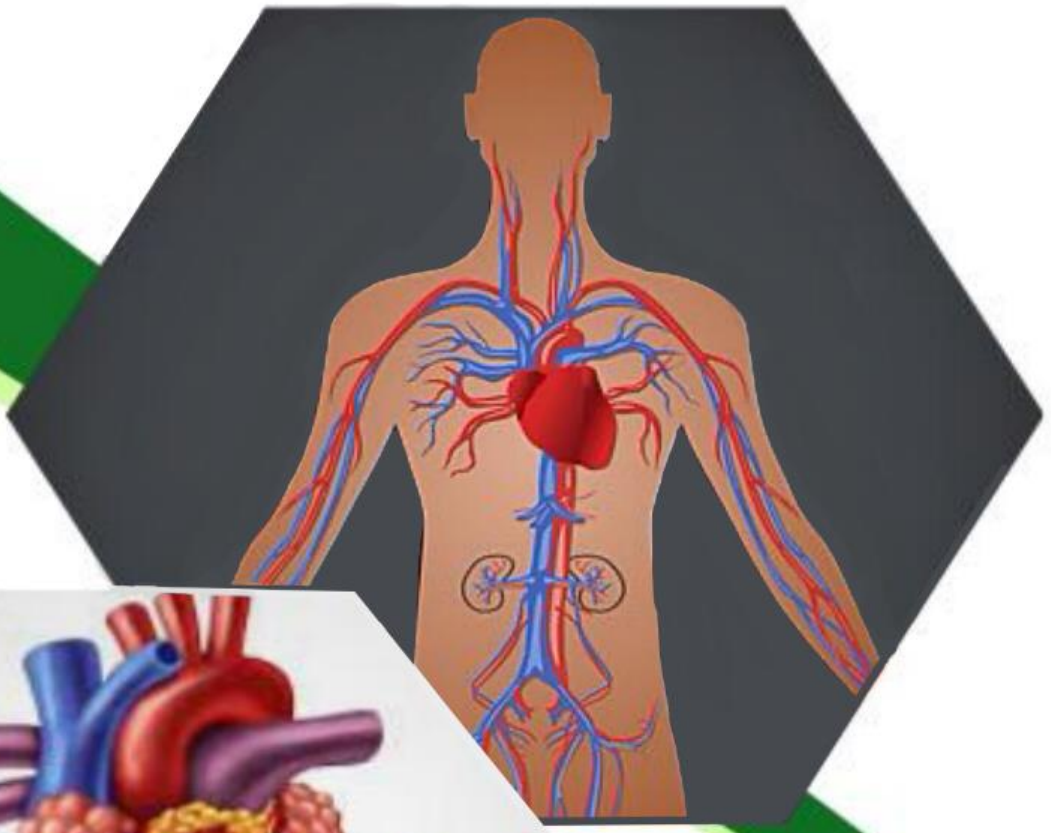
Doctor.021

no. 1

CVS PHYSIOLOGY



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It is better to watch the lec with this sheet, the numbers in this lec are required ·͡·

Introduction to CVS

Let's start by taking about **heart failure**; there are three symptoms that are common among heart failure patients (this triad is manifested in every heart failure patient, with other symptoms and signs): **Dyspnea** (shortness of breath and difficulty in breathing), **Fatigue** (taking multiple breaks during a long walk), **Palpitations** الإحساس بدقات القلب.

Heart failure is never said to be black or white or all or none, it's rather grey and has multiple stages (1-4), stage 1 is the mildest and 4 is the worst. In stage 1 symptoms are only manifested **during sever exercises** (the highest speed on a treadmill with increased angle), in stage 2 symptoms are manifested **during moderate exercises**, in stage 3 symptoms are manifested **during mild exercises** (being unable to walk short distances, in stage 4 symptoms are manifested **at rest.**

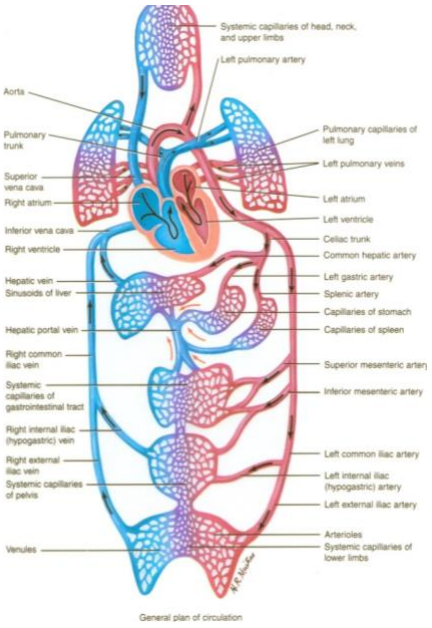
Class	Patient Symptoms
Class I (Mild)	No limitation of physical activity. Ordinary physical activity does not cause undue fatigue, palpitation, or dyspnea (shortness of breath).
Class II (Mild)	Slight limitation of physical activity. Comfortable at rest, but ordinary physical activity results in fatigue, palpitation, or dyspnea.
Class III (Moderate)	Marked limitation of physical activity. Comfortable at rest, but less than ordinary activity causes fatigue, palpitation, or dyspnea.
Class IV (Severe)	Unable to carry out any physical activity without discomfort. Symptoms of cardiac insufficiency at rest. If any physical activity is undertaken, discomfort is increased.

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 upstairs 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 (dyspnea). 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 cardiac transplantation and has to wait until to find a donor. 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.

This patient has a heart failure because he had the three symptoms of heart failure (underlined).

Cardio-vascular system



In this system we are going to talk about two things (as the name implies) the heart and the vascular circulation which has two types:

1. **Pulmonary or central or lesser circulation** (from the right ventricle to the lungs then to the left atrium).
2. **Peripheral or systemic or greater circulation** (from the left ventricle to the aorta then to the rest of the body), the special thing about it is that it **faces high resistance,** but what does that mean?

According to ohm's low (one of the most important lows in physiology) "**the flow is directly proportional to the driving force and inversely proportional to the resistance**".

$$\text{Flow} \propto \frac{\text{Driving force}}{\text{Resistance}}$$

In the heart, the left ventricle ejects **5 litres per min** (the flow), also called the **cardiac output** (is the volume of blood ejected from the left or right ventricle per min).

-The driving force for that flow of blood needs a pressure difference (pA-pB), for example if we want to calculate the pressure difference between the aorta (pA) and the right ventricle (pB), pB is usually going to be 0atm or 760mmHg, and **pA of the aorta is on average 100atm.**

(*Note: if the pressure was 761mmHg it is said to be +1, 759mmHg is -1, 740mmHg=-20, 840mmHg= +80 and so on.)

-The total peripheral resistance of the vascular bed (TPR = R1+R2+….) (is the resistance of arteries + arterioles + capillaries + venules + veins) resistances are connected in series بالتوالي, **TBR (total peripheral resistance) is greater than the pulmonary resistance in 7 folds**, meaning that the pressure needed to overcome the resistance of the peripheral (TBR) is 7 times more than in it's in the pulmonary; **pressure in lungs** 14*7=**98atm (TBR).**

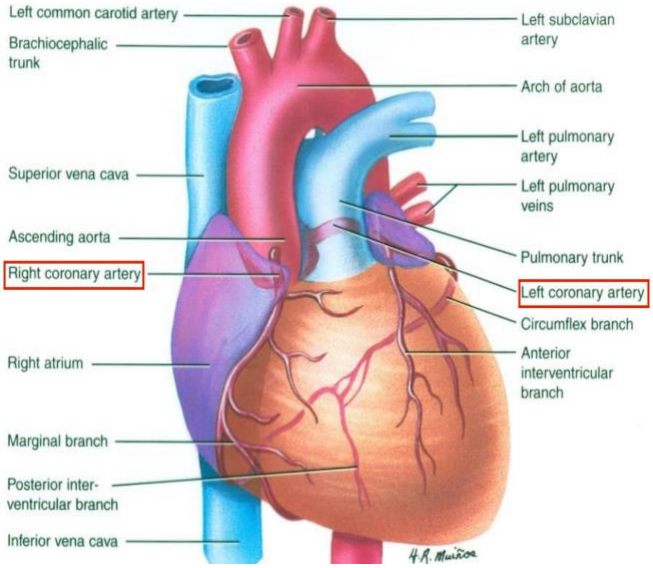
Systemic and pulmonary circulation – circuits in series

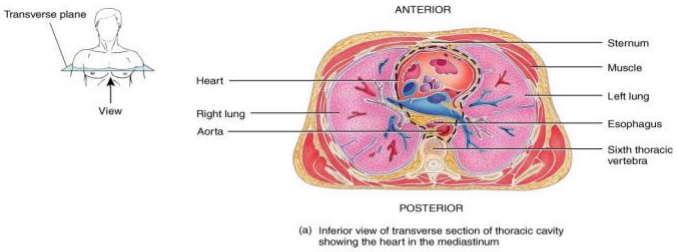
- Systemic circuit…high resistance circulation.
- From left side of heart (LV) to right atrium.
- Receives blood from lungs → to left atrium.
- Ejects blood from LV to aorta.
- Systemic arteries → arterioles → capillaries → venules → veins → back to right atrium.
- Gas and nutrient exchange in systemic capillaries.
- Pulmonary circuit…low resistance circulation: only one seventh.
- Right side of heart RA and RV.
- Receives blood from systemic circulation.
- Ejects blood into pulmonary trunk then pulmonary arteries.
- Gas exchange in pulmonary capillaries.
- Pulmonary veins take blood back to left atrium.

Heart and lungs are neighbors in the thorax and are highly connected, which means heart problems affect the lungs and vice versa.

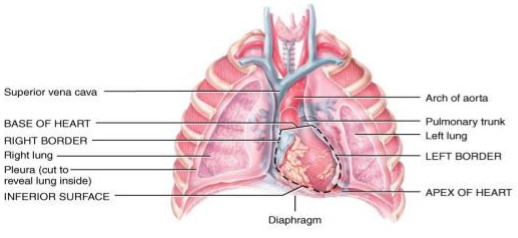
Anatomy of the heart

The heart has right and left coronary arteries which supply the heart itself with blood, **the coronary blood flow (perfusion of the coronaries) is 250ml per min at rest.** During exercise it increases reaching 500-1000ml per min.





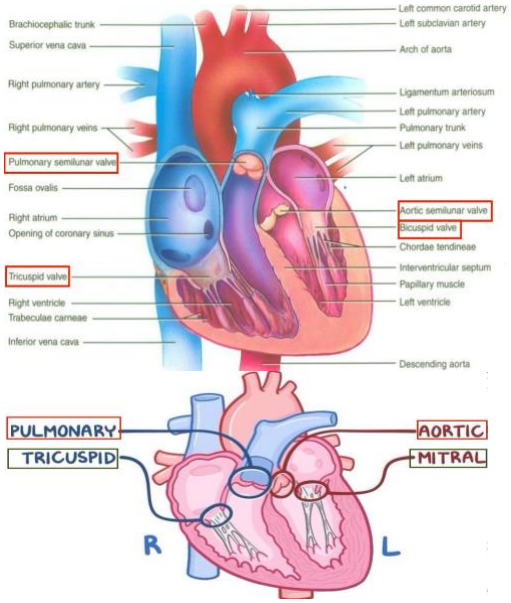
(a) Inferior view of transverse section of thoracic cavity showing the heart in the mediastinum



(b) Anterior view of the heart in the mediastinum

Cardiac valves

The heart is composed of 4 chambers; the two atria receive blood, and the two ventricles eject blood, and it has 4 valves; two between every atrium and ventricle, and two between the ventricles and the arteries, and they differ from each other.



-The first two valves are between the ventricles and atria (responsible for the filling of the heart) are:

1. **Bicuspid valve or or mitral valve or left AV** (atrium ventricle) **valve,** separates the left atrium from the left ventricle.
2. **Tricuspid valve or right AV valve.**

Those valves (bi and tricuspids) only open if the pressure in the atrium exceeds the pressure in the ventricle (**P. atria>PV→ bi and tricuspid valves open**), on the other hand, if the pressure in the ventricle exceeds the pressure in the atrium those valves close.

-Cardiac valves (not just the two above) **open and close *passively*** (not actively) **due to pressure difference** زي الباب انت بتفتحه وبتسكره هو بعملش اشي لحاله, meaning that in valves and cusps there are no muscles that contract and open them (contraction by a muscle= active).

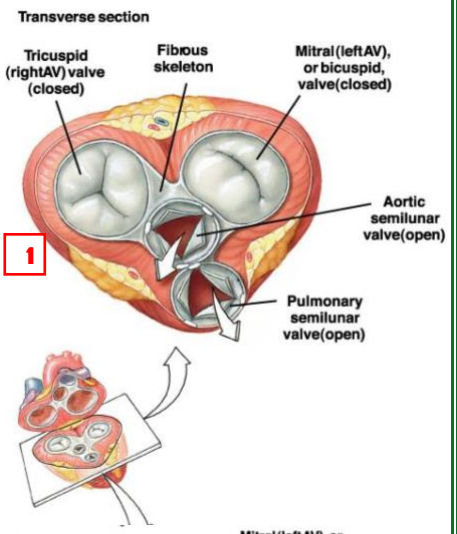
-The two other valves are between the ventricles and arteries (responsible for the emptying of the heart):

1. **Semilunar aortic valve**, between the left ventricle and the aorta.
2. **Pulmonary semilunar valve**, between the right ventricle and the pulmonary trunk.
   Those valves allow the blood to go from the ventricle to the artery and prevent the blood from going back, so when the pressure in the ventricle exceeds the pressure in the artery (aorta or pulmonary) this valve opens and blood goes out of the heart (to the aorta or pulmonary trunk).
   (PV>P. Arteries→ aortic and pulmonary valves open)

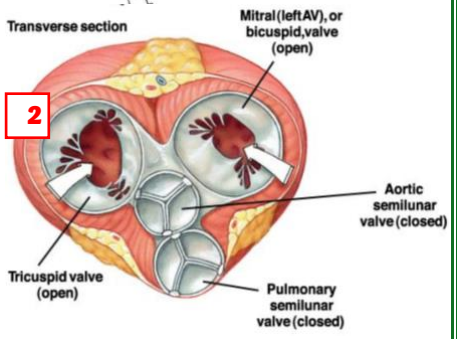
Cardiac cycle

The cardiac cycle has 7 phases (we will take them later on), two of them are shown here in those two pictures:

- **1** In the first picture (during ejection), you can see that the aortic semilunar and the pulmonary semilunar valves are open, while the bicuspid and tricuspid valves are closed, PV>P. Arteries.



- **2** In the second picture (during filling), bicuspid and tricuspid valves are open, and the others are closed, P. Atria>PV.

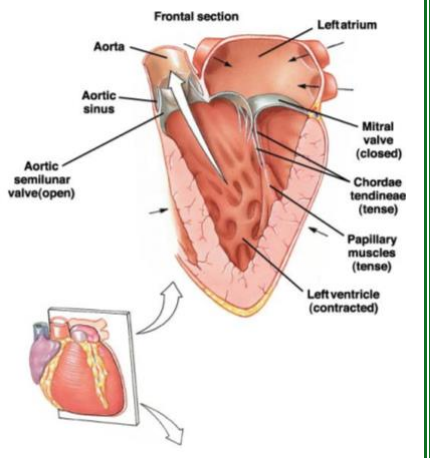


- There is another phase where the 4 valves are closed, in this case the amount of blood in the heart stays constant, doesn't get in or out, it is also called **isovolumic phase.**

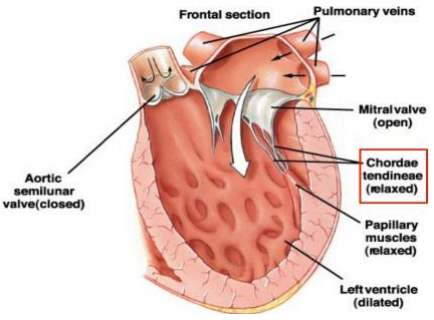
- There isn't any phase at which the 4 valves are open.

Importance of Chordae Tendineae

The thickness of the **left ventricle is 10-15mm**, and the thickness of the **right ventricle is 3-5mm**, and the thickness of the **atrium is 2mm**.
The reason why the left ventricle is so thick is because it faces a very high resistance in the periphery, 7 times its resistance so it takes too much muscle mass.



Because the left ventricle face 7 times higher resistance than the right ventricle, it produces 7 times more electricity used to eject blood.



The chordae tendineae: are cords connect between the mitral valve cusps and the papillary muscles on the floor of the left ventricle.

During contractions of the heart, chordae tendinae also contract to prevent the eversion of the heart and prevents the back flow of blood.

If chordae tendineae didn't exist or were ruptured, upon heart contraction a total loss of tension to the mitral valve would happen and the valve would turn into the inside causing **mitral regurgitation** and back flow of blood into the atria instead of going out of it.

Stenosis is another pathological condition that might affect the valves which reduces the blood flow.

Functional Anatomy of the Heart Valves

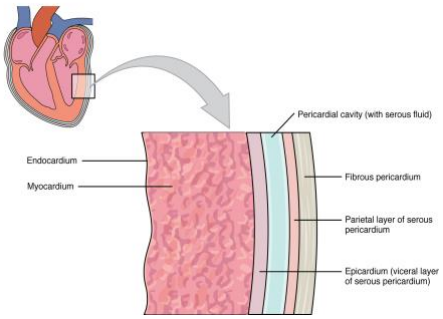
Function is to prevent back flow.

- Atrioventricular Valves:
  - Prevent back flow to the atria.
  - Prolapse is prevented by the chordae tendinae. Tensioned by the papillary muscles.
- Semilunar Valves:
  - Prevent back flow into ventricles.

Layers of the Heart Wall

The pericardium has tough collagen and lacks elastic fibres, so it's not elastic or a stretchable tissue. Without the pericardium we will die.

1. Epicardium (external layer) …prevent the heart from **overstretching** as we will see later when we discuss Frank-Starling law of the heart.
   - Visceral layer of serous pericardium.
   - Smooth, slippery texture to outermost surface.
2. Myocardium:
   - 95% of heart is cardiac muscle.
3. Endocardium (inner layer):
   - Smooth lining for chambers of heart, valves.



Heart Valves and Circulation of Blood

Atrioventricular valves…all valves open and close passively.

- Tricuspid and bicuspid valves (also known as mitral valve).
- When Atria are contracting the ventricles are relaxing. The opposite is true (atrial systole and diastole: ventricular systole and diastole).

- AV valve opens, cusps project into ventricle.
- In ventricle, papillary muscles are relaxed and chordae tendinae slack.

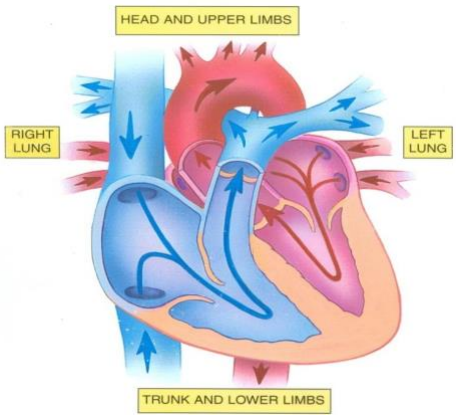
- Atria relaxed/ ventricle contracts…there is a time where both atria and ventricles are relaxing…but there is no way both are contracting simultaneously…the importance of the AV delay as we will discuss later. There are two phases in the cardiac cycle in which all 4 valves are closed simultaneously. Never open simultaneously.
  - Pressure drives cusps upward until edges meet and close the opening.
  - Papillary muscles contract tightening chordae tendinae Regurgitation from ventricle to atrium is prevented.

Movement of blood in the heart

The cardiac cycle is essentially split into two phases, systole (the contraction or emptying phase) and diastole (the relaxation or filling phase).

There are two contractions in the heart atrial and ventricular and the word "systole" alone refers to the ventricular systole, and atrial contraction is referred to as the "atrial systole", and the same applies to the diastole; diastole= ventricular diastole, atrial diastole= atrial diastole:)

Superior and inferior vena cava bring blood back to the right atrium, then it goes to the right ventricle through the tricuspid valve, then it will be pumped out through pulmonary arteries to the lungs in order to be oxygenated, then it will come back to left atrium via pulmonary veins, then through the bicuspid valve (mitral valve) to the left ventricle which pumps it to the aorta by through the aortic valve to start the systemic circulation.



The main job of the heart is to eject blood **5L/min (cardiac output)**.
If the pressure in the aorta is 80mmHg, the pressure in the left ventricle is zero, and the pressure in the left atrium is 5 (765mmHg), here the mitral valve will be open (filling of the heart), and the aortic valve will be closed.

When the heart contracts, the pressure of the left ventricle increases and when it reaches 6 (higher than the atrial pressure) the mitral valve will close, and the aortic valve will remain closed (not become closed because it already is), meaning all the ventricle chamers would be closed and isolated from its surrounding (the atrium and the aorta) this phase is called the **isovolumic phase**.
In order for the heart to eject blood it needs to open the aortic valve, and to do that the pressure of the ventricle should exceed the pressure of the aorta, and this is done by the contraction of the left ventricle, and for that to happen it needs a stimulus (excitation).

- **P. Atria>PV→ bi and tricuspid valves open.**
- **PV>P. Arteries→ aortic and pulmonary valves open.**

The order for heart events:

1. Electrical stimulation.
2. Mechanical contraction (excitation-contraction coupling) **.
3. Increased intra-ventricular pressure.
4. Opening of the aortic and pulmonary valves.
5. Ejection.

Before we talk about the causes of heart failure, there are two types of heart failure, isolated and pan heart failure. The isolated heart failure happens in one of the heart compartments, this happens at first then it leads to failure in all the heart compartments which is then called pan heart failure.
Failure in any of the 5 steps results in heart failure and the ventricle can't behave normally, there are a lot of reasons for that: electrical, mechanical, valvular or no ejection.
Reasons why the heart is unable to eject blood (heart failure): electrical problems can be caused by cardiomyopathy or carditis, pericardial effusion, pressure in the ventricle can be so high that the ejection can't happen, or valves are calcified or inflamed, or congenital abnormalities in valves. (most commonly affected in clinical practice is mitral> aortic> tricuspid> pulmonary),

Another reason for heart failure is that the volume of blood is too low (because of bleeding, dehydration, over sweating, overuse of diuretics, cholera, and burns).

Pressure of the left ventricle can be measured by measuring the tone of the heart; by clamping the leaving and entry points of the blood to left ventricle (at the aortic and mitral valves), so that the measurement would be isometric, then we give it a maximum stimulus and we measure the pressure, **the left intra-ventricular pressure will reach 240mmHg** (the maximum pressure of the left ventricle), and here if the aortic pressure was also 240mmHg the aortic valve can never open. And if the PV (left ventricle pressure) was 240mmHg and the aortic pressure was 200, the aortic valve can open but with some difficulty. And if the aortic pressure was from 120-90 and the left ventricular pressure was 240, the aortic valve will open easily, because the load the left ventricle facing is decreased.

Excitation-contraction **uncoupling can also happen (excitation happens by depolarizing the sarcolemma but the contraction doesn't happen).

But when does that happen? سؤال ممكن للإمتحان

This question is answered in the second lec:

In the skeletal muscle, long T-tubules correspond effectively and essentially in their function of electric propagation, thus, osmotic-shock-mediated de-tabulation (TT removal) uncouples excitation from contraction (no mechanical response to the electrical impulse) and is severely harmful, however short, and broad cardiac T-tubules importance in excitation-contraction coupling is questionable in the degree of benefit they provide as they poorly reach calcium stores... For example, in frog and birds, their ventricles contain no TT. In mammals, atria contain no TT. Also, Ca2+ depletion can cause that.

- Additional video for this lec if you have time you can watch it:
  https://youtu.be/xamYVlNF5Zo?si=2MxXdXnHy2mYuk7y

Past paper: The AV valve remains open in:

A. Ventricular diastole.
B. Passive filling.
C. C wave.
Answer: B

اللهم سخر لأهل غزة جنود الأرض وملائكة السماء واحمهم وانصرهم وثبت أقدامهم وأرح قلوبهم والطف بحالهم يا ربنا.

V2:

- In the last page the answer of the **question was changed.
- PA was replaced with p. atria in bi and tricuspid valves, and p. arteries in pulmonary and aorta valves, it was written pages 5,6,9.

V3:

- The highlighted things in the third and last page.