كلية المستقبل الجامعة

قسم الفيزياء الطبية

المرحلة الثالثة

Medical Physics

Lecture Nine

Bernoulli’s Principle Applied to the Cardiovascular System

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Blood Pressure and its Measurement:

The heart supplies the organs and tissues of the body with blood. With every beat, it pumps blood into the large blood vessels of the circulatory system. As the blood moves around the body, it puts pressure on the walls of the vessels. Blood pressure readings are made up of two values:

- **Systolic blood pressure**: is the pressure when the heart beats – while the heart muscle is contracting (squeezing) and pumping oxygen-rich blood into the blood vessels.

- **Diastolic blood pressure**: is the pressure on the blood vessels when the heart muscle relaxes. The diastolic pressure is always lower than the systolic pressure.

Blood pressure is measured in units of millimeters of mercury (mmHg). The readings are always given in pairs, with the upper (systolic) value first, followed by the lower (diastolic) value.

So someone who has a reading of 132/88 mmHg (often spoken "132 over 88") has a systolic blood pressure of 132 mmHg, and a diastolic blood pressure of 88 mmHg.

Blood pressure measurements are categorised according to these boundaries:

Category	Systolic (mmHg)		Diastolic (mmHg)
Hypotension	<90		<60
Normal	90-119		60-79
Prehypertension	121-139		80-89
Stage 1 Hypertension	140-159		90-99
Stage 2 Hypertension	160-179		100-109
Stage 3 Hypertension	>180		>110

Blood Pressure and A sphygmomanometer :

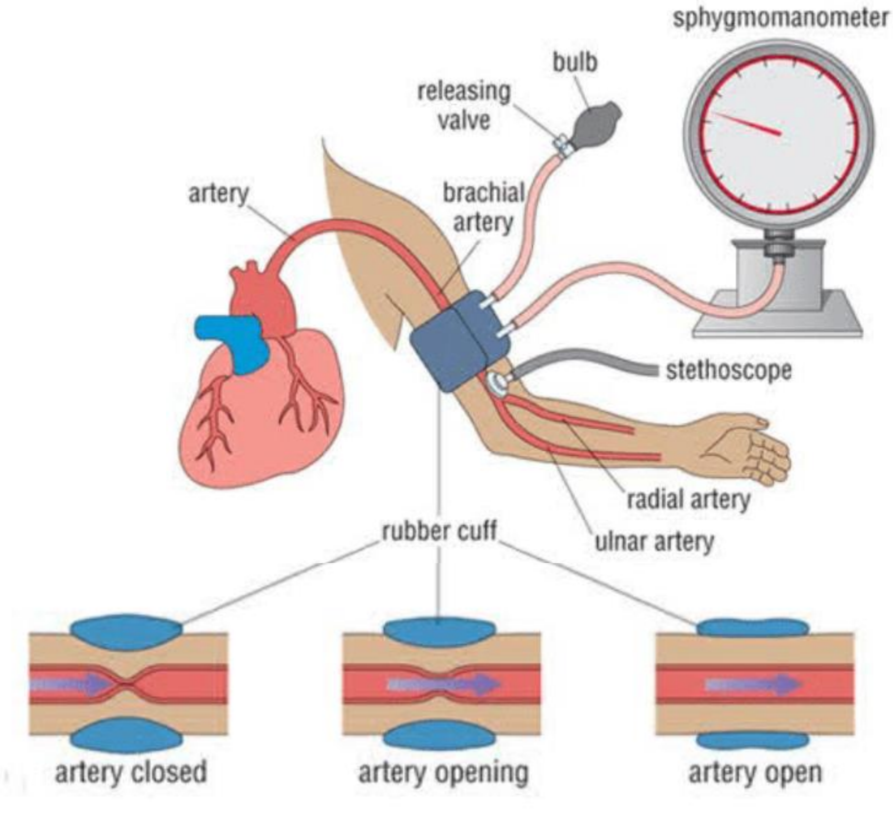
A sphygmomanometer has three parts:

1- A cuff that can be inflated with air.

2- A pressure meter (manometer) for measuring air pressure in the cuff .

3- A stethoscope for listening to the sound the blood makes as it flows through the brachial artery (the major artery found in your upper arm).

The scale of the pressure meter ranges from 0 to 300 mmHg. The pressure meter has a rubber pump on it for inflating the cuff and a button for letting the air out .



To measure blood pressure, the cuff is placed around the bare and stretched out upper arm, and inflated until no blood can flow through the brachial artery. Then the air is slowly let out of the cuff.

As soon as the air pressure in the cuff falls below the systolic blood pressure in the brachial artery, blood will start to flow through the arm once again. This creates a pounding sound when the arteries close again and the walls of the vessels hit each other after a heart beat.

The sound can be heard by placing the stethoscope close to the elbow. Right when you start to hear this pounding for the first time you can read your systolic blood pressure off the pressure meter .

The pounding sound stops when the air pressure in the cuff falls below the diastolic blood pressure in the brachial artery. Then the blood vessels remain open. Right when the pounding stops, you can read the diastolic blood pressure off the pressure meter.

Systole :

1- The period of contraction of the ventricles.

2- Occurs between the first and second heart sounds.

3- Causes ejection of blood into the aorta and the pulmonary trunk.

4- Arterial blood pressure reaches its peak .

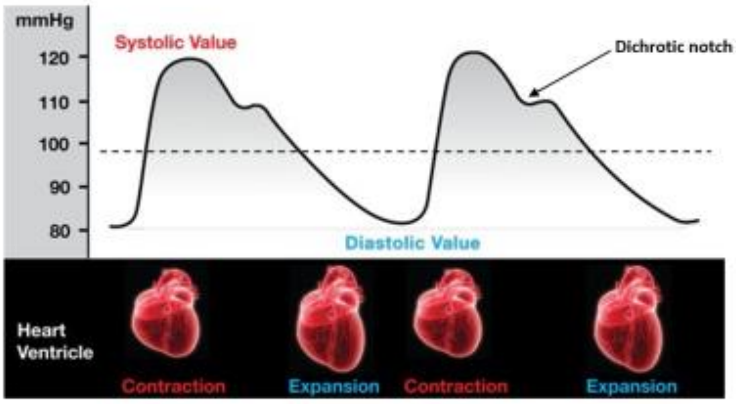
Diastole:

1- The period of relaxation of the cardiac muscle.

2- Followed by systole in the cardiac cycle.

3- When atria are in systole, blood pressure is at its minimum.

4- Arterial pressure is troughed.



Bernoulli's Principle Applied to the Cardiovascular System:

Bernoullis principle is based on the law of conservation of energy . Pressure in fluid is a form of potential energy PE since it has abillity

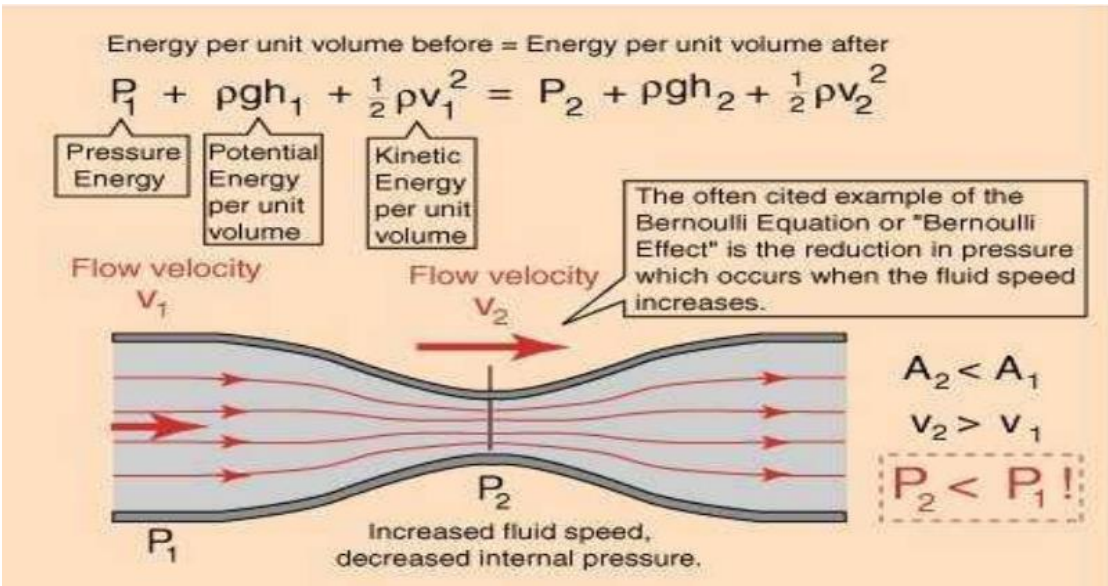
to perfom useful work.

In a moving fluid is kinetic energy KE due to motion. Kinetic energy can be expressed as energy per unit volume .

Because flowing blood has mass and velocity it has kinetic energy (KE). This KE is proportionate to the mean velocity squared (V2; from KE = ½ mV2). Furthermore, as the blood flows inside a vessel, pressure is exerted laterally against the walls of the vessel; this pressure represents the potential or pressure energy (PE).

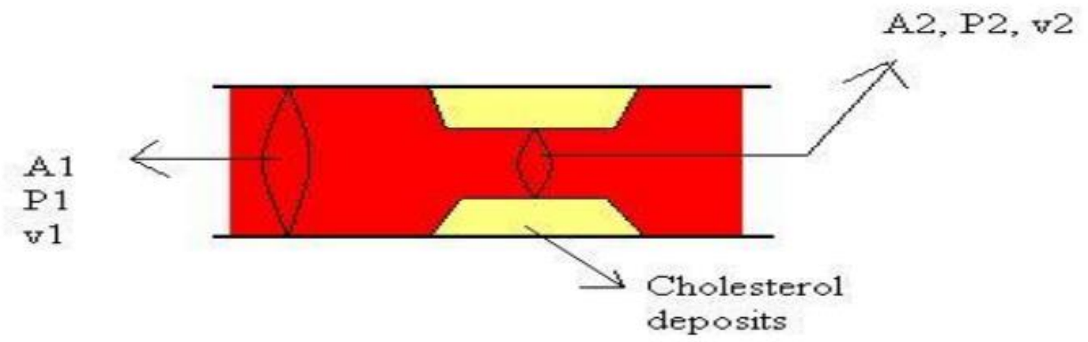
The total energy (E) of the blood flowing within the vessel, therefore, is the sum of the kinetic and potential energies (assuming no gravitational effects) as shown below:

$$E = KE + PE \quad (\text{where } KE \propto V^2) \qquad \text{Therefore, } E \propto V^2 + PE$$



Relating the continuity of flow equation ($A_1V_1 = A_2V_2$) with Bernoulli's equation:

Continuity of flow equation tells us this: when the area decreases, the velocity increases in order to maintain a constant flow rate .



From continuity and Bernoulli's equations

From the continuity equation, $A_1v_1 = A_2v_2$.

Due to cholesterol deposits, $A_1 > A_2 \longrightarrow v_1 < v_2$.

From Bernoulli's equation, $\frac{1}{2}\rho v_2 + \rho gh + P = \text{constant}$.

Thus, since $v_1\downarrow \longrightarrow P_1\uparrow$

There are two important concepts that follow from this relationship:

1- Blood flow is driven by the difference in total energy between two points.

2- Kinetic energy and pressure energy can be interconverted so that total energy remains unchanged. This is the basis of Bernoulli's Principle .