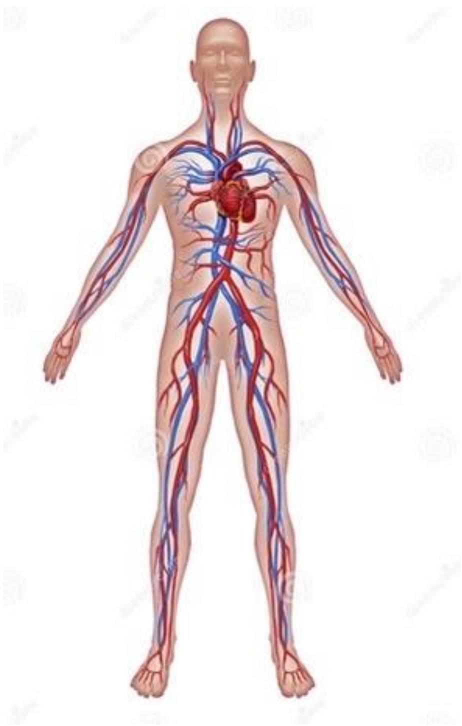
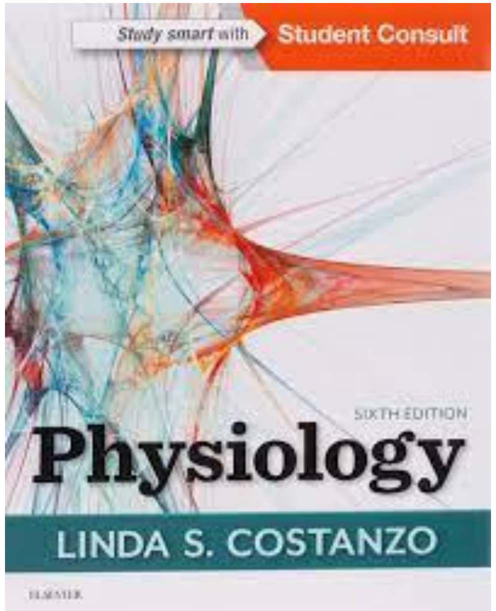
Cardiovascular Physiology

Fatima Ryalat, MD, PhD
Assistant Professor, Physiology and Biochemistry Department
School of Medicine, University of Jordan



References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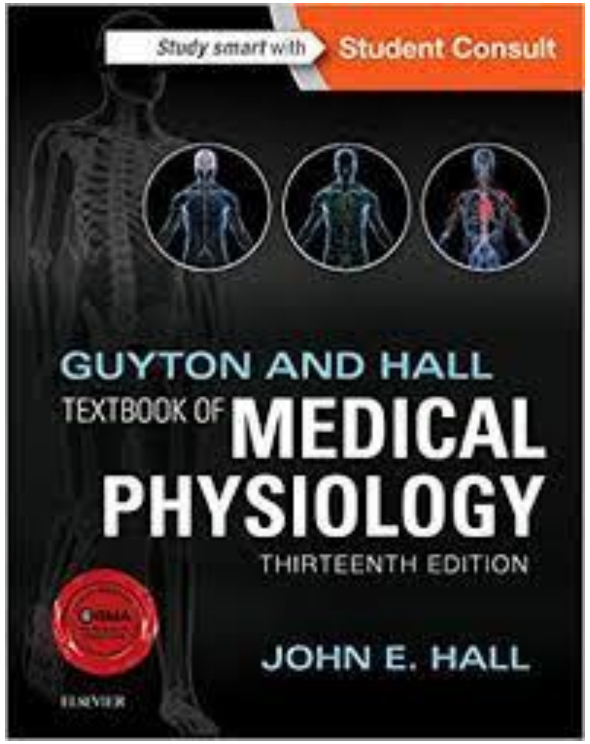
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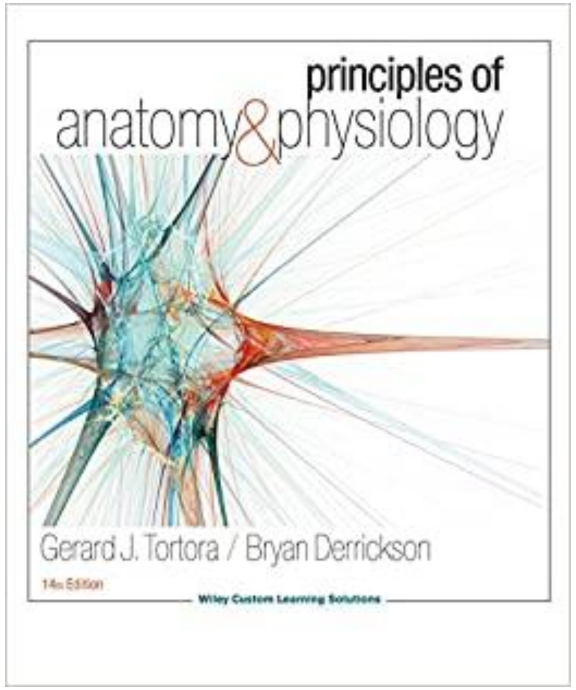
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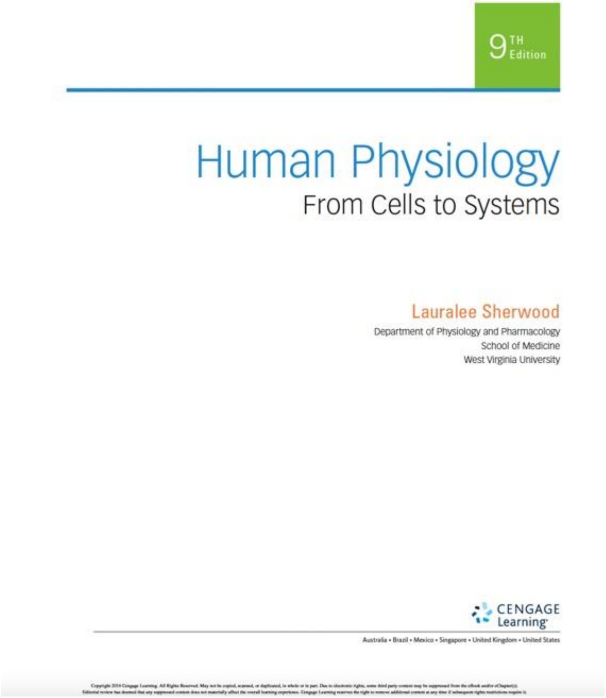
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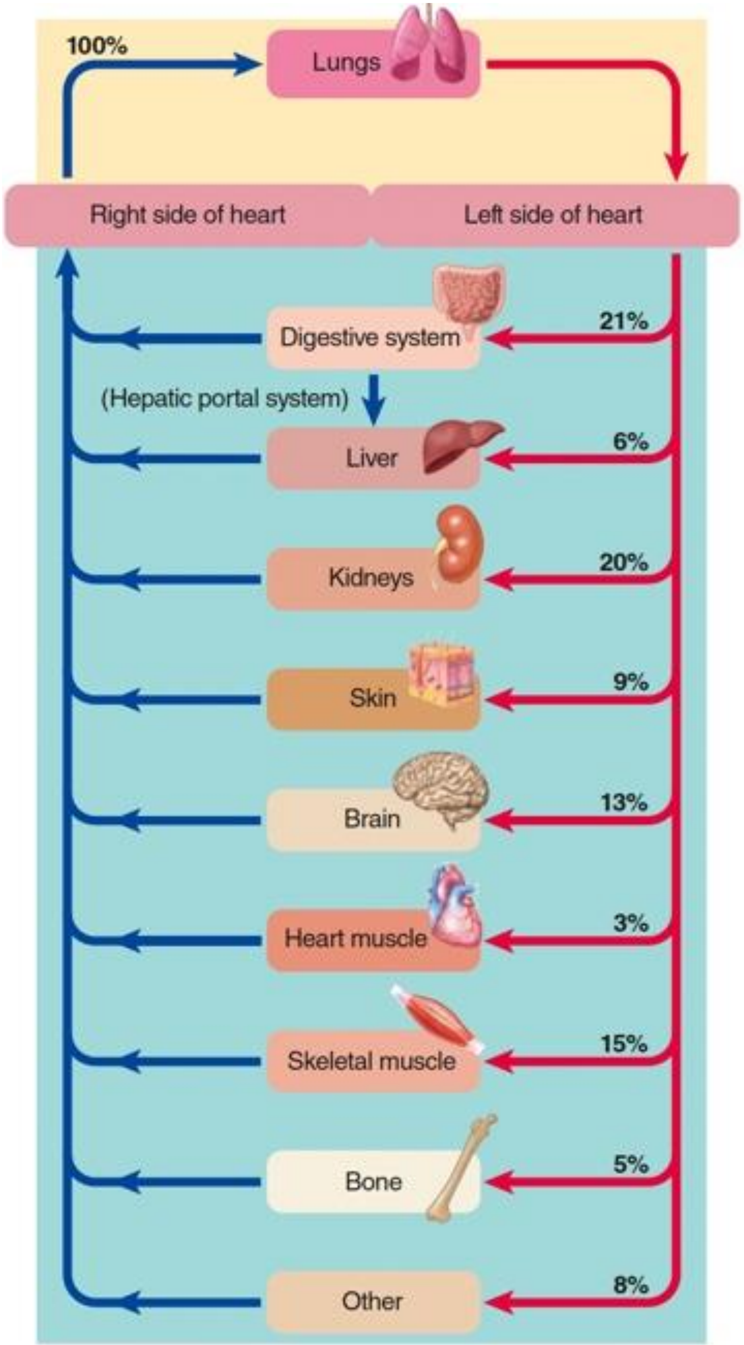
Vascular hemodynamics-1

Hemodynamics

- The principles that govern blood flow in the cardiovascular system.



100%
Lungs
Right side of heart
Left side of heart
Digestive system
21%
(Hepatic portal system)
Liver
6%
Kidneys
20%
Skin
9%
Brain
13%
Heart muscle
3%
Skeletal muscle
15%
Bone
5%
Other
8%

The parallel arrangement

- The blood pumped by the left side of the heart into the systemic circulation is distributed in various proportions to the systemic organs through a parallel arrangement of vessels that branch from the aorta.
- This arrangement ensures that:
- 1. all organs receive blood of the same composition.
- 2. blood flow through each systemic organ can be independently adjusted as needed.

Reconditioning organs

- Blood is constantly “reconditioned” so that its composition remains relatively constant despite an ongoing drain of supplies to support metabolic activities and despite continual addition of wastes from the tissues.
- Organs that recondition the blood normally receive much more blood flow than is necessary to meet their basic metabolic needs, so they can adjust the extra blood to achieve homeostasis.

Reconditioning organs

- Blood flow to the other organs is for filling these organs' metabolic needs and can be adjusted according to their level of activity.
- Because reconditioning organs—digestive organs, kidneys, and skin—receive blood flow in excess of their needs, they can withstand temporary reductions in blood flow much better than other organs can that do not have this extra margin of blood supply.

Reconditioning organs

- the brain, which can least tolerate disrupted blood supply, is a high priority in the overall operation of the circulatory system.
- In contrast, the reconditioning organs can tolerate significant reductions in blood flow for quite a long time, and often do.

Flow rate

- The flow rate of blood through a vessel is the volume of blood passing through per unit of time.
- It is directly proportional to the pressure gradient and inversely proportional to vascular resistance.
- $F = \Delta P/R$

Pressure gradient

- the difference in pressure between the beginning and the end of a vessel.
- Blood flows from an area of higher pressure to an area of lower pressure down a pressure gradient.
- It is generated by contraction of the heart.
- Because of resistance, the pressure drops as blood flows throughout the vessel’s length.
- The greater the pressure gradient, the greater the flow rate through the vessel.

Resistance

- a measure of opposition to blood flow through the vessel, caused by friction between the moving fluid and the vascular walls.
- As resistance to flow increases, it is more difficult for blood to pass through the vessel, so flow rate decreases.

Total peripheral resistance

- The resistance of the entire systemic vasculature is called the total peripheral resistance (TPR) or the systemic vascular resistance (SVR).
- TPR can be measured with the flow, pressure, and resistance relationship by substituting cardiac output for flow (Q) and the difference in pressure between the aorta and the vena cava for ΔP.

Resistance in a single organ

SAMPLE PROBLEM. Renal blood flow is measured by placing a flow meter on a woman's left renal artery. Simultaneously, pressure probes are inserted in her left renal artery and left renal vein to measure pressure. Renal blood flow measured by the flow meter is 500 mL/min. The pressure probes measure renal arterial pressure as 100 mm Hg and renal venous pressure as 10 mm Hg. *What is the vascular resistance of the left kidney in this woman?*

SOLUTION. Blood flow to the left kidney, as measured by the flow meter, is Q. The difference in pressure between the renal artery and renal vein is ΔP. The resistance to flow in the renal vasculature is calculated by rearranging the blood flow equation:

$$Q = \Delta P/R$$

Rearranging and solving for R,

$$\begin{aligned} R &= \Delta P/Q \\ &= (\text{Pressure in renal artery} - \text{Pressure in renal vein})/\\ &\quad \text{Renal blood flow} \end{aligned}$$

$$\begin{aligned} R &= (100\ \text{mm Hg} - 10\ \text{mm Hg})/500\ \text{mL per min} \\ &= 90\ \text{mm Hg}/500\ \text{mL per min} \\ &= 0.18\ \text{mm Hg/mL per min} \end{aligned}$$

Resistance

- 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.
- Poiseuille equation:

$$R = \frac{8\eta l}{\pi r^4}$$

Viscosity

- the friction developed between the molecules of a fluid as they slide over each other during flow of the fluid.
- The thicker a liquid is, the greater its viscosity, the greater the resistance to flow.
- Blood viscosity is determined primarily by the number of circulating red blood cells.

Vessel length and radius

- the longer the vessel, the greater the surface area and the greater the resistance to flow.
- resistance is inversely proportional to the fourth power of the radius.
- the radius of arterioles can be regulated and is the key factor in controlling resistance to blood flow throughout the vascular circuit.

Velocity of blood flow

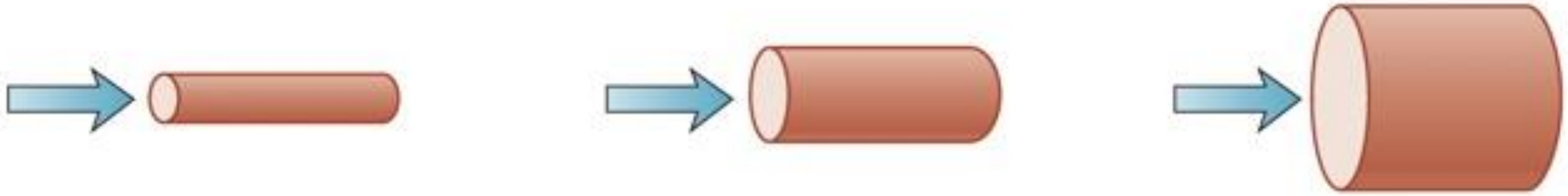
- The velocity of blood flow is the rate of displacement of blood per unit time.
- The blood vessels of the cardiovascular system vary in terms of diameter and cross sectional area. These differences in diameter and area, in turn, have profound effects on velocity of flow.
- The relationship between velocity, flow, and cross-sectional area (which depends on vessel radius or diameter) is
- $V = Q/A$

Velocity of blood flow

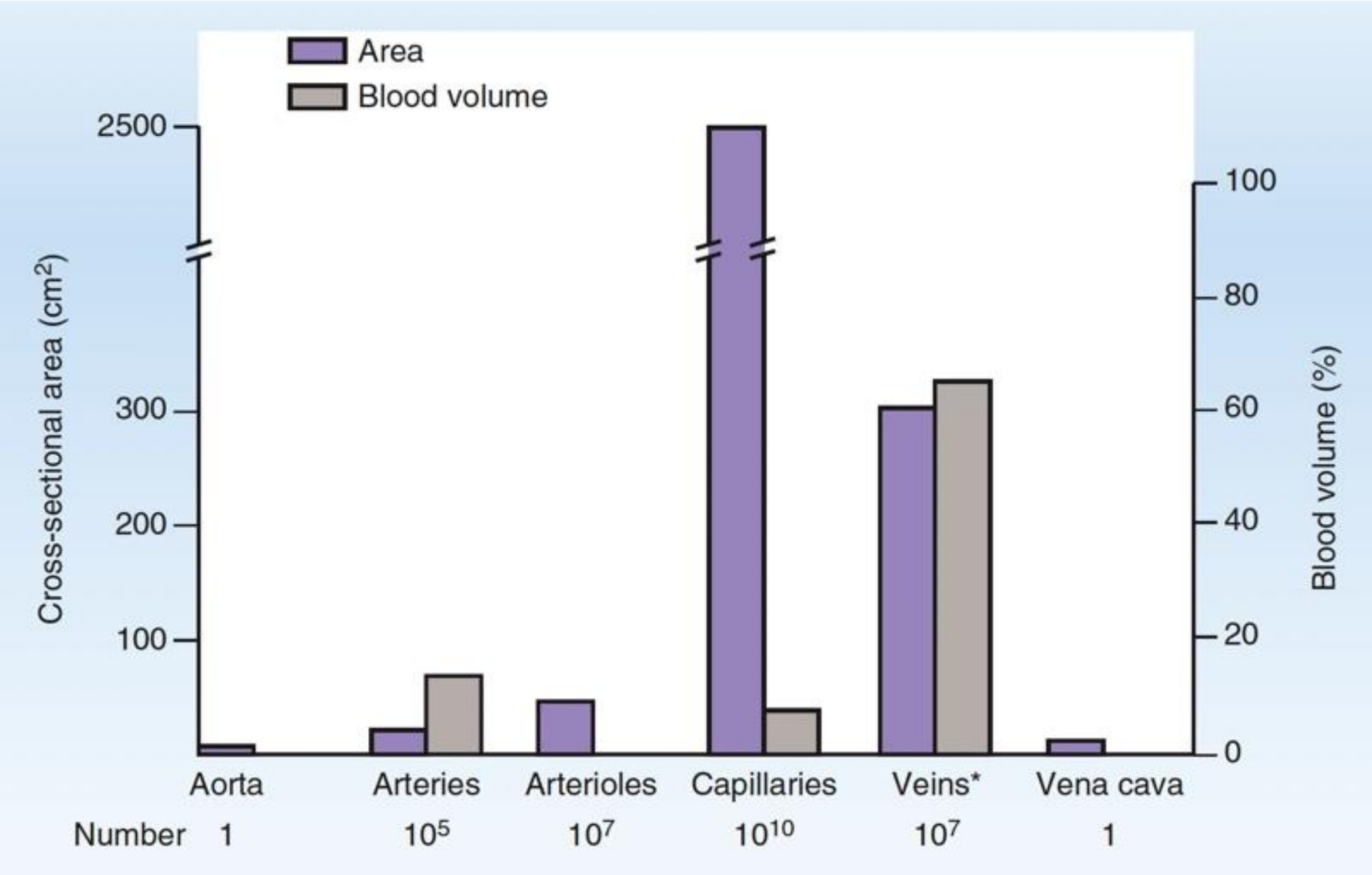
- Because of the inverse relationship between velocity and total cross-sectional area, the velocity of blood flow will be highest in the aorta and lowest in the capillaries.
- From the standpoint of capillary function (i.e., exchange of nutrients, solutes, and water), the low velocity of blood flow is advantageous, as it maximizes the time for exchange across the capillary walls.

$$v = Q/A$$

10 mL/s



Area (A)	1 cm^2	10 cm^2	100 cm^2
Flow (Q)	10 mL/s	10 mL/s	10 mL/s
Velocity (v)	**10 cm/s**	**1 cm/s**	**0.1 cm/s**



Area
Blood volume
2500
300
200
100
Cross-sectional area (cm²)
100
80
60
40
20
0
Blood volume (%)
Aorta
Arteries
Arterioles
Capillaries
Veins*
Vena cava
Number
1
10⁵
10⁷
10¹⁰
10⁷
1

Thank you