THE CARDIOVASCULAR SYSTEM
CARDIAC SKELETON
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.
The structures that form the cardiac skeleton are:

- **the FIBROUS TRIGONES**

  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
The structures that form the cardiac skeleton are: the CONUS LIGAMENT

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.
The structures that form the cardiac skeleton are:

the **MEMBRANOUS PORTION** of the interventricular septum

It is the portion that faces the atria, being formed by connective tissue and not by muscular tissue.
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

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

**CONDUCTION SYSTEM of HEART**

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

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.
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

\[\text{CONTRACTION of the RIGHT and LEFT ATRIUM occurs}\]

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

*A DELAYED 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.
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
(sterneocostal 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)
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
Coronary Arteries and Cardiac Veins
Sternocostal Surface

**Course of CORONARY ARTERIES**
(sternocostal surface of the heart)

- 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.
Coronary Arteries and Cardiac Veins
Diaphragmatic Surface

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.*