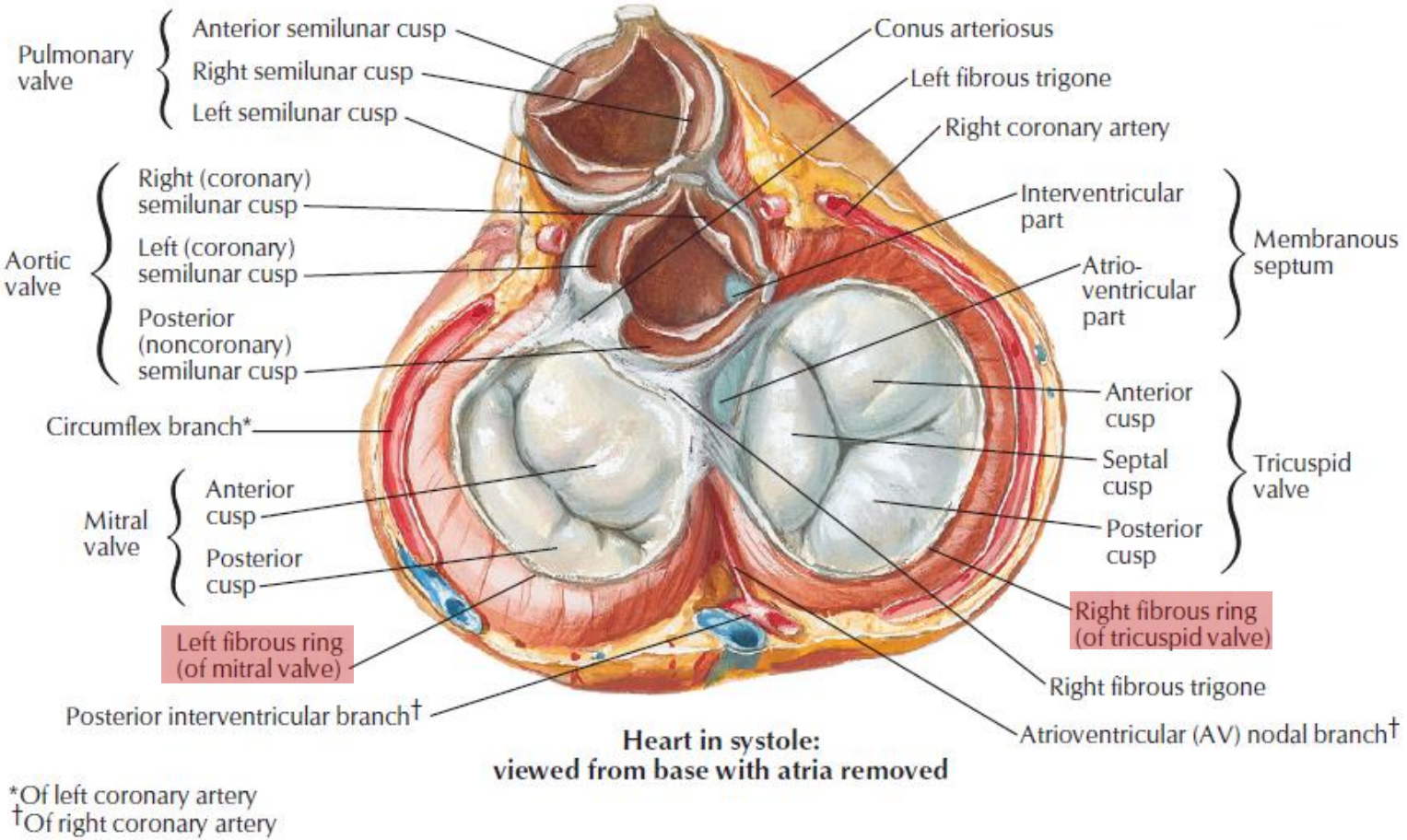
ANATOMY AND PHYSIOLOGY (C.I.)

HUMAN ANATOMY
(Mod. A)

THE CARDIOVASCULAR SYSTEM

CARDIAC SKELETON



Heart in systole: viewed from base with atria removed

*Of left coronary artery
†Of right coronary artery

FIBROUS SKELETON OF HEART

It is a set of connective structures (i.e., dense, fibrous connective tissue) that form a separation plane between the atria and ventricles

The image represents the 4 heart valves seen from the atrial side after removal of the 2 atria (2 atrioventricular valves, 2 semilunar valves)

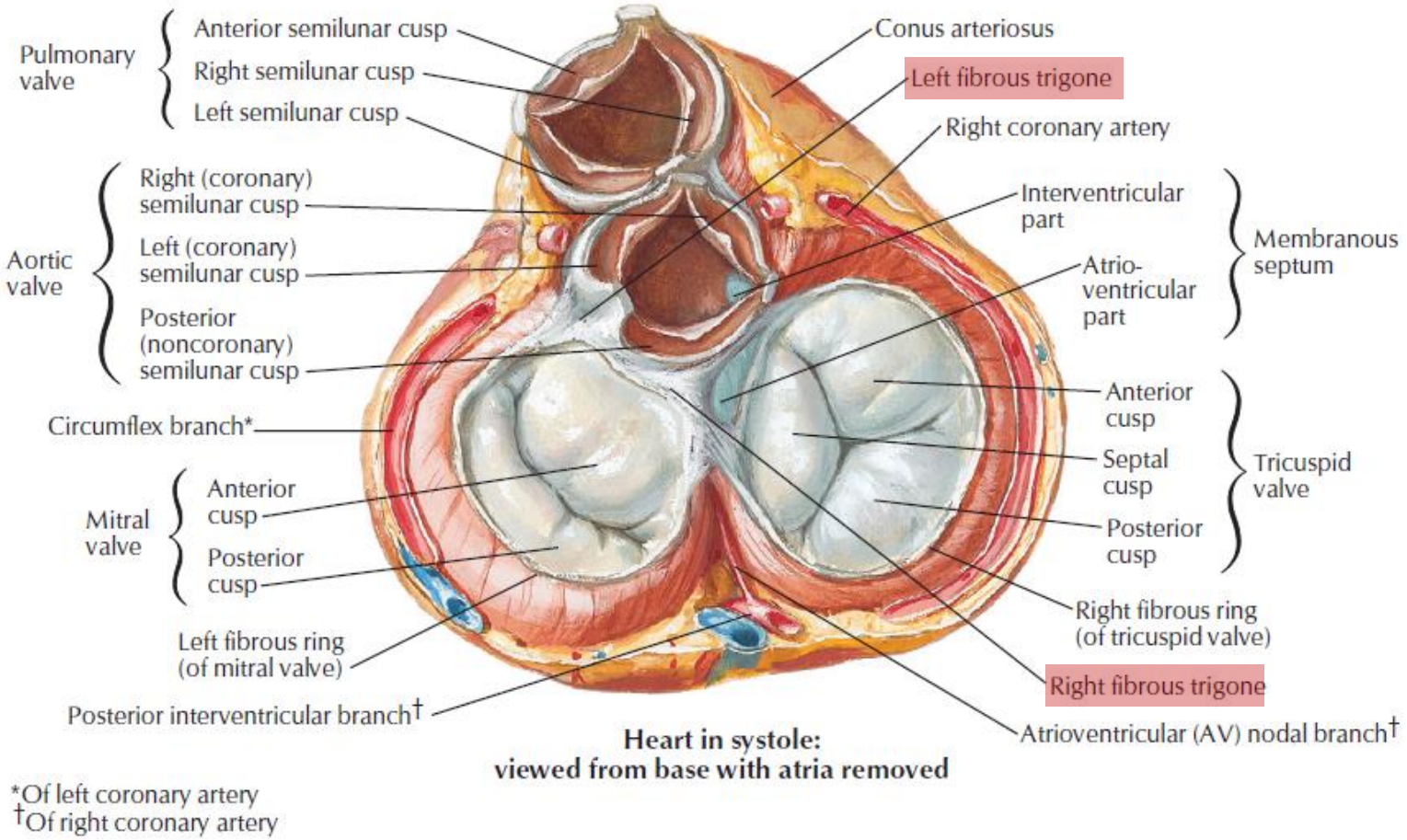
The structures that form the cardiac skeleton are:

the **FIBROUS RINGS of heart valves**

↓

the 4 fibrous rings composed of dense, fibrous connective tissue that encircle the orifices of the heart valves:

- the left fibrous ring encircles the left atrioventricular valve (mitral valve)
- the right fibrous ring surrounds the right atrioventricular valve (tricuspid valve)
- The pulmonary ring encircles the pulmonary valve
- the aortic ring surrounds the aortic valve.



FIBROUS SKELETON OF HEART

The structures that form the cardiac skeleton are:

the **FIBROUS TRIGONES**

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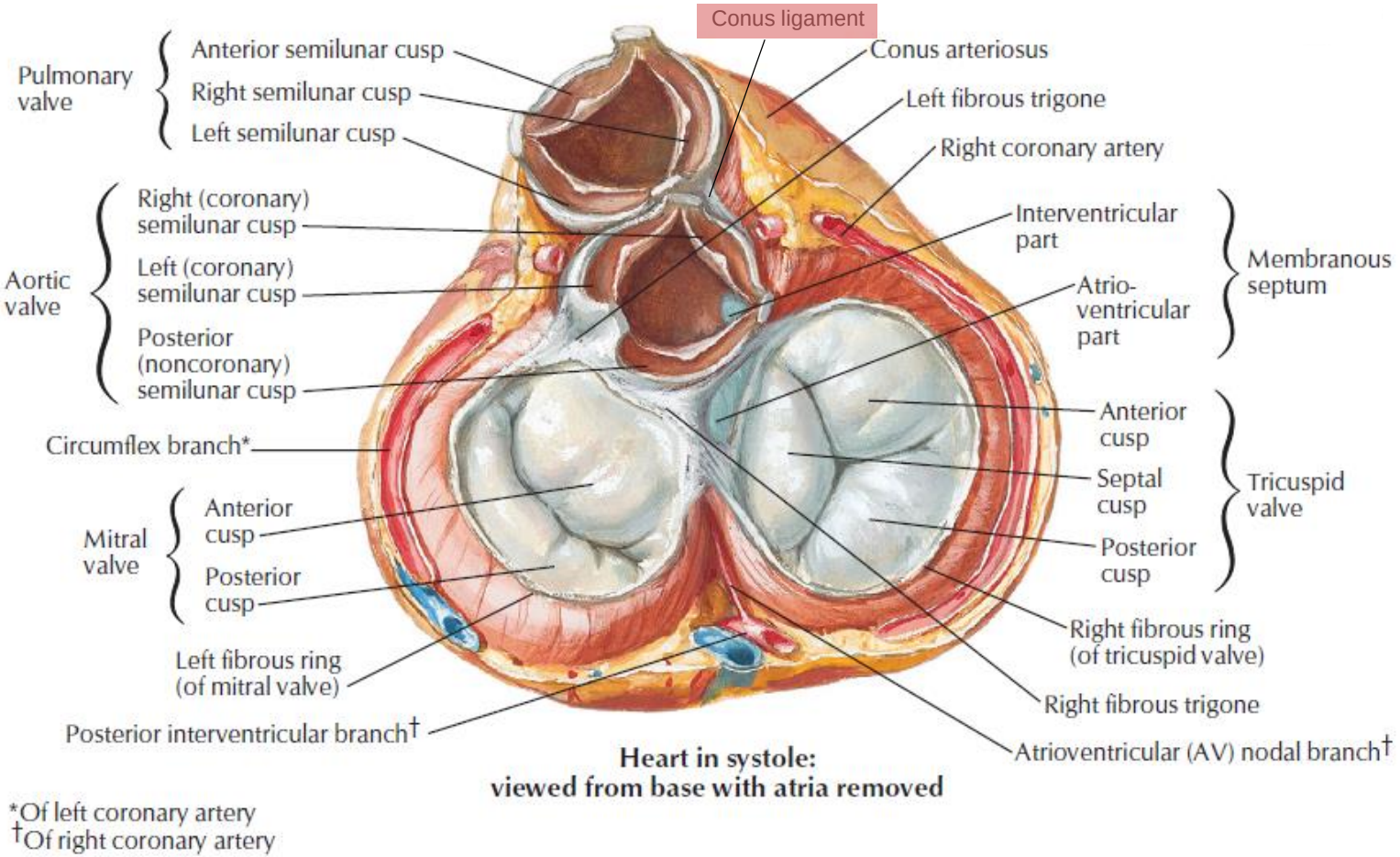
they are fibrous connective structures of triangular-like shape that interconnect the fibrous rings of the valves

There are 2 fibrous trigones:
- the RIGHT FIBROUS TRIGONE
- the LEFT FIBROUS TRIGONE

The **right fibrous trigone** is the interconnection between the **fibrous rings of the tricuspid, mitral and aortic valves**

The **left fibrous trigone** is the interconnection between the **fibrous rings of the mitral and aortic valves**



Heart in systole: viewed from base with atria removed

*Of left coronary artery
†Of right coronary artery

FIBROUS SKELETON OF HEART

The structures that form the cardiac skeleton are:

the **CONUS LIGAMENT**

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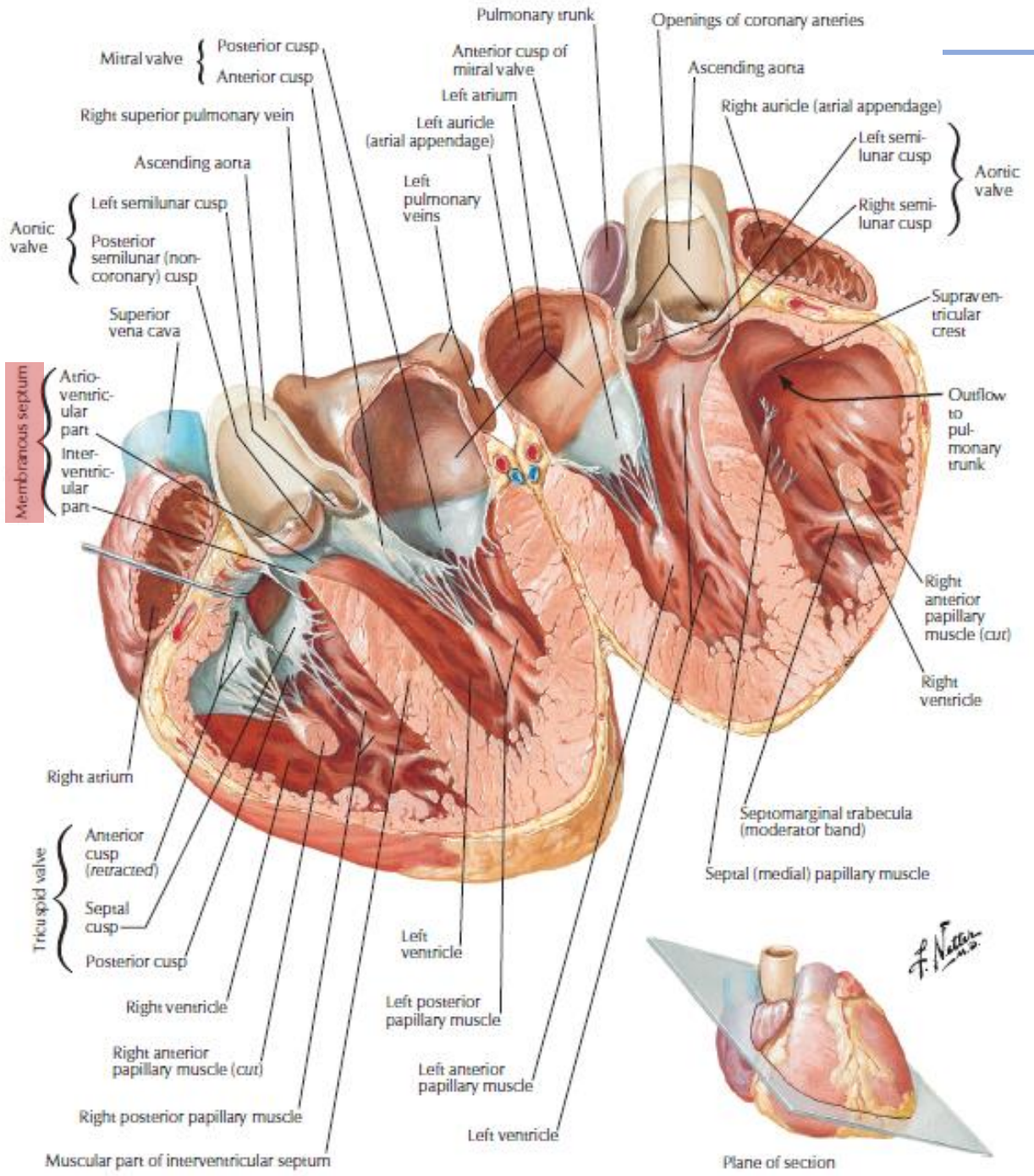
It is a fibrous cord that starts from the fibrous ring of the pulmonary valve, it passes by the fibrous ring of the aortic valve and ends at the junction between the fibrous ring of the aortic valve and the fibrous ring of the tricuspid valve



FIBROUS SKELETON OF HEART

The structures that form the cardiac skeleton are:

the **MEMBRANOUS PORTION**
of the interventricular septum
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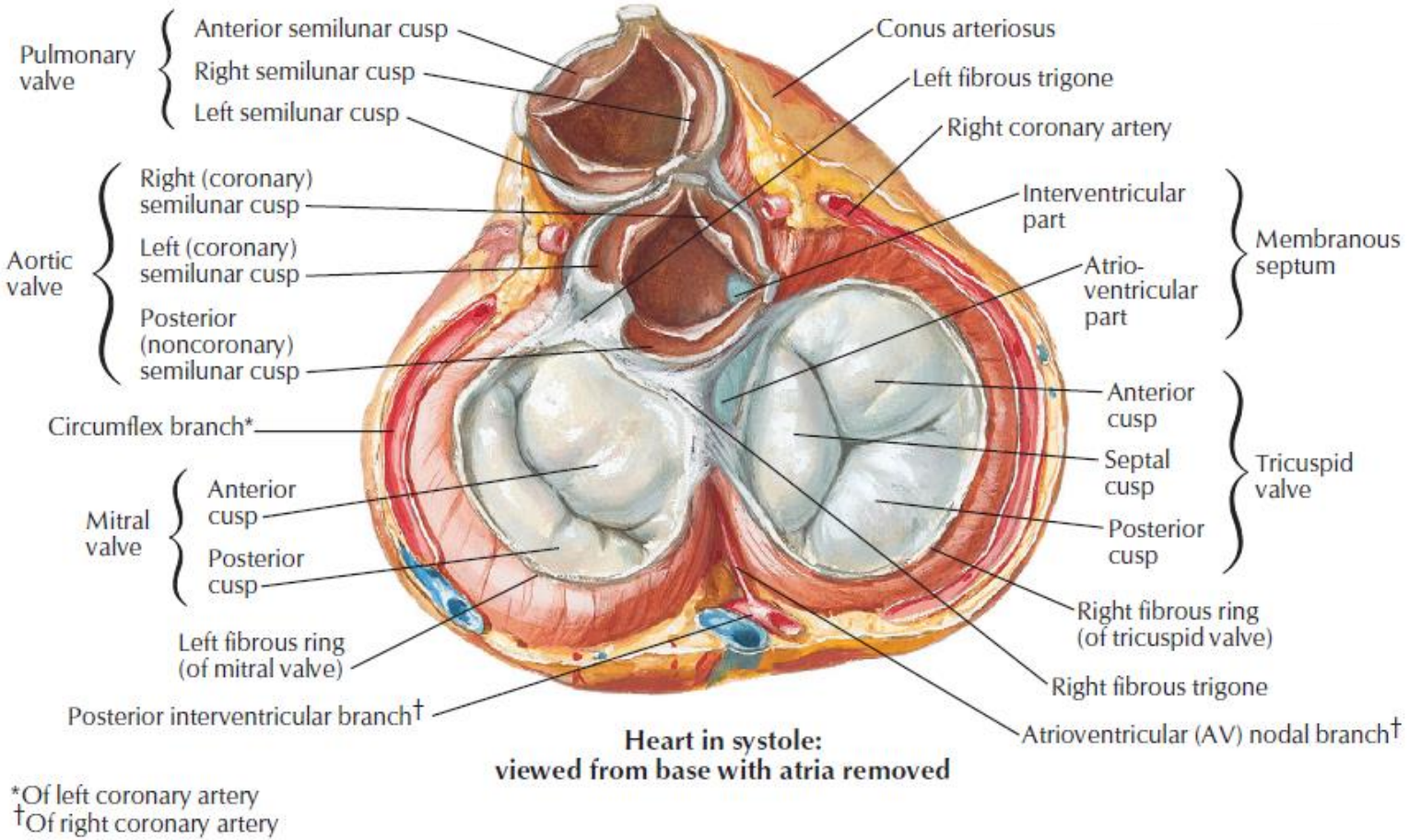
It is the portion that faces the atria, being formed by connective tissue and not by muscular tissue



Heart in systole: viewed from base with atria removed

*Of left coronary artery
†Of right coronary artery

FUNCTIONS

The fibrous skeleton of the heart performs several important functions, playing a vital role in supporting both the structure and function of the heart.

- It keeps the orifices of the valves patent, serving as point of insertion for the valve cusps

- It **separates the atrial musculature from that of the ventricles**. It serves as the framework for the attachment of myocardial fibers, with atrial fibers arising from the upper border of the rings and ventricular fibers originating from the lower border of the rings

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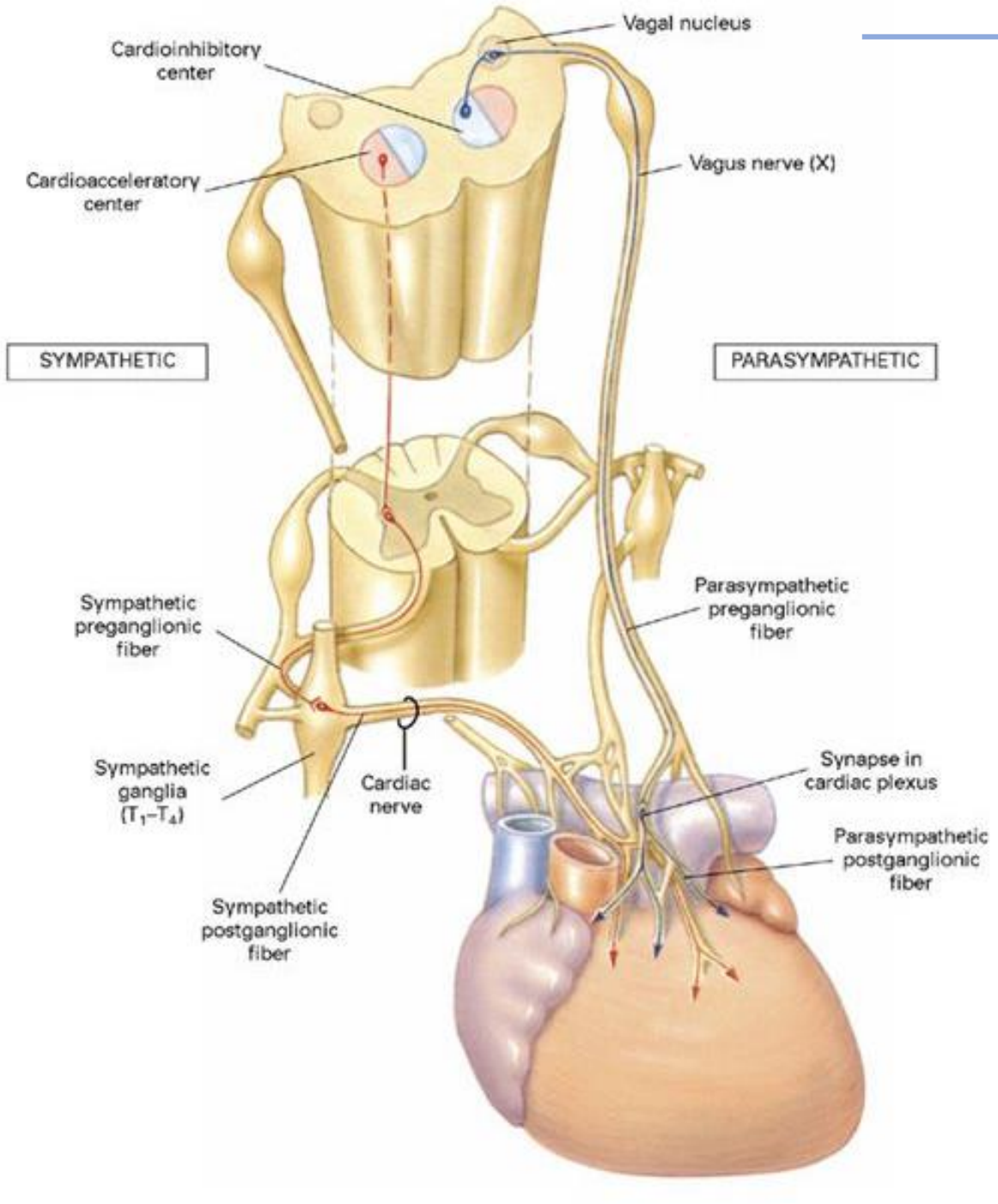
- It serves as an **ELECTRICAL INSULATOR**, partitioning electrical impulses conducted through the musculature of the atria and ventricles, allowing them to contract independently.

CONDUCTION SYSTEM OF HEART

CONDUCTION SYSTEM OF HEART



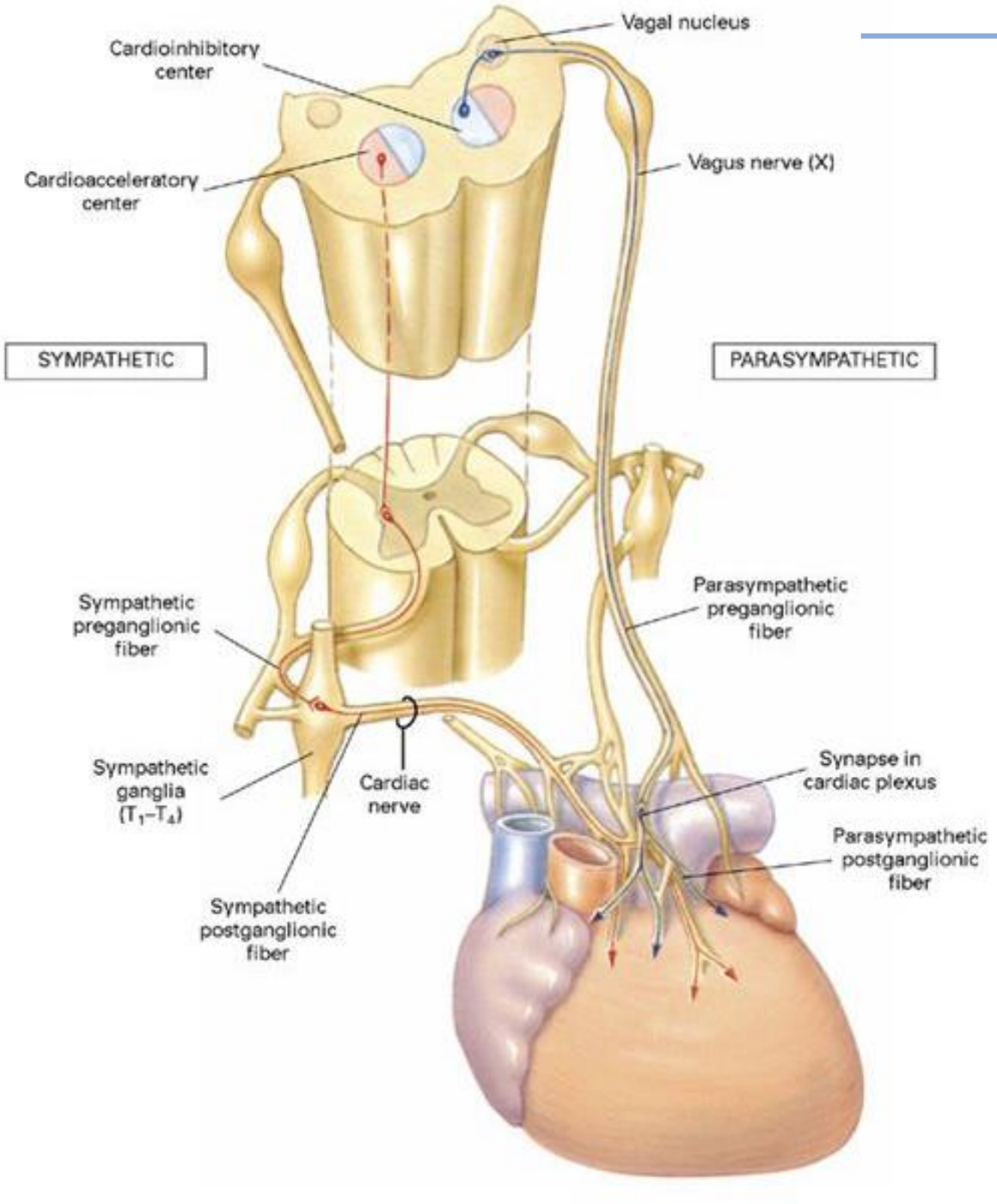
Premise:
the contraction of a muscle such as the biceps of the arm occurs because the nerve that innervates it depolarizes it and makes it contract

WHAT HAPPENS TO THE HEART?
Why does the cardiac muscle depolarize rhythmically?

The heart is also innervated through a nervous plexus, that is, a set of nerve fibers that innervates the heart, BUT...

THE INNERVATION IS NOT RESPONSIBLE OF A NORMAL HEART RHYTHM

If the heart is denervated, it keeps on beating and it beats a rhythmically



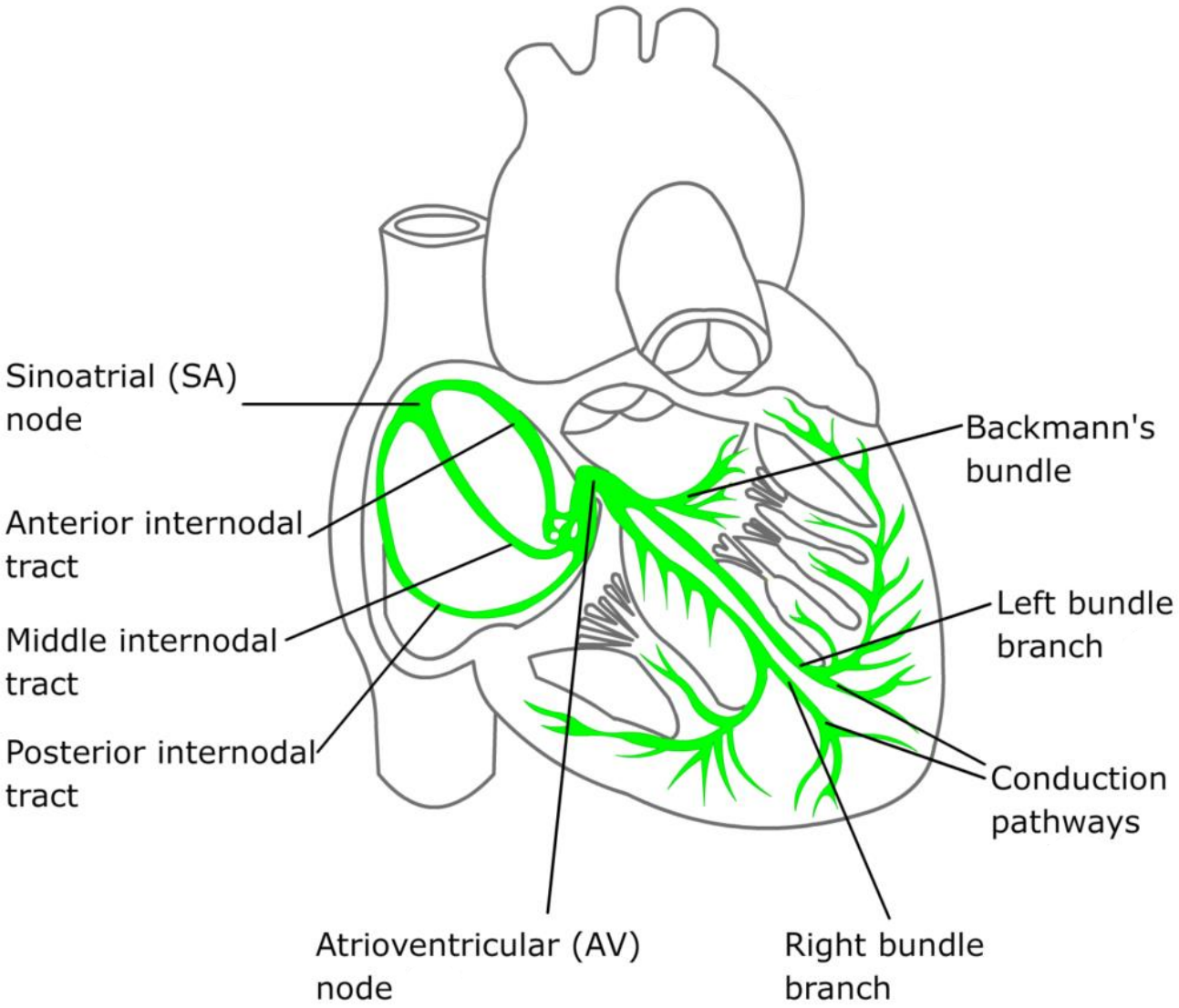
The innervation of the heart, which is a visceral motor innervation, i.e. orthosympathetic and parasympathetic, serves above all to REGULATE THE HEART RHYTHM, accelerating it or slowing it down.

In particular:

- the orthosympathetic nervous system stimulates and accelerates the heart rate

- the parasympathetic nervous system reduces, slows down the heart rate

CONDUCTION SYSTEM OF HEART



HEART RHYTHM is an intrinsic automatic process that is mediated by an anatomical-functional system called:

CONDUCTION SYSTEM of HEART

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Anatomical structures that allow that
the action potential – or depolarization –
is produced in a rhythmic manner and is regularly conducted into the heart

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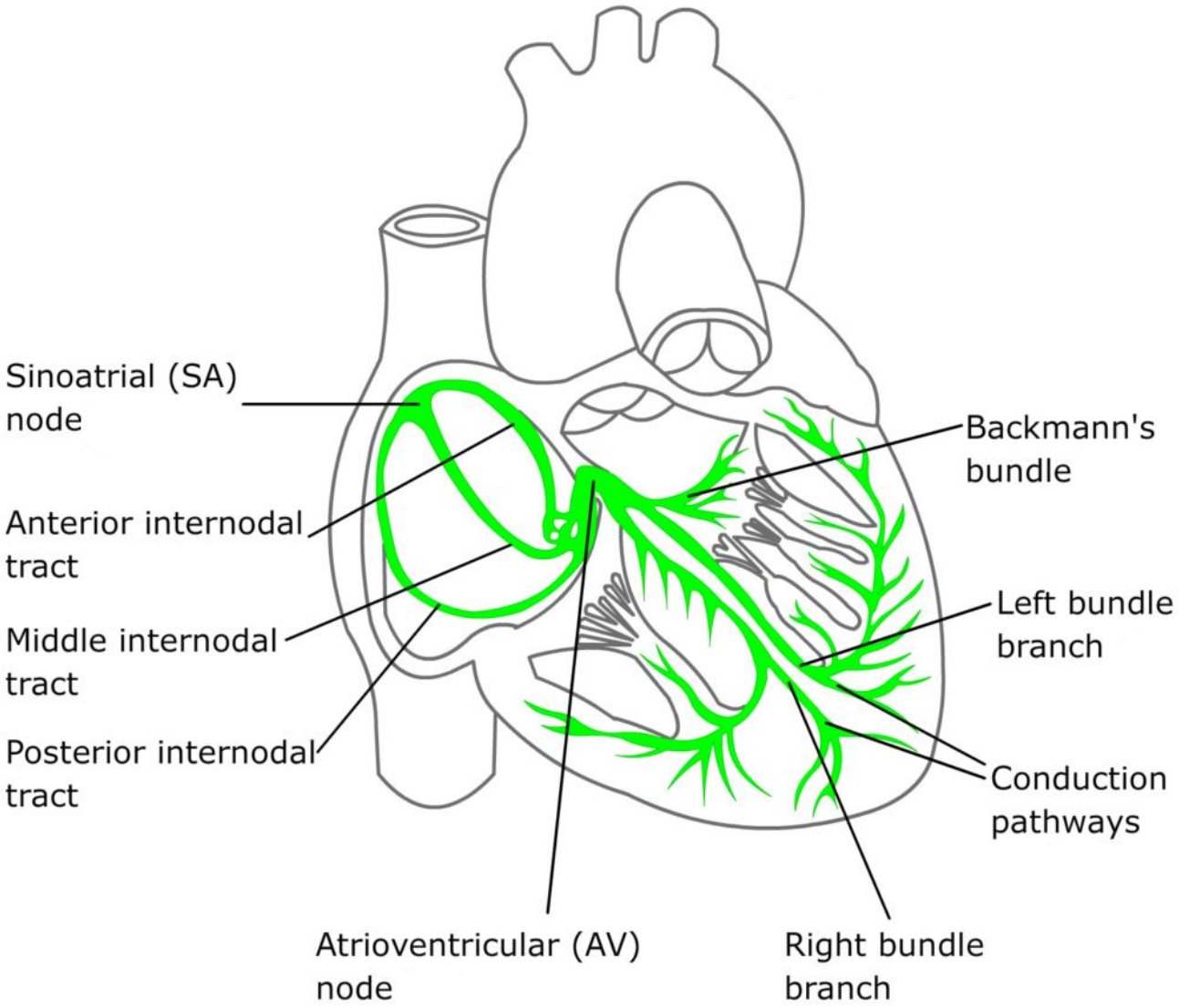
This system assures that
THE ATRIA CONTRACT FIRST
and THEN THE VENTRICLES CONTRACT



The cardiac conduction system is located in the walls of the heart chambers and is made up of tissue that is a

SPECIALIZED MYOCARDIAL TISSUE

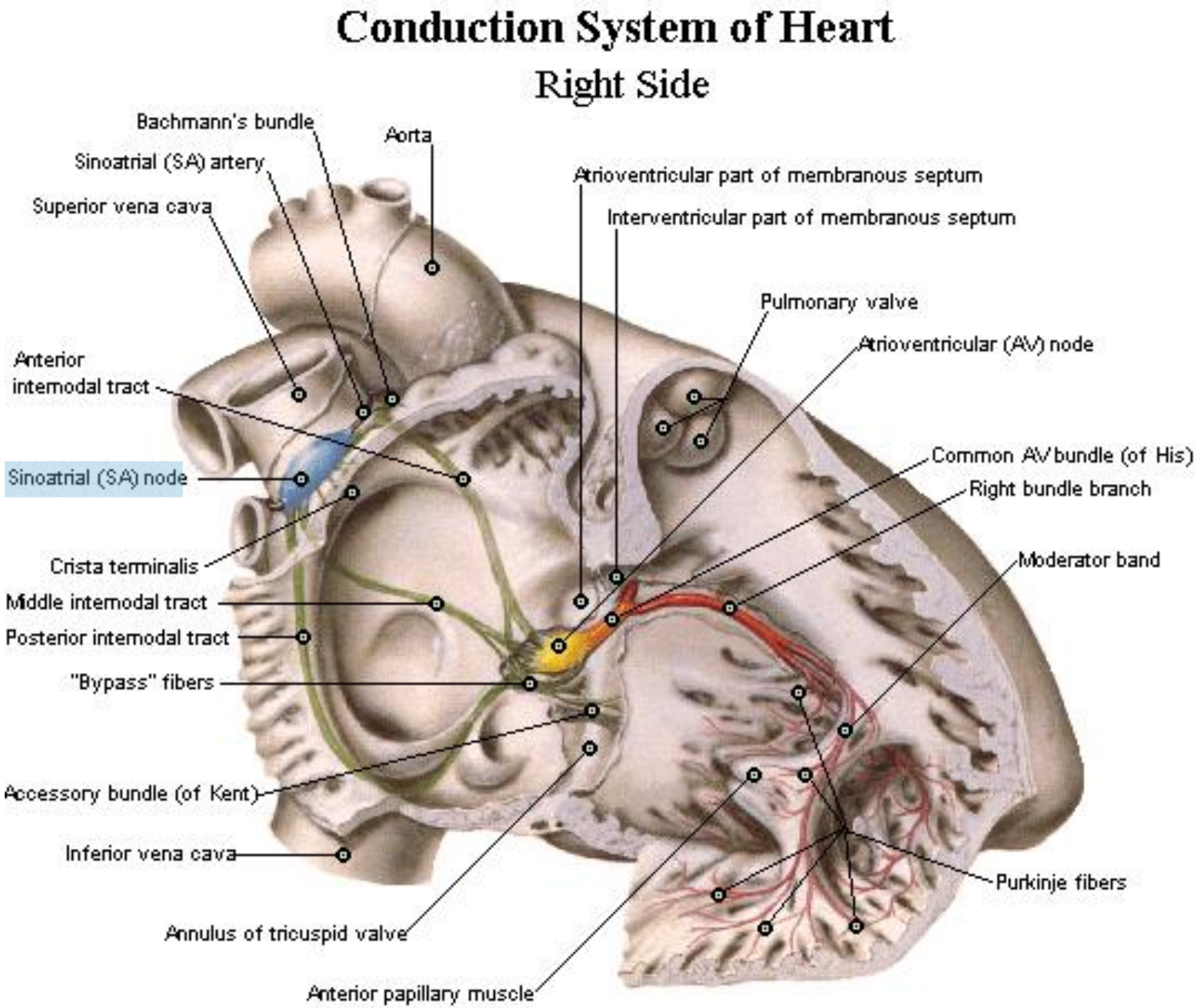
↓

the **SPECIFIC MYOCARDIUM**

These are specialized cardiac muscle fibers, which have the capacity to depolarize in a rhythmic manner (automatism) and the ability to conduct the depolarization

▼

AUTOMATISM and SIGNAL CONDUCTION



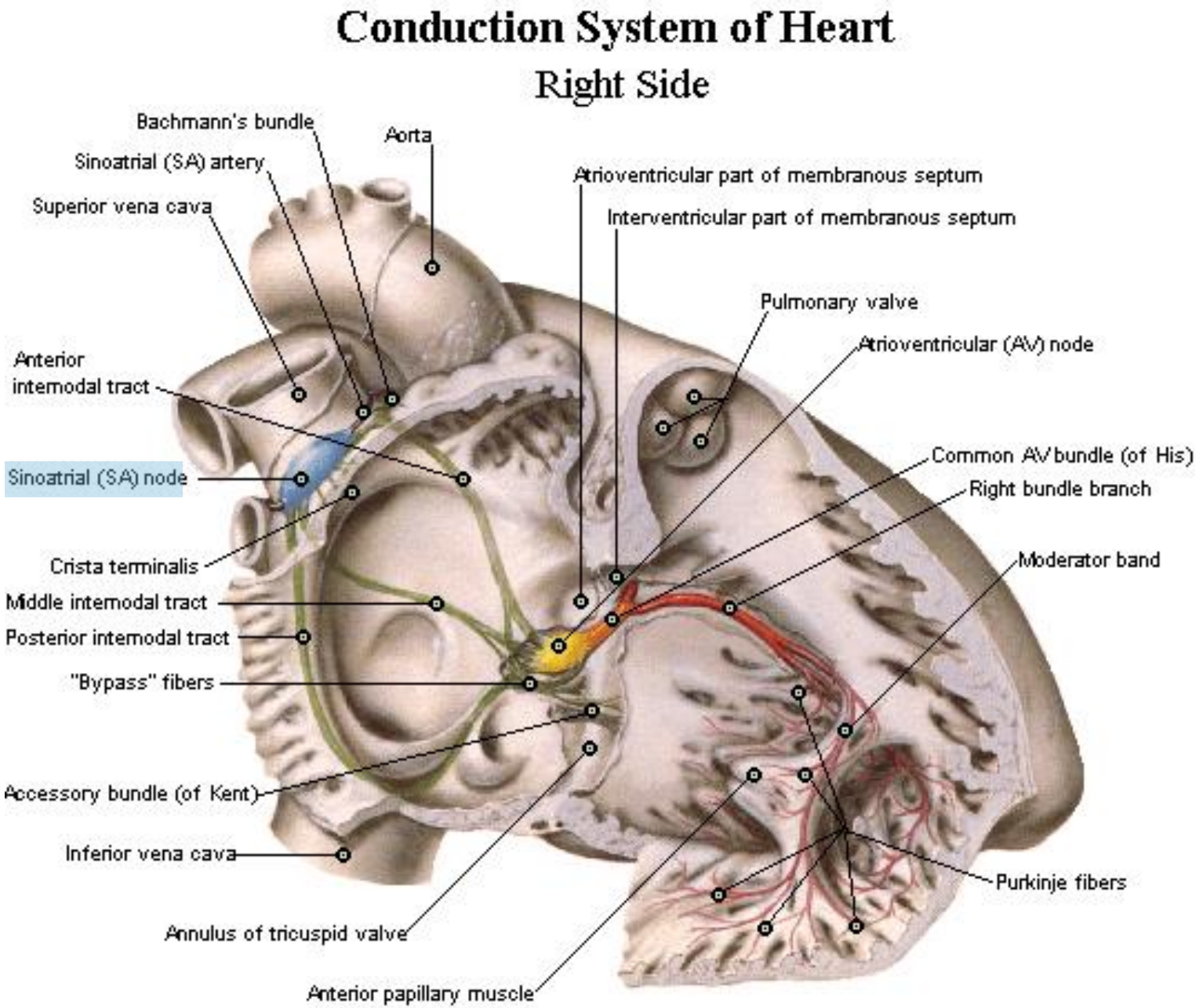
The anatomical structures of the cardiac conduction system are:

1.the **SINOATRIAL NODE**
it is located in the upper back wall of the right atrium, next to the orifice for the SUPERIOR VENA CAVA.
It consists of specialized myocardial tissue and it is the so-called natural pacemaker of the heart

↓

It produces an electrical impulse known as a cardiac action potential, that travels through the electrical conduction system of the heart, causing it to contract.

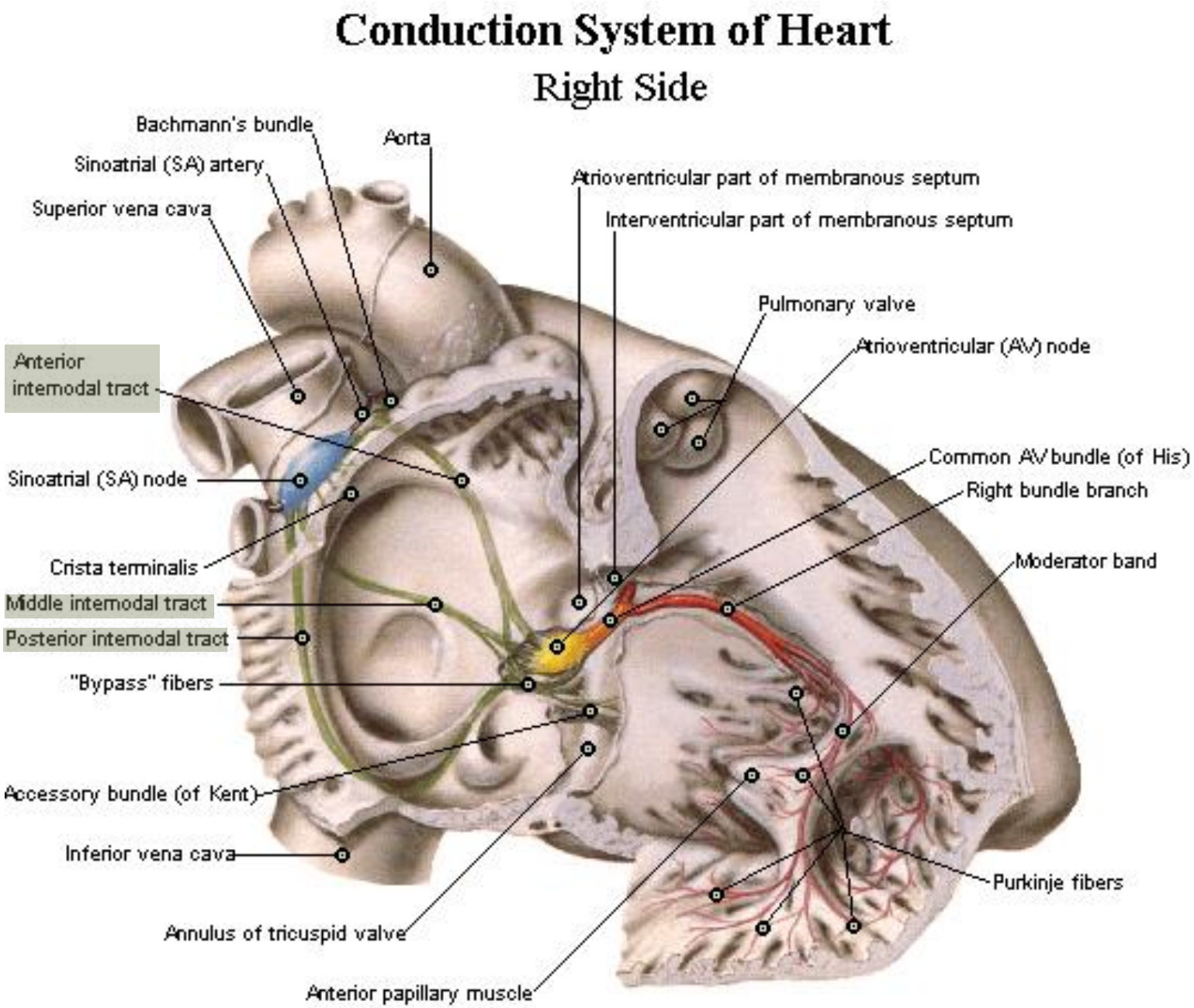
In a healthy heart, it continuously produces action potentials, setting the rhythm of the heart, i.e., it is the structure that gives the heart rhythm, that is, the frequency of rhythmic, automatic depolarization of the heart



WHY?

All components of the cardiac conduction system, but also normal myocardial tissue, have an intrinsic capacity to depolarize in a rhythmic and automatic manner

The sinoatrial node is the structure that sets the heart rhythm because **it is the structure that depolarizes with the highest frequency**, therefore it transmits the depolarization to all the other components of the heart's conduction system



Depolarization is generated by the sinoatrial node, and it is then conducted – through the atrial muscle tissue – throughout the atria

After the sinoatrial node, the muscles of the two atria depolarize simultaneously, and therefore

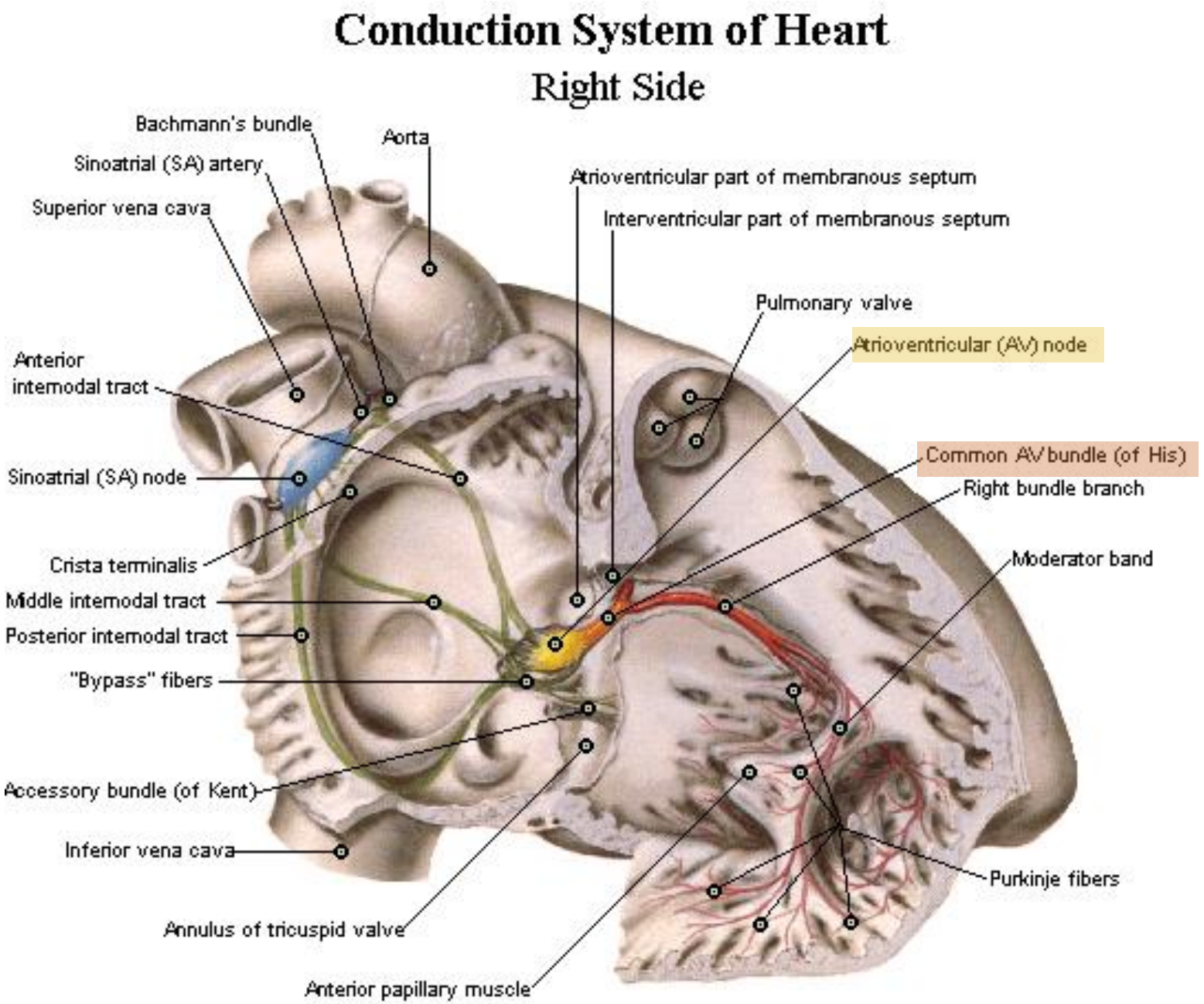
▼

CONTRACTION of the RIGHT and LEFT ATRIUM occurs

The electrical impulse is conducted through
2. the **anterior, mIddle and posterior INTERNODAL TRACTS**

To the next component of the heart conduction system:

3. the **ATRIOVENTRICULAR NODE**



3. the **ATRIOVENTRICULAR NODE**
which is located between atria and ventricles

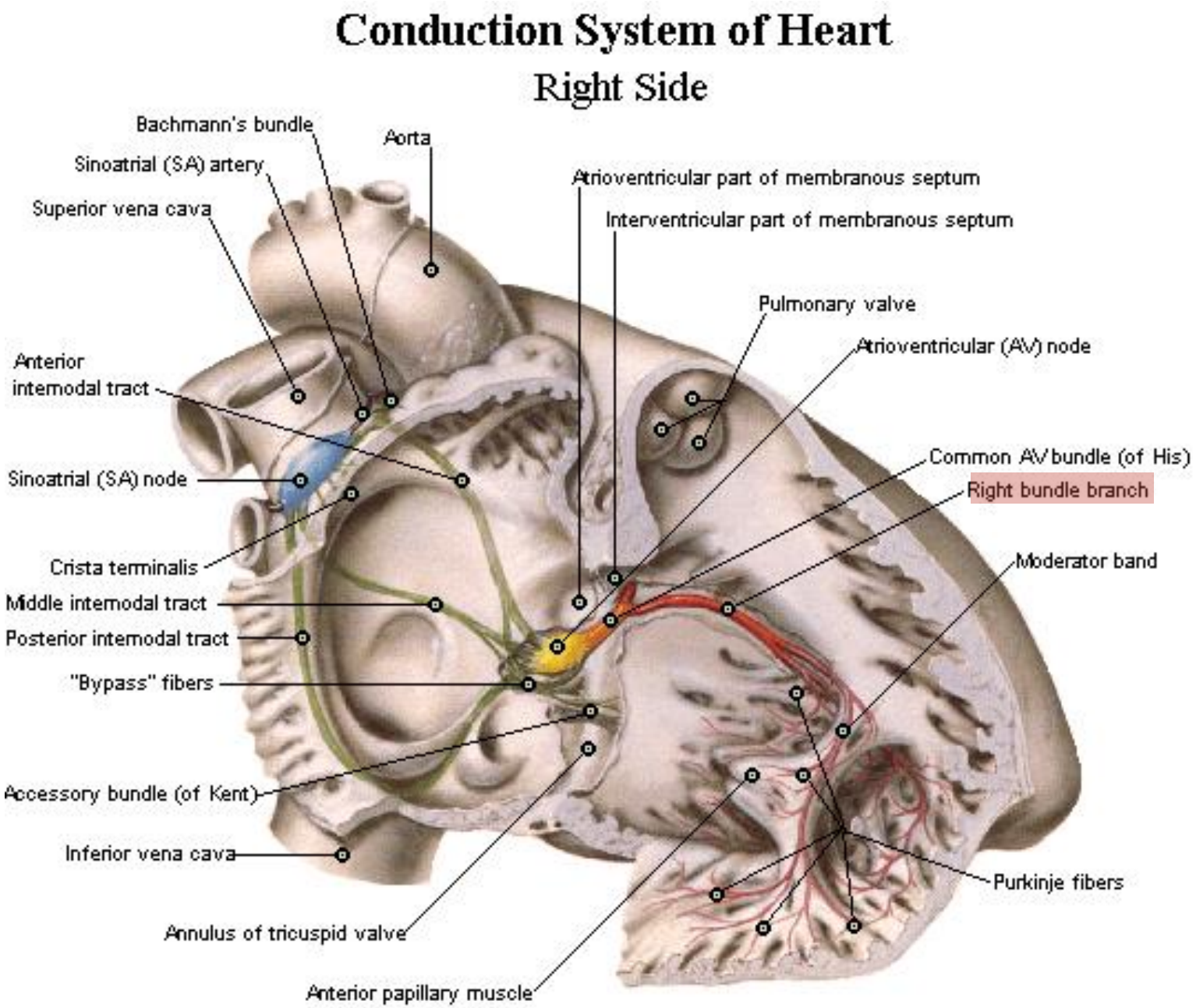
↓

it is still located within the right atrium, lying at the right side of the interatrial septum, on the ATRIAL side of the fibrous ring of the tricuspid valve

Conduction of the electrical impulse reaches the atrioventricular node and continues towards:

4. the **COMMON ATRIOVENTRICULAR BUNDLE (OF HIS)**

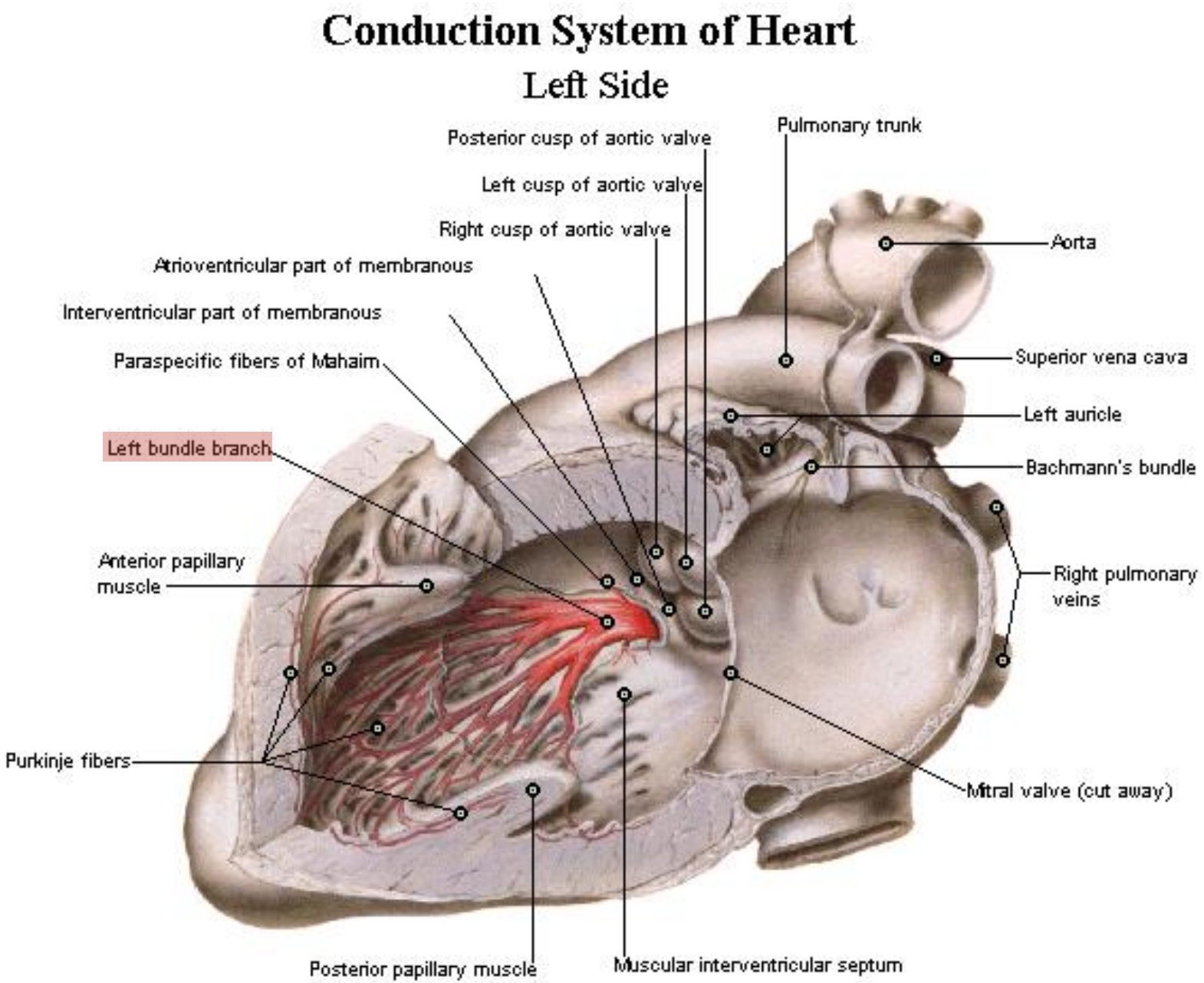
which extends across the fibrous skeleton of the heart, perforating the right fibrous trigone, and passes from the atrial side to the ventricular side



On the ventricle side, the common atrioventricular bundle divides into:

- the right bundle branch

- the left bundle branch



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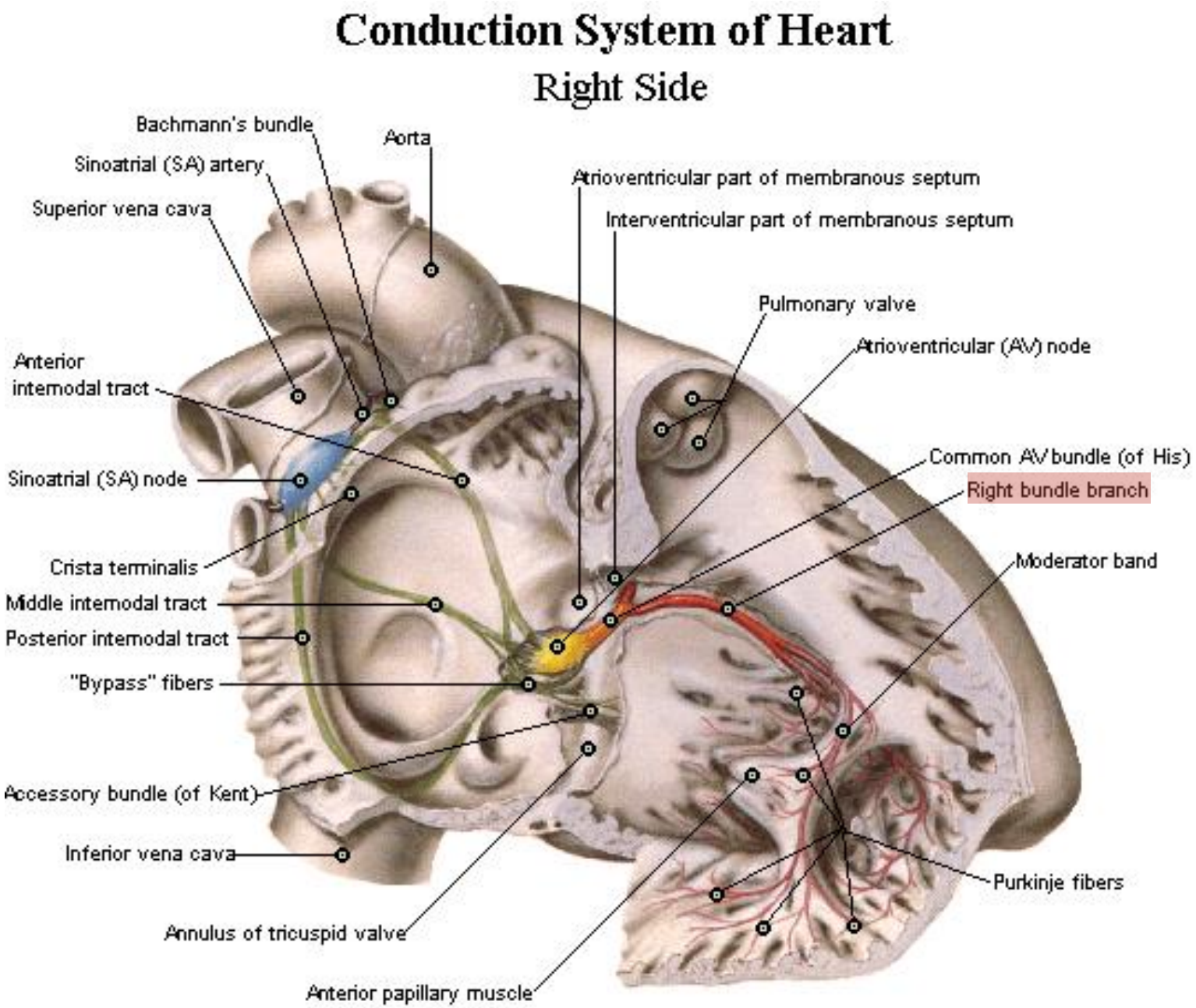


On the ventricle side, the common atrioventricular bundle divides into:

- the right bundle branch

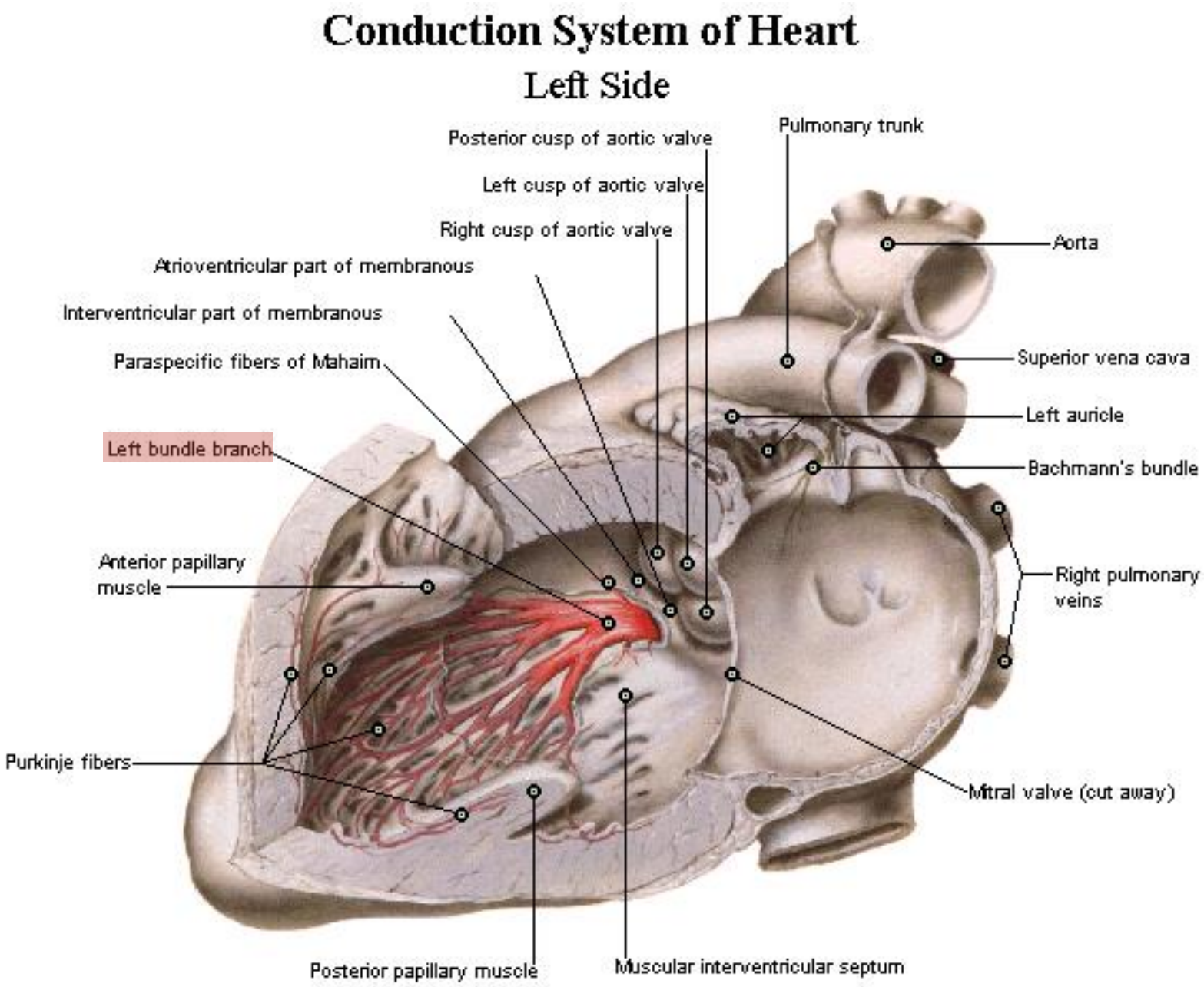
- the left bundle branch

The RIGHT BUNDLE BRANCH descends along the right side of the interventricular septum and also runs along the septomarginal trabecula (along both the septal band and the moderator band)

In particular, at a certain level it divides into smaller branches and a component enters Leonardo da Vinci's moderator band to divide at the level of the anterior papillary muscle

Smaller branches are then distributed along the entire musculature of the right ventricle

THE TRANSMISSION OF THE ELECTRIC IMPULSE THROUGH THE RIGHT BUNDLE BRANCH PRODUCES THE CONTRACTION OF THE RIGHT VENTRICLE



On the ventricle side, the common atrioventricular bundle divides into:

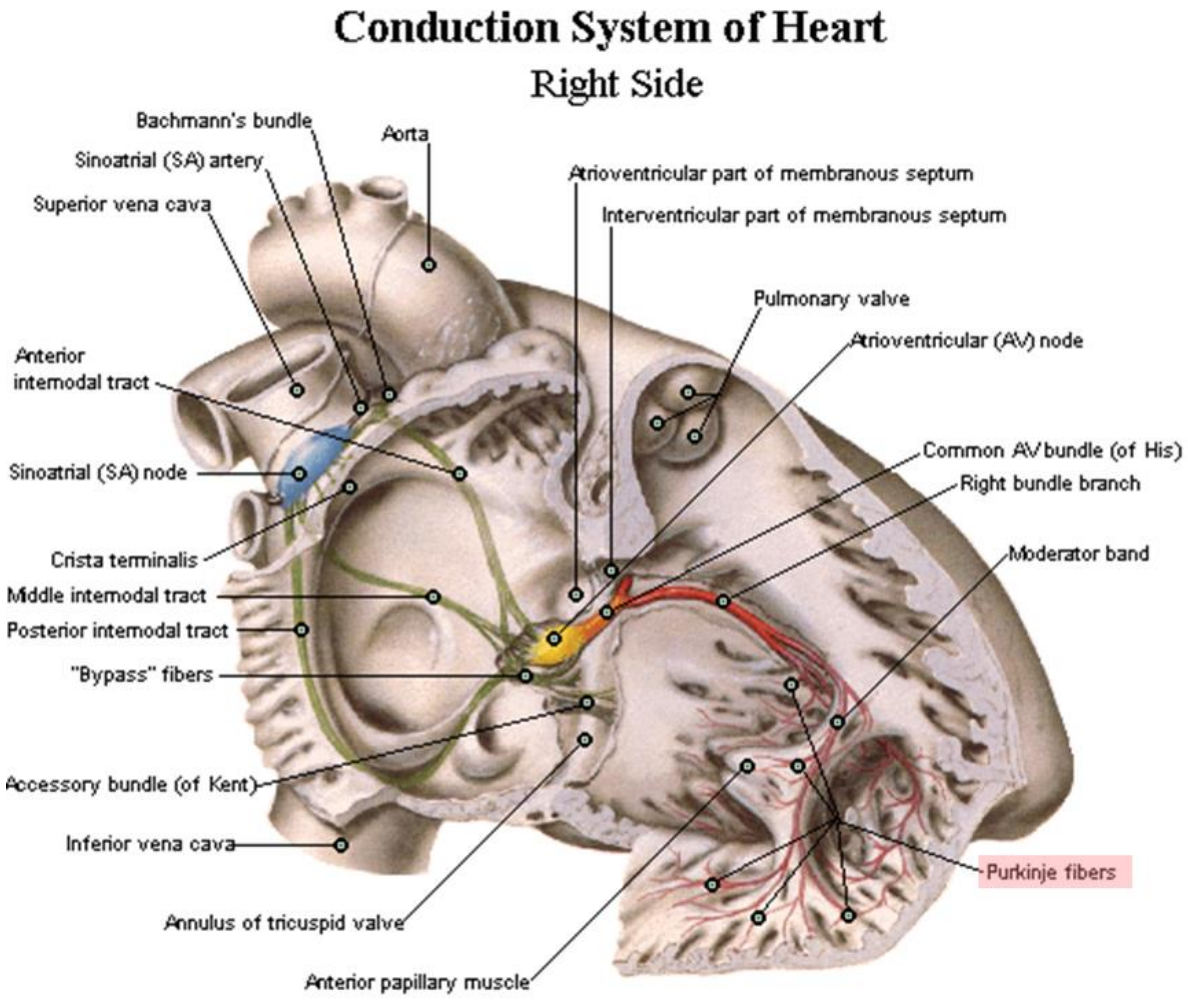
- the right bundle branch

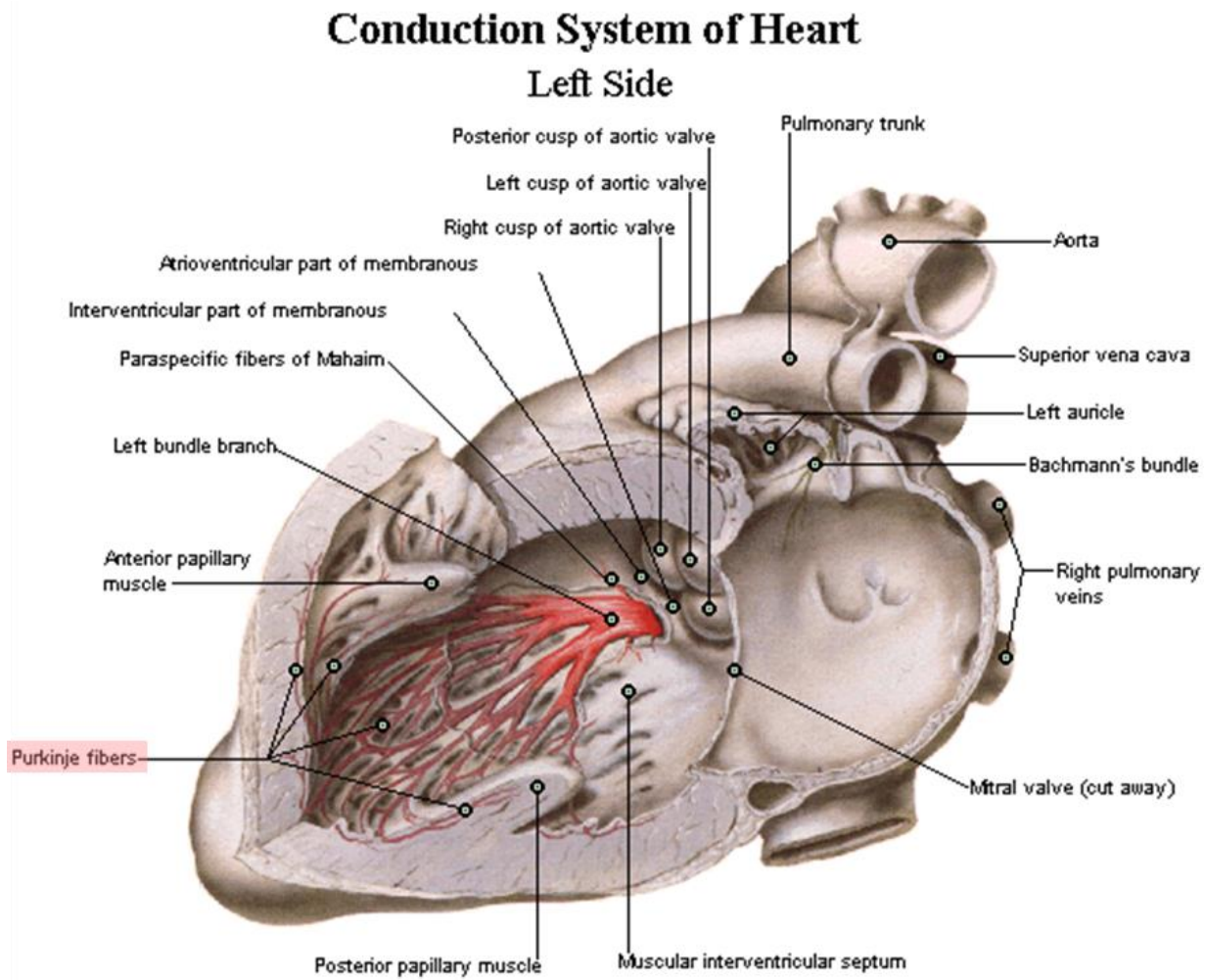
- the left bundle branch

The LEFT BUNDLE BRANCH develops on the left side of the heart, that is on the left side of the interventricular septum

THE TRANSMISSION OF THE ELECTRIC IMPULSE THROUGH THE LEFT BUNDLE BRANCH PRODUCES THE CONTRACTION OF THE LEFT VENTRICLE together with the right ventricle

The left branch is thicker because the muscle wall of the left ventricle is thicker than the muscle wall of the right ventricle

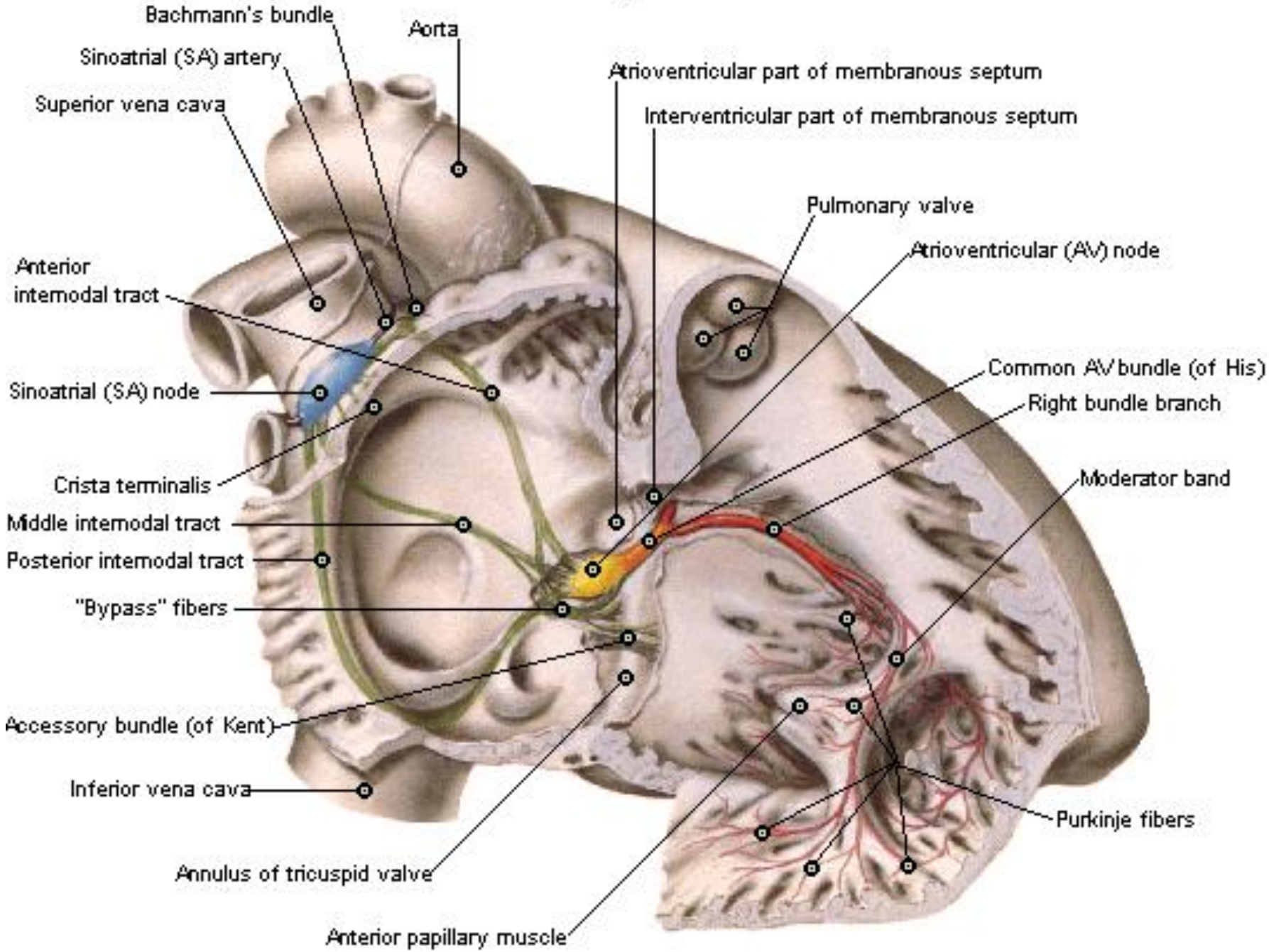




The two branches of the atrioventricular bundle will divide into a whole series of smaller branches, until arriving at a network of cells which are called:

4. **PURKINJE CELLS**
which are located within the right and left ventricular wall thickness, and are the last component of the cardiac conduction system

Right Side


Bachmann's bundle
Aorta
Sinoatrial (SA) artery
Atrioventricular part of membranous septum
Superior vena cava
Interventricular part of membranous septum
Pulmonary valve
Anterior internodal tract
Atrioventricular (AV) node
Common AV bundle (of His)
Sinoatrial (SA) node
Right bundle branch
Moderator band
Crista terminalis
Middle internodal tract
Posterior internodal tract
"Bypass" fibers
Accessory bundle (of Kent)
Inferior vena cava
Purkinje fibers
Annulus of tricuspid valve
Anterior papillary muscle

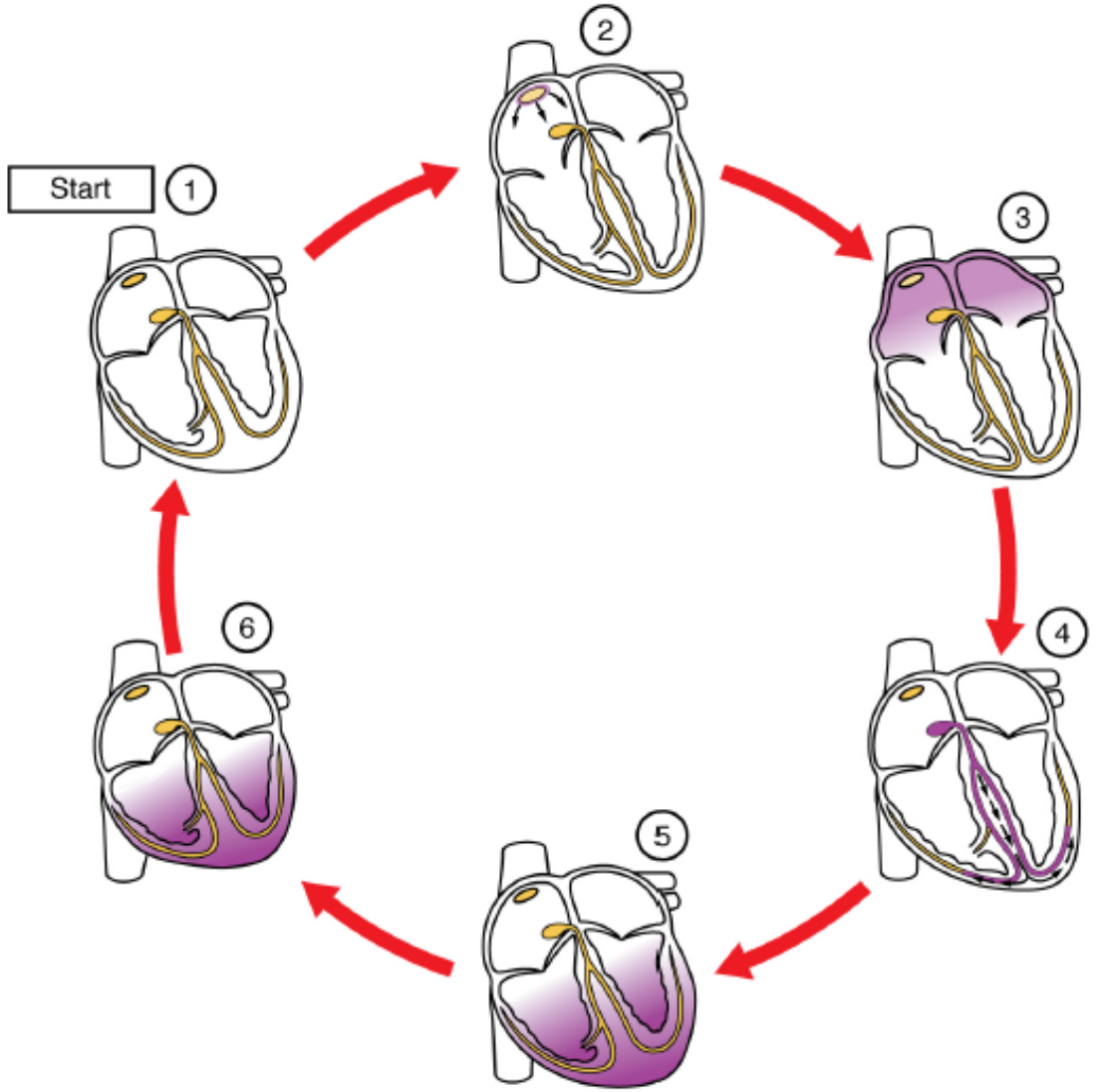


FIGURE 19.19 **Cardiac Conduction** (1) The sinoatrial (SA) node and the remainder of the conduction system are at rest. (2) The SA node initiates the action potential, which sweeps across the atria. (3) After reaching the atrioventricular node, there is a delay of approximately 100 ms that allows the atria to complete pumping blood before the impulse is transmitted to the atrioventricular bundle. (4) Following the delay, the impulse travels through the atrioventricular bundle and bundle branches to the Purkinje fibers, and also reaches the right papillary muscle via the moderator band. (5) The impulse spreads to the contractile fibers of the ventricle. (6) Ventricular contraction begins.

We can talk about:
- AUTOMATISM at the sinoatrial node
- CARDIAC IMPULSE CONDUCTION through the other components of the heart conduction system

At the atrioventricular node and common atrioventricular bundle the impulse conduction SLOWS DOWN

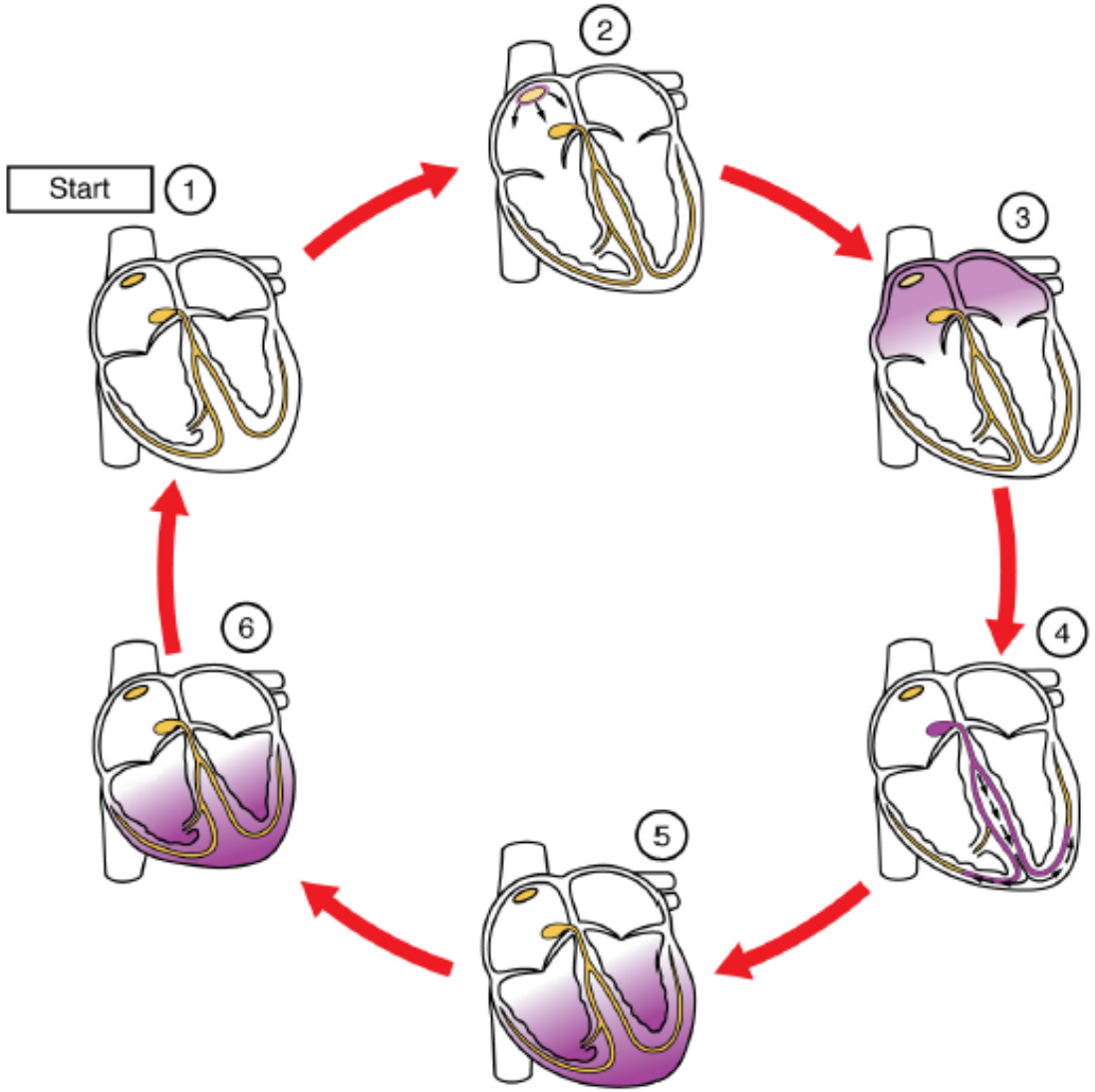
- The depolarization of the sinoatrial node occurs
- This is followed by the almost immediate and simultaneous depolarization of the right and left atria
- Then the depolarization reaches the atrioventricular node and the His bundle, where THE CONDUCTION IS SLOWED DOWN

↓

THE FIBROUS SKELETON OF THE HEART
IS AN ELECTRICAL INSULATOR
BETWEEN ATRIA AND VENTRICLES

↓

Atrial depolarization can reach the ventricles by ONLY ONE PATHWAY, which is the His bundle crossing the fibrous trigone of the cardiac skeleton



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The slowed impulse conduction at the level of the atrioventricular node and the His bundle is responsible for

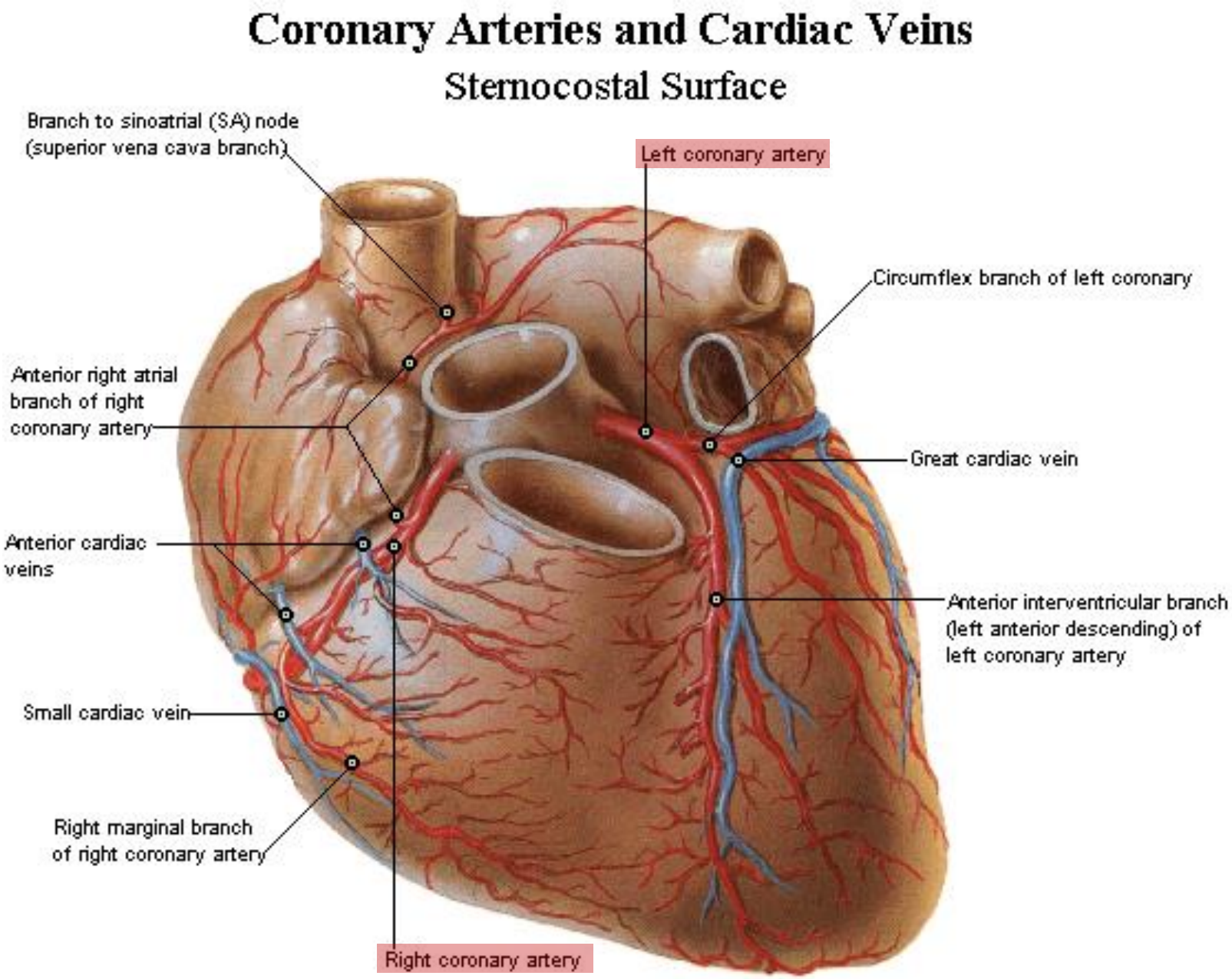
A DELAIED DEPOLARIZATION OF THE VENTRICLES
which is the basis of
↓
the ASYNCHRONOUS CONTRACTION of ATRIA and VENTRICLES
(= atrial systole and ventricular systole occur one after the other)

This is the ANATOMICAL BASIS of the functionality of ALTERNATE DEPOLARIZATION BETWEEN ATRIA AND VENTRICLES, i.e. of a normal HEART RHYTHM

Normally at rest, as the electrical impulse moves through the heart, the heart contracts about 60 to 100 times a minute, depending on a person's age.

Each contraction of the ventricles represents one heartbeat. The atria contract a fraction of a second before the ventricles so their blood empties into the ventricles before the ventricles contract.

HEART VASCULARIZATION

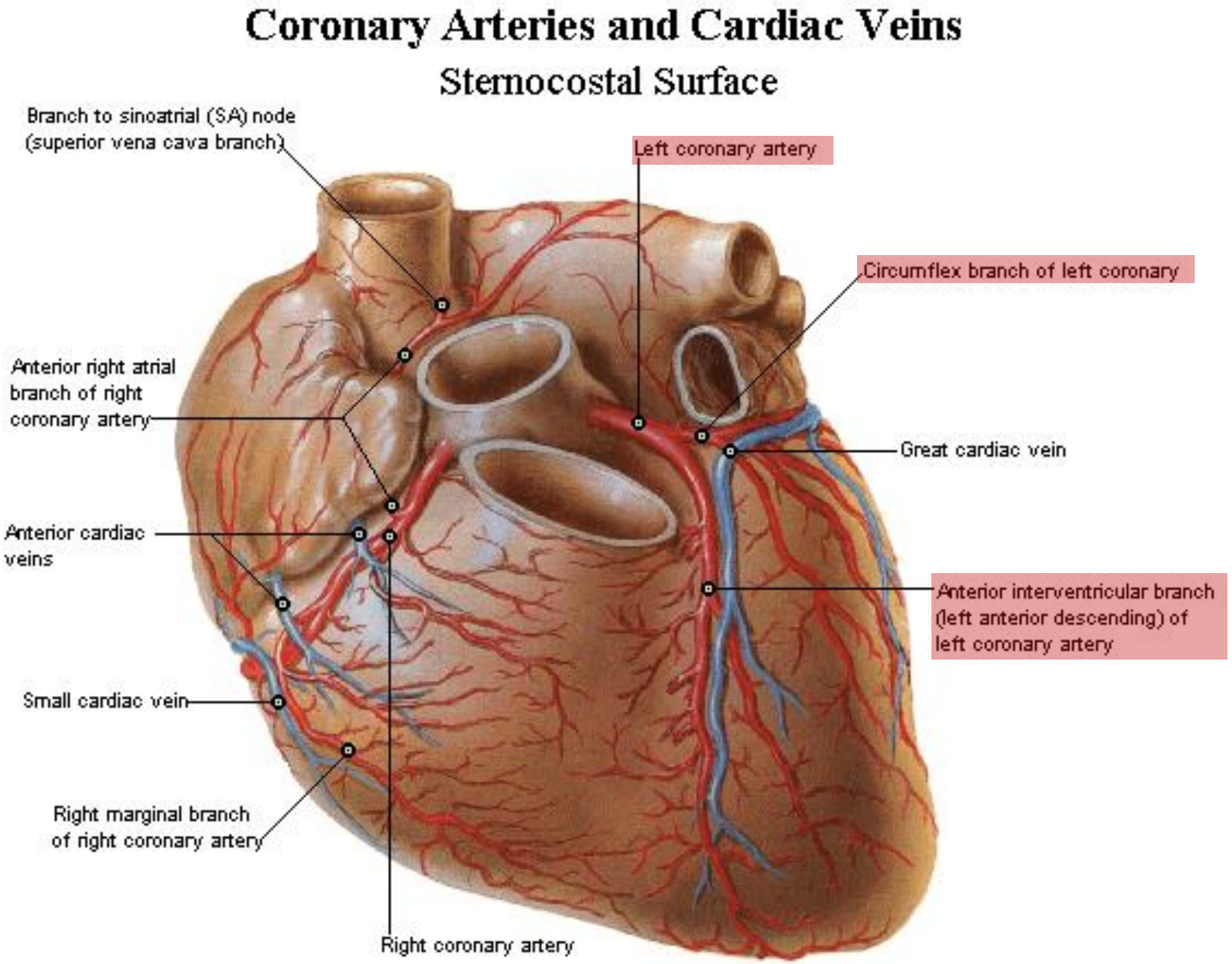


CORONARY ARTERIES

There are 2 coronary arteries (colored red in the figure):

- RIGHT CORONARY ARTERY
- LEFT CORONARY ARTERY

They originate from the ASCENDING AORTA, respectively from the RIGHT and LEFT VALSALVA SINUS



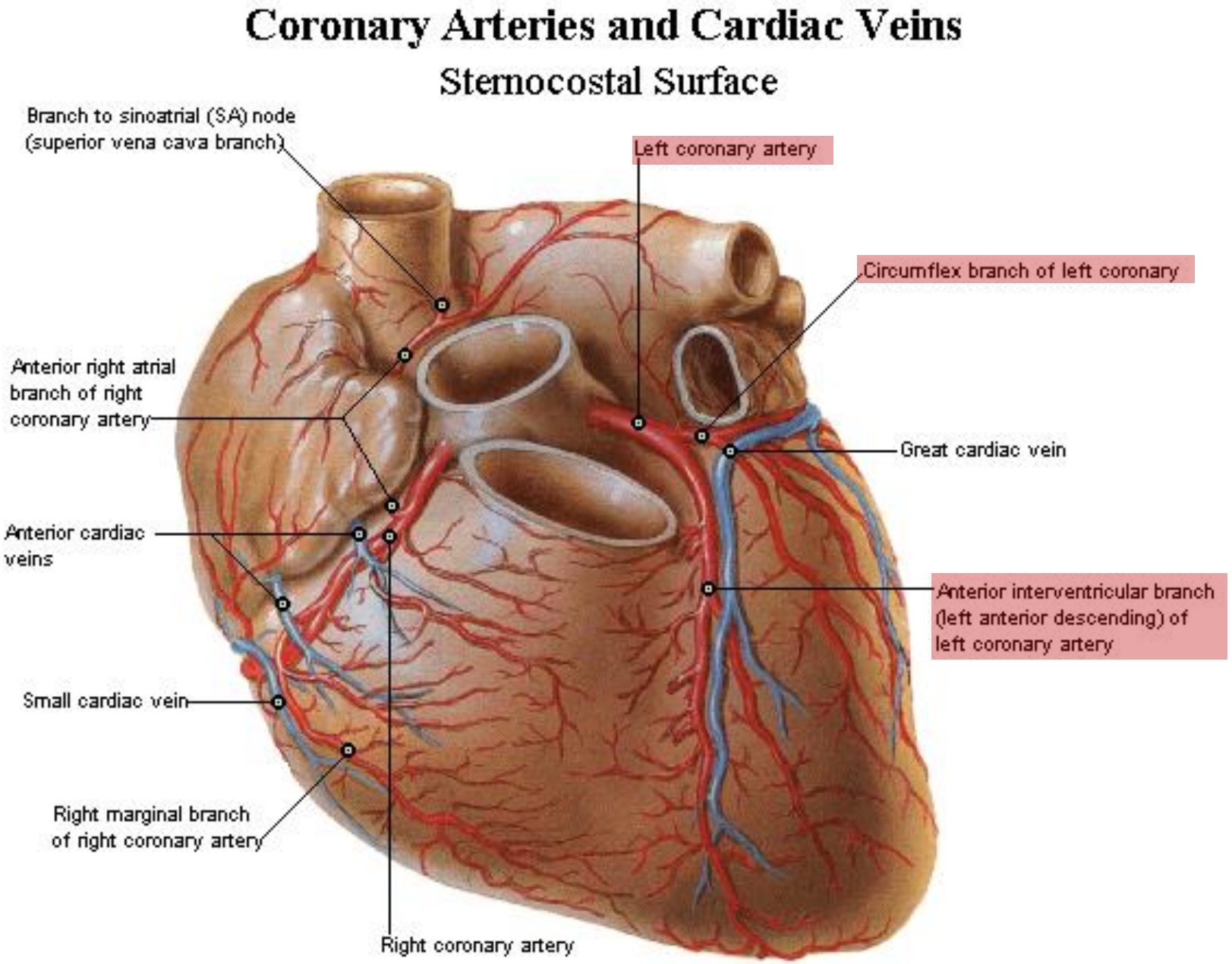
Course of
CORONARY ARTERIES
(sternocostal surface of the heart)

LEFT CORONARY ARTERY

- It originates from the ASCENDING AORTA at the level of the LEFT SINUS of VALSALVA
- It presents an initial trunk, called COMMON TRUNK of the left coronary artery, which directs towards the atrioventricular sulcus
- at the level of this sulcus, it divides into 2 branches:

1. LEFT ANTERIOR DESCENDING BRANCH or ANTERIOR INTERVENTRICULAR BRANCH

2. CIRCUMFLEX BRANCH



Course of
CORONARY ARTERIES
(sternocostal surface of the heart)

LEFT CORONARY ARTERY

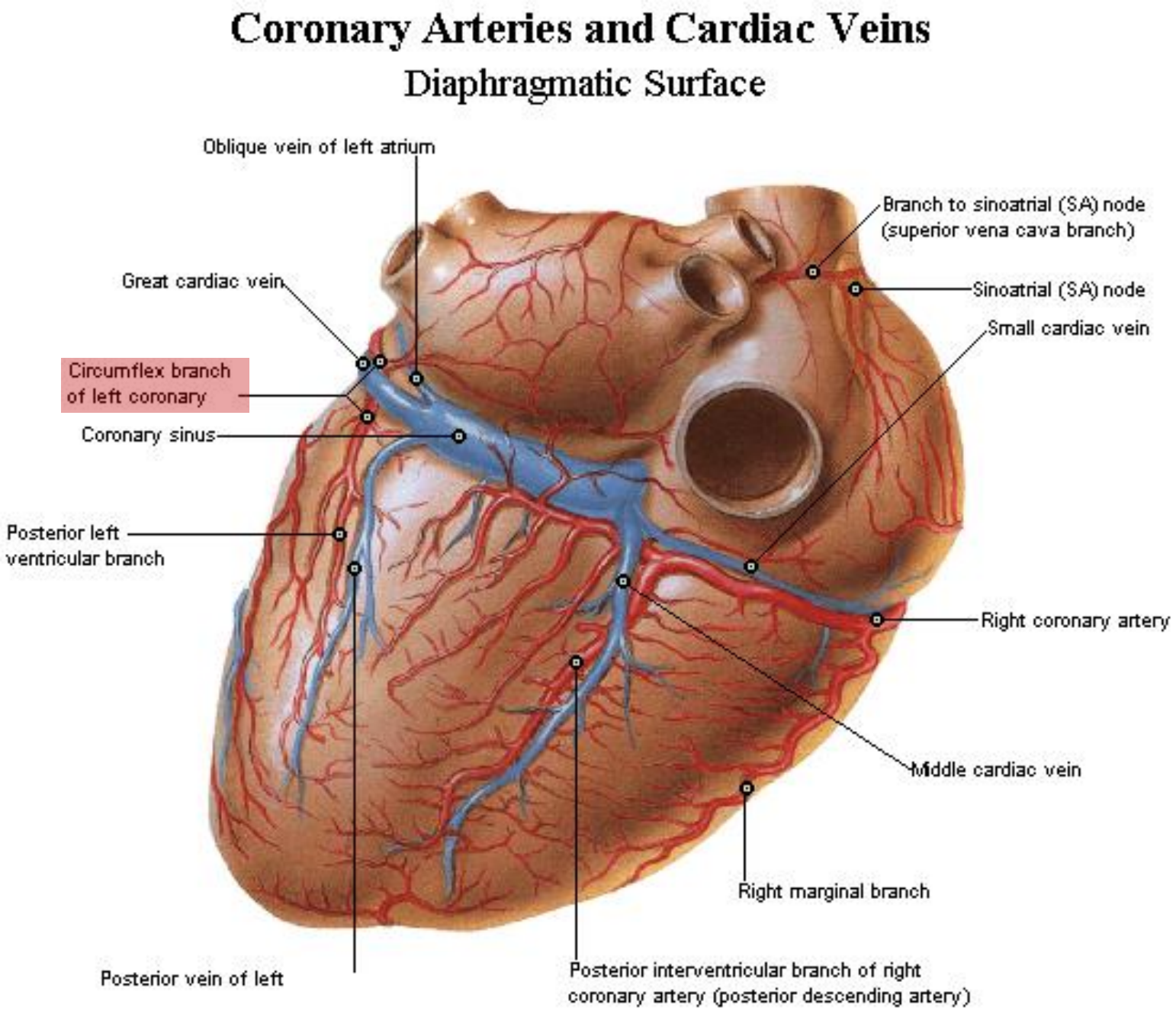
1. ANTERIOR DESCENDING BRANCH or ANTERIOR INTERVENTRICULAR BRANCH:

- It descends and runs along the anterior interventricular sulcus

- It descends towards the apex, arriving next to the acute margin of the heart, where it ends by dividing into its last branches

2. CIRCUMFLEX BRANCH:

- It runs along the atrioventricular sulcus, on the left anterior side (between the left atrium and left ventricle)



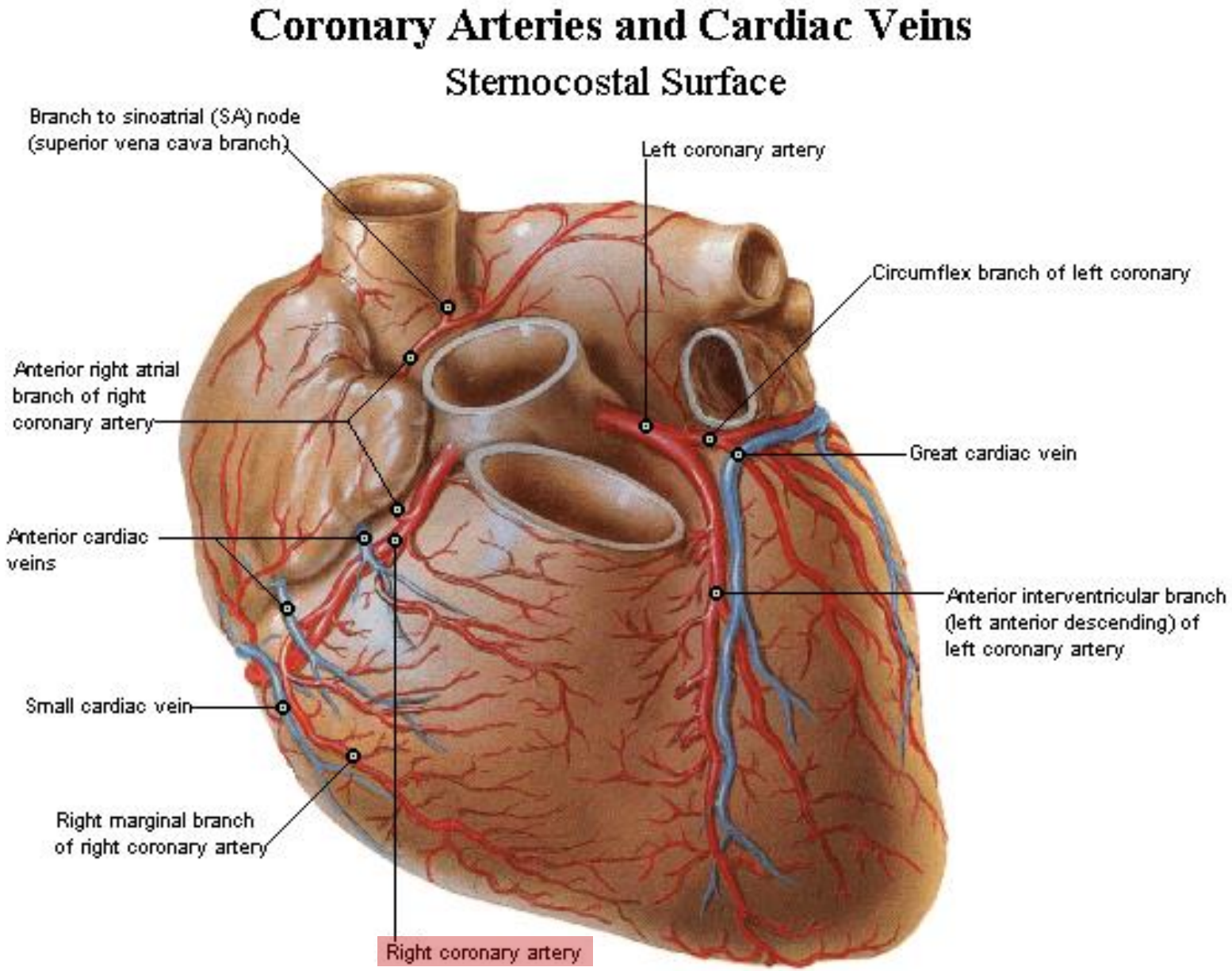
Course of
CORONARY ARTERIES
(diaphragmatic surface of the heart)

LEFT CORONARY ARTERY

2. CIRCUMFLEX BRANCH:
   - It runs along the atrioventricular sulcus on the left anterior side (between the left atrium and left ventricle)

   - It goes beyond the obtuse margin of the heart, continuing to run along the posterior side of the atrioventricular sulcus, always between the left chambers of the heart

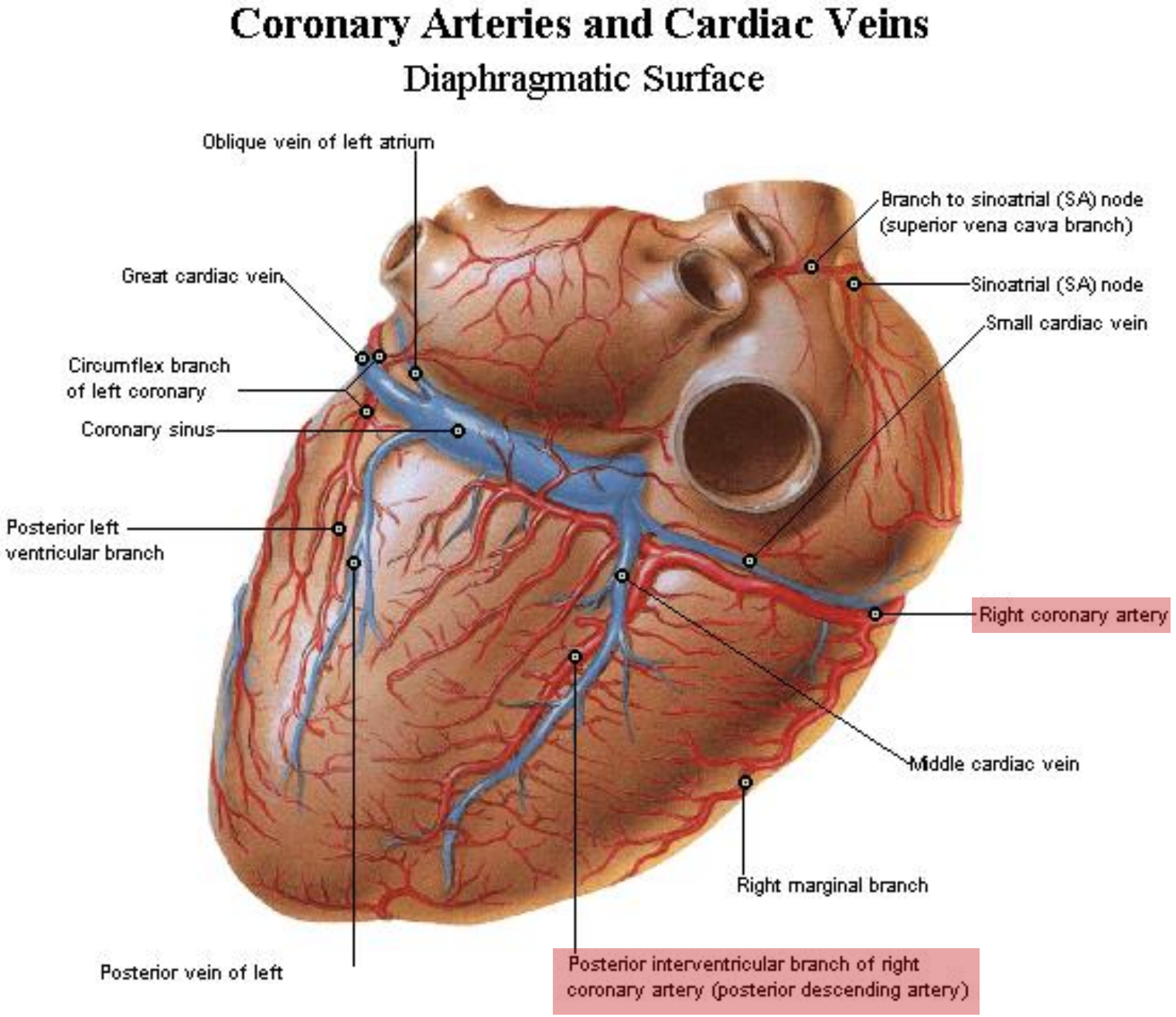
   - It runs on the posterior side of the atrioventricular sulcus for until it ends, producing branches mainly towards the ventricles



Course of
CORONARY ARTERIES
(sternocostal surface of the heart)

RIGHT CORONARY ARTERY

- It originates from the ASCENDING AORTA at the level of the RIGHT SINUS of VALSALVA
- It directs towards the right, running along the right atrioventricular sulcus on the anterior side, between the right chambers of the heart
- It overcomes the acute margin of the heart



Course of
CORONARY ARTERIES
(diaphragmatic surface of the heart)

RIGHT CORONARY ARTERY

- It overcomes the acute margin of the heart and continues its course on the posterior side of the atrioventricular sulcus, between the right atrium and the right ventricle
- It reaches the so-called CRUX CORDIS (= “cross of the heart”, or the crossing point between the atrioventricular sulcus and the posterior interventricular sulcus)
- from here, it continues its course along the posterior atrioventricular sulcus, also running between the left atrium and left ventricle
- moreover, from the *crux cordis*, it produces a collateral branch which is called the
  POSTERIOR INTERVENTRICULAR BRANCH
  or POSTERIOR DESCENDING BRANCH

  It corresponds to the anterior interventricular branch