Cardiovascular Physiology

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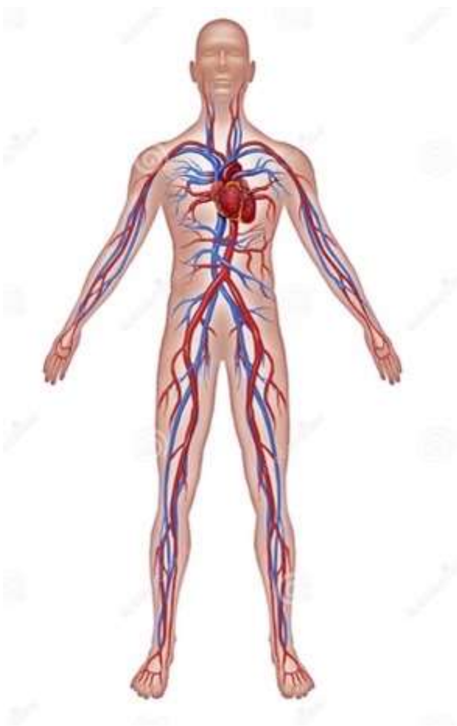
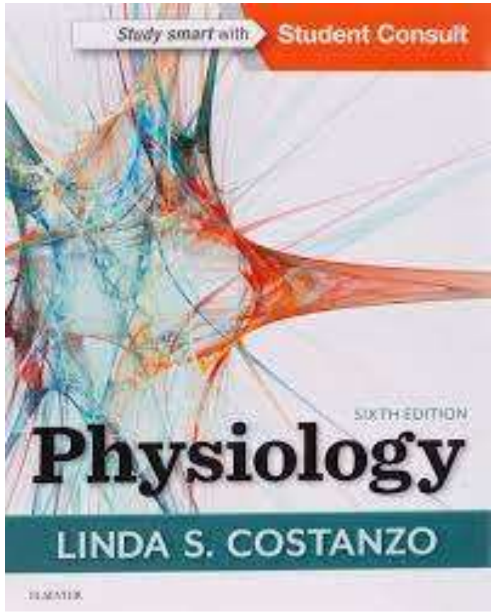


References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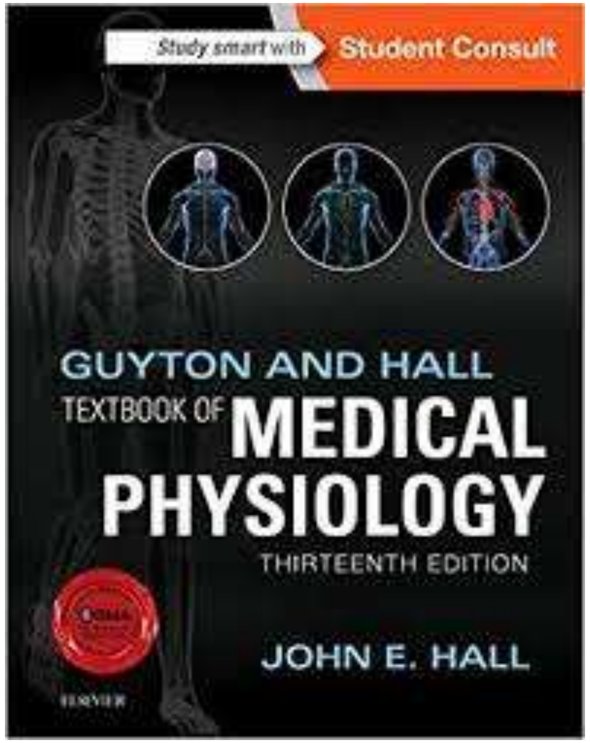
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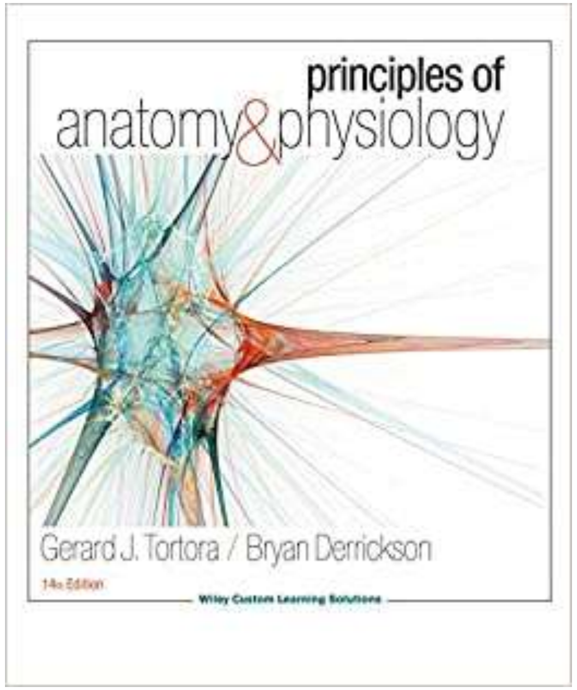
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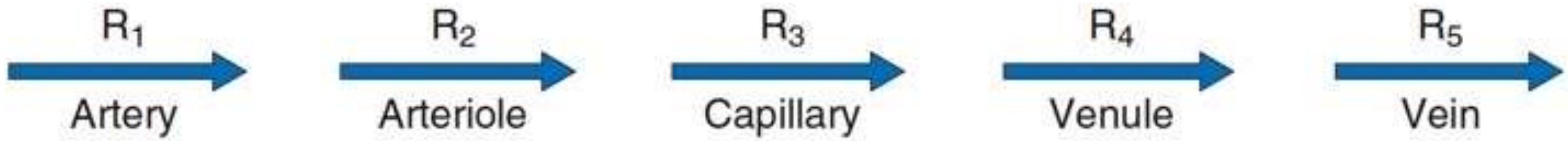
Vascular hemodynamics-2

Series resistances

- Within organ.
- The total resistance of the system arranged in series is equal to the sum of the individual resistances.
- The total resistance of a vascular bed is determined in large part by the arteriolar resistance.
- When resistances are arranged in series, the total flow at each level of the system is the same.

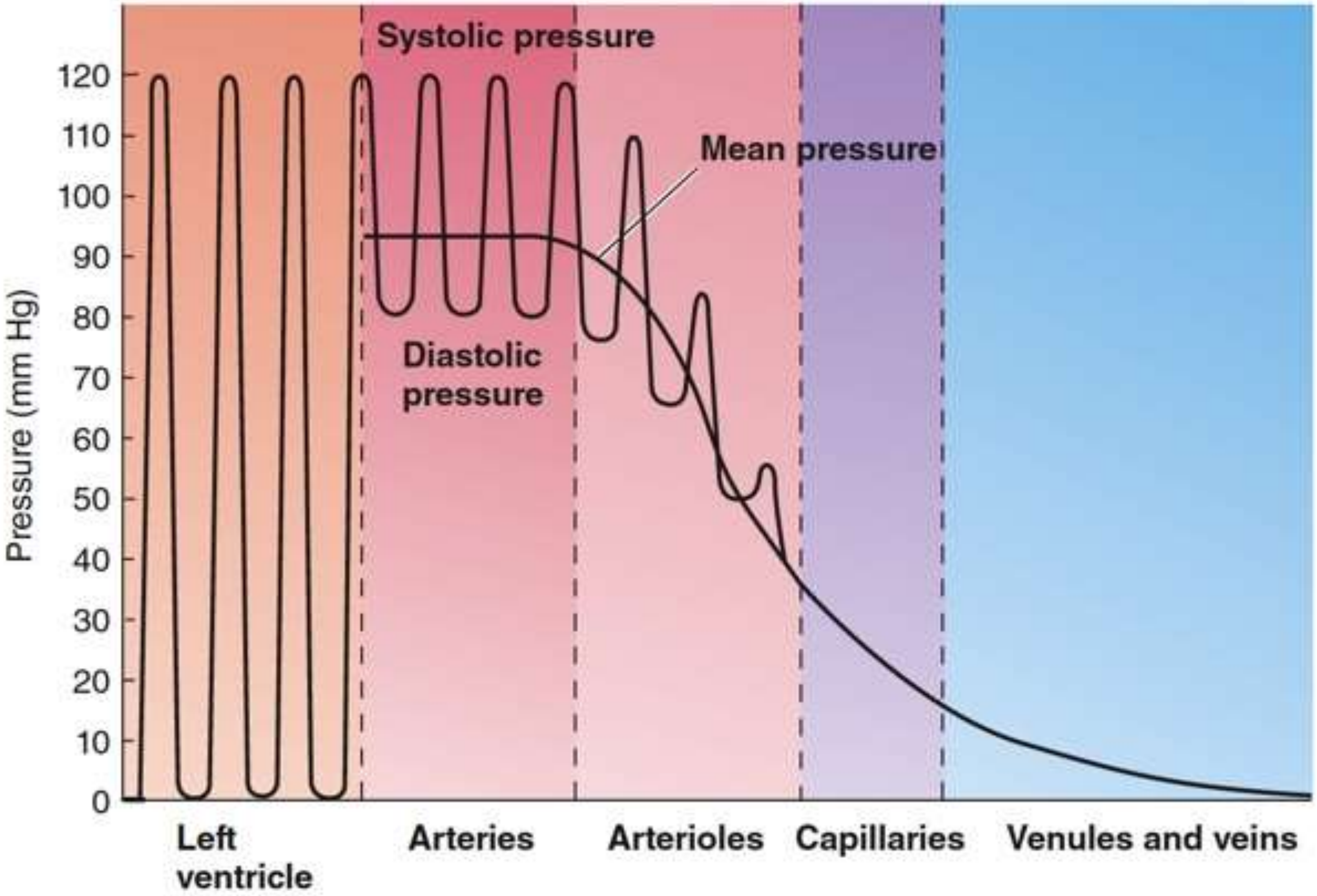
SERIES RESISTANCES

$$R_{total} = R_1 + R_2 + R_3 + R_4 + R_5$$



Series resistances

- Although total flow is constant at each level in the series, the pressure decreases progressively as blood flows through each sequential component.
- The greatest decrease in pressure occurs in the arterioles because they contribute the largest portion of the resistance.



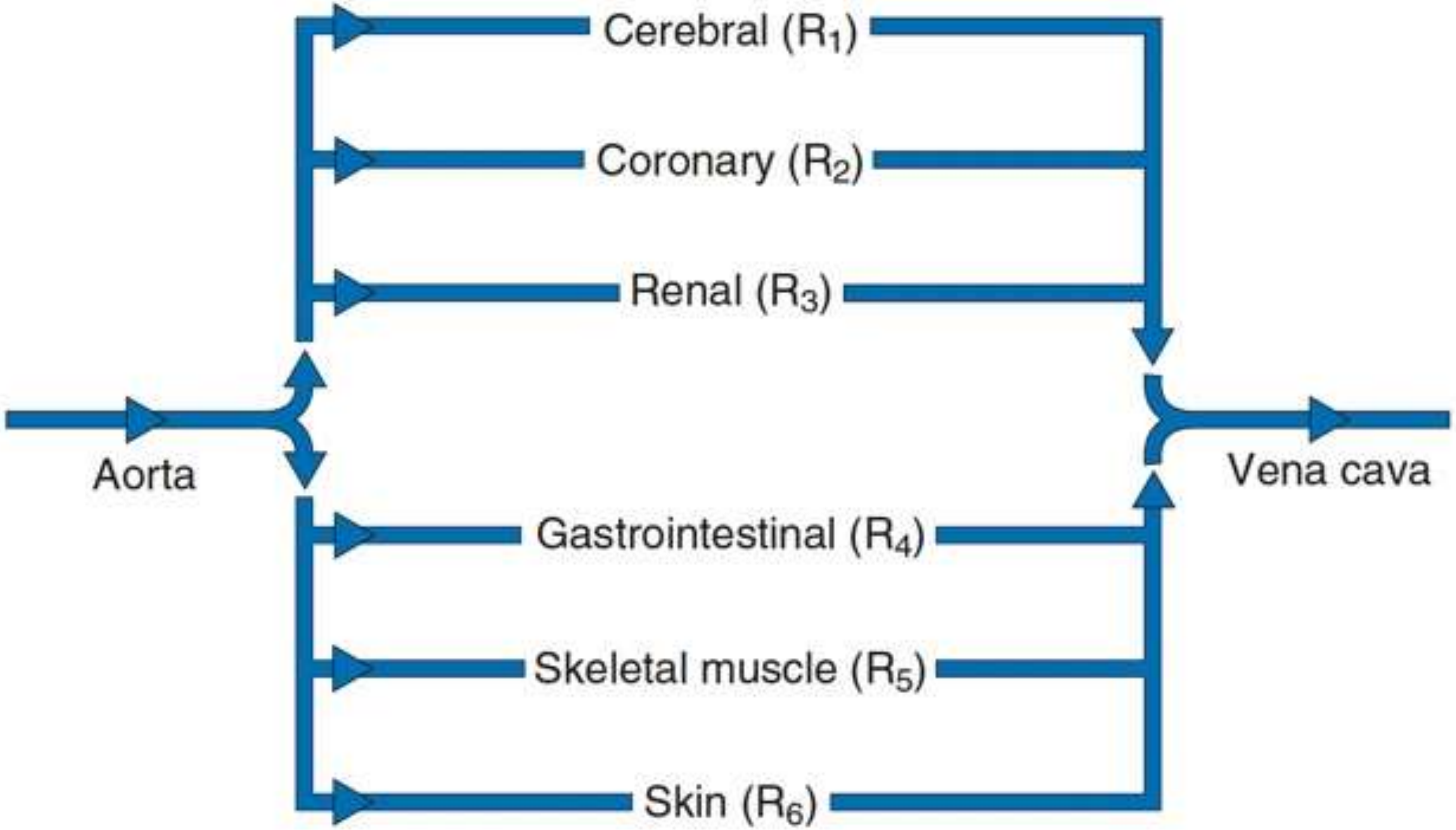
Systolic pressure
Mean pressure
Diastolic pressure
Pressure (mm Hg)
120
110
100
90
80
70
60
50
40
30
20
10
0
Left ventricle
Arteries
Arterioles
Capillaries
Venules and veins

Parallel resistances

- the total resistance in a parallel arrangement is less than any of the individual resistances.
- When blood flow is distributed through a set of parallel resistances, the flow through each organ is a fraction of the total blood flow.
- The effects of this arrangement are that there is no loss of pressure in the major arteries and that mean pressure in each major artery will be the same and be approximately the same as mean pressure in the aorta.

PARALLEL RESISTANCES

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_6}$$

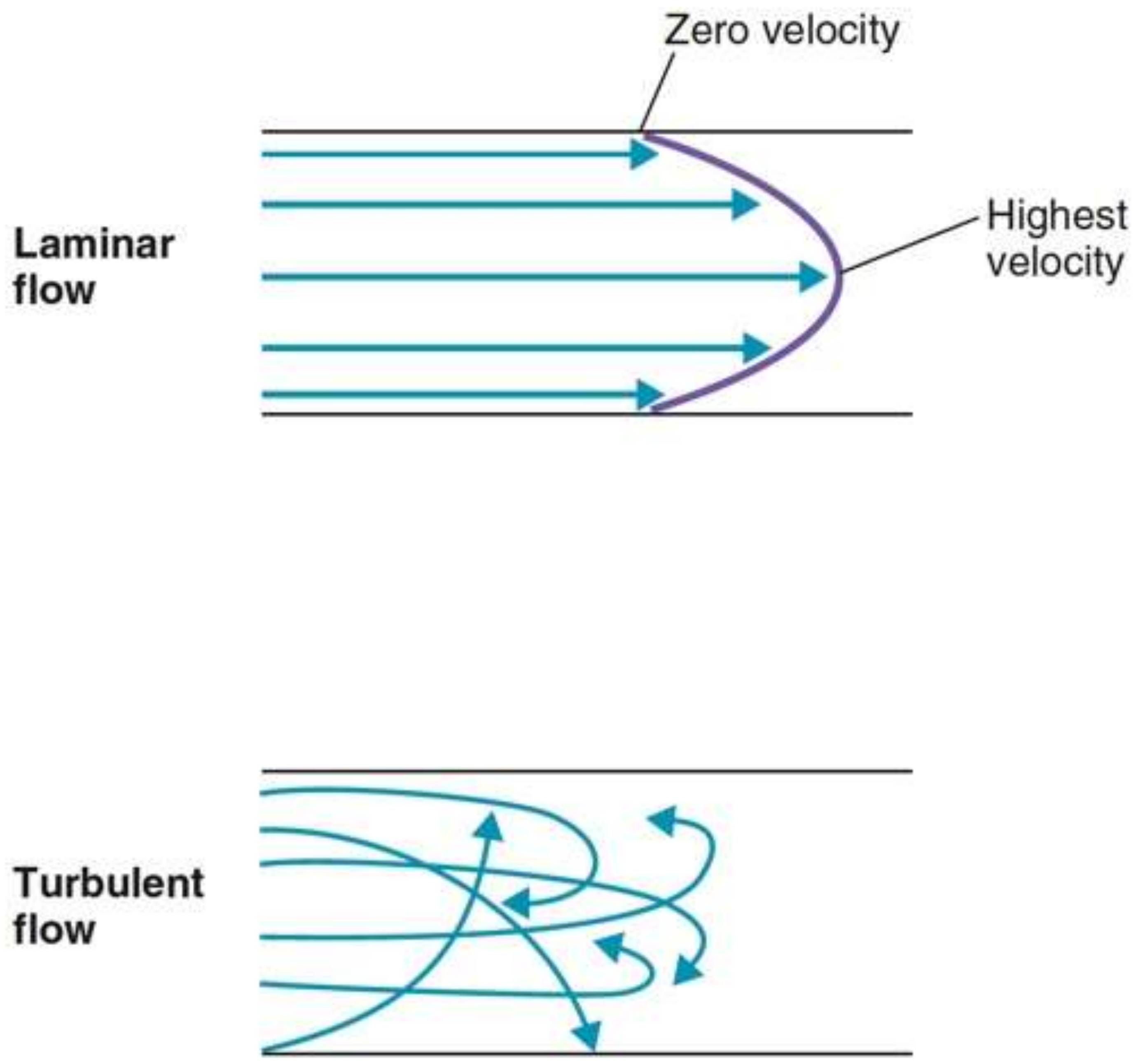


Parallel resistances

- Another predictable consequence of a parallel arrangement is that adding a resistance to the circuit causes total resistance to decrease.
- if the resistance of one of the individual vessels in a parallel arrangement increases, then total resistance increases.

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 less than 2000, blood flow will be laminar.
- If Reynolds number is greater than 3000 always predict turbulent flow.

$$N_R = \frac{\rho d v}{\eta}$$

where

$$N_R = \text{Reynolds number}$$
$$\rho = \text{Density of blood}$$
$$d = \text{Diameter of blood vessel}$$
$$v = \text{Velocity of blood flow}$$
$$\eta = \text{Viscosity of blood}$$

Reynold number

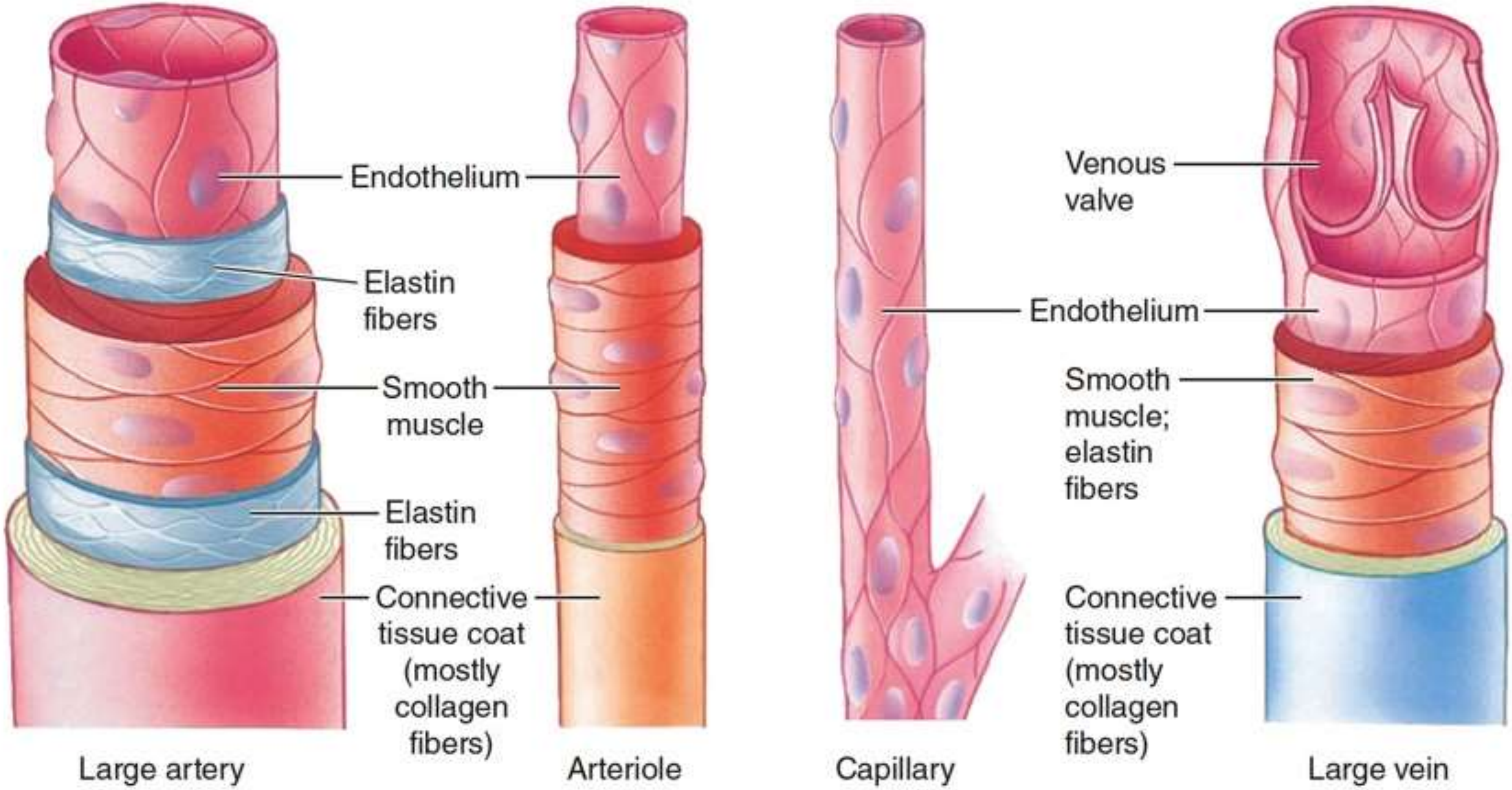
- Anemia:

- Reynolds number is increased in anemia due to decreased blood viscosity.
- A second cause is a high cardiac output, which causes an increase in the velocity of blood flow.

Reynold number

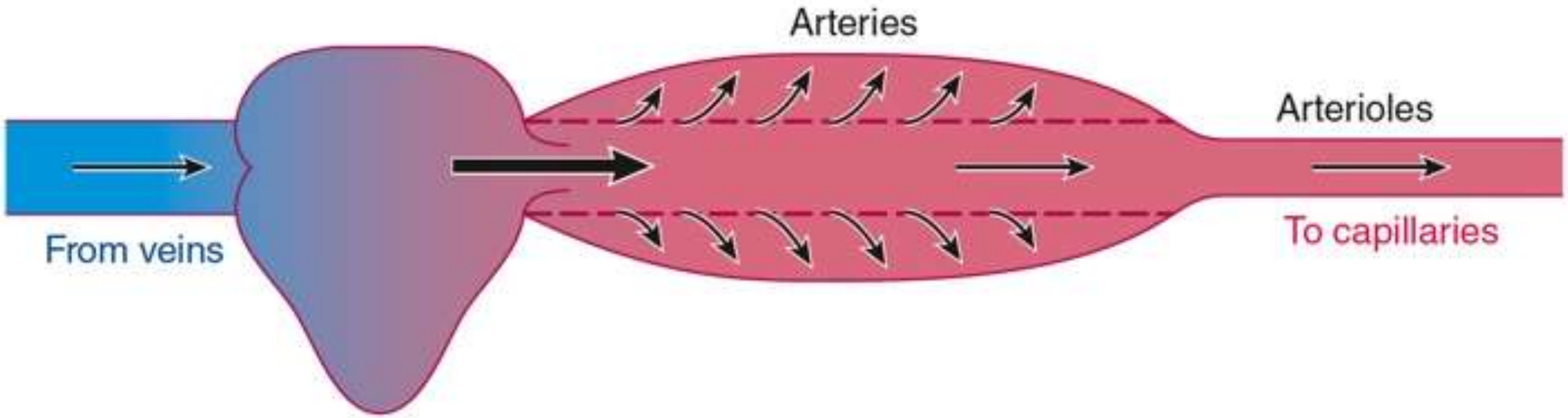
- Thrombi:

- narrow the diameter of the blood vessel, which causes an increase in blood velocity at the site of the thrombus, thereby increasing Reynolds number and producing turbulence.

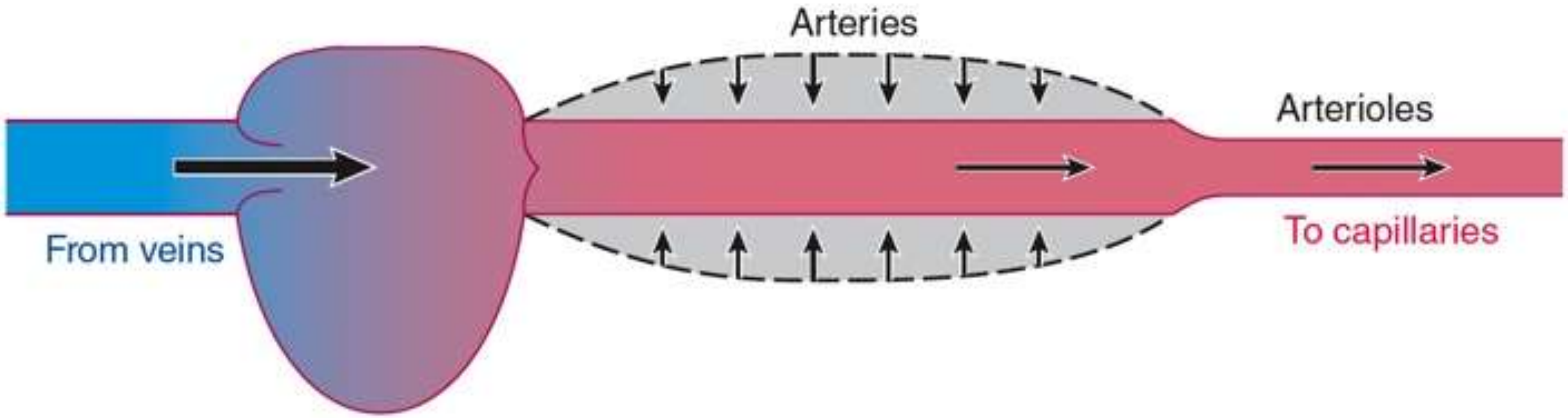

Endothelium
Elastin fibers
Smooth muscle
Elastin fibers
Connective tissue coat (mostly collagen fibers)
Large artery
Arteriole
Capillary
Venous valve
Endothelium
Smooth muscle; elastin fibers
Connective tissue coat (mostly collagen fibers)
Large vein

Arteries

- Arteries are specialized
- (1) to serve as rapid-transit passageways for blood from the heart to the organs.
- (2) to act as a pressure reservoir to provide the driving force for blood when the heart is relaxing.



(a) Heart contracting and emptying



Elastic arteries

- 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 and 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.

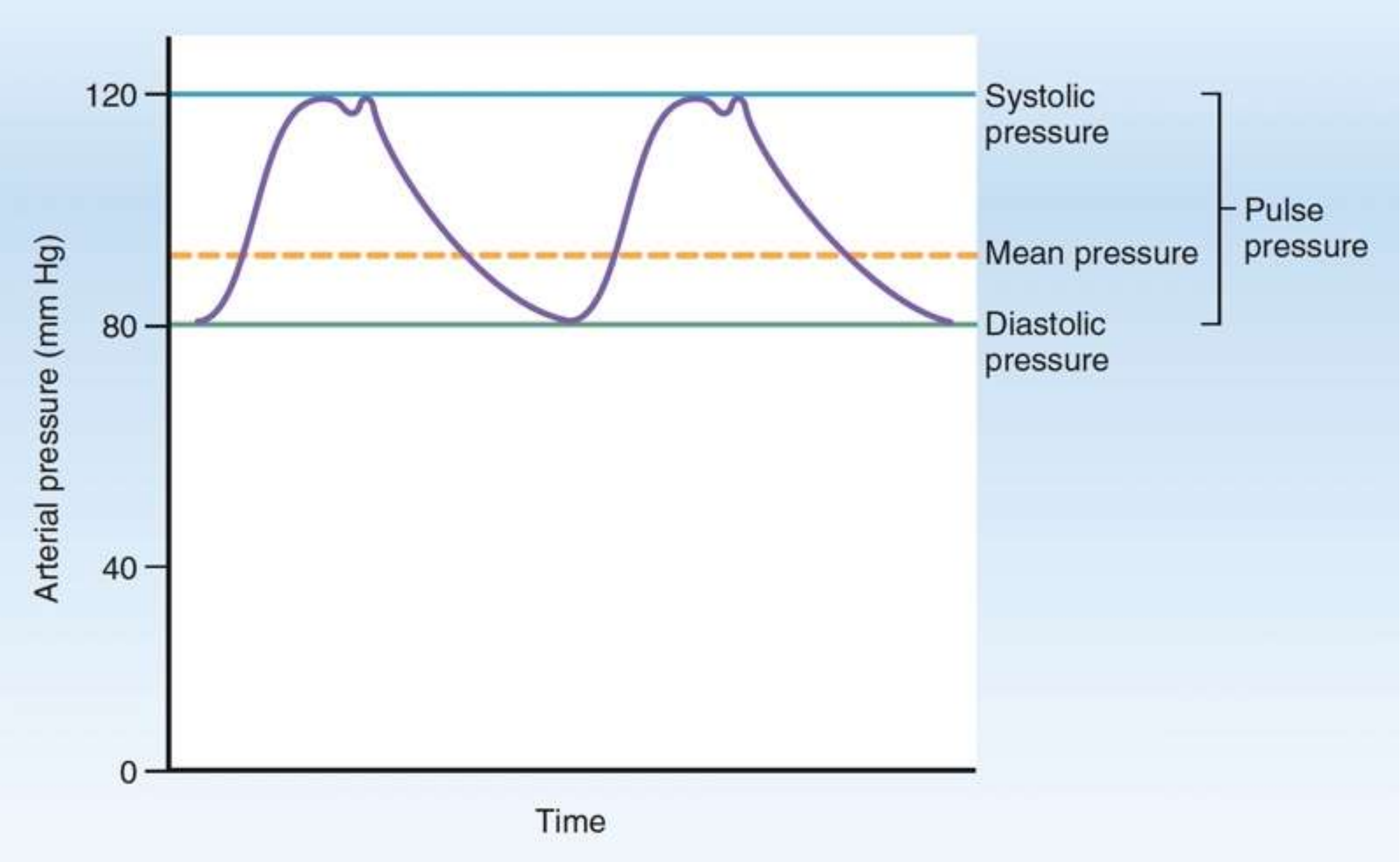
Stressed vs unstressed volumes

- The volume of blood contained in the arteries is called the stressed volume (meaning the blood volume under high pressure).

- The volume of blood contained in the veins is called the unstressed volume (meaning the blood volume under low pressure).

Blood pressure

- Blood pressure: the force exerted by the blood against a vessel wall.
- depends on the volume of blood contained within the vessel and the compliance, or distensibility, of the vessel walls (how easily they can be stretched).
- Systolic pressure (SBP): the maximum pressure exerted in the arteries when blood is ejected into them during systole.
- Diastolic pressure (DBP): the minimum pressure within the arteries when blood is draining off into the rest of the vessels during diastole.



120
80
40
0
Arterial pressure (mm Hg)
Time
Systolic pressure
Mean pressure
Diastolic pressure
Pulse pressure

Blood pressure

- Although ventricular pressure falls to 0 mm Hg during diastole, arterial pressure does not fall to 0 mm Hg.
- Pulse pressure (PP): the difference between systolic and diastolic pressures.
- Because the pulse can be felt each time the ventricles pump blood into the arteries, the pulse rate is a measure of the heart rate.

Mean arterial pressure

- The mean arterial pressure (MAP) is the average pressure driving blood forward into the tissues throughout the cardiac cycle.
- MAP, not the systolic or diastolic pressure, is the pressure that is monitored and regulated.
- MAP is not the halfway value between systolic and diastolic pressure.
- The reason is that arterial pressure remains closer to diastolic than to systolic pressure for a longer portion of each cardiac cycle.
- At resting heart rate, about two thirds of the cardiac cycle is spent in diastole and only one third in systole.

Arterial blood pressure

- MAP = DBP + 1/3 PP
- Because arteries offer little resistance to flow, only a negligible amount of pressure energy is lost in them because of friction.
- Therefore, arterial pressure—systolic, diastolic, pulse, or mean—is essentially the same in all arteries.

Thank you