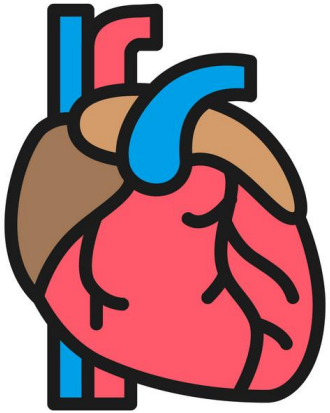


Coronary circulation

MED441
KING SAUD UNIVERSITY

Color Index:

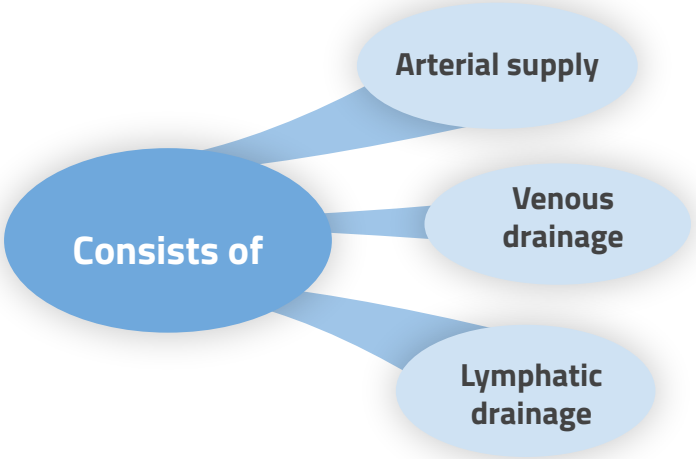
- Main text
- Important
- Girls Slides
- Boys Slides
- Notes
- Extra

Objectives

- Normal coronary blood flow.
- Facts about Coronary blood flow.
- Coronary blood flow in systole and diastole.
- Discuss the regulation of coronary blood flow.
- Explain and differentiate between angina and myocardial infarction.
- Coronary circulation & areas of supply.
- Coronary collateral circulation.
- Coronary dominance.
- Coronary blood flow & factors affecting it.
- Control of coronary blood flow.

Coronary circulation

It’s the circulation of blood in the blood vessels that supply the heart muscle (myocardium)



- **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.

Importance of coronary circulation

One third of all deaths in the world result from coronary artery disease

Almost all elderly people have at least some impairment of the coronary artery circulation

Heart uses primarily **free fatty acids** and to lesser extent glucose and lactate for metabolism

Two third of coronary blood flow occurs during diastole

70% of oxygen is extracted by the myocardial tissue of the heart, while rest of the body extract 25%

Coronary sinus and arteries

Arterial supply:

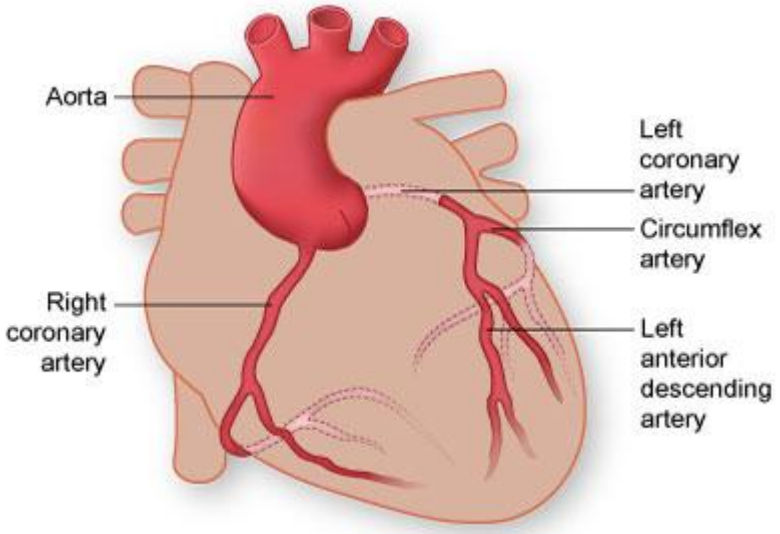
Cardiac muscle is supplied by two coronary arteries:

- Left coronary artery (LCA)
- Right coronary artery (RCA)

Both arise from the coronary sinus 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 arteries deliver **oxygenated** blood to the cardiac muscle.



Coronary sinus and arteries

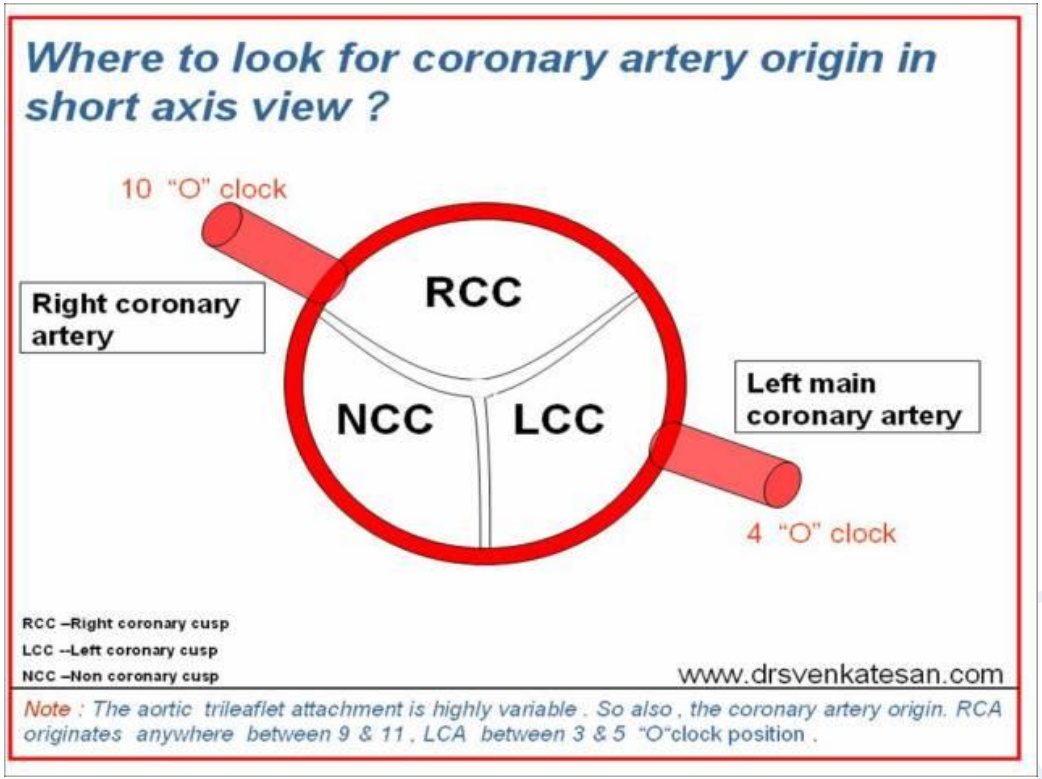
Coronary sinus:

Aortic valve has three cusps:

- Left coronary cusp (LCC)
- Right coronary cusp (RCC)
- Posterior non-coronary cusp (NCC)

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**.



Right coronary artery (RCA)

- 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.

Main Branches of right coronary artery:

Right posterior descending artery (RPD): Also called posterior interventricular artery.

Right acute marginal artery (AM).

Left coronary artery (LCA)

- 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).

Main Branches of left coronary artery:

Left anterior descending artery (LAD):

Also called anterior interventricular artery.

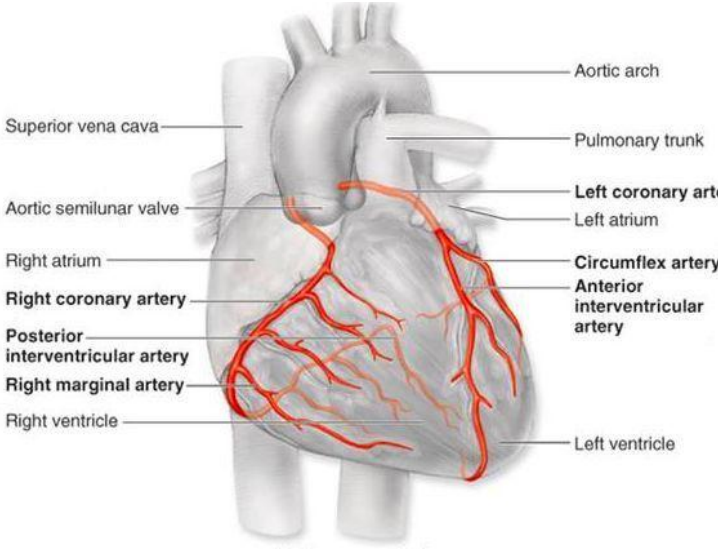
Circumflex artery (CX).

Right posterior descending artery (RPD)

- Also called posterior interventricular artery.
- 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.

Smaller branches:

1- Atrial branch: gives off SA nodal artery, which supplies the SA- node in 60%(~50-73%) of hearts & the surrounding myocardium.
2- Right conus arteriosus artery.
3- Right anterior ventricular artery.
4- Septal perforator (SP) artery.



Right acute marginal artery (AM)

- Also called anterior interventricular artery.
- Runs down the right margin of the heart.
- Supplies blood to the right margin of the right ventricle with minimal supply to the apex.

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):

1. The anterolateral of the left ventricle.
2. The apex of the heart.
3. The anterior 2/3 of the interventricular (IV) septum.
4. The front of the right ventricle.
5. The right & left bundle branches.

Further divides into:

- Diagonal arteries.
- Left conus arteriosus artery.
- Septal perforator (SP) artery.

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.

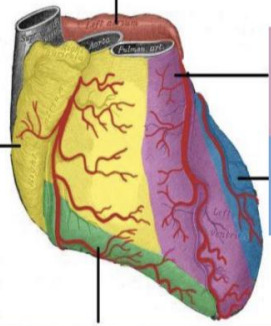
Front view

Left circumflex artery
Supplies the left atrium and left ventricle

Left anterior descending artery
Supplies the right ventricle ,left ventricle and interventricular septum

Right Coronary artery
Supplies the right atrium and right ventricles

Left marginal artery
Supplies the left ventricle

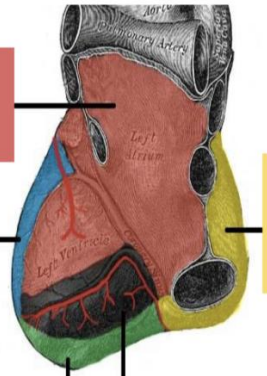


Right marginal artery
Supplies the right ventricle and apex

Back view

Left circumflex artery
Supplies the left atrium and left ventricle

Left marginal artery
Supplies the left ventricle



Right Coronary artery
Supplies the right atrium and right ventricles

Right marginal artery
Supplies the right ventricle and apex

Posterior interventricular artery
Supplies the right ventricle ,left ventricle and interventricular septum

1- Anastomosis:

Cardiac anastomosis: the two coronary arteries anastomose in the myocardium.

Extracardiac 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.

2- Collateral Circulations:

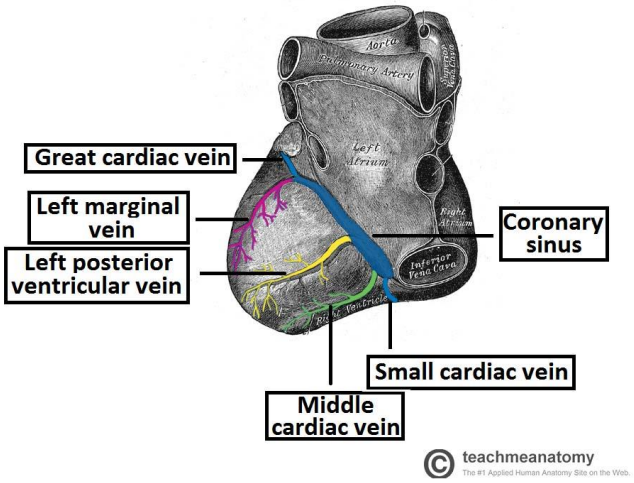
Definition: Collateral circulation is a network of extra-cardiac channels formed of tiny blood vessels.

Under normal conditions it is not open, **it opens only 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, and protecting the heart tissue from injury.

3- Venous Drainage Of The Heart:



Most of the venous blood returns 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.

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).

4- 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) supplies the AV node. -Usually, the right coronary artery is the dominant artery in 85-90% of hearts, as it supplies the AV- node.

There are three types

Left dominant (8-10)%

Right dominant (85-90)%

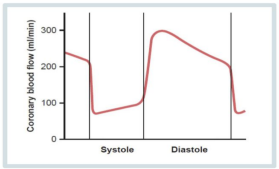
Co-dominant "Balanced" (7-10)%
where the posterior interventricular artery is formed by both right coronary & Left CX arteries.

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.

Blood flow to Heart during systole and diastole

In right ventricle	In left ventricle
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. The pressure gradient between aorta & 2 ventricles affects the CBF (fluids move from higher to lower) 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.	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. 

Pressure gradient between Aorta and heart chambers affect CBF

	Pressure (mmHg) in			Pressure difference (mmHg) between Aorta	
	Aorta	**Lt Ven**	**Rt Ven**	**Lt Ven**	**Rt Ven**
Systole	120	120	25	0	95
Diastole	80	0-2	0-2	80	80

Changing in CBF during systole and diastole

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

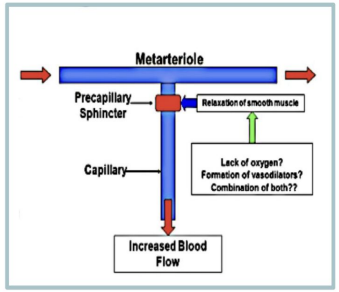
Coronary blood flow

- Coronary blood flow (CBF) at rest in human is about 225-250 ml/min , about 5% of cardiac output.
- CBF increases in proportion to exercise or work output
- At rest, the heart extract 60-70% of oxygen from each unit of blood delivered to the heart due to presence of more mitochondria which generates energy for contraction by aerobic metabolism (other tissues (rest of the body) extract only 25% of Oxygen)

Factors affecting coronary blood flow

Metabolic control

(chemical factors)



Pressure in the aorta

Chemical factors

Neural factors

Regulation of coronary blood flow

1. Metabolic control
2. Auto regulation
3. Endothelial vascular tone
4. Extravascular compressive force
5. Neural control

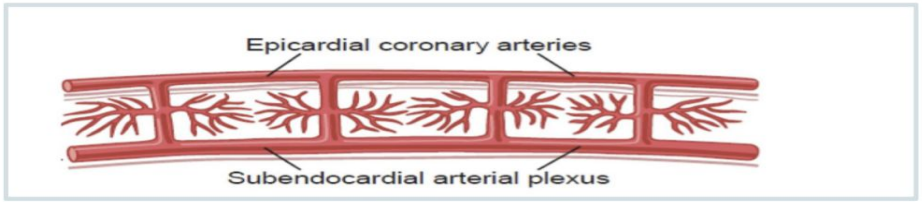
Coronary vascular resistance

We recommend that you see the picture and explanation first.

Explanation:

We have said earlier that during systole there is a decline in Coronary blood flow (increase in coronary vascular resistance), this is because of the compression on the intramyocardial arteries by cardiac muscles. But the epicardial conductance vessels are not surrounded by muscles (no compression during systole). Therefore the vessels which are responsible of Coronary vascular resistance are the intramyocardial vessels not the epicardial vessels.

Epicardial conductance vessels: Contribute only to a **small** percentage of coronary vascular resistance.
Intramyocardial vessels (arterioles): Contribute to **most** of the total coronary vascular resistance.
- Blood flows to the subendocardial portion of left ventricle only during diastole, therefore this portion of left ventricle is prone to ischemic changes & is the most common site of myocardial infarction.
- However, the extra vessels of the subendocardial plexus normally compensate for this reduction .



Cont.Regulation of Coronary blood flow

1 Metabolic control

Local muscle metabolism is the primary controller:

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

Coronary circulation is very sensitive to myocardial tissue oxygen tension.

Increased oxygen demand results in a lower tissue oxygen tension.

This causes vasodilation and increased coronary blood flow due to chemical factors like:

1- ↑NO. 2- ↑Prostaglandins. 3 -Lack of O2 , High conc. of CO2. 4-↑Adenine

5- ↑Adenosine. 6-↑Lactate 7-↑K+ and H+ 8-NOTE: ↑Ca it does not increase CBF

2 Auto regulation

- **Ability of a vascular network to maintain constant blood flow over a range of arterial pressures.**
- **CBF shows considerable auto regulation.**
- **Auto regulation is an independent determinant of coronary blood flow.**
- **The set point at which coronary blood flow is maintained depends on myocardial O2 consumption.**

Cont.Regulation of Coronary blood flow

Endothelial control of coronary Vascular tone control:

3

Damage to the endothelial which leads to:-

1. ↓NO and prostacyclin (vasodilators) production.

2. ↑ endothelin production, cell can lead to: Vasoconstriction, Vasospasm and Thrombosis

Extravascular compressive force:

4

Left ventricle

- **Earlier systole**: initial flow reversal.
- **Remainder of systole**: flow follows aortic pressure curve but at a much reduced pressure.
- **Earlier diastole**: Abrupt pressure rise (80-90 % of of LV flow in earlier diastole).
- **Remainder of diastole**: pressure decline slowly as aortic pressure decline

Right ventricle

- lower pressure generated by right ventricle in systole.
- No reversal blood flow during early systole.

- Systolic constitutes a much greater proportion of total blood flow

Cont.Regulation of Coronary blood flow

Neural control

Coronary arteries have:

1-Alpha Adrenergic receptors

which mediate vasoconstriction (more epicardial)

2-Beta Adrenergic receptors

which mediate vasodilation (more in the intramuscular arteries "B2 with resistance Arteries")

- **Neural control of the coronary circulation complements the above local effects**

-Activation of sympathetic nerves innervating the coronary vasculature causes only transient **vasoconstriction** mediated by α-adrenoreceptors, This brief (and small) vasoconstrictor response is followed by vasodilation caused by enhanced production of vasodilator metabolites (active hyperemia or Metabolic demand) due to increased mechanical and metabolic activity of the heart resulting from beta

-adrenoceptor activation of the myocardium Therefore, sympathetic activation to the heart results in coronary **vasodilation** and increased coronary flow due to increased metabolic activity (increased heart rate,contractility) despite direct vasoconstrictor effects of sympathetic activation on the coronaries. This is termed "functional sympatholysis".

-Direct effects of nervous stimuli on the coronary vasculature.

-Sympathetic greater effects than parasympathetic.

*coronary blood flow is reduced with tachycardia due to shortened diastolic period

Effect of Sympathetic Stimulation:

Direct

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

Indirect

Sympathetic stimulation in intact body will lead to release of **adrenaline & noradrenaline** , increasing HR & force of contraction. However, coronaries will vasodilate due to the release of vasodilator metabolites. (Example: Athletes) despite direct vasoconstrictor effects of sympathetic activation on the coronaries. This is termed "functional sympatholysis."

Benefits of indirect effect of more adrenergic discharge: when systemic BP 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.

Parasympathetic stimulation

Vagal stimulation (Parasympathetic) causes coronary vasodilatation. However, parasympathetic distribution is NOT great.

There is more sympathetic innervation of coronary vessels.

However, if parasympathetic activation of the heart results in a significant decrease in myocardial oxygen demand due to a reduction in heart rate, then intrinsic metabolic mechanisms will increase coronary vascular resistance by constricting the vessels

Factors increasing myocardial O2 consumption

1. Increased heart rate
2. Increased inotropy contractility
3. Increased preload
4. Increased afterload

Diseases linked with coronary circulation

Angina

- **Investigation**

ECG might be normal, but does not exclude the condition.

- **Treatment for the attack**

-if exercise-induced, stop exercise
-glyceryl trinitrate (0.5mg sublingual)

MI

- **Investigation**

-cardiac enzymes: CK-MB, AST, LDH, etc.
-ECG:deep Q wave, ST elevation, T inversion

- **clinical feature**

Chest pain (even at rest & lasts for hours) with sudden onset, but can develop gradually.
Associated with: sweating, vomiting, hypotension.

Take Home Messages

- YOU DID IT
- الله يوفقكم جميعًا وتجيبون أعلى الدرجات

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