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Lecture title: **Cardiac output**

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Summary: Cardiac output depends on heart rate and stroke volume, regulated by neural, hormonal, and mechanical factors, influencing blood pressure and flow.

Cardiac output

- ***The heart rate***, which is the number of beats per minute.
- ***The stroke volume*****,** is the amount of blood pumped out by each ventricle during each beat. Normal value: 70 mL (60 to 80 mL) when the heart rate is normal (72/minute).

SV= End Diastolic Volume (EDV)- End Systolic Volume (ESV)=135-65=70 EDV= is the volume of blood in the ventricle at the end of diastole.

ESV= is the volume of blood in the ventricle at the end of systole.

- ***The cardiac output***, is the amount of blood pumped out by each ventricle in one minute. It is the product of stroke volume and heart rate (CO = HR X SV= 70 X 72= 5L./min.).

- ***Cardiac index*** is the minute volume expressed in relation to square meter of body surface area. It is defined as the amount of blood pumped out per ventricle/minute/ *square* meter of the body surface area.

Factors controlling cardiac output:

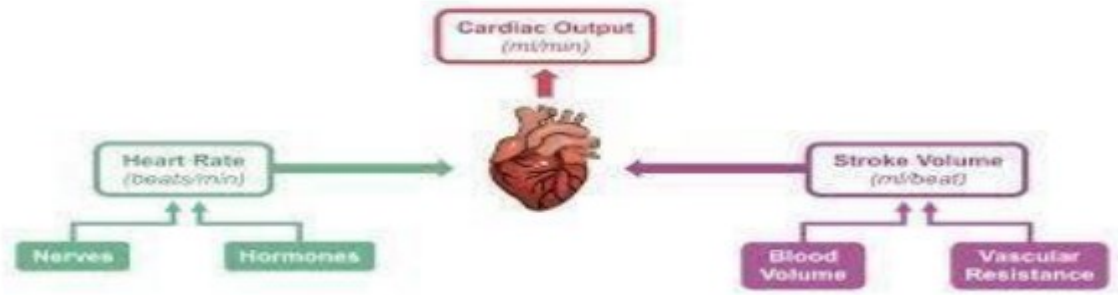
Variations in cardiac output can be produced by changes in heart rate or stroke volume.

Heart rate:

1- The heart is controlled by the autonomic nervous system (sympathetic and parasympathetic (vagal) nerves) and baroreceptors. Sympathetic stimulation (adrenaline) increasing the heart rate and the parasympathetic (Ach) stimulation decreasing it.
2- The heart rate is also sensitive to changes in temperature, plasma electrolyte concentrations and hormones. These are generally of lesser importance, and the heart rate is primarily regulated by the cardiac innervations.

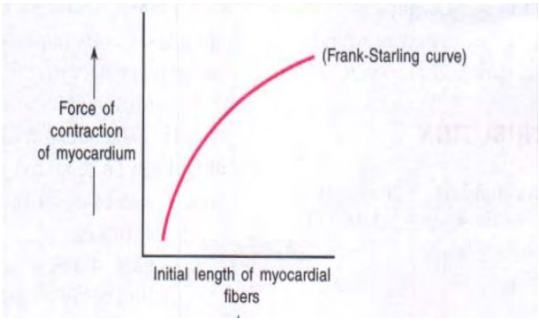
Stroke volume:

1- The stroke volume is also determined in part by neural input. Sympathetic stimuli making the myocardial muscle fibers contract with greater strength, and parasympathetic stimuli having the opposite effect.
2- Stroke volume varies with the length of the cardiac muscle fibers (preload, it means the degree to which the myocardium is stretched before it contracts, Preload in the intact heart is closely related to end-diastolic volume of the ventricle. Increased preload is associated with increased force of contraction, and hence, increased stroke volume) and this effect is independent of innervations.
3- An increased flow of blood from the veins into the heart (venous return) automatically forces an increase in cardiac output by distending the ventricle and increasing stroke volume.



Starlings law of the heart.

Refer to that the stroke volume of the heart increases in response to an increase in the volume of blood in the ventricles, before contraction (the end diastolic volume), when all other factors remain constant.



Blood flow:

The blood flow of blood is controlled by:

1- Pumping action of the heart.
2- The characteristic of the blood as fluid.
3- The characteristics of the blood vessels.

Blood flow refers to the movement of blood through a vessel, tissue, or organ, and is usually expressed in terms of volume of blood per unit of time.

The blood flow starts from the ventricular contraction which ejects blood into the major arteries, resulting in flow from regions of higher pressure to regions of lower pressure, as blood encounters smaller arteries and arterioles, subsequently capillaries, afterwards the venules and veins of the venous system.

Types of blood flow: There are two types of blood flow - laminar (or streamline) and turbulent blood flow.

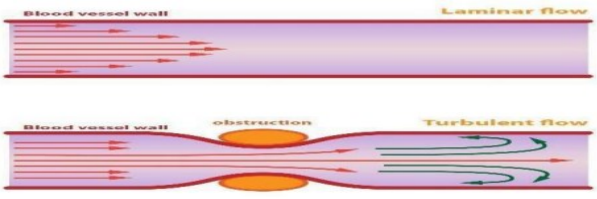
The laminar blood flow: is the normal condition for blood flow throughout most of the circulatory system. It is characterized by:

- ✓ concentric layers of blood moving in parallel down the length of a blood vessel.
- ✓ The highest velocity (V_{max}) is found in the center of the vessel.

✓ Laminar flow occurs at velocities up to a certain critical velocity. At or above this critical velocity, flow is turbulent.

✓ Streamline flow is a silent, but turbulent flow creates sounds.

✓ The probability of turbulence is related to the diameter of the vessel and the viscosity of the blood.

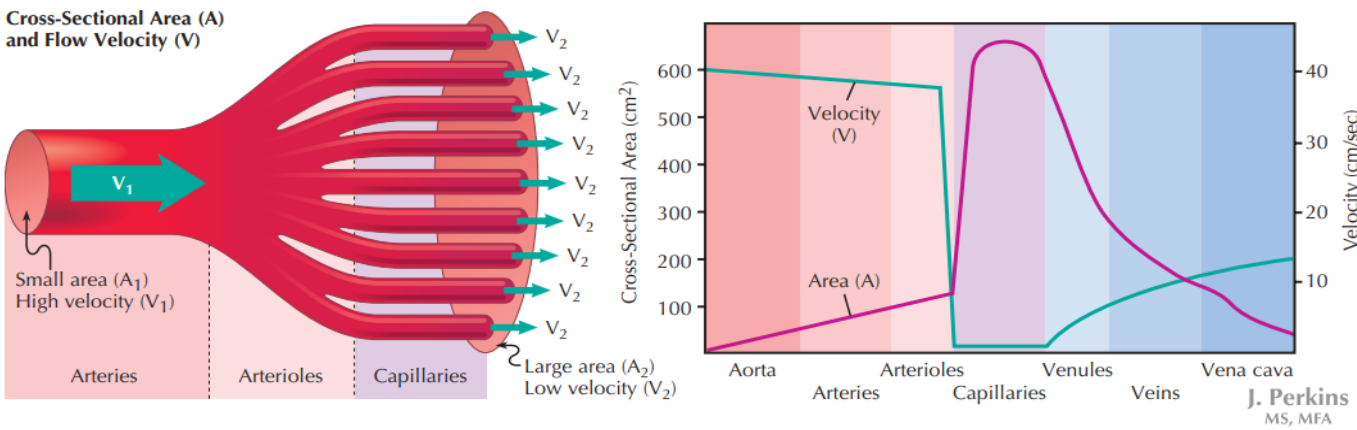


Turbulent blood flows

- ✓ occur in all directions in the vessel and continuously mixing within the vessel. Thus, it causes a Ventricles and aorta are the normal sites of turbulence. None of the sma11 resistance vessels of vascular system show turbulence.

- ✓ It is noisy flow.
- ✓ Turbulence is given by Reynold's number (Re)= Vpd/11, where V velocity of flow in cm/sec, p(Rho) = density of blood equal to 1, (d)diameter of vessel (in cm) ŋ (eta) viscosity of blood in poise.
- ✓ greater energy loss as compared to laminar flow.

➢ The average velocity of fluid movement at any point in a system of tubes **is inversely** proportionate to the total cross- sectional area. Therefore, the average velocity of the blood is rapid in the aorta, declines in the smaller vessels, and is slowest in the capillaries. The average velocity of blood increases again in the veins and is relatively rapid in the vena cava.



The resistance of blood flow is determined by:

- ✓ the radius of the blood vessels.
- ✓ the viscosity of the blood which depends on *the hematocrit as well as the plasma composition.*

Blood pressure:

It may be defined as the pressure blood exerts against the vessel walls. The pressure of blood within the cardiovascular system depends upon:

1. Cardiac output.

2. Peripheral resistance.

3. Total blood volume.

4. Viscosity of the blood.

5. Elasticity of the arterial wall.

The first number, called **systolic blood pressure**, measures the pressure in your blood vessels when your heart beats. The second number, called **diastolic blood pressure**, measures the pressure in your blood vessels when your heart rests between beats. A blood pressure less than 120/80 mmHg is normal.

Pulse *pressure* *is the difference between the systolic and diastolic blood pressure*.
It is measured in millimeters of mercury (mmHg).
For example, if resting blood pressure is 120/80 mmHg, then the pulse pressure is 40 mmHg.

The pressure falls very slightly in the large and medium-sized arteries because their resistance to flow is small, but it falls rapidly in the small arteries and arterioles, which are the main sites of the peripheral resistance.