The Cardio-VASCULAR System

- ○ Anatomy
- ○ Histology
- ○ Pathology
- ○ Pharmacology
- ● Physiology
- ○ Microbiology

Lec #: 1

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Done By: Doa'a dahboor

- ○ Handout
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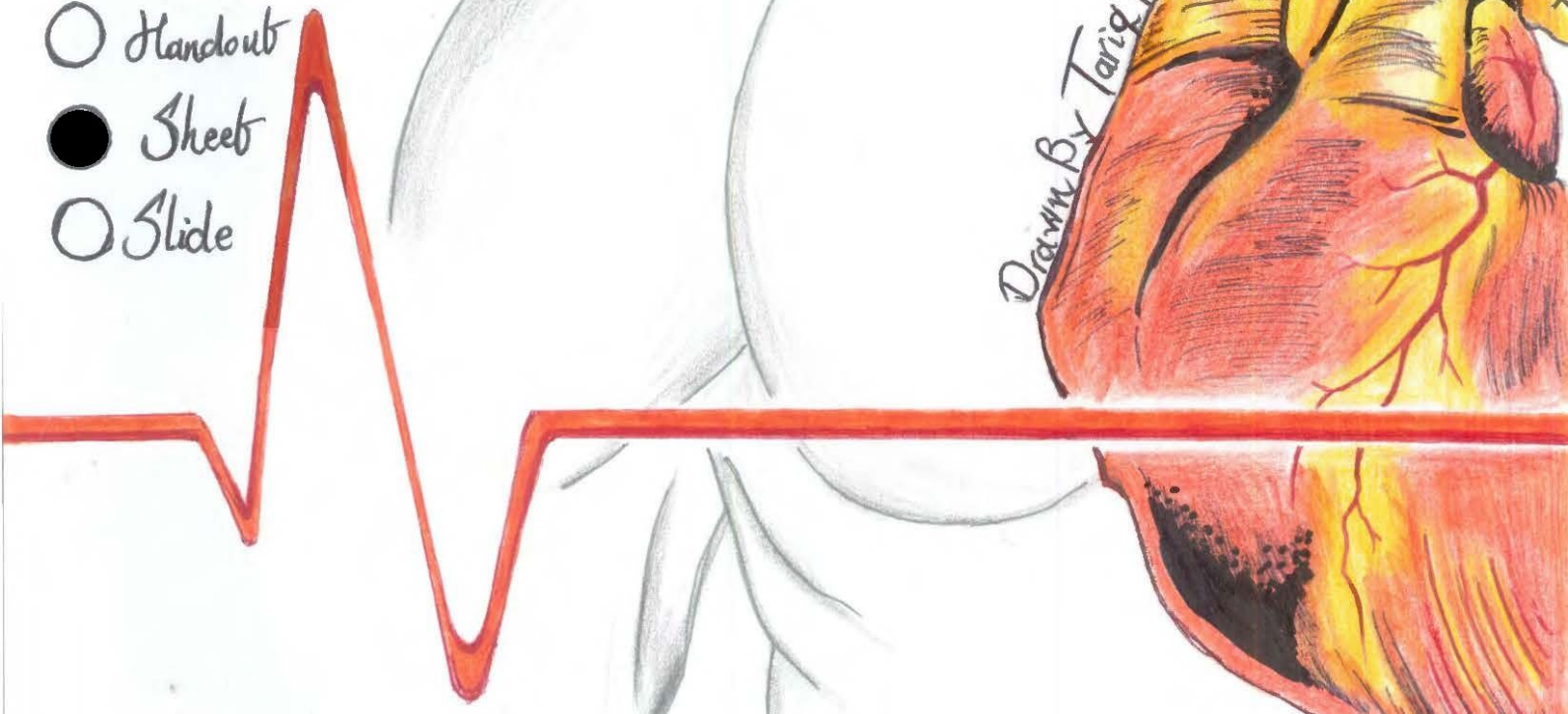


(وَأَنْ لَيْسَ لِلْإِنْسَانِ إِلَّا مَا سَعَى * وَأَنَّ سَعْيَهُ سَوْفَ يُرَى)

INTRODUCTION TO CVS PHYSIOLOGY

THIS IS THE EASIEST LECTURE IN LIFE EVER ☺

-Before we start:

Dr. Faisal will give us 18 CVS physiology lectures, you have some idea about CVS physiology from your first year in medical school. Indeed, CVS physiology is a very important branch of physiology. It needs DEEP understanding and not only memorizing.

Reference / Recommended book: Guyton (11th or 12th edition). The doctor said that he might ask some questions from the book and that's why you have to refer to it, but MOSTLY his questions will be from what he says in the lectures.

-Why do we study CVS physiology?

As you know, physiology is a field that studies the NORMAL function of the body. You cannot understand pathology which is the field that studies abnormal alterations of body functions unless you understand what is normal i.e. unless you understand physiology. So assessing cardiac patients' signs and symptoms and understanding the progression of cardiac diseases is totally dependent on well understanding of CVS physiology. Let us illustrate this by an example:

Clinical Problem

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

Written by Doa'a S. Dahboor

Let us now analyze this clinical problem step by step:

** Severe weakness and fatigue: The patient easily and frequently gets tired (e.g. while he's walking).

** Dry cough: You might think about a respiratory problem. Indeed, it can really be a respiratory problem but cardiac diseases must be also put into consideration. The cardiac and the respiratory systems are strongly related to each other. In our example, the dry cough could be a result of a heart problem that led to congestion of lungs.

** Weight gain: Due to fluid retention. If the heart is diseased, then it cannot pump blood (fluid) properly so it's retained in the body.

** Difficulty in breathing and severe shortness of breath while walking upstairs: The cause is that not enough amount of blood is being pumped to lungs due to the diseased heart i.e. the patient has inadequate oxygenation. Symptoms are more severe while walking upstairs because this action requires good oxygenation and energy. In contrast, symptoms are much lesser at rest because there's no need of much oxygen and energy.

** Suffocating – الشعور بالاختناق: The cause is the retained fluid in the chest that impairs lungs' function. Impaired lungs' function means there's no adequate oxygenation and thus not enough amount of oxygen being delivered. The patient feels he's suffocating; he wakes up at night and goes to an open-air area or opens the windows to take a breath! The patient improves after doing that but indeed it's not (taking a breath) that solved the problem! What happens is that when the patient wakes up i.e. when he stands, fluid goes downward away from lungs by the force of gravity. This improves lungs' efficiency and the patient feels relaxed ☺ When he goes back to sleep , fluid again accumulates in the chest disrupting lungs' function , suffocation returns back and the patient wakes up again and this goes on and on and on ☹

** Sleeping with 3 pillows under head: Pillows raise the head. If patient's head was in a flat plane along with his body, fluid goes to lungs causing edema (collection of fluid prevents adequate oxygenation) which causes suffocation.

** Falling asleep while watching TV: Low levels of oxygen lead to the feeling of drowsiness (tendency to sleep).

** Repeated urination while sleeping: Due to fluid retention. Filtration of fluid in kidneys during sleeping leads to repeated urination. So if a patient comes to you complaining of excessive urination while sleeping, don't only think about kidneys! Think about the heart. Notice the interrelation between different body systems: The cardiac, the pulmonary, the renal and the urinary.

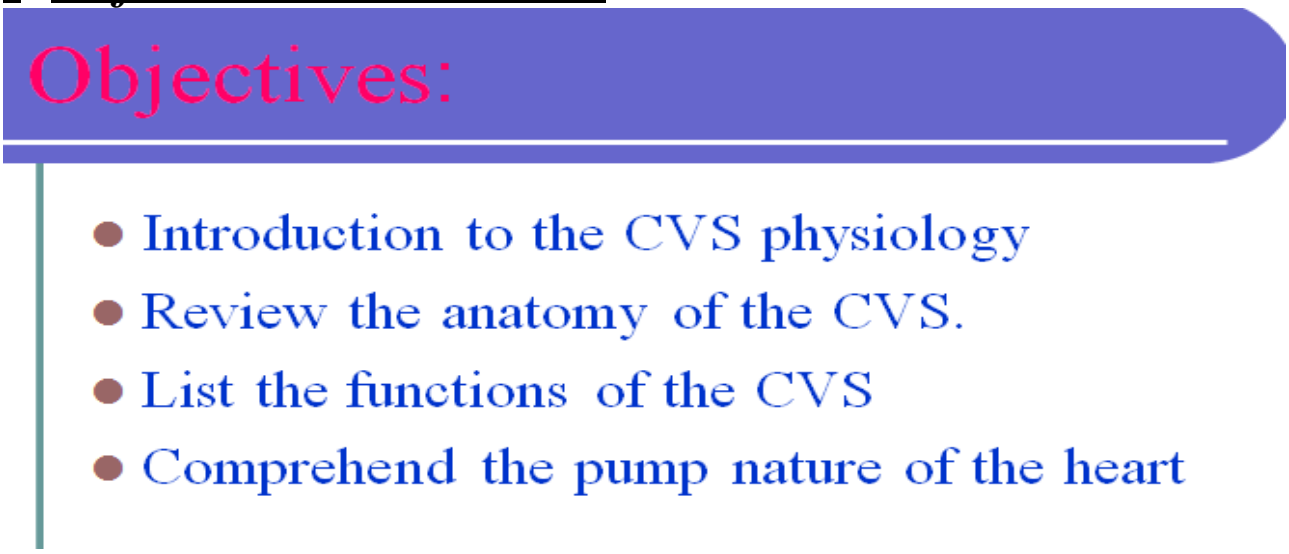
** Hospitalized with heart problem 2 months ago, efficiency of heart is 30%: Efficiency of heart will be discussed later in details. Now due to the low efficiency of the heart, the patient was told that he needs HEART TRANSPLANT. The heart is a pump, if this pump is defective (diseased), we can either fix it if the defect is correctable by drugs and continuous therapy, or replace it by heart transplant if the pump is beyond correction. The problem is that heart transplant is unlike other organs transplant. In case of kidney, liver or lung transplant, the organ is gotten from a compatible donor (the donor is alive and able to live with one kidney, lung or part of the liver after donation) and if there's no rejection by the recipient's body, then everything is okay ☺ However, in cardiac transplant, the patient has to wait until someone dies to take his heart which must be healthy (usually from a young person who died because of a car accident). Compatibility is also a must to avoid rejection problems .Heart can be replaced by a natural heart (of a human or an animal) or by an artificial (mechanical) heart – مُصنَّع. Artificial heart issue is still under study and the doctor sees that it'll be one of the greatest inventions in life .

** Examination: Is done to assess signs and symptoms by measuring weight, height, BP, heart beats and respiratory rate.

** Auscultation reveals abnormal heart sounds: **Auscultation** is listening to the sounds of the heart using a stethoscope. Usually you hear two sounds (S1 and S2), however; those with a musical ear :p can hear four sounds (S1, S2, S3 & S4). Nevertheless, auscultation nowadays is not that important and is not much used because a new technique **(Phonocardiogram)** has appeared. Phono- means recoding i.e. phonocardiogram is recording of the sounds made by the heart.

** **ECG (Electrocardiography):** Recording of electrical changes that occur in the heart.

- Objectives of this lecture :



** The cardiovascular system is composed of 2 parts:
CARDIO- = the heart (which is a pump).

VASCULAR = the blood vessels.

** The vascular part: There are 2 types of blood vessels; arteries and veins. Arteries are the vessels that take blood away from the heart whether it's oxygenated or not .** Veins** are the vessels that take blood **toward the heart** whether it's oxygenated or not . The biggest artery that originates from the heart and takes blood away from it is the aorta. The aorta has three branches:

Aorta → Left common carotid artery.
Aorta → Left subclavian artery.
Aorta → Right brachiocephalic artery (Brachiocephalic trunk) → Right common carotid artery
Right brachiocephalic artery (Brachiocephalic trunk) → Right subclavian artery

After giving these 3 branches, the aortic arch descends downward to become the thoracic aorta, abdominal aorta ... distributing blood to all parts of the body.

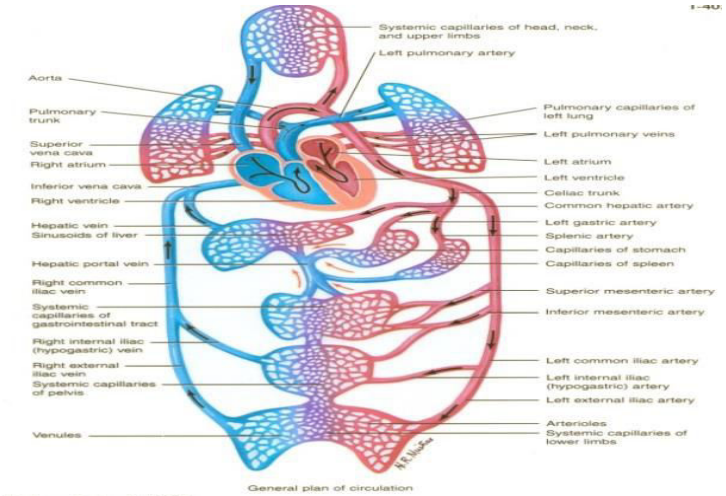
The biggest arteries divide into big arteries ⟶ medium-sized arteries ⟶ small arteries ⟶ arterioles ⟶ capillaries.

That was the arterial side of the circulation.

Capillaries collect into venules ⟶ small veins ⟶ medium-sized vein ⟶ large veins ⟶ Superior vena cava collects blood from upper part of the body and inferior vena cava collects blood from lower part of the body to heart again.

That was the venous side of the circulation.

One note about the arterial part is that before arterioles, there's no exchange of substances between plasma and tissues. Exchange-المقصود توصيل الدم للأنسجة- starts beyond arterioles, particularly at the level of capillaries.



So here in the picture you can see the **microcirculation**. It's hard to fix the microcirculation if it has a problem (unlike the heart which can be treated by drugs or replaced if it's beyond correction). From this we conclude that the microcirculation is EXTREMELY important, may be more important than the heart itself!

** There are 2 completely separate circulations in our circulatory system and these circulations are:

1) The greater / systemic circulation – الدورة الدموية الكبرى:

Blood is pumped from the heart to almost all body systems (except the lungs).

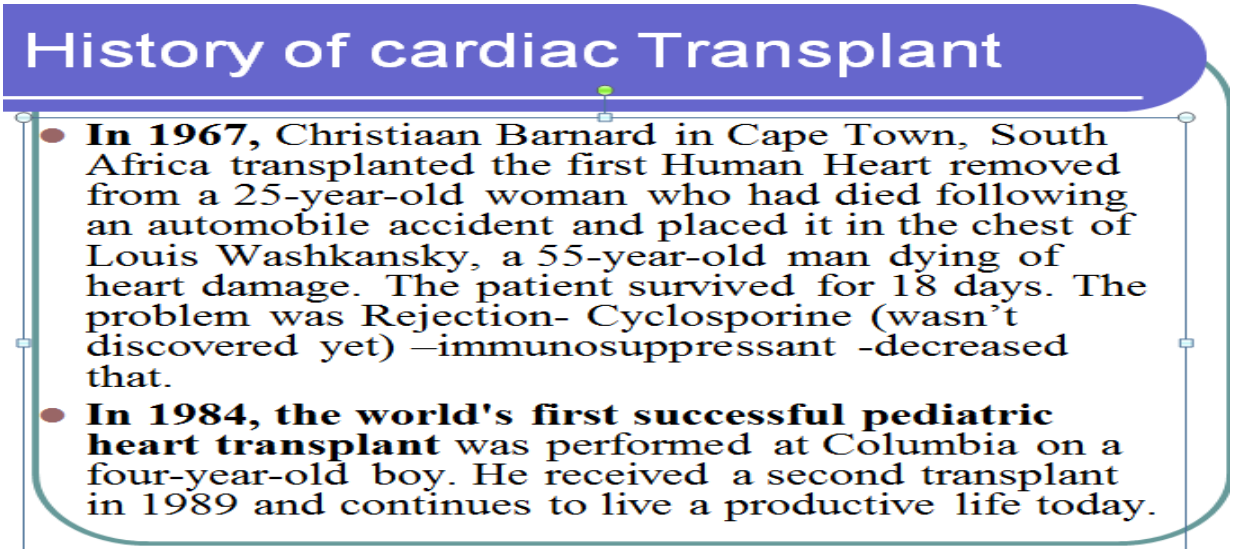
2) The lesser / pulmonary circulation – الدورة الدموية الصغرى:

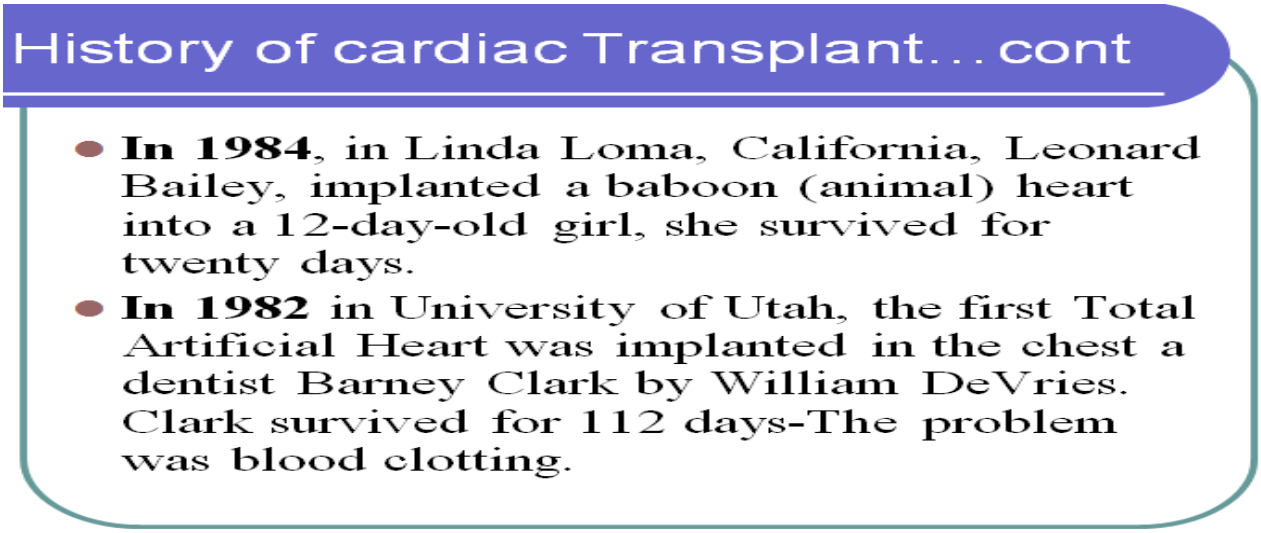
Blood goes from the heart through the pulmonary artery to the lungs, and then it comes back to the heart through pulmonary veins.

The amount of blood that's pumped by the heart to the systemic circulation per minute is equal to the amount of blood pumped to the pulmonary circulation per minute which is known as **the cardiac output** (discussed later in details).

- **History of cardiac transplant:**

This is for your own information, just read it ☺

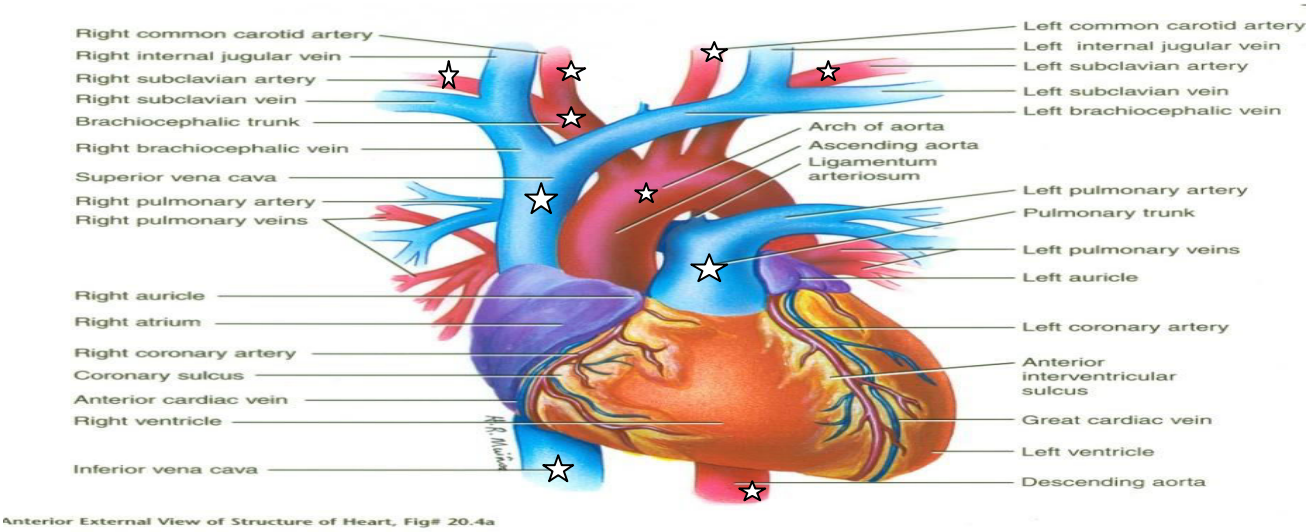




** One note about the artificial heart transplant in 1982: As you know, the artificial heart is a foreign body that stimulates coagulation, doctors tried to solve this problem by giving anti-coagulants to the patient, excessive administration of anti-coagulants led to bleeding in the GI tract of the patient and that was the actual cause of death. In fact, the artificial heart was functioning perfectly!

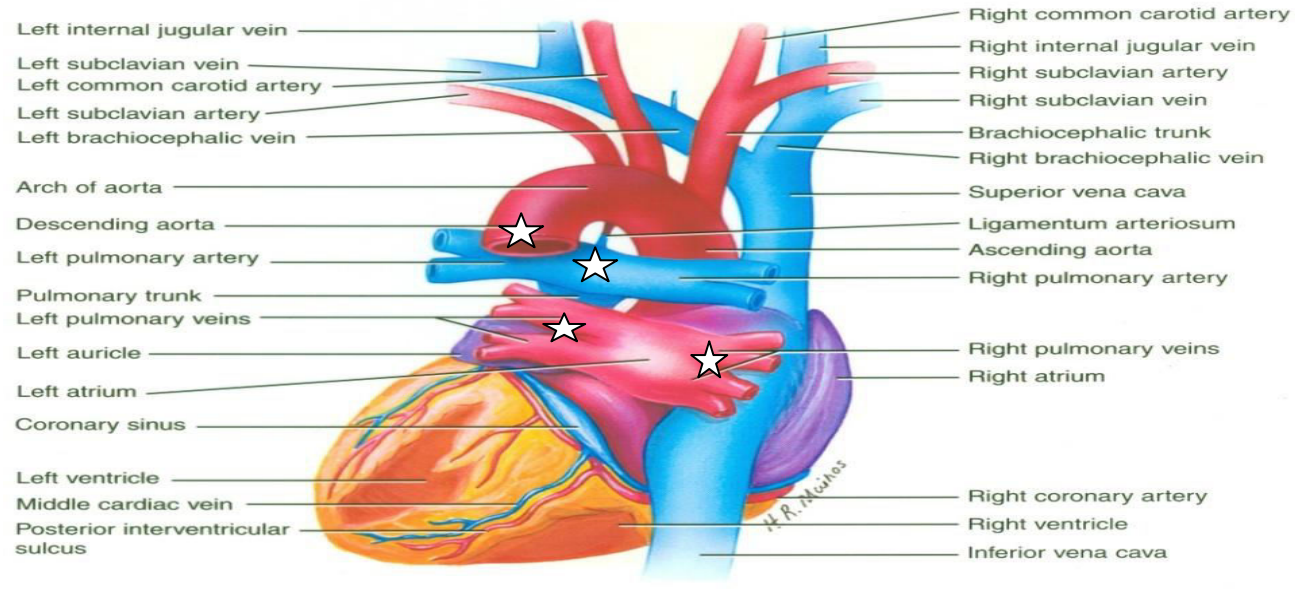
- Anatomy of the heart :

As you know, the heart is a pump that's located in the chest (in the mediastinum). These are two views of the heart, kindly notice the blood vessels that we talked about previously, I'll mark them by a star ☆



Anterior External View of Structure of Heart, Fig# 20.4a

Anterior view of the heart.



Posterior External View of Structure of Heart, Fig# 20.4c

Posterior view of the heart.

** If you dissect the heart, you'll find that it consists of 4 chambers; the 2 upper chambers are the atria- الأُذينان and the 2 lower chambers are the ventricles –البُطينان.

The atria are separated from each other by the interatrial septum and the ventricles are separated from each other by the interventricular septum. In fact, the interventricular septum is considered part of the ventricular muscle and it contracts when the muscle contracts.

Each atrium is separated from its corresponding ventricle by a valve; the atrioventricular valve (AV valve). The right AV valve that separates the right atrium from the right ventricle has 3 cusps and that's why it's called **the tricuspid valve– الصمام ثلاثي الشرفات**. The left AV valve that separates the left atria from the left ventricle has 2 cusps and that's why it's called **the bicuspid valve-الصمام ثنائي الشرفات** . The bicuspid valve has another more common name which is **the mitral valve**.

The exit of blood from the ventricles to the arterial system (from the left ventricle to the aorta and from the right ventricle to the pulmonary trunk) is also controlled by valves. **The aortic valve** controls the flow of blood at the left side from the left ventricle to the aorta .**The pulmonary valve** controls the flow of blood at the right side from the right ventricle to the pulmonary artery. Each of these two valves has three semilunar cusps that are why they are called **the semilunar valves – الصمامات نصف القمرية**.

The importance of these valves is to prevent backflow of blood i.e. to ensure that blood movement is unidirectional (in one way). If the blood tries to go back, the controlling valve closes. Ex.: The AV valves open toward the ventricles; they close if blood tries to go back from the ventricles to the atria. Similarly, semilunar valves open toward the arterial system (Right towards pulmonary artery, left towards aorta); they close if blood tries to go back from arteries to the ventricles.

These valves open and close PASSIVELY (not actively, not due to contraction or relaxation). The only thing that controls these valves is the **pressure gradient** around them. See the following examples to understand what we mean by this: (P means pressure)

P atria > P of the corresponding ventricle: AV valve opens.

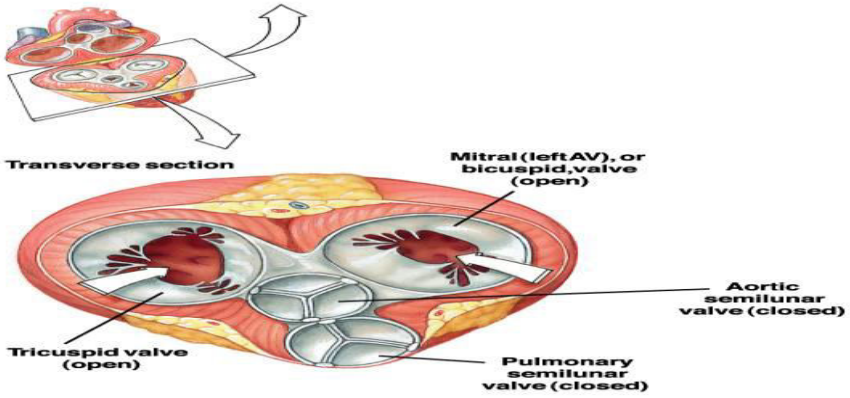
P ventricle > P of corresponding atrium: AV valve closes to prevent backflow of blood.

P ventricle > P artery (pulmonary on the right and aorta on the left): Semilunar valve opens.

P aorta > P left ventricle: Blood tends to go back from the aorta (higher P) to the left ventricle (lower P), so the left semilunar valve closes to prevent this backflow.

P pulmonary artery > P right ventricle: Right semilunar valve closes to prevent backflow.

This picture shows you the different valves we talked about:



** **AV Valves:**

The edges of the AV valves are attached to a tendonous structure; the **chordae tendinae.**

Chordae tendinae are inserted in a papillary muscle (named according to its papilla-like shape). This papillary muscle is a part of the ventricular muscle, so when the ventricular muscle contracts, the papillary muscle also contracts (it's tensioned). This contraction pulls the chordae tendinae downwards and the AV valve closes (this necessarily occurs when P ventricle > P of corresponding atrium). By this mechanism, blood flow is maintained unidirectional i.e. blood was prevented from flowing backwards to the atria again which disrupts the circulation. On the other hand, when the ventricular muscle is relaxed, the papillary muscle will be also relaxed and the valve is open (this occurs when P atrium > P of the corresponding ventricle).

** **Valve Prolapse:**

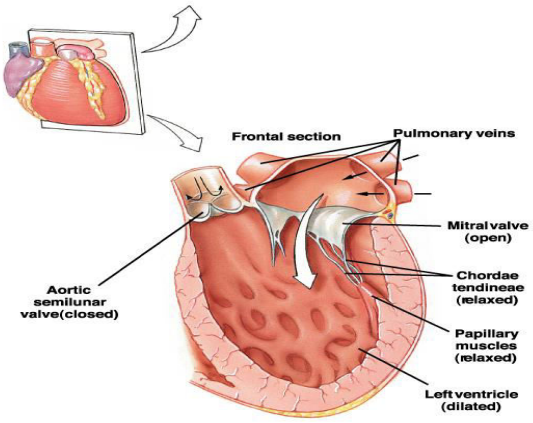
Now what happens if the chordae tendinae are cut or if the papillary muscle is destroyed (being necrotic for example)? When this happens, the mechanism by which the valve is kept closed and pulled downward when there's high pressure in the ventricle is disturbed. When the ventricle contracts, the high pressure pushes the AV valve towards the atrium and it opens (we call this valve prolapse) and this causes backflow of the blood from the ventricle to its corresponding atrium instead of being pumped to the arteries (we call this regurgitation of blood). The prefix Re- means return. So we conclude that the function of chordae tendinae is to prevent valve prolapse and thus helping the valves in doing their function which is maintaining the unidirectionality of blood movement.

Valve prolapse commonly accompanies myocardial infarction- احتشاء عضلة القلب ، الجلطة.
Myocardial = muscle of the heart, Infarction = death (abbreviation: MI).

What's the difference between infarction and ischemia?
Ischemia = decreased blood flow to a tissue, this leads to ischemic pain.

Infarction = Cessation of blood flow to a tissue (stop of blood flow). The tissue dies.

Prolapse and regurgitation may occur in any valve. For example there's mitral valve prolapse in which blood flows back from the left ventricle to the left atrium instead of going to the aorta, tricuspid regurgitation in which blood flows back to the right atrium, aortic valve regurgitation in which blood flows back from the aorta to the left ventricle, and pulmonary regurgitation in which blood flows back from the pulmonary artery to the right ventricle.



This picture shows the importance of chordae tendinae; which is to prevent prolapse of the valve. They're tense when the ventricular muscle contracts so the AV valve closes.

- **Movement of blood :**

The blood comes from the superior and inferior vena cava to the right atrium, and then it goes to the right ventricle through the AV (tricuspid) valve. The blood is then pumped to the pulmonary artery through the pulmonary valve. In the lungs, the blood is oxygenated. Oxygenated blood comes back to the left atrium through pulmonary veins, and then it goes from the left atrium to the left ventricle through the mitral valve. From the left ventricle it's pumped to the aorta to be distributed to all parts of the body through the systemic circulation.

- **Introduction to the next lecture :**

** Objectives:

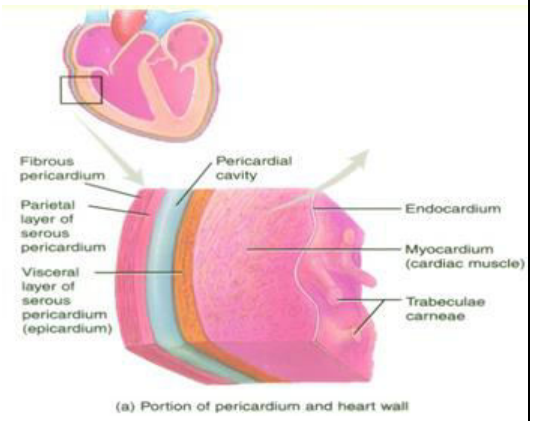
Objectives:

By The end of this lecture students should be able to:

- Distinguish the cardiac muscle cell microstructure
- Describe cardiac muscle action potential
- Point out the functional importance of the action potential
- Follow the cardiac muscle mechanism of contraction
- Delineate cardiac muscle energy sources
- Outline the intracellular calcium homeostasis
- Explain the relationship between muscle length and tension of cardiac muscle (Frank-Starling law of the heart)

** Before studying the cardiac muscle, let's talk about the wall of the heart:

The wall of the heart is composed of 3 layers (from inside – outside):



(a) Portion of pericardium and heart wall

1) The innermost layer is the **endocardium**.
2) The intermediate layer is actually the main layer, it's a muscle and that's why it's called the **myocardium**.
3) The outermost layer that covers the muscle is the **pericardium**. The pericardium consists of 2 layers:
   a- The parietal layer which is the outer one.
   b- The visceral layer which is the closer to the myocardium.

   In between the parietal and the visceral layers of the pericardium, there's a space (cavity) known as the pericardial cavity (space). The pericardial space has fluid inside. This fluid isproteinacious i.e. has proteins (not too much, around 50 ml). This pericardial fluid is very important since it works as a cushion for the heart (shock absorber) so it protects the heart.

Clinical application: Cardiac tamponade:
When the pericardial fluid increases excessively, it'll compress the heart and thus it'll not be filled with blood, accordingly, if there's no filling of blood, there'll be no pumping i.e. the cardiac output is zero. The patient feels he's suffocating. This commonly occurs in car accidents when an internal bleeding fills the pericardial cavity with blood. Treatment is by taking the fluid out of the pericardial cavity (by a syringe for example); the patient takes a deep breath after doing that as if he was hungry for air!

The end ☺

" و النفسُ إن لم تشتغل بشيء شغلت صاحبَها . "

Dedicated to Asma Jisrawi <3

أعتذر عن أي خطأ علمي أو لغوي ..

Written by: Doa'a S. Dahboor.