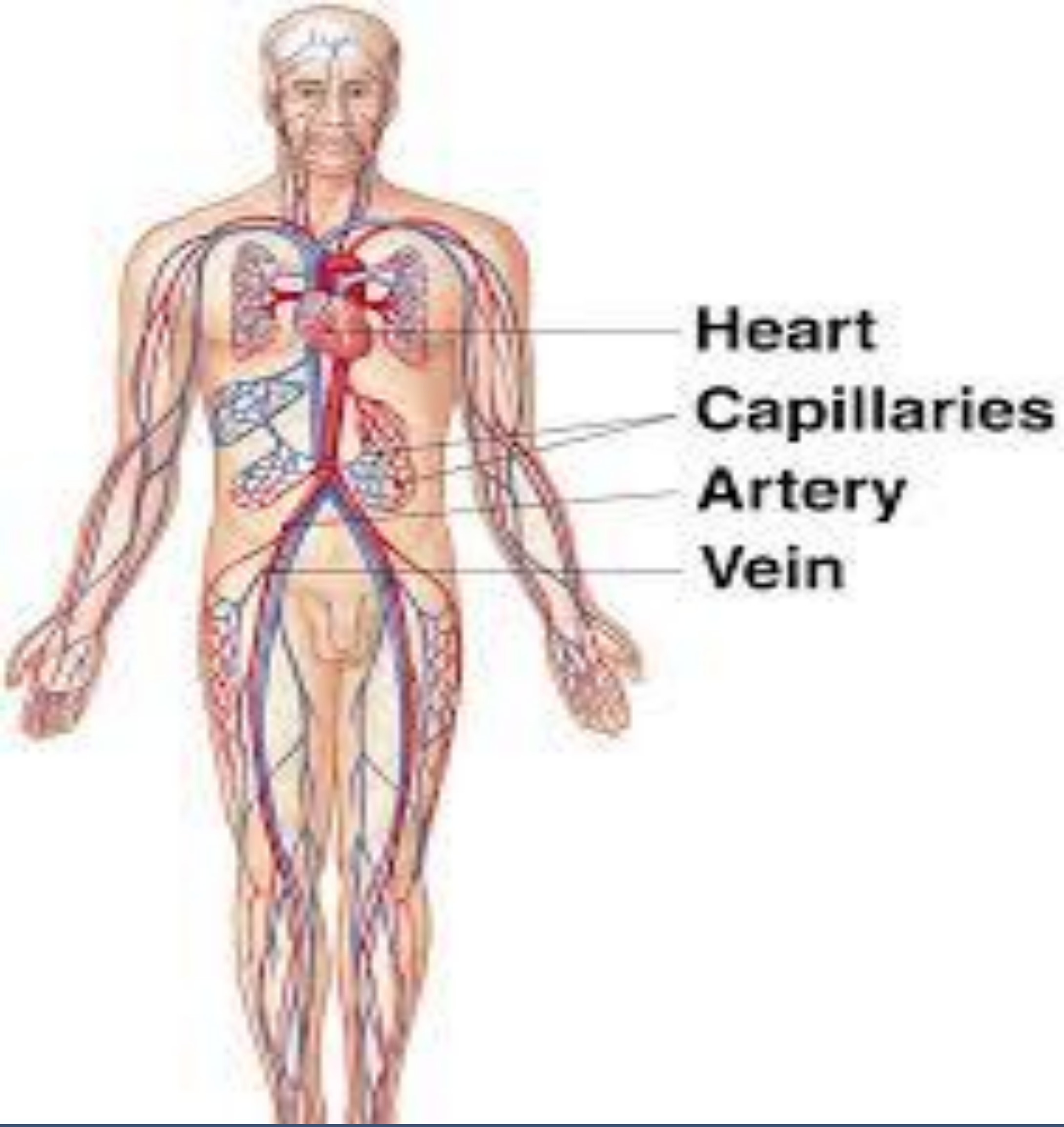
Physiology of Cardiovascular System

1^{st} Lecture

2^{nd} Term


Heart
Capillaries
Artery
Vein

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The cardiovascular system provides blood supply throughout the body.

By responding to various stimuli, it can control the velocity and amount of blood carried through the vessels.

The cardiovascular system consists of the heart, arteries, veins, and capillaries. The heart and vessels work together intricately to provide adequate blood flow to all parts of the body.

The regulation of the cardiovascular system occurs via a myriad of stimuli, including changing blood volume, hormones, electrolytes, osmolarity, medications, adrenal glands, kidneys, and much more. The parasympathetic and sympathetic nervous systems also play a key role in the regulation of the cardiovascular system

Osmolarity	Osmolality
$\text{osmolarity} = \frac{\text{\# of osmoles of solute}}{\text{1 liter of solution}}$	$\text{osmolality} = \frac{\text{\# of osmoles of solute}}{\text{1 Kg water}}$

Blood vessels are critical because they control the amount of blood flow to specific parts of the body. Blood vessels include arteries, capillaries, and veins.

Arteries carry blood away from the heart and can divide into large and small arteries. Large arteries receive the highest pressure of blood flow and are thicker and more elastic to accommodate the high pressures. Smaller arteries, such as arterioles, have more smooth muscle, which contracts or relaxes to regulate blood flow to specific portions of the body.

Arterioles face a smaller blood pressure, meaning they don't need to be as elastic. Arterioles account for most of the resistance in pulmonary circulation because they are more rigid than larger arteries. Furthermore, the capillaries branch off of arterioles and are a single-cell layer. This thin layer allows for the exchange of nutrients, gases, and waste with tissues and organs.

Also, the veins transport blood back to the heart. They contain valves to prevent the backflow of blood.

Physiology of the heart

The cardiac cycle involves events, patterns of contraction and relaxation of the heart to complete one complete heartbeat. The cardiac output is the measure of the rate of flow of blood through the heart involving blood vessels.

The change in pressure enables the flow of blood through the cardiac cycle. This is regulated by the cardiac conduction system and controlled by the medulla through the autonomic nervous system.

It is important to understand the concept of cardiac output CO, stroke volume SV, preload, Frank-Starling law, afterload, and ejection fraction to understand the physiology of the heart.

The cardiac output is the amount of blood ejected from the left ventricle, and normally it is equal to the venous return.

The calculation is = stroke volume x heart rate. Also equals the rate of oxygen consumption divided by the difference in arterial and venous oxygen content.

The stroke volume is the amount of blood pumped out of the heart after one contraction. It is the difference in end-diastolic (EDV) and end-systolic volume (ESV).

The diastole indicates ventricular filling, while the systole indicates ventricular ejection or contraction. Though with varying pressures, the systole and diastole occur in both the right and left heart.

The EDV is the filled volume of the ventricle before contraction, and the ESV is the residual volume of blood remaining in the ventricle after ejection.

In a typical heart, the EDV is about 120 mL of blood and the ESV is about 50 mL of blood. The difference in these two volumes, 70 mL, represents the SV (SV = EDV – ESV). Therefore, any factor that alters either the EDV or the ESV will change the SV. For example, an increase in EDV increases SV, whereas an increase in ESV decreases SV.

Stroke Volume Control Factors

1- End-Diastolic Volume (EDV) or Preload

- Filling time
- Rate of venous return

2- End-Systolic Volume (ESV)

- Preload ↑ preload → ↓ ESV
- Contractility ↑ Contractility → ↓ ESV
- Afterload ↑ Afterload → ↑ ESV

The preload is the pressure on the ventricular muscle by the ventricular EDV. Frank-Starling law describes the relationship between EDV and SV. This law states that the heart attempts to equalize CO with venous return. As venous return increases, there is a larger EDV in the left ventricle, which leads to further stretching of the ventricle.

Further stretching of the ventricle leads to a larger contraction force and a larger SV. A larger stroke volume leads to a larger CO, thus equalizing CO with venous return.

The afterload is the pressure that the left ventricular pressure must exceed to push blood forward. Mean arterial pressure best estimates this. Also, afterload can be estimated by the minimum amount of pressure needed to open the aortic valve, which is equivalent to the diastolic pressure. Thus, diastolic blood pressure is one of the better ways to index afterload. Finally, the ejection fraction (EF) is equal to SV/EDV.

EF of the left ventricle is an index for contractility. A normal EF is greater than 55%. A low EF indicates heart failure

↑ Preload → ↑ SV (↑ EDV)

↑ Afterload → ↓ SV (↑ ESV)

↑ Inotropy → ↑ SV (↓ ESV)