الفسلجة
مرحلة ثانية

الأستاذ المساعد الدكتور
خالد سعود صالح

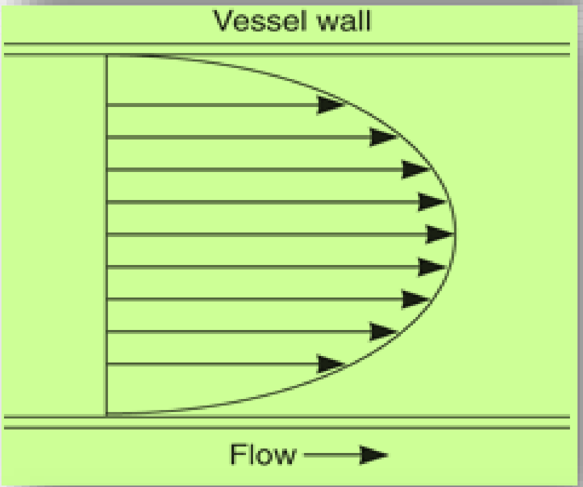
Cardoivascular System
CARDIAC OUTPUT

Biophysical Considerations for Circulatory Physiology: ***Flow***, ***Pressure***, & ***Resistance***

- Blood always flows from areas of high pressure to areas of low pressure, except in certain situations.
- The relationship between mean flow, mean pressure, and resistance in the blood vessels is analogous in a general way to the relationship in an electrical circuit expressed in **Ohm's law**:
- **Physical Principles of Blood Flow in Blood Vessels:**
- The behavior of the circulation deviates from that predicted by physical principles that describe the behavior of perfect fluids in rigid tubes.

$$\text{Current (I)} = \frac{\text{Electromotive force (E)}}{\text{Resistance (R)}}$$

$$\text{Flow (F)} = \frac{\text{Pressure (P)}}{\text{Resistance (R)}}$$



$$Re = \frac{\rho D \dot{V}}{\eta}$$

where:
Re is the Reynolds number;
ρ is the density of the fluid;
D is the diameter of the tube
V̇ is the velocity of the flow;
η is the viscosity of the fluid.

The flow of blood in straight blood vessels, like the flow of liquids in narrow rigid tubes, is normally ***laminar (layered)***.

An infinitely thin layer of blood in contact with the wall of the vessel does not move.

The next layer within the vessel has a low velocity, then a higher velocity, and so forth, velocity being greatest in the center of the stream.

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

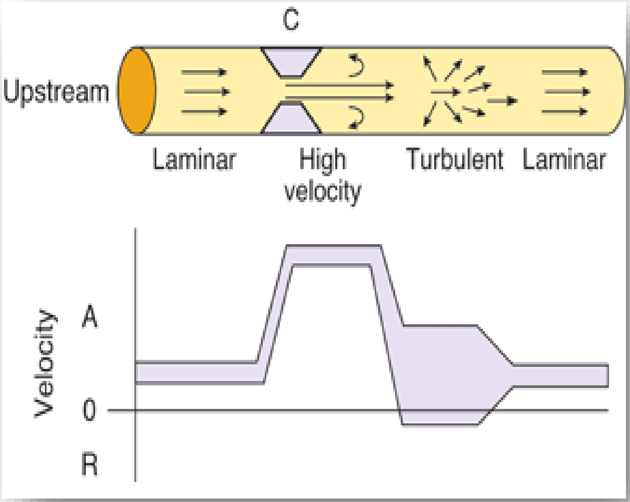
Laminar flow is silent, but turbulent flow creates sounds.

The probability of turbulence can be expressed by the following equation:

The higher the value of Re, the greater the probability of turbulence. Flow is usually not turbulent if Re is less than 2000.

Biophysical Considerations for Circulatory Physiology: *Flow, Pressure, & Resistance*

- Laminar flow can be disturbed at the branching points of arteries,
- Likewise, constriction of an artery increases the velocity of blood flow, producing turbulence and sound beyond the constriction, examples.
- Turbulence occurs more frequently in anemia because the viscosity of the blood is lower, explaining systolic murmurs.



$$\dot{V} = \frac{Q}{A}$$

Average Velocity:

Velocity, which is displacement per unit time (e.g., cm/s), and
Flow, which is volume per unit time (e.g., cm^3/s).

Velocity ($\dot{V}$) is proportional to flow (Q) divided by the area of the conduit (A):

Therefore if flow stays constant, velocity increases in direct proportion to any decrease in A.

The average velocity of fluid movement in a system of parallel tubes is inversely proportional to the ***total*** cross-sectional area at that point.

So, the average velocity of the blood is high in the aorta, declines steadily in the smaller vessels, and is lowest in the capillaries.

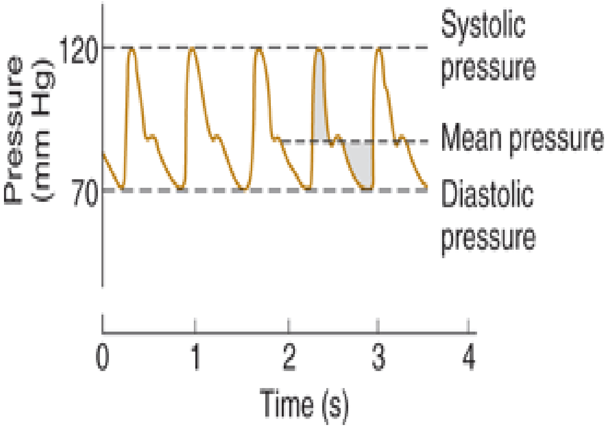
The average velocity of blood flow increases again as the blood enters the veins and is relatively high in the vena cava.

Arterial Pressure:

- At rest, at least 50% of the circulating blood volume is in the systemic veins.
- The veins are an important blood reservoir; therefore, they are called **capacitance vessels**.

- The small arteries and arterioles are referred to as **resistance vessels** because they are the principal site of the peripheral resistance.

- The pressure in the aorta and other large arteries in a young adult rises to a peak value (**systolic pressure**) of about 120 mm*Hg* during each heart cycle and falls to a minimum (**diastolic pressure**) of about 70 mm*Hg*.



Brachial artery pressure curve of a normal young human

The arterial pressure: is conventionally written as 120/70 mm*Hg*.

The pulse pressure: the difference between the systolic and diastolic pressures, is normally about 50 mm*Hg*.

The mean pressure: is the average pressure throughout the cardiac cycle.

Because systole is shorter than diastole, the mean pressure is slightly less than the halfway value.

Approximately, ***mean pressure equals the diastolic pressure plus one-third of the pulse pressure.***

The pressure falls very slightly in the large- and medium-sized arteries, but falls rapidly in the small arteries and arterioles,

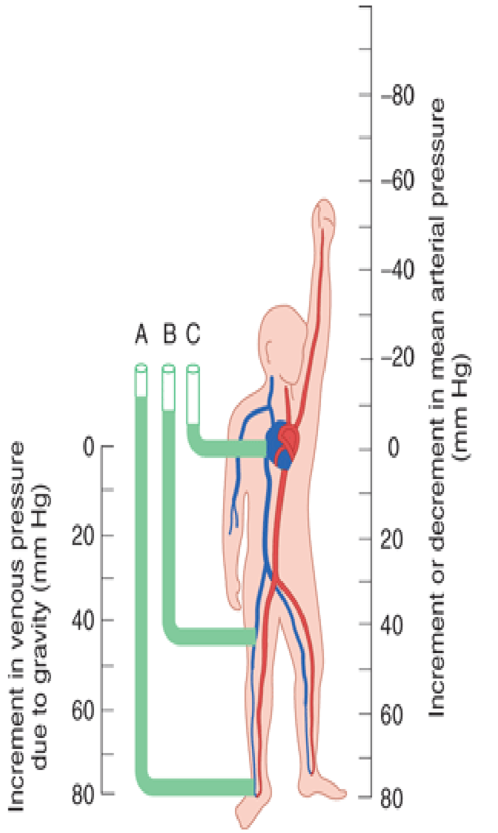
Hence, they are the main sites of the peripheral resistance.

Arterial Pressure: Effect of Gravity:

- The blood pressures discussed so far are those in blood vessels at heart level.
- The pressure in any vessel below heart level is increased and that in any vessel above heart level is decreased by the effect of gravity.
- ***The magnitude of the gravitational effect is*** 0.77 mmHg /cm ***of vertical distance at the density of normal blood.***
- Thus, in an adult human in the upright position, when the mean arterial pressure at heart level is 100 mm*Hg*:

  mean pressure in a large artery in the head (50 cm above the heart) = 62 mm*Hg* (100 – [0.77 × 50]).

  mean pressure in a large artery in the foot (105 cm below the heart) = 180 mmHg (100 + [0.77×105]).



Effects of gravity on arterial and venous pressure

Arterial Pressure:

Methods of Measuring Blood Pressure: Direct Method:

- If a cannula is inserted into an artery, the arterial pressure can be measured directly with a mercury manometer or other strain gauge.

- When an artery is tied off beyond the insertion of the cannula; flow is interrupted, an ***end pressure*** is recorded.

Indirect Method:

Auscultatory Method:

- An inflatable cuff attached to a mercury manometer (***sphygmomanometer***) is wrapped around the arm and a stethoscope is placed over the brachial artery at the elbow.
- The cuff is rapidly inflated until the pressure is above the expected systolic pressure. The artery is occluded by the cuff, and no sound is heard.
- The pressure is then lowered slowly. At the point at which systolic pressure in the artery just exceeds the cuff pressure, a gush (jet) of blood passes through with each heartbeat and, synchronously, a tapping sound is heard.

*The cuff pressure at which the sounds are first heard is **the systolic pressure***.

As the cuff pressure is lowered further, the sounds become louder, then dull and muffled (barely audible, soft). Finally, in most individuals, they disappear.

These are ***the sounds of Korotkoff***.

When direct and indirect measurements are made simultaneously in resting adults, *diastolic pressure correlates best with the pressure at which the sound disappears.*

However; in children, adults after exercise and in diseases such as hyperthyroidism and aortic insufficiency, *diastolic pressure correlates best when the sounds become muffled.*

Sounds of Korotkoff are produced by turbulent flow in the brachial artery: when the velocity of flow through the narrowing produced by the cuff exceeds the critical

Auscultatory Method:

The auscultatory method is accurate when used properly, but a number of precautions must be observed:

a. The cuff must be at heart level to obtain a pressure uninfluenced by gravity.

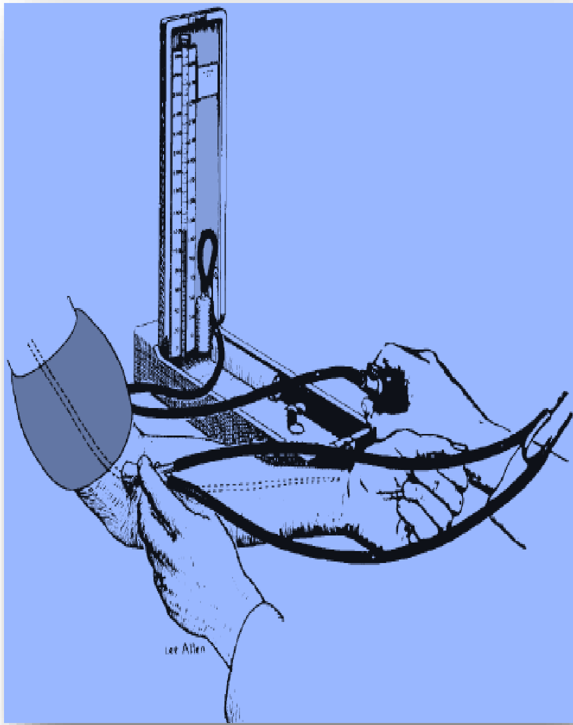
b. **Pressures obtained by using the standard arm cuff are falsely high** when applied to individuals with obese arms or around the thigh, because the blanket of fat dissipates some of the cuff pressure.

In both situations, accurate pressures can be obtained by using a wider cuff.

c. If the cuff is left inflated for some time, discomfort may cause generalized reflex vasoconstriction, raising the blood pressure.

d. It is always wise to compare the blood pressure in both arms when examining an individual for the first time.

Persistent major differences between the pressure on the two sides indicate the presence of vascular obstruction.



Palpation Method:

The systolic pressure can be determined by inflating an arm cuff and then letting the pressure fall and determining the pressure at which the radial pulse first becomes palpable.

Because of the difficulty in determining exactly when the first beat is felt, ***pressures obtained by this method are usually 2–5 mm Hg lower than those measured by the auscultatory method.***

It is wise to form a habit of palpating the radial pulse while inflating the pressure cuff during the auscultatory method.

When the cuff pressure is lowered, the ***sounds of Korotkoff*** sometimes disappear at pressures well above diastolic pressure, then reappear at lower pressures ("**auscultatory gap**").

If the cuff is initially inflated until the radial pulse disappears, the examiner can be sure that the cuff pressure is above systolic pressure, and falsely low pressure values will be avoided.

The **normal arterial blood pressure i**n the brachial artery in young adults in the sitting position at rest is approximately 120/70 mm*Hg*.

Because the arterial pressure is the product of the cardiac output and the peripheral resistance, it is affected by conditions that affect either or both of these factors:

Emotion increases the CO and PR, and about 20% of hypertensive patients have blood pressures that are higher in the doctor's office than when going about their regular daily activities ("***white coat hypertension***").