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
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* → ________________
- Systemic circuit *high-pressure circuit* → ________________

**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 → 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  \( \rightarrow \) 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. ________________  \( \rightarrow \)
    \( \rightarrow \) post. interventricular (post. descending a.)
    \( \rightarrow \) marginal branch

  - 2. left coronary artery  \( \rightarrow \)
    \( \rightarrow \) ________________  \( \rightarrow \) 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

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

**Purkinje fiber system**

- Purkinje fiber system:
  - Atrioventricular bundle (______________)
  - Right and left _________________
  - Purkinje fibers
    - located in ventricular walls

---

**ELECTROPHYSIOLOGY OF CARDIAC MUSCLE**

**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 __________________________
QRS complex represents _______________________

T wave represents ____________________________

What’s missing??

**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
  → 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 (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
  - 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*

---

**STRUCTURE AND FUNCTION OF ARTERIES AND VEINS**

• Artery vs vein:
  o **Arteries**
    - _______________ → reflects arteries’ role in controlling *BP* and *blood flow*
      - more extensive internal and external elastic → 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

Treatment:

→ **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 *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:
  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 \textit{backward flow}
  – __________ in vein walls VC by SNS
  – _________________
  – \textit{Respiratory pump} (difference in P between abdominal & thoracic cavity)

\begin{center}
\textbf{Varicose Veins}
\end{center}

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

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

\textbf{Module 18.3 Maintenance of Blood Pressure}

\begin{center}
\textbf{SHORT-TERM MAINTENANCE OF BP}
\end{center}

• Neural and Hormonal Control

1. _______
   
   SNS \rightarrow \text{________________________} \rightarrow VC \rightarrow \_ BP
   
   PSN \rightarrow \text{________________} \rightarrow \text{decr. C. O.} \rightarrow \_ BP
   
   \text{(CN X \rightarrow SA node, AV node)}

\textbf{Baroreceptor reflex:}

\text{________________________} \rightarrow

\rightarrow \text{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*

**Capillary Exchange via:**

1. Diffusion & osmosis
2. Diffusion
3. Transcytosis

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

→ *Module 18.5  Capillary Pressures and Water Movement*

**BLOOD FLOW THROUGH CAPILLARY BEDS**

When precapillary sphincters are open:

When precapillary sphincters are closed:

**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

**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) → **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)

  **HP – COP = 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 = 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 ______ → RA

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

VEINS OF THE HEAD AND NECK

Head and neck:

- internal jugular veins

- ______________

- external jugular veins
• Hepatic portal circulation:
  – Drains nutrient-rich, oxygen-poor blood from digestive organs
  – Superior and inferior mesenteric veins
    → _________________
    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**

- 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\textsubscript{2}-binding

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

- Hemoglobin:
  - Releases oxygen into tissues where oxygen conc. is low
  - Binds to CO\textsubscript{2} \(\rightarrow\) ___________________ 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→) bilirubin
    
    4a. Bilirubin → _____________________
    
    4b. Fe and a.a. recycled → ____________________

**ANEMIA**

- Anemia =
  
  Causes: decreased Hb, decreased Hct, and abnormal Hb
  
  Symptoms: pallor, weakness, fatigue, incr. HR
  
  Types: Iron-deficiency anemia (decr. Hb)
          Pernicious anemia (decr. Hct)
          SCA (abnormal Hb)

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

Two basic categories:
- ___________________ contain cytoplasmic granules
- Agranulocytes _______________

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**
  
  **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
  
- **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

→ **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 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

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

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

• 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 Rh(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