Doctor.021
no.

CVS PHYSIOLOGY

DR.FATEMA HAND OUT 1&2

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Learning Objectives:

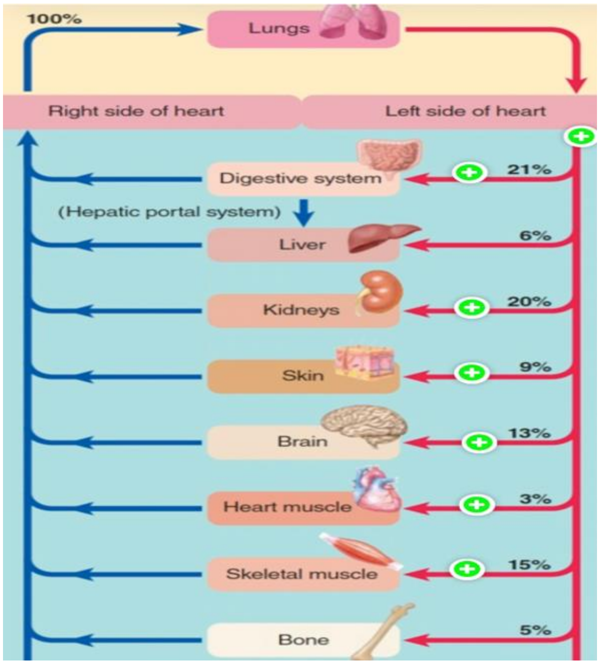
By the end of this book, the student is expected to:

1. Understand the distribution of blood flow in the systemic circulation.
2. Know the hemodynamic principles for blood flow and the factors affecting blood flow.
3. Recognize the functions of arteries and how structure serves function.
4. Understand the pathophysiological mechanisms of arterial stiffness.
5. Know the different parameters of arterial blood pressure (SBP, DBP, PP, MAP).
6. Understand the physiology underlying changes in blood pressure across different segments in the circulation.
7. Recognize changes in pulse pressure contour in different pathological conditions compared to normal.
8. Apply the above knowledge in different clinical senarios.

Introduction:

- The function of the vascular system is to serve the needs of the body tissues by transporting nutrients to the cells, waste products away, transporting hormones from one part of the body to another, and to maintain appropriate environment in all the tissue fluids for survival and optimal function of the cells.

Distribution of blood flow at rest:



Parallel arrangement of vessels ensure they all organs receive blood of the same composition?

- TRUE
- Also because of this parallel arrangement, blood flow through each systemic organ can be independently adjusted as needed.
- The blood pumped by the left ventricle into the systemic circulation is distributed in various proportions to the organs through a parallel arrangement of vessels that branch from the aorta.
- The overall blood flow in the total circulation of an adult person at rest is about 5000 ml/min. This is called the cardiac output.
- **Kidneys, skin, digestive system:** This is a Reconditioning organ, meaning it normally receives much more blood flow than is necessary to meet its basic metabolic needs, so it can adjust the extra blood to achieve homeostasis, and can withstand temporary reductions in blood flow much better.
- The brain in particular suffers permanent damage when transiently deprived of blood supply. Therefore, constant delivery of adequate blood to the brain is a high priority.
- **Skeletal muscles, heart** :Blood flow to this organ matches its metabolic needs and can be adjusted according to its level of activity.

Flow rate:

Hemodynamics

The principles that govern blood flow in the cardiovascular system.

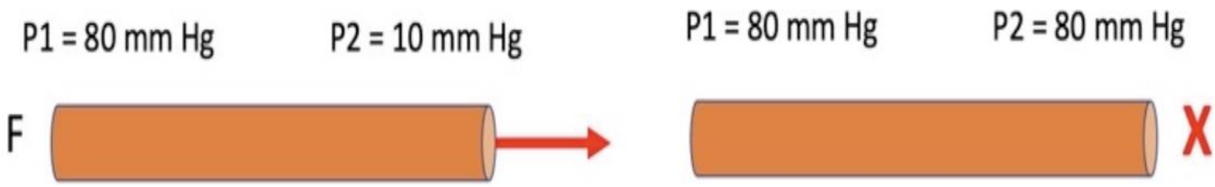
Blood flow

Blood flow through a blood vessel is determined by two factors:

(1) pressure difference of the blood between the two ends of the vessel, also called the pressure gradient, which pushes the blood through the vessel.

$$F = \frac{\Delta P}{R}$$

(2) the impediment to blood flow through the vessel, which is called vascular resistance.
Note that it is the difference in



pressure between the two ends of the vessel, not the absolute pressure in the vessel, that determines flow rate.

If P = 90 mm Hg at the beginning of vessel 1, and P = 10 mm Hg at the end of vessel 1, whereas P = 190 mm Hg at the beginning of vessel 2, and P = 110 mm Hg at the end of vessel 2. Which one has higher flow rate?

- Vessels 2
- The information given isn't enough
- Vessel 1
- Both have the Same flow rate ✓

Blood flows from an area of higher pressure to an area of lower pressure down a pressure gradient.

Contraction of the heart imparts pressure to the blood, which is the main driving force for flow through a vessel.

Because of frictional losses (resistance), the pressure drops as blood flows throughout the vessel's length. establishing a pressure gradient for forward flow of blood through the vessel.

The greater the pressure gradient forcing blood through a vessel, the greater the flow rate through that vessel.

Resistance

As resistance to flow increases, it is more difficult for blood to pass through the vessel, so as long as the pressure gradient does not change, the flow rate will decrease.
In order to maintain a uniform flow rate, the pressure gradient will have to increase accordingly if resistance is increased.

Resistance to blood flow is
(1) directly proportional to viscosity of the blood,
(2) directly proportional to vessel length,
(3) inversely proportional to vessel radius, which is by far the most important.

Resistance occurs as a result of friction between the flowing blood and the intravascular endothelium all along the inside of the vessel.

The factors that affect flow rate through a vessel are integrated in Poiseuille's law

$$\text{Flow rate} = \frac{\pi \Delta P r^4}{8\eta L}$$

ΔP is the pressure difference between the ends of the vessel
r is the radius of the vessel
l is length of the vessel
η is viscosity of the blood

Because the circulatory system is a closed system, the volume of blood flowing through any level of the system must equal the CO.

Therefore, the flow rate is the same at all levels of the circulatory system.

Watch this vide about laminar blood flow
https://www.youtube.com/watch?v=a8QVUWI5-jk

One of the following statements is correct regarding laminar flow:

- **All blood particles flow in the same speed within a vessel**
- **It has hyperbolic profile of velocity.** ✓
- **Turbulent flow is always pathological**

Reynold's number is a dimensionless number that is used to predict whether blood flow will be laminar or turbulent.

When Reynolds' number rises above approximately 2000, turbulence will usually occur, even in a straight, smooth vessel.

Reynolds' number for flow in the vascular system normally rises to 200 to 400, even in large arteries. As a result, there is almost always some flow turbulence at the branches of these vessels.

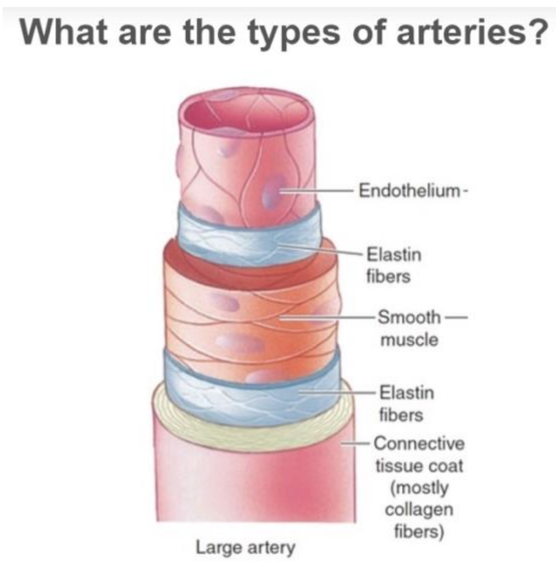
In the proximal portions of the aorta and pulmonary artery, Reynolds' number can rise to several thousand during the rapid phase of ejection by the ventricles.

$$Re = \frac{\nu \cdot d \cdot \rho}{\eta}$$

P= Density of blood
d= Diameter of blood vessel
V= Velocity of blood flow
n= Viscosity of blood

Reynolds number is increased in anemia due to Decrease in blood viscosity, and Increase in the velocity of blood flow. Because of turbulent blood flow, functional murmurs can be heard in patients with anemia.

Arteries



(1) Elastic arteries (2) Muscular arteries

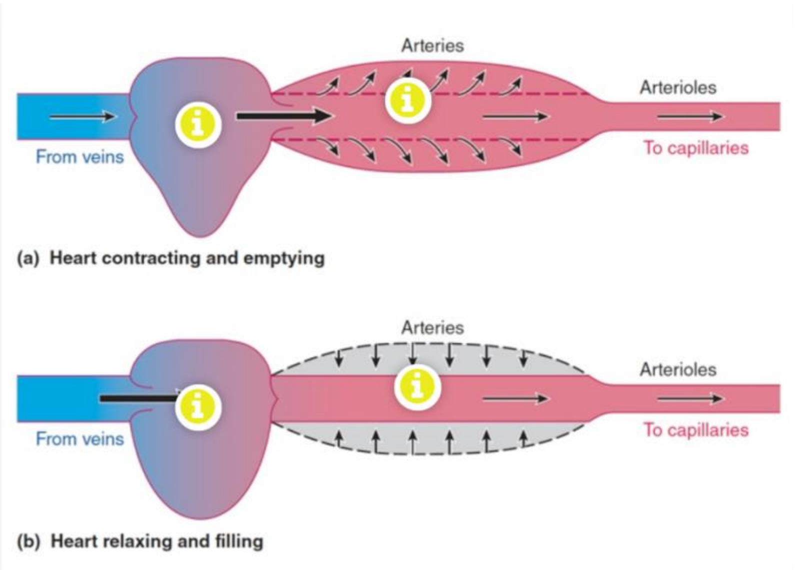
Functions of arteries
1. Serve as rapid-transit passageways for blood from the heart to the organs.

2. Act as a pressure reservoir to provide the driving force for blood when the heart is relaxing.

Rapid-transit passageways for blood from the heart to the organs.
Because of their large radius, arteries offer little resistance to blood flow.

Pressure reservoir when the heart is relaxing.

The heart alternately contracts to pump blood into the arteries and then relaxes to refill with blood from the veins. When the heart is relaxing and refilling, no blood is pumped out.
However, capillary flow does not fluctuate between cardiac systole and diastole—that is, blood flow is continuous through the capillaries supplying the organs.
The driving force for the continued flow of blood to the organs during cardiac relaxation is provided by elastic recoil of the walls of large arteries.



- The heart pumps blood into the arteries during ventricular systole.
- The highly elastic large arteries expand to temporarily hold the excess volume of ejected blood, storing some of the pressure energy imparted by cardiac contraction in their stretched walls.
- When the heart relaxes, it temporarily stops pumping blood into the arteries.
- The stretched arterial walls passively recoil. This elastic recoil exerts pressure on the blood in the large arteries during diastole.

- The pressure pushes the excess blood contained in the arteries into the vessels downstream, ensuring continued blood flow to the organs when the heart is relaxing and not pumping blood into the system.

Self reading:

You are required to read about arterial stiffness.

Arterial Blood Pressure

Blood pressure (BP) depends on the volume of blood contained within the vessel and the compliance, or distensibility, of the vessel walls.

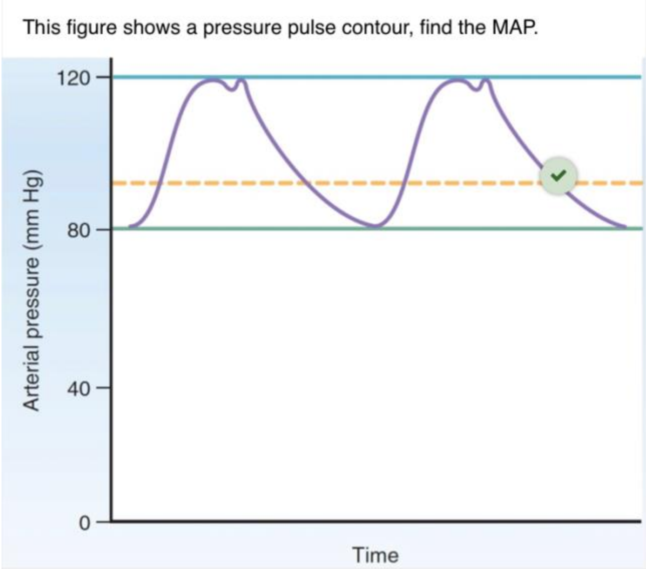
During ventricular systole, a stroke volume of blood enters the arteries from the ventricle, while only about one third as much blood leaves the arteries to enter the arterioles. During diastole, no blood enters the arteries, while blood continues to leave, driven by elastic recoil.

Systolic pressure (SBP) is the highest arterial pressure measured during a cardiac cycle. It is the pressure in the arteries after blood has been ejected from the left ventricle during systole.

Diastolic pressure (DBP) is the lowest arterial pressure measured during a cardiac cycle and is the pressure in the arteries during ventricular relaxation when no blood is being ejected from the left ventricle.

Pulse pressure (PP) is the difference between systolic and diastolic blood pressures, Two major factors affect the pulse pressure are (1) the stroke volume of the heart; and (2) the compliance (total distensibility) of the arterial tree.

The mean arterial pressure (MAP) is the average of the arterial pressures over a period of time. It is not half way between the systolic and diastolic pressures because at normal heart rates, a greater fraction of the cardiac cycle is spent in diastole than in systole. Thus, the arterial pressure remains closer to diastolic pressure than to systolic pressure during the greater part of the cardiac cycle. The mean arterial pressure is therefore determined about 60% by the diastolic pressure and 40% by the systolic pressure. However, at very high heart rates, diastole comprises a smaller fraction of the cardiac cycle, and the mean arterial pressure is more closely approximated as the average of systolic and diastolic pressures.



Arteriosclerosis: The pulse pressure in old age sometimes rises to twice normal because the arteries have stiffened with arteriosclerosis and therefore are relatively noncompliant.

Aortic stenosis: In persons with aortic valve stenosis, the diameter of the aortic valve opening is reduced significantly, and the aortic pressure pulse is decreased significantly because of diminished blood flow outward through the stenotic valve.

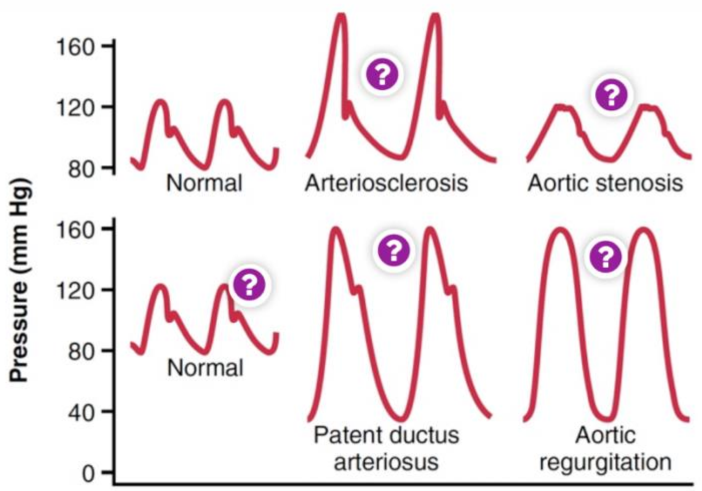


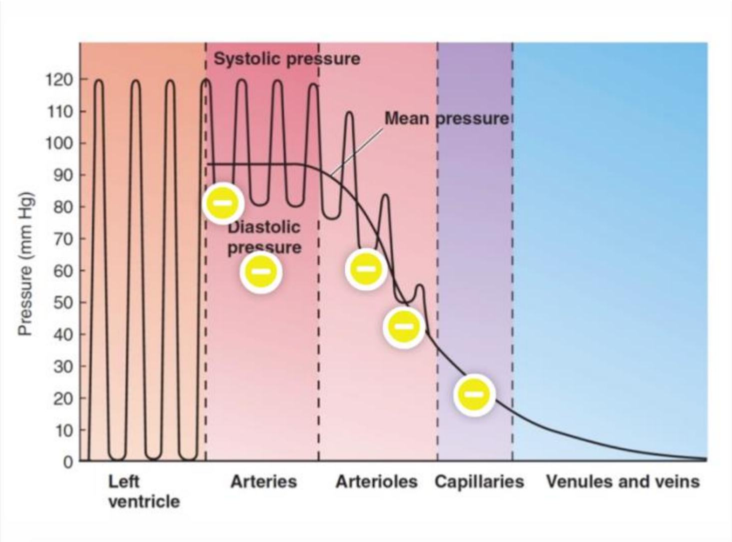
Figure 15-4. Aortic pressure pulse contours in arteriosclerosis, aortic stenosis, patent ductus arteriosus, and aortic regurgitation.

Normal: dicrotic notch (or incisura), is produced when the aortic valve closes. Aortic valve closure produces a brief period of retrograde flow from the aorta back toward the valve, briefly decreasing the aortic pressure below the systolic value.

Patent ductus ateriosus:

In persons with patent ductus arteriosus, 50% or more of the blood pumped into the aorta by the left ventricle flows immediately backward through the wide open ductus into the pulmonary artery and lung blood vessels, thus allowing the diastolic pressure to fall very low before the next heartbeat and increasing the pulse pressure.

Aortic regurgitation:In persons with aortic regurgitation, the aortic valve is absent or does not close completely. Therefore, after each heartbeat, the blood that has just been pumped into the aorta flows immediately backward into the left ventricle. As a result, the aortic pressure can fall all the way to zero between heartbeats. Also, there is no incisura in the aortic pulse contour because there is no aortic valve to close.



- Although ventricular pressure falls to 0 mm Hg during diastole, arterial pressure does not fall to 0 mm Hg because the next cardiac contraction refills the arteries before all the blood drains off

- Pressure is of the same magnitude throughout the arteries.

- Because of the arterioles' high resistance, the pressure drops significantly and the systolic-todiastolic swings in pressure are converted to a nonpulsatile pressure when blood flows through the arterioles.

- This progressive diminution of the pulsations in the periphery is called damping of the pressure pulses. The cause of this damping is twofold: (1) resistance to blood movement in the vessels; and (2) compliance of the vessels.

- The pressure continues to decline but at a slower rate as blood flows through the capillaries and venous system.

Glossary

- Autoregulation is local arteriolar myogenic and chemical mechanisms that keep tissue blood flow fairly constant despite rather wide deviations in mean arterial driving pressure.
- Blood pressure is the force exerted by the blood against any unit area of the vessel wall.
- Compliance or capacitance of a blood vessel is the volume of blood the vessel can hold at a given pressure.
- Conductance is a measure of the blood flow through a vessel for a given pressure difference.
- Diastolic blood pressure is the minimum pressure within the arteries when blood is draining off into the rest of the vessels during diastole.
- Distensibility of the vessel walls is how easily they can be stretched.
- Flow rate of blood is the quantity of blood that passes a given point in the circulation in a given period of time.
- Hemodynamics is the principles that govern blood flow in the cardiovascular system.
- Mean arterial pressure is the average pressure driving blood forward into the tissues throughout the cardiac cycle.
- Pressure gradient is the difference in pressure between the beginning and the end of a vessel.
- Pulse Pressure is the difference between systolic blood pressure and diastolic blood pressure.

- **Resistance is a measure of the hindrance or opposition to blood flow through the vessel, caused by friction between the moving fluid and the stationary vascular walls.**
- **Reynolds number is a dimensionless number that is used to predict whether blood flow will be laminar or turbulent.**
- **Shear stress is longitudinal force applied on the endothelial cells in the direction of the flow.**
- ***Systolic blood pressure* is the maximum pressure exerted in the arteries when blood is ejected into them during systole.**
- **Velocity of blood flow is the rate of displacement of blood per unit time.**
- **Viscosity is the friction developed between the molecules of a fluid as they slide over each other during flow of the fluid.**

References

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-Costanzo, Physiology Textbook, 6th edition.

-Tortora and Derrickson, Principles of Anatomy and Physiology Textbook, 14th edition.

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Page 1 added:

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