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

Fig 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.

- 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 valves = one-way valve at exit of each atrium to prevent backflow of blood into atria
- 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 trunk (the beginning of the pulmonary loop)
        - – Left ventricle expels blood into the aorta (the beginning of the systemic loop)
    - √ Semilunar valves = one-way valve at exit of each ventricle to prevent backflow of blood into ventricles

Figs 1.17, 19.4, 19.9, and 19.27

Cardiac cycle

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

• Makes "lub-dup" sound of heartbeat

Figs 19.27 and 19.29

Systole

The contraction of a heart chamber

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

Figs 19.27 and 19.29

Diastole

The relaxation of a heart chamber

• "Dup" sound = The 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 and 19.29

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 contact and relax 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

- Heart can be defibrillated by electric shock (from defibrillator device)

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

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 usually have higher heart rates than men

√ Younger people usually 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

Stroke volume

The amount of blood expelled from each ventricle per beat

- Average stroke volume = 70 mL per beat

- Controlled by the heart's force of contraction

  √ More force = Larger stroke volume

- Also controlled by the end diastolic volume (the volume of blood that returns to the heart each beat)

  √ Higher end diastolic volume = Larger stroke volume (to expel the larger amount of returned blood)

    -"Starlings law of the heart"

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 CO is the meaningful measurement of the body's tissues being adequately supplied with O_2

- The body will adjust the CO to meet the body's current oxygen need

  √ The body can change the CO by changing the heart rate and/or the stroke volume

  √ Example: The body increases CO when we exercise by increasing HR and SV

  √ If the need body's need for oxygen has not changed but one of the CO factors (heart rate or stroke volume) changes, the heart automatically changes the other factor in the opposite direction so as to maintain a steady CO

Fig 19.31

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 ventricular systole) is always higher than diastolic pressure (BP during ventricular diastole)
  - √ 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

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

Fig 20.17

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

Figs 20.17 and 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, 20.17, and 20.19

Disorders of the cardiovascular system:

Atherosclerosis (heart disease)

Arteries are partially clogged with plaque (cholesterol and fat deposits), especially in the coronary arteries (the arteries that supply heart muscle with O_2)

- Increases peripheral resistance, which increases BP

- Treatments: Lifestyle changes (low fat diet, exercise), Cholesterol-lowering drugs, bypass surgery, 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")