



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

DNS DEPARTMENT OF NEUROSCIENCE



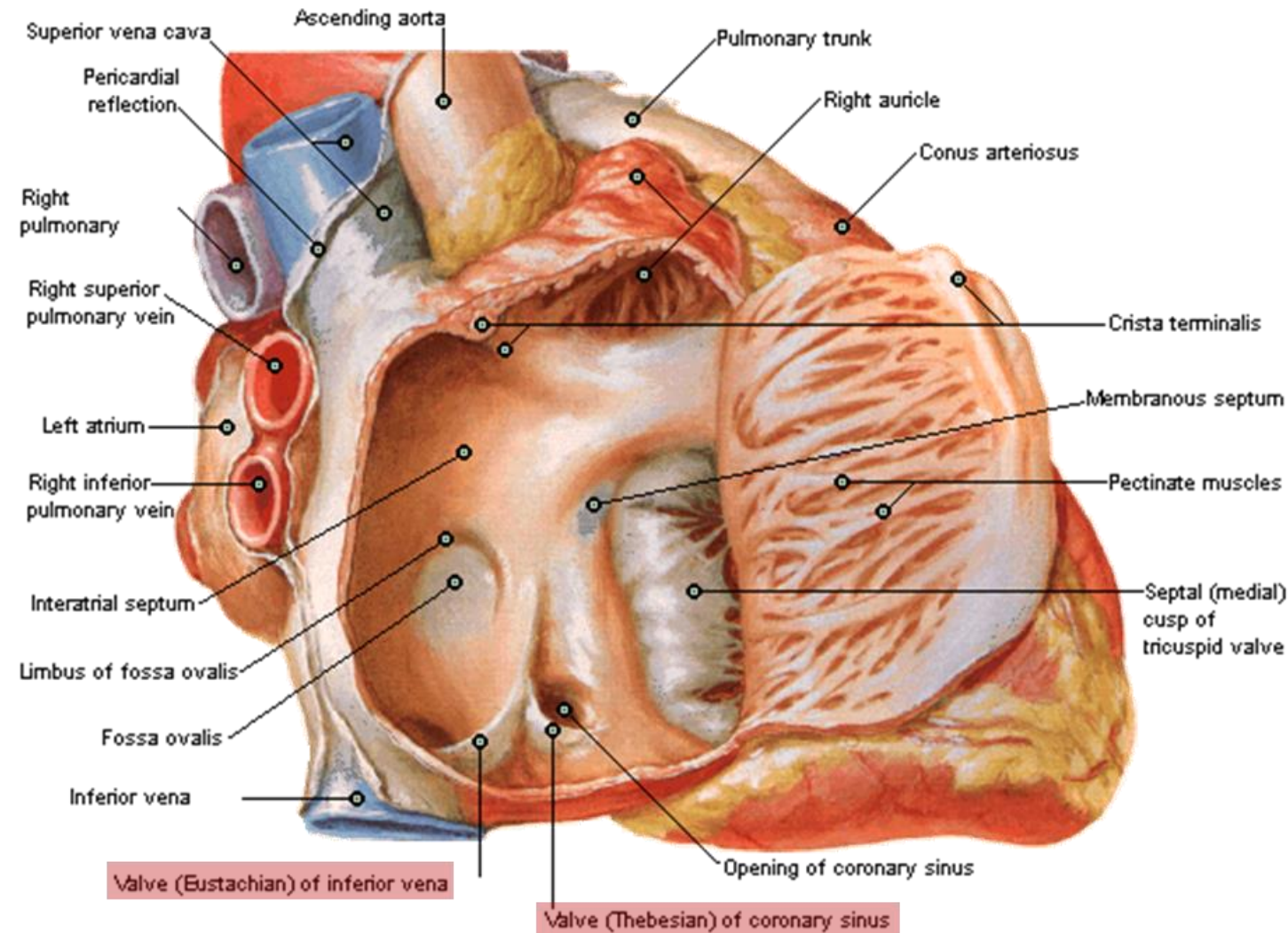
ANATOMY AND PHYSIOLOGY (C.I.)

HUMAN ANATOMY
(Mod. A)

THE CARDIOVASCULAR SYSTEM

HEART: INTERNAL EXAMINATION – The Right Atrium

Opened Right Atrium Right Lateral View



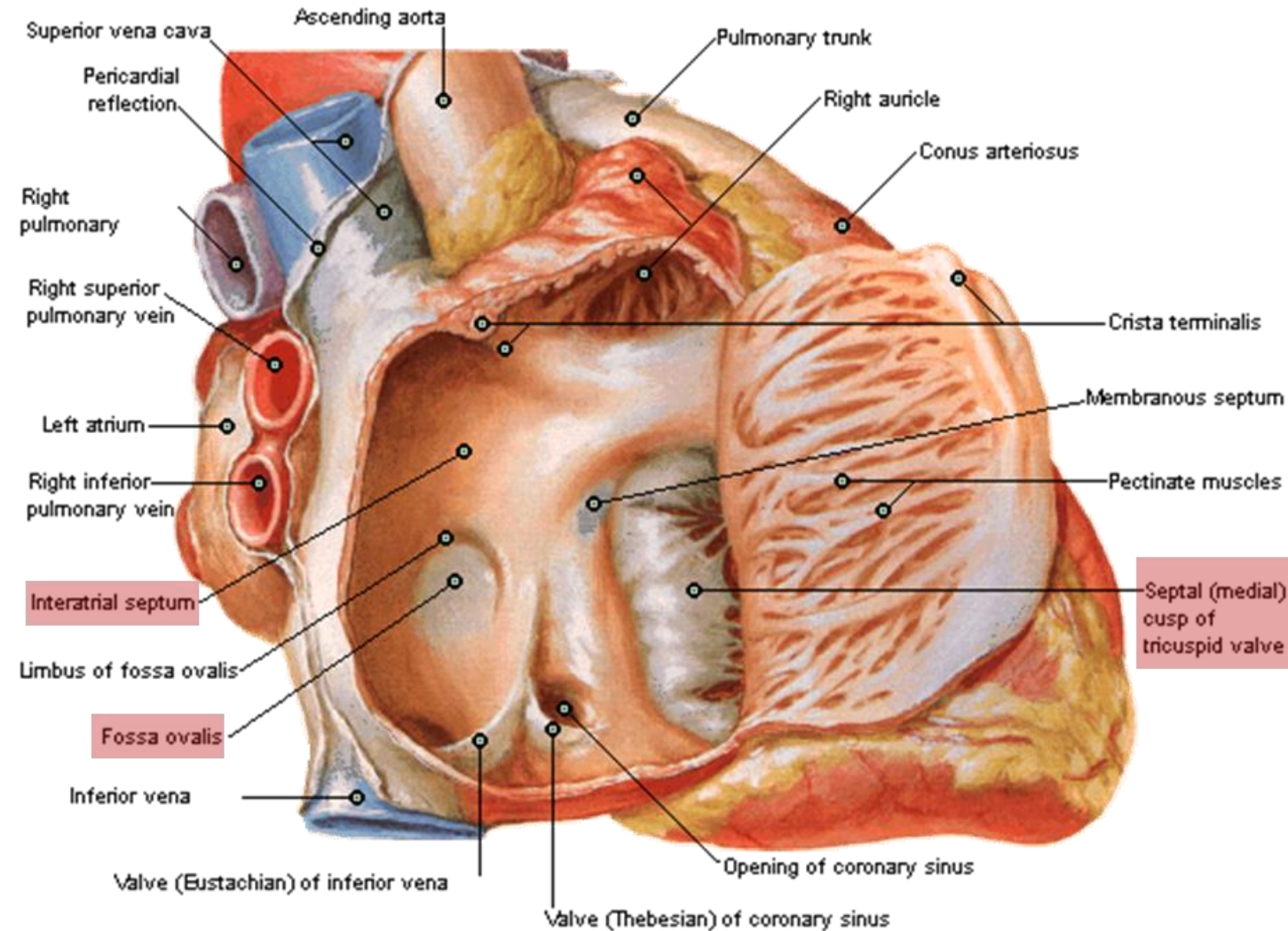
INTERNAL EXAMINATION OF THE HEART - Right atrium -

Access to the right atrium is obtained by cutting on the posterior side of the heart, starting from the inferior vena cava and going up to the superior vena cava

Inside the right atrium it is possible to observe:

1. the **ORIFICES (or foramina) where the VESSELS** (i.e., superior vena cava, inferior vena cava, coronary sinus) **drain into the right atrium**
2. the **EUSTACHIAN VALVE** that lies at the junction of the inferior vena cava and right atrium. It is a rudimentary/not functional valve, formed by an incomplete valve leaflet
3. the **THEBESIAN VALVE**, a semicircular valve leaflet at the orifice of the coronary sinus.

Opened Right Atrium Right Lateral View



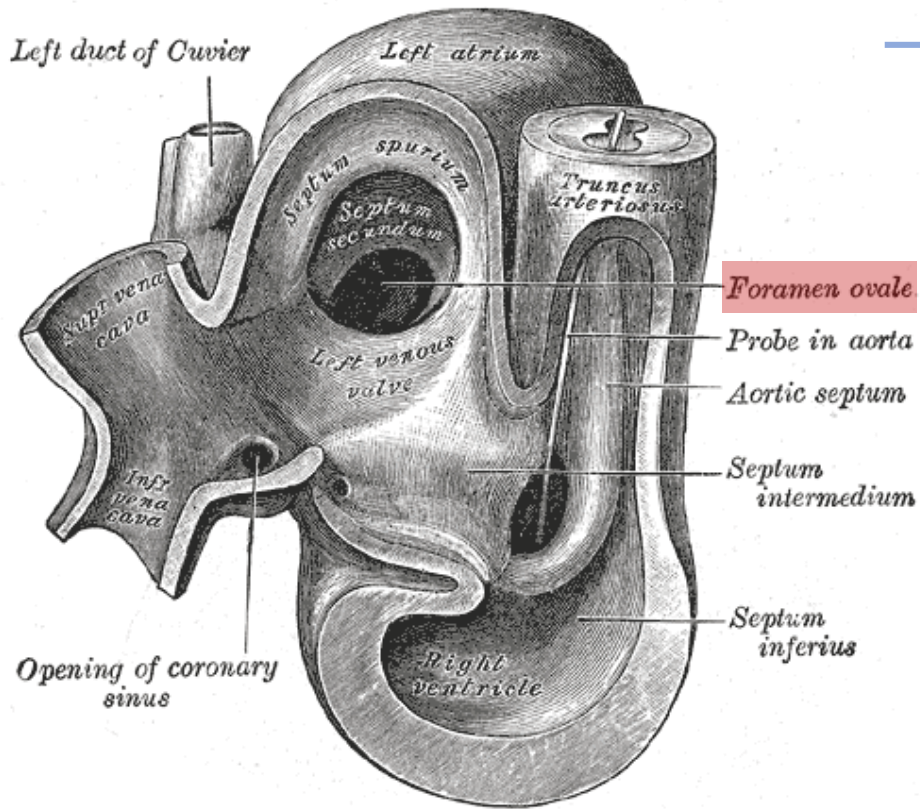
INTERNAL EXAMINATION OF THE HEART - Right atrium -

Inside the right atrium it is possible to observe:

4. The **RIGHT ATRIOVENTRICULAR FORAMEN** with the right atrioventricular valve (*tricuspid valve*)
5. the **INTERATRIAL SEPTUM** which divides the right atrium from the left atrium; it shows a depressed structure which is named **FOSSA OVALIS**

↓
It is a depression representing the remnant of an *interatrial opening* which had a significant role in fetal circulation

↓
the **FORAMEN OVALE**



FORAMEN OVALE

During fetal development, at the level of the interatrial septum, this foramen **allows blood flowing between the right and left atria**

Fetal circulation is different from circulation after birth, just think that the lungs do not work and the blood is oxygenated by the placenta

Actually, the foramen ovale IS NOT A COMPLETE OPENING, otherwise it would hardly close immediately after birth



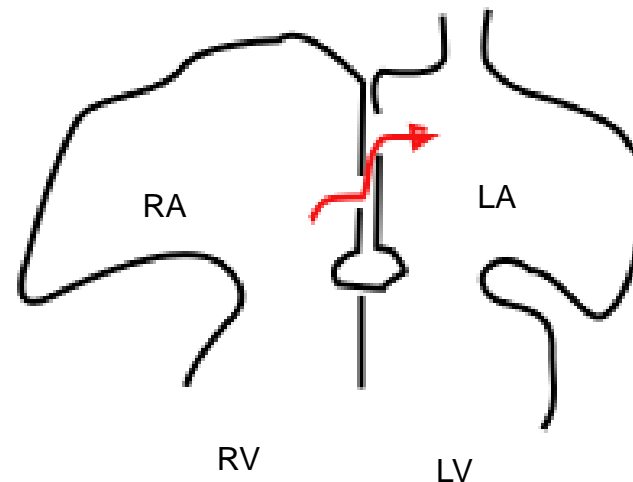
It is made up of 2 membranous septa very close to each other, which have 2 holes/openings which are not aligned

As long as the two septa are separated from each other due to a specific pressure gradient, the blood flows from the right to the left atrium following an "S" path:

enters the first opening - passes between the 2 septa - exits from the second opening

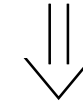
Diagram of the foramen ovale in a fetal heart. The red arrows show how the blood comes from the inferior vena cava.

RA: right atrium; LA: left atrium;
RV and LV: right and left ventricles.



FORAMEN OVALIS

At birth, the umbilical cord is clamped and cut, the placenta is detached, and the baby ventilates his lungs for the first time



The pressure between the right and left atrium changes and the two septa of the foramen join/fuse together

The foramen ovale closes

- At the beginning: functional closure given by the pressure variation
- Over time: fusion of the two sheets with the formation of a complete anatomical septum where the *fossa ovalis* remains visible

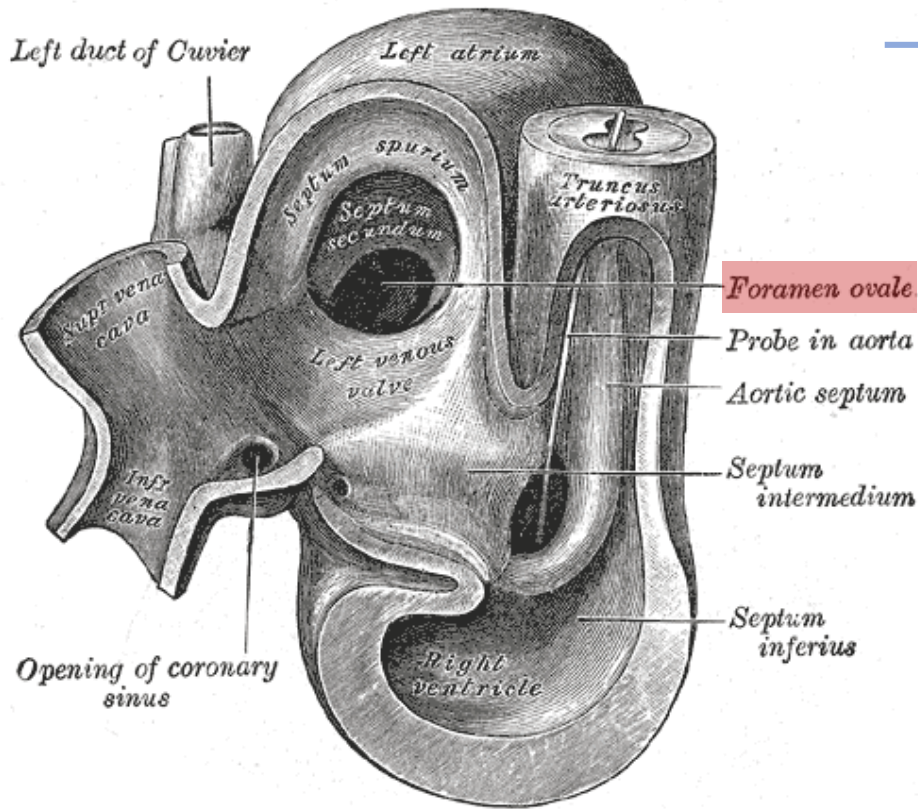
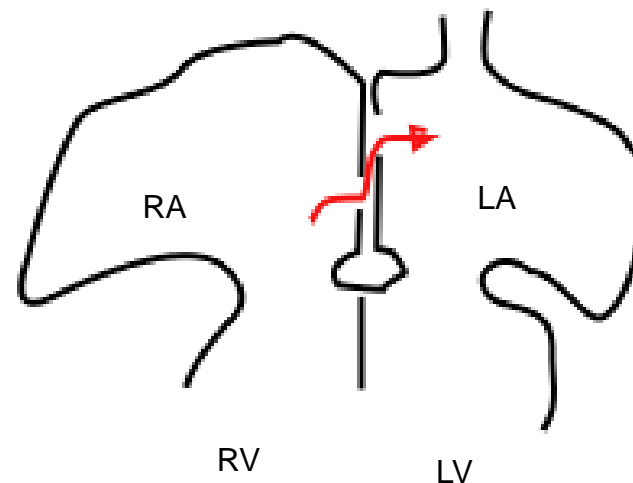
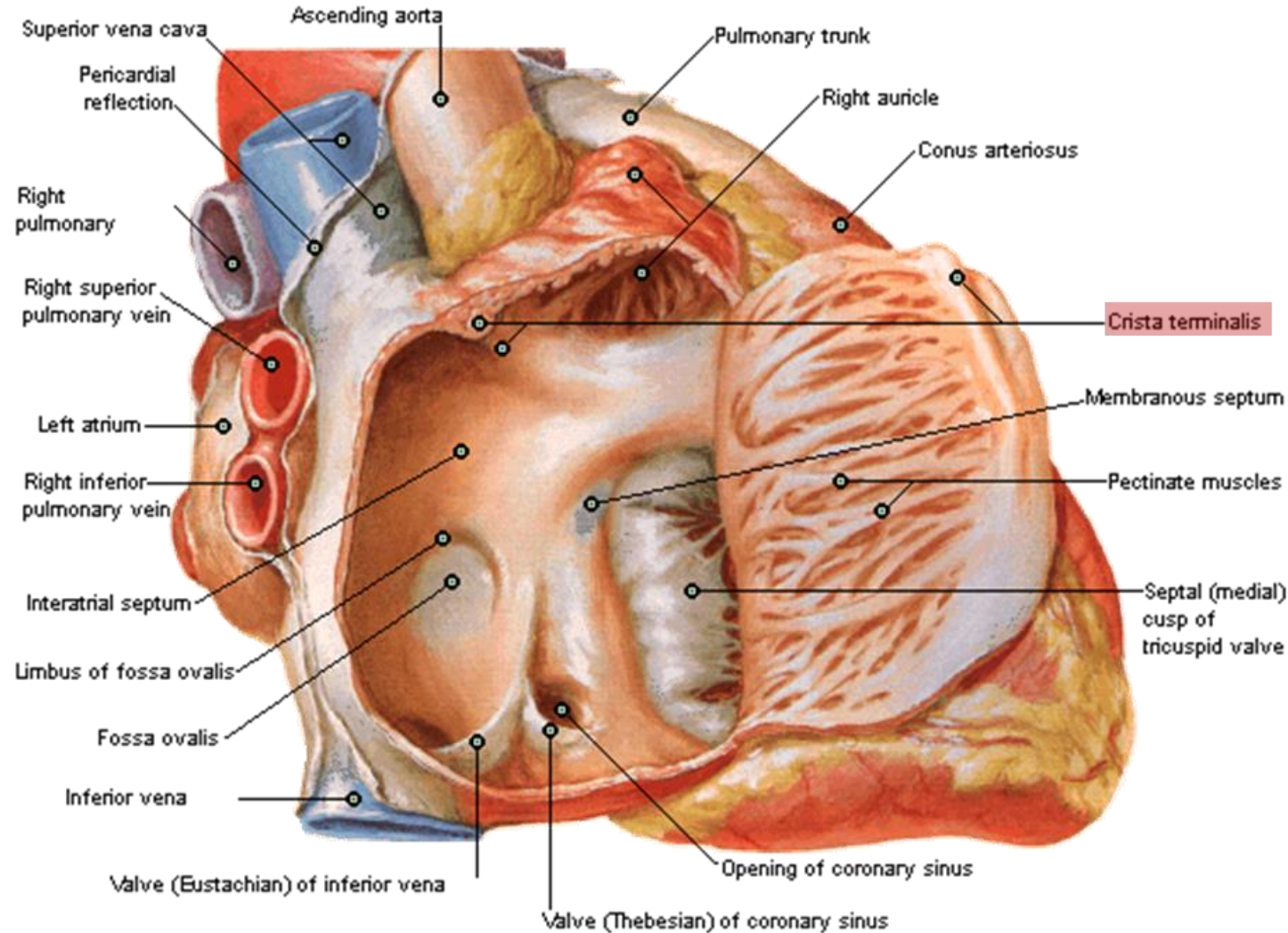


Diagram of the foramen ovale in a fetal heart. The red arrows show how the blood comes from the inferior vena cava.

RA: right atrium; LA: left atrium;
RV and LV: right and left ventricles.



Opened Right Atrium Right Lateral View



INTERNAL EXAMINATION OF THE HEART - Right atrium -

Inside the right atrium it is possible to observe:

- the **ATRIUM PROPER**, with a rough/irregular surface because of the **PECTINATE MUSCLES**
- the **SINUS OF VENAE CAVAE**, with a smooth wall

The separation between the 2 portions is marked by

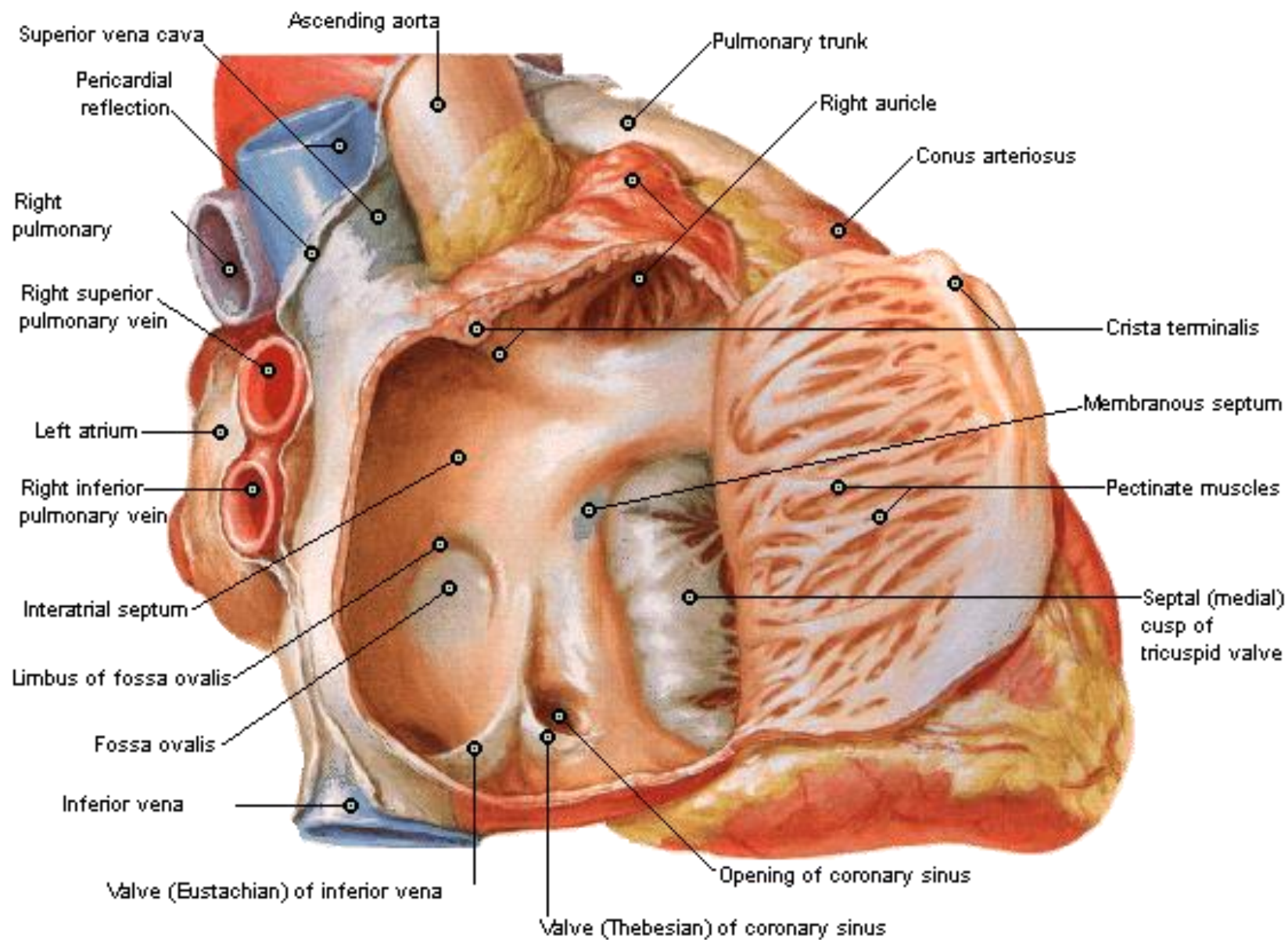
the **TERMINAL CREST** (or *crista terminalis*)



a vertical ridge of the inner surface of the right atrium, extending from the superior vena cava to the inferior vena cava → *it corresponds to the terminal sulcus found on the external surface of the right atrium*

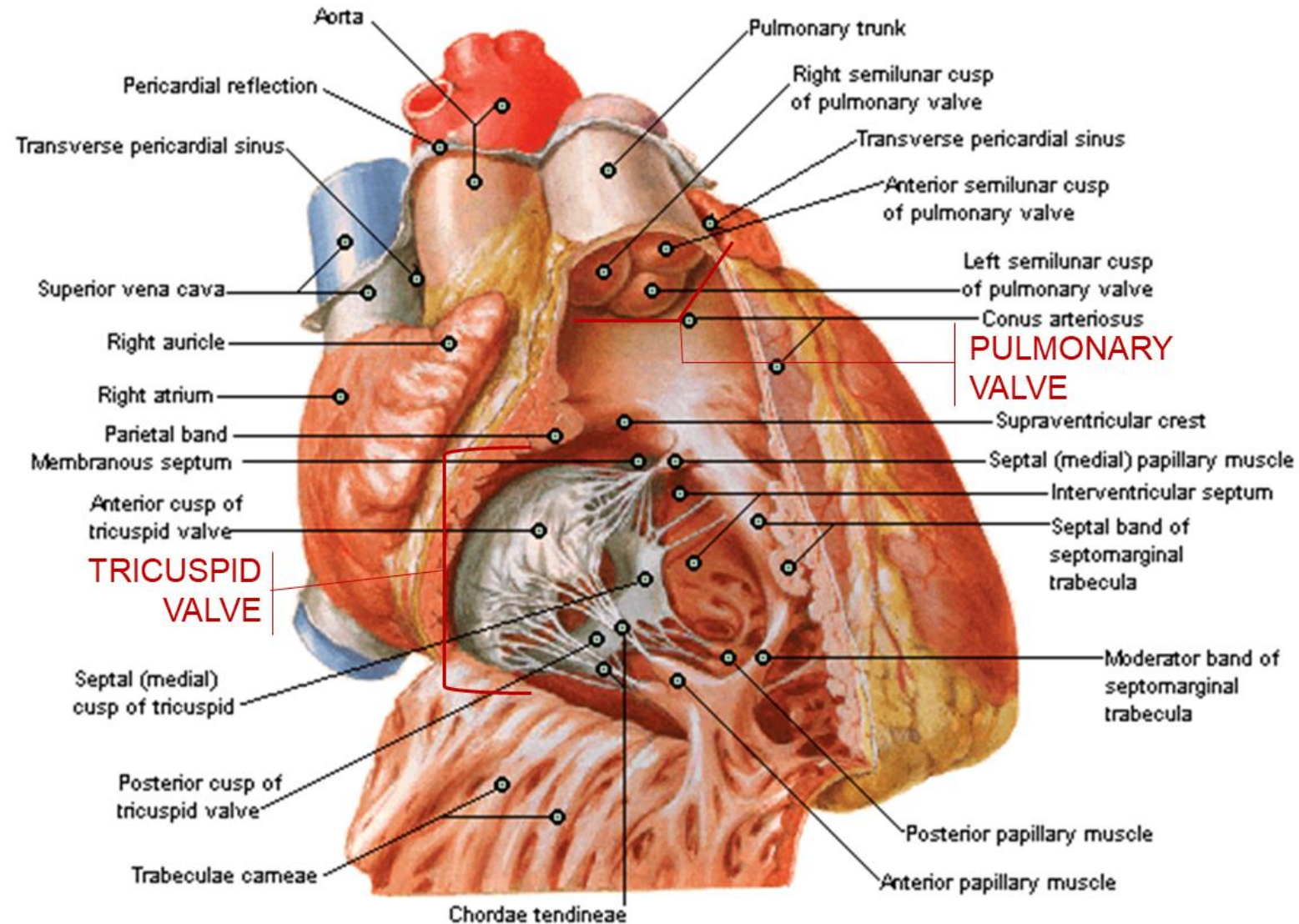
Opened Right Atrium

Right Lateral View



HEART: INTERNAL EXAMINATION – The Right Ventricle

Opened Right Ventricle Anterior View



INTERNAL EXAMINATION OF THE HEART - Right ventricle -

In this image we can observe:

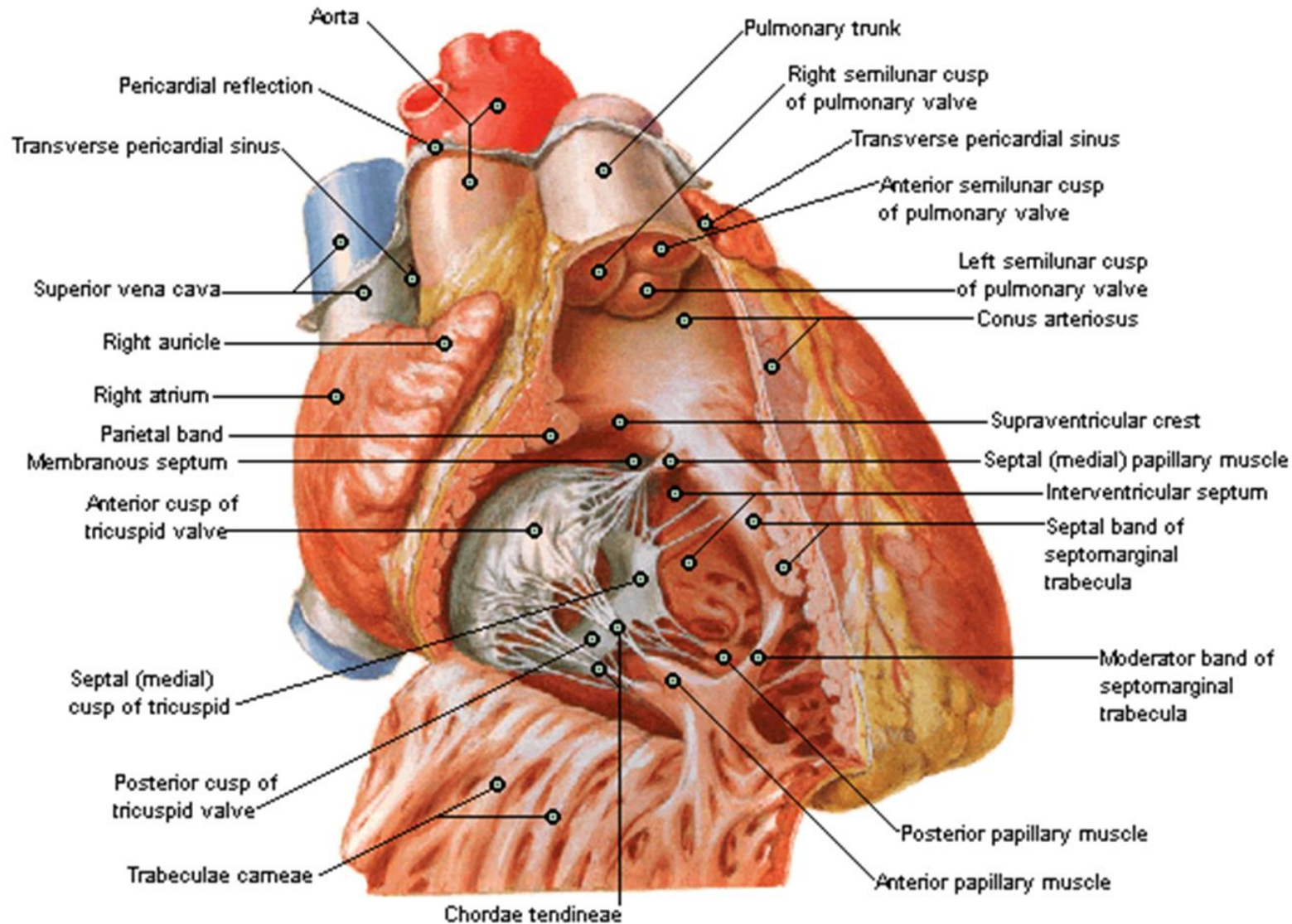
- the right atrium, closed
- the right ventricle, opened

In the image, the sternocostal wall of the heart at the level of the right ventricle has been sectioned.

Two important structures of the right ventricle are identifiable, namely the TWO VALVES:

- 1) TRICUSPID VALVE
- 2) PULMONARY VALVE

Opened Right Ventricle Anterior View



INTERNAL EXAMINATION OF THE HEART - Right ventricle -

1) TRICUSPID VALVE:

valve of the right atrioventricular foramen → it is located between the right atrium and the right ventricle

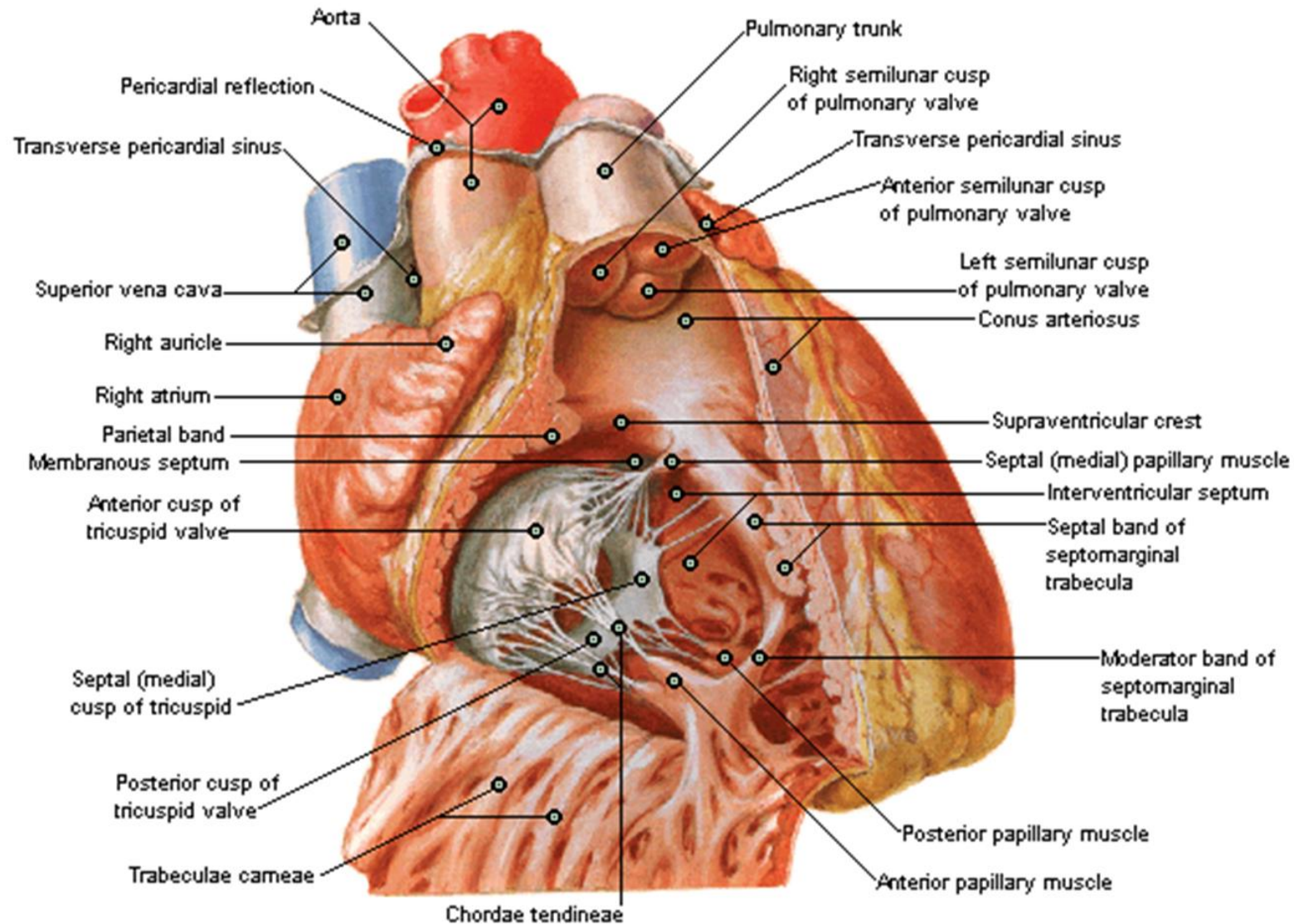
The portion of the right ventricle that follows the right atrioventricular ostium is the

↓ INFLOW TRACT OF THE RIGHT VENTRICLE

(it is the part of the right ventricle where the blood enters from the right atrium through the tricuspid valve)

Opened Right Ventricle

Anterior View



INTERNAL EXAMINATION OF THE HEART - Right ventricle -

2) PULMONARY VALVE:

it is located at the origin of the pulmonary trunk (which will then divide into right and left pulmonary arteries)

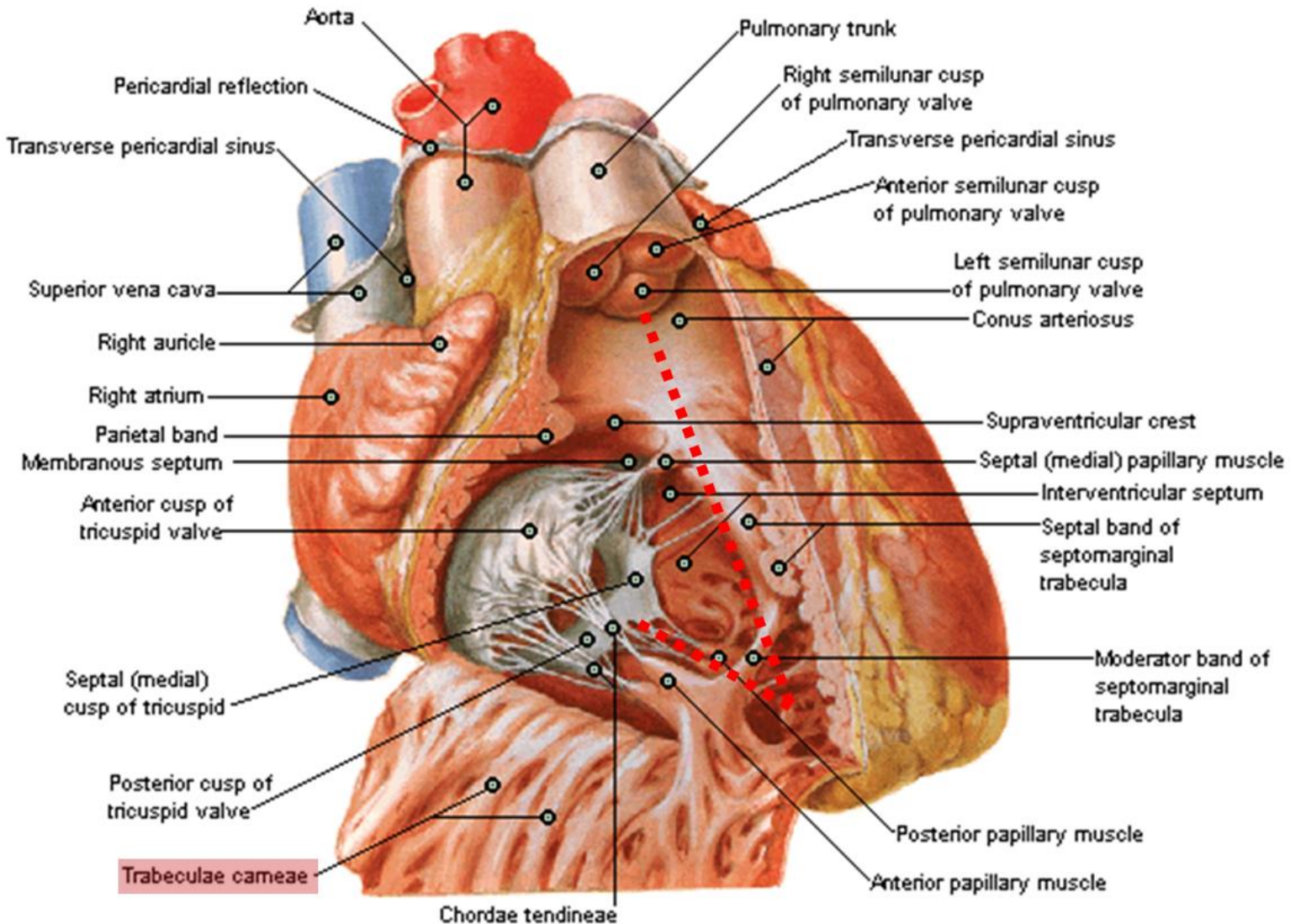
It is located at the exit part of the right ventricle, i.e. the part of the right ventricle that is called



OUTFLOW TRACT OF THE RIGHT VENTRICLE

(it's the part where the blood flows out the heart to enter the pulmonary circulation)

Opened Right Ventricle Anterior View



INTERNAL EXAMINATION OF THE HEART - Right ventricle -

In the right ventricle we can identify:

- an **INFLOW TRACT**, which immediately follows the right atrioventricular foramen and tricuspid valve
- an **OUTFLOW TRACT**, which leads to the pulmonary valve and the origin of the pulmonary trunk

The **INFLOW** and **OUTFLOW TRACTS** are positioned to form a «V» with:

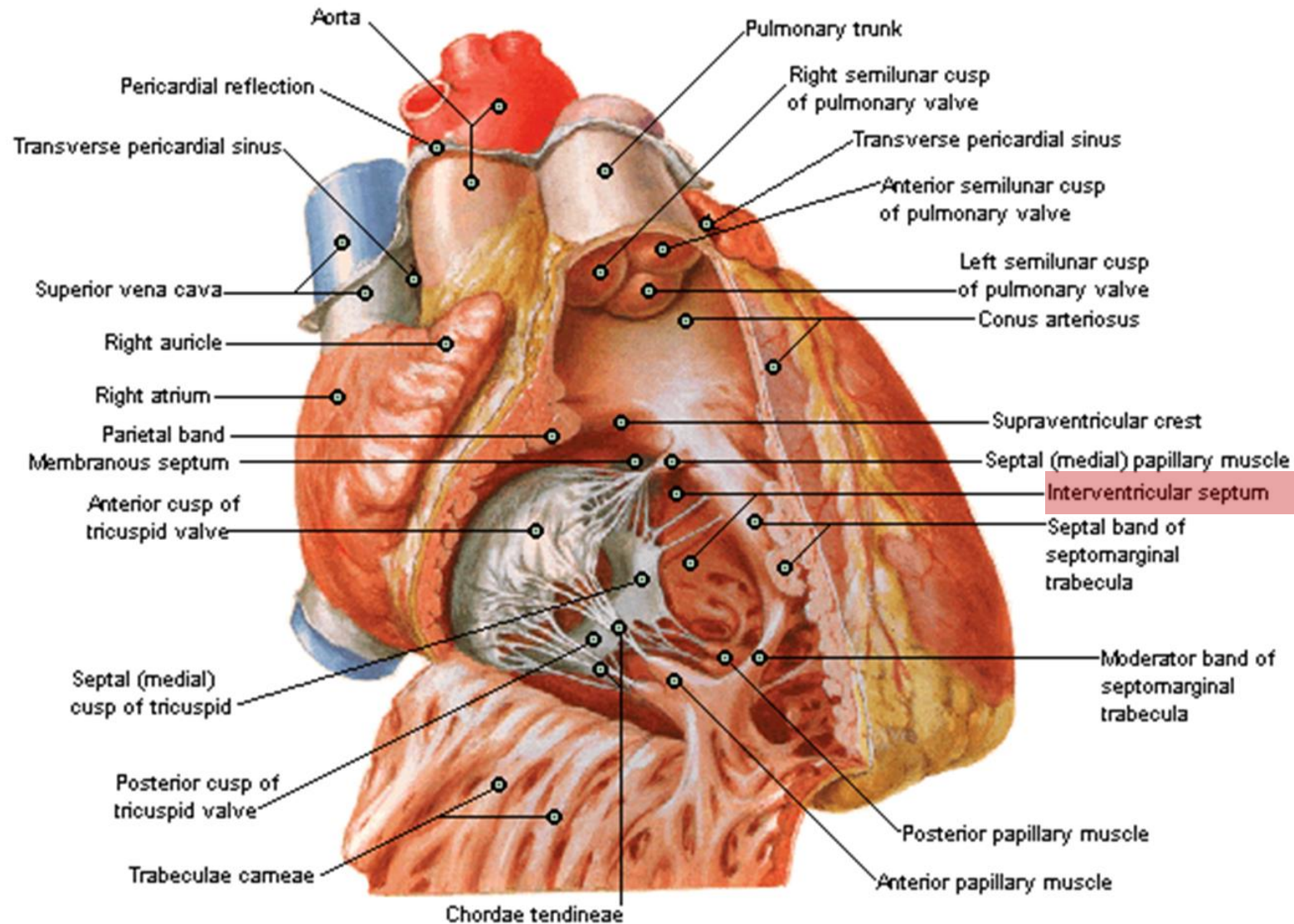
- the inflow tract directed towards the apex of the heart;
- the outflow tract facing the base of the heart

The inflow tract shows an irregular internal side due to the presence of muscular ridges (myocardium) → **TRABECULAE CARNEAE**

The outflow part has a smooth internal side

Opened Right Ventricle

Anterior View



INTERNAL EXAMINATION OF THE HEART - Right ventricle -

Inside the right ventricle it is possible to identify the **INTERVENTRICULAR SEPTUM**



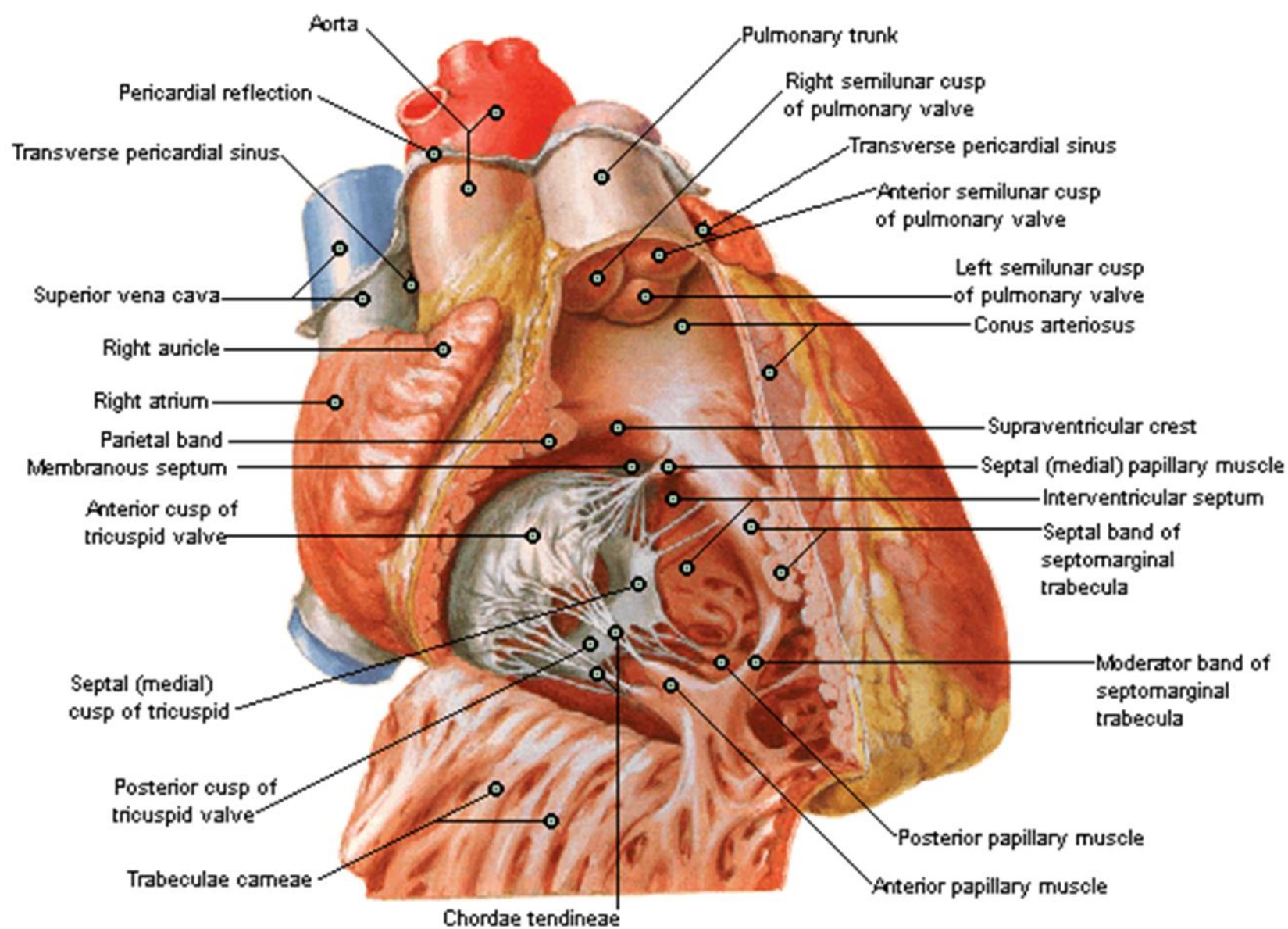
it is the muscular wall separating the right and left ventricles



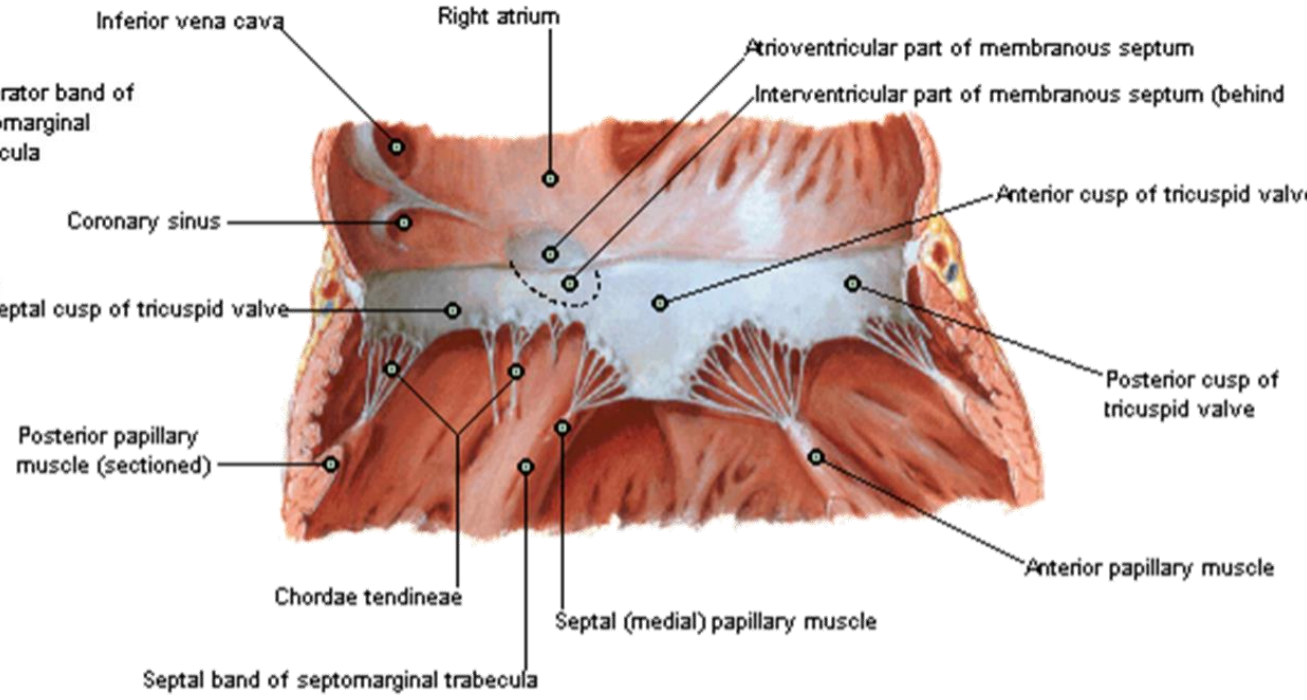
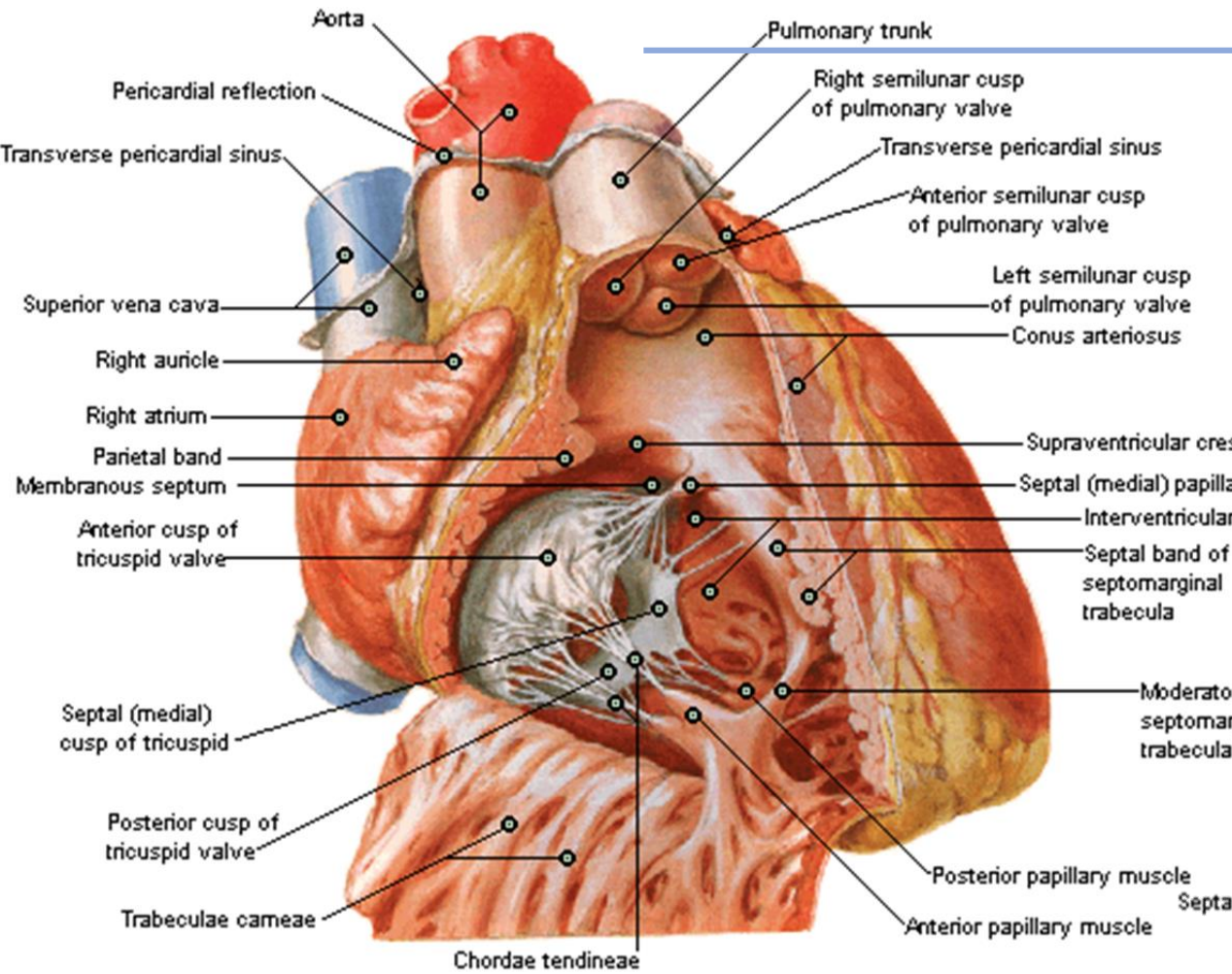
It defines a **COMPLETE** division between the two ventricles

Opened Right Ventricle

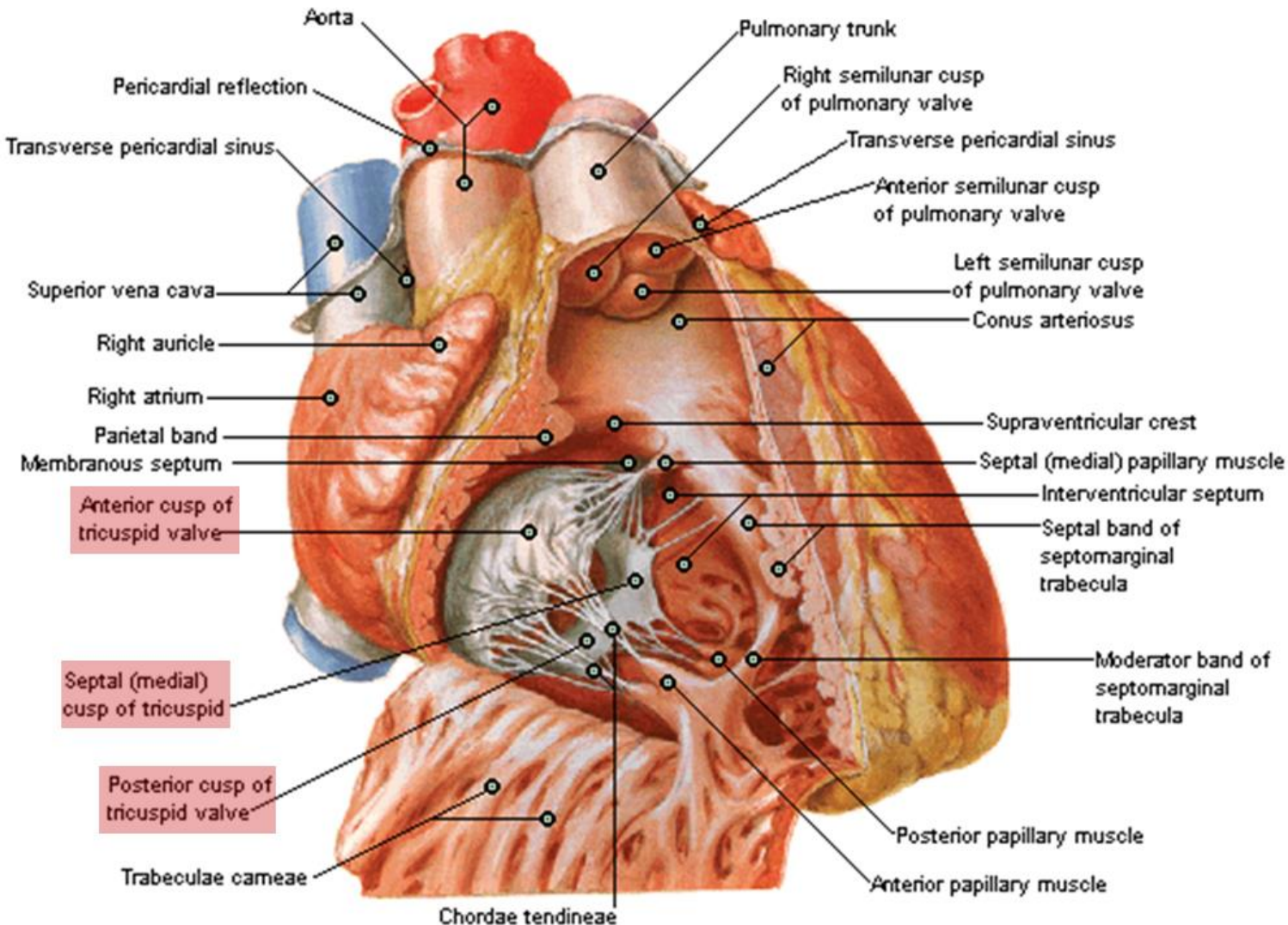
Anterior View



TRICUSPID VALVE



Opened Right Ventricle Anterior View



TRICUSPID VALVE

It is a CIRCUMFERENTIAL connective structure, made up of dense fibro-connective tissue

It is described as a FIBROUS RING that delimits the perimeter of the atrioventricular orifice

3 CUSPS are inserted into this fibrous ring:

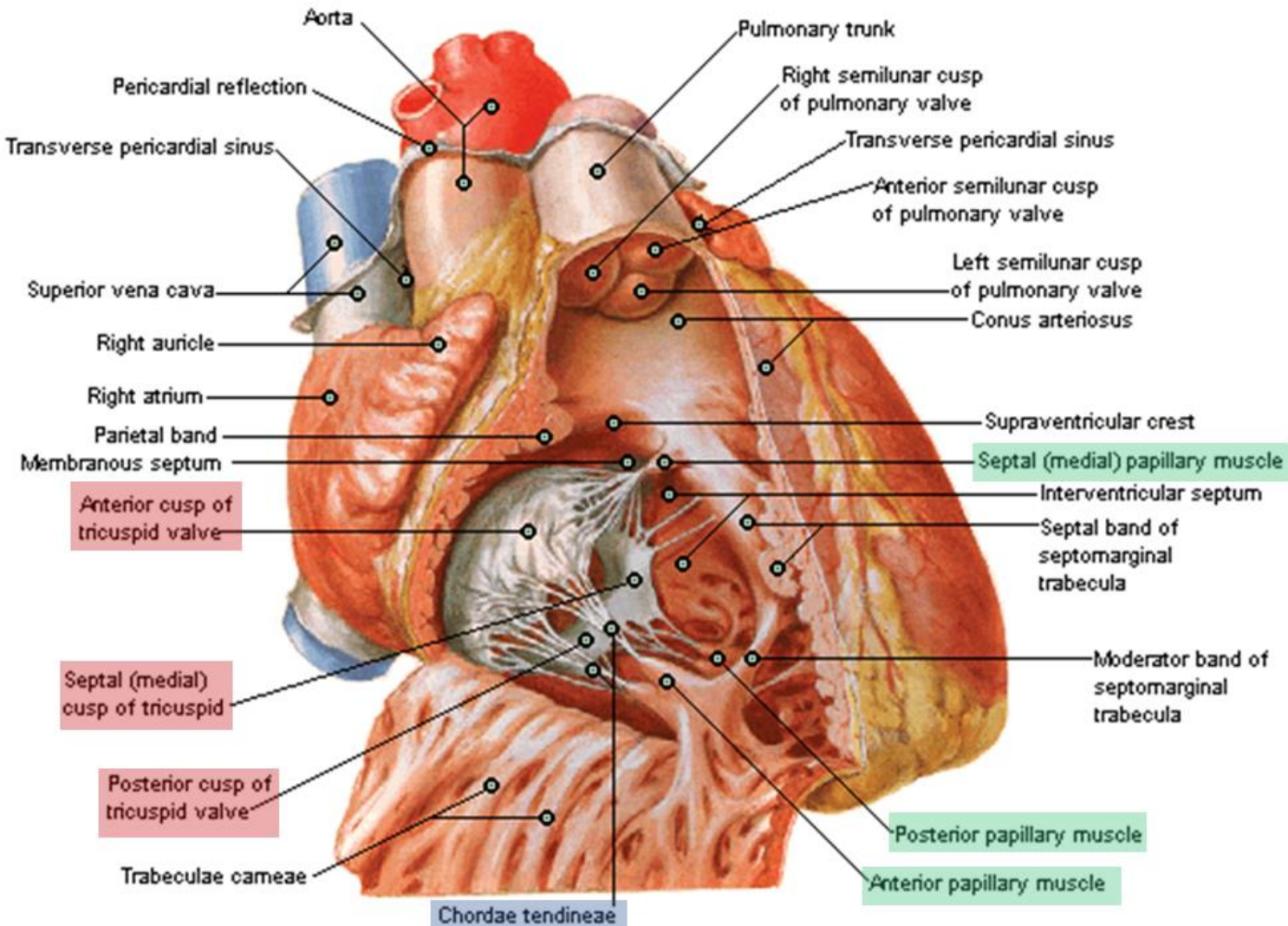
- ANTERIOR CUSP
- POSTERIOR CUSP
- SEPTAL (or MEDIAL) CUSP

CUSPS = flaps of dense connective tissue that **have the ability to move under the action of hemodynamic and muscular forces**

The cusps:

- by moving closer to each other they close the valve = they prevent the reflux of blood from the right ventricle to the right atrium
- by distancing themselves from each other, they cause the valve to open = they allow the passage of blood from the right atrium to the right ventricle

Opened Right Ventricle Anterior View



TRICUSPID VALVE

In the free margin of the cusps, fibrous cords are inserted, which are called **TENDINOUS CORDS (CHORDAE TENDINEAE)**

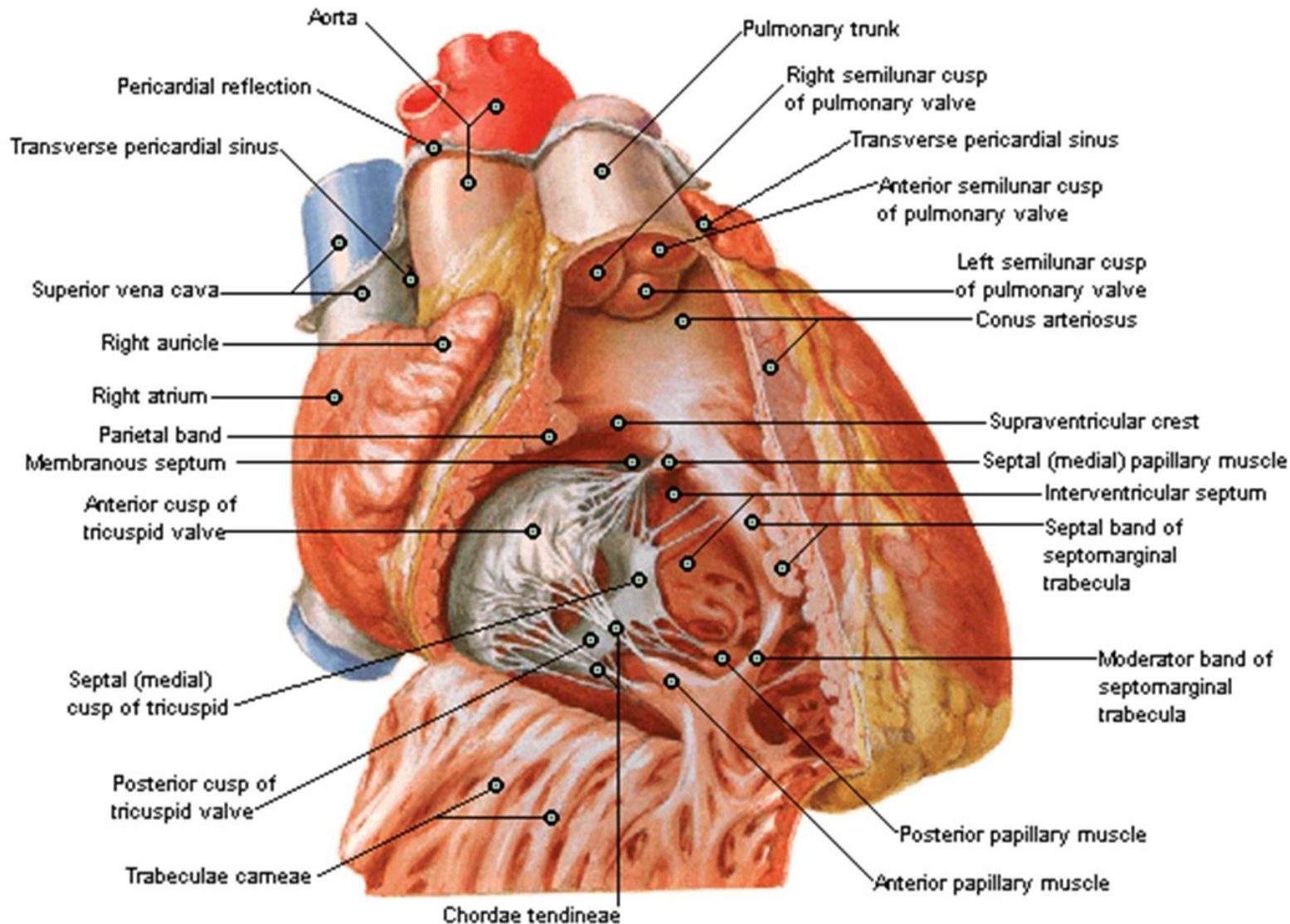
The tendinous cords insert on:

a) the **FREE MARGIN/EDGE OF THE VALVE CUSPS** extending even beyond it and inserting on the ventricular side of the cusps (i.e. the side facing the ventricle)
On the other hand, the atrial side of the cusp is smooth.

b) **PAPILLARY MUSCLES (n=3, like the cusps)** they are digit-shaped muscular projections (= myocardium) that arise from the internal side of the right ventricle and direct towards the cusps. They are:

- the anterior papillary muscle
- the posterior papillary muscle
- the medial (or septal) papillary muscle

Opened Right Ventricle Anterior View



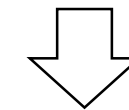
*How the cusps connect
with the related papillary muscles?*

RATIO 1:2

Each valve cusp is connected by the tendinous cords to 2 papillary muscles

And viceversa...

Each papillary muscle is connected by the tendinous cords to 2 valve cusps

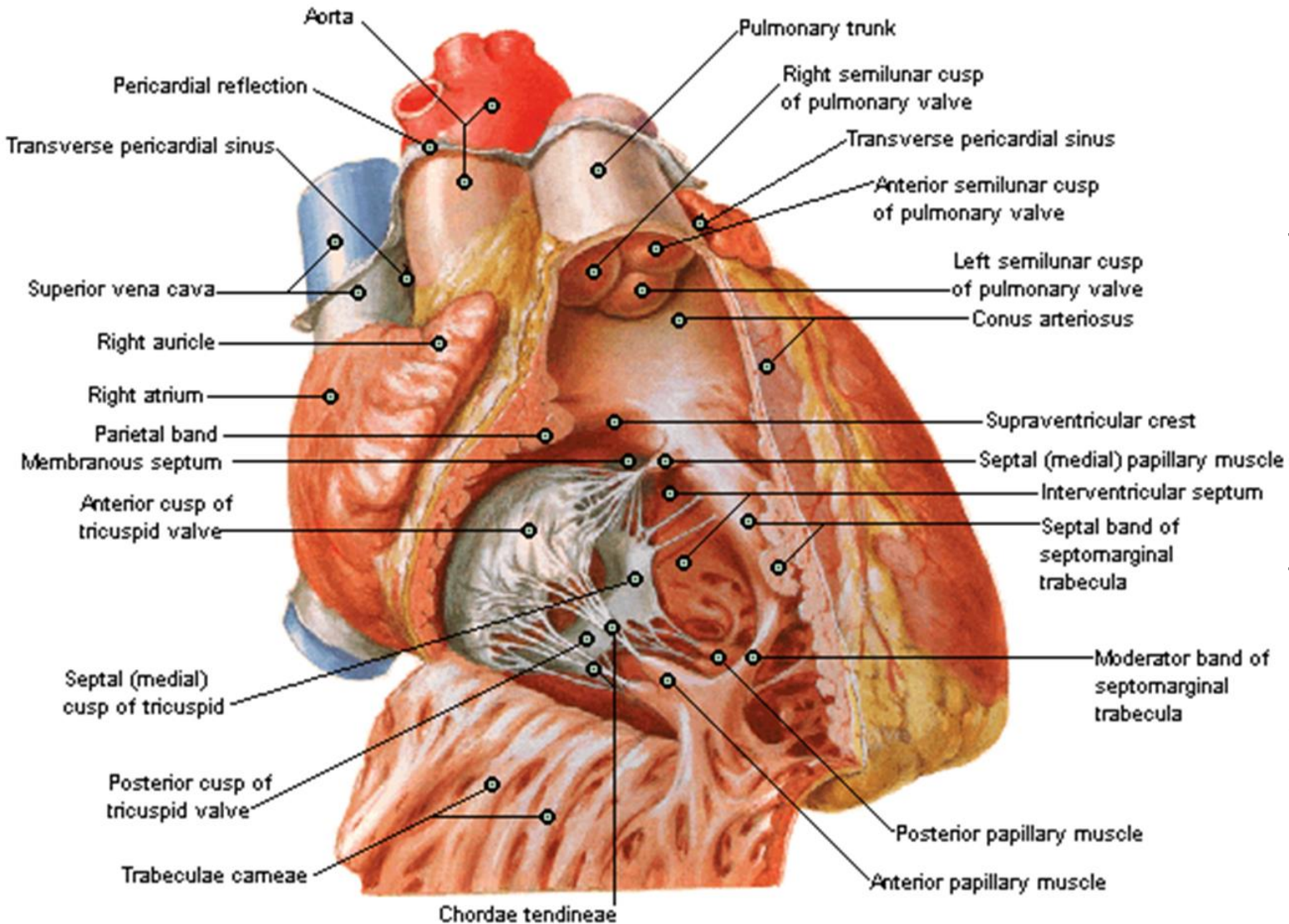


CUSPS
+ **TENDINOUS CORDS**
+ **PAPILLARY MUSCLES**



ATRIOVENTRICULAR VALVE COMPLEX

Opened Right Ventricle Anterior View



*How the cusps connect
with the related papillary muscles?*

RATIO 1:2

Example:

The **ANTERIOR CUSP**:

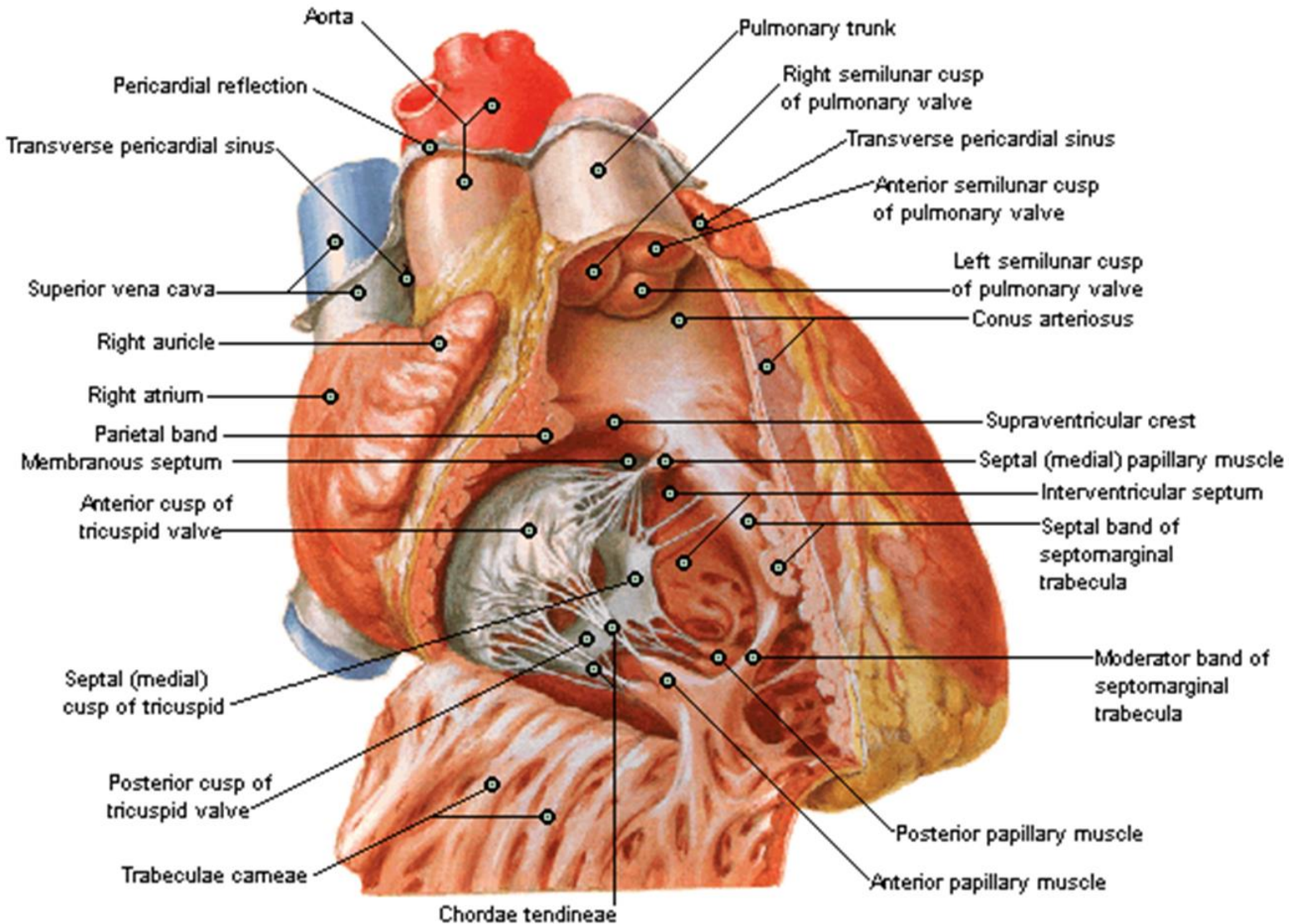
- is connected by tendinous cords to the anterior papillary muscle
- is connected by tendinous cords to the medial (or septal) papillary muscle

Moreover...

The **MEDIAL PAPILLARY MUSCLE**:

- is connected by tendinous cords to the anterior cusp
- is connected by tendinous cords to the septal or medial cusp

Opened Right Ventricle Anterior View



*How the cusps connect
with the related papillary muscles?*

RATIO 1:2

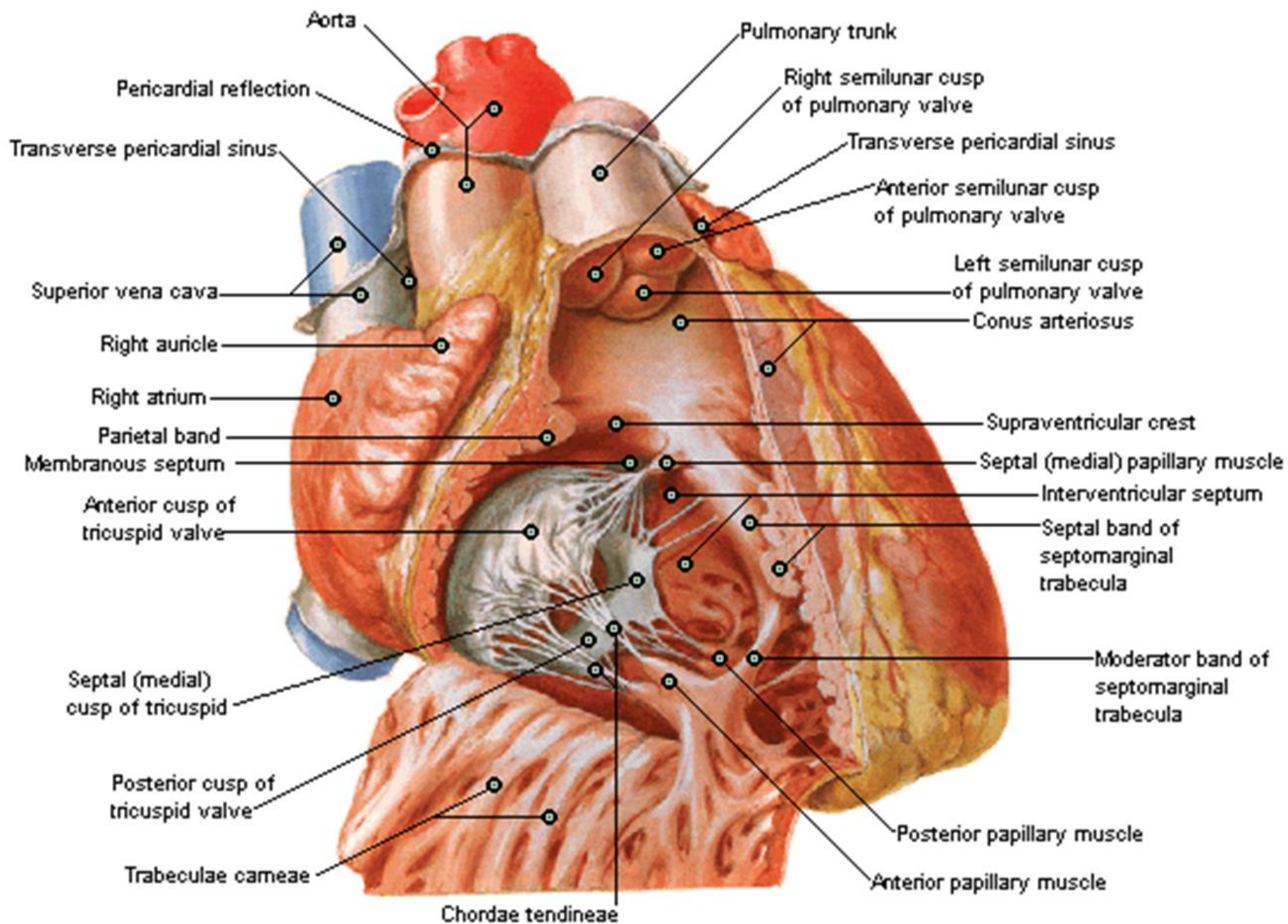


This guarantees that, when a problem with a papillary muscle or a group of tendinous cords occurs, there is no total loss of functionality of a valve cusp

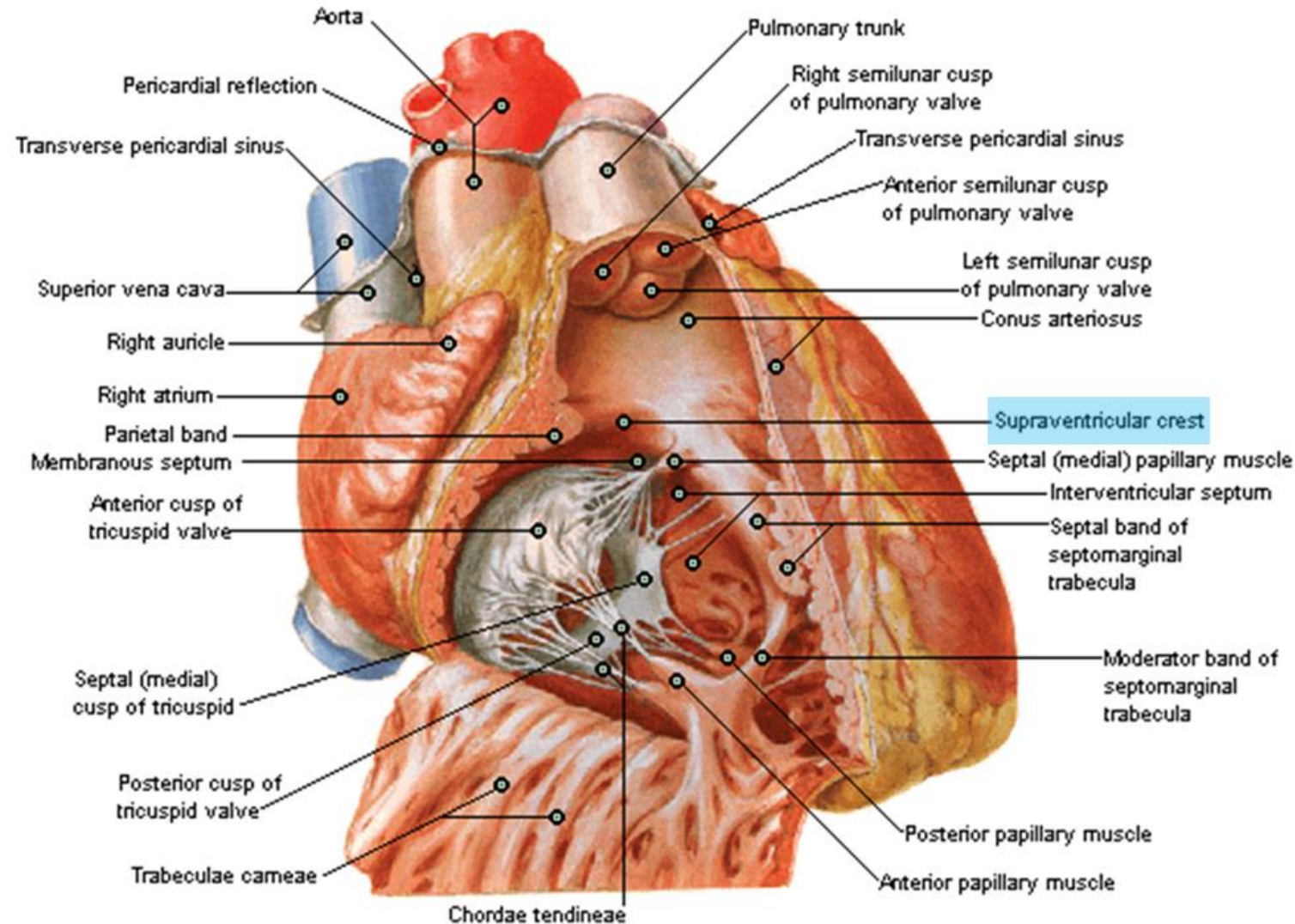
For example, in case of RUPTURE OF THE ANTERIOR PAPILLARY MUSCLE:

- two cusps will work at 50% efficacy
- there will be no completely inefficient cusps

It is preferable to have two cusps working at 50% than one cusp which does not work at all



Opened Right Ventricle Anterior View



DESCRIPTION of the PASSAGE FROM THE INFLOW TRACT TO THE OUTFLOW TRACT

↓
Several structures contribute to separate the two tracts

SUPRAVENTRICULAR CREST

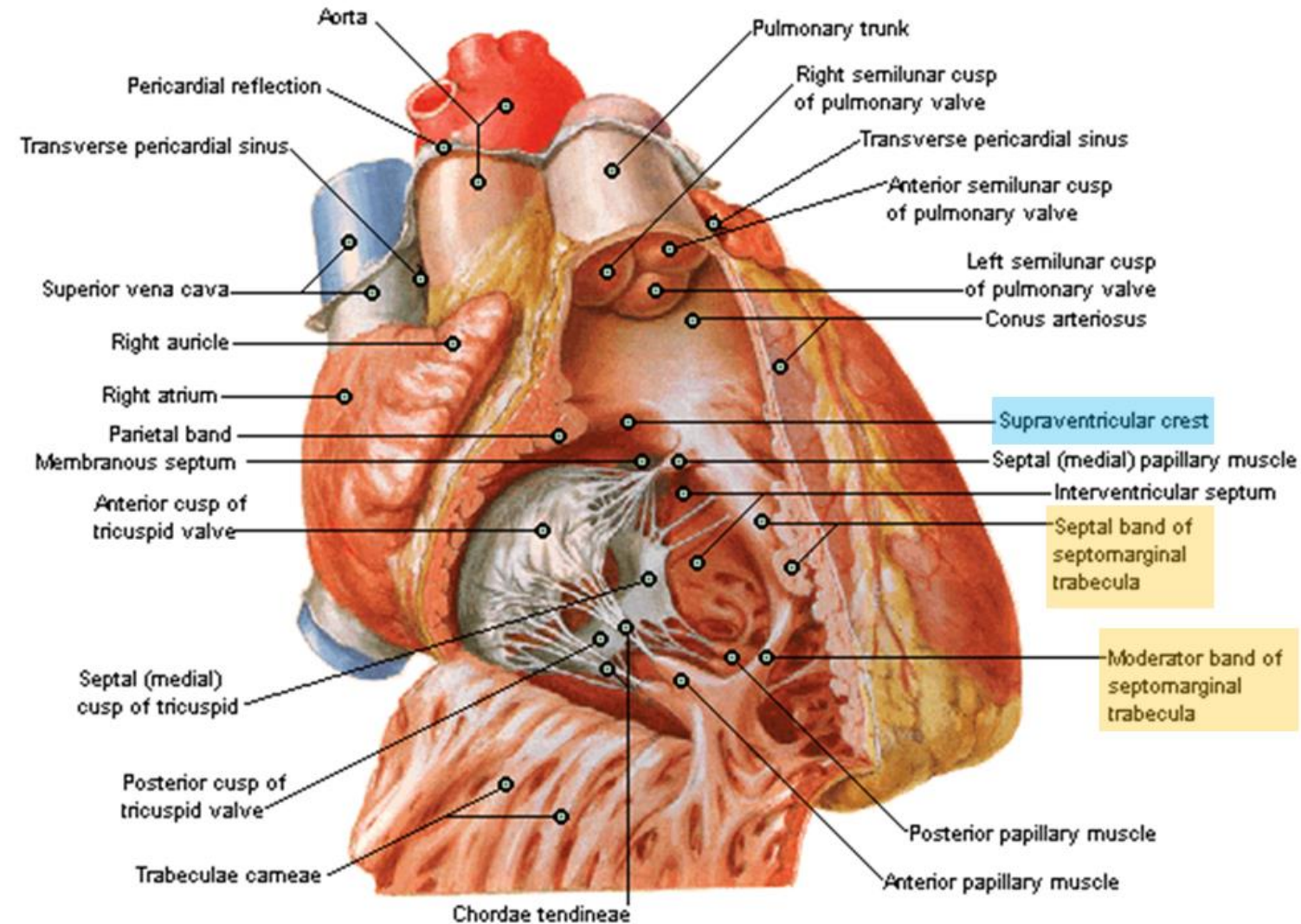
Muscular structure or muscular ridge (myocardium) that separates the right atrioventricular valve and the pulmonary valve

(this anatomical situation is not found in the left ventricle)

IT'S TO ENSURE VALVE SAFETY!

↓
By KEEPING the 2 valves of the right ventricle apart, the supraventricular crest reduces the risk of transmission of infections from one valve to the other
(this risk is instead greater into the left ventricle)

Opened Right Ventricle Anterior View



SUPRA-VENTRICULAR CREST

It is continuous with another muscular ridge, called

SEPTOMARGINAL TRABECULA

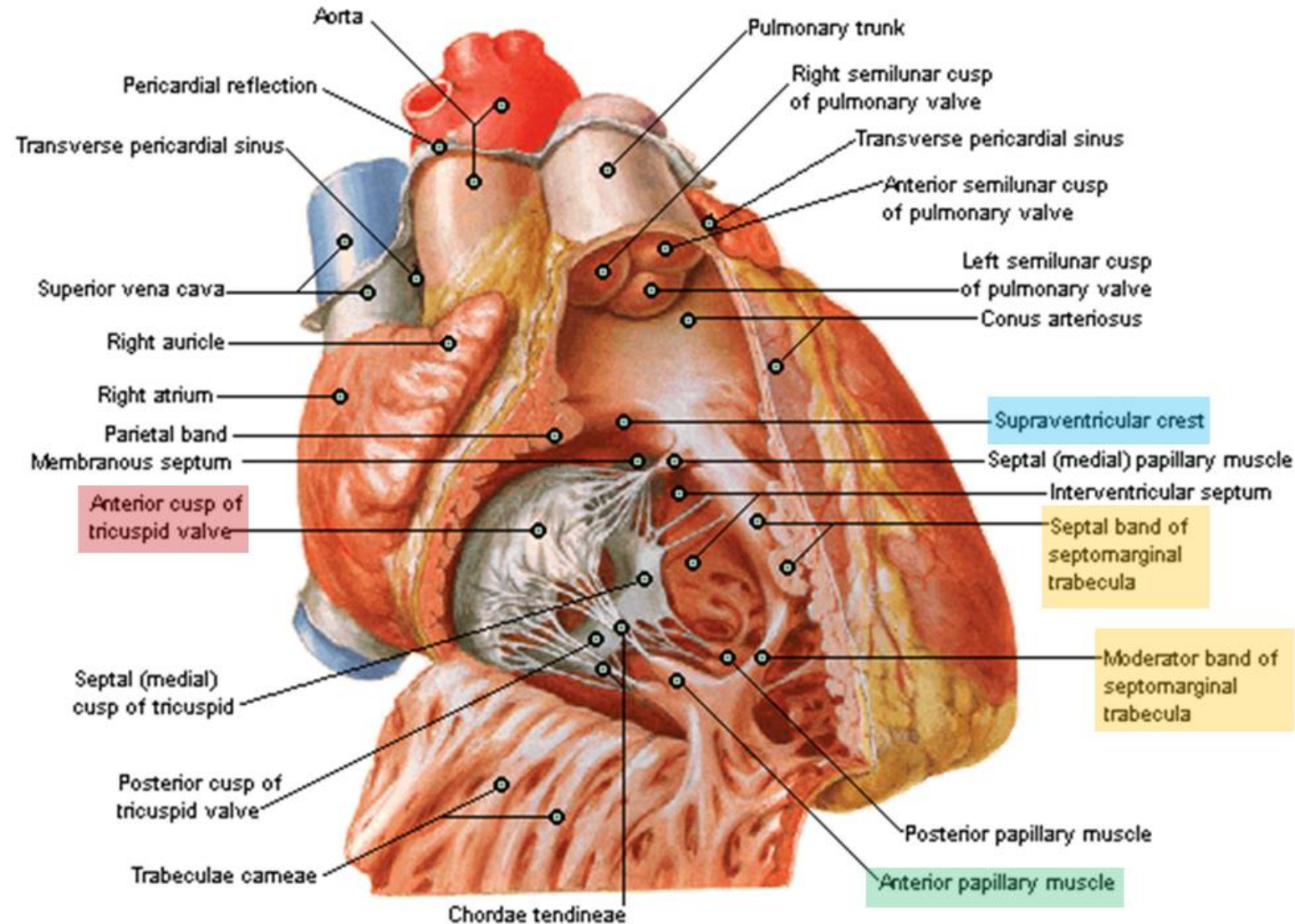
It is made up of 2 components:

a) **SEPTAL BAND**, a ridge on the right side of the interventricular septum

The septal band continues with:

b) **MODERATOR BAND**, a muscular bridge that from the interventricular septum goes to the base of the anterior papillary muscle and is also called «Leonardo da Vinci Moderator band»

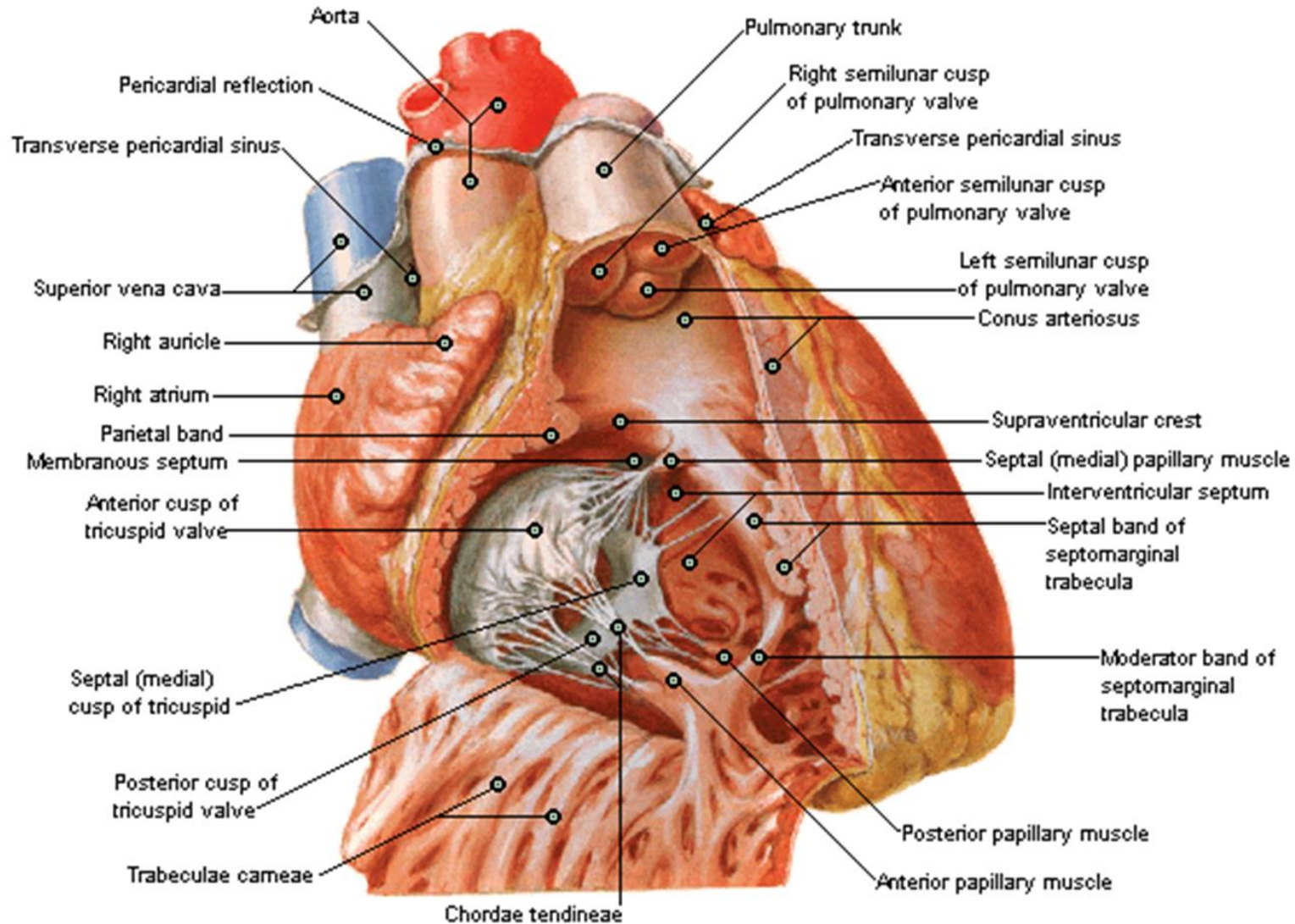
Opened Right Ventricle Anterior View



The separation between the inflow and the outflow tracts is given by the following structures:

1. SUPRAVENTRICULAR CREST
2. SEPTOMARGINAL TRABECULA (septal band + moderator band)
3. ANTERIOR PAPILLARY MUSCLE
4. ANTERIOR CUSP of the right atrioventricular valve

Opened Right Ventricle Anterior View



PULMONARY VALVE

In the image you can see the pulmonary valve from the ventricular side.

The PULMONARY VALVE is made up of
THREE SEMILUNAR CUSPS
→ RIGHT SEMILUNAR VALVE

Since the **tricuspid valve is open**, and the **pulmonary valve is closed**, the image represents a situation of
VENTRICLE DIASTOLE

↓
the blood is entering from the right atrium (which is in atrial systole), therefore the ventricle is in diastole

When the ventricle systole occurs, the atrioventricular valve will close and the pulmonary valve will open.

PULMONARY VALVE

It is made up of **THREE SEMILUNAR CUSPS** with the concavity facing towards the pulmonary trunk
right cusp – anterior cusp – left cusp

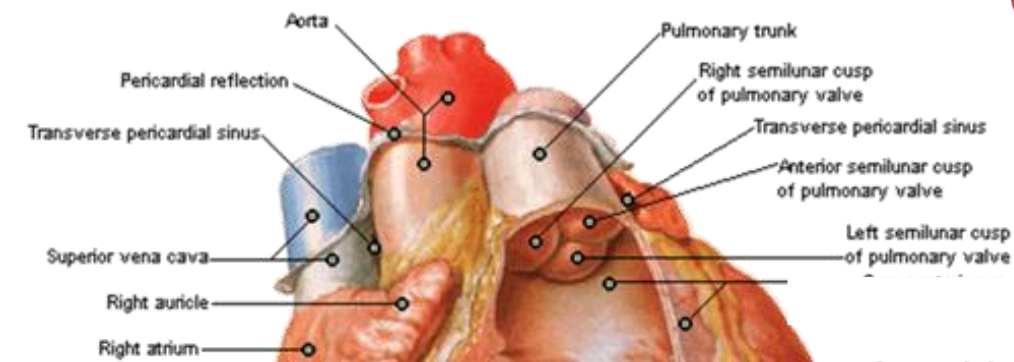
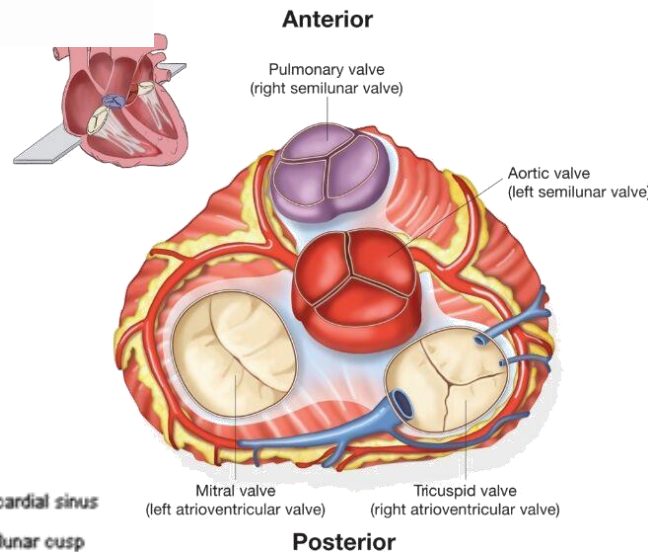
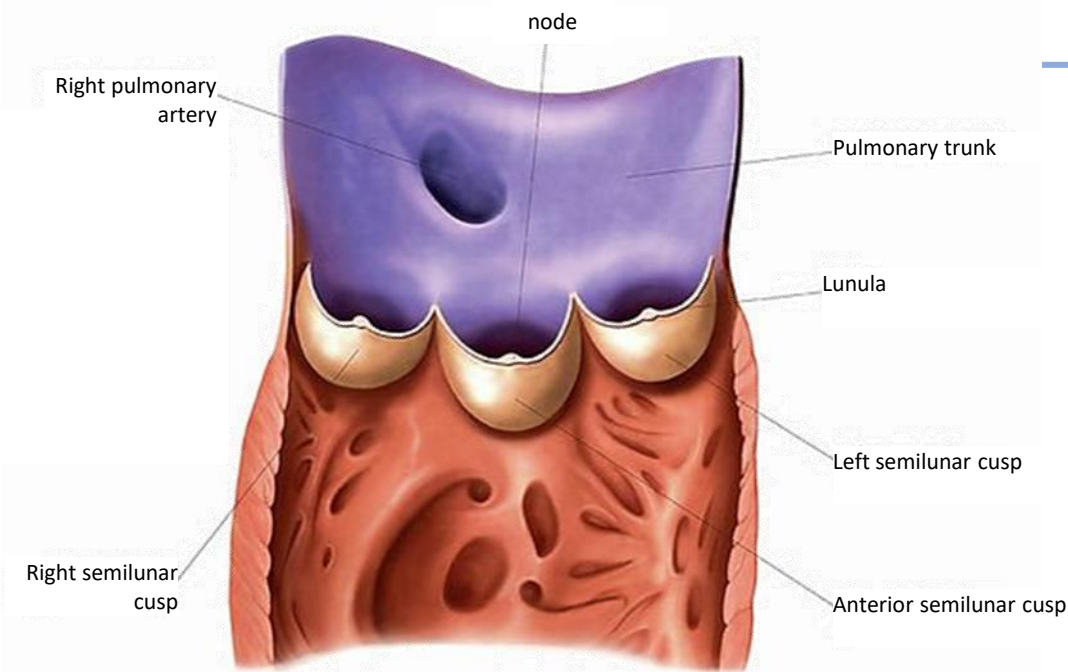
Each cusp has its **free edges**
(Tendinous cords and papillary muscles are NOT present)

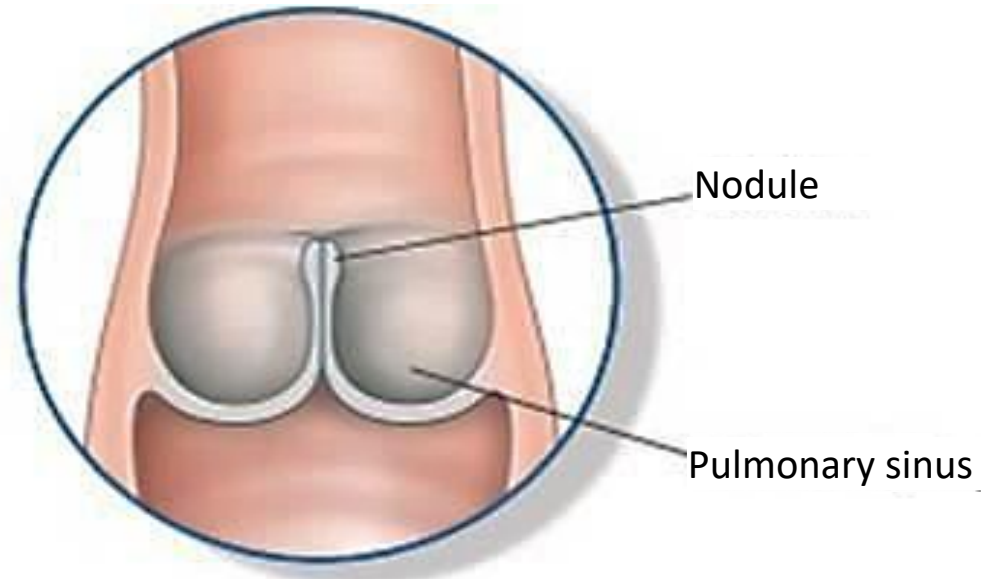
When the valve closes, the three free edges get close to each other and close the lumen of the origin of the artery

THE CENTER OF THE ARTERY LUMEN IS THE MOST DIFFICULT POINT TO CLOSE

↓
this is why at the midpoint of the free edges there are **FIBROUS CONNECTIVE NODULES** or **NODES** which allow the closure of the lumen in its central portion

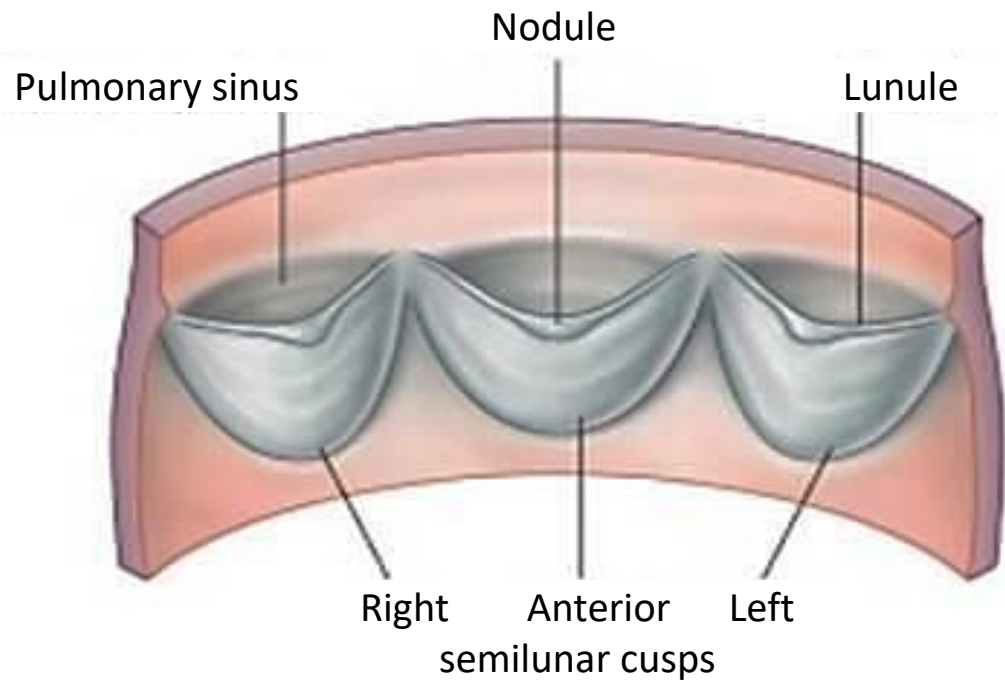
↓
MORGAGNI NODULES





PULMONARY VALVE

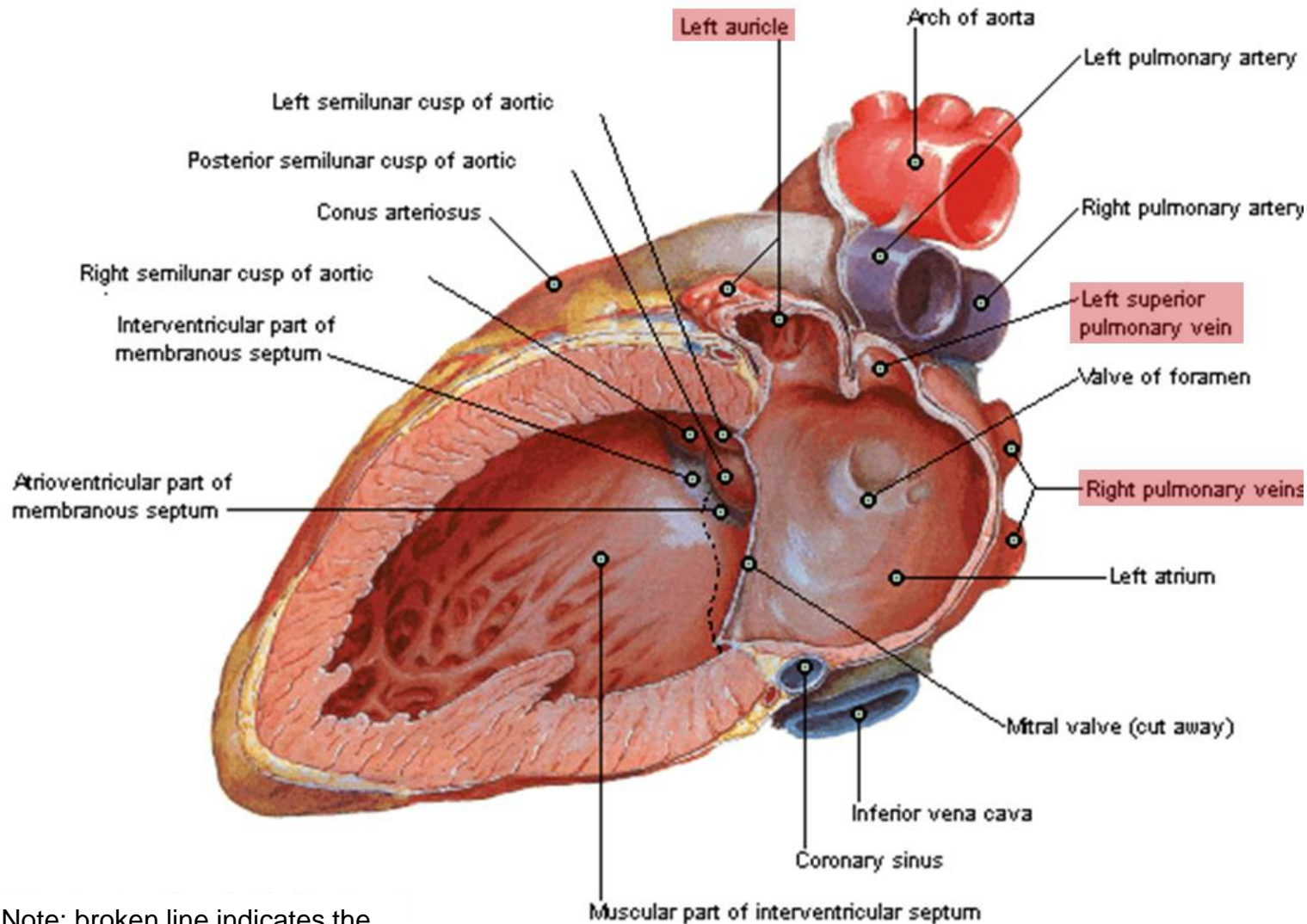
When the ventricular contraction occurs, the blood is pumped through the pulmonary valve and the cusps distance themselves from each other, approaching the arterial wall and allowing the blood to flow into the pulmonary trunk



At the end of the ventricle contraction, the cusps return close to each other to close the lumen of the pulmonary trunk

HEART: INTERNAL EXAMINATION – The Left Atrium

Left Atrium and Ventricle Sectioned with Mitral Valve Cut Away



INTERNAL EXAMINATION OF THE HEART - Left atrium -

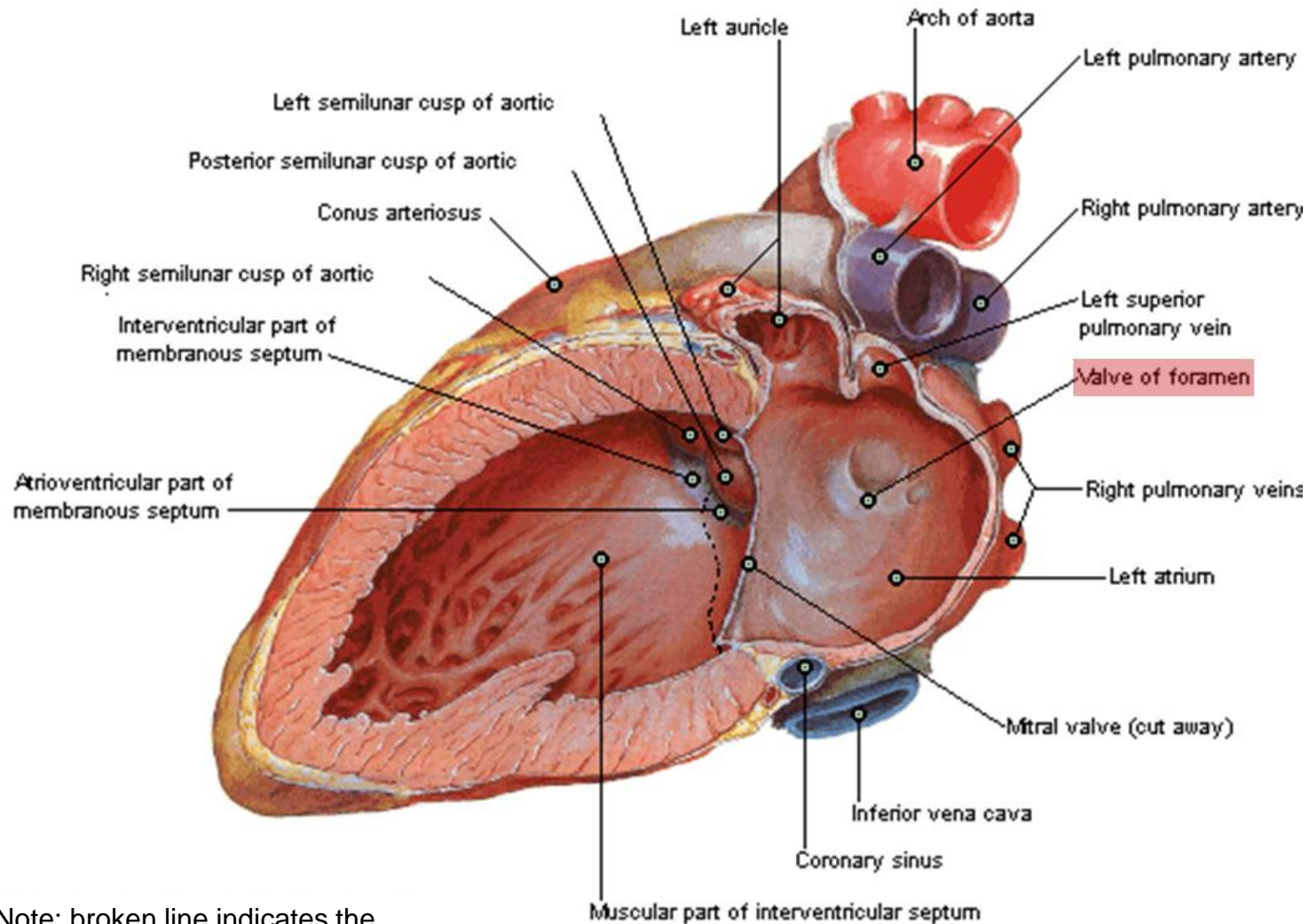
Into the left atrium we observe the orifices where the four pulmonary veins open without valves

It has a less evident internal division than in the right atrium

- the **walls** have mainly a **smooth surface**
- The portion that corresponds to the **left auricle** shows muscular ridges similar to those seen on the right atrium

Note: broken line indicates the origin of bicuspid valve

Left Atrium and Ventricle Sectioned with Mitral Valve Cut Away



Note: broken line indicates the origin of bicuspid valve

INTERNAL EXAMINATION OF THE HEART - Left atrium -

The interatrial septum can also be recognized in the left atrium

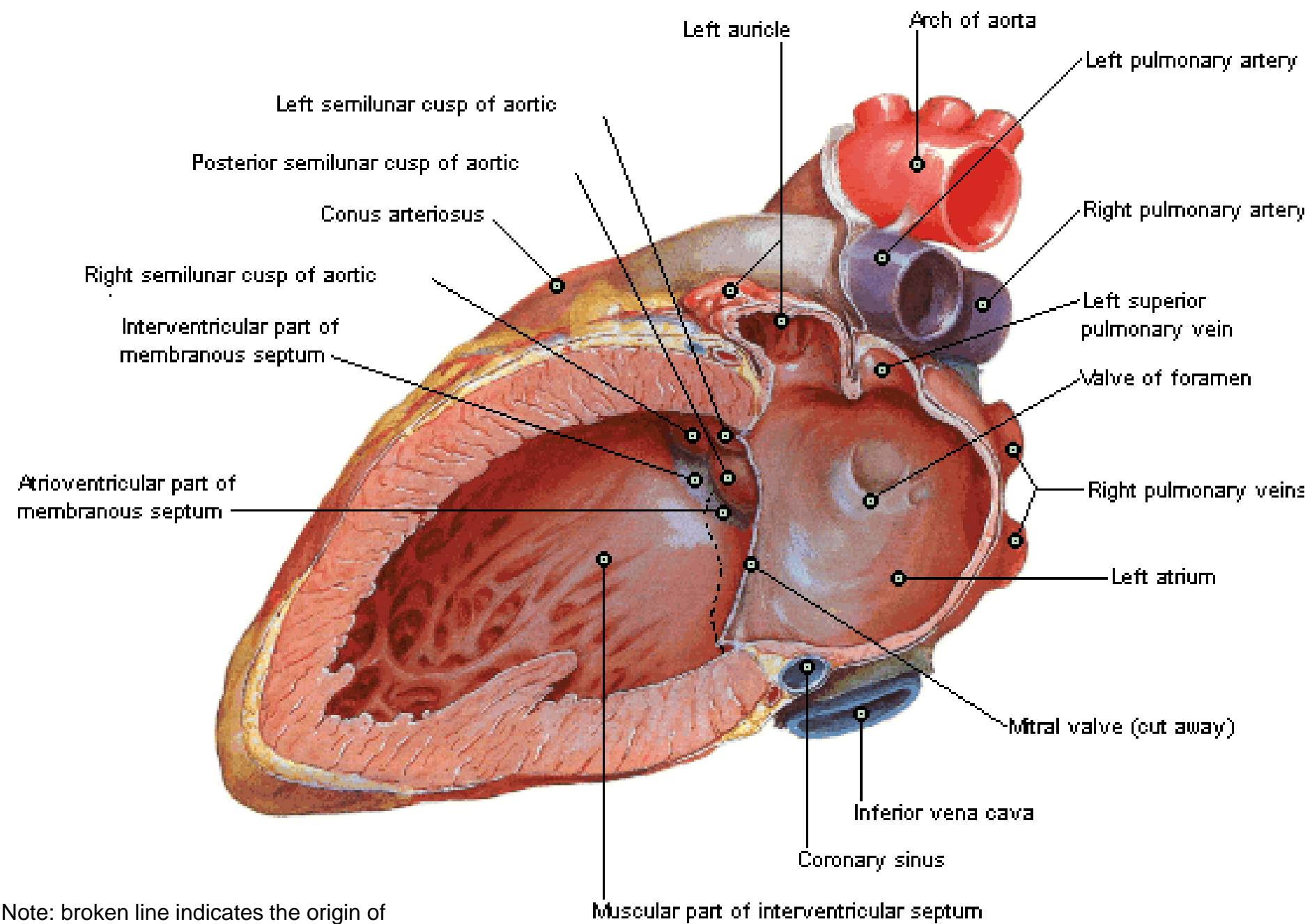


In this muscular wall there is the residue of the foramen ovale, which however is less evident than on the right atrium



The septum shows a depression representing **the residue of the opening of the foramen ovale at the level of the left atrium**

The posterior portion of the left atrium, between the two pairs of pulmonary veins ► **ROOF OF THE LEFT ATRIUM**

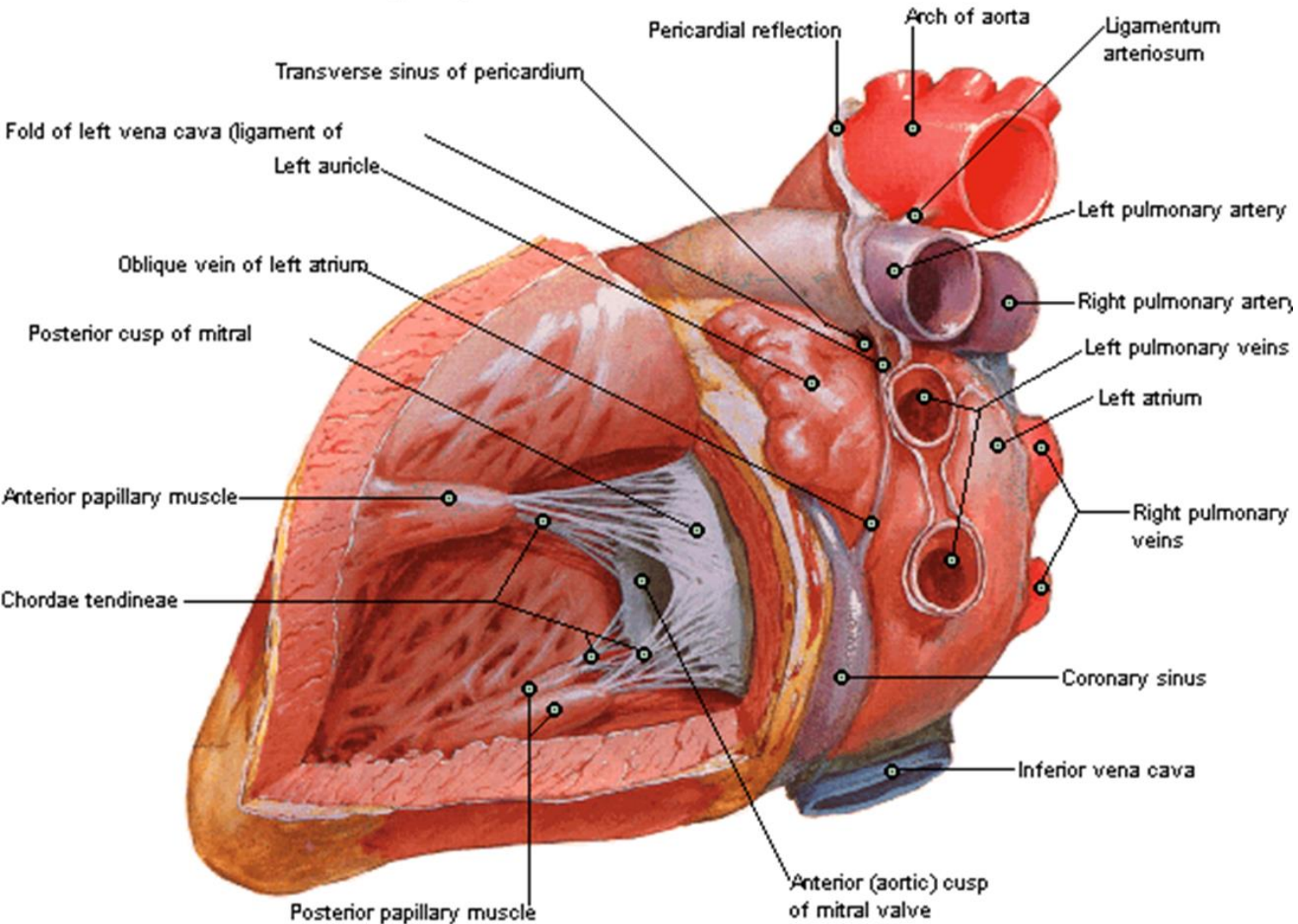


Note: broken line indicates the origin of bicuspid valve

HEART: INTERNAL EXAMINATION – The Left Ventricle

Left Ventricle

Flap Opened in Posterolateral Wall



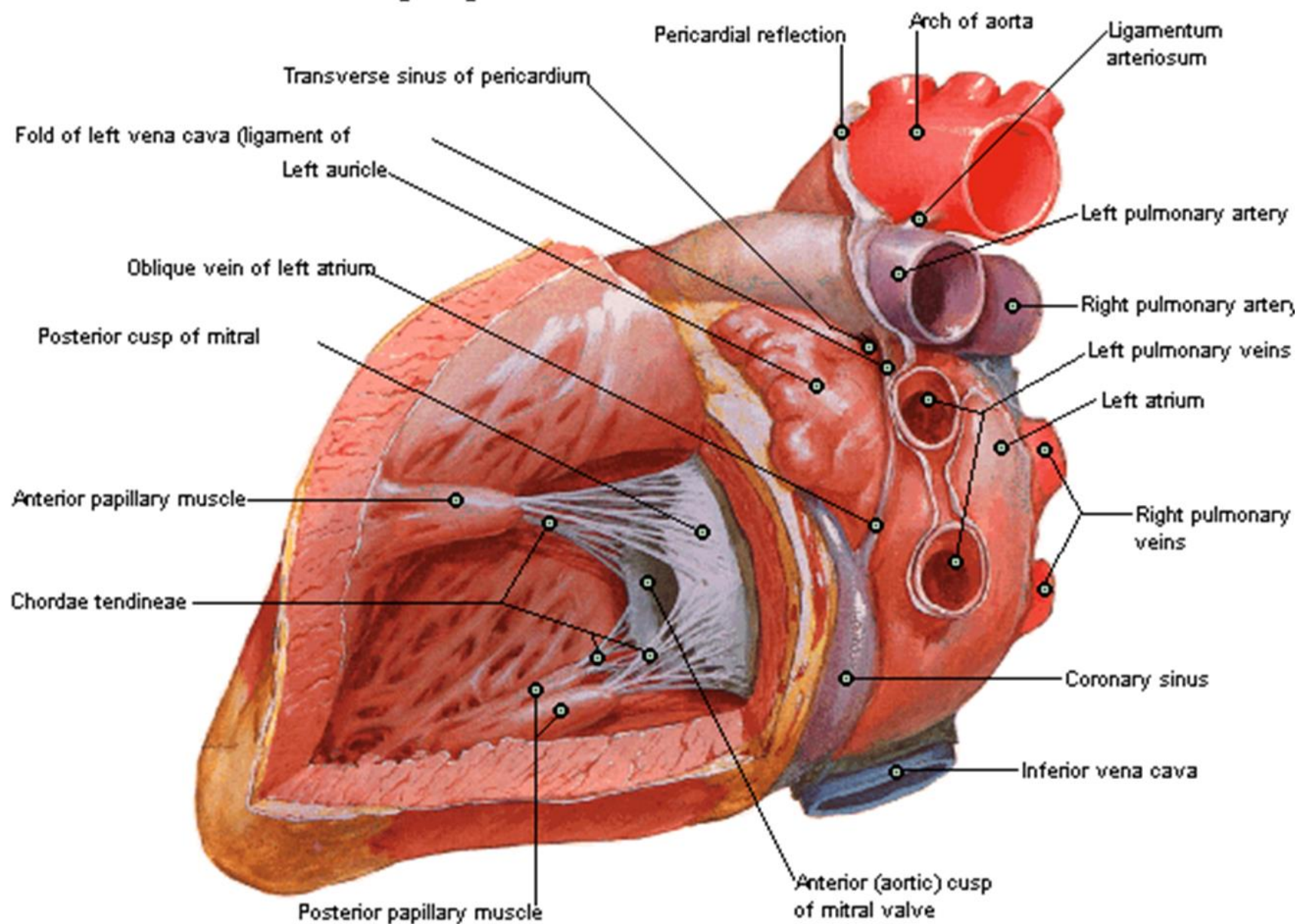
INTERNAL EXAMINATION OF THE HEART - Left ventricle -

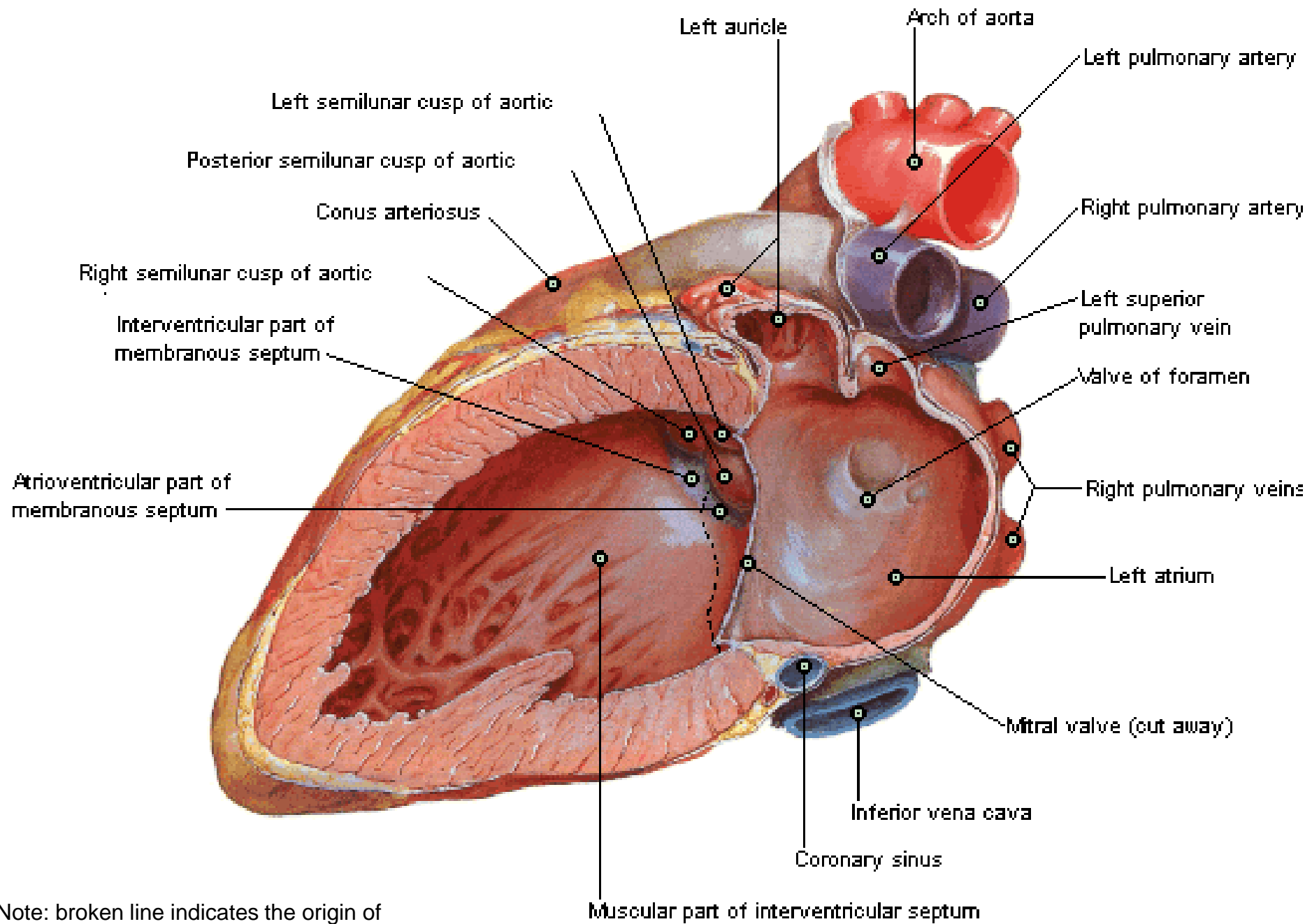
It is possible to identify a left atrioventricular valve complex that regulates the entry of blood from the left atrium to the left ventricle

- The **INFLOW tract** has an irregular surface due to the presence of muscular ridges which are the **TRABECULAE CARNEAE**
- Entering from the left atrium through the atrioventricular valve (inflow tract), the blood flows towards the cardiac apex
- Subsequently, the blood follows a "V" path to return towards the cardiac base, corresponding to the **OUTFLOW tract**
- The **OUTFLOW tract** ends at the origin of the **AORTIC VALVE**, through which the blood flows into the aorta

Left Ventricle

Flap Opened in Posterolateral Wall





WHICH IS THE DIFFERENCE BETWEEN LEFT AND RIGHT VENTRICLE?

Into the left ventricle:

**LEFT ATRIOVENTRICULAR VALVE
and
AORTIC VALVE**

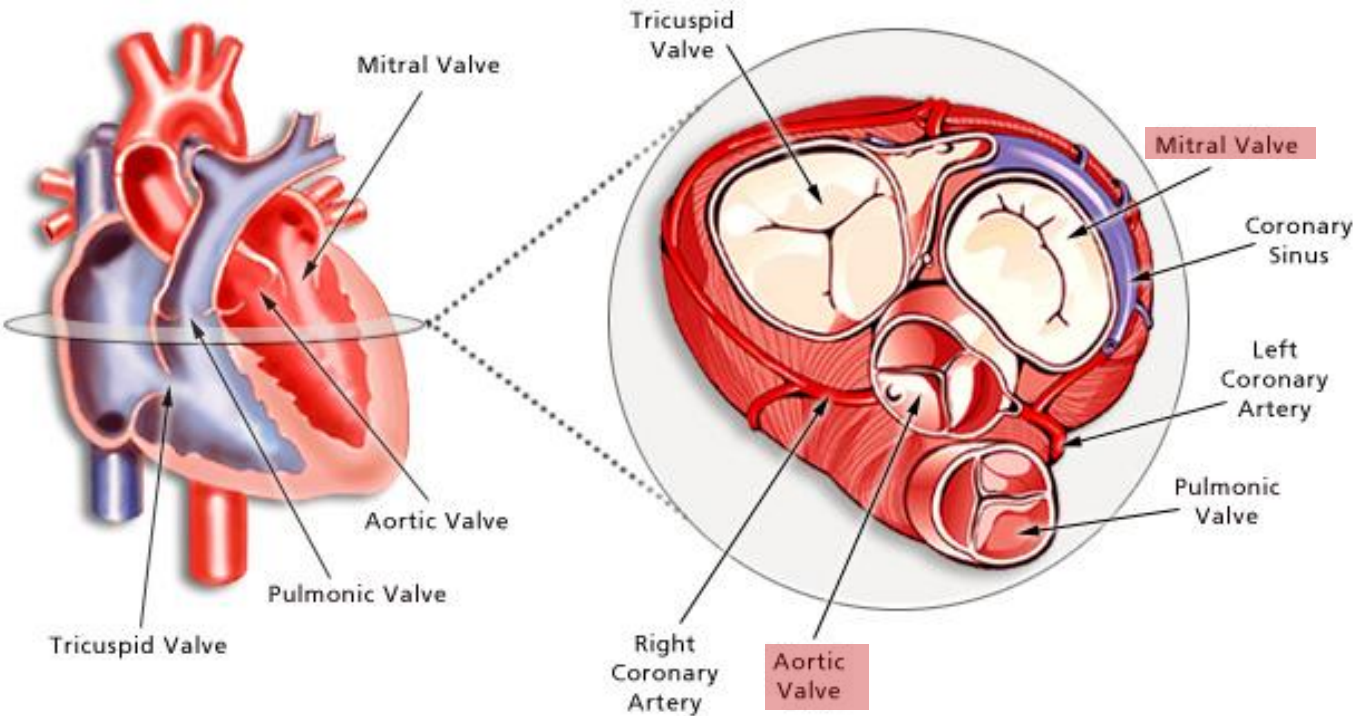
▼
Are CLOSE to each other

There is no muscular structures such as the supra-ventricular crest on the right ventricle that separates the fibrous rings of the two valves

(each valve is made up of cusps that fit onto fibrous rings)

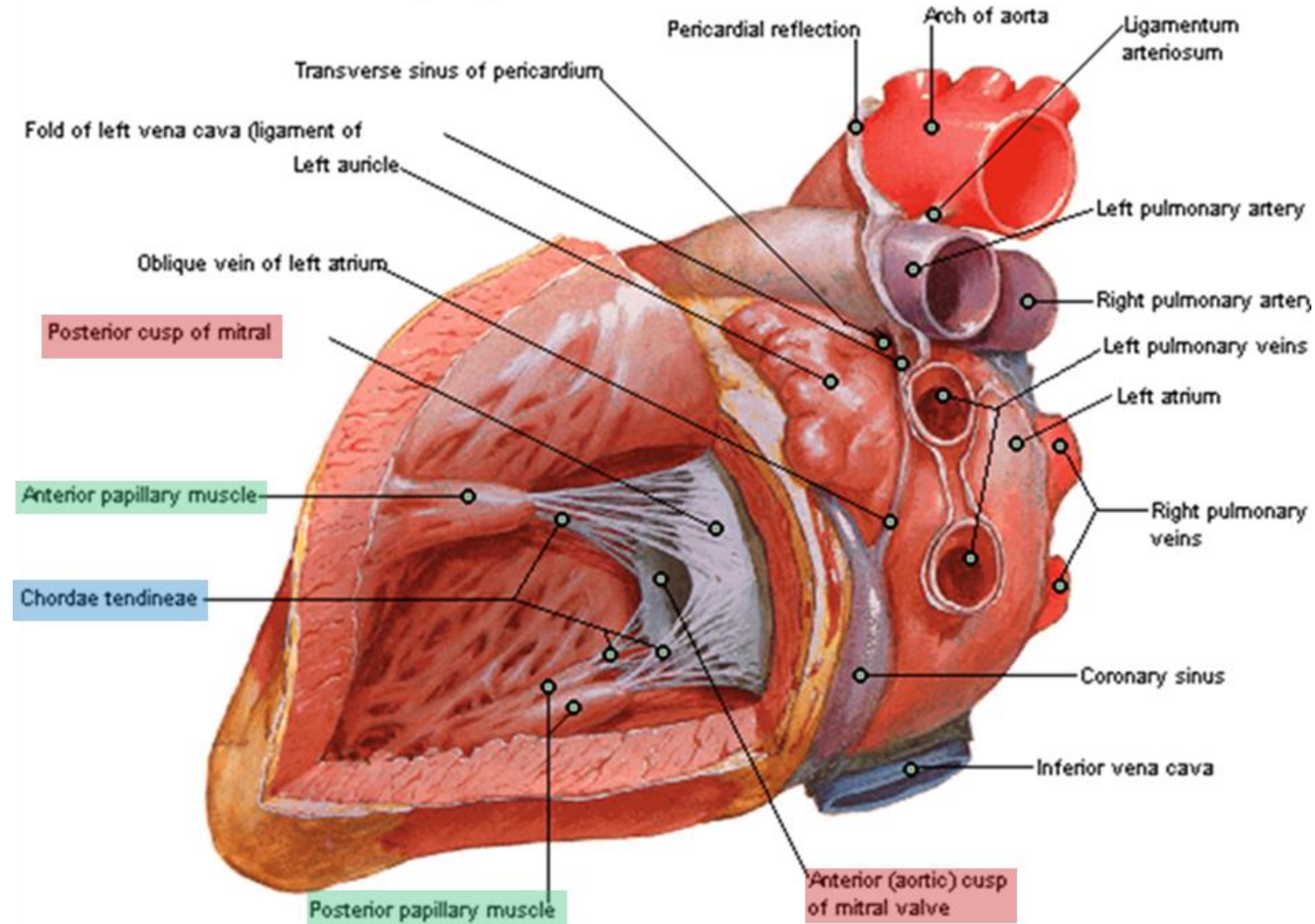
SIDE VIEW
Cross-Section

TOP VIEW
Cross-Section



Left Ventricle

Flap Opened in Posterolateral Wall



LEFT ATRIOVENTRICULAR VALVE (Mitral valve)

The LEFT ATRIOVENTRICULAR VALVE COMPLEX consists of **2 CUSPS** (= bicuspid valve):

- ANTERIOR CUSP
- POSTERIOR CUSP

The cusps are connected by **TENDINOUS CORDS** to **PAPILLARY MUSCLES**, which are 2 muscles, the ANTERIOR one and the POSTERIOR one.

Also in this case, the connection between papillary muscles is in a 1:2 ratio

The anterior papillary muscle is connected by tendinous cords to both the posterior and anterior cusps, as well as the posterior papillary muscle.

The tendinous cords insert on the free edge (i.e., the portion that is NOT inserted into the fibrous ring of the valve) and extend onto the ventricular surface of the cusps.

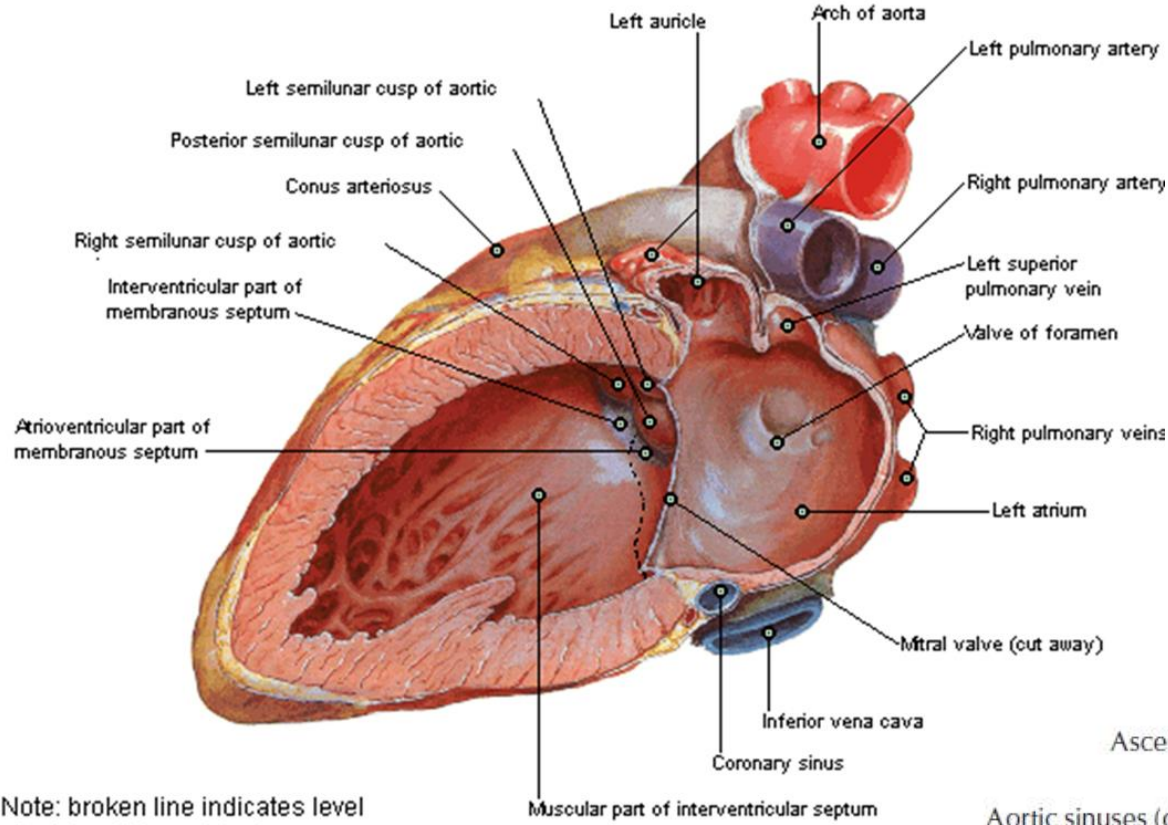
The internal or atrial surface is smooth

AORTIC VALVE

In the left ventricle, the **OUTFLOW** tract:

Shows a smooth appearance
it is not separated from the inflow part by muscular/valve structures
it is characterized by the presence of the **AORTIC VALVE**

The **AORTIC VALVE** regulates the exit of blood from the left ventricle



Note: broken line indicates level of origin of tricuspid valve

It is a **SEMILUNAR VALVE**

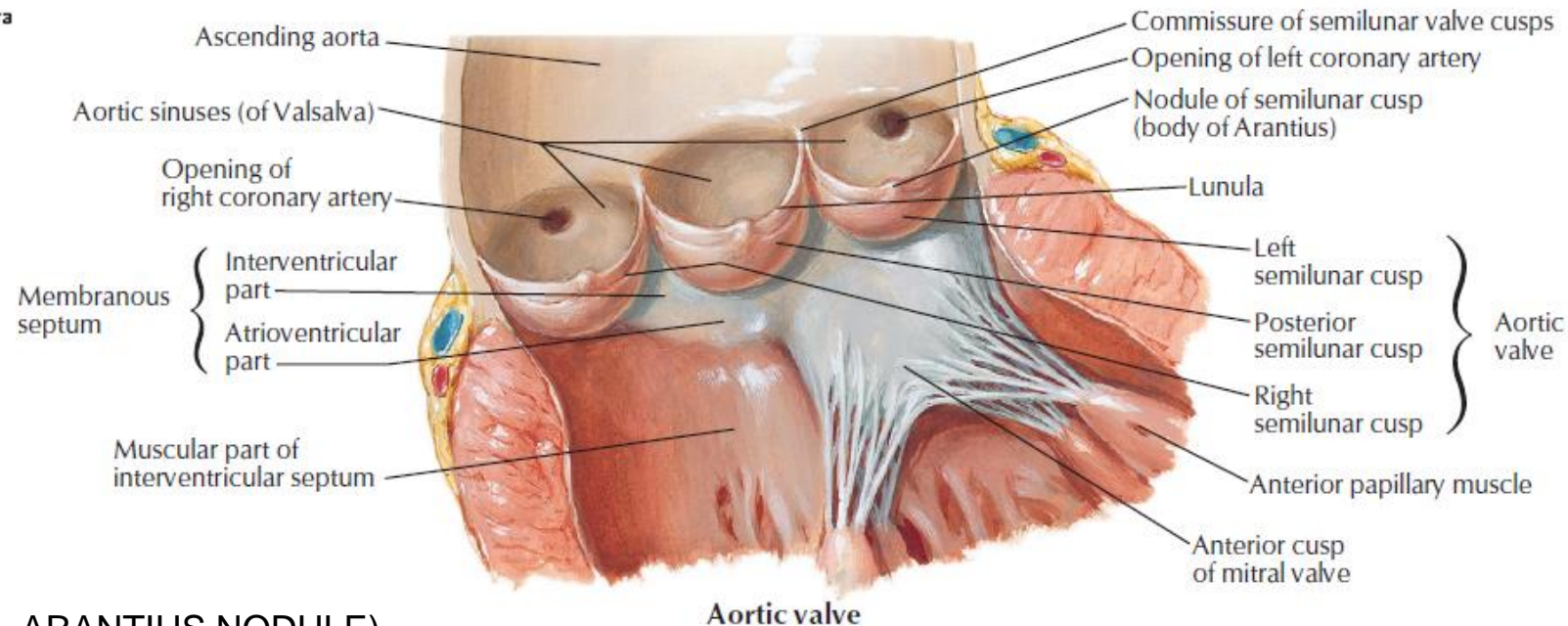


it consists of **3 semilunar cusps**

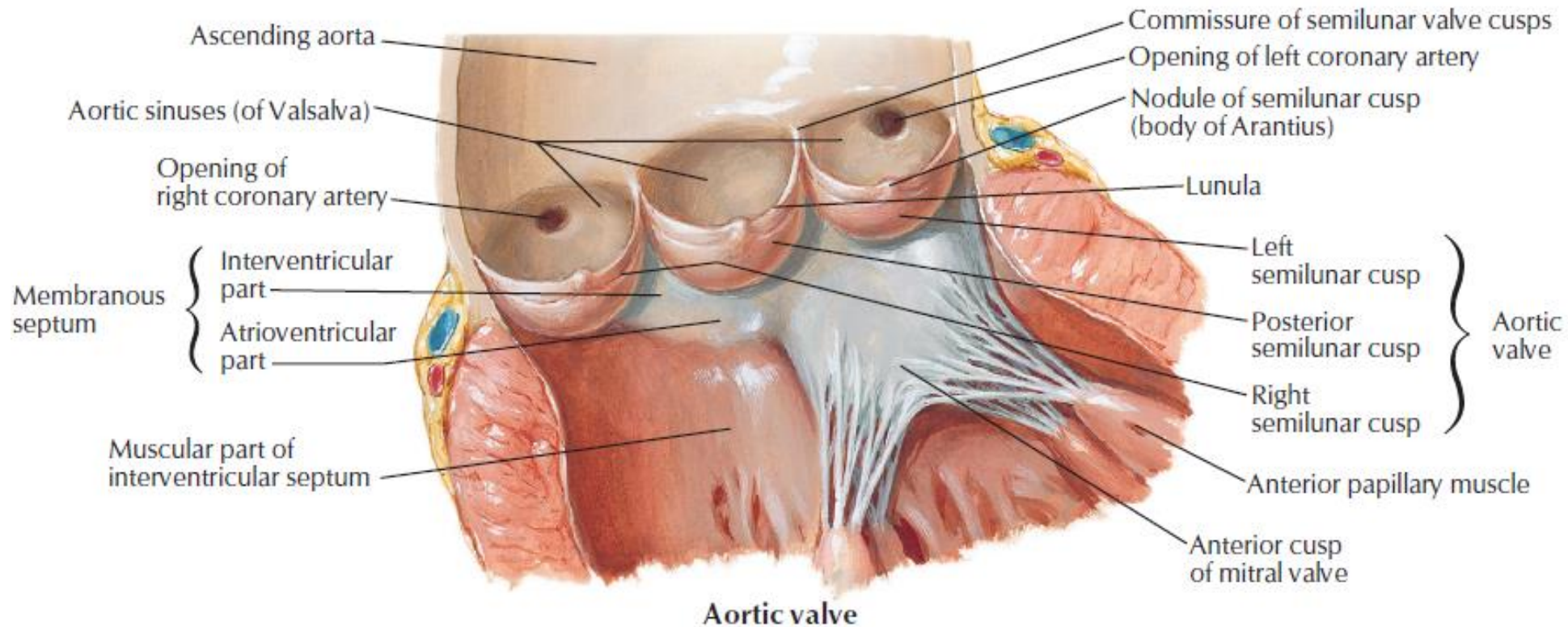
Right cusp, left cusp and posterior cusp

Each cusp has:

- a free edge
- a nodule/node in the midline of the free edge (= **ARANTIUS NODULE**)



Aortic valve



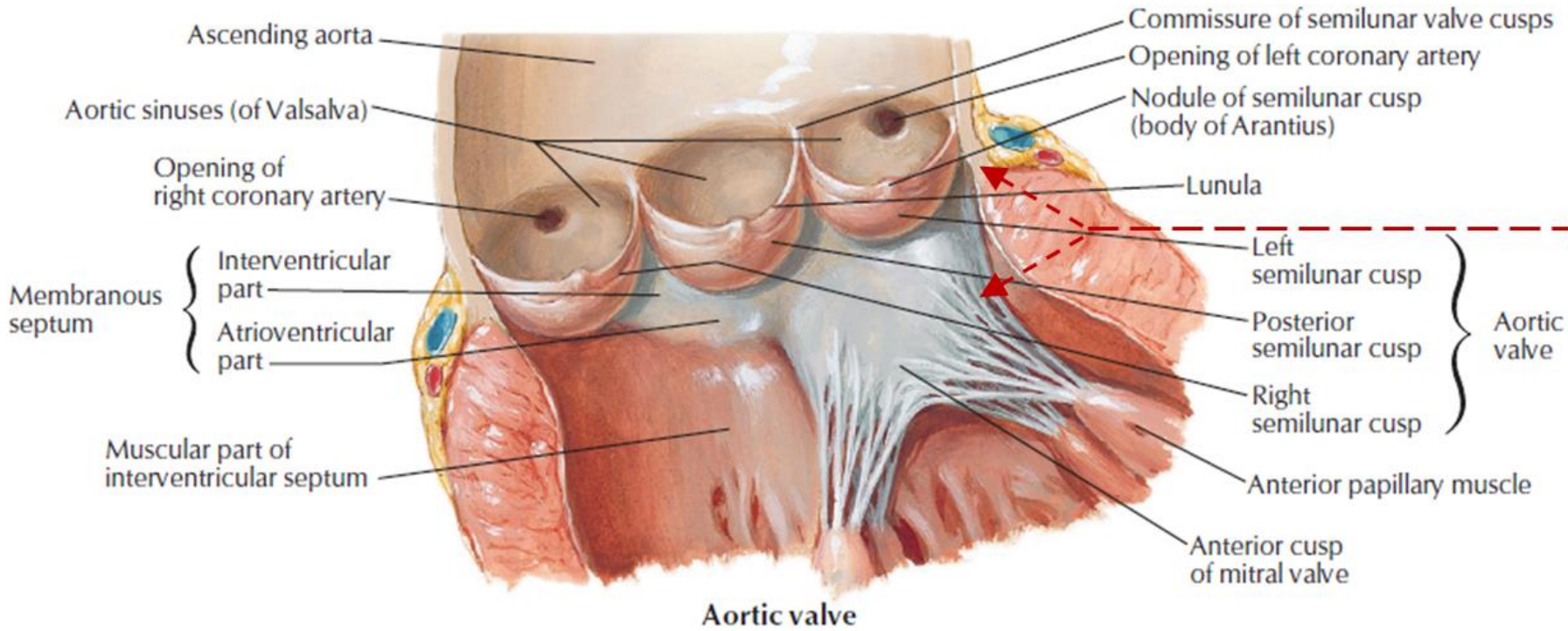
The AORTIC VALVE is characterized by the presence of the **AORTIC SINUSES**, also known as **SINUSES OF VALSALVA**. An aortic sinus is each one of the anatomic dilations of the ascending aorta, which occurs just above the aortic valve. These widenings are between the wall of the aorta and each of the three cusps of the aortic valve.

Within the right and left cusps and the corresponding sinuses of Valsalva - right and left - we distinguish:

CORONARY ORIFICES → openings of the two **coronary arteries**:

1. the right coronary artery, which opens at the level of the right cusp
2. the left coronary artery, which opens at the level of the left cusp

The two coronary arteries are the only two collateral branches of the very first trait of the ascending aorta



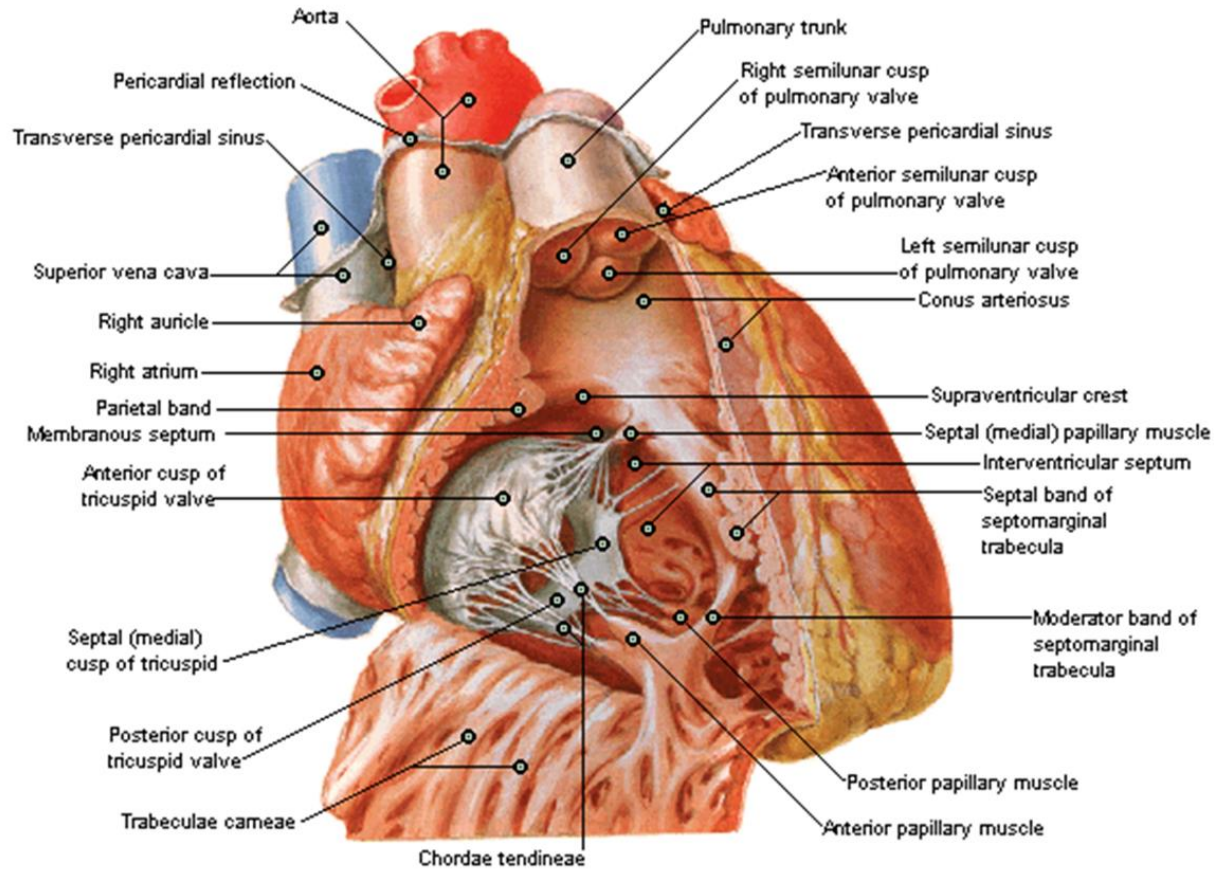
POSITION OF MITRAL VALVE and AORTIC VALVE

The two valves are close together

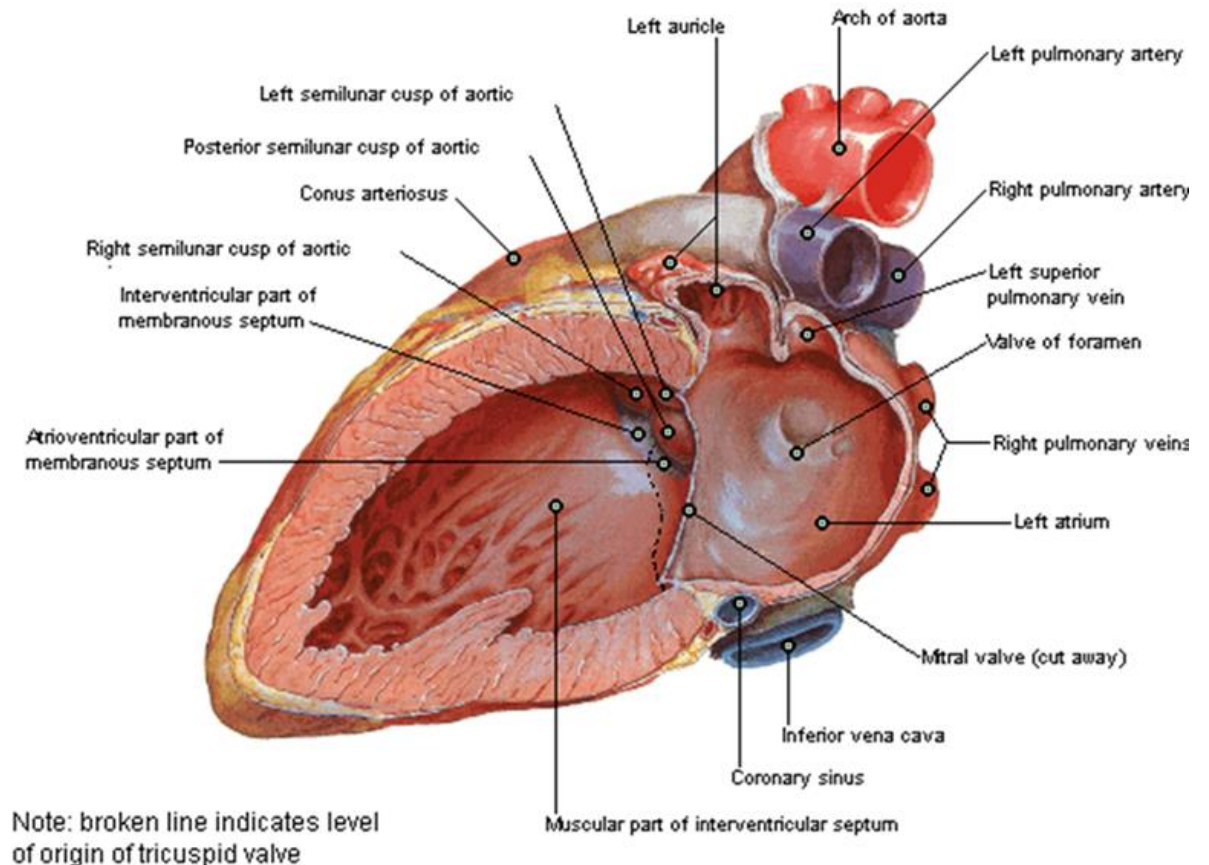
Unlike the right atrioventricular valve and semilunar valves!

WHAT IS ANOTHER DIFFERENCE BETWEEN THE RIGHT VENTRICLE AND THE LEFT VENTRICLE?

Opened Right Ventricle
Anterior View

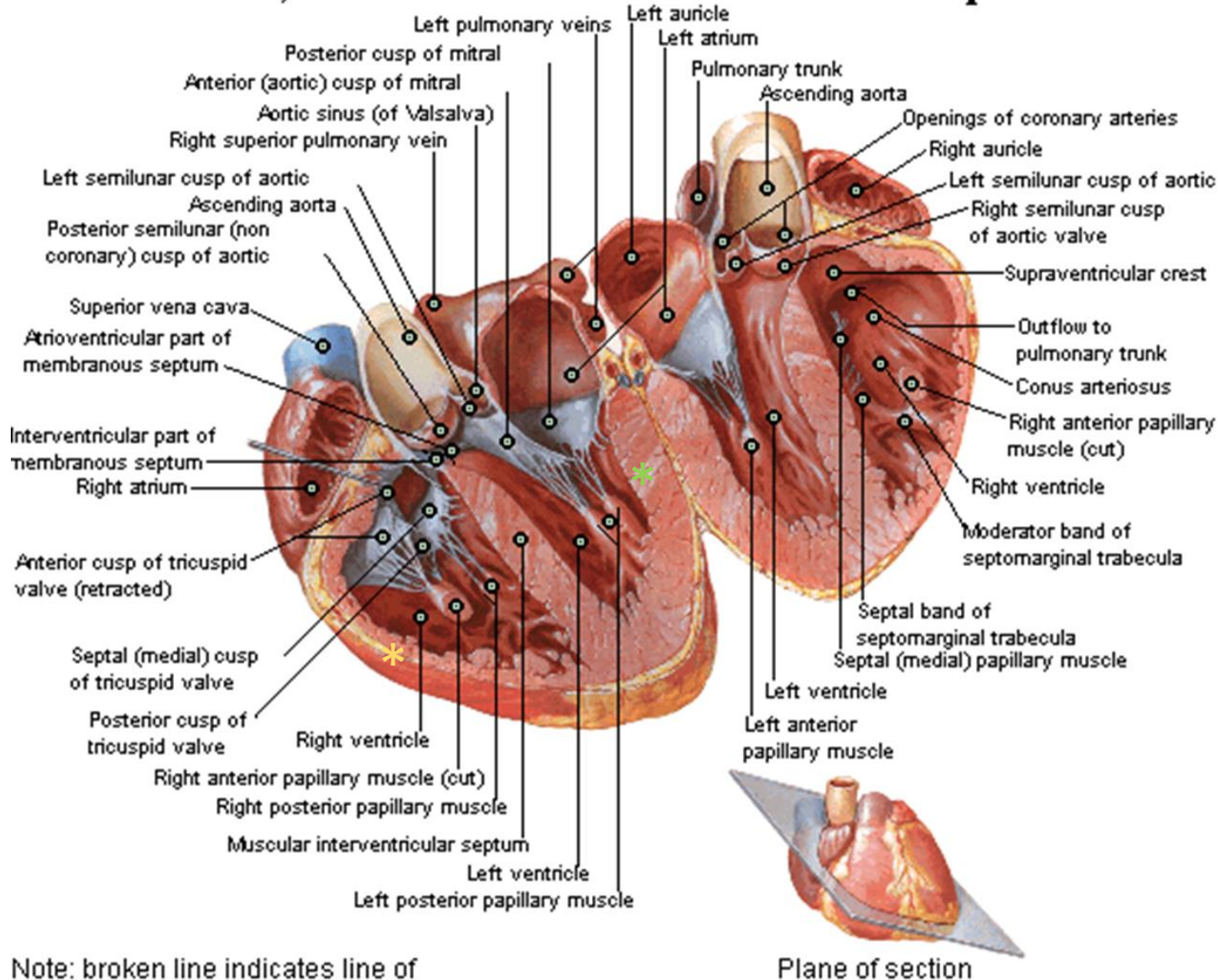


Left Atrium and Ventricle
Sectioned with Mitral Valve Cut Away



→ The **THICKNESS** of the **WALL!** (That is the thickness of the **myocardium**)

Atria, Ventricles and Interventricular Septum



Note: broken line indicates line of attachment of septal leaflet of tricuspid valve.

The image presents a section of the heart through the 4 cardiac chambers

A comparison can be made between the thickness of:

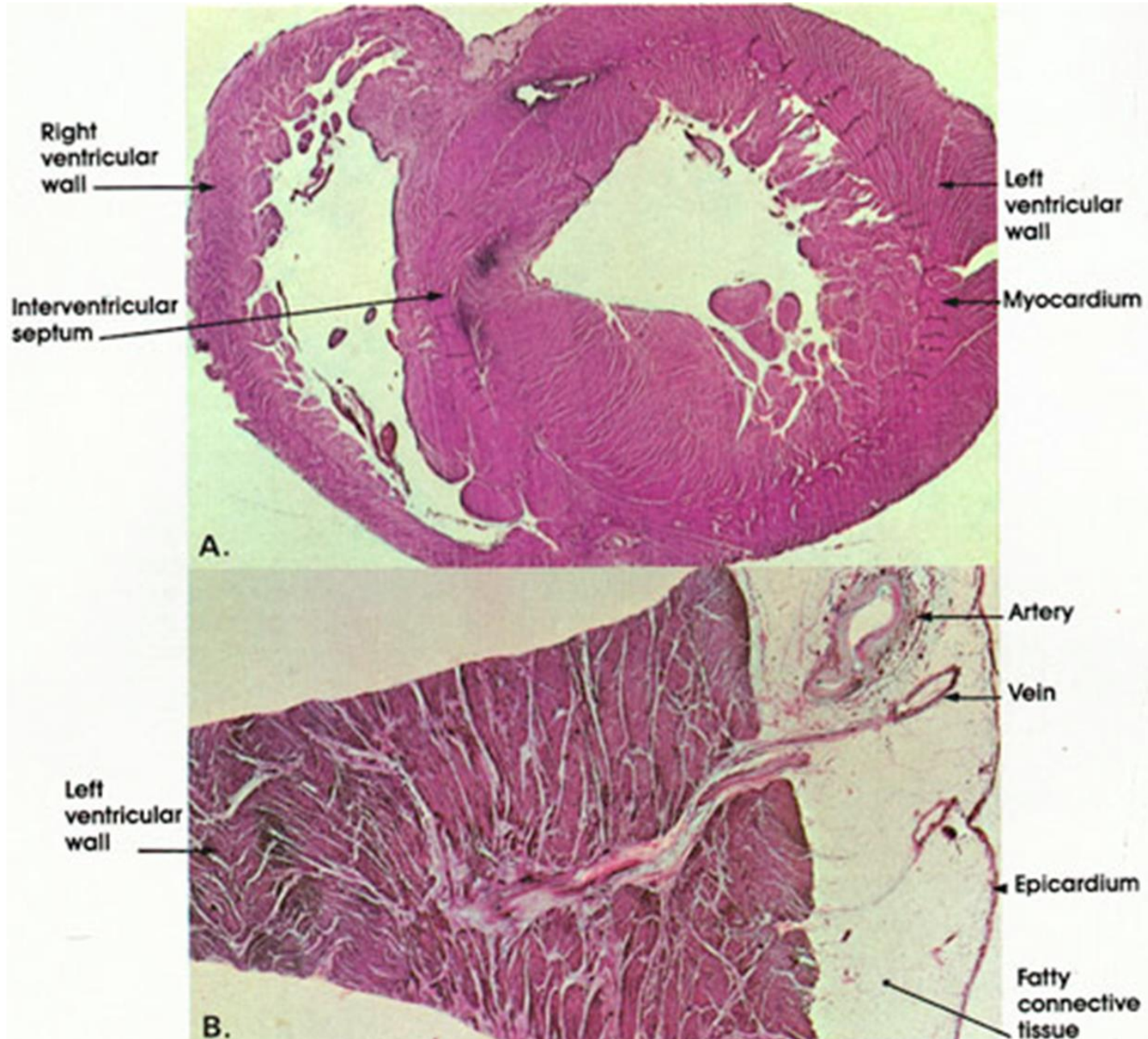
→ **the free wall of the left ventricle** (3 times thicker)

→ **the free wall of the right ventricle**

The interventricular septum also has a thickness similar to that of the free wall of the left ventricle = it is approximately three times the free wall of the right ventricle

Why?

The left ventricle must pump blood into the systemic circulation and so it needs a greater contraction force = a thicker myocardium



Cross section of the heart through the two ventricles

Observe that:

- the free wall of the left ventricle is 3 times thicker than the free wall of the right ventricle
- the interventricular septum is three times thicker than the free wall of the right ventricle and analogous to the free wall of the left ventricle
- the left ventricle has a circular profile, while the right ventricle has a semilunar profile