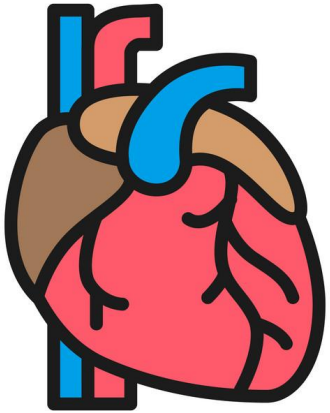
Revised & Reviewed by: Abdulaziz & Bahammam
Faye Wael Sendi



Venous return & cardiac output

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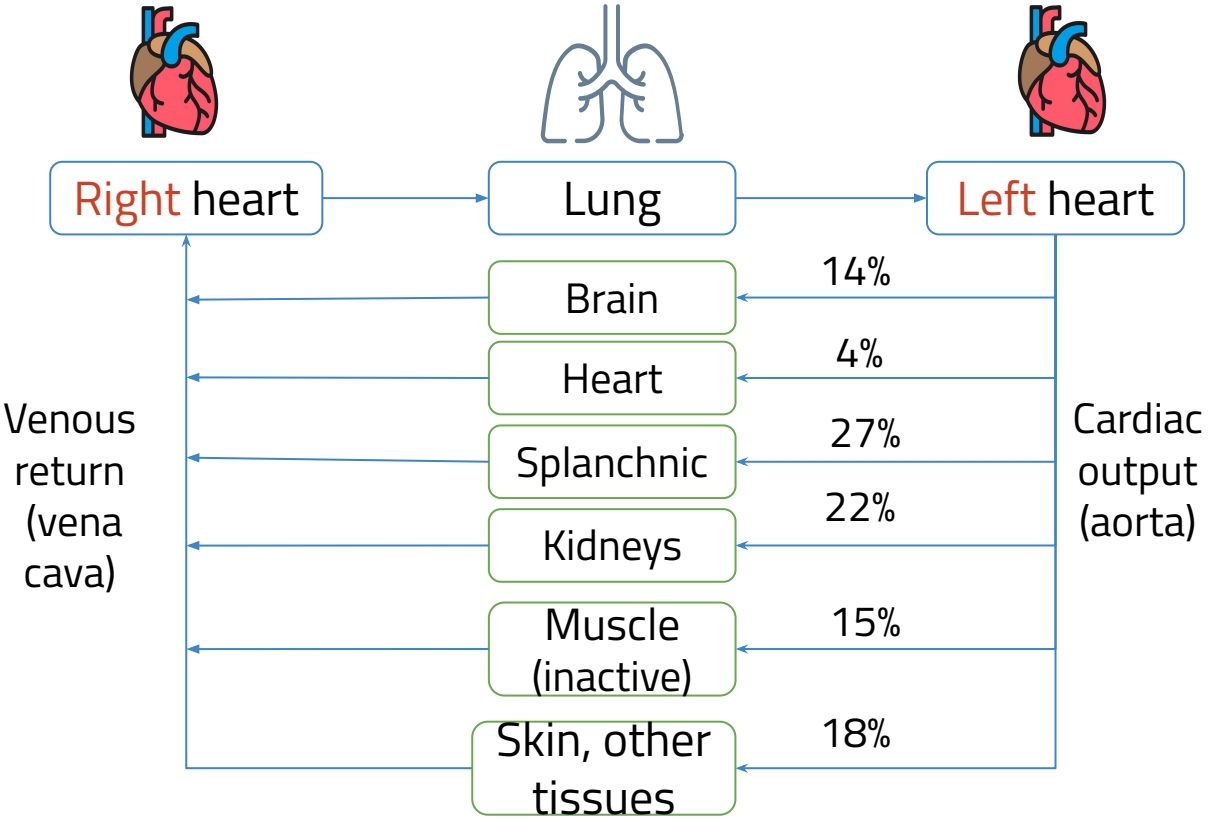
Objectives

- Discuss functions of the veins as blood reservoirs.
- Know the pressure variations in systemic blood vessels.
- Describe measurement of central venous pressure (CVP) and state its physiological and clinical significance.
- Describe vascular and cardiac function curves.
- State determinants of venous return and explain how they influence it:

1- Pressure gradient
2- Blood volume
3- Vascular capacity
4- Sympathetic activity
5-Total peripheral resistance
6- Venous valves
7- Skeletal muscle pumps.
8- Respiratory activity
9- Gravity

Cardiac Output= Total Tissue Blood Flow

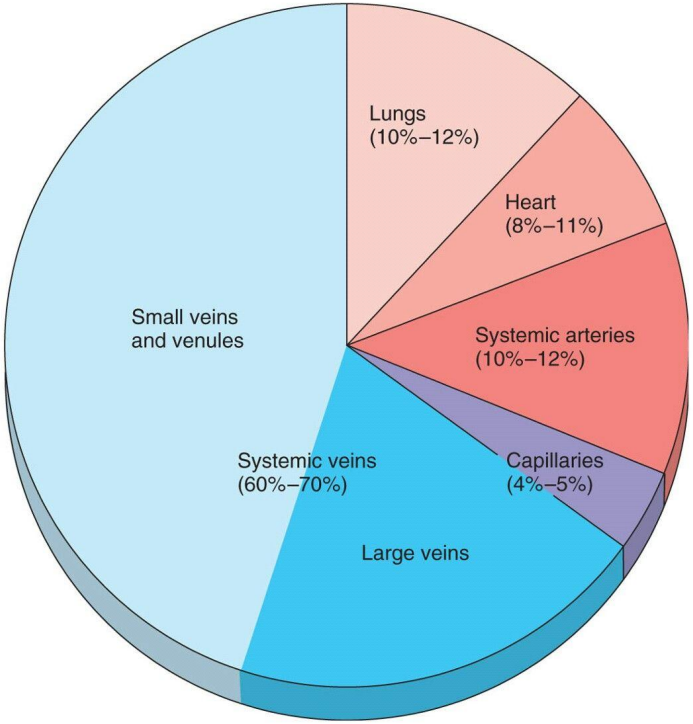


Why does the normal venous return must equal cardiac output?
From the figure : cardiovascular system is essentially a closed loop.Otherwise, blood would accumulate in either the systemic or pulmonary circulations.

From Guyton: The venous return and the cardiac output must equal each other except for a few heartbeats at a time when blood is temporarily stored in or removed from the heart and lung

What is about the veins?

- Veins hold most of blood in body (70%).
- They are called capacitance vessels.
- They have thin walls & stretch easily to accommodate more blood without increased pressure (= higher compliance).
- They have only 0 -10 mm Hg pressure.



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 (without significant change in pressure due to venodilation), 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.

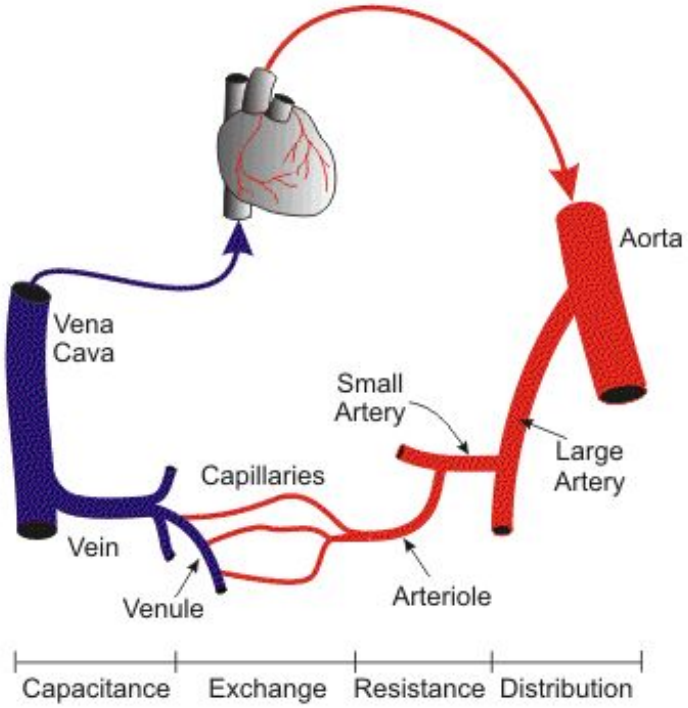
- **what changes will occur during exercise?** arterioles will dilate, veins undergo constriction, this will lead to supplying more blood to muscular tissue when needed.

Systemic circulation

Arterioles (resistance vessels) offer maximum resistance.

Capillaries (exchange vessels) are responsible for gas exchange between blood and tissues but offer minimum resistance.

veins (capacitance vessels) are responsible for accommodating blood when needed during blood loss.

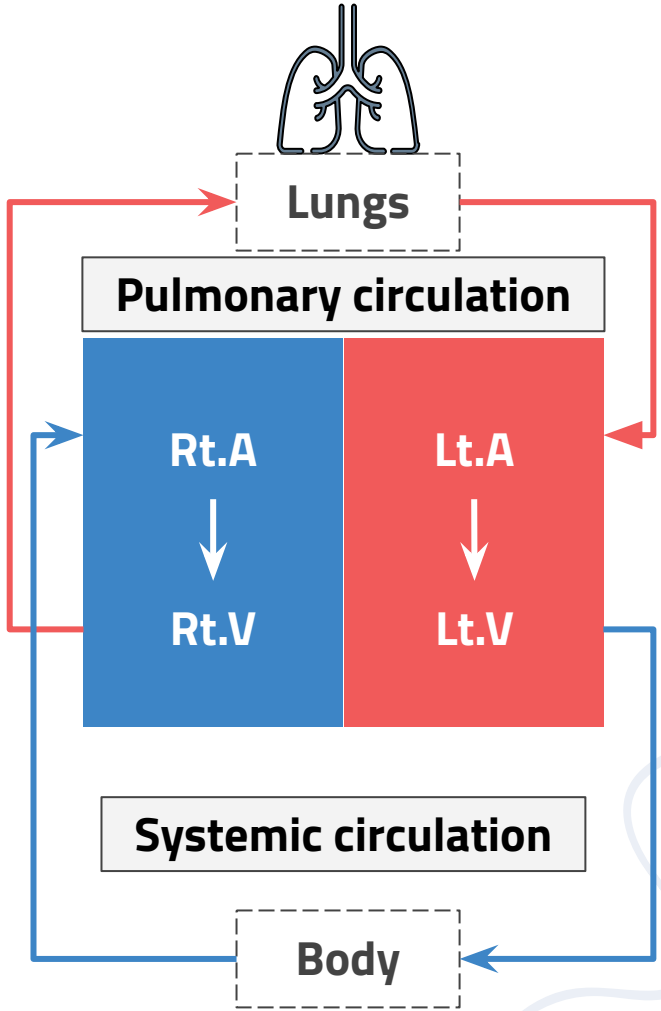


VENOUS RETURN (VR)

- Normally VR must equal CO when averaged over time because the CVS is essentially a closed loop. Otherwise, blood would accumulate in either the systemic or pulmonary circulations.

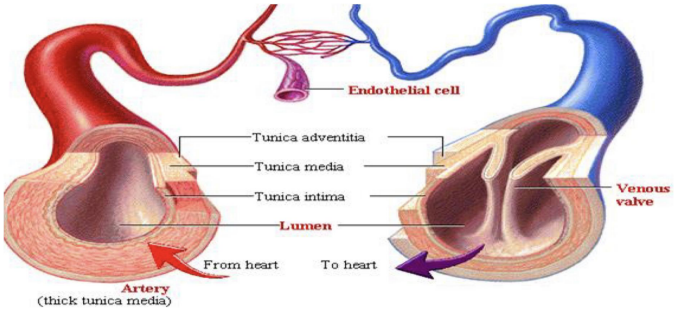
- VR is determined by the difference between the venous pressure nearest to the tissues (mean circulatory pressure; MCP) and the venous pressure nearest to the heart (CVP).

- VR = MCP — CVP



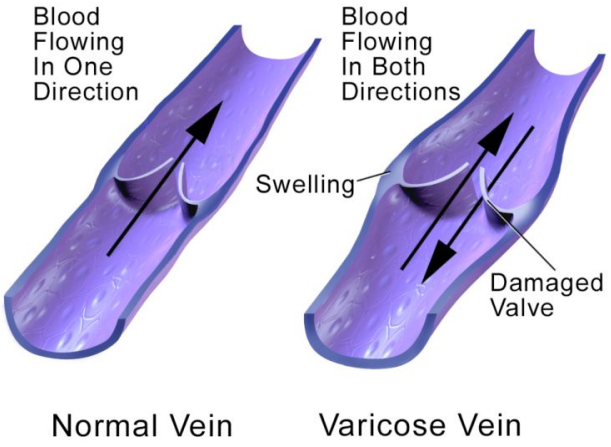
Structures of Veins

- All 3 layers of veins are present:
  - tunica adventitia
  - tunica media
  - tunica intima
- layers in veins are thinner than in arteries of corresponding size (external diameter).
- Veins have paired semilunar, bicuspid valves to restrict backflow in lower extremities.

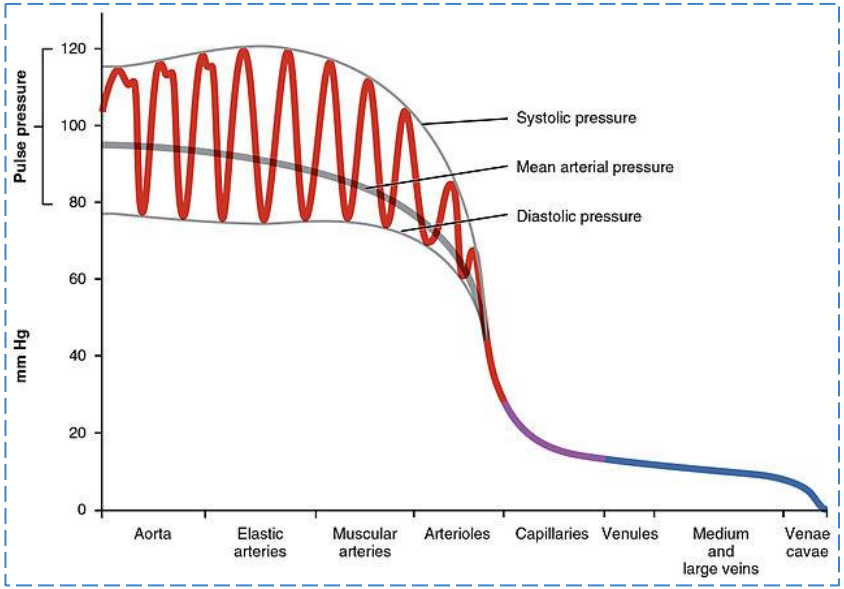


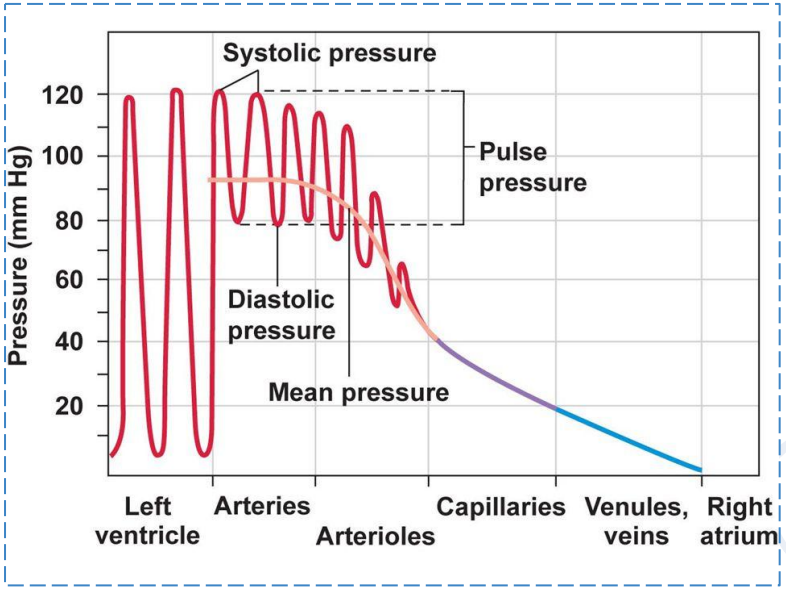
Varicose veins

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



Pressure Variations in Systemic Blood Vessels

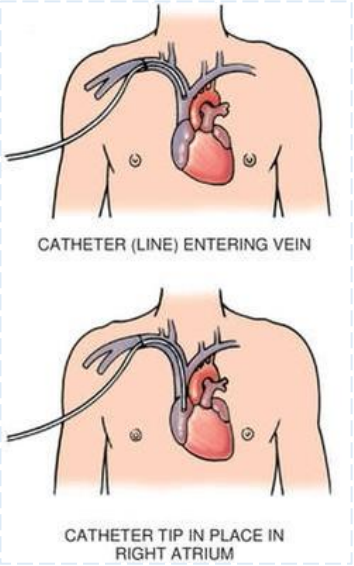


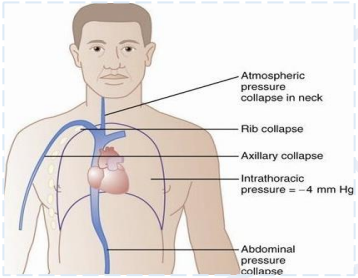


Central Venous Pressure (CVP)

Pressure in the right atrium is called **central venous pressure.**

- **CVP:** is the pressure in the right atrium and the big veins of thorax (right atrial pressure (RAP) = jugular venous pressure).
- **CVP** is measured with a catheter inserted in SVC. (superior vena cave)
- 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.**

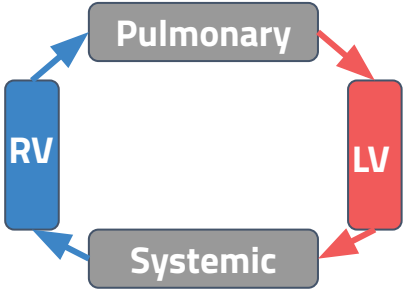




Mean Circulatory Pressure (MCP)

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.

↑Blood volume ↑MCP
↓Blood volume ↓MCP

Venoconstriction ↑MCP
Venodilation ↓MCP

The Venous Return Curve (The Vascular Function Curve)

- The curve relates VR To Right Atrial Pressure (RAP).
- Mean systemic filling pressure (Psf) is the point at which the vascular function curve intersects the X-axis
- **For example** if VR is zero and RAP is at its highest value, Psf =7 mm Hg).

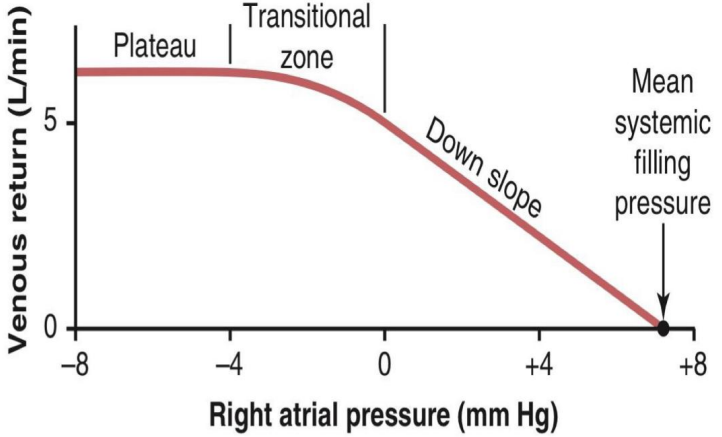
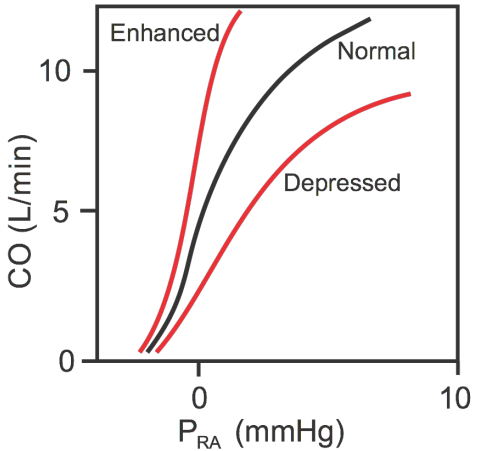


Figure 20-10. Normal *venous return curve*. The plateau is caused by *collapse* of the large veins entering the chest when the right atrial pressure falls below atmospheric pressure. Note also that venous return becomes zero when the right atrial pressure rises to equal the mean systemic filling pressure.

Cardiac Function Curve

Female slides

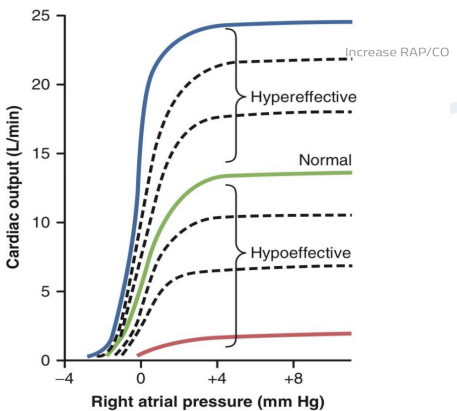
It relates pumping of blood by the heart to right atrial pressure (RAP).



- Normally, Rt atrial pressure (RAP) fluctuates with atrial contraction and respiration.
- When the mean RAP is about Zero mmHg, the CO in an adult is about 5 L/min.

Effect of RAP Changes on Cardiac Function Curve

Because of the steepness of the cardiac function curve, very small changes in RAP (just a few mmHg), can lead to large changes in cardiac output.



Basic Principles

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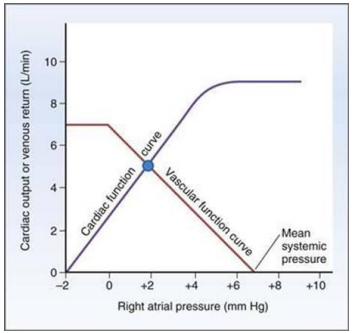
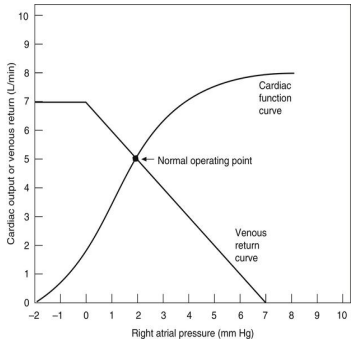
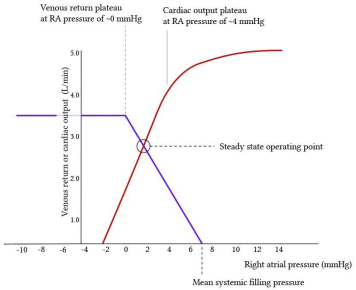
Cardiac Function Curve & Vascular Function Curve







Flow of any fluid (blood) through a tube (vessel) depends on:

- The pressure difference between the two ends (Pressure gradient).
- Blood flows from high pressure to low pressure.

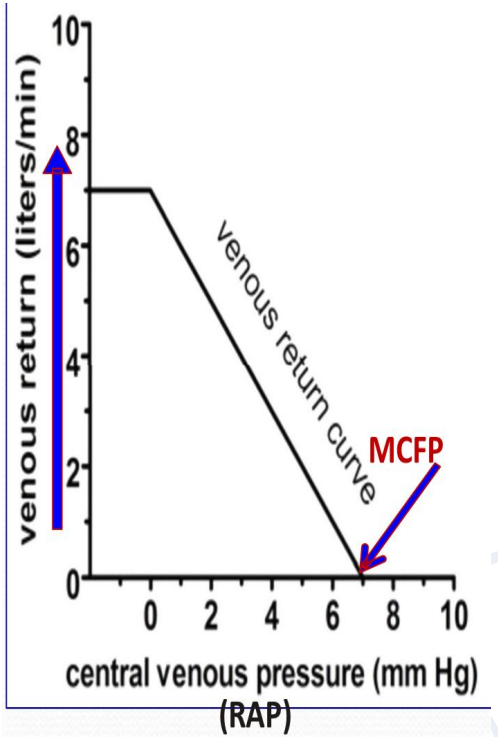
- The resistance to blood flow through the vessel.
- Controlled by the diameter of the vessel.

Determinants of venous return

1. Pressure Gradient
2. Blood volume
3. Venous capacity
4. Sympathetic activity
5. Total peripheral resistance
6. Skeletal muscle activity
7. Venous Valves
8. Thoracic Pump

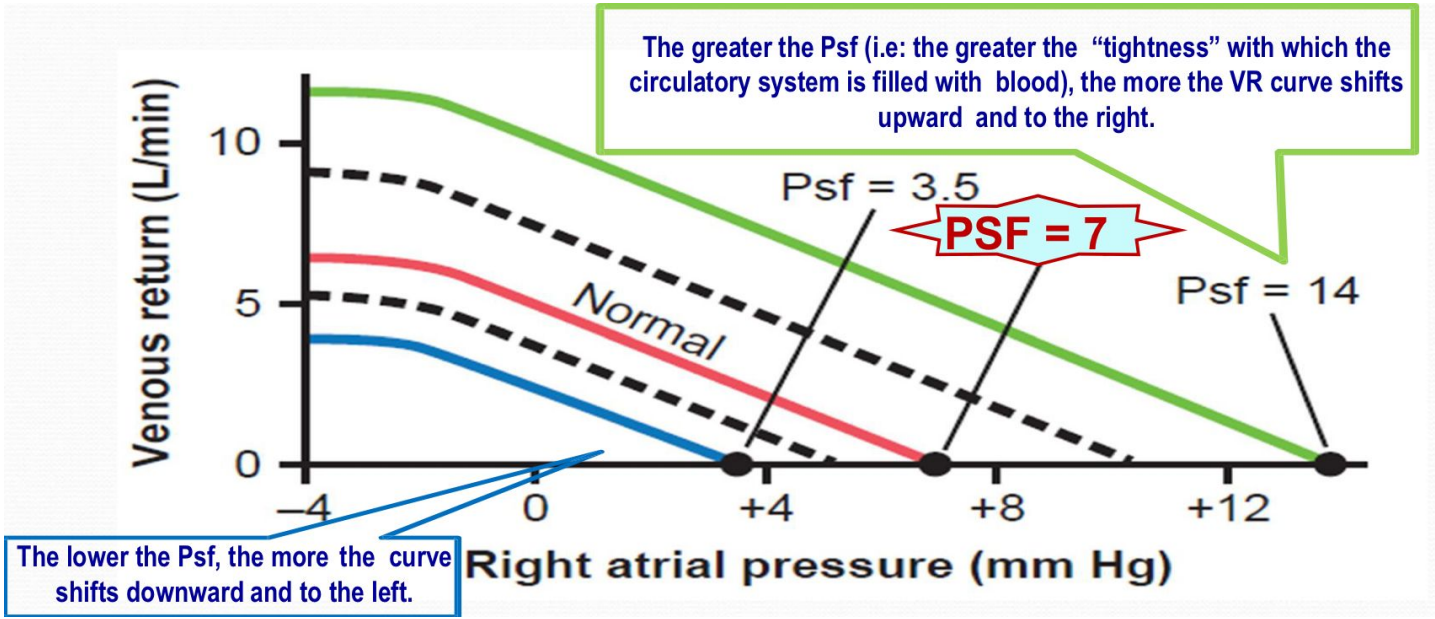
Determinants of venous return
1-Pressure Gradient:

- VR back to the heart is driven by a pressure gradient. (VR= MCP - RAP (CVP))
- There is an inverse relationship between VR andRAP (CVP).
- The lower the RAP, the higher the pressure gradient and the greater the VR.
- Thus as RAP ↑, pressure gradient ↓ and VR also ↓. When the RAP falls below zero (i.e at negative values of RAP., no further increase in VR and a plateau (the knee, flat portion) is reached.
- Cause: collapse of the veins entering the chest . This impedes VR inspite of high pressure gradient.



The greater the difference between the mean circulatory filling pressure (psf) and the greater becomes VR

When the RAP=psf, there's no longer pressure difference between the peripheral vessels and the right atrium.



Female slides

Determinants of venous return Cont.

2. Blood volume

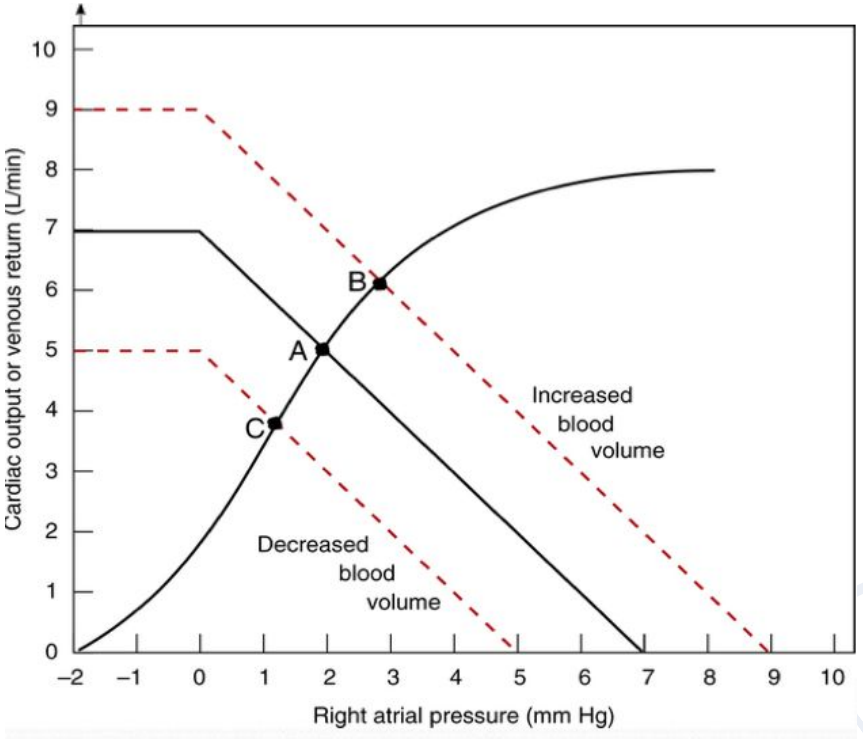
At constant venous capacity:

- ↑ blood volume → ↑ MCP → ↑ VR,

i.e: The intersection point of the vascular function curve shifts to the right.

- ↓ blood volume → ↓ MCP → ↓ VR,

i.e: The intersection point of the vascular function curve shifts to the left.



Determinants of venous return Cont.
3.Venous capacity

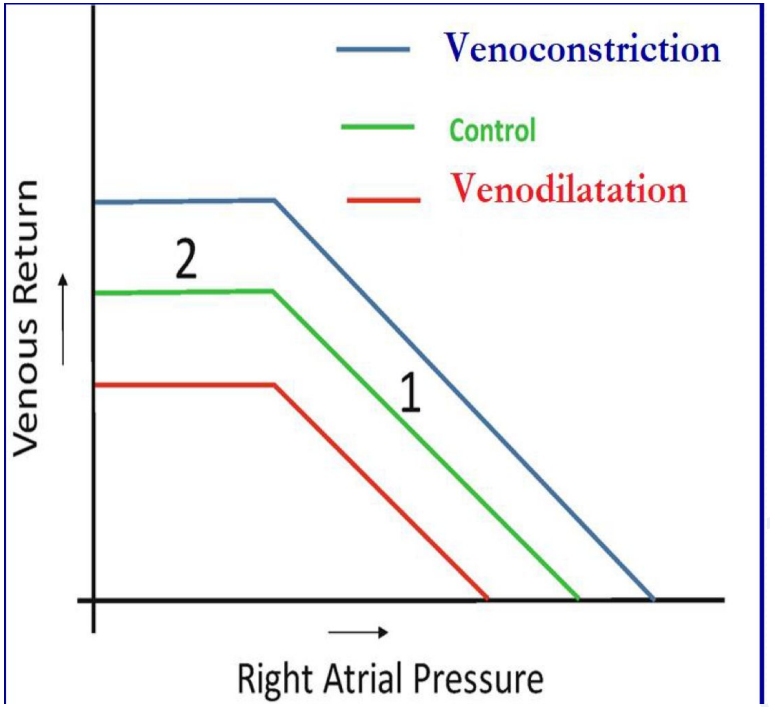
At a constant blood volume,

- ↓ venous capacity

(venoconstriction) → ↑ MCP → ↑ VR, i.e: The intersection point of the vascular function curve shifts to the right.

- ↑ venous capacity (venodilation) →

↓ MCP → ↓ VR, i.e: The intersection point of the vascular function curve shifts to the left.



Determinants of Venous Return (Cont.)

4. Sympathetic activity

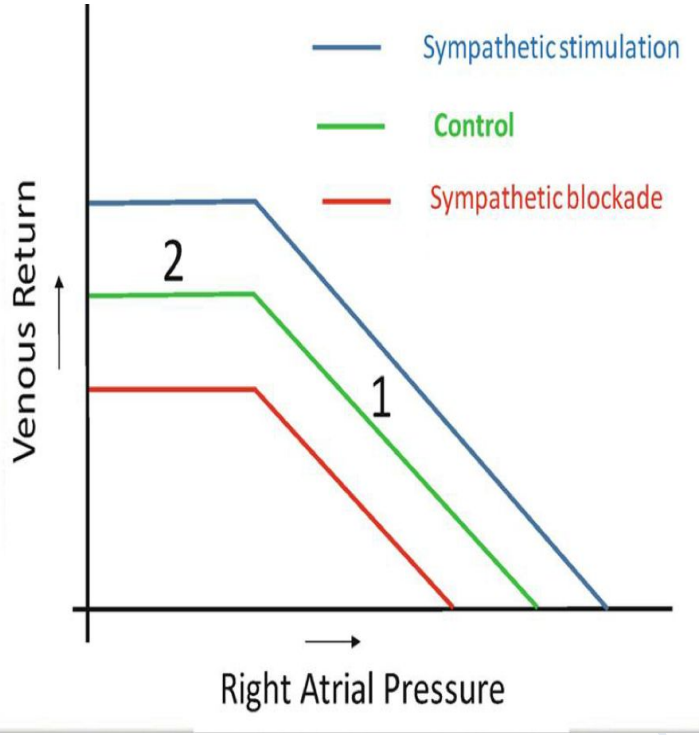
- Venous smooth muscle is profusely

supplied with sympathetic fibers.

- ↑ Sympathetic nervous system (SNS) activity → venoconstriction

→ ↓ venous capacity → modest ↑MCP → ↑ 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 (Cont.)

5- Total peripheral resistance (TPR)

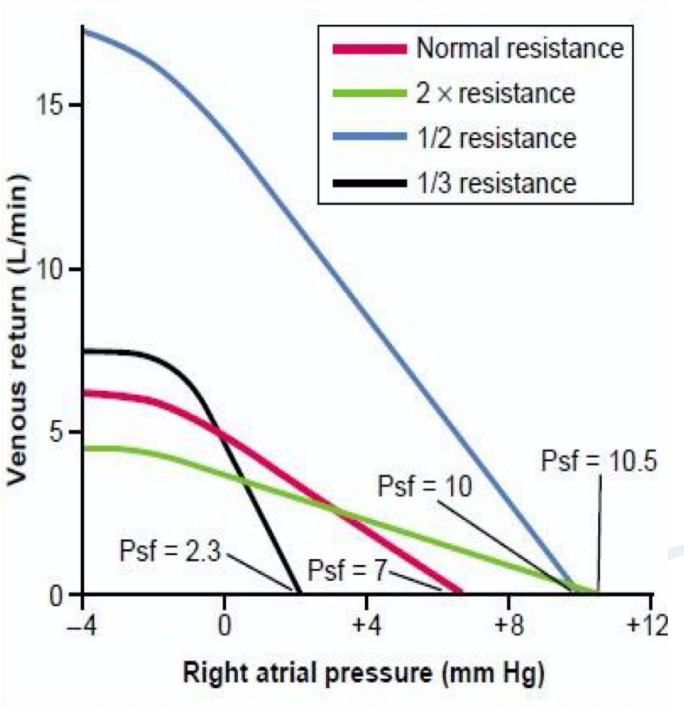
For a given RAP:

- ↓ **TPR** → ↑ **VR**, i.e: decreased

resistance of the arterioles makes it easier for blood to flow from the arterial to the venous side of the circulation and back to the heart.

- ↑ **TPR** → ↓ **VR**, i.e: increased

resistance of the arterioles makes it more difficult for blood to flow from the arterial to the venous side of the circulation and back to the heart.



Determinants Of Venous Return (Cont.)

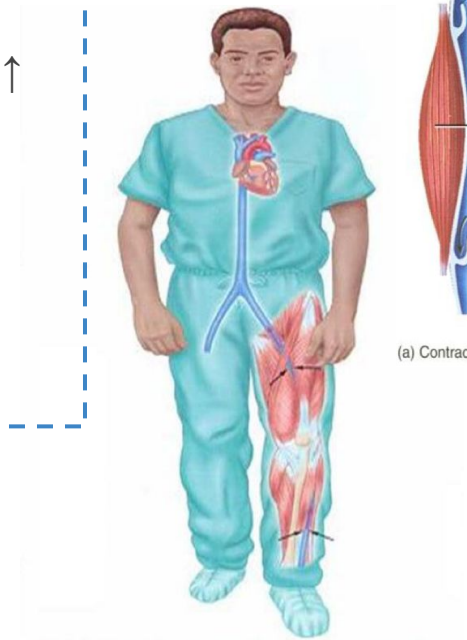
6. Skeletal muscle activity:

- Skeletal muscle contraction →

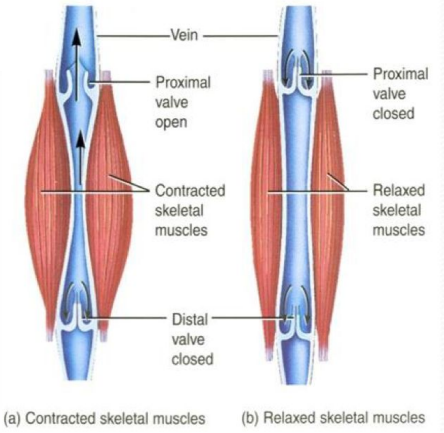
external venous compression → ↓ venous capacity → ↑ VR (This is known as skeletal muscle pump).

- Skeletal muscle activity also

counter the effects of gravity on the venous system.



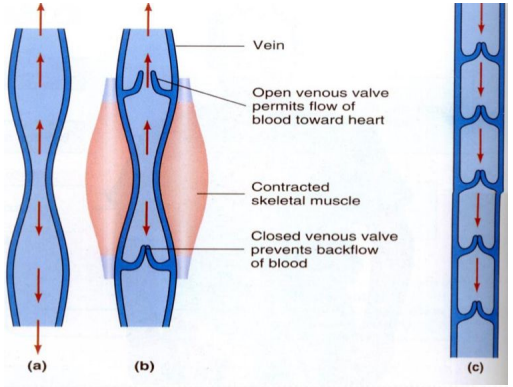
Skeletal muscle pump enhancing venous return



Determinants of Venous Return (Cont.)

7. Venous valves:

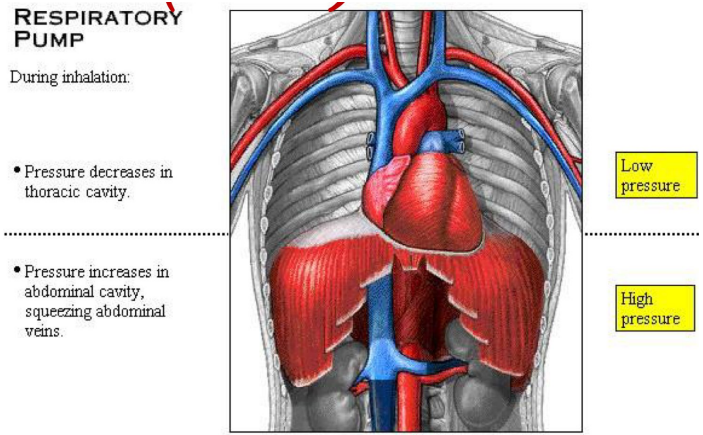
- These valves permit blood to move forward towards the heart but prevent it from moving back toward the tissues.
- These valves also play a role in counteracting the gravitational effects of the upright posture.
- Skeletal muscle pump is ineffective when the venous valves are incompetent.
- Chronically 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).



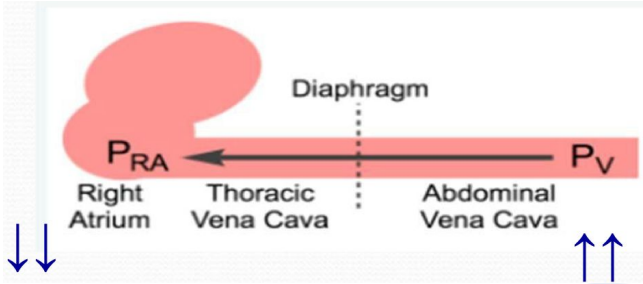
Determinants of Venous Return (Cont.)

8. Respiratory or thoracic pump:

- 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 5mmHg 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 VR (respiratory pump).



Negative intrathoracic pressure
Increases VR



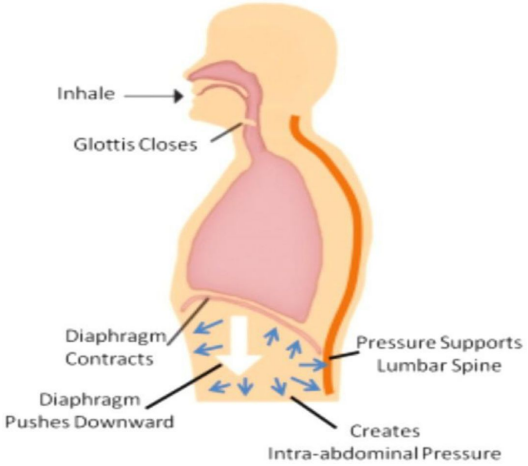
The effect of Valsalva Maneuver on VR

❖ **What is Valsalva maneuver?**

It is forceful expiration against a closed glottis .

❖ **What is the effect on VR**

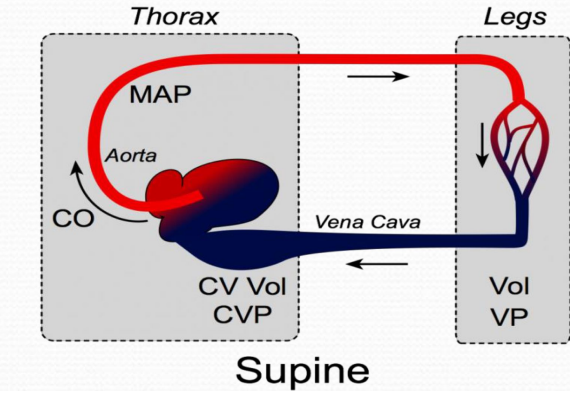
Intrapleural pressure become positive which is transmitted to the large veins in the chest → ↓ venous return.

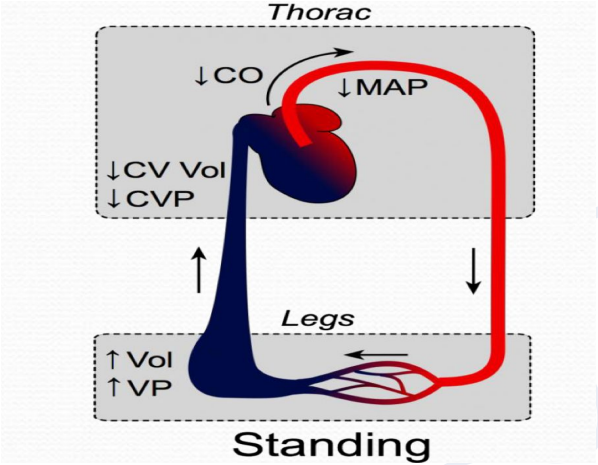


Determinants of Venous Return (Cont.)

9- Effect of gravity

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





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