Vascular Physiology

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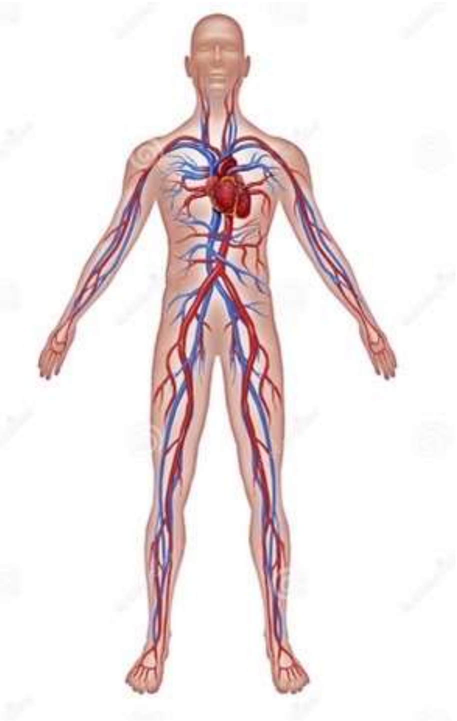

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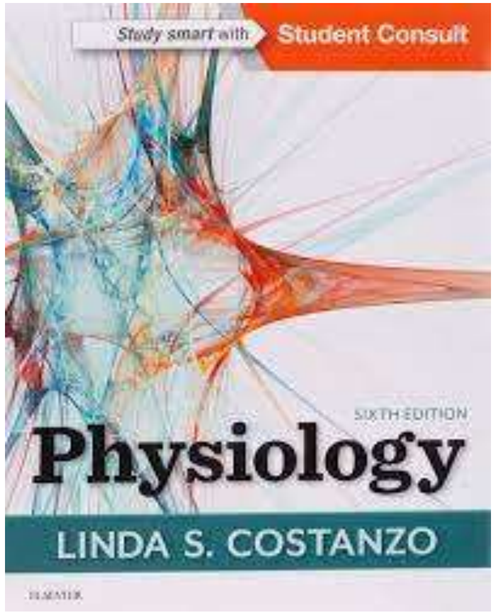
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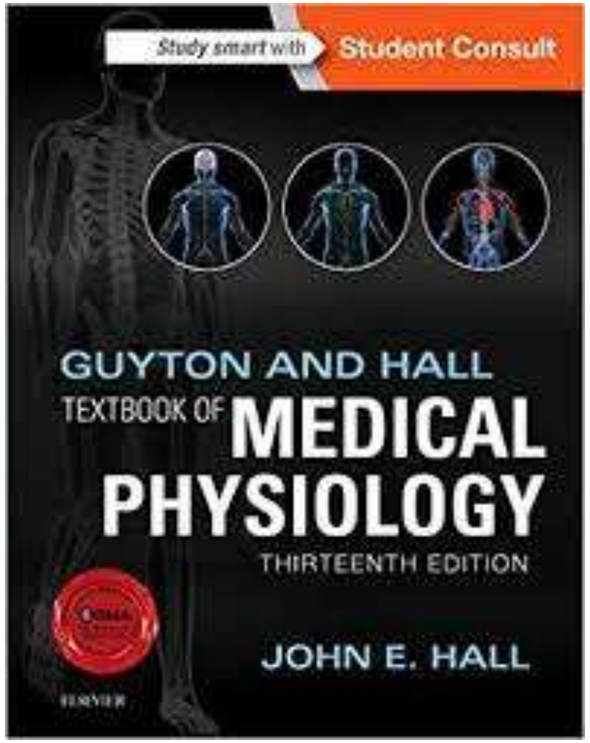
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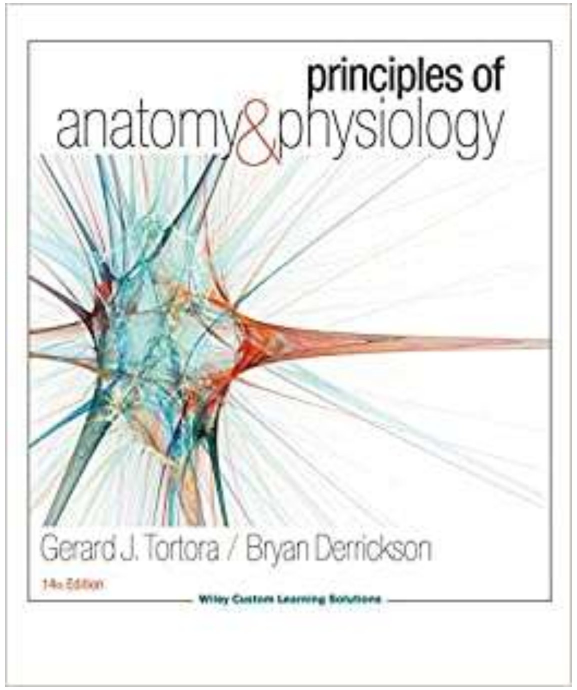
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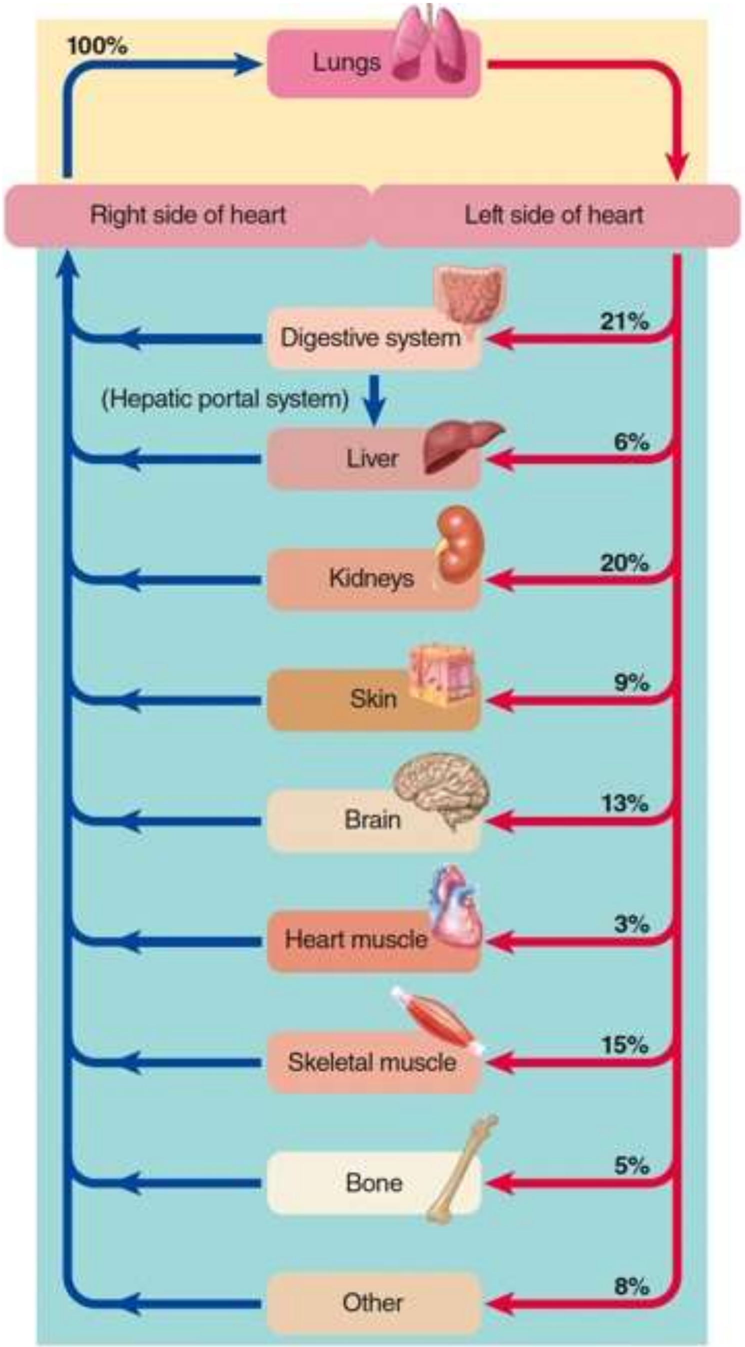
Vascular hemodynamics-1

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%

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.

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.

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.
- $F = \triangle P/R$

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 (F or 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

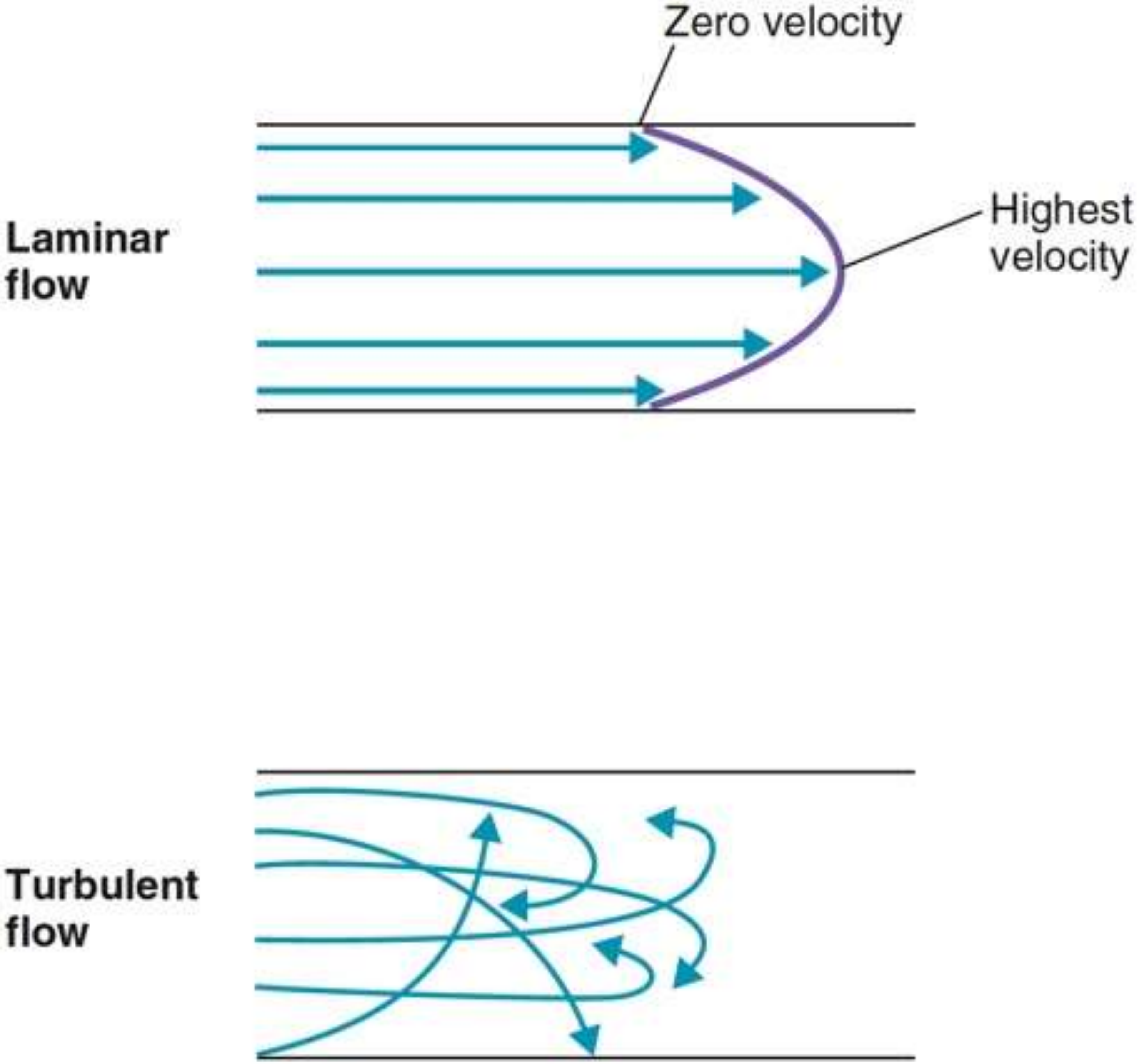
- the friction developed between the molecules of a fluid as they slide over each other during flow of the fluid.
- The thicker a liquid is, the greater its viscosity, the greater the resistance to flow.
- Blood viscosity is determined primarily by the number of circulating red blood cells.

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.

Laminar blood flow

- Ideally, blood flow in the cardiovascular system is laminar, or streamlined.
- In laminar flow, there is a smooth parabolic profile of velocity within a blood vessel, with the velocity of blood flow highest in the center of the vessel and lowest toward the vessel walls.


Zero velocity
Laminar flow
Highest velocity
Turbulent flow

Laminar blood flow

- The parabolic profile develops because the layer of blood next to the vessel wall adheres to the wall and, essentially, does not move.
- The next layer of blood slips past the motionless layer and moves a bit faster.
- Each successive layer of blood toward the center moves faster yet, with less adherence to adjacent layers.
- Thus the velocity of flow at the vessel wall is zero, and the velocity at the center of the stream is maximal.

Turbulent blood flow

- In turbulent flow, the fluid streams do not remain in the parabolic profile; instead, the streams mix radially and axially.
- Because kinetic energy is wasted in propelling blood radially and axially, more energy (pressure) is required to drive turbulent blood flow than laminar blood flow.
- Laminar flow is silent, while turbulent flow is audible.

Reynold number

- A dimensionless number that is used to predict whether blood flow will be laminar or turbulent.
- If Reynolds number is 200-400, blood flow is turbulent at some branches.
- If Reynolds number is greater than 2000 it is turbulent flow even in straight smooth vessels.

Thank you