

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

Consists of:



Arterial supply.



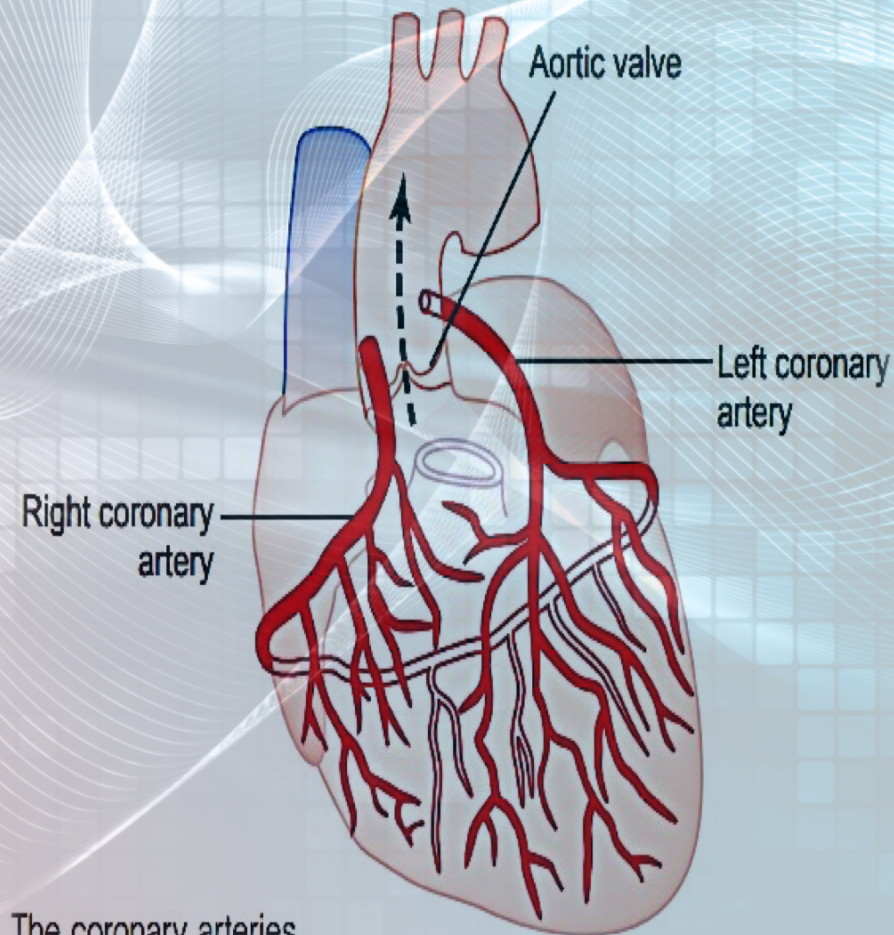
Venous drainage.



Lymphatic drainage.

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.

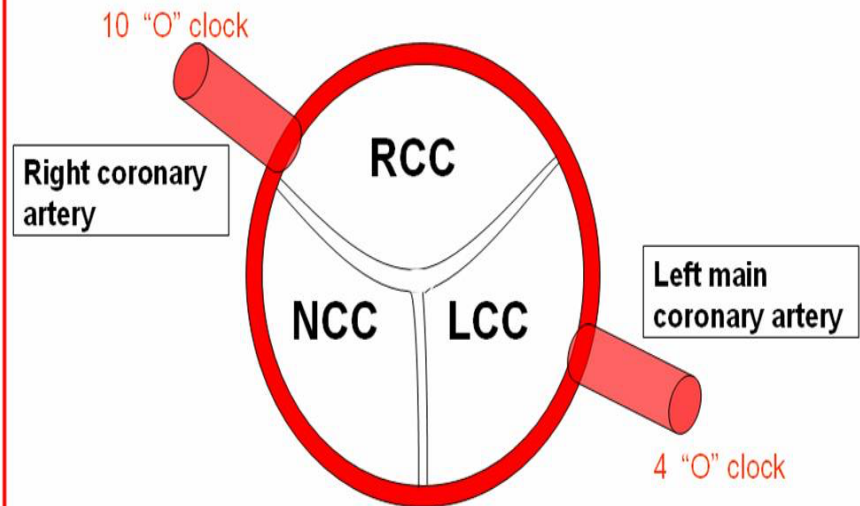


The coronary arteries.

Coronary Sinuses

- ❑ The aortic valve has three cusps: left coronary (LCC), right coronary (RCC), & posterior non-coronary (NCC) cusps.
- ❑ 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

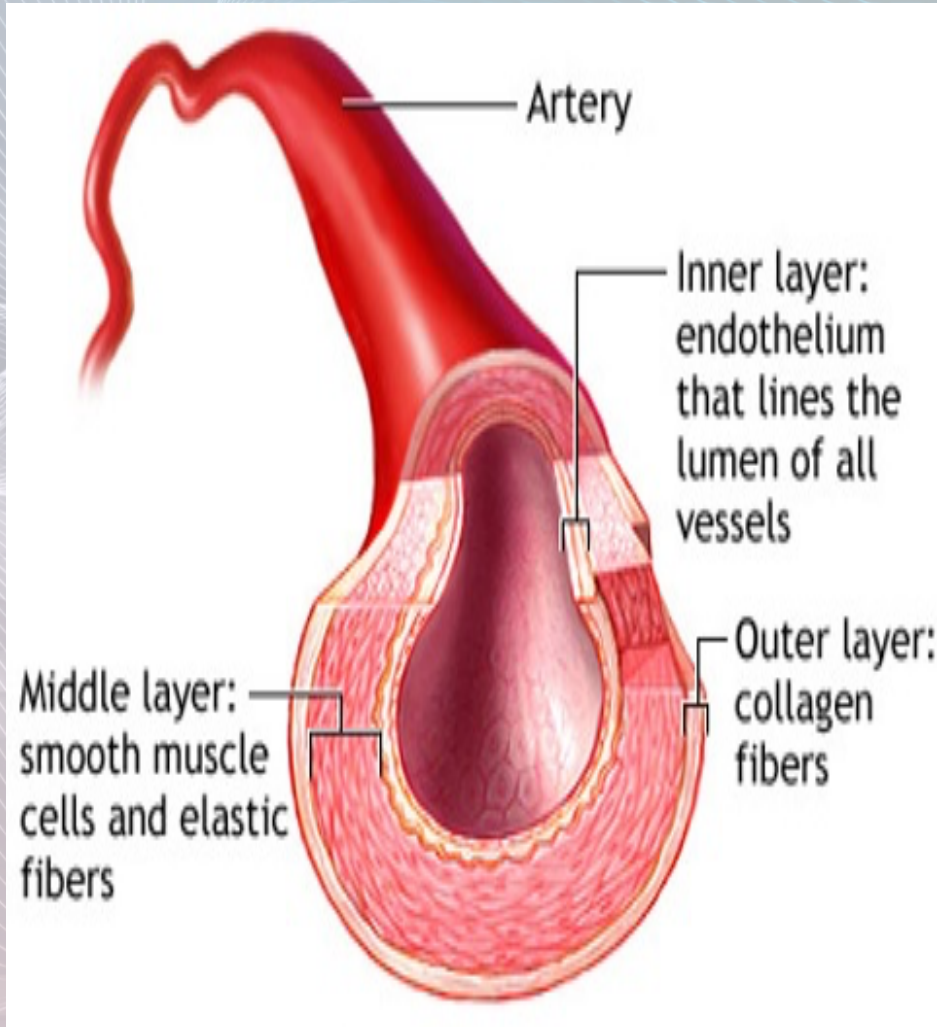
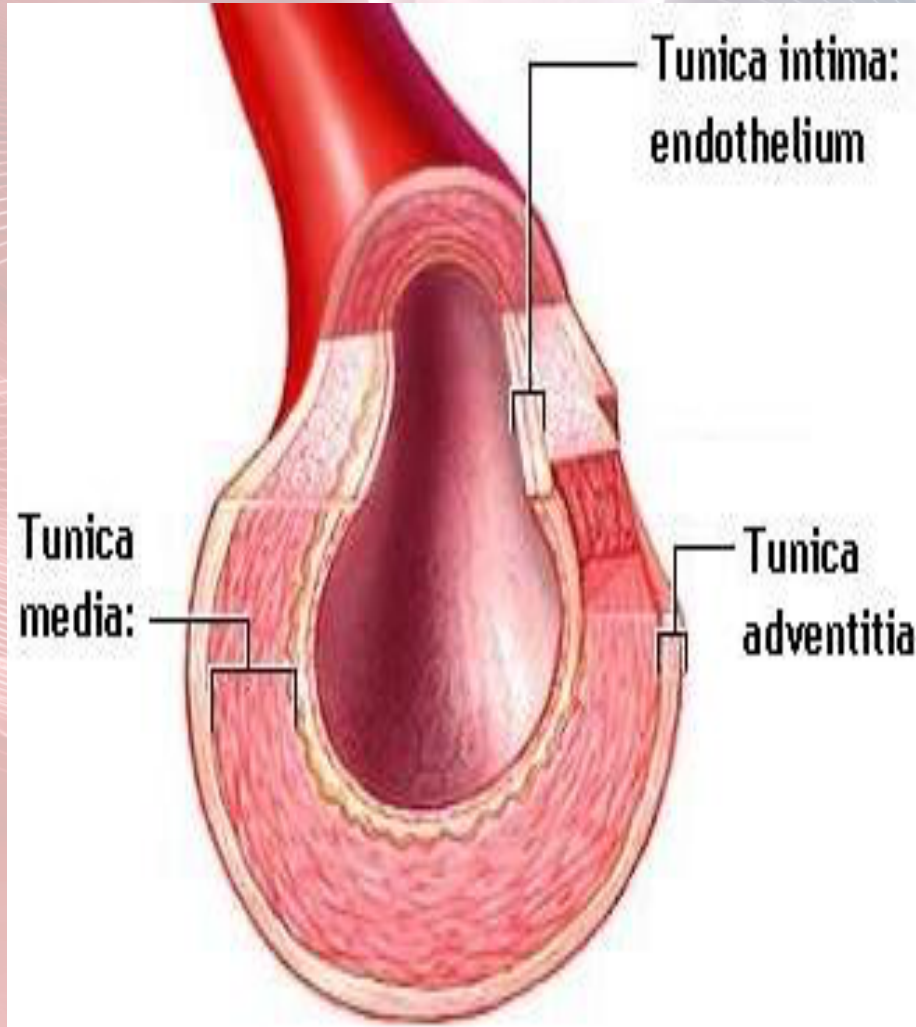
LCC --Left coronary cusp

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 arteries of the heart

Right
coronary
artery

Right
(acute)
marginal
artery

Left coronary
artery

Circumflex
artery

Left (obtuse)
marginal
artery

Left anterior
descending
artery

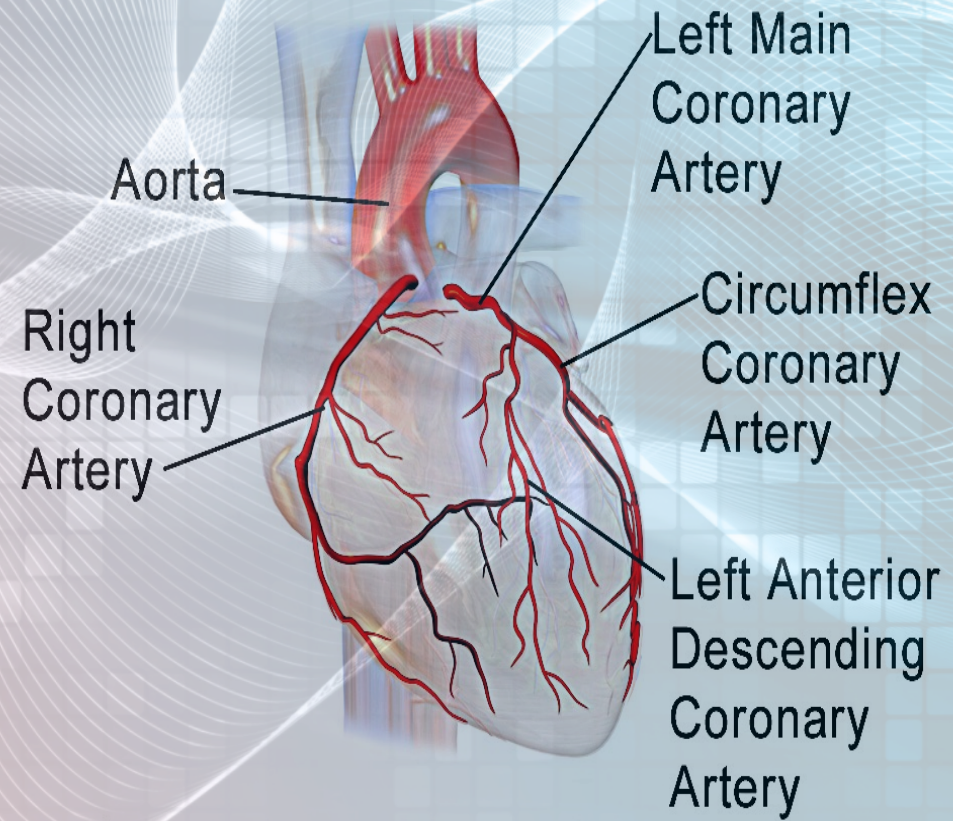
Diagonal
arteries

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

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.

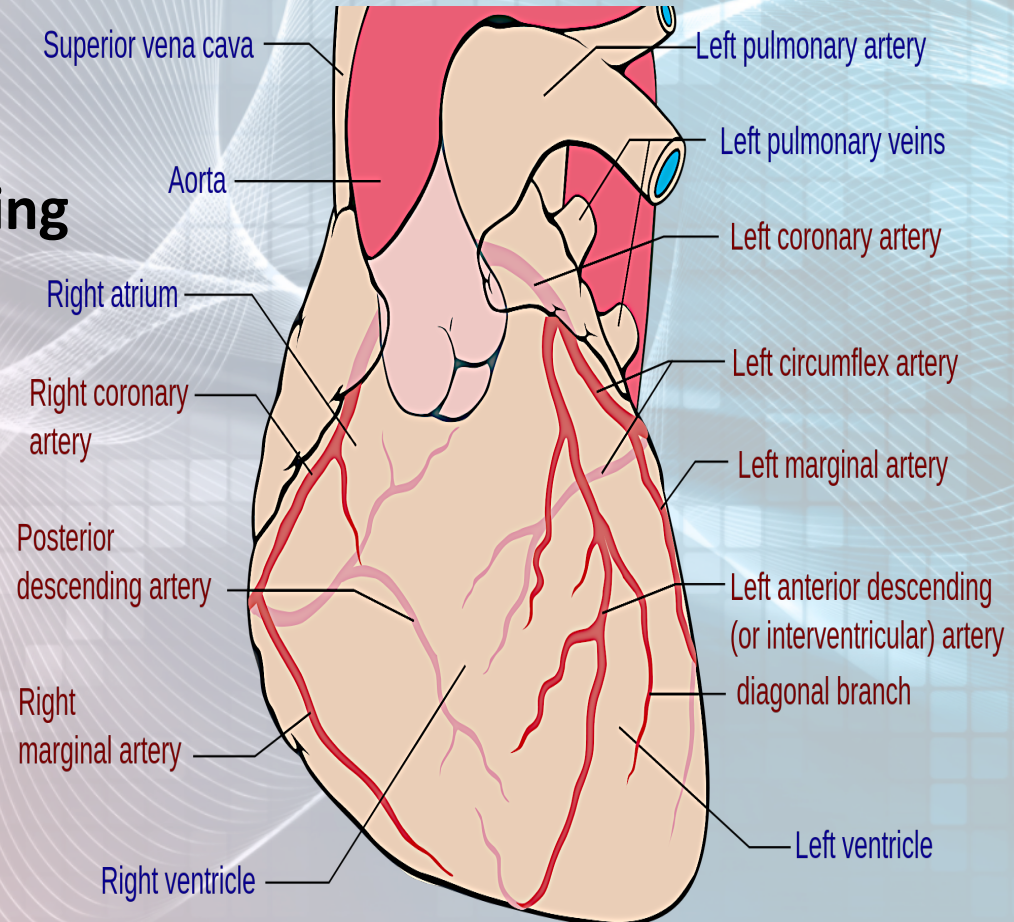
Right Coronary Artery: Main Branches

Two main branches:

Right posterior descending artery (RPD):

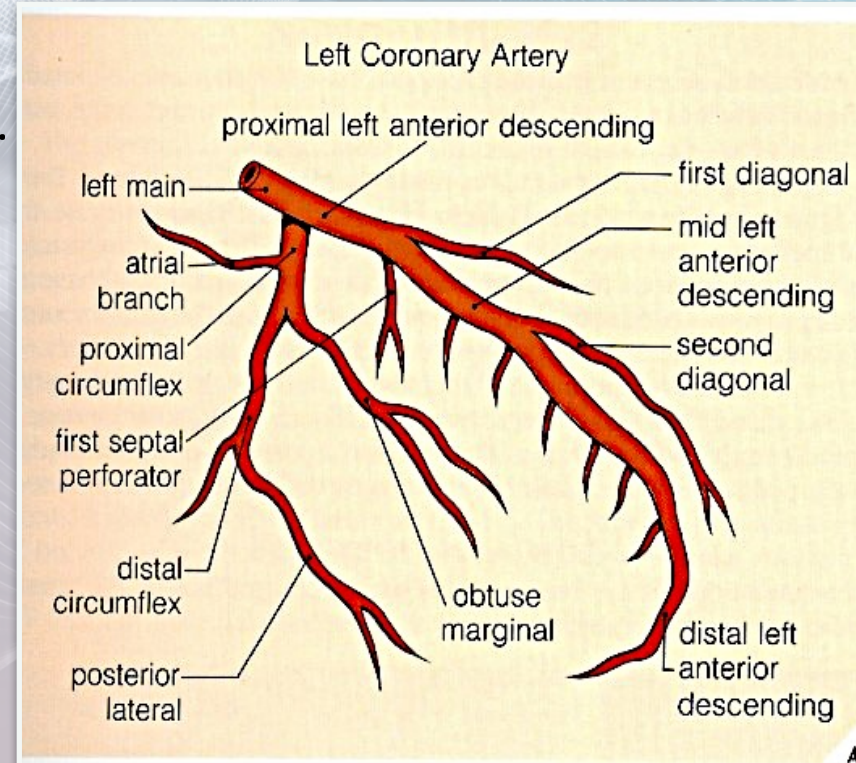
Also called anterior interventricular artery.

Right acute marginal artery:



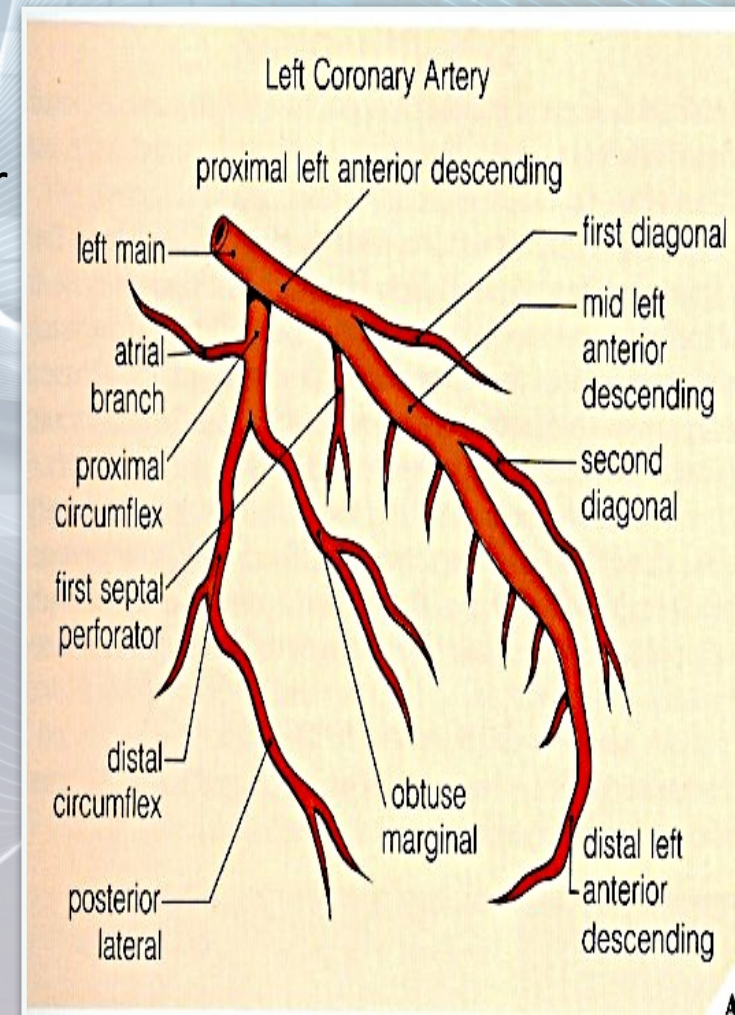
Left Coronary Artery: **Branches**

- **Left anterior descending artery (LAD):**
 - Considered the most critical vessel in terms of myocardial blood supply, as 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 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**.



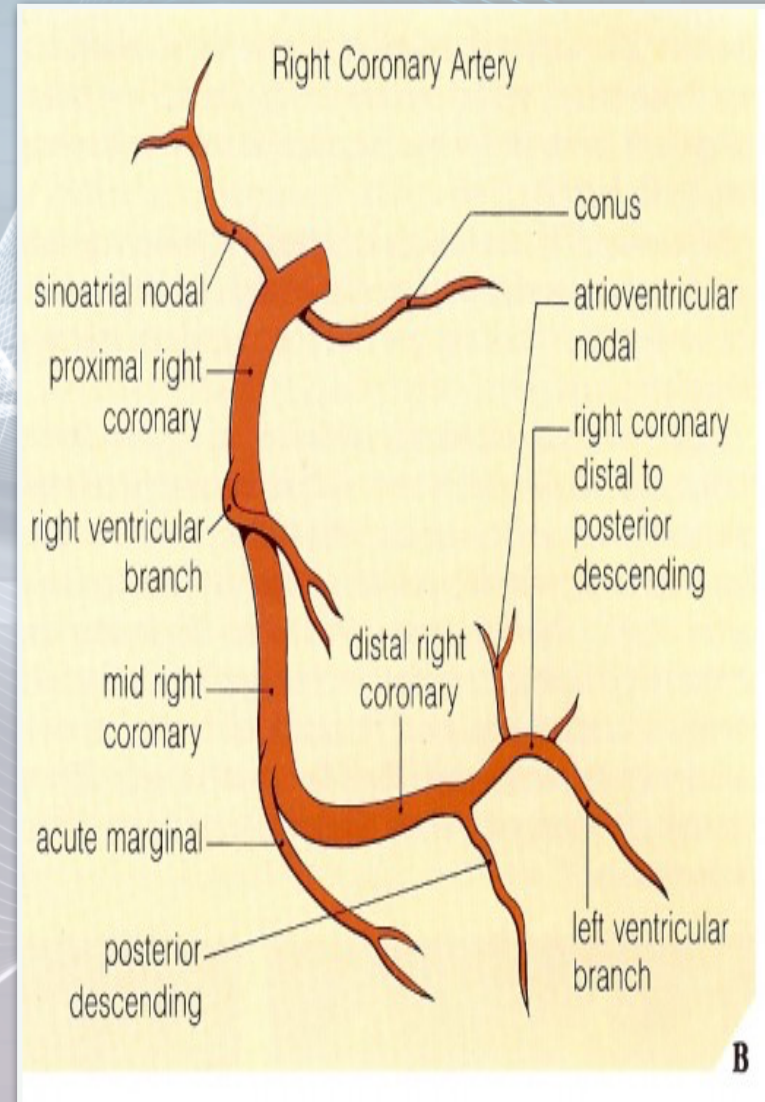
Right Coronary Artery: **Branches**

■ 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 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.

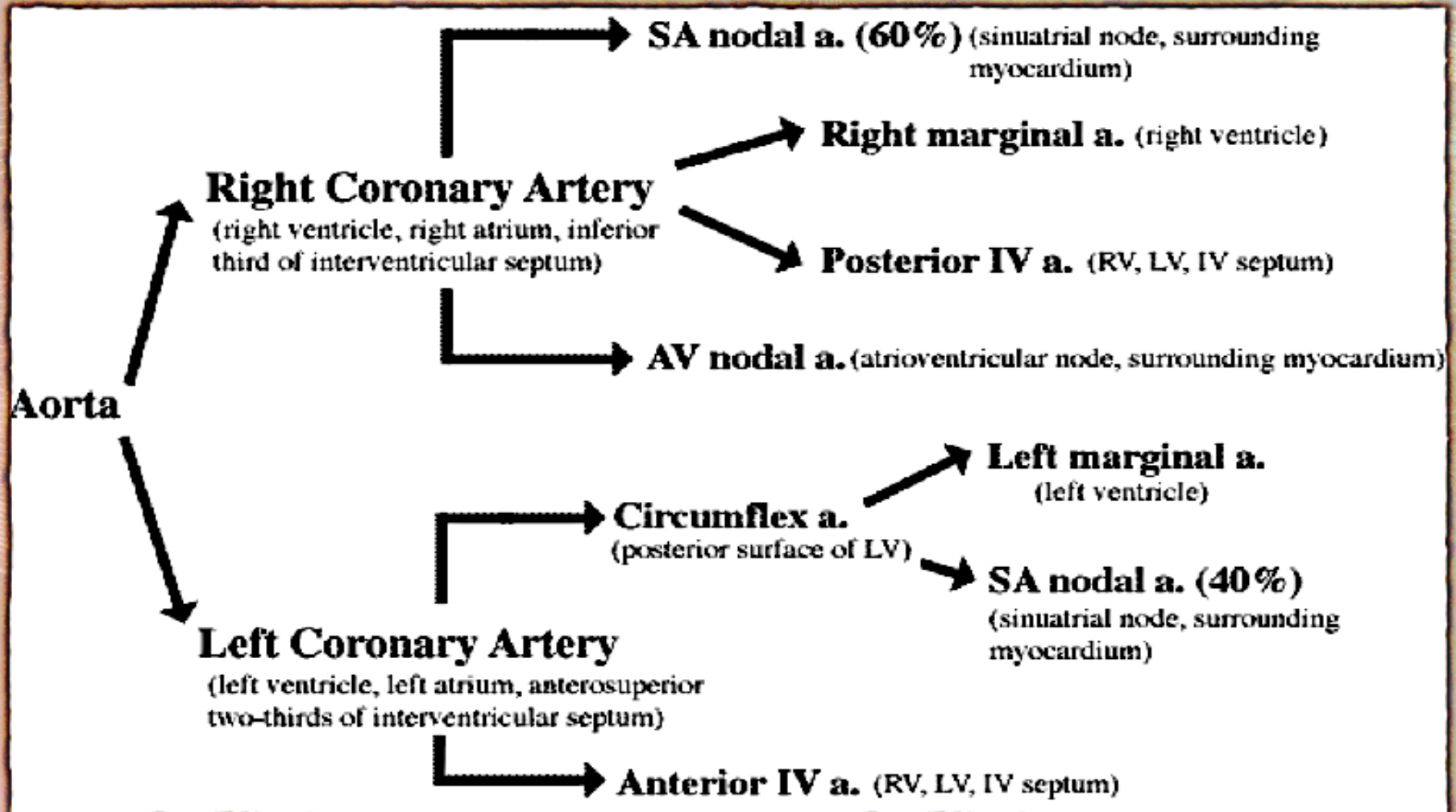


Right Coronary Artery: **Branches**

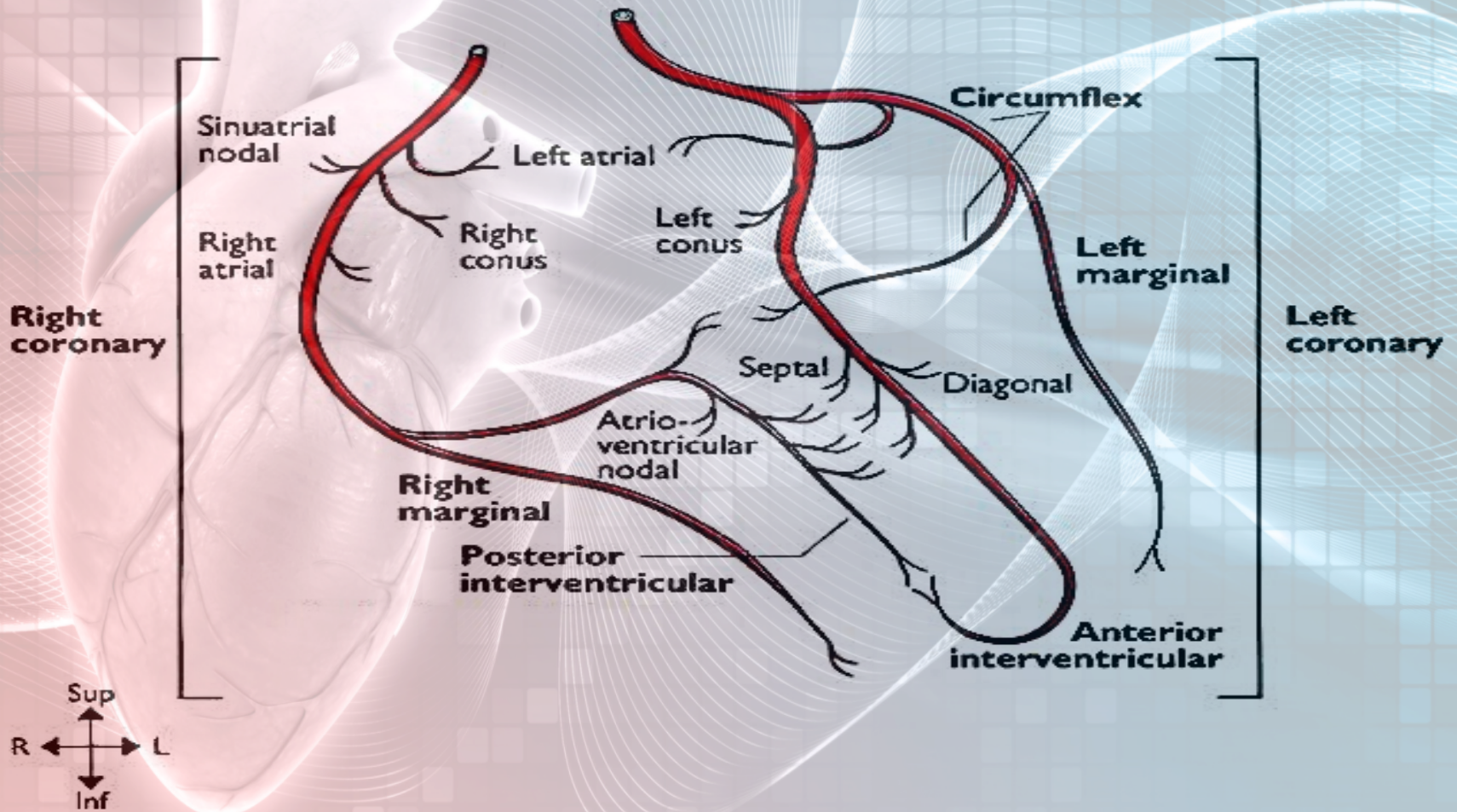
□ Smaller branches:

- **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.**

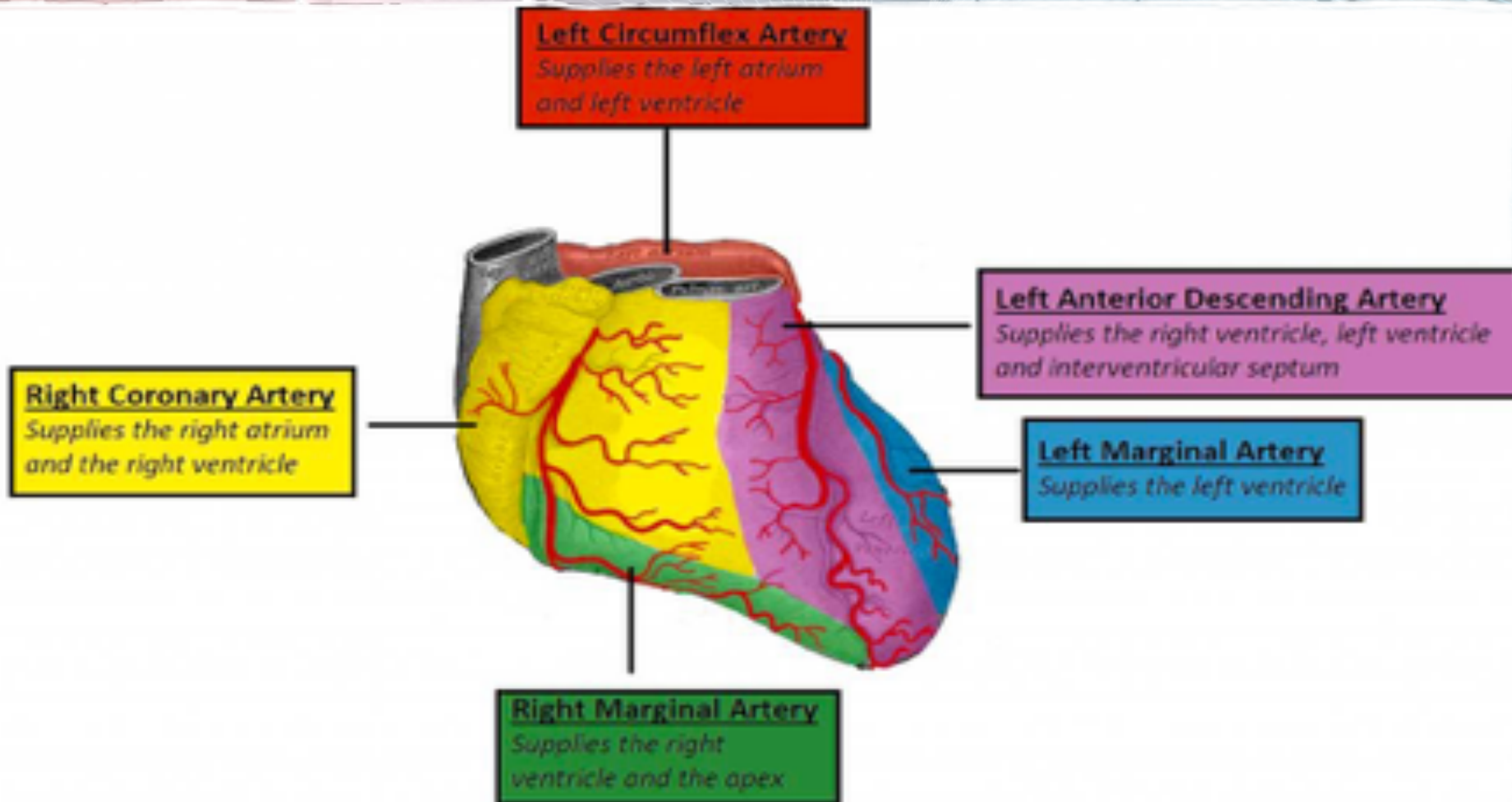
Branches Of The Coronary Arteries: Summary



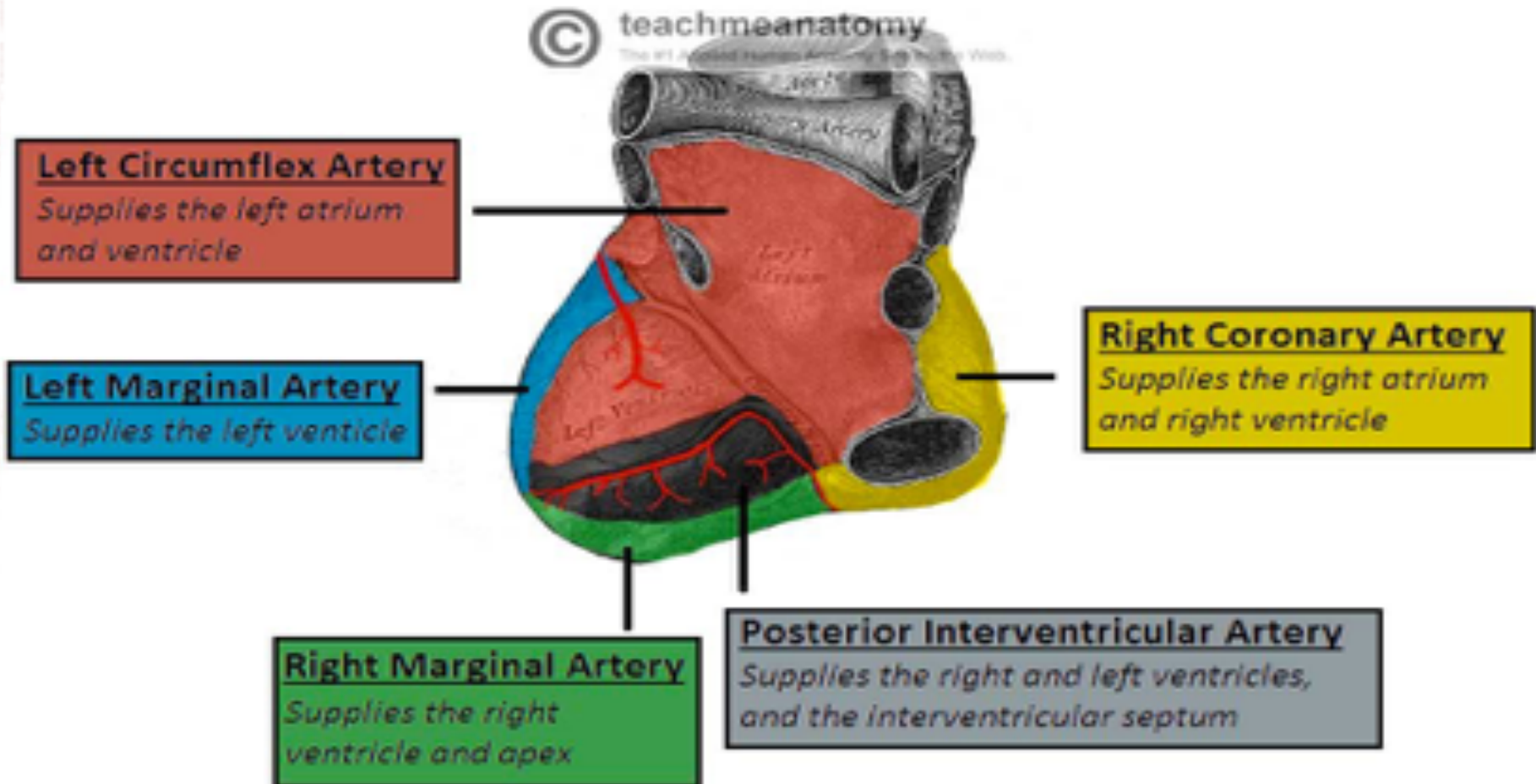
Coronary Arteries: **Branches**



Coronary Circulation: Areas of Distribution: Front View



Coronary Circulation: Areas of Distribution: Back View



Coronary Circulation: Cardiac Anastomosis

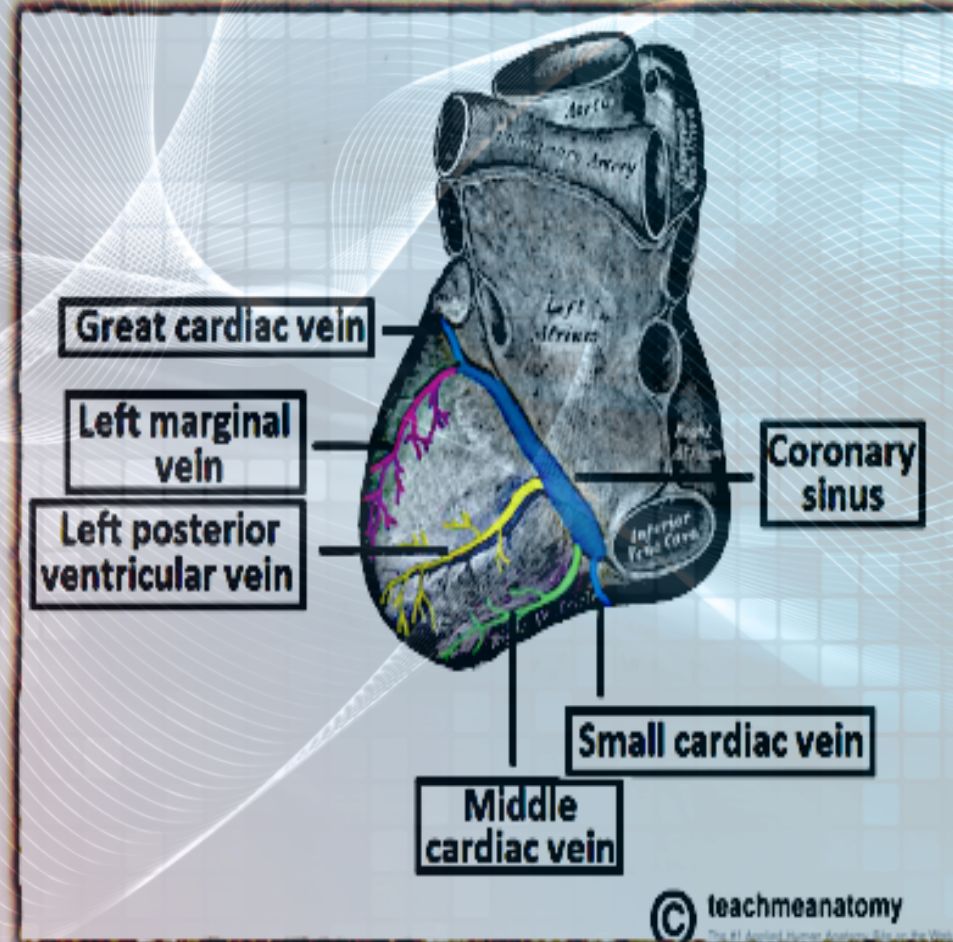
- ❑ **Cardiac anastomosis:**
 - The two coronary arteries anastomose in the myocardium.
- ❑ **Extra cardiac anastomosis: the two coronary arteries anastomose with,**
 - Vasa vasorum of the aorta.
 - Vasa vasorum of pulmonary arteries.
 - Internal thoracic arteries.
 - The bronchial arteries.
 - Phrenic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

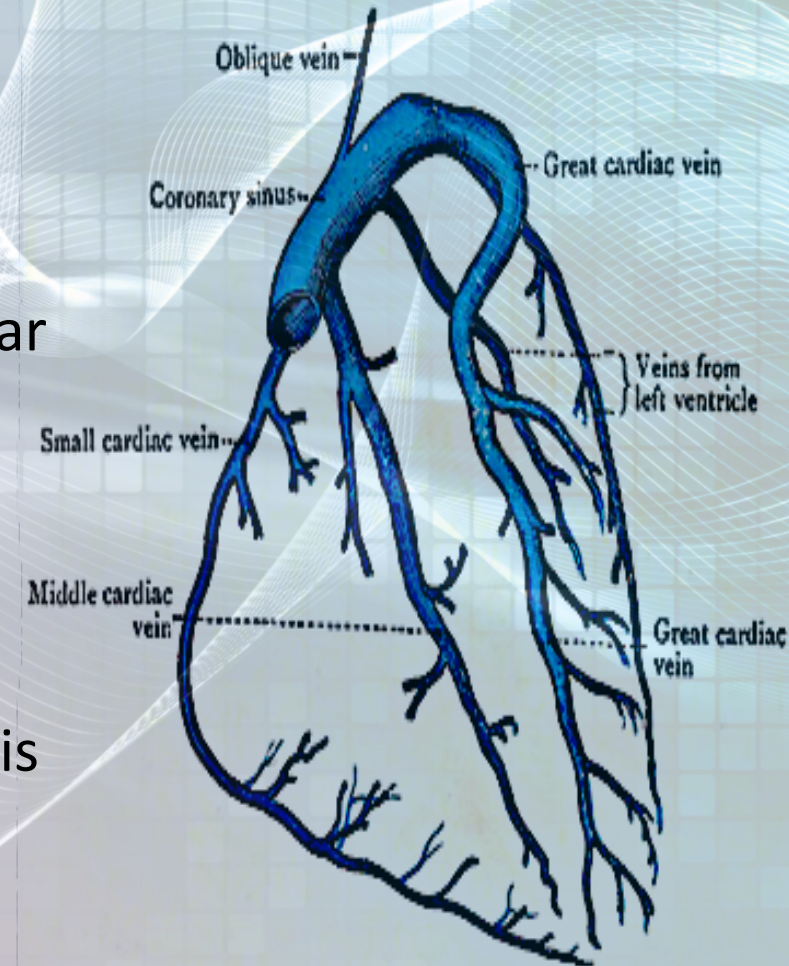
Coronary Circulation: Venous Drainage Of The Heart

- ❑ 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.

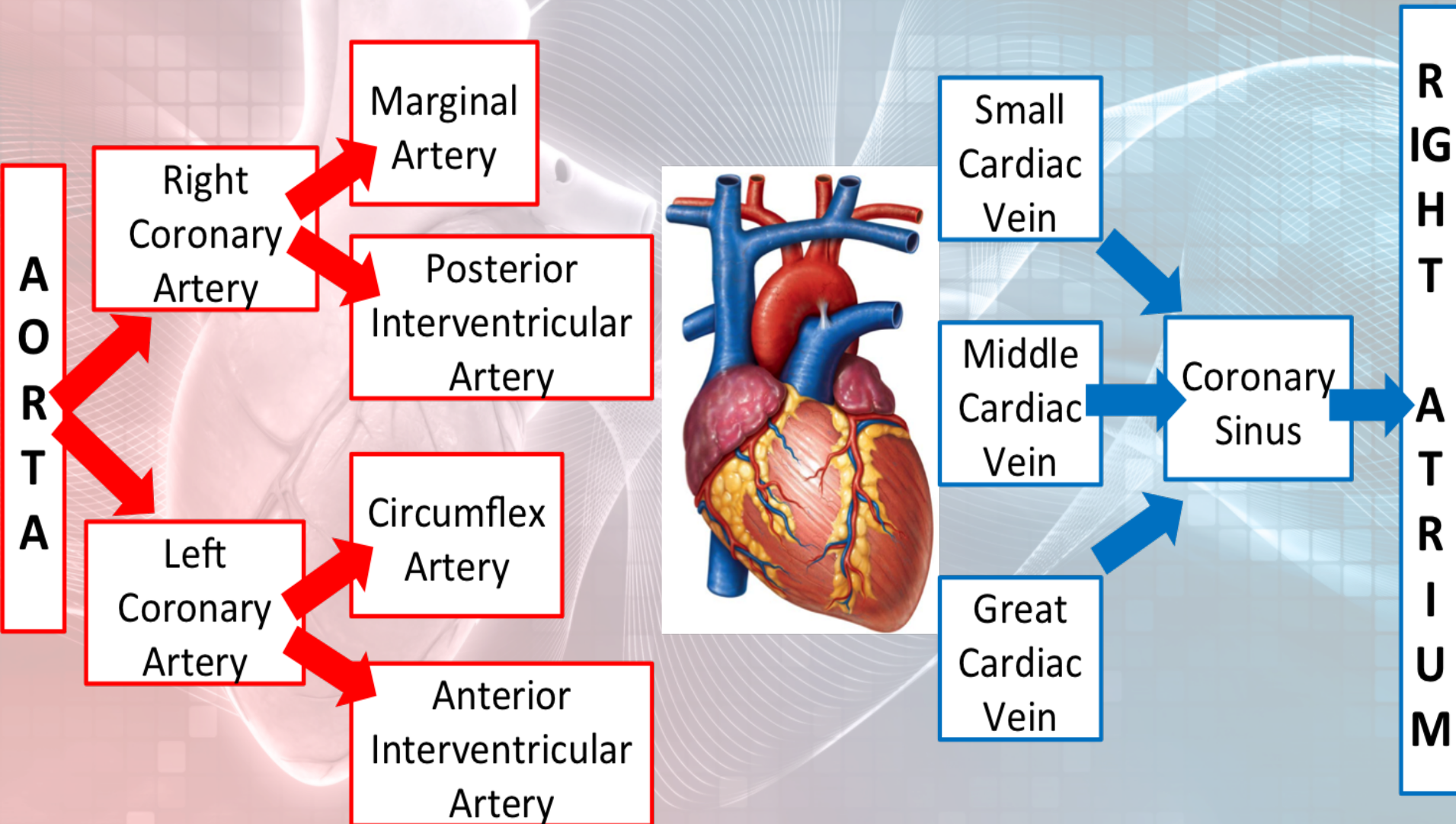


Coronary Circulation: Venous Drainage Of The Heart

- ❑ 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 & 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 O_2 .)

Factors Affecting Coronary Blood Flow

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

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

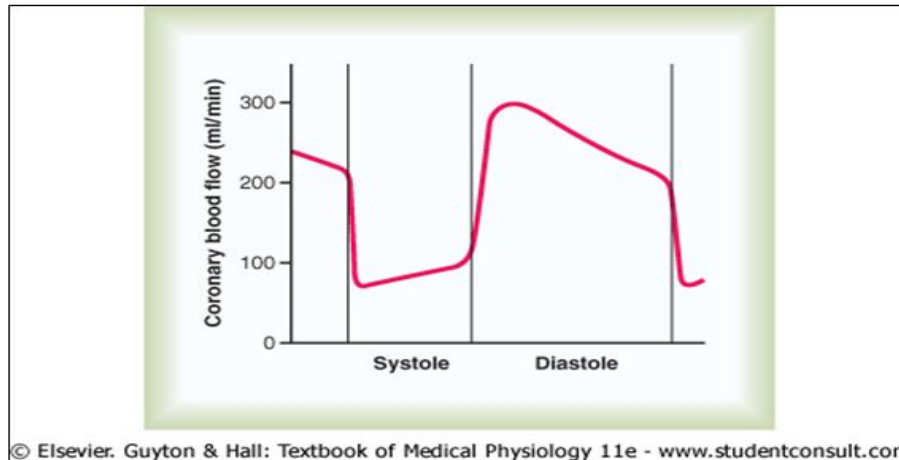
- ◆ During systole, coronary arteries are compressed & the blood flow to the left ventricle is reduced.
- ◆ CBF to the right side of the heart is not much affected during systole, & so more blood will flow to the right ventricle than the left one.
- ◆ **Explanation:** Pressure difference between the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

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.



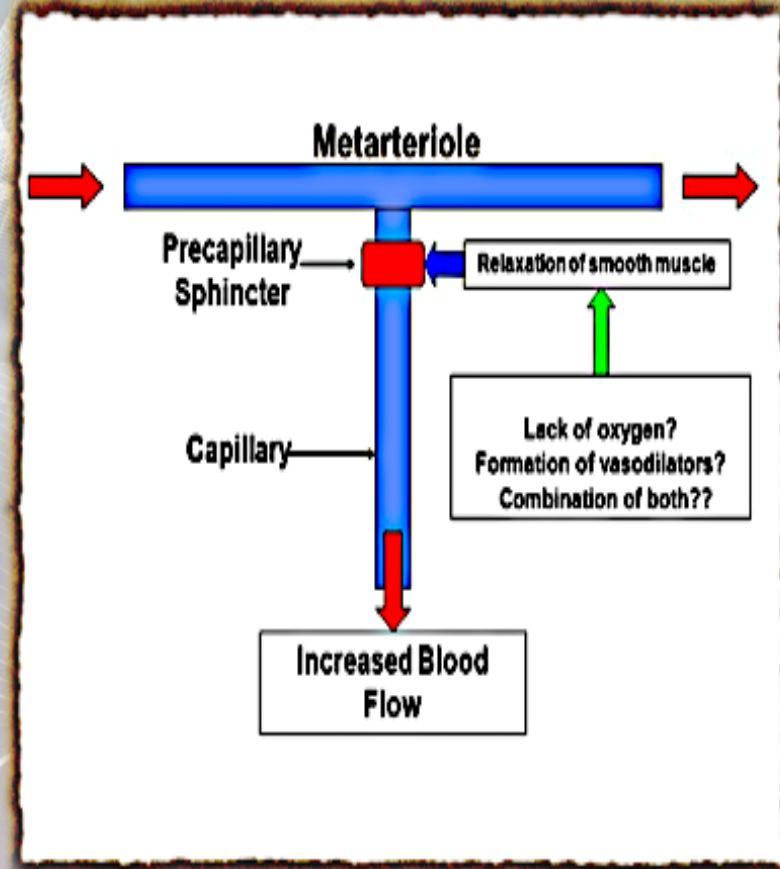
- Blood flow to the subendocardial portion of the Lt ventricle occurs only during diastole, & is not there during systole.
- ◆ Therefore, this subendocardial region of Lt ventricle is prone to ischemic damage & is most common site of Myocardial infarction.

Chemical Factors Affecting Coronary Blood Flow

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

- Lack of oxygen.
- Increased local conc. of CO_2 .
- Increased local conc. of H^+ ion.
- Increased local conc. of K^+ ion.
- Increased 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 in the intramuscular arteries.)

❑ **Indirect effect of sympathetic stimulation:**

- Sympathetic stimulation in intact body will lead to release of adrenaline & nor-adrenaline, increasing 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-adrenalin** after **blocking of 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