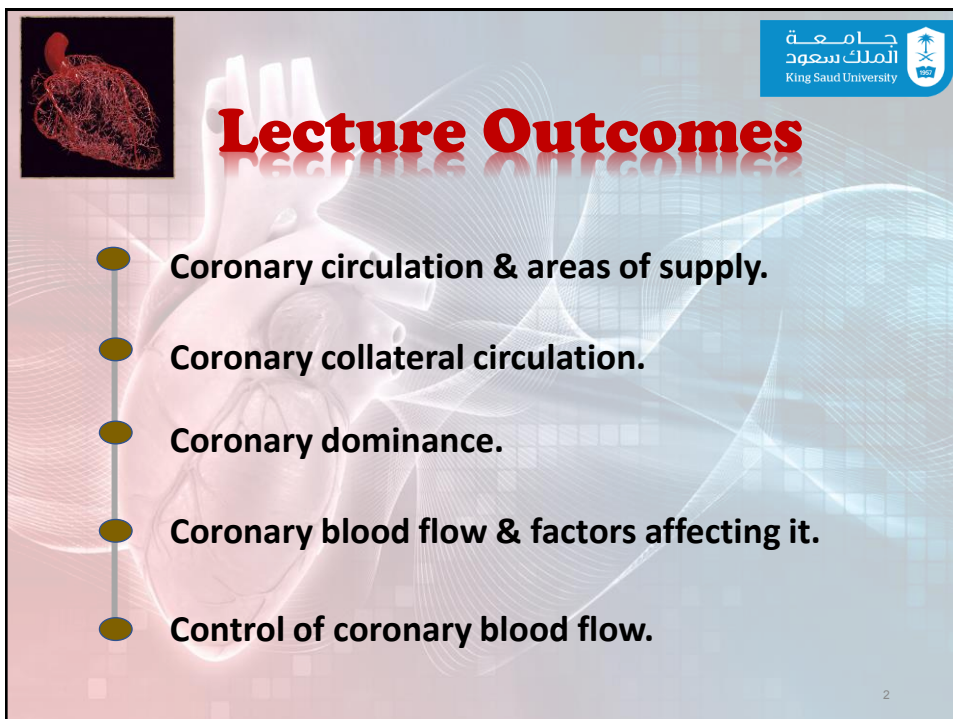


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**Cardiovascular Physiology**

# 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.

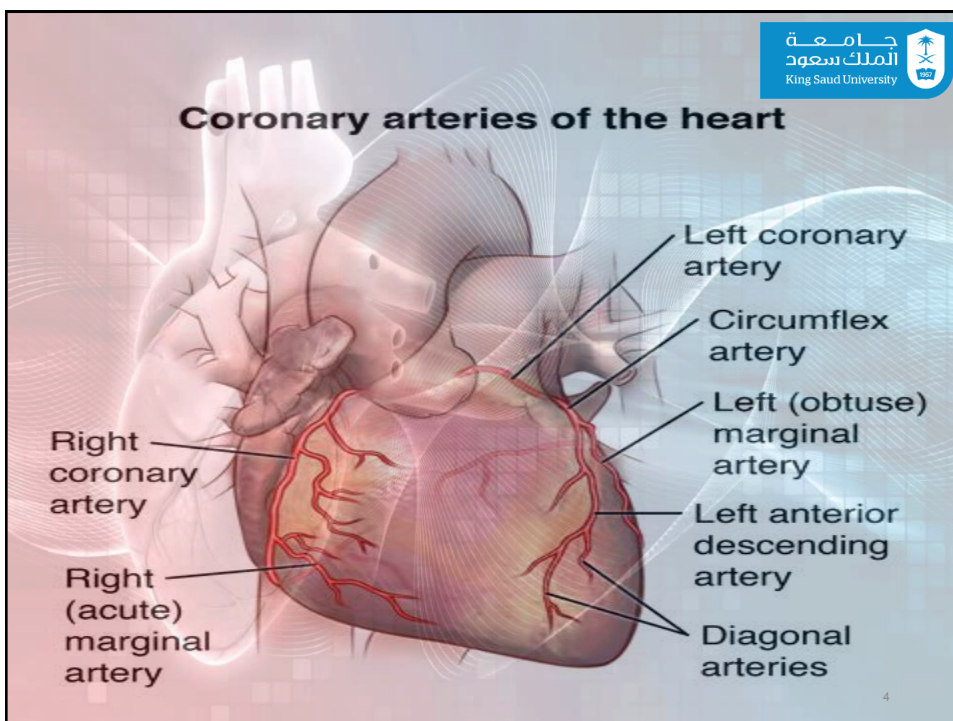
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## Coronary Circulation

- ❑ **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, and 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 and even the level of consciousness of the brain from moment to moment.

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## 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.

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## 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.

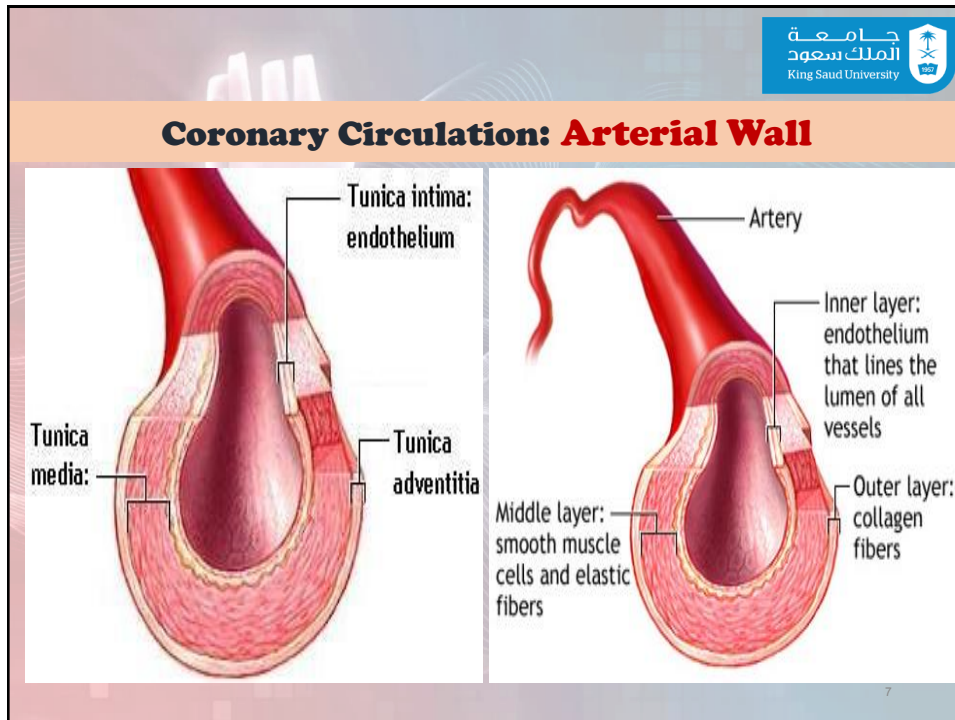
*Where to look for coronary artery origin in short axis view ?*

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

[www.drsvenkatesan.com](http://www.drsvenkatesan.com)

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.

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### 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).

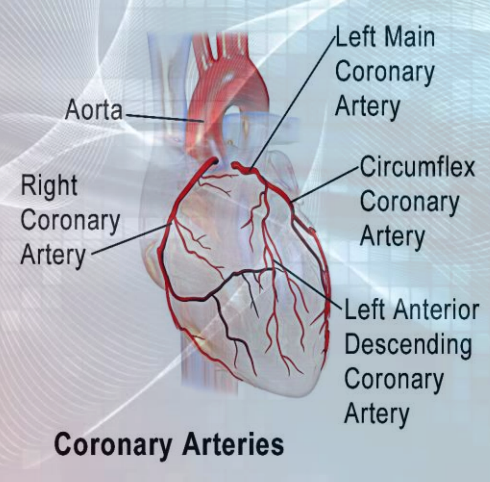
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## Left Coronary Artery: Main Branches

□ **Two main branches:**

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



Coronary Arteries

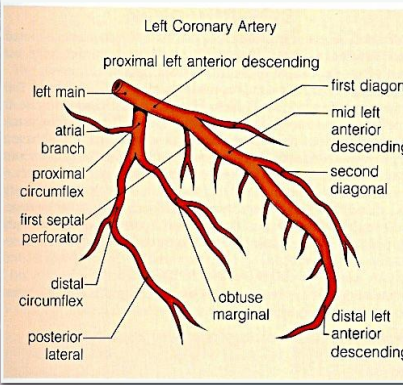
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## Left Coronary Artery: Branches

▪ **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.

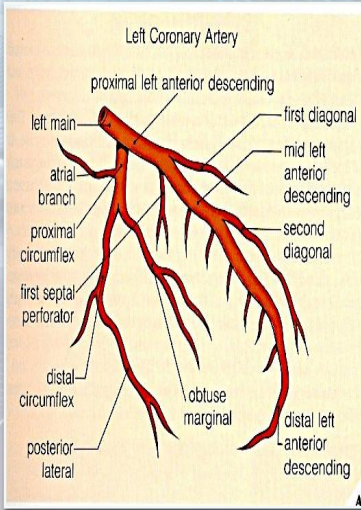


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## Left Coronary Artery: **Branches**

- **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.



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## 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.

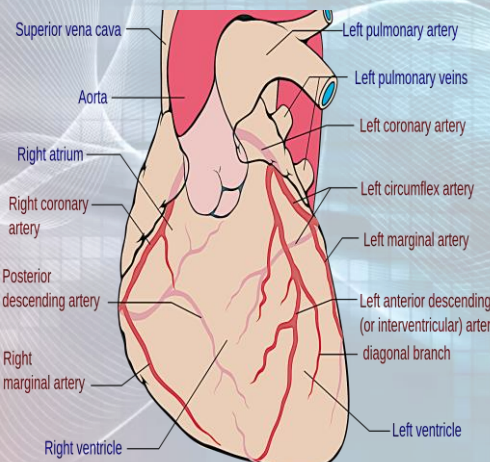
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## Right Coronary Artery: Main Branches

□ **Two main branches:**

- **Right posterior descending artery (RPD):**  
Also called posterior interventricular/descending artery.
- **Right acute marginal artery:**

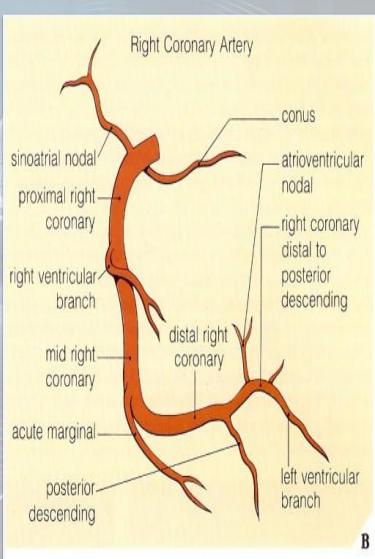


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## Right Coronary Artery: Branches

- **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.



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## 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.**

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## Coronary Arteries: **Branches**

The diagram illustrates the branching of the coronary arteries. The **Right coronary artery** branches into the Sinuatrial nodal, Right atrial, Right conus, and Right marginal arteries. The **Left coronary artery** branches into the Left atrial, Left conus, Circumflex, Left marginal, Diagonal, and Septal arteries. The **Septal artery** further branches into the Atrio-ventricular nodal, Posterior interventricular, and Anterior interventricular arteries.

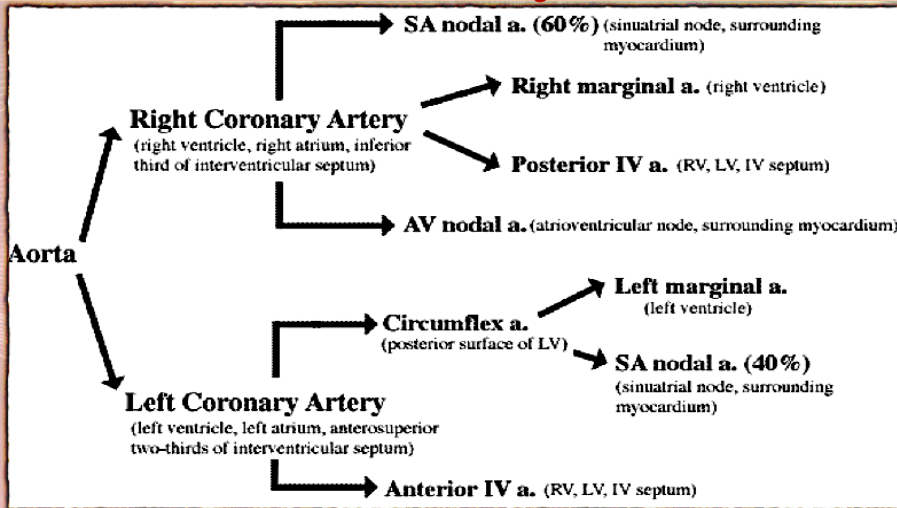
Coronary arteries

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### Branches Of The Coronary Arteries:

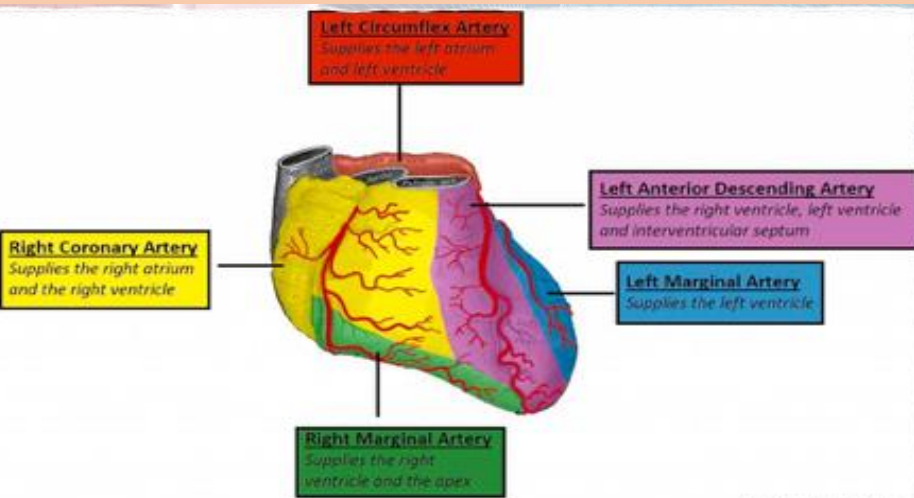
#### Summary



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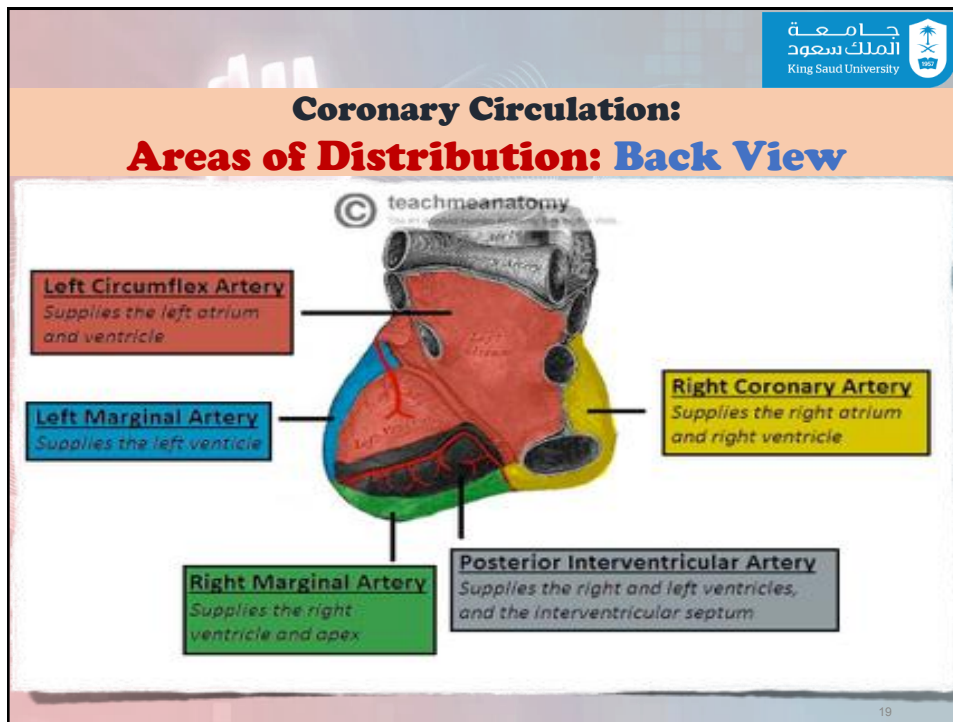
### Coronary Circulation:

#### Areas of Distribution: Front View



teachmeanatomy

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### 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.

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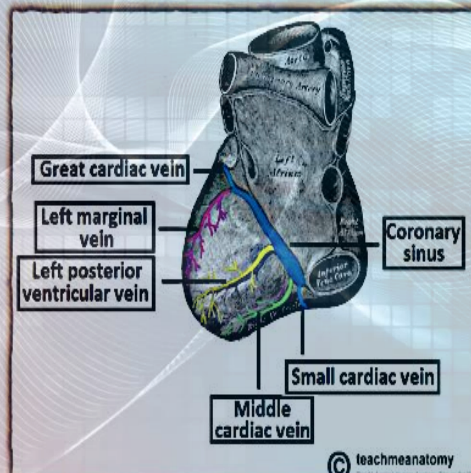
## Coronary Circulation: Collateral Circulations

- ❑ 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.

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## Coronary Circulation: Venous Drainage Of The Heart

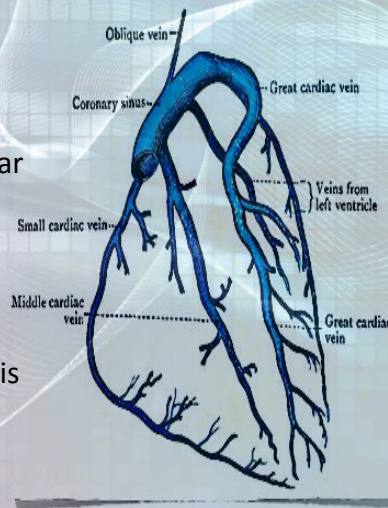
- ❑ Venous drainage brings deoxygenated cardiac blood back to the heart.
- ❑ Most of the venous blood return to the heart into the right atrium through the coronary sinus via the **cardiac veins**.
- ❑ 5- 10% drains **directly** into heart chambers, right atrium & right ventricle, by the anterior cardiac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



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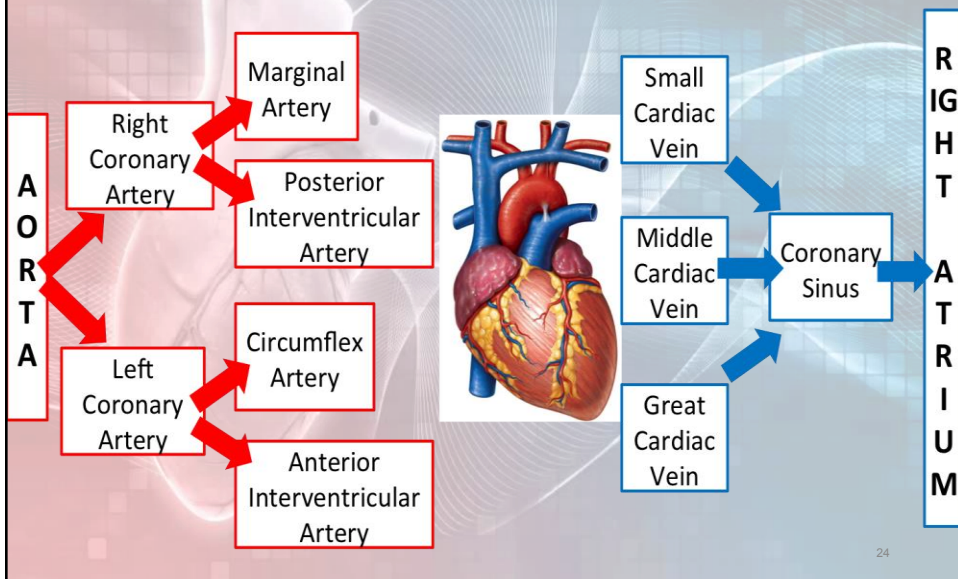
## Coronary Circulation: Venous Drainage Of The Heart

- ❑ 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).

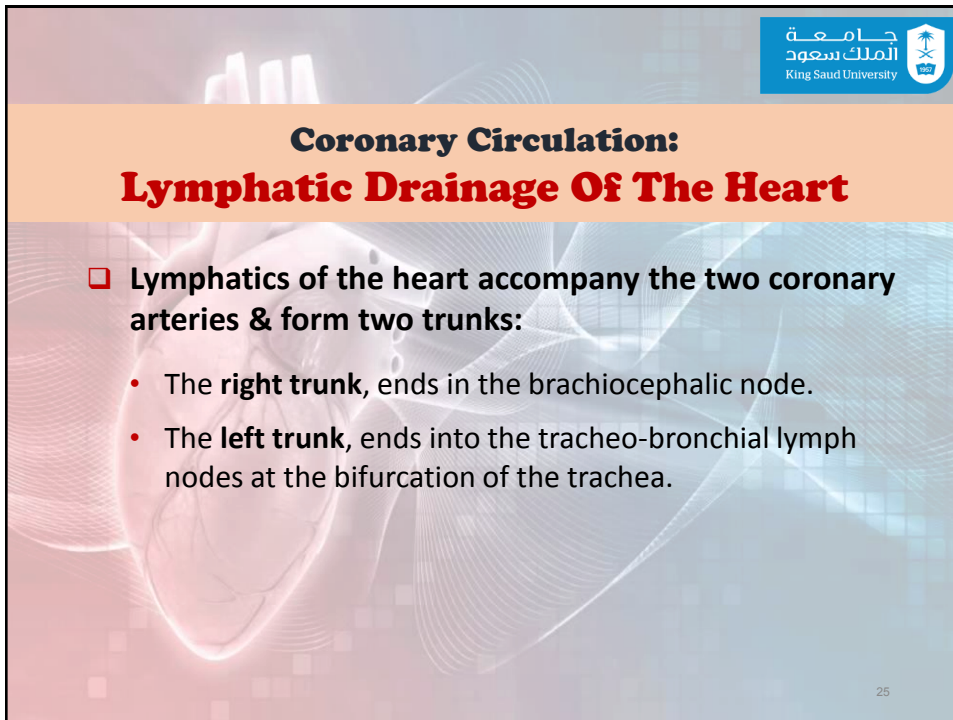


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## Coronary Circulation



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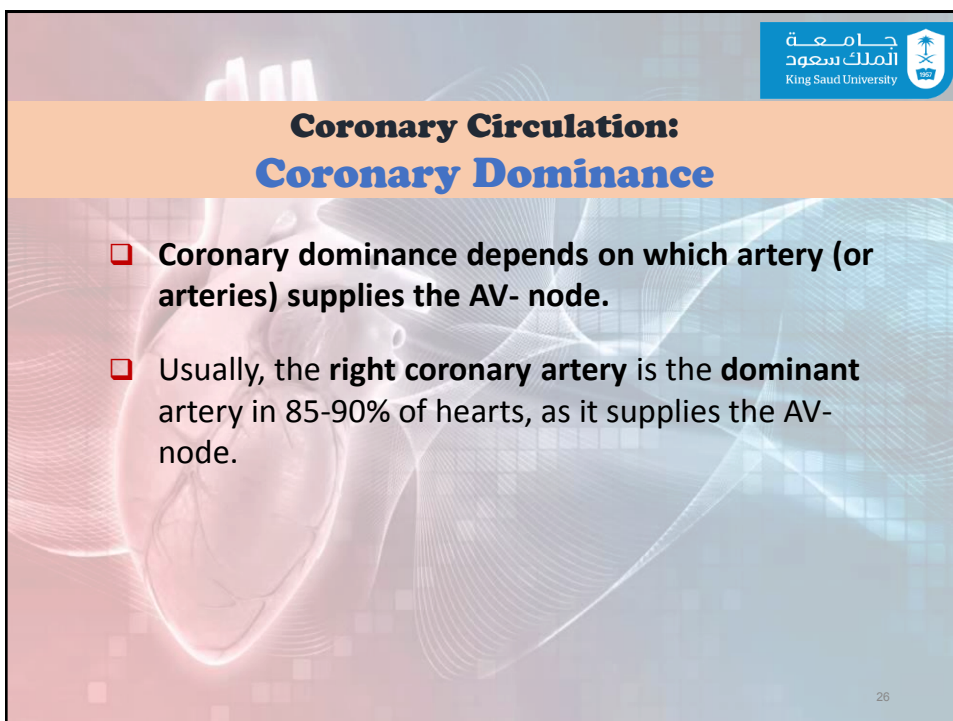


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### Coronary Circulation: **Lymphatic Drainage Of The Heart**

- ❑ 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.

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### 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.

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## 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.

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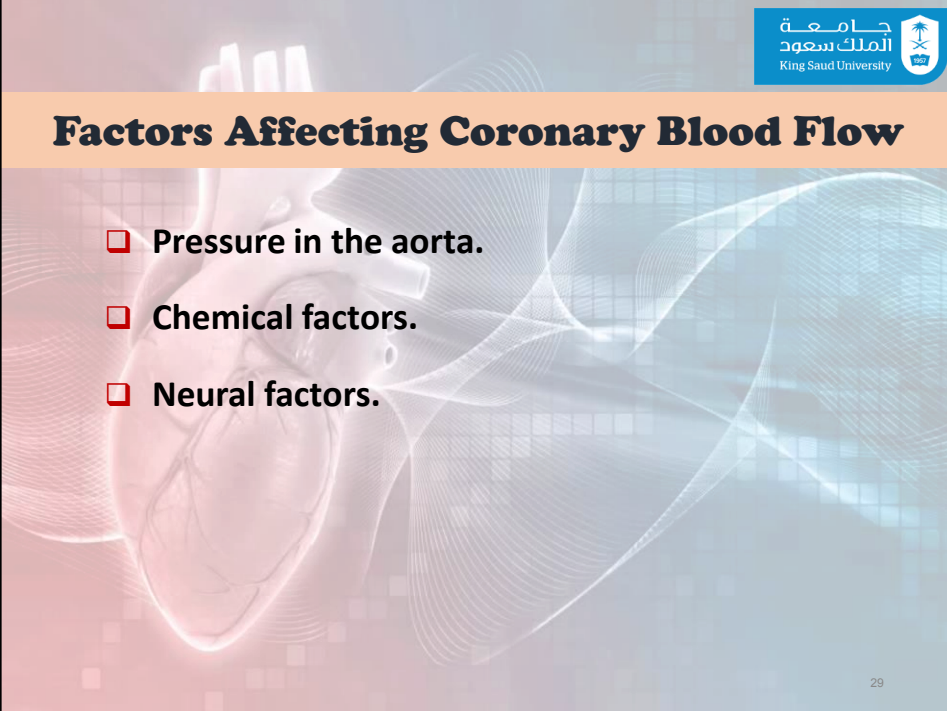


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## Coronary Blood Flow

- ❑ 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<sub>2</sub>.)

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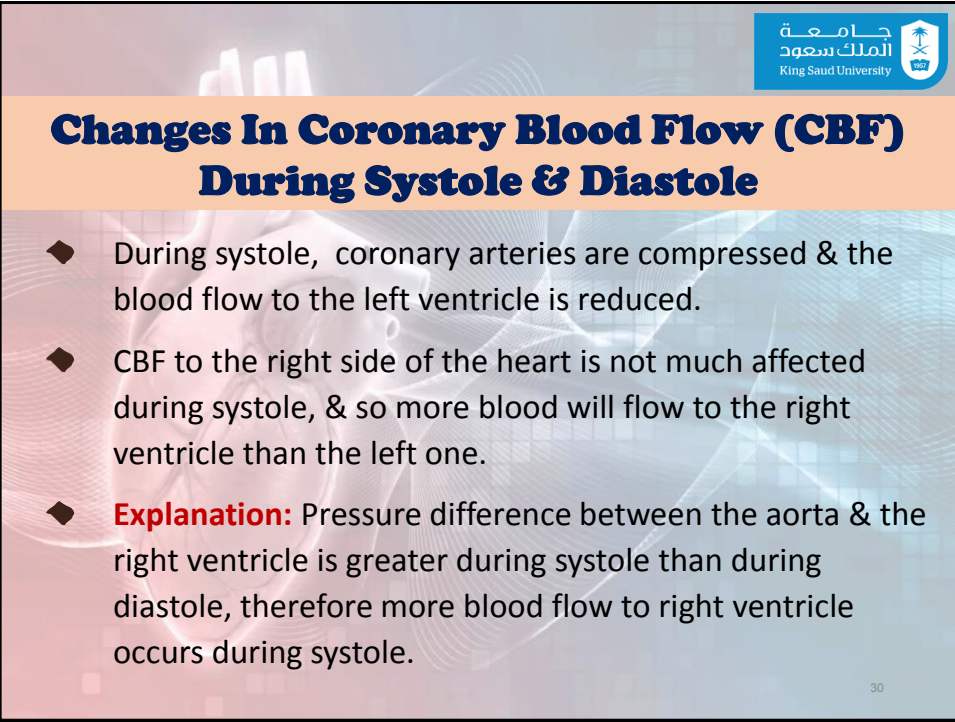


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## Factors Affecting Coronary Blood Flow

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

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## 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.

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

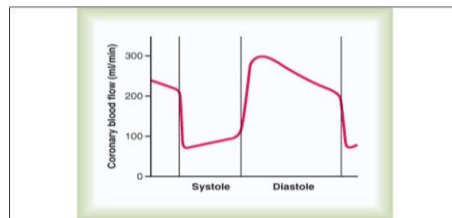
	Pressure (mmHg) in			Pressure difference (mmHg) between aorta &	
	Aorta	Lt Ventricle	Rt Ventricle	Lt Ventricle	Rt Ventricle
Systole	120	120	25	0	95
Diastole	80	0-2	0-2	80	80

- ◆ 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.

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## 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.




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- 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.

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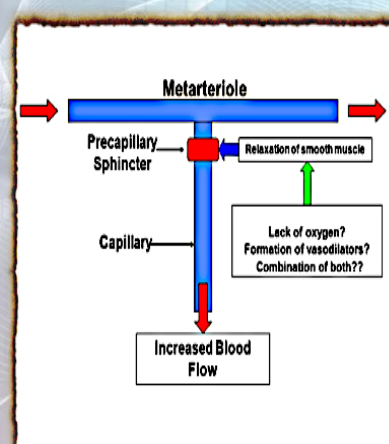




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## Chemical Factors Affecting Coronary Blood Flow

- ❑ **Chemical factors causing Coronary vasodilatation (Increased coronary blood flow):**
  - Lack of **oxygen**.
  - High conc. of **CO<sub>2</sub>**.
  - High conc. of **NO**.
  - High local conc. of **H<sup>+</sup>** ion.
  - High local conc. of **K<sup>+</sup>** ion.
  - High local conc. of **Lactate, Prostaglandin, Adenosine, Adenine nucleotides**.
- ❑ **Note:** An increase in Ca<sup>+2</sup> conc. does not increase the CBF.



The diagram illustrates a horizontal **Metarteriole** with red arrows indicating flow direction. A vertical branch leads to a **Capillary**. A **Precapillary Sphincter** is located at the junction. A box labeled **Relaxation of smooth muscle** has a blue arrow pointing to the sphincter. Below this, a box asks **Lack of oxygen? Formation of vasodilators? Combination of both??** with a green arrow pointing up to the relaxation box. A final box at the bottom indicates **Increased Blood Flow** exiting the capillary.

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## Neural Factors Affecting Coronary Blood Flow

- ❑ **Sympathetic stimulation.**
- ❑ **Parasympathetic stimulation.**

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## 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 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-adrenalin** after **blocking of the Beta adrenergic receptors** in an anesthetized animals elicits **coronary vasoconstriction**.

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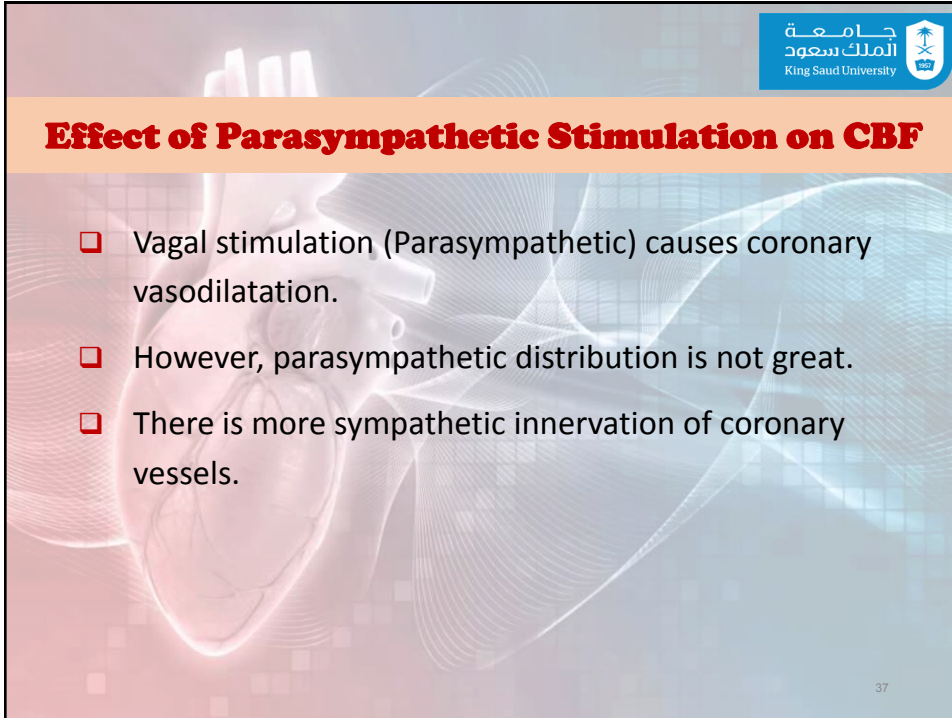


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## Benefits of indirect effect of nor-adrenergic discharge

- ❑ 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.

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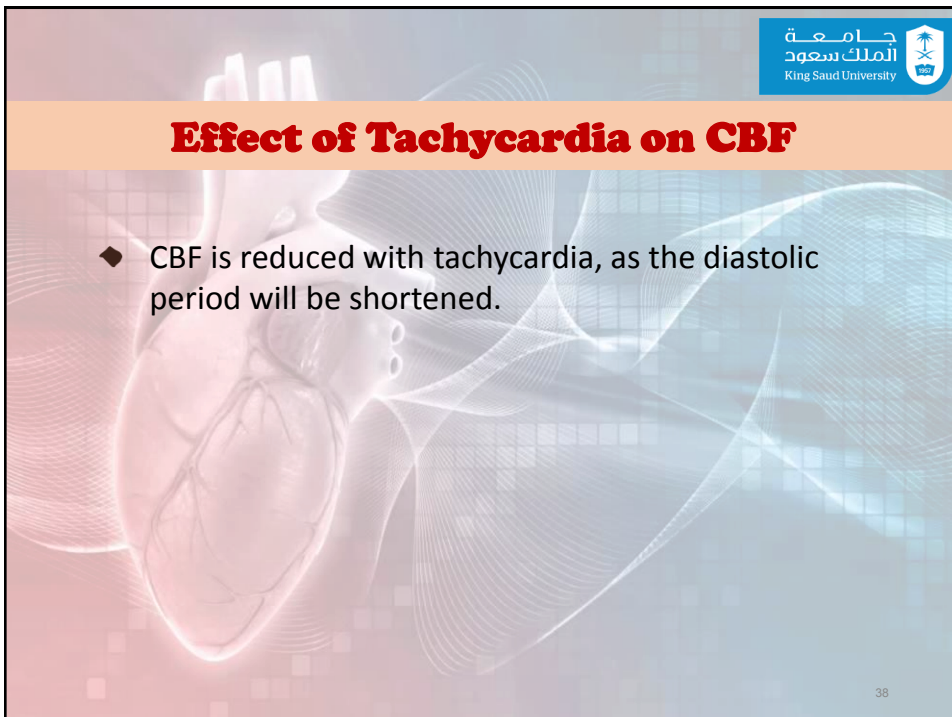


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## Effect of Parasympathetic Stimulation on CBF

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

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## Effect of Tachycardia on CBF

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

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## 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.

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