

# CARDIOVASCULAR SYSTEM

SUBJECT : physiology

LEC NO. : 1

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وَقُلْ رَبِّ زِدْنِي عِلْمًا



SCAN ME!

# Functional design of the CVS

ملاحظات

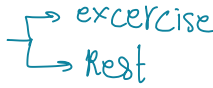
اللون الابيض هو كلام السلايدات  
و في تحت ١٦ سؤال من quizlet

Dr. Waleed R. Ezzat

# Lecture Objectives:

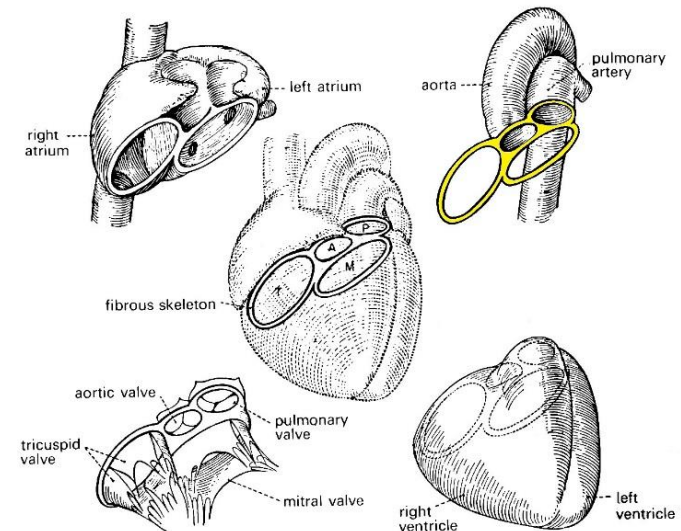
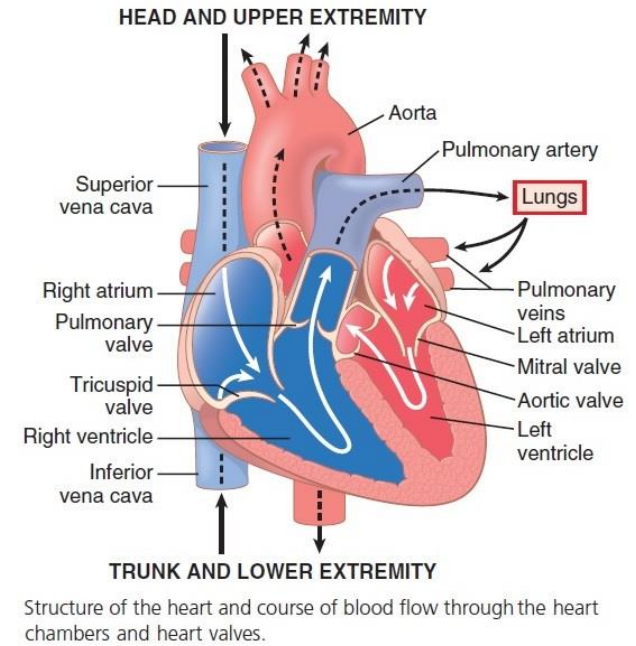
1. Describe the basic function of the CVS.
2. Explain how structural differences of various parts of CVS subserve their functions.
3. Describe the systemic and pulmonary circulations.
4. Describe blood velocity & blood flow through various parts of CVS in relation to their cross sectional area.

# MAIN FUNCTIONS OF THE CIRCULATORY SYSTEM

- Transport and distribute essential substances to the tissues
- Remove metabolic byproducts
- Adjustment of oxygen and nutrient supply in different physiologic states 
- Regulation of body temperature (thermoregulation) and maintenance of fluid balance
- Humoral communication

# Functional anatomy of the heart

- The heart looks like two cups facing each other mouth to mouth
- Atrial and ventricular myocardial fibers are attached to the **fibrous skeleton** of the heart
- The fibrous skeleton is made up from the union of **four** fibrous rings to which the four cardiac valves are attached
- There is no muscular communication between the atria and the ventricles
- The heart acts as two pumps arranged in series within a closed circuit



# Functions of CVS

What is the role of CVS in maintaining homeostasis?

① transport & distribute essential substances  
After the substances being absorbed by the GIT the circulation is responsible for providing the absorbed substances to the tissues

② Remove metabolic material

CVS circulate blood around the tissue taking the waste products of metabolic reactions to the excreting organs which are 1) kidney which excrete the water soluble substances

2) Liver excrete lipid soluble substances by conjugating the substances and make them water soluble which then is excreted from the liver by bile 3) back to circulation to the kidney then get excreted

Lungs for gases removal & sweat excrete some waste products (not main excreting organs)

③ adjustment of oxygen & nutrient supply in different physiological states

transport  $O_2$  from the lungs to tissues as needed & transport  $CO_2$  from tissues to the lung to be excreted

④ Regulation of body temperature (thermoregulation) and maintain fluid balance

→ excess heat can be excreted by vasodilation of blood vessels in the skin which is going to radiate heat out of the body

Radiation of the skin which mean infrared rays are being radiated from the body in greater quantity than is radiated to the body *vice versa* when temperature ↓ 2) by sweating

\* temperature is produced by the chemical reactions → some organs in our body carry more reactions than other, eg. Liver > bone but despite that their temperature are the same *how?* blood circulate to the liver & transport the excess heat to maintain a constant temperature in all organs

④ humoral communication

Chemical product being secreted in the body to signal something eg. hormones such as insulin *how?* insulin will be secreted into the blood then blood will deliver it to the targeted tissues to increase glucose uptake & use

the heart act as two pumps arranged in series within a closed circuit

RV pump the blood to the pulmonary artery then from the lung to the LA through pulmonary vein then to the LV which pump the heart to the systemic circulation then IVC & SVC bring the blood to the RA then to the RV and this cycle repeat itself

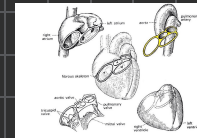
so we can conclude that whatever amount of blood is being pumped by the RV = to the amount of blood pumped by the LV  
\* the circulation is unidirectional mean the blood in the blood vessels can only go to the right or left NOT both

## functional anatomy of the heart

\* the heart looks like two cups facing each other mouth to mouth



→ fibrous skeleton which surround the heart as place of insertion for the muscles instead of the bones



\* it doesn't transfer action potential so there is no muscular communication between the atria & the ventricles

the fibrous skeleton is made up from 4 fibrous rings to which the 4 cardiac valves are attached

# The Myocardium

- Myocardial fibers are arranged in a latticework, with the fibers dividing, recombining, and then spreading again.
- Cardiac muscle is *red and striated* as in skeletal muscle, however, cardiac muscle behaves like smooth muscle, i.e. it is *nerve regulated* and not nerve operated.
- Cardiac muscle is a **syncytium**. Individual myocardial cells are connected in series and in parallel with one another by the *intercalated discs*. These discs have gap junctions that allow rapid diffusion of ions and action potential.
- The heart actually is composed of two syncytiums: the *atrial syncytium*, and the *ventricular syncytium*.
- This division of the muscle of the heart into two functional syncytiums allows the atria to contract a short time ahead of ventricular contraction, which is important for effectiveness of heart pumping.



Syncytial, interconnecting nature of cardiac muscle fibers.

# Differences Between Myocardium and Skeletal Muscle

- The myocardium is red and striated, but it is nerve regulated (No motor units)
- Contraction can be graded
- Initial length is not fixed
- Requires extracellular  $\text{Ca}^{2+}$  for its contraction
- Cannot be tetanized  $\longrightarrow$  Acts as repeated simple muscle twitches
- Less powerful but cannot be fatigued practically
- Has high resting tension (tone) which is not nerve dependent (visco-elastic property)
- Highly stretchable (4-6X that of skeletal muscle)
- The mode of contraction is isotonic and auxotonic



# The myocardium

what is the difference between the skeletal muscles & the heart muscle?

myocardial muscles are arranged in lattice works with the fibres dividing, recombining & then spread again. so the fibres are connected together which allow the the action potential at one point of the fiber to be transmitted to all fibers  
→ stimulation of one spot will make the entire myocardium to contract - while skeletal muscles are arranged in fibres that are parallel to each other like the wires in a cable so (no connection between the skeletal fibers)  
so when fiber is being stimulated only one fibre will contract not the entire cable

→ Myocardial contract as a unit

the myocardial muscles are nerve regulated not nerve operated what that does mean?  
smooth muscles and myocardium contract without nerve carried impulses, so it is nerve regulated which means the nerve connected to the myocardium only increase or decrease the contraction rate or strength  
in skeletal muscles motor nerve is connected to the muscle fiber by junction called the motor end plate → the Ach is secreted then stimulate the muscle fibre, the skeletal muscle is only contracted by impulse through the nerve so the skeletal muscles are "nerve operated"

Cardiac muscle is a syncytium similar to the skeletal muscle, syncytium is like arrange cells in tube like structure, then remove the walls between them making it like a tube filled with cytoplasm and the nucleus are scattered in this tube this is what syncytium mean which is found in both skeletal & cardiac muscles

individual myocardial cells are connected in series & parallel with one another by the internal discs they are fused 2 walls of 2 cardiac cells but they are filled with holes (like filter) these holes called gap junctions so the cells are connected so that is why they are called syncytium

these discs have gap junctions that allow rapid diffusion ions & action potential so in stimulation the nat can pass through the junctions to the adjacent cells and transfer the action potential

the heart is composed of 2 syncytium 1) atrial syncytium 2) ventricle syncytium why 2?  
to prevent the contraction of the atrium & the ventricle at the same time, the atrium must pump first to move the blood from atrium to ventricle then the ventricle contract & pump the blood  
The division of the muscle of the heart into two functional syncytiums allow the atria to contract a short time ahead of ventricle contraction, which is important for effectiveness of heart pumping

intercalated discs transfer action potential & fibrous skeleton isolate the atrium from the ventricle so the syncytium of atrium contract first then the contraction of ventricle syncytium which improve the pumping mechanism

the myocardium is red & striated, but it's nerve regulated (no motor unit)

motor unit: single motor neuron & all muscle fibers it innervates

in cardiac muscle all the muscle contract as unit while in skeletal muscle contract depend on how many motor unit they have

contraction can be graded

in skeletal muscle the contraction is all or non so the muscle contract to the max or doesn't contract, but how it increase the strength or its contraction? by stimulating more motor units

in myocardial muscles can be graded (the strength of the contraction not the action potential → all or non)

initial length is not fixed

in skeletal muscle the length between the origin and insertion is fixed (doesn't change if we carried 1 kg or 10 kg), but the heart can change its length depend on the amount of the blood in it before it contract

Requires extracellular  $Ca^{2+}$  for its contraction  
in skeletal muscles doesn't need extracellular  $Ca^{2+}$  for  
its contraction because it has a large storage of  $Ca^{2+}$   
in cytoplasmic reticulum which is secreted when AP  
arrive to the muscle allowing  $Ca^{2+}$  to get out and  
making the contraction to its maximum  
but in myocardial muscle can't contract without  
 $Ca^{2+}$ , this is called calcium induced - calcium released

it can't be tetanized <continuous contraction>

→ acts as repeated simple muscle twitches  
in skeletal muscle works in tetanization all the  
time eg. when we are standing or back, chest &  
abdominal muscles are continuously contraction  
but in cardiac muscle if it's continuously  
is being contracted the heart can't be filled  
up with blood & we will die so it works in  
repeated muscle twitch, impulse - stop - impulse -  
stop <repeated loop>. Systole contraction  
& diastole relaxation

less powerful but can't be fatigued  
practically

in skeletal muscle fatigue is when muscle that  
were initially generating a normal amount of  
force then experience a declining ability to  
generate force. For eg. carry a 0.25 kg then  
stretch your arm each time your heart pump  
≈ 70/min you won't be able to do it for long  
your biceps will fatigue while cardiac muscle  
won't be fatigued <the mechanism will be  
explained later>

has high resting tension <tone> which is not nerve-  
dependent <visco-elastic property>

muscle tone: the partial muscle contraction which  
mean when we are awake part of the skeletal  
muscle in any moment some <few> motor units must be  
in contraction state this called muscle tone, in sleeping  
it is at its lowest during the day it increase  
depend on the situation, the tone in skeletal  
muscle is controlled by the nerves.

in cardiac muscle the tone is high & not  
nerve dependent

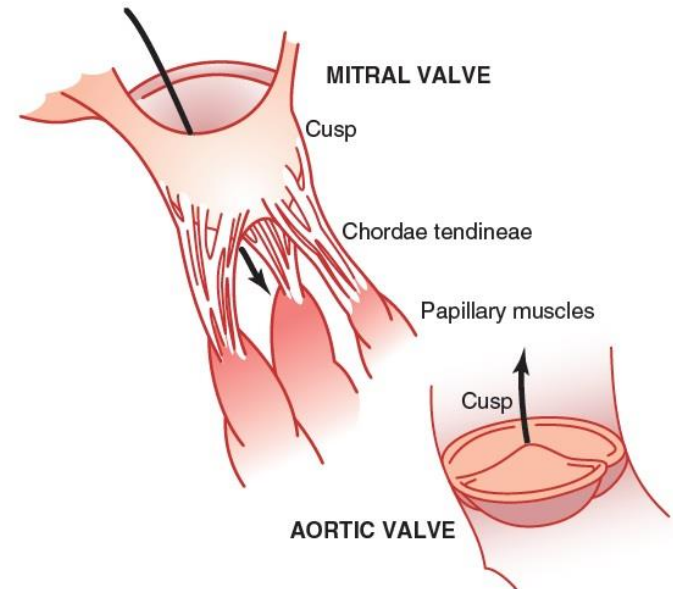
Highly stretchable <4-6x that of skeletal muscle>  
if we put a weight and attach to a skeletal &  
myocardial muscles the cardiac muscle will stretch  
4-6 times more than the skeletal muscle

The mood of contraction is isotonic & auxotonic  
isotonic: increase in the length of the muscle  
while the tone stay the same → cardiac muscle  
auxotonic: No increase in the tone or fiber length  
of the muscle → cardiac muscle  
isometric: increase in tone while length is  
fixed.

skeletal muscle contract in isometric way which  
mean it generate force = to the gravity force  
on the object we are trying to carry but it  
can't generate greater force than body weight

# Cardiac Valves

- The cardiac valve leaflets consist of thin flaps of flexible, tough, endothelium-covered fibrous tissue that are firmly attached at the base to the fibrous skeleton rings.
- Movement of the valve leaflets is essentially passive, and the orientation of the cardiac valves is responsible for the unidirectional flow of blood through the heart.
- There are two types of valves in the heart: **atrioventricular (AV)** and **semilunar**.
- Atrioventricular valves are the **tricuspid valve** (located between the right atrium and the right ventricle), is made up of three cusps, whereas the **mitral valve** (lies between the left atrium and the left ventricle), has two cusps.
- AV valves (also called the inlet valves) are funnel in shape. Attached to the free edges of these valves are fine, strong ligaments (chordae tendineae) that arise from the powerful papillary muscles of the respective ventricles.



Mitral and aortic valves (the left ventricular valves).

# Cardiac Valves (cont.)

- The chordae tendineae prevent the valves from becoming everted during ventricular systole.
- The semilunar valves (also called the outlet valves) are the **pulmonic** and **aortic valves** are located between the right ventricle and the pulmonary artery and between the left ventricle and the aorta, respectively.
- Four sounds are usually generated by the heart, but **only two** are ordinarily audible through a stethoscope.
- The first heart sound is initiated at the onset of ventricular systole and reflects closure of the AV valves.
- The second heart sound occurs with the abrupt closure of the semilunar valves.
- Valvular lesions (such as stenosis or incompetence) are usually associated with heart **murmurs**.

# The cardiac valve

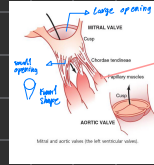
the heart consist of 4 valves, its main function is to allow the blood to move in one direction and prevent the movement of the blood in the other way.

units that forming the valve they are leaflets consist of thin flaps of flexible, tough, endothelium-covered fibrous tissue that are firmly attached at the base of the fibrous skeleton rings.

There are two types of valve which are AV (atrioventricular) valve a valve between the atrium & ventricle. and in the name the atrium is at first because we name it according to the blood movement, there is 2 AV one located between the right atrium & right ventricle which is made up of 3 cusps so it's called tricuspid valve. the second one is mitral valve which is located between the left atrium & the left ventricle and it has two cusps

semilunar: semi: like lunar: moon so it is like the moon, it's found between the ventricles & the arteries that are attached to the ventricles, 1) pulmonary valve between the RV & the pulmonary artery 2) aortic valve between the LV & the aortic artery

AV valves (or called inlet valves) are funnel in shape, their free edges are attached to fine, strong ligaments (chordae tendineae) that arise from the powerful papillary muscle of the respective ventricles.



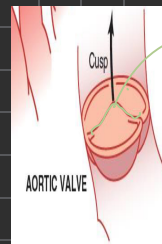
muscles arise from the myocardium of the ventricle they are called papillary muscle their function is to prevent the leaf of the valves to go up wards it doesn't have anything related to the opening & closing of the valve

Note that aortic valve doesn't have them

the chordae tendineae prevent the valves becomes everted during ventricular systole.

the semilunar valves (also called the outlet valves) are the pulmonary & aortic valves are located between the right ventricle & pulmonary artery & left ventricle & the aorta

they are made up of 3 like moon leafs which go apart when the ventricle pump allowing the blood to move to the arteries, when the ventricle is relaxed the blood try to go back to the ventricle because the artery pressure is higher



في الهلال the blood pressure on the concave area leading to close of the valve preventing the blood from coming back to the ventricle respectively

Four sounds are usually generated by the heart, but only two are ordinarily audible through a stethoscope

the first heart sound is initiated at onset of ventricular systole & reflects closure of the AV valves

the second heart sound occurs with the abrupt closure of the semilunar valves.

the other two sounds are heard by special devices

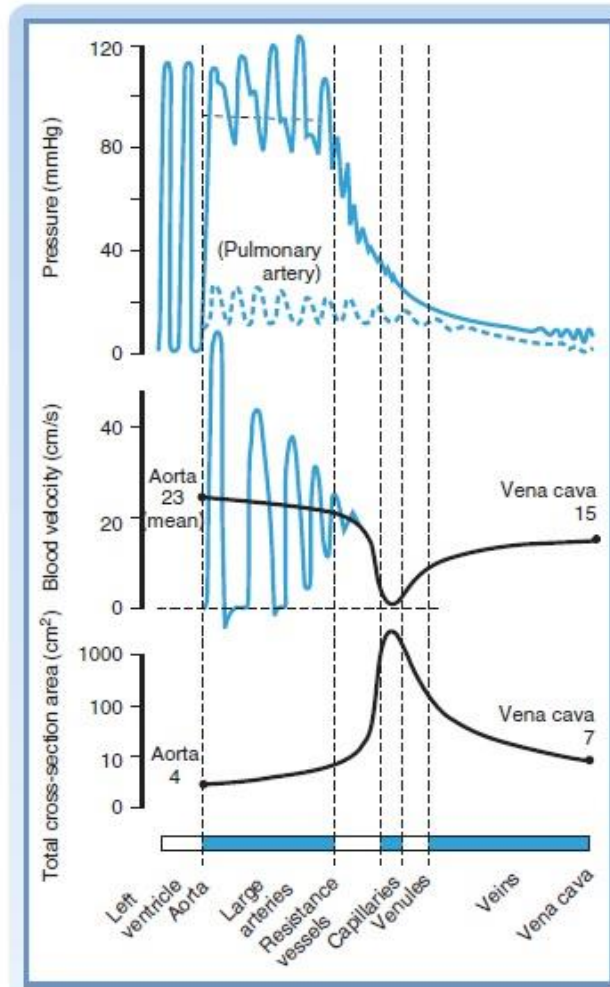
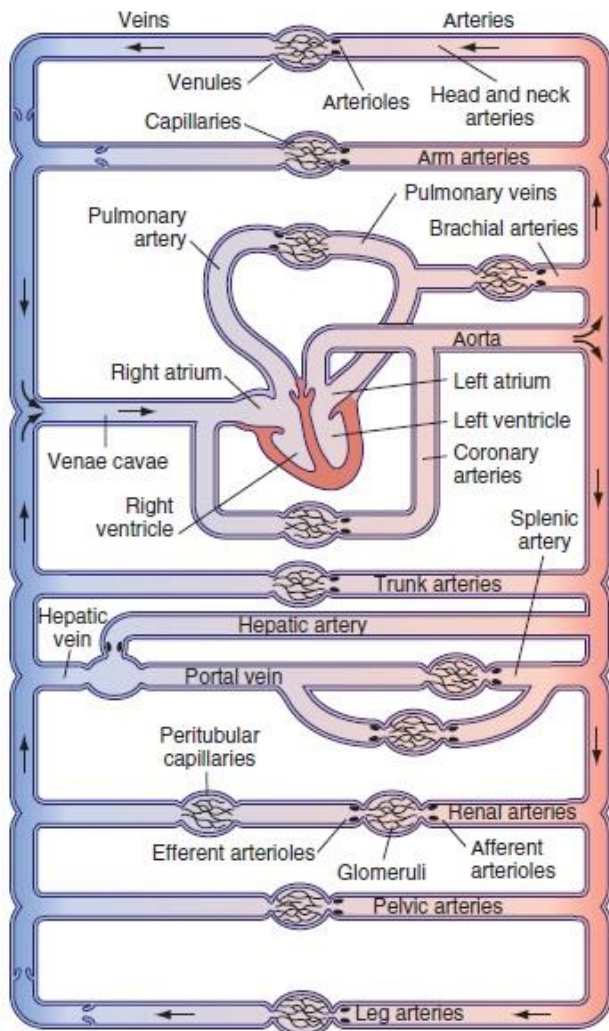
any abnormal sounds that can be heard by the stethoscope other than the 1<sup>st</sup> & 2<sup>nd</sup> sounds called murmurs

Valvular lesion (such as stenosis or incompetence) are usually associated with heart murmurs

incompetence: "leaking valves" which mean they don't close fully allowing blood to move in the opposite direction

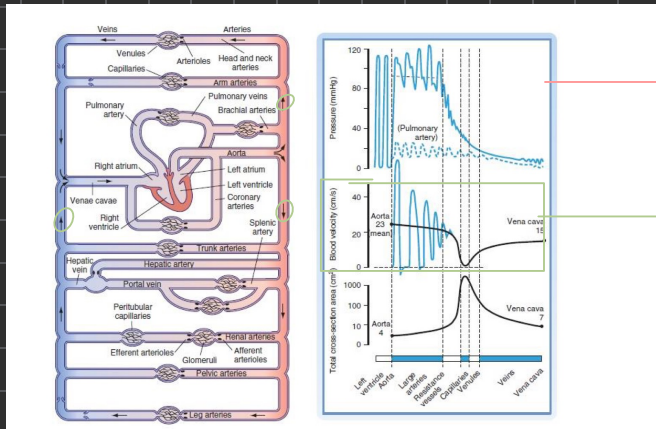
stenosis: "narrowing of the valve" so the valves won't be able to open fully

atrial septal defect → if the defect between atrium ventricular septal defect → between the ventricles  
↳ the defect will cause the blood to move from the LV to RV because the pressure in the LV higher than RV making a murmur



**Right Fig.** Schematic Diagram of the Parallel and Series Arrangement of the Vessels That Constitute the Circulatory System.

**Left Fig.** Phasic Pressure, Velocity of Flow, and Cross-Sectional Area of the Systemic Circulation. The important features are the major pressure drop across the small arteries and arterioles, the inverse relationship between blood flow velocity and cross-sectional area, and the maximal cross-sectional area and minimal flow rate in the capillaries.



→ blood pressure decrease going away from the ventricle

→ it will be explained later but now that capillaries have larger cross sectional area than arteries & veins

\* all the blood move in uni-directional way

\* arterioles - mixed blood - venioles

\* velocity is inversely  $\frac{1}{x}$  proportional with the cross section

# Test Question:

**Which one of the following statements concerning the mitral valve is correct?**

- A. It requires contraction of the papillary muscle in order to initiate closing *No their function is to prevent the valve from being everted during contraction*
- B. A murmur is produced when it fails to close properly *true*
- C. It closes at the end of ventricular contraction *↳ No at the beginning of contraction*
- D. Its closure normally generates the second heart sound *No it generate the first sound it's an AV valve*
- E. It prevents backflow of blood into the ventricle during ventricular relaxation (diastole) *No the opposite it allow the blood to go from the LA to the LV when it relax (relaxed ventricle opened valve vice versa)*



Question Verified

Which is true of heart valves?

- A) Heart valves are made of dense connective tissue.
- B) Heart valves are made of epithelial tissues.
- C) Heart valves allow the backflow of blood.
- D) A myocardial infarction occurs in heart valves

Question Verified

What causes the lub-dub heart sounds?

- a. Ventricles contracting during a heartbeat
- b. Opening of the heart valves
- c. Conduction pathway that is seen in an ECG
- d. Closing of the heart valves

Question Verified

Normal heart sounds are caused by which of the following events?

- A) excitation of the SA node
- B) closure of the heart valves
- C) friction of blood against the chamber walls
- D) opening and closing of the heart valves

Question Verified

What does the cardiac cycle reveal about the opening and closing of the heart valves?

- A. There are no times when all four heart valves are closed.
  - B. The AV valves open, then the semilunars open, then the AV valves close, followed by closure of the semilunars.
  - C. There are times when all four heart valves are open.
  - D. The AV valves close first, then the semilunars open and close, then the AV valves open.
- not sure

Question Verified

Choose the correct answer. The simple squamous epithelium covering the heart valves is the:

- (a) epicardium
- (b) endocardium
- (c) myocardium
- (d) endothelium

Question Verified

Opening and closing of the heart valves is caused by:

- a. gravity
- b. breathing
- c. pressure gradients
- d. valves contracting and relaxing

Question Verified

Which factor causes the opening and closing of the heart valves?

- a. Atrial Pressure,
- b. Ventricular Pressure,
- c. Aorta and Pulmonary Trunk Pressure,
- d. AV valves,
- e. SL valves

Question Verified

All of the following are functions of the cardiovascular system except

- a) deliver oxygen to the body.
- b) transportation of hormones.
- c) all of the above.
- d) body temperature regulation
- e) assist the immune system.

The cordlike tendons that anchor the mitral and tricuspid heart valves to the floor of the ventricles are

- a. semilunar
- b. intraventricular
- c. mesenteric
- d. chordae tendinae
- e. fibrotic

Question Verified

Why do the heart valves open and close?

- a They are attached to the heart muscle.
- b There is a pressure difference on the two sides of the valve.
- c Na+ and K+ fluxes occur during ventricular depolarization.
- d There is turbulent flow in the atria and ventricles.

Question Verified

What is the major function of the heart valves?

- A. Separate the right side of the heart from the left
- B. Permit the flow of blood in one direction
- C. Separate the upper chambers from the lower chambers
- D. Augment the flow of blood through the heart

4. What connects cardiac muscle cells and allows for electrical communication between them?

- o (A) Gap junctions
- o (B) Intercalated disks
- o (C) Desmosomes
- o (D) Tight junctions

2. Due to its features, the myocardium functions as a syncytium with synchronized contraction. What is the main function of the myocardium?

- o (A) To facilitate the contraction and relaxation of the heart walls
- o (B) To provide a scaffold for heart chambers
- o (C) To conduct electrical stimuli
- o (D) To regulate blood flow

7. What is the role of intercalated discs in cardiac muscle tissue?

- o (A) To provide mechanical support
  - o (B) To allow for electrical communication between adjacent cells
  - o (C) To store calcium ions
  - o (D) To regulate blood flow
8. Which type of contraction occurs when the myocardium contracts forcefully against a closed valve, resulting in increased intraventricular pressure?
- o (A) Isotonic contraction
  - o (B) Isometric contraction
  - o (C) Eccentric contraction
  - o (D) Concentric contraction

Question Verified

Which is not one of the main functions of the cardiovascular system?

- a. Fighting disease
- b. Removing wastes from cells
- c. Taking oxygen into the body
- d. Delivering materials to cells

Question Verified

The pancreas functions as part of the endocrine system and as part of the \_\_\_\_ system.

- A. cardiovascular
- B. immune
- C. digestive
- D. respiratory
- E. reproductive