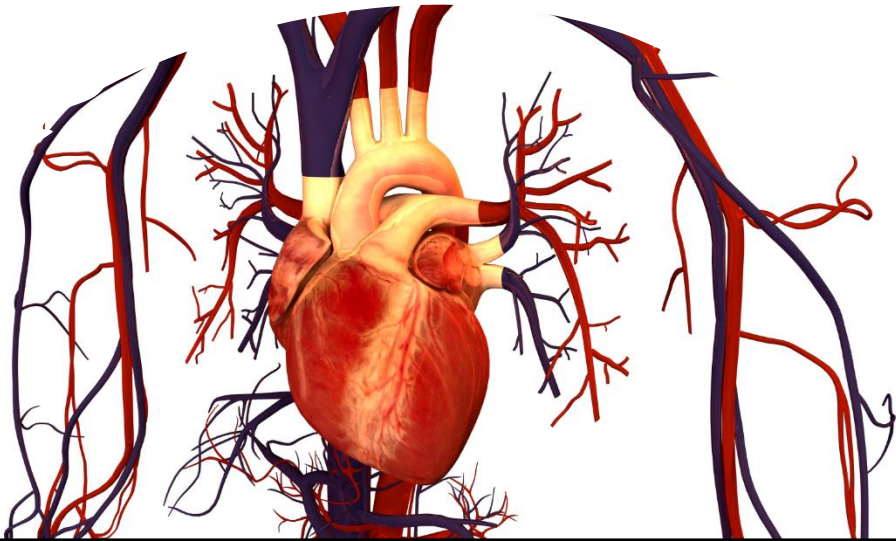
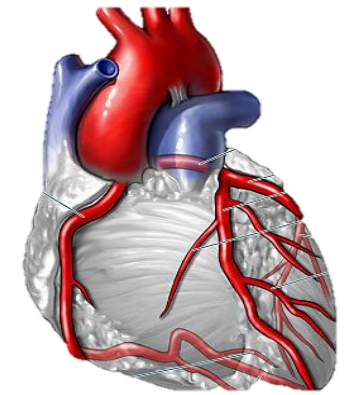


Coronary Circulation

Dr. Abeer A. Al-Masri, MBBS, PhD

*A. Professor,
Consultant Cardiovascular Physiology,
Faculty of Medicine, KSU.*



Coronary Circulation



Lecture Outcomes

- ◆ To identify the Coronary circulation & areas of their supply in the heart.
- ◆ To understand Coronary dominance & collateral circulation.
- ◆ To understand the Coronary blood flow & factors affecting it.
- ◆ To understand the mechanisms of control of Coronary blood flow.

The Coronary Circulation

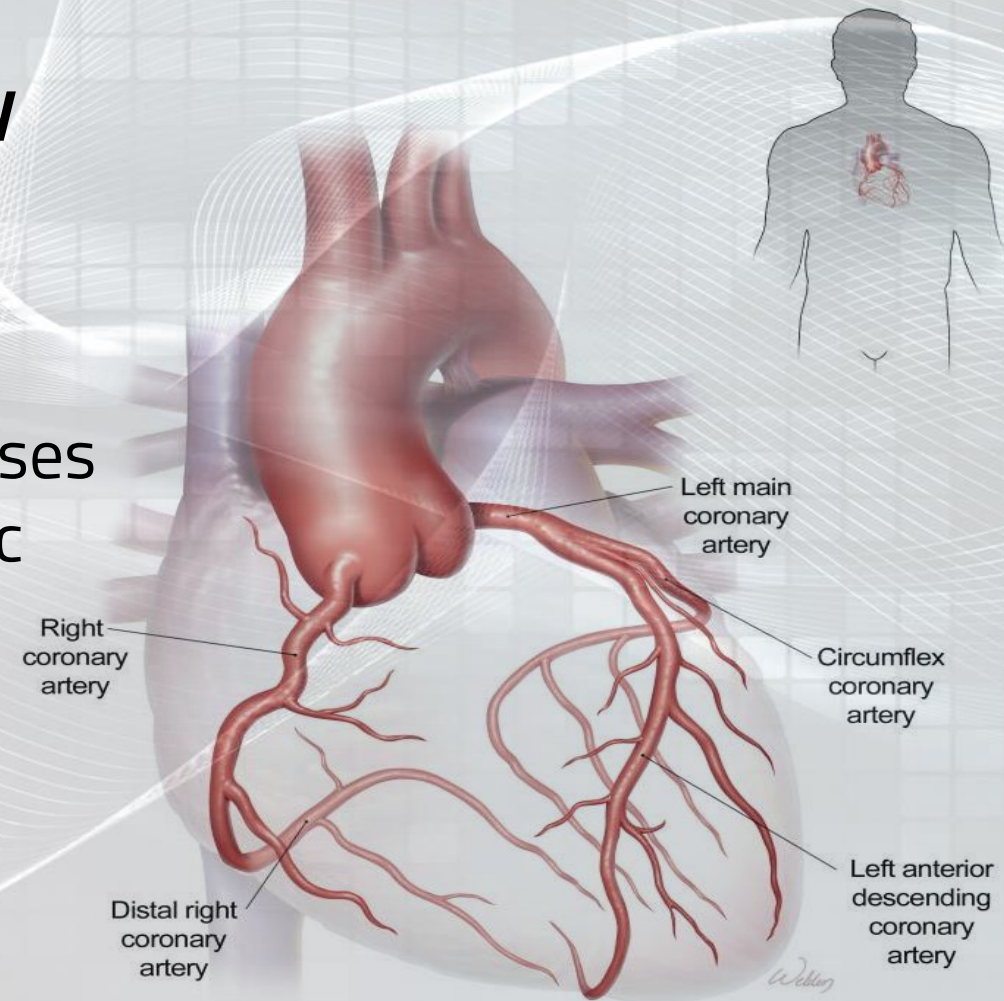
- ❑ **Coronary circulation** is the circulation of blood in blood vessels that supply the heart muscle (myocardium).
- ❑ **Consists of:**
 - Arterial supply.
 - Venous drainage.
 - Lymphatic drainage.
- ❑ **Coronary arteries** supply oxygenated blood to the heart muscle.
- ❑ **Cardiac veins** drain away deoxygenated blood from to the cardiac muscle.
- ❑ 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.

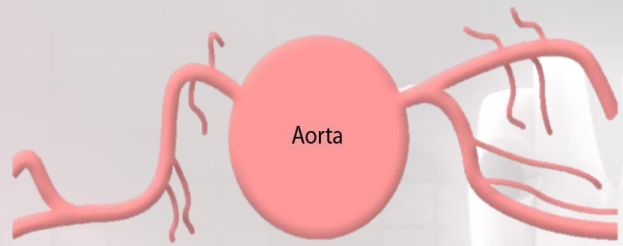




Coronary Circulation: Arterial Supply

- ❑ Cardiac muscle is supplied by **two coronary arteries**:
 - a. Right Coronary Artery (RCA.)
 - b. Left Coronary Artery (LCA.)
- ❑ Both arteries **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.

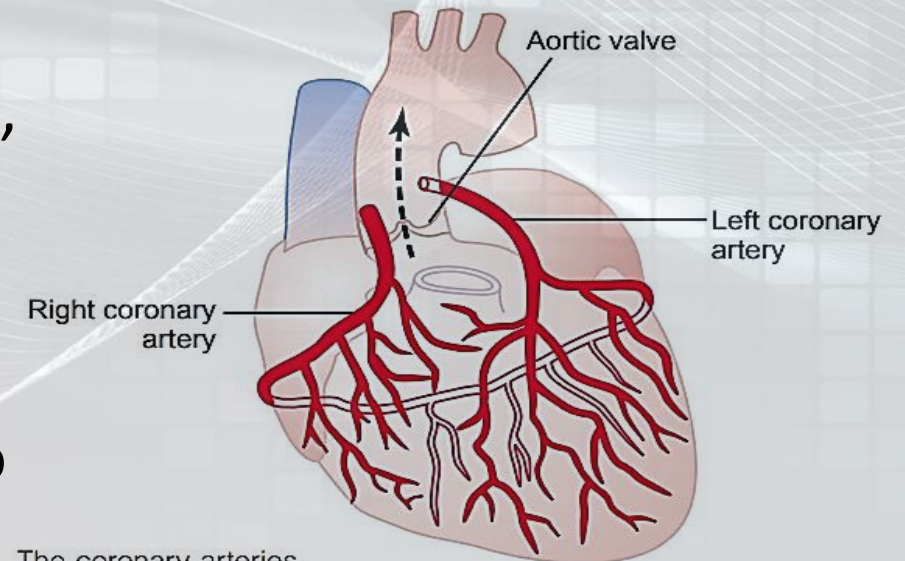
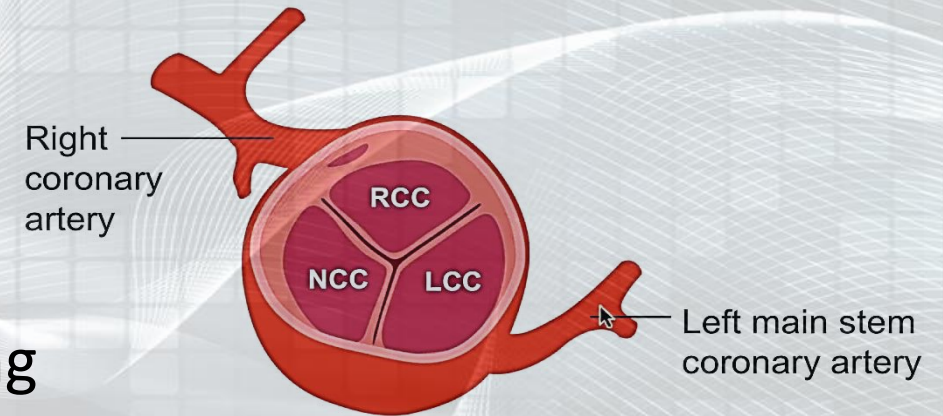




Coronary Sinuses

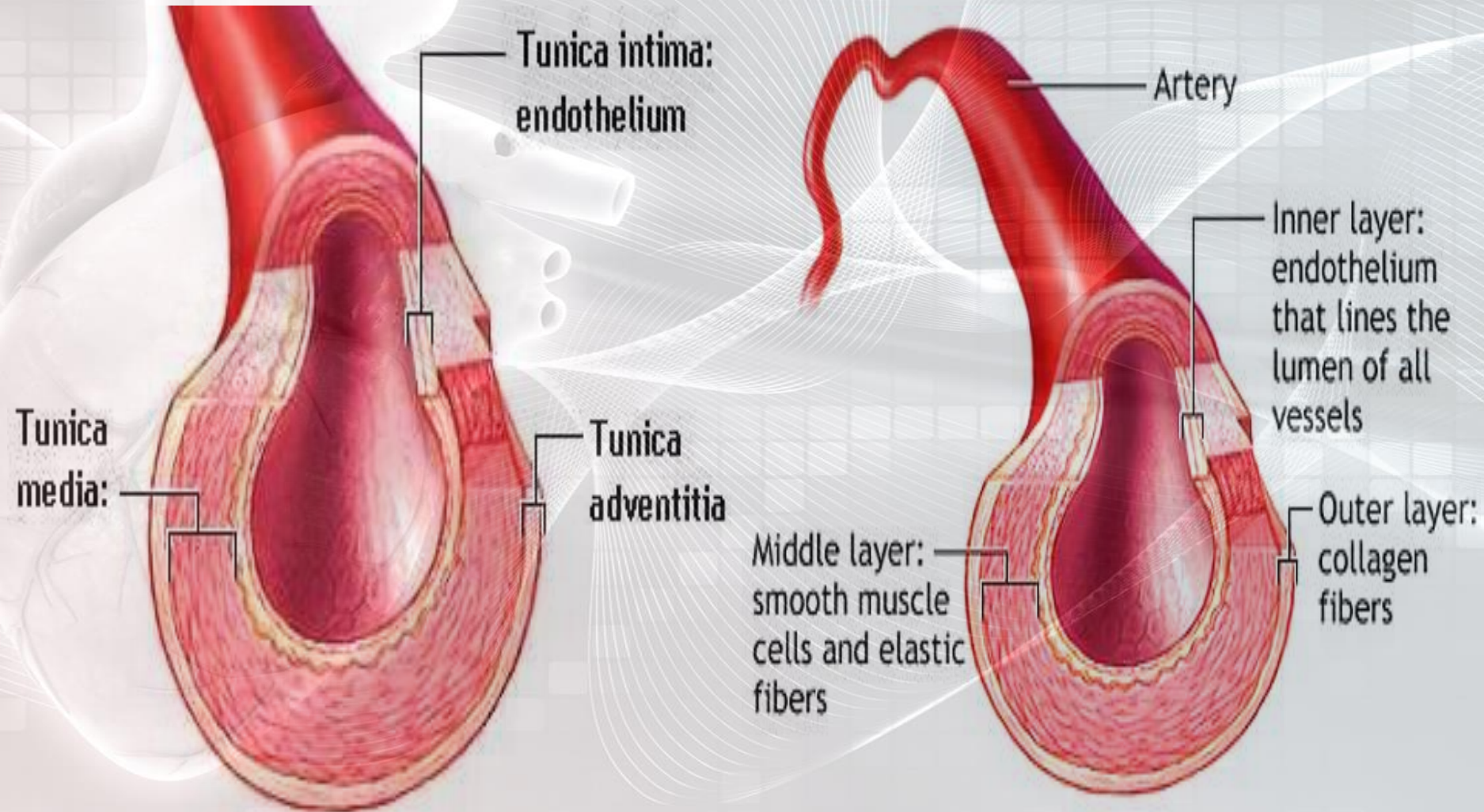
- ❑ **Aortic valve has three cusps:**
 - Left coronary cusp (LCC).
 - Right coronary cusp (RCC).
 - Posterior non-coronary (NCC) cusp.
- ❑ Coronary sinus is just above the corresponding cusps, where the coronary ostia arise.
- ❑ There may be **variations** in the number, shape, & location of coronary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

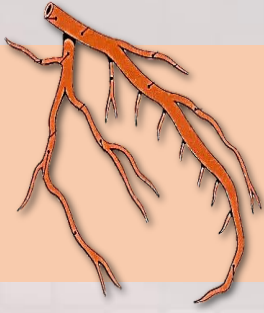
Coronary artery origins



The coronary arteries.

Coronary Circulation: **Arterial Wall**

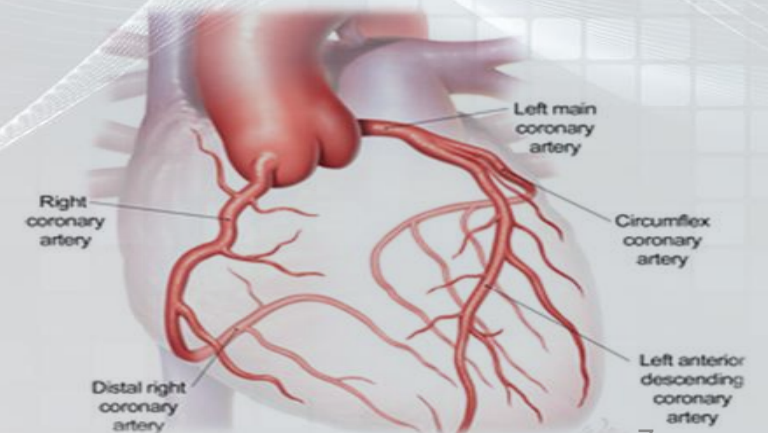
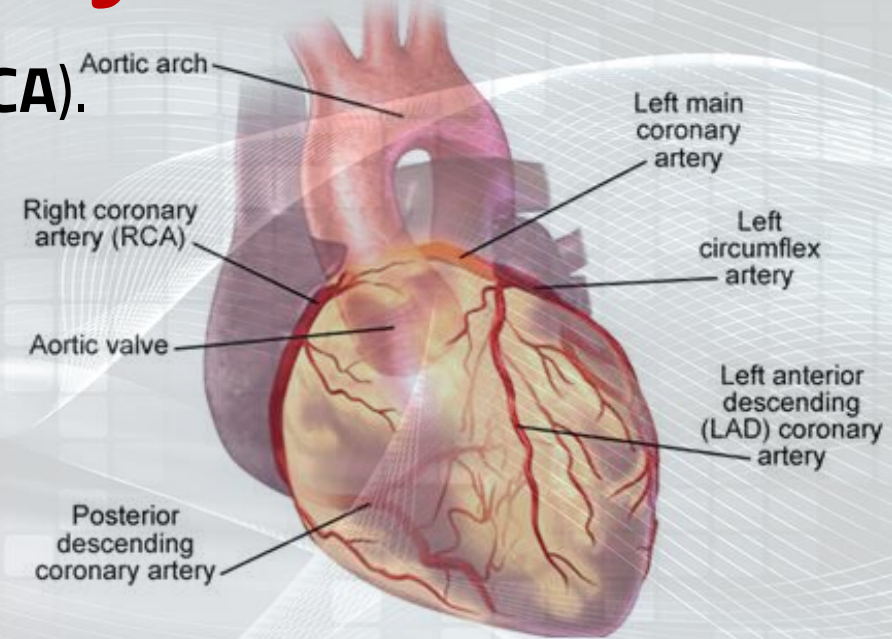


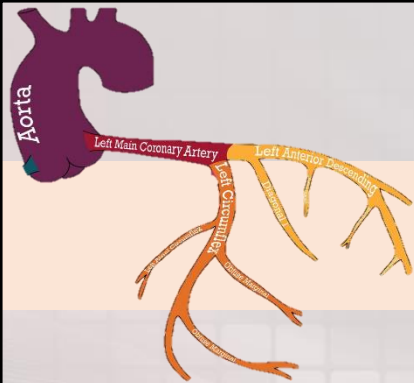


Coronary Circulation:

I: Left Coronary Artery

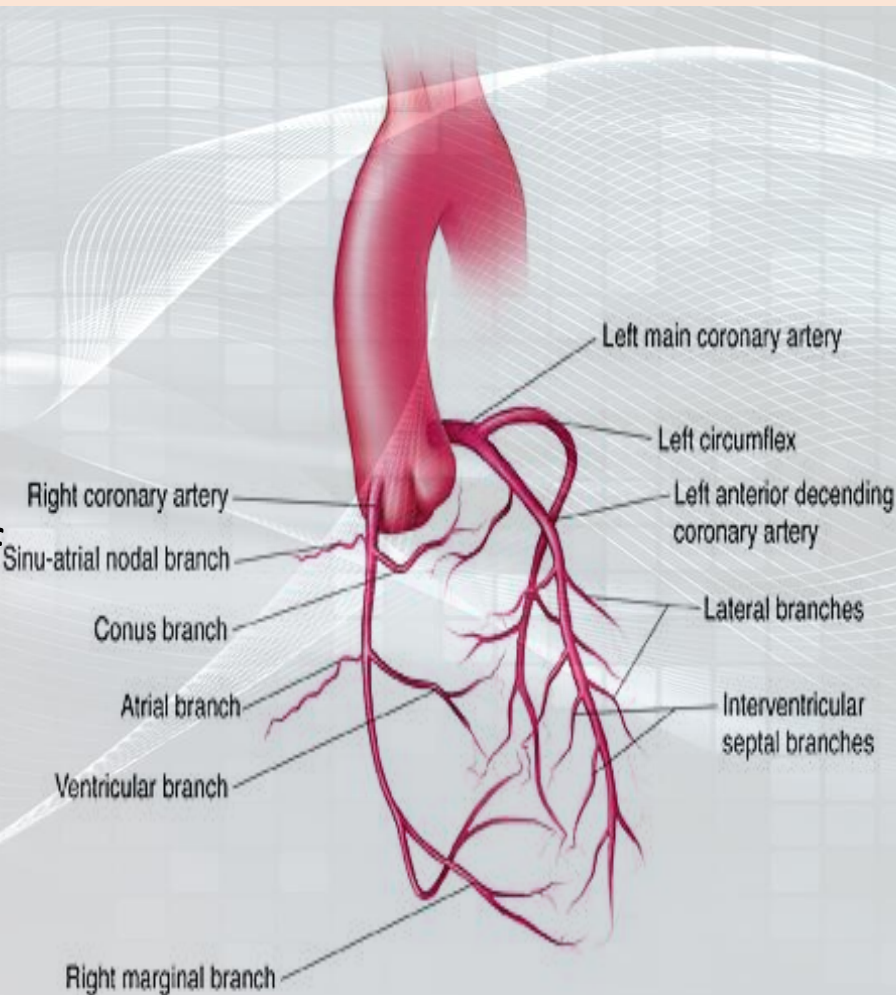
- ❑ Also known as the **Left Main Coronary Artery (LMCA)**.
- ❑ Larger than the Right Coronary Artery.
- ❑ Arises from the left coronary sinus.
- ❑ Runs for 10-25 mm before bifurcating.
- ❑ Terminates by anastomosing with the Right coronary artery.
- ❑ Supplies blood to the left side of the heart muscle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

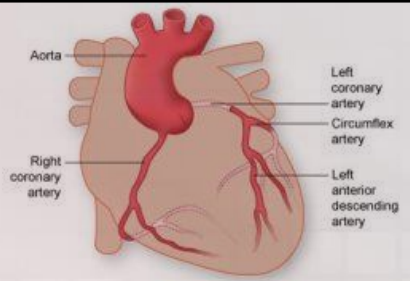




The Left Coronary Artery: **Main Branches**

- ❑ **The Left Coronary Artery divides into two main branches:**
 - **Left Anterior Descending Artery (LAD):**
 - Also called "Anterior Interventricular Artery."
 - Considered the **most critical vessel** in terms of myocardial blood supply.
 - **Circumflex Artery (CX).**
 - Encircles the heart muscle.





Branches of The Left Coronary Artery

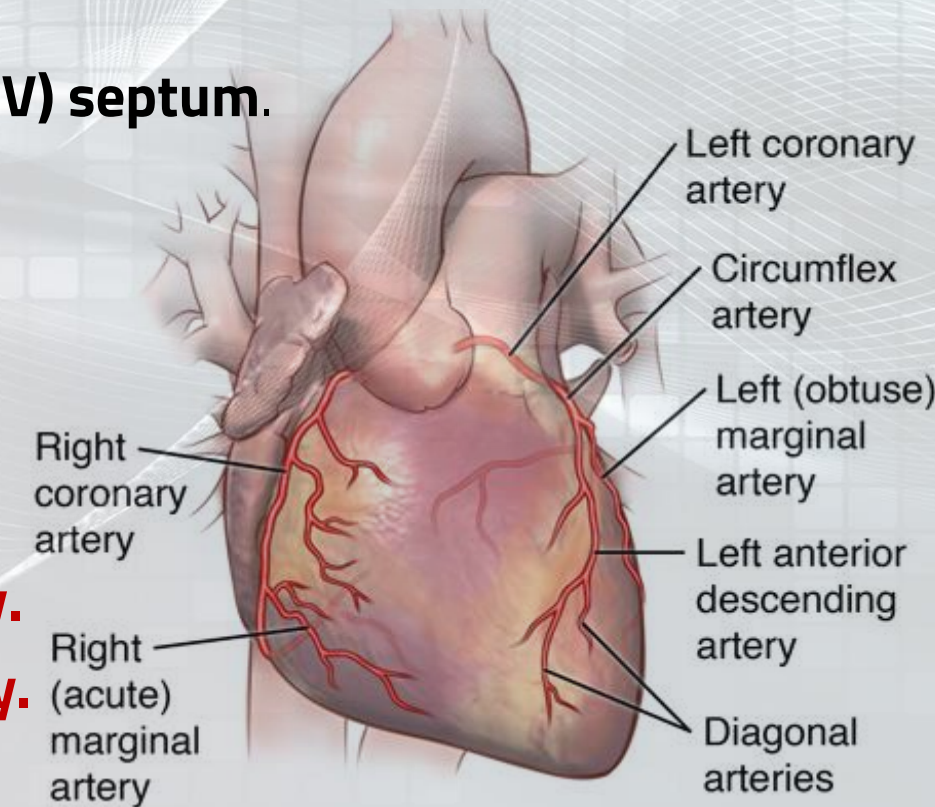
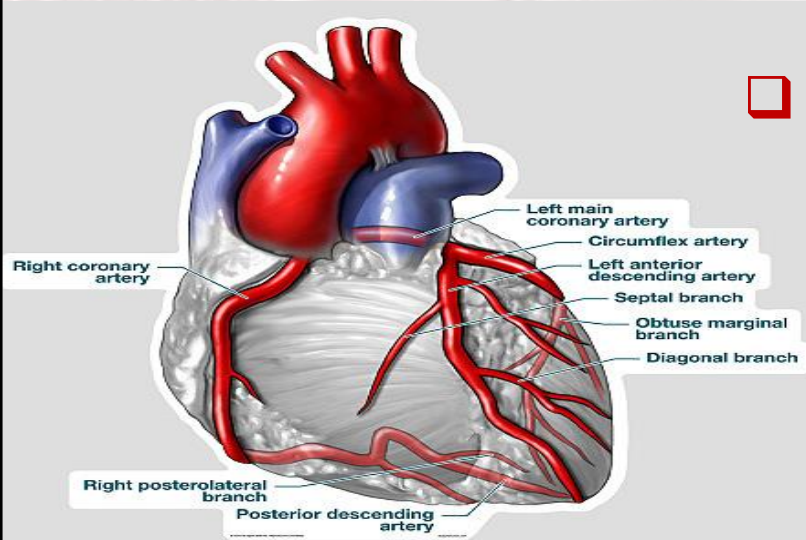
1. Left Anterior Descending Artery (LAD)

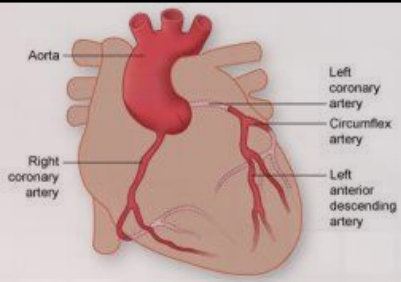
❑ Areas of myocardial blood supply:

- ❑ It supplies **45-55% of the left ventricle** (anterior & apical parts of the heart):
 - The Anterolateral of the left ventricle.
 - The Apex of the heart.
- ❑ It supplies the **anterior 2/3 of the Interventricular (IV) septum.**
- ❑ It supplies the **right & left bundle branches.**
- ❑ It supplies the **front of the right ventricle.**

❑ Further divides into:

- **Diagonal arteries (D1, D2).**
- **Left Conus Arteriosus artery.**
- **Septal Perforator (SP) artery.**





Branches of The Left Coronary Artery

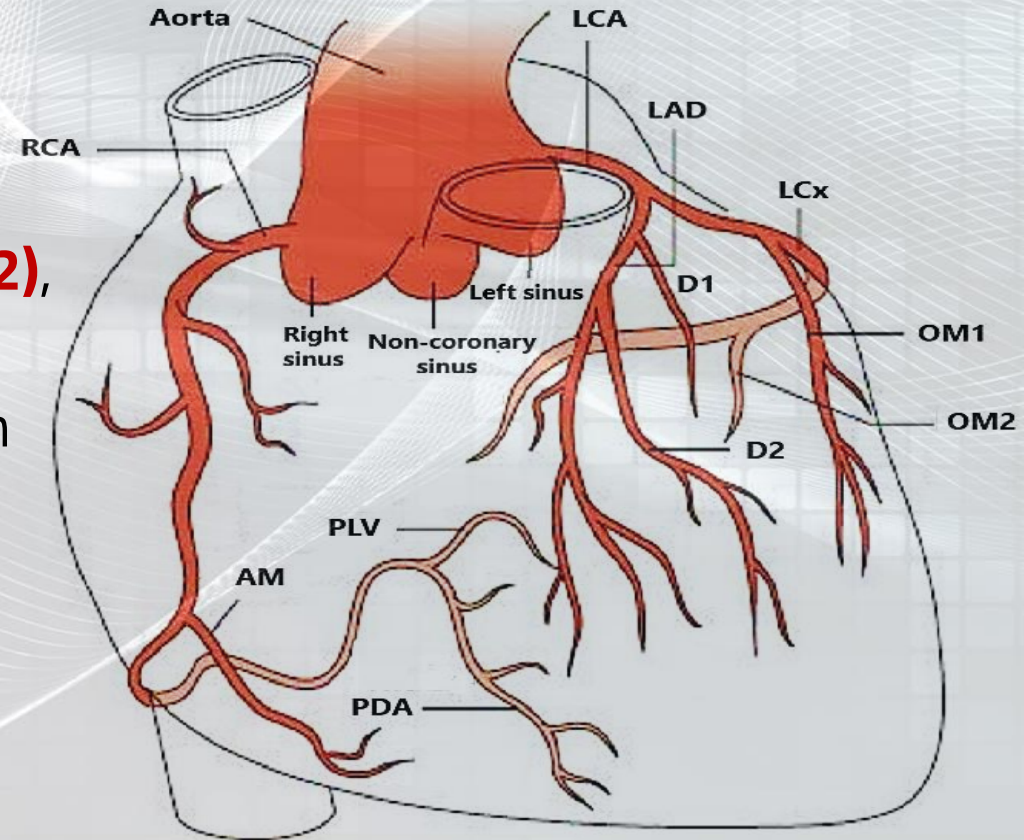
2. Circumflex Artery (CX)

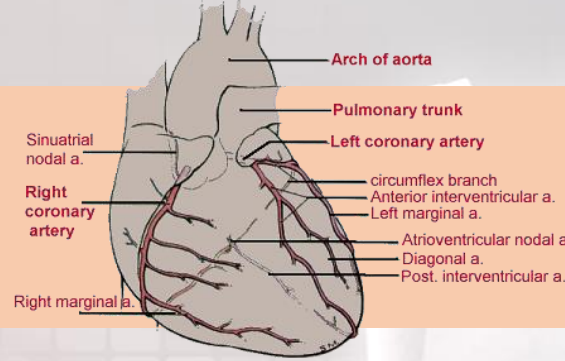
□ Areas of myocardial blood supply:

- It 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) arteries (OM1, OM2)**, which supply 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.

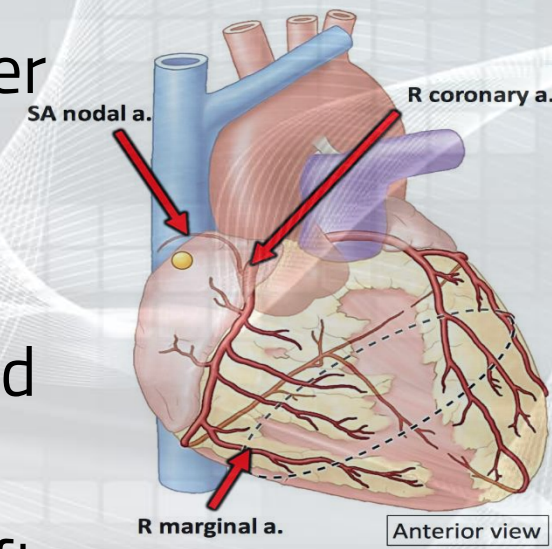




Coronary Circulation:

II: Right Coronary Artery

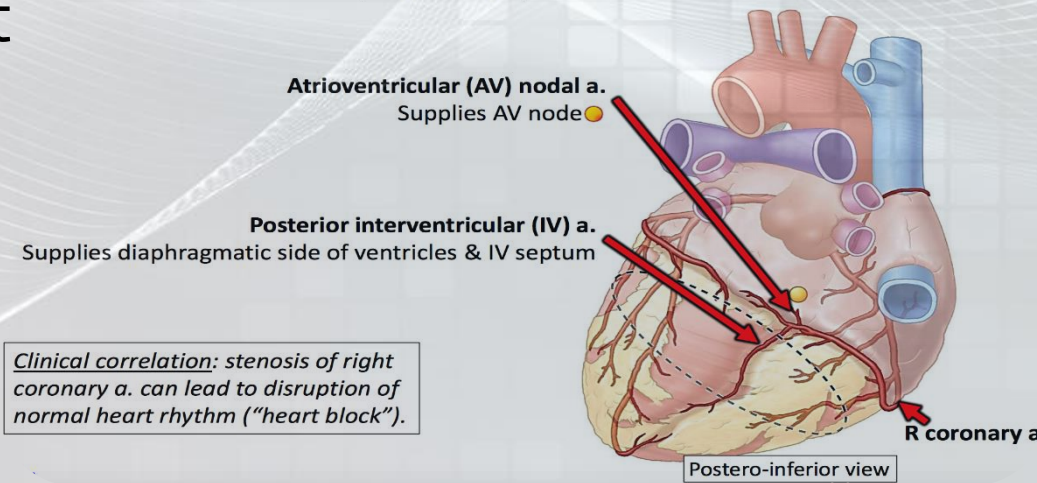
- ❑ The **Right Coronary Artery (RCA)** is smaller than the Left Coronary Artery.
- ❑ Arises from the right coronary sinus.
- ❑ **Curves posteriorly & descends** downward on the posterior surface of the heart.
- ❑ Terminates by anastomosing with the Left Coronary Artery.
- ❑ **Supplies blood to** the right atrium, SA (Sinoatrial) node, AV (Atrioventricular) node, right ventricle, bottom portion of both ventricles, & the back of septum.



Right coronary artery
Runs in the coronary sulcus

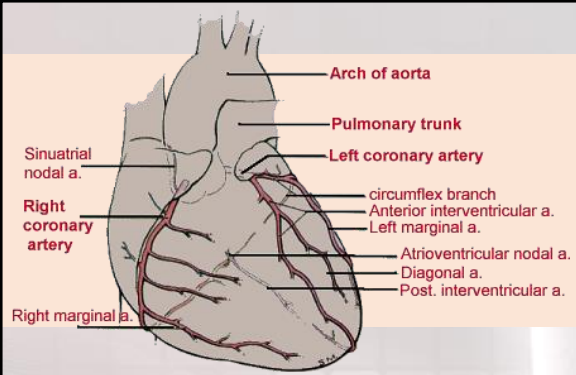
Sinu-atrial (SA) nodal a.
Supplies SA node

Right marginal a.
Supplies right ventricle
Does not reach apex



Clinical correlation: stenosis of right coronary a. can lead to disruption of normal heart rhythm ("heart block").

The Right Coronary Artery: Main Branches

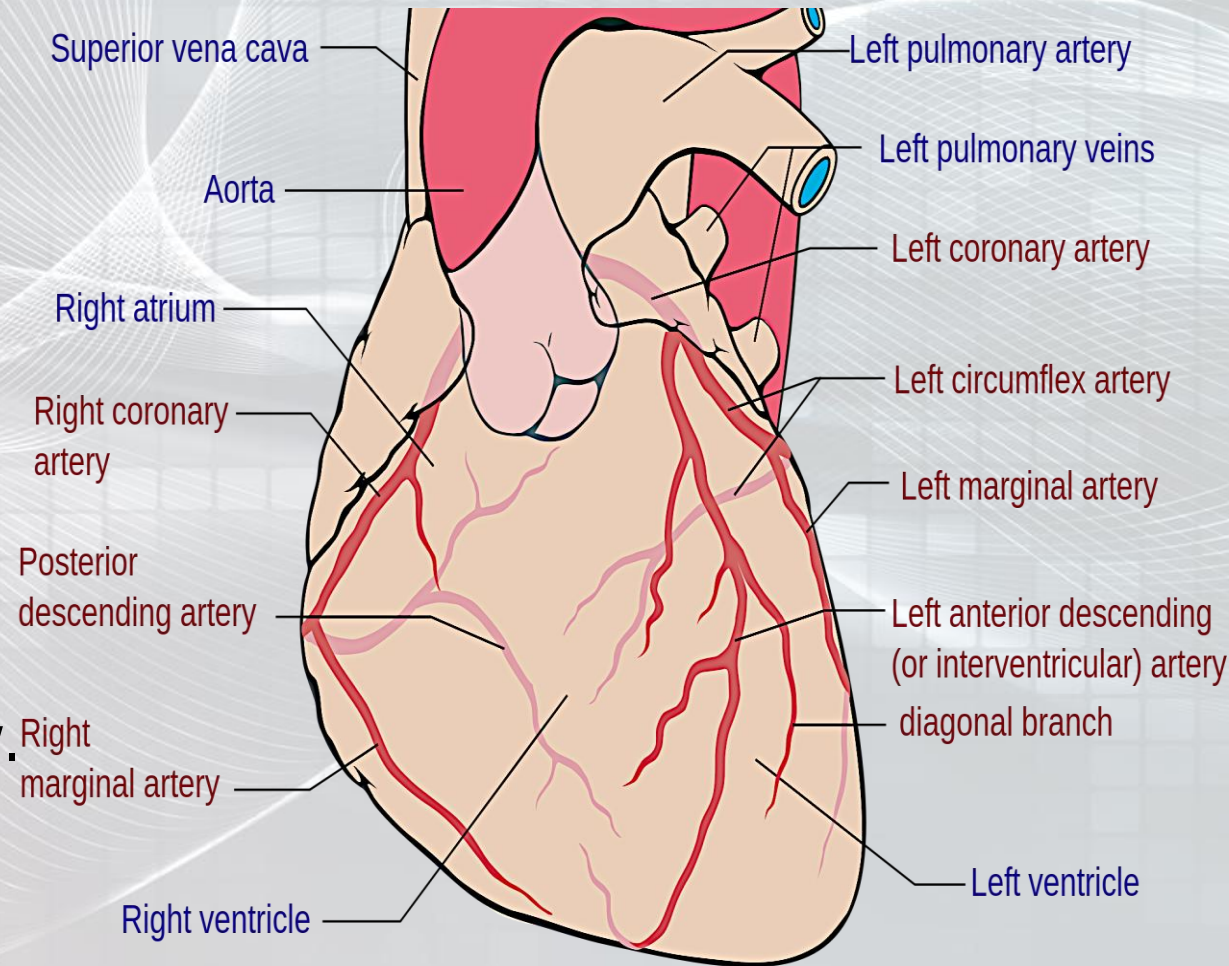


□ **The Right Coronary Artery divides into two main branches:**

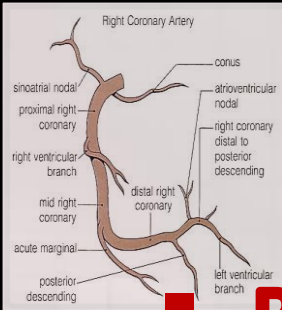
■ **Right Posterior Descending Artery (RPD):**

Also called posterior interventricular/descending artery.

■ **Right Acute Marginal Artery.**



Branches of The Right Coronary Artery

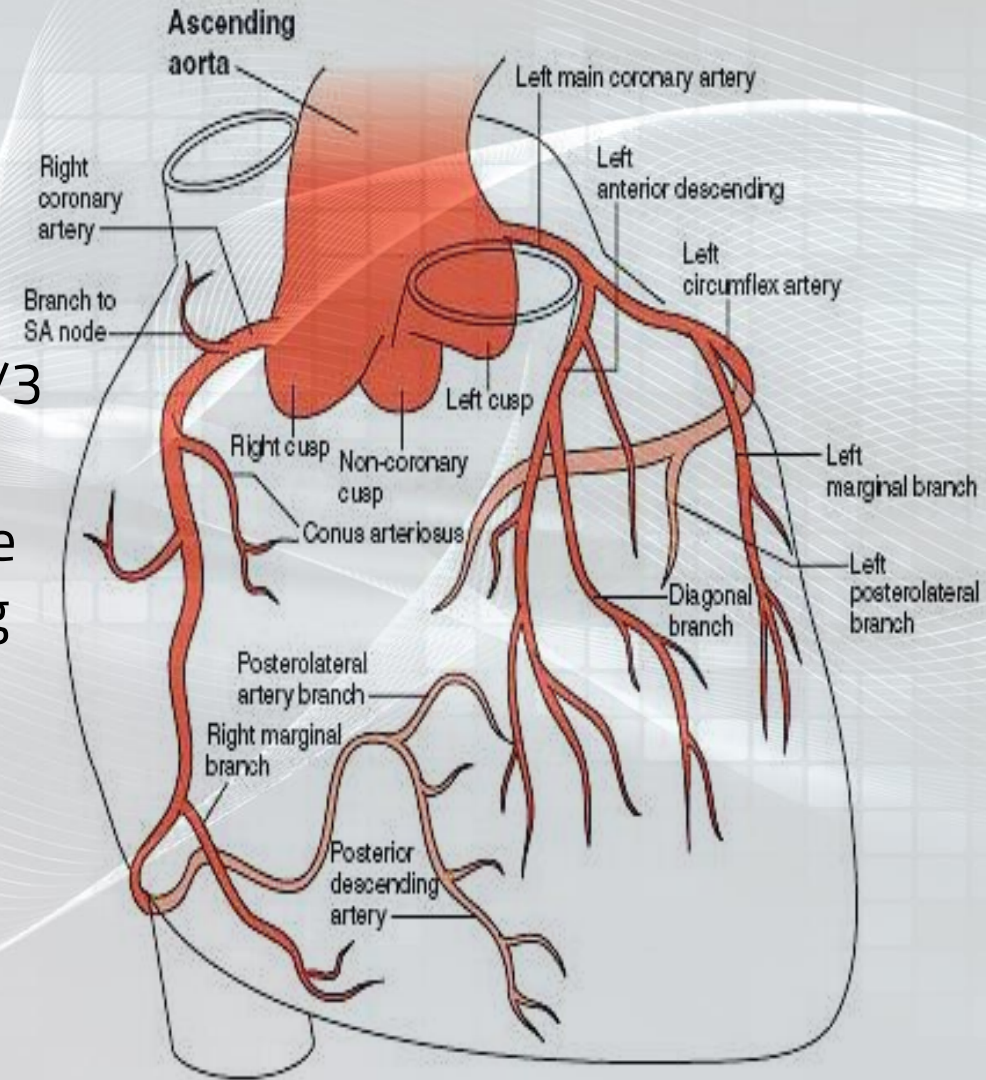


■ Right Posterior Descending Artery (RPD):

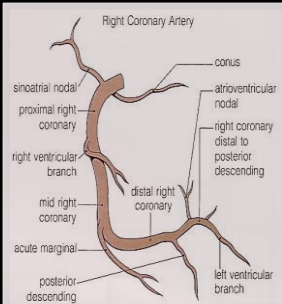
- **Curves** posteriorly & **descends** downward on the posterior surface of the heart.
- **Supplies blood to** the right atrium, right ventricle, bottom portion of the left ventricle, & posterior 1/3 of the interventricular (IV) septum.
- **Branches** into **AV nodal artery**, which supplies the AV-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

■ Right Acute Marginal Artery (AM):

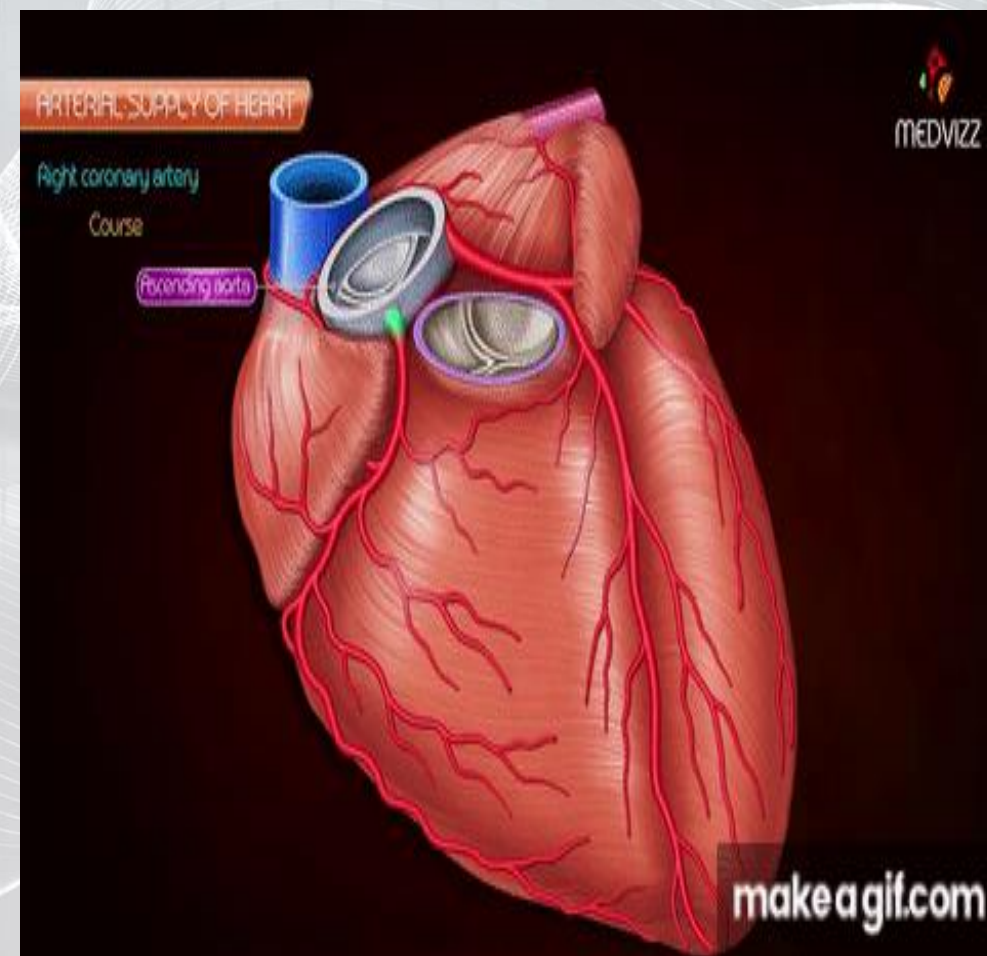
- **Runs down** the right margin of the heart.
- **Supplies blood to** the right margin of the Right ventricle, with minimal supply to the Apex.



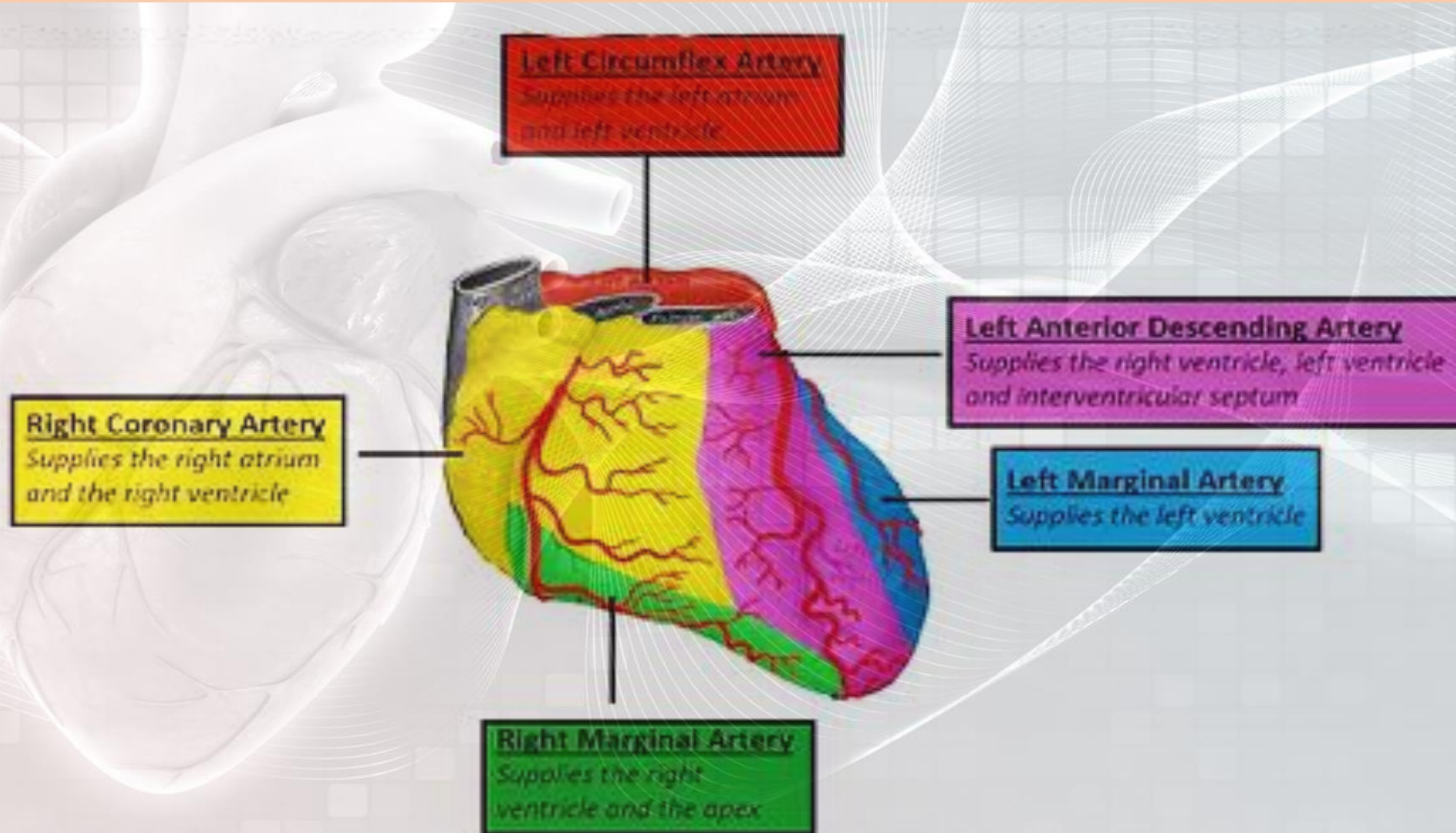
Right Coronary Artery: **Other Branches**



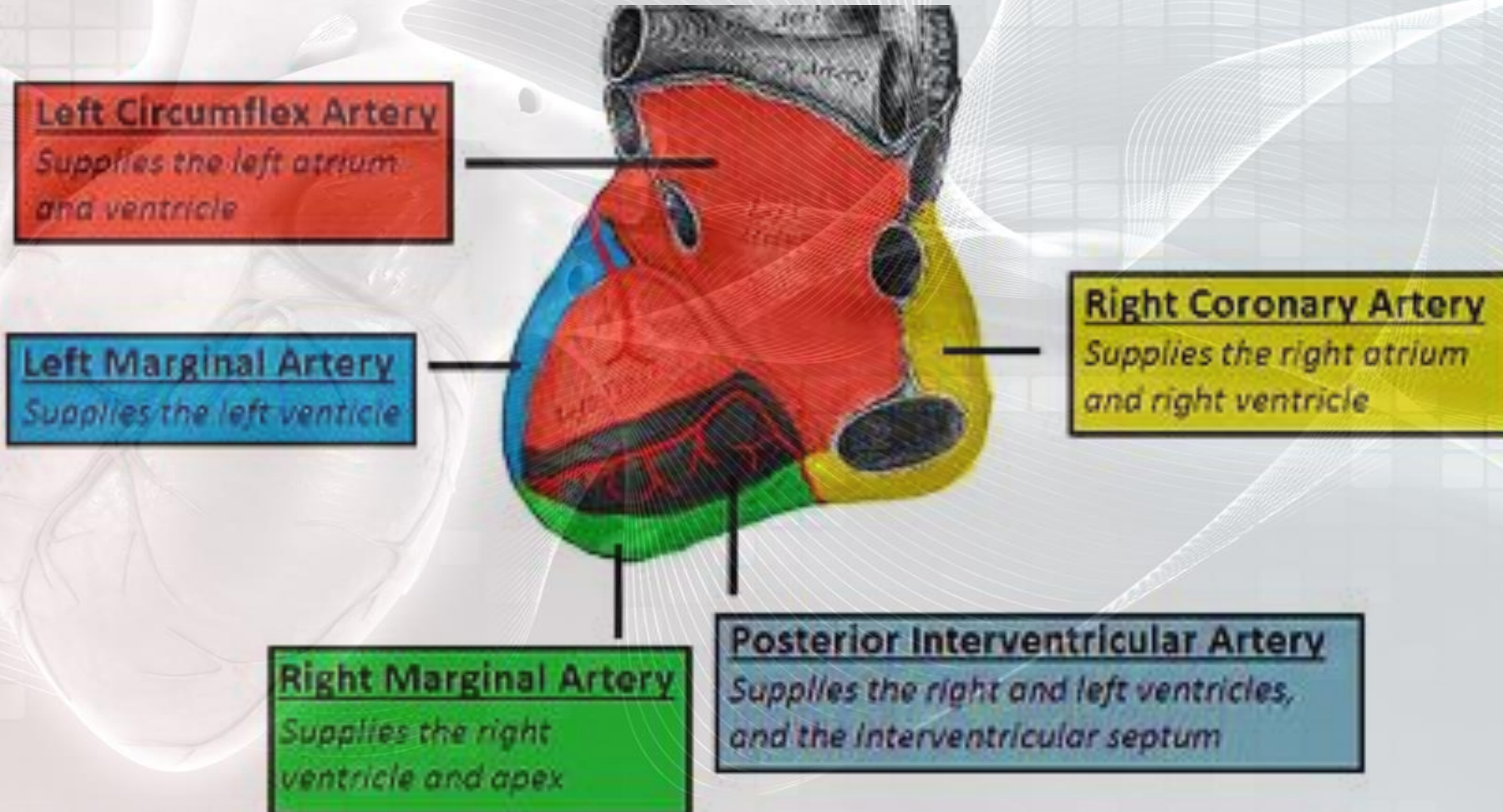
- ❑ **Smaller arteries branch from the right coronary artery:**
 - **Atrial branch**, gives off:
 - **SA nodal artery**, which supplies the SA- node in **60% (~50-73%)** of hearts & the surrounding myocardium.
 - **Right conus arteriosus artery.**
 - **Right anterior ventricular artery.**
 - **Septal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

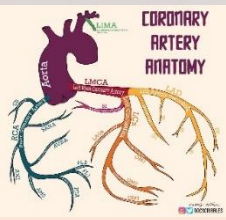


Coronary Circulation: Areas of Distribution: Front View

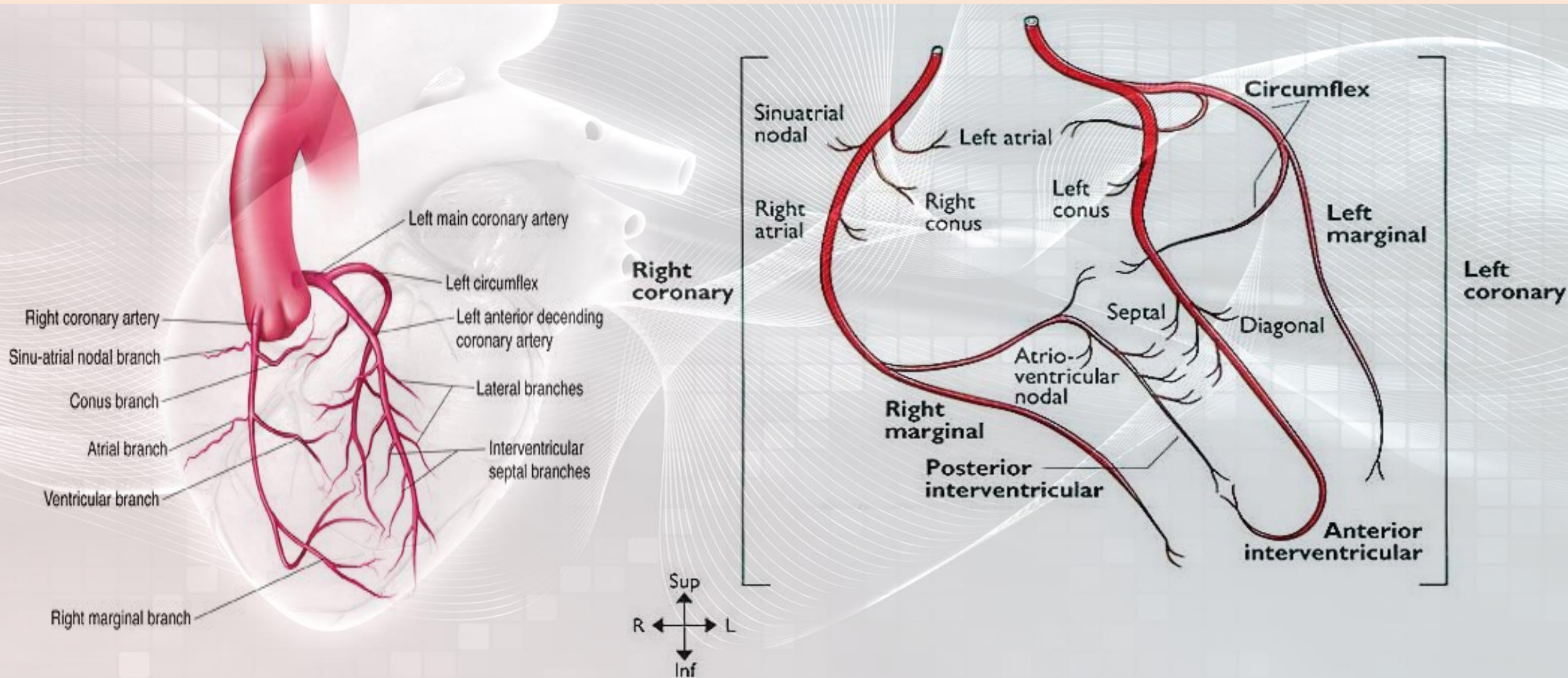


Coronary Circulation: Areas of Distribution: Back View



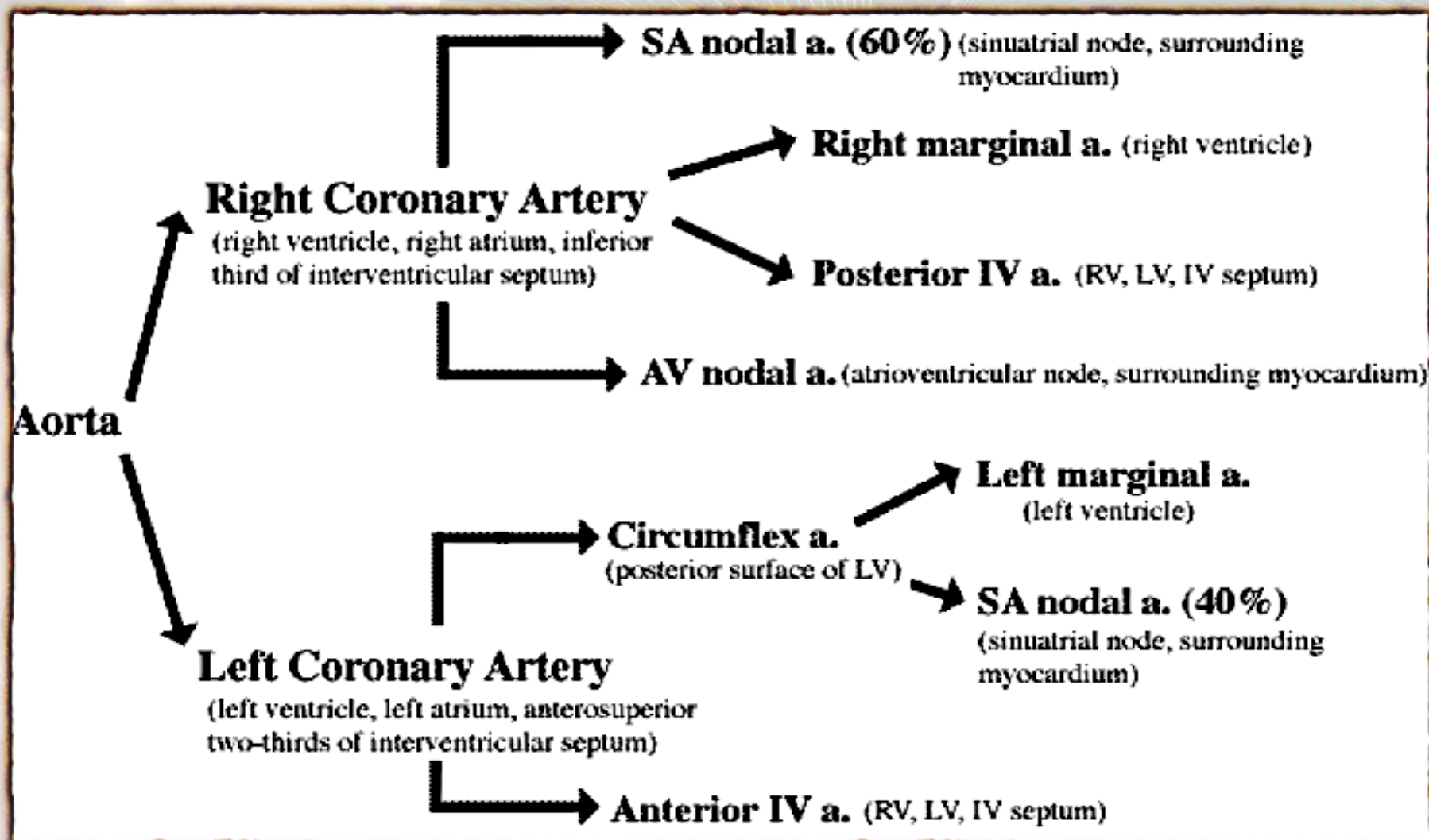


In Summary: Coronary Arteries & Their Branches



In Summary

Coronary Arteries: Branches & Areas of Supply



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.**

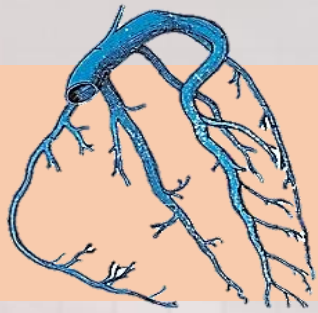
When the coronary arteries are blocked or narrowed to the point that the blood flow to the heart muscle is limited (coronary artery disease).



Collateral vessels enlarge & become active.

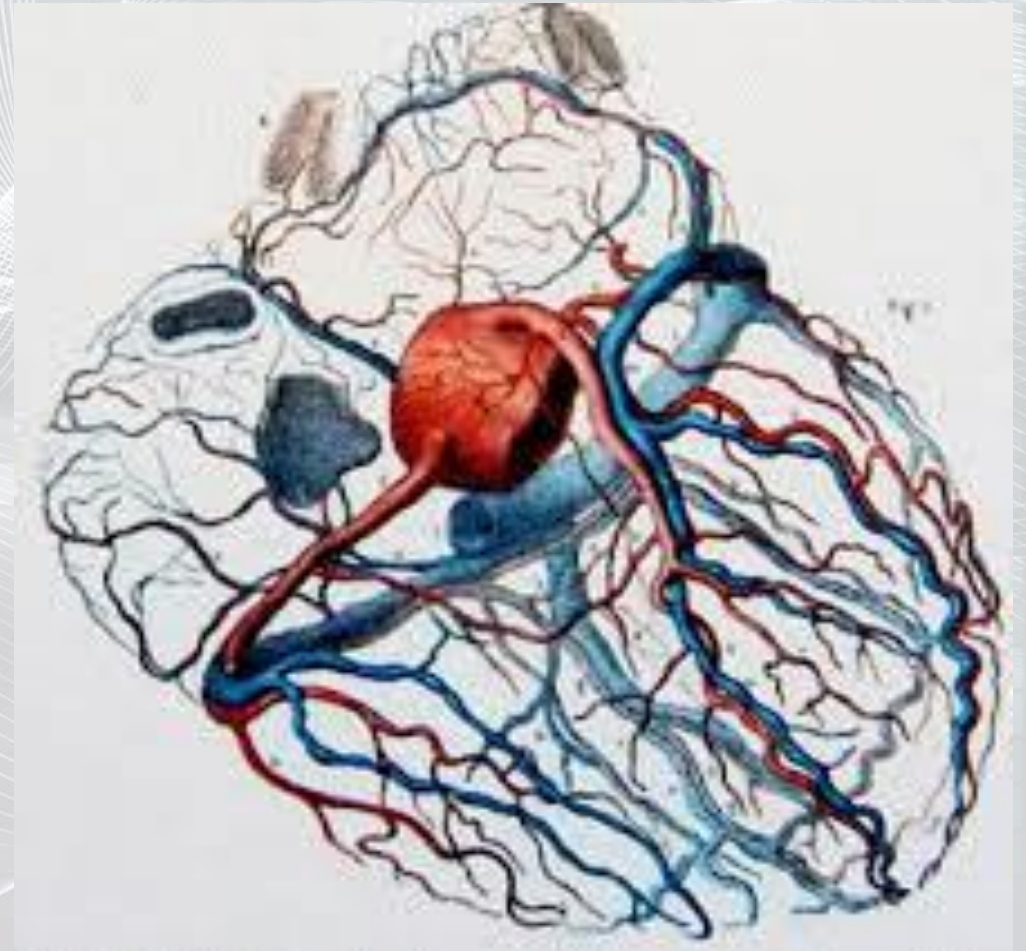


This allows blood to flow around the blocked artery to another artery nearby or to the same artery past the blockage, protecting the heart tissue from injury.

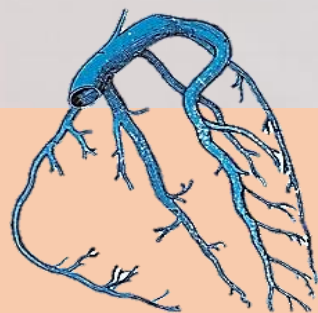


Coronary Circulation: Venous Drainage of The Heart

- ❑ **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.

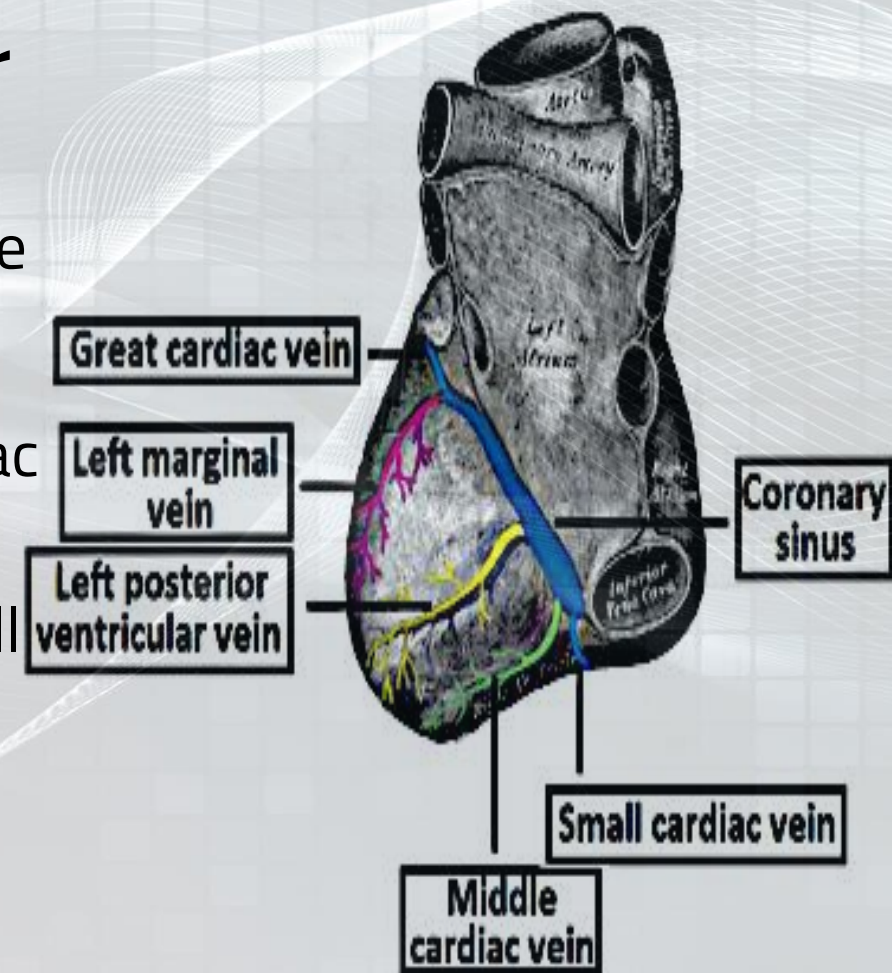
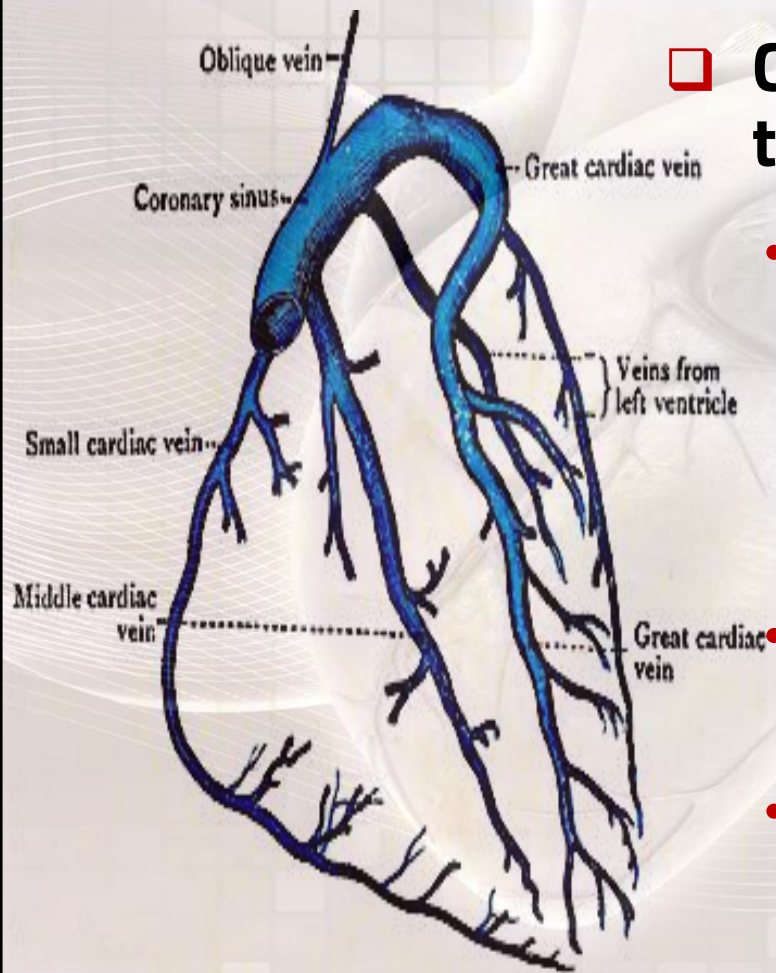


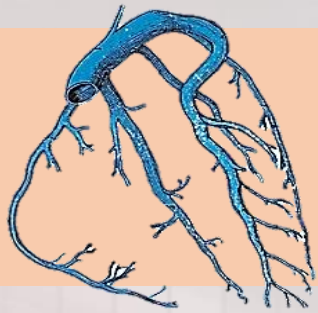
Coronary Circulation: Venous Drainage of The Heart



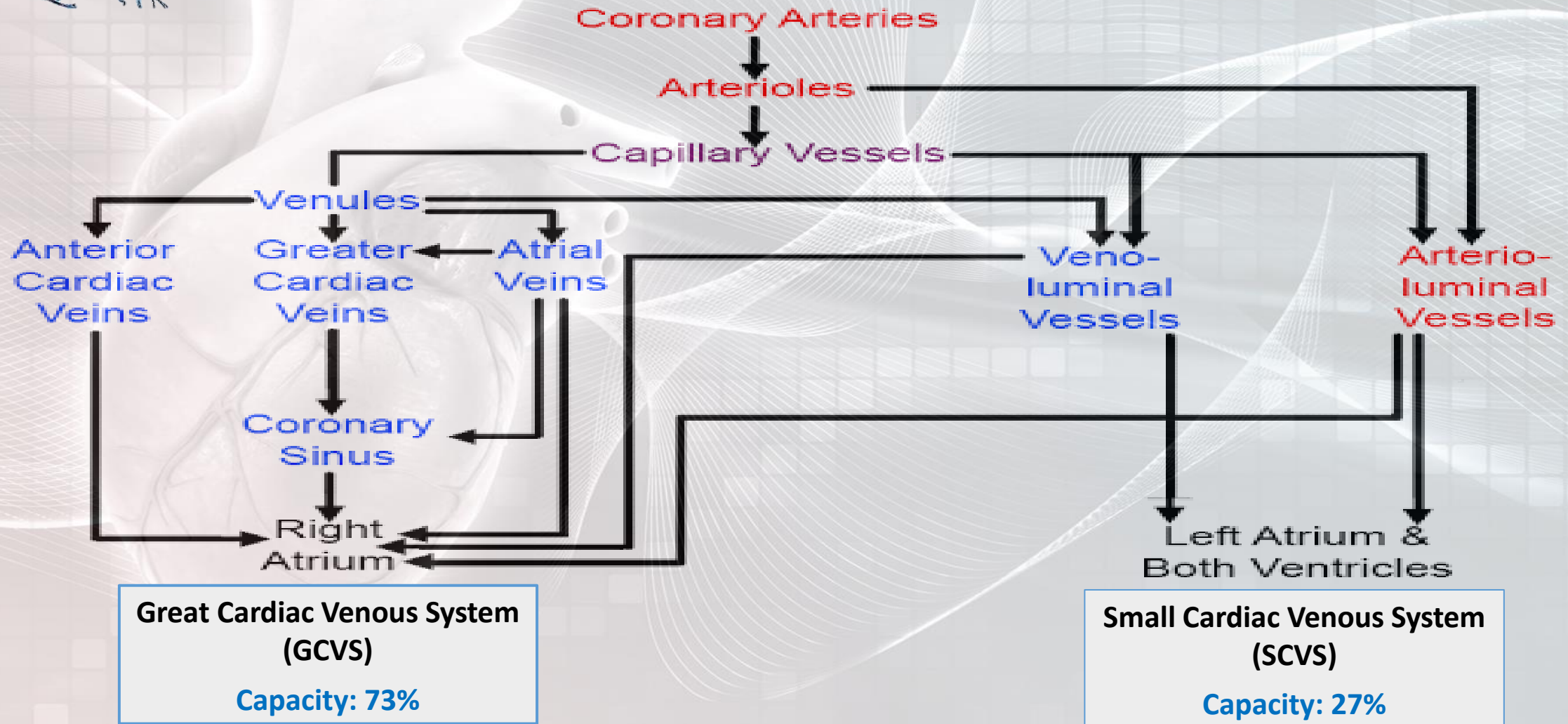
❑ Cardiac venous drainage occur through:

- 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).

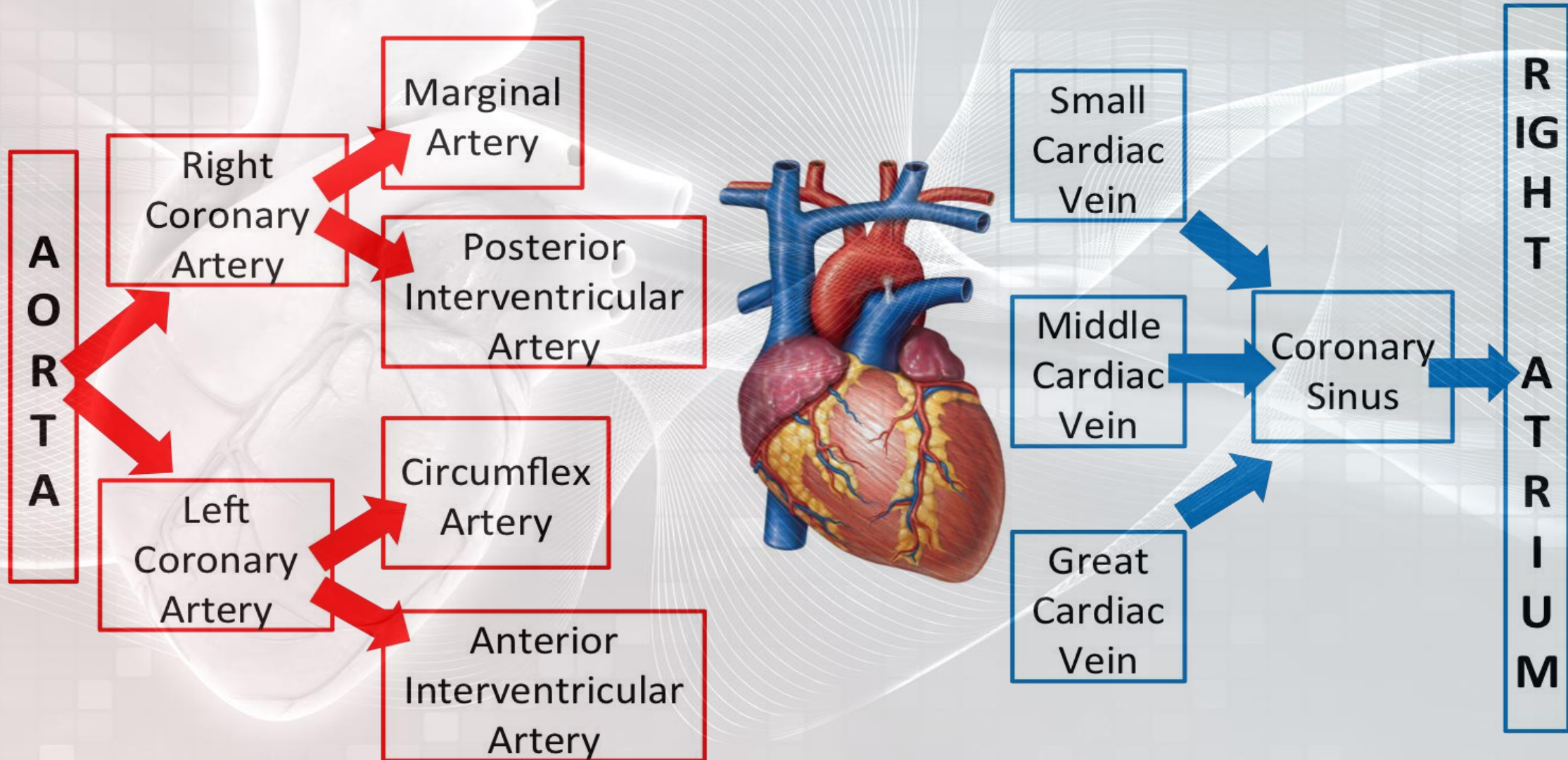




Coronary Circulation: Venous Drainage Of The Heart



Coronary Circulation



Coronary Circulation: Lymphatic Drainage of The Heart

- ❑ Lymphatics of the heart accompany the two coronary arteries.
- ❑ Lymphatics of the heart form two trunks:

**The
Right
trunk**

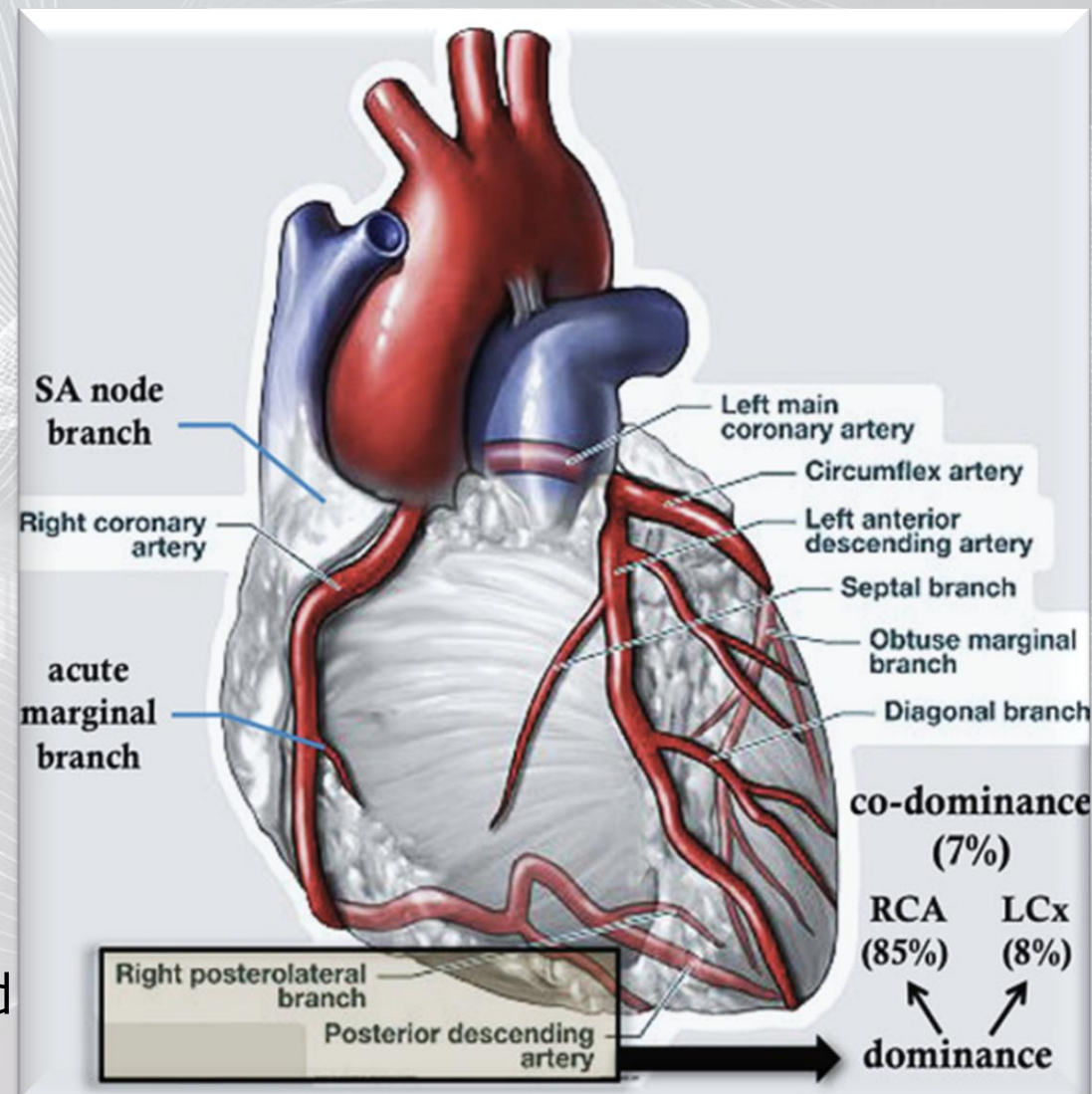
**Ends in the
brachiocephalic
node.**

**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.
- ❑ **A person can be:**
 - **Right dominant** (in 85-90% of population),
 - **Left dominant** through the CX branch (in 8-10% of population), or
 - **Balanced or Co-dominant** (in 7-10% of population).
- ❑ The Posterior Inter- Ventricular artery is formed by both the Right coronary & Left CX arteries.



Coronary Dominance: **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.

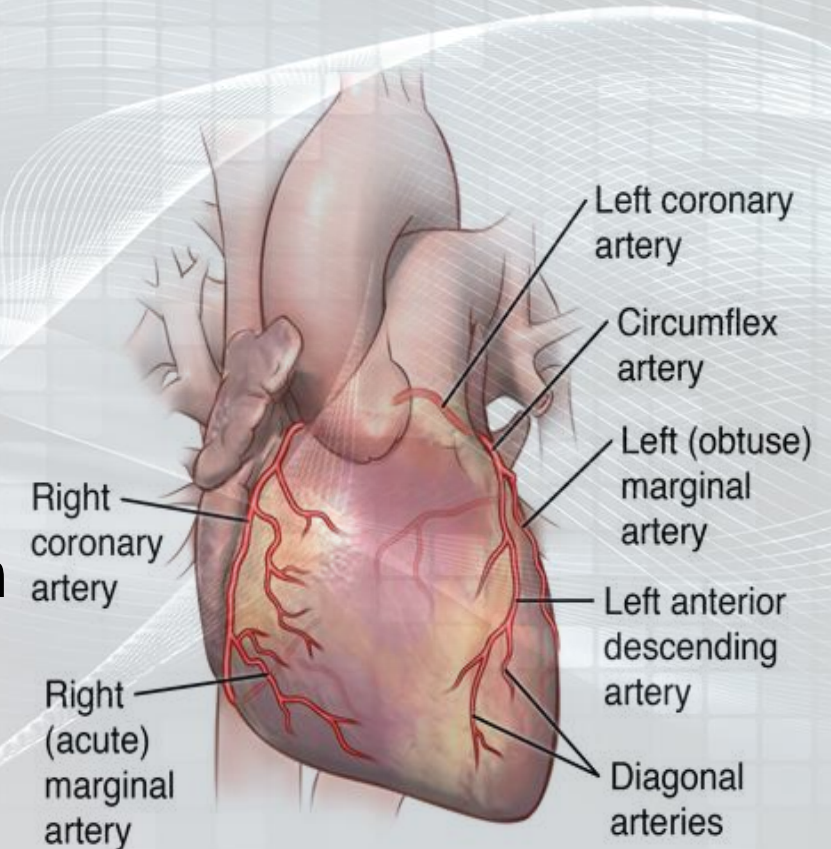
Coronary Artery	Cardiac Muscle	Conduction System
RCA	RV-lateral/posterior wall LV-inferior wall	SA node (45%)* AV node (90%)* Bundle of His Right Bundle
LAD	RV-anterior wall LV-septum/apex/ anterior wall	Left Bundle
LCx	LV-lateral/posterior wall	Left Bundle SA node (55%)* AV node (10%)*

* Represents the percentage of the population in which this feature occurs.



Coronary Blood Flow (CBF)

- ❑ Coronary blood flow (**CBF**) at rest in humans is about **225-250 mL/min**, which is about **5%** of the cardiac output (**CO**).
- ❑ 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 O_2 .)



Factors Affecting Coronary Blood Flow (CBF)

- 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.

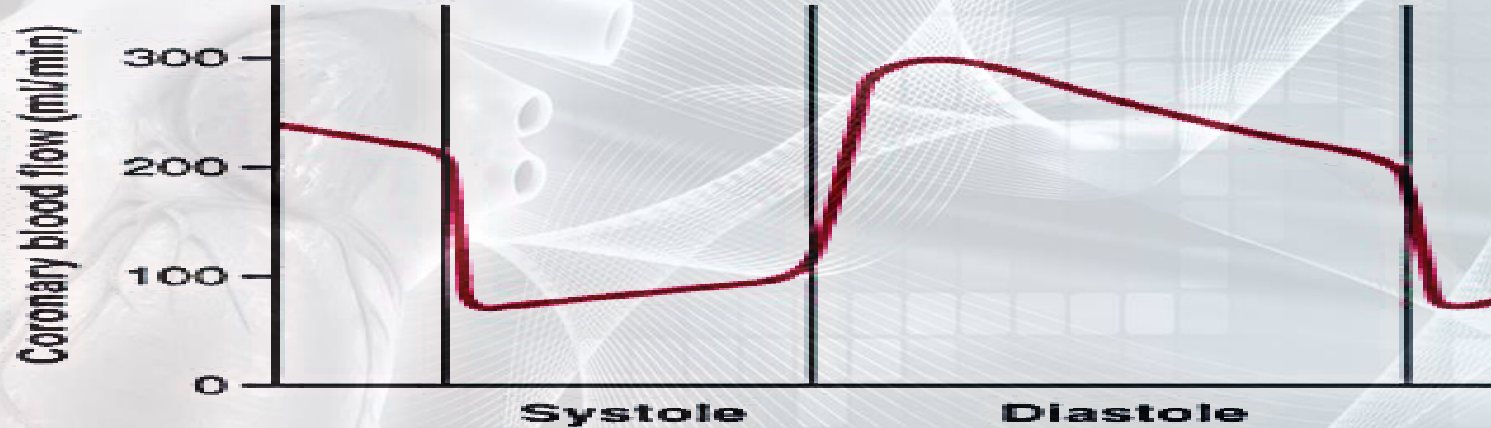
Effect of Pressure Gradient between Aorta & Different Chambers of the Heart On Coronary Blood Flow

	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 (**LV**) is **reduced**.



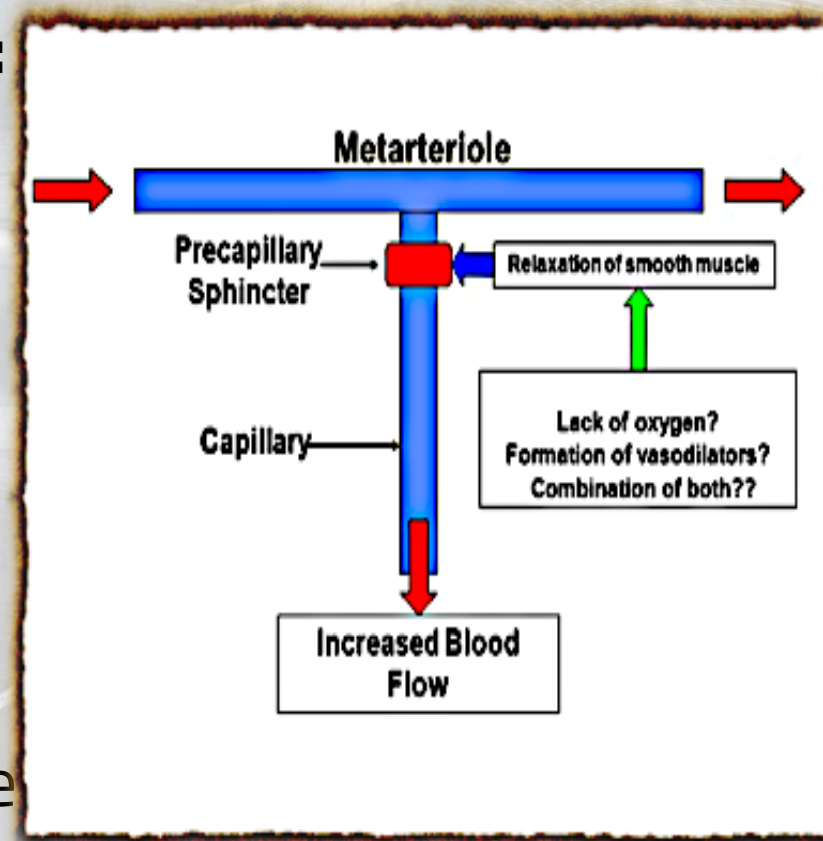
- ◆ **Blood flow** to the **Subendocardial** portion of the left ventricle occurs only **during diastole** & is not there during systole.
- ◆ Therefore, **Sub-endocardial** region of the left ventricle is **prone to ischemic** damage & it is the most common site of myocardial infarction.

Chemical Factors Affecting Coronary Blood Flow

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

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

❑ **Note:** An increase in Ca²⁺ conc. does not increase the Coronary blood flow (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 the systemic blood pressure (**BP**) **decreases** (very low), it will cause a **reflex increase** of **nor-adrenergic discharge**.
- ❑ This will lead to an **increase** in the Coronary blood flow (**CBF**) secondary to metabolic changes in the myocardium.
- ❑ **In this way, circulation of the heart is preserved, while the flow to other organs is 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 Coronary Blood Flow

- ◆ Coronary blood flow (**CBF**) is **reduced** with **tachycardia**.
- ◆ **Why?**
 - With tachycardia, the **diastolic period** will be **shortened**.

Control of Coronary Blood Flow

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



Thank You