

Cardiovascular Physiology

Coronary Circulation

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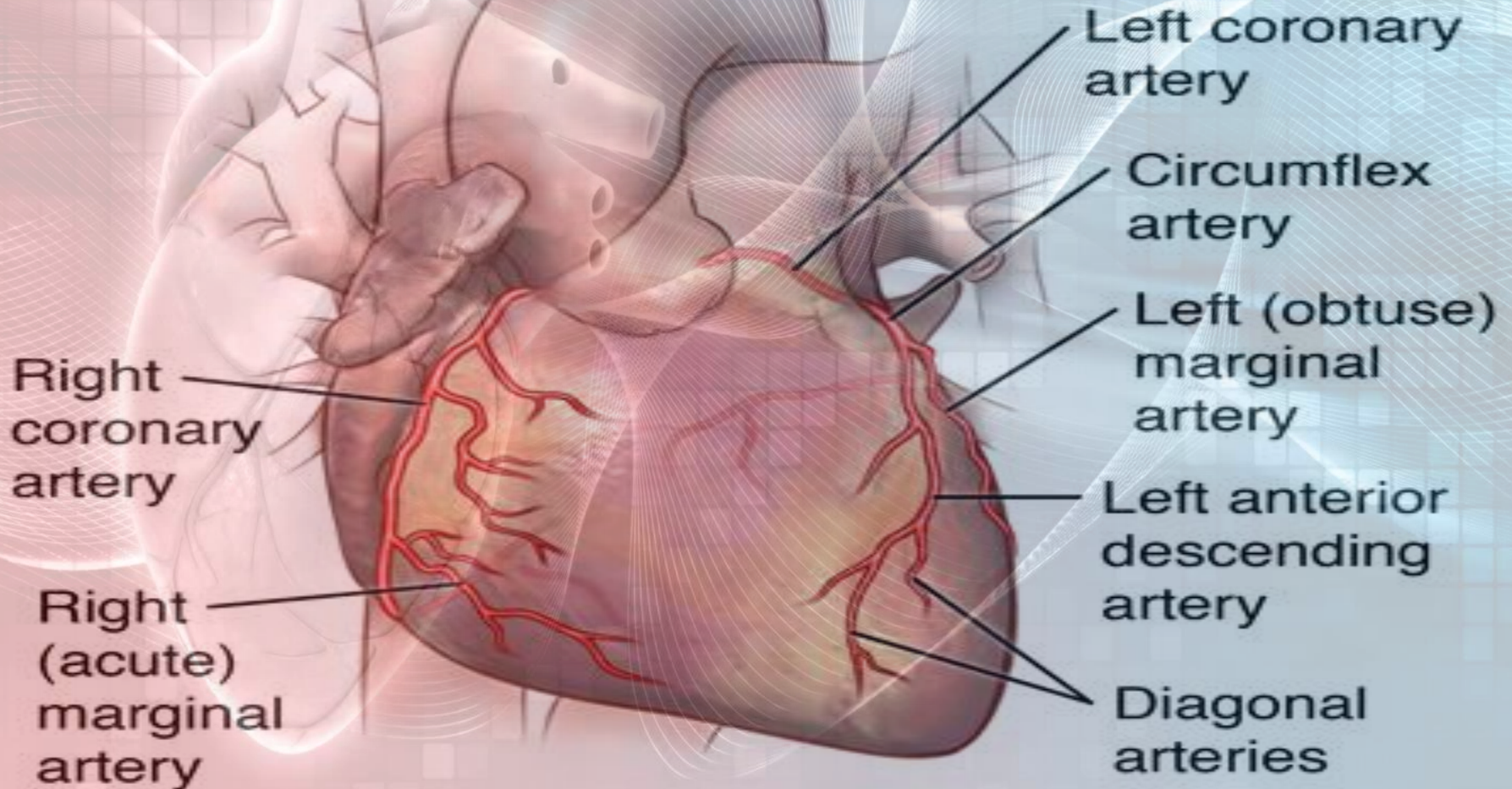
Lecture Outcomes

- **Coronary circulation & areas of supply.**
- **Coronary collateral circulation.**
- **Coronary dominance.**
- **Coronary blood flow & factors affecting it.**
- **Control of coronary blood flow.**

Coronary Circulation

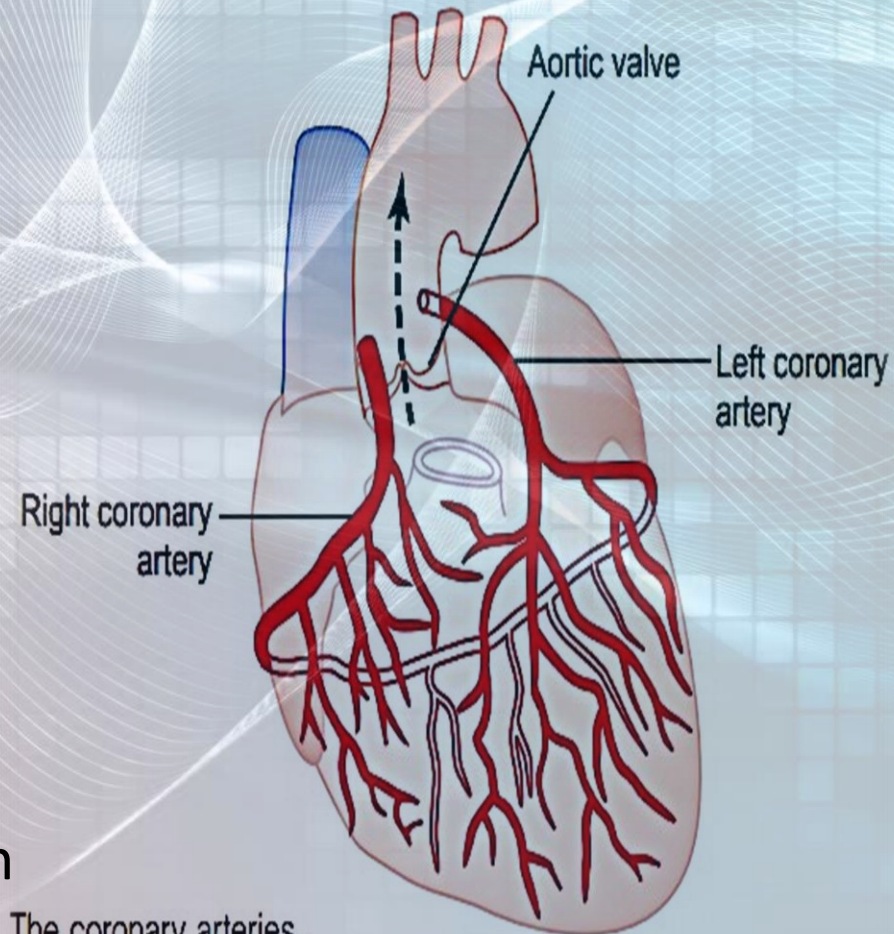
- ❑ **Coronary circulation** is the circulation of blood in the blood vessels that supply the heart muscle (myocardium).
- ❑ **Consists of:**
 - Arterial supply.
 - Venous drainage.
 - Lymphatic drainage.
- ❑ Coronary arteries supply oxygenated blood to the heart muscle, while cardiac veins drain away the blood once it has been deoxygenated.
- ❑ Coronary circulation is of major importance not only to its own tissues but to the entire body & even to the level of consciousness of the brain from moment to moment.

Coronary arteries of the heart



Coronary Circulation : Arterial Supply

- ❑ Cardiac muscle is supplied by **two coronary arteries**:
 - A. Right coronary artery (RCA.)
 - B. Left coronary artery (LCA.)
- ❑ Both **arise from** the coronary sinuses at the aortic root, just superior to the aortic valve cusps.
- ❑ They **wrap** with their branches around the outside of the heart to supply all cardiac muscle with blood.

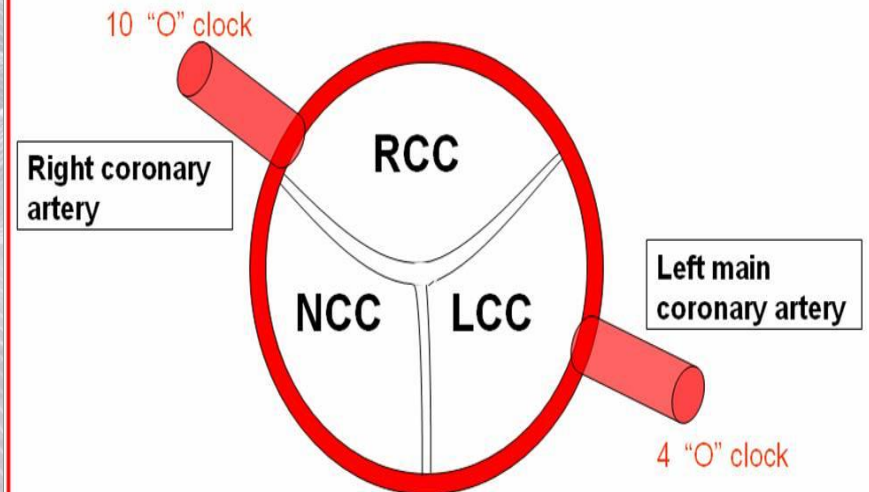


The coronary arteries.

Coronary Sinuses

- ❑ Aortic valve has three cusps:
 - Left coronary cusp (LCC).
 - Right coronary cusp (RCC).
 - Posterior non-coronary (NCC) cusp.
- ❑ There may be variations in the number, shape, & location of coronary ostia or origins of the coronary arteries, most of which are of no clinical significance.
- ❑ Coronary arteries deliver oxygenated blood to the cardiac muscle.

Where to look for coronary artery origin in short axis view ?

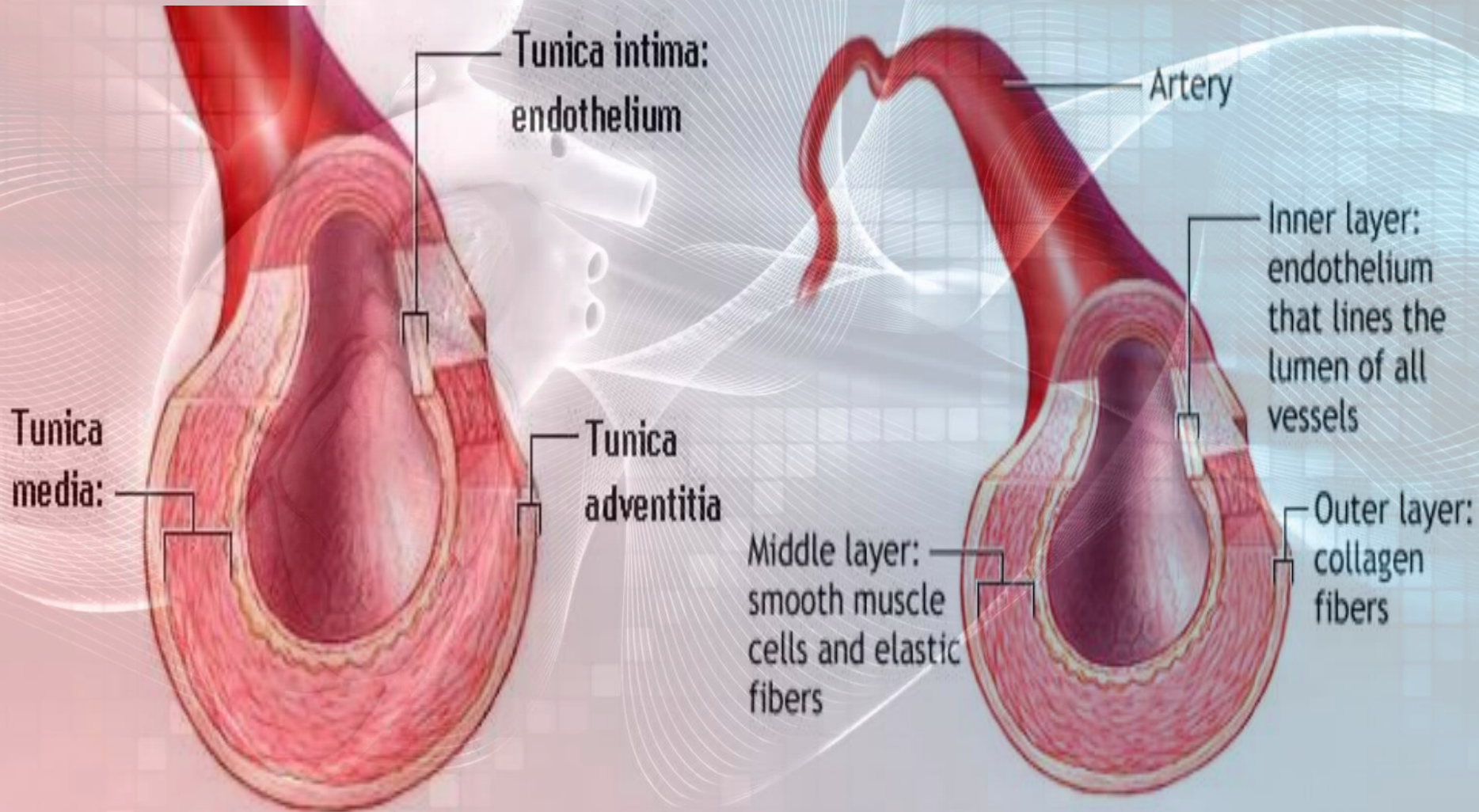


RCC –Right coronary cusp
LCC –Left coronary cusp
NCC –Non coronary cusp

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Note : The aortic trileaflet attachment is highly variable . So also , the coronary artery origin. RCA originates anywhere between 9 & 11, LCA between 3 & 5 "O"clock position .

Coronary Circulation: **Arterial Wall**

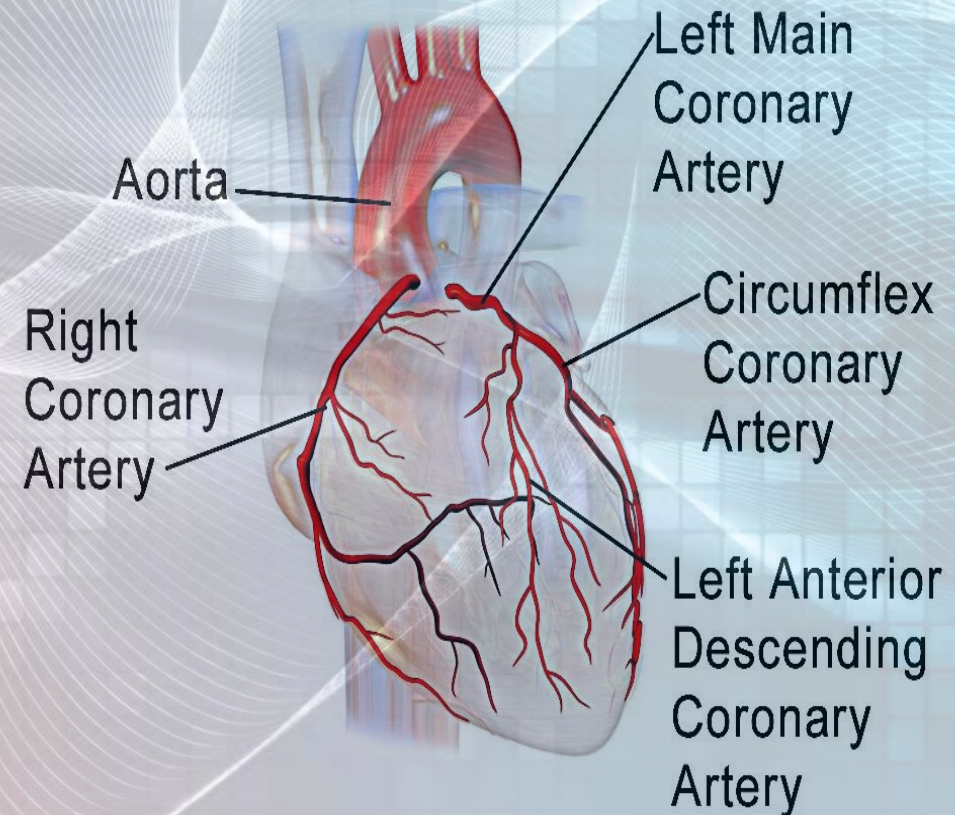


Coronary Circulation: **Left Coronary Artery**

- ❑ Also known as the **left main coronary artery (LMCA)**.
- ❑ Larger than the right coronary artery.
- ❑ Arises from the left coronary sinus.
- ❑ Runs for 10-25mm before bifurcating.
- ❑ Terminates by anastomosing with the right coronary artery.
- ❑ Supplies blood to the left side of the heart muscle (left ventricle & left atrium).

Left Coronary Artery: Main Branches

- Two main branches:
 - **Left anterior descending artery (LAD):**
Also called anterior interventricular artery.
 - **Circumflex artery (CX):**

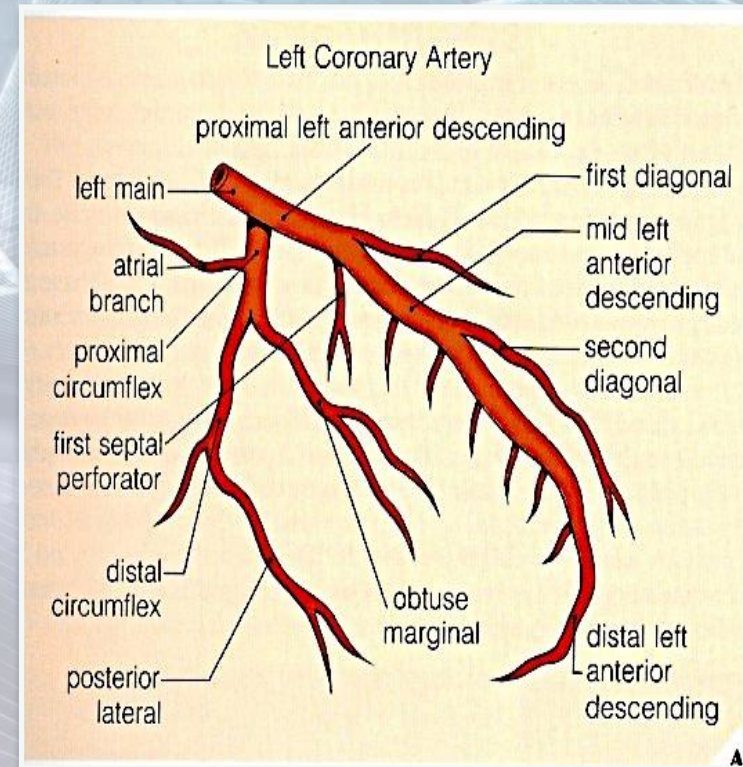


Coronary Arteries

Left Coronary Artery: **Branches**

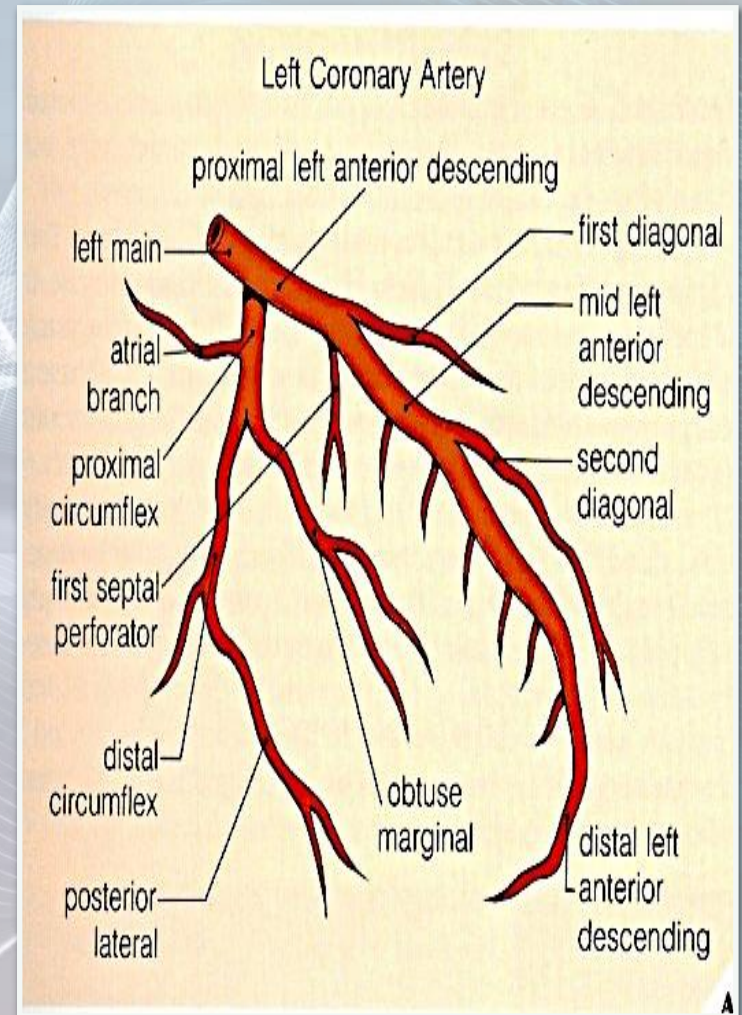
■ **Left Anterior Descending Artery (LAD):**

- Considered the **most critical vessel** in terms of myocardial blood supply.
- It **supplies 45-55% of the left ventricle** (the anterior & apical part of the heart):
 - The anterolateral of the left ventricle.
 - The apex of the heart.
 - The anterior 2/3 of the interventricular (IV) septum.
 - The front of the right ventricle.
 - The right & left bundle branches.
- **Further divides into:**
 - **Diagonal arteries.**
 - **Left conus arteriosus artery.**
 - **Septal perforator (SP) artery.**



Left Coronary Artery: **Branches**

- **Circumflex Artery (CX):**
 - **Encircles the heart muscle.**
 - **Supplies blood to the lateral & posterior surface of the heart: left atrium, & the posterolateral of the left ventricle.**
 - **Further divides into:**
 - **Left obtuse marginal (OM) artery,** which supplies the left ventricle.
 - **SA nodal artery,** which supplies the SA- node in ~40% of hearts & the surrounding myocardium.
 - **Left branch to the AV- Bundle.**
 - **Posterior ventricular branch.**
 - **Anterior ventricular branch.**



Coronary Circulation: **Right Coronary Artery**

- ❑ The **right coronary artery (RCA)** is smaller than the left coronary artery.
- ❑ Arises from the right coronary sinus.
- ❑ Curves posteriorly & descends downward on the posterior surface of the heart.
- ❑ Terminates by anastomosing with the left coronary artery.
- ❑ Supplies blood to the right atrium, the SA (sinoatrial) & AV (atrioventricular) nodes, right ventricle, bottom portion of both ventricles, & back of the septum.

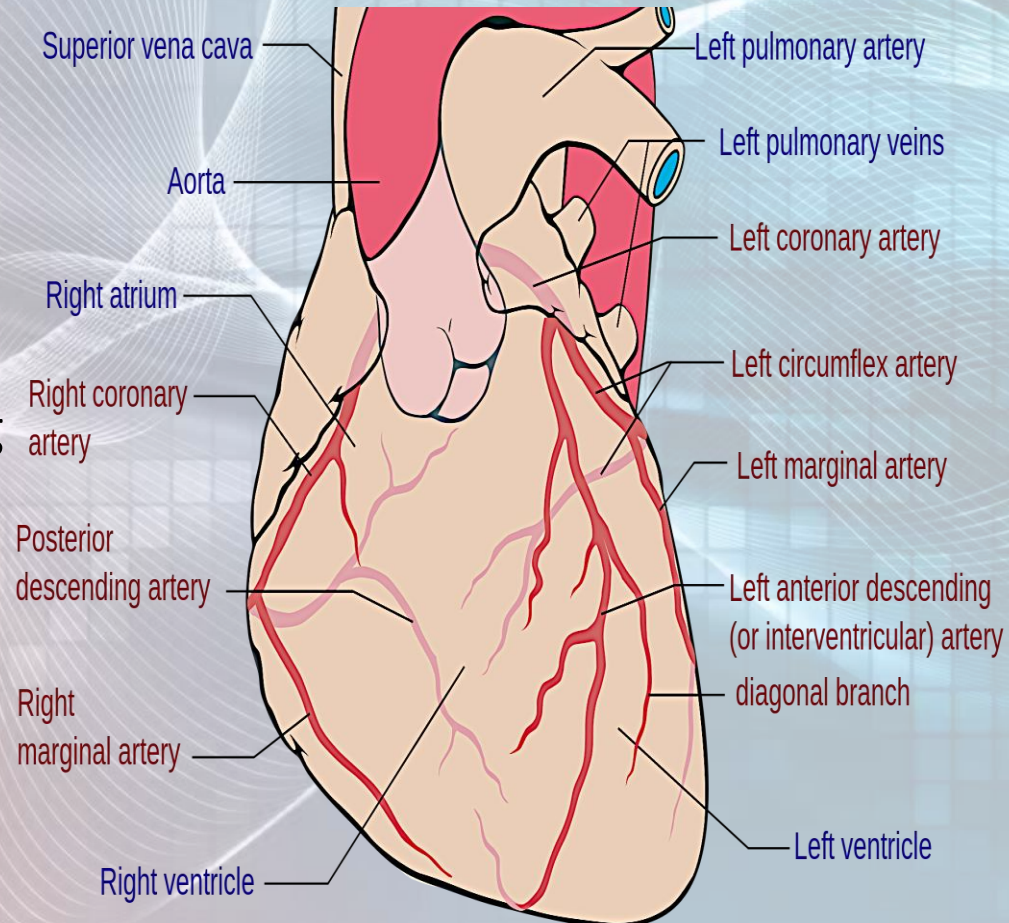
Right Coronary Artery: Main Branches

□ Two main branches:

- **Right posterior descending artery (RPD):**

Also called posterior interventricular/descending artery.

- **Right acute marginal artery:**



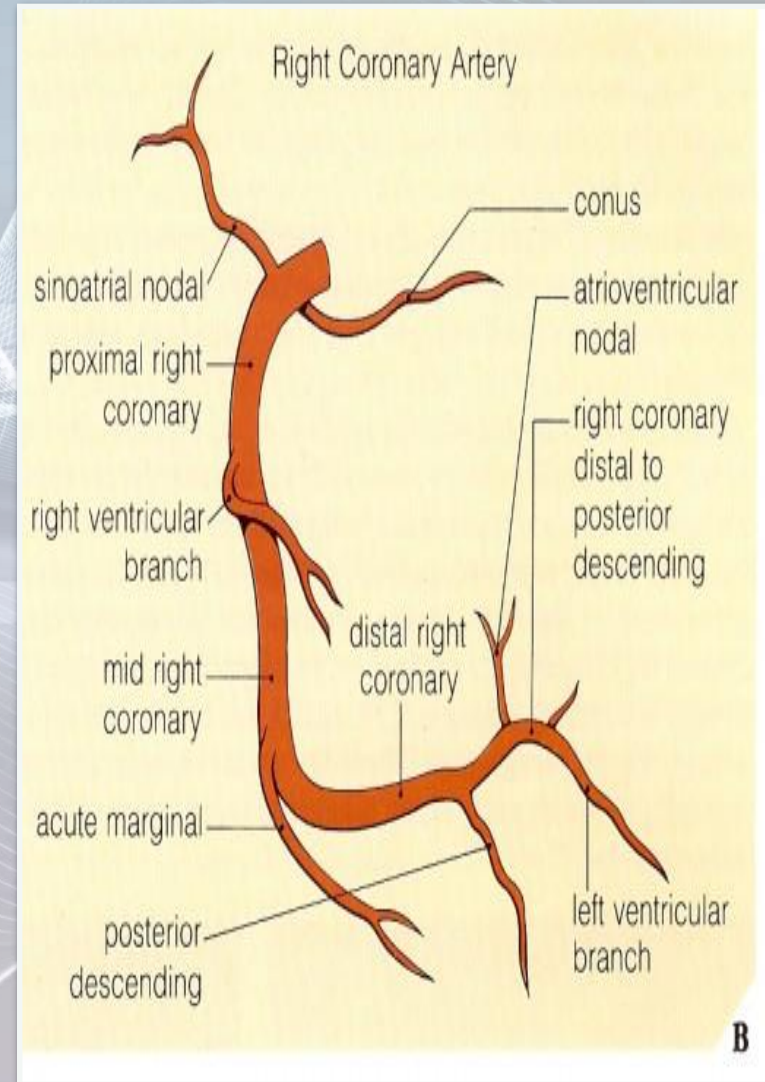
Right Coronary Artery: **Branches**

■ **Right Posterior Descending Artery (RPD):**

- **Curves** posteriorly & **descends** downward on the posterior surface of the heart.
- Supplies blood to the right atrium, right ventricle, bottom portion of the left ventricle, & posterior 1/3 of the Interventricular (IV) septum.
- Branches into **AV nodal artery**, which supplies the AV- node (in **60-90 %** of hearts) & the surrounding myocardium.

■ **Right Acute Marginal Artery (AM):**

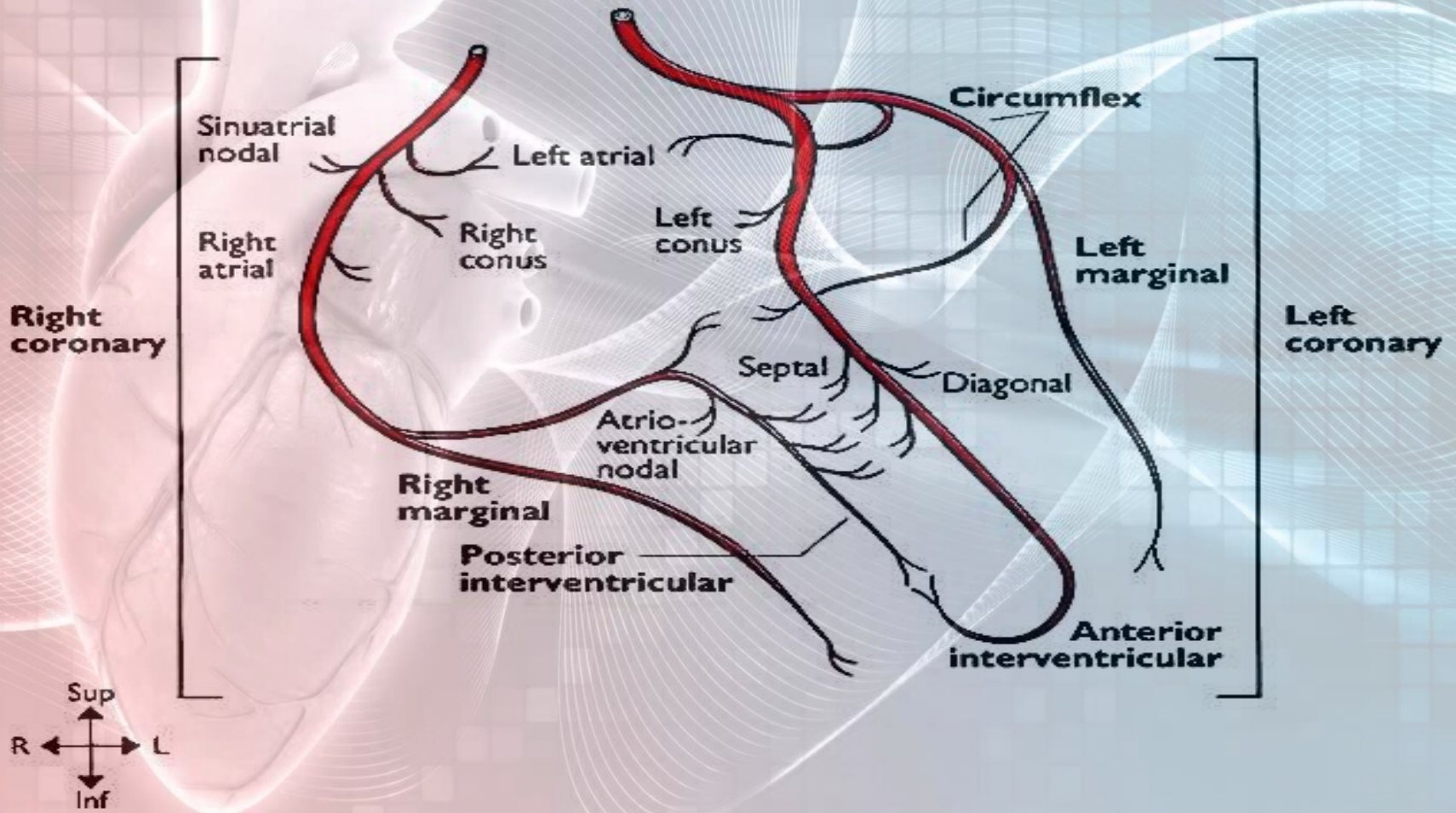
- Runs down the right margin of the heart.
- Supplies blood to the right margin of the right ventricle, with minimal supply to the apex.



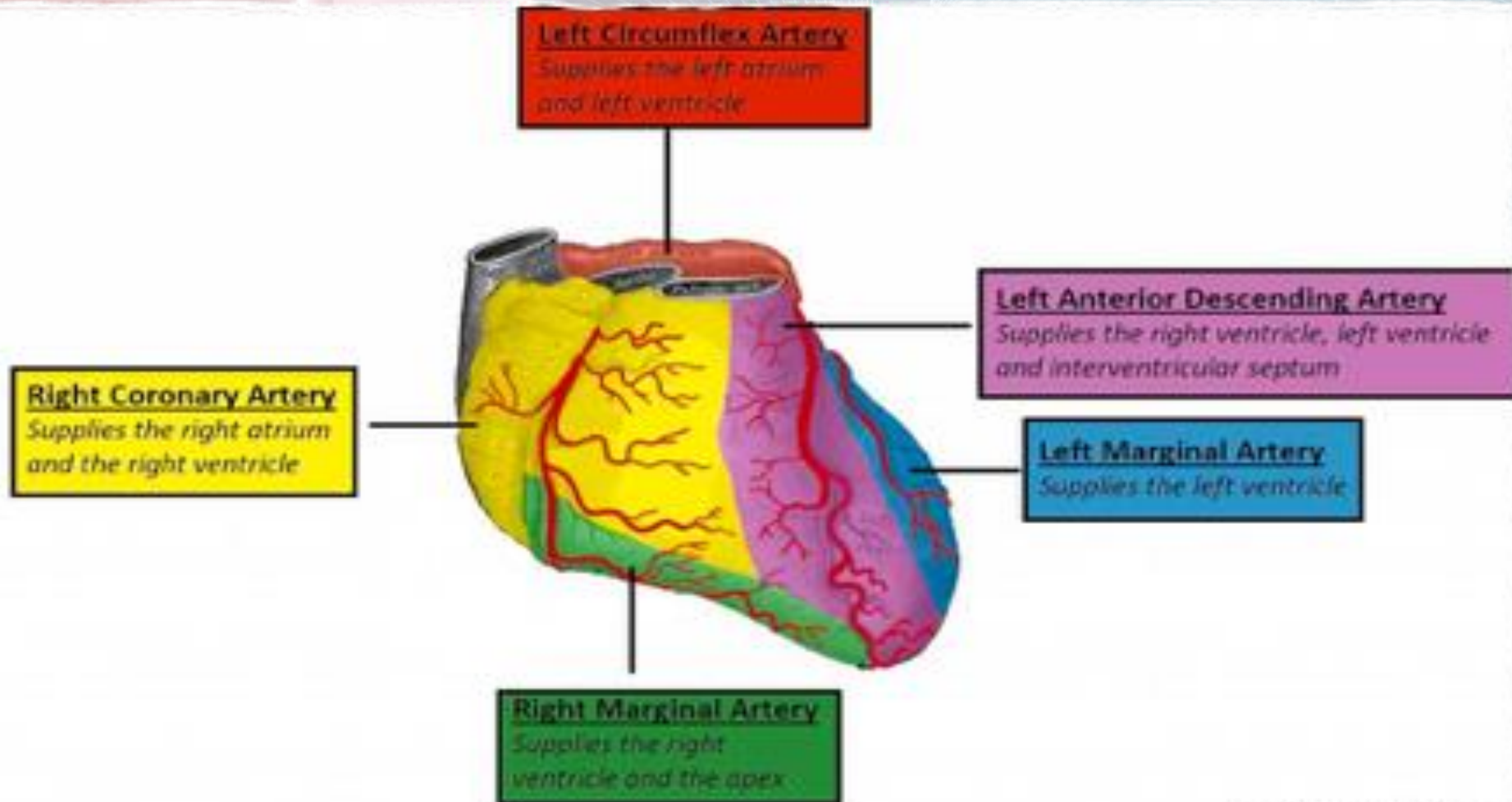
Right Coronary Artery: **Branches**

- ❑ **Smaller arteries branch from the right coronary artery:**
 - **Atrial branch**, gives off:
 - **SA nodal artery**, which supplies the SA- node in **60%** (~50-73%) of hearts & the surrounding myocardium.
 - **Right conus arteriosus artery.**
 - **Right anterior ventricular artery.**
 - **Septal perforator (SP) artery.**

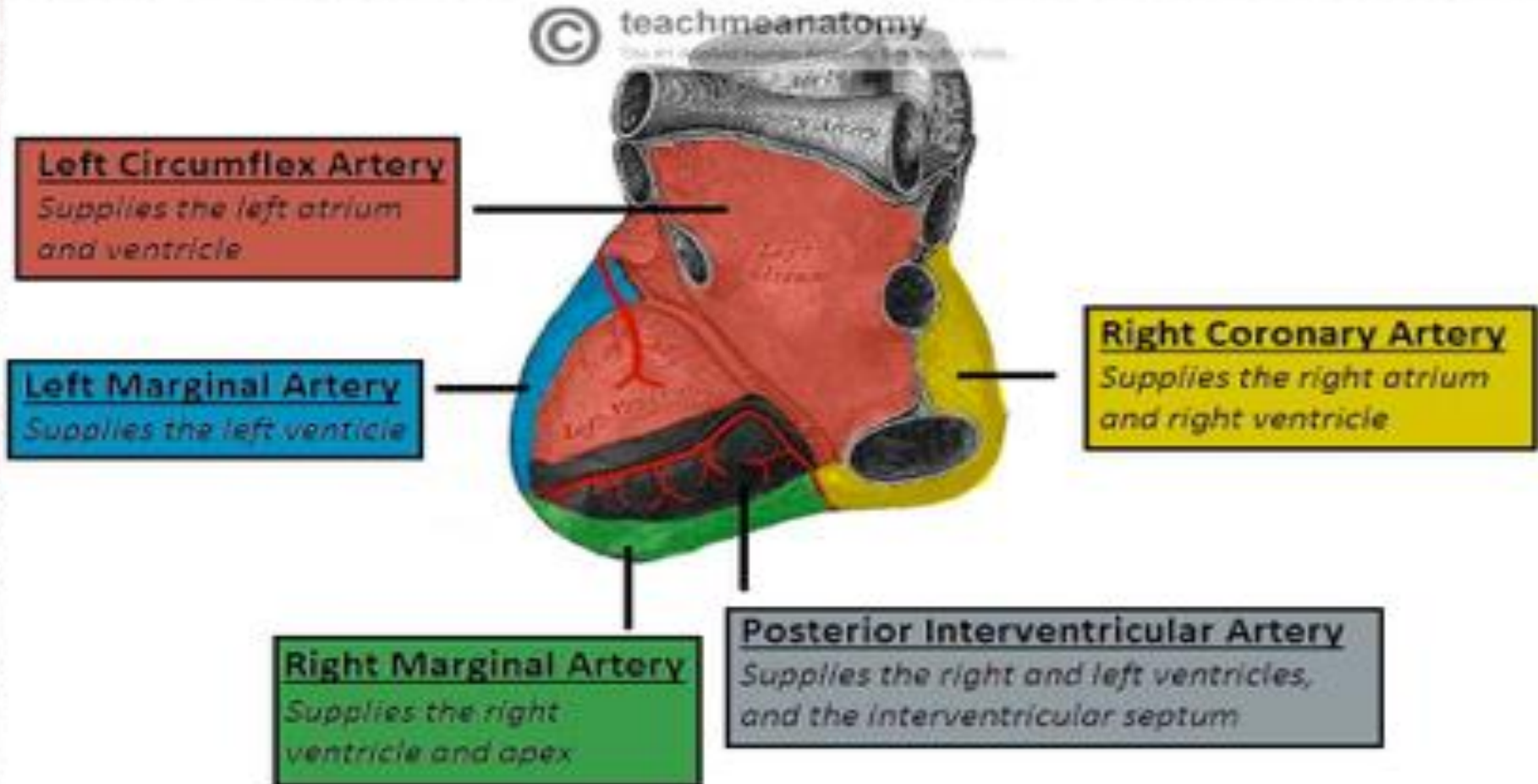
Coronary Arteries: **Branches**



Coronary Circulation: Areas of Distribution: Front View

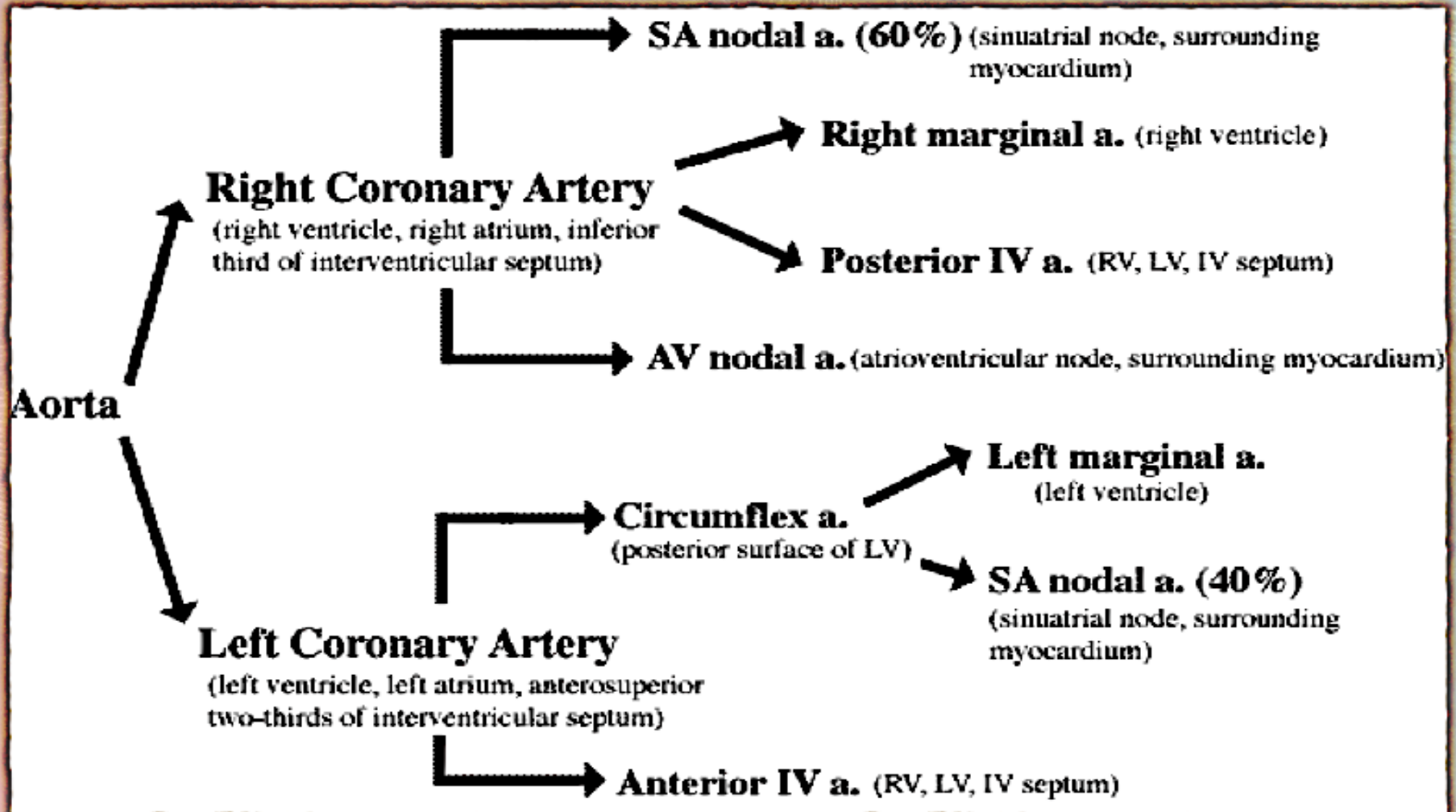


Coronary Circulation: Areas of Distribution: **Back View**



Branches & Supply Of Coronary Arteries:

Summary



Coronary Circulation: Cardiac Anastomosis

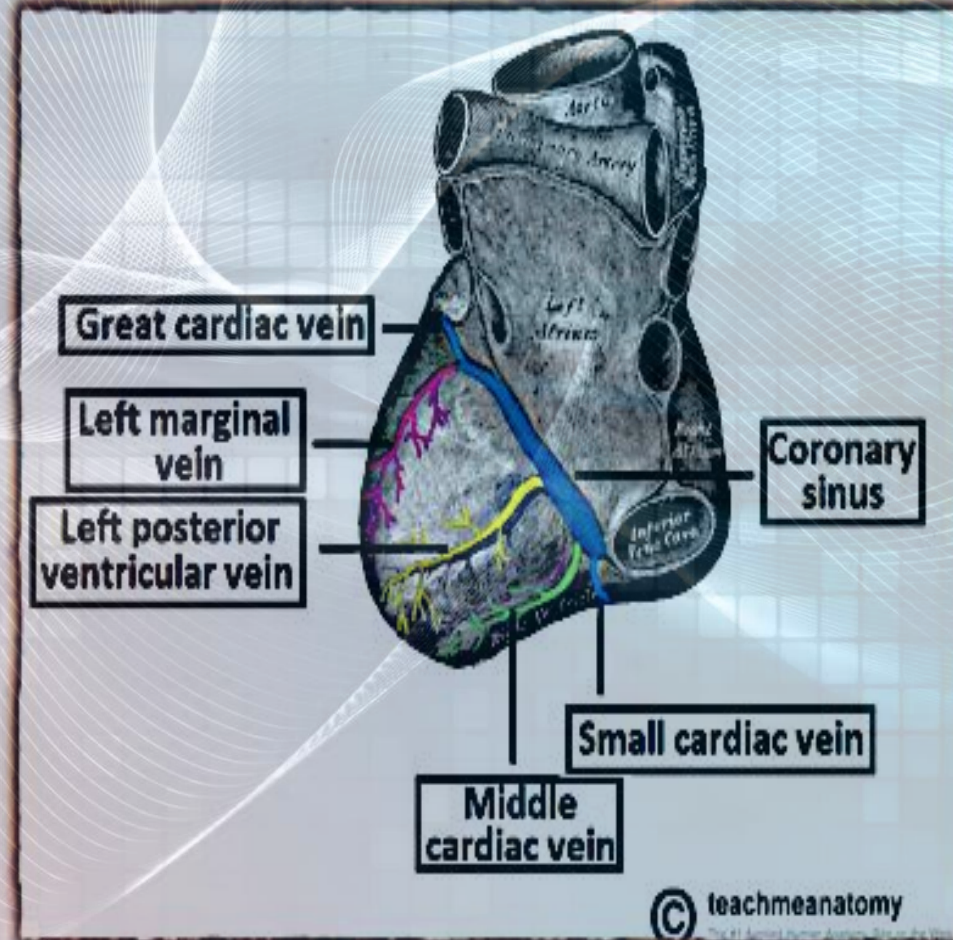
- ❑ **Cardiac anastomosis:**
 - The two coronary arteries anastomose in the myocardium.
- ❑ **Extra cardiac anastomosis: the two coronary arteries anastomose with,**
 - Vasa vasorum of the aorta.
 - Vasa vasorum of pulmonary arteries.
 - Internal thoracic arteries.
 - The bronchial arteries.
 - Phrenic arteries.

Coronary Circulation: Collateral Circulations

- ❑ Collateral circulation is a network of extra-cardiac channels formed of tiny blood vessels.
- ❑ Under normal conditions it is not open.
- ❑ It opens in emergencies when the coronary arteries are blocked:
 - When the coronary arteries narrow to the point that blood flow to the heart muscle is limited (coronary artery disease), collateral vessels may enlarge & become active.
 - This allows blood to flow around the blocked artery to another artery nearby or to the same artery past the blockage, protecting the heart tissue from injury.

Coronary Circulation: Venous Drainage Of The Heart

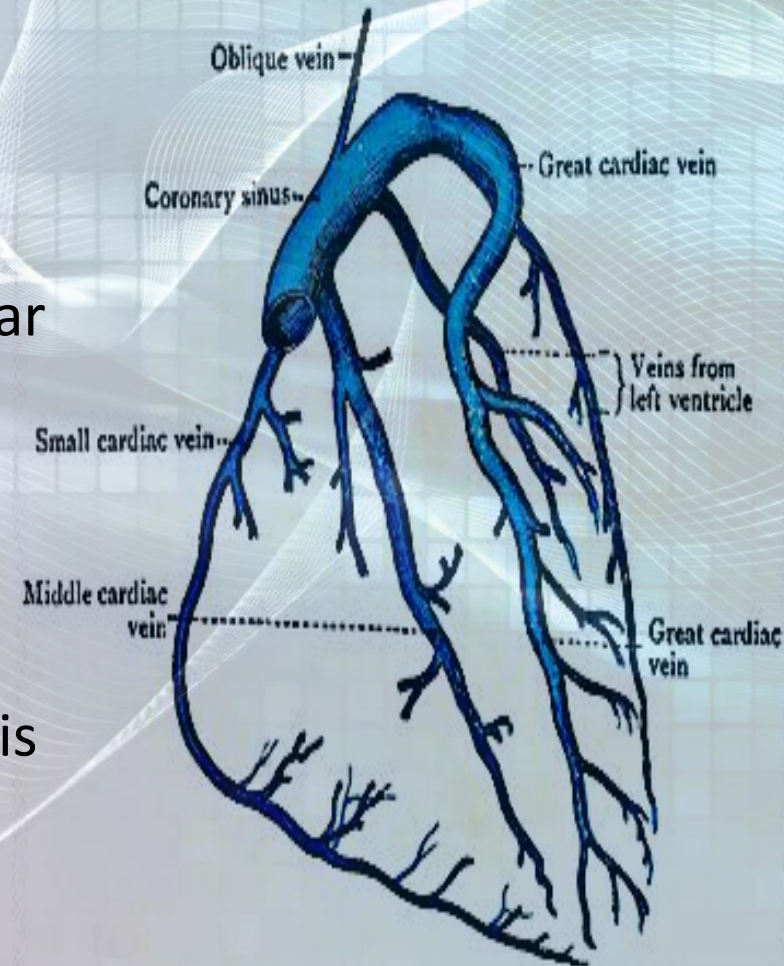
- ❑ Venous drainage brings deoxygenated cardiac blood back to the heart.
- ❑ Most of the venous blood return to the heart into the right atrium through the coronary sinus via the **cardiac veins**.
- ❑ 5- 10% drains **directly** into heart chambers, right atrium & right ventricle, by the anterior cardiac vein & by the small veins that open directly into the heart chambers.



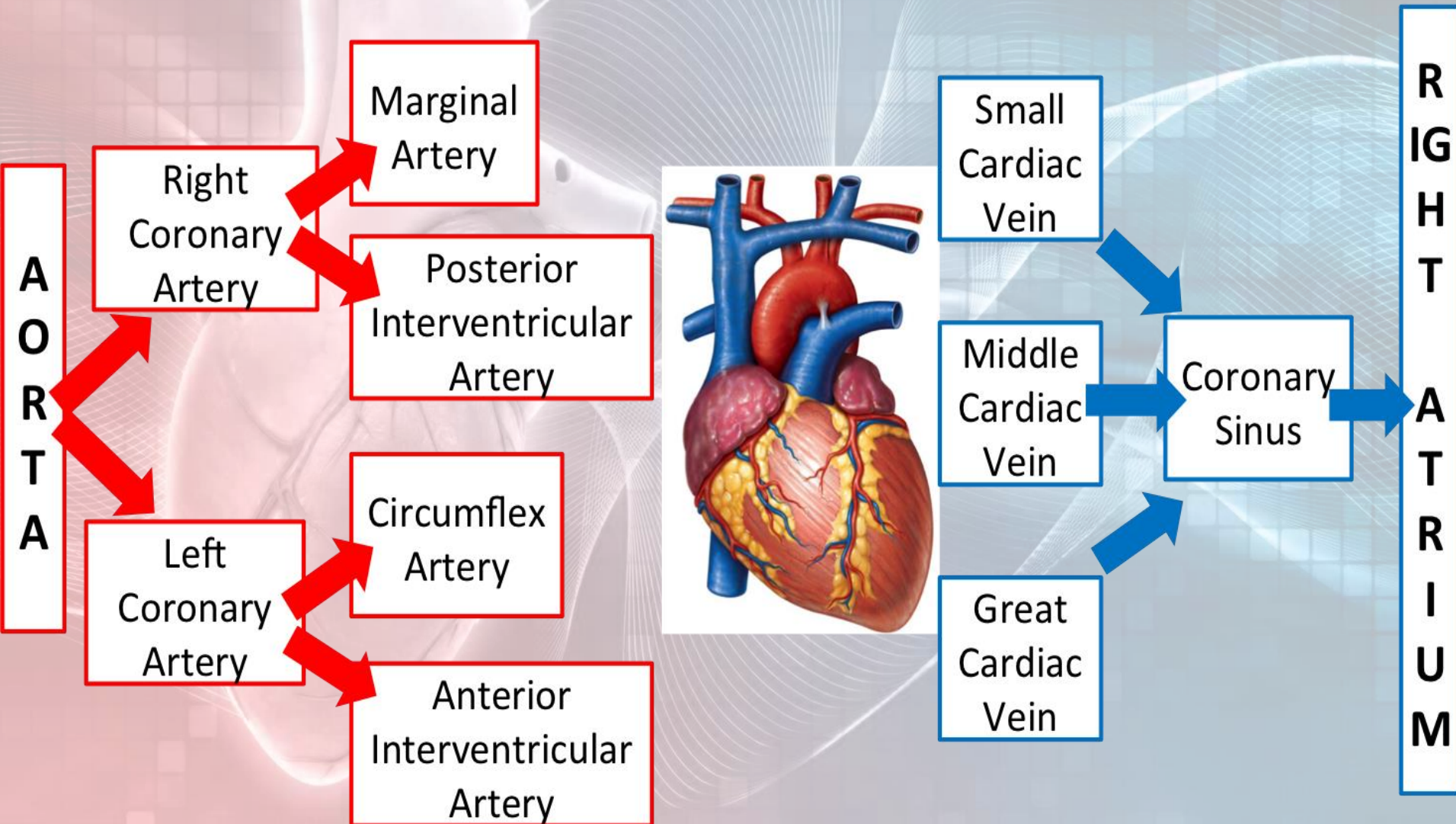
Coronary Circulation: Venous Drainage Of The Heart

❑ Cardiac venous drainage occur through:

- Coronary sinus, which lies in the posterior part of the atrioventricular groove & is a continuation of the great cardiac vein.
- Anterior (great), middle, & small cardiac veins.
- Smallest cardiac veins (Venae Cordis Minimae).



Coronary Circulation



Coronary Circulation: Lymphatic Drainage Of The Heart

- ❑ Lymphatics of the heart accompany the two coronary arteries & form two trunks:
 - The **right trunk**, ends in the brachiocephalic node.
 - The **left trunk**, ends into the tracheo-bronchial lymph nodes at the bifurcation of the trachea.

Coronary Circulation: Coronary Dominance

- ❑ Coronary dominance depends on which artery (or arteries) supplies the AV- node.
- ❑ Usually, the **right coronary artery** is the **dominant** artery in **85-90% of hearts**, as it supplies the AV- node.

Coronary Circulation: **Coronary Dominance**

- ❑ **A person can be:**
 - Right dominant,
 - Left dominant (in 8-10%), or
 - Co-dominant.
- ❑ Balanced or co-dominance is found in 7-10% of population where the posterior inter ventricular artery is formed by both right coronary & Left CX arteries.
- ❑ **Clinical importance:**
 - In case of left dominance, a block in LCA will affect the entire left ventricle & Interventricular (IV) septum.
 - In case of right or balanced dominance, a block in RCA will at least spares part of the septum (2/3) & the left ventricle.

Coronary Blood Flow

- ❑ Coronary blood flow (CBF) at rest in humans is about 225-250 mL/min, which is about 5% of the cardiac output.
- ❑ CBF increases in proportion to exercise or work output.
- ❑ At rest, the **heart extracts 60-70% of oxygen** from each unit of blood delivered to the heart, due to presence of **more mitochondria** which generate energy for contraction by aerobic metabolism (other tissue extract only 25% of O₂.)

Factors Affecting Coronary Blood Flow

- Pressure in the aorta.
- Chemical factors.
- Neural factors.

Changes In Coronary Blood Flow (CBF) During Systole & Diastole

- ◆ During systole, coronary arteries are compressed & the blood flow to the left ventricle is reduced.
- ◆ CBF to the right side of the heart is not much affected during systole, & so more blood will flow to the right ventricle than the left one.
- ◆ **Explanation:** Pressure difference between the aorta & the right ventricle is greater during systole (95 mmHg) than during diastole (80 mmHg), therefore more blood flow to right ventricle occurs during systole.

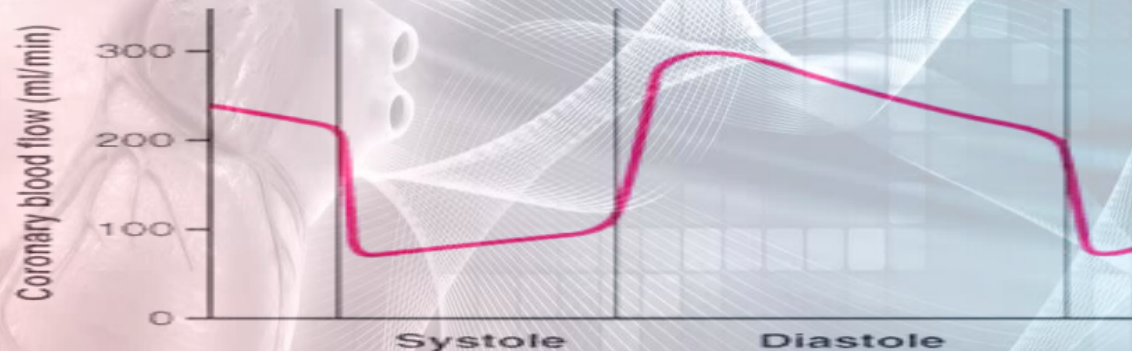
Effect of Pressure Gradient between Aorta & Different Chambers of the Heart On Coronary Blood Flow

	Pressure (mmHg) in			Pressure difference (mmHg) between aorta &	
	Aorta	Lt Ventricle	Rt Ventricle	Lt Ventricle	Rt Ventricle
Systole	120	120	25	0	95
Diastole	80	0-2	0-2	80	80

- ◆ In general, maximal coronary blood flow occurs during the early part of diastole (Isometric Relaxation Phase); however, CBF for the right ventricle could be better during systole (difference of 95 mmHg).

Phasic Changes in Left Coronary Blood Flow During Systole & Diastole

- ◆ During systole, coronary arteries are compressed & the blood flow to the left ventricle is reduced.



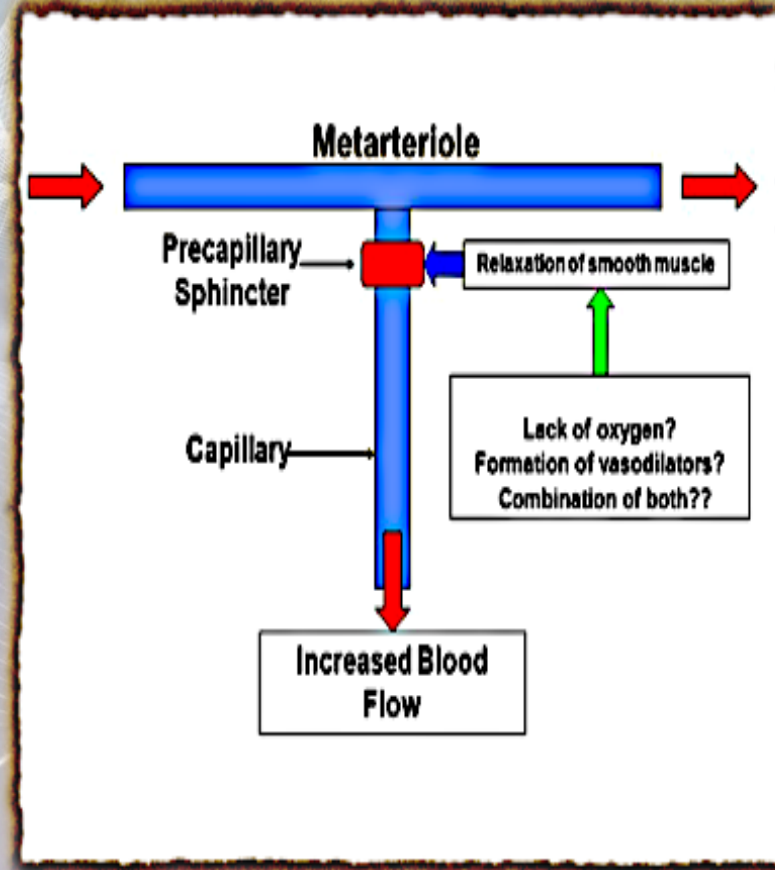
- ◆ Blood flow to the subendocardial portion of the left ventricle occurs only during diastole, & is not there during systole.
- ◆ Therefore, subendocardial region of the left ventricle is prone to ischemic damage & it is the most common site of myocardial infarction.

Chemical Factors Affecting Coronary Blood Flow

Chemical factors causing Coronary vasodilatation (Increased coronary blood flow):

- Lack (\downarrow) of **oxygen**.
- High (\uparrow) conc. of **CO₂**.
- High (\uparrow) conc. of **NO**.
- High (\uparrow) local conc. of **H⁺** ion.
- High (\uparrow) local conc. of **K⁺** ion.
- High (\uparrow) local conc. of **Lactate**,
Prostaglandin, **Adenosine**, **Adenine nucleotides**.

□ **Note:** An increase in Ca⁺² conc. does not increase the CBF.



Neural Factors Affecting Coronary Blood Flow

- Sympathetic stimulation.
- Parasympathetic stimulation.

Effect of Sympathetic Stimulation On CBF

❑ **Coronary arteries have:**

- **Alpha Adrenergic receptors**, which mediate vasoconstriction (more epicardial).
- **Beta Adrenergic receptors**, which mediate vasodilatation (more intramuscular).

❑ **Indirect effect of sympathetic stimulation:**

- Sympathetic stimulation in intact body will lead to release of adrenaline & nor-adrenaline, increasing heart rate (HR) & force of contraction. However, **coronaries will vasodilate** due to the release of **vasodilator metabolites**. Example: **Athletes**.

❑ **Direct effect of sympathetic stimulation:**

- Experimentally, injection of **nor-adrenaline** after **blocking the Beta adrenergic receptors** in un anesthetized animals elicits **coronary vasoconstriction**.

Benefits of indirect effect of nor-adrenergic discharge

- ❑ When systemic blood pressure decreases very low.
- ❑ Reflex increase of nor-adrenergic discharge.
- ❑ Increase CBF secondary to metabolic changes in the myocardium.
- ❑ In this way, circulation of the heart is preserved while the flow to other organs compromised.

Effect of Parasympathetic Stimulation on CBF

- ❑ **Vagal stimulation** (Parasympathetic) causes coronary vasodilatation.
- ❑ However, **parasympathetic distribution is not great.**
- ❑ There is more sympathetic innervation of coronary vessels.

Effect of Tachycardia on CBF

- ◆ CBF is **reduced** with tachycardia, as the diastolic period will be shortened.

Control Of Coronary Blood Flow

- ❑ CBF shows considerable **auto regulation**.
- ❑ **Local muscle metabolism is the primary controller:**
 - Oxygen demand is a major factor in local coronary blood flow regulation.
- ❑ **Nervous control of CBF:**
 - Direct effects of nervous stimuli on the coronary vasculature.
 - Sympathetic greater effects than parasympathetic.



Thank You