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* → _____

- 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 H_2O 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 <u>excess</u> fluid → cardiac tamponade
- Causes:
- Fibrous pericardium - strong but <u>not</u> 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 <u>most</u> 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 <u>not</u> 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 <u>other</u> type of cardiac muscle cell (_____)

HISTOLOLOGY 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*) <u>before</u> 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 <u>same</u> *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, <u>decreased</u> 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) → ____ HR, ____ force of contraction

- _____

  - _____ – 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.

- 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 <u>reduces</u> heart's ability to pump *effectively*:

- _____ and/or M.I, valvular heart diseases, any disease of heart muscle (cardiomyopathy) and electrolyte imbalances
- Heart failure → <u>decreased</u> *SV* → _____
- 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** → _____

- Both RV and LV failure →**peripheral edema**, in which blood *backs up* in systemic capillaries (**systemic congestion**)

- _____ in legs and feet
- Peripheral edema exacerbated by kidneys *retain* excess fluid

- **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***

STRUCTURE AND FUNCTION OF ARTERIES AND VEINS

• Artery vs vein:
  - 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*

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* 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 *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**

- 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**

– **Effects of chemoreceptor stimulation**:

- **Peripheral chemoreceptors** play a role in reg. *breathing*, but also affect BP; receptors respond to _____
- **Central chemoreceptors** respond to decreases _____ ; triggers another feedback loop that indirectly increases SNS; →*VC* and __ 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 → adosterone → conserve H_2O
   → ADH → conserve H_2O

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

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

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 <u>fully</u> 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) → **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 = **22mmHg**
- **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 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 _____

S<u>uperior</u> 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

VEINS OF THE THORAX AND ABDOMEN

- 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 – 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
  - 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 <u>decrease</u> in *production of plasma proteins*; leads to decreased _____; results in fluid loss to extracellular spaces, producing *severe edema* in the abdomen; termed _____
- <u>Decline</u> 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→) *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

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

Two *basic categories*:

- _____ 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

      _____ 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
    -
    -

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

- **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; <u>inhibits</u> platelet aggregation
    - Nitric oxide – causes vasodilation
  - Endothelial cells and hepatocytes produce anticoagulants; <u>inhibit</u> coagulation:
    - Antithrombin III (AT-III) – protein that binds and inhibits activity of both factor Xa and thrombin; also <u>prevents</u> 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
-

BLOOD TYPING

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_o (D) immune globulin; contains anti-Rh antibodies that *bind fetal cells in maternal circulation*; <u>prevents</u> 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 <u>not</u> 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 <u>still</u> 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 <u>against</u> gravity
- **Valves** _____

Lymphedema

-
- _____ (swelling) is an accumulation of <u>excess</u> 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 <u>prevent</u> 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