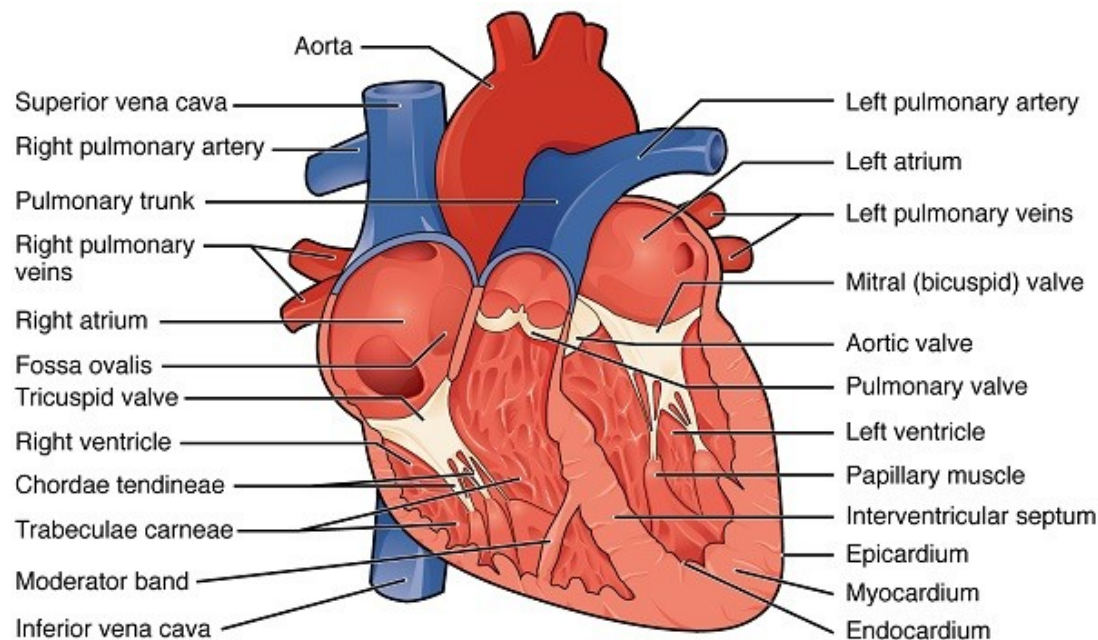


Anatomy & Pathology of the Heart and Components of the Cardiovascular System

[See online here](#)

The heart is a hollow muscular organ that contracts approx. 100,000 times a day and pumps approx. five liters of blood into the circulation every minute. It is not only characterized by the unique features of muscle tissue specialized to meet the constant physical demands of pumping blood, but also by muscle cells that send spontaneous rhythmic electrical impulses to stimulate contraction. This article gives an overview of the structure of the heart wall and of cardiac muscle tissue.



Layers of the Heart Wall

The layers and blood vessels of the heart wall have the same basic structure. The layers of the heart, starting from the innermost layer, include the endocardium, myocardium, and epicardium. They correspond to the blood vessels **tunica intima**, **tunica media**, and **tunica externa**, respectively.

The endocardium

The endocardium is the inner layer of the heart, consisting of the following components:

- The **lamina epithelialis**, which is composed of a flat single-layer squamous epithelium that provides a low-friction, non-thrombogenic surface

- The **basal lamina**, which anchors the endothelium to connective tissue
- The **lamina propria**, which is the connective tissue layer of the heart containing a network of elastic fibers and smooth muscle cells. The **lamina propria** can be further divided into:
 - **Stratum subendotheliale**
 - **Stratum myoelasticum** (the primary component of the heart valves)
- The **tela subendothelialis**, which is connected to the myocardium. It contains the muscle fibers that initiate and conduct electrical impulses

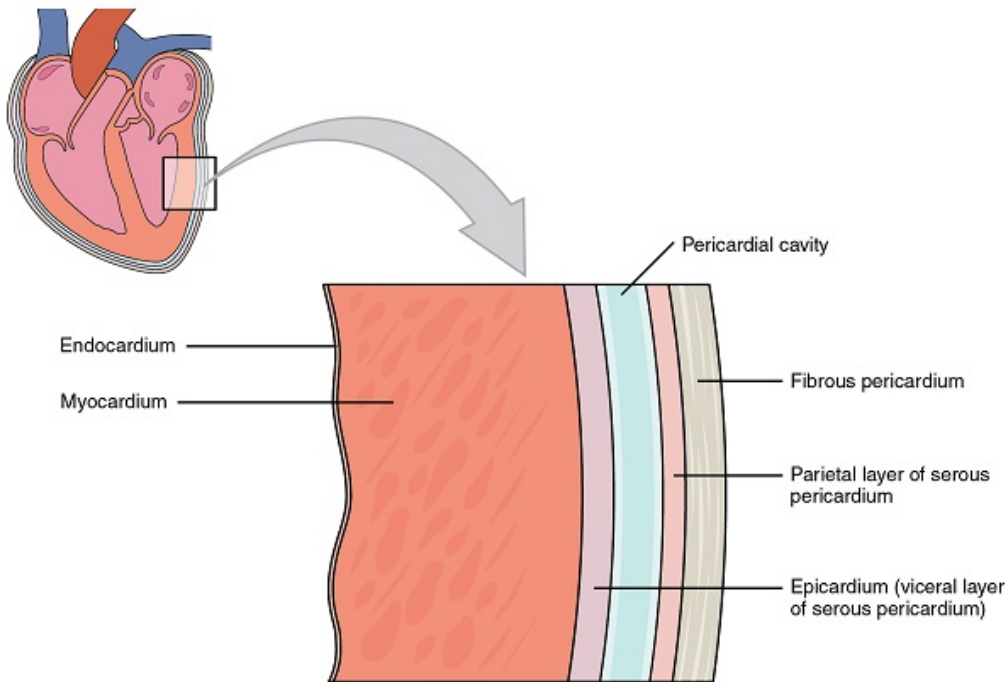


Image: "Pericardial Membranes and Layers of the Heart Wall" by Phil Schatz. License: [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Structure of the heart valves

The heart valves exhibit the same general structure as the endocardium, with the addition of a specialized lamina propria, composed of dense collagenous connective tissue designed to withstand an especially high mechanical load. This specialized endocardium is also known as **valvular endocardium**, which has the following layers:

- **Lamina epithelialis** (single-layer squamous endothelium)
- **Basal lamina**
- **Lamina propria** (composed of a stratum subendotheliale and a stratum myoelasticum)

The stratum myoelasticum, the specialized tissue layer of the heart valves, is composed of **fibrosa** and **spongiosa**. The fibrosa is a layer of non-vascular, dense collagenous connective tissue. In the atrioventricular valves, the fibrosa is located on the side facing the ventricles, while in the semilunar valves, it is located on the side facing the arteries. The spongiosa is a layer of loose connective tissue.

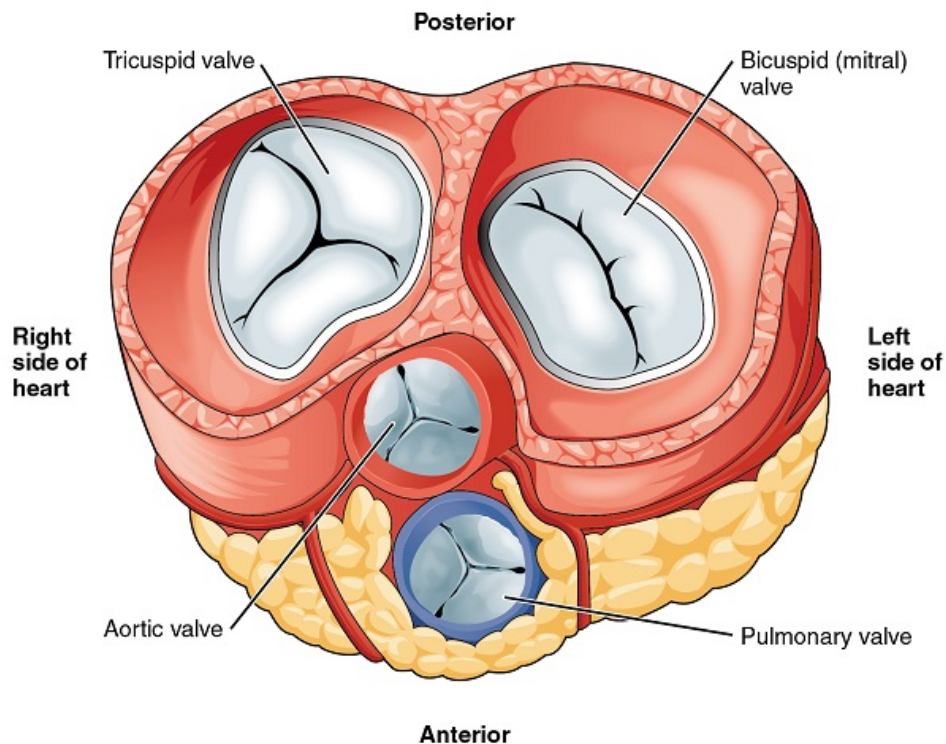


Image: "Heart Valves" by Phil Schatz. License: [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Cardiac skeleton located on the valvular plane

The cardiac skeleton is composed of dense collagenous connective tissue carrying the heart valves in a plane. The valves are anchored by the **anuli fibrosi**, four collagenous fibrous rings called:

- Anulus fibrosus dexter et sinister (tricuspid and mitral valve)
- Anulus trunci pulmonalis et anulus aortae (pulmonary and aortic valve)

These heart valves allow blood flow in only a single direction, or 'valvular plane' of the heart. The muscle tissue of the atria is almost completely insulated from that of the ventricles by the electrically non-conductive cardiac skeleton. The only structure that conducts impulses through the cardiac skeleton is the bundle of His, part of the specialized muscle cells of the impulse-forming system and the conducting system. The bundle of His ensures that the ventricles contract after the atria. The collagenous muscle tissue structure of the cardiac skeleton also acts as a firm base and source of the heart musculature.

Clinical observations

Endocarditis



Endocarditis is an inflammation of the inner layer of the heart. It is caused by bacterial infection or an immune reaction to a Streptococcus infection of the tonsillar ring—a secondary infection resulting from rheumatic fever. Endocarditis most frequently occurs in the valve region, especially on the left side of the heart, which bears a greater mechanical load than the right side of the heart. Endocarditis triggered by using infected peripheral venous catheters and injection materials (e.g., with substance use or substance use disorder) occurs primarily on the tricuspid valve because the pathogen travels directly via the venous system and enters the right side of the heart.

Myocardium

This muscle layer is the thickest of the three heart wall layers. Its thickness is determined by mechanical load, and it is thinner in the atria than in the ventricles as well as thicker on the left side of the heart. It is composed of striated cardiac muscle tissue, which is similar in structure to striated skeletal muscle; however, a few key differences are present.

What are the key differences between cardiac and skeletal striated muscle?

1. Cardiac muscle cells, or myocytes, are connected by specialized cell contacts called the **disci intercalares** (intercalated discs). There are three types: **maculae adhaerentes**, **fasciae adhaerentes**, and **gap junctions**
2. Skeletal muscle fibers are unbranched, whereas cardiac muscle cells form a three-dimensional network
3. Skeletal myocytes carry a peripheral nucleus, whereas cardiac myocytes have an oval or rectangular nucleus located at the center that extends in the direction of the myofibrils. At both ends of the nucleus is the sarcoplasm, which contains glycogen granules, mitochondria, and **lipofuscin**. Lipofuscin is a brown pigment that accumulates in the cells with age

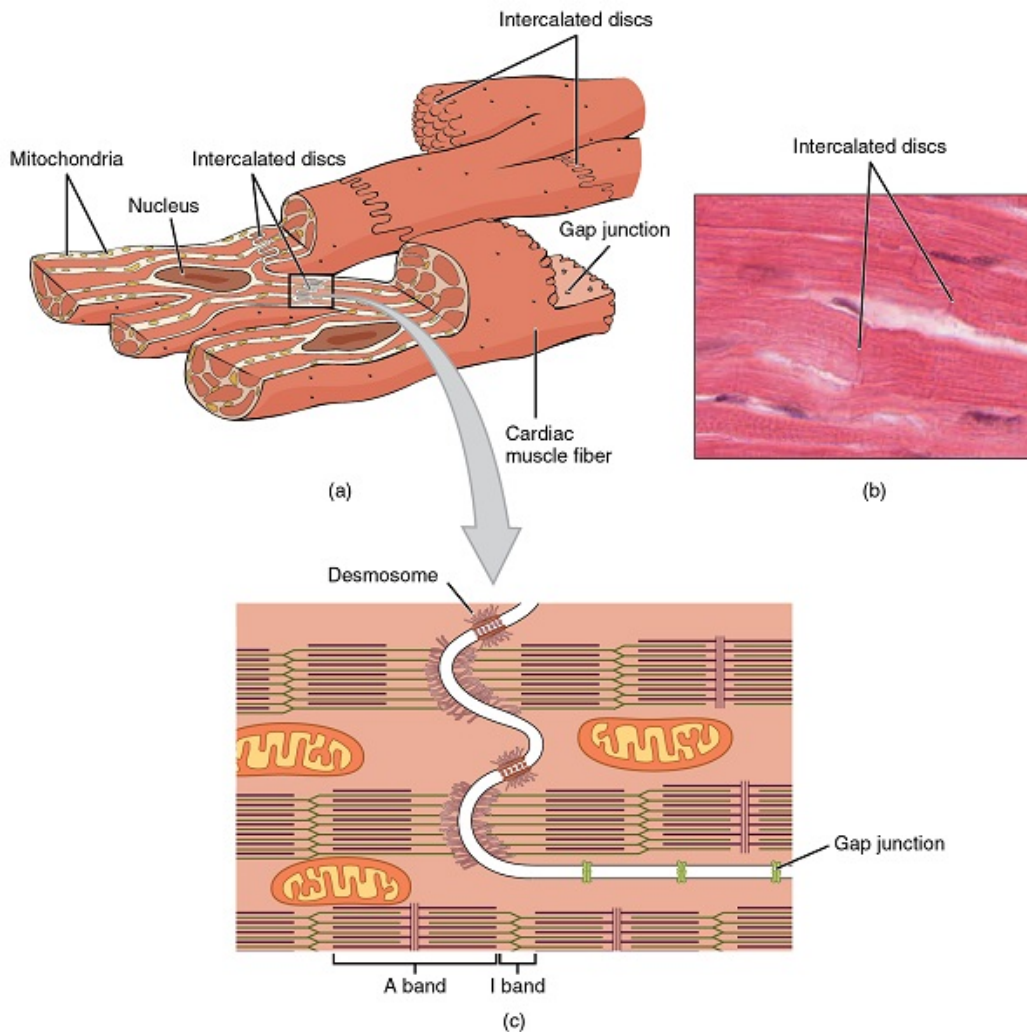


Image: "Cardiac Muscle" by Phil Schatz. License: [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Additional differences between cardiac and skeletal muscle:

Cardiac muscle cells have a basal lamina and a surrounding network of capillaries to support their high metabolic rate. The sarcoplasmic reticulum is less developed in cardiac muscle than in skeletal muscle. In the cardiac sarcoplasmic reticulum, the transverse tubules of the sarcolemma (i.e. the T-system) are located next to the Z-lines and form the primary calcium reservoir; the longitudinal system (the L-system) is less pronounced. The T-tubules and L-tubules form a **dyad**. The higher metabolic demands of the cardiac muscle cells result in a smaller diameter and larger quantities of sarcoplasm and mitochondria.

The heart is a specialized organ in the cardiovascular system, whose function is to pump blood throughout the body via contraction of cardiomyocytes. There are two types of cardiomyocytes: the cells of the working musculature and the pacemaker cells that initiate and conduct electrical impulses, as well as function as myoendocrine cells to regulate circulatory function.

The cardiac working musculature

Function: contraction of the cardiac muscle

The three layers of the cardiac working musculature are oriented in a corkscrew fashion in relation to each other. The external longitudinal layer runs from the **cardiac skeleton**

to the **Vortex cordis**. The middle layer is composed of circular fiber bundles and is especially thick in the left ventricle in order to support a greater pumping force. The inner layer is composed of fibers that radiate from this circular layer and includes the **trabeculae carneae** and the **musculi papillares**.

Clinical observations

Cardiac insufficiency

If the pumping action of the heart is weakened due to a pre-existing condition (e.g., valve defects, heart attack), blood may be retained within a portion of the circulatory system. Depending on the location, cardiac insufficiency is defined as right, left, or global cardiac insufficiency. Each of these has specific consequences:

- **Right cardiac insufficiency:** Blood retention in the systemic circulation causes a volume burden on the right heart. Symptoms include engorgement of the neck veins and peripheral edema that is compensated by nocturnal reabsorption, resulting in nocturia
- **Left cardiac insufficiency:** Blood retention in the pulmonary circulation leads to pressure in the lungs, resulting in pulmonary edema and dyspnea

Specialized cells of the cardiac musculature

Pacemaker cells initiate and conduct electrical impulses in the heart.

Function: the spontaneous, rhythmic initiation and conduction of electrical impulses.

Note: Pacemaker cells are cardiac muscle cells, not nerve cells.

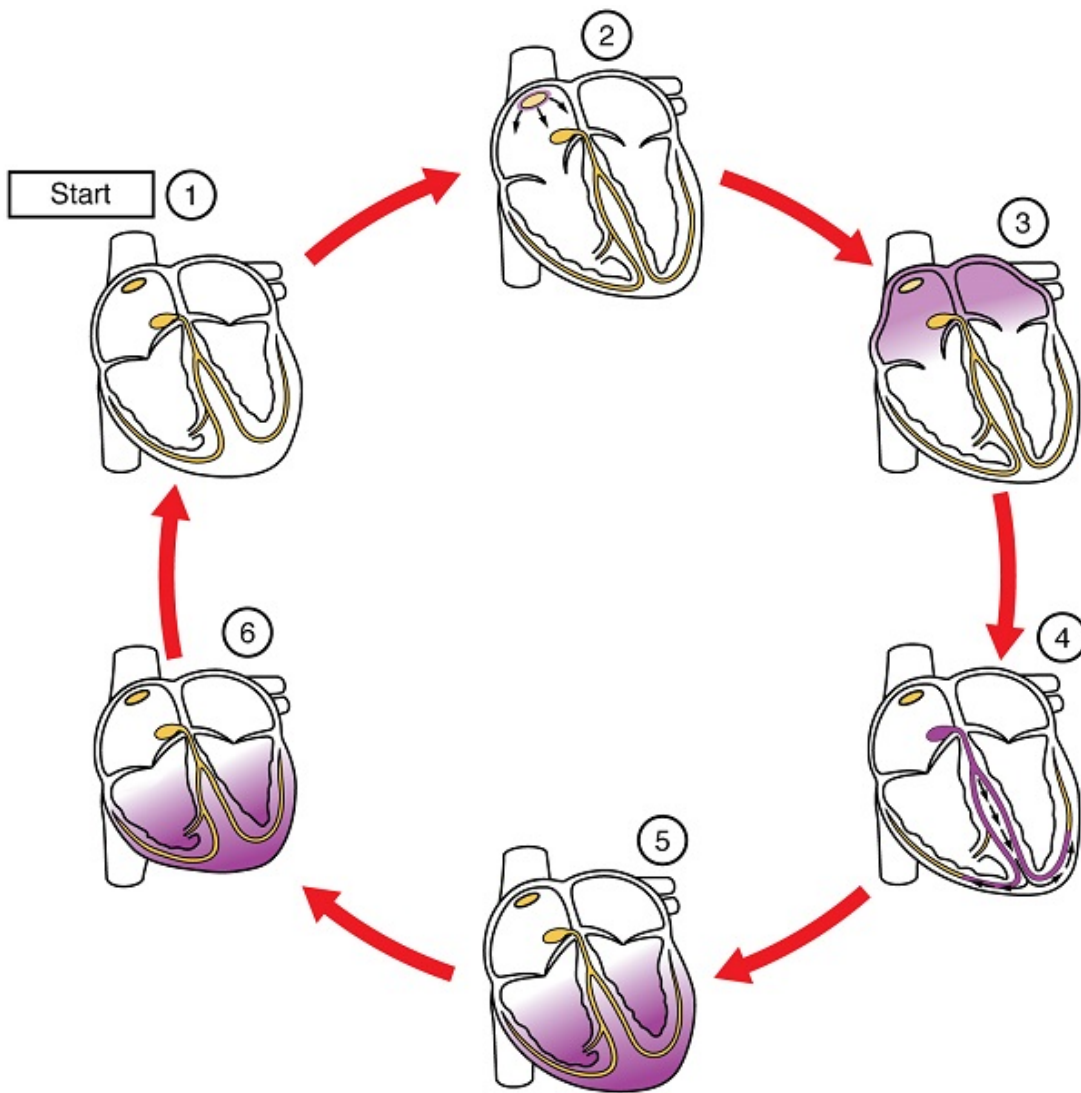


Image: "Cardiac Conduction" by Phil Schatz. License: [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

The cardiac conduction system has several components: the sinoatrial node, the atrioventricular node, the bundle of His, the bundle branch block, and the Purkinje fibers. The pacemaker runs from the right atrium, down through the ventricular septum to the cardiac apex, and crosses the cardiac skeleton, which separates the atrial and ventricular musculature.

The pacemaker components are arranged hierarchically. The sinoatrial node is the primary pacemaker with the highest characteristic frequency. If it malfunctions, the atrioventricular node, situated downstream, can use its lower characteristic frequency to act as the primary pacemaker. Pacemaker cells contain a high quantity of glycogen and few myofibrils, and are larger than the cells of the working musculature.

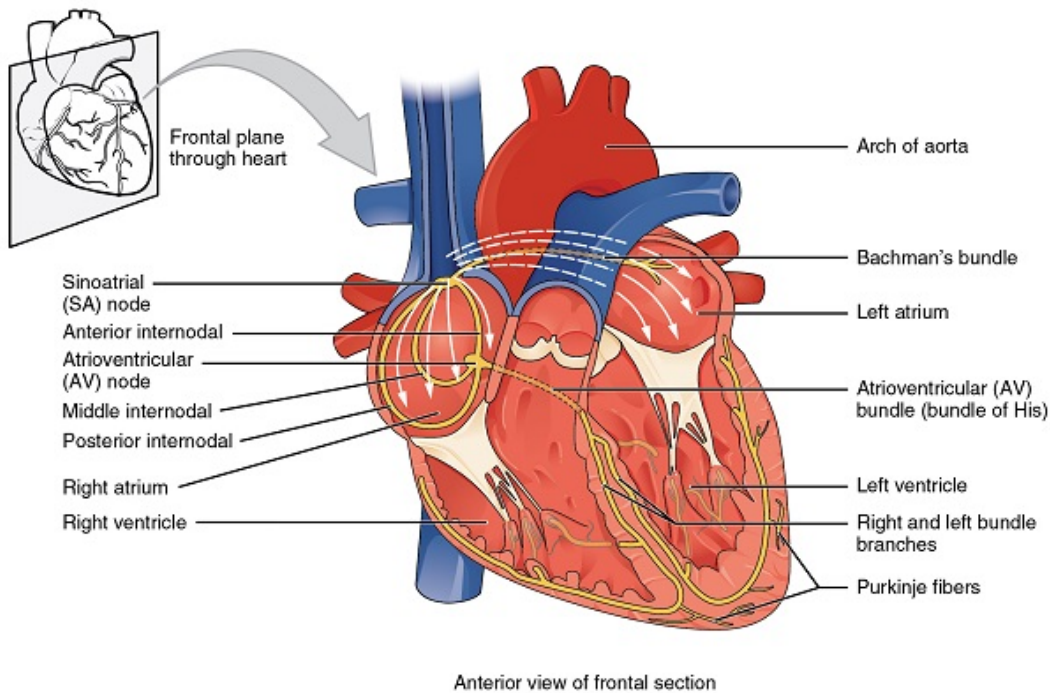


Image: "Conduction System of the Heart" by Phil Schatz. License: [CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)

Myoendocrine cells

Function: endocrine regulation of the circulatory system.

Atrial natriuretic peptide (ANP)

ANP, otherwise known as **cardiodilatin**, is secreted in the cardiac cells of the atrial auricles. This peptide hormone prevents cardiac overload via two mechanisms:

1. ANP causes a reduction in blood volume by signaling the kidneys to reabsorb less NaCl. NaCl is excreted along with water, causing increased **diuresis**
2. ANP stimulates vasodilation of the blood vessel walls, reducing peripheral vascular resistance

Secretion of ANP is stimulated by increased stretching of the right atrium (e.g., due to cardiac insufficiency) or when activated by the sympathetic nervous system.

Brain natriuretic peptide (BNP)

BNP is produced by cardiomyocytes in the ventricles. Secretion of BNP is stimulated mainly by increased ventricular stretching (e.g., due to cardiac insufficiency). BNP and ANP exhibit antifibrotic and antihypertrophic effects on the heart.

Clinical observations

Cardiac muscle hypertrophy

Cardiac muscle hypertrophy refers to an increase in cardiac muscle mass. It is caused by enlarged cardiomyocytes as a reaction to chronic overload, either physiologically (e.g., additional loading is the desired outcome of high performance sport or exercise), or pathologically, by increased ventricular pressure or volume load.

Epicardium

The epicardium is the visceral lobe of the **pericardium serosum** that firmly adheres to the heart, forming part of the pericardial sac. Similar to all other serous membranes, it is composed of:

- Tunica serosa: serosa epithelium, composed of a single-layered squamous mesothelium
- Lamina propria: serosa connective tissue with numerous elastic fibers, along with blood and lymph vessels
- Tela subserosa: a sliding layer whose adipose tissue cushions the surface of the heart and envelopes the coronary vessels in the sulci

Both the outer and inner surfaces of the heart are low friction and elastic, perfectly suited to withstand the high mechanical load on an active heart.

Pericardium

The pericardium is the connective tissue surrounding the heart. It has two components:

1. Pericardium serosum (serous epicardial membrane = visceral lobe and parietal lobe)
2. Pericardium fibrosum

The richly vascularised tela subpericardialis is situated between these layers.

Pericardium serosum

The pericardium serosum is the serous membrane surrounding the heart. Similar to all serous membranes, it carries two serous lobes:

- Lamina visceralis = epicardium (the outer layer of the cardiac wall)
- Lamina parietalis, which firmly adheres to the pericardium fibrosum

Both lobes merge at a reflecting fold to form the **cavitas pericardiaca**, or pericardial cavity. This capillary-rich space is filled with a few milliliters of serous fluid, an ultrafiltrate derived from the blood, which facilitates low-friction sliding movements of the organs.

Pericardium fibrosum

The collagenous pericardium fibrosum reinforces the lamina parietalis. This layer has very little elasticity.

The reflecting folds of the serous lobes (mesocardium) form the following sinuses:

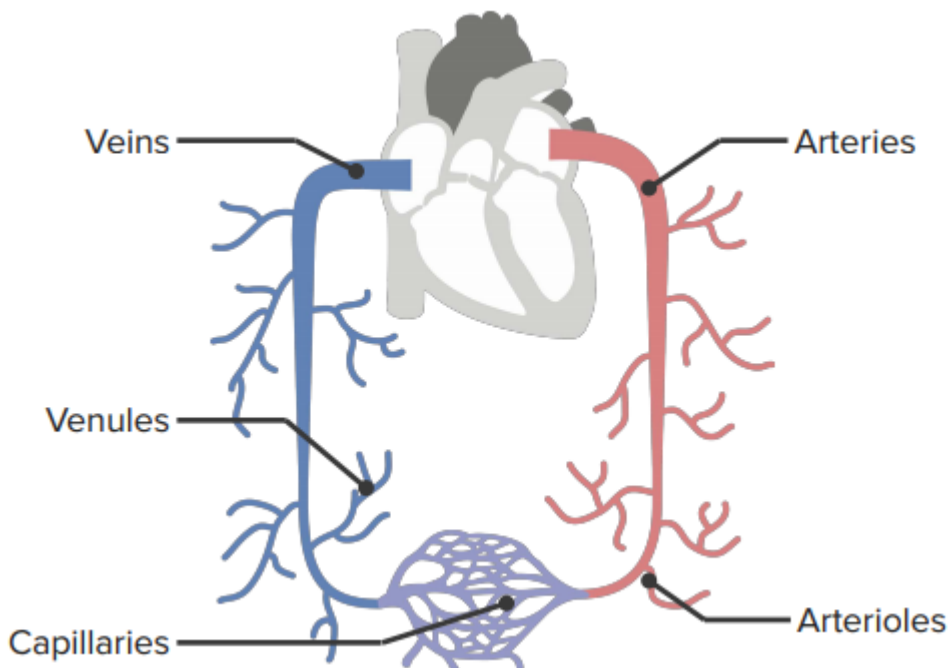
- Sinus transversus pericardii
- Sinus obliquus pericardii

In addition, the heart is attached to its surroundings via the following structures:

- Ligamenta phrenicopericardiaca
- Membrana bronchopericardiaca
- Ligamenta sternopericardiaca

Lymphatic Vessels

Components of the cardiovascular system (CVS)



Anatomy

- Lymph nodes scattered throughout the body (thymus, spleen)
- Vessels

Functions

- Returns excess body fluid to the blood
- Transports fats from intestines to blood
- Defense

Main classes of blood vessels

Arteries

- Convey blood away from the heart to the body tissues
- Bifurcate into smaller vessels (arterioles) as they travel further from the heart until they feed into the capillaries

Capillaries

- Exchange oxygen, carbon dioxide, nutrients, and waste products

Veins

- Return blood to the heart
- Become progressively smaller as they split and travel further away from the heart (venules)

Anastomosis

- Occurs where two or more vessels merge to supply the same body region

- Veins tend to form many more anastomoses than arteries do

Diseases of the Heart

Pericardial effusion



[Image](#): "Computed tomography of pericardial effusion" by James Heilman, MD. License: [CC BY-SA 3.0](#)

Pericardial effusion is defined as the accumulation of fluid in the pericardium. This condition can have a variety of causes:

Hemic effusion

- Myocardial ischemia can cause extensive necrosis of the cardiac wall leading to the formation of weak points that rupture and cause hemorrhage into the pericardium
- Ruptured aneurysm of the aorta ascendens
- Hemorrhagic diathesis
- Physical trauma

Serous effusion

- Transudate due to right cardiac insufficiency or **hypoalbuminemia**

Effusion caused by a viral infection

- E.g., **Coxsackievirus**

Purulent effusion = empyema

- During the course of sepsis
- When the infection spreads from the surrounding structures to the heart

Pericardial tamponade

Pericardial effusion leads to increased pressure on the pericardial cavity and afferent veins, causing incomplete filling of the heart during diastole. Decreased blood ejection during systole lowers the blood pressure and results in shock.

Pericarditis

Causes of infection of the pericardial sac include:

- Viral, bacterial, or fungal infection; can also occur via spread from surrounding structures (e.g., pneumonia)

- Uremic pericarditis caused by chronic kidney infection
- Tuberculosis
- Tumor
- Irradiation of the thorax
- Autoimmune disorders such as **systemic lupus erythematosus** (SLE)
- Post-traumatic consequence of a heart attack or **Dressler syndrome** following surgery

Pericarditis calcarea

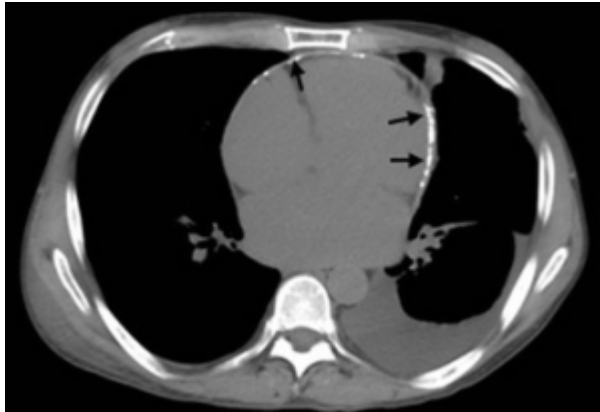


Image: "Chylous ascites and chylothorax due to constrictive pericarditis in a patient infected with HIV: a case report" by Summachiwakij S, Tungsubutra W, Koomanachai P, Charoenratanakul S. License: [CC BY 2.0](https://creativecommons.org/licenses/by/2.0/)

Pericarditis calcarea is caused by recurring inflammation of the pericardium, which leads to tissue scarring and calcification, preventing flexible and low-friction gliding of the pericardial lobes. The heart can no longer completely dilate during the filling phase, causing venous blood retention and resulting in visible internal and external symptoms. Pericarditis calcarea may also lead to secondary diseases warranting surgical intervention.

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