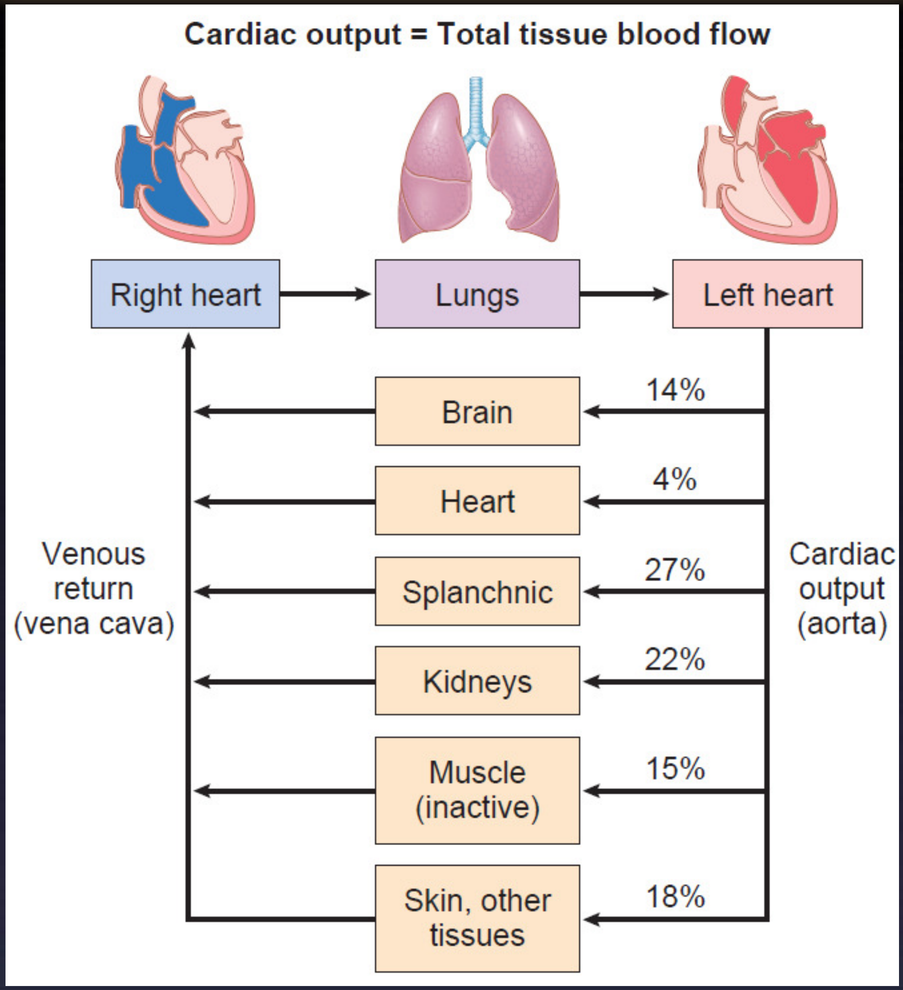
VENOUS RETURN & FACTORS AFFECTING VR



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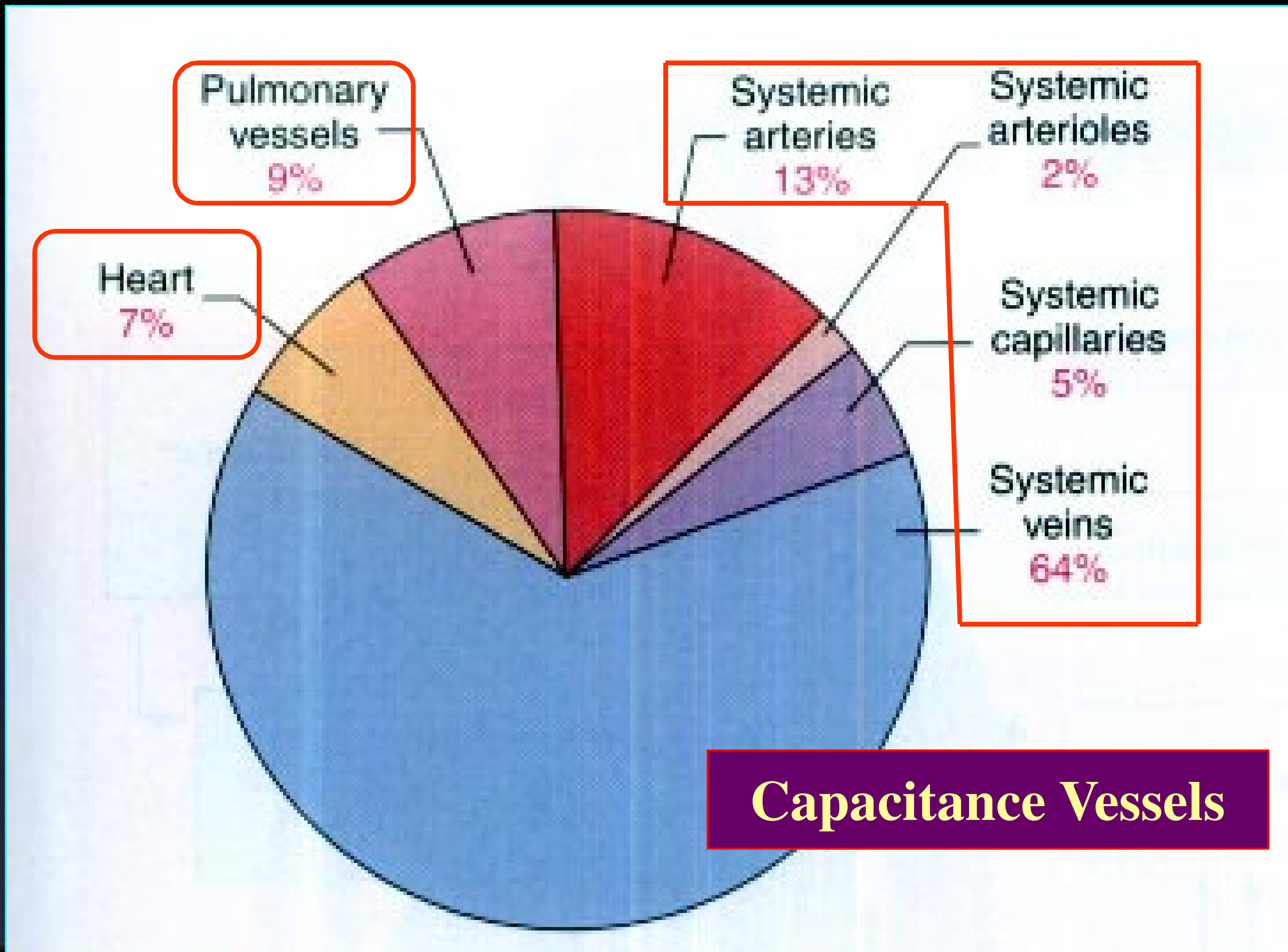
OBJECTIVES

- ❖ **At the end of the lecture you should be able to …..**

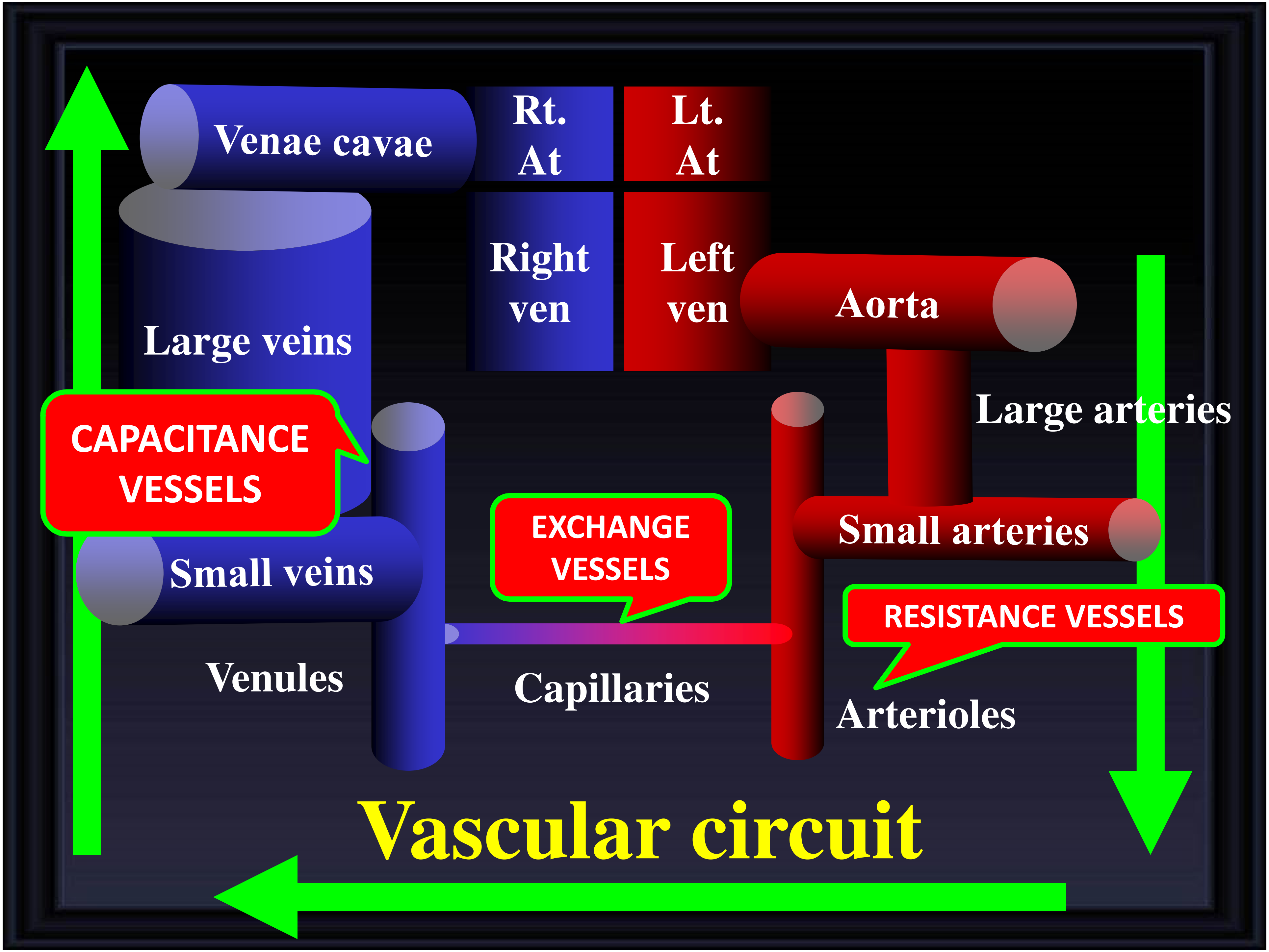
- Discuss functions of the veins as blood reservoirs.
- Describe measurement of central venous pressure (CVP) and state its physiological and clinical significance.
- State determinants of venous return and explain how they influence venous return.
- Define mean systemic filling pressure, give its normal value and describe the factors which affect it.
- Explain the effect of gravity on venous pressure and explain pathophysiology of varicose veins.
- Describe vascular and cardiac function curves under physiological and pathophysiological conditions.

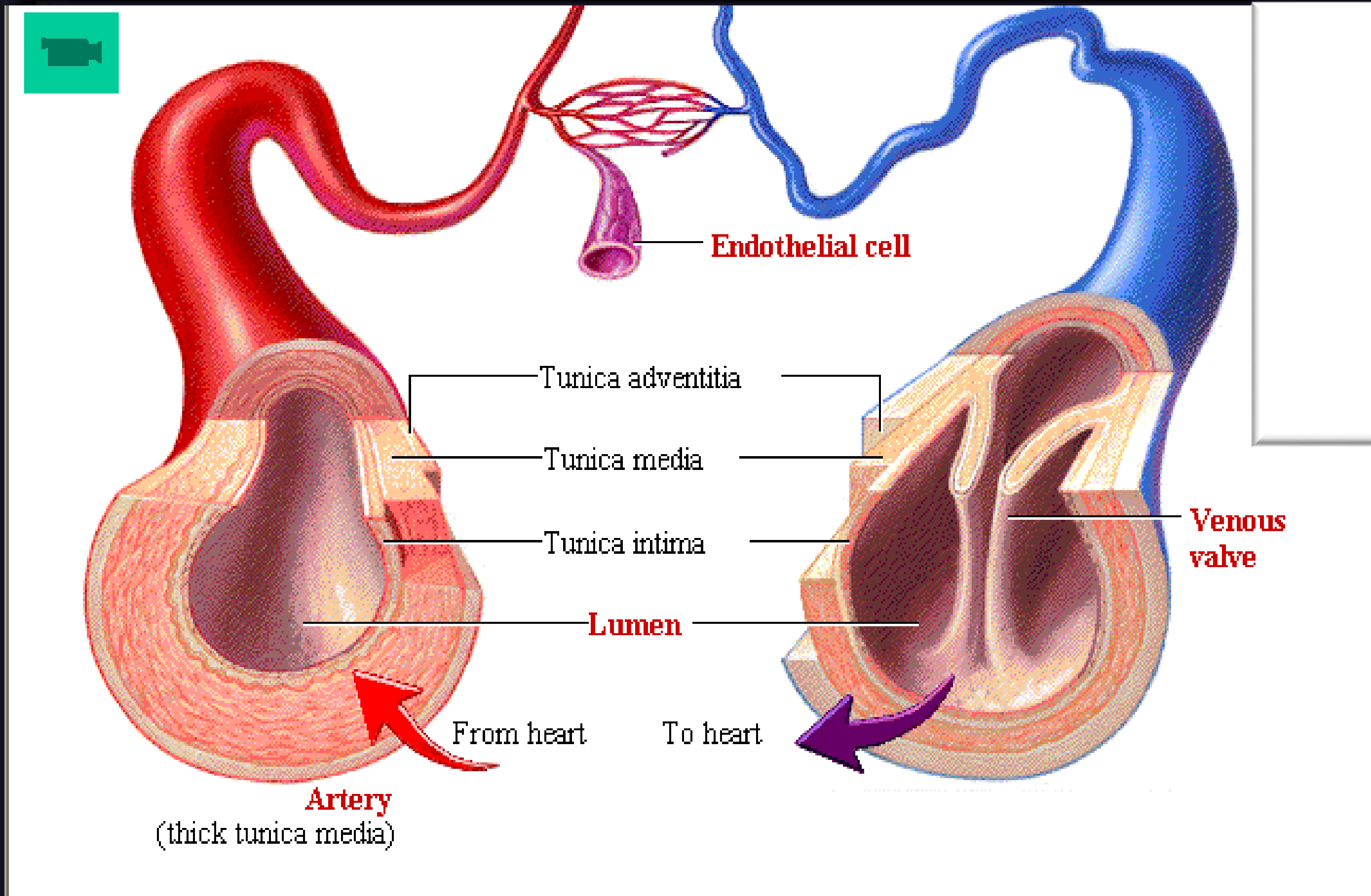
DISTRIBUTION OF BLOOD

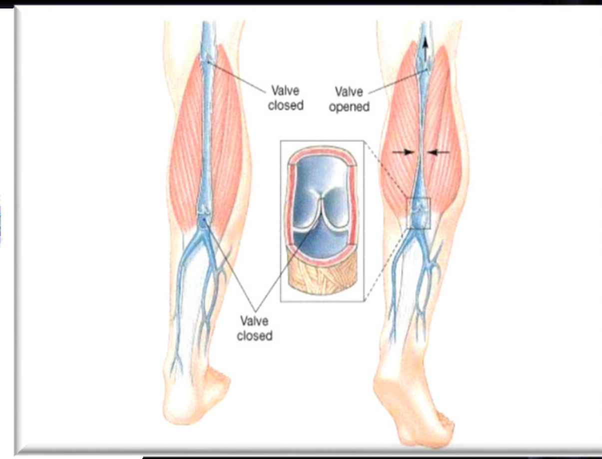


Veins are blood reservoirs

- When the body is at rest and many of the capillaries are closed, the capacity of the venous reservoir is increased as extra blood bypasses the capillaries and enters the veins.
- When this extra volume of blood stretches the veins, the blood moves forward through the veins more slowly because the total cross sectional area of the veins has increased as a result of the stretching. Therefore, blood spends more time in the veins.
- When the stored blood is needed, such as during exercise, extrinsic factors reduce the capacity of the venous reservoir and drive the extra blood from the veins to the heart so that it can be pumped to the tissues.


Venae cavae
Rt. At
Lt. At
Right ven
Left ven
Aorta
Large veins
Large arteries
CAPACITANCE VESSELS
EXCHANGE VESSELS
Small arteries
Small veins
RESISTANCE VESSELS
Venules
Capillaries
Arterioles
Vascular circuit





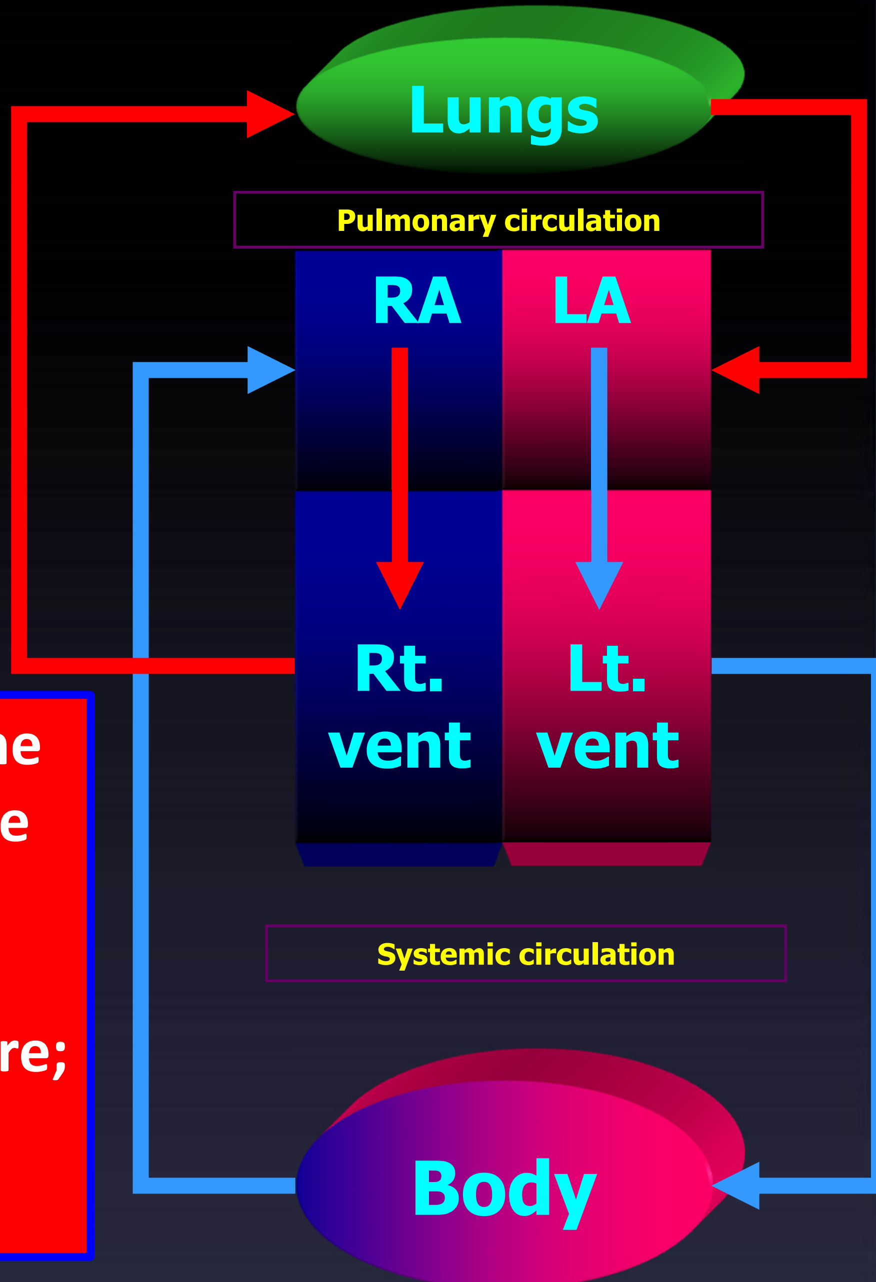
- **all 3 layers are present, but thinner than in arteries of corresponding size (external diameter).**
- **Veins have paired semilunar, bicuspid valves to restrict backflow in lower extremities:**

In varicose veins, blood pools because valves fail causing venous walls to expand.

VENOUS RETURN

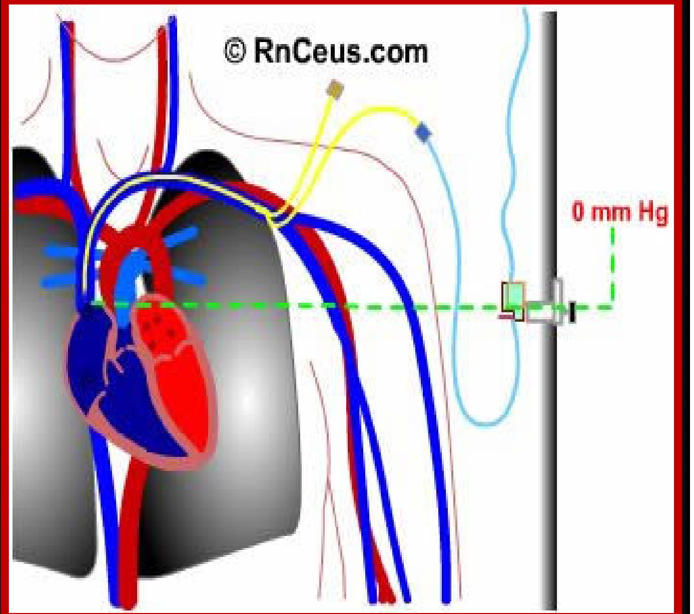
Normally venous return must equal cardiac output (CO) when averaged over time because the cardiovascular system is essentially a closed loop. Otherwise, blood would accumulate in either the systemic or pulmonary circulations.

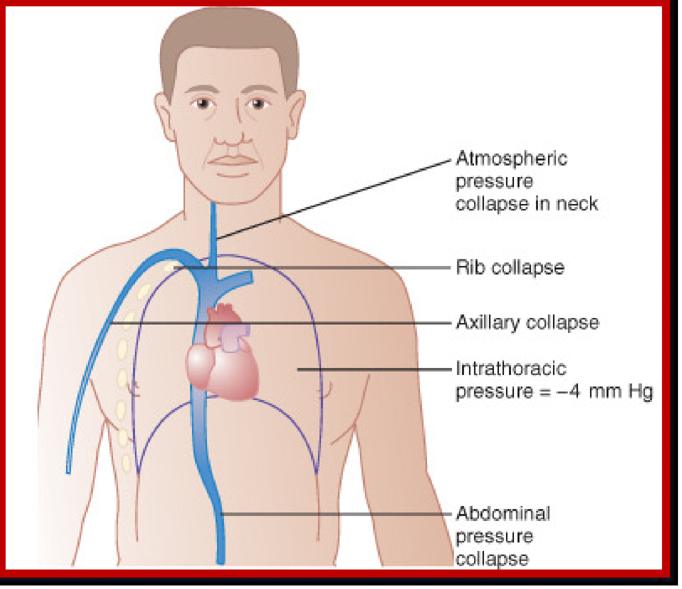
Venous return is determined by the difference in pressure between the venous pressure nearest to the tissues (mean systemic filling pressure; mean circulatory pressure; MCP) and the venous pressure nearest to the heart (CVP).



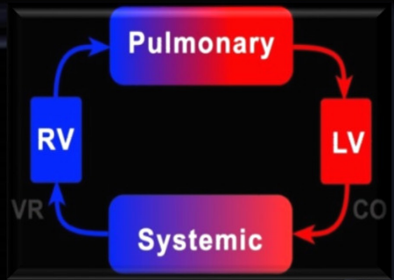
Central venous pressure (CVP)

- CVP: is the pressure in the right atrium and the big veins of the thorax (right atrial pressure (RAP) = jugular venous pressure).
- CVP is measured with a catheter inserted in SVC.
- The normal range of the CVP = 0 - 4 mm Hg.
- It is the force responsible for cardiac filling.
- CVP is used clinically to assess hypovolaemia and during IV transfusion to avoid volume overloading.
- CVP is raised in right-sided heart failure.





Mean Systemic Filling Pressure (MSFP)
Mean Circulatory Pressure (MCP)



- ❑ It is the pressure nearest to the tissues and is about 7 mm Hg.
- ❑ The value for right atrial pressure at which venous return is zero is called the mean systemic filling pressure.

IT IS AFFECTED BY:

- ❑ Blood volume (it is directly proportional to blood volume).
- ❑ Venous capacity (it is inversely proportional to the venous capacity).

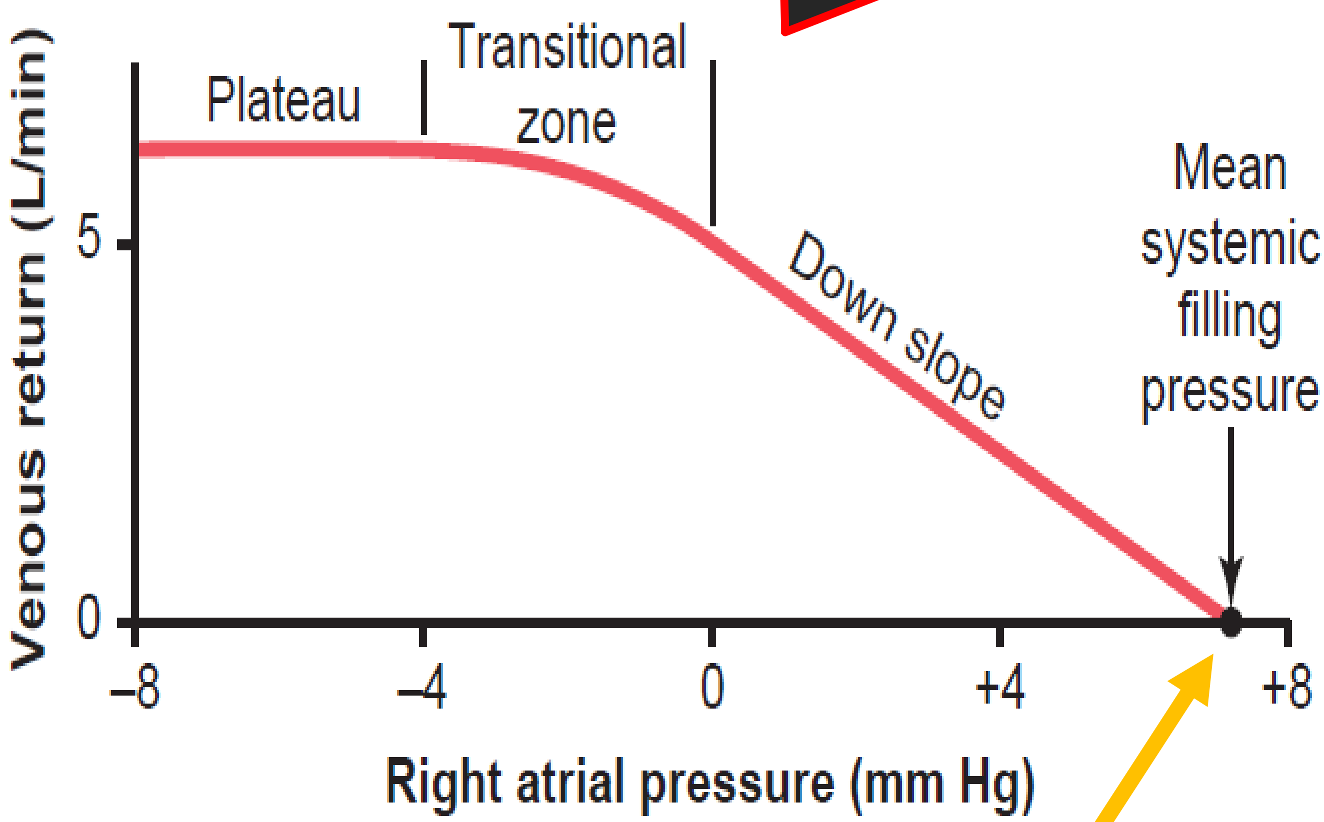
↑ VOLUME ↑ MCP

↓ VOLUME ↓ MCP

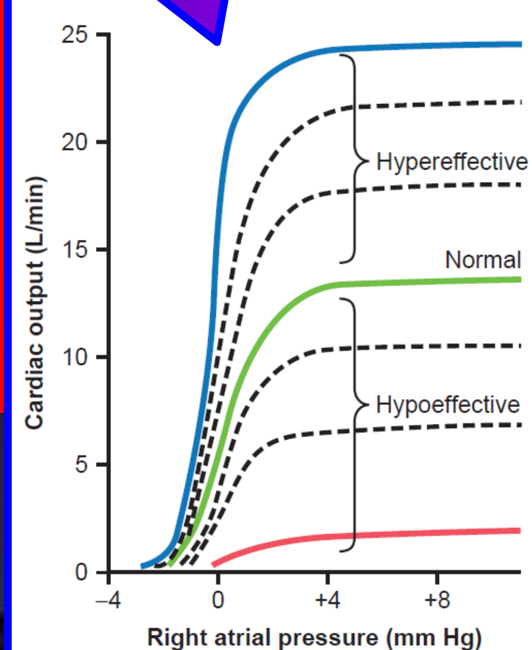
VENOCONSTRICTION ↑ MCP

VENODILATION ↓ MCP

The **VENOUS RETURN CURVE** relates venous return also to right atrial pressure



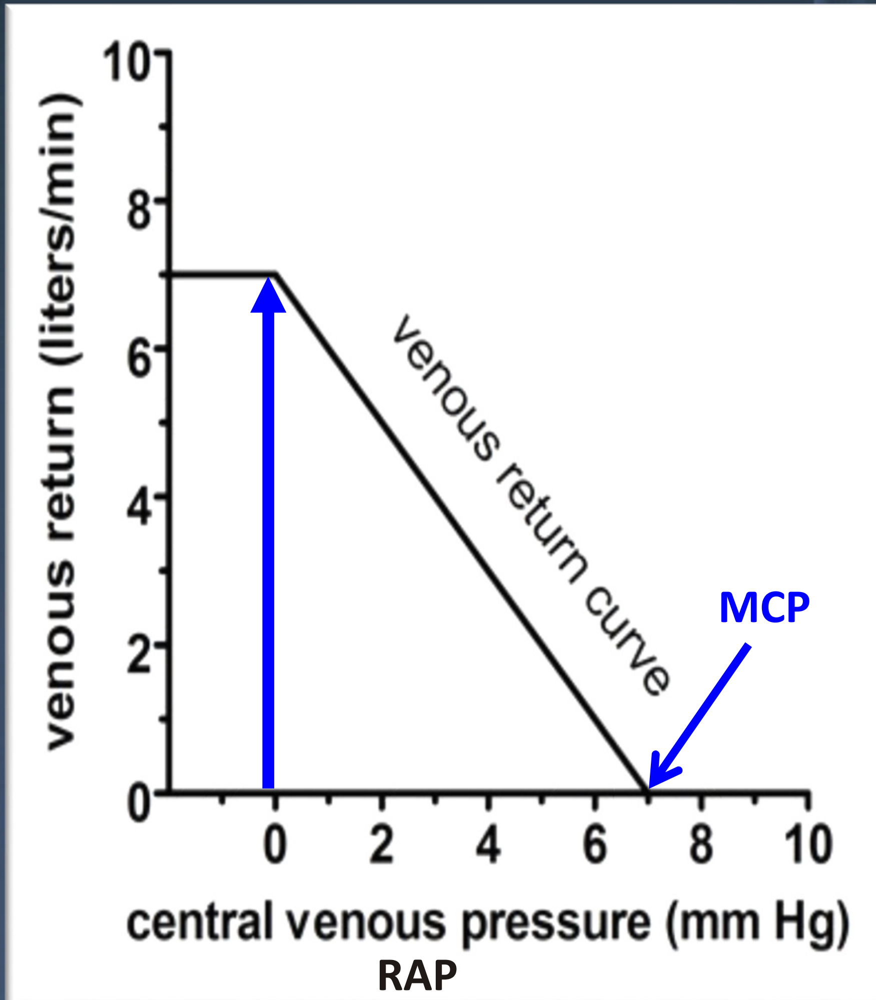
The cardiac output curve relates pumping of blood by the heart to right atrial pressure



It is the point at which the vascular function curve intersects the X-axis (i.e., where venous return is zero and right atrial pressure is at its highest value).

Venous return curve
Vascular function curve

- There is an inverse relationship between venous return and right atrial pressure (RAP).
- Venous return back to the heart, like all blood flow, is driven by a pressure gradient. The lower the pressure in the right atrium, the higher the pressure gradient the greater the venous return.
- Thus as RAP increases, this pressure gradient decreases and venous return also decreases.
- The knee (flat portion) of the vascular function curve occurs at negative values of RAP. At such negative values, the veins collapse & impedes VR inspite of high pressure gradient.

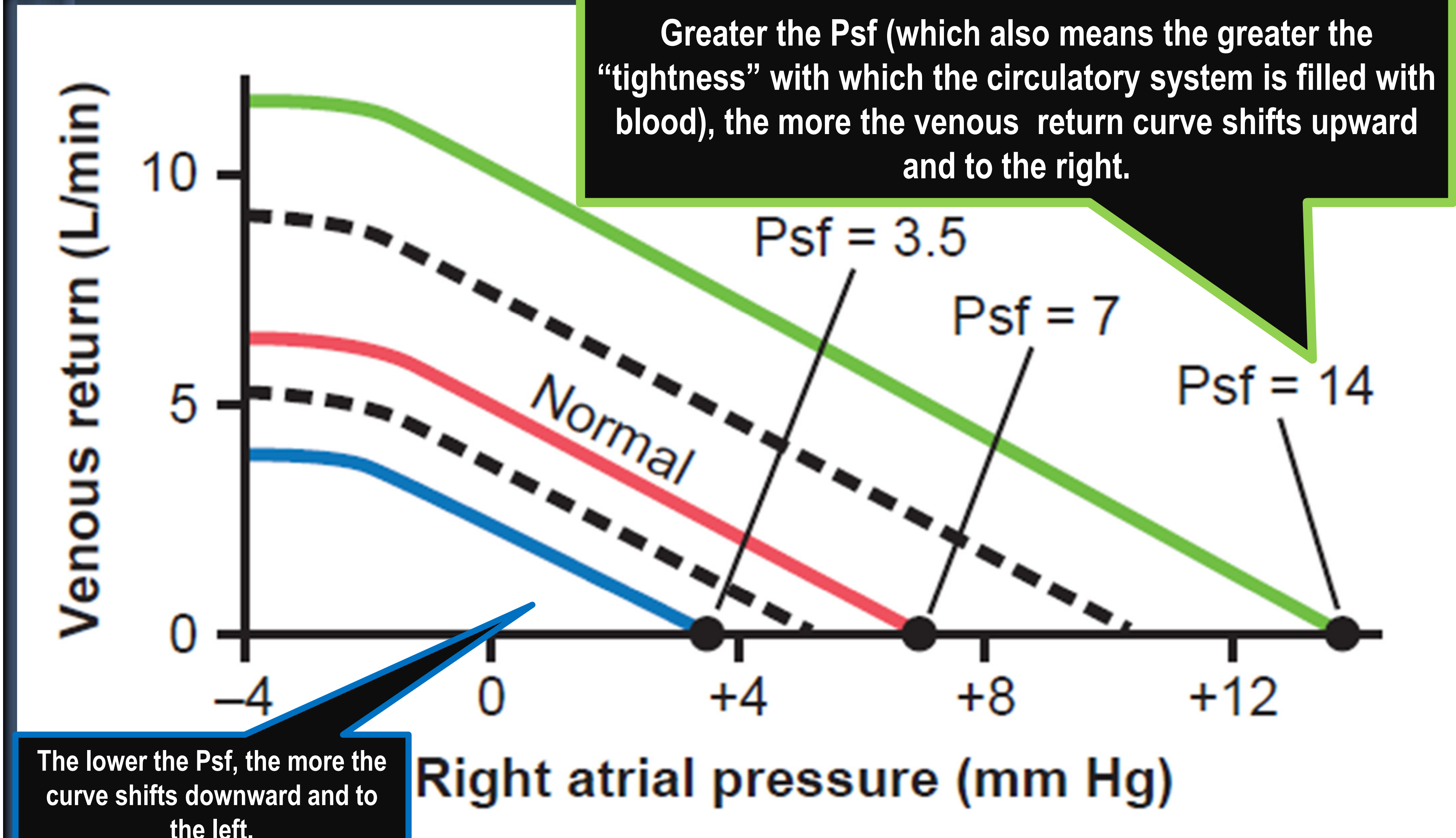


PRESSURE GRADIENT FOR VENOUS RETURN:

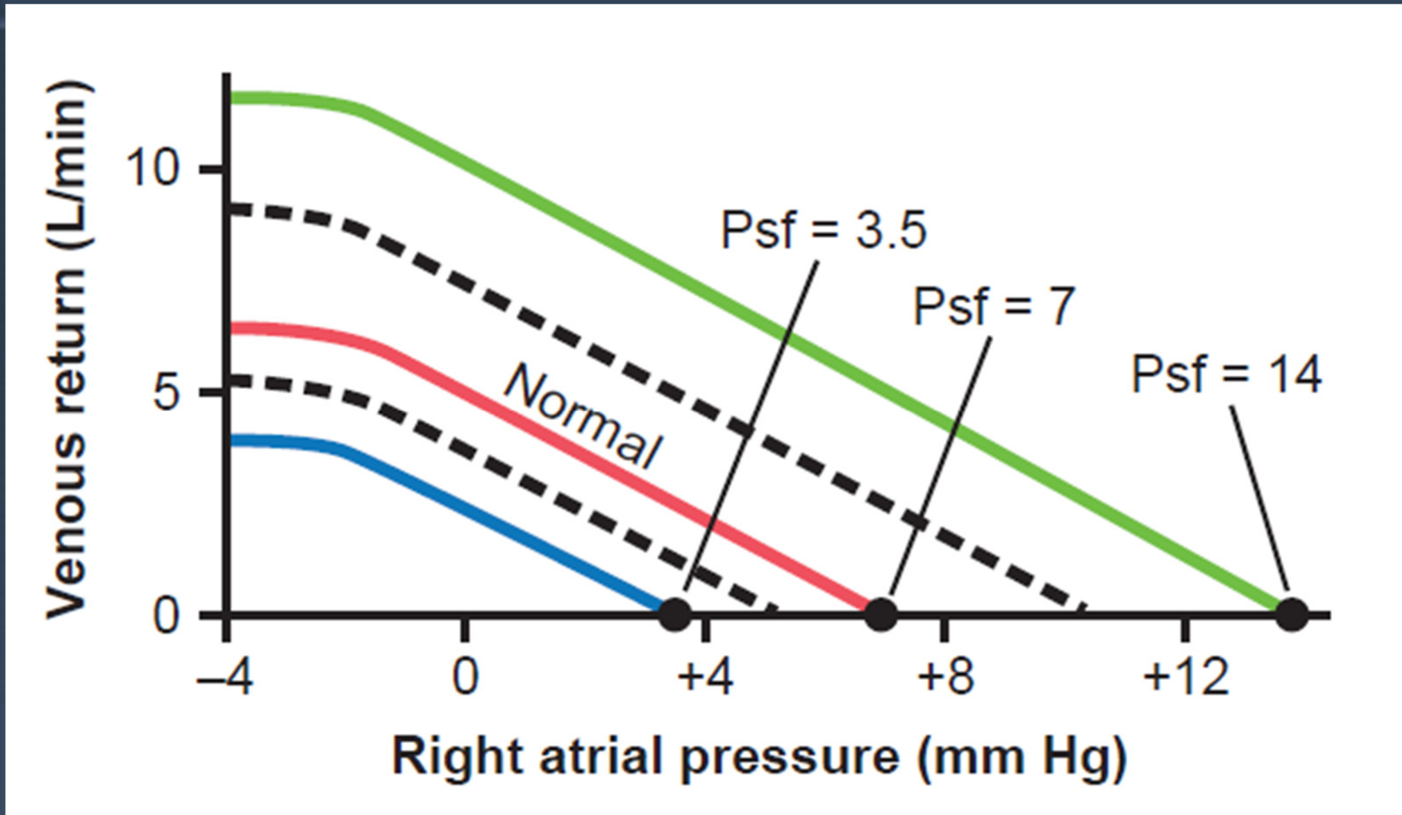
Greater the difference between the Psf and the RAP, the greater becomes the VR

When the RAP = Psf, there is no longer any pressure difference between the peripheral vessels and the right atrium. Resulting in ???

Greater the Psf (which also means the greater the “tightness” with which the circulatory system is filled with blood), the more the venous return curve shifts upward and to the right.



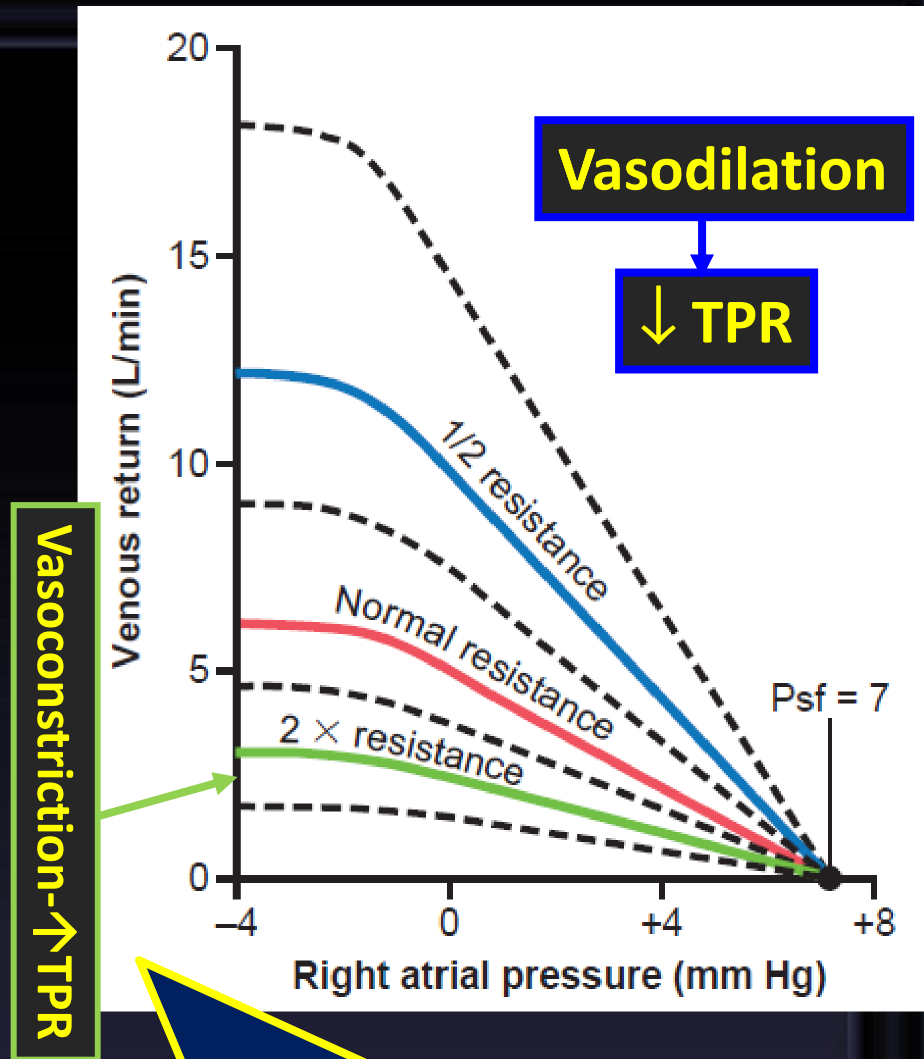
The lower the Psf, the more the curve shifts downward and to the left.



- If blood volume increases, Psf increases and the vascular function curve and its intersection point with the X-axis shift to the right. The same effect is seen with venoconstriction. [↑Stressed volume]
- If blood volume decreases, Psf decreases, and the vascular function curve and its intersection point with the X-axis shift to the left. The same effect is seen with venodilation. [↓stressed volume]

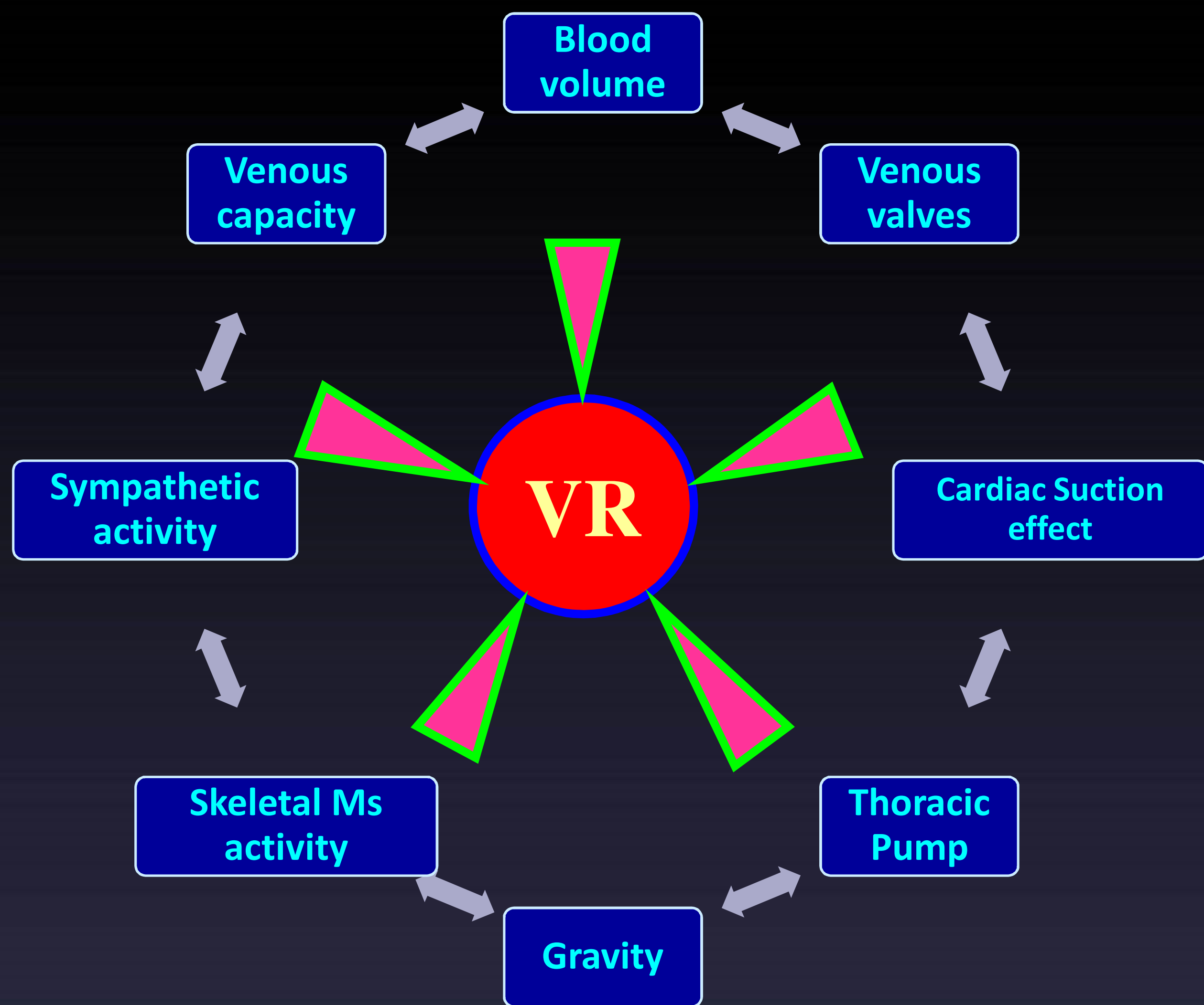
❑When the TPR is decreased, for a given RAP, venous return is increased. In other words, decreased resistance of the arterioles (decreased TPR) makes it easier for blood to flow from the arterial to the venous side of the circulation and back to the heart.

❑When the TPR is increased, for a given RAP, venous return is decreased. In other words, increased resistance of the arterioles (increased TPR) makes it more difficult for blood to flow from the arterial to the venous side of the circulation and back to the heart.



Effect of altering the TPR on VR

Determinants of venous return



Determinants of venous return

1. Blood volume:

- At constant venous capacity, as the blood volume↑ → the MCP ↑ → ↑ VR.
- At constant venous capacity, as the blood volume ↓ → the MCP ↓ → ↓ VR.

2. Venous capacity: is the volume of the blood that the veins can accommodate.

- At a constant blood volume, as the venous capacity ↑ → the MCP ↓ → ↓ VR.
- As the venous capacity ↓ → ↑ VR.

Determinants of venous return

3. Sympathetic activity:

Venous smooth muscle is profusely supplied with sympathetic nerve fibers.

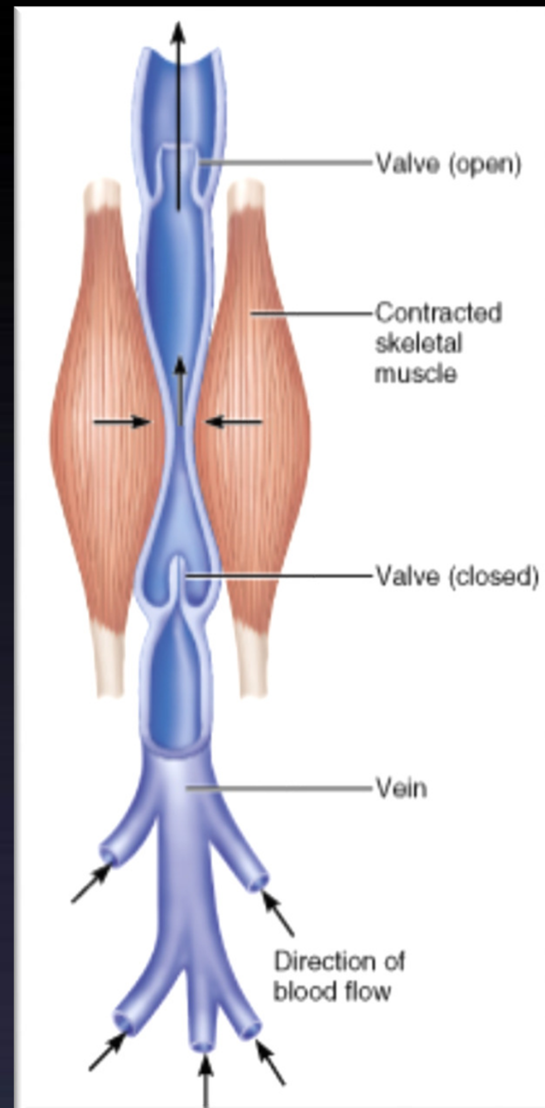
- Sympathetic stimulation → venous vasoconstriction → modest ↑ in mean systemic filling pressure (MCP) → ↑ VR.
- Sympathetic stimulation → ↓ venous capacity → ↑ VR.

The veins normally have such a large diameter that the moderate vasoconstriction accompanying sympathetic stimulation has little effect on resistance to flow.

Determinants of venous return

4. Skeletal muscle activity:

- Skeletal muscle contraction → external venous compression → ↓ venous capacity → ↑ VR (This is known as skeletal muscle pump).
- Skeletal muscle activity also counter the effects of gravity on the venous system.



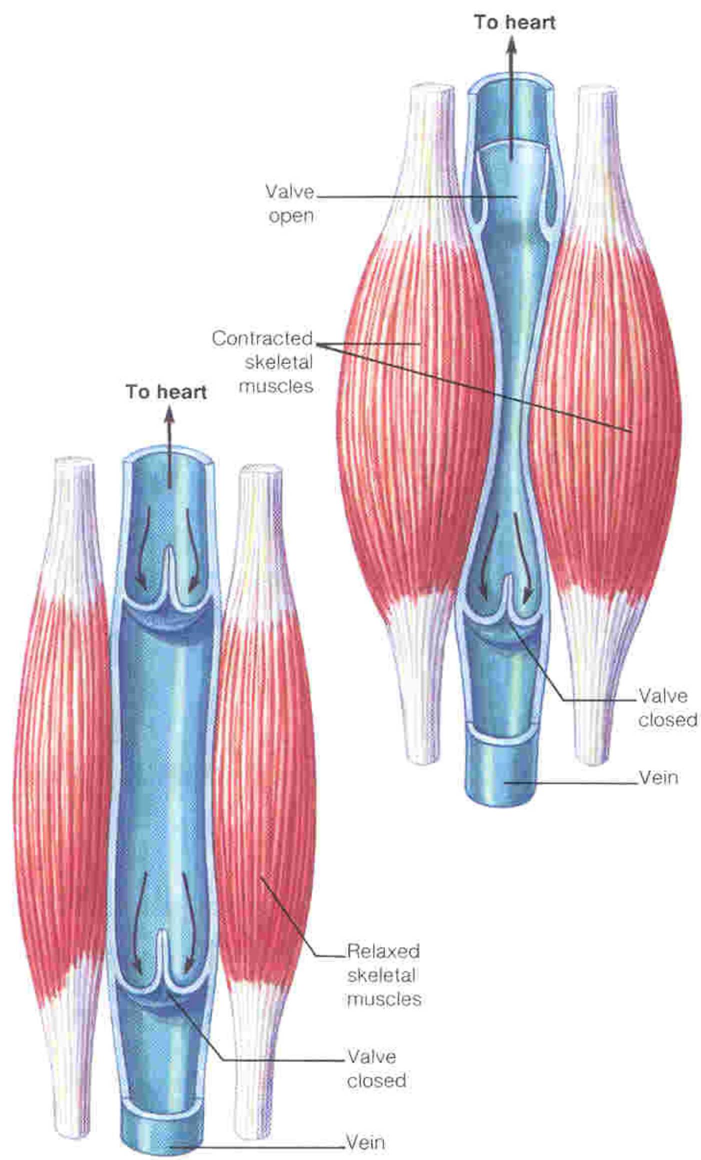
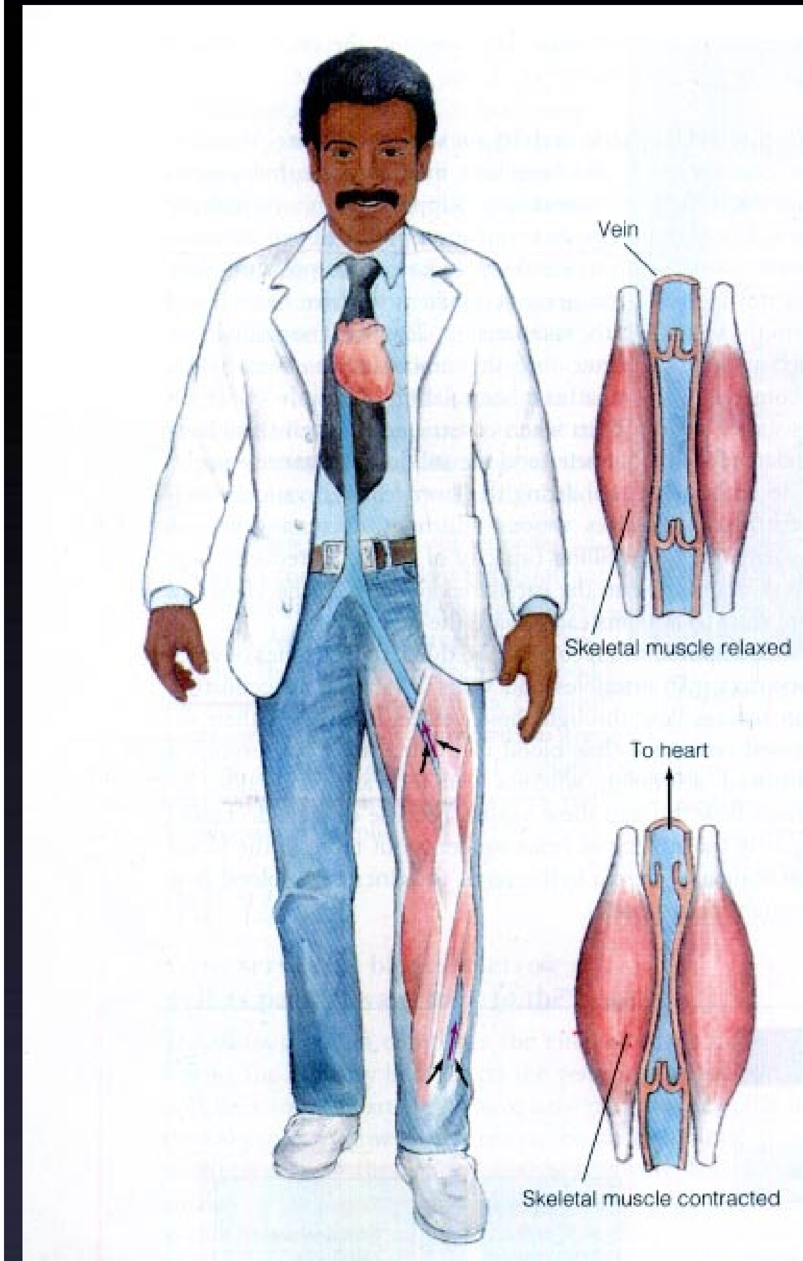


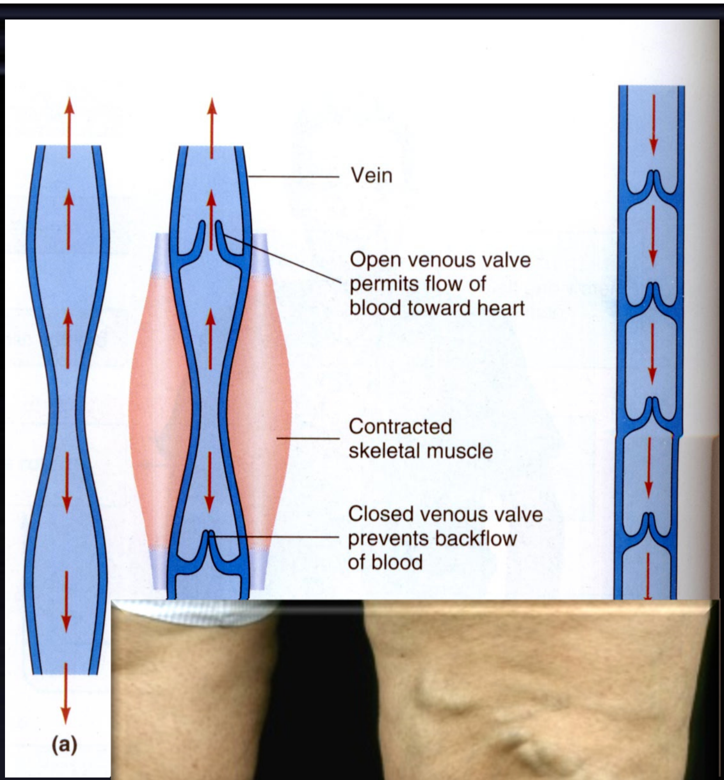
Figure 13.28 The action of the one-way venous valves. Contraction of skeletal muscles helps to pump blood toward the heart, but the flow of blood away from the heart is prevented by closure of the venous valves.



Determinants of venous return

5. Venous valves:

- These valves permit blood to move forward towards the heart but prevent it from moving back toward the tissues.
- These valves also play a role in counteracting the gravitational effects of the upright posture.



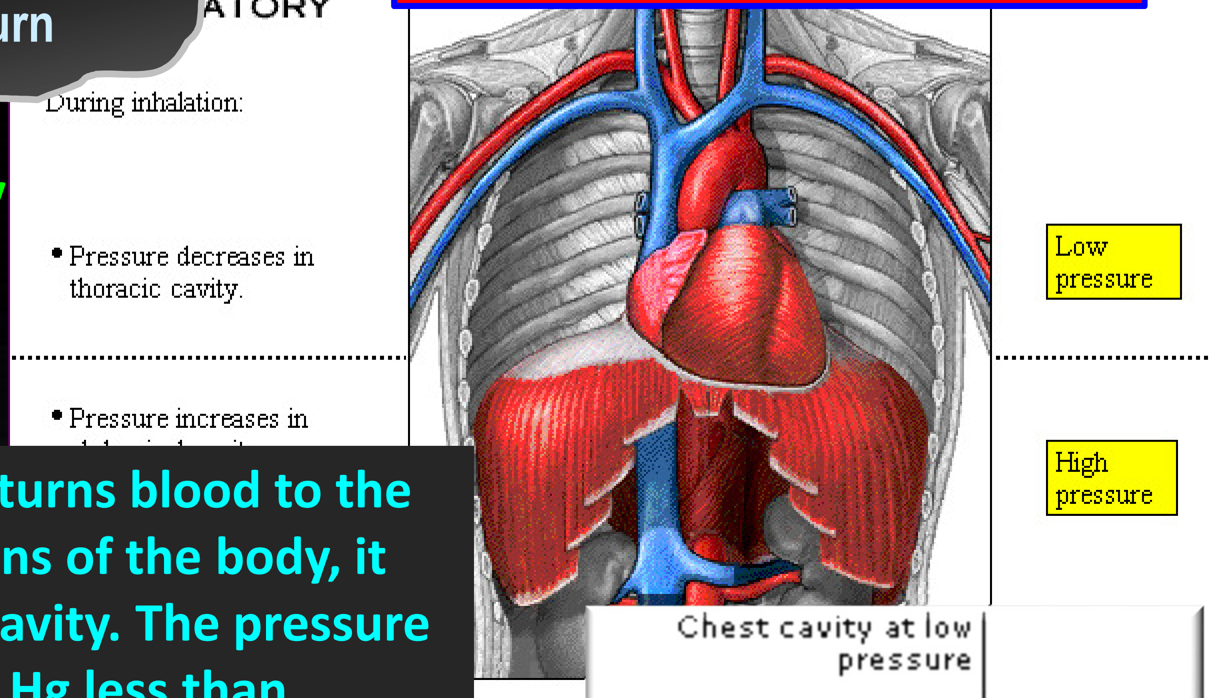
Skeletal muscle pump is ineffective when the venous valves are incompetent.

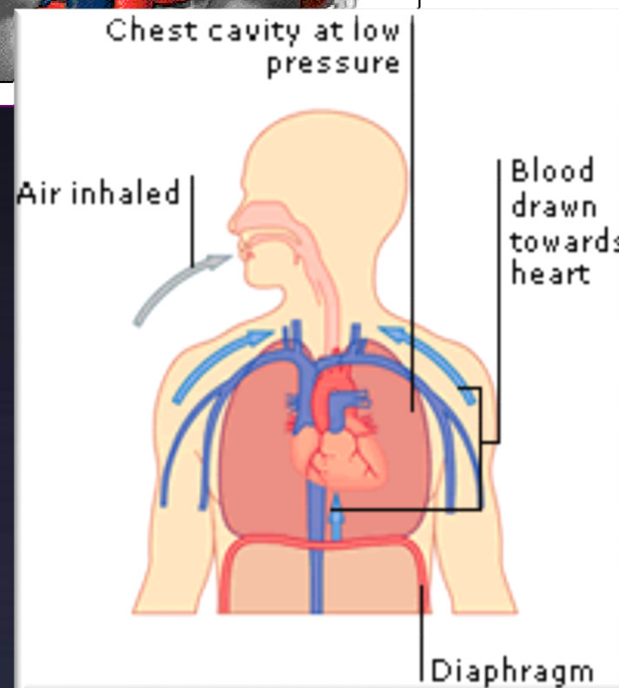
- ❑ Chronically raised pressure in the veins leads to pathological distension of the veins (varicose veins).
- ❑ Increased capillary filtration leads to swelling (edema) with trophic skin changes and ulceration (venous ulcers).

Determinants of venous return

6. Respiratory activity (respiratory pump; thoracic pump):

Negative intrathoracic pressure (IncreasesVR)

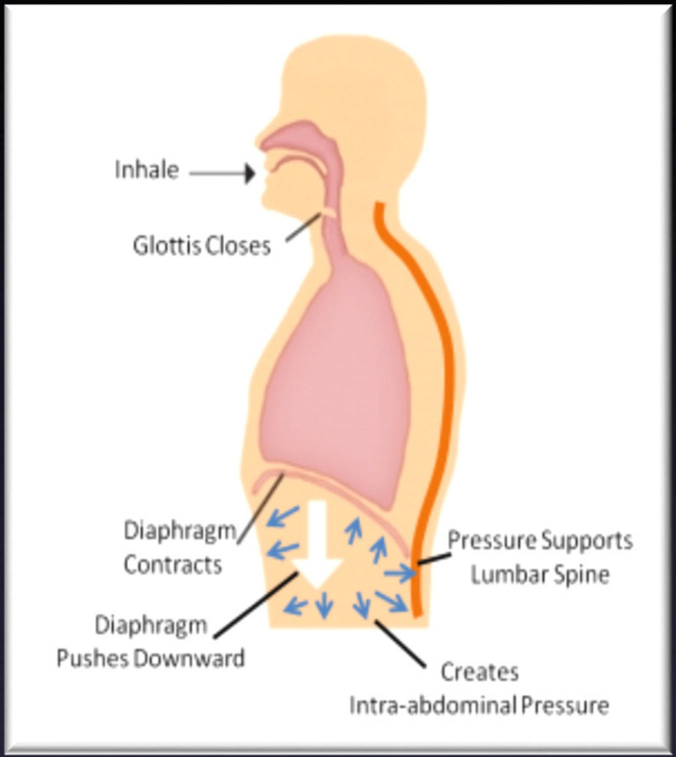




- As the venous system returns blood to the heart from the lower regions of the body, it travels through the chest cavity. The pressure in the chest cavity is 5 mm Hg less than atmospheric pressure.
- The venous system in the limbs and abdomen is subjected to normal atmospheric pressure.
- Thus, an externally applied pressure gradient exists between the lower veins and the chest veins, promoting venous return (this is known as the respiratory pump).

Determinants of venous return

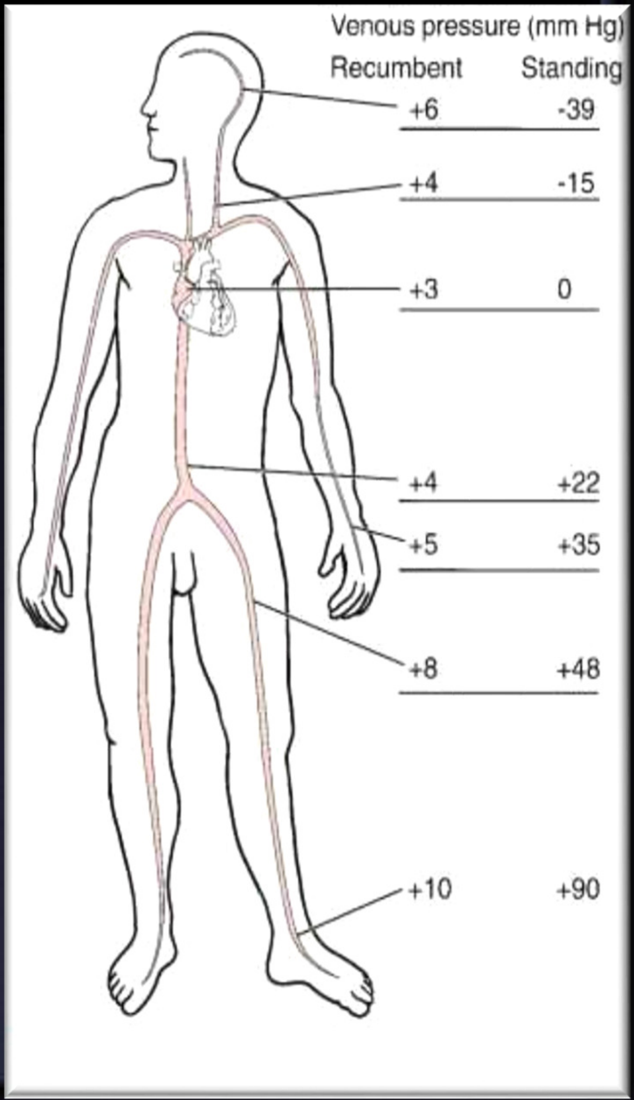
What is the effect of Valsalva maneuver on venous return?



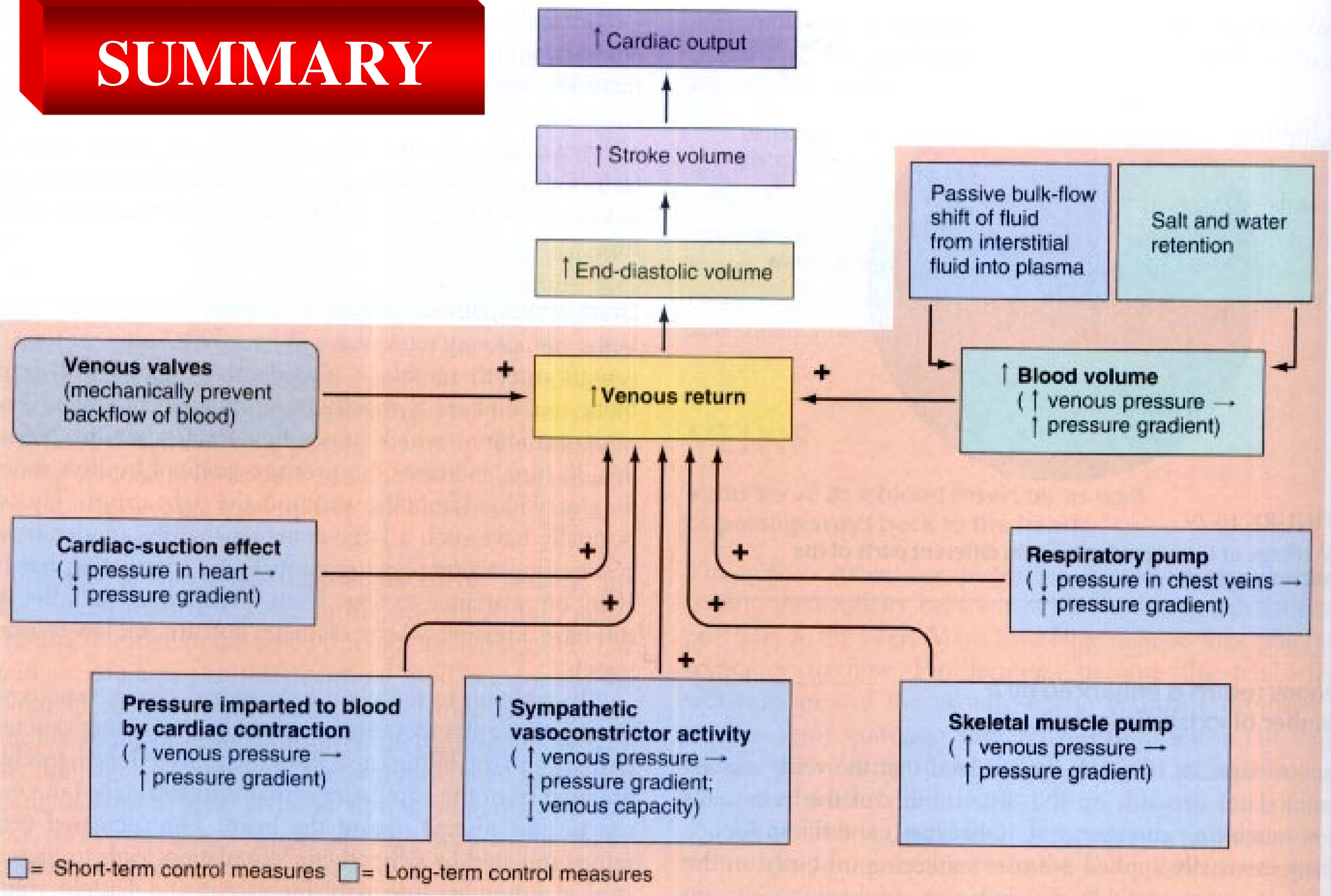
7. Effect of gravity on VR

Determinants of venous return

- In standing, venous volume and pressure become very high in the feet and lower limbs
- This shift in blood volume decreases thoracic venous blood volume and therefore CVP decreases.
- This decreases right ventricular filling pressure (preload), leading to a decline in stroke volume by the Starling mechanism.
- Left ventricular stroke volume also falls because of reduced pulmonary venous return (decreased left ventricular preload). This causes CO and mean arterial pressure (MAP) to fall.
- If arterial pressure falls significantly upon standing, this is termed orthostatic or postural hypotension.
- This fall in arterial pressure can reduce cerebral blood flow to the point where a person might experience syncope (fainting).



SUMMARY



↑ Cardiac output
↑ Stroke volume
↑ End-diastolic volume
↑ Venous return
Venous valves (mechanically prevent backflow of blood)
Passive bulk-flow shift of fluid from interstitial fluid into plasma
Salt and water retention
↑ Blood volume (↑ venous pressure → ↑ pressure gradient)
Cardiac-suction effect (↓ pressure in heart → ↑ pressure gradient)
Respiratory pump (↓ pressure in chest veins → ↑ pressure gradient)
Pressure imparted to blood by cardiac contraction (↑ venous pressure → ↑ pressure gradient)
↑ Sympathetic vasoconstrictor activity (↑ venous pressure → ↑ pressure gradient; ↓ venous capacity)
Skeletal muscle pump (↑ venous pressure → ↑ pressure gradient)
+
= Short-term control measures
= Long-term control measures