Chapter 42

Circulation and Gas Exchange

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: Trading Places

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

- For most cells making up **multicellular organisms**, **direct exchange** with the environment **is not possible**
- Gills الخياشيم are an example of a specialized exchange system in animals
- **Internal transport and gas exchange** are **functionally related** in most animals

Fig. 42-1

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

- In most animals, transport systems connect the organs of exchange with the body cells
- Most complex animals have internal transport systems that circulate fluid

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 الدَّمَلِمْف)
  - A set of **tubes** (blood vessels)
  - A muscular **pump** (the heart)

- In **insects**, other arthropods, and most molluscs, blood bathes the organs directly in an **open circulatory system**

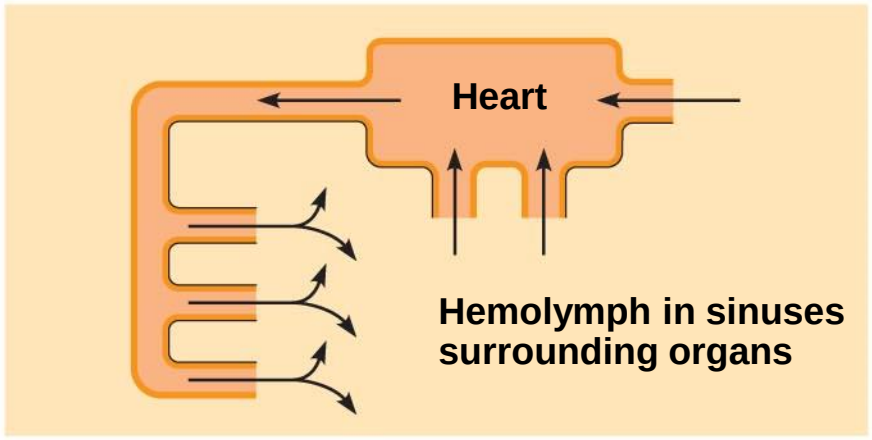
- In an open circulatory system, there is **no distinction between blood and interstitial fluid** سائل خِلاَلِيّ, and this general body fluid is more correctly called **hemolymph**

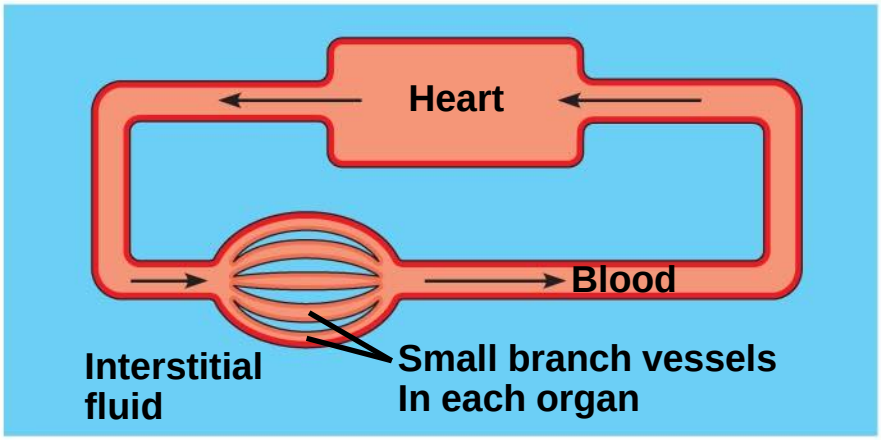
- **What is *interstitial fluid*?**

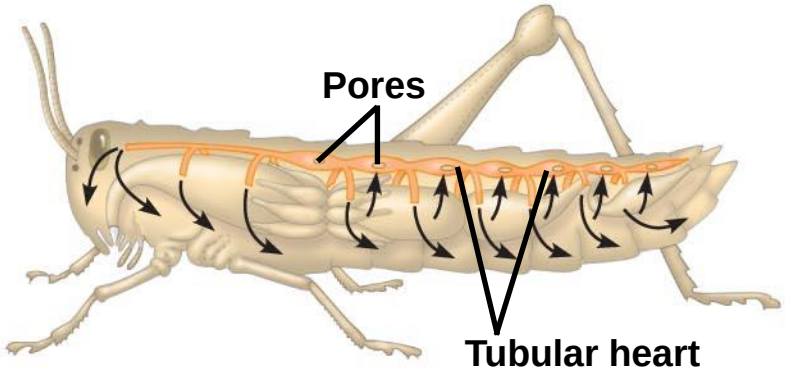
- In a **closed circulatory system**, blood is **confined** مَقْصُور على to vessels and is distinct from the interstitial fluid

- Closed systems are **more efficient** at transporting circulatory fluids to tissues and cells

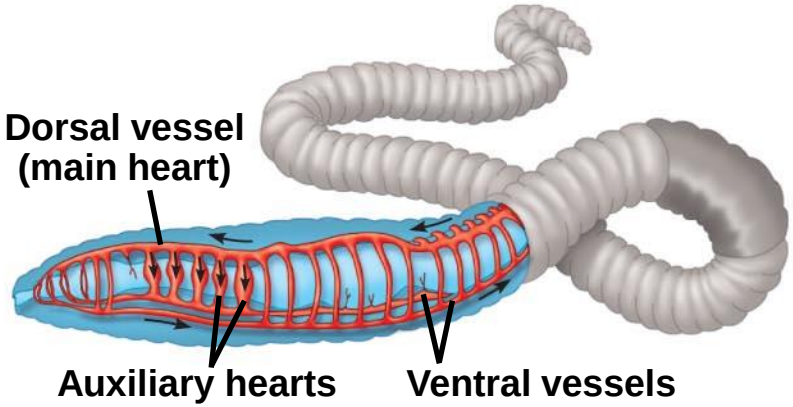
Fig. 42-3







(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 شرّايين**
  - **Veins أوردة,**
  - **and**
  - **Capillaries الأوعية الشعرية**

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

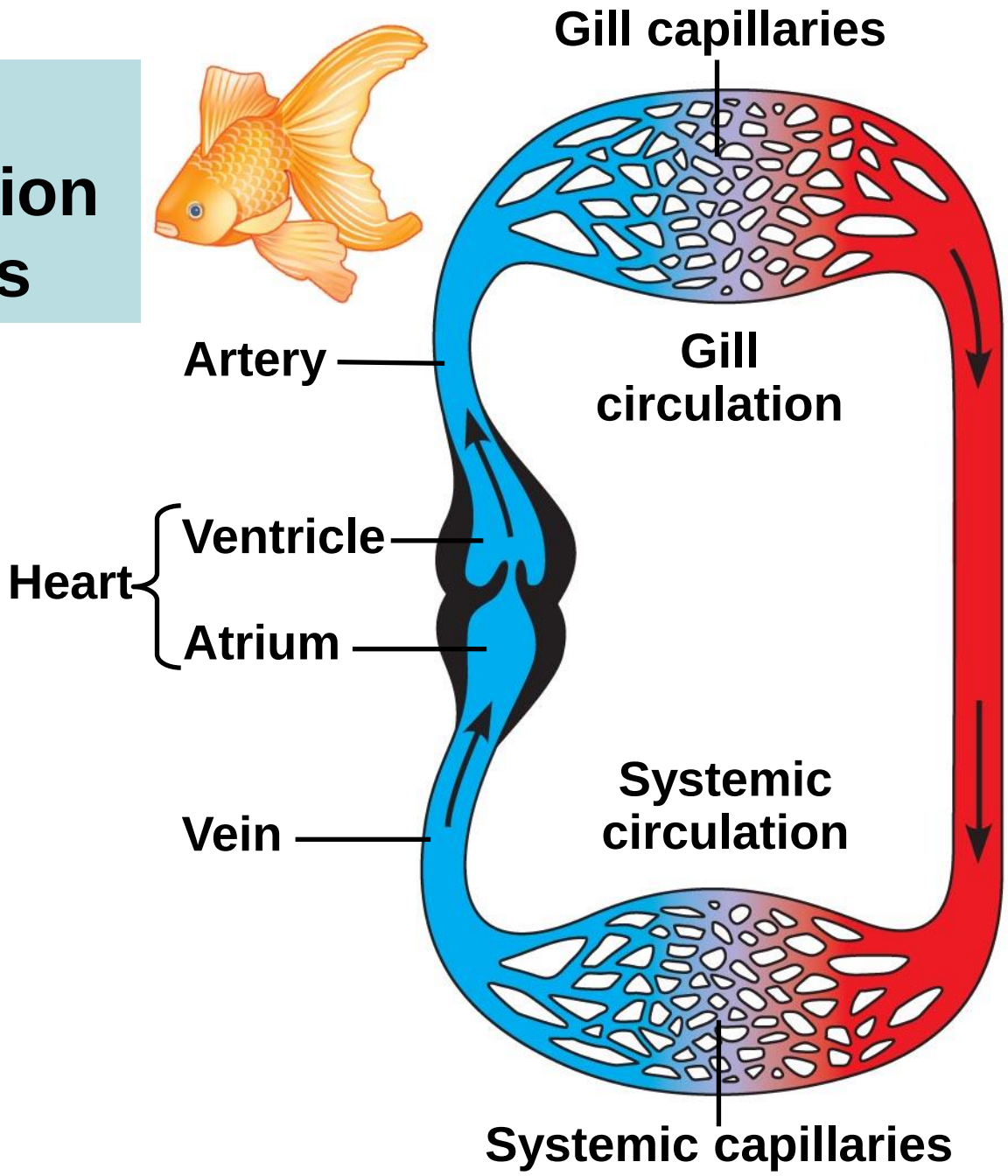
- **Vertebrate hearts contain <u>two or more chambers</u>**
- **Blood enters through an atrium أُذَين and is <u>pumped</u> out through a ventricle بطين**

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**

Fig. 42-4

Single circulation in fishes

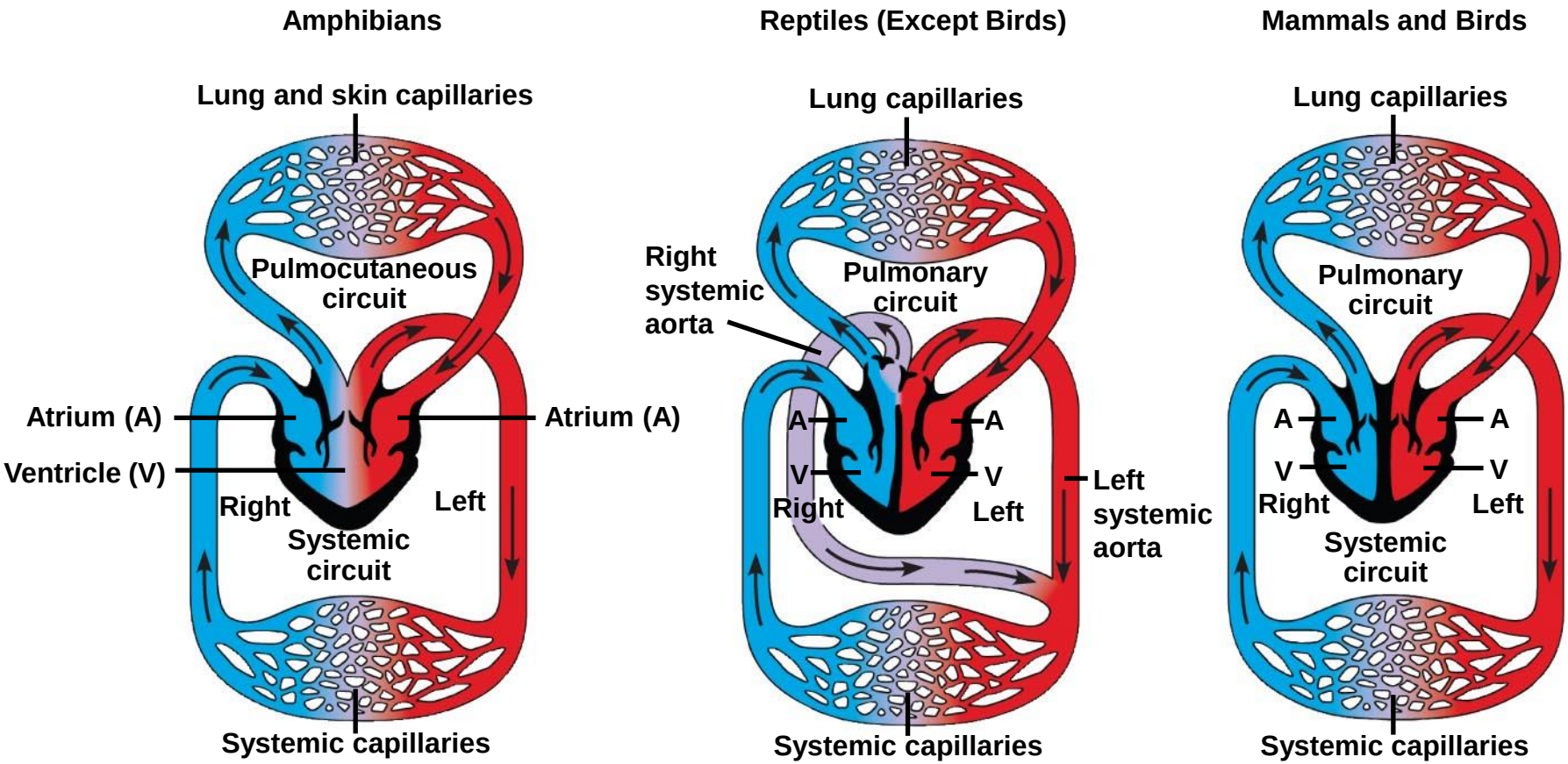


Double Circulation

- **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**

Fig. 42-5



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

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**

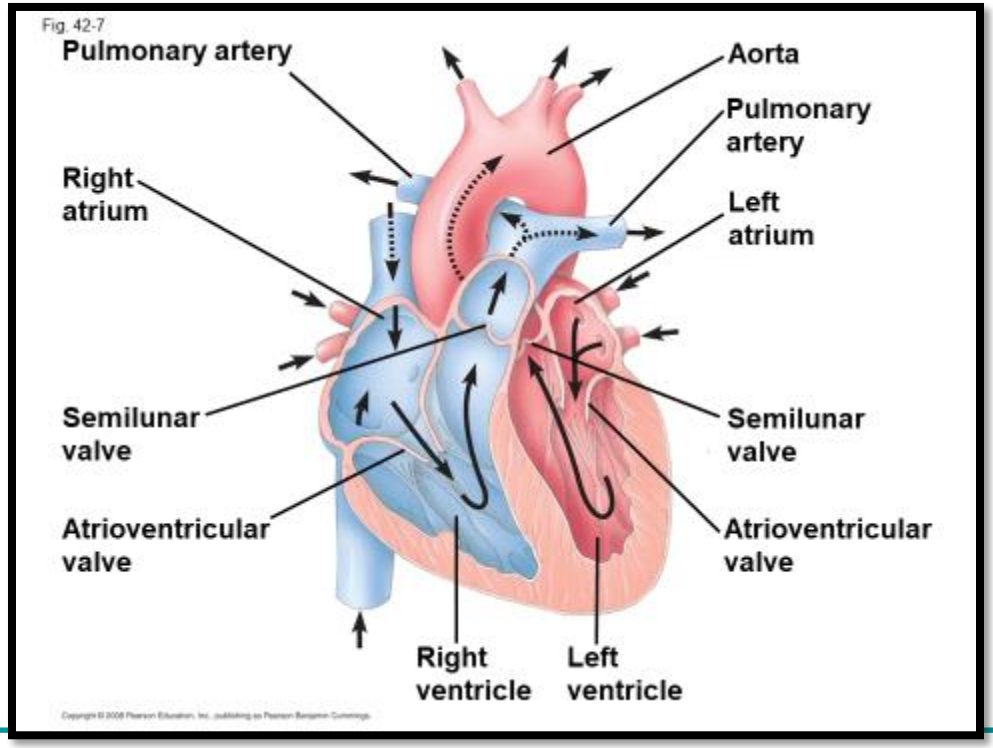
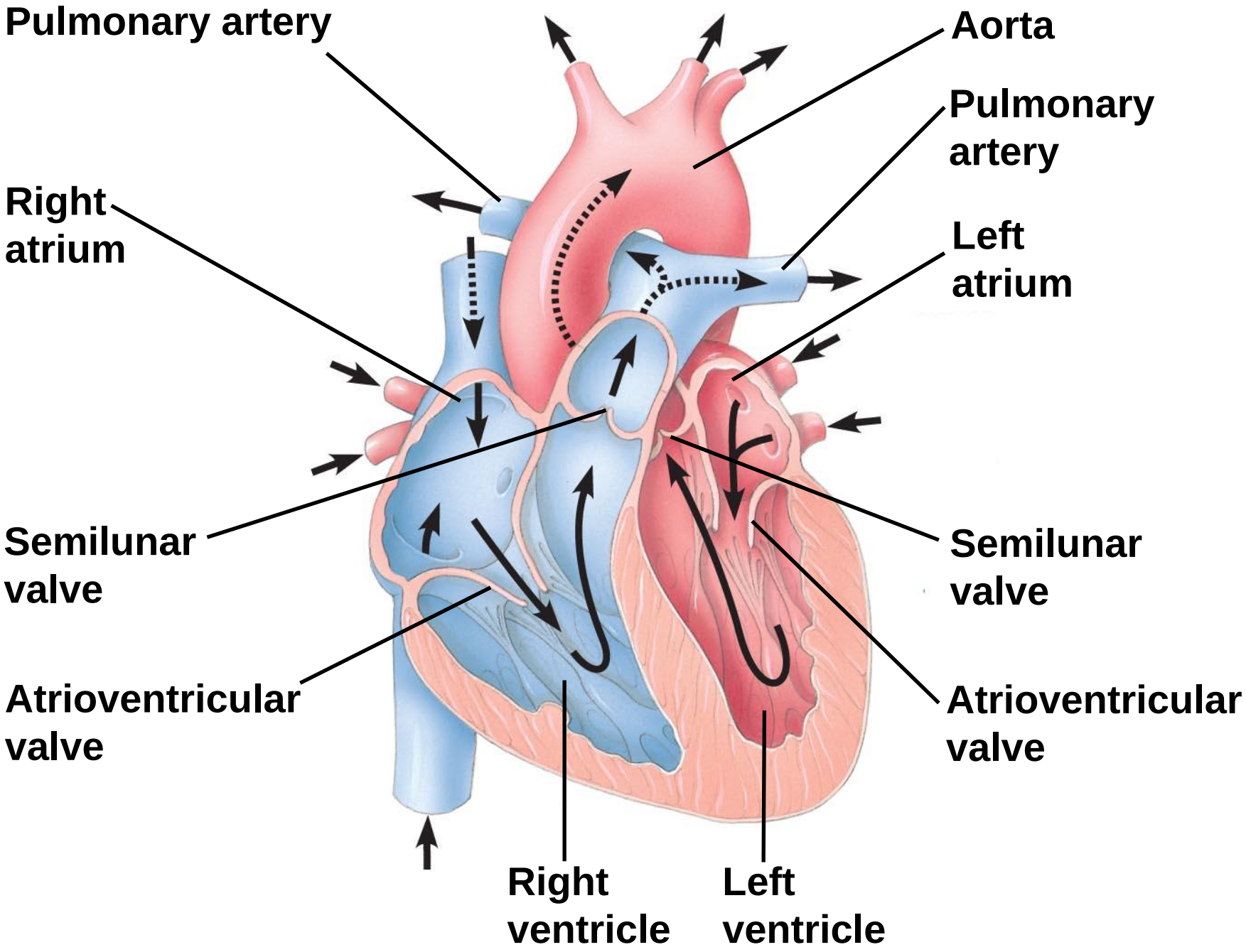
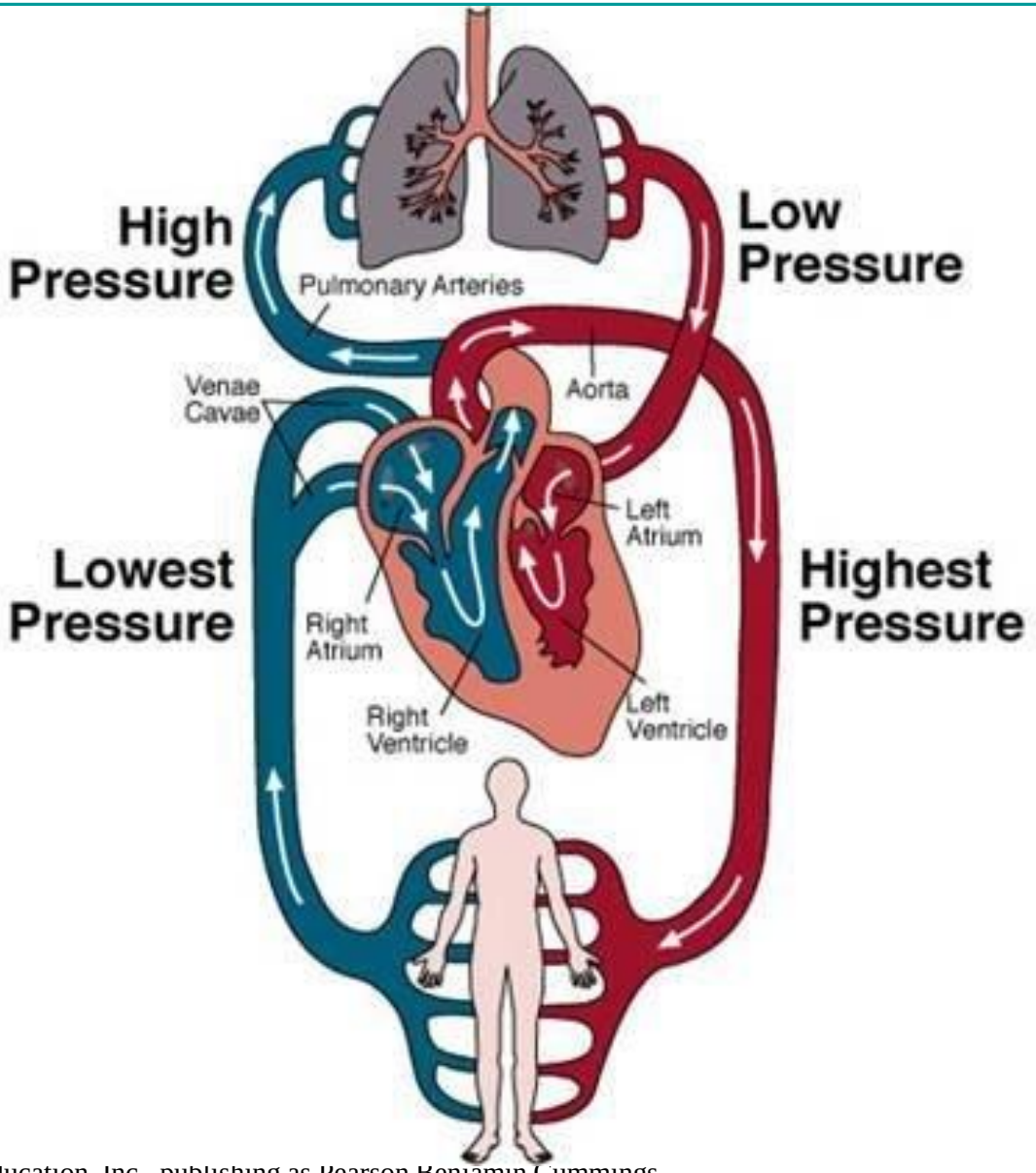


Fig. 42-7

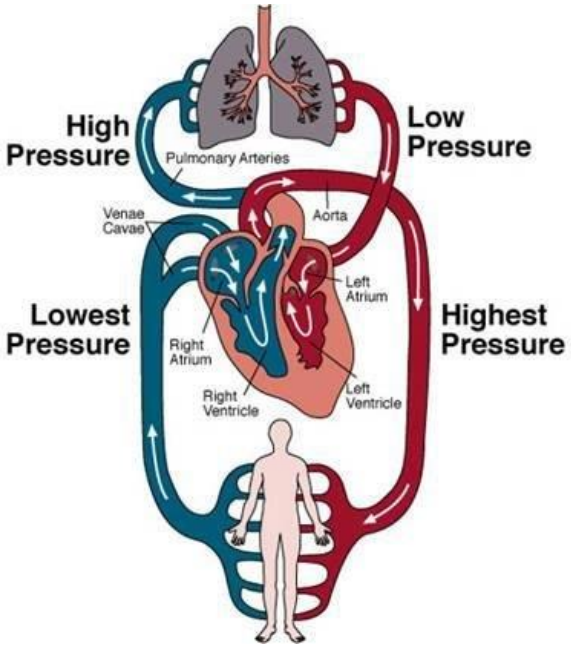


Mammalian Circulation

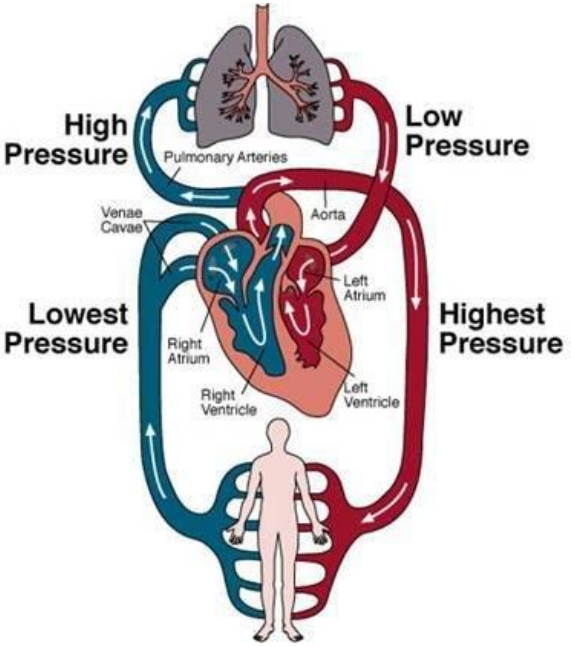


Mammalian Circulation

- **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**



- 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

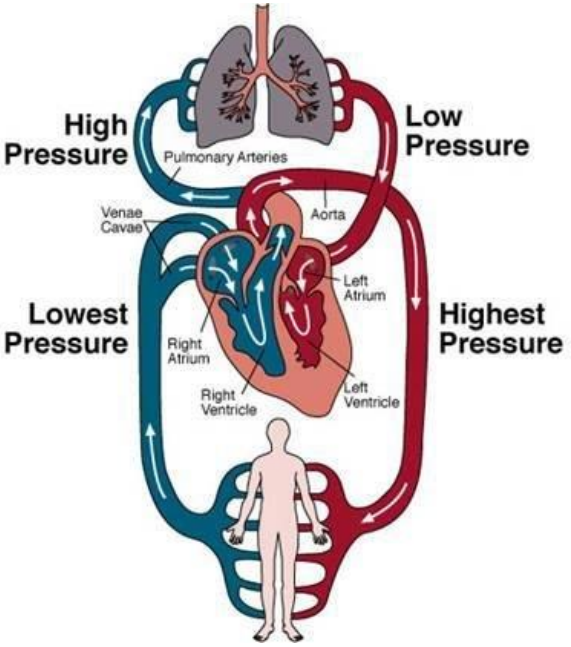
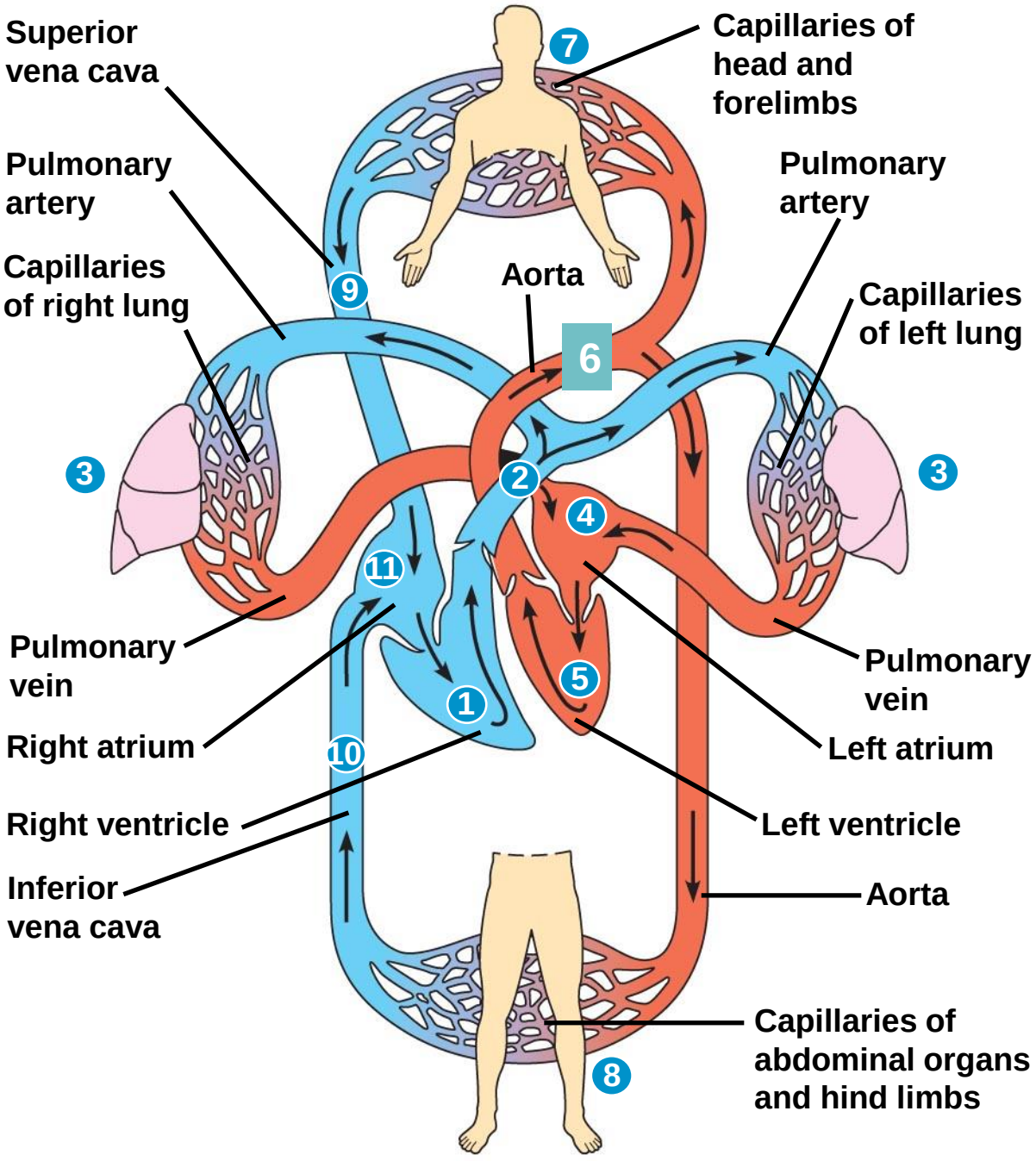
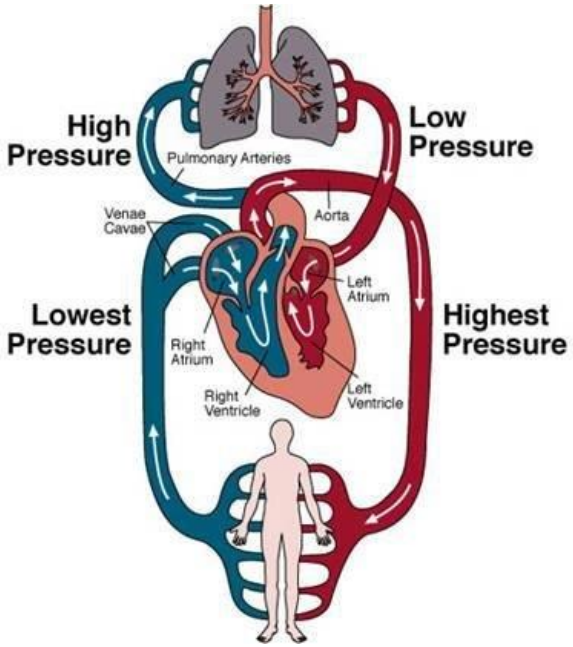


Fig. 42-6



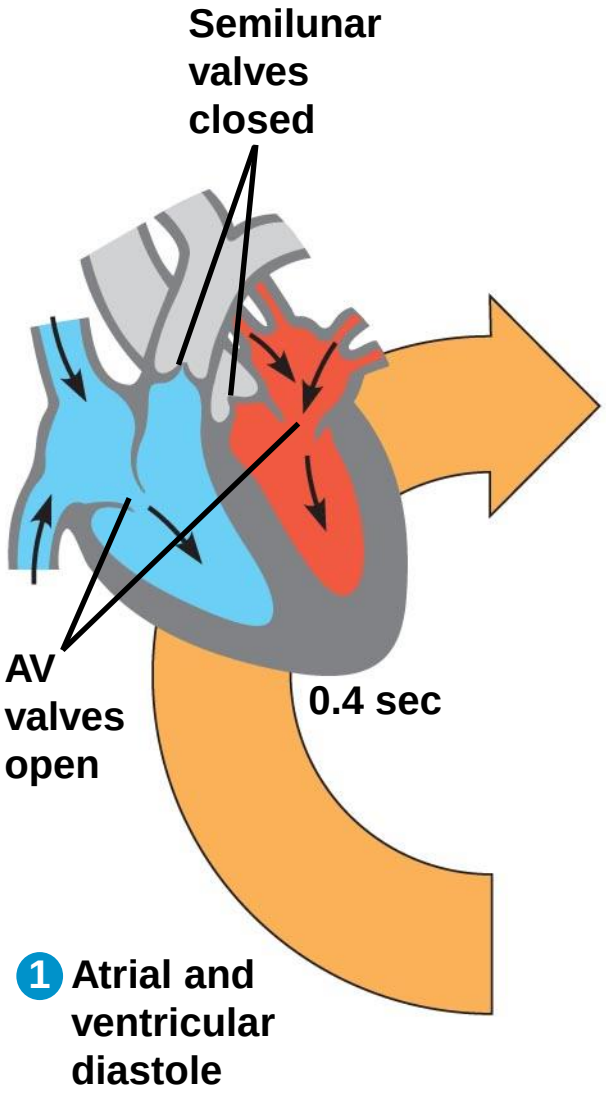
The Mammalian Heart: *A Closer Look*

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



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

Fig. 42-8-1



The cardiac cycle

For an adult human, the heart rate is 72 beats/min; one complete cardiac cycle takes ~0.8 seconds

Fig. 42-8-2

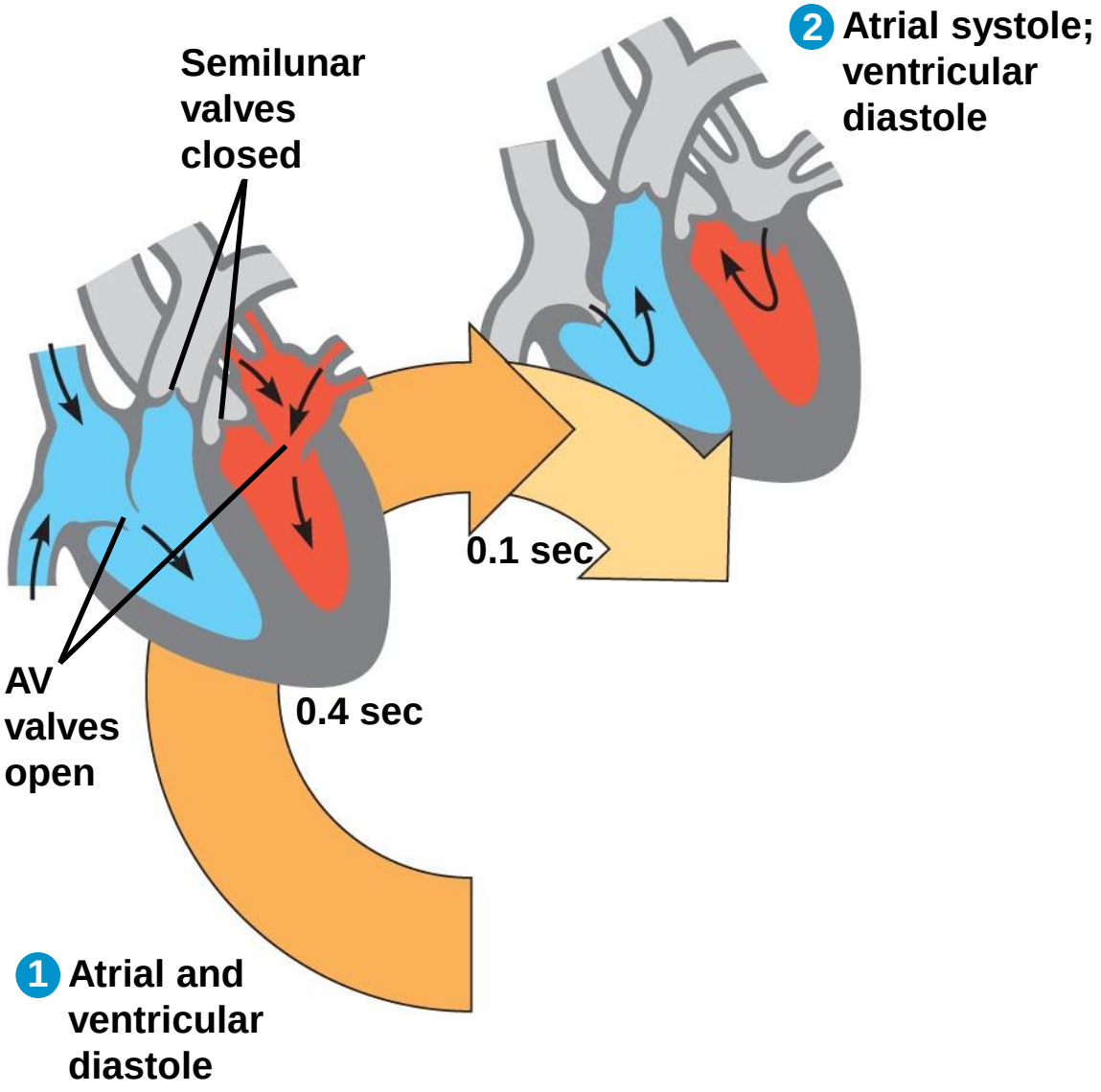
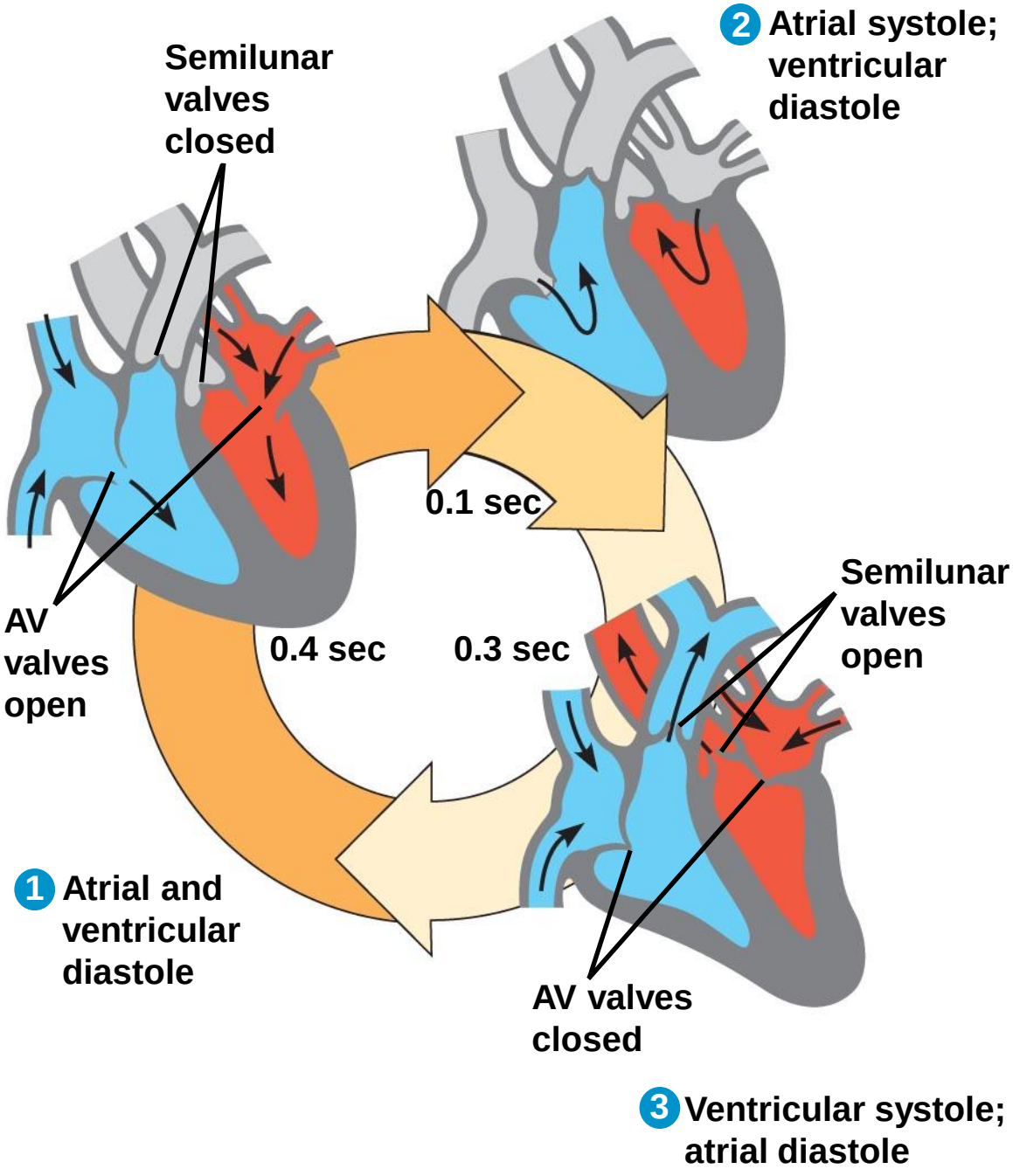


Fig. 42-8



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

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

- **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 نَفْخَةٌ قَلْبِيَّة**

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** العُقْدَةُ الجَيْبِيَّةُ الأُذَيْنِيَّة , or ***pacemaker*** *منظم ضربات القلب*, sets the rate and timing at which cardiac muscle cells contract
- Impulses from the SA node travel to the **atrioventricular (AV) node** العُقْدَةُ الأُذَينِيَّةُ البُطَينِيَّة
- At the AV node, the impulses are delayed and then travel to the Purkinje fibers that make the ventricles contract

- **Impulses that travel during the cardiac cycle can be recorded as an electrocardiogram (ECG or EKG)**
  مخطط كهربائى للقلب

Fig. 42-9-1

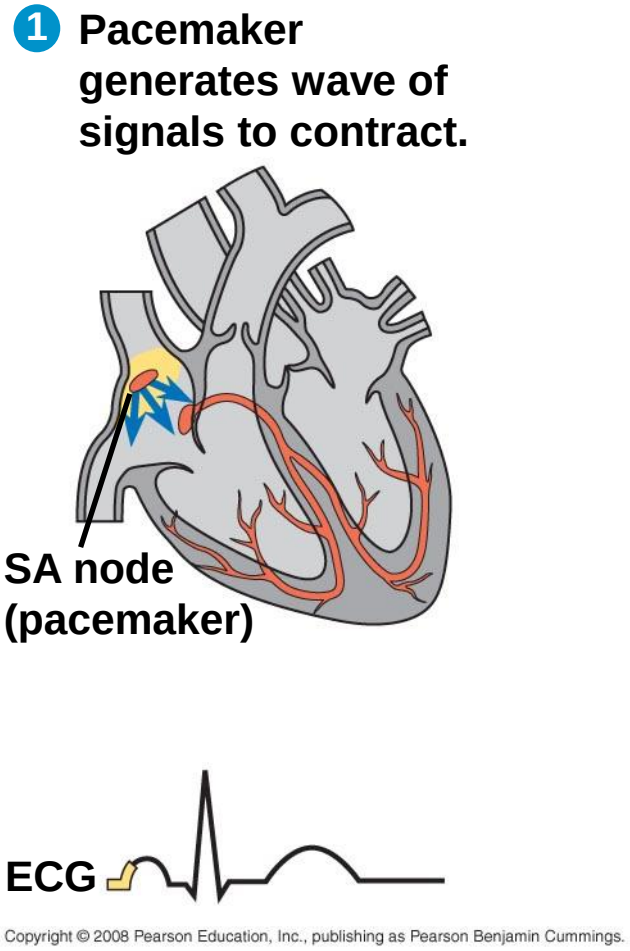


Fig. 42-9-2

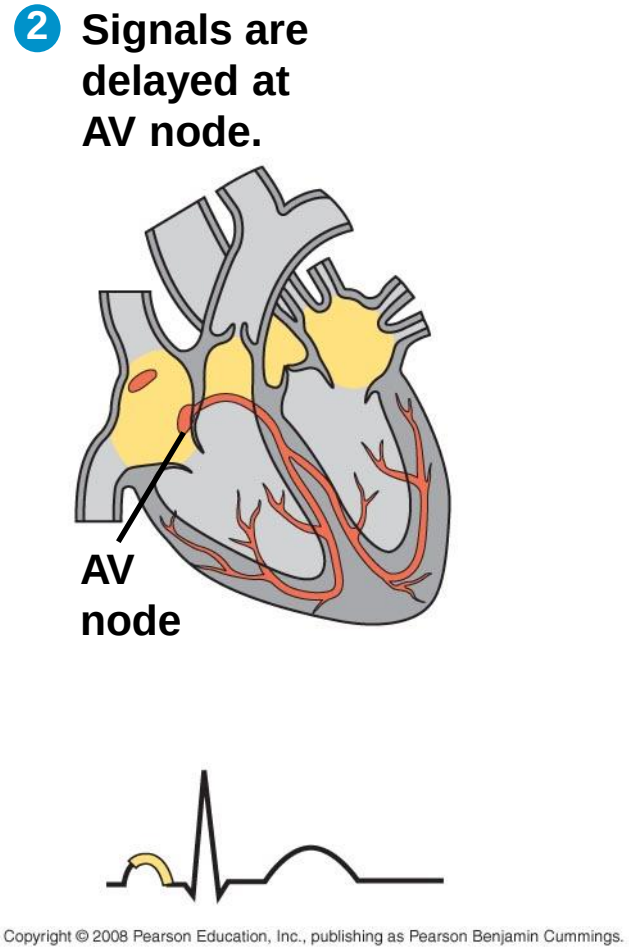


Fig. 42-9-3

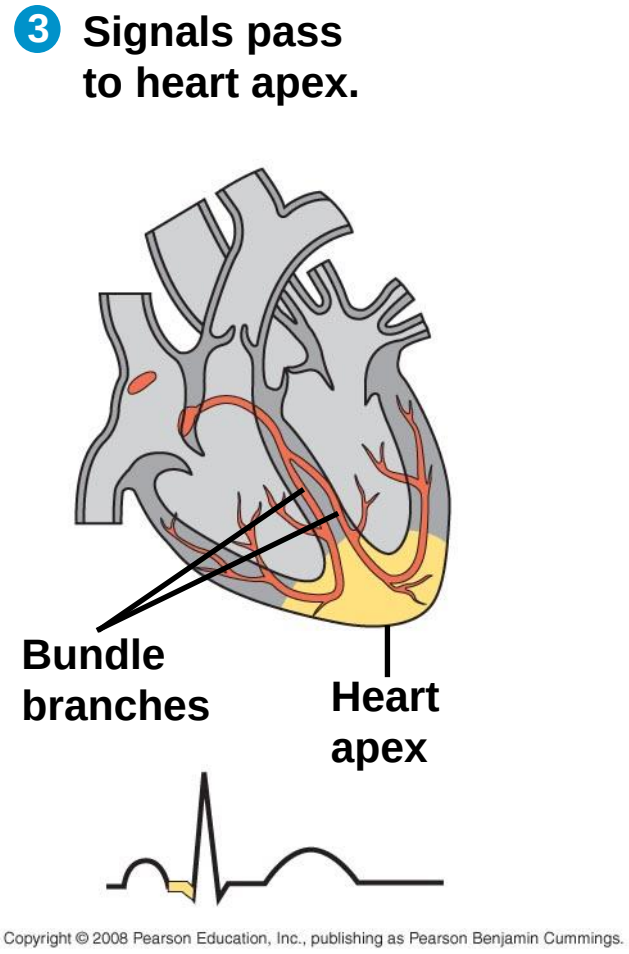


Fig. 42-9-4

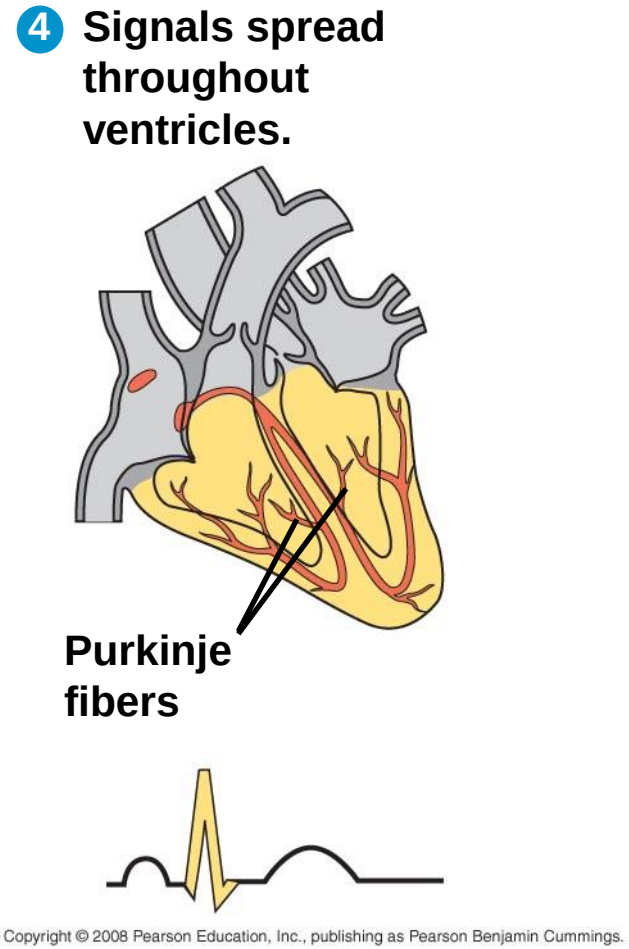
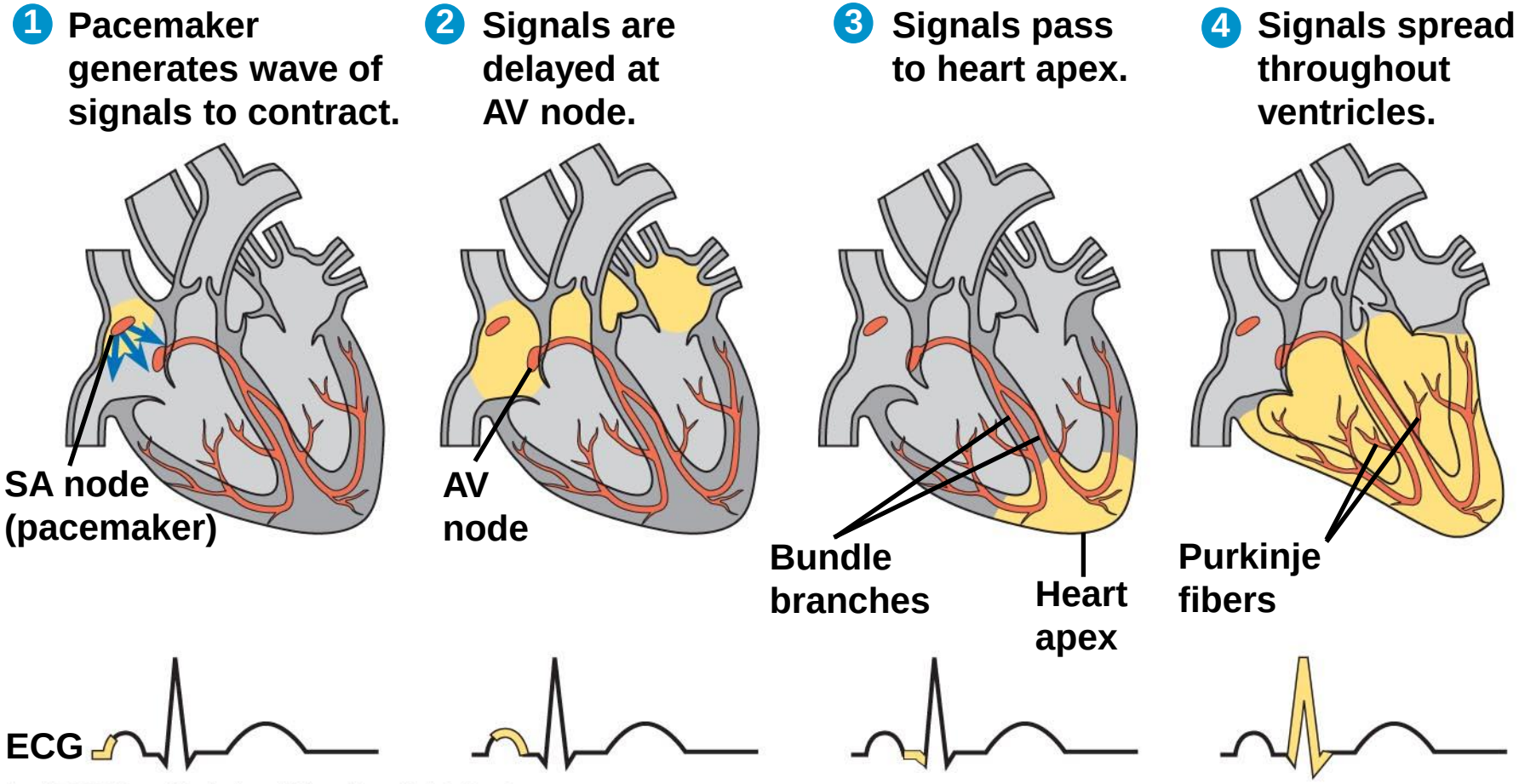


Fig. 42-9-5



- **The pacemaker is influenced by nerves, hormones (i.e., epinephrine), body temperature, and exercise**
- **An increase of body temperature by 1C, increases heart rate by 10 beats /min**

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

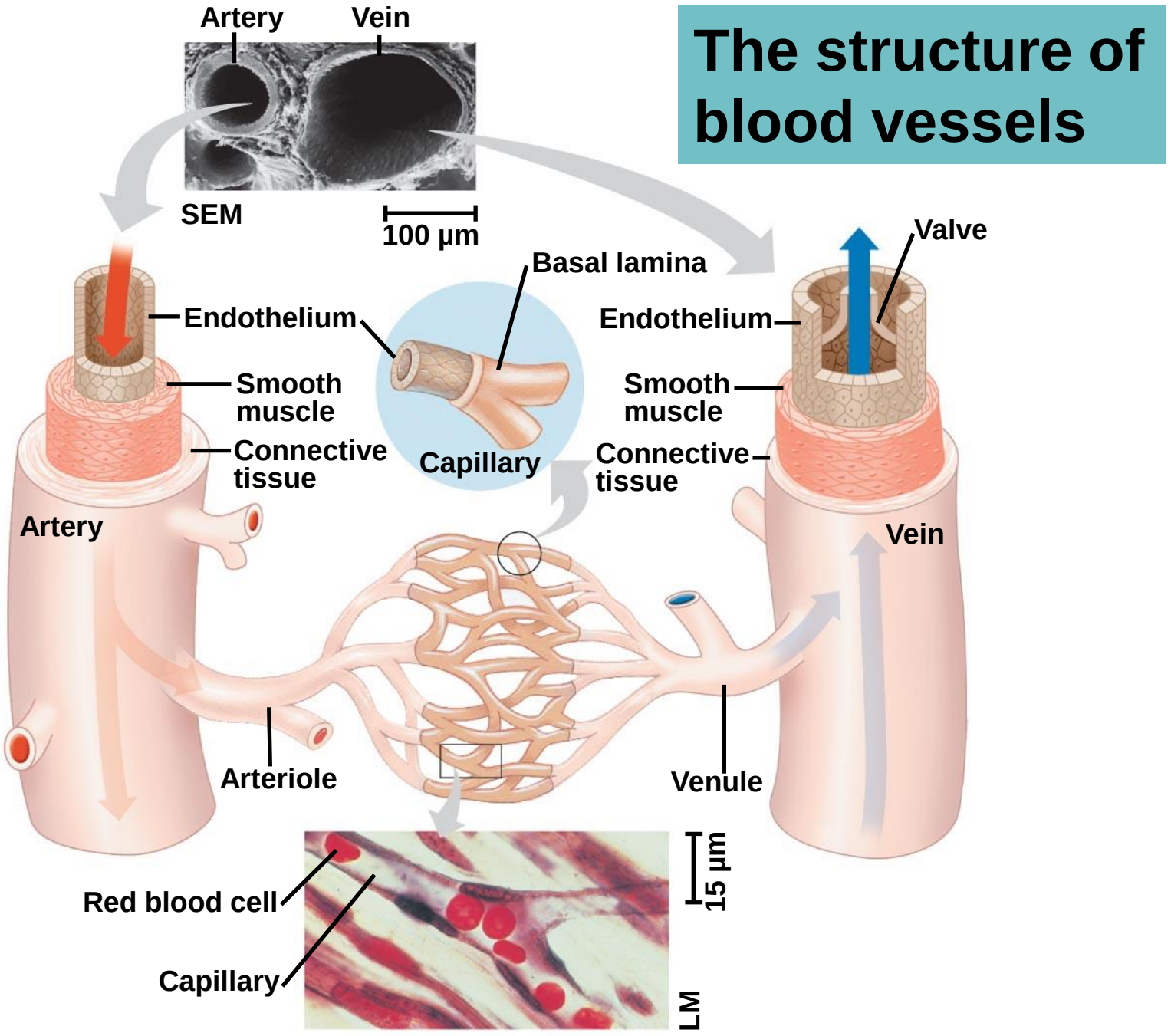
- **The physical principles that govern movement of water in plumbing systems also influence the functioning of animal circulatory systems**

Blood Vessel Structure and Function

- The epithelial layer that lines blood vessels is called the **endothelium** بطانة الأوعية الدموية

Fig. 42-10

The structure of blood vessels



- **Capillaries have thin walls, the endothelium plus its basement membrane, to facilitate the exchange of materials**

- **Arteries and veins have an endothelium, smooth muscle, and connective tissue**

- **Arteries شرّايين 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**

Blood Flow Velocity

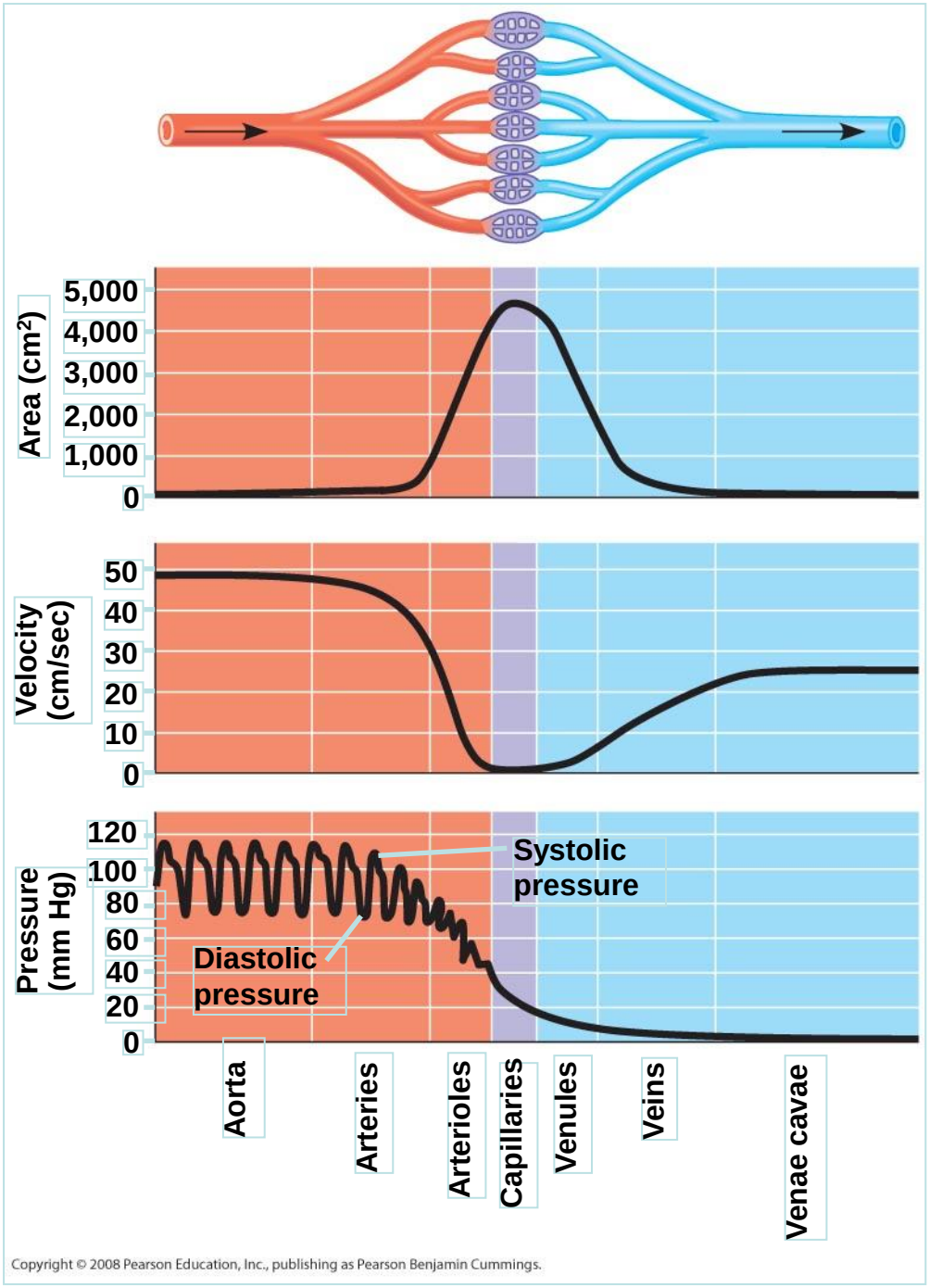
- **Physical laws governing movement of fluids through pipes affect blood flow and blood pressure**

- **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**

Fig. 42-11

The interrelationship of cross-sectional area of blood vessels, blood flow velocity, and blood pressure



Blood Pressure

- **Blood pressure is the hydrostatic pressure that blood exerts against the wall of a vessel**

BLOOD PRESSURE CATEGORY	SYSTOLIC mm Hg (upper number)		DIASTOLIC mm Hg (lower number)
NORMAL	LESS THAN 120	and	LESS THAN 80
ELEVATED	120 – 129	and	LESS THAN 80
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 1	130 – 139	or	80 – 89
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 2	140 OR HIGHER	or	90 OR HIGHER
HYPERTENSIVE CRISIS (consult your doctor immediately)	HIGHER THAN 180	and/or	HIGHER THAN 120

Changes in Blood Pressure During the Cardiac Cycle

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

Regulation of Blood Pressure

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

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**

Fig. 42-13-1

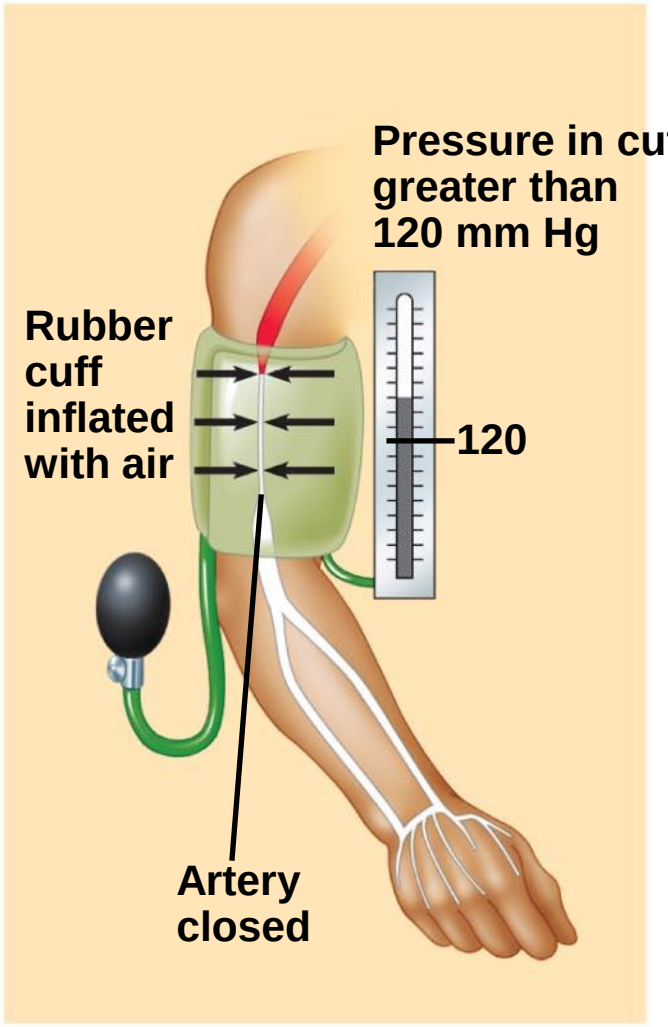


Fig. 42-13-2

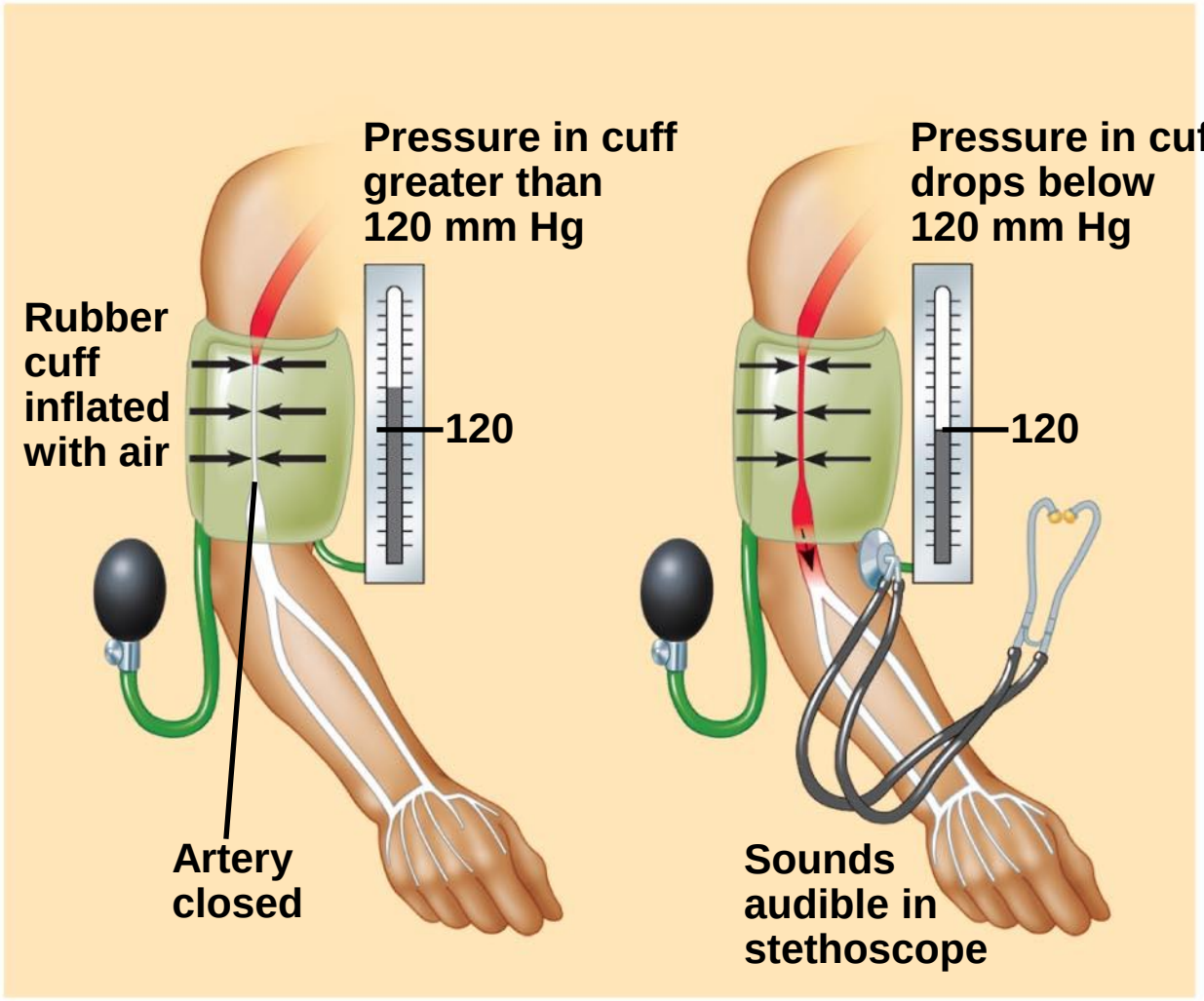


Fig. 42-13-3

Measurement of blood pressure

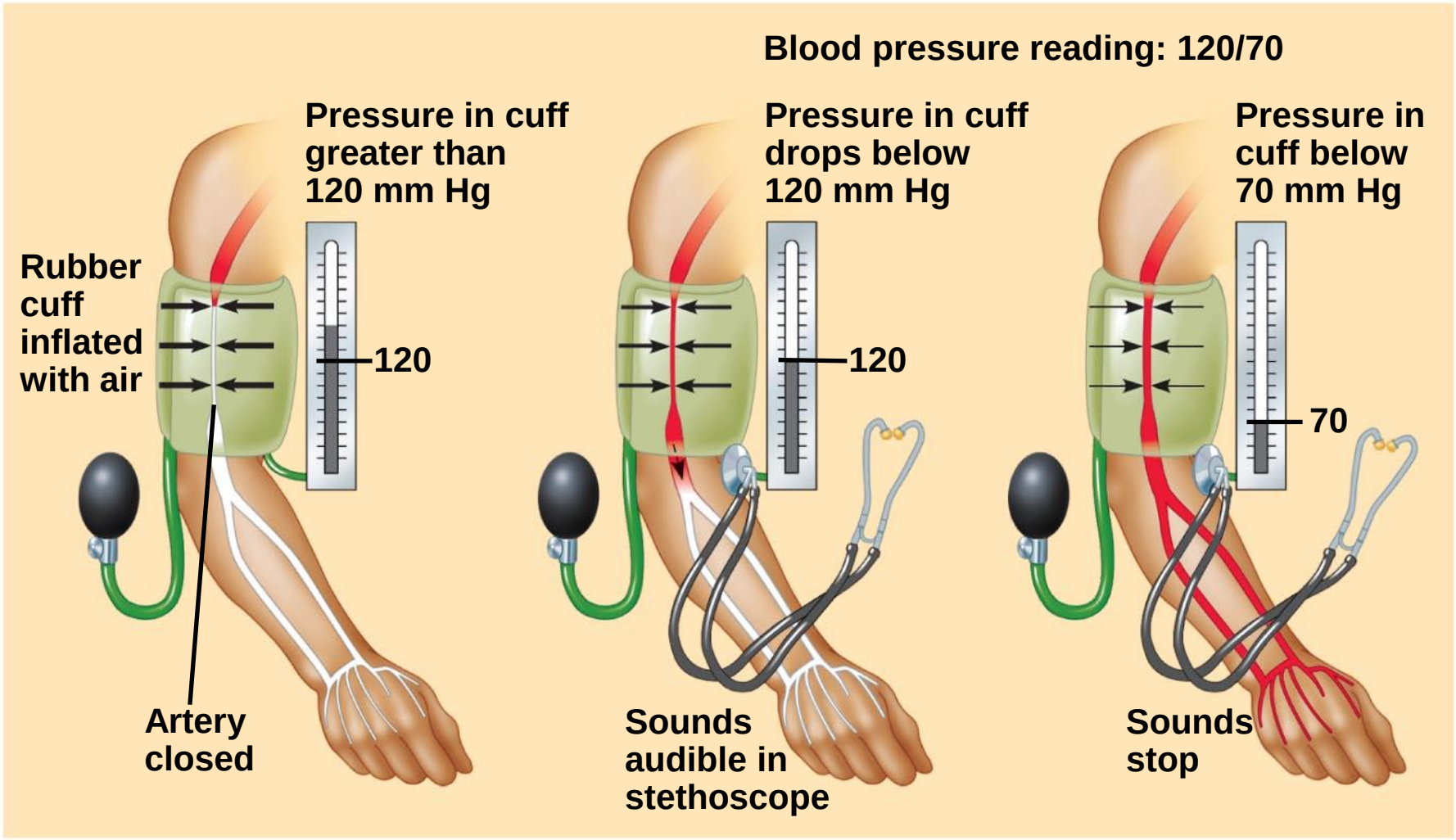
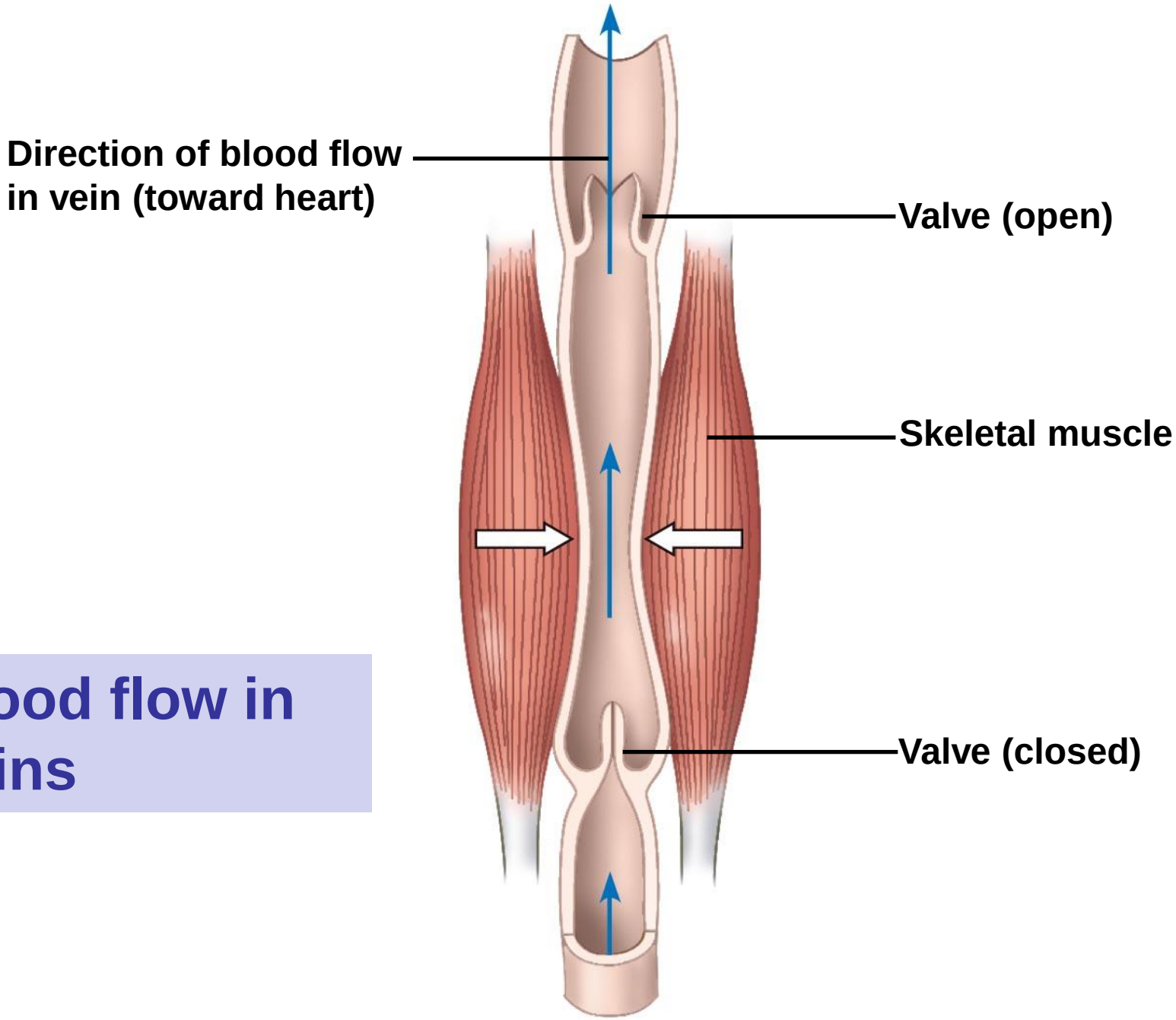


Fig. 42-14



Blood flow in veins

Capillary Function

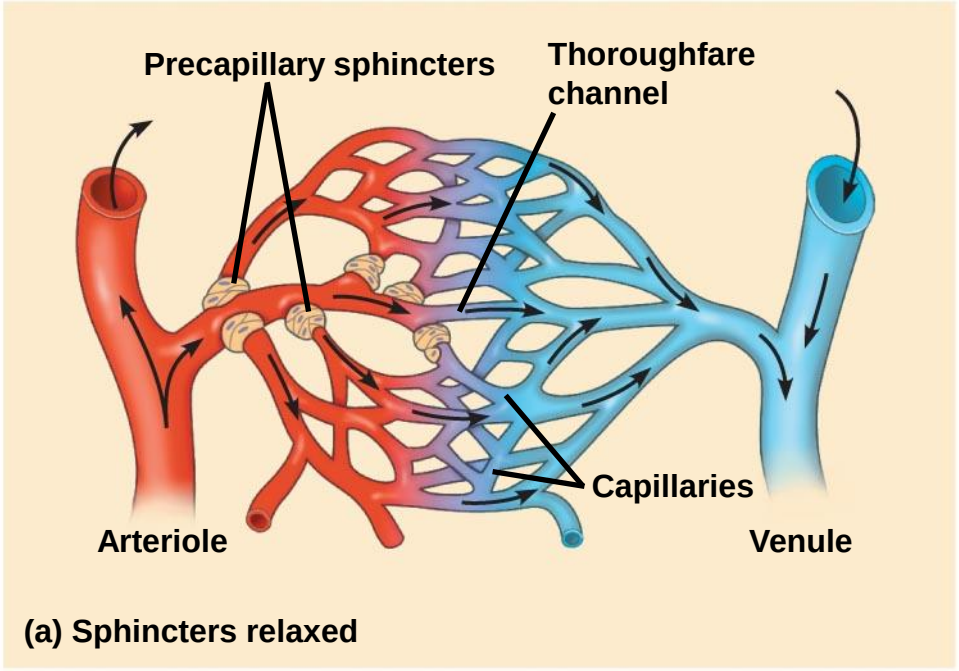
- **Capillaries in major organs are <u>usually filled to capacity</u>**

- **Blood supply varies in many other sites**

- **Two mechanisms regulate distribution of blood in capillary beds:**
  - **Contraction of the smooth muscle layer in the wall of an arteriole constricts يقلّص the vessel**
  - **Precapillary sphincters المَصرَّةُ قَبْلَ الشُّعَيريَّة control flow of blood between arterioles شُرَيْنات and venules الوُرَيداتُ**

Fig. 42-15

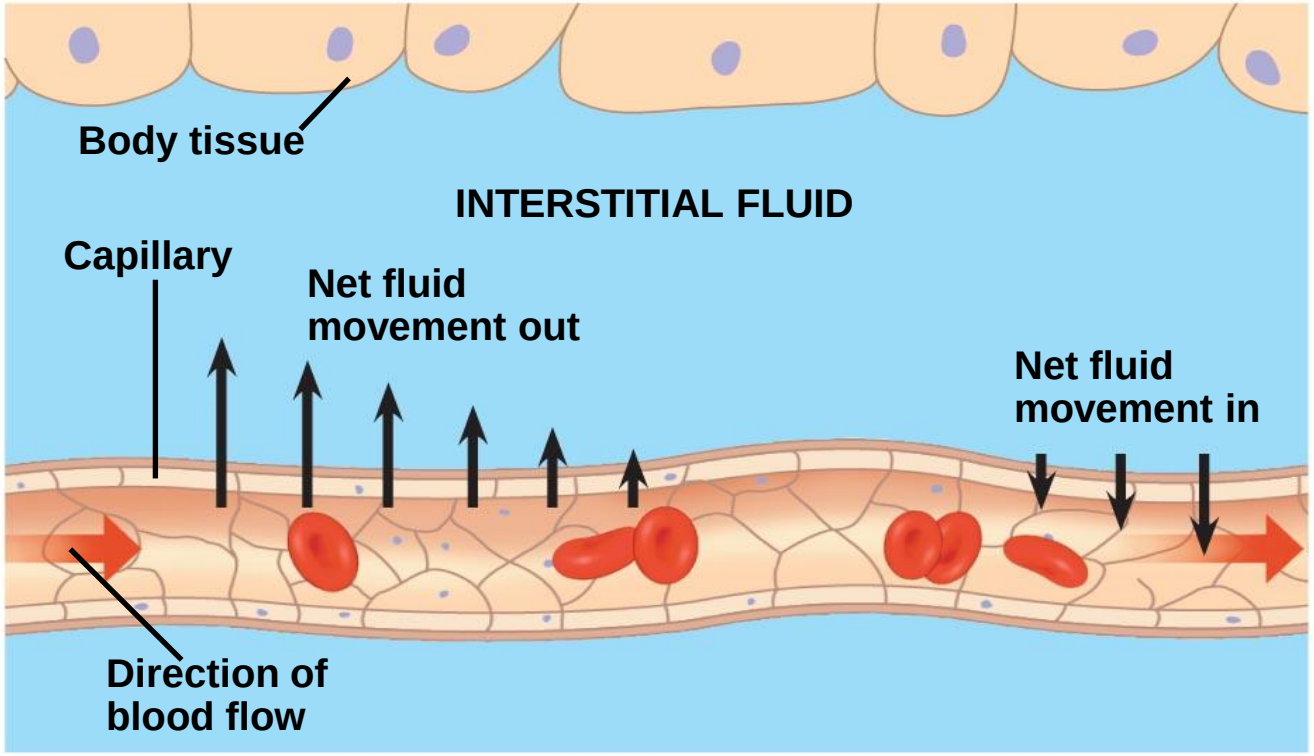
Blood flow in capillary beds



- **The critical exchange of substances between the blood and interstitial fluid takes place across the thin endothelial walls of the capillaries**

Fig. 42-16

Fluid exchange between capillaries and the interstitial fluid



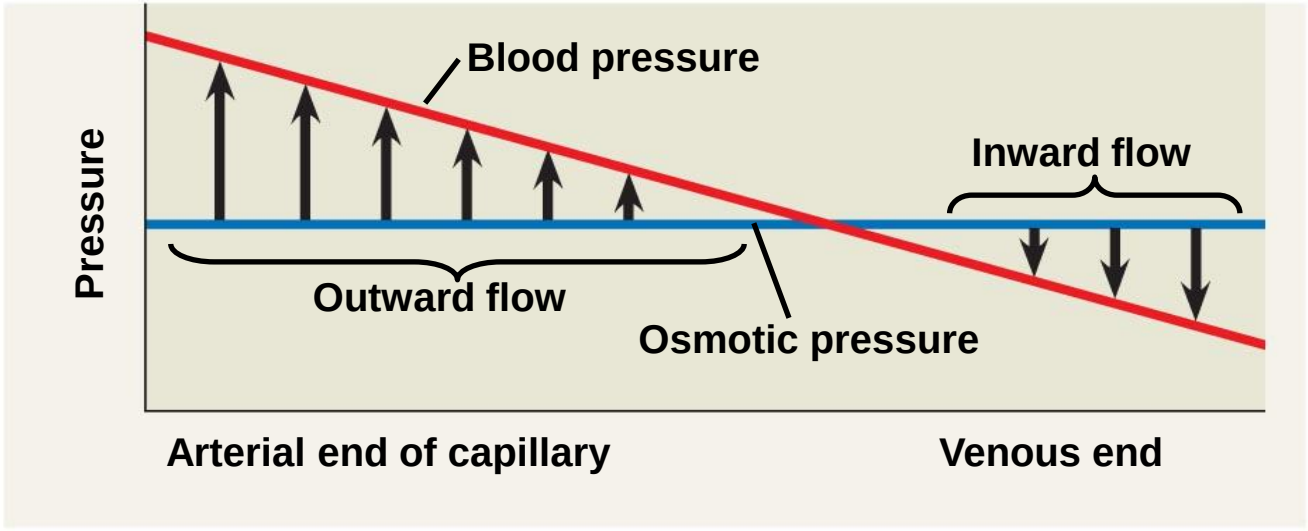


Fig. 42-16a

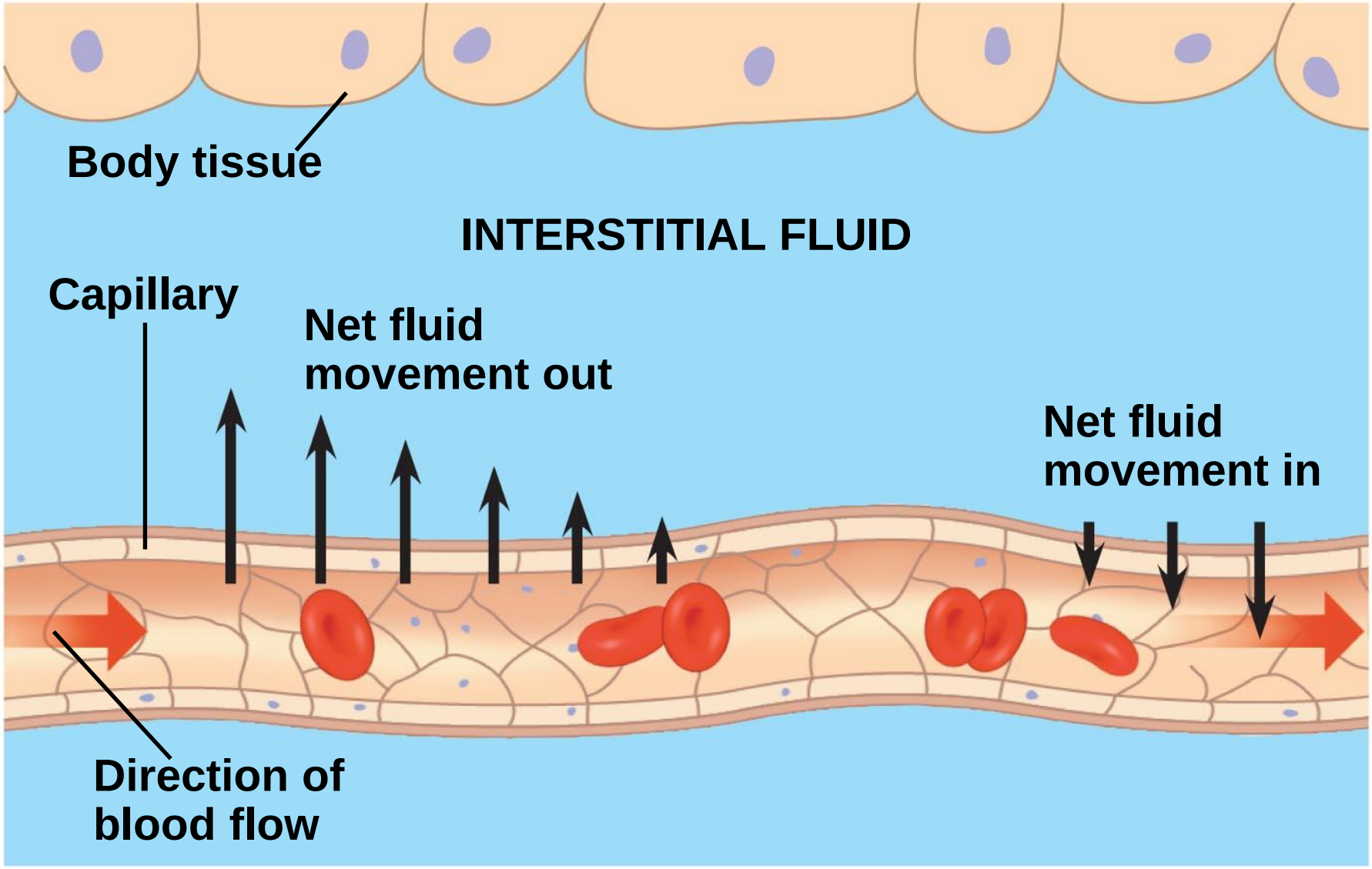
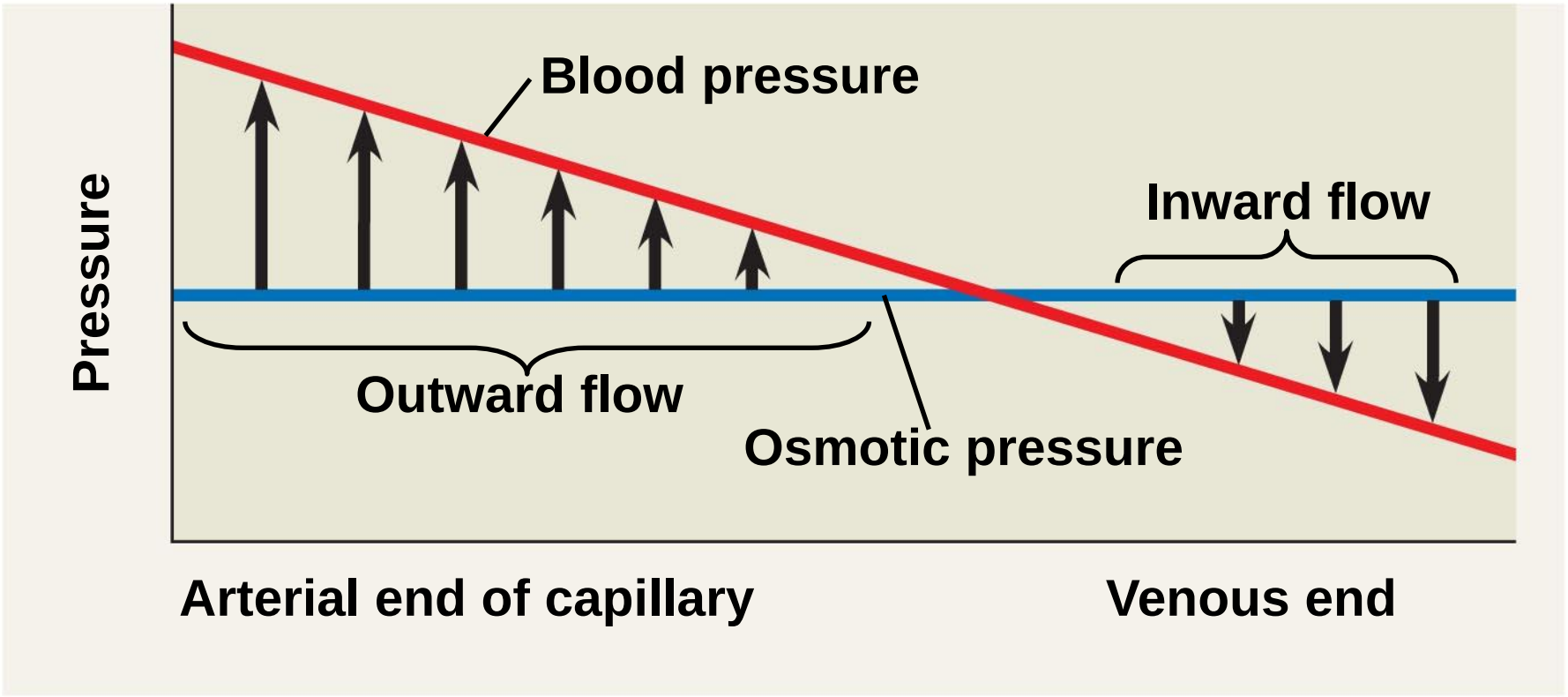


Fig. 42-16b



Fluid Return by the Lymphatic System

- The **lymphatic system** الجِهازُ اللِّمْفِيّ returns fluid that leaks out in the capillary beds
- This system aids in body defense
- Fluid, called **lymph**, **reenters** the circulation directly at the venous وريدى end of the capillary bed
- The lymphatic system drains into veins in the neck

- **Lymph nodes العقد اللمفاوية are organs that filter lymph and play an important role in the body's defense**

- **Edema اِسْتِسْقاء is swelling caused by disruptions in the flow of lymph**