Lecture 8

The Cardiovascular System

1. Introduction

The cardiovascular system is a vital network responsible for the circulation of blood, ensuring delivery of oxygen and nutrients to tissues and removal of metabolic waste. The **heart** acts as the central pump, generating pressure to circulate blood through the **systemic** and **pulmonary circuits**, while the **vessels** form an extensive network of arteries, veins, and capillaries that direct blood to all parts of the body. Understanding its structure and function is essential in sports science, as cardiac output and vascular efficiency directly affect exercise performance, endurance, and recovery.

2. Heart: Location and General Orientation

The heart lies in the **mediastinum**, posterior to the sternum and between the lungs, resting on the **diaphragm**. Its apex points **inferiorly, anteriorly, and to the left**, producing the **apical impulse** at the fifth intercostal space along the midclavicular line, while its base is oriented **posteriorly and superiorly**, receiving the **pulmonary veins** and the **superior and inferior vena cava**. Approximately **two-thirds of the heart** is to the left of the midline and one-third to the right. This orientation is essential for understanding relationships between chambers, valves, and great vessels.

3. Heart: Structure of the Wall

The heart wall consists of **three layers**, each with a specific role:

Epicardium: outer layer corresponding to the **visceral layer of the serous pericardium**, containing coronary vessels and fat for protection.

·**Fibrous pericardium**: tough, outer layer, anchors the heart.

·**Serous pericardium**: parietal and visceral layers; pericardial cavity between them with lubricating fluid.

·**Myocardium**: thick muscular layer responsible for contraction; the **left ventricle** is the thickest due to systemic pressure requirements.

·Thick middle muscular layer.

·Responsible for contraction of the heart.

·Left ventricle has the thickest myocardium.

Endocardium: smooth inner lining of chambers and valves, reducing friction and supporting valvular function.

·Innermost layer, lining the heart chambers and valves.

·Composed of endothelium and subendothelial connective tissue.

·Provides a smooth surface for blood flow.

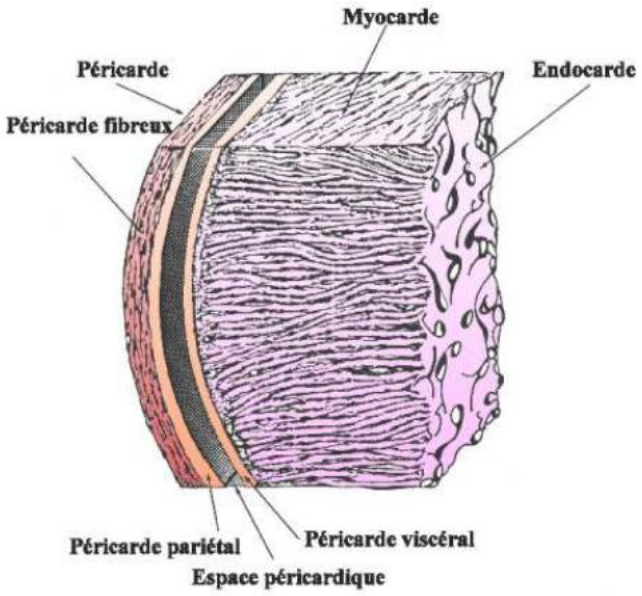

Figure n° 04 : Structure de la paroi cardiaque

4. Heart: External Configuration

The heart has a **conical or pyramidal shape** with defined **apex, base, surfaces, and borders**.

·**Shape**: The heart is roughly a triangular pyramid with a base, apex, and three surfaces (sternocostal, diaphragmatic, and pulmonary).

·**Base**: Broad, posterior aspect, directed toward the vertebral column, mainly formed by the atria, particularly the left atrium.

·**Apex (apex cordis)**: Formed by the tip of the left ventricle, pointing downwards, forwards, and to the left, located near the 5th intercostal space.

Surfaces:

·*Sternocostal*: faces anteriorly, mainly right ventricle.

·*Diaphragmatic*: rests on the diaphragm, mainly left ventricle.

·*Pulmonary*: faces the lungs; left surface mainly left ventricle, right surface mainly right atrium.

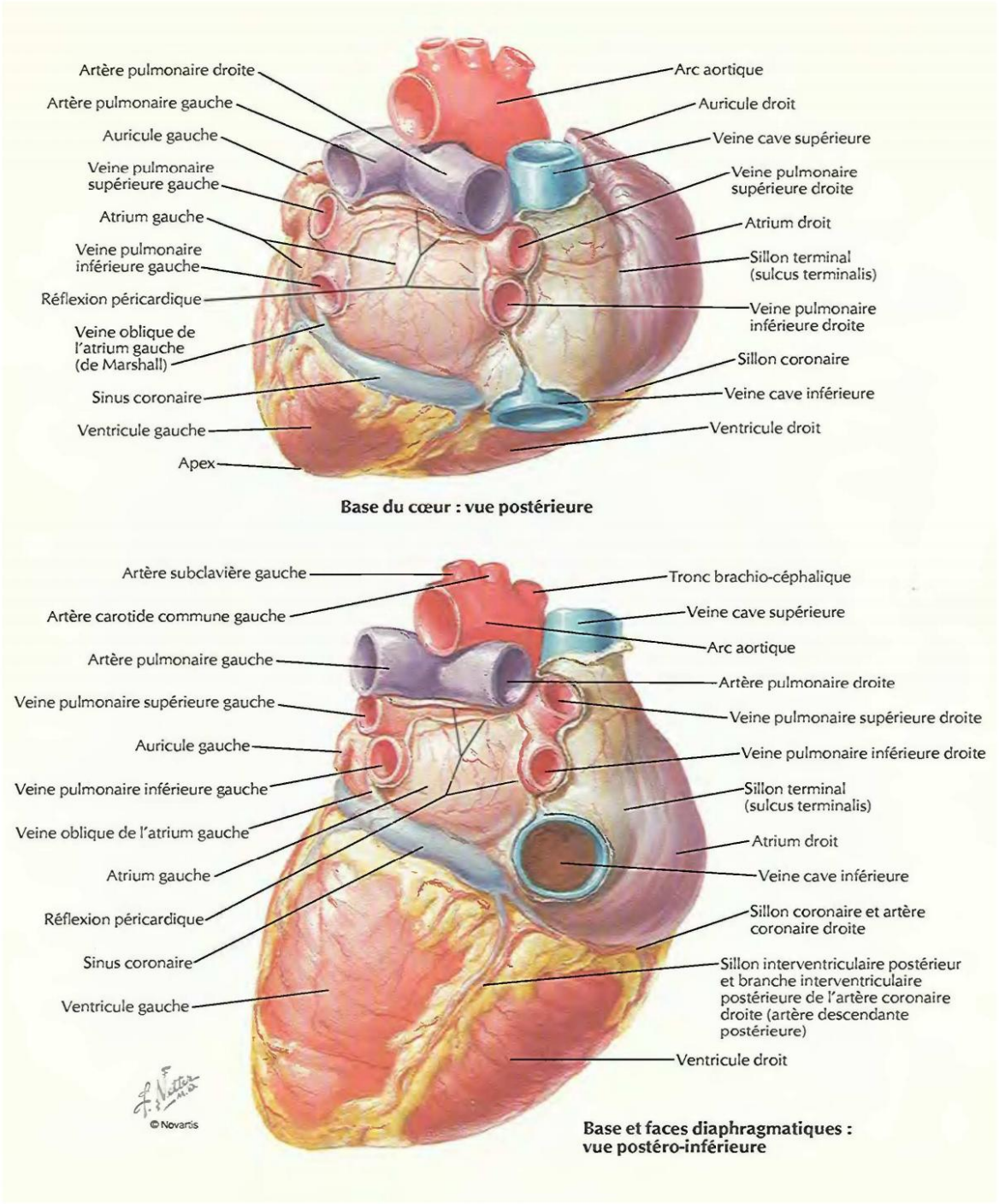

Figure n° 02 : Le cœur (base et face diaphragmatique)

5. Heart: Internal Configuration

The heart is a **four-chambered organ**, composed of **two atria** and **two ventricles**, separated by septa that prevent the mixing of oxygenated and deoxygenated blood. This internal organization ensures efficient circulation through both the pulmonary and systemic circuits.

Atria – Receiving Chambers

The **atria** are thin-walled chambers that primarily function to **collect blood** returning to the heart.

- **Right atrium**: receives **deoxygenated blood** from the **superior vena cava**, **inferior vena cava**, and **coronary sinus**. It contains the **fossa ovalis**, a remnant of the fetal foramen ovale, and the **pectinate muscles**, which are parallel ridges enhancing atrial contraction. The **crista terminalis** marks the boundary between the smooth and muscular parts of the atrial wall.
- **Left atrium**: receives **oxygenated blood** from the **four pulmonary veins** (two from each lung). The left atrium has smooth walls, with minimal pectinate muscles, and serves as a conduit to the **left ventricle**, ensuring efficient transfer of oxygenated blood to systemic circulation.

Ventricles – Pumping Chambers

The **ventricles** are thick-walled chambers responsible for **propelling blood** into the arteries.

- **Right ventricle**: receives blood from the right atrium through the **tricuspid valve** and pumps it into the **pulmonary trunk**, leading to the lungs. Its wall is thinner than the left ventricle, as it only needs to overcome pulmonary resistance. Internally, it contains **trabeculae carneae**, **papillary muscles**, and **chordae tendineae** which anchor the tricuspid valve. The **conus arteriosus** leads to the pulmonary valve and smooths blood flow into the pulmonary artery.
- **Left ventricle**: receives blood from the left atrium through the **mitral valve** and pumps it into the **aorta**. Its walls are the **thickest of all chambers**, providing the high pressure required for systemic circulation. The left ventricle also contains **trabeculae carneae**, **papillary muscles**, and **chordae tendineae** for the mitral valve, as well as a **smooth outflow tract (aortic vestibule)** leading to the aortic valve.

Valves – Ensuring Unidirectional Flow

The heart valves maintain **unidirectional blood flow** and prevent backflow during contraction:

- **Atrioventricular (AV) valves**: the **tricuspid valve** on the right and the **mitral (bicuspid) valve** on the left. They are anchored by **chordae tendineae** connected to **papillary muscles**, which contract during ventricular systole to prevent valve prolapse.
- **Semilunar valves**: the **pulmonary valve** (right ventricle) and **aortic valve** (left ventricle), located at the ventricular outlets. These valves open during systole to allow ejection and close during diastole to prevent backflow into the ventricles.

6. Heart: Coronary Circulation

The myocardium is supplied by **coronary arteries**:

Right coronary artery (RCA): right atrium, right ventricle, SA and AV nodes

Left coronary artery (LCA): divides into **left anterior descending (LAD)** (anterior interventricular septum and ventricles) and **circumflex artery** (left atrium and ventricle)

Venous return occurs mainly through the **coronary sinus**, with minor drainage via **Thebesian veins**. Knowledge of coronary circulation is essential for understanding ischemia and infarction patterns.

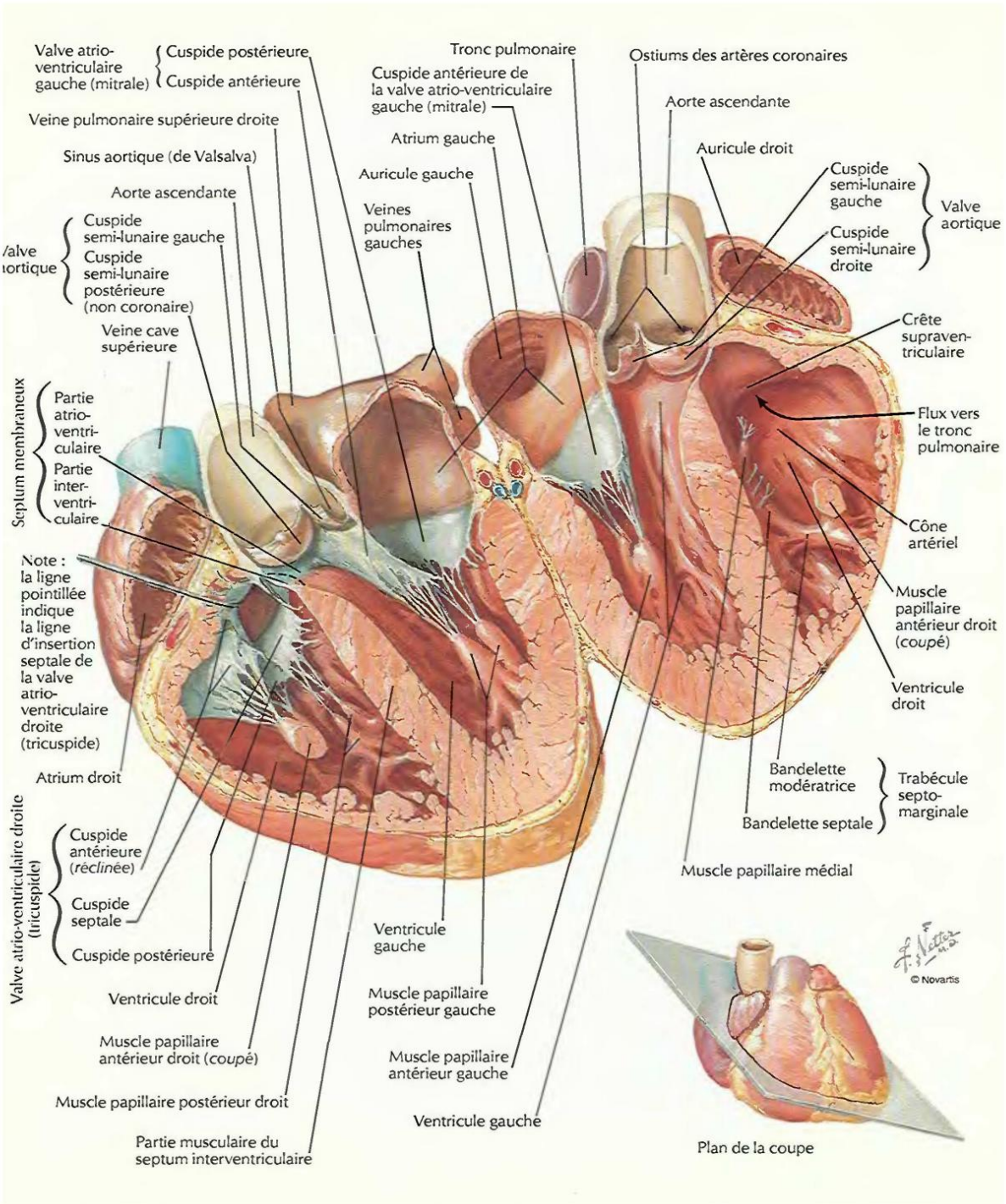

Figure n° 03 : Configuration interne du cœur.

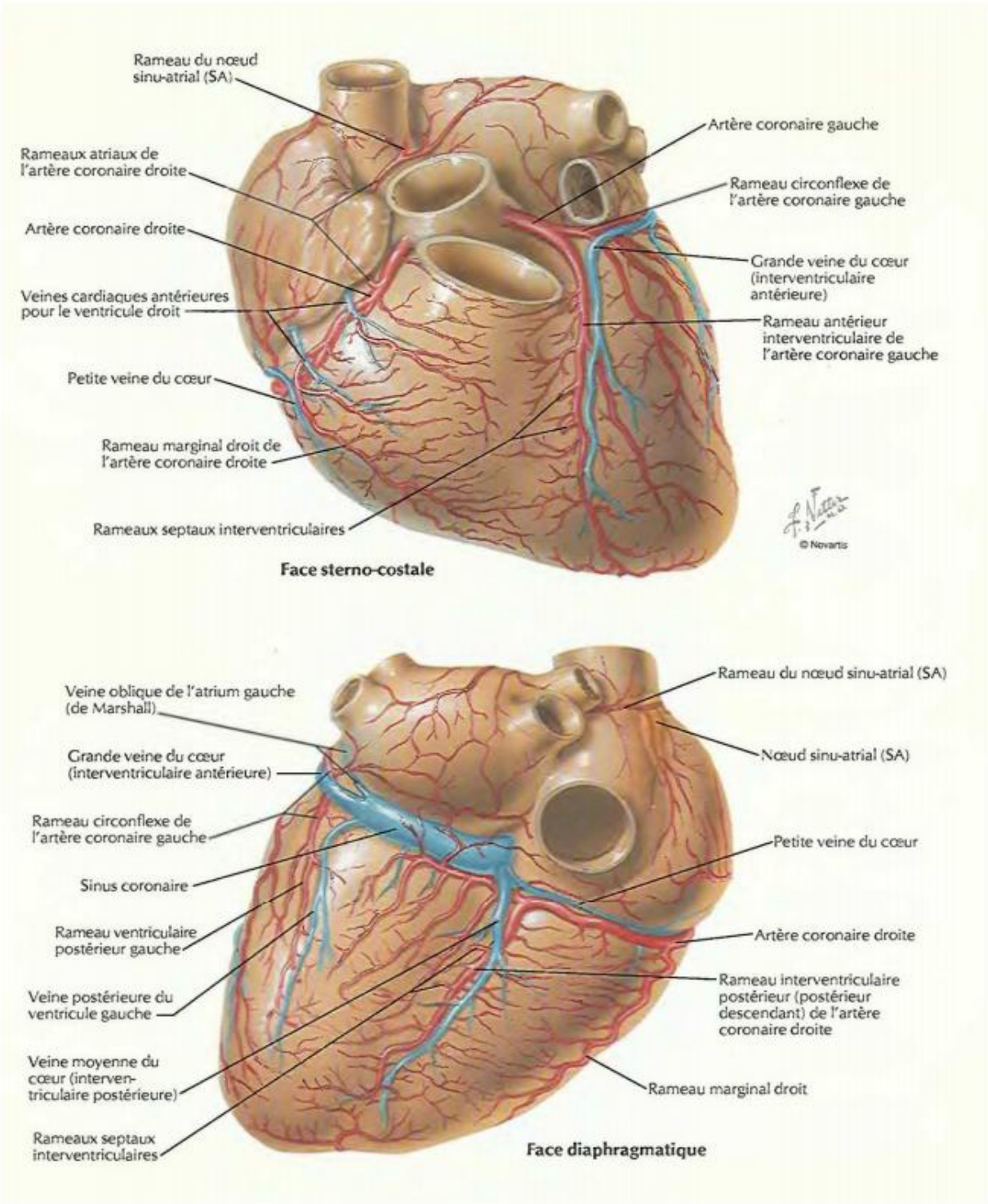

Figure n° 05 : Artères coronaires et veines cardiaques.

7. Heart: Intrinsic and Extrinsic Innervation

The heart possesses a **specialized conduction system** that coordinates the rhythmic contraction of the atria and ventricles, ensuring efficient blood flow. This system is composed of **nodal tissue, conduction fibers, and autonomic inputs**.

Intrinsic Conduction System

The intrinsic system is responsible for generating and propagating electrical impulses without external stimulation.

1. **Sinoatrial (SA) node**: Located in the **superior wall of the right atrium**, near the entrance of the **superior vena cava**, the SA node acts as the **primary pacemaker** of the heart. It spontaneously generates impulses at **70–80 beats per minute** under resting conditions. These impulses initiate atrial contraction and set the baseline heart rate.
2. **Atrioventricular (AV) node**: Situated in the **interatrial septum near the opening of the coronary sinus**, the AV node **delays the electrical signal** slightly to allow the ventricles to fill completely before contraction. This delay is crucial for synchronizing atrial and ventricular activity.
3. **Bundle of His**: Originating from the AV node, the Bundle of His travels along the **interventricular septum** and divides into **right and left bundle branches**, which conduct impulses toward the apex of the heart.
4. **Purkinje fibers**: Terminal branches of the conduction system that spread throughout the ventricular myocardium, ensuring **rapid and coordinated ventricular contraction**. These fibers facilitate synchronous contraction of the left and right ventricles, optimizing the ejection of blood into the pulmonary trunk and aorta.

Extrinsic (Autonomic) Regulation

The **autonomic nervous system (ANS)** modulates the intrinsic rhythm of the heart to adapt cardiac output to physiological demands.

1. **Sympathetic fibers** (originating from **T1–T5 spinal segments**) increase the **heart rate (positive chronotropy)**, enhance **ventricular contractility (positive inotropy)**, and accelerate **conduction velocity (positive dromotropy)** through the AV node. These effects prepare the heart to respond to stress or exercise.
2. **Parasympathetic fibers**, primarily via the **vagus nerve (cranial nerve X)**, decrease **heart rate**, slow conduction through the AV node, and slightly reduce atrial contractility. This modulation dominates at rest, conserving energy and maintaining a lower baseline heart rate.

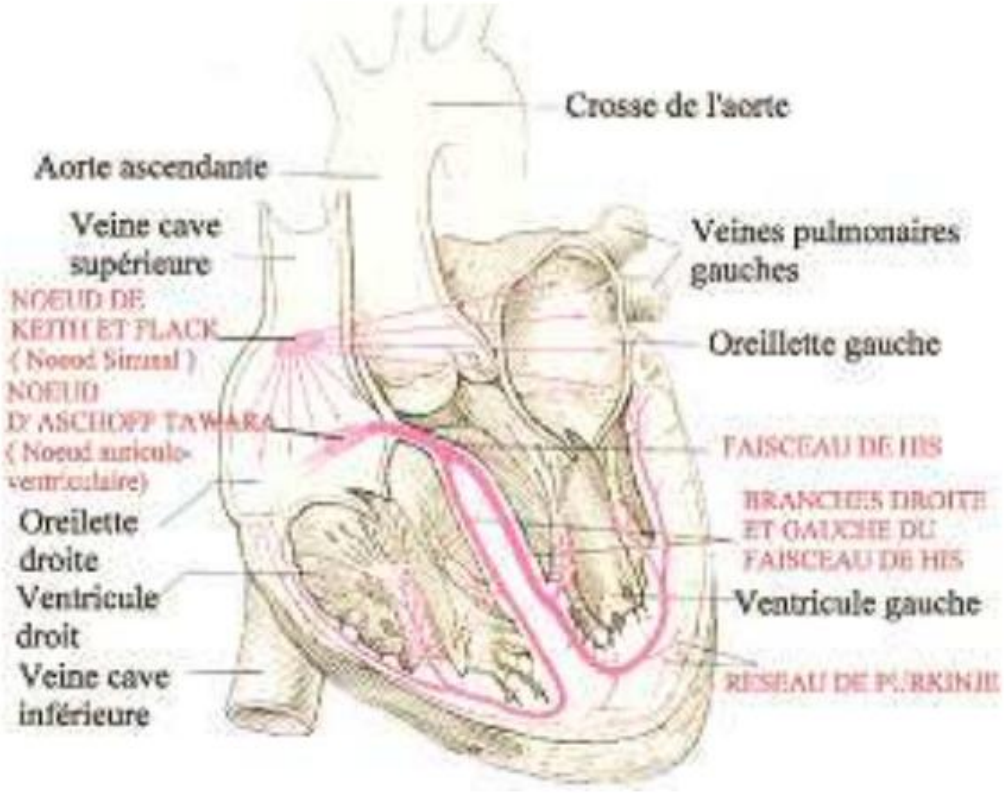

Figure n° 06 : Tissu nodal.

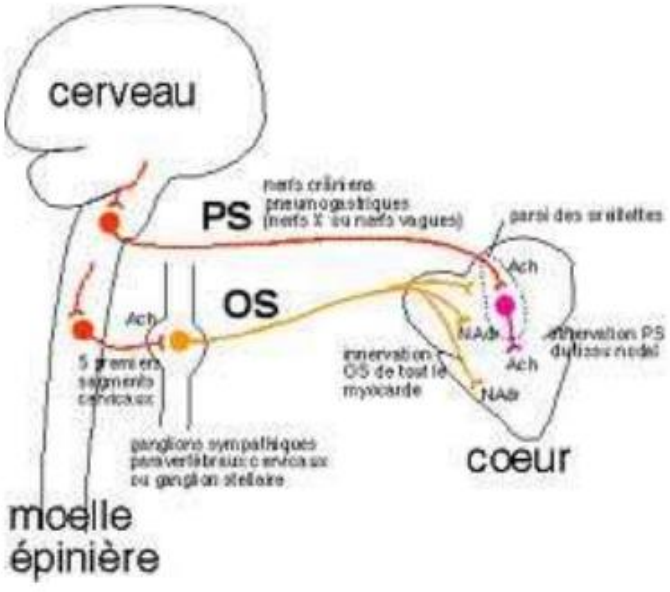

Figure n° 07 : Innervation végétative du cœur.

8. Structural Characteristics of Blood Vessels

I. Arteries

Definition:
Arteries are musculo-membranous vessels responsible for transporting blood from the heart to organs and tissues. They are cylindrical, contractile, elastic, and compressible vessels. Their rhythmic pulsations, synchronized with cardiac contractions, constitute the arterial pulse.

Structure:
The arterial wall is composed of three concentric layers (tunics):

- **Tunica externa (adventitia):** connective tissue layer providing protection and anchorage
- **Tunica media:** thick musculo-elastic layer responsible for vasoconstriction and vasodilation
- **Tunica intima:** inner endothelial layer ensuring smooth blood flow

1. Pulmonary Trunk (Pulmonary Artery)

The pulmonary trunk, also referred to as the pulmonary artery, transports deoxygenated (venous) blood from the heart to the lungs for gas exchange. Despite carrying venous blood, it presents all the structural characteristics of an artery.

- **Origin:** arises from the right ventricle at the pulmonary orifice
- **Course and termination:** follows an oblique upward course and divides after approximately 5 cm into two branches:
    - right pulmonary artery
    - left pulmonary artery
      which supply the corresponding lungs

Remark: the left pulmonary artery is shorter and narrower than the right.

2. Aorta

The aorta is the main arterial trunk of the systemic circulation and gives rise to all arteries supplying the various regions of the body.

- **Origin:** emerges from the left ventricle through the aortic orifice
- **Course and termination:** ascends upward and to the left, forming the aortic arch, then descends vertically within the posterior mediastinum along the vertebral column. It crosses the diaphragm and continues as the abdominal aorta, terminating at the level of the fourth lumbar vertebra (L4) by bifurcating into the right and left common iliac arteries.

Remark: along its entire course, the aorta gives off numerous collateral branches supplying organs and tissues.

II. Veins

Definition:
Veins are vessels that return blood from organs and tissues to the heart. They are cylindrical and easily compressible, less resistant than arteries, non-pulsatile, and do not bleed under pressure when injured. Many veins contain valves that prevent blood backflow.

Structure:
Veins have the same three-layer organization as arteries; however, the **tunica media is thinner and primarily muscular**, with less elastic tissue.

1. Pulmonary Veins

There are four pulmonary veins (two from each lung). They transport oxygenated (arterial) blood from the lungs to the heart.

- **Origin, course, and termination:** they originate from the pulmonary capillary networks of the alveoli through venules that merge into veins. These veins form a superior and an inferior pulmonary vein on each side, which course medially and open into the left atrium.

2. Venae Cavae

- **Superior Vena Cava**

The superior vena cava returns venous blood from the supra-diaphragmatic regions of the body (head, neck, thorax, and upper limbs).

- **Origin:** formed by the union of the right and left brachiocephalic veins behind the first right costal cartilage
- **Course and termination:** descends obliquely downward and posteriorly and opens into the right atrium

Remark: the left brachiocephalic vein is longer than the right.

- **Inferior Vena Cava**

The inferior vena cava drains venous blood from infra-diaphragmatic regions.

- **Origin:** formed by the union of the right and left common iliac veins
- **Course and termination:** ascends vertically in the retroperitoneal abdominal region, closely applied to the lumbar vertebral wall, crosses the diaphragm, and opens into the right atrium.

3. Azygos Venous System

The azygos vein constitutes a venous system that drains most of the venous blood from the thoracic wall, providing an important collateral pathway between the superior and inferior venae cavae.

4. Portal Vein

The portal vein is a venous trunk associated with the digestive system. It transports venous blood from the gastrointestinal tract, spleen, and pancreas to the liver for metabolic processing and detoxification.

- **Origin, course, and termination:** formed by the convergence of three veins:
    - superior mesenteric vein
    - splenic vein
    - inferior mesenteric vein

    It ascends obliquely upward and to the right and terminates at the hepatic hilum, where it divides into right and left branches supplying the liver.

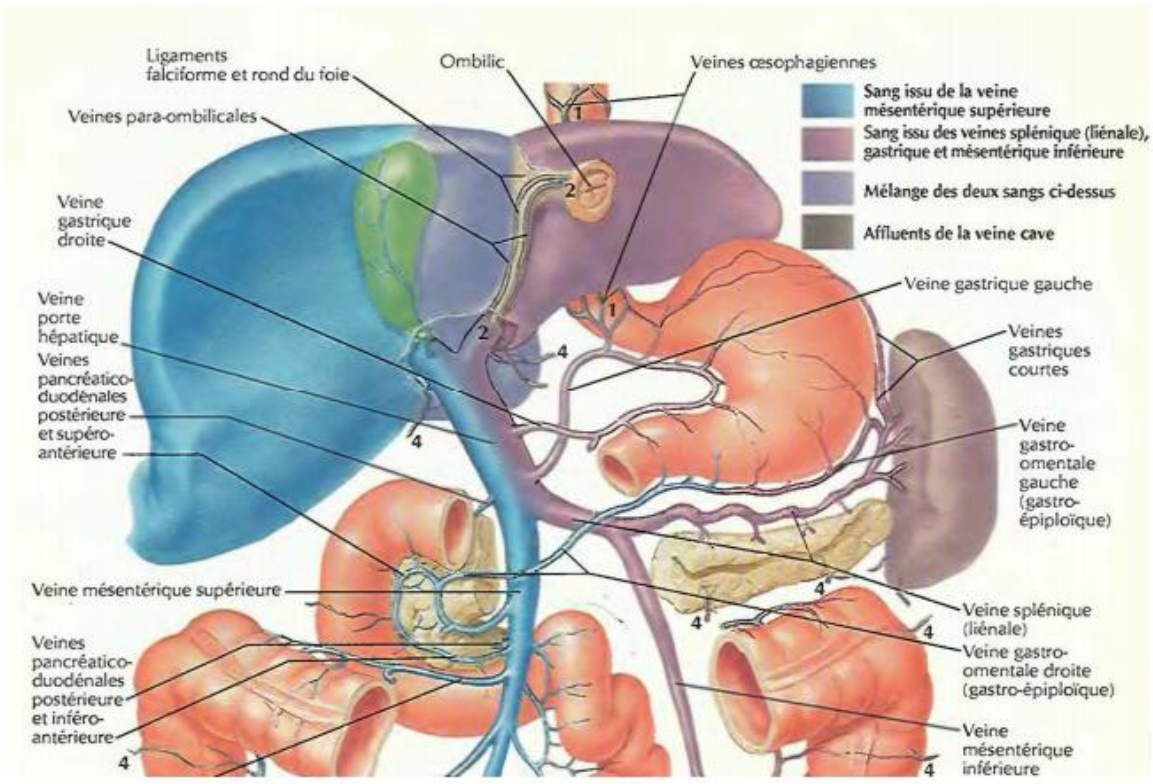

Figure n° 08 : La veine porte.

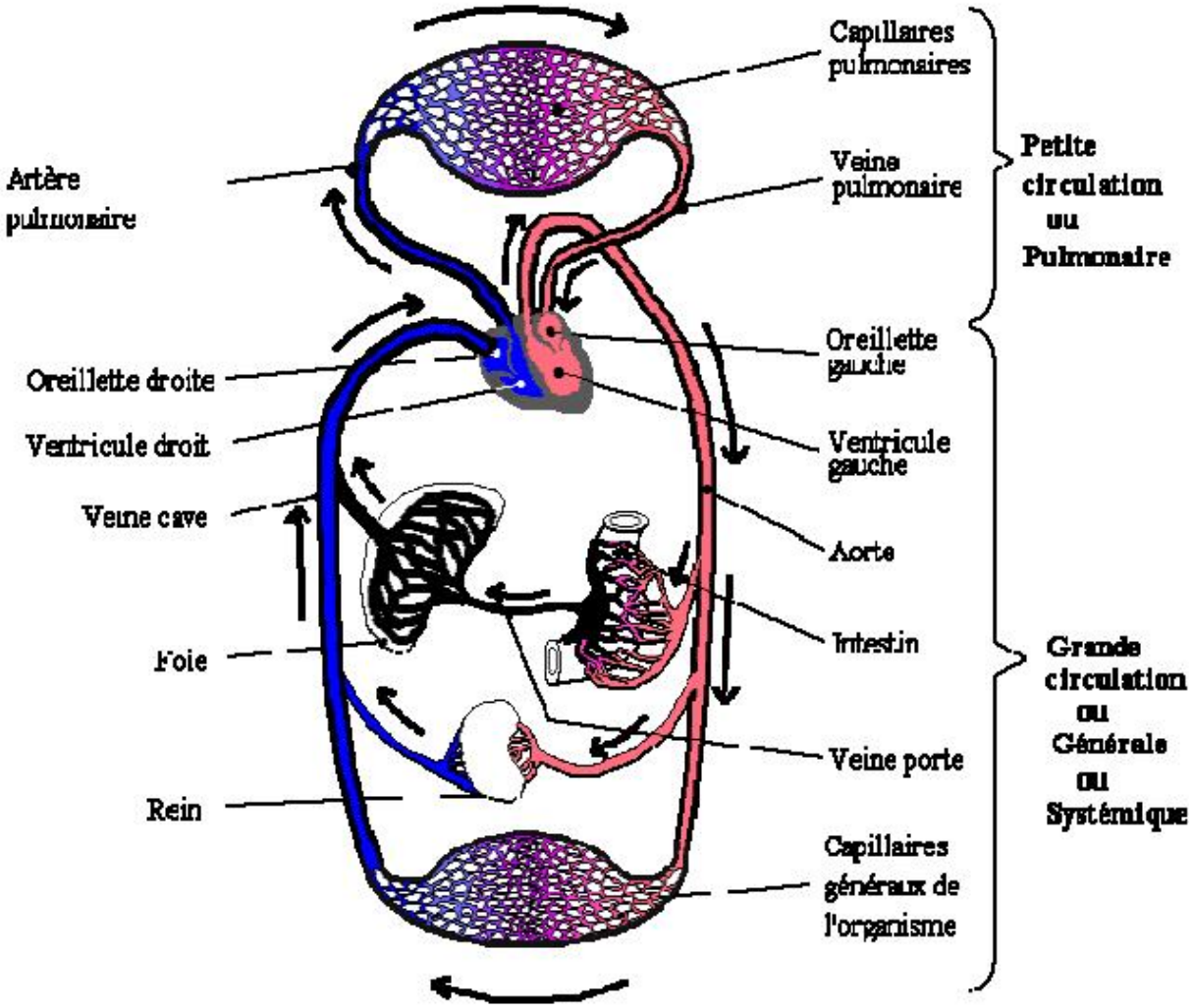

Figure n° 01 : Circulation sanguine.