13-1 Arteries, arterioles, capillaries, venules, and veins differ in size, structure, and function
Classes of Blood Vessels

- **Arteries**
  - Carry blood *away* from the heart

- **Arterioles**
  - Are the smallest branches of arteries

- **Capillaries**
  - Are the smallest blood vessels
  - Location of exchange between blood and interstitial fluid

- **Venules**
  - Collect blood from capillaries

- **Veins**
  - Return blood *to* heart
The Structure of Vessel Walls

• Tunica Intima
  – Innermost endothelial lining and connective tissue

• Tunica Media
  – Is the middle layer
  – Contains concentric sheets of smooth muscle in loose connective tissue

• Tunica Externa
  – Contains connective tissue sheath
Figure 13-1
Arteries

• From heart to capillaries, arteries change
  – From elastic arteries
  – To muscular arteries
  – To arterioles
Arteries

• Elastic Arteries
  – Also called conducting arteries
  – Large vessels (e.g., pulmonary trunk and aorta)
  – Tunica media has many elastic fibers and few muscle cells
  – Elasticity evens out pulse force
Arteries

• Muscular Arteries
  – Also called distribution arteries
  – Are medium sized (most arteries)
  – Tunica media has many muscle cells
• Arterioles
  – Are small
  – Have little or no tunica externa
  – Have thin or incomplete tunica media
Figure 13-2
A Plaque within an Artery

Figure 13-3

(a) Tunica externa

(b) Plaque deposit in vessel wall

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Capillaries

- Are smallest vessels with thin walls
- Microscopic capillary networks permeate all active tissues
- Capillary function
  - Location of all exchange functions of cardiovascular system
  - Materials diffuse between blood and interstitial fluid
Capillaries

• Capillary Structure
  – Endothelial tube, inside thin basal lamina
  – No tunica media
  – No tunica externa
  – Diameter is similar to that of red blood cell
Capillaries

- Capillary Beds *(Capillary Plexus)*
  - Connect one arteriole and one venule
Organization of a Capillary Bed

Figure 13-4a

KEY

Continuous blood flow

Variable blood flow
Organization of a Capillary Bed

Figure 13-4b

(b)

Small artery
Arteriole
Capillary beds
Capillaries

• Collaterals
  – Multiple arteries that contribute to one capillary bed
  – Allow loose circulation if one artery is blocked
  – Arterial anastomosis:
    • Fusion of two collateral arteries
Veins

- Collect blood from capillaries in tissues and organs
- Return blood to heart
- Are larger in diameter than arteries
- Have thinner walls than arteries
- Have lower blood pressure
Veins

• Vein Categories
  
  – Venules:
    • Very small veins
    • Collect blood from capillaries
  
  – Medium-sized veins:
    • Thin tunica media and few smooth muscle cells
    • Tunica externa with longitudinal bundles of elastic fibers
  
  – Large veins:
    • Have all three tunica layers
    • Thick tunica externa
    • Thin tunica media
Veins

• Venous Valves
  – Folds of tunica intima
  – Prevent blood from flowing backward
  – Compression pushes blood toward heart
Valves in the Venous System

Figure 13-5
13-2 Pressure and resistance determine blood flow and affect rates of capillary exchange
Factors Affecting Blood Flow

• Total Capillary Blood Flow
  – Equals cardiac output
  – Is determined by:
    • Pressure and resistance in the cardiovascular system
Factors Affecting Blood Flow

• Pressure (P)
  – The heart generates P to overcome resistance
  – Absolute pressure is less important than pressure gradient

• The Pressure Gradient ($\Delta P$)

• Circulatory Pressure = Pressure Gradient
  – The difference between:
    • Pressure at the heart
    • And pressure at peripheral capillary beds
Factors Affecting Blood Flow

• Force (F)
  – Is proportional to the pressure difference (ΔP)
  – Divided by R
Factors Affecting Blood Flow

• Measuring Pressure
  – Blood pressure (BP):
    • Arterial pressure (mm Hg)
  – Capillary pressure (CP):
    • Pressure within the capillary beds
  – Venous pressure:
    • Pressure in the venous system
Factors Affecting Blood Flow

- Circulatory Pressure
  - $\Delta P$ across the systemic circuit (about 100 mm Hg)
  - Circulatory pressure must overcome total peripheral resistance:
    - $R$ of entire cardiovascular system
Factors Affecting Blood Flow

• Vascular Resistance
  – Due to friction between blood and vessel walls
  – Depends on vessel length and vessel diameter:
    • Adult vessel length is constant
    • Vessel diameter varies by vasodilation and vasoconstriction:
      – R increases exponentially as vessel diameter decreases
Factors Affecting Blood Flow

• Viscosity
  – R caused by molecules and suspended materials in a liquid
  – Whole blood viscosity is about four times that of water
Factors Affecting Blood Flow

• Turbulence
  – Swirling action that disturbs smooth flow of liquid
  – Occurs in heart chambers and great vessels
  – Atherosclerotic plaques cause abnormal turbulence
Cardiovascular Pressures within the Systemic Circuit

- **Systolic Pressure**
  - Peak arterial pressure during ventricular systole

- **Diastolic Pressure**
  - Minimum arterial pressure during diastole

- **Pulse Pressure**
  - Difference between systolic pressure and diastolic pressure
Cardiovascular Pressures within the Systemic Circuit

- **Elastic Rebound**

  - Arterial walls:
    - Stretch during systole
    - Rebound (recoil to original shape) during diastole
    - Keep blood moving during diastole
Cardiovascular Pressures within the Systemic Circuit

Figure 13-6
Cardiovascular Pressures within the Systemic Circuit

• Capillary Pressures and Capillary Exchange
  – Vital to homeostasis
  – Moves materials across capillary walls by:
    • Diffusion
    • Filtration
    • Osmosis
Cardiovascular Pressures within the Systemic Circuit

• **Filtration**
  
  – Driven by hydrostatic pressure
  
  – Water and small solutes forced through capillary wall
  
  – Leaves larger solutes in bloodstream
Cardiovascular Pressures within the Systemic Circuit

• Osmosis

  – Blood osmotic pressure:
    • Equals pressure required to prevent osmosis
    • Caused by suspended blood proteins that are too large to cross capillary walls
Cardiovascular Pressures within the Systemic Circuit

- Interplay between Filtration and Osmosis
  - **Hydrostatic pressure:**
    - Forces water *out* of solution
  - **Osmotic pressure:**
    - Forces water *into* solution
  - Both control filtration and reabsorption through capillaries
• **Net Filtration Pressure (NFP)**
  – The difference between:
  • Net hydrostatic pressure
  • And net osmotic pressure

\[
NFP = (CHP - IHP) - (BCOP - ICOP)
\]
Cardiovascular Pressures within the Systemic Circuit

• Capillary Exchange
  – At arterial end of capillary:
    • Fluid moves *out* of capillary
    • *Into* interstitial fluid
  – At venous end of capillary:
    • Fluid moves *into* capillary
    • *Out* of interstitial fluid
  – Transition point between filtration and reabsorption:
    • Is closer to venous end than arterial end
  – Capillaries filter more than they reabsorb:
    • Excess fluid enters lymphatic vessels
Forces Acting across Capillary Walls

**Figure 13-7**

**KEY**
- CHP (Capillary hydrostatic pressure)
- BOP (Blood osmotic pressure)

3.6 L/day flows into lymphatic vessels

Return to circulation

Arteriole

Filtration 24 L/day

25 mm Hg

35 mm Hg

No net fluid movement

Reabsorption 20.4 L/day

25 mm Hg

25 mm Hg

18 mm Hg

25 mm Hg

CHP > BOP Fluid forced out of capillary

CHP = BOP No net movement of fluid

BOP > CHP Fluid moves into capillary

Venule
Cardiovascular Pressures within the Systemic Circuit

• Venous Pressure
  – Determines the amount of blood arriving at right atrium each minute
  – Low effective pressure in venous system
  – Low venous resistance is assisted by:
    • Muscular compression of peripheral veins:
      – compression of skeletal muscles pushes blood toward heart (one-way valves)
    • The respiratory pump:
      – thoracic cavity action
      – inhaling decreases thoracic pressure
      – exhaling raises thoracic pressure
13-3 Cardiovascular regulation involves autoregulation, neural mechanisms, and endocrine responses
Cardiovascular Regulation

• Tissue Perfusion

  – Blood flow through the tissues
  – Carries O$_2$ and nutrients to tissues and organs
  – Carries CO$_2$ and wastes away

  – Is affected by:
    • Cardiac output
    • Peripheral resistance
    • Blood pressure
Cardiovascular Regulation

- Cardiovascular regulation changes blood flow to a specific area
  - At an appropriate time
  - In the right area
  - Without changing blood pressure and blood flow to vital organs
Cardiovascular Regulation

• Controlling Cardiac Output and Blood Pressure
  – Autoregulation:
    • Causes immediate, localized homeostatic adjustments
  – Neural mechanisms:
    • Respond quickly to changes at specific sites
  – Endocrine mechanisms:
    • Direct long-term changes
Figure 13-9

HOMEOSTASIS
Normal blood pressure and volume

HOMEOSTASIS DISTURBED
Physical stress (trauma, high temperature)
or Chemical changes (decreased O₂ or pH, increased CO₂ or prostaglandins)
or Increased tissue activity

HOMEOSTASIS RESTORED
Long-term increase in blood volume and blood pressure

HOMEOSTASIS RESTORED
Activation of cardiovascular centers

HOMEOSTASIS RESTORED
Stimulation of receptors sensitive to changes in systemic blood pressure or chemistry

HOMEOSTASIS RESTORED
Neural mechanisms

HOMEOSTASIS RESTORED
If autoregulation is ineffective

HOMEOSTASIS RESTORED
Local mechanisms

AUTOREGULATION
Local decrease in resistance and increase in blood flow

Endocrine mechanisms

Stimulation of endocrine response
Autoregulation of Blood Flow within Tissues

• Adjusted by peripheral resistance while cardiac output stays the same
  – Local vasodilators:
    • Accelerate blood flow at the tissue level
  – Local vasoconstrictors:
    • Decrease blood flow at the tissue level
Neural Control of BP and Flow

• **Cardiovascular (CV) Centers** of the Medulla Oblongata
  – Cardiac centers:
    • Cardioacceleratory center: increases cardiac output
    • Cardioinhibitory center: reduces cardiac output
  – Vasomotor center:
    • Vasoconstriction:
      – controlled by adrenergic nerves (NE)
      – stimulates smooth muscle contraction in arteriole walls
    • Vasodilation:
      – controlled by cholinergic nerves (NO)
      – relaxes smooth muscle
Neural Control of BP and Flow

• Baroreceptor Reflexes
  – Stretch receptors in walls of:
    • Carotid sinuses: maintain blood flow to brain
    • Aortic sinuses: monitor start of systemic circuit
    • Right atrium: monitors end of systemic circuit
  – When blood pressure rises, CV centers:
    • Decrease cardiac output
    • Cause peripheral vasodilation
  – When blood pressure falls, CV centers:
    • Increase cardiac output
    • Cause peripheral vasoconstriction
Baroreceptor Reflexes

Figure 13-10

(a) Decreased cardiac output leads to vasodilation, which reduces blood pressure. The baroreceptors are stimulated, and the cardioinhibitory center is stimulated. The vasomotor center is inhibited, and the heart rate decreases.

(b) Increased cardiac output leads to vasoconstriction, which elevates blood pressure. The baroreceptors are inhibited, and the cardioacceleratory center is stimulated. The vasomotor center is stimulated, and the heart rate increases.

KEY:
- Inhibition
Neural Control of BP and Flow

• Chemoreceptor Reflexes
  – **Peripheral** chemoreceptors in carotid bodies and aortic bodies
    monitor blood
  – **Central** chemoreceptors below medulla oblongata:
    • Monitor cerebrospinal fluid
  – Changes in pH, O\(_2\), and CO\(_2\) concentrations
  – Produced by coordinating cardiovascular and respiratory activities
Figure 13-11
Hormones and Cardiovascular Regulation

• Hormones have short-term and long-term effects on cardiovascular regulation
  – For example, E and NE from suprarenal medullae stimulate cardiac output and peripheral vasoconstriction
Figure 13-12a

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The Hormonal Regulation of Blood Pressure and Blood Volume

Figure 13-12b
13-4 The cardiovascular system adapts to physiological stress
Cardiovascular Adaptation

• Blood, heart, and blood vessels
  – Work together as a unit
  – Respond to physical and physiological changes (for example, exercise, blood loss)
  – Maintains homeostasis
Exercise and the Cardiovascular System

• The Cardiovascular Response to Exercise
  – Extensive vasodilation occurs:
    • Increasing circulation
  – Venous return increases:
    • With muscle contractions
  – Cardiac output rises:
    • Due to rise in venous return (Frank–Starling principle) and atrial stretching
Exercise and the Cardiovascular System

• Heavy Exercise
  – Activates sympathetic nervous system
  – Cardiac output increases to maximum:
    • About four times resting level
  – Restricts blood flow to “nonessential” organs (e.g., digestive system)
  – Redirects blood flow to skeletal muscles, lungs, and heart
  – Blood supply to brain is unaffected
The Cardiovascular Response to Hemorrhage

• Entire cardiovascular system adjusts to
  – Maintain blood pressure
  – Restore blood volume
The Cardiovascular Response to Hemorrhage

**Short-Term Elevation of Blood Pressure**

- Carotid and aortic reflexes:
  - Increase cardiac output (increasing heart rate)
  - Cause peripheral vasoconstriction

- Sympathetic nervous system:
  - Triggers hypothalamus
  - Further constricts arterioles
  - Venoconstriction improves venous return
The Cardiovascular Response to Hemorrhage

• Short-Term Elevation of Blood Pressure
  – Hormonal effects:
    ▪ Increase cardiac output
    ▪ Increase peripheral vasoconstriction (E, NE, ADH, angiotensin II)
The Cardiovascular Response to Hemorrhage

- Long-Term Restoration of Blood Volume
  - Recall of fluids from interstitial spaces
  - Aldosterone and ADH promote fluid retention and reabsorption
  - Thirst increases
  - Erythropoietin stimulates red blood cell production
13-5 The pulmonary and systemic circuits of the cardiovascular system exhibit three general functional patterns
Pulmonary and Systemic Patterns

• Three General Functional Patterns
  – Peripheral artery and vein distribution is the same on right and left, except near the heart
  – The same vessel may have different names in different locations
  – Tissues and organs usually have multiple arteries and veins:
    • Vessels may be interconnected with anastomoses
13-6 In the pulmonary circuit, deoxygenated blood enters the lungs in arteries, and oxygenated blood leaves the lungs in veins.
The Pulmonary Circuit

1. Deoxygenated blood arrives at heart from systemic circuit
   - Passes through right atrium and right ventricle
   - Enters pulmonary trunk

2. At the lungs
   - CO\textsubscript{2} is removed
   - O\textsubscript{2} is added

3. Oxygenated blood
   - Returns to the heart
   - Is distributed to systemic circuit
The Pulmonary Circuit

• Pulmonary Vessels
  – Pulmonary arteries:
    • Carry deoxygenated blood
    • **Pulmonary trunk:**
      – branches to left and right pulmonary arteries
    • **Pulmonary arteries:**
      – branch into pulmonary arterioles
    • **Pulmonary arterioles:**
      – branch into capillary networks that surround alveoli
The Pulmonary Circuit

- Pulmonary Vessels
  - Pulmonary veins:
    - Carry oxygenated blood
    - Capillary networks around alveoli:
      - join to form venules
    - Venules:
      - join to form four pulmonary veins
  - Pulmonary veins:
    - empty into left atrium
The Pulmonary Circuit

Figure 13-14
13-7 The systemic circuit carries oxygenated blood from the left ventricle to tissues other than the lungs’ exchange surfaces, and returns deoxygenated blood to the right atrium
The Systemic Circuit

• Contains 84% of blood volume

• Supplies entire body
  – Except for pulmonary circuit
Systemic Arteries

• Blood moves from left ventricle
  – Into *ascending aorta*

• Coronary arteries
  – Branch from aortic sinus
Systemic Arteries

Figure 13-15
Systemic Arteries

Figure 13-15

- Popliteal
- Femoral
- Descending genicular
- Posterior tibial
- Anterior tibial
- Fibular
- Dorsalis pedis
- Plantar arch
Arteries of the Chest and Upper Limb

Figure 13-16

(a) Arteries of the chest and upper limb
Systemic Arteries

Figure 13-17
Systemic Arteries

• Branches of the Aortic Arch
  – Deliver blood to head and neck:
    • Brachiocephalic trunk
    • Left common carotid artery
    • Left subclavian artery
The Subclavian Arteries

- Leaving the thoracic cavity:
  - Become *axillary artery* in arm
  - And *brachial artery* distally
Systemic Arteries

• The Brachial Artery

  – Divides at coronoid fossa of humerus:
    • Into radial artery and ulnar artery:
      – fuse at wrist to form:
        » superficial and deep palmar arches
        » which supply digital arteries
Arteries of the Chest and Upper Limb

Figure 13-16

(a) Arteries of the chest and upper limb

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Systemic Arteries

• The Common Carotid Arteries
  – Each common carotid divides into:
    • **External carotid artery** — supplies blood to structures of the neck, lower jaw, and face
    • **Internal carotid artery** — enters skull and delivers blood to brain:
      – divides into three branches:
        » ophthalmic artery
        » anterior cerebral artery
        » middle cerebral artery
Figure 13-18b
Systemic Arteries

• The Descending Aorta
  – Thoracic aorta:
    • Supply organs of the chest:
      – bronchial arteries
      – pericardial arteries
      – esophogeal arteries
      – mediastinal arteries
    • Supply chest wall:
      – intercostal arteries
      – superior phrenic arteries
Systemic Arteries

Figure 13-19

Vertebral
Thyrocerveal trunk
Internal thoracic
Pericardials
Descending aorta
(Thoracic aorta)
Phrenics
Diaphragm
Common hepatic
Suprarenal
Renal
Lumbar
Common iliac
External iliac
Internal iliac

Common carotid
Subclavian
Axillary
Bronchials
Mediastinals
Intercostals
Celiac trunk
Left gastric
Spleenic
Superior mesenteric
Descending aorta
(Abdominal aorta)
Gonadal
Inferior mesenteric
Terminal segment of the aorta
Figure 13-19
Systemic Arteries

• The Descending Aorta
  – Abdominal aorta:
    • Divides at terminal segment of the aorta into:
      – left common iliac artery
      – right common iliac artery
    • Unpaired branches:
      – major branches to visceral organs
    • Paired branches:
      – to body wall
      – kidneys
      – urinary bladder
      – structures outside abdominopelvic cavity
Systemic Arteries

Figure 13-19

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Figure 13-19

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The Systemic Circuit

• Arteries of the Pelvis and Lower Limbs
  – Femoral artery:
    • Deep femoral artery
  – Becomes popliteal artery:
    • Posterior to knee
    • Branches to form:
      – posterior and anterior tibial arteries
      – posterior gives rise to fibular artery
Systemic Veins

- Complementary Arteries and Veins
  - Run side by side
  - Branching patterns of peripheral veins are more variable

- In neck and limbs
  - One set of arteries (deep)
  - Two sets of veins (one deep, one superficial)

- Venous system controls body temperature
Systemic Veins

Figure 13-20

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Systemic Veins

Figure 13-20

KEY
- Superficial veins
- Deep veins
Systemic Veins

• The Superior Vena Cava (SVC)
  – Receives blood from the tissues and organs of:
    • Head
    • Neck
    • Chest
    • Shoulders
    • Upper limbs
Major Veins of the Head and Neck

Figure 13-21

- Superior sagittal sinus
- Great cerebral
- Dural sinuses
- Temporal
- Maxillary
- Facial
- Vertebral
- Internal jugular
- External jugular
- Right subclavian
- Clavicle
- First rib
- Right brachiocephalic
- Left brachiocephalic
- Superior vena cava
- Internal thoracic
Venous Drainage of the Upper Limb and Thorax

Figure 13-22

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The Superior and Inferior Venae Cavae

Figure 13-23a

(a) Tributaries of the superior vena cava
The Superior and Inferior Venae Cavae

Figure 13-23b

(b) Tributaries of the inferior vena cava

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Systemic Veins

• The Hepatic Portal System
  – Connects two capillary beds
  – Delivers nutrient-laden blood:
    • From capillaries of digestive organs
    • To liver sinusoids for processing
Systemic Veins

Tributaries of the Hepatic Portal Vein

1. Inferior mesenteric vein: drains part of large intestine
2. Splenic vein: drains spleen, part of stomach, and pancreas
3. Superior mesenteric vein: drains part of stomach, small intestine, and part of large intestine
4. Left and right gastric veins: drain part of stomach
5. Cystic vein: drains gallbladder
Systemic Veins

• Blood Processed in Liver
  – After processing in liver sinusoids (exchange vessels), blood collects in hepatic veins and empties into inferior vena cava
The Hepatic Portal System

Figure 13-24
13-8 Modifications of fetal and maternal cardiovascular systems promote exchange of materials, and independence is achieved at birth.
Fetal and Maternal Circulation

• Embryonic lungs and digestive tract nonfunctional

• Respiratory functions and nutrition provided by placenta
Placental Blood Supply

• Blood flows to the placenta
  – Through a pair of **umbilical arteries**
  – Which arise from internal iliac arteries
  – And enter umbilical cord

• Blood returns from placenta
  – In a single **umbilical vein**
  – Which drains into **ductus venosus**

• Ductus venosus
  – Empties into inferior vena cava
Circulatory Changes at Birth

- Newborn breathes air
- Lungs expand
  - Pulmonary vessels expand
  - Reduced resistance allows blood flow
  - Rising $O_2$ causes **ductus arteriosus** constriction
  - Rising left atrium pressure closes **foramen ovale**
- Pulmonary circulation provides $O_2$
Figure 13-25a
Fetal Circulation

Figure 13-25b

(b) After delivery

Ductus arteriosus (closed)

Pulmonary trunk

Foramen ovale (closed)

Right atrium

Left atrium

Inferior vena cava

Right ventricle

Left ventricle

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Aging affects the blood, heart, and blood vessels
Aging and the CV System

- Cardiovascular capabilities decline with age
- Age-related changes occur in:
  - Blood
  - Heart
  - Blood vessels
Aging and the CV System

• Three Age-Related Changes in Blood
  – Decreased hematocrit
  – Peripheral blockage by blood clot (thrombus)
  – Pooling of blood in legs
    • Due to venous valve deterioration
Aging and the CV System

• Five Age-Related Changes in the Heart
  – Reduced maximum cardiac output
  – Changes in nodal and conducting cells
  – Reduced elasticity of cardiac (fibrous) skeleton
  – Progressive atherosclerosis
  – Replacement of damaged cardiac muscle cells by scar tissue
Aging and the CV System

• Three Age-Related Changes in Blood Vessels
  – Arteries become less elastic:
    • Pressure change can cause aneurysm
  – Calcium deposits on vessel walls:
    • Can cause stroke or infarction
  – Thrombi can form:
    • At atherosclerotic plaques
13-10 The cardiovascular system is both structurally and functionally linked to all other systems
• There are many categories of cardiovascular disorders:
  – Disorders may:
    • Affect all cells and systems
    • Be structural or functional
    • Result from disease or trauma
The Cardiovascular System in Perspective

Functional Relationships Between the Cardiovascular System and Other Systems
The Integumentary System’s stimulated mast cells produce localized changes in bloodstream and capillary permeability.

The Cardiovascular System delivers immune system cells to injury sites; clotting response seals breaks in skin surface; carries away toxins from sites of infection; provides heat.
The Skeletal System provides calcium needed for normal cardiac muscle contraction; protects blood cells developing in bone marrow.

The Cardiovascular System provides calcium and phosphate for bone deposition; delivers EPO to bone marrow, parathyroid hormone and calcitonin to osteoblasts and osteoclasts.
The Nervous System controls patterns of circulation in peripheral tissues; modifies heart rate and regulates blood pressure; releases ADH.

The Cardiovascular System’s endothelial cells maintain bloodbrain barrier; help generate CSF.
The Endocrine System’s hormone EPO regulates production of RBCs; several hormones elevate blood pressure; epinephrine stimulates cardiac muscle, elevating heart rate and contractile force.

The Cardiovascular System distributes hormones throughout the body; heart secretes ANP.
The Muscular System assists in moving blood through veins; protects superficial blood vessels, especially in neck and limbs.

The Cardiovascular System delivers oxygen and nutrients, removes carbon dioxide, lactic acid, and heat during skeletal muscle activity.
The Lymphoid System defends against pathogens or toxins in blood; fights infections of cardiovascular organs; returns tissue fluid to circulation.

The Cardiovascular System distributes WBCs; carries pathogen-attacking antibodies; restricts spread of pathogens with clotting response.
The Respiratory System provides oxygen to cardiovascular organs and removes carbon dioxide.

The Cardiovascular System’s RBCs transport oxygen and carbon dioxide between lungs and peripheral tissues.
The Digestive System provides nutrients to cardiovascular organs; absorbs water and ions to maintain normal blood volume.

The Cardiovascular System distributes digestive tract hormones; carries absorbed nutrients, water, and ions away; delivers nutrients and toxins to liver.
The Urinary System

- The Urinary System releases renin to elevate blood pressure and EPO to accelerate red blood cell production.

- The Cardiovascular System delivers blood to kidneys, where filtration occurs; accepts fluids and solutes reabsorbed during urine production.
The Reproductive System maintains healthy vessels and slows development of atherosclerosis with age by estrogens.

The Cardiovascular System distributes reproductive hormones; provides nutrients, oxygen, and waste removal for developing fetus; local blood pressure changes responsible for physical changes during sexual arousal.