**CV system** = ________, ________, and ________

*heart pumps blood into blood vessels throughout the body*

---

**MODULE 17.1 OVERVIEW OF THE HEART**

---

**Location & Structure of the Heart**

- **Heart**
  - cone-shaped organ
  - located slightly to left side in thoracic cavity (in ________)
  - rests on diaphragm (Figure 17.1a)
  - ________: inferior aspect
  - ~ 250 to 350 grams (< 1 lb.)

---

**Location & Structure of the Heart**

- **Chambers and external anatomical features:**
  - Chambers – RA and LA atria (atrium)
  - RV and LV ventricles
  - ________ sulcus
    - external indentation between the atria and ventricles
  - ________ sulcus
    - external depression between RV and LV

---

**Location & Structure of the Heart**

- **Figure 17.1a** Location and basic anatomy of the heart in the thoracic cavity.

---

**Location & Structure of the Heart**

- **Figure 17.1b** Location and basic anatomy of the heart in the thoracic cavity.
Veins - carry blood \_\_\_\_\_\_
Arteries carry blood \_\_\_\_\_\_

- **Great vessels** = main veins and arteries that bring blood to and from heart
  - [SVC, IVC, pulmonary V., pulmonary A., aorta]

**Pulmonary Circuit**
- Right side of heart (pulmonary pump)
  - \_\_\_\_\_\_\_\_ deliver oxygen-poor (deoxygenated) blood to lungs
  - Gas exchange between alveoli and pulmonary capillaries
  - \_\_\_\_\_\_\_\_ deliver oxygen-rich \_\_\_\_\_\_\_\_\_ blood to left side of heart

**Systemic Circuit**
- Systemic pump (left side of heart)
  - receives oxygenated blood from pulmonary veins and pumps it to rest of body
  - \_\_\_\_\_\_\_\_ pump oxygen-rich \_\_\_\_\_\_\_\_\_ blood to all systems of body (not lungs)
  - Gas exchange at systemic capillaries
  - \_\_\_\_\_\_\_\_ return oxygen-poor (deoxygenated) blood to \_\_\_\_\_\_\_\_\_
Systemic Circuit

Functions of the Heart

- Heart helps maintain BP (blood pressure)
  - ____________ influence BP and blood flow to organs
- Atria produce hormone: atrial natriuretic peptide (ANP)
  - ANP _________ BP by __________ Na+ retention in kidneys → decr. osmotic H₂O reabsorption

Pericardium

Pericardium – membrane surrounding heart
1. Fibrous pericardium – outermost layer
2. Serous pericardium – produces serous fluid
   - ____________ [pericardial cavity]
   - Visceral pericardium – (aka ____________)

Heart Wall

1. Epicardium - outmost layer
2. ____________
   - middle muscle layer
   [What type of muscle??]
   - fibrous skeleton (dense irregular collagenous CT)
3. Endocardium - innermost ____________
**Pericardium & Heart Wall**

![Diagram of Pericardium & Heart Wall]

**Cardiac Tamponade** (p. 635)
- Pericardial cavity fills with excess fluid → cardiac tamponade
- Causes:
  - Fibrous pericardium - strong but not very flexible, excess fluid in pericardial cavity squeezes heart;
  - Treatment -

**Coronary Circulation**

**Coronary vessels (supply heart wall):**
- Branch off ascending aorta:
  1. __________ ➔
     ➔ post. interventricular (post. descending a.) ➔ marginal branch
  2. left coronary artery ➔ __________ branch
     ➔ ant. interventricular a. (left ant. descending) ______

**Coronary Circulation**

- Coronary veins
  - Great cardiac vein ➔ ________ ➔ RA
  - Small cardiac vein
  - Middle cardiac vein

**Coronary Circulation**

- Coronary artery disease (CAD)
  - buildup of ________ (fatty material) in coronary arteries
  - decreases blood flow to myocardium ➔
  - Symptoms: angina pectoris
  - leading cause of death worldwide
**Coronary Circulation**

- **Myocardial infarction (MI)** or __________
  - Most dangerous potential consequence of CAD
  - Occurs when __________
  - Clot forms → myocardial tissue infarct
  - **Symptoms** include chest pain radiates to left arm, shortness of breath, sweating, anxiety, and nausea and/or vomiting
  - Women may present with __________

- Survival after MI depends on **extent and location** of damage
  - Dead cells are replaced with __________
  - Death of part of myocardium __________
  - **Risk factors** include smoking, incr. BP, poorly controlled diabetes, high levels of certain lipids, obesity

**Coronary Circulation**

__________ diagnostic test for CAD

Treatments
- *modify* Lifestyle
- *medications*
- then invasive treatments

**Coronary Circulation**

- **Coronary angioplasty** - __________
  - **Coronary artery bypass grafting** (CABG)
    - other vessels are __________

**Path of Blood through the Heart**

- Heart consists of four chambers: (Figures 17.5–17.7):
  1. **2 Atria**
     - receive blood from veins
     - *pump* through __________ (AV)
  2. **2 Ventricles**
     - __________
     - carry blood through systemic or pulmonary circuit

**Path of Blood through the Heart**

- Superior vena cava (______)
- Inferior vena cava (______)
  1. **Right Atrium (RA)**
     <Right atrioventricular (AV) valve>
     (__________)

  2. **Right Ventricle (RV)**
     chordae tendineae
     papillary muscles
Path of Blood through the Heart
- <Pulmonary semilunar valve>
  → pulmonary trunk
  → LUNGS → __________

3. Left Atrium (LA)

<left Atrioventricular (AV) valve>
(________________)

4. Left Ventricle (LV)
  chordae tendineae
  papillary muscles

---

Path of Blood through the Heart

< aortic semilunar valve >
→ Ascending aorta:
  ○ __________

→ Aortic Arch
  ○ __________ artery
  ○ __________ (RCC) artery
  ○ __________

---

Great Vessels, Chambers, and Valves

- Pectinate muscles – muscular ridges inside RA
- Interatrial septum – __________
- Fossa ovalis – indentation in interatrial septum; remnant of opening (__________) from fetal circulation
- Trabeculae carneae – ridged surface in Ventricles “beams of flesh”

---

Figure 17.5a: The external anatomy of the heart.

Figure 17.5b: The external anatomy of the heart.

Figure 17.5c: The external anatomy of the heart.
Great Vessels, Chambers, and Valves

**Great Vessels, Chambers, and Valves**

RV – low pressure
LV – high pressure

<table>
<thead>
<tr>
<th>WALL</th>
<th>CHAMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>Thin</td>
</tr>
<tr>
<td>Left</td>
<td>Thick</td>
</tr>
</tbody>
</table>

LV wall = 3x thicker than RV

**Heart Valves**

Pulmonary semilunar (right AV)
Mitrail (mitral, left AV)
Aortic semilunar

**The Big Picture**

- Blood flow through the heart: Blood enters the right atrium from the veins,流入 left atrium through the mitral valve, into left ventricle, and out through the aortic valve.

**Great Vessels, Chambers, and Valves**

Figure 17.6 The internal anatomy of the heart, anterior dissection.

Figure 17.7b Anatomy of the atrioventricular and semilunar valves.

**The Big Picture**

Figure 17.8 The Big Picture of Blood Flow through the Heart.
Valvular Heart Diseases (p. 643)

- **Diseases of heart valves**
  - _________ (present at birth) or _________ (infection, cancer, or immune system disorder)
- Two major types of valvular defects:
  - **Insufficient valve**
    - fails to close fully, blood leaks backward
  - _________ valve (narrowing)
    - calcium deposits → hard and inflexible

- Both valve disorders may cause _______

- Symptoms: enlargement of heart, fatigue, dizziness, and heart palpitations

- Mitral and aortic valves are ones most commonly affected _______

---

**Module 17.3 Cardiac Muscle Tissue Anatomy and Electrophysiology**

Electrophysiology

- Cardiac muscle exhibits _______

- Cardiac muscle cells contract in response to electrical excitation in form of APs

- Cardiac muscle cells do not require stimulation from _________ to generate APs

Histology of Cardiac Muscle Tissue and Cells

- Cardiac muscle cells
  - _________
    - branched, _________
    - _________
      - generate tension through sliding-filament mech.
  - Ex. of Structure-Function Core Principle
Histology of Cardiac Muscle Tissue and Cells

- Like skeletal muscle fibers, cardiac muscle cells contain **selective gated ion channels**
- Opening & closing action of these ion channels → both pacemaker & contractile cardiac APs

Electrophysiology of Cardiac Muscle

- **Cardiac conduction system**
  - Pacemaker cells undergo rhythmic, spontaneous depolarizations → APs
  - Permits heart to contract as a **unit** and

Electrophysiology of Cardiac Muscle

- Sequence of events of contractile cell AP resembles that of skeletal muscle fiber AP with one exception: **plateau phase**
  - Plateau phase **lengthens** cardiac AP → __________ providing time required for heart to **fill** with blood;
  - also increases _______________ (sustained contraction) in heart by **lengthening refractory period**

---

**Figure 17.9** Cardiac muscle cells.

**Figure 17.10** A contractile cell action potential.
Electrophysiology of Cardiac Muscle

- Refractory period in cardiac muscle cells is so long that cells cannot maintain a sustained contraction
- Allows heart to _________ before cardiac muscle cells are stimulated to contract again

Cardiac conduction system:

- **SA node** (60 bpm influenced by SNS & PSN)
- **AV node** (40 bpm, AV node delay)

Purkinje fiber system

AV node delay
- Allows atria to depolarize (and contract) before ventricles, giving ventricles time to fill with blood
- Also helps to prevent current from flowing backward from _________ into AV node and atria

Figure 17.12 The cardiac conduction system.
Electrophysiology of Cardiac Muscle

- SA node = main pacemaker of heart

- Sinus rhythms = ____________

Electrophysiology of Cardiac Muscle

- Electrocardiogram (ECG)
  - ____________ in cardiac muscle cells over time (Figure 17.13)
  - electrodes placed on patient's skin (6 on chest, 2 on each leg)
  - detects disturbance in electrical rhythm = ________ or arrhythmia (= no rhythm)

Electrophysiology of Cardiac Muscle

- ECG represents depolarization or repolarization of parts of heart
  - P wave represents ____________
  - QRS complex represents ____________
  - T wave represents ____________

What's missing??

Electrophysiology of Cardiac Muscle

- Determine HR
- Spread of depolarization through atria
- Spread of depolarization through ventricles

Electrophysiology of Cardiac Muscle

- Ventricular plateau phase

Figure 17.13 A normal electrocardiogram (ECG) tracing.
Dysrhythmias (p. 652)

Cardiac dysrhythmias have 3 basic patterns:

1. Disturbances in heart rate (HR):
   - _________ = HR < 60 bpm
   - Tachycardia = HR > 100 bpm
   - Sinus tachycardia = regular, fast rhythm

2. Disturbances in conduction pathways
   - disrupted by accessory pathways between upper & lower chambers or by _________
   - Heart block at AV node;
     - P-R interval is longer than normal, due to incr. time for impulses to spread to ventricles through AV node; extra P waves are present, indicates that some APs from SA node are not being conducted through AV node

3. _________ = electrical activity goes haywire → parts of heart to depolarize and contract while others are repolarizing and not contracting → bag of worms writhing

   - Atrial fibrillation
     - generally not life threatening
     - atrial contraction isn’t necessary for ventricular filling
     - ECG tracing “irregularly irregular” rhythm (one that has no discernible pattern) that lacks P waves
Dysrhythmias

– Ventricular fibrillation
  • immediately life-threatening
  • ECG exhibits chaotic activity
    • defibrillation (an electric shock to heart) depolarizes all ventricular muscle cells simultaneously
    • SA node will resume pacing heart after shock is delivered (ideally)

“Flat-lining” = ____________
- defibrillation is not used for asystole because heart is not fibrillating and there is no electrical activity to reset
- instead, treated with CPR and pharmacological agents that stimulate heart such as atropine and Epi

MODULE 17.4 MECHANICAL PHYSIOLOGY OF THE HEART: THE CARDIAC CYCLE

Introduction to Mechanical Physiology

• Mechanical physiology - actual processes by which blood fills and is pumped out of chambers
• Heartbeat =

• Cardiac cycle - sequence of events that take place from one heartbeat to next (systole followed diastole for each chamber)

Pressure Changes, Blood Flow, and Valve Function

Blood flows in response to pressure gradients (Gradients Core Principle); as ventricles contract and relax, pressure in chambers changes, causing blood to push on valves and open or close them Figure 17.14):

• ______________ (contraction phase)
  – Both of AV valves are forced shut by blood pushing against them
  – Both of semilunar valves are forced open by outgoing blood

Figure 17.14a Pressure changes, blood flow, and valve function.
Pressure Changes, Blood Flow, and Valve Function

- **Relaxation phase** –
  - Press. In ventricles falls **below** those in atria and in pulmonary trunk and aorta → forces AV valves **open**.
  - Higher pressures in pulmonary trunk and aorta push cusps of semilunar valves **closed**.

- **Stethoscope** – used to listen to (auscultate) rhythmic **heart sounds** (Fig. 17.15):
  - **S1** ("lub") = ______________
  - **S2** ("dub") = ______________

- **Heart murmurs and extra heart sounds** (p. 654)
  - **Heart murmur** - turbulent blood flow through heart often due to **defective valves**, defective chordae tendineae, or holes in interatrial or interventricular septum.

- **Cardiac cycle** =
  (Fig. 17.16, 17.17)
  - Cycle is divided into four main phases that are defined by actions of ventricles and positions of valves: **filling**, **contraction**, **ejection**, and **relaxation**.
1. **Ventricular filling phase** of cardiac cycle
   - Blood drains ________________
   - Pressures in LV and RV are lower than in atria, pulmonary trunk, and aorta
   - Higher pressures in pulmonary trunk and aorta cause semilunar valves to be closed; prevents backflow of blood into ventricles

Figure 17.16 Events of the cardiac cycle.
MODULE 17.5 CARDIAC OUTPUT AND REGULATION

Introduction to Cardiac Output and Regulation

Heart rate (HR)
- 60–80 cardiac cycles or bpm

Stroke volume
- ~70 ml/beat (amt. of blood ejected from each _______ in a beat)

Cardiac output (CO)
- __________ into pulmonary & systemic circuits

Determination of Cardiac Output

- \[ \text{C.O.} = \text{heart rate} \times \text{stroke volume} \]
  \[ \text{72 beats/min} \times \text{70 ml/beat} = 5040 \text{ ml/min} \approx 5 \text{ liters/min (C.O.)} \]

- Resting C.O. ~ averages about 5 liters/min;
  RV pumps ~ 5 liters into pulmonary circuit
  LV pumps same amt. to systemic circuit

Normal adult blood volume = ~ 5 liters

Factors that Influence Stroke Volume

Frank-Starling law
- Increased ventricular muscle cells stretch, leads to __________
- Ensures that vol. of blood discharged from heart is equal to vol. that enters it
- Important during exercise, when C.O. must increase to meet body’s needs
Factors that Influence Heart Rate

- **HR** due to rate at which SA node generates APs
- **________________** at which SA node depolarizes = **chronotropic agents**
  - **Positive** chronotropic agents
    - SNS, some hormones, increased body temp.
  - **Negative** chronotropic agents
    - PSN, decreased body temperature

Regulation of Cardiac Output

Heart is autorhythmic but still requires regulation to ensure C.O. meets body’s needs at all times

- Regulated by **_____** (ANS) and **______** systems
  - SNS (NEpi) \(\rightarrow\) **___** HR, **___** force of contraction
  - PSN (ACh) \(\rightarrow\) **___** HR, **___** force of contraction

Regulation of Cardiac Output

- **__________**
  - **__________** affected by SNS \(\rightarrow\)
    - Epi and NEpi
  - **thyroid hormone** and **glucagon**

- **__________**
  - Aldosterone and antidiuretic hormone
    - increase blood vol. \(\rightarrow\) incr. C.O.
  - ANP decreases blood vol. \(\rightarrow\) reduces C.O.
Regulation of Cardiac Output

- Other factors that influence cardiac output (Figure 17.21):
  - [Electrolyte] in ECF
  - __________
    - SA node fires more rapidly at higher body temp. and more slowly at lower body temp.
  - Age
  - Exercise

Heart Failure

**Heart failure** (formerly CHF) = any condition that reduces heart’s ability to pump effectively:
- __________ and/or M.I., valvular heart diseases, any disease of heart muscle (cardiomyopathy) and electrolyte imbalances
- Heart failure → decreased SV → __________

Heart Failure

- Both RV and LV failure → peripheral edema, in which blood backs up in systemic capillaries (systemic congestion)
  - __________ in legs and feet
  - Peripheral edema exacerbated by kidneys retain excess fluid

Heart Failure

- Treatment – __________
  - Lifestyle modifications - weight loss and mild exercise, dietary sodium and fluid restrictions
  - Drug therapy
    - Heart transplant and/or pacemaker

Heart Failure

- Signs and symptoms of heart failure depend on type of heart failure and side of heart that is affected
  - LV failure, blood often backs up within pulmonary circuit; known as pulmonary congestion → __________
Vasculature = __________
60,000 miles of vessels
Capillaries alone would circle the world (25,000 miles)

Introduction to the Vasculature
• Blood vessels
  – Transport blood to tissues (gases, nutrients, and wastes are exchanged) and back to heart
  – __________ to tissues
  – __________
  – Secrete a variety of chemicals

Introduction to the Vasculature
– __________ – transports blood between heart (RV) and ________
– Systemic circuit – transports blood between heart (LV) and __________
– Coronary circuit: circulation of blood to __________ (coronary arteries & veins)

Structure and Function of Arteries and Veins
• 3 basic layers or tunics of vessel wall
  ➢ Tunica intima
    - innermost layer
  ➢ Tunica media
    - middle layer
    - __________ (VC and VD) and elastic fibers
  ➢ Tunica externa (adventitia)
    - __________
    - Vaso vasorum
Structure and Function of Arteries and Veins

• Artery vs vein (Figure 18.2):
  - Arteries: reflects arteries' role in controlling BP and blood flow
  - more extensive internal and external elastic reflects arteries are under much higher press.

Figure 18.2 A comparison of the walls of arteries and veins.

3 classes of arteries
 Ø 1. ________ (conducting) arteries
    - Aorta and immediate branches
    - highest pressure
 Ø 2. ________ (distributing) arteries
    - well dev. tunica media of SMC
    - Smaller diameter (named branches to organs)
 Ø 3. __________
    - smallest diameter
    - thin tunica media (1-3 layers of SMC)

Arterioles – ________ = smallest arterioles that directly feed capillary beds
- precapillary sphincter SMC that encircles metarteriole-capillary junc.

Certain arteries monitor pressure and chemicals
  - Baroreceptors –
  - Chemoreceptors –

Structure and Function of Arteries and Veins

• Veins
  - outnumber arteries
  - larger lumens
  - serve as __________ (70% of total blood located in veins) (systemic & pulmonary veins)
  - __________
    - fewer elastic fibers
    - less SMC

Veins classified by size:
 Ø Venules – smallest veins; drain blood from capillary beds
    - 3 tunics become more distinct as venules merge → larger venules → veins
    - thin tunica media
    - ________ prevent backflow of blood
**Structure and Function of Arteries and Veins**

**Table 18.1 Types of Arteries and Veins.**

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Structure</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0-2.0 mm</td>
<td>Large muscular and elastic</td>
<td>Conduct blood from the heart to organs.</td>
</tr>
<tr>
<td>3.0-7.0 mm</td>
<td>Medium muscular and elastic</td>
<td>Distribution of blood to organs.</td>
</tr>
<tr>
<td>7.0-20 mm</td>
<td>Small arteries and arterioles</td>
<td>Aneurysms may form.</td>
</tr>
</tbody>
</table>

**Atherosclerosis**

- Atherosclerosis – leading cause of death in developed world; characterized by formation of atherosclerotic plaques (buildups of lipids, cholesterol, calcium salts, and cellular debris within arterial tunica intima)
- Plaques tend to form at branching points where blood undergoes sudden changes in velocity and direction
- Plaques form due to endothelial injury

**Atherosclerosis**

- Vessel wall becomes inflamed, which attracts **phagocytes** to “clean up” area → damage to blood vessel → plaque formation
- SMC proliferation → secrete ECM
- Clot may form → MI or stroke
- 10% of world pop. may have Atherosclerosis

Treatment: ____________

**Module 18.2 Physiology of Blood Flow**

**Introduction to Hemodynamics**

- **Hemodynamics** – physiology of blood flow
  - Heart provides **force** that drives blood through blood vessels by creating a **pressure gradient**
    - (ex. of **Gradients Core Principle**)
  - Pressure is **highest**
  - Blood flows **down** pressure gradient from area of higher P (near heart) to area of lower P (in peripheral vasculature)

- **Blood pressure** (mmHg) – outward force that blood exerts on walls of blood vessels
  - **Varies**
    - ____________ in large systemic arteries
    - ____________ in large systemic veins

---

*Bio 104 Chapters 17 - 20: Cardiovascular System 53*
Introduction to Hemodynamics

Blood flow (vol. of blood/min) determined by:

1. **Magnitude of _________**
   - Generally, blood flow matches C.O. (avg. ~ 5–6 L/min)
   - Blood flow directly proportional to pressure gradient,
     (blood flow increases when pressure gradient incr.)

2. **__________(R)** = any impedance to blood flow
   - Blood flow inversely proportional to R

3. **_________** related to X-sec. area
   - incr. branching  \( \rightarrow \) incr. total x-sec. area
   - fastest in aorta, slowest in capillaries

Factors That Determine Blood Pressure

- BP influenced by 3 main factors : (Fig. 18.4):
  1. **_________**(PR)
     - any factor that hinders blood flow
     - PR is greatest further away from heart
     - as PR increases, BP increases
     - vessel radius, viscosity, vessel length
  2. **_____** = SV \( \times \) HR
  3. **_________** – influenced by water loss and gain

BP in Different Portions of the Circulation

- Pulmonary circuit ~ 15 mmHg
- Systemic circuit ~ 95 mm Hg

**Pressure** averages ~ 120 mm Hg
**Diastolic** pressure averages ~80 mm Hg (at rest)

- Pulse pressure = systolic - diastolic pressures
  \[ \approx 40 \text{ mm Hg} \]
- MAP = diastolic pressure + 1/3 (pulse pressure)

Blood Pressure in Different Portions of the Circulation

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonary Circuit</td>
<td></td>
</tr>
<tr>
<td>Pulmonary arteries</td>
<td>15 mm Hg</td>
</tr>
<tr>
<td>Pulmonary veins</td>
<td>5 mm Hg</td>
</tr>
<tr>
<td>Systemic Circuit</td>
<td></td>
</tr>
<tr>
<td>Arteries</td>
<td>120 mm Hg (systolic), 80 mm Hg (diastolic)</td>
</tr>
<tr>
<td>Arterioles</td>
<td>80–35 mm Hg</td>
</tr>
<tr>
<td>Capillaries</td>
<td>35–15 mm Hg</td>
</tr>
<tr>
<td>Venules</td>
<td>15–5 mm Hg</td>
</tr>
<tr>
<td>Veins</td>
<td>5–0 mm Hg</td>
</tr>
</tbody>
</table>
BP in Different Portions of Circulation

- Increase venous return:
  - ______ prevent backward flow
  - ______ in vein walls VC by SN
  - ________
  - Respiratory pump (difference
  P between abdominal &
thoracic cavity)

Varicose Veins (p.679)

- Varicose veins
  - characterized by dilated, bulging, hardened
  veins
  - located in superficial veins of lower limb

Varicose Veins

Hemorrhoids

- High pressure in abdominopelvic cavity
during defecation or childbirth decreases
return of venous blood from anal veins;
also superficial and not well supported by
surrounding tissues, and thus may weaken
and dilate because of high pressure

Module 18.3 Maintenance of Blood Pressure

Short-Term Maintenance of BP

- Neural and Hormonal Control
  1. _______
  SNS → ______
     → VC ⇒ BP

  PSN ⇒ ___________ decr. C.
  ⇒ ______ BP
  (CN X → SA node, AV node)

Figure 18.7a Effects of the autonomic nervous system on blood pressure.
**Baroreceptor reflex:**

→ via CN IX to medulla oblongata
→ PSN response = decr. BP
or SNS response = incr. BP

---

**Short-Term Maintenance of BP**

**Response to increased BP**

1. Subject bears down and tries to expire against a closed glottis (airway in larynx), as occurs during coughing, sneezing, defecation, and heavy lifting
2. Raises pressure in thoracic cavity and reduces return of venous blood to heart
3. → drop in BP; should trigger baroreceptor reflex and generate increased HR

---

**Short-Term Maintenance of BP**

**Response to decrease in BP**

---

**Short-Term Maintenance of BP**

**Effects of chemoreceptor stimulation:**

- Peripheral chemoreceptors play a role in reg. breathing, but also affect BP; receptors respond to ________
- Central chemoreceptors respond to decreases _______; triggers another feedback loop that indirectly increases SNS, → VC and __________

---

**Short-Term Maintenance of BP**

- ________ responses are much slower
  1. Hormones that control __________: Epi, NEpi, thyroid hormone
  2. Hormones that control ________
     - Adrenal medulla → Epi, NEpi → VC
     - Atria → ANP → VD
     - Angiotensin II → VC
  3. Hormones that reg. ________
     - Kidneys → Renin → Angiotensin II → aldosterone → conserve H₂O
     → ADH → conserve H₂O
Summary of BP Maintenance

**MECHANISMS AFFECTING PERIPHERAL RESISTANCE**

<table>
<thead>
<tr>
<th>Endocrine</th>
<th>EFFECT on PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epinephrine</td>
<td>Increased peripheral resistance</td>
</tr>
<tr>
<td>Norepinephrine</td>
<td>Decreased peripheral resistance</td>
</tr>
<tr>
<td>Angiotensin II</td>
<td>Increased peripheral resistance</td>
</tr>
<tr>
<td>Renin secretion</td>
<td>Decreased peripheral resistance</td>
</tr>
<tr>
<td>Neural</td>
<td>Increased sympathetic activity</td>
</tr>
<tr>
<td>Decreased renin secretion</td>
<td>Decreased peripheral resistance</td>
</tr>
<tr>
<td>Increased parasympathetic activity</td>
<td>Decreased peripheral resistance</td>
</tr>
</tbody>
</table>

**Disorders of Blood Pressure**

- **Essential (primary) hypertension** – cause is unknown
- **Secondary hypertension** – cause can be determined
- **Hypotension** – systolic pressure < 90 mm Hg and/or diastolic pressure < 60 mm Hg
- **Circulatory shock** = severe hypotension - due to hypovolemia

**Capillary Structure and Function**

- **Module 18.4 Capillaries and Tissue Perfusion**
- **Figure 18.10** The structure of a generalized capillary.
**Capillary Structure and Function**

Capillary Exchange via:
1. Diffusion & osmosis (gaps)
2. Diffusion (membranes)
3. Transcytosis

- **Types of capillaries** — (Table 18.3):
  - _______ — skin, nervous, CT, muscle
  - **Fenestrated capillaries** — kidneys, endocrine, SI.
  - _______ — liver, lymphoid

**Blood Flow through Capillary Beds**

- **Autoregulation** (self-regulation)
  - ensures that correct amount of blood is delivered to match a tissue’s *level of activity*
- _______ ~ 25% of body’s capillary beds are fully open
Module 18.5 Capillary Pressures and Water Movement

Pressures at Work in a Capillary

- Drives movement of water across capillary wall (passive process)

Hydrostatic Pressure

- Pressures at work across capillary bed:
  - 35 mmHg (arterial end) \( \rightarrow \) 15 mmHg (venule end)

Osmotic Pressure

- 25 mmHg throughout capillary bed

Figure 18.13a: Hydrostatic and osmotic pressures in capillary blood and interstitial fluid.

- Solute particles in a solution exert a force, or "pull," on water molecules called osmotic pressure (OP)

- Osmotic pressure is determined by:

\[
\text{COP} =OP_{\text{capillary blood}} - OP_{\text{interstitial fluid}} = 25 \text{ mmHg} - 3 \text{ mmHg} = 22 \text{ mmHg}
\]
Pressures at Work in a Capillary

• **Capillary net filtration pressure** (NFP)
  – colloid OP and HP gradient drive water in opposite directions
  \[ \text{HP} - \text{COP} = \text{NFP} \] (Figure 18.14)

At arteriolar end:
  • 35 mm Hg – 22 mmHg = \[ \text{NFP} \] (out of cap.)

At venule end:
  • 15 mmHg – 22 = \[ \text{NFP} \] (into cap.)

Pressures at Work in a Capillary

• **Edema**

Causes:
  – increase in CHP gradient due to HT
  – decrease in COP due to liver disease, cancer, or starvation
  – **Peripheral edema** - in hands and feet due to gravity
  – Ascites – accumulation of interstitial fluid in abdomen
Anatomy of the Systemic Arteries

Aorta (4 sections)
1. Ascending aorta
   - Rt & Lt coronary arteries
2. Aortic arch
3. Descending thoracic aorta
4. Descending abdominal aorta
   - Rt and Lt common iliac A.

Cerebrovascular Accident (p. 697)

- Cerebrovascular accident (CVA), or stroke
  - damage to brain caused by a disruption to blood flow
  - 4th most common cause of death (US)
- Causes
  1. blockage of cerebral arteries due to a clot
  2. loss of blood (hemorrhage) due to ruptured cerebral artery
- Symptoms
  - sudden-onset paralysis (paresis or weakness)
  - loss of vision,
  - difficulty speaking or understanding speech
  - Headache
- Risk factors
  - HT
  - Atherosclerosis
  - DM
  - Smoking
  - Atrial fibrillation
- Treatment
  - medications to dissolve clot and thin blood
  - surgery to repair damaged vessels

Pulse Points

- Pulse = Pressure changes cause arteries to expand and recoil with each heartbeat
- Pulse points

Figure 18.15 The major systemic arteries.

Figure 18.22 Common pulse points.
**Introduction to the Systemic Veins**

- Superior to diaphragm:
  - Rt and Lt brachiocephalic veins merge to form ______ → RA (Figure 18.23)

- Blood draining lower limbs and pelvis:
  - external and internal iliac veins merge to form common iliac veins → merge to form ______ → RA

**Veins of the Head and Neck**

- Head and neck:
  - internal jugular veins
  - external jugular veins

**Veins of the Thorax and Abdomen**

- Hepatic portal circulation:
  - Drains nutrient-rich, oxygen-poor blood from digestive organs
  - Superior and inferior mesenteric veins
    → ______ (Figure 18.27b)
  - Liver then detoxifies substances including drugs
    - blood then goes to IVC
Veins of the Thorax and Abdomen

Figure 18.27b: Veins of the abdomen.

The Big Picture of Blood Vessel Anatomy

Figure 18.30b: Blood vessels of the head and neck.

Figure 18.31: Blood vessels of the abdomen.

Figure 18.32: Blood vessels of the upper and lower limbs.

Figure 18.33: The Big Picture of Systemic Blood Flow in the Body.

Blood = 5 L. of fluid CT, 8% TBW comprised of __________________.
**Module 19.1 Overview of Blood**

**Blood Overview**

- **Plasma** – _______ ECM of blood
- **Formed elements** – __________ suspended in plasma

![Fig. 19.1b](image)

**Blood Overview**

**Formed elements:**
- _______ – also known as red blood cells (RBCs)
- _______ – also known as white blood cells (WBCs)
- _______ – small cellular fragments (thrombocytes)

**Blood Overview**

- **Centrifuged** blood sample (Fig. 19.1):
  - **Top layer** – plasma
  - **Middle layer** – leukocytes and platelets (buffy coat) ~1% of total volume
  - **Bottom layer** – erythrocytes ______

**Blood Overview**

- **Overview of Blood Functions**
  - **Functions:**
    - **Exchanging gases** – O₂ and CO₂
    - _______ – transports ions, nutrients, hormones, and wastes, and regulating [ions]
    - **Immune functions** – both leukocytes and immune system proteins are transported in blood
    - _______ – platelets
    - **Acid-Base balance:** 7.35 – 7.45 pH
    - **BP:** determined by blood vol.
Plasma

- **Plasma** (Table 19.1)
  - Pale yellow liquid
  - 90% water, determining **viscosity**
  - _________ (9% of plasma vol.)

  Albumins (COP)
  Immune & Transport (Gamma globulins, lipoproteins)
  Clotting (Fibrinogen)

  glucose, a.a., gases, wastes

---

Cirrhosis (p. 725)

- Liver disease (cirrhosis) has many causes, including cancer, alcoholism, and viral hepatitis
- Common in US; 10th leading cause of death for men; 12th for women
- Results in progressive **decrease** in production of plasma proteins;
  - ascites
  - Decline in clotting factor levels

---

**MODULE 19.2 ERYTHROCYTES AND OXYGEN TRANSPORT**

Erythrocyte Structure

**Erythrocyte, or red blood cell (RBC)**

- anucleated, more space for O₂-binding
- Hemoglobin

---

**Table 19.1 Components of Plasma.**

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>90% of plasma volume where that diffusion and exchange occur through the body.</td>
</tr>
<tr>
<td>Albumin</td>
<td>Maintains oncotic pressure.</td>
</tr>
<tr>
<td>Immune proteins</td>
<td>Transported by immune system.</td>
</tr>
<tr>
<td>Transport proteins</td>
<td>Maintains and transports molecules.</td>
</tr>
<tr>
<td>Clotting proteins</td>
<td>Functions in blood clotting.</td>
</tr>
<tr>
<td>Other Solutes</td>
<td>Functions vary, multiple functions are involved.</td>
</tr>
<tr>
<td>Water</td>
<td>Functions building block for protein synthesis</td>
</tr>
</tbody>
</table>

---

**Figure 19.2a Erythrocyte structure.**
Erythrocyte Structure
- 2 alpha (α) chains and 2 beta (β) chains
- Heme group = ______________________
- Fe ion in each heme group is oxidized when it binds to oxygen → ______________________

Erythrocyte Structure
- Hemoglobin:
  - Releases oxygen into tissues where oxygen conc. is low
  - Binds to CO₂ → ______________________ where oxygen levels low

Erythrocyte Structure
(b) Heme groups
Figure 19.3b: Hemoglobin structure.

Erythrocyte Life Span
- Life span of an erythrocyte: __________
- Hematopoiesis – process in red bone marrow where formed elements in blood are produced by hematopoietic stem cells (HSCs)
- Erythropoiesis produces erythrocytes from HSCs
  - takes 5 to 7 days

Erythropoiesis
Figure 19.4: Erythropoiesis: formation of erythrocytes.
Erythropoiesis

- Regulation of Erythropoiesis
  - ________ (EPO) triggers neg. feedback
  - maintains hematocrit within normal
  - Stimulus: Blood levels of oxygen fall below normal
  - Receptor: Kidney cells detect falling oxygen levels
  - Control center: Kidneys produce more EPO
  - Effector/Response: RBC production increases

Homeostasis: _______________________

Erythrocyte Death

- Erythrocyte destruction:
  1. Erythrocytes trapped in sinusoids of spleen
  2. Spleen macrophages digest erythrocytes
  3. Hemoglobin is broken down into a.a, Fe, and (biliverdin→) bilirubin
  4a. Bilirubin → __________
  b. Fe and a.a. recycled → __________

Anemia

- Anemia
  = _______________________

Causes: decreased Hb, decreased Hct, and abnormal Hb

Symptoms: pallor, weakness, fatigue, incr. HR

Types: Iron-deficiency anemia (decr. Hb)
  Pernicious anemia (decr. Hct)
  SCA (abnormal Hb)

Anemia

- Abnormal hemoglobin
  - most common ex. sickle-cell disease (SCD)
  - Individuals with single copy of defective gene have __________
  - Individuals with two defective copies of gene have sickle-cell disease: produce abnormal hemoglobin called hemoglobin S (HbS)

Figure 19.5 Regulation of erythropoiesis.

Figure 19.6 Erythrocyte death.

Figure 19.7a Erythrocytes in sickle-cell disease.
Anemia

• Abnormal hemoglobin (continued):
  – When oxygen levels are low, RBCs containing HbS change into a sickle shape; leads to erythrocyte destruction in small blood vessels and a reduction in circulating erythrocytes.

Leukocytes

• Leukocytes or white blood cells (WBCs)
  – larger than erythrocytes
  – nucleated
  – use blood-stream as transportation only

  Two basic categories (Figure 19.8):
  ▪ ___________ contain cytoplasmic granules
  ▪ Agranulocytes ______________

Granulocytes

• Granulocytes
  – readily distinguished by their unusual nucleus
  – 3 categories based on granule color
  • light lilac, dark purple, or red when stained with Me blue or acidic (eosin) dye
    __________
    Eosinophils
    Basophils

Granulocytes

• Neutrophils (PMNs)
  – most numerous leukocyte
  – light lilac color
  – phagocytosis
  – nucleus composed of ____________

Granulocytes

• Eosinophils
  – __________
  – appear red due to uptake of eosin dye
  – Phagocytes that ingest foreign molecules
  – Respond to parasitic infections and allergic rxn.
  – Granules contain enz. specific to __________

**Granulocytes**

- **Basophils** – least numerous leukocyte
  - *S-shaped nucleus* and appear *dark purple* due to methylene blue dye
  - Chemicals in granules

![Basophil Image](image)

**Agranulocytes**

- **Agranulocytes**
  - **Lymphocytes**
    - 2nd most common leukocyte
    - contain large, spherical nuclei and light blue rim of cytoplasm
    - B lymphocytes (B cells)
    - T lymphocytes (T cells)

![Lymphocyte Image](image)

**Agranulocytes**

- **Monocytes**
  - largest leukocyte
  - *large U-shaped nuclei*
  - Some mature into __________
    - Macrophages – phagocytic cells that ingest dead and dying cells, bacteria, antigens, and other cellular debris

![Monocyte Image](image)

**Complete Blood Count, (p. 732)**

- **Complete Blood Count (CBC)** – important test for *anemia* and other conditions
  - RBC count in cells per milliliter; used to calculate hematocrit
  - Hemoglobin concentration
Complete Blood Count

- RBC characteristics – size, volume, and concentration of hemoglobin in cytosol
- Platelet count and volume
- Numbers and types of leukocytes

Leukopoiesis

- **Leukopoiesis** – formation of WBCs from **hematopoietic stem cells** (HSCs) (Figure 19.9):
  - **Myeloid cell line** – produces most formed elements (RBCs, monocytes, and platelets)
  - **Lymphoid cell line** – produces lymphoblasts, committed to becoming B and T lymphocytes
    - B cells in bone marrow
    - T cells in thymus

Leukemia (p. 733)

- **Leukemias** are cancers of blood cells or bone marrow;
- Also classified by cell line from which abnormal cells derive:
  - **Lymphocytic** – from lymphoid cell line; generally abnormal B lymphocytes
  - **Myelogenous** – from myeloid cell line; can involve any of myeloid cells

Module 19.4 Platelets

- **Platelets**
  - **small cell fragments** of megakaryocyte
  - involved in ________ (stops blood loss from an injured blood vessel)
  - several types of **granules**: contain clotting factors, enzymes
  - Lifespan: ________
Hemostasis - Vascular Spasm

- Hemostasis Part 1: __________ begins immediately when a blood vessel is injured and blood leaks into ECF with following two responses (Figure 19.11):
  - __________ and increased tissue pressure both act to decrease blood vessel diameter
  - Blood loss is minimized as both BP and blood flow are reduced locally by these responses
Concept Boost: Making Sense of the Coagulation Cascade

- What's the best way to approach the coagulation cascade? Remember that the entire process has three simple goals:
  - Produce factor Xa – goal of both intrinsic and extrinsic pathways, activates prothrombin
  - Produce thrombin – produces enzyme thrombin
  - Produce fibrin – thrombin, in turn, accomplishes third goal of coagulation: producing fibrin to hold platelet plug together and seal wound
Putting it All Together: The Big Picture of Hemostasis

Regulation of Clotting

• Blood clotting is produced by a _______ example of Feedback Loops Core Principle; must be tightly regulated to prevent mishaps (Table 19.3)
  – Endothelial cells \(\rightarrow\) two chemicals that regulate 1st and 2nd stages of clot formation
    • Prostacyclin – prostaglandin; inhibits platelet aggregation
    • Nitric oxide – causes vasodilation

Regulation of Clotting (continued):

– Endothelial cells and hepatocytes produce anticoagulants; inhibit coagulation:
  • Antithrombin III (AT-III) – protein that binds and inhibits activity of both factor Xa and thrombin; also prevents activation of new thrombin
  • Heparin sulfate – polysaccharide that enhances antithrombin activity
  • Protein C – when activated by protein S, catalyzes reactions that degrade clotting factors Va and VIIIa

Disorders of Clotting

• Clotting Disorders
  1. Bleeding disorders:
     Hemophilias - ________________
  2. Hypercoagulable conditions:
     • DVT (deep vein thrombosis)
     \(\rightarrow\) PE pulmonary embolism

Anticlot Medications (p. 744)

– Patients with thrombi or emboli are treated with drugs that prevent clotting process
– Anticoagulants – widely used group of medications; manage and prevent emboli; include:
  – Heparin
  – Warfarin (Coumadin)

Anticlot Medications

• Antiplatelet drugs:
  – Aspirin –
  – Clopidogrel –

• Thrombolytic agents (tPA or urokinase)
Blood Transfusions

- Blood transfusions
  - blood taken from a donor is given to a recipient
  - Discovery of antigens (surface marker) found on all cells, including RBCs

Blood Transfusions (continued):
- Antigens on erythrocytes (genetically determined carbohydrate chains) give rise to different blood groups
- Two groups of the 30 different antigens found on erythrocytes are particularly useful for clinical use: ABO blood group and Rh blood group

Blood Typing

ABO blood group features two antigens, A and B antigens; gives rise to four ABO types (Figures 19.17, 19.18; Table 19.4):
- Type A – only _________ is present on RBC
- Type B – only _________ is present
- Type AB – both A and B antigens are present
- Type O – neither _________ antigens are present

Blood Typing

- Rh blood group
- Rh antigen first discovered in rhesus monkeys; individuals with Rh antigen (D antigen)
- Rh-positive (Rh+) _________
- Rh-negative (Rh–) _________
- Type O+ is most common blood type in U.S. populations while AB– is least common

Blood Typing

- Blood typing in the lab uses antibodies (agglutinins) that bind to antigens on RBCs
- Causes them to ____________
- Ultimately, agglutination promotes _______
Blood Typing

**Figure 19.17** How antibodies agglutinate erythrocytes.

**Figure 19.18** Blood type testing. Blood samples from four patients are combined with antibodies. Agglutination indicates that a specific antigen is present on that patient’s erythrocytes.

---

**Blood Transfusions**

- Note that anti-A and anti-B antibodies are pre-formed; they are present in plasma even if individual has never been exposed to those antigens
- Anti-Rh antibodies, however, are produced only if a person ____________________
- Therefore, an Rh- individual generally has no anti-Rh antibodies unless he or she has been exposed (sensitized) to Rh+ erythrocytes

---

**Hemolytic Disease of the Newborn (HDN) (p. 747)**

- Also known as erythroblastosis fetalis; occurs when an Rh- mother gives birth to an Rh+ fetus
- During birth fetal RBCs enter mother’s blood; stimulates her immune system to produce anti-Rh antibodies
- First pregnancy is not typically at risk; in subsequent pregnancies maternal anti-Rh antibodies can cross placenta and hemolyze Rh+ fetal RBCs

---

**Blood Transfusions**

- Antigens and antibodies are basis for blood matching: blood taken from a donor is screened for compatibility prior to its administration to a recipient
  - A match occurs if donor blood type is compatible with recipient blood type
  - Transfusion reaction — recipient antibodies bind to donor antigens; causes agglutination that destroys donor erythrocytes, possibly leading to kidney failure and death

---

**Figure 19.19** Matching blood types for blood transfusions.
Blood Transfusions

• **Universal donor** – Blood type \_

  - Can be given to *any other blood type* in an emergency when blood matching is *not an option*

Blood Transfusions

• **Universal recipient** – blood type \_

  - These individuals *do not make antibodies* to A, B, or Rh antigens
  - Individuals with AB+ blood type can generally *receive blood from any blood type donors*
  - Matching is *still* safest practice

---

**Concept Boost: What about the Donor’s Antibodies?**

• Donor antibodies can bind to a recipient’s antigens, and unless blood types are *exactly matched*, some donor antibodies might destroy a few recipient’s erythrocytes

**Example 1:**

– Donated O– erythrocytes from Ed
  – 100 anti-A, anti-B, and anti-Rh antibodies from Ed’s blood
  – Tom’s AB+ erythrocytes

• Ed’s 100 antibodies might destroy 100 of Tom’s erythrocytes; but Tom has received *millions* of new erythrocytes from Ed, so he won’t really miss 100
MODULE 20.1 STRUCTURE AND FUNCTION OF THE LYMPHATIC SYSTEM

Introduction to the Immune and Lymphatic Systems

- **Lymphatic system**
  - group of organs and tissues that work with immune system
  - functions ________
  - 2 main components: (Figure 20.1):
    - **Lymphatic vessels**: blind-ended tubes
    - **Lymphatic tissue and organs**: tonsils, lymph nodes, ______

Functions of the Lymphatic System

- Lymphatic system functions:
  1. **Regulation of** ________
     - return excess fluid lost from plasma to CV system
  2. **Absorption of** ________
     - breakdown products of fats in diet are too large to pass into blood cap. (absorbed into lacteal)
  3. **Imune functions**
     - filter pathogens from lymph and blood

Lymphatic Vessels and Lymph Circulation

- **Lymph-collecting vessels**
  - lymph trunks ➔ cisterna chyli

  2 lymph ducts

  Right lymphatic duct ➔ ______ duct

  Right Subclavian Vein ➔ ______ Subclavian Vein

Functions of the Lymphatic System

[Figure 20.1 Overview of the lymphatic system.]

Lymphatic Vessels and Lymph Circulation

[Figure 20.2 Main lymph trunks and ducts.]
Lymphatic Vessels and Lymph Circulation

Lymphatic vessels
- **low-pressure** circuit because no main pump to drive lymph through vessels, and most of them are transporting lymph against gravity
- **Valves**

Figure 20.3 Structure and function of lymphatic capillaries.

Lymphedema (p. 755)
- Edema (swelling) is an accumulation of excess interstitial fluid; many conditions can cause mild to moderate edema, including trauma, vascular disease, and heart failure
- However, edema seen with lymphedema is typically severe and can be disfiguring

Lymphedema
- Lymphedema is generally due to removal of lymphatic vessels during surgery or blockage of vessels from pathogens such as parasites
- Both conditions prevent lymphatic vessels from transporting excess interstitial fluid back to cardiovascular system; fluid therefore accumulates in tissues of affected body part, causing it to enlarge
- Photo shows a case of lymphedema in arm of a breast cancer patient resulting from surgical removal of lymph nodes

Lymphoid Tissues and Organs
- Mucosa-Associated Lymphatic Tissue (MALT)
  - Tonsils (palatine, pharyngeal, lingual)
  - Peyer’s patches (aggregated lymphoid nodules)
  - Appendix
- Lymph nodes
- Spleen