Vasculature and innervation of the heart

A. Bendelic

Human Anatomy Department

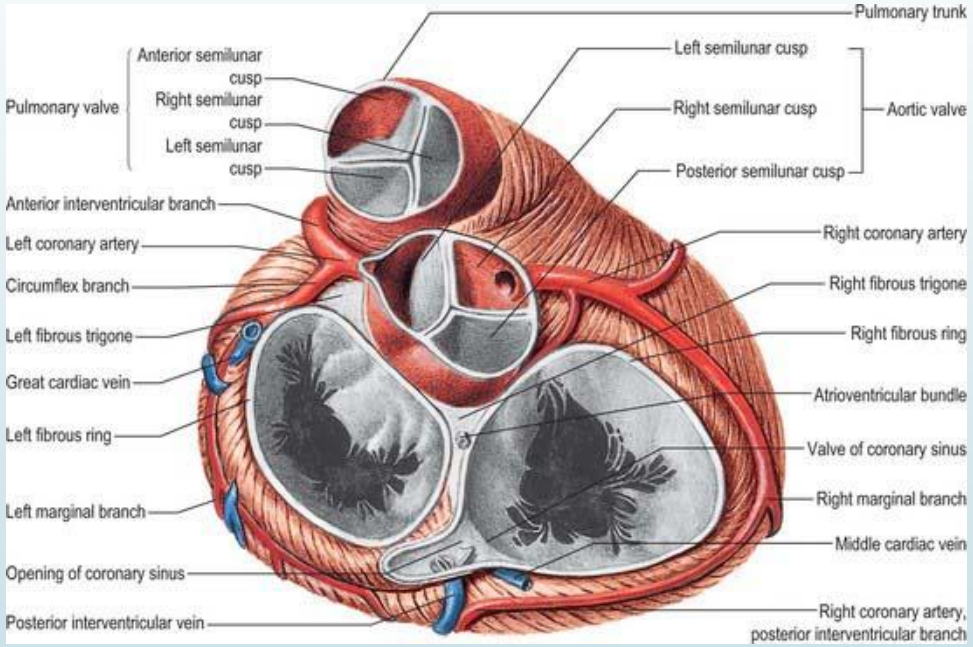
Plan:

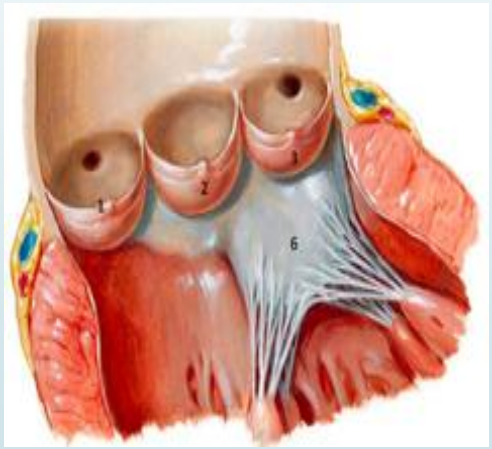
1. Arterial blood supply of the heart. **Coronary arteries**
2. Venous drainage of the heart. **Cardiac veins**
3. Innervation of the heart. **Cardiac plexus**
4. **Afferent** and **efferent** (sympathetic and parasympathetic) **innervation** of the heart

Arterial blood supply of the heart

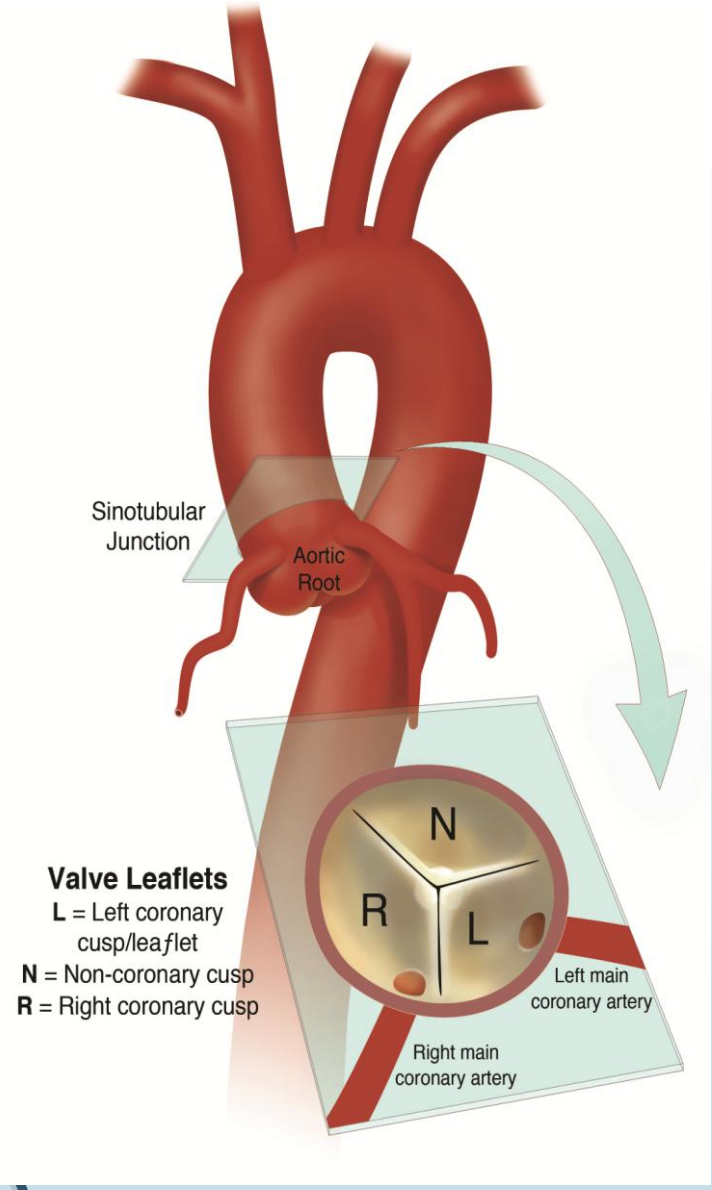
- The **coronary arteries** (**right** and **left**), the first branches of the **aorta**, supply the myocardium and epicardium.
- The left and right coronary arteries arise from the corresponding **aortic** (**coronary**) **sinuses**.
- The coronary arteries supply both the **atria** and the **ventricles**, however the ***atrial branches*** are usually small and not readily apparent in the cadaveric heart.

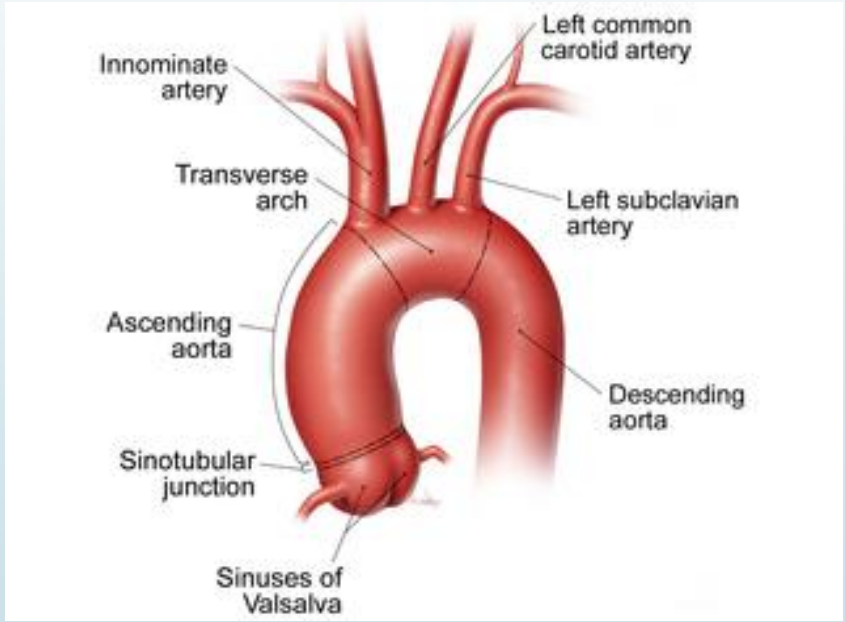
Aortic valve, aortic sinuses and coronary ostia



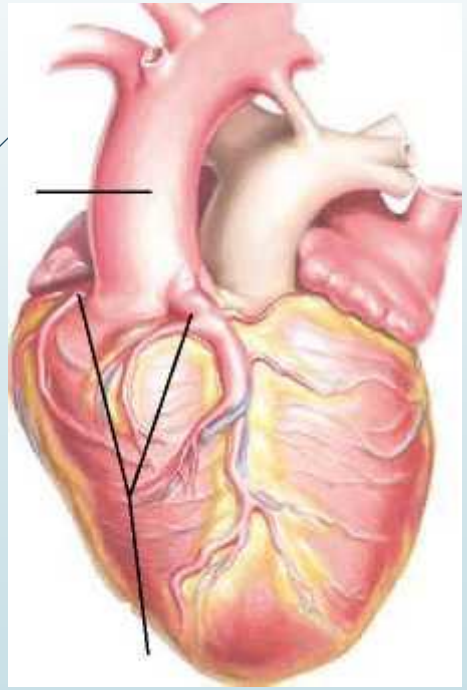


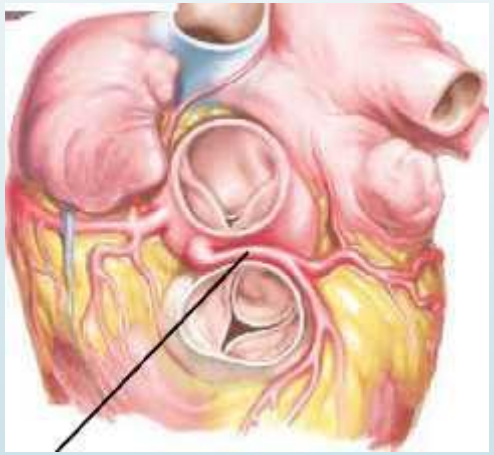
Aortic valve, aortic sinuses and coronary ostia

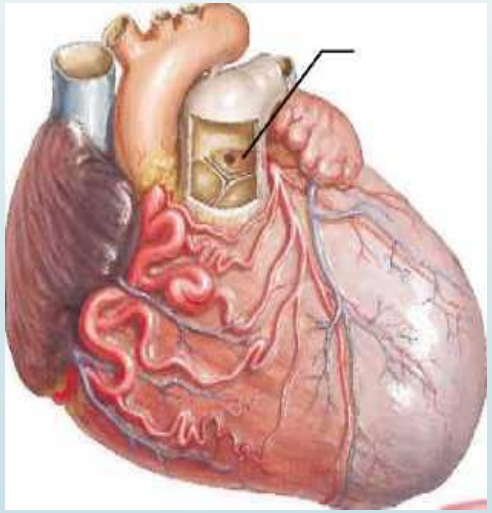




Anomalous origin of coronary arteries



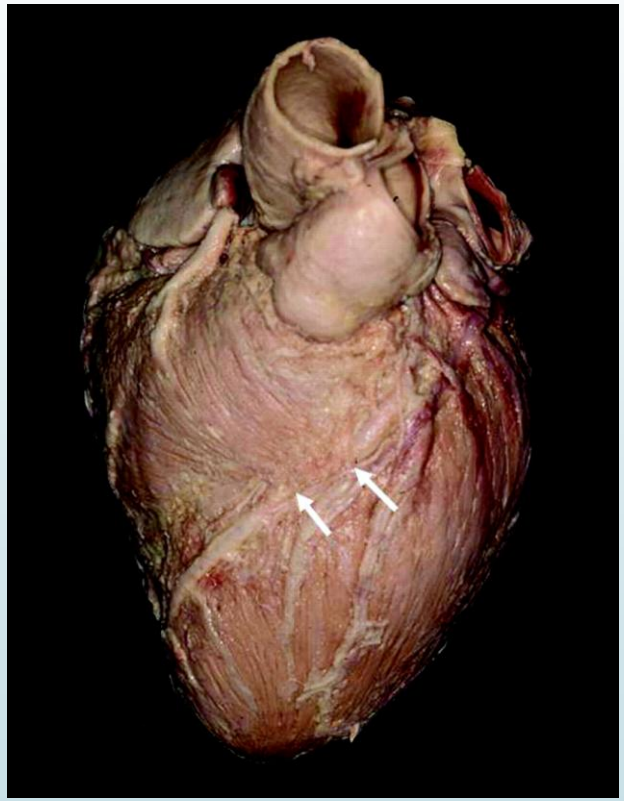


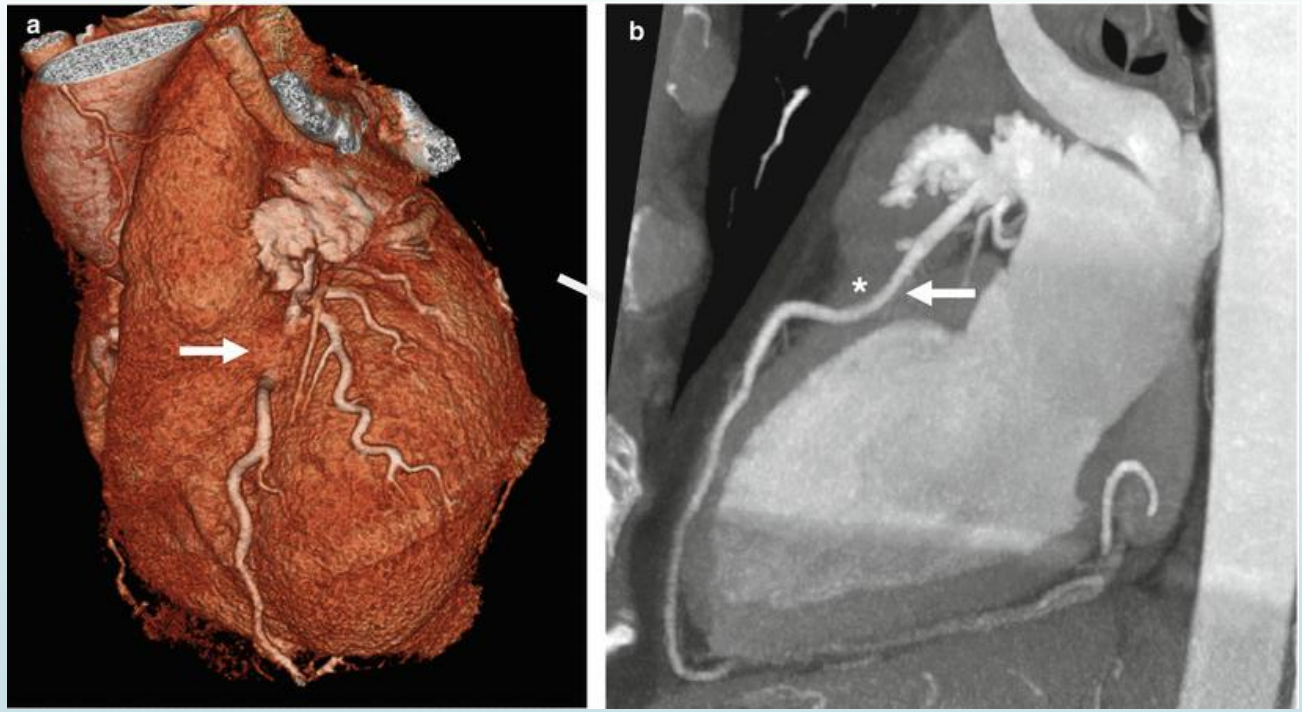


Coronary arteries

- Coronary arteries and their major branches are usually located **subepicardially**.
- Some individuals, however have regions in which a bunch of cardiac muscle fibers passes over the coronary artery like a bridge. The following terms have been used to describe this anatomical finding: **myocardial bridge** or **intramural coronary artery**.
- The **anterior interventricular branch** of the left coronary artery is the branch most frequently involved with myocardial bridges.

Myocardial bridging





Right coronary artery

- Origin – **right aortic sinus (right coronary sinus);**
- Course – follows **coronary sulcus** between atria and ventricles;
- Distribution – **right atrium,**
  SA and AV nodes,
  most of right ventricle,
  part of left ventricle (diaphragmatic surface);
  posterior part of interventricular septum (one third).

Branches of the right coronary artery

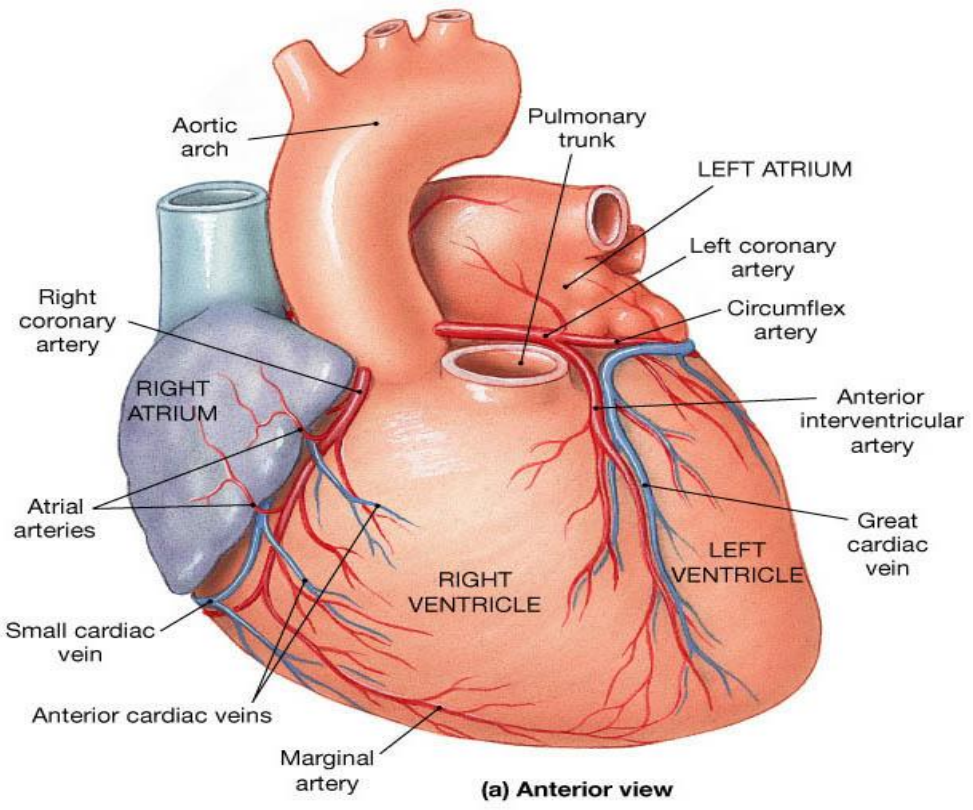
- ***Sinu-atrial nodal branch*** (in approximately 60% of people);
- ***Atrial branches*** (anterior, lateral and posterior);
- ***Anterior ventricular branches*** (usually 2-3);

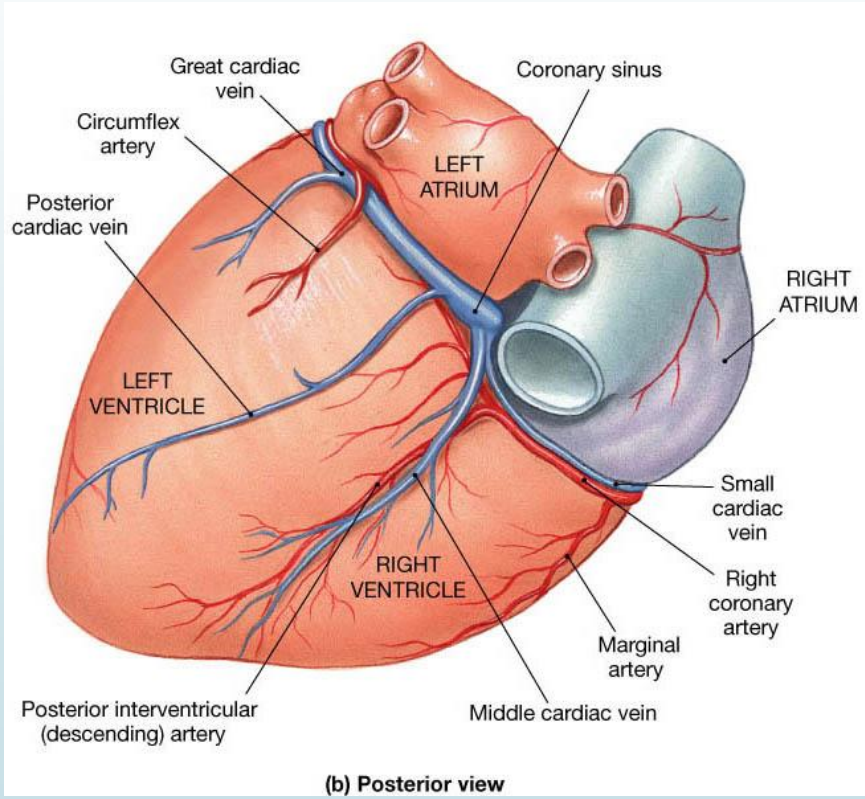
Right marginal branch is greater in caliber than the other anterior ventricular branches and long enough to reach the apex;

- ***Posterior ventricular branches*** (usually 2-3);
- **Posterior interventricular branch** (major branch which descends into the posterior interventricular sulcus), its interventricular septal branches supply the posterior one third of the interventricular septum;
- ***Atrioventricular nodal branch*** (in approximately 80% of people) is the largest interventricular septal artery);

In the most common pattern (67%), the ***right coronary artery is dominant***, giving rise to the ***posterior interventricular branch***.

Blood supply of the heart





Left coronary artery

- Origin – **left aortic sinus (left coronary sinus);**
- Course – runs in **coronary sulcus** and gives off 2 branches: a) **anterior interventricular branch** and b)**circumflex branch;**
- Distribution – **left atrium,**

  most of left ventricle,

  part of right ventricle,

  most of interventricular septum (anterior two thirds),

  SA node.

Branches of the left coronary artery

- **Anterior interventricular branch** (passes along the anterior interventricular sulcus);

A. *Anterior right ventricular branches* are small and rarely number more than one or two;

B. *Anterior left ventricular branches* (from two to nine);

C. *Left diagonal artery* (reported in 33-50% individuals) is one of the anterior left ventricular branches;

D. *Interventricular septal branches* (supply anterior 2/3 of the interventricular septum).

- **Circumflex branch** (follows the coronary sulcus around the left border of the heart to the posterior surface of the heart);

A. *Atrial branches*;

B. *Left marginal branch*;

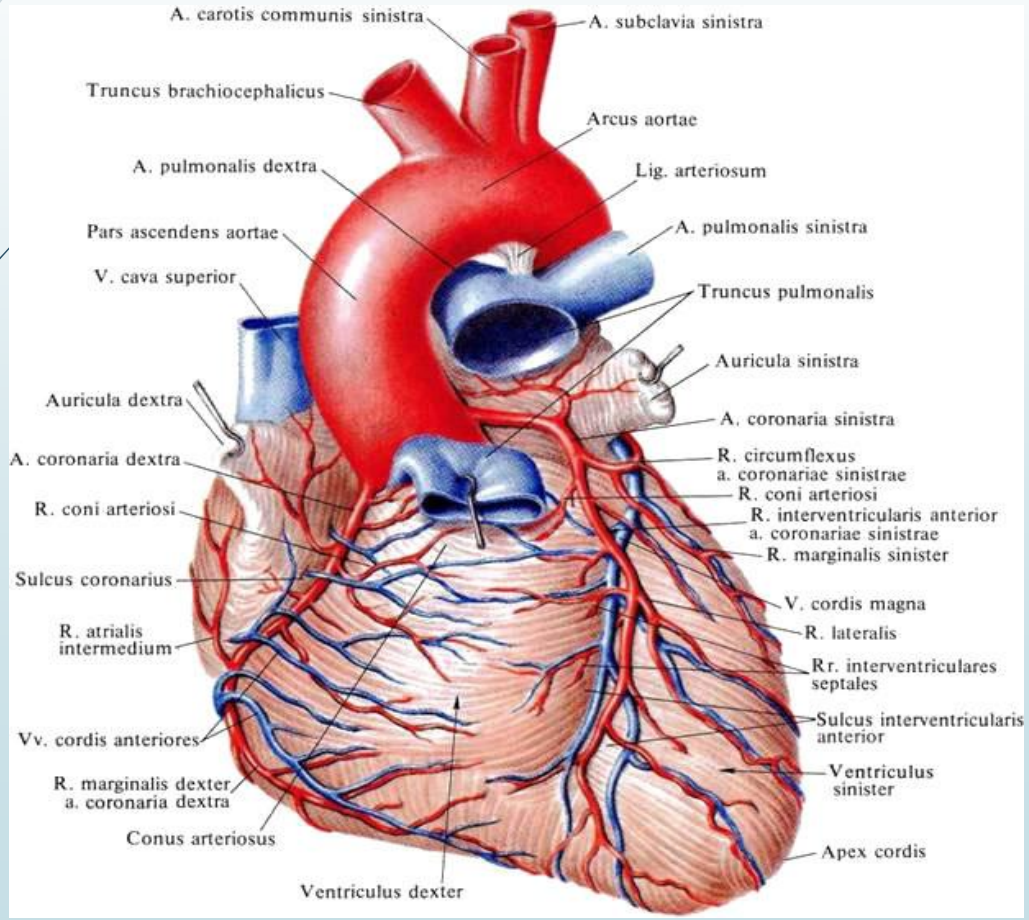
C. *Posterior left ventricular branches*;

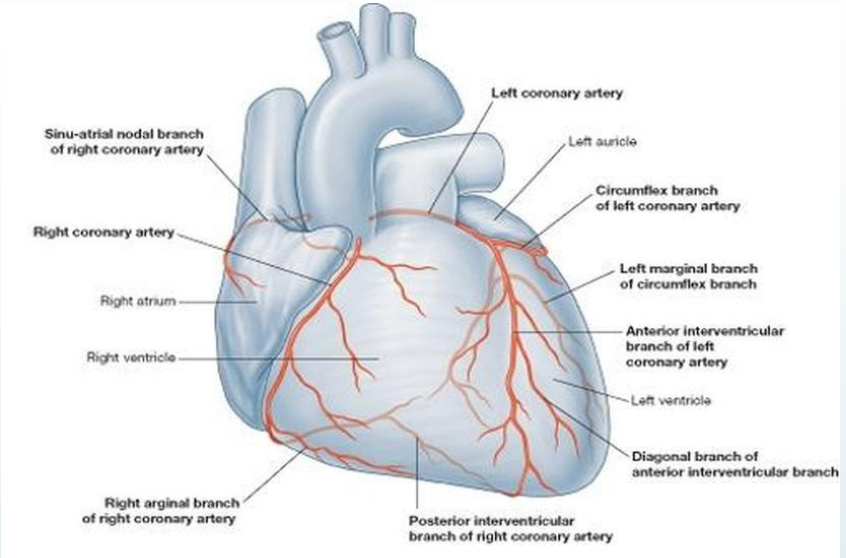
D. (Posterior interventricular branch (in 33% of cases));

E. (Sinu-atrial nodal branch (in approximately 40% of people));

F. (Atrioventricular nodal branch (in approximately 20% of people)).

Coronary arteries



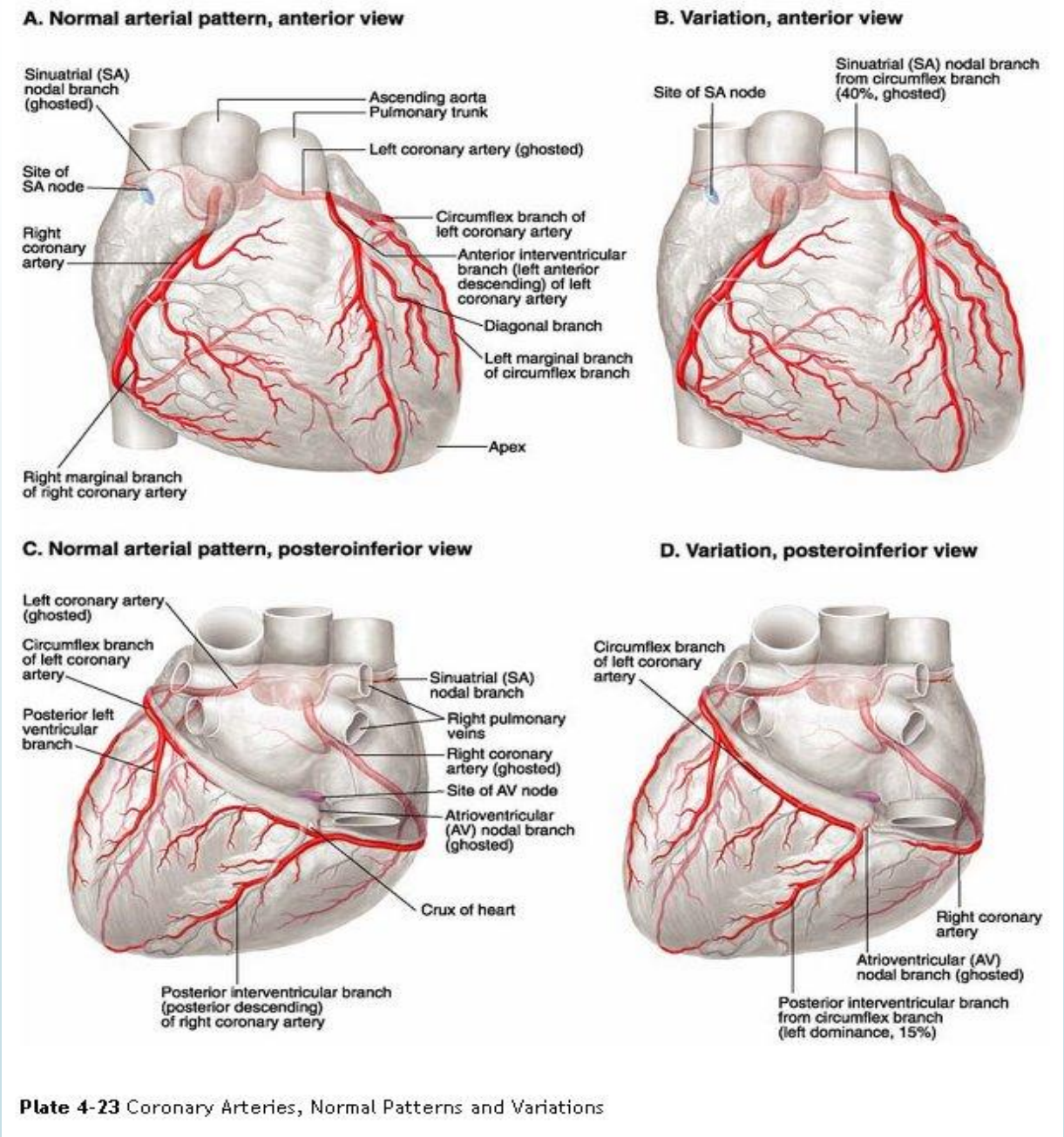


Coronary dominance

Variations of the branching patterns and distribution of the coronary arteries are common. The term `***dominant***` is used to refer to the coronary artery giving off the **posterior interventricular branch.**

- In the most common right dominant pattern (**right-dominance**), present in approximately 67% of people, RCA gives rise to the posterior interventricular branch; the RCA and LCA share about equally in the blood supply of the heart.
- In approximately 15% of people, the LCA is dominant (**left-dominance**) in that the posterior interventricular branch is a branch of the circumflex artery (from LCA).
- There is **codominance** in approximately 18% of people, in which branches of both the RCA and LCA give rise to the posterior interventricular branches.

Variations of coronary arteries



Variations of the coronary arteries

- A few people have only a **single coronary artery**.
- In other people, the circumflex branch arises from the right aortic sinus.
- Approximately 4% of people have an **accessory coronary artery**.
- **Anomalous coronary origins** (from pulmonary trunk)

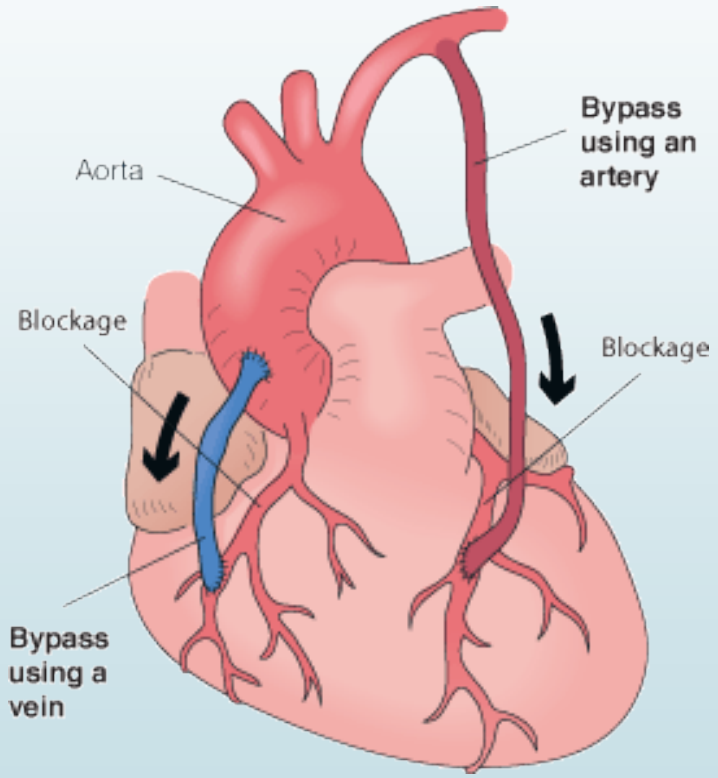
Coronary collateral circulation

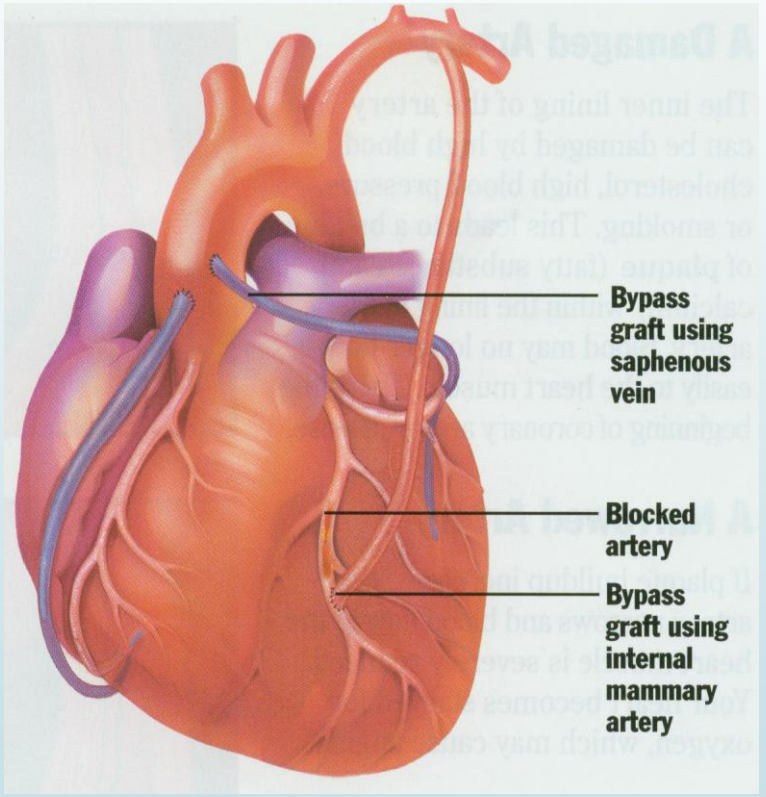
- The branches of the coronary arteries are considered to be **end arteries**, arteries that supply regions of myocardium lacking sufficient anastomoses from other large branches to maintain viability of tissue should occlusion occur.
- However, anastomoses do exist between branches of the coronary arteries (subepicardial or myocardial) and between these arteries and extracardiac vessels (such as thoracic vessels).
- Anastomoses exist between the terminations of the RCA and LCA in the coronary sulcus and between the interventricular branches around the apex in approximately10% of people.

Coronary artery disease or coronary heart disease

- **Coronary arteries disease** is one of the leading causes of death. An area of myocardium that has undergone **necrosis** (pathological tissue death) constitutes a **myocardial infarction**. The most common cause of *ischemic heart disease* is coronary artery insufficiency resulting from *atherosclerosis*.
- **Coronary bypass graft** shunts blood from the aorta to a stenotic coronary artery to increase the flow distal to the obstruction. A segment of an artery (the radial or internal thoracic arteries) or a vein (the great saphenous vein) is connected to the ascending aorta and to the coronary artery distal to the stenosis.

Coronary bypass graft

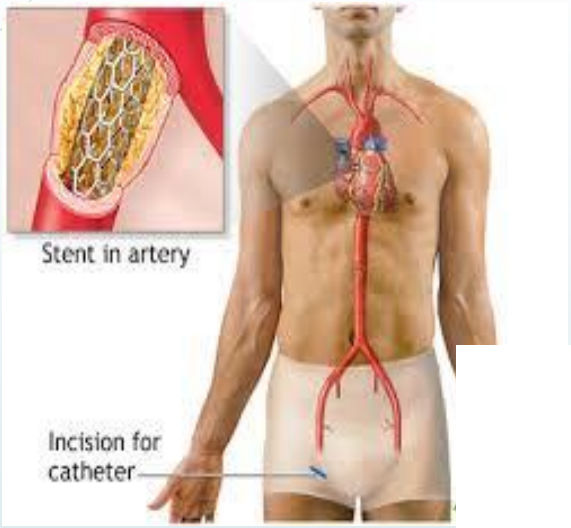


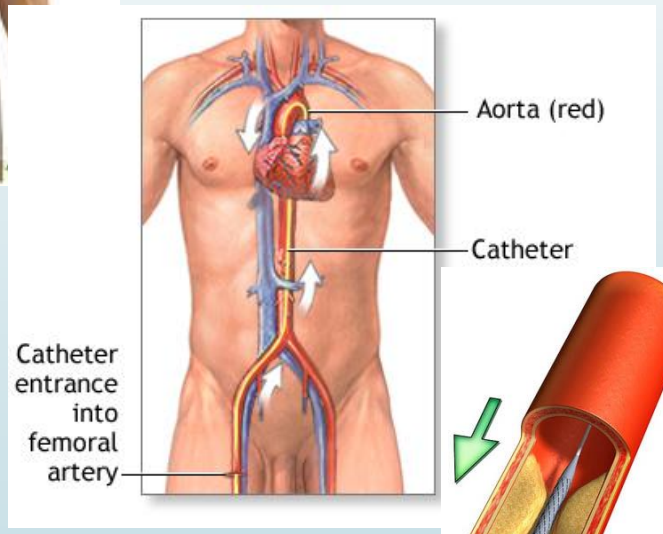


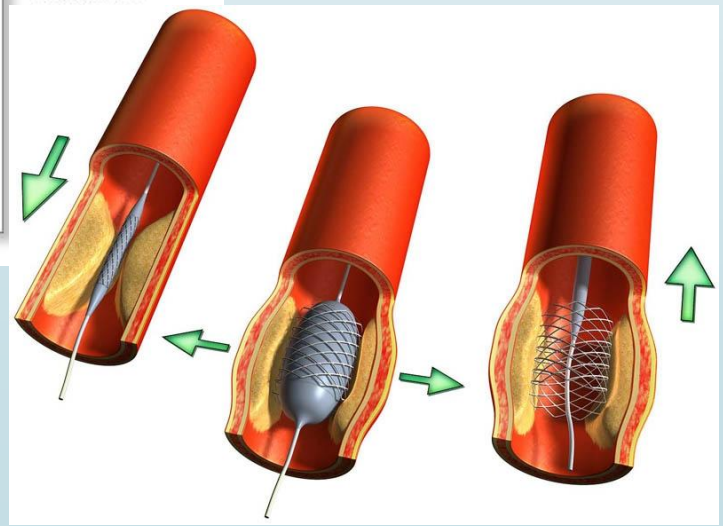
Coronary artery disease or coronary heart disease

- **Coronary angioplasty** (percutaneous transluminal coronary angioplasty) in which a catheter with a small inflatable balloon attached to its tip is introduced into the obstructed coronary artery. When the catheter reaches the obstruction the balloon is inflated, flattening the atherosclerotic plague against the vessel`s wall and the vessel increases the size of the lumen.

Coronary angioplasty







Venous drainage of the heart (**cardiac veins**)

- The heart is drained mainly by veins that empty into the **coronary sinus** and partly by **small veins** (*anterior cardiac veins* and *smallest veins of the heart*) that empty into the right atrium.
- The **coronary sinus**, the main vein of the heart, is a wide venous channel that runs from the left to the right in the posterior part of the *coronary sulcus*.

A. Coronary sinus

- The coronary sinus receives:

a) the **great cardiac vein** (*v. cordis magna*), the main tributary of the coronary sinus, its first part (*anterior interventricular vein*) starts near the apex of the heart and ascends with the anterior interventricular branch of the LCA;

b) the **middle cardiac vein** (*v. cordis media*), also named *posterior interventricular vein,* accompanies the posterior interventricular branch of the RCA;

c) the **small cardiac vein** (*v. cordis parva*) accompanies the right marginal branch of the RCA;

d) the **posterior vein of left ventricle** runs on the diaphragmatic surface of the left ventricle;

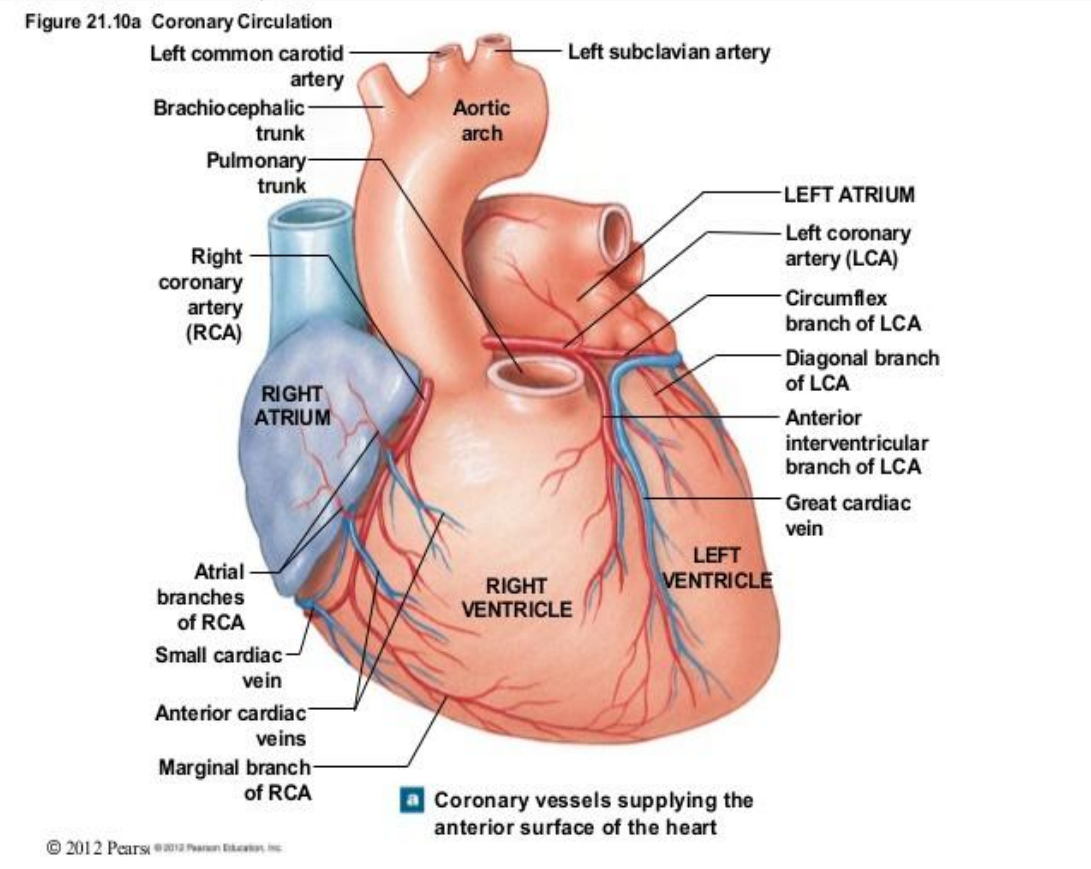
e) the **oblique vein of left atrium**.

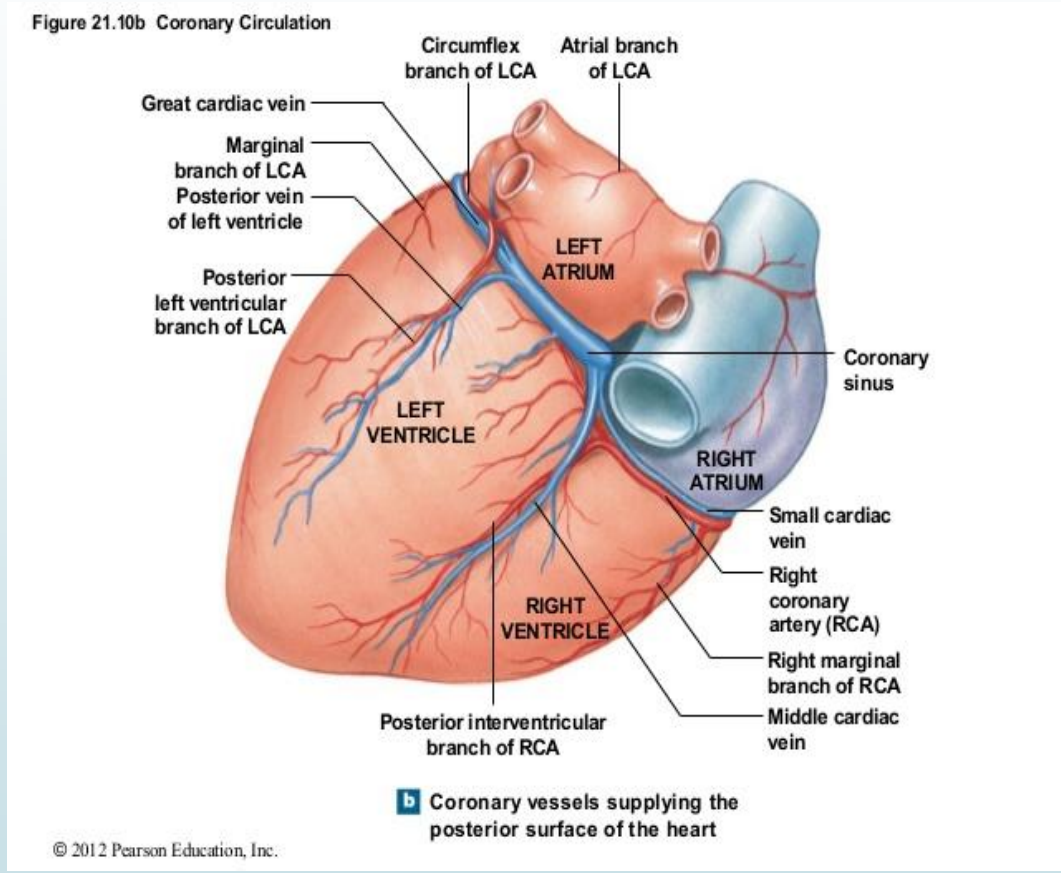
A. Coronary sinus

- The **oblique vein of the left atrium** is a small vessel, relatively unimportant postnatally, that descends over the posterior wall of left atrium. The remnant of the embryonic **left superior vena cava**, which usually atrophies during the fetal period, but occasionally persists in adults (replacing or augmenting the right superior vena cava.).

  It is a small vein (**Marshall oblique vein**) that merges with great cardiac vein to form the coronary sinus. Occasionally persists as a left superior vena cava.

Cardiac veins





B. Small cardiac veins

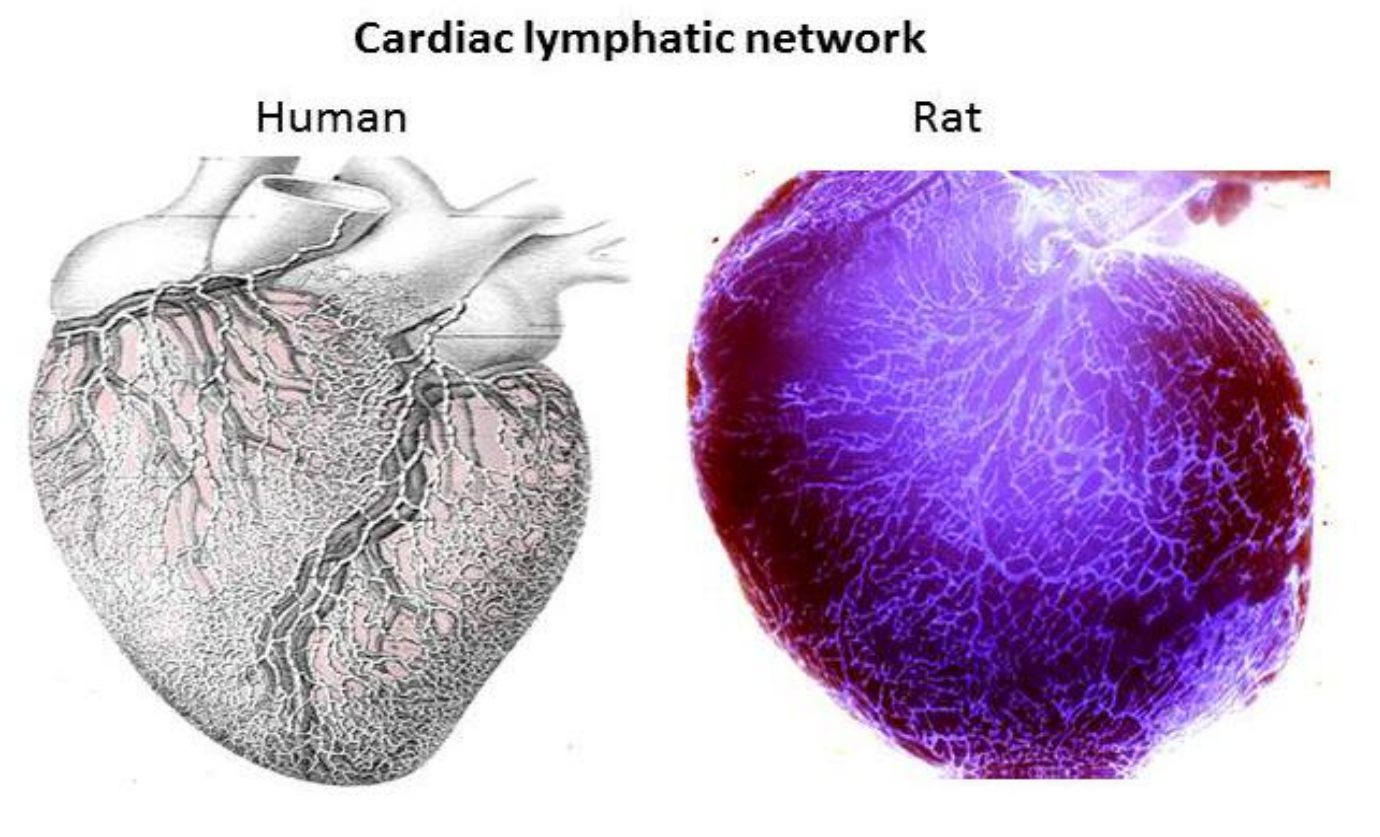
Some cardiac veins do not drain via the coronary sinus.

- Several small **anterior cardiac veins** (*vv. cordis anteriores*) begin over the anterior surface of the right ventricle, cross the coronary sulcus, and usually end directly in the right atrium.
- The **smallest cardiac veins** (*vv. cordis minimae*) are minute vessels that begin in the capillary beds of the myiocardium and open directly into the chambers of the heart, chiefly the atria. Although called veins, they are valveless communications with the capillary beds of the myocardium and may carry blood from the heart chambers to the myocardium.

Lymphatic drainage of the heart

- Lymphatic vessels in the myocardium and subendocardial connective tissue pass to the **subendocardial lymphatic plexus**. Vessels from this plexus pass to the coronary groove and follow the coronary arteries.
- The lymphatic vessels that follow the right coronary artery empty into the **anterior mediastinal lymph nodes** or **brachiocephalic lymph nodes**. The lymphatic vessels that follow the left coronary artery empty into the **inferior tracheobronchial lymph nodes**.

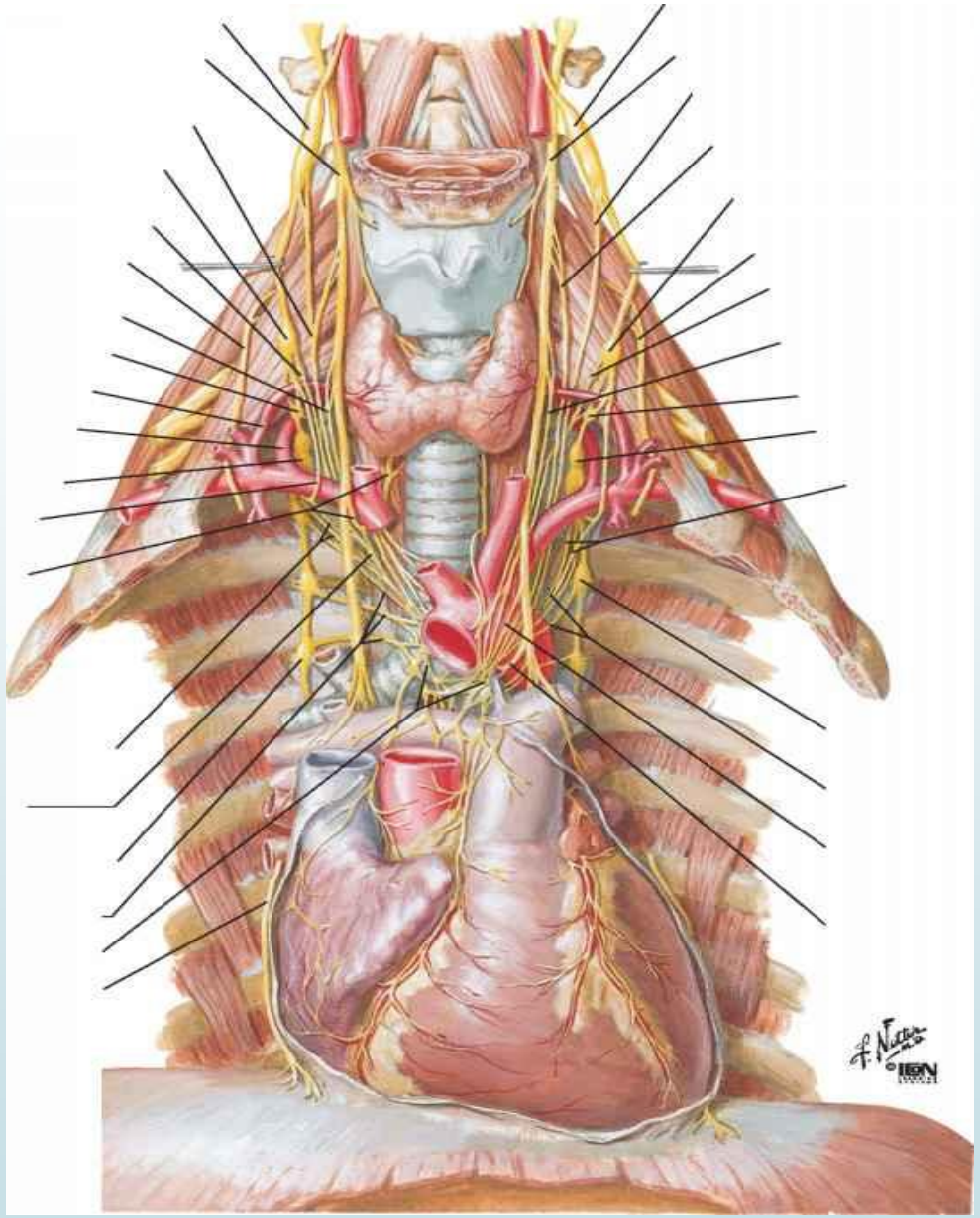
Lymphatic drainage of the heart



Innervation of the heart

- The heart is supply by the vegetative nerve fibers from the **cardiac plexus**, which is often (quite artificially) divided into the **superficial** and **deep portions.**
- This nerve network is most commonly described as lying on the anterior surface of the bifurcation of the trachea.
- The cardiac plexus is formed of both **sympathetic** and **parasympathetic fibers**.
- Fibers are distributed along and to the **coronary arteries,** and to the components of **conducting system of the heart**, particularly the **SA and AV nodes.**

Cardiac plexus



Sources of formation of cardiac plexus

A. Cardiac nerves of sympathetic trunk:

- ***Superior cervical cardiac nerve*** (from superior cervical ganglion);
- ***Middle cervical cardiac nerve*** (from middle cervical ganglion);
- ***Inferior cervical cardiac nerve*** (from inferior cervical ganglion or cervicothoracic ganglion);
- ***Thoracic cardiac nerves*** (from superior thoracic ganglia of the sympathetic trunk).

Sources of formation of cardiac plexus

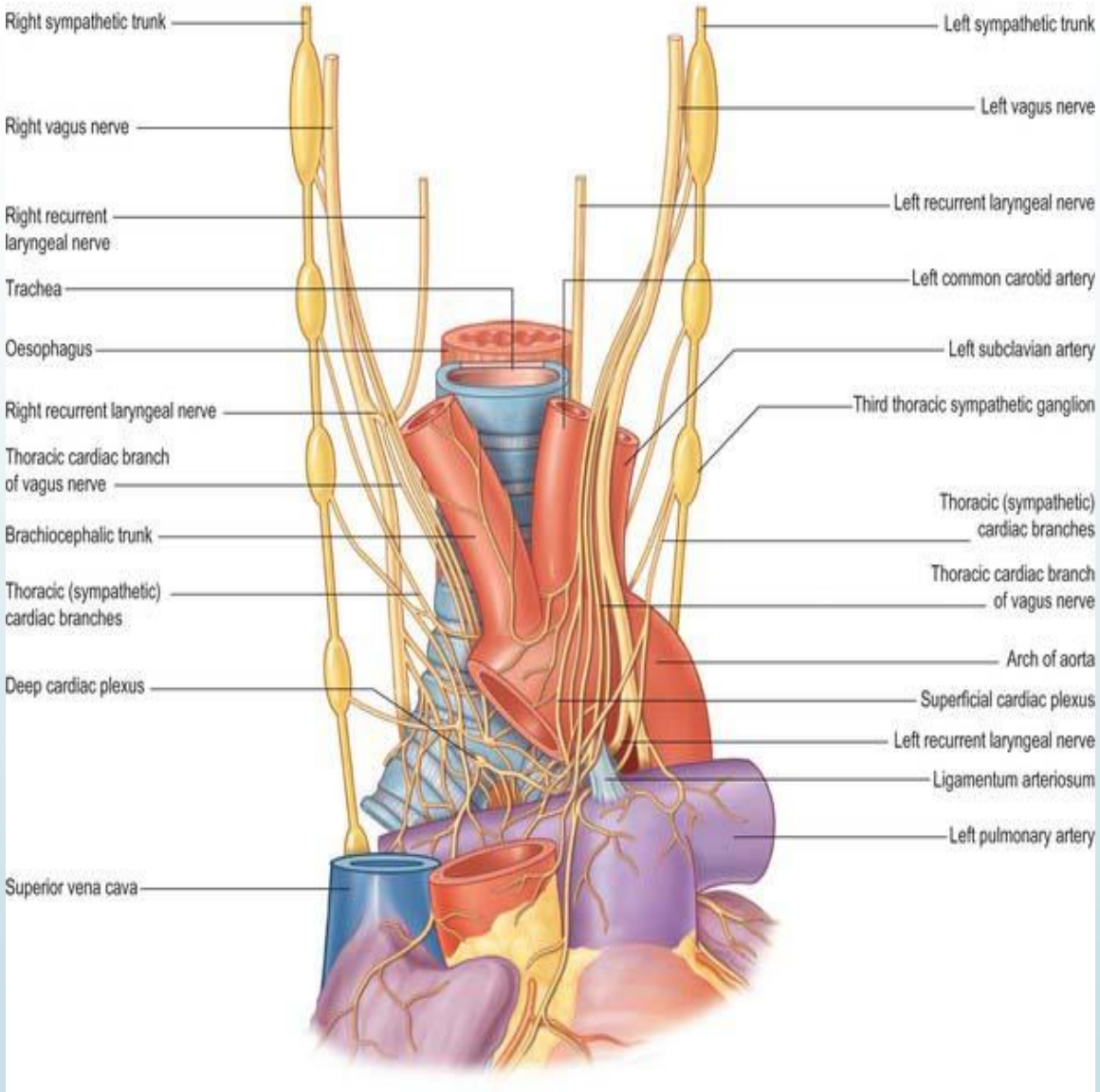
B. Cardiac branches of vagus nerve:

- ***Superior cervical cardiac branches*** (from cervical part of vagus nerve);
- ***Inferior cervical cardiac branches*** (from recurrent laryngeal nerve);
- ***Thoracic cardiac branches*** (from thoracic part of vagus nerve).

Two parts of (extraorganic) cardiac plexus

- **Superficial** (or ventral) **part** is located below the aortic arch, between it and pulmonary trunk. It is formed by the **left superior cervical cardiac nerve** (from left superior cervical ganglion) and the **left superior cervical cardiac branches** (from the left vagus nerve).
- **Deep** (or dorsal) **part** is situated behind of the aortic arch and in front of the bifurcation of the trachea. It is formed by the **cervical and thoracic cardiac nerves** (from cervical and thoracic paravertebral ganglia of sympathetic trunk) and the **cervical and thoracic cardiac branches** (from vagus nerve), except the nerves which form the superficial part.

Two parts of cardiac plexus



Intraorganic cardiac plexus

- **Right coronary plexus**, formed by superficial and deep parts of cardiac plexus, accompanies the right coronary artery and supply the right atrium and the right ventricle.
- **Left coronary plexus**, formed by deep part of cardiac plexus, accompanies the left coronary artery and supply the left atrium and left ventricle.

Intracardiac branches of cardiac plexus, right and left coronary plexuses supply the **conducting system of the heart**, **myocardium** and **coronary arteries.**

The branches of vagus nerve supply:

- **sinuatrial (SA) node,**
- **atrioventricular (AV) node,**
- **myocardium of atria.**

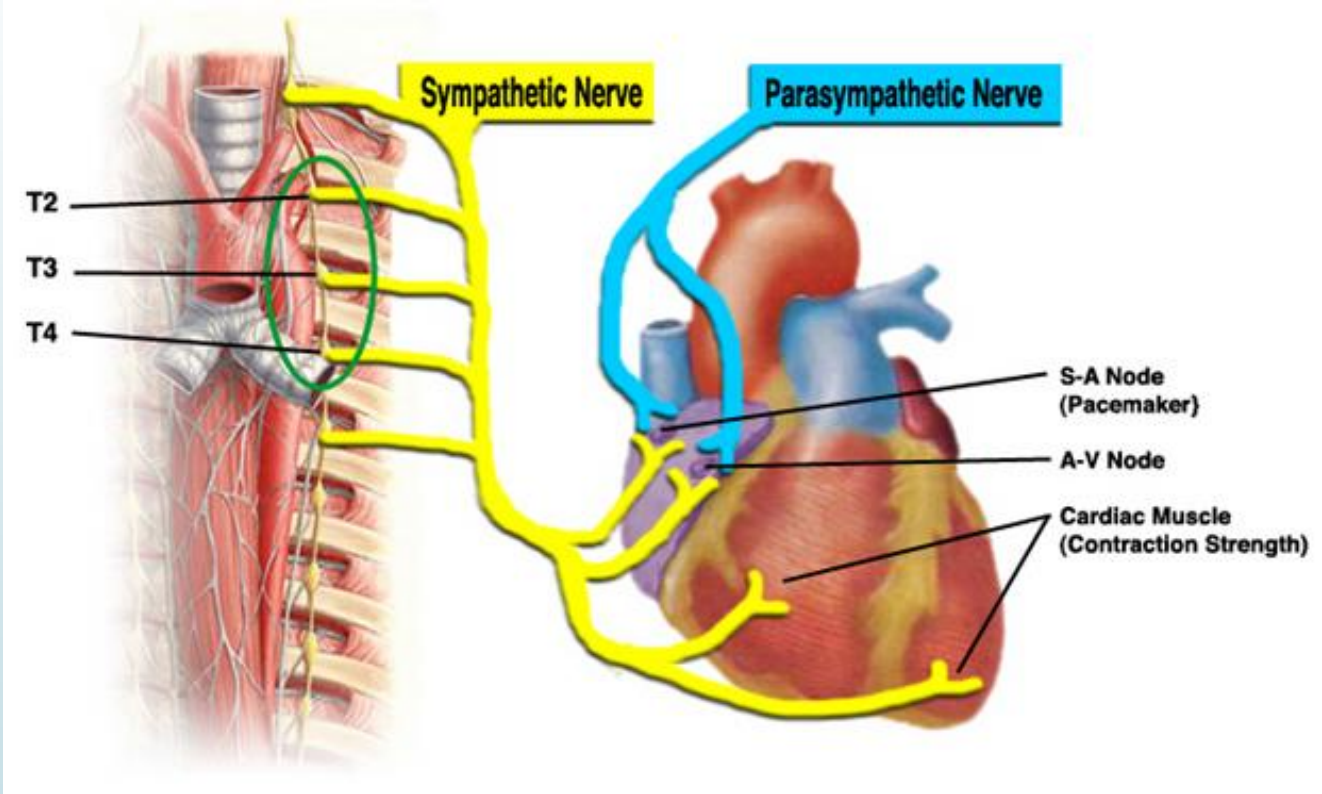
The *right vagus nerve* especially supply the **SA node**, however the *left vagus nerve* especially supply the **AV node**.

The branches of sympathetic trunk supply:

- **sinuatrial (SA) node,**
- **atrioventricular (AV) node,**
- **myocardium of atria,**
- **myocardium of ventricles,**
- **bundle of His and fibers of Purkinje.**

The *right cardiac nerves* supply the **conducting system of the heart**, however the *left cardiac nerves* supply the **myocardium**.

Innervation of the heart



Afferent innervation of the heart

The afferent (sensory) innervation of the heart is provided by the **pseudounipolar neurons**, located in the **spinal ganglia** and in the **ganglia of vagus nerve**. These neurons are responsible for sending information to the CNS.

Sensory neurons innervating the heart also have been identified in **intrinsic cardiac ganglia.** These sensory neurons are in a position to initiate the **local reflexes** and, therefore, have a significant impact on the heart rate and contractility via the modulation of the activity of efferent parasympathetic neurons located in the intrinsic cardiac ganglia.

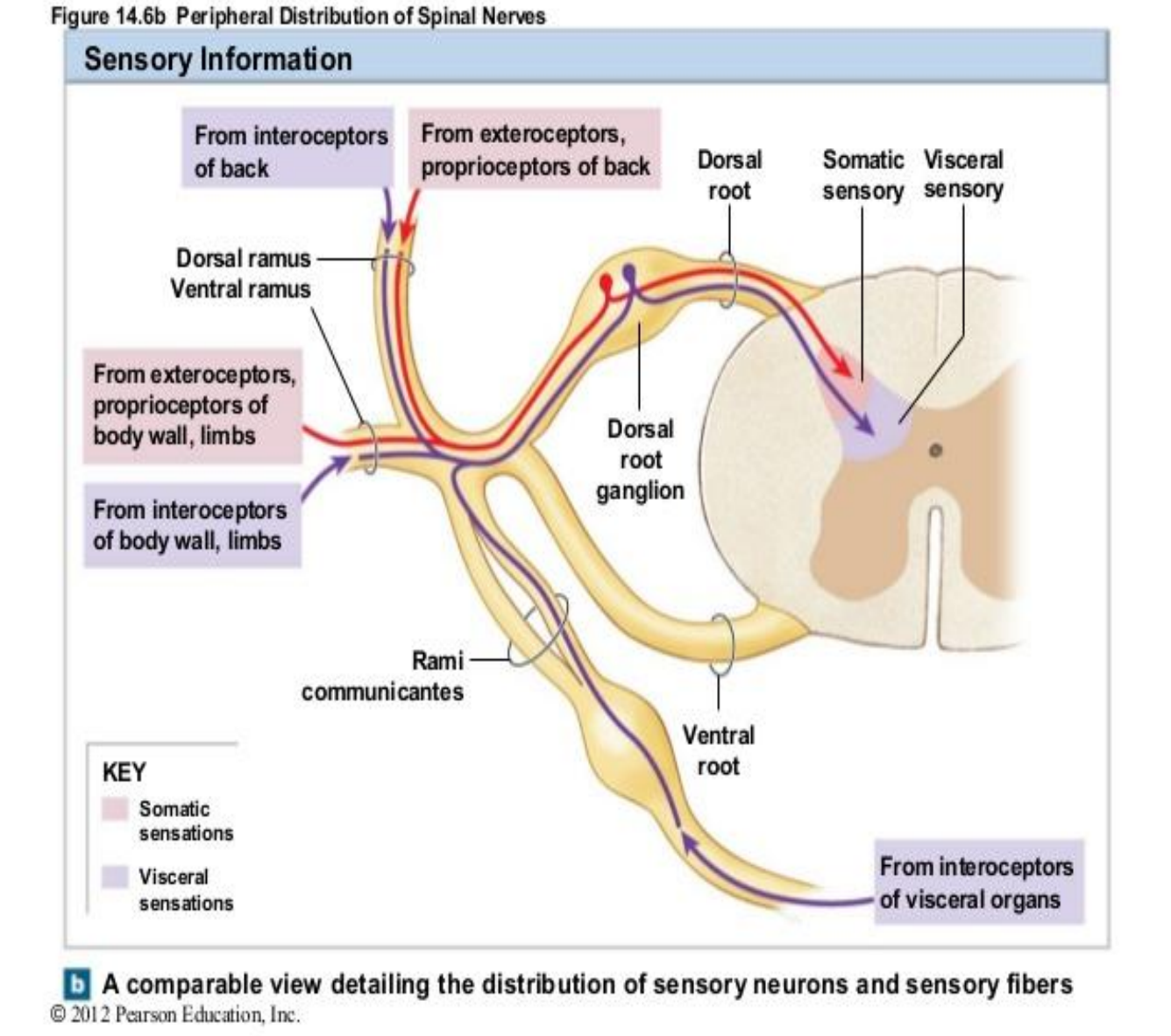
Afferent innervation of the heart

The peripheral stimuli are transmitted through the sympathetic afferents to the **spinal ganglia** (of dorsal roots) and then, principally via the spinothalamic tract to the posterior thalamus.

Through the vagal afferents the peripheral stimuli reach the **superior** and **inferior ganglia** of the vagus nerve and **solitary tract nucleus**, and from there to the posterior thalamus.

The **nucleus of tractus solitarius** is a vital integrating center for the reflex control of cardiac circulation. The efferent fibers from this nucleus pass to the dorsal nucleus of vagus nerve, to the nuclei of reticular formation of the brain steam, to the hypothalamus and other centers of the brain.

Afferent (sensory) innervation



Efferent innervation of the heart

Both the *sympathetic* and *parasympathetic portions* of the autonomic nervous system have a *two neurons pathway* from the central nervous system to the peripheral organ:

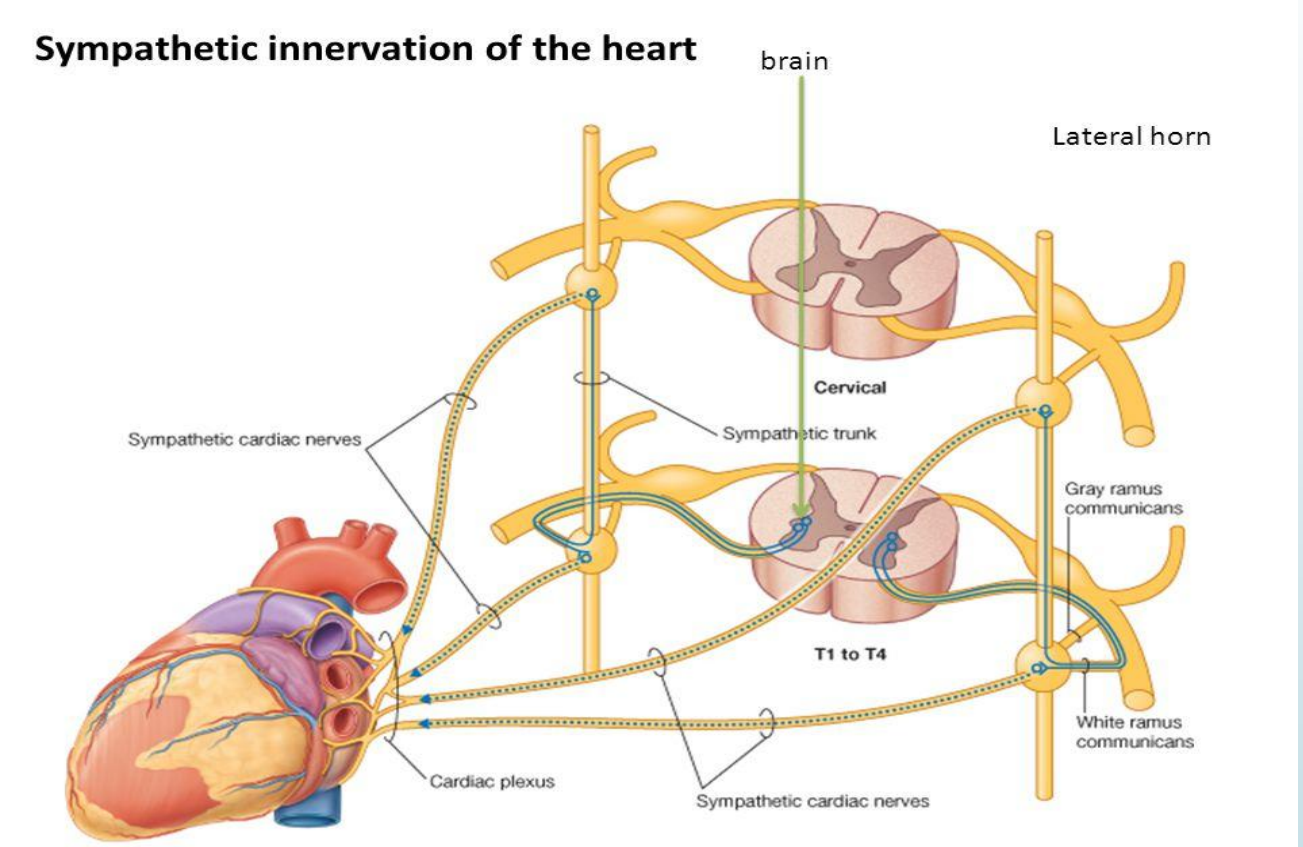
1. **Preganglionic neurons** located in the foci (centers) of autonomic nervous system;
2. **Postganglionic neurons** located in the autonomic (vegetative) nerve ganglia.

(Mediator of the preganglionic (sympathetic and parasympathetic) neurons is *acetylcholine* (**cholinergic neurons**); mediator of sympathetic postganglionic neurons – *adrenalin* and *noradrenalin* (**adrenergic neurons**); mediator of parasympathetic postganglionic neurons – *acetylcholine* (**cholinergic neurons**)).

Efferent sympathetic innervation of the heart

- The *sympathetic preganglionic neurons* are located in the **intermediolateral nucleus** of the superior *five* or *six thoracic segments* of the spinal cord.
- The *sympathetic postganglionic neurons* are located in the **cervical** and **thoracic** (paravertebral) **ganglia of the sympathetic trunks.**
- The postganglionic fibers travers the **cardiac nerves** and the **cardiac plexus** to end in the SA and AV nodes, in the myocardium and on the coronary arteries.
- **Sympathetic stimulation** causes *increased heart rate*, impulse conduction, force of contraction, and, at the same time, *increased blood flow through the coronary vessels* to support the increased activity.

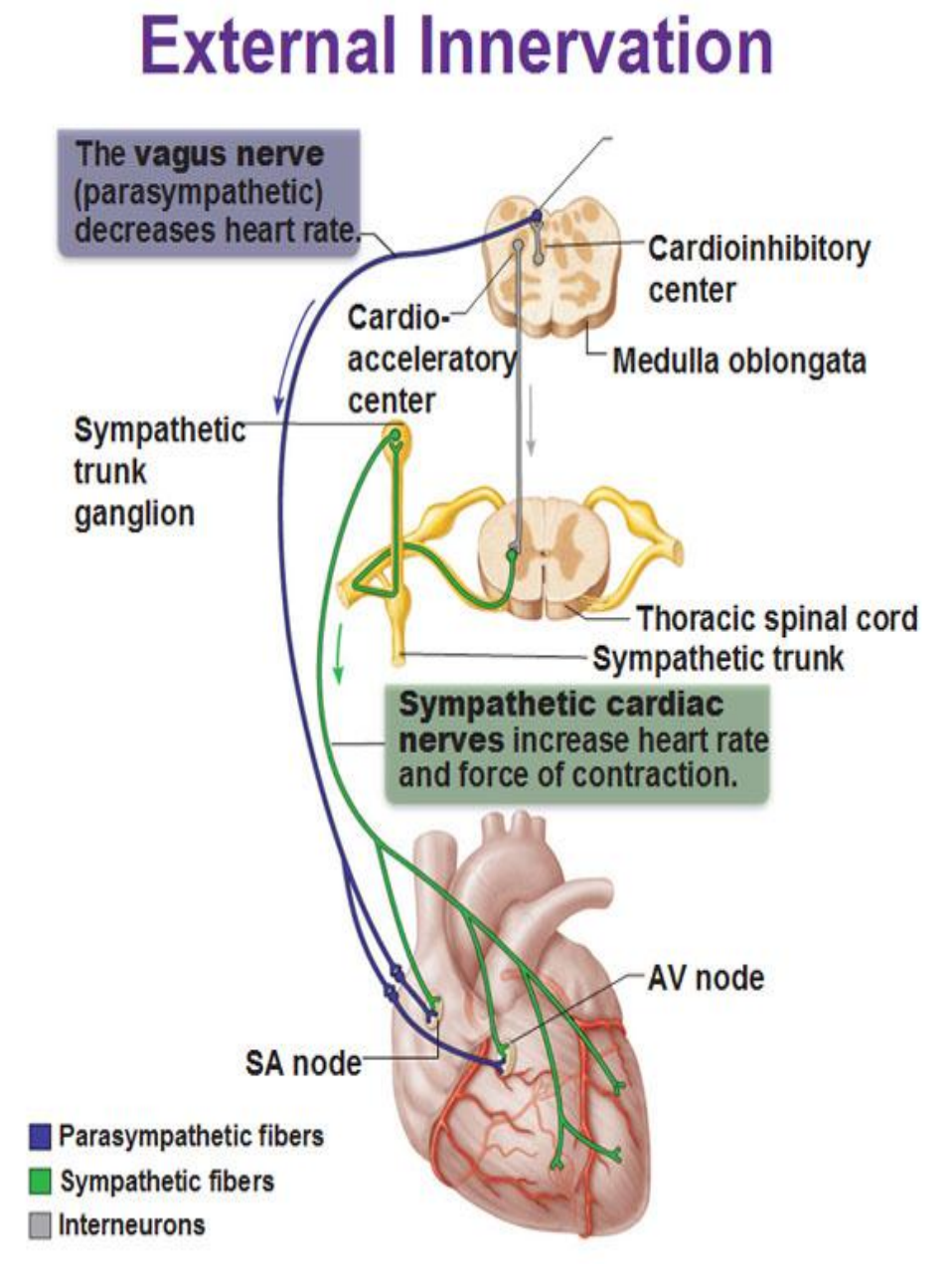
Efferent sympathetic innervation of the heart



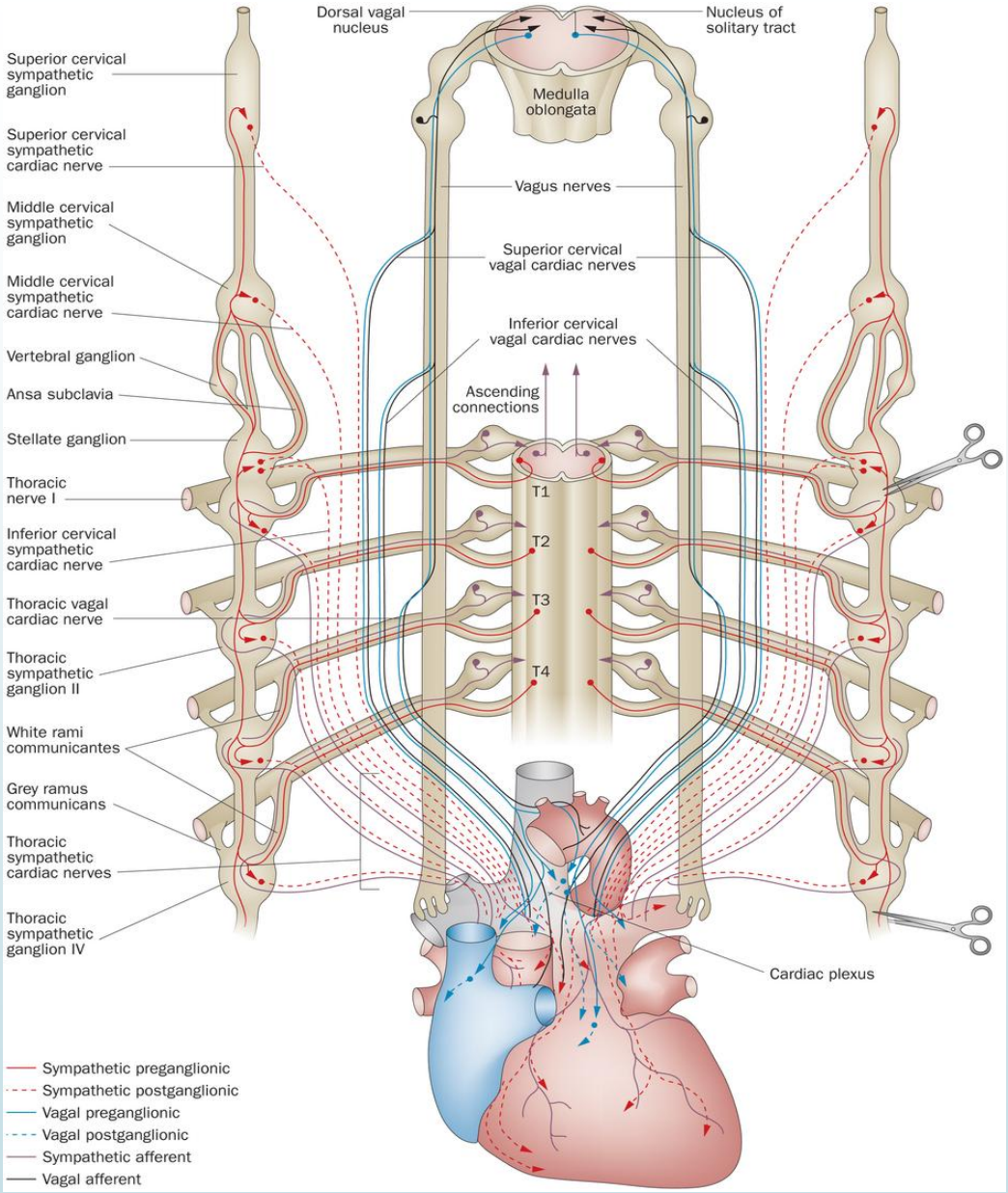
Efferent parasympathetic innervation of the heart

- The *parasympathetic preganglionic neurons* are located in the **dorsal nucleus of vagus nerve.**
- The preganglionic fibers (axons of the preganglionic neurons) pass through the **cardiac branches of vagus nerve** to reach the **cardiac plexus**.
- The *parasympathetic postganglionic neurons* lie in the **terminal** (intrinsic) **ganglia** situated in the *atrial wall* and *interatrial septum* near the SA and AV nodes and along the coronary arteries.
- **Parasympathetic stimulation** *slows the heart rate*, reduces the force of the contraction, and *constricts the coronary arteries*, saving energy between periods of increased demand.

Efferent parasympathetic innervation of the heart



Cardiac plexus



Autonomic cardiovascular control

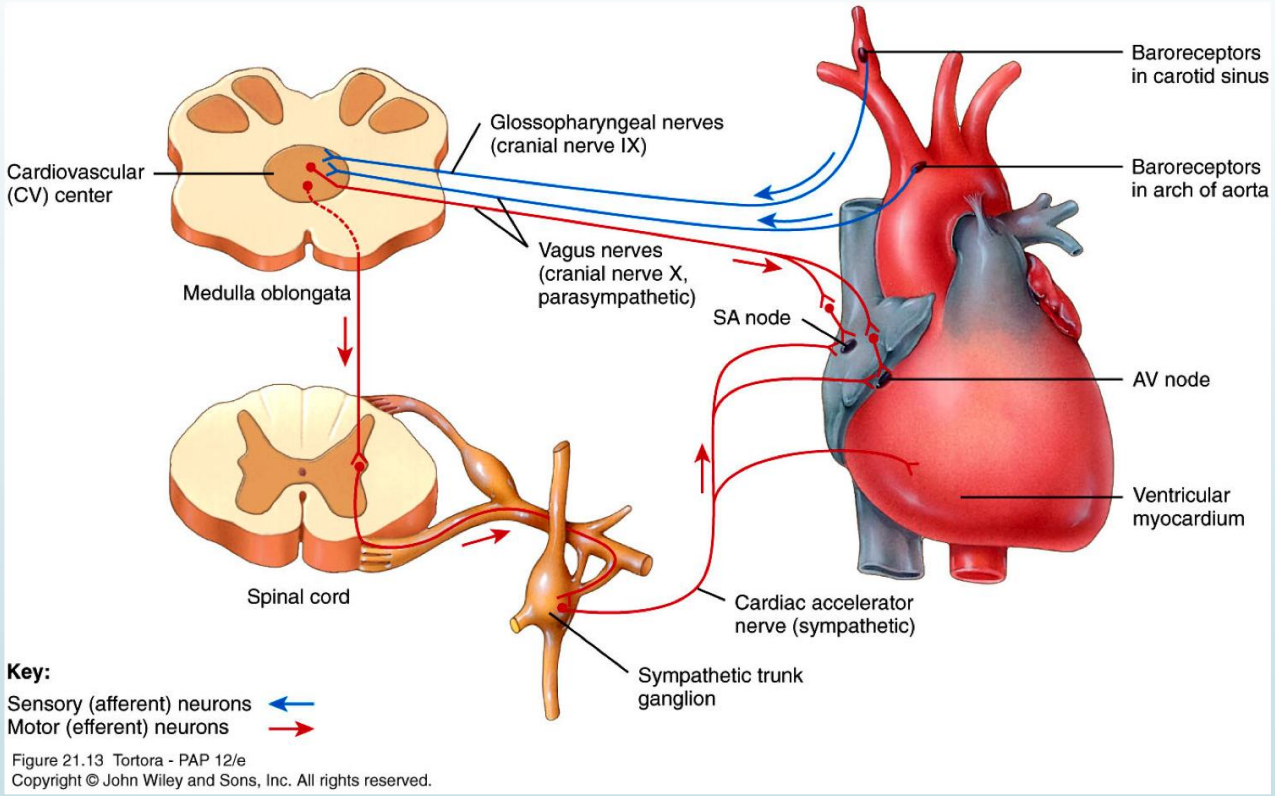


Figure 21.13 Tortora - PAP 12/e

Thank you!