

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

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- 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

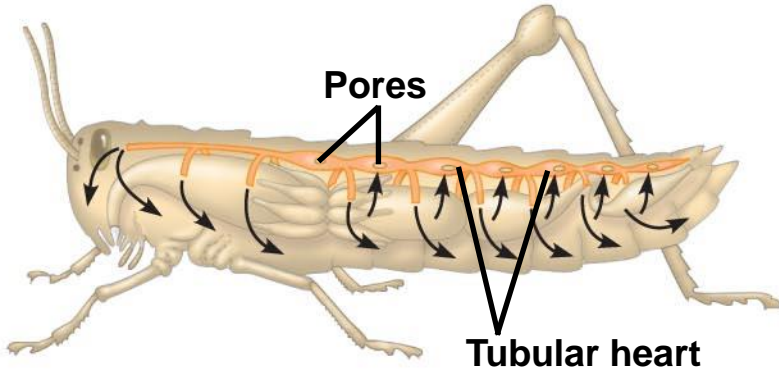
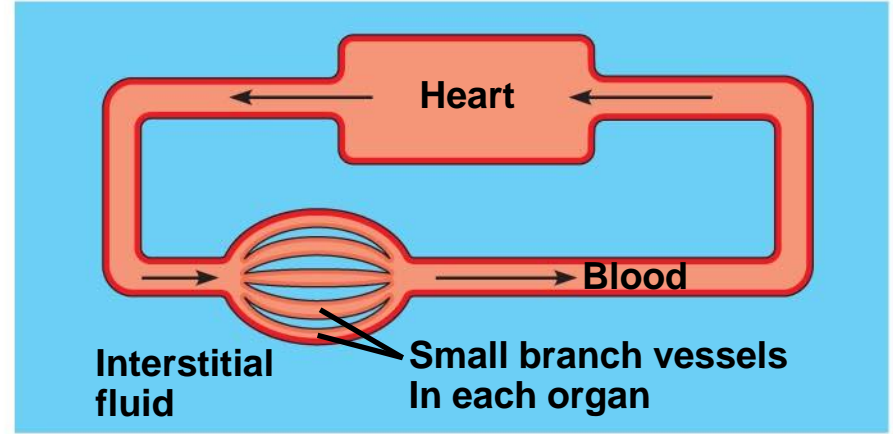
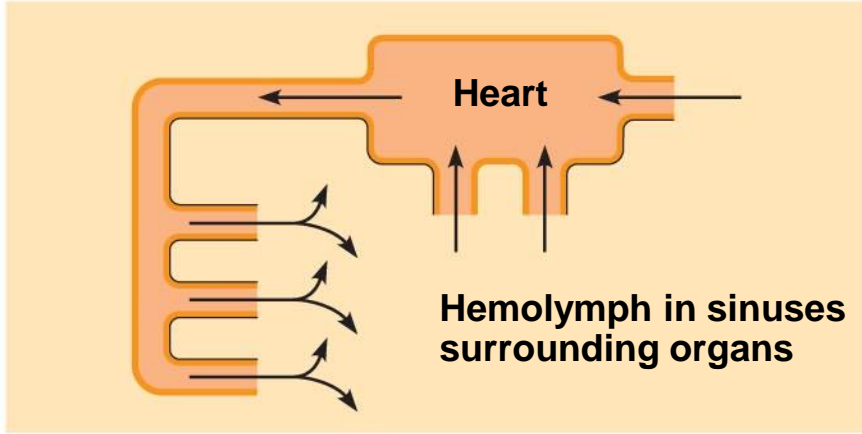
- In most animals, transport systems connect the organs of exchange with the body cells
- Most complex animals have **internal transport systems that circulate fluid**

Open and Closed Circulatory Systems

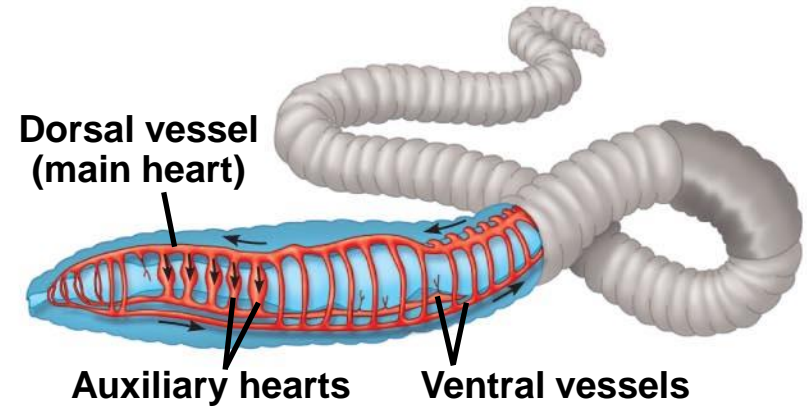
- More complex animals have either open or closed circulatory systems
- Both systems have **three basic components**:
 - A circulatory **fluid** (blood or hemolymph (الدَّمْلَمْف))
 - A set of **tubes** (blood vessels)
 - A muscular **pump** (the heart)

- 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?**

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



(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 شرايين
 - Veins أوردة,
 - and
 - Capillaries الأوعية الشعرية

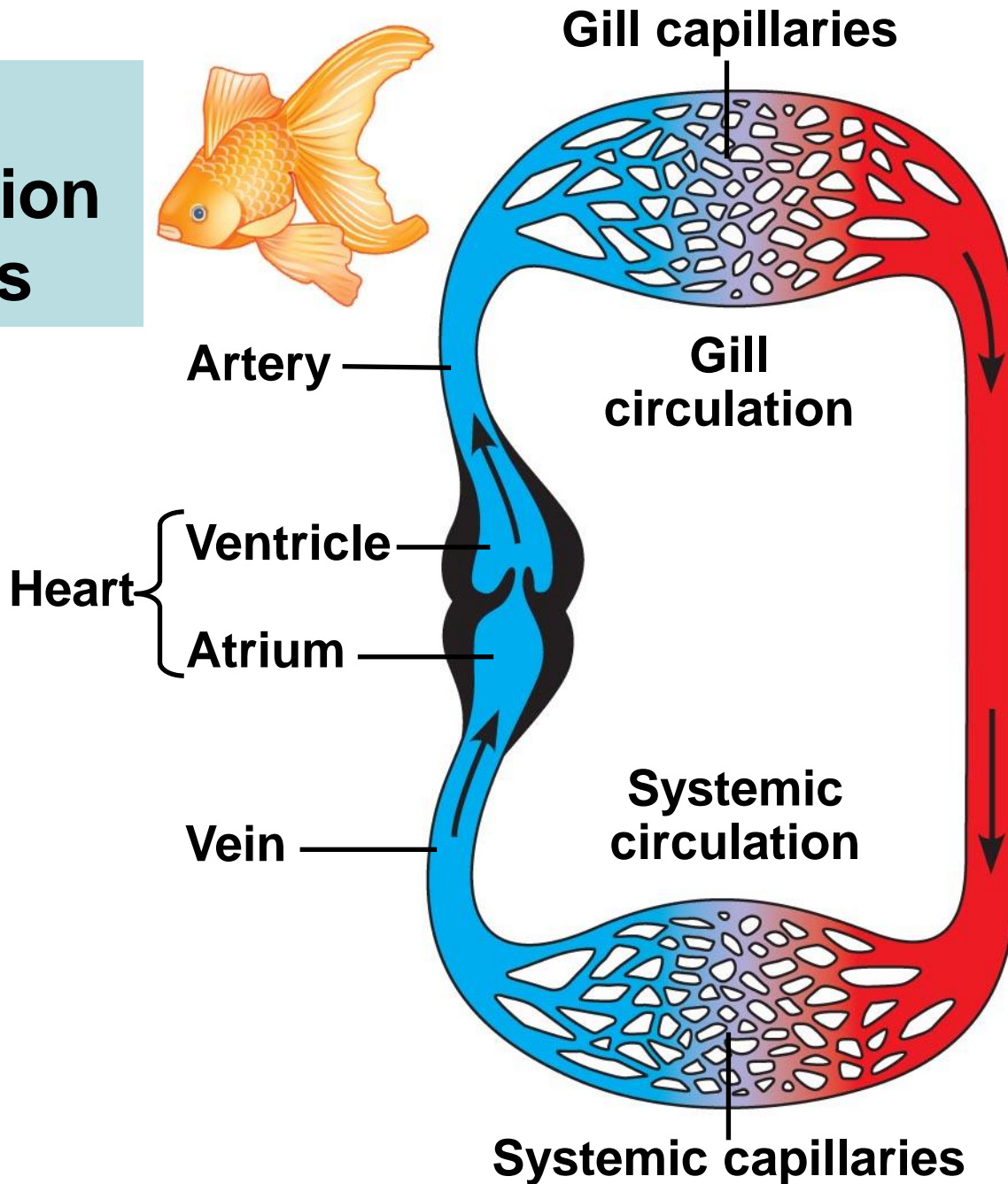
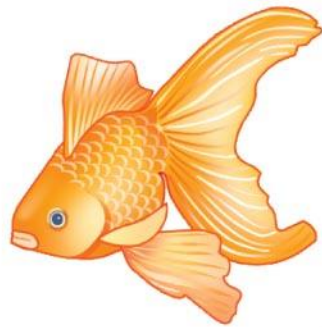
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- **Arteries** branch into **arterioles** **شُرَيْنَات** and carry blood to **capillaries**
 - Networks of capillaries called **capillary beds** are the sites of chemical exchange between the blood and interstitial fluid
 - **Venules** **الْوَرِيدَاتُ**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

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- Vertebrate hearts contain two or more chambers
 - Blood enters through an **atrium** أُذَيْن and is pumped out through a **ventricle** بَطِين

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

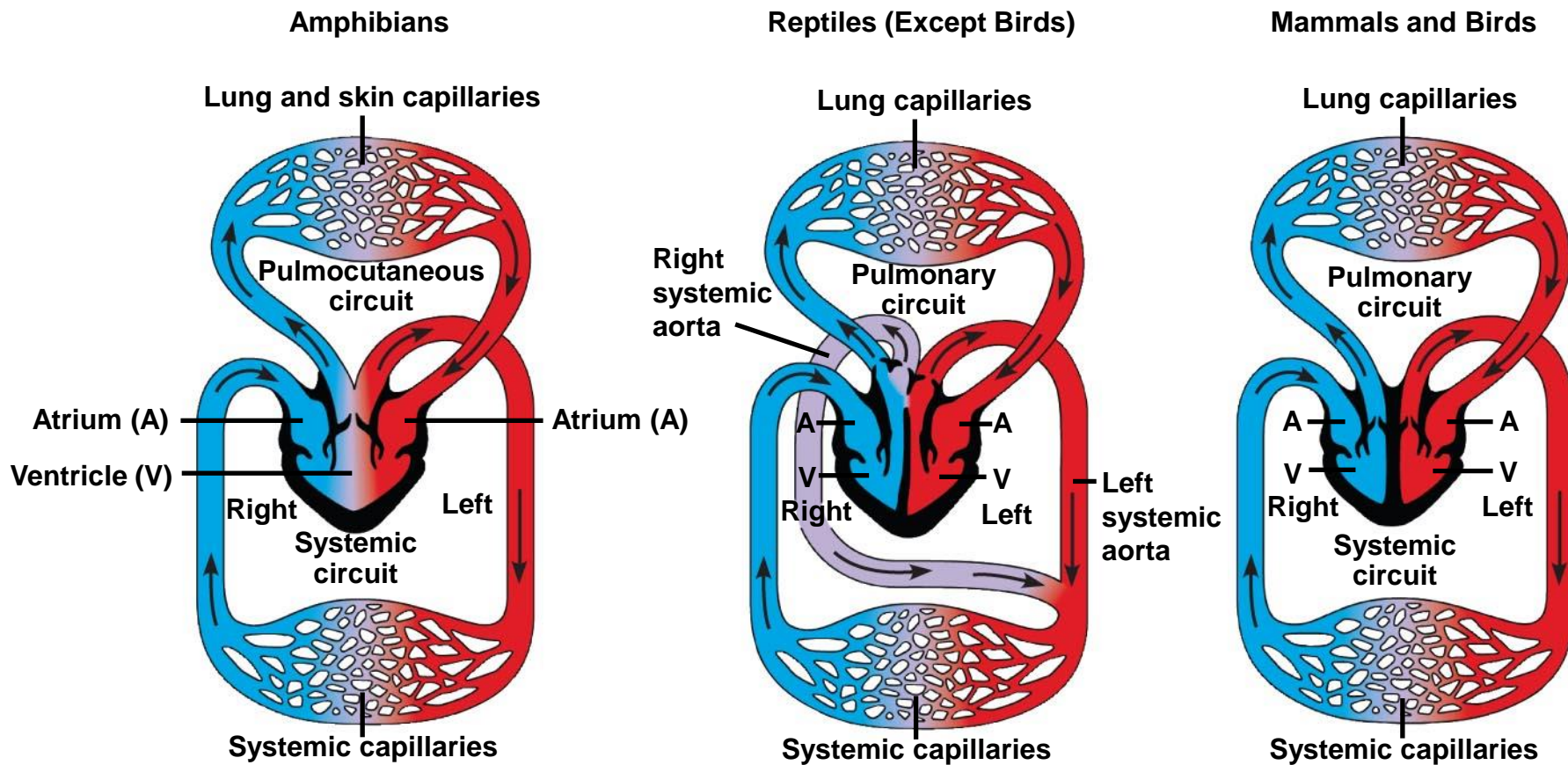
Single circulation in fishes



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



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- 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 جهازى 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 O₂**

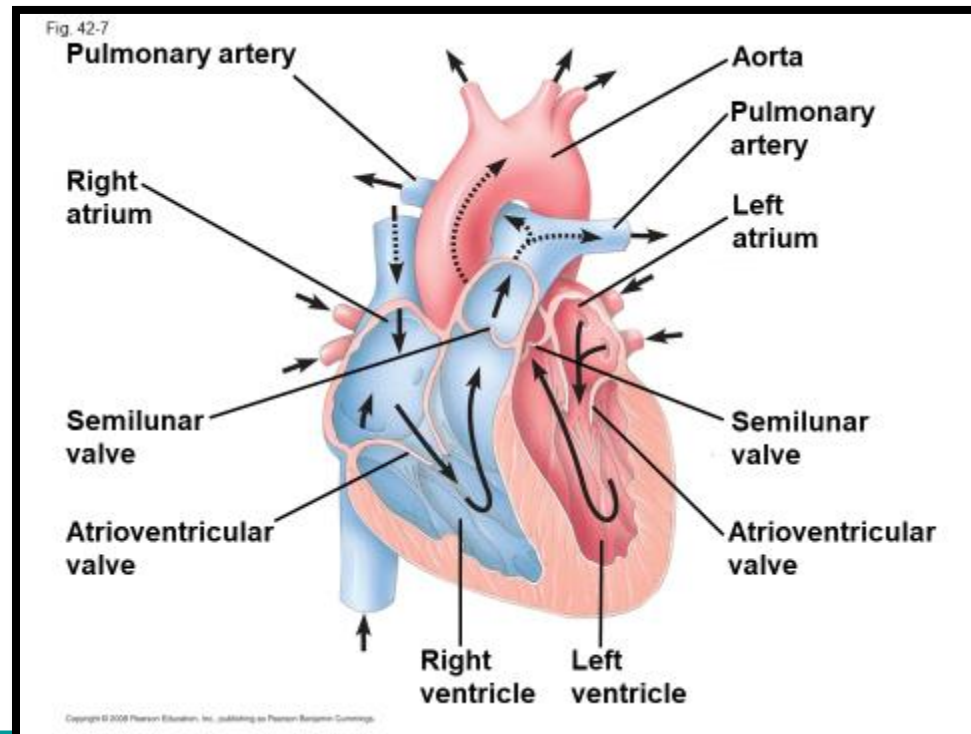


Fig. 42-7

Pulmonary artery

Aorta

Right atrium

Pulmonary artery

Left atrium

Semilunar valve

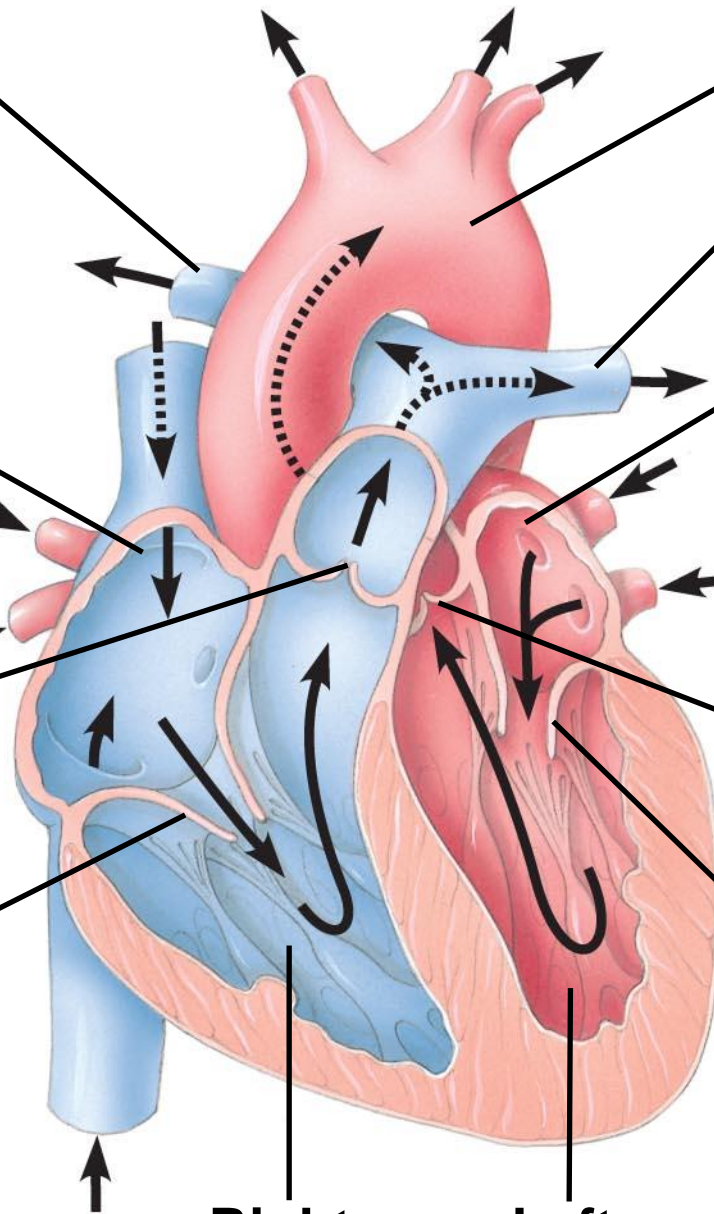
Semilunar valve

Atrioventricular valve

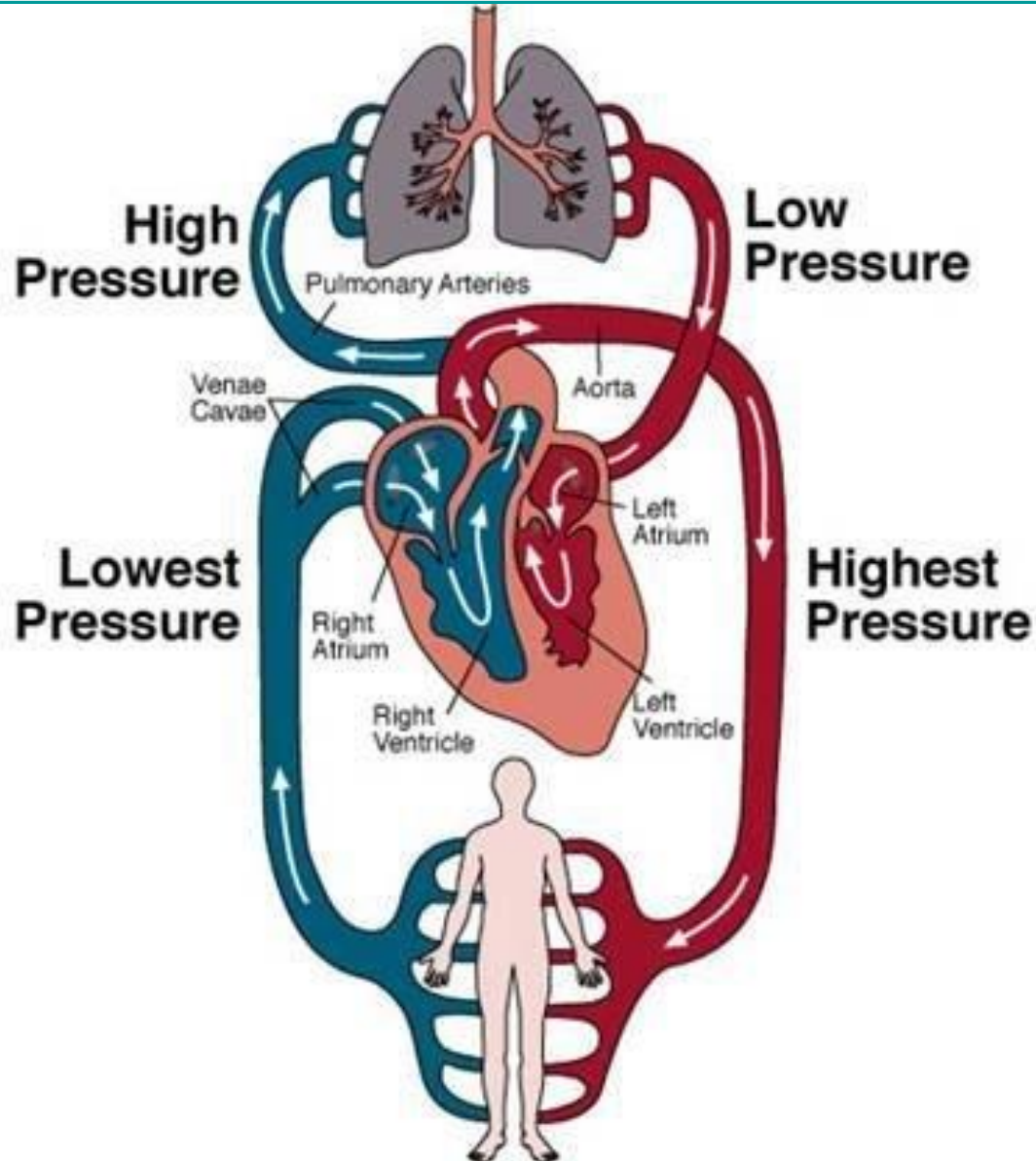
Atrioventricular valve

Right ventricle

Left ventricle

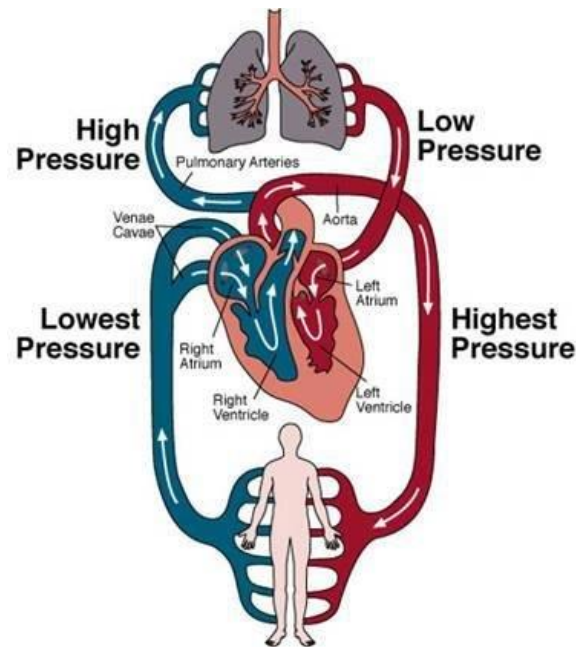


Mammalian Circulation

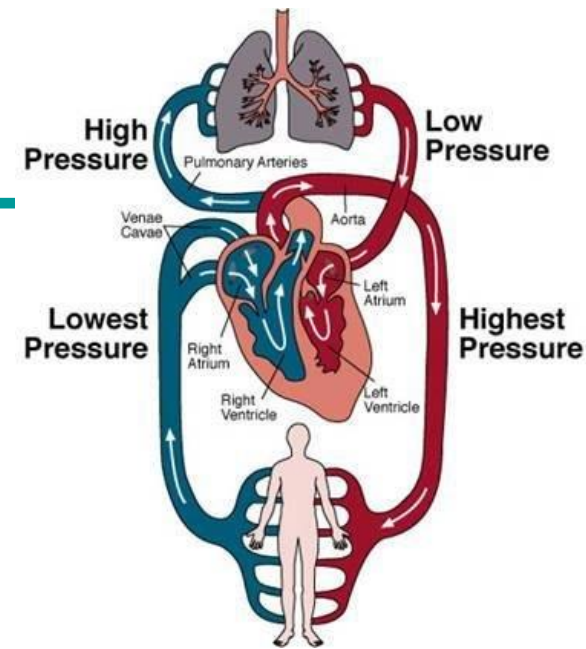


Mammalian Circulation

- 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

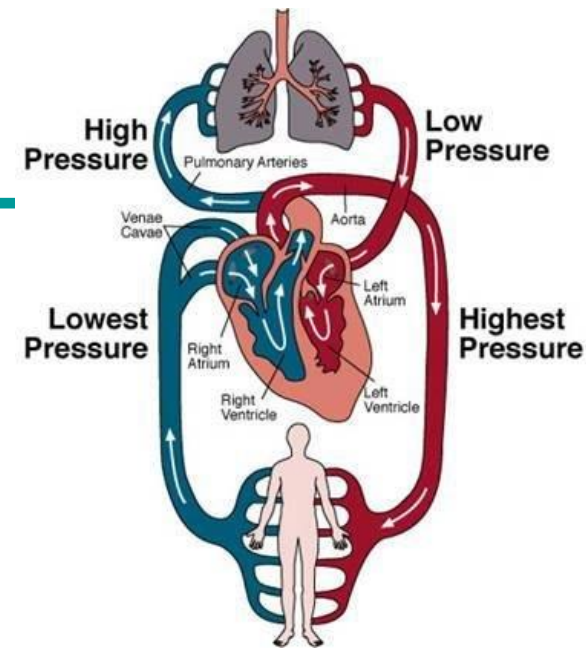
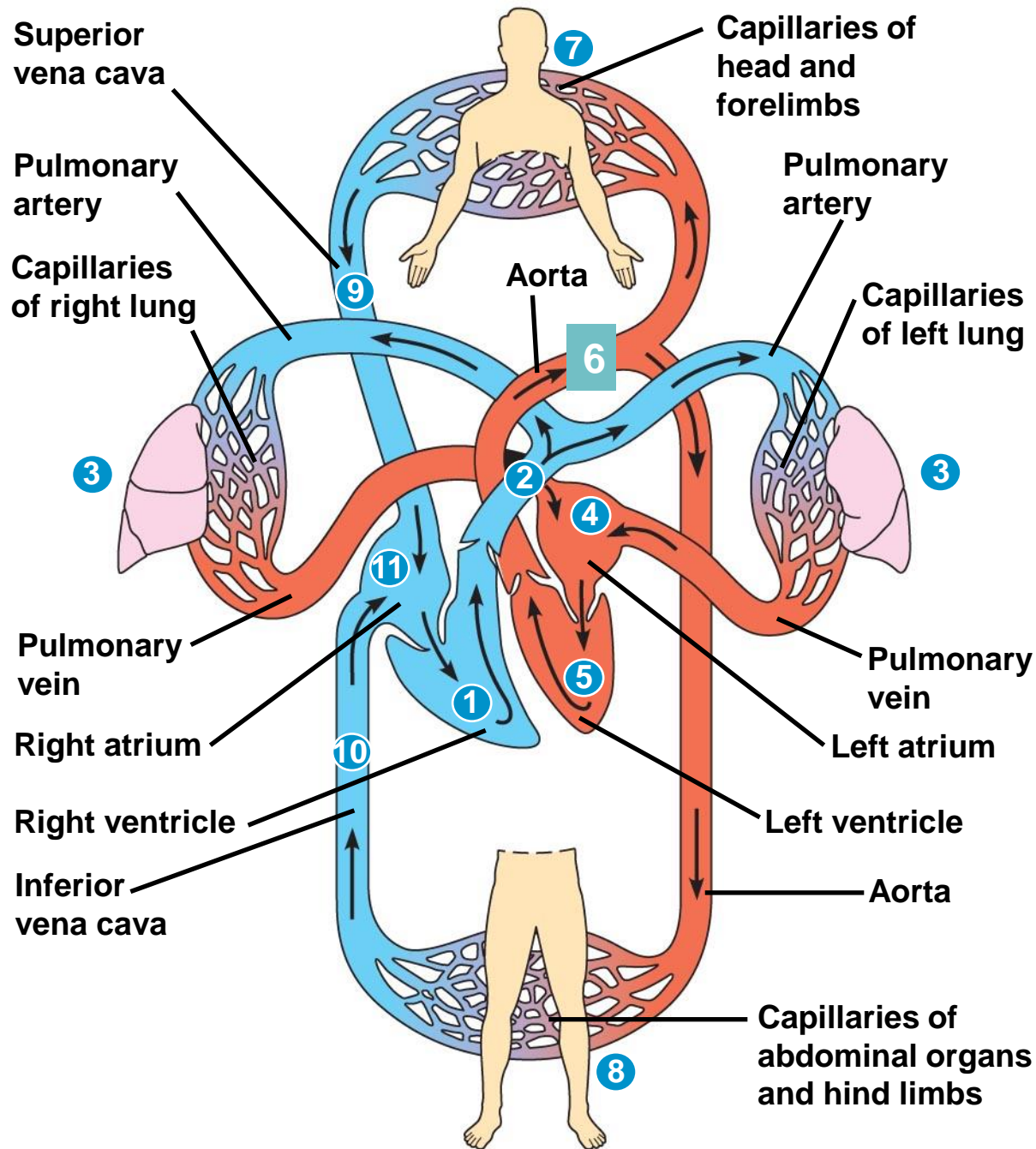
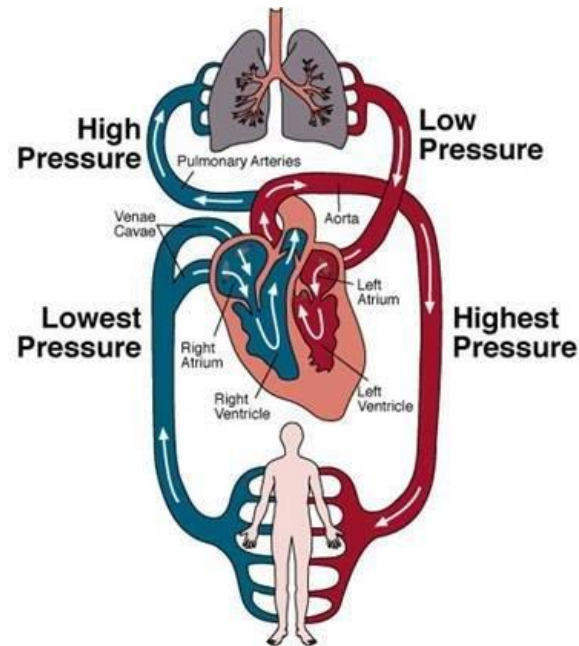


Fig. 42-6

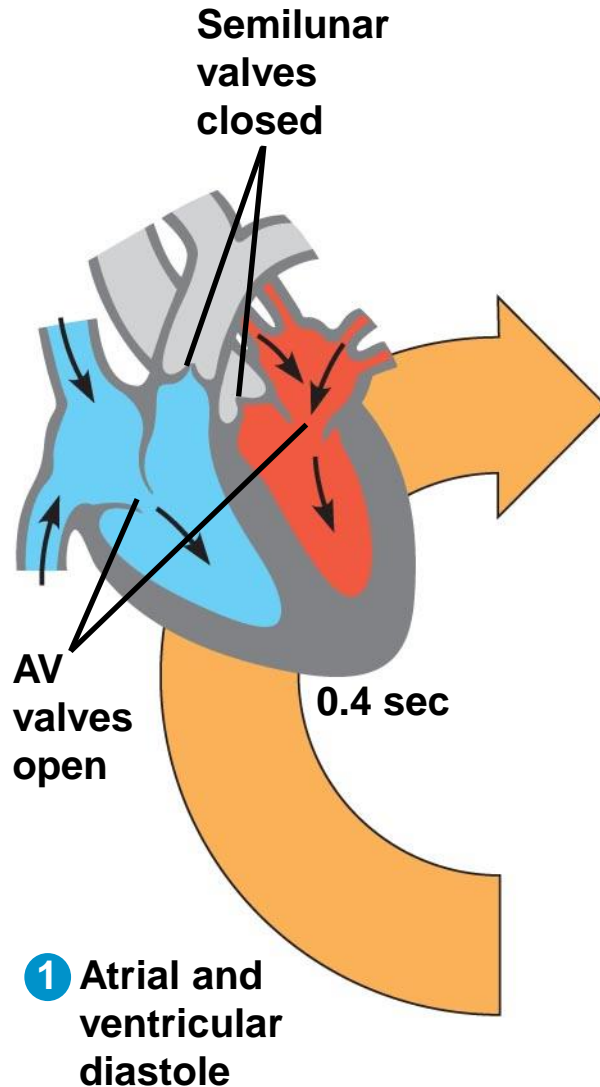


The Mammalian Heart: *A Closer Look*

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



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



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

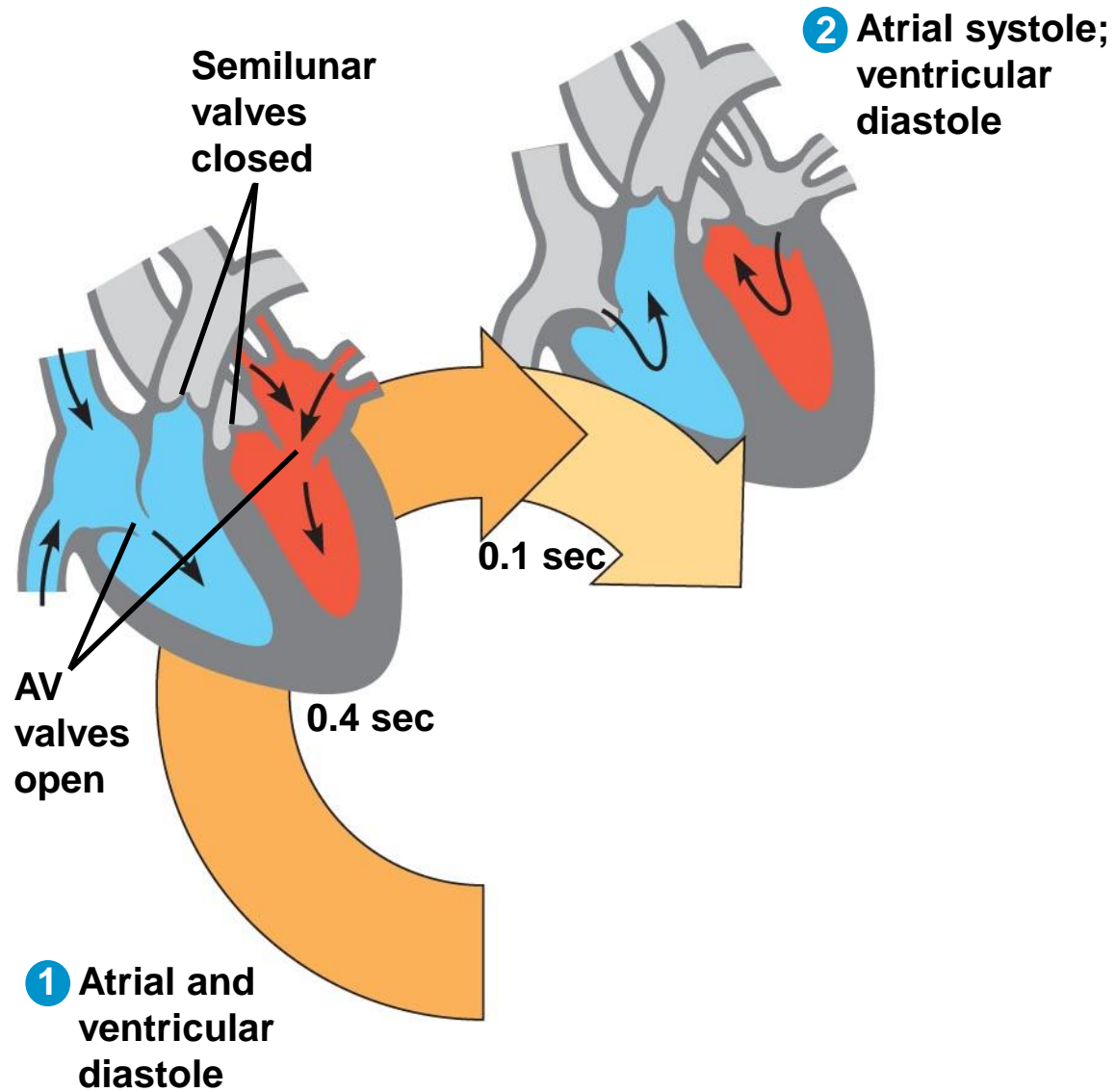
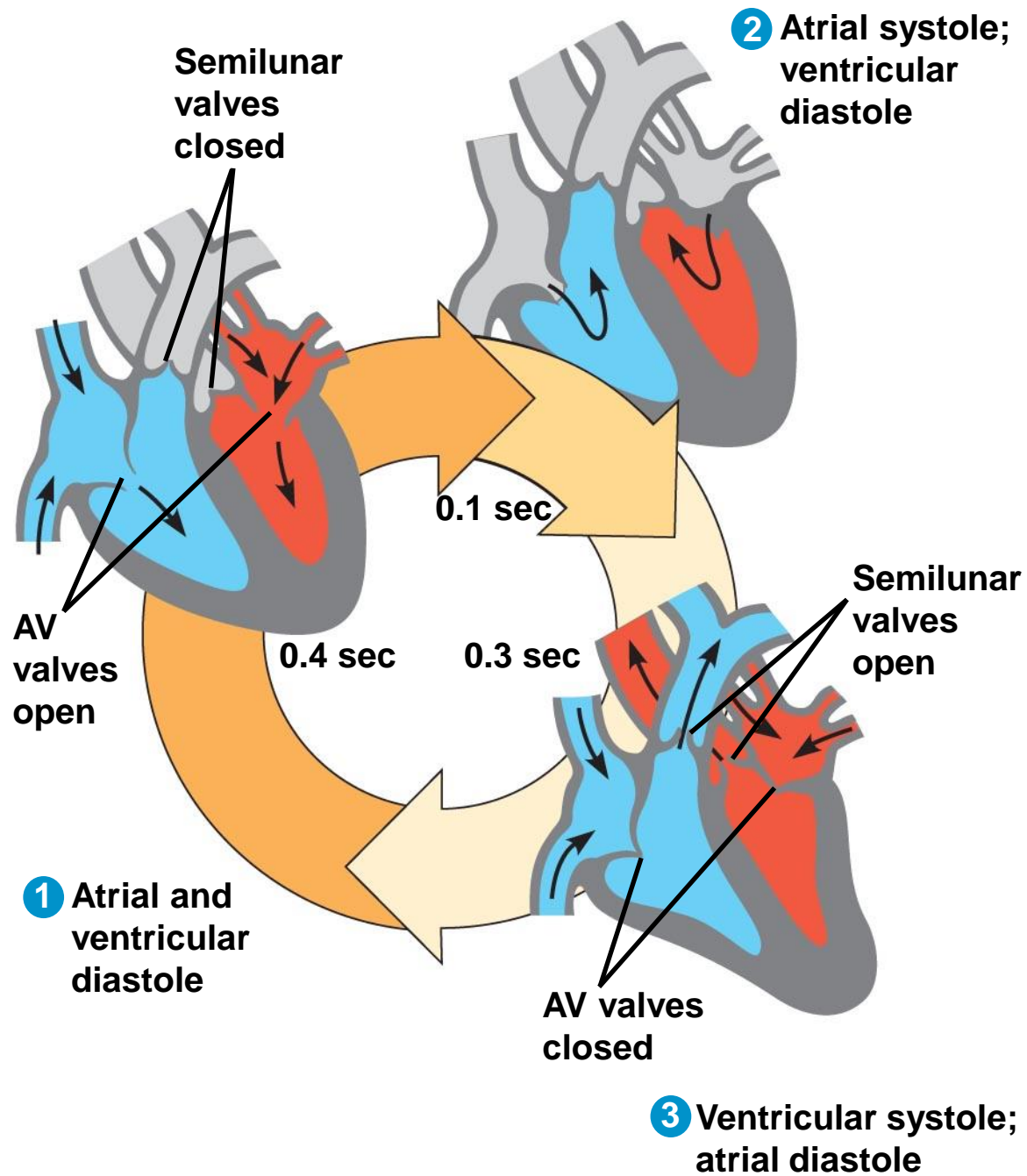


Fig. 42-8



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

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

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- 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 قَلْبِيَّةٌ

Maintaining the Heart's Rhythmic Beat

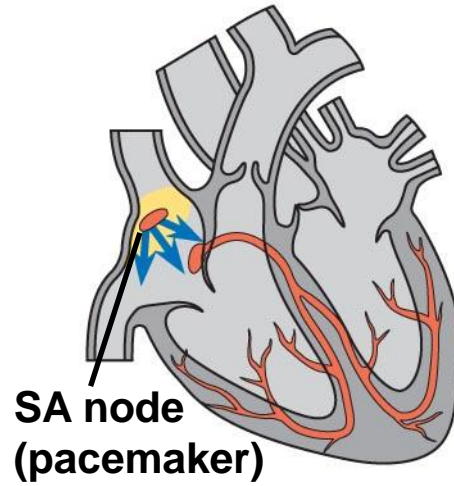
- Some cardiac muscle cells are **self-excitabile**, meaning they contract without any signal from the nervous system

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- The **sinoatrial (SA) node** **العُقْدَةُ الجَيْبِيَّةُ** **الأذينية** , 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 الأذينية** **البطينية**
 - At the AV node, the impulses are delayed and then travel to the Purkinje fibers that make the ventricles contract
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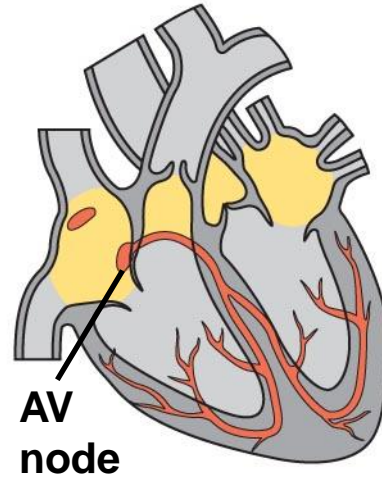
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- **Impulses that travel during the cardiac cycle can be recorded as an electrocardiogram (ECG or EKG)**

مخطط كهربائي للقلب

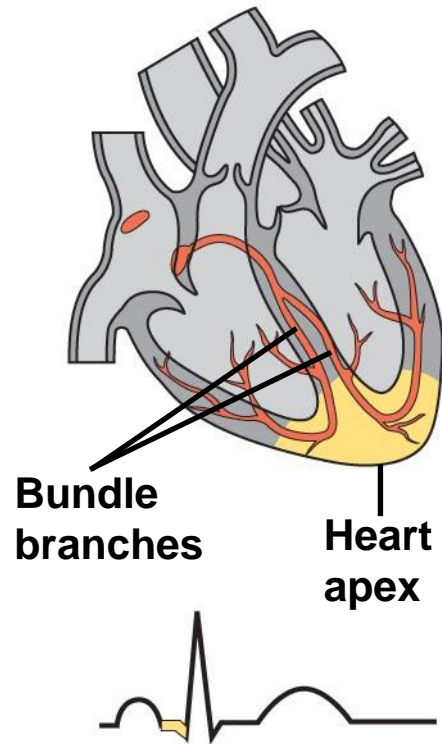
- 1 Pacemaker generates wave of signals to contract.**



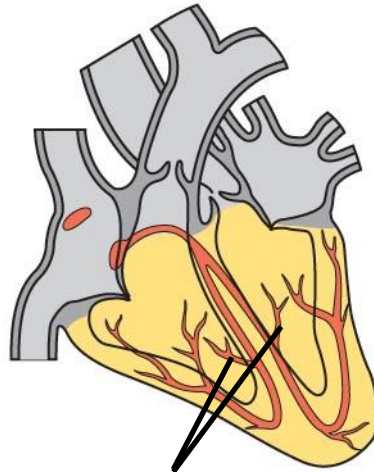
- 2 Signals are delayed at AV node.



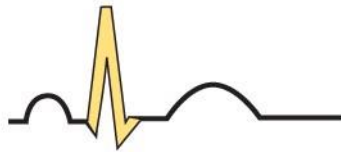
3 Signals pass to heart apex.



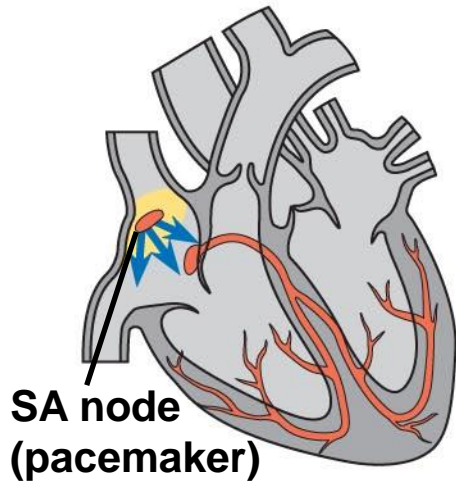
4 Signals spread throughout ventricles.



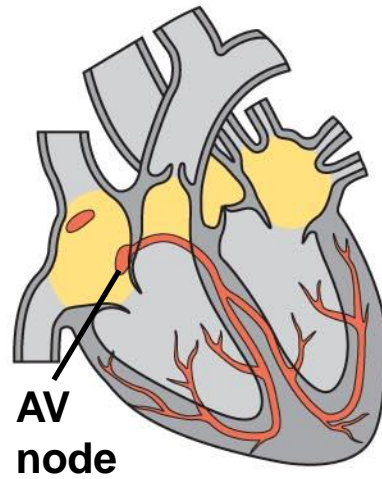
**Purkinje
fibers**



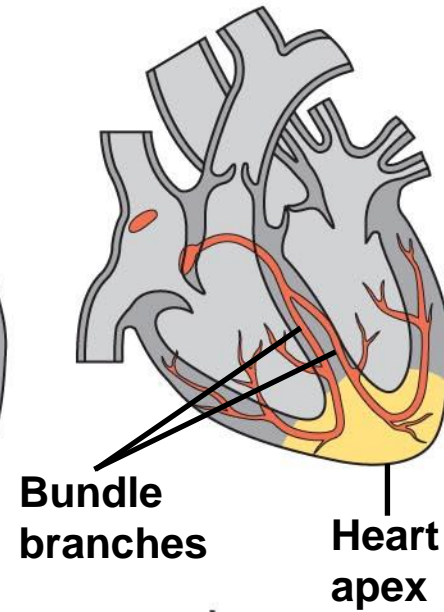
1 Pacemaker generates wave of signals to contract.



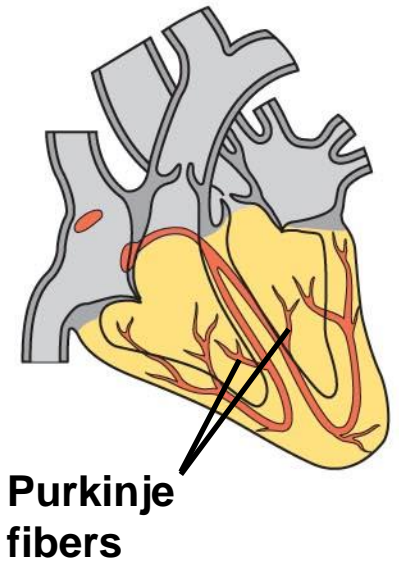
2 Signals are delayed at AV node.



3 Signals pass to heart apex.



4 Signals spread throughout ventricles.



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- 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

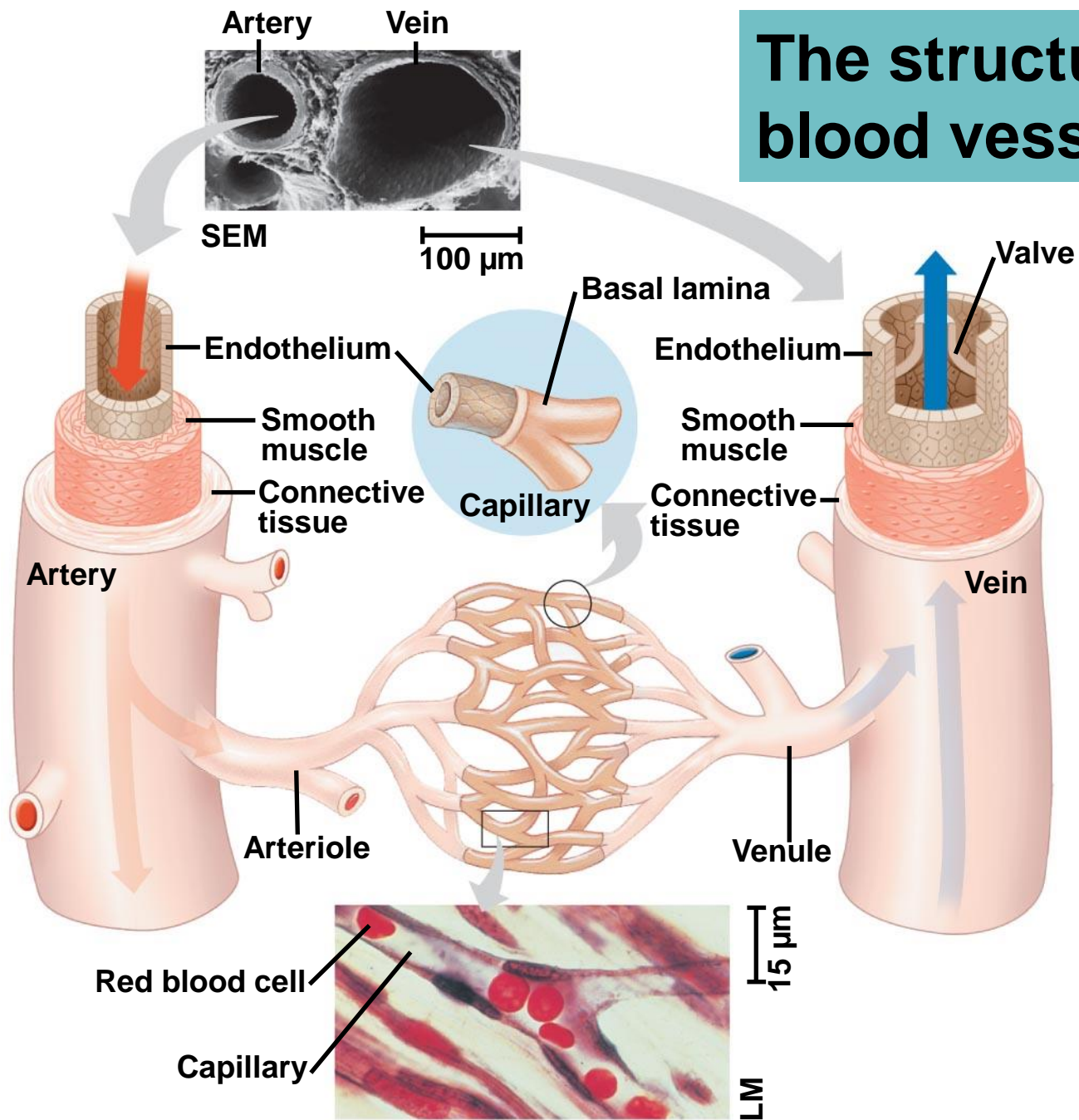
- The physical principles that govern movement of water in plumbing systems also influence the functioning of animal circulatory systems

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



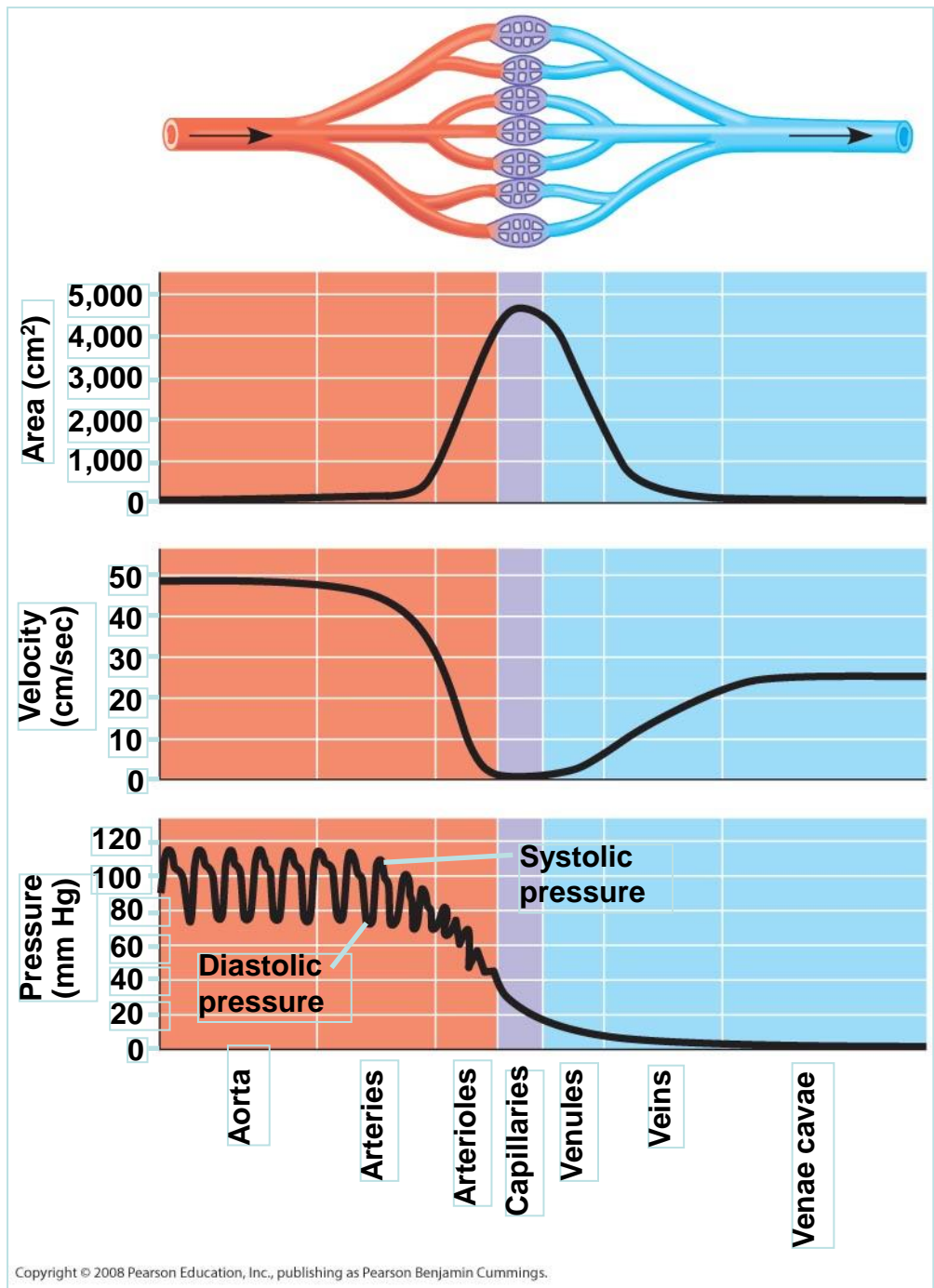
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- **Capillaries** have thin walls, the endothelium plus its **basement membrane**, to facilitate the exchange of materials
 - Arteries and veins have an endothelium, smooth muscle, and connective tissue

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- **Arteries شرايين 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

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** **انقباض**; it is the **highest** pressure in the **arteries** **بطيني**
- **Diastolic pressure** **الضغط الانبساطي** 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 تَضْيِيق of arterioles
- **Vasoconstriction** تَضْيِيق الأوعية is the contraction of smooth muscle in arteriole walls; it increases blood pressure
- **Vasodilation** تَوْسُّع الأوعية 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

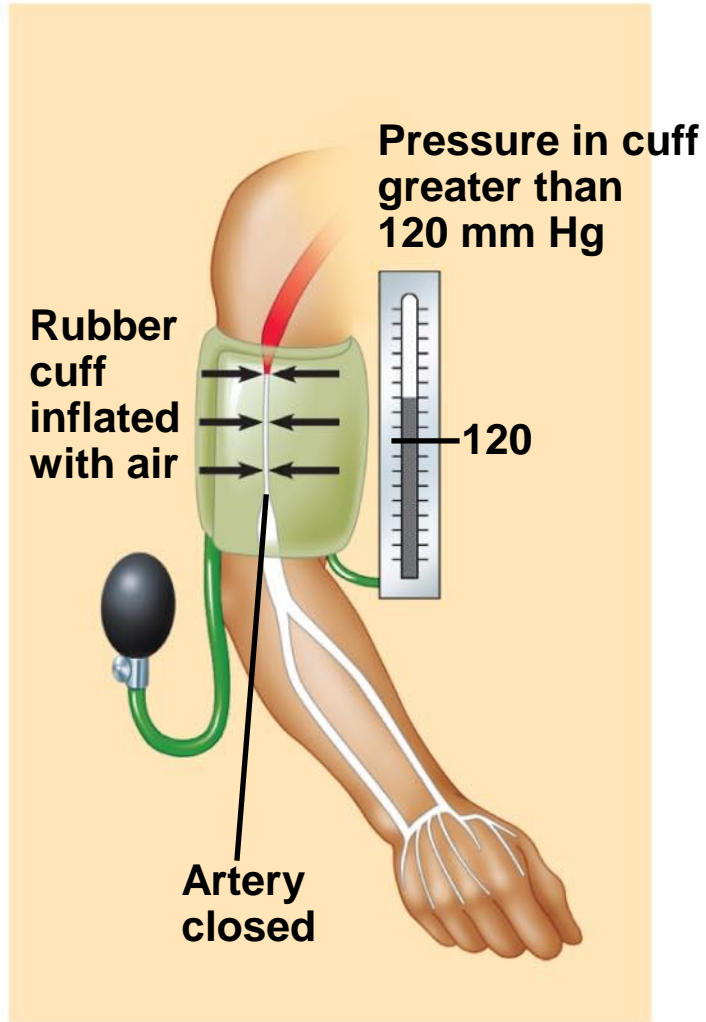
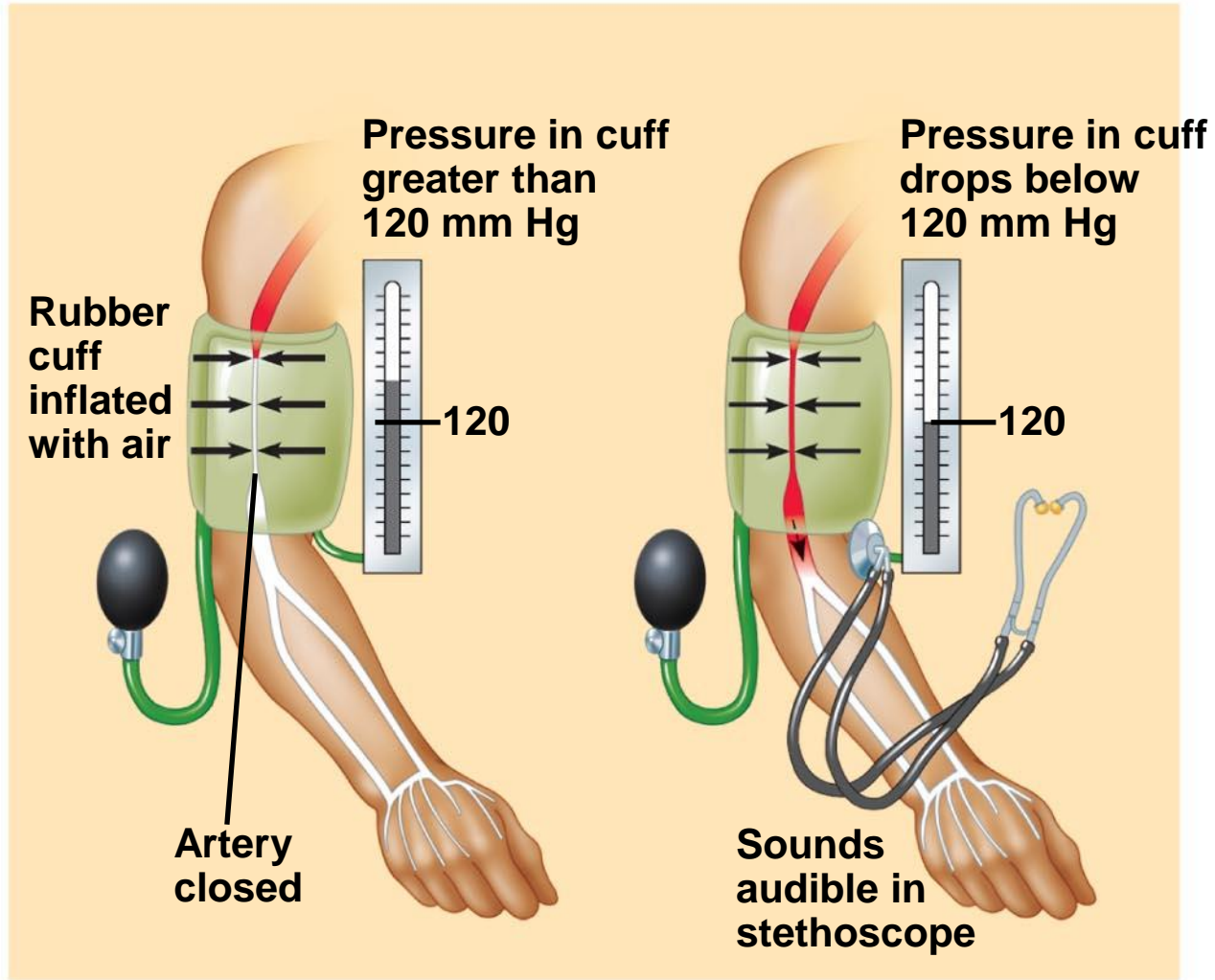
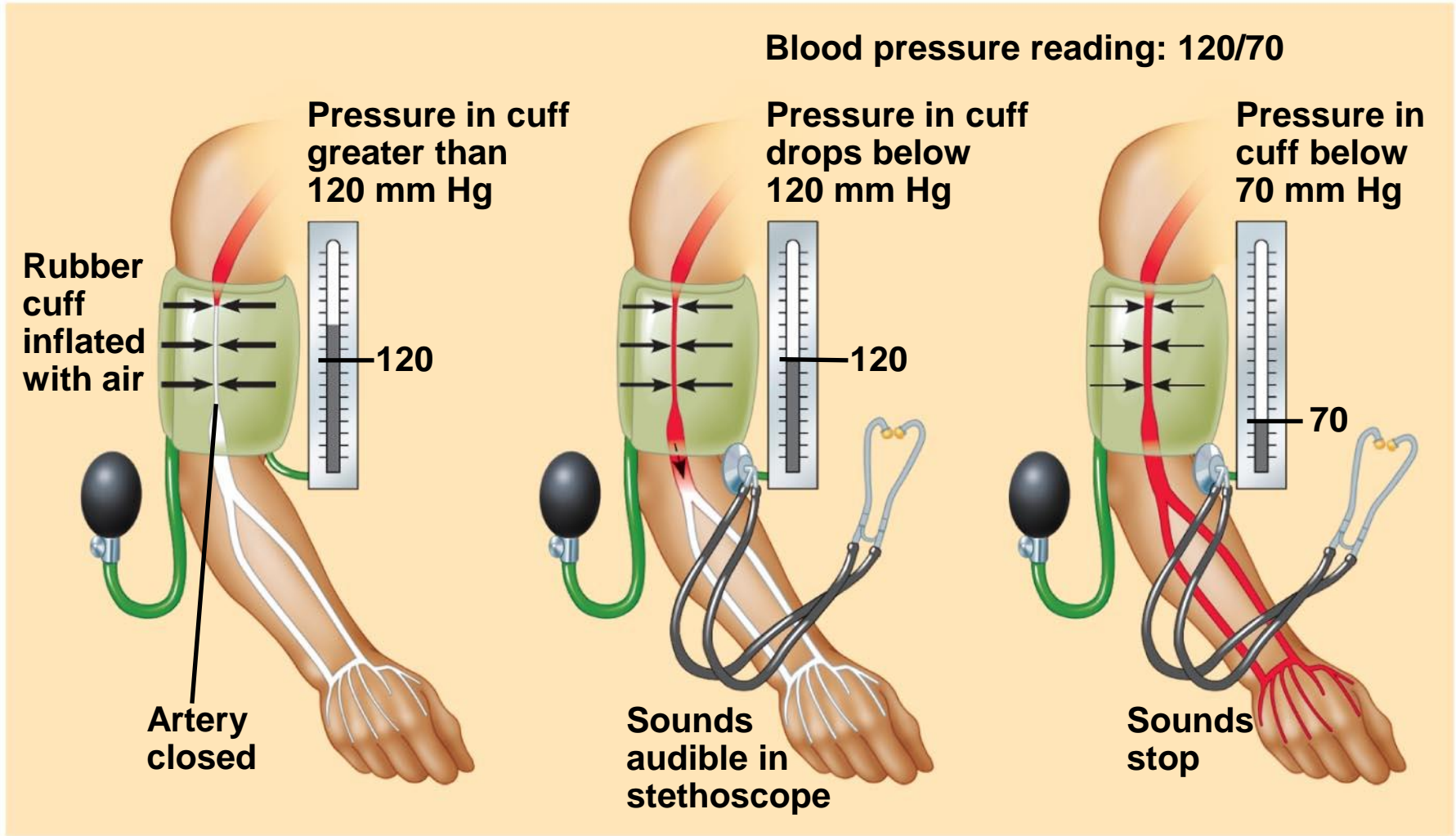


Fig. 42-13-2



Measurement of blood pressure



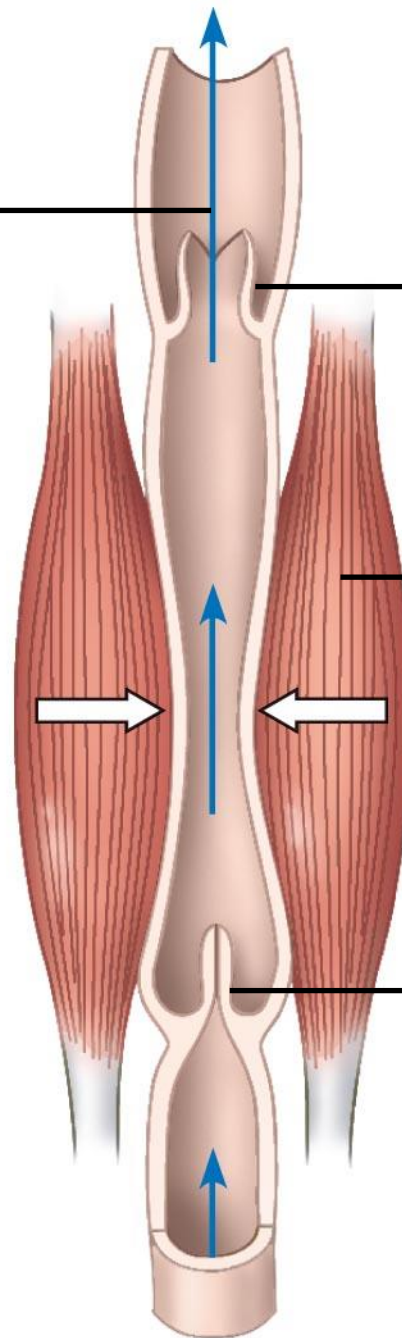
**Direction of blood flow
in vein (toward heart)**

Valve (open)

Skeletal muscle

Valve (closed)

Blood flow in veins



Capillary Function

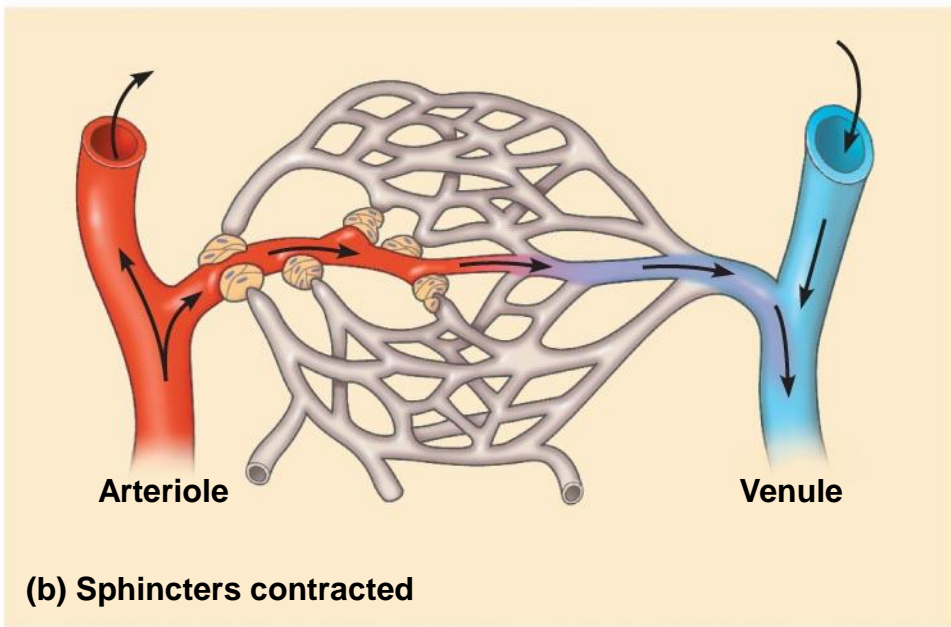
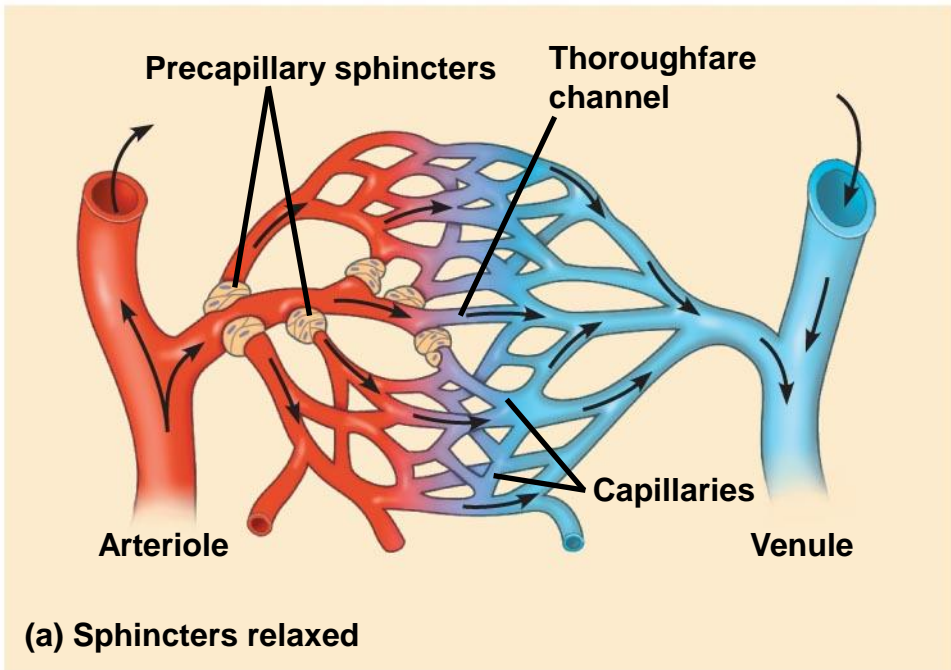
- Capillaries in major organs are **usually filled to capacity**
- **Blood supply varies in many other sites**

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- Two mechanisms regulate **distribution of blood in capillary beds:**

- Contraction of the smooth muscle layer in the wall of an arteriole constricts **يقلِّص** the vessel

- Precapillary sphincters **المَصْرَّةُ قَبْلَ** الشُّعَيْرِيَّةِ control flow of blood between arterioles **شُرَيْنَات** and venules **الْوَرَيْدَاتُ**

Blood flow in capillary beds



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

Fluid exchange between capillaries and the interstitial fluid

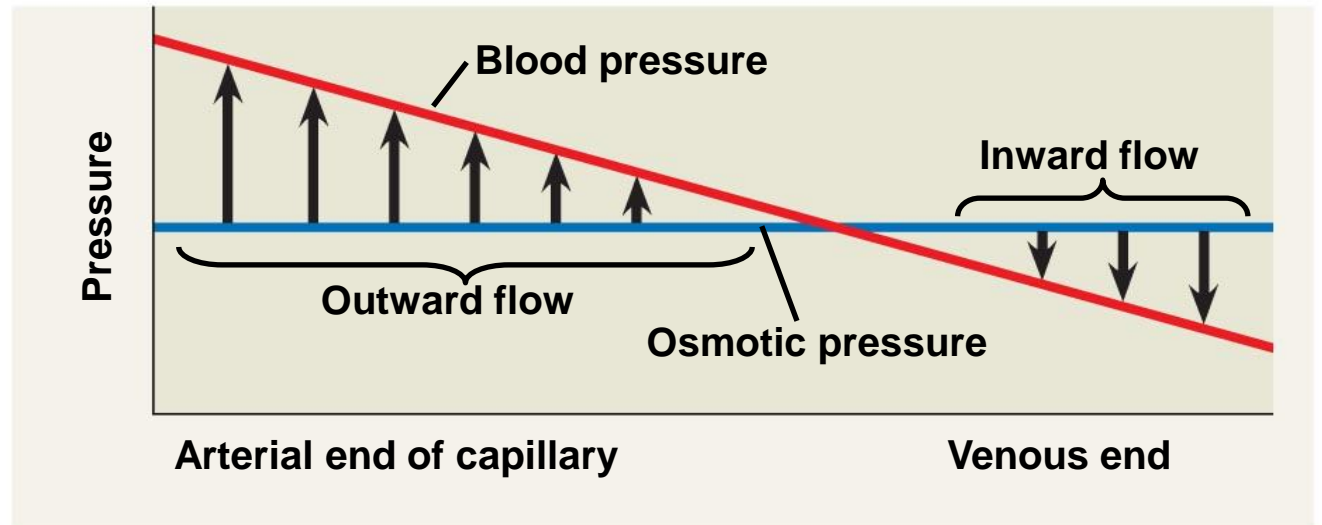
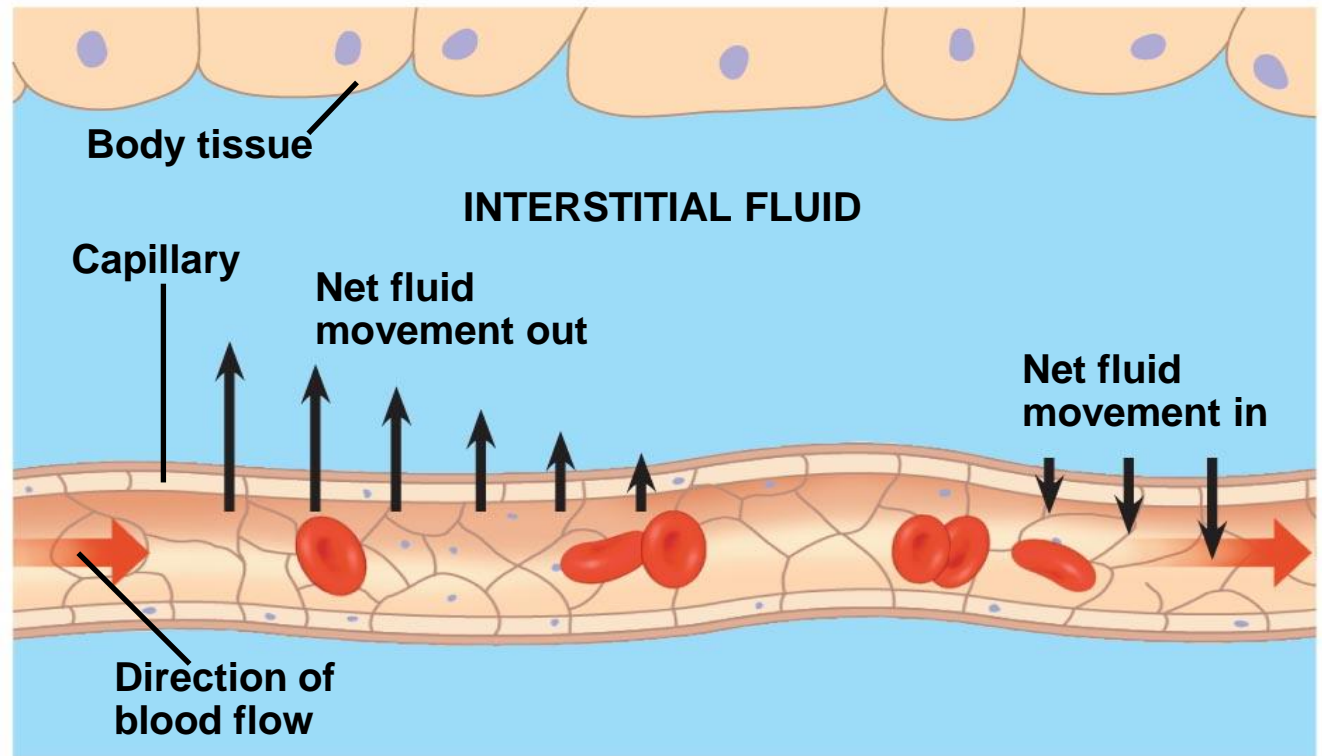


Fig. 42-16a

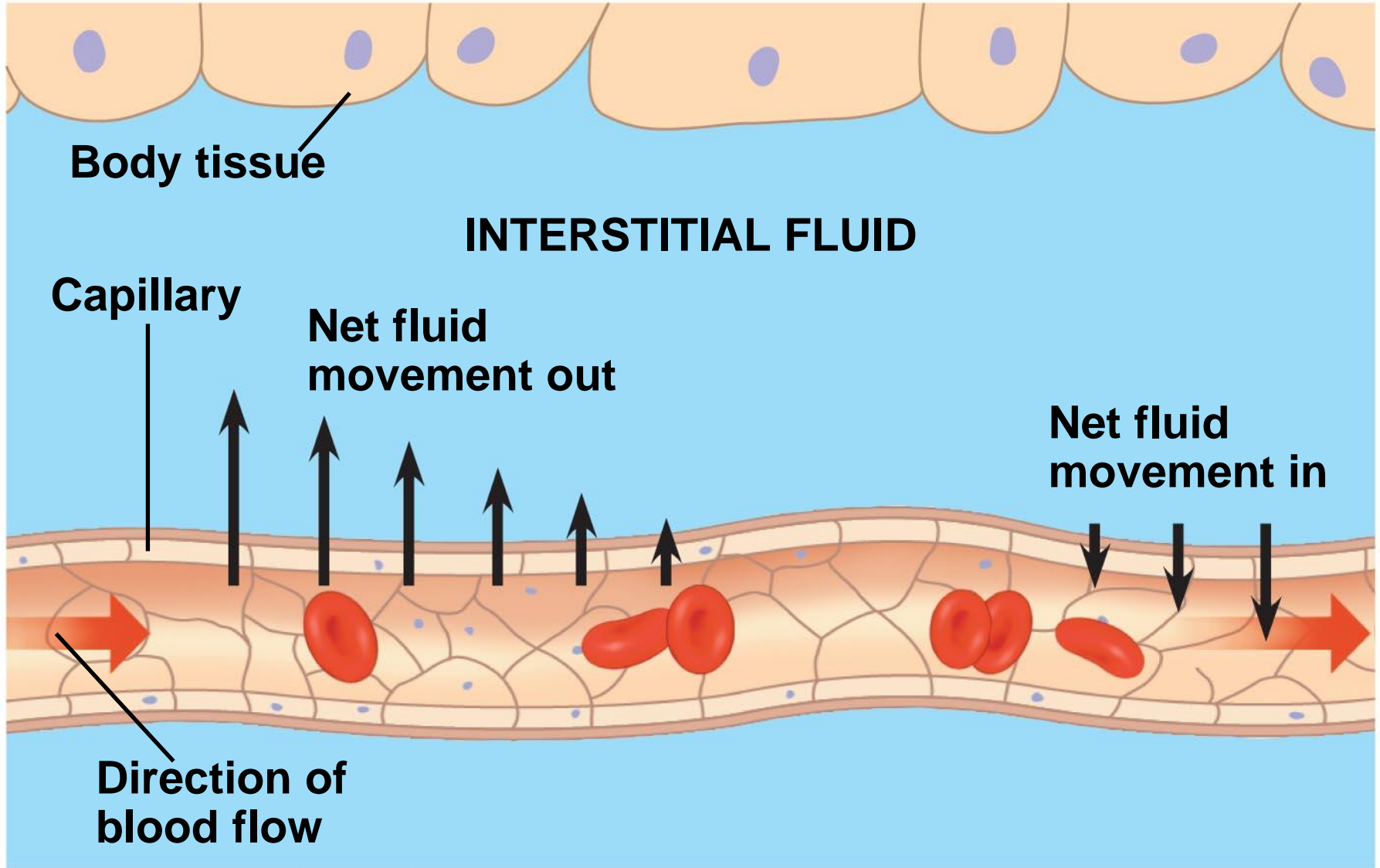
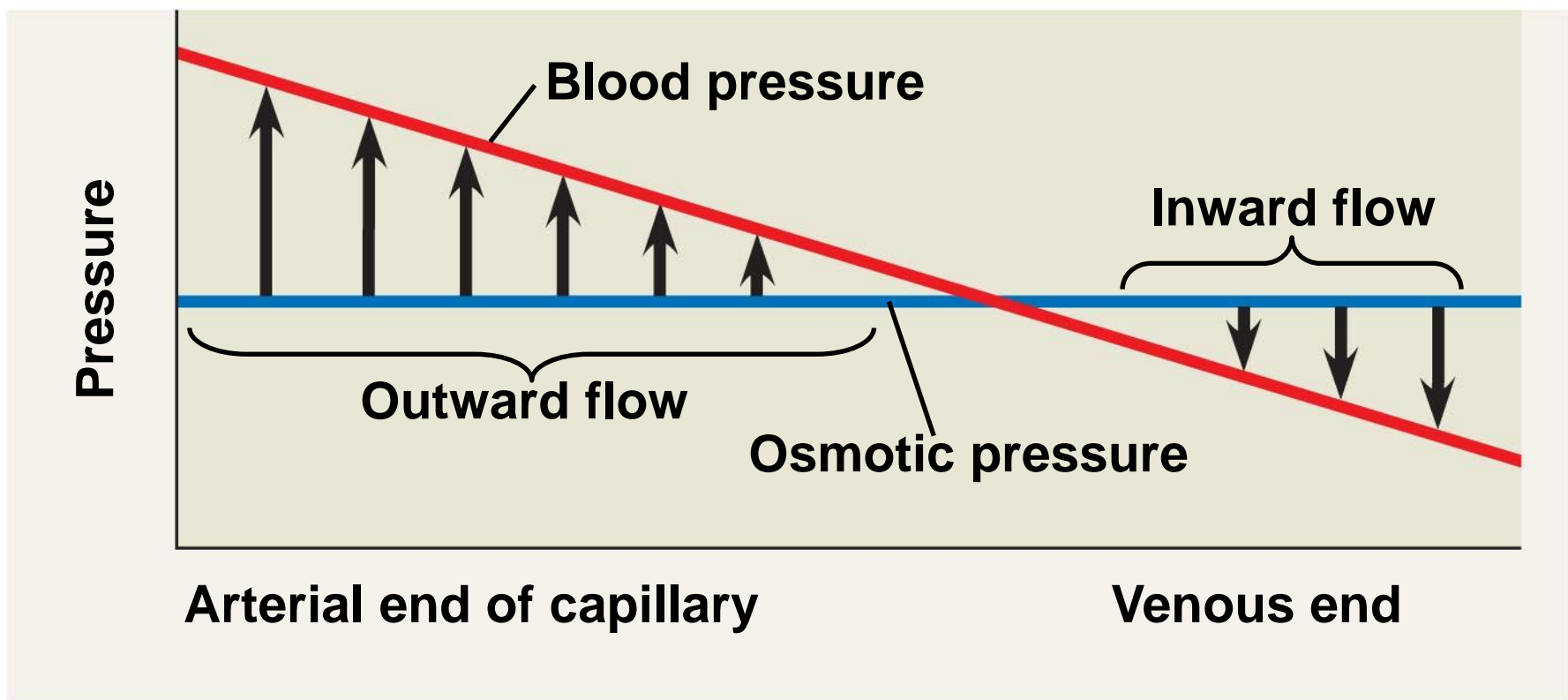


Fig. 42-16b



Fluid Return by the Lymphatic System

- The **lymphatic system** **الجهاز اللمفيّ** 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 **وریدی** end of the capillary bed
- The lymphatic system drains into veins in the neck

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