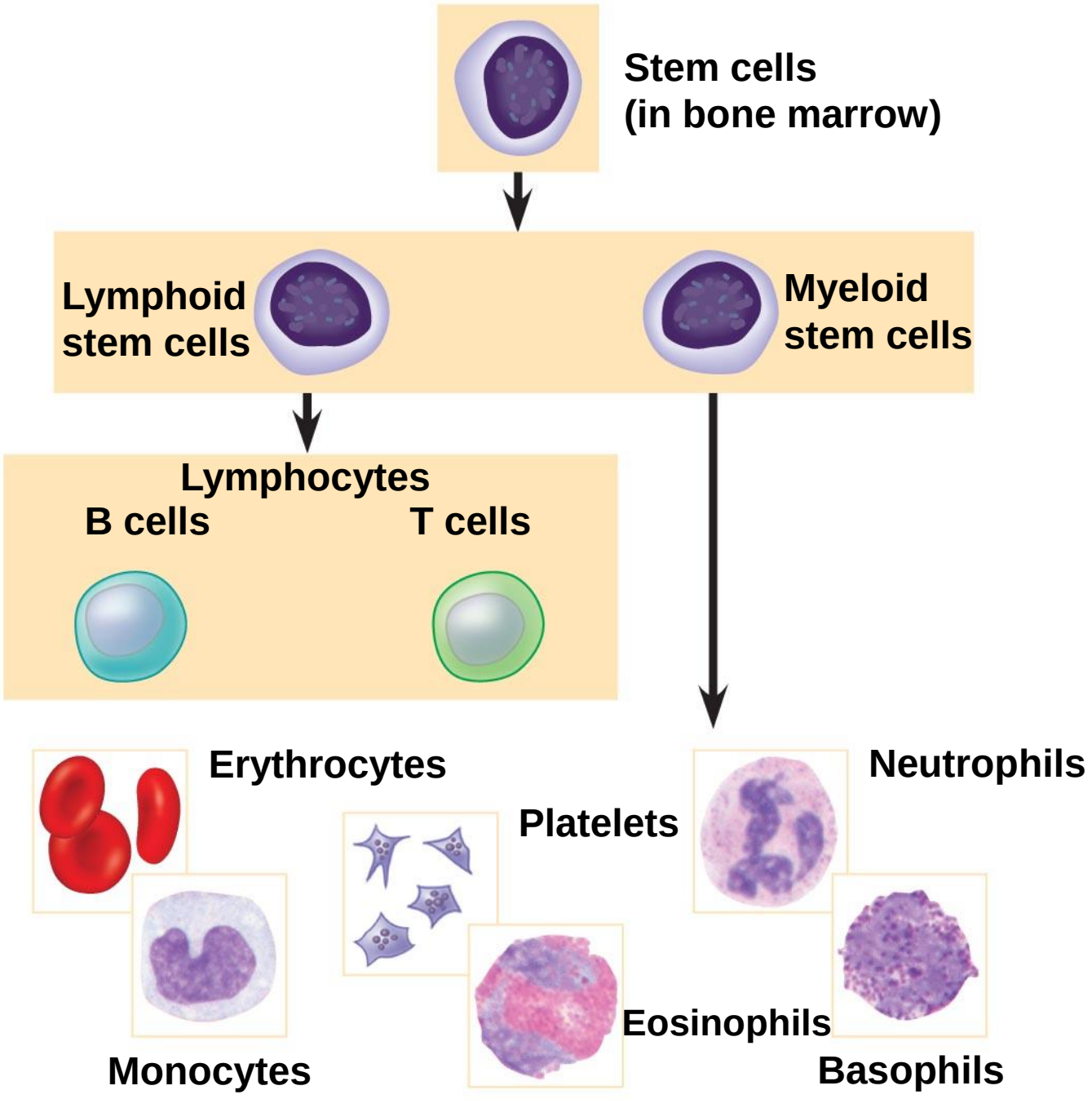
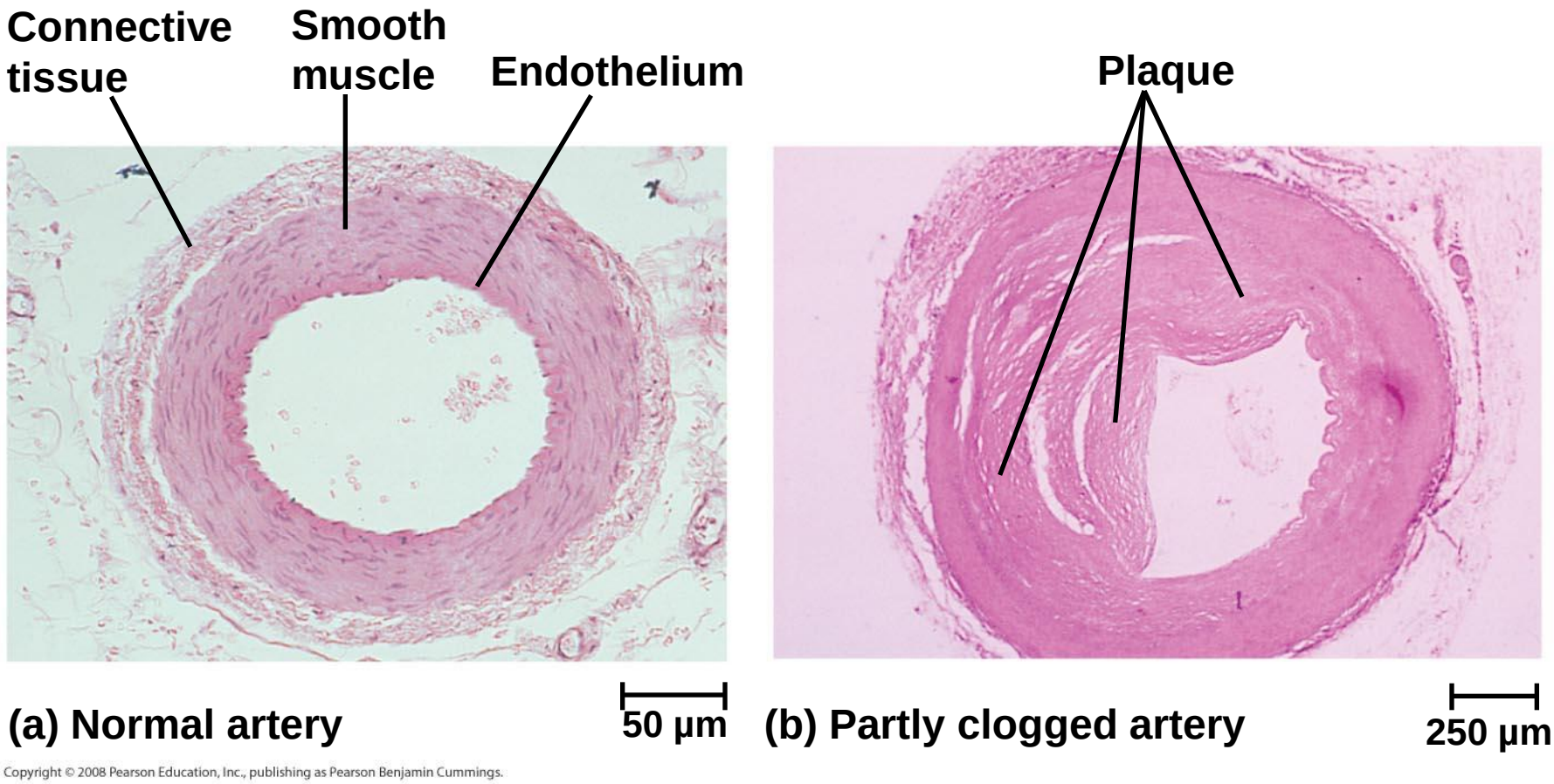


Fig. 42-20

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



Heart Attacks and Stroke

- A **heart attack** is the death of cardiac muscle tissue resulting from blockage of one or more coronary arteries
- A **stroke** is the death of nervous tissue in the brain, usually resulting from rupture or blockage of arteries in the head

Treatment and Diagnosis of Cardiovascular Disease

- Cholesterol is a major contributor to atherosclerosis
- **Low-density lipoproteins (LDLs)** are associated with plaque formation; these are "bad cholesterol"
- **High-density lipoproteins (HDLs)** reduce the deposition of cholesterol; these are "good cholesterol"
- The proportion of LDL relative to HDL can be decreased by exercise, not smoking, and avoiding foods with *trans* fats

Fig. 42-21

Gills are outfoldings of the body that create a large surface area for gas exchange

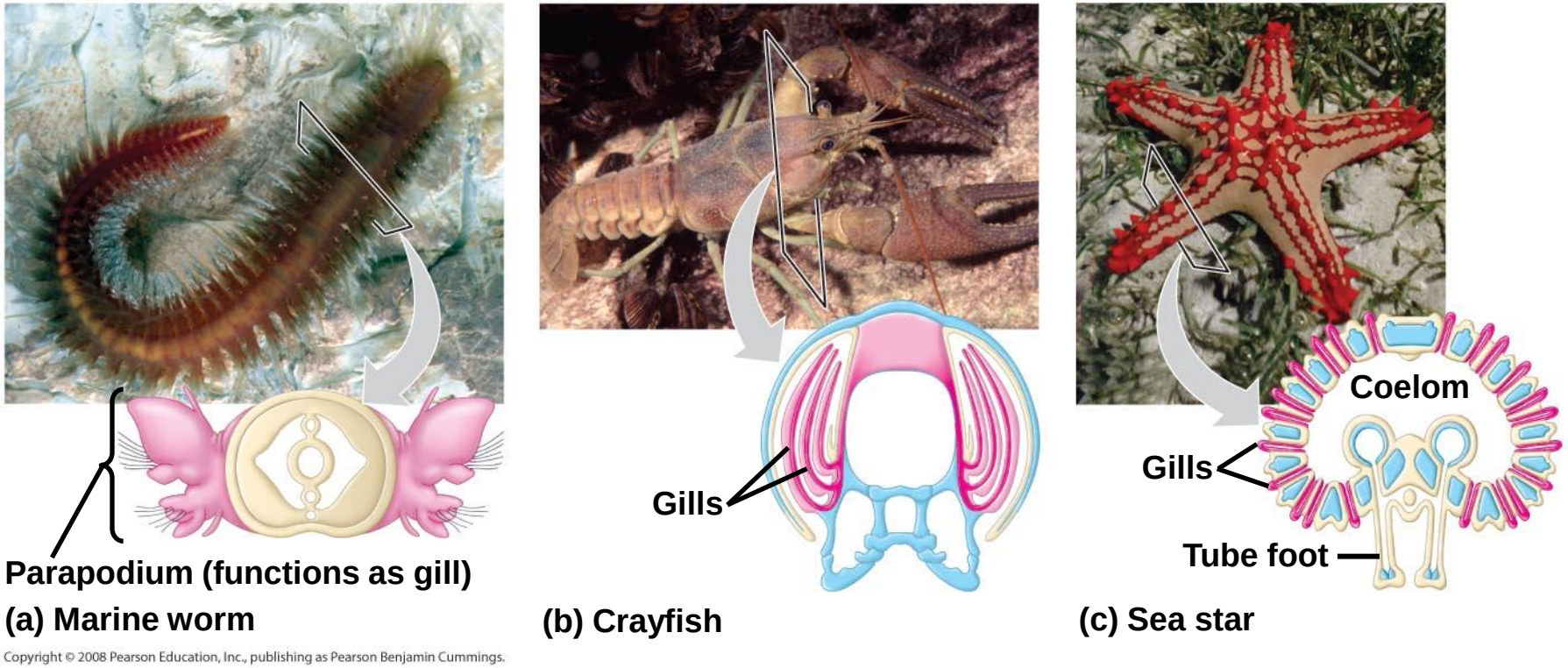


Fig. 42-22

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

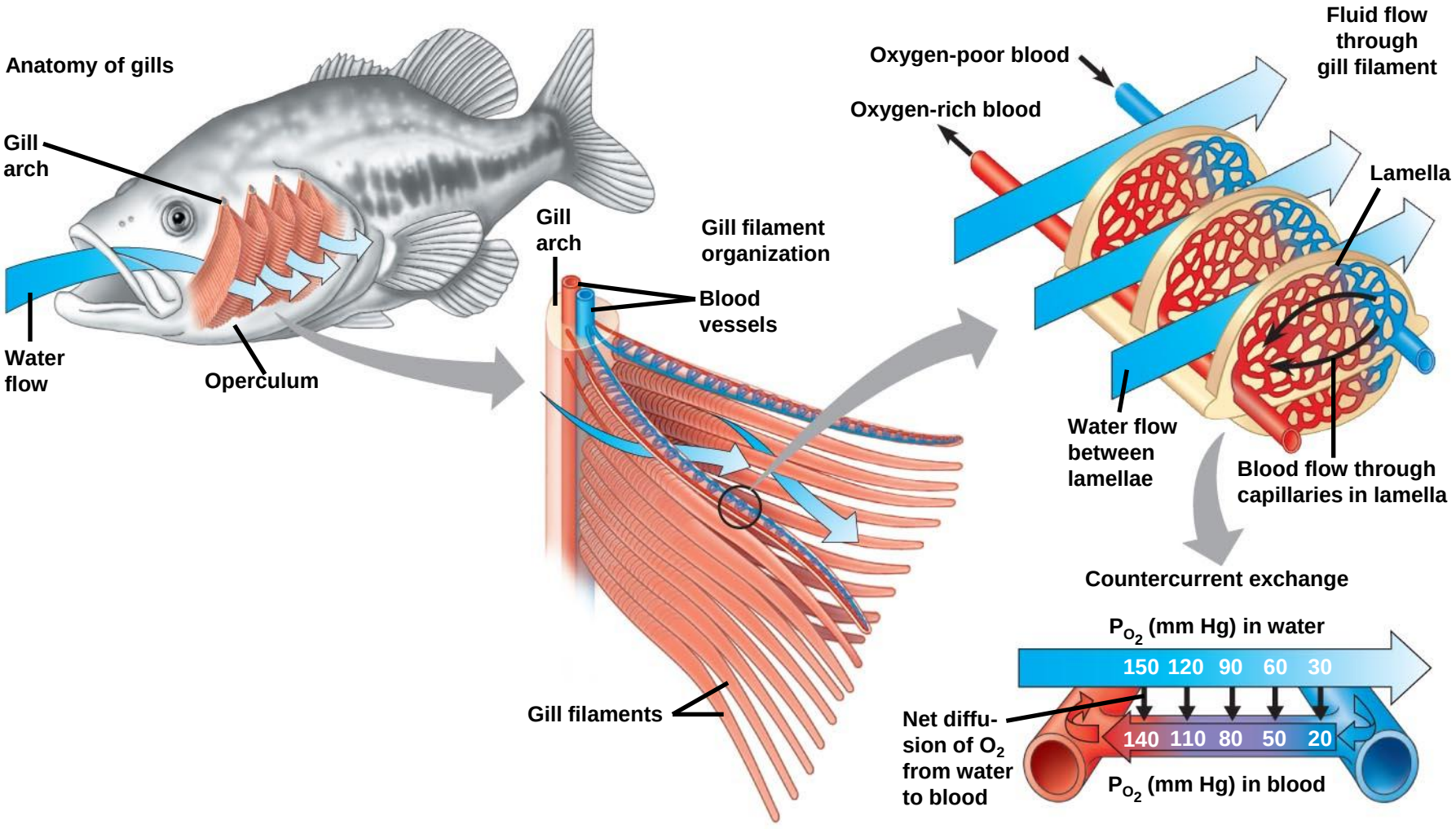


Fig. 42-23

The **tracheal system** of insects consists of tiny branching tubes that penetrate the body

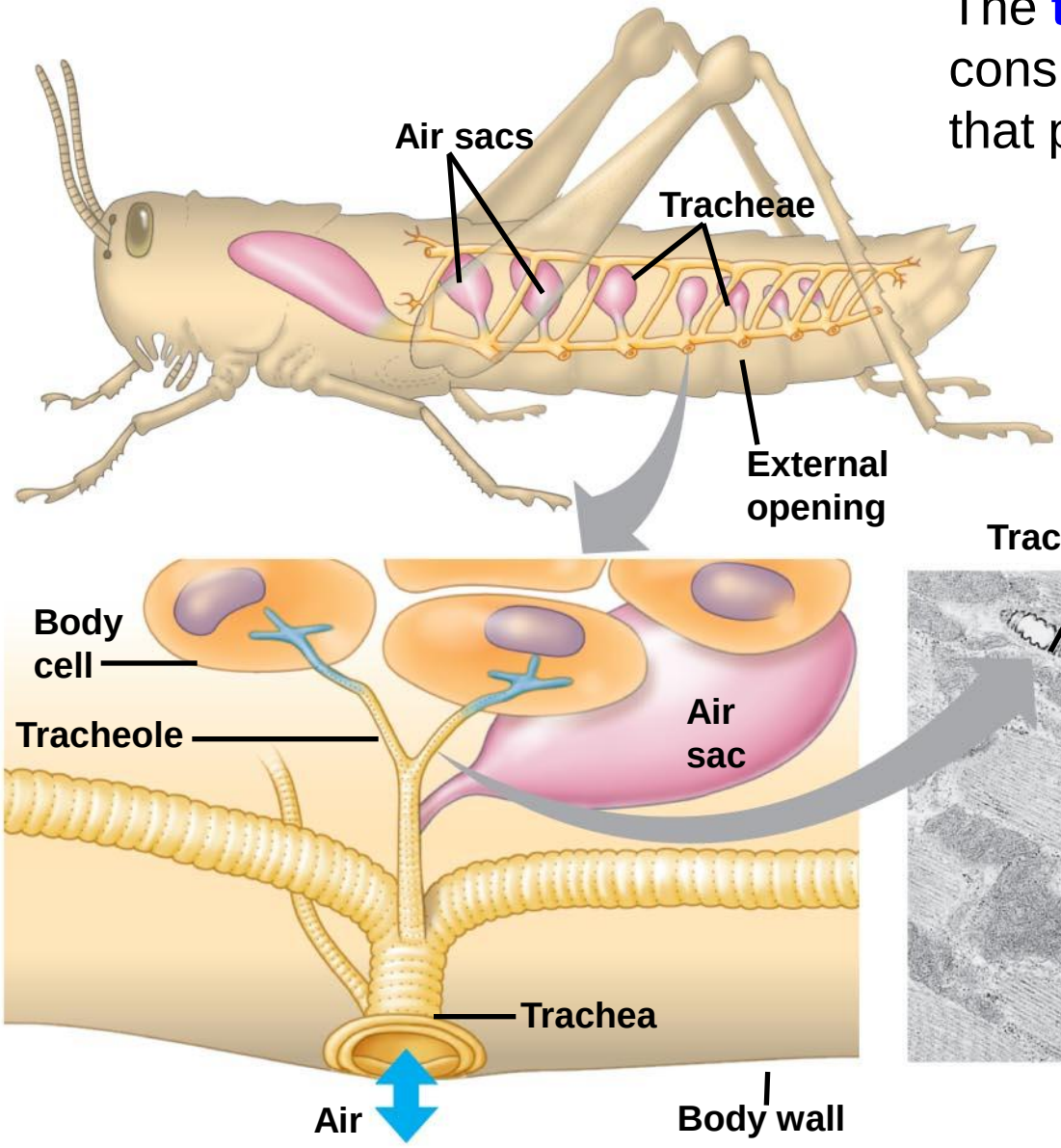
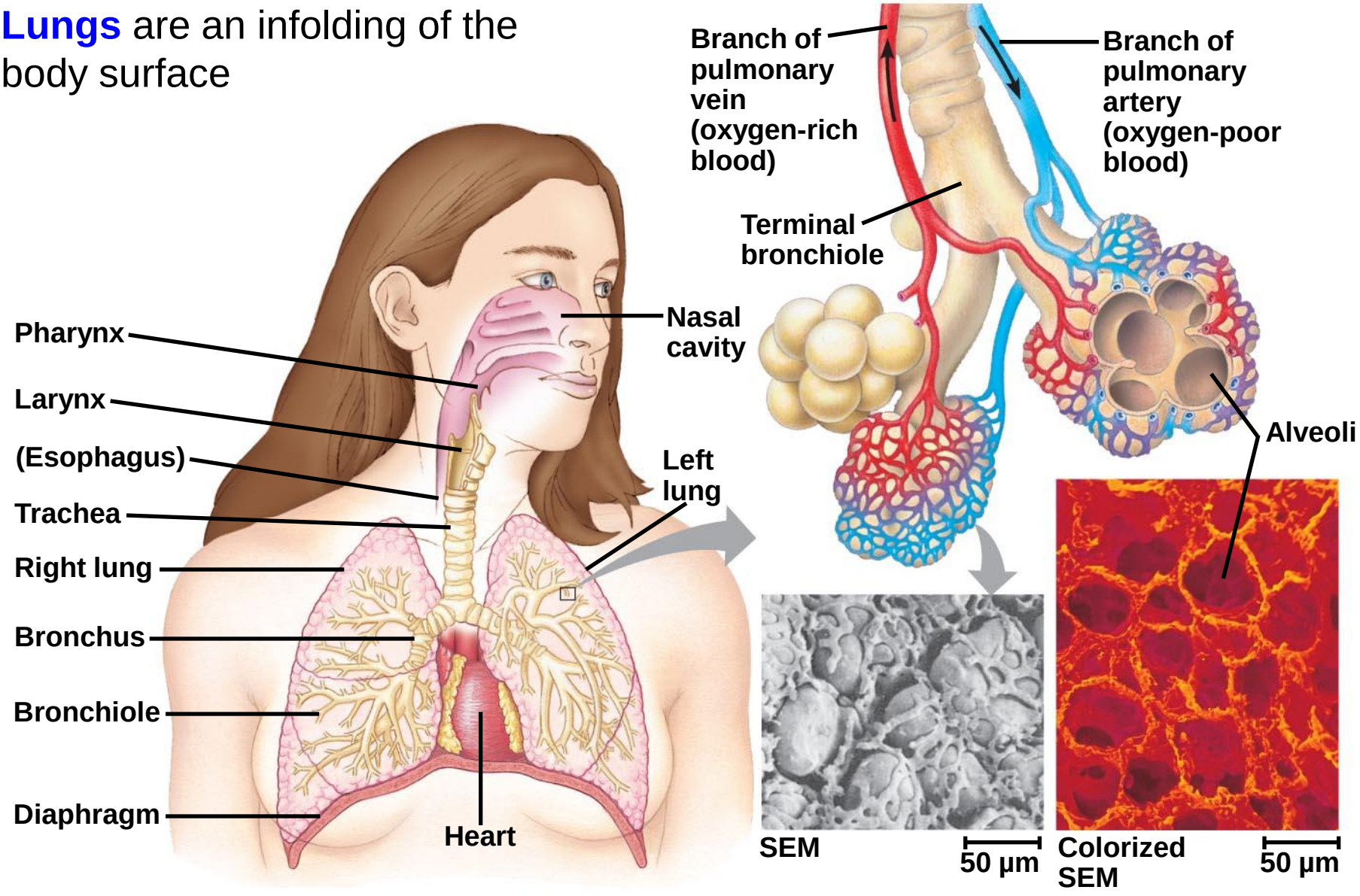


Fig. 42-24

Lungs are an infolding of the body surface



Concept 42.6: Breathing ventilates the lungs

- The process that ventilates the lungs is **breathing**, the alternate inhalation and exhalation of air
- An amphibian such as a frog ventilates its lungs by **positive pressure breathing**, which forces air down the trachea
- Mammals ventilate their lungs by **negative pressure breathing**, which pulls air into the lungs

Fig. 42-25

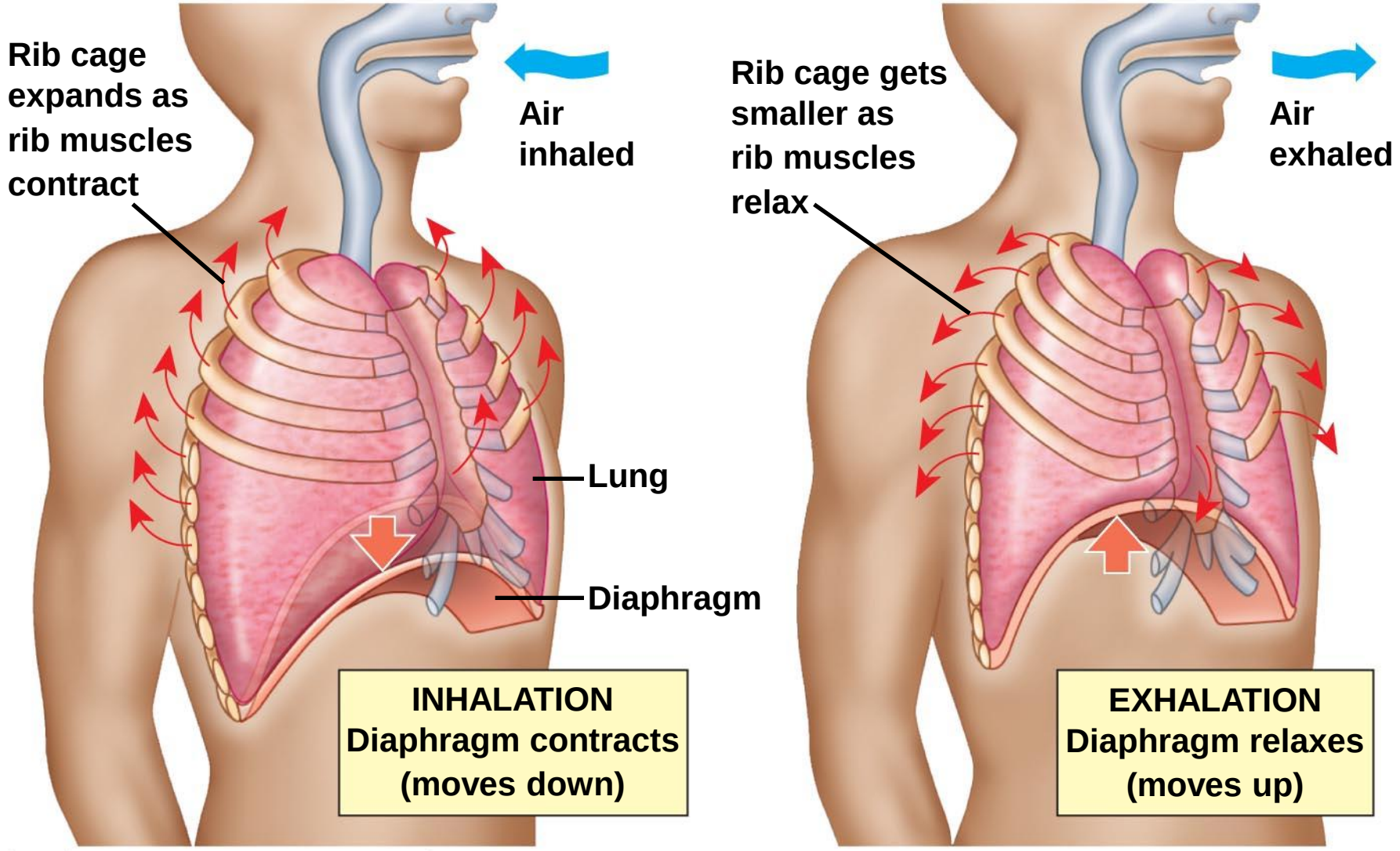
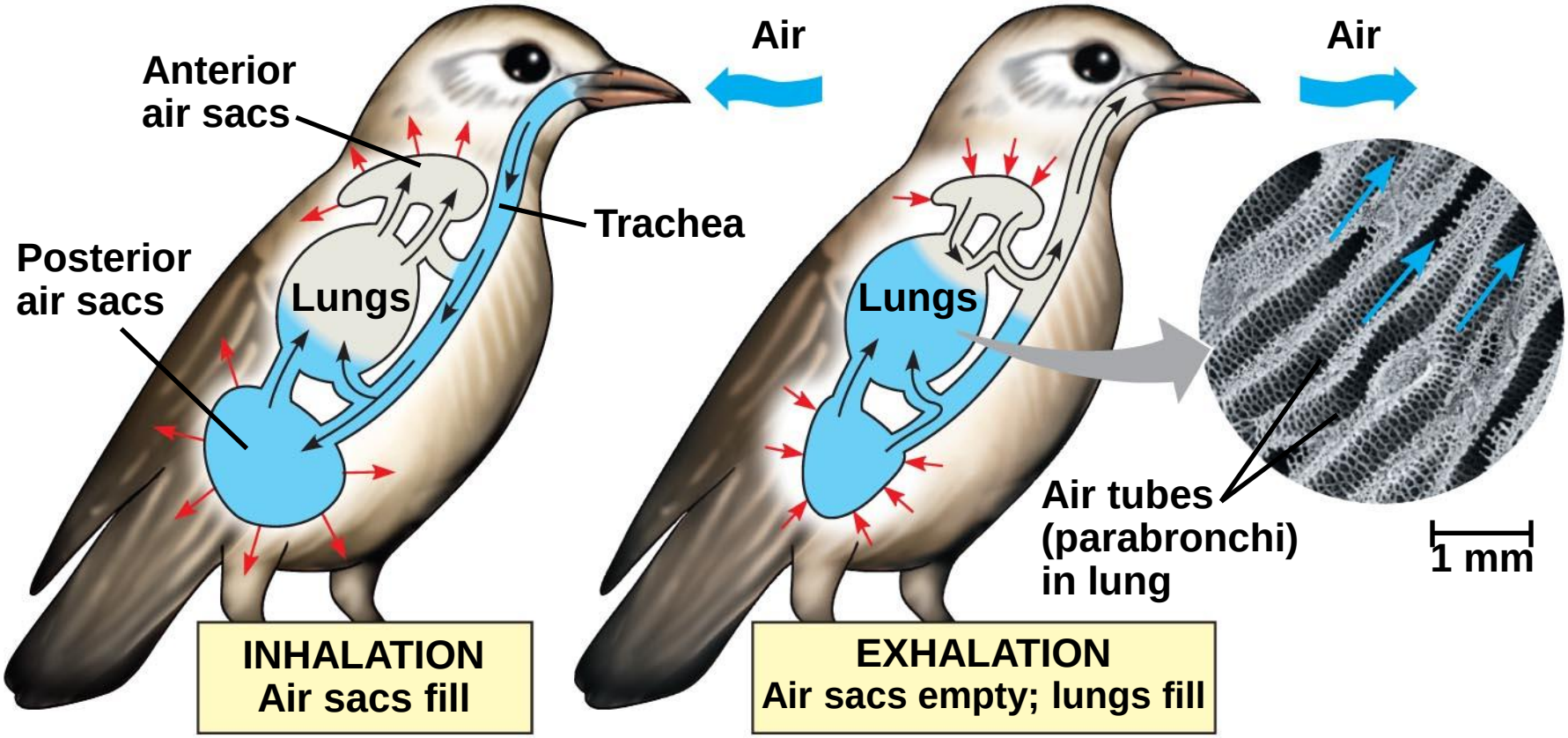


Fig. 42-26

Every exhalation completely renews the air in the lungs



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

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

Fig. 42-27

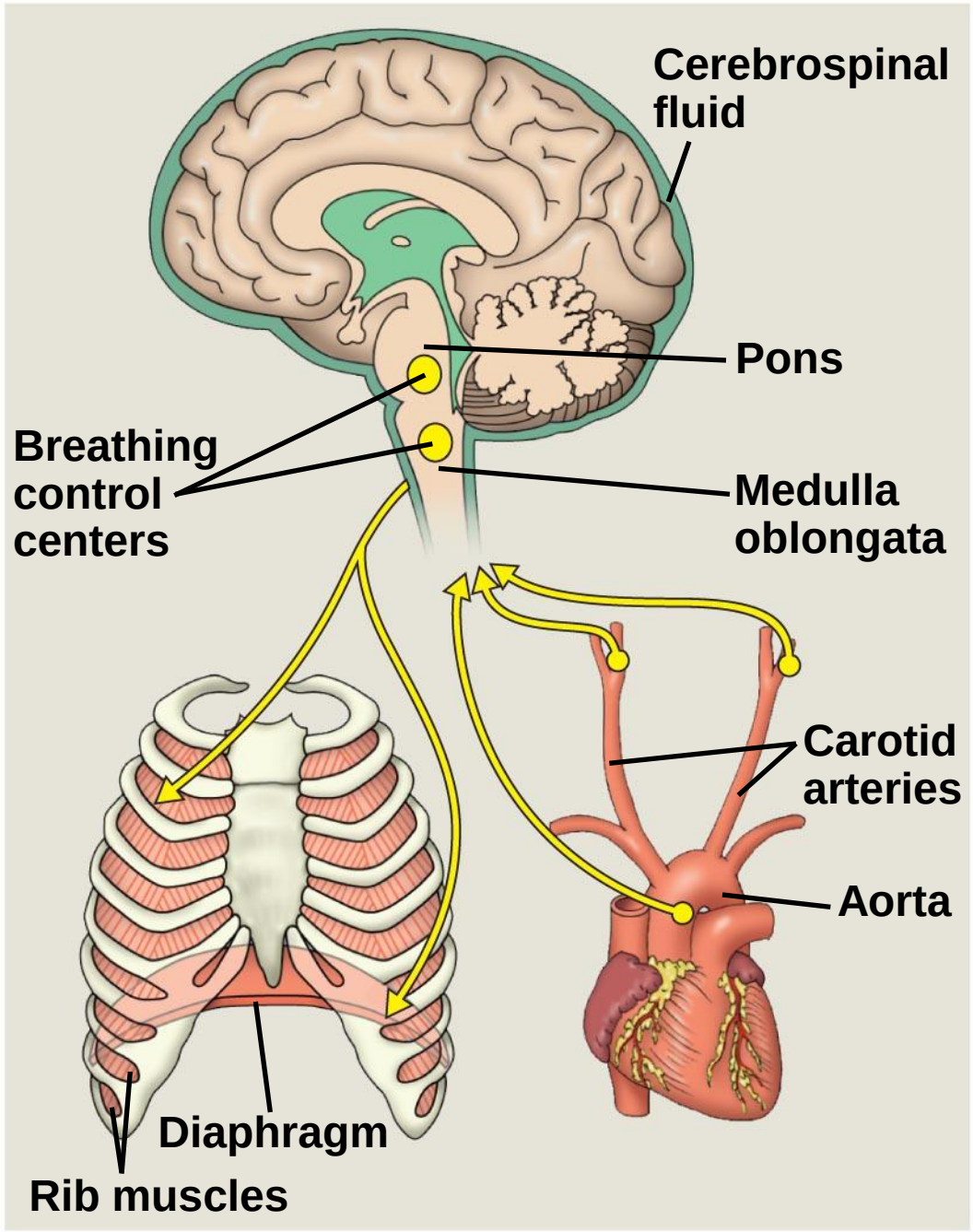
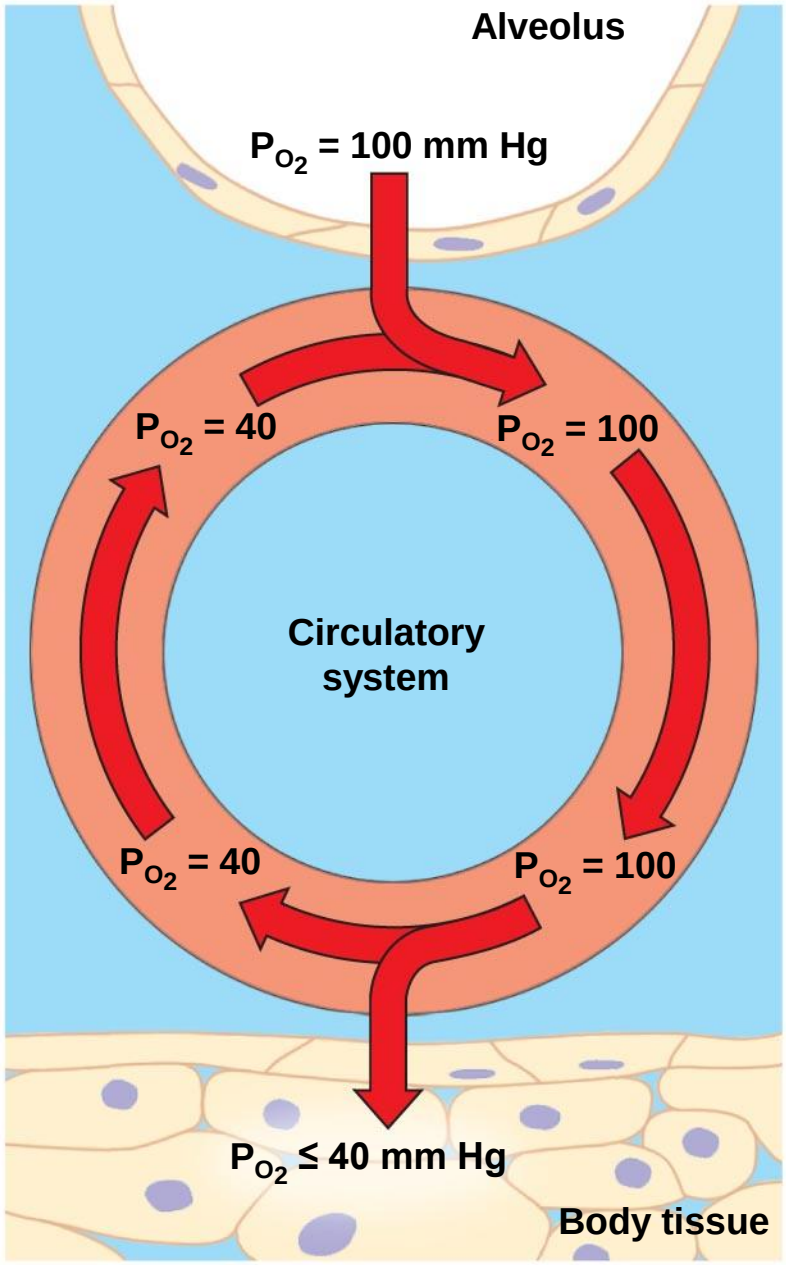
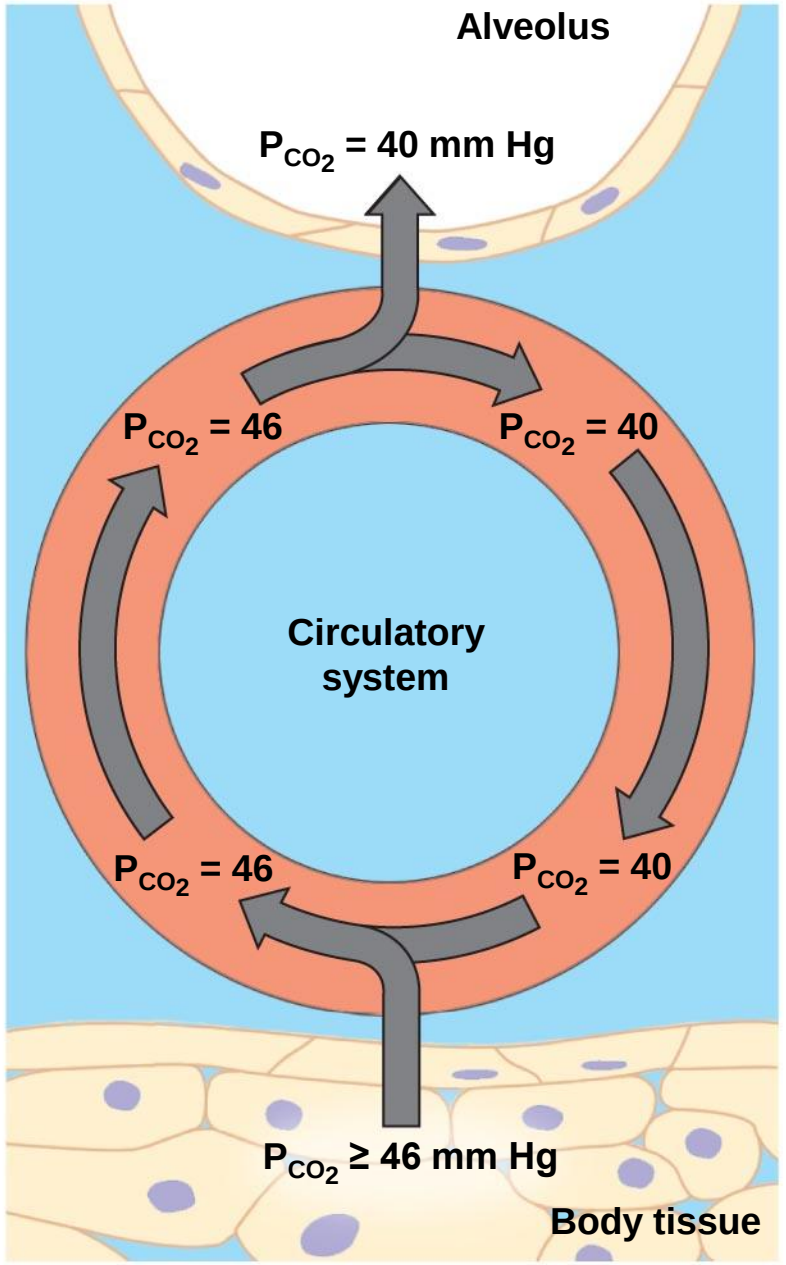


Fig. 42-28



(a) Oxygen



(b) Carbon dioxide

Fig. 42-UN1

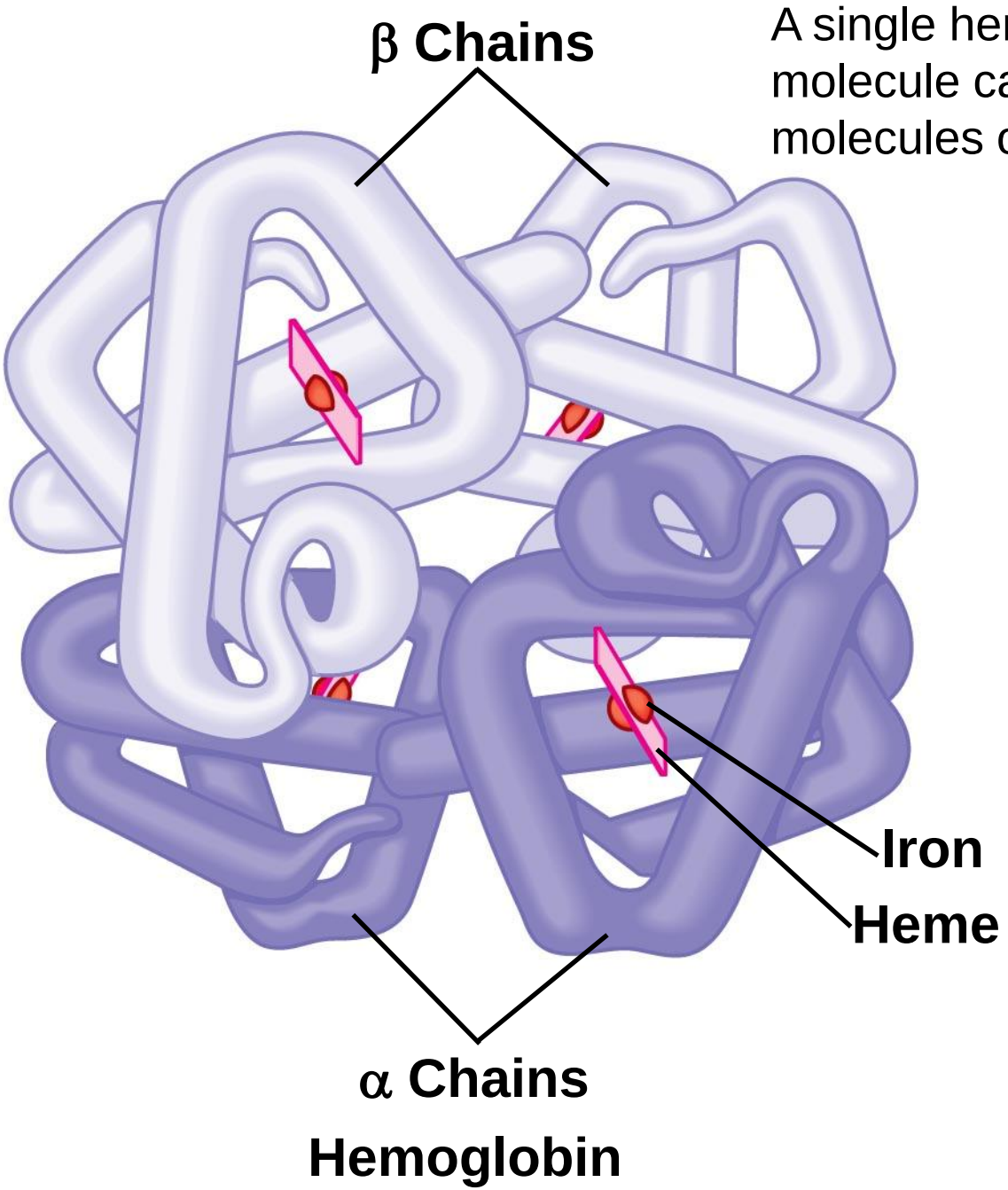
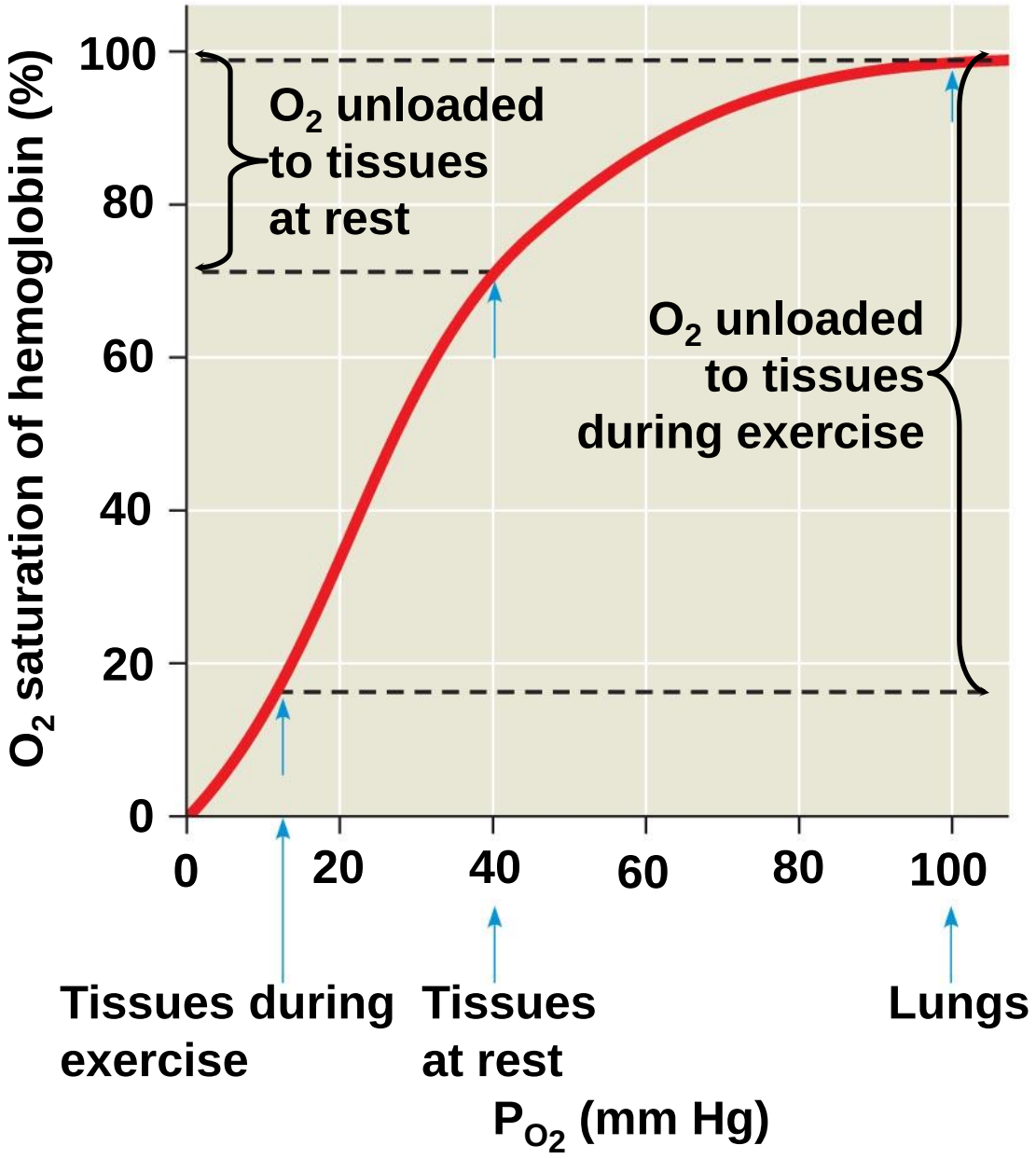
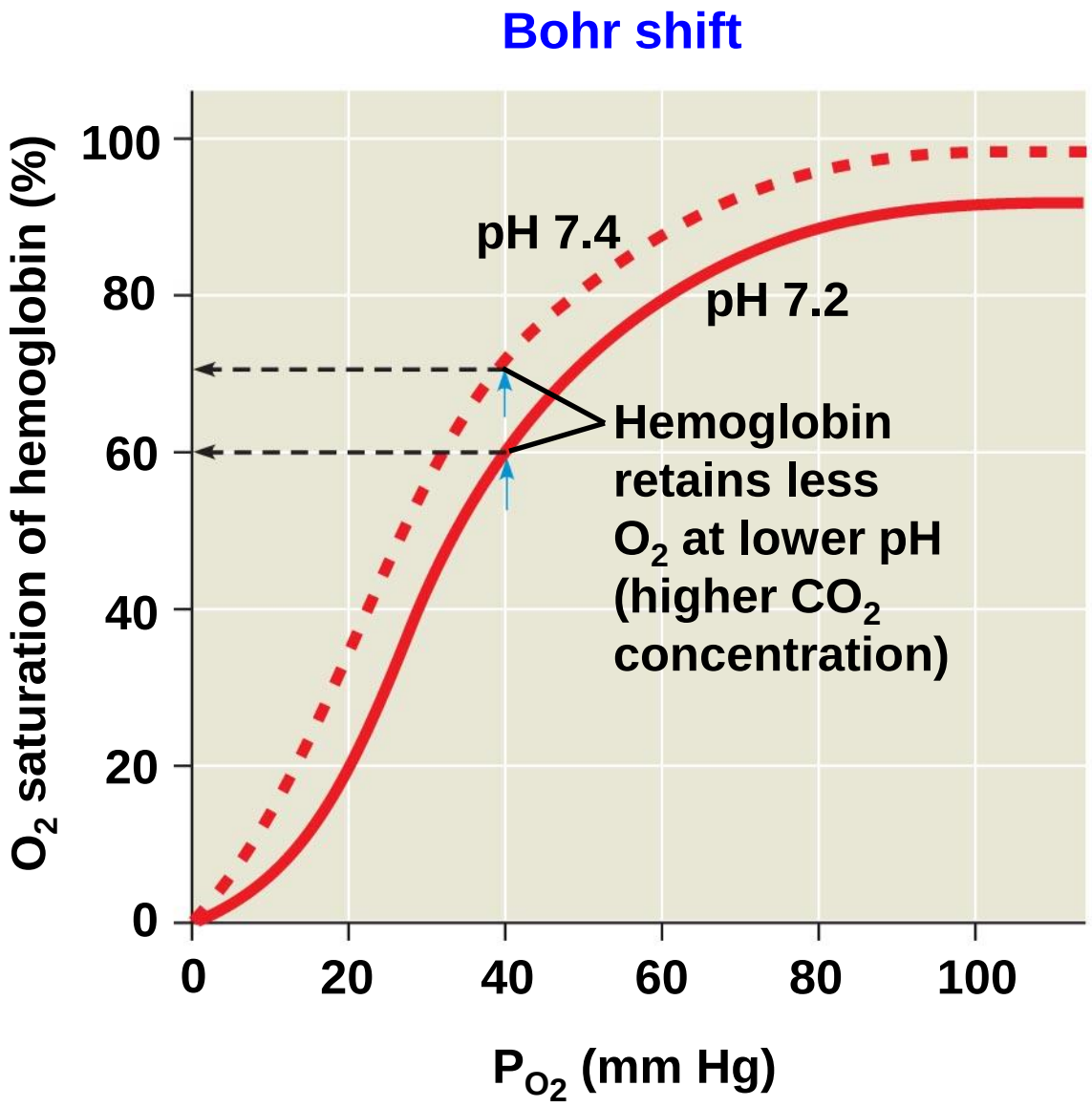


Fig. 42-29a



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

Fig. 42-29b



(b) pH and hemoglobin dissociation

Fig. 42-30a

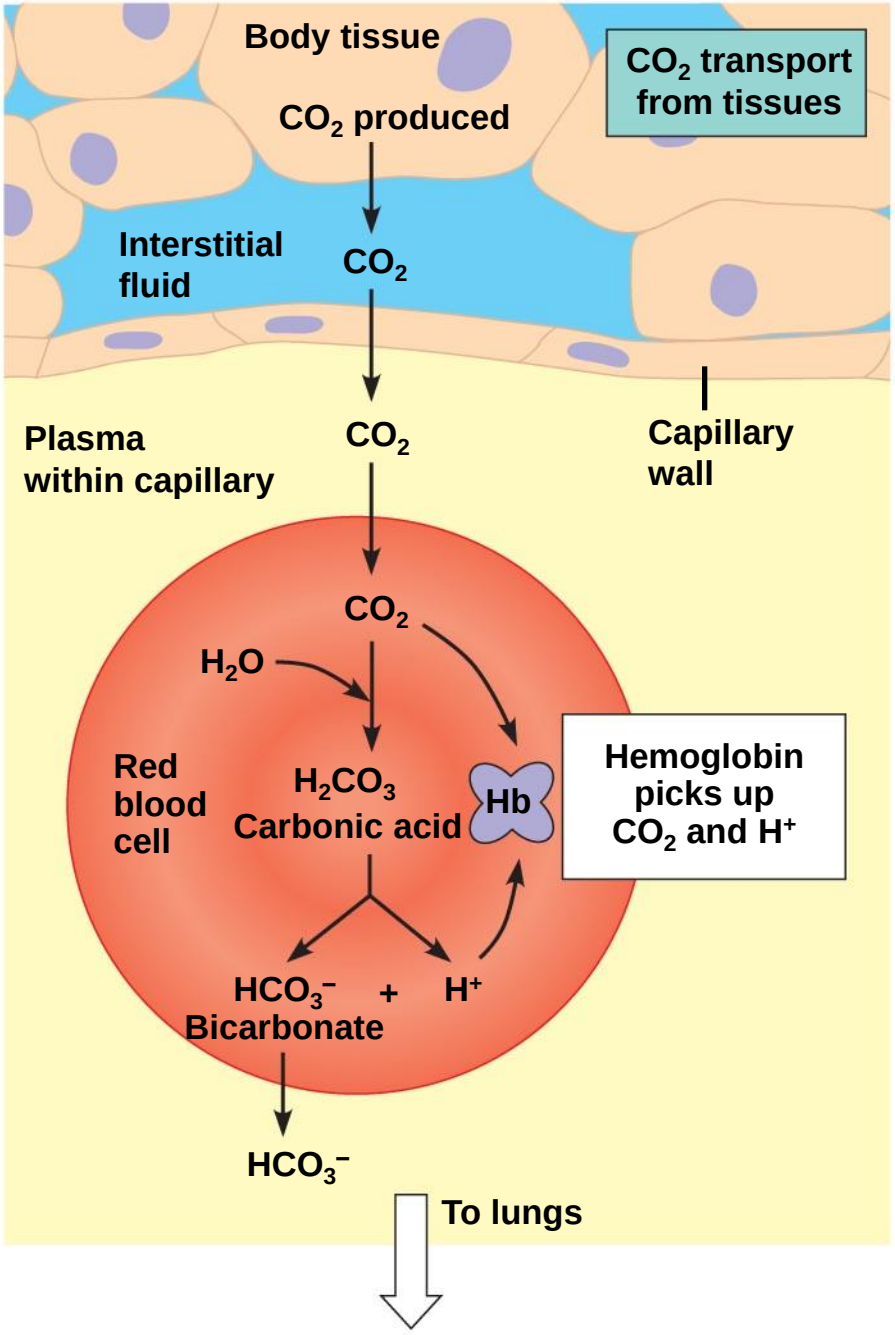
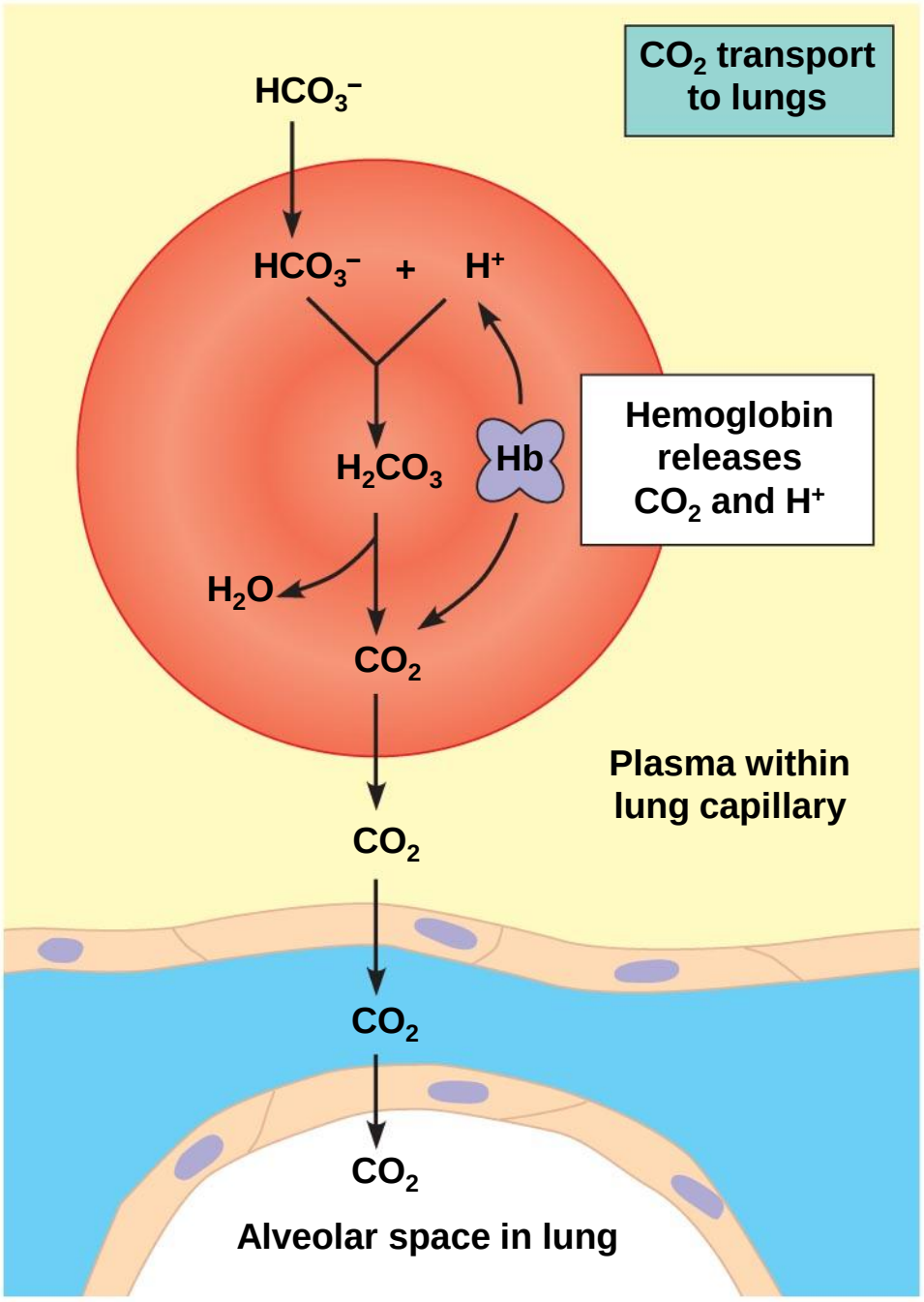


Fig. 42-30b

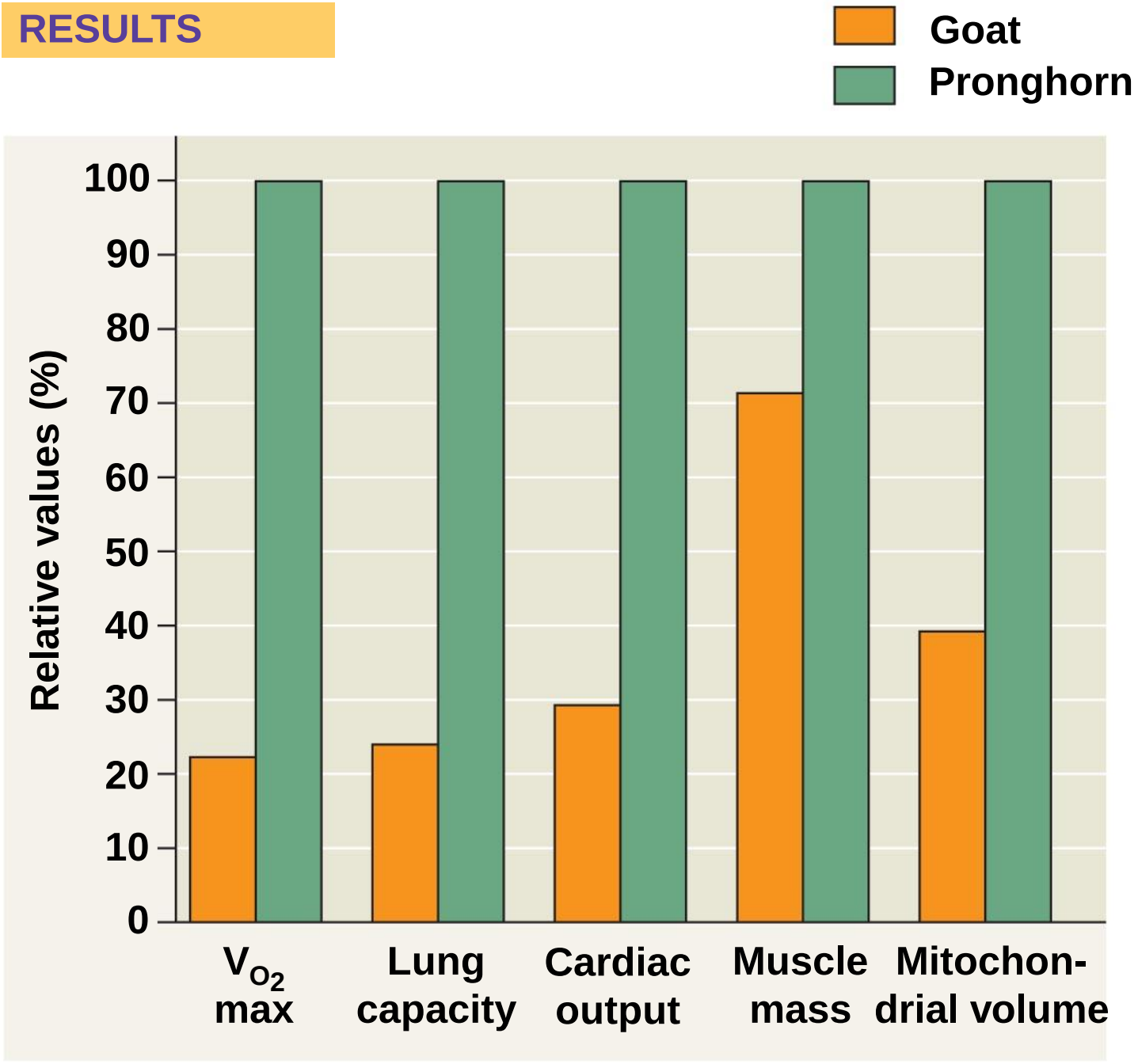


The Ultimate Endurance Runner

- The extreme O_2 consumption of the antelope-like pronghorn underlies its ability to run at high speed over long distances

Fig. 42-31

RESULTS



Diving Mammals

- Deep-diving air breathers stockpile O_2 and deplete it slowly
- Weddell seals have a high blood to body volume ratio and can store oxygen in their muscles in **myoglobin** proteins

You should now be able to:

1. Compare and contrast open and closed circulatory systems
2. Compare and contrast the circulatory systems of fish, amphibians, non-bird reptiles, and mammals or birds
3. Distinguish between pulmonary and systemic circuits and explain the function of each
4. Trace the path of a red blood cell through the human heart, pulmonary circuit, and systemic circuit

5. Define cardiac cycle and explain the role of the sinoatrial node

6. Relate the structures of capillaries, arteries, and veins to their function

7. Define blood pressure and cardiac output and describe two factors that influence each

8. Explain how osmotic pressure and hydrostatic pressure regulate the exchange of fluid and solutes across the capillary walls

9. Describe the role played by the lymphatic system in relation to the circulatory system

10. Describe the function of erythrocytes, leukocytes, platelets, fibrin

11. Distinguish between a heart attack and stroke

12. Discuss the advantages and disadvantages of water and of air as respiratory media

13. For humans, describe the exchange of gases in the lungs and in tissues

14. Draw and explain the hemoglobin-oxygen dissociation curve