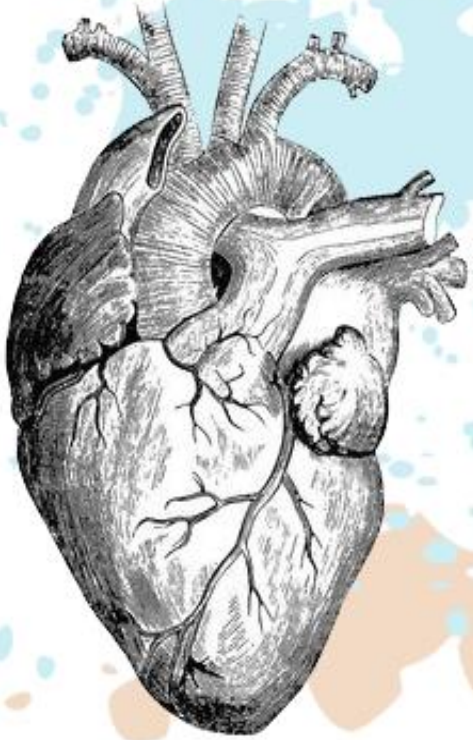


Very important

Extra information

Physiology

OF THE CARDIOVASCULAR SYSTEM

* Guyton corners, anything that is colored with grey is EXTRA explanation

Coronary Circulation

Objectives :

- Define autoregulation and its mechanism (metabolic & myogenic).
- Identify the vasodilator metabolites.
- List vasodilator and vasoconstrictor agents and those secreted by the endothelium.
- Identify vessels supplying the heart (coronaries).
- Understand and list factors affecting coronary blood flow (cardiac cycle, autoregulation, chemical factors & neural factors.

*** We recommend studying anatomy lecture (Blood supply of the heart) first.**

Contact us : Physiology435@gmail.com

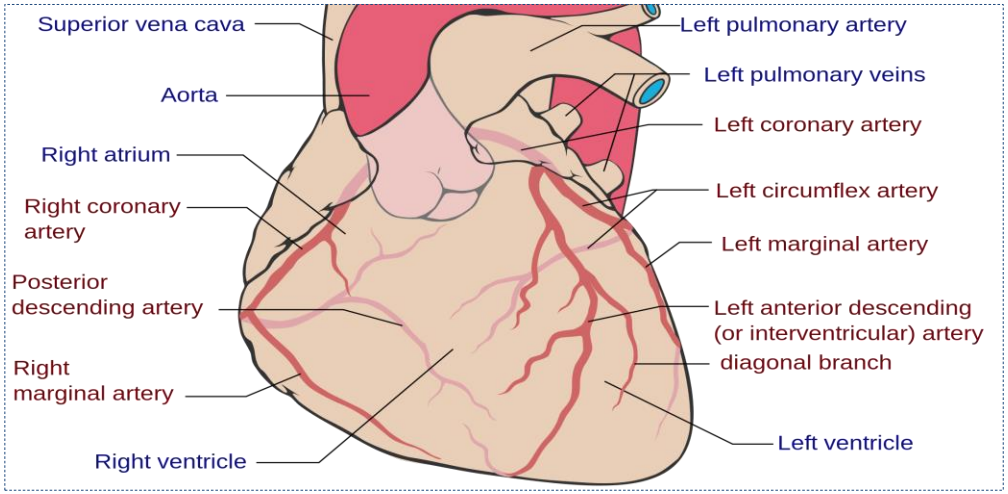
Coronary Circulation

It is important ! Why?

One third of all deaths in the world result from coronary artery disease.
Also it's most likely to be seen in elderly patients.

Consists of :

1. Arterial supply. *(supply of O_2 to the cardiac muscle.)*
2. Venous drainage. *(removal of wastes and CO_2)*
3. Lymphatic drainage. *(wastes removal)*



- Anterior descending > left side of the heart
- Posterior descending > right side of the heart

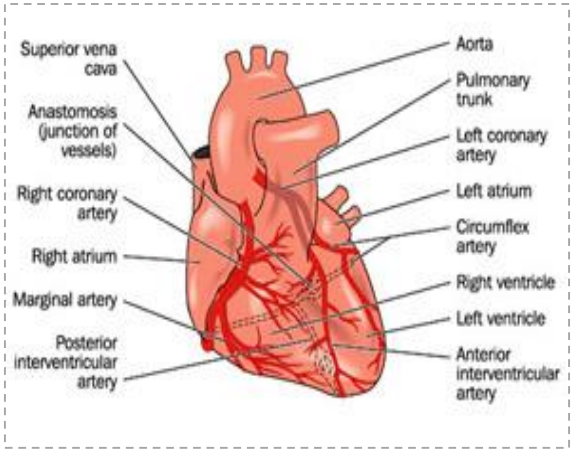
1-Arterial Supply

Cardiac muscle is supplied by two coronary arteries:

A. Right coronary artery (RCA.)
B. Left coronary artery (LCA.)

**both arise from the coronary sinuses just superior to the aortic valve cusps at the aortic root.*

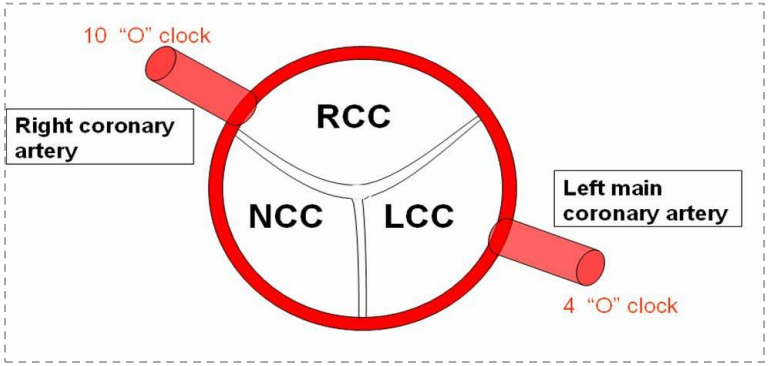
- Coronary arteries deliver oxygenated blood to the cardiac muscle.



The aortic valve has three cusps:

A. left coronary (LC) cusp.
B. Right coronary (RC) cusp.
C. Posterior non-coronary (NC) 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.



Right coronary cusp gives rise to right coronary artery.
Left coronary cusp gives rise to left coronary artery.

1-Arterial Supply- EXTRA

Guyton corner : **Figure 21-3** shows the heart and its coronary blood supply. Note that the main coronary arteries lie on the surface of the heart and smaller arteries then penetrate from the surface into the cardiac muscle mass. It is almost entirely through these arteries that the heart receives its nutritive blood supply. Only the inner 1/10 millimeter of the endocardial surface can obtain significant nutrition directly from the blood inside the cardiac chambers, so this source of muscle nutrition is minuscule.
The *left coronary artery* supplies mainly the anterior and left lateral portions of the left ventricle, whereas the *right coronary artery* supplies most of the right ventricle, as well as the posterior part of the left ventricle in 80 to 90 percent of people.
Most of the coronary venous blood flow from the left ventricular muscle returns to the right atrium of the heart by way of the *coronary sinus*, which is about 75 percent of the total coronary blood flow. On the other hand, most of the coronary venous blood from the right ventricular muscle returns through small *anterior cardiac veins* that flow directly into the right atrium, not by way of the coronary sinus. A very small amount of coronary venous blood also flows back into the heart through very minute *thebesian veins*, which empty directly into all chambers of the heart. *Page 262*

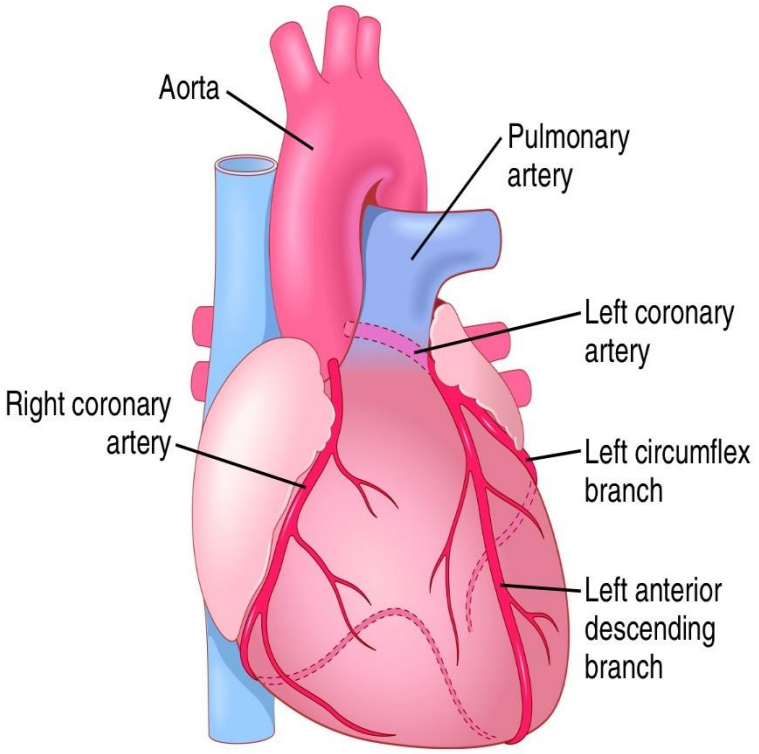
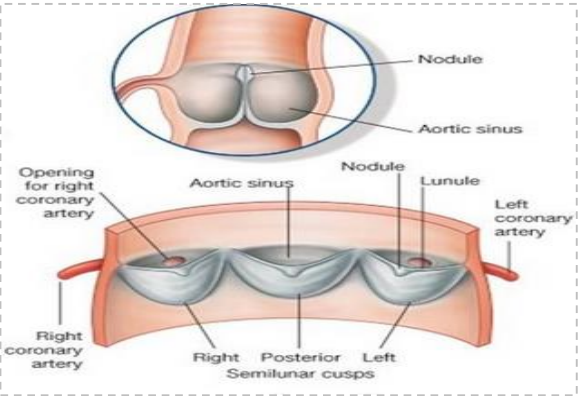


Figure 21-3. The coronary arteries.

Coronary arteries

	Left coronary artery (LCA)	Right coronary artery (RCA)
Size	larger	smaller
origin*	**Left posterior aortic sinus**	**Anterior aortic sinus**
Termination	By anastomosing with the right coronary artery	By anastomosing with the left coronary artery
Branches	• Left Anterior Descending (LAD) (= Anterior interventricular) • Marginal artery • Circumflex artery (CX)	• Posterior Descending Branch (= posterior interventricular) • Marginal artery

*Regarding the origin of coronary arteries, we are not quite sure about the points written in this physiology lecture "not mentioned in Guyton" So, we prefer you cover this from anatomy (read more from the box below).

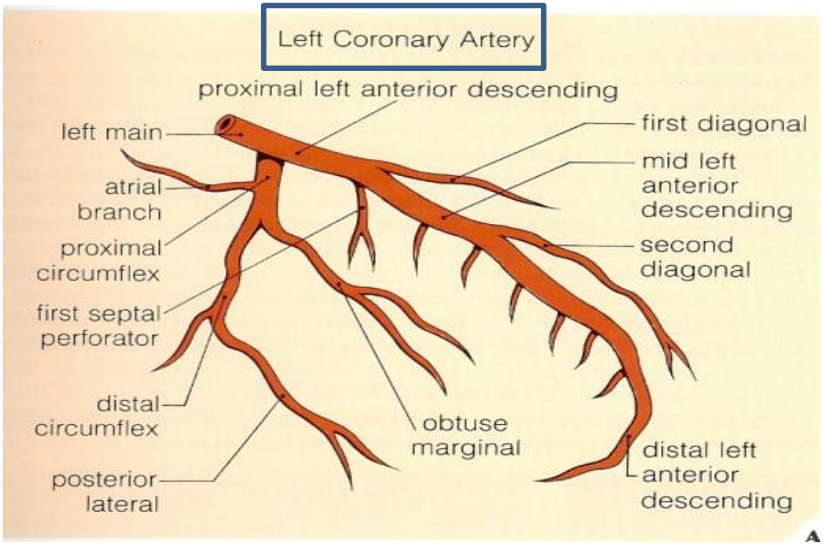


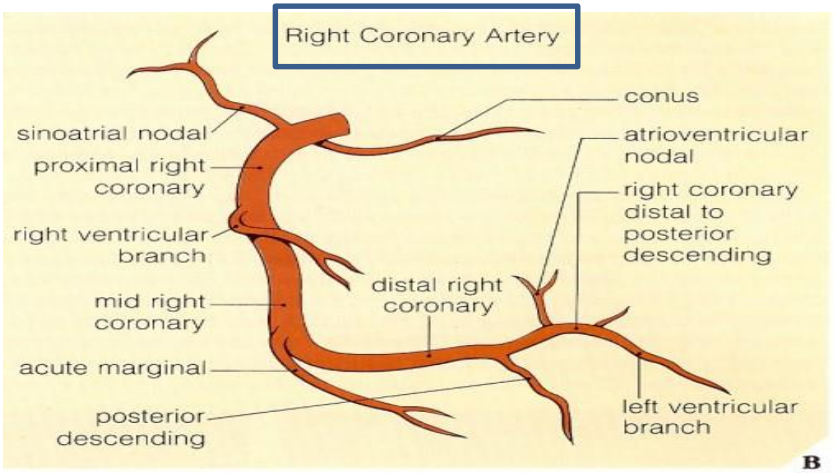
- **SNELL Corner :**

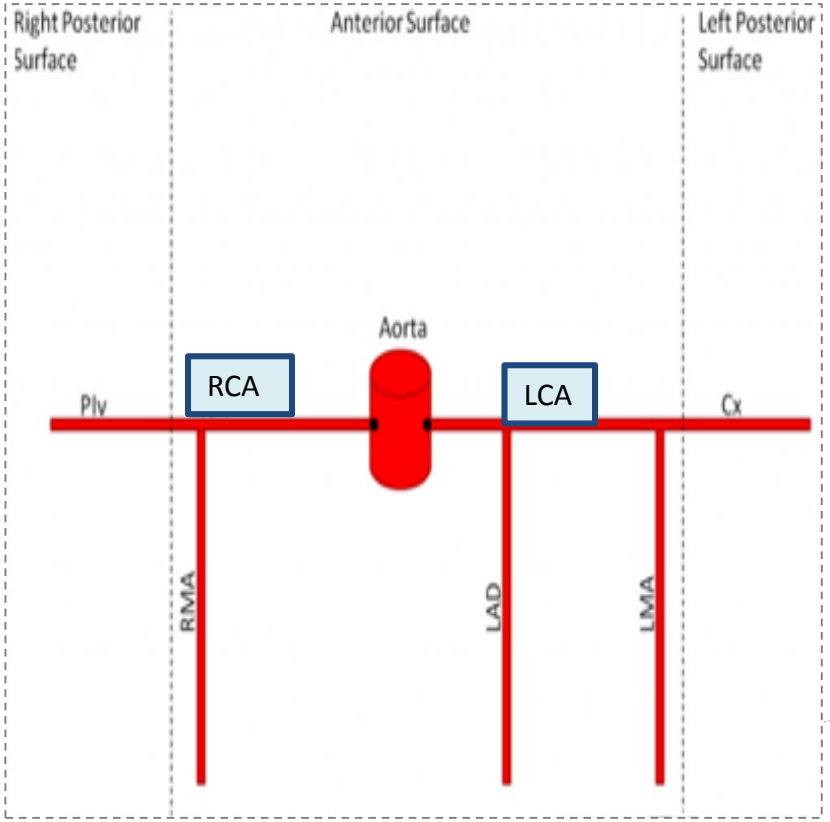
The **aortic valve** guards the aortic orifice and is precisely similar in structure to the pulmonary valve. One cusp is situated on the anterior wall (right cusp), and two cusps are located on the posterior wall (left and posterior cusps). Behind each cusp, the aortic wall bulges to form an aortic sinus. The anterior aortic sinus gives origin to the right coronary artery, and the left posterior sinus gives origin to the left coronary artery.

"Page 143 from Clinical Anatomy By Systems by Richard S. SNELL"

Coronary arteries







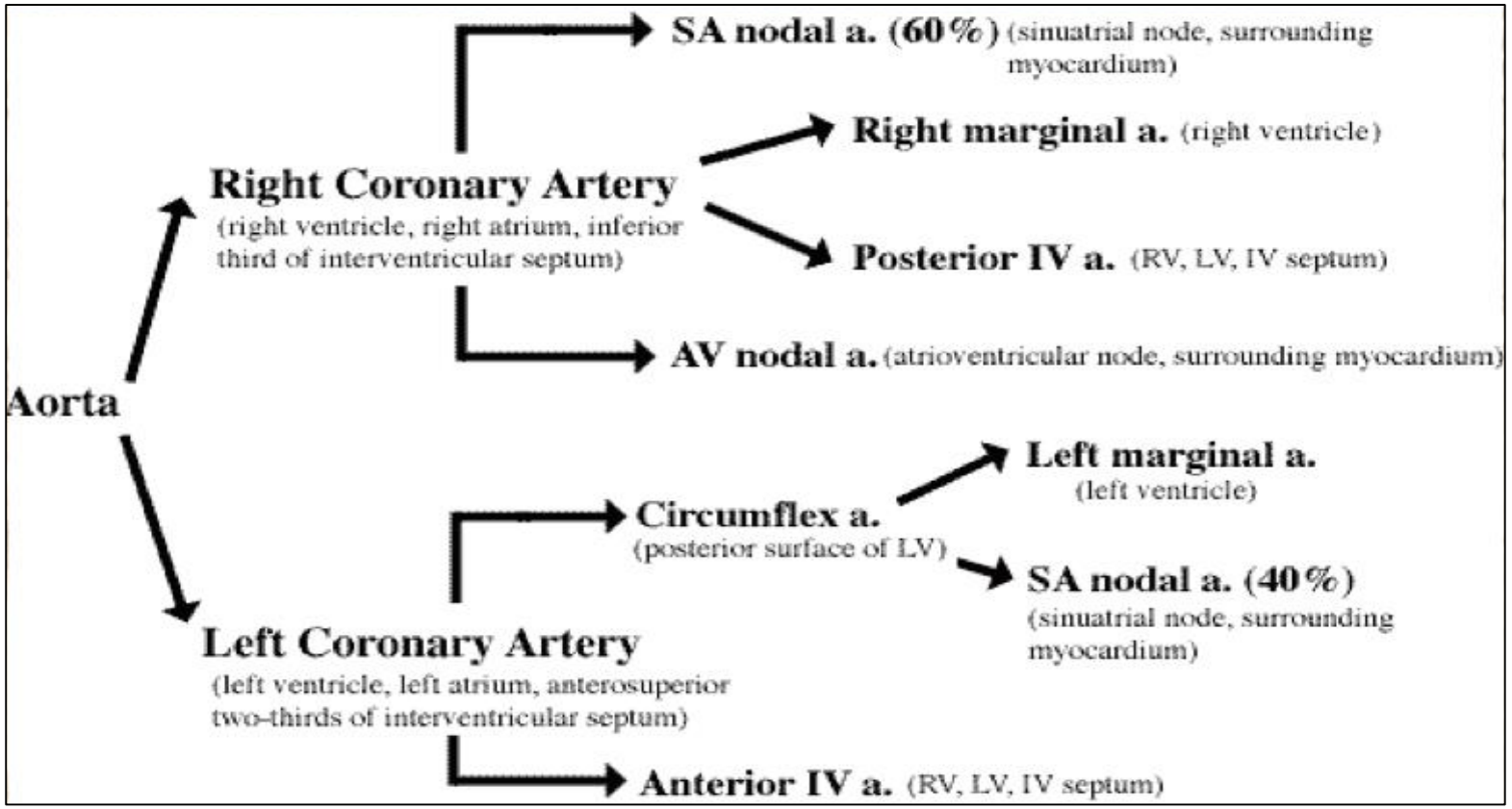
Left coronary artery branches :

1) Left anterior ascending "LAD"
2) Left marginal artery "LMA"
3) Circumflex artery "CX"

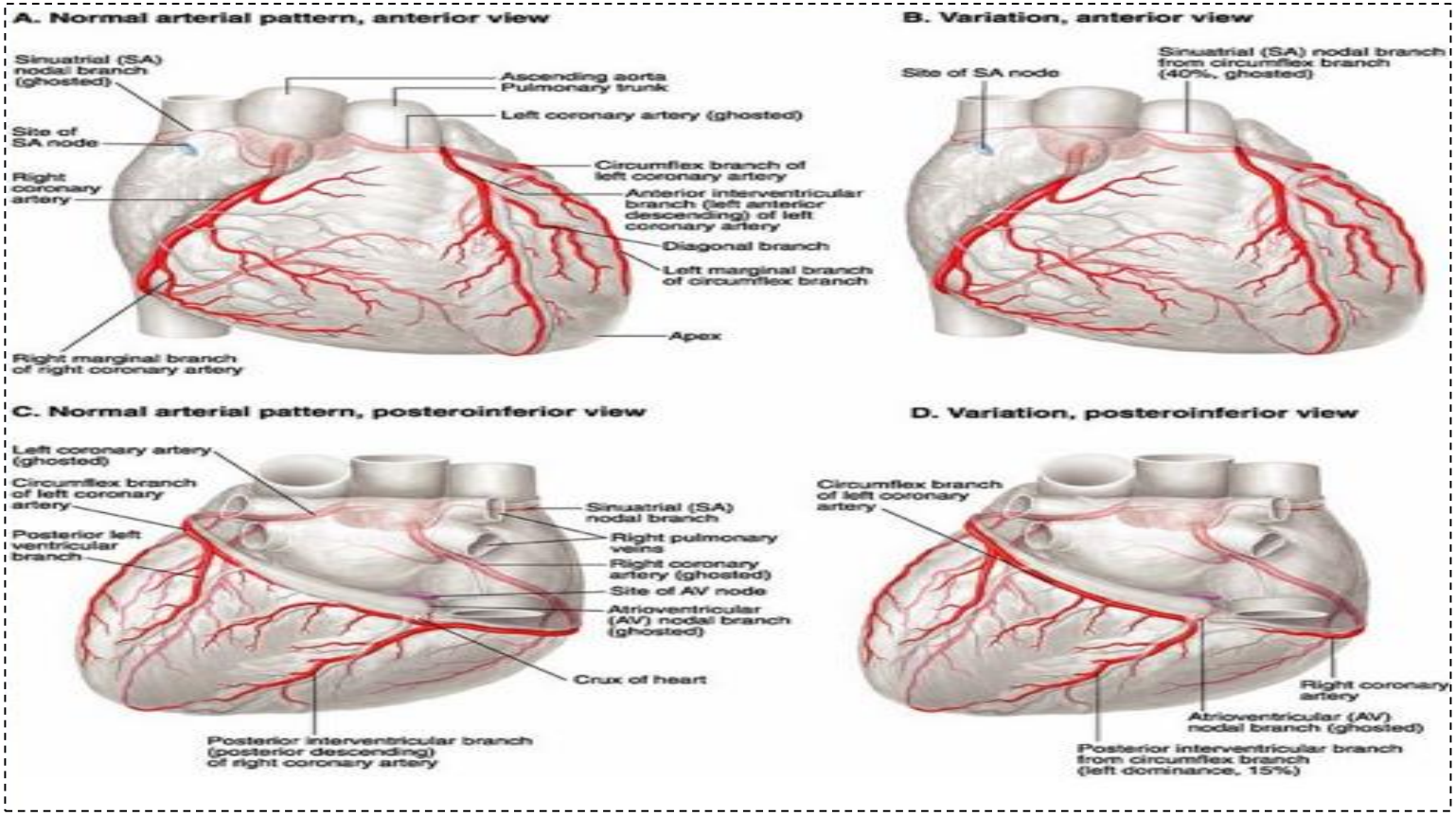
Right coronary artery branches :

1) Right marginal artery "RMA"
2) Posterior descending artery (posterior interventricular artery) "PIv"

Summary - Branches of the coronary arteries



variations



Variations in coronary anatomy are often seen in association with structural forms of congenital heart disease like Fallot's tetralogy, transposition of the great vessels, Taussig-Bing heart (double-outlet right ventricle), or common arterial trunk. Importantly, coronary artery anomalies are a cause of sudden death in young athletes even in the absence of additional heart abnormalitiesPrior knowledge of such variants and anomalies is necessary for planning various interventional procedures

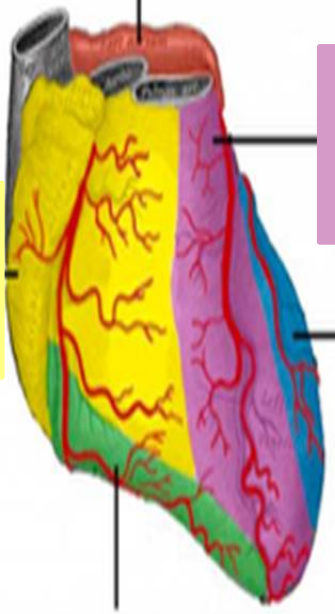
Areas of Distribution of Coronary Arteries

Left Circumflex Artery
Supplies the left atrium and left ventricles

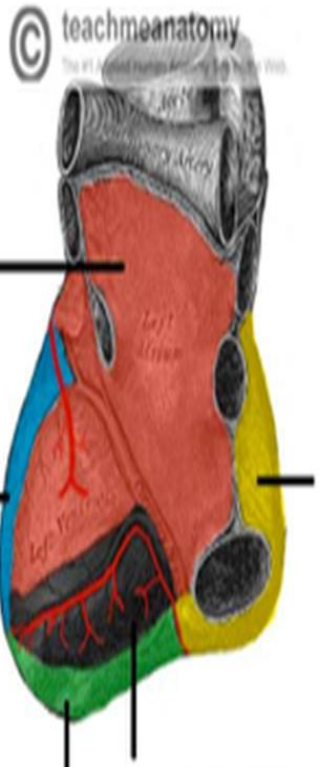
Left Anterior Descending Artery
Supplies the right ventricles ,left ventricles and interventricular septum

Right Coronary Artery
Supplies the right atrium and right ventricles

Left Marginal Artery
Supplies left ventricles



Right Marginal Artery
Supplies the right ventricles and the apex



Left Circumflex Artery
Supplies the left atrium and left ventricles

Left Marginal Artery
Supplies left ventricles

Right Coronary Artery
Supplies the right atrium and right ventricles

Right Marginal Artery
Supplies the right ventricles and the apex

Posterior Interventricular Artery
Supplies the right and left ventricles and interventricular septum

Areas of Distribution of LCA & RCA

Areas of distribution of Left Coronary Artery	Areas of distribution of Right Coronary Artery
• **Left Coronary Artery (LCA) supplies:** - Anterior & apical parts of the heart. - Anterior 2/3rd of the inter ventricular (IV) septum. • **Circumflex (CX) branch supplies:** - Lateral & posterior surfaces of the heart.	• **Right atrium.** • **Ventricles:** - Greater part of Right ventricle, except the area adjoining the anterior inter ventricular groove. - Inferior part of Lt ventricle adjoining the posterior inter ventricular groove • **posterior 1/3rd of the inter ventricular septum.** • **The conducting system of the heart, except :** - A part of the Lt branch of AV- Bundle. - The SA- node is supplied by the LCA in 40% of cases.

Collateral Circulation

- **Cardiac Anastomosis:**

  The two coronary arteries anastomose in the myocardium

- **Extra cardiac anastomosis:**

  the two coronary arteries anastomose with:

1. Vasa vasorum of the aorta.
2. Vasa vasorum of pulmonary arteries.
3. Internal thoracic arteries.
4. The bronchial arteries.
5. Phrenic arteries

- **Extra cardiac channels open up in emergencies when the coronary arteries are blocked.**

- Collateral circulation = anastomosis
- What's the benefit of the extra anastomosis?

It just open in emergency, when the coronary arteries have poor supply of the O2 and we need more O2 it'll open

- It's found originally in the heart, but it won't be activated unless there's emergency

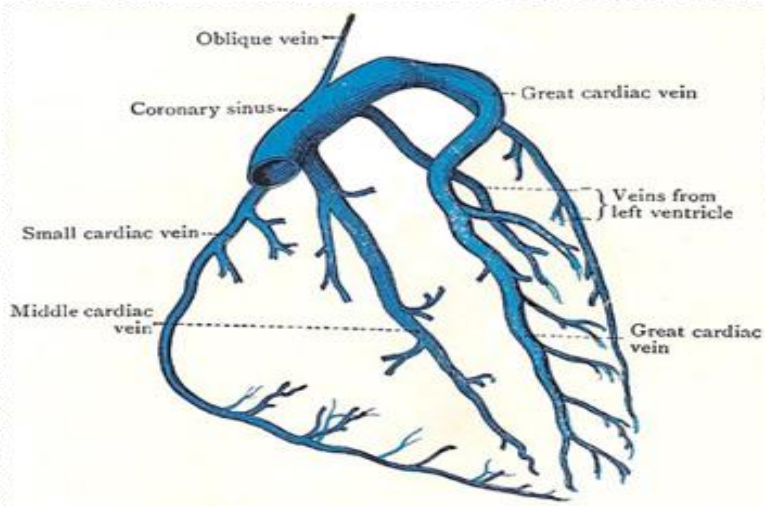
2-Venous Drainage of The Heart

- Venous drainage brings deoxygenated cardiac blood back to 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, middle & small cardiac veins.
  - Venae Cordis Minimae (smallest cardiac veins.)

- 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.



3-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 Dominance

Coronary dominance depends on which artery (or arteries) gives rise to the posterior descending artery (PDA), which runs along the posterior side of the heart & supplies the AV- node.

A person can be:

- Right dominant
- Co-dominant
- Left dominant

Clinical importance

In right or balances dominance, a block in right coronary artery at least spares part (2/3) of the septum & left ventricle.

In left dominance, a block in left coronary artery affect the entire Lt ventricle & IV septum.

Guyton corner : P 246, 12TH edition

The left coronary artery supplies mainly the anterior and left lateral portions of the left ventricle, whereas the right coronary artery supplies most of the right ventricle, as well as the posterior part of the left ventricle in 80 to 90 percent of people.

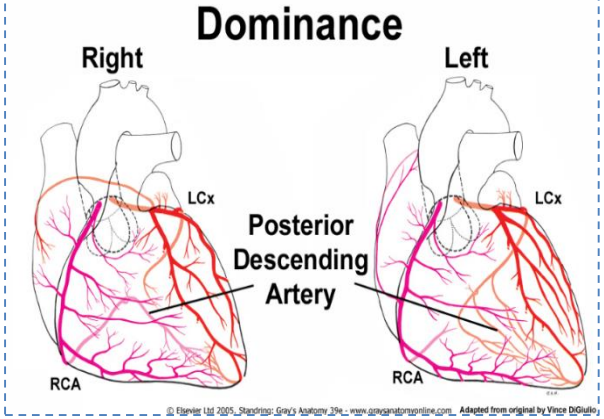
Coronary Dominance

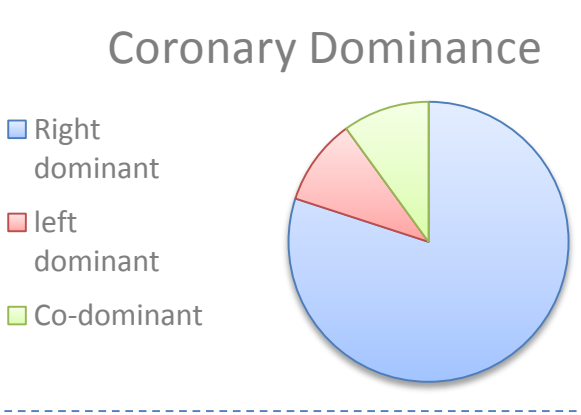
- Coronary Dominance is recognized by the presence of septal perforating branches arise from:

The right coronary artery is dominant, in 80–85% cases.

Balanced or co-dominance is found in 7-10% of population where the posterior inter ventricular artery is formed by both right coronary & circumflex branch of the left coronary arteries.

The circumflex branch of the left coronary artery, in 8-10% cases.





Coronary Blood Flow (CBF)

At rest

- CBF is about 225-250 mL/min (5% of cardiac output.)
- Heart extracts 60-70% of O_2, due to presence of more mitochondria which generate energy for contraction by aerobic metabolism (other tissue extract only 25%.)

CBF increases during exercise or work output.

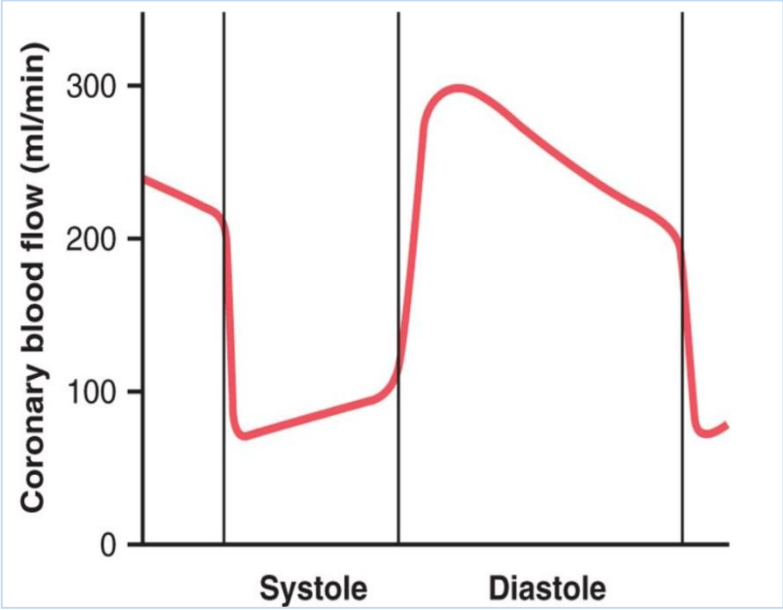
- **Guyton corner :**

During strenuous exercise, the heart in the young adult increases its cardiac output fourfold to sevenfold, and it pumps this blood against a higher than normal arterial pressure. Consequently, the work output of the heart under severe conditions may increase sixfold to ninefold. At the same time, the coronary blood flow increases threefold to fourfold to supply the extra nutrients needed by the heart. This increase is not as much as the increase in workload, which means that the ratio of energy expenditure by the heart to coronary blood flow increases. Thus, the "efficiency" of cardiac utilization of energy increases to make up for the relative deficiency of coronary blood supply.

Phasic changes in CBF during systole & diastole

During Systole

- Coronary arteries are compressed.
- Blood flow to the left ventricle is reduced.



During Diastole

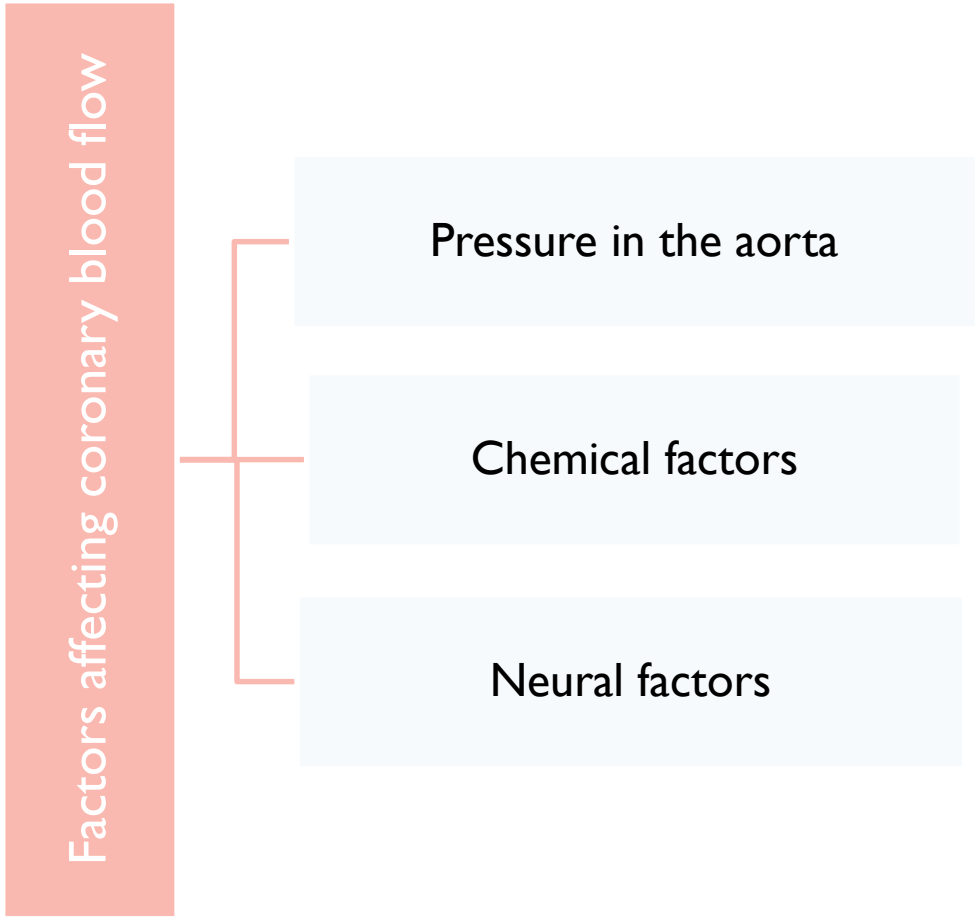
Blood flows to the subendocardial portion of the left ventricle occurs only during diastole, and is not there during systole. Therefore, this region (subendocardial) is prone to ischemic damage & it is the most common site of myocardial infarction.

Notes:

- Less flow of blood in the systole, and more in the diastole.
- The blood reaches the subendocardial portion only during diastole.

Guyton corner: Figure shows the changes in blood flow through the nutrient capillaries of the left ventricular coronary system in ml/min in the human heart during systole and diastole, as extrapolated from studies in experimental animals. Note from this diagram that the coronary capillary blood flow in the left ventricle muscle falls to a low value during systole, which is opposite to flow in vascular beds elsewhere in the body. The reason for this is strong compression of the left ventricular muscle around the intramuscular vessels during systolic contraction.
During diastole, the cardiac muscle relaxes and no longer obstructs blood flow through the left ventricular muscle capillaries, so blood flows rapidly during all of diastole.

Factors Affecting CBF



Effect of Pressure Gradient of Aorta & Different Chambers of the Heart

		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

- CBF to the right side is <u>not much affected</u> during systole.
- Pressure difference between the aorta & right ventricle is **greater** during systole than during diastole, therefore, more blood flow to right ventricles occurs during systole.

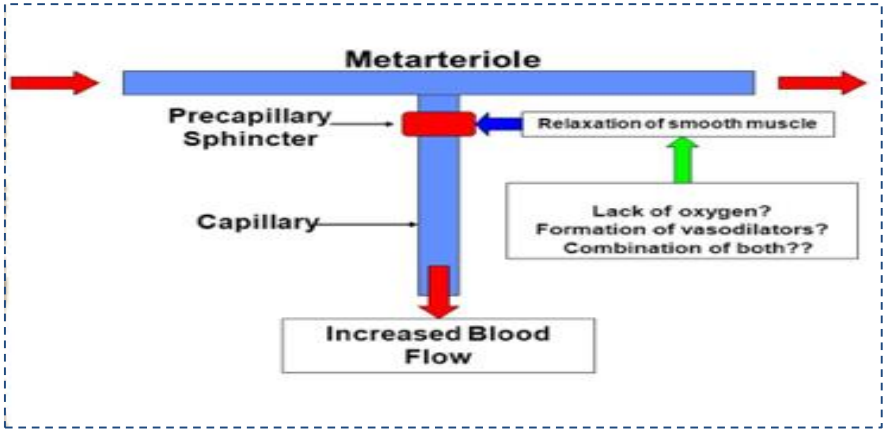
Factors Affecting Coronary Blood Flow

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

- Lack of oxygen.
- Increased local concentration of Co2.
- Increased local concentration of H+ ion.
- Increased local concentration of k + ion.
- Increased local concentration of Lactate, Prostaglandin, Adenosine, Adenine nucleotides.

Neural Factors Affecting Coronary Blood Flow:

- Sympathetic stimulation.
- Parasympathetic stimulation.



Effect of Sympathetic Stimulation on Coronary Blood Flow

Coronary arteries have:

- Alpha Adrenergic receptors, which mediate vasoconstriction (Epicardial.)
- Beta Adrenergic receptors, which mediate vasodilatation (Intramuscular.)

Sympathetic stimulation can either be Indirect or Direct.

Indirect effect of sympathetic stimulation:

Sympathetic stimulation in intact body will lead to release of adrenaline & nor adrenaline, which in turn increase heart rate & force of contraction.
Vasodilator metabolites will be released leading to coronary vasodilatation.

Direct effect of sympathetic stimulation:

Experimentally, injection of noradrenalin after blocking of the Beta adrenergic receptors in un anesthetized animals elicits coronary vasoconstriction.

Benefits of the indirect effect of Nor adrenergic discharge

What are the benefits of the indirect effect of Nor adrenergic discharge?

- The answer is : to preserve circulation of the heart while the flow to other organs is compromised.

When systemic blood pressure gets low.

As a Reflex nor adrenergic discharge will increase.

Coronary Blood Flow will increase secondary to metabolic changes in the myocardium.

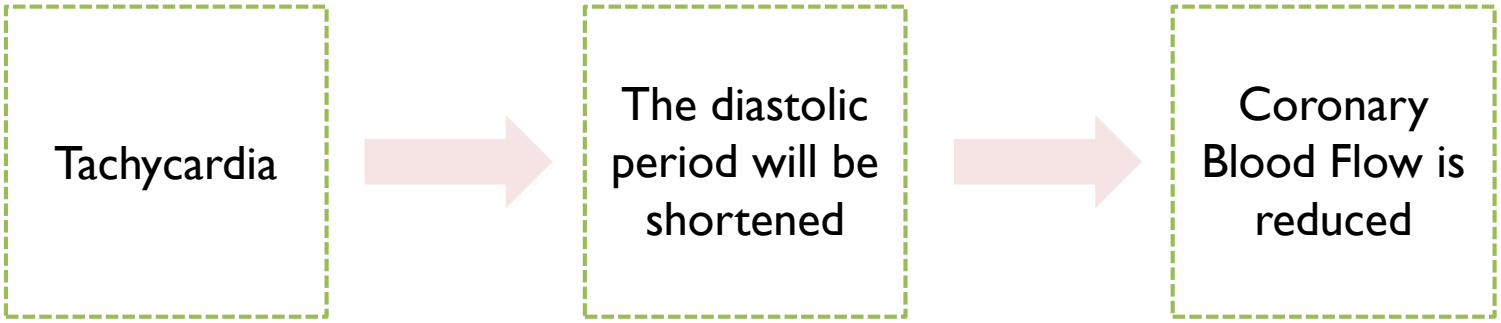
PHYSIOLOGY TEAM 435

Effect of Parasympathetic Stimulation on Coronary Blood Flow

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

Coronary Blood Flow

Effect of Tachycardia on Coronary Blood Flow



Control of Coronary Blood Flow

- Coronary Blood Flow shows considerable auto regulation.

- **Local muscle metabolism is the primary controller:**

1. Oxygen demand is a major factor in local coronary blood flow regulation.

- **Nervous control of Coronary Blood Flow:**

1. Direct effects of nervous stimuli on the coronary vasculature.
2. Sympathetic greater effects than parasympathetic.

- **Guyton corner :**

Nervous Control of Coronary Blood Flow

Stimulation of the autonomic nerves to the heart can affect coronary blood flow both directly and indirectly. The direct effects result from action of the nervous transmitter substances acetylcholine from the vagus nerves and norepinephrine from the sympathetic nerves on the coronary vessels. The indirect effects result from secondary changes in coronary blood flow caused by increased or decreased activity of the heart.

The indirect effects, which are mostly opposite to the direct effects, play a far more important role in normal control of coronary blood flow. Thus, sympathetic stimulation, which releases norepinephrine from the sympathetic nerves and epinephrine as well as norepinephrine from the adrenal medullae, increases both heart rate and heart contractility and increases the rate of metabolism of the heart. In turn, the increased metabolism of the heart sets off local blood flow regulatory mechanisms for dilating the coronary vessels, and the blood flow increases approximately in proportion to the metabolic needs of the heart muscle. In contrast, vagal stimulation, with its release of acetylcholine, slows the heart and has a slight depressive effect on heart contractility. These effects decrease cardiac oxygen consumption and, therefore, indirectly constrict the coronary arteries

Direct Effects of Nervous Stimuli on the Coronary Vasculature.

The distribution of parasympathetic (vagal) nerve fibers to the ventricular coronary system is not very great. However, the acetylcholine released by parasympathetic stimulation has a direct effect to dilate the coronary arteries.

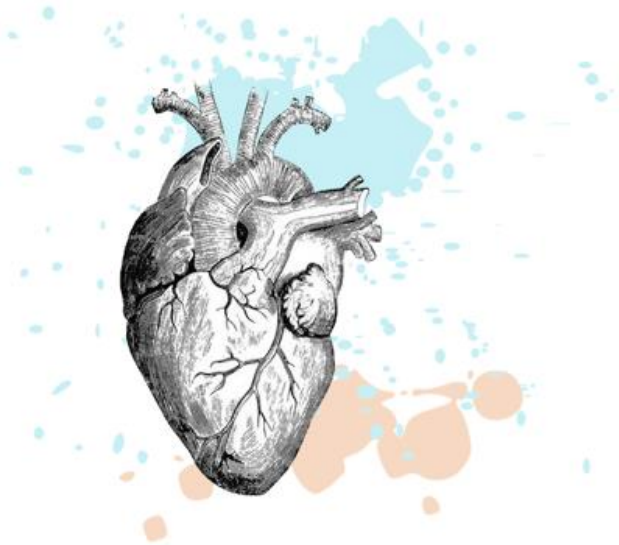
Much more extensive sympathetic innervation of the coronary vessels occurs. In Chapter 61, we see that the sympathetic transmitter substances norepinephrine and epinephrine can have either vascular constrictor or vascular dilator effects, depending on the presence or absence of constrictor or dilator receptors in the blood vessel walls. The constrictor receptors are called *alpha receptors* and the dilator receptors are called *beta receptors.* Both alpha and beta receptors exist in the coronary vessels. In general, the epicardial coronary vessels have a preponderance of alpha receptors, whereas the intramuscular arteries may have a preponderance of beta receptors. Therefore, sympathetic stimulation can, at least theoretically, cause slight overall coronary constriction or dilation, but usually constriction. In some people, the alpha vasoconstrictor effects seem to be disproportionately severe, and these people can have vasospastic myocardial ischemia during periods of excess sympathetic drive, often with resultant anginal pain.

Metabolic factors, especially myocardial oxygen consumption, are the major controllers of myocardial blood flow. Whenever the direct effects of nervous stimulation reduce coronary blood flow, the metabolic control of coronary flow usually overrides the direct coronary nervous effects within seconds.

Physiology
OF THE CARDIOVASCULAR SYSTEM

Physiology Leaders :

Khawla Alammari
Nojood Alhaidri
Rawaf Alrawaf



Girls team :

- Atheer Alnashwan
- Asrar Batarfi
- Afnan Almalki
- Alhanouf Aljlaoud
- Deema AlFaris
- Elham Alzahrani
- Johara Almalki
- Lojain alsiwat
- Malak Alsharif
- Monirah Alsalouli
- Nora AlRomaih
- Nurah Alqahtani
- Nouf Alabdulkarim
- Nora Albusayes
- Nora Alsomali
- Norah Alakeel
- Reem Alageel
- Rawan Aldhuwayhi
- Reham Al-Obaidan
- Samar AlOtaibi
- Shamma Alsaad

Boys team :

- Abdullah Aljaafar
- Omar Alotaibi
- Abdulrahman Albarakah
- Adel Alshehri
- Abdulaziz Alghanaym
- Abdulmajeed Alotaibi
- Khalil Alduraibi
- Hassan Albeladi
- Omar Alshehri
- Saleh Alshawi
- Abdulaziz Alhammad
- Faisal Alabdulatif
- Abdulnasser Alwabel
- Saad Almutairy