Cardiovascular System I: The Heart Chapter 17

CV system = 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
    (________________________)
  ➢ rests on diaphragm
  ➢ __________: inferior aspect
  ➢ ~ 250 to 350 grams (< 1 lb.)

• 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 & SYSTEMIC CIRCUITS

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 (oxygenated) blood to left side of heart

**Systemic Circuit:**

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

- Pulmonary circuit - low-pressure circuit \( \rightarrow \) ____________
- Systemic circuit high-pressure circuit \( \rightarrow \) ____________

**FUNCTIONS OF THE HEART**

- Heart helps maintain BP (blood pressure)
  - ____________ of contraction influence BP and blood flow to organs

- Atria produce hormone: atrial natriuretic peptide (ANP)
  - ANP ____________ BP by decreasing Na+ retention in kidneys \( \rightarrow \) 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 ____________)
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 endothelial layer

Cardiac Tamponade
- Pericardial cavity fills with excess fluid → cardiac tamponade
- Causes:
  - Fibrous pericardium - strong but not very flexible, excess fluid in pericardial cavity squeezes heart; reduces filling of ventricles
- Treatment

CORONARY CIRCULATION
Coronary vessels (supply heart wall):
- Branch off ascending aorta:
  ➢ 1. ________________
     → post. interventricular (post. descending a.)
     → marginal branch
  ➢ 2. left coronary artery
    → ________________ → ant. interventricular
    a. (left ant. descending) _______
• Great cardiac vein
• Small cardiac vein
• Middle cardiac vein

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

**Myocardial infarction (MI) or heart attack**
- 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 increases
- Risk factors include smoking, incr. BP, poorly controlled diabetes, high levels of certain lipids, obesity

__________________ diagnostic test for CAD

Treatments
• modify Lifestyle
• medications
• then invasive treatments

**Coronary** - balloon is inflated in blocked artery and________inserted
**Coronary artery bypass grafting (CABG)**
- other vessels are grafted onto diseased coronary artery to bypass blockage
PATH OF BLOOD THROUGH THE HEART

- Heart consists of four chambers:
  - 2 Atria
    - ________________
    - pump through atrioventricular (AV) valves into ventricles
  - 2 Ventricles
    - ________________
    - carry blood through systemic or pulmonary circuit

  - Superior vena cava (_____)
  - Inferior vena cava (_____)
  - ________________

1. Right Atrium (RA)
   <Right atrioventricular (AV) valve>
   (______________)

2. Right Ventricle (RV)
   chordae tendineae
   papillary muscles
   < Pulmonary semilunar valve>
   → pulmonary trunk
   → LUNGS → ________________

3. Left Atrium (LA)
   <left Atrioventricular (AV) valve>
   (______________)

4. Left Ventricle (LV)
   chordae tendineae
   papillary muscles

   < aortic semilunar valve >

   → Ascending aorta:
   → ________________
Aortic Arch
- Brachiocephalic artery
- LCC artery
- Artery

GREAT VESSELS, CHAMBERS, AND VALVES

- Pectinate muscles – muscular ridges inside RA
- Interatrial septum – wall between RA & LA
- Fossa ovalis – indentation in interatrial septum; remnant of opening
  from fetal circulation
- Trabeculae carneae – ridged surface in Ventricles “beams of flesh”
  RV – ______________
  LV – ______________
  LV wall = 3x______________ than RV

HEART VALVES
Tricuspid (______________)
  Pulmonary semilunar
  Bicuspid (______________)
  Aortic semilunar
Pulmonary semilunar valve - ________________________________

Valvular Heart Diseases
  - 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 nervous system to generate APs

• __________
  – 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
  –
  –
• generate tension through sliding-filament mech.
  • Ex. of Structure-Function Core Principle

• Like skeletal muscle fibers, cardiac muscle cells contain selective

• 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 ____________________________

• Sequence of events of contractile cell AP resembles that of skeletal muscle fiber AP
  with one exception: ____________________________
  – Plateau phase lengthens cardiac AP → ____________ providing time required for heart to fill with blood;
  – also increases ____________________________;
  – ____________________________ (sustained contraction) in heart by
    lengthening refractory period
  – 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 to 100 bpm influenced by SNS & PSN
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
  - SA node = main pacemaker of heart
- Sinus rhythms = ________________________________

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

- ECG represents depolarization or repolarization of parts of heart

- P wave represents __________________________
Dysrhythmias

**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

   - **Right** or **left bundle branch block**
     - generally widens **QRS complex** due to depolarization taking longer to spread through ventricles

3. **Fibrillation** = 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*
– 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” = asystole
– 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:

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

• ______________(relaxation phase) –

  Press. In ventricles falls below those in atria and in pulmonary trunk and aorta

  \rightarrow 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:
  - S1 (“lub”) = ________________
  - S2 (“dub”) = ________________

Heart Murmurs and Extra Heart Sounds

- **Heart murmur** - turbulent blood flow through heart often due to defective valves, defective chordae tendineae, or holes in interatrial or interventricular septum

- **Cardiac cycle** =

- 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

**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

- C.O. = heart rate x stroke volume:
- 72 beats/min × 70 ml/beat = 5040 ml/min
  ~5 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

Ventricular Hypertrophy

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) → __ HR, _____ force of contraction
PSN (ACh) $\rightarrow$ ____ HR, ____ force of contraction

• ____________
  - ____________ – 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.

• Other factors that influence cardiac output:
  – [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 $\rightarrow$ decreased SV $\rightarrow$ ____________

• 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 $\rightarrow$ ____________

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

- **Treatment** – increase cardiac output
  
  - **Lifestyle modifications** - weight loss and mild exercise, dietary sodium and fluid restrictions
  
  - **Drug therapy**
  
  - **Heart transplant** and/or **pacemaker**
Cardiovascular System II: The Blood Vessels
Chapter 18

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

  – __________________________ – transports blood between heart (RV) and _________
  – **Systemic circuit** – transports blood between heart (LV) and ___________
  – **Coronary circuit**: circulation of blood to __________________________
    (coronary arteries & veins)

• 3 types of vessels
  1. Arteries
    – *distribution system* of vasculature
      - 
  2. Capillaries
    – *exchange system* of vasculature
      - smallest vessels
      - 
  3. Veins
    - *collection system* of vasculature
      - 
• 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

• Artery vs vein:
  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 press.

• 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)
• Arterioles
  – ______________ = smallest arterioles that directly feed capillary beds

  - precapillary sphincter SMC that encircles metarteriole-capillary junc.

Certain arteries monitor pressure and chemicals:
  *Baroreceptors* –
  *Chemoreceptors* –

• Veins
  - outnumber arteries
  - larger lumens
  - serve ______________ (70% of total blood located in veins (systemic & pulmonary veins))

  - fewer elastic fibers
  - less SMC

• **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
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
- 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

Treaement:

**Module 18.2 Physiology of Blood Flow**

**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 near

- 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
    and
    → ___________ in large systemic veins
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 *increases*)

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:

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**

**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)
• Increase venous return:
  – __________ prevent backward flow
  – __________ in vein walls VC by SNS
  – _______________
  – Respiratory pump (difference in P between abdominal & thoracic cavity)

Varicose Veins

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

• 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. O. → _BP
     (CN X → SA node, AV node)

Baroreceptor reflex:

______________ →

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

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

- Effects of chemoreceptor stimulation:
  
  o Peripheral chemoreceptors play a role in reg. breathing, but also affect BP; receptors respond to ____________
  
  o Central chemoreceptors respond to decreases ________________; triggers another feedback loop that indirectly increases SNS; → VC and __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

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

<table>
<thead>
<tr>
<th>CAPILLARY STRUCTURE AND FUNCTION</th>
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<tbody>
<tr>
<td>Capillary Exchange via:</td>
</tr>
<tr>
<td>1. Diffusion &amp; osmosis</td>
</tr>
<tr>
<td>2. Diffusion</td>
</tr>
<tr>
<td>3. Transcytosis</td>
</tr>
</tbody>
</table>

• **Types of capillaries** –
  
  - ________________ – skin, nervous, CT, muscle
    - Most capillaries
    - **Fenestrated capillaries** – kidneys, endocrine, S.I.
  
  - ________________ – liver, lymphoid

<table>
<thead>
<tr>
<th>BLOOD FLOW THROUGH CAPILLARY BEDS</th>
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<tbody>
<tr>
<td>When precapillary sphincters are open:</td>
</tr>
<tr>
<td>When precapillary sphincters are closed:</td>
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</table>

<table>
<thead>
<tr>
<th>LOCAL REGULATION OF TISSUE PERFUSION</th>
</tr>
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<tbody>
<tr>
<td>• <strong>Autoregulation</strong> (self-regulation)</td>
</tr>
<tr>
<td>- ensures that correct amount of blood is delivered to match a tissue’s <strong>level of activity</strong></td>
</tr>
<tr>
<td>• ________________ ~ 25% of body’s capillary beds are fully open</td>
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### Module 18.5 Capillary Pressures and Water Movement

<table>
<thead>
<tr>
<th>PRESSURES AT WORK IN A CAPILLARY</th>
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<tbody>
<tr>
<td>________________ drives movement of water across cap. wall (passive process)</td>
</tr>
</tbody>
</table>
• 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

• Hydrostatic pressure –

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

• ____________________
  – OP of capillary blood = 25 mmHg
    • Plasma proteins pull fluid into cap.
  – OP of interstitial fluid = 3 mmHg
    • Proteins in interstium pull fluid out of cap.

________________________ (COP) =

\[25 - 3 = 22 \text{mmHg}\]

• Capillary net filtration pressure (NFP)
  – colloid OP and HP gradient drive water in opposite directions

________________________ (NFP)

\[\text{HP} - \text{COP} = \text{NFP}\]

At arteriolar end:
  • 35 mm Hg – 22 mmHg = ________________ (out of cap.)

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

• 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 ____________________

• 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**

- 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**
• **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**

---

**Module 18.7 Anatomy of the Systemic Veins**

**INTRODUCTION TO THE SYSTEMIC VEINS**

Systemic veins carry ____________________________

Superior to diaphragm:

Rt and Lt **brachiocephalic veins** merge to form _____ \(\rightarrow\) RA

Blood draining **lower limbs** and **pelvis**: \(\Rightarrow\) **external and internal iliac veins**
merge to form **common iliac veins** \(\Rightarrow\) merge to form _____ \(\rightarrow\) RA

**VEINS OF THE HEAD AND NECK**

Head and neck:

- internal jugular veins
- __________________
- external jugular veins
Hepatic portal circulation:
- Drains nutrient-rich, oxygen-poor blood from digestive organs
- Superior and inferior mesenteric veins
  \[\rightarrow\]
  Liver then detoxifies substances including drugs
  - Blood then goes to IVC
Blood:
Chapter 19

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
  - _________  – also known as red blood cells (RBCs)
  - _________  – also known as white blood cells (WBCs)
  - ____________  – small cellular fragments (thrombocytes)
- **Centrifuged** blood sample
  - Top layer  – **plasma**
  - Middle layer  – leukocytes and platelets **(buffy coat)**
  - Bottom layer  – **erythrocytes**
    - hematocrit =

**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
  - Pale yellow liquid
  - 90% water, determining viscosity
  - ___________ (9% of plasma vol.)
    Albumins (COP)

  Immune & Transport (Gamma globulins, lipoproteins)

  Clotting (Fibrinogen)

  Other Solutes: glucose, a.a., gases, wastes

**Cirrhosis**

- *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; leads to decreased__________; results in fluid loss to extracellular spaces, producing *severe edema* in the abdomen; termed ___________
- **Decline** in_________ levels also causes *easy bruising* and *delays clotting*; may be fatal
Module 19.2 Erythrocytes and Oxygen Transport

ERYTHROCYTE STRUCTURE

Erythrocyte, or red blood cell (RBC)
- anucleated, more space for O_2-binding

- Hemoglobin (Hb)
  - 2 alpha (α) chains and 2 beta (β) chains
  - heme group = __________________________________
  - Fe ion in each heme group is oxidized when it binds to oxygen
    → __________________________________

- Hemoglobin:
  - Releases oxygen into tissues where oxygen conc. is low
  - Binds to CO_2 → __________________ where oxygen levels low

ERYTHROCYTE LIFESPAN

- 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

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 ____________
  2. Spleen macrophages digest erythrocytes
  3. Hemoglobin is broken down into *a.a, Fe*, and (biliverdin $\rightarrow$) *bilirubin*
    - 4a. *Bilirubin $\rightarrow$ _______
    - 4b. *Fe and a.a. recycled $\rightarrow$ _______________

**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)*

- **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
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:

- ____________ contain cytoplasmic granules
- Agranulocytes ________________

GRANULO CYTES

- 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
    ____________ 60-70%
    Eosinophils <4%
    Basophils <1%

- Neutrophils (PMNs)
  - most numerous leukocyte
  - light lilac color
  - phagocytosis
    - nucleus composed of ________________

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

  **AGRANULOCYTES**

• **Agranulocytes**
  - **Lymphocytes** 20-25%
    - 2nd most common leukocyte
    - contain large, spherical nuclei and light blue rim of cytoplasm
  - **B lymphocytes** (B cells)
    -
  - **T lymphocytes** (T cells)
    -
  - **Monocytes** 3-8%
    - largest leukocyte
    - *large U-shaped nuclei*
    - Some mature into ________________
    - **Macrophages** – *phagocytic* cells that ingest dead and dying cells, bacteria, antigens, and other cellular debris

**Complete Blood Count**

- **Complete Blood Count (CBC)** – important test for *anemia* and other conditions
- Blood sample is drawn and examined under the *microscope* and by an *automated analyzer* to evaluate number and characteristics of blood cells:
  -
  -
  - 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):
  - **Myeloid cell line** – produces **most** formed elements (RBCs, monocytes, and platelets)
  - **Lymphoid cell line** – produces **lymphoblasts**, committed to becoming B and T lymphocytes

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**Leukemia**

- 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

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**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:
    -
Module 19.5 Hemostasis

- **Hemostasis** - forms **blood clot** to plug broken vessel
  - to *limit significant blood loss*
  - 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: Vascular Spasm** begins immediately when a *blood vessel is injured* and blood leaks into ECF with following two responses:
  - ________________ 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 – PLATELET PLUG**

**HEMOSTASIS – COAGULATION**

**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**

**HEMOSTASIS – THROMBOLYSIS**

**REGULATION OF CLOTTING**

• Blood clotting is produced by a ____________________________; example of Feedback Loops Core Principle; must be tightly regulated to prevent mishaps
  – Endothelial cells → two chemicals that regulate 1st and 2nd stages of clot formation
    • Prostacyclin – prostaglandin; inhibits platelet aggregation
    • Nitric oxide – causes vasodilation
  – 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) → 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)
- 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 surface marker found on all cells, including RBCs; genetically determined CHO chain
    - 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: _________blood group and _______blood group
ABO blood group features two antigens, A and B antigens; gives rise to four ABO types:

- **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

**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 in the lab uses **antibodies (agglutinins)** that bind to antigens on RBCs
  - Causes them to clump together or __________
  - Ultimately, agglutination promotes __________

**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

- 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)

• Also known as _______________________; 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

• Effectively prevented with blood type screening; if woman is Rh−, can be given Rho (D) immune globulin; contains anti-Rh antibodies that bind fetal cells in maternal circulation; prevents maternal production of anti-Rh antibodies

• Universal donor – Blood type_________

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

• 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
The Lymphatic System and Immunity
Chapter 20

Immune System =
Lymphatic System works with immune system

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:
  – 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______________)
  3. Immune 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  Thoracic duct
  Right Subclavian Vein  Left Subclavian Vein

Lymphatic vessels

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

– **Valves**

**Lymphedema**

• (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 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