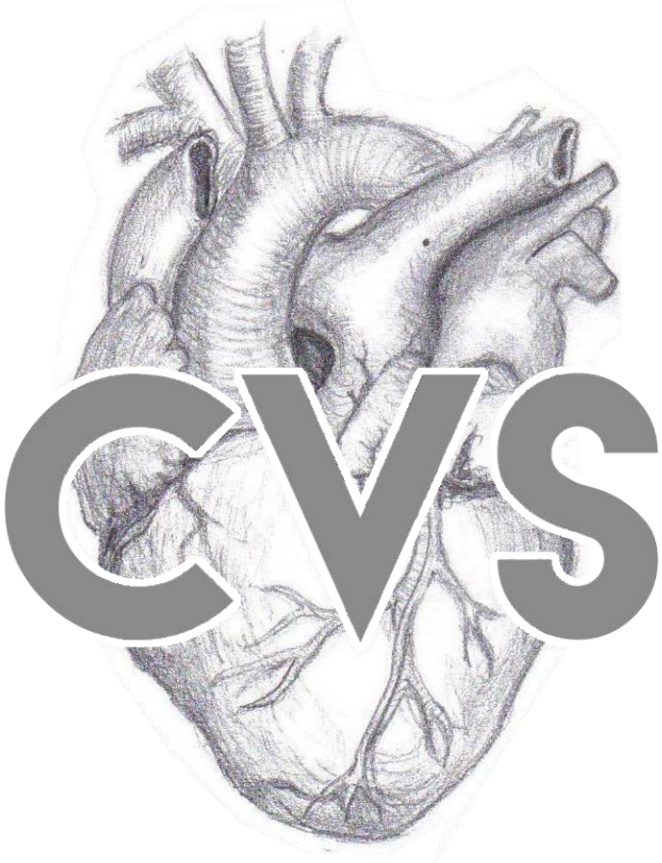

PHYSIOLOGY

☑ Sheet ◯ Slide ◯ Handout

Number

1

Subject

Introduction to CVS physiology

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Date: **00/00/2016**

Price:

➢ Before we start:

- Physiology of the cardiovascular system is one of the most interesting subjects. So try to enjoy our **18 lectures** with Dr. Faisal Mohammad.
- Our reference book is "textbook of medical physiology by Guyton & Hall" [11th edition, 12th edition or the latest 2016, 13th edition]. You can find the pages needed in the first two slides. Dr. Faisal encouraged us to read from the book, because not all the details are included in the slides and we may be asked about them.
- The cardiovascular system is composed of two parts:
  Cardiac --> Heart.
  Vascular --> Blood vessels.
  -We will start by studying the cardiac part in the first 10 lectures, then we'll continue with the vascular part. But keep in mind that nothing works alone in our body, it's all connected!
- In our first year's physiology course we've studied the cardiac muscle action potential, these lectures will be revised but not in details, you should refer to them when needed.
- This lecture will be an introduction and it'll be one of the **easiest** lectures you've ever encountered.

➢ Why do we need basic sciences like physiology, pharmacology and microbiology as doctors?

- Simply to solve problems for our patients. Let's have a look on a **clinical problem** to show us how:

A 54 years old man seen in the cardiology clinic complaining of severe weakness, fatigue, dry cough, weight gain and difficulty in breathing. He feels severe shortness of breath while walking up stairs of his second floor apartment. He still complains of lesser severity of symptoms at rest. He states he often awakens at night feeling like he was suffocating. He is now sleeping with three pillows under his head. Lately he has taken to fall asleep while he is sitting watching T.V. He also complains of having to urinate 3-4 times per night. He was hospitalized with heart problem two months ago and was told that the efficiency of his heart is less than 30% and he needs ?? and has to wait until??. On examination his weight is 95Kg, height is 165 cm, blood pressure was 140/85 mmHg, his heart rate 90 beats/min and regular, his resp. rate is 28/min and labored.

Auscultation of the heart reveals abnormal heart sounds

**Let's discuss every single symptom:

- **[Severe weakness]**: The cardiovascular system is what deliver oxygen to the tissues, so lack of oxygen --> no energy --> weakness.
- **[Fatigue]**: Unable to move especially when walking up stairs and during other heavy activities, because it needs extra energy to be done.
- **[Dry cough]**: Because of the fluid in the lung (Edema) will irritate the lung resulting in coughing and It's dry because no inflammation took place.
- **[Weight gain]**: Because of fluid retention.
- **[Difficulty in breathing]**: Because the fluid in the alveoli broadens its membrane making the diffusion of gases much harder (If the membrane is thinner the diffusion is faster). Plus, the fluid makes it easier for CO_2 to pass, because it's 20 times more soluble than O_2.

- **[Severe shortness of breath while walking up stairs and less symptoms at rest]**: Because the severity of symptoms depends on the amount of energy and, as a result, oxygen needed.

- **[Awakens at night feeling like he was suffocating]:** While sleeping the fluid accumulates in the lungs causing the feeling of suffocation, the patient wakes up, goes to the window to breathe some air, he feels better and think that the fresh air did that, go back to sleep and it all happens again, it's not the fresh air which made him feel better its simply the **gravity** pulling the fluid downward when he stands up making him feel better.
  The patient's episodes have the medical name:
  "Paroxysmal nocturnal Dyspnea"
  - Dyspnea → Difficulty in breathing.
  - Nocturnal → At night.
  - Paroxysmal → Attacks one after the other.

- **[He's sleeping with 3 pillows under his head]:** He found out that it's much more comfortable and that's because he's avoiding "orthopnea" which is dyspnea when lying flat. [Sleeping with three pillows will, to a lesser extent, prevent pleural edema that is causing this difficulty in breathing]

- **[Sleeping while watching TV]:** Decreased amount of oxygen that carries out metabolic actions, & because of increased CO_2 content. (High CO_2 & Low O_2).

- **[Urinate 3-4 times per night]:** Some doctors might quickly decide that this patient has a renal failure or urinary tract infection! But NO, too much fluid in his body, increases fluid filtration in the kidneys, filling his bladder, therefor too much urine excreted.

  So when a patient comes to you with excessive urination, take Heart failure into consideration, not only renal failure. Here you can see the interrelation between different body systems [Cardiac/Respiratory/Urogenital]

- **[His heart efficiency is less than 30%]:**
  The efficiency is the percentage of blood pumped out of the ventricle over the total amount of blood in the ventricle.

  A normal person will have a heart efficiency of about 50-75%
  The patient here has only 30% which is very low.

  We will find out what does that mean in more details later on during this physiology course.

- **[He was told that he need a heart transplant and he need to wait for someone *young* to die]:** Before a heart transplant decision is made, we need to try to solve any cardiac problem by fixing the patients diet[nutrition], drugs, and a continuous therapy. If all of these don't work then we decide to make a transplant. It's not an easy process, first we need to find a healthy heart, it's usually found when someone young die usually from a car accident. And next we have to avoid rejection by matching antigens, especially HLA antigens (MHC) and using immunosuppressant drugs like cephalosporins.

Note: The transplanted heart can be:
[1] Natural Heart – A young dead human being or even an animal [mammal].
[2] Mechanical Heart – This heart is being made in medical laboratories, it's easier that waiting for a young healthy person to die.
But the main problem with the mechanical heart is that, its transplant will lead to blood clot and therefor the doctors will give the patient anticoagulants, leading to excessive bleeding →Death. So most of the times the mechanical heart transplant will lead to the death by excessive bleeding not because another heart failure.

- **[His weight= 95 KG, blood pressure= 140/85, respiratory rate= 28]:**
  His weight is high due to fluid retention [edema].
  His blood pressure is slightly high.
  His respiratory rate is high. {Normal respiratory rate is 12-20 breaths/min}

- **[Auscultation of the heart reveals abnormal heart sounds]:**
  Listening to the heart sound using stethoscope revealed an abnormality.{Using stethoscope we can hear two heart sound; S1 and S2 as a result of closing the valves}

- From this case you should have realized that you need to understand the *physiology* in order to *analyze* the symptoms, need <u>pharmacology</u> to determine the <u>drugs</u> needed to be taken, and you need *microbiology* to figure out what *microorganisms* may have caused a particular disease.
  Basic sciences are much more important than you think.

➢ Objectives of this lecture:

1. Introduction to the CVS physiology and a brief history of cardiac transplant.
2. Review the anatomy of the CVS (Just basic anatomy is needed to understand physiology).
3. List the function of the CVS (carry oxygen & hormones from area to another and carry carbon dioxide back to the heart).
4. Comprehend the pump nature of the heart (may be repaired, replaced, made mechanically).

➢ History of cardiac Transplant:

As we said, the heart is a pump and it can be replaced.

- ✓ In 1967, Cape Town, South Africa
  The first human heart which was transplanted, was taken from a **25 year** old woman who had **died** from a **car accident** and placed in a 55 year old man dying of heart damage by Dr. Barnard.
  18 days later, the recipient **died because of rejection**.
  Immunosuppressants (cyclosporins) were not known back then.

- ✓ In 1984, Columbia
  The first pediatric heart transplant on four year old boy, he received a second transplant in 1989 and lived a productive life till 2006, he died from non-cardiologic problem. It is thought that the transplant was more successful in pediatrics because of their less differentiated immune system.

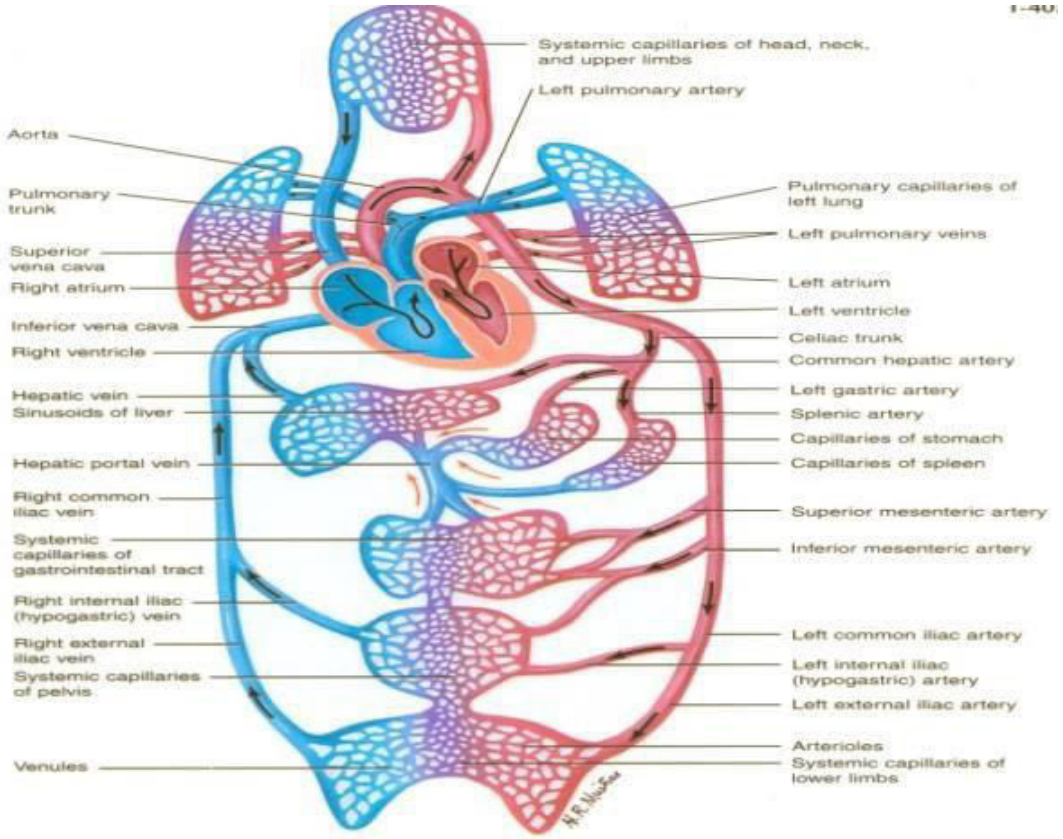
- ✓ In 1984, California
  Baboon heart was transplanted into a 12 day old girl, she survived for twenty days and **died because of rejection**.

- ✓ In 1982, Utah
  The first artificial *[mechanical]* heart was implanted in a dentist named Barney Clarck, he **died** after 112 days because of **bleeding**. Why? Because as mentioned earlier when blood is exposed to foreign bodies it clots, to avoid this we give anticoagulants, and because it's hard to regulate the anticoagulant dose, he died from bleeding.

- ✓ The experiments didn't stop there. Ventricular support by muscles like the pectoralis muscle has been tested.

➢ Introduction to the anatomy of CVS:

- **Anatomy of the Vascular part:**

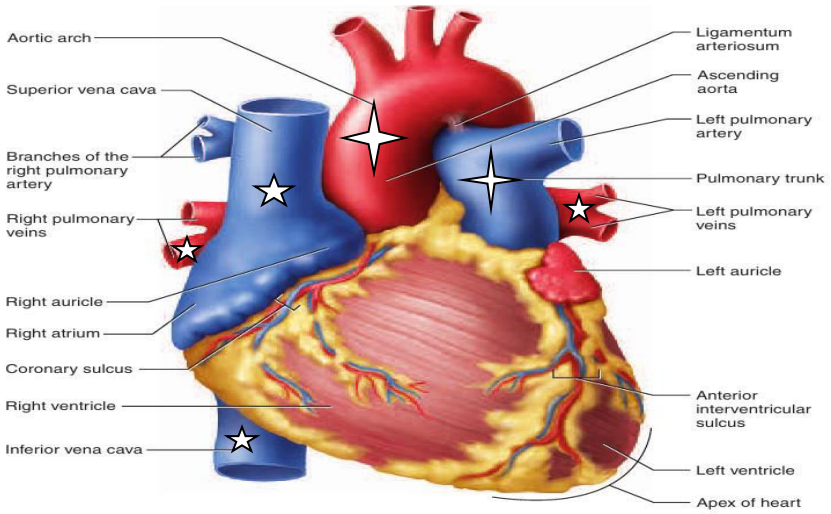


General plan of circulation

- We have two types of blood vessels:
  Artery = **A**way from the heart.
  Vein = towards the heart.
  "Regardless of the oxygenation"
- The main blood vessel is the aorta and it has an arch going from anterior to posterior, and it gives three branches:
  On the right side: brachiocephalic artery which divides into right common carotid and right subclavian.
  On the left side: common carotid artery (to the head and neck) and subclavian artery (to the upper limb).
  Then the arch descends downward forming the thoracic aorta. After piercing the diaphragm it's named the abdominal aorta which gives a lot of branches (superior and inferior mesenteric arteries, renal arteries, etc...) and end up in forming two common iliac arteries.
  So the aorta distributes blood to all parts of the body.

- The major arteries divide into big arteries and end up in forming arterioles then capillaries (arterial side of the circulation). Capillaries collect into venules that end up in forming large veins that forms at the very end, Superior and inferior vena cava that brings blood to the heart again (venous side of the circulation).
- We have two types of circulation: **systemic circulation** (greater circulation) and **pulmonary circulation** (lesser circulation, pulmonary arteries and veins).
- These circulations are more important than the heart. Why? Because we can fix the heart by drugs or transplantation but not the microcirculation (where filtration and reabsorption and sometimes edema take place).

- **Anatomy of the cardiac part:**
  - The heart is located in the mediastinum (middle of the chest).
  - The figure below shows an anterior view of the heart:

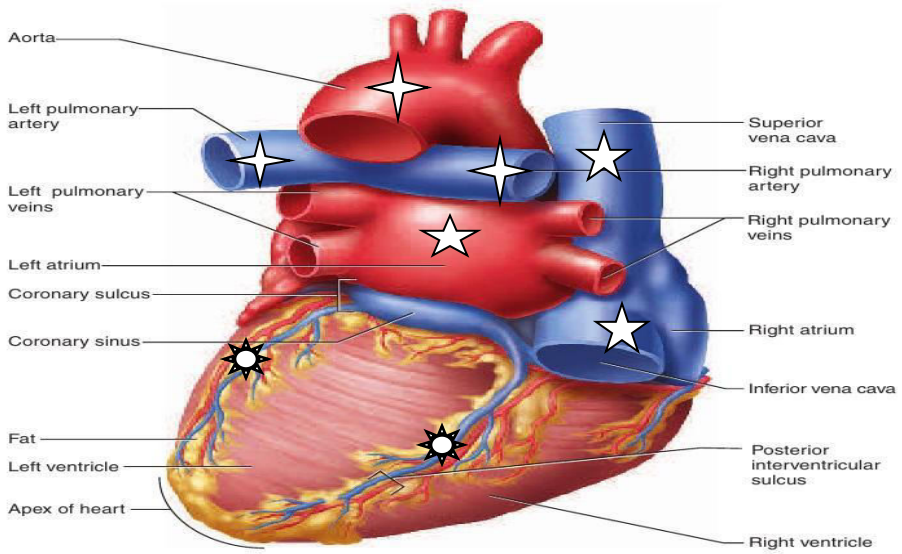


(a) Anterior view

**Notice the marked blood vessels that we've talked about.

** The pulmonary arteries carry deoxygenated blood but still called arteries.

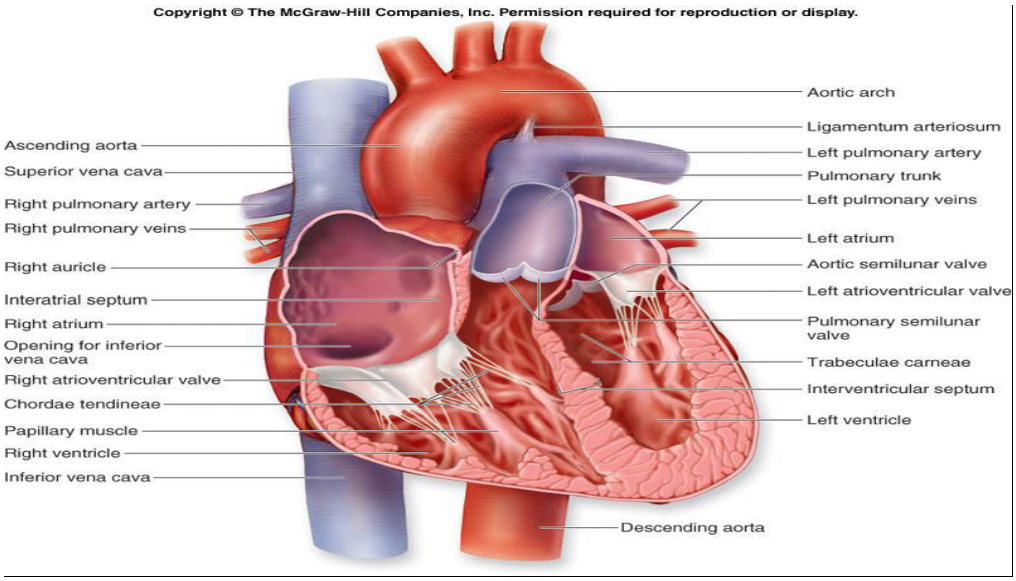
  - The figure below shows a posterior view of the heart



(b) Posterior view

- Notice the arteries that supply the heart (coronary arteries {☼}) run superficially (unlike arteries of other systems) and that has a huge advantage, if they get blocked we can make a <u>bypass</u> [replace the damaged artery] from other vessel (saphenous vein) or we can use a string or a balloon to release the blockage.

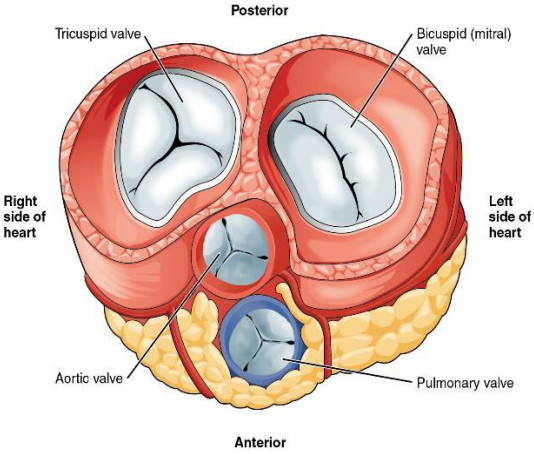
- The heart is composed of **4 champers** (two atria and two ventricles), see the next figure and notice the following:

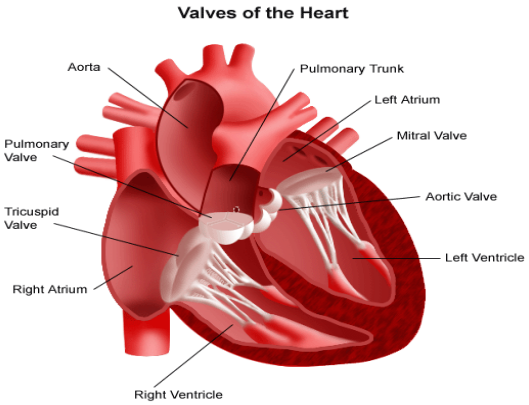


** Each one of the atria and ventricles is separated from each other by atrioventricular septum (fibrous tissue), so the atria and ventricles are not continued muscularly.

** The atria are continuous muscularly and the ventricles are continuous too. So any stimulus that goes for one of the atria it goes for both atria at the same time. And any stimulus that goes for one of the ventricles it goes for both ventricles at the same time. This is called syncytium (one unit), so we have two syncytia; atrial syncytium and ventricular syncytium.

- Cardiac valves are shown in the figure below:





** Each atrium is separated from its corresponding ventricle by a valve; so we have:

One the right side= atrioventricular valve (AV valve) = **Tricuspid valve**.

One the left side= atrioventricular valve (AV valve) = **Bicuspid valve**= Mitral valve.

** We also have two other valves:

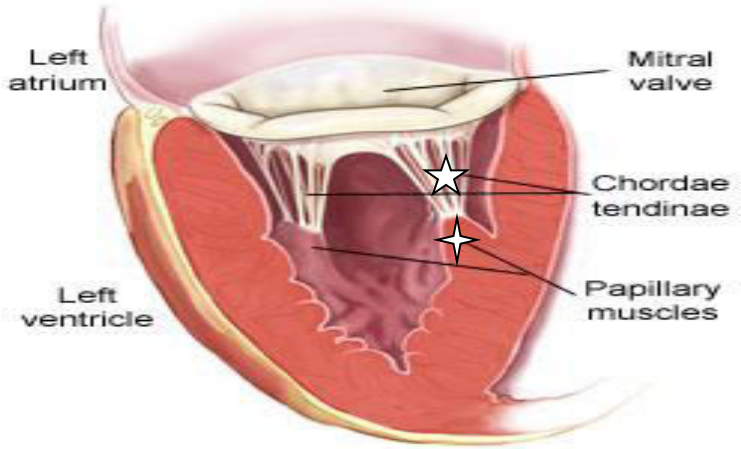
<u>Aortic valve</u> and **<u>pulmonary valve</u>**:

-Prevent the backflow of blood from the aorta to the left ventricle. And from the pulmonary trunk to the right ventricle respectively.

-They are called semilunar valves because each of those valves has leaflets that are shaped like half-moons.

** These valves open or close passively; according to pressure gradient.

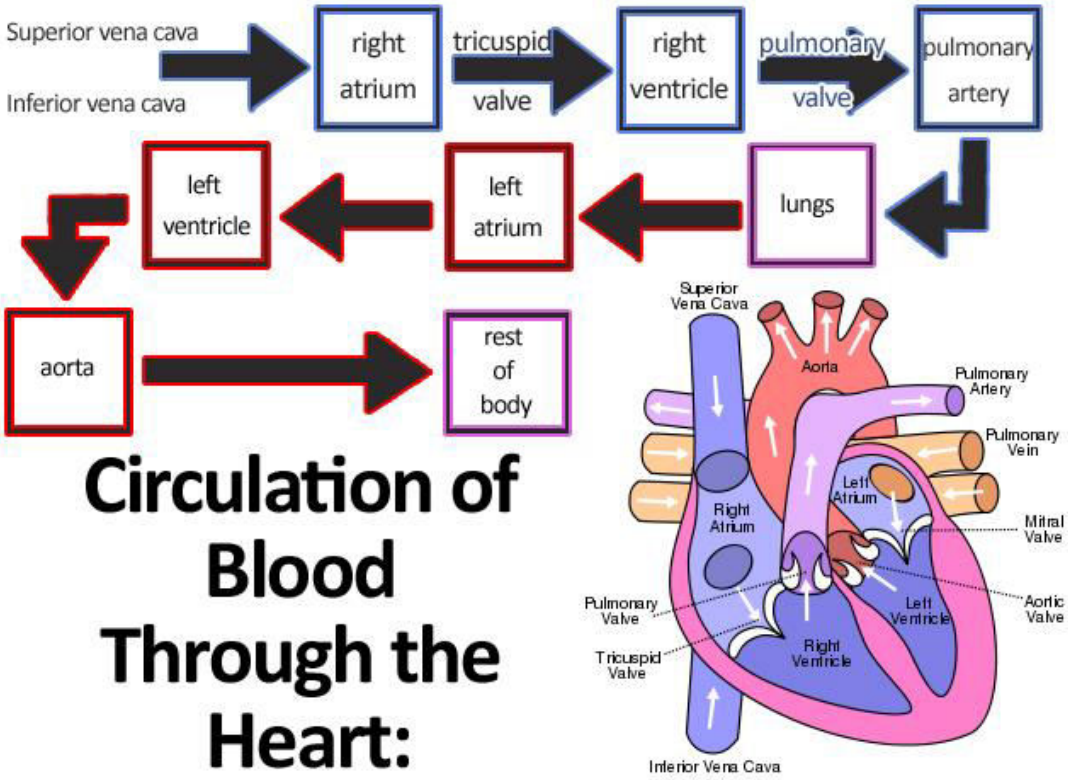
** The edges of AV valves are attached to a tendinous structure called Chorda Tendineae (☆) they're inserted in a muscle called papillary muscle (✧). Notice the figure next page:



[Papillary muscle is part of the ventricular muscle, so when the ventricles contracts the papillary muscle does too and when the ventricle relaxes, it relaxes too. Chordae tendineae prevent <u>regurgitation (prolapse)</u> which is the movement of blood from the ventricle to the atrium. When the ventricle contracts to empty its content, the AV valves close and the papillary muscle contracts pulling the edges of the valve limiting its movement. So papillary muscle neither closes nor opens the valve, it regulates its movement.**]**

- ✓ **We conclude the importance of the heart valves:**
  - Atrioventricular Valves:
    - Prevent backflow to the atria
    - Prolapse is prevented by the chorda tendineae.
      - ➢ Tensioned by the papillary muscle.
  - Semilunar valves:
    - Prevent backflow into the ventricles.

➢ Movement of blood in the heart:



** Follow the flow of the blood in the heart and make sure you know it well.

** Notice that the arterial system (of the systemic circulation) supplies the lung through bronchial arteries but bronchial veins do not empty in the venous system (of the systematic circulation) they drain through pulmonary veins to the left side of the heart.

Forgive me for any mistake may have occurred.

Good luck all.