Cardiovascular system

The organ system responsible for transportation of substances within the body

- Blood
- Heart
- Blood vessels

Heart function

The heart pumps blood through two blood vessel loops

- Pulmonary loop = Carries blood from heart to lungs and then back to the heart
  - √ The smaller loop
  - √ In the lungs, the blood picks up O_2 and releases CO_2
- Systemic loop = Carries blood from heart to all organs in body (except the lungs) and then back to heart
  - √ The larger loop
  - √ Delivers O_2 and nutrients to cells; picks up CO_2

Figs 19.4 and 20.2

Artery

A blood vessel that carries blood away from the heart (toward another organ)

- The pulmonary trunk is the first artery of the pulmonary loop

- The aorta is the first artery of the systemic loop

Figs 19.4, 19.9, and 20.2

Vein

A blood vessel that carries blood away from an organ (back toward heart)

- The pulmonary veins are the last veins of the pulmonary loop

- Superior vena cava and inferior vena cava are the last veins of the systemic loop

Figs 19.4, 19.9, and 20.2

Heart anatomy

Heart is myocardium tissue (cardiac muscle) with four hollow Chambers. It is surrounded by the pericardium (a serosa)

- Left atrium and right atrium = smaller chambers that receive blood returning to the heart
    - √ In sync with each other, each atrium fills with blood and then contracts (expelling blood from atrium into ventricle)
        - – Right atrium receives blood from the superior and inferior vena cavae (the end of the systemic loop)
        - – Left atrium receives blood from the pulmonary veins (the end of the pulmonary loop)
    - √ AV valve = one-way valve at exit of each atrium to prevent backflow
- Left ventricle and right ventricle = larger chambers that expel blood out of the heart
    - √ After being filled by atrium, ventricles contract in sync to expel blood out of heart
        - – Right ventricle expels blood into the pulmonary arteries (the beginning of the pulmonary loop)
        - – Left ventricle expels blood into the aorta (the beginning of the systemic loop)
    - √ Semilunar valve = one-way valve at exit of each ventricle to prevent backflow

Figs 1.17, 19.4, 19.9, and 19.27

Cardiac cycle

The repeated series of events in the heart that result in pumping blood

• Makes "lub-dup" sound of heartbeat

Figs 19.27, 19.28, and 19.29

Systole

Contraction of a heart chamber

• "Lub" sound = AV valves shutting at beginning of ventricular systole

Figs 19.27, 19.28, and 19.29

Diastole

Relaxation of a heart chamber

• "Dup" noise = Semilunar valves shutting at beginning of ventricular diastole

• During ventricular diastole, the atria do two things: (1) refill themselves with blood returning to the heart, and then (2) contract to refill the ventricles with blood

Figs 19.27, 19.28, and 19.29

Pulmonary trunk

The blood vessel where blood exits the right ventricle

• The pulmonary trunk branches into the left and right pulmonary arteries, which carry the blood to the left and right lungs

Figs 19.4 and 19.9

Bicuspid valve/Mitral valve

The left AV valve

Fig 19.4 and 19.9

Tricuspid valve

The right AV valve

Fig 19.4 and 19.9

Chordae tendineae

String-like structures at the bottom of the AV valves that anchor the valves

Fig 19.9

Aortic valve

The left semilunar value (the semilunar valve inside the aorta)

Fig 19.4 and 19.9

Pulmonary valve

The right semilunar value (the semilunar valve inside the pulmonary trunk)

Fig 19.4 and 19.9

Auricles

Two pouches on the exterior of the heart that are the top of each atria

Fig 19.6

Coronary arteries

Arteries on the surface of the heart that supply the heart muscle with oxygen

Fig 19.6

The conducting tissues of the heart

A network of cells in the heart that generate and conduct electrical signals to cause the atriums and ventricles to beat at the proper times

- Sinoatrial (SA) node = A conducting tissue node in the upper right atrium
    - √ It sends out signals to contract both atria simultaneously
    - √ The pacemaker for the heart (sets heart rate for entire heart)
        - Sympatheic stimulation increases the rate of the SA node and parasympathetic stimulation decreases the rate of the SA node
- Atrioventricular (AV) node = A conducting tissue node in the lower right atrium
    - √ It receives SA node signals, delays briefly, then sends a signal downward to contract both ventricles simultaneously

Figs 19.18 and 19.19

Ventricular fibrillations (cardiac arrest)

Rapid uncoordinated contractions of the ventricles; no effective pumping occurs so the circulation of blood in the body halts

- Can be caused by damage to the conducting tissues (such as occurs during a heart attack)
- Can also be caused if K^+, Na^+, or Ca^{2+} is outside its normal concentration range in body fluids
    - √ The conducting tissues and the cardiac muscle use these three ions for depolarization and repolarization

Blood vessels

The tubes that carry the blood

- Blood vessel types = arteries, veins, and capillaries
- Lumen = the hollow space inside
- Tunica interna = The innermost tissue (simple squamous epithelial tissue)
    - √ Provides smooth surface for blood flow
- Tunica media = The middle tissue (smooth muscle)
    - √ Controls blood flow by changing the lumen size
- Tunica externa = the outermost tissue (dense connective tissue)
    - √ Protects and strengthens the blood vessel

Fig 20.3; Table 20.1

	Arteries	Veins
Lumen	smaller	larger
Tunica media	thicker	thinner
In systemic loop…	carry red O_2-rich Blood to organs	carry blue O_2-poor blood from organs
Small ones called…	arterioles	venules
Other features	higher blood pressure	one-way valves

Figs 20.3, 20.7, and 20.15; Tables 20.1 and 20.2

Major blood vessels connected to the heart

- Aorta = Carries blood out of the left ventricle
  - √ The first artery of the systemic loop
  - √ Has 4 regions: The ascending aorta, the aortic arch, the descending aorta, and the abdominal aorta
- Pulmonary truck = Carries blood out of the right ventricle
  - √ The first artery of the pulmonary loop
- Superior and inferior vena cavae = Return blood to the right atrium
  - √ The last veins of the systemic loop
- Pulmonary veins = Return blood to the left atrium
  - √ The last veins of the pulmonary loop
- Coronary arteries = Arteries on the surface of the heart
  - √ The coronary arteries supply the heart muscle with oxygen

Figs 19.4, 19.6, 19.9, 20.24, and 20.25; Tables 20.4 and 20.5

Major blood vessels that branch from the aortic arch

- Brachiocephalic artery = Ascends to the right clavicle bone, then it branches into the right subclavian artery and the right carotid artery

- The left carotid artery = Ascends to the left side of the neck and brain

- The left subclavian artery = Ascends to the left clavicle bone

Figs 20.24, 20.26, 20.31, 20.32, and 20.37; Table 20.6

Major blood vessels of the shoulder, arm, and forearm

- Subclavian artery and vein = Under the clavicle bone of the shoulder

- Brachial artery and vein = In the arm

- Radial and ulnar arteries and veins = In the forearm and the wrist

Figs 20.24, 20.31, 20.32, 20.35, 20.36, and 20.38
Tables 20.6, 20.9, and 20.11

Major blood vessels of the pelvis and thighs

- Iliac artery and vein = Branch from the abdominal aorta in the pelvis

- Femoral artery and vein = In thigh

Figs 20.24, 20.28, 20.33, 20.34, 20.36, and 20.41

Capillaries

The smallest blood vessels

• Capillaries are only found in organs

√ They carry blood from arterioles to venules

• The only blood vessel type that exchanges substances with tissues (delivers O_2 and nutrients and picks up CO_2 and other cellular wastes)

√ The capillaries exchange substances with the tissue fluid (the watery liquid surrounding the cells in tissues)

√ The tissue fluid exchanges substances with the tissue cells

• The capillary wall is only the tunica interna (no tunica media or tunica externa)

√ The thinness of wall allows efficient passage of substances

√ Small substances can diffuse directly through the wall

√ Large molecules and WBCs must squeeze through gaps between the wall cells

Figs 20.5 and 20.6

Heart rate

The number of heart beats per minute

- Average heart rate = 72 beats per minute
- The autonomic nervous system is the major heart rate regulator
  - √ ANS nerves synapse with SA node
  - √ The sympathetic division increases heart rate
  - √ The parasympathetic division decreases heart rate
- Other factors can also affect heart rate:
  - √ Women have higher heart rates than men
  - √ Younger people have higher heart rates than older people
  - √ The concentration of blood ions (Na^+, K^+, Ca^{2+}) affects the heart rate
    - - The heart can stop entirely if these ions are extremely outside their normal ranges
  - √ Exercise increases the heart rate while exercising, but being physically fit lowers the resting heart rate

Figs 19.31 and 19.32; Tables 19.1 and 19.2

Pulse

The rhythmic expansion of the arteries that occurs with every heartbeat

- The pulse is usually taken to determine a patient's heart rate, since the pulse rate equals the heart rate

- The pulse is usually taken at one of the following three locations:

- Radial pulse: The pulse taken at the radial artery (near the wrist)

  √ The radial artery is palpitated (felt) between the radius bone and the tendon at the wrist, using one or two fingers (but not the thumb)

- Carotid pulse: The pulse is taken at the carotid artery (on the neck)

  √ The carotid pulse is palpitated either on the left side or on the right side of the trachea, near the lower jaw

- Apical pulse: The pulse is taken on the chest, near the heart

  √ The apical pulse is taken by auscultation (listening) to heart beat sounds ("lub-dup") using a stethoscope

  √ The clearest lub sound is heard at the left fifth intercostal space

  √ The clearest dup sound is heard at the second intercostal space

Figs 19.30 and 20.11

Stroke volume

The amount of blood pumped out of each ventricle per beat

- Average stroke volume = 70 mL per beat
- Controlled by the heart's force of contraction
  - √ Stronger heart contraction = Larger stroke volume

Fig 19.31

Cardiac output (CO)

The amount of blood pumped out of each ventricle per minute

- CO = heart rate x stroke volume
- CO is about 5000 mL of blood pumped per minute for an average adult at rest
- The heart will increase the CO when the body needs more oxygen
  - √ Example: During exercise the CO can become up to 7X higher
  - √ The body increases the CO by increasing the heart rate and increasing the stroke volume, but the heart rate increase plays a larger role

Figs 19.31 and 19.35

Blood pressure (BP)

The blood's outward force on the blood vessel walls

- BP measured in arteries
  - √ Units are mm Hg (millimeters of mercury)
- Systolic pressure (BP during systole) is always higher than diastolic pressure
  - √ Average BP = 120 / 80 (systolic over diastolic pressure)
- BP decreases throughout systemic loop
  - √ Highest in arteries closest to heart
  - √ Essentially zero in veins at end of systemic loop

Fig 20.10

Steps for taking blood pressure:

(a) The sphygmomanometer (blood pressure cuff) is wrapped around the patient's arm.
- √ Blood is flowing through the brachial artery in the arm, but the flow is laminar flow (smooth silent flow) because nothing is obstructing the artery at this point in the exam

(b) The cuff is inflated to above the patient's systolic pressure.
- √ Usually a cuff pressure of 160 is sufficient
- √ No blood is flowing through the artery now because the cuff pressure squeezes the artery shut, obstructing all blood flow

(c) The pressure in the cuff is slowly decreased by opening a valve.

(d) The examiner listens to the patient's brachial artery with a stethoscope as the cuff deflates.

- √ The patient's systolic pressure = The cuff pressure when the sounds of Korotkoff (spurting sounds) are first heard.
  - The blood comes through the artery in spurts because only during systole is the blood pressure able to match the cuff pressure and push the artery open (The diastolic pressure is still below the cuff pressure so no blood flows during diastole)

- √ The patient's diastolic pressure = The cuff pressure when the sounds of Korotkoff (spurting sounds) vanish.
  - The spurting sounds vanish when the cuff pressure falls below the diastolic pressure because now both the diastolic and systolic pressure are larger than the cuff pressure, so the artery is unobstructed again and the blood returns to silent laminar flow

Fig 20.12

The two factors that determine a person's BP are their cardiac output and their peripheral resistance

- The larger the CO the higher the BP
- The larger the peripheral resistance the higher the BP

Peripheral resistance

The blood vessels' resistance to blood flow

- Changes in BP usually due to changes in peripheral resistance (not changes in CO)
- High peripheral resistance = The heart must contract harder on the blood to make it flow = Stronger heart contraction causes higher BP
  - √ *And visa versa*
- Peripheral resistance is controlled by
  - √ Lumen size of arteries
    - – Smaller lumen = larger peripheral resistance
    - – Larger lumen = smaller peripheral resistance
  - √ Total blood volume
    - – Larger blood volume = larger peripheral resistance
    - – Smaller blood volume = smaller peripheral resistance

Kidneys are major regulators of blood pressure

- The kidneys can increase blood pressure by changing the blood volume
  - √ The kidneys increase the blood volume by adding sodium to the blood (which adds water by osmosis)

- The kidneys can also increase blood pressure by activating the blood protein Angiotensin II
  - √ Angiotensin II causes vasoconstriction throughout the entire cardiovascular system

Fig 20.19

Other factors affecting blood pressure:

- Sympathetic nervous system decreases lumen size in response to danger or drop in blood pressure

- Salts in diet or atherosclerosis increase blood pressure

Figs 20.14 and 20.19

Disorders of the cardiovascular system:

Atherosclerosis (heart disease)

Arteries partially clogged with plaque (fatty deposits), especially the aorta and the coronary arteries

• Increases peripheral resistance, which increases BP

• Treatments: Lifestyle changes (low fat diet, exercise), Cholesterol-lowering drugs, surgical placement of a stent in clogged artery

Figs 19.16 and 20.14

Chronic hypertension

Long term blood pressure above 140 / 90

• Usually caused by atherosclerosis

• After several years, hypertension weakens the heart and arteries

Congestive heart failure

The heart is too weak for adequate blood circulation

• Symptoms: Fatigue, edema in legs, and fluid in lungs

• Usual cause: Years of chronic hypertension

Myocardial infarction (heart attack or coronary)

Damage to heart muscle due to sudden blockage of coronary arteries

• Usually the block is plaque and a thrombus together

• Major symptom = angina pectoris (chest pain)

• Requires immediate medical attention

Shock

Hypoperfusion (inadequate flow) of blood to the organs due to too little blood volume in the cardiovascular system

- The major symptoms include low BP, rapid heat rate, cold/pale skin, confusion and unconsciousness

- There are several causes of shock

  √ Hemorrhage (bleeding), burns, dehydration, and other loss of fluid from body

  √ Anaphylatic shock = A severe allergic reaction to substances such as peanuts, bee stings, or penicillin

- Shock can be a fatal if not treated

  √ Treatments involve restoring the blood volume by blood transfusion or by hypertonic IV solutions (“plasma expanders”)