Cardiac output and its relation to venous return

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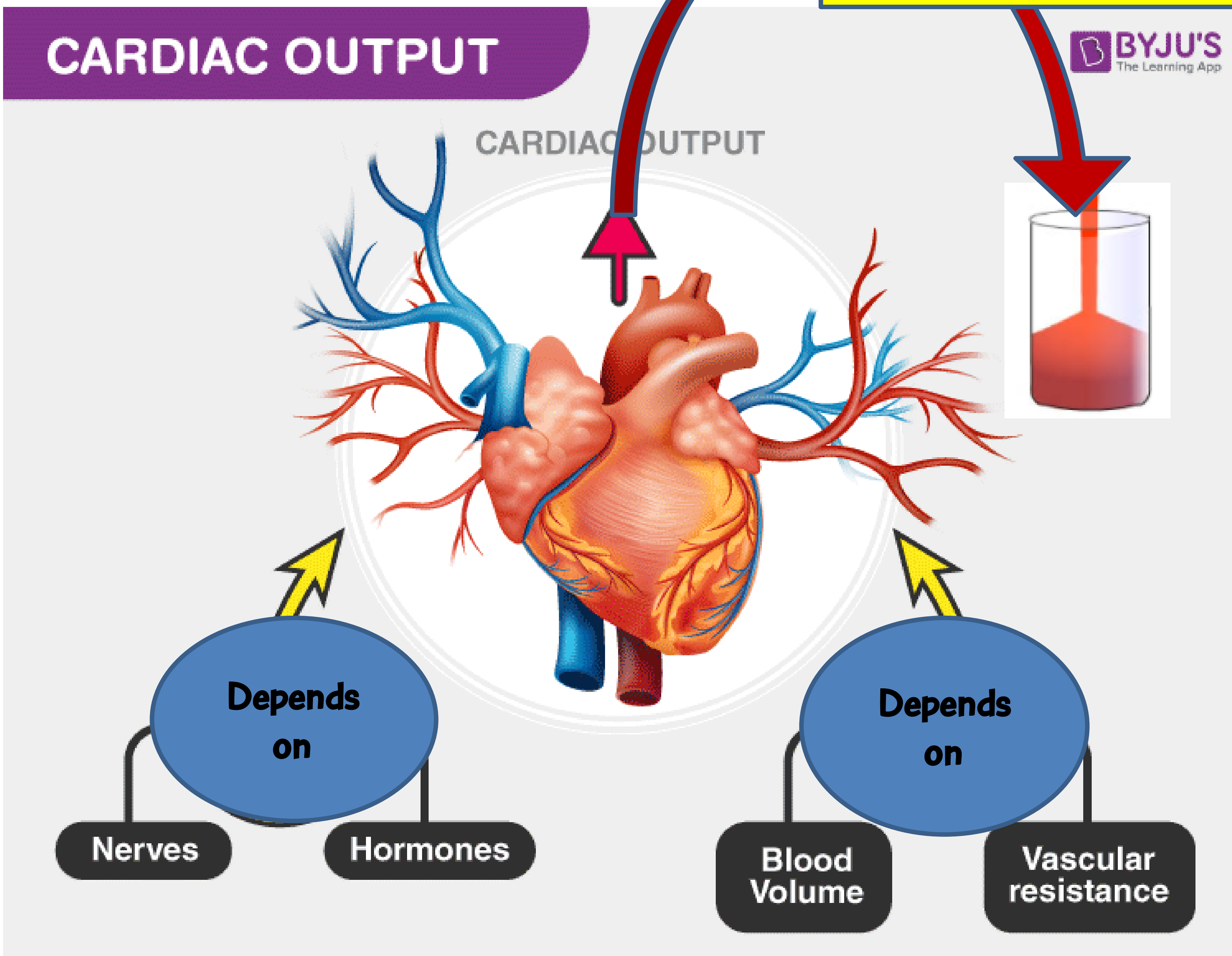
Lecturer physiology
KGMC

Objectives

- At the end of the lecture 1st year MBBS student should be able to

1. Explain normal venous return curve
2. Explain factors affecting venous return

The amount of blood the heart pumps through the circulatory system in a minute.



Cardiac output

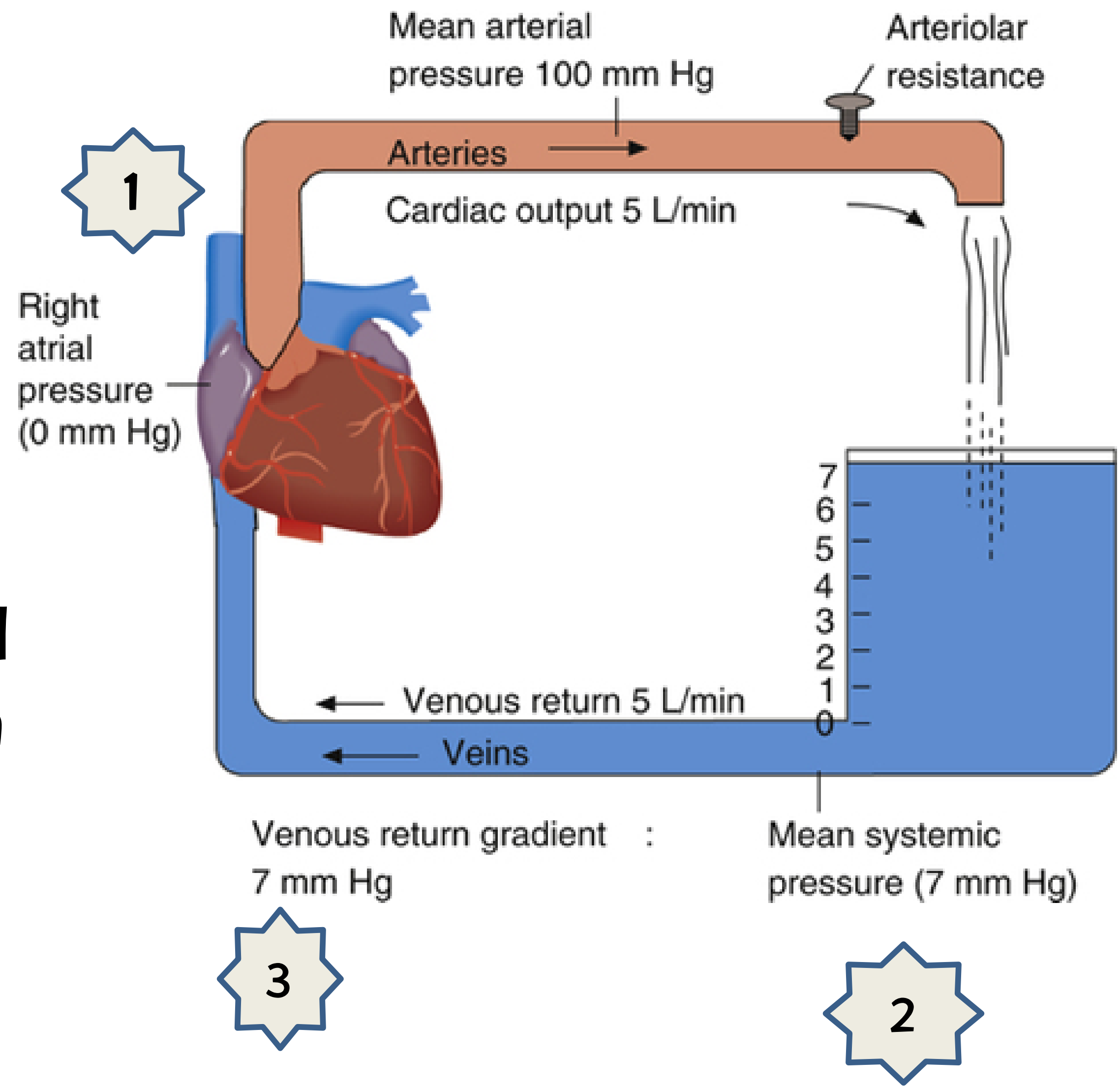
Cardiac output is controlled by the heart itself and **venous return** which is normally the **primary controller** of cardiac output. And it's the more important one.

Why ?

the heart has a built-in mechanism that normally allows it to pump automatically whatever amount of blood that flows into the right atrium from the veins ***(Frank-Starling law of the heart)***

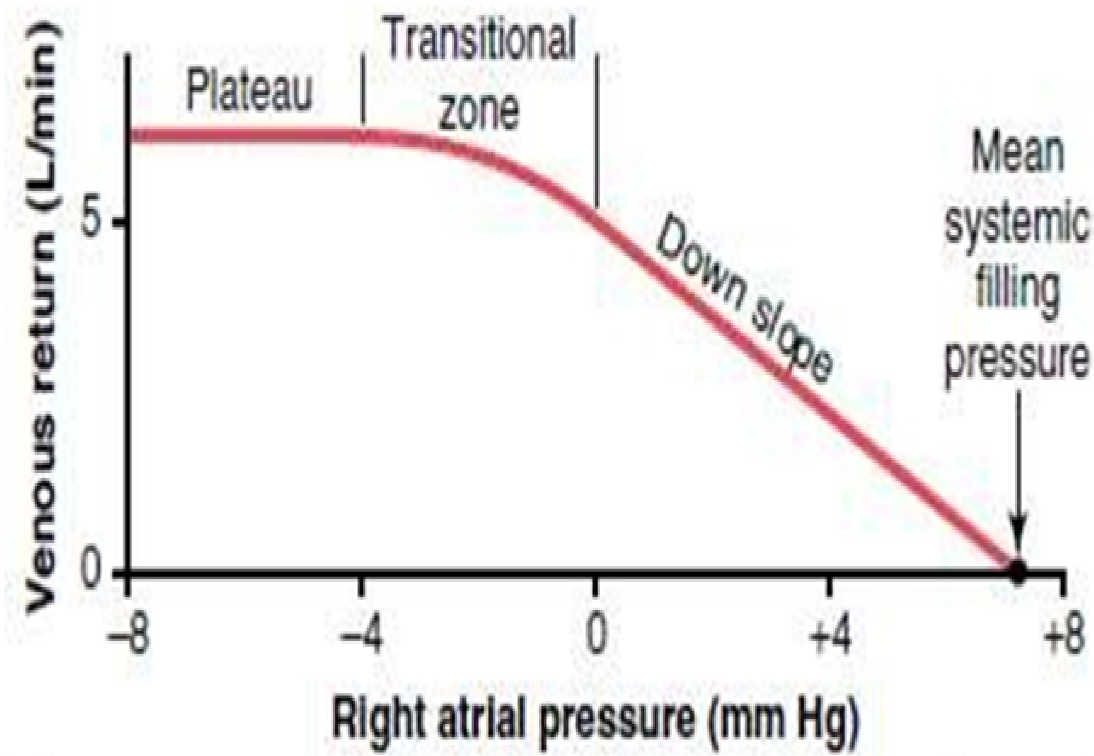
Factors effecting venous return

1. Right atrial pressure
2. Mean systemic filling pressure(pressure in systemic circulation when all blood flow is stopped)
3. Resistance to blood flow between peripheral vessels and right atrium



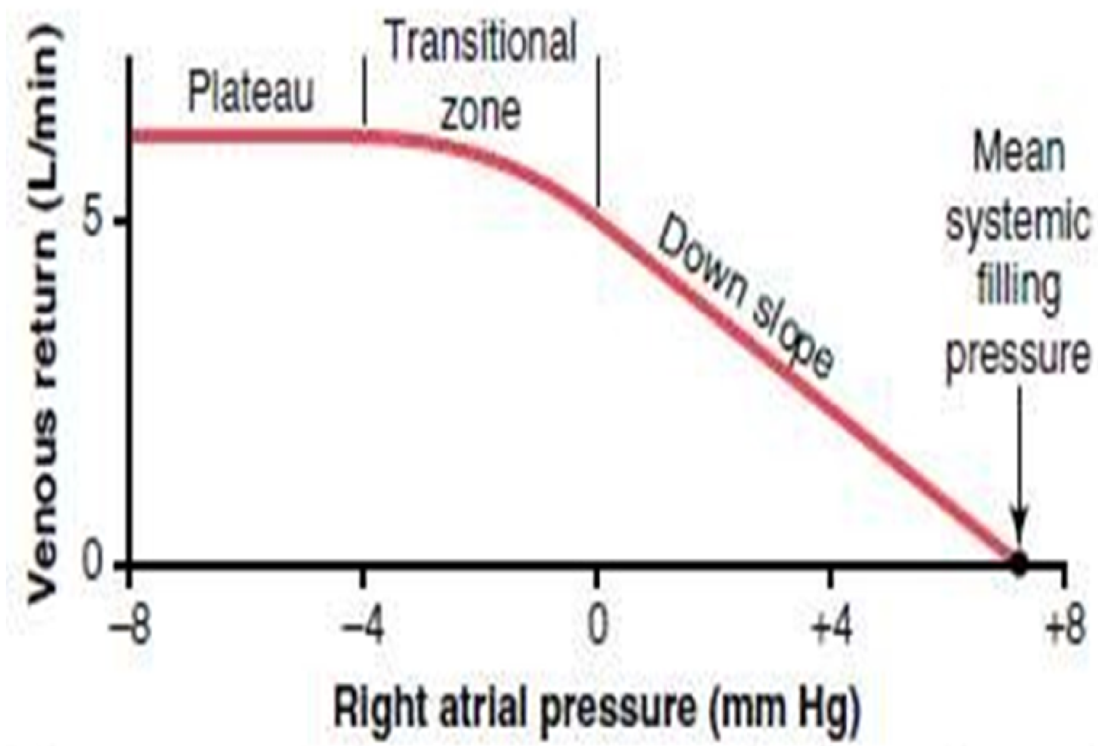
Normal venous return curve

It relates **venous return** to **right atrial pressure**—that is, the relation of the venous flow of blood into the heart from the systemic circulation at different levels of right atrial pressure



Study this curve & Fill in the blanks

1. Venous return increase when pressure is
   0 - -2 mmHg
2. Venous return reaches plateau at.. **- 2 mmHg** Value of right atrial pressure
3. VR become 0 L/min at ….. **+ 7 mmHg** .. …



If the right atrial pressure rises

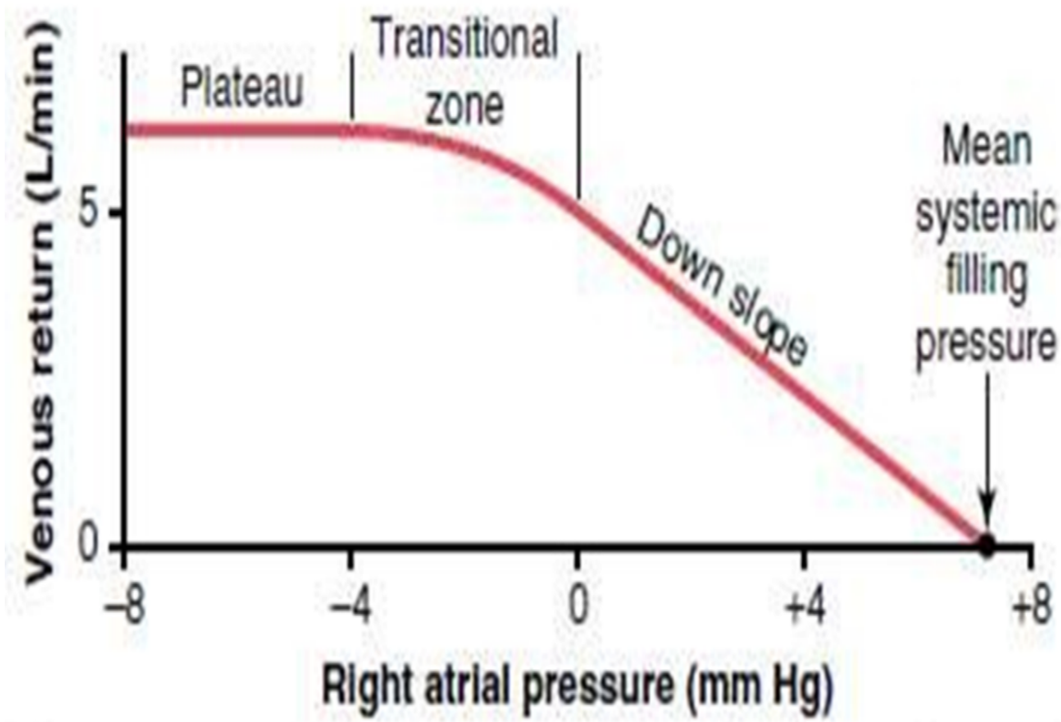
the backward force of the rising atrial pressure

on the veins of the systemic circulation

increase which **decreases venous return** of

blood to the heart.

venous return decreases to **zero** when the right atrial pressure rises to about **+7 mm Hg.** *(assuming all nervous circulatory reflexes are prevented from acting)*

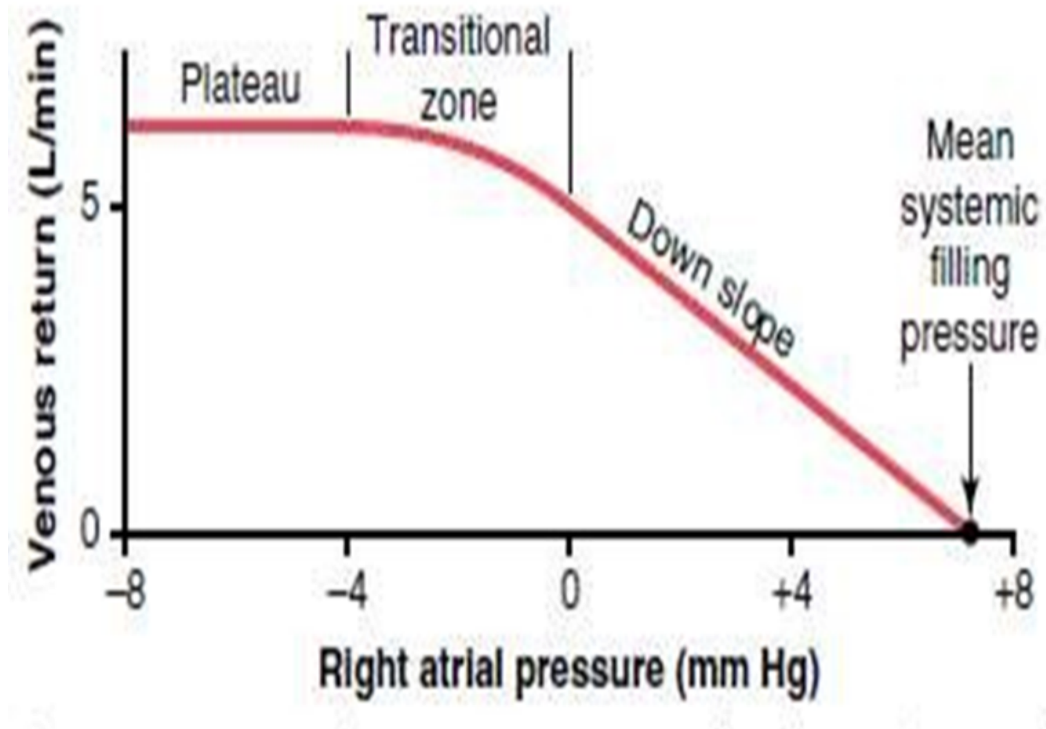


When the right atrial pressure falls *below* zero

there will be almost **NO**

increase in venous return.

- And when the right atrial pressure has fallen to about **−2 mm Hg**, the venous return will have reached a **plateau.**



What Causes the plateau?

Coz the ... ve pressure in the ... atrium

sucks the wa ... *the veins)* of

th... to ... r t... st,

which **preve** ... v of blood

from the ... iphe...

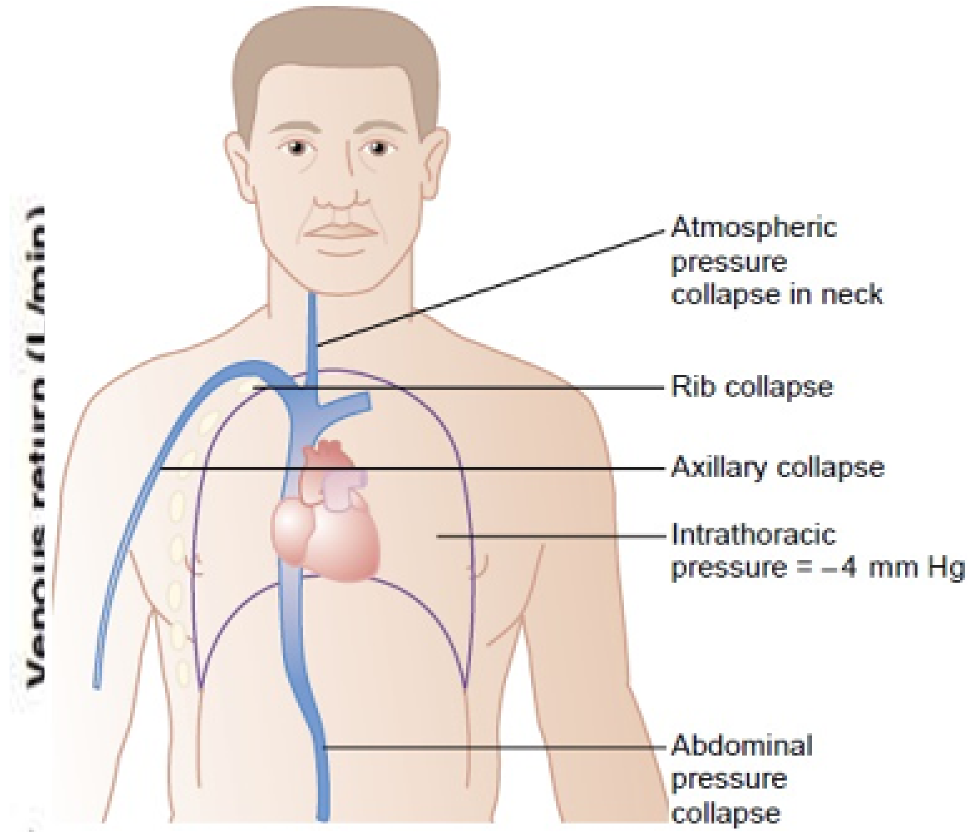
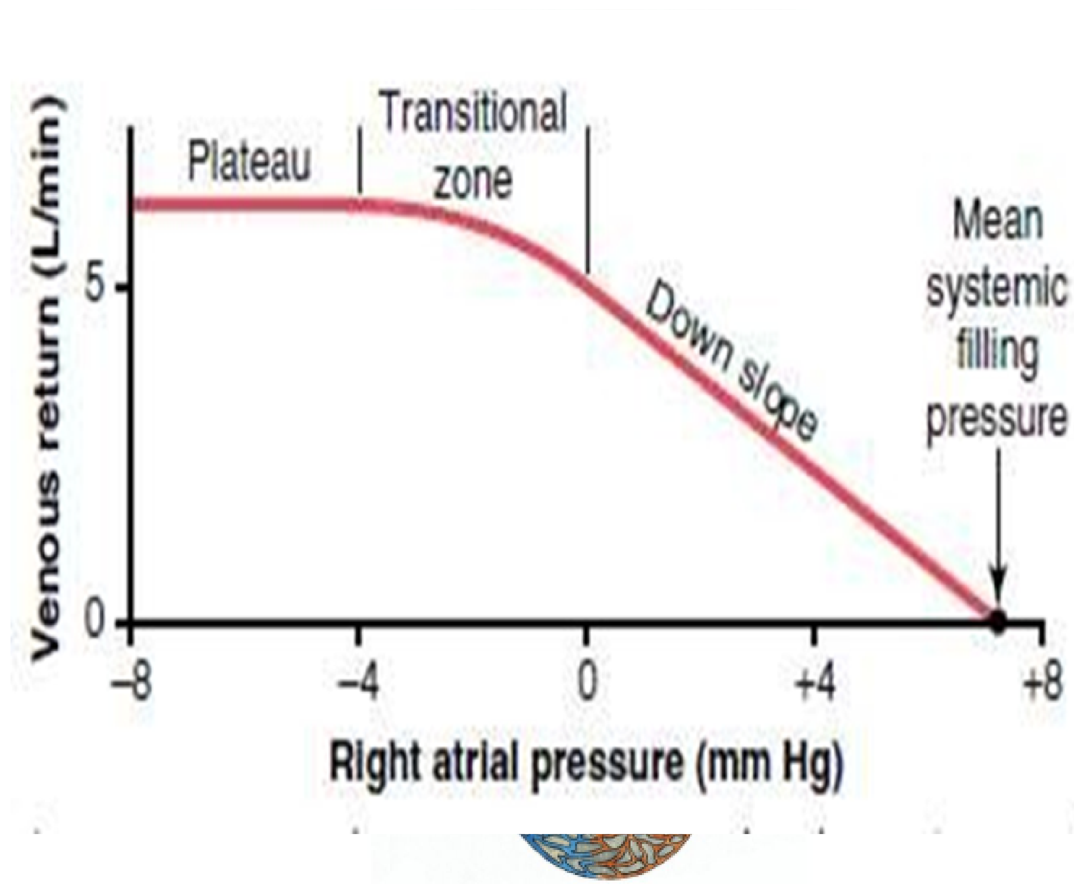


Figure 15–9

Compression points that tend to collapse the veins entering the thorax.

Mean systemic filling pressure

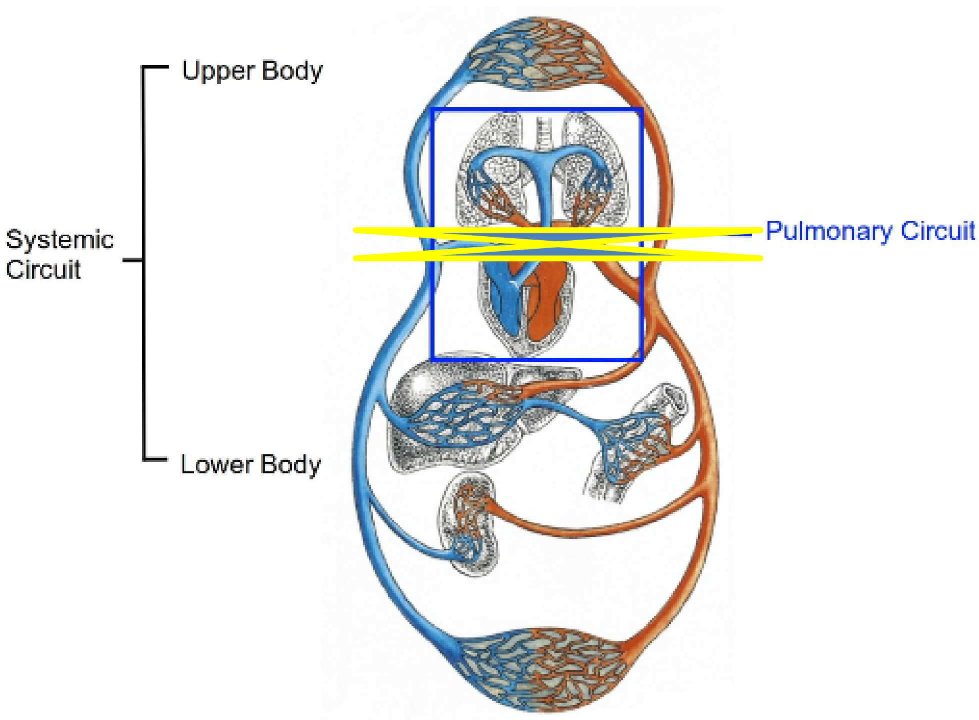
- the pressure in only the *systemic* circuit, i.e. ignoring the heart and pulmonary circulation, also in the absence of flow. This is usually the pressure people are interested in when they are discussing cardiac preload and vascular function curves, because this is the pressure which is thought to push blood towards the right atrium along a pressure gradient.



Mean circulatory filling pressure

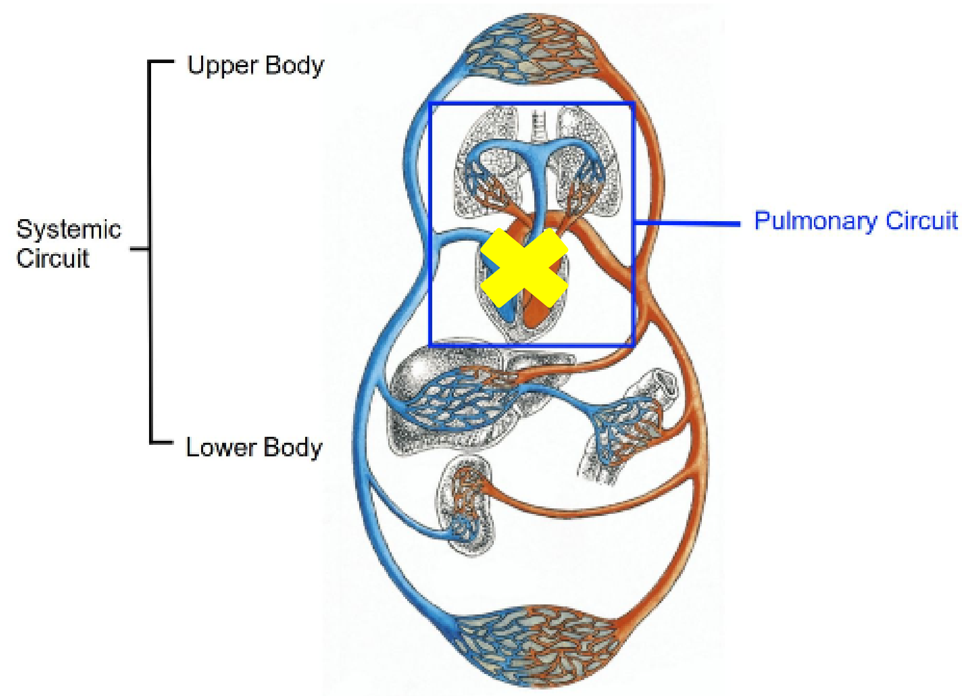
- average integrated pressure **throughout the circulatory system**.
- It can be measured by stopping the pumping of heart and allowing the pressures throughout the circulatory system to reach equilibrium.
- It may be thought of as a **measure of the elastic recoil potential** stored in the walls of the *entire* circulatory system (including the heart and pulmonary circulation).
- As such, it is a function of the volume of fluid within the system and the capacitance of the system. As more fluid enters the circulatory system (such as during transfusion), the MCFP increases because the elastic energy within the system increases. In contrast, increasing the capacitance of the system (due to vessel wall relaxation) will decrease MCFP.

Mean systemic filling pressure



Determines the cardiac preload because this is the pressure which is thought to push blood towards the right atrium along a **pressure gradient.**

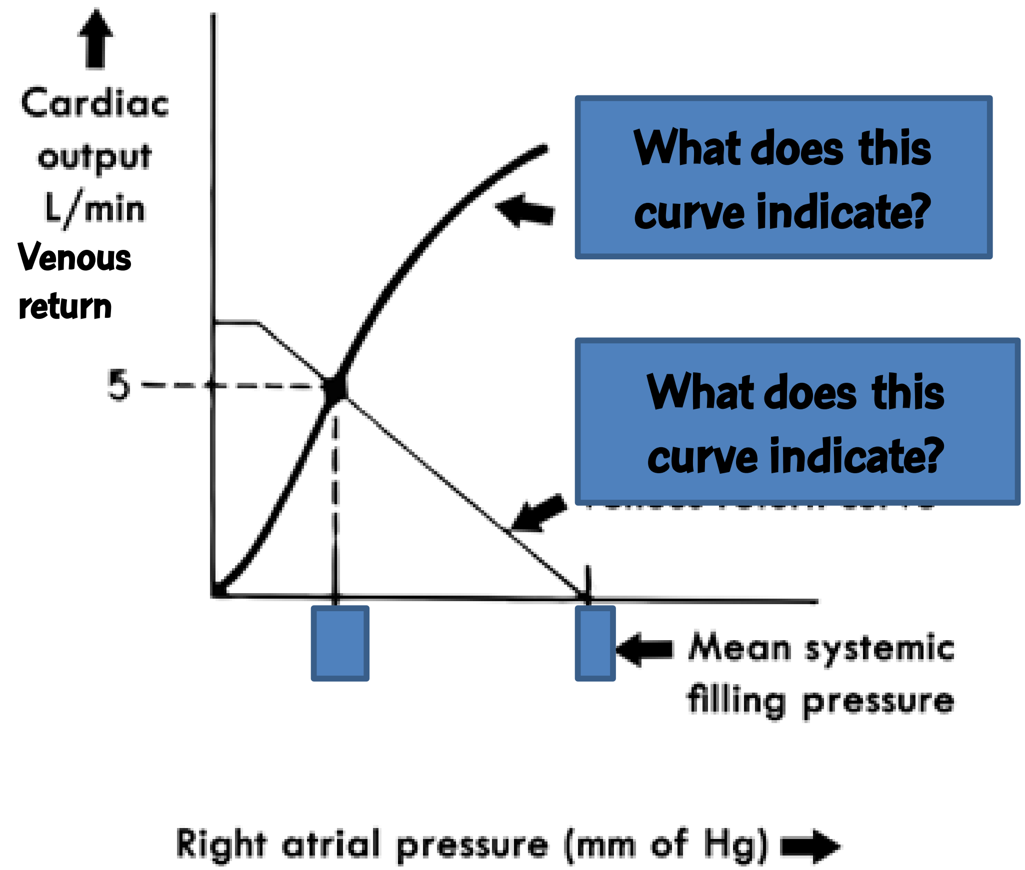
Mean circulatory filling pressure



Pressure exerted by the walls of the circulation (including the heart and pulmonary vessels) on its fluid content, and so can be thought of as a measure of the elastic recoil potential stored in those walls.

Read page 254, study figure 20.15

- *Calculate the right atrial pressure from this graph when cardiac output is 5 L?*
- *What is the value of mean systemic pressure on this graph ?*



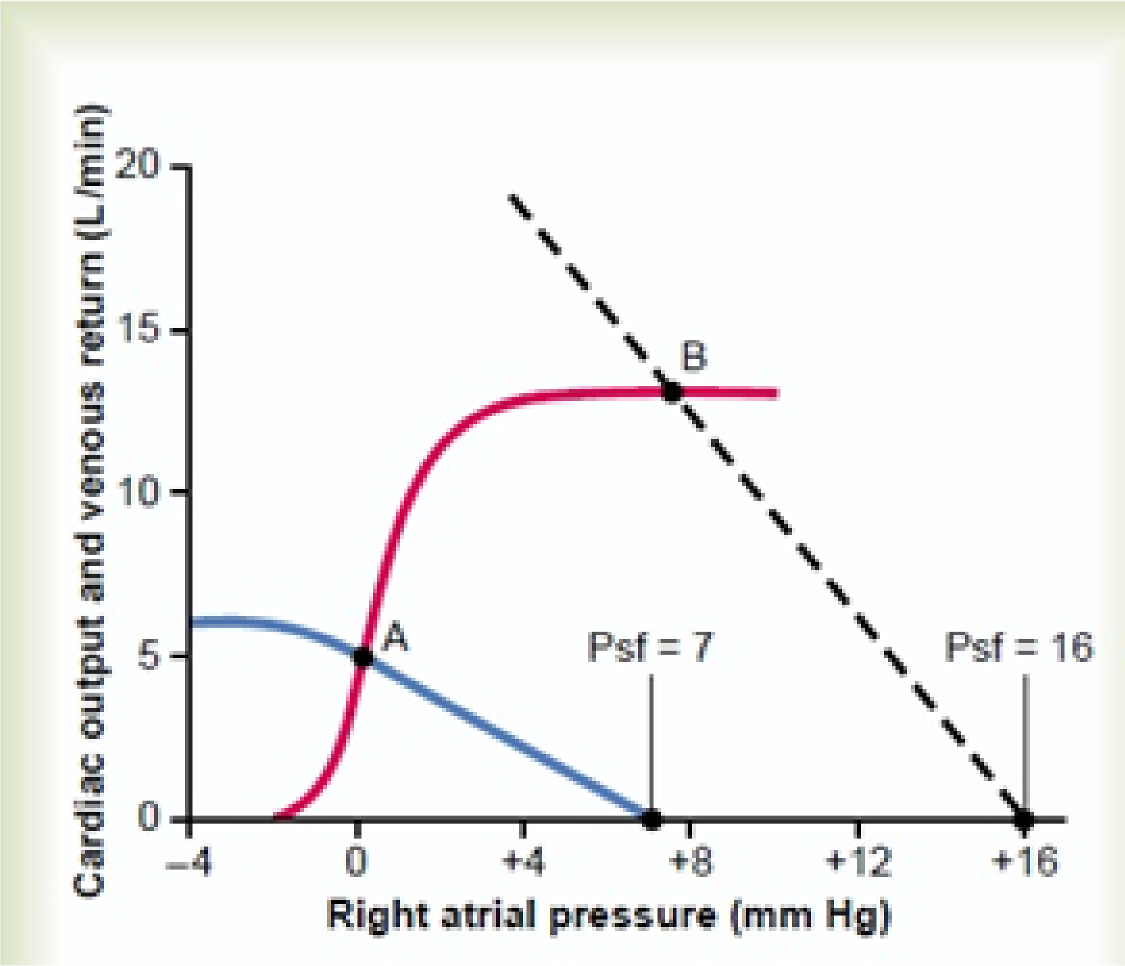
Right atrial pressure is indicated by the point at which CO curve intersect VR curve.

(0) point A

Mean systemic filling pressure is the point where VR becomes 0 and

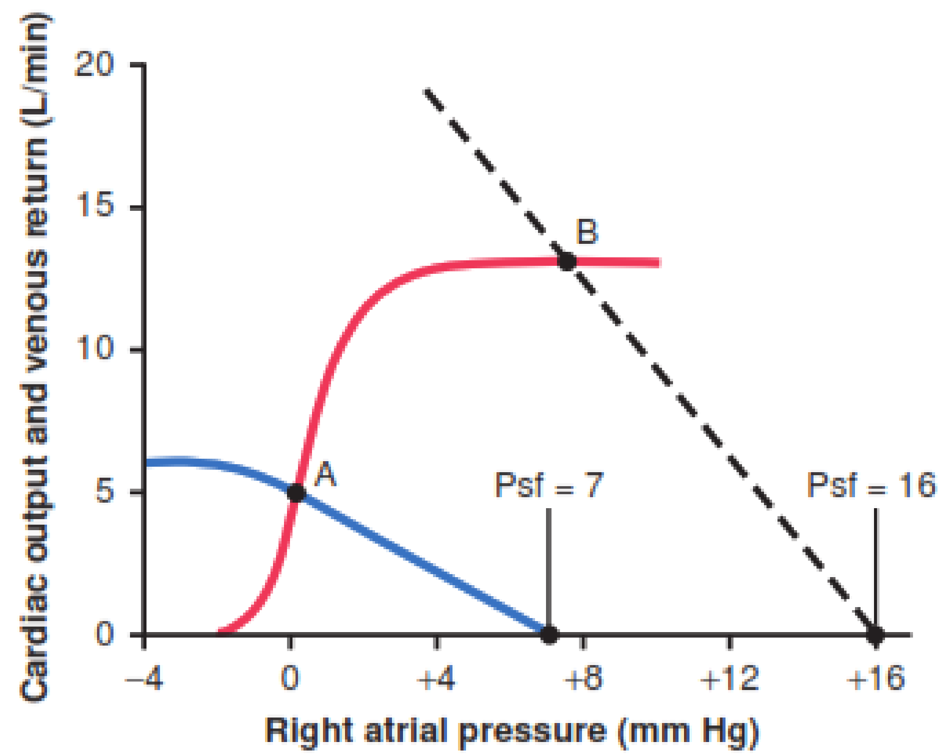
When it touches x axis.

(7mmHg)



Effect of blood volume on Mean circulatory filling pressure

- At a blood volume of about 4000 milliliters, the mean circulatory filling pressure is close to zero because this is the “unstressed volume” of the circulation
- At a volume of 5000 milliliters the filling pressure is the normal value of 7 mm Hg.



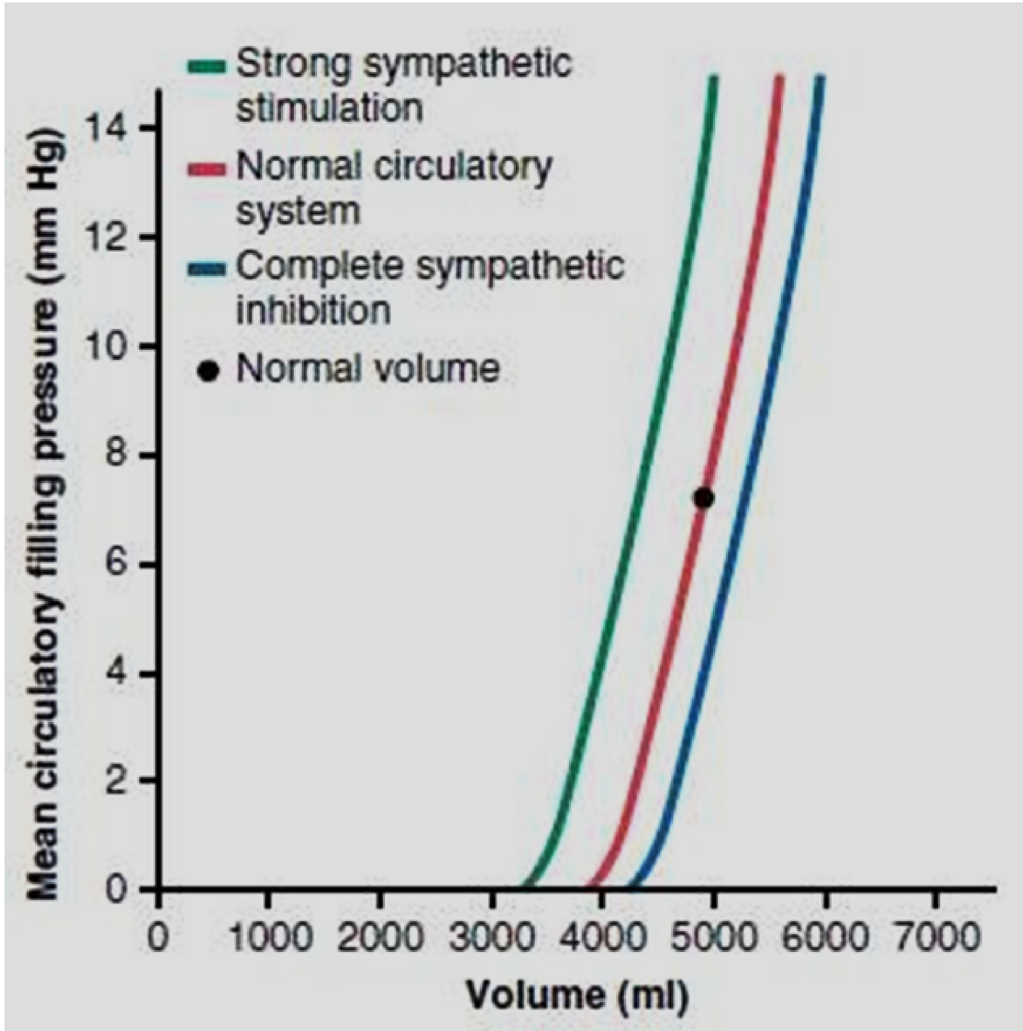
A sudden increase in blood volume of about 20 percent increases the cardiac output to about 2.5 to 3 times normal.

Effect of sympathetic stimulation on Mean circulatory filling pressure

- **Strong sympathetic** stimulation **constricts** all
- **the systemic blood vessels**
- **Pulmonary blood vessels**
- **Even chambers of heart**

the mean circulatory filling pressure is **increased** from 7 to 17 mmHg

- **Inhibition** of the **sympathetic** nervous system **decreasing** the mean circulatory filling pressure from 7 to 4mmHg.



Resistance to Venous Return

- **Most** of the resistance to venous return occurs in the **veins**, although some occurs in the arterioles and small arteries as well.

- when the **resistance** in the veins **increases** >> **blood flow** into the right atrium **decreases** drastically**. (Note that: the venous pressure rises very little because the veins are highly distensible)**

Formula for calculating venous return

VR = Psf - PRA / RVR

Psf = 7mmHg

PRA = 0 mmHg

RVR = 1.4mmHg/L/min of blood flow

Effect of increasing of decreasing resistance to venous return

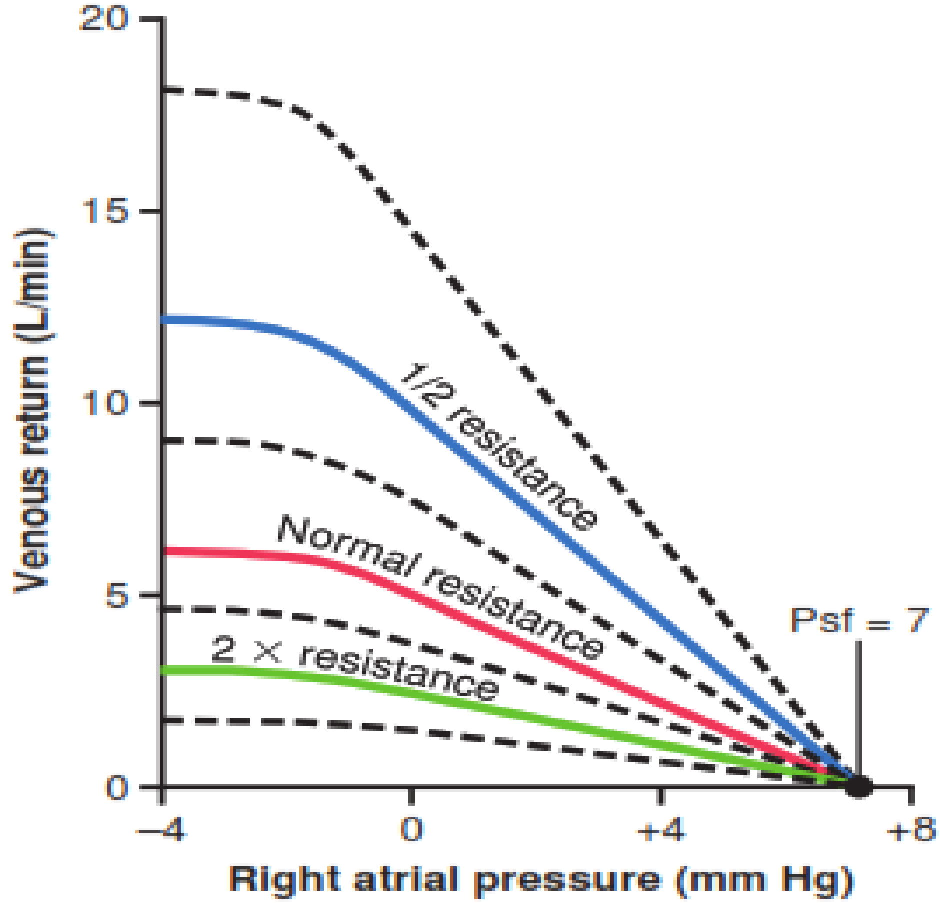


Figure 20-13. Venous return curves depicting the effect of altering the resistance to venous return. Psf, mean systemic filling pressure. *(Modified from Guyton AC, Jones CE, Coleman TB: Circulatory Physiology: Cardiac Output and Its Regulation, 2nd ed. Philadelphia: WB Saunders, 1973.)*

“Pressure Gradient for Venous Return”—When This Is Zero, There Is No Venous Return

- When the **right atrial pressure** rises to **equal** the **mean systemic filling pressure**, there is **no** longer any **pressure difference** between the peripheral vessels and the right atrium >>> there can **no** longer be any **blood flow** from any peripheral vessels back **to the right atrium.** Now …
- When the **right atrial pressure falls** progressively **lower** than the **mean systemic filling pressure, the flow** to the heart **increases proportionately.**

With decreasing cardiac function in a subject (as after myocardial infarction) and if MCFP is unchanged,

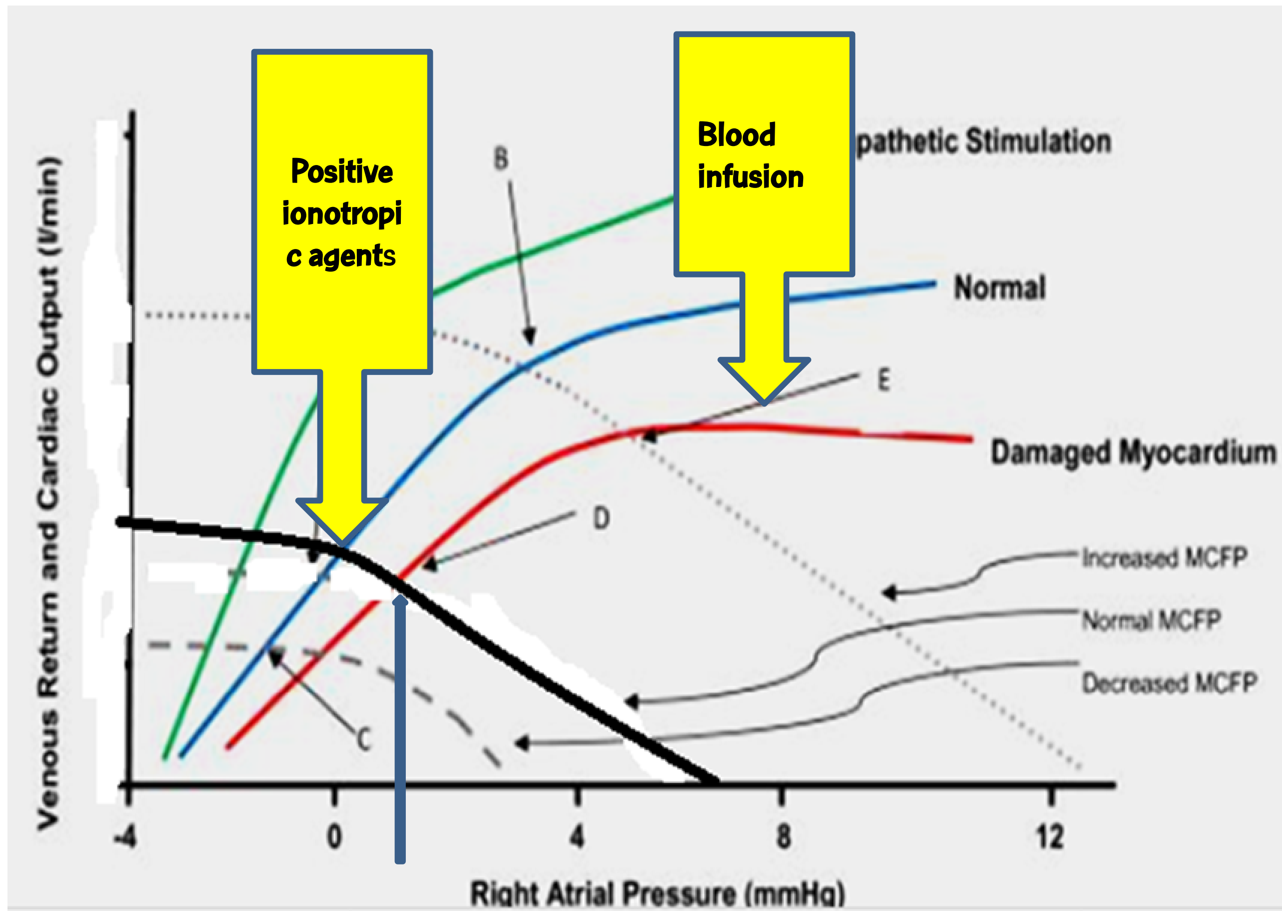
cardiac output will decrease (point D).

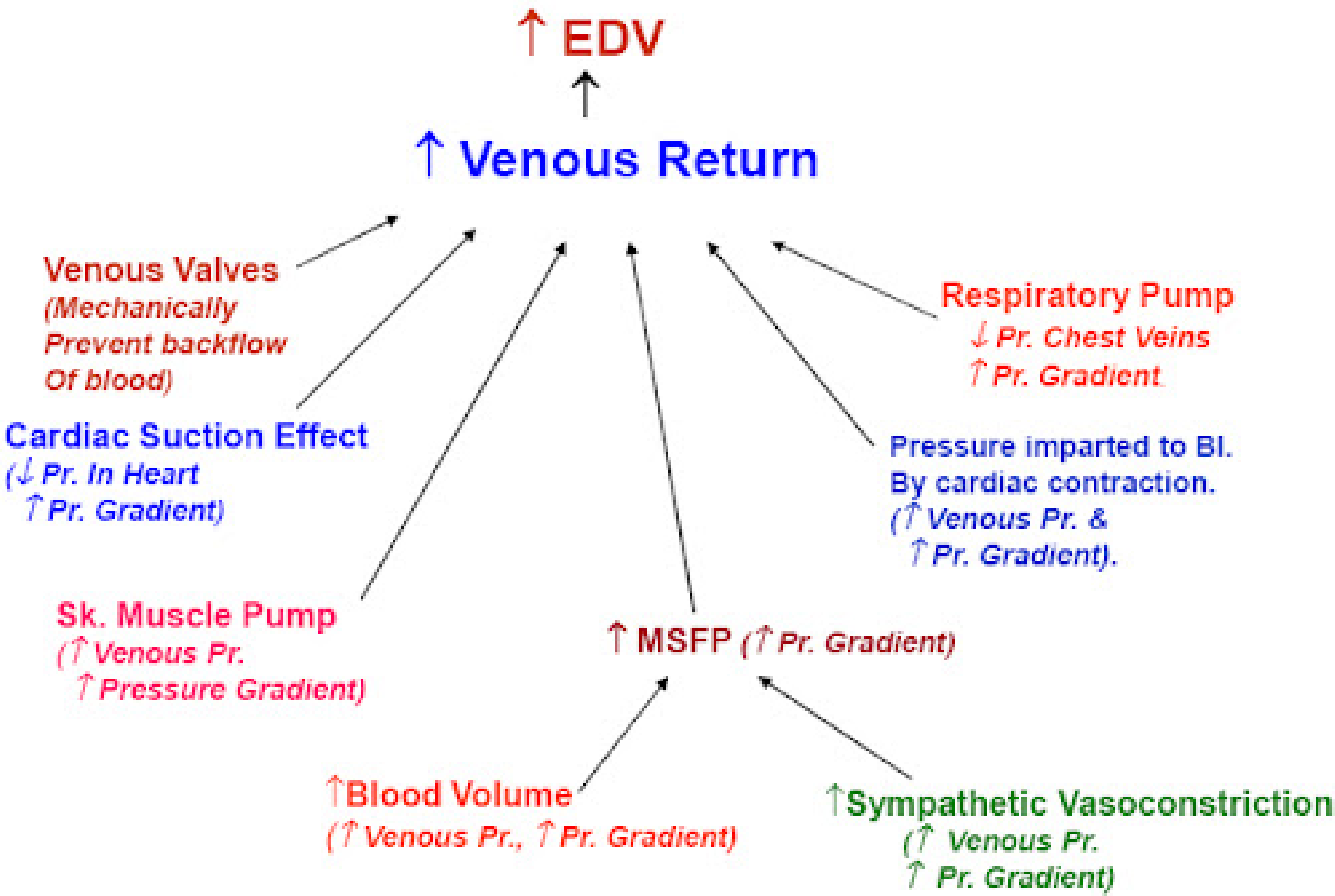
P_{RA} will increase.

solutions

Either **increasing cardiac function (via inotropic medications**) will return the subject to a normal cardiac output, point A

or **increasing MCFP** (via volume infusion or venoconstrictors will increase the cardiac output: point E.



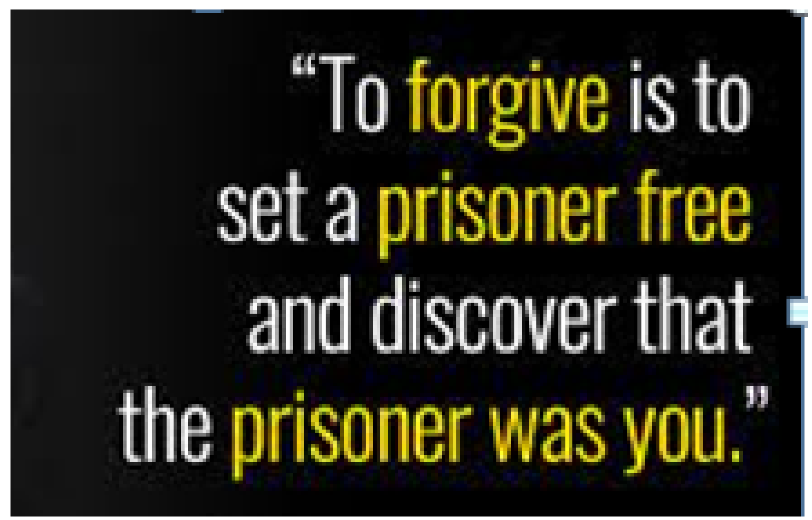


(Regulation of Venous Return)


We are human.
We are not perfect.
We are alive.
We try things.
We make mistakes.
We stumble. We fall.
We get hurt. We rise again.
We try again.
We keep learning.
We keep growing.
And we are thankful
for this priceless
opportunity called Life.
mediawebapps.com

THANKS


Humans are social beings, and we are happier, and better, when connected to others.
Paul Bloom
BrainyQuote

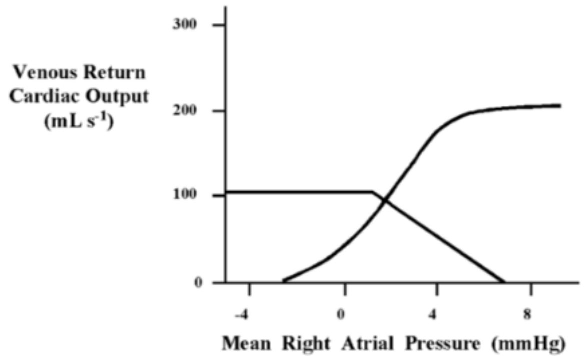

"To forgive is to set a prisoner free and discover that the prisoner was you."

Cardiac output is very sensitive to the pressure gradient for venous return. An increase in mean systemic pressure of only a few mm Hg, such as those occurring in muscular activity or with an increase in blood volume, will result in immediate increases in cardiac output. Conversely, even small increases in right atrial pressure of a few mm Hg, such as those occurring in acute heart failure following myocardial infarction, will result in significant reductions in cardiac output. Furthermore, the most that right atrial pressure can possibly increase is to a level approaching mean systemic pressure.

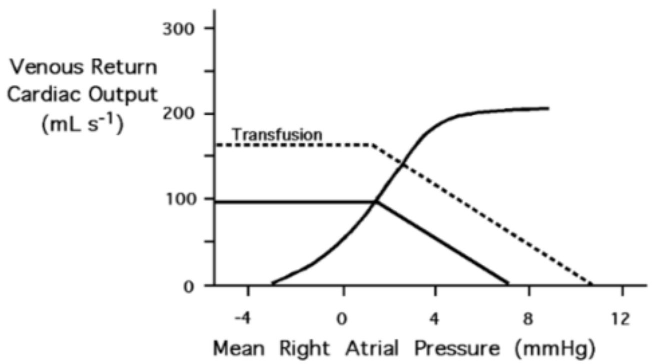
Cardiac output is affected by systemic vascular resistance, which is the sum of capacitance-weighted arterial and venous resistances, with an increase in total systemic resistance resulting in a reduction in cardiac output. Changes in venous resistance will have a much greater effect on total systemic resistance than equivalent percentage changes in arterial resistance.

- Recent research and clinical guidelines have promoted early goal-directed therapy (EGDT) as a useful paradigm for the resuscitation of patients with severe sepsis or septic shock. A central strategy in EGDT is to maintain central venous pressure (CVP) between 8 and 12 mm Hg - purportedly to improve cardiac output [31]. Despite the widespread belief that CVP reflects the adequacy of cardiac preload in critically ill patients, there is a large body of evidence suggesting that the relationship between CVP and cardiac output is tenuous [32]. Rather, CVP represents the interaction between pump function and venous return and can give meaningful information about volume status if some measurement of cardiac function is known

(b) On the diagram below draw a curve to indicate what happens to the cardiac output curve during cardiac failure.



(c) What are the equilibrium values for cardiac output and MRAP after blood transfusion for the heart shown in the diagram below? (Show on the graph how you estimate these values).

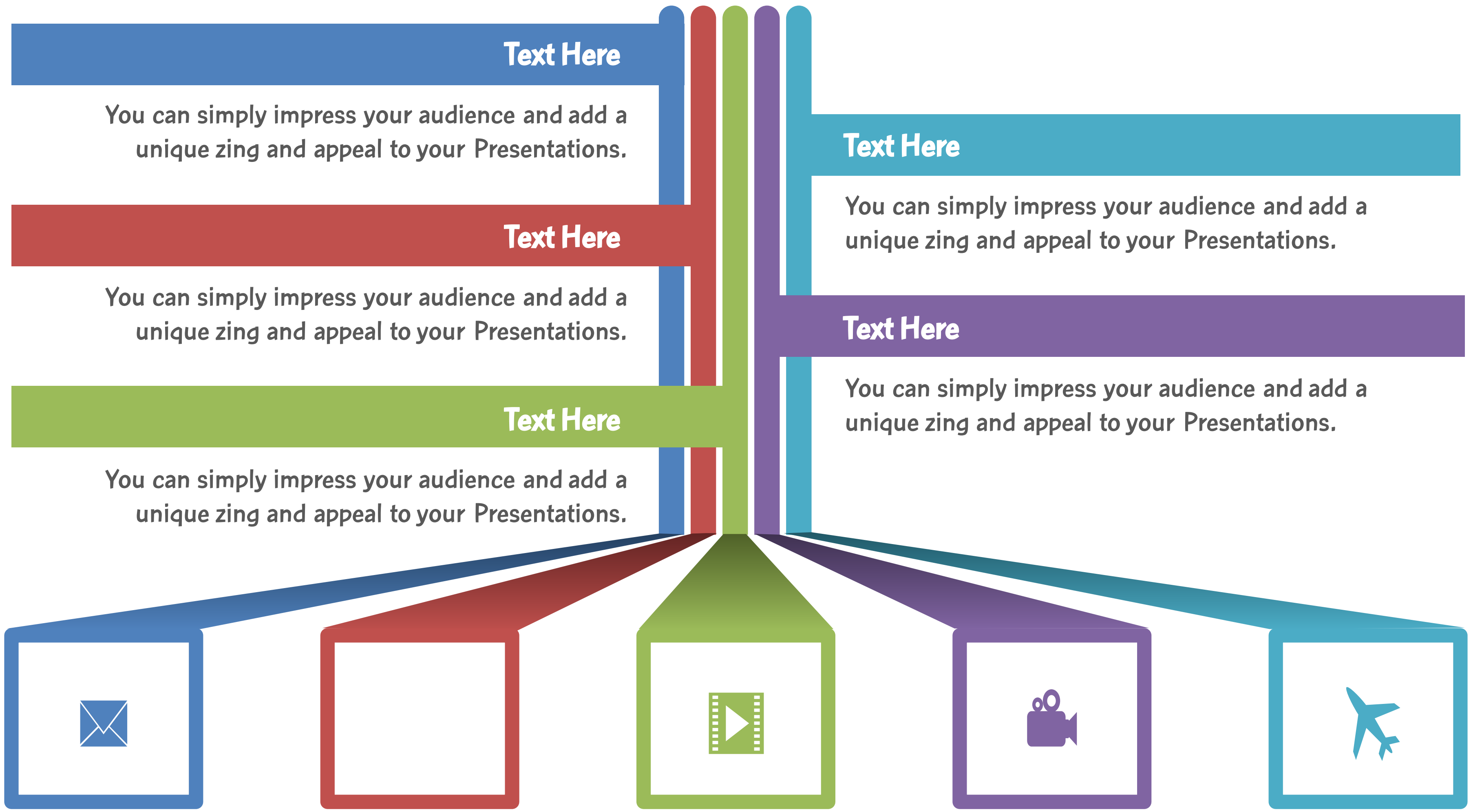


(d) What is the maximum cardiac output that can be achieved for this heart by increasing blood volume alone?

(e) By what other mechanisms can cardiac output be increased?

- **Mean circulatory filling pressure** (MCFP) is the pressure that would be measured at all points in the entire circulatory system if the heart were stopped suddenly and the blood were redistributed instantaneously in such a manner that all pressures were equal.
- MCFP and MSFP is usually about 7-8 mmHg
- This is also the pressure in the small (<1mm) venules
- This pressure in the venules is thought to remain relatively constant irrespective of the cardiac output, and is said to be the "pivot pressure" of the circulation
- **Mean *systemic* filling pressure** (MSFP) is the pressure in only the *systemic* circuit, i.e. ignoring the heart and pulmonary circulation, also in the absence of flow.
- **Mean cardiopulmonary filling pressure** (MCPFP) is the mean pressure in the motionless cardiac chambers and the pulmonary circulation. It is usually about 3 mmHg higher.
- **The main determinants of MCFP and MSFP** are total blood volume and venous resistance
- Of the total blood volume, only about 15% exerts the pressure, and the rest is said to be **"unstressed volume"**, which theoretically exerts no pressure (or minimal pressure) on the walls of the vess

Infographic Style



- **Mean circulatory filling pressure** (MCFP) is the pressure in the entire circulatory system in the absence of flow. It is the pressure exerted by the walls of the circulation (including the heart and pulmonary vessels) on its fluid content, and so can be thought of as a measure of the elastic recoil potential stored in those walls. It was defined by Arthur Guyton as
- *"The pressure that would be measured at all points in the entire circulatory system if the heart were stopped suddenly and the blood were redistributed instantaneously in such a manner that all pressures were equal."*

- **Mean *systemic* filling pressure** (MSFP) is the pressure in only the *systemic* circuit, i.e. ignoring the heart and pulmonary circulation, also in the absence of flow. This is usually the pressure people are interested in when they are discussing cardiac preload and vascular function curves, because this is the pressure which is thought to push blood towards the right atrium along a pressure gradient.