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
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) pumps blood to lungs
  - ______________ deliver oxygen-poor (deoxygenated) blood to lungs
  - Gas exchange between alveoli and pulmonary capillaries
  - ______________ deliver oxygen-rich (____________) blood to left side of heart

---

**Pulmonary Circuit**

1. Deoxygenated blood is pumped to the lungs by the right side of the heart.
2. Gas exchange occurs between air in the alveoli and blood in the pulmonary capillaries.
3. Oxygenated blood is returned to the left side of the heart.

Figure 17.2a

(a) The pulmonary circuit
Pulmonary & Systemic Circuits

**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 _____

**Pulmonary & Systemic Circuits**

- **Pulmonary circuit** *low-pressure circuit*
  →________________________

- **Systemic circuit** *high-pressure circuit*
  → pumps blood to rest of body
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
Module 17.2 Heart Anatomy and Blood Flow Pathway

Pericardium

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


Pericardium

Pericardial cavity
- contains serous fluid (pericardial fluid)
- acts as a ______________

Heart Wall

1. Epicardium - outmost layer

2. ______________
   - middle muscle layer
     [What type of muscle??]

   - fibrous skeleton (dense irregular collagenous CT)

3. Endocardium - innermost ______________
Cardiac Tamponade \((p. 635)\)

- Pericardial cavity fills with excess fluid
  \[\rightarrow\text{cardiac tamponade}\]

- 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) _____

Figure 17.4a The coronary circulation.
**Coronary Circulation**

- **Coronary veins**
  - Great cardiac vein
  - Small cardiac vein
  - Middle cardiac vein

  \[ \rightarrow \underline{\text{_______}} \rightarrow \text{RA} \]

- **Coronary artery disease (CAD)**
  - buildup of ______ (fatty material) in coronary arteries
  - decreases blood flow to myocardium \[ \rightarrow \underline{\text{______________}} \]
  - 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 ________________

Coronary Circulation

- Survival after MI depends on **extent** and **location** of damage
- Dead cells are replaced with ______
- Death of part of myocardium increases ________________
- **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):
  
  ➢ **2 Atria**
    
    - *receive* blood from veins
    - *pump* through ____________ (AV) **valves** into ventricles

  ➢ **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:
  o __________________________

  -> Aortic Arch

  o _____________ artery
  o _____________ (RCC) artery
  o ______________
Great Vessels, Chambers, and Valves

Figure 17.5a The external anatomy of the heart.

Great Vessels, Chambers, and Valves

Figure 17.5b The external anatomy of the heart.
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"
Great Vessels, Chambers, and Valves

LV wall = 3x thicker than RV

RV – low pressure
LV – high pressure

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

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

Figure 17.7b Anatomy of the atrioventricular and semilunar valves.
The Big Picture
- Blood Flow through the Heart

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

Valvular Heart Diseases

• Both valve disorders may cause ______

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

• Mitral and aortic valves are ones most commonly affected (_______)
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
Electrophysiology

- _______________
  – specialized cardiac muscle cells
  (=1% of cardiac muscle cells)
  - coordinate cardiac electrical activity
  - *rhythmically* and *spontaneously*
    generate APs to _other_ type of cardiac muscle cell (________
                    _______________)

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

---

**Figure 17.10** A contractile cell action potential.
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
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:

___________ node (SA node)
- located in upper RA
- 60 bpm influenced by SNS & PSN

___________ node (AV node)
- located near tricuspid valve
- 40 bpm
- AV node delay

Purkinje fiber system

Electrophysiology of Cardiac Muscle

• Purkinje fiber system:
  ➢ Atrioventricular bundle (___________)
    ➢ Right and left _____________
      ➢ _________________
      - located in ventricular walls
Electrophysiology of Cardiac Muscle

AV node delay
- allows atria to depolarize (and contact) 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??

![Figure 17.13](image)

*Figure 17.13*  A normal electrocardiogram (ECG) tracing.
Electrophysiology of Cardiac Muscle

**Figure 17.13** A normal electrocardiogram (ECG) tracing.

- **ECG FINDING**
  - R-R interval
  - P-R interval
  - Q-T interval

- **MEANING**
  - Determine HR
  - Spread of depolarization through atria
  - Spread if depolarization through ventricles

**ECG FINDING**

- **MEANING**
  - Ventricular plateau phase

**Figure 17.13** A normal electrocardiogram (ECG) tracing.
Electrophysiology of Cardiac Muscle

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
Dysrhythmias

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

Dysrhythmias

Right or left bundle branch block
- generally widens QRS complex due to depolarization taking longer to spread through ventricles
3. __________ = electrical activity goes haywire → parts of heart to depolarize and contract while others are repolarizing and not contracting
- bag of worms writhing

Dysrhythmias

– 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
  - \( \Rightarrow \) forces AV valves *open*, ____________

  __________________________________________________________

  \( \Rightarrow \) Higher pressures in pulmonary trunk and aorta push cusps of semilunar valves *closed*

---

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

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

Figure 17.15 Heart sounds.
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

Pressure Changes, Blood Flow, and Valve Function

• **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
Pressure Changes, Blood Flow, and Valve Function

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

---

Pressure Changes, Blood Flow, and Valve Function

1. **Ventricular Diastole** (filling phase)

*Figure 17.16* Events of the cardiac cycle.
Pressure Changes, Blood Flow, and Valve Function

2. Ventricular Systole (Contraction Phase)

- **Isovolumetric contraction phase:**
  - Ventricular systole begins.
  - AV and semilunar (aortic and pulmonary) valves close when enough pressure builds in the ventricles.
  - Atrial diastole begins.

**Figure 17.16** Events of the cardiac cycle.

3. Ventricular Ejection

- **Ventricular ejection phase:**
  - Ventricular systole continues.
  - AV valves are still closed.
  - Atrial diastole continues.
  - Pressure opens SL valves, and blood is ejected into the pulmonary artery and aorta.

**Figure 17.16** Events of the cardiac cycle.
Pressure Changes, Blood Flow, and Valve Function

4. Ventricular Relaxation (diastole)

Figure 17.16 Events of the cardiac cycle.
Pressure Changes, Blood Flow, and Valve Function

Figure 17.17 Comparison of pressure changes in left and right ventricles during the cardiac cycle.

Figure 17.18 Wigger's diagram showing an overview of electrical and mechanical events in the heart during the cardiac cycle.
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

• **C.O. = heart rate x stroke volume:**
  – 72 beats/min \( \times \) 70 ml/beat = 5040 ml/min
    \( \sim \) 5 liters/min (C.O.)
  – Resting C.O. \( \sim \) averages about 5 liters/min;
    RV pumps \( \sim \) 5 liters into pulmonary circuit
    LV pumps same \textit{amt.} to systemic circuit

Normal adult blood volume = \( \sim \) 5 liters

Factors that Influence Stroke Volume

Frank-Starling law

• Increased ventricular muscle cells \textit{stretch}, leads to \( \rightarrow \) ____________

• \textit{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
How Changes in Preload, Contractility, and Afterload Affect Stroke Volume

Factors that determine stroke volume—preload, contractility, and afterload—illustrated using only the left ventricle for simplicity.

Ventricular Hypertrophy (p. 662)
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

Figure 17.20 Innervation and nervous regulation of the heart.

Regulation of Cardiac Output

- __________ – affected by SNS → Epi and NEpi
  - thyroid hormone and glucagon

- __________
  - Aldosterone and antidiuretic hormone increase blood vol. → incr. C.O.
  - ANP decreases blood vol. → 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

Figure 17.21 Regulation of cardiac output.
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 $\rightarrow$ decreased SV
  $\rightarrow$ _______________

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 $\rightarrow$ _______________
Heart Failure

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

Heart Failure

- \textbf{Treatment} – ______________
  - \textbf{Lifestyle modifications} - weight loss and mild exercise, dietary sodium and fluid restrictions
  - \textbf{Drug therapy}

  - Heart \textit{transplant} and/or \textit{pacemaker}
8
The Cardiovascular System
II: The Blood Vessels

Vasculature = ____________
60,000 miles of vessels
Capillaries alone would circle the world (25,000 miles)

MODULE 18.1 OVERVIEW OF ARTERIES AND VEINS
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)
Introduction to the Vasculature
3 types of vessels

1. Arteries
   – *distribution system* of vasculature
     - ___________________ 

2. Capillaries
   – *exchange system* of vasculature
     - smallest vessels
     - ________________ 

3. Veins
   - *collection system* of vasculature
     - ________________ 

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):
  o Arteries
    - ___________ \( \rightarrow \) reflects arteries’ role in controlling BP and blood flow
    - more extensive internal and external elastic \( \rightarrow \) reflects arteries are under much higher

---

Figure 18.2  A comparison of the walls of arteries and veins.
Structure and Function of Arteries and Veins

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

Structure and Function of Arteries and Veins

- 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

Structure and Function of Arteries and Veins

• **Veins** classified by **size**:
  - **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>Types</th>
<th>Diameter</th>
<th>Structure</th>
<th>Function(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic arteries</td>
<td>2.5–1.0 cm</td>
<td>Large arteries with well-developed elastic laminae</td>
<td>• Conduct blood under high pressure to organs</td>
</tr>
<tr>
<td>Muscular arteries</td>
<td>1.0 cm–0.3 mm</td>
<td>Thick-walled arteries with well-developed tunica media</td>
<td>• Control blood flow to organs • Regulate blood pressure</td>
</tr>
<tr>
<td>Arterioles</td>
<td>0.3 mm–10 μm</td>
<td>Thin walls with all three tunics</td>
<td>• Control blood flow to tissues • Feed capillary beds</td>
</tr>
<tr>
<td>Veins</td>
<td>80–100 μm</td>
<td>Small veins have only a tunica intima; larger veins have all three tunics</td>
<td>• Drain capillary beds</td>
</tr>
<tr>
<td>Veins</td>
<td>100 μm–1.5 cm</td>
<td>Thin-walled vessels with large lumens, little smooth muscle, and valves</td>
<td>• Return blood to the heart</td>
</tr>
</tbody>
</table>

---

### Atherosclerosis (p. 672)

- **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)

---

Introduction to Hemodynamics

• **Blood pressure** (mmHg) – *outward* force that blood exerts on walls of blood vessels

  ➢ *Varies*

  ➢ __________ in large systemic arteries and

  ➢ __________ in large systemic veins
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 → 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 x HR

3. ________ – influenced by water loss and gain
Factors That Determine Blood Pressure

BP in Different Portions of Circulation

- Pulmonary circuit ~ 15 mmHg
- Systemic circuit ~ 95 mm Hg (Fig. 18.5, 18.6; Table 18.2)

___________ pressure averages ~ 120 mm Hg
___________ pressure averages ~80 mm Hg (at rest)

Pulse pressure = systolic - diastolic pressures
= ~ 40 mm Hg

MAP = diastolic pressure + 1/3 (pulse pressure)
BP in Different Portions of the Circulation

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulmonary Circuit</strong></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><strong>Systemic Circuit</strong></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>

**Table 18.2** Pressures in Pulmonary and Systemic Circuits.

**Blood Pressure in Different Portions of the Circulation**

**Figure 18.5** Pressure profile of the systemic circuit.
BP in Different Portions of Circulation

- Increase venous return:
  - ________ prevent backward flow
  - _____ in vein walls VC by SN
  - ______________

- Respiratory pump (difference in 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

Figure 18.7a Effects of the autonomic nervous system on blood pressure.

Maintenance of BP

• Neural and Hormonal Control

1. _______
SNS → ______________
   → VC =>↑ BP

PSN → _____ → decr. C.
   => ↓ BP
(CN X → SA node, AV node)
Baroreceptor reflex:

\[ \text{____________________} \rightarrow \]
\[ \rightarrow \text{via CN IX to medulla oblongata} \]
\[ \rightarrow \text{PSN response} = \text{decr. BP} \]
or
\[ \text{SNS response} = \text{incr. BP} \]

**Short-Term Maintenance of BP**

*Figure 18.8a* Maintaining homeostasis: Regulation of blood pressure by the baroreceptor reflex.
Short-Term Maintenance of BP

**Response to decrease in BP**

- **Stimulus:** Blood pressure decreases below normal range.
- **Receptor:** Baroreceptors in the carotid sinus detect the decreased pressure and lower their rate of firing.
- **In homeostatic range:** Blood pressure increases, and feedback restores the autonomic response to normal.
- **Control center:** The impulses travel to the medulla of the brainstem for integration.
- **Effect:** Medulla oblongata increases sympathetic output and decreases parasympathetic output, increasing heart rate and contractility and allowing vasoconstriction.

**Figure 18.8b** Maintaining homeostasis: Regulation of blood pressure by the baroreceptor reflex.

---

**Short-Term Maintenance of BP**

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

Short-Term Maintenance of BP

- __________ responses are much slower

  1. Hormones that control ______:
     - Epi, NEpi, thyroid hormone
  2. Hormones that control ______:
     - Adrenal medulla \( \rightarrow \) Epi, NEpi \( \rightarrow \) VC
     - Atria \( \rightarrow \) ANP \( \rightarrow \) VD
     - Angiotensin II \( \rightarrow \) VC
  3. Hormones that reg. __________
     - Kidneys \( \rightarrow \) Renin \( \rightarrow \) Angiotensin II \( \rightarrow \)
       adosterone \( \rightarrow \) conserve H\(_2\)O
       \( \rightarrow \) ADH \( \rightarrow \) conserve H\(_2\)O
### Summary of BP Maintenance

#### EFFECT on PR

<table>
<thead>
<tr>
<th>MECHANISMS AFFECTING PERIPHERAL RESISTANCE</th>
<th>EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Endocrine</strong></td>
<td>Increased peripheral resistance</td>
</tr>
<tr>
<td>Epinephrine</td>
<td></td>
</tr>
<tr>
<td>Norepinephrine</td>
<td></td>
</tr>
<tr>
<td>Angiotensin-II</td>
<td></td>
</tr>
<tr>
<td>Renin secretion</td>
<td></td>
</tr>
<tr>
<td><strong>Neural</strong></td>
<td></td>
</tr>
<tr>
<td>Increased sympathetic activity</td>
<td></td>
</tr>
<tr>
<td><strong>Endocrine</strong></td>
<td>Decreased peripheral resistance</td>
</tr>
<tr>
<td>Decreased renin secretion</td>
<td></td>
</tr>
<tr>
<td><strong>Neural</strong></td>
<td></td>
</tr>
<tr>
<td>Increased parasympathetic activity</td>
<td></td>
</tr>
<tr>
<td>Decreased sympathetic activity</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 18.9* Blood pressure maintenance.

#### EFFECT on HR

<table>
<thead>
<tr>
<th>MECHANISMS AFFECTING CARDIAC OUTPUT</th>
<th>EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Endocrine</strong></td>
<td>Increased rate and force</td>
</tr>
<tr>
<td>Thyroid hormone</td>
<td></td>
</tr>
<tr>
<td>Epinephrine</td>
<td></td>
</tr>
<tr>
<td>Norepinephrine</td>
<td></td>
</tr>
<tr>
<td><strong>Neural</strong></td>
<td></td>
</tr>
<tr>
<td>Increased sympathetic activity</td>
<td></td>
</tr>
<tr>
<td>Decreased parasympathetic activity</td>
<td></td>
</tr>
<tr>
<td><strong>Endocrine</strong></td>
<td>Decreased rate</td>
</tr>
<tr>
<td>Atrial natriuretic peptide</td>
<td></td>
</tr>
<tr>
<td><strong>Neural</strong></td>
<td></td>
</tr>
<tr>
<td>Increased parasympathetic activity</td>
<td></td>
</tr>
<tr>
<td>Decreased sympathetic activity</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 18.9* Blood pressure maintenance.
Summary of BP Maintenance

<table>
<thead>
<tr>
<th>MECHANISMS AFFECTING BLOOD VOLUME</th>
<th>EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Endocrine</strong></td>
<td></td>
</tr>
<tr>
<td>Angiotensin-II</td>
<td>Increased blood volume</td>
</tr>
<tr>
<td>ADH</td>
<td></td>
</tr>
<tr>
<td>Aldosterone</td>
<td></td>
</tr>
<tr>
<td><strong>Renal</strong></td>
<td></td>
</tr>
<tr>
<td>Increased H₂O retention</td>
<td></td>
</tr>
<tr>
<td><strong>Endocrine</strong></td>
<td>Decreased blood volume</td>
</tr>
<tr>
<td>Atrial natriuretic peptide</td>
<td></td>
</tr>
<tr>
<td><strong>Renal</strong></td>
<td>Decreased H₂O retention</td>
</tr>
</tbody>
</table>

Figure 18.9 Blood pressure maintenance.

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**
Module 18.4 Capillaries and Tissue Perfusion

Capillary Structure and Function

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

Figure 18.11 Capillary exchange mechanisms.

Capillary Structure and Function

• **Types of capillaries** – (Table 18.3):
  – ________________ – skin, nervous, CT, muscle
  • Most capillaries
  – **Fenestrated capillaries** – kidneys, endocrine, S.I.
  – ________________ – liver, lymphoid
Capillary Structure and Function

Table 18.3 Types of Capillaries

<table>
<thead>
<tr>
<th>Type</th>
<th>Structure</th>
<th>Location</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous capillaries</td>
<td>Tight junctions between cells</td>
<td>Most nervous and connective tissue, Muscle tissue</td>
<td>Least &quot;leaky&quot;—permit a narrow range of substances to cross the capillary walls</td>
</tr>
<tr>
<td>Fenestrated capillaries</td>
<td>Contain fenestrations in the endothelial cells</td>
<td>Kidneys, Endocrine glands, Small intestine</td>
<td>Moderately leaky—allow large volumes of fluid and larger molecules to cross capillary walls</td>
</tr>
<tr>
<td>Sinusoidal capillaries</td>
<td>Discontinuous sheet of endothelium, Irregular basal lamina, very large pores</td>
<td>Liver, Lymphoid organs, Bone marrow, Spleen</td>
<td>Leakiest—allow large substances such as cells to cross the capillary walls</td>
</tr>
</tbody>
</table>

Table 18.3 Types of Capillaries.

Blood Flow through Capillary Beds

Figure 18.12a Structure of and blood flow through a capillary bed.
Blood Flow through Capillary Beds

Figure 18.12b Structure of and blood flow through a capillary bed.

Local Regulation of Tissue Perfusion

• **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 cap. wall (passive process)

- **Pressures at work across capillary bed:**
  - _________ (HP) moves water out of cap.
    - **35 mmHg** (arterial end) \(\rightarrow\) **15 mmHg** (venule end)
  - _________ (OP) draws fluid into cap.
    - **25 mmHg** throughout cap. bed
Pressures at Work in a Capillary

• Hydrostatic pressure –

**Figure 18.13a** Hydrostatic and osmotic pressures in capillary blood and interstitial fluid.
Pressures at Work in a Capillary

- Solute particles in a solution exert a force, or “pull,” on water molecules called osmotic pressure (OP).
  - Osmotic pressure is determined by

\[
\text{COP} = \text{OP of capillary blood} - \text{OP of interstitial fluid} = 25 - 3 = 22 \text{ mmHg}
\]
Figure 18.13b  Hydrostatic and osmotic pressures in capillary blood and interstitial fluid.

Figure 18.13c  Hydrostatic and osmotic pressures in capillary blood and interstitial fluid.
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 = ________ (out of cap.)

At venule end:
  • 15 mmHg – 22 = ________ (into cap.)

Pressures at Work in a Capillary

• NFP is not exactly even at 2 ends of cap. bed
  – overall NFP favors filtration of water out of capillary

• Excess fluid in interstitium returned to blood
Figure 18.14 Net filtration (NFP) in capillaries.

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*
Module 18.6 Anatomy of the Systemic Arteries

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
Cerebrovascular Accident

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

Superior to diaphragm:
Rt and Lt brachiocephalic veins merge to form \( \rightarrow \) RA (Figure 18.23)

Blood draining lower limbs and pelvis:
\( \rightarrow \) external and internal iliac veins merge to form common iliac veins \( \rightarrow \) merge to form \( \rightarrow \) RA
Introduction to the Systemic Veins

Veins of the Head and Neck

Head and neck:
- internal jugular veins
- external jugular veins
Veins of the Head and Neck

Figure 18.24 Veins of the neck and superficial head.

Veins of the Thorax and Abdomen

- Hepatic portal circulation:
  - Drains nutrient-rich, oxygen-poor blood from digestive organs
  - Superior and inferior mesenteric veins
    \[\rightarrow\text{____________________ (Figure 18.27b)}\]
    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.
The Big Picture of Blood Vessel Anatomy

Figure 18.31 Blood vessels of the abdomen.

The Big Picture of Blood Vessel Anatomy

Figure 18.32 Blood vessels of the upper and lower limbs.
The Big Picture of Blood Vessel Anatomy

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** – ________ \textit{ECM} of blood
• **Formed elements** – ________________ suspended in plasma

\textit{Fig. 19.1b} The three visible layers of blood
Blood Overview

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

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

Figure 19.1 The three visible layers of blood.

Overview of Blood Functions

Functions:
- **Exchanging gases** – $O_2$ and $CO_2$
- _______________ – 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

### Table 19.1 Components of Plasma

<table>
<thead>
<tr>
<th>Plasma Component</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>60% of plasma volume; solvent that dissolves and transports many solutes through the body</td>
</tr>
<tr>
<td>Plasma Proteins</td>
<td>9% of plasma volume; multiple functions (see below)</td>
</tr>
<tr>
<td>Albumin</td>
<td>Maintains osmotic pressure</td>
</tr>
<tr>
<td>Immune proteins</td>
<td>Produced by leukocytes; function in immunity</td>
</tr>
<tr>
<td>Transport proteins</td>
<td>Bind and transport hydrophobic molecules through the blood</td>
</tr>
<tr>
<td>Clotting proteins</td>
<td>Function in blood clotting</td>
</tr>
<tr>
<td>Other Solute</td>
<td>1% of plasma volume; multiple functions (see below)</td>
</tr>
<tr>
<td>Glucose, amino acids</td>
<td>Nutrition; building blocks for protein synthesis</td>
</tr>
<tr>
<td>Ions</td>
<td>Electrolyte and acid-base homeostasis</td>
</tr>
</tbody>
</table>

**Dissolved gases** (small amounts of oxygen and carbon dioxide)
- Oxygen delivered to the tissues; carbon dioxide delivered to the lungs to be exhaled

**Wastes**
- Delivered to the appropriate organ for excretion

Table 19.1 Components of Plasma.
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 O\textsubscript{2}-binding

Hemoglobin

Figure 19.2a  Erythrocyte structure.
Erythrocyte Structure

- 2 alpha ($\alpha$) chains and 2 beta ($\beta$) chains
- heme group = __________________________
- Fe ion in each heme group is oxidized when it binds to oxygen $\rightarrow$ __________________

Erythrocyte Structure

- Hemoglobin:
  - Releases oxygen into tissues where oxygen conc. is low
  - Binds to CO$_2$ $\rightarrow$ __________________
    where oxygen levels low
Erythrocyte Structure

(b) Heme groups

Heme in oxyhemoglobin
Heme in deoxyhemoglobin

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.

CFU= colony forming unit

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: ____________________

Figure 19.5 Regulation of erythropoiesis.
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 $\rightarrow$ __________
  4b. Fe and a.a. recycled $\rightarrow$ __________

Figure 19.6 Erythrocyte death.
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*)

- 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 19.7a* 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.

![Figure 19.7b](b) Sickled erythrocytes block small blood vessels.

**Module 19.3 Leukocytes and Immune Function**
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

---

Figure 19.8 Classes of leukocytes.
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)

• **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
Agranulocytes

**Figure 19.8** Classes of leukocytes.

### AGRANULOCYTES

<table>
<thead>
<tr>
<th>细胞类型</th>
<th>特征</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lymphocyte</td>
<td>核是球形的。薄的一层浅蓝色的细胞质可见，当细胞被染色时。</td>
</tr>
<tr>
<td>Monocyte</td>
<td>核是U形的。浅蓝色至紫色的细胞质在细胞被染色时变得可见。</td>
</tr>
</tbody>
</table>

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

- **Complete Blood Count (CBC)** – 重要测试用于区分贫血（anemia）和其他条件

- RBC计数，每毫升细胞；用于计算血红蛋白
- 氧和血红蛋白浓度
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 ________________ (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**

- **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: ________
Thrombopoiesis

Figure 19.10b  Structure and formation of platelets.

Module 19.5 Hemostasis
Hemostasis

- **Hemostasis** - forms **blood clot** to plug broken vessel
  
  - Part 1: **Vascular Spasm**
  - Part 2: **Platelet Plug Formation**
  - Part 3: **Coagulation** (Intrinsic and Extrinsic Pathway)
  - Part 4: **Clot Retraction**
  - Part 5: **Thrombolysis**

**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
Hemostasis – Vascular Spasm

Figure 19.11 Hemostasis, part 1: vascular spasm.

Hemostasis – Platelet Plug

Figure 19.12 Hemostasis part 2: platelet plug formation.
Hemostasis – Coagulation

**Figure 19.13** Hemostasis part 3: coagulation cascade.
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*
Hemostasis - Clot Retraction

Figure 19.14 Hemostasis part 4: clot retraction.

Hemostasis - Thrombolysis

Figure 19.15 Hemostasis part 5: thrombolysis.
Putting it All Together: The Big Picture of Hemostasis

Figure 19.16 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 → two chemicals that regulate 1st and 2nd stages of clot formation
    • Prostacyclin – prostaglandin; inhibits platelet aggregation
    • Nitric oxide – causes vasodilation
Regulation of Clotting

• Blood 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 Vlla

Disorders of Clotting

• Clotting Disorders
  1. Bleeding disorders:
     Hemophilias - ________________
  2. Hypercoagulable conditions:
     ____________________________
     DVT (deep vein thrombosis)
     → PE pulmonary embolism
**Anticlot Medications**

- 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*)
MODULE 19.6 BLOOD TYPING AND MATCHING

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

• **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.

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.
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

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
### Table 19.4 The Eight Major Blood Types

<table>
<thead>
<tr>
<th>Blood Type</th>
<th>Antigen on Donor</th>
<th>Antigen on Recipient</th>
<th>Antibody Present in Donor</th>
<th>Antibody Present in Recipient</th>
<th>Red Cells Matched by Donor</th>
<th>Red Cells Matched by Recipient</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>A</td>
<td>Anti-B</td>
<td>Anti-A</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>B</td>
<td>Anti-A</td>
<td>Anti-B</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>AB</td>
<td>A and B</td>
<td>A and B</td>
<td>Anti-A and B</td>
<td>Anti-A and B</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>0 (A-)</td>
<td>0</td>
<td>0</td>
<td>Anti-B and anti-A</td>
<td>Anti-B and anti-A</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>0 (B-)</td>
<td>0</td>
<td>0</td>
<td>Anti-A and anti-B</td>
<td>Anti-B and anti-A</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>0 (AB-)</td>
<td>A and B</td>
<td>0</td>
<td>Anti-A and anti-B</td>
<td>Anti-B and anti-A</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>0 (0-)</td>
<td>0</td>
<td>0</td>
<td>Anti-B and anti-A</td>
<td>Anti-B and anti-A</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
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<td>0</td>
<td>0</td>
<td>Anti-B and anti-A</td>
<td>Anti-B and anti-A</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

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

• 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

Immune System =

Lymphatic System works with immune 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. **Immune functions**
   - filter pathogens from lymph and blood

---

Figure 20.1 Overview of the lymphatic system.
Lymphatic Vessels and Lymph Circulation

- Lymph-collecting vessels → lymph trunks → cisterna chyli

2 lymph ducts

Right lymphatic duct _______ duct

Right Subclavian Vein _______ Subclavian Vein

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