Venous Return

Venous return is the quantity of blood flowing from large veins into the right atrium each min.

Factors controlling venous return :-

1- Skeletal muscle pump → ↑ venous return.

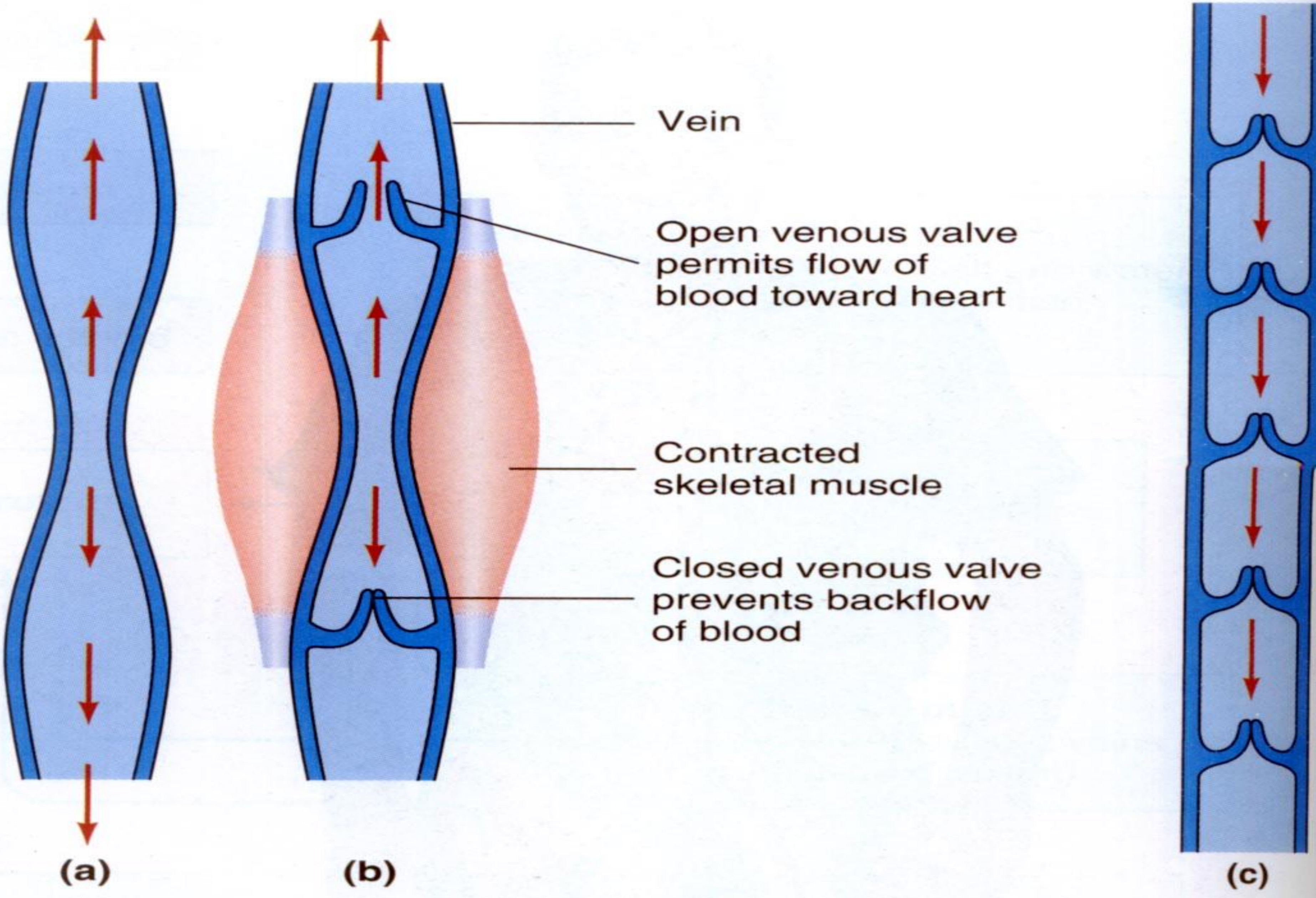
2- Pressure drop during inspiration → ↑ venous return.
Forceful expiration (Valsalva maneuver) → ↓ venous return.

3- ↑Blood volume → ↑ venous return.

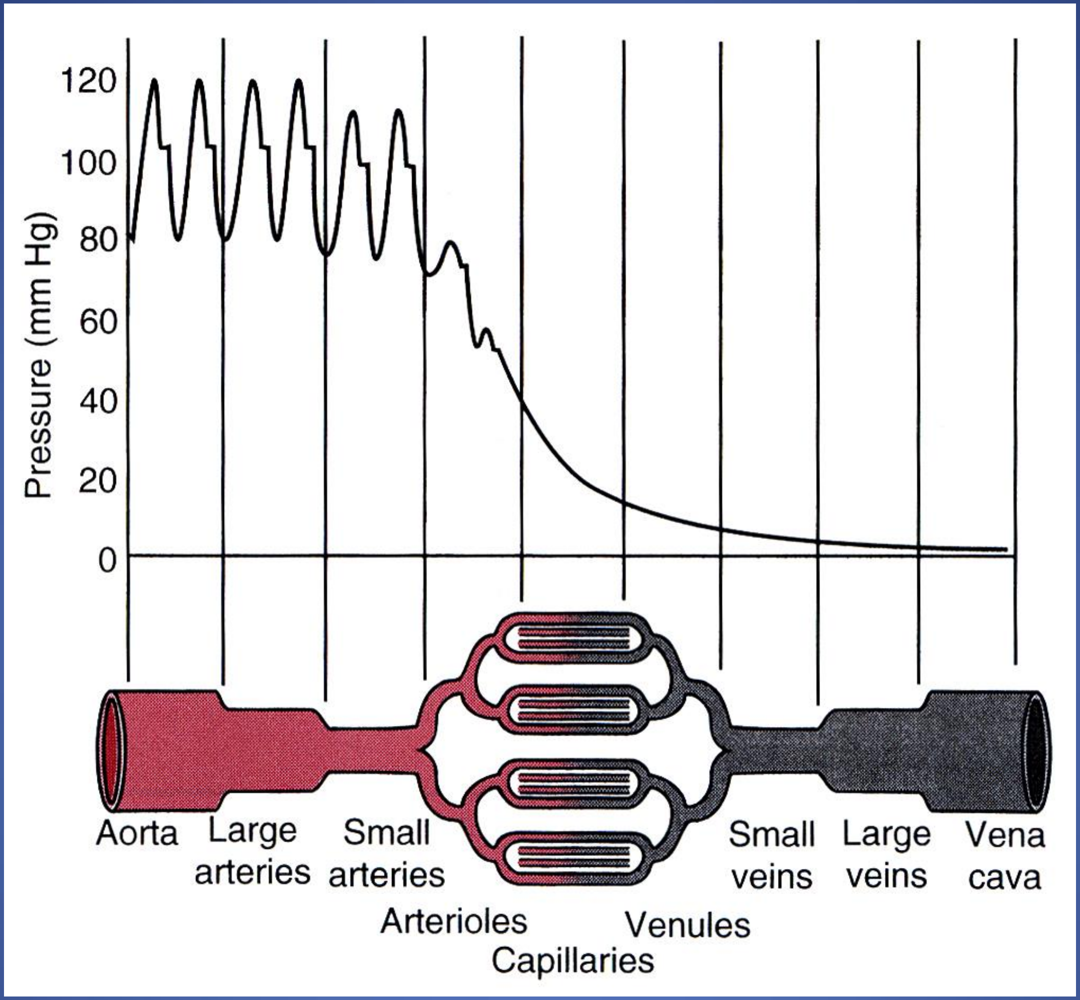
4- ↑Pressure gradient → ↑ venous return.

5- ↑Venous pressure → ↑ venous return.

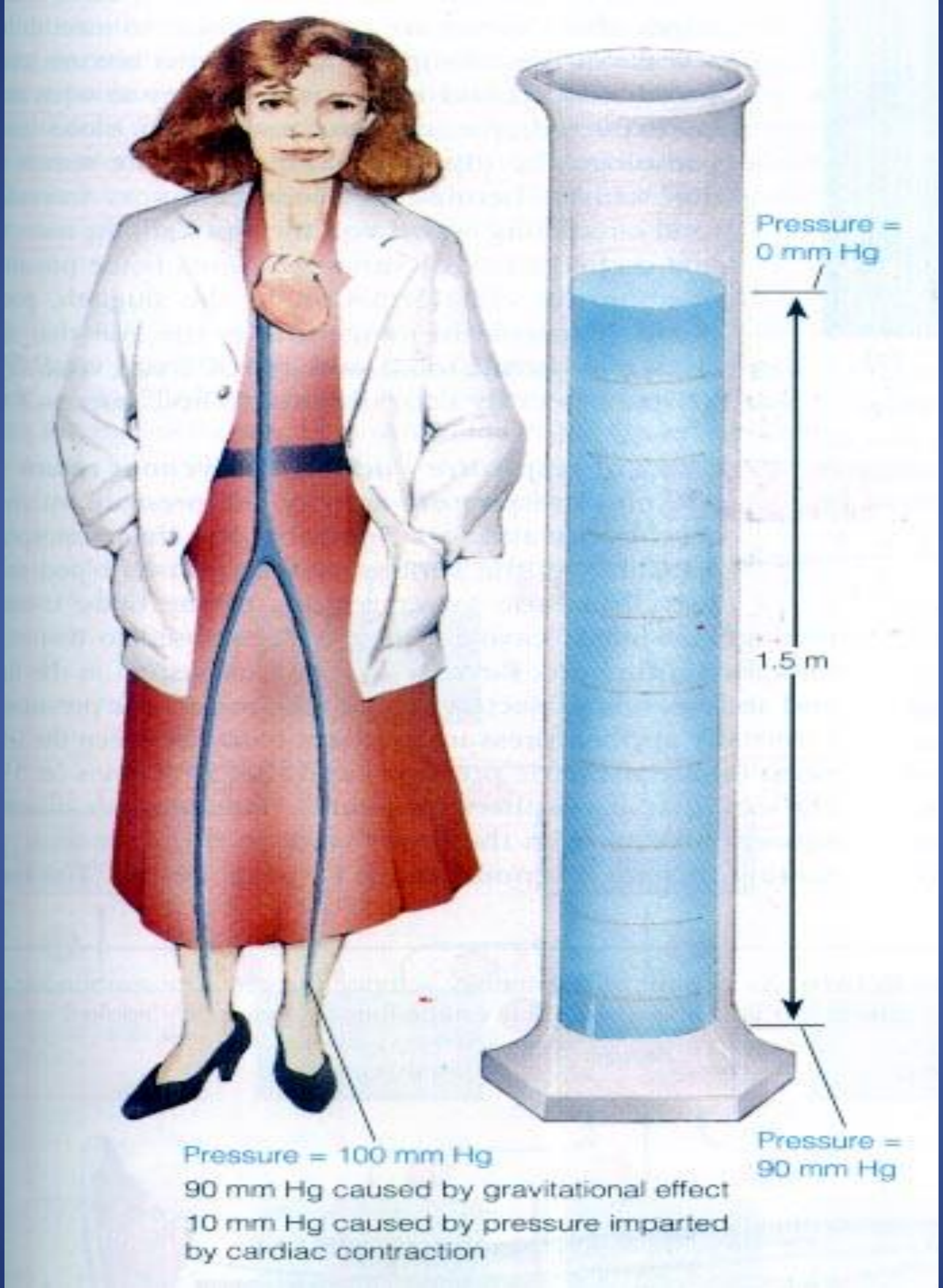
6- Gravity → ↓ venous return.



Vein
Open venous valve
permits flow of
blood toward heart
Contracted
skeletal muscle
Closed venous valve
prevents backflow
of blood
(a)
(b)
(c)



Pressures in different vessels of the systemic circulation. Pulse pressure is greatest in the aorta and large arteries. The greatest drop in pressure occurs in the arterioles.

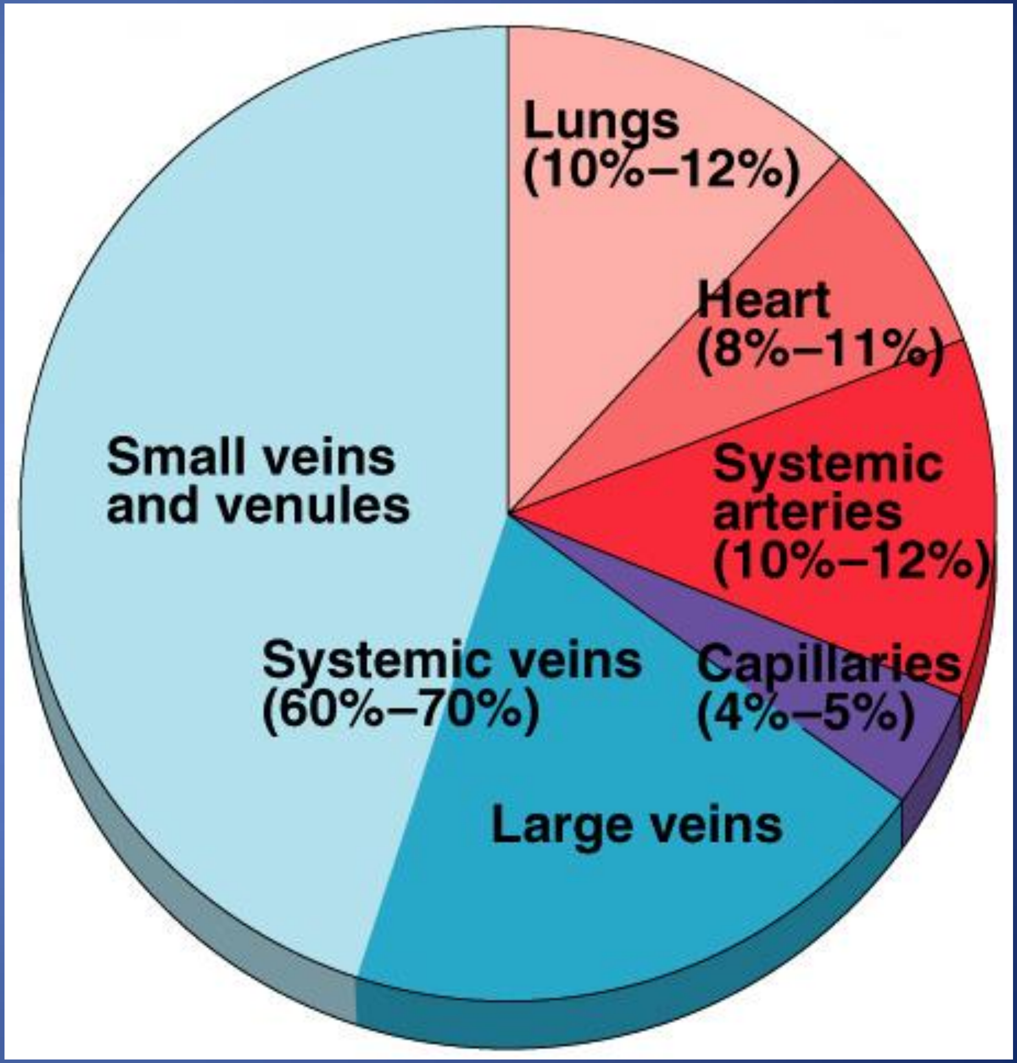

Pressure =
0 mm Hg
1.5 m
Pressure =
90 mm Hg
Pressure = 100 mm Hg
90 mm Hg caused by gravitational effect
10 mm Hg caused by pressure imparted
by cardiac contraction

Venous Return

Veins hold most of blood in body (70%) & are thus called capacitance vessels

Have thin walls & stretch easily to accommodate more blood without increased pressure (=higher compliance)

Have only 0 -10 mm Hg Pressure.



Venous Return

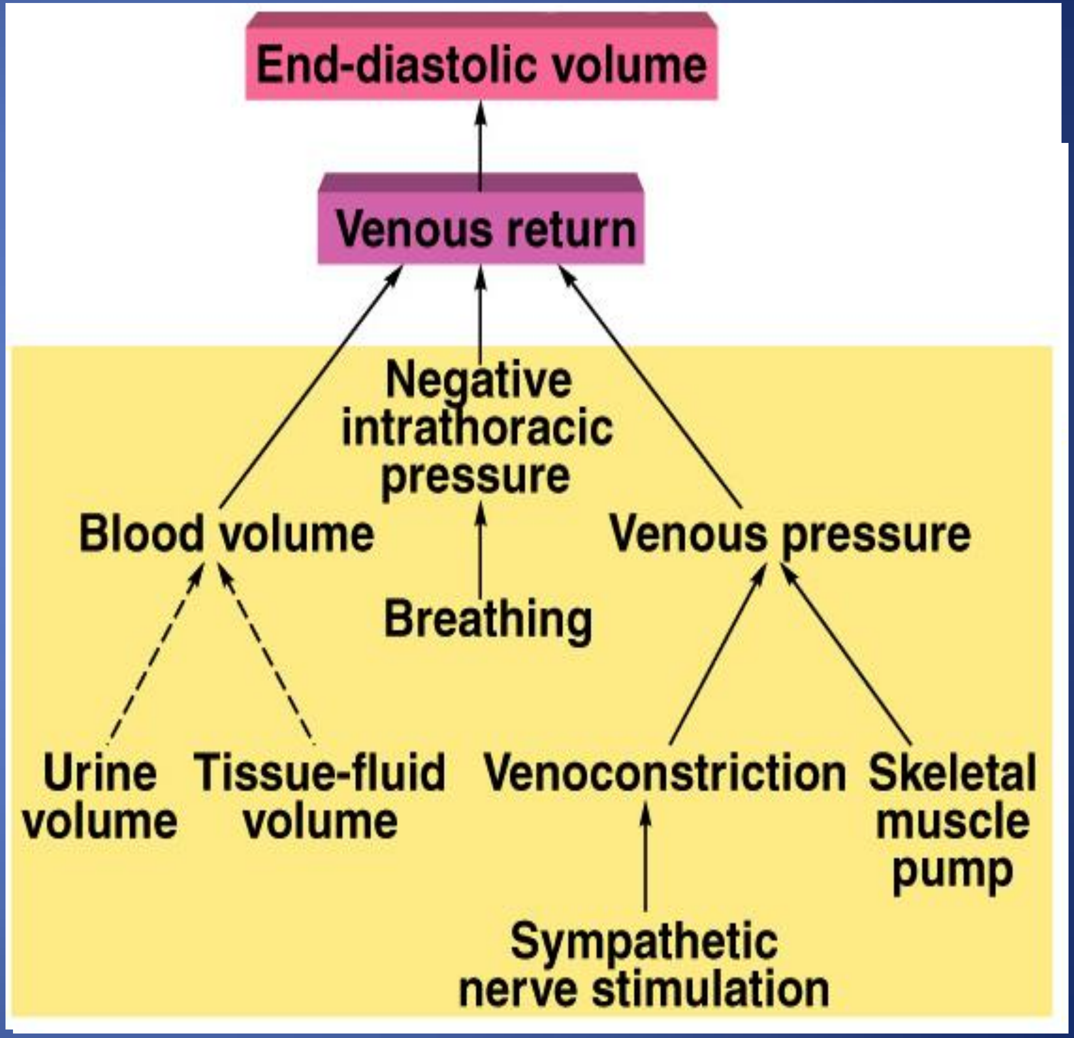
Dependens on:-

1- Blood volume & venous pressure.

2- Venoconstriction caused by Sympathetic

3- Skeletal muscle pumps.

4- Pressure drop during inhalation.



Venous return curve

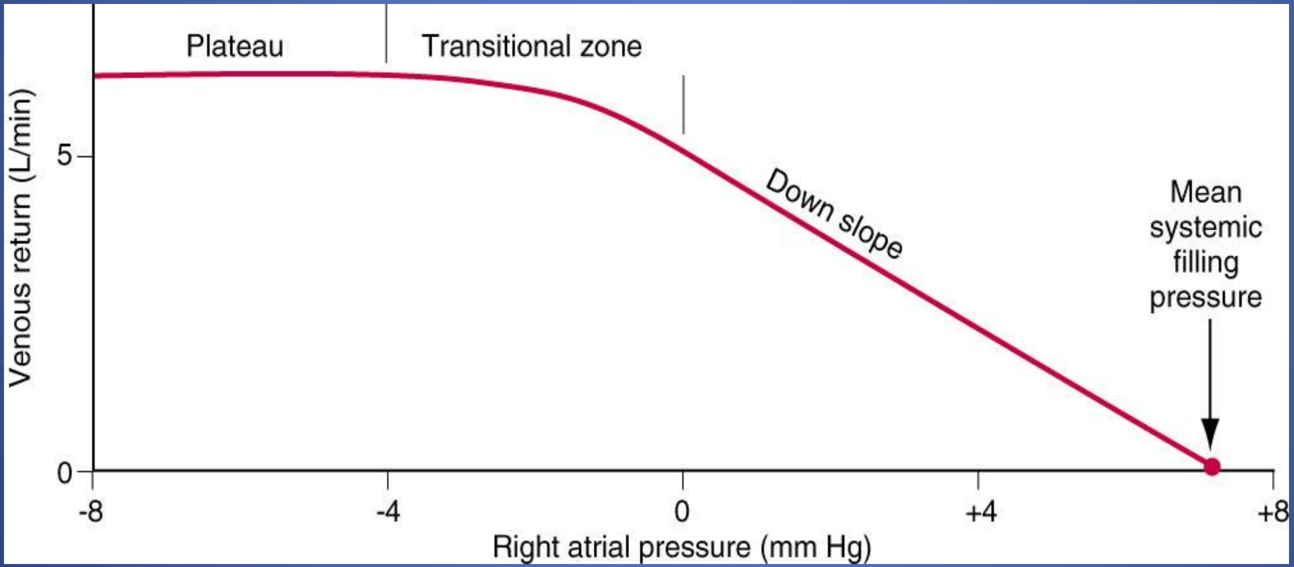
Venous return (VR) curve relates VR to right atrial pressure.

Venous return is decreased when:

1- The right atrial pressure (RAP) is increased,

2- Pumping capability becomes diminished.

3- The nervous circulatory reflexes are absent.



In Valsalva maneuvre (forceful expiration against a closed glottis) the intrapleural pressure become positive which is transmitted to the large veins in the chest → decrease venous return.

Venous return curve

Plateau in the venous return curve at negative atrial pressures caused by

Collapse of the large veins.

When the RAP falls below zero, no further increase in VR and a plateau is reached.

The value for right atrial pressure at which venous return is zero is called the mean systemic pressure or mean circulatory pressure which is the pressure that would be measured throughout the cardiovascular system if the heart were stopped.

Effect of blood volume on mean circulatory filling pressure :

When the blood volume ranges from 0 to 4 L, all of the blood will be in the unstressed volume (the veins), producing no pressure, and the mean systemic pressure will be zero. When blood volume is greater than 4 L, some of the blood will be in the stressed volume (the arteries) and produce pressure. For example, if the total blood volume is 5 L, 4 L is in the unstressed volume, producing no pressure, and 1 L is in the stressed volume, producing a pressure of approximately 7 mm Hg.

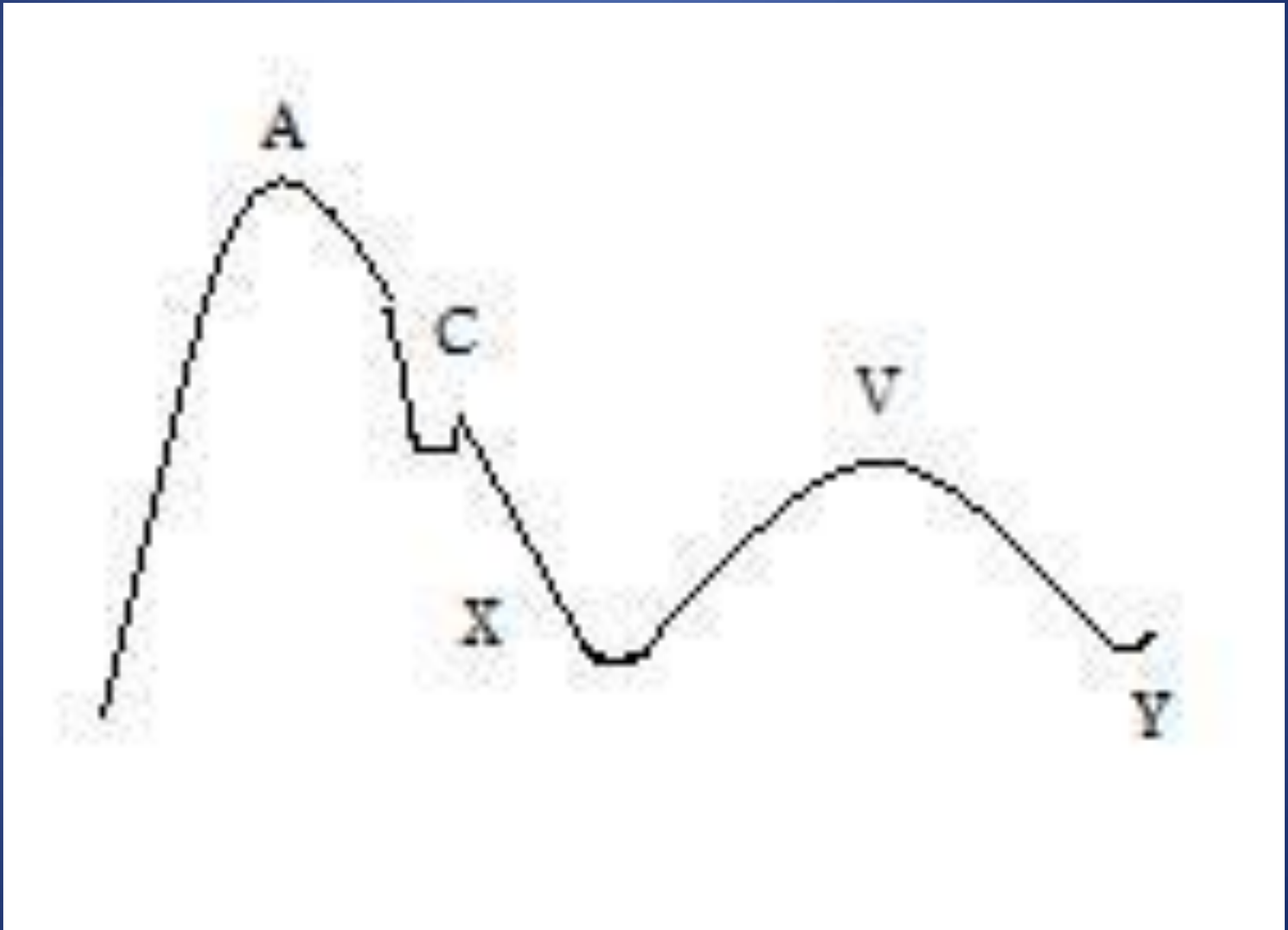
Jugular Venous Pressure (Pulse)

Is the indirectly observed pressure over the venous system.

It can be useful in the differentiation of different forms of heart and lung disease.

Classically three upward deflections and two downward deflections have been described.

Jugular Venous Pressure (Pulse)



The upward deflections are:

The "a“ (atrial contraction),

The "c" (ventricular contraction and resulting bulging of tricuspid valve into the right atrium during isovolumetric contraction),

and The "v“ (atrial venous filling),

The downward deflections of the wave are:

the "x“ (the atrium relaxes and the tricuspid valve moves downward).

and the "y" descent (filling of ventricle after tricuspid opening).

What does this show?

Raised Jugular Venous Pressure

Causes of a raised JVP may be classified into those due to:

1- Increased right ventricular filling pressure e.g in heart failure , fluid overload.

2- Obstruction of blood flow from the right atrium to the right ventricle e.g tricuspid stenosis.

3- Superior vena caval obstruction e.g retrosternal thyroid goitre.

4- Positive intrathoracic pressure e.g pleural effusion, pneumothorax.

The JVP usually drops on inspiration along with intrathoracic pressure.

The Cardiac Output (C.O.)

It is the volume of blood ejected from the right or left ventricle per minute = 5 L./min. at rest.

C.O. = Heart rate x Stroke volume.

Stroke volume is the volume of blood ejected from each ventricle per beat = 70 mls /beat at rest.

Heart rate at rest = 72 beats /min.

Normal Values of Cardiac Output at Rest and During Activity

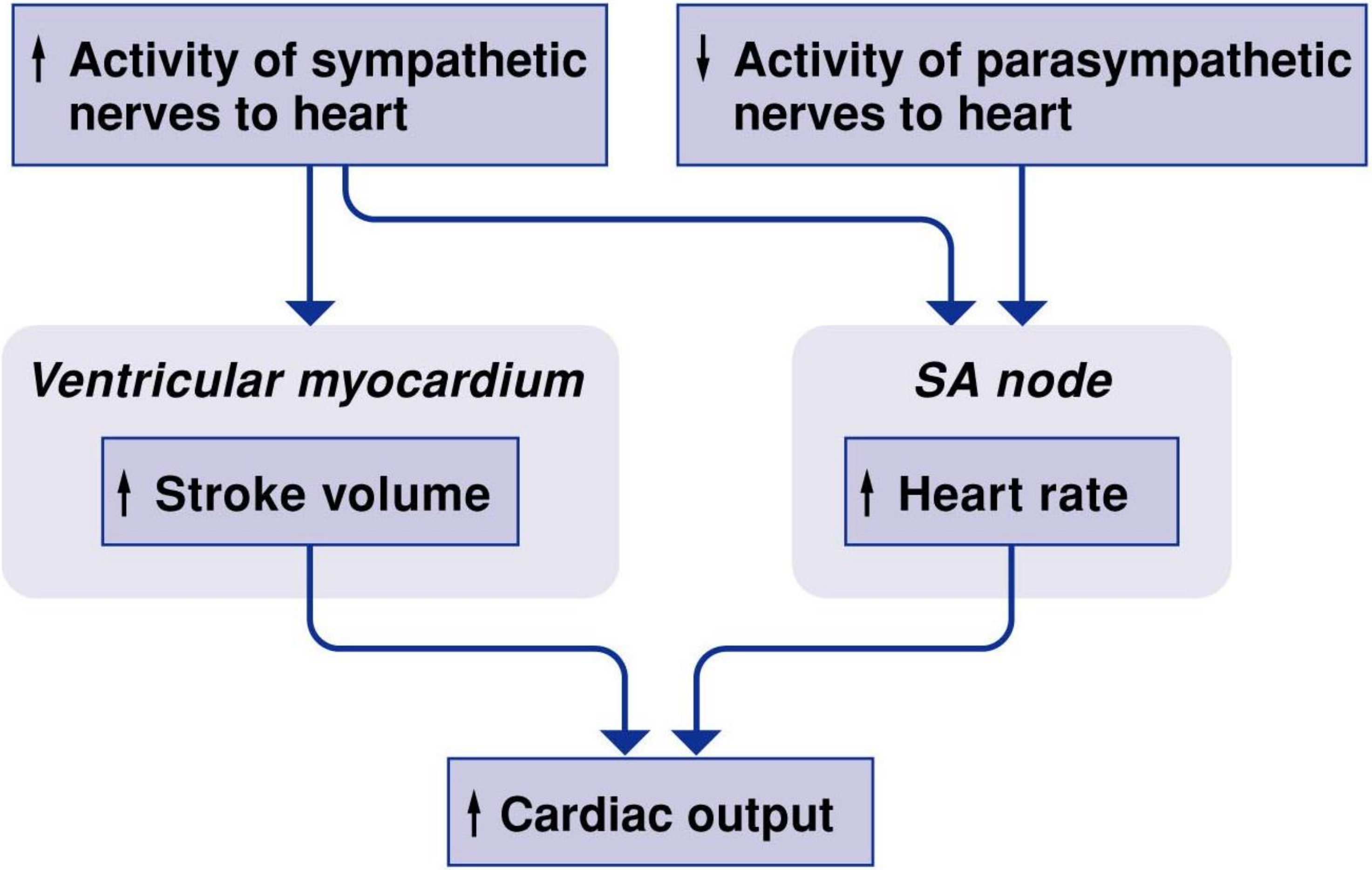
- Cardiac output is the quantity of blood pumped into the aorta each minute by the heart.

- Venous return is the quantity of blood flowing from veins into the right atrium each min.

- Cardiac output varies widely with the level of activity of the body. The factors affecting cardiac output are: (1) Body metabolism (2) Exercise (3) Hyperthyroidism (4) Age (5) Pregnancy (6) Increase body temperature.

- Resting cardiac output for men is 5.6 L/min, but for women is about 4.9 L/min (but the average cardiac output for the resting adult is 5L/min).

Regulation of Cardiac Output



Regulation of Heart Rate

Increased heart rate by:

1- Sympathetic nervous system

- **Crisis**
- **Low blood pressure**

2- Hormones

- **Epinephrine**
- **Thyroxine**

3- Exercise

4- Decreased blood volume

Regulation of Heart Rate

Atrial Reflex:

Also called Bainbridge reflex

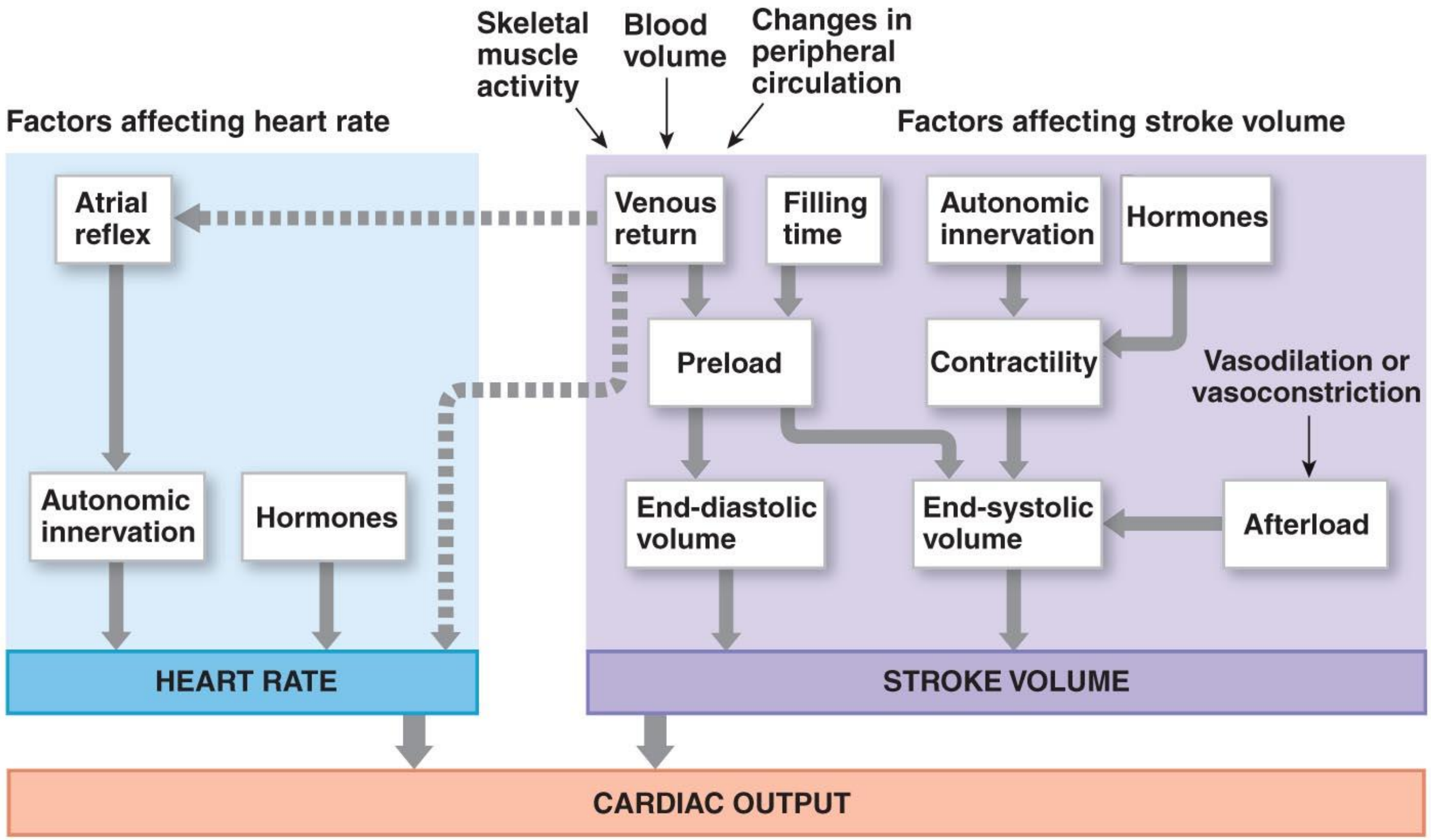
Adjusts heart rate in response to venous return

Stretch receptors in right atrium trigger increase in heart rate through increased sympathetic activity.

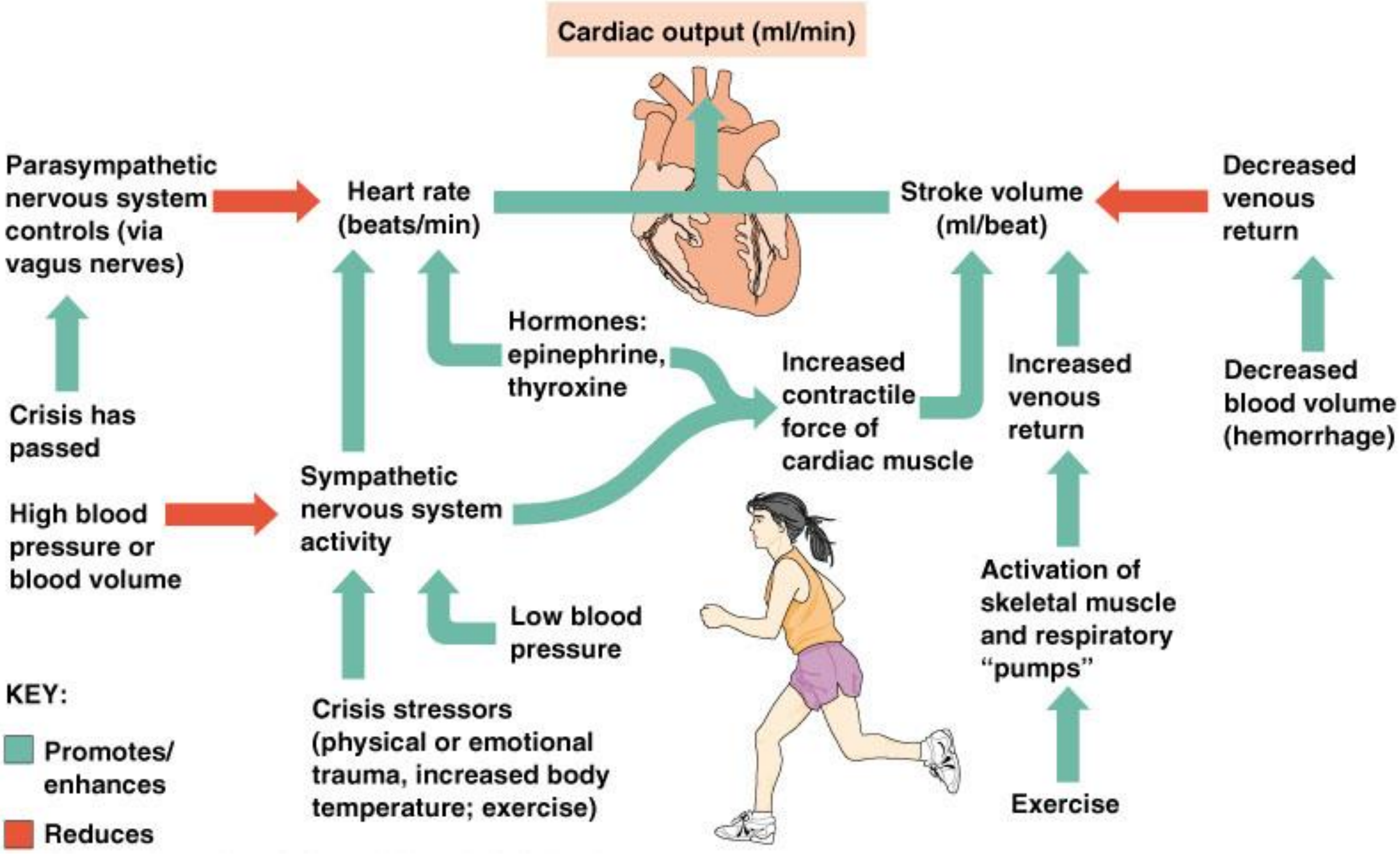
Regulation of Heart Rate

- **Decreased heart rate by:**
  - **Parasympathetic nervous system**
  - **High blood pressure or blood volume**

Summary of the Factors Affecting Cardiac Output



Cardiac Output Regulation



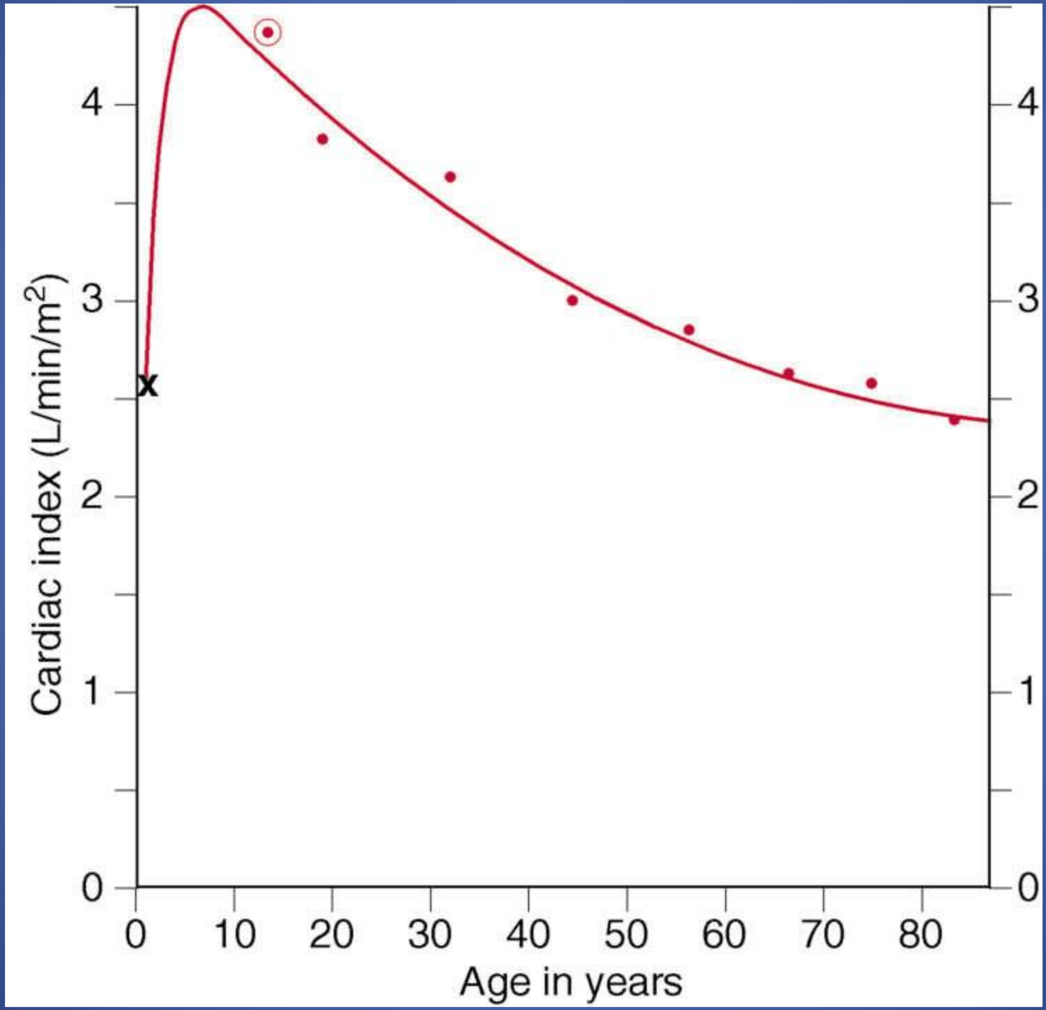
Cardiac index:

It relates the cardiac output to body surface area.

Thus relating heart performance to the size of the individual.

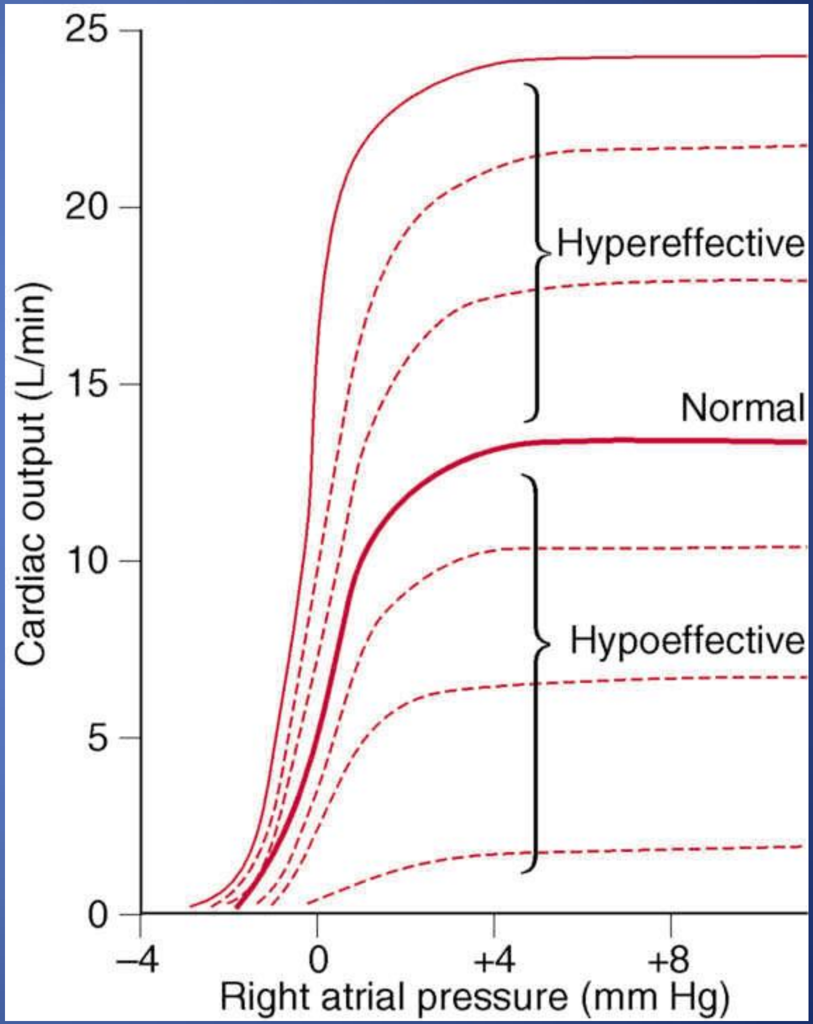
The unit of measurement is liter per minute per square meter of body surface area ($L/min/m^2$).

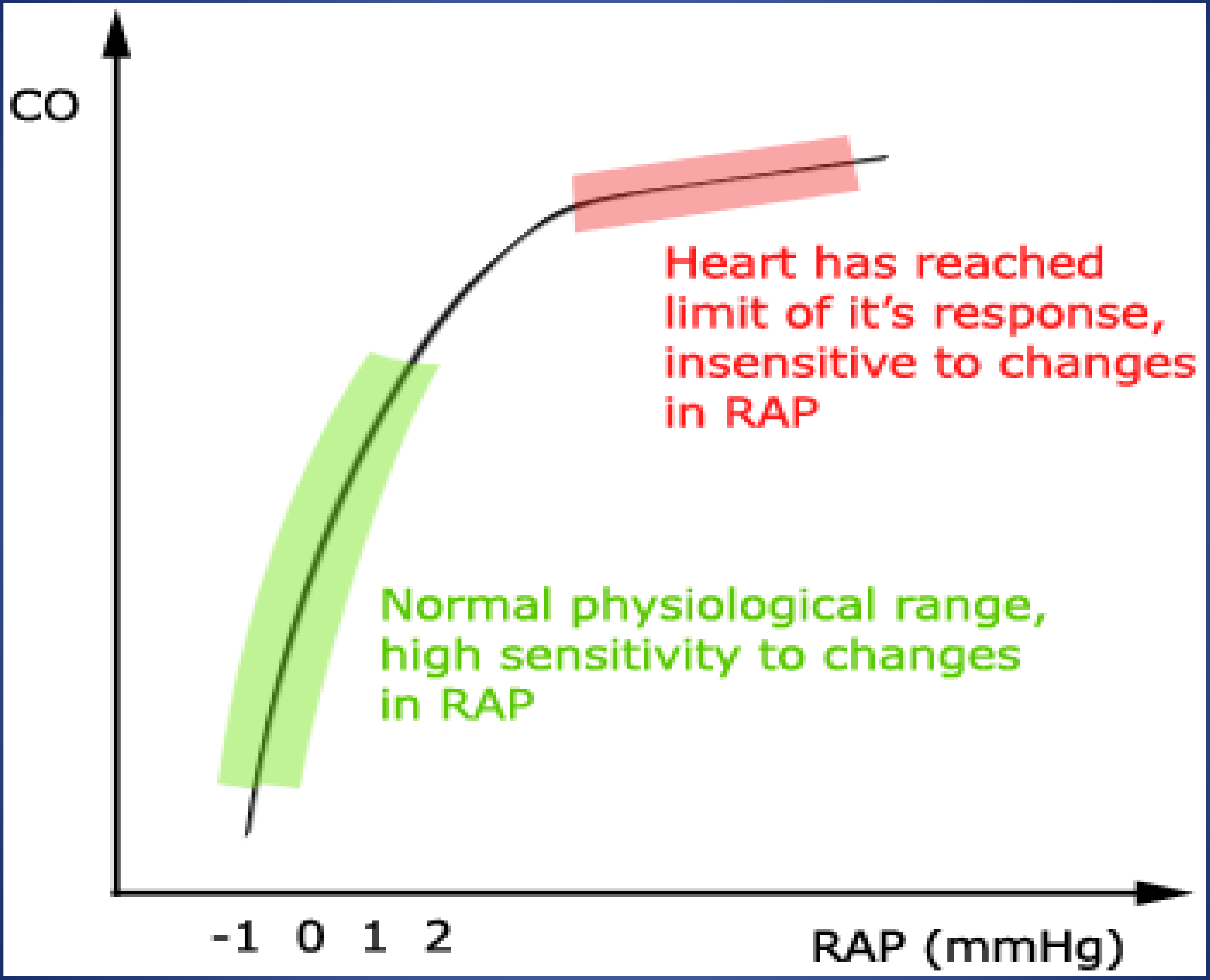
Cardiac index for the human being at different ages.



The heart has limits for cardiac output that can achieve

- This figure shows the normal cardiac output curve at each level of right atrial pressure. The plateau level of this normal cardiac output is 13 L/min. This means that the heart can pump an amount of venous return up to 2.5 times the normal venous return before the heart becomes a limiting factor in the control of cardiac output.
- Factors that can cause hypereffective heart: (1) nervous stimulation and (2) hypertrophy of the heart muscle. Sympathetic stimulation and parasympathetic inhibition can increase the effectiveness of the heart via: (1) increasing the heart rate, (2) increasing the strength of heart contraction.
- Increased pumping effectiveness caused by heart hypertrophy. 50-75% increase in the heart mass of marathon runners, which increases the plateau of cardiac output 60-100%.




CO
Heart has reached limit of it's response, insensitive to changes in RAP
Normal physiological range, high sensitivity to changes in RAP
-1 0 1 2
RAP (mmHg)

Measurement Of C.O.

The Direct Fick's Method:-

It states that, the amount or volume of any substance taken up by an organ or by the whole body is equal to:

(The arterial level of the substance − the venous level) X blood flow.

$$\textbf{Blood flow} = \frac{\textbf{Amount}}{\textbf{(Arterial level} - \textbf{Venous level)}}$$

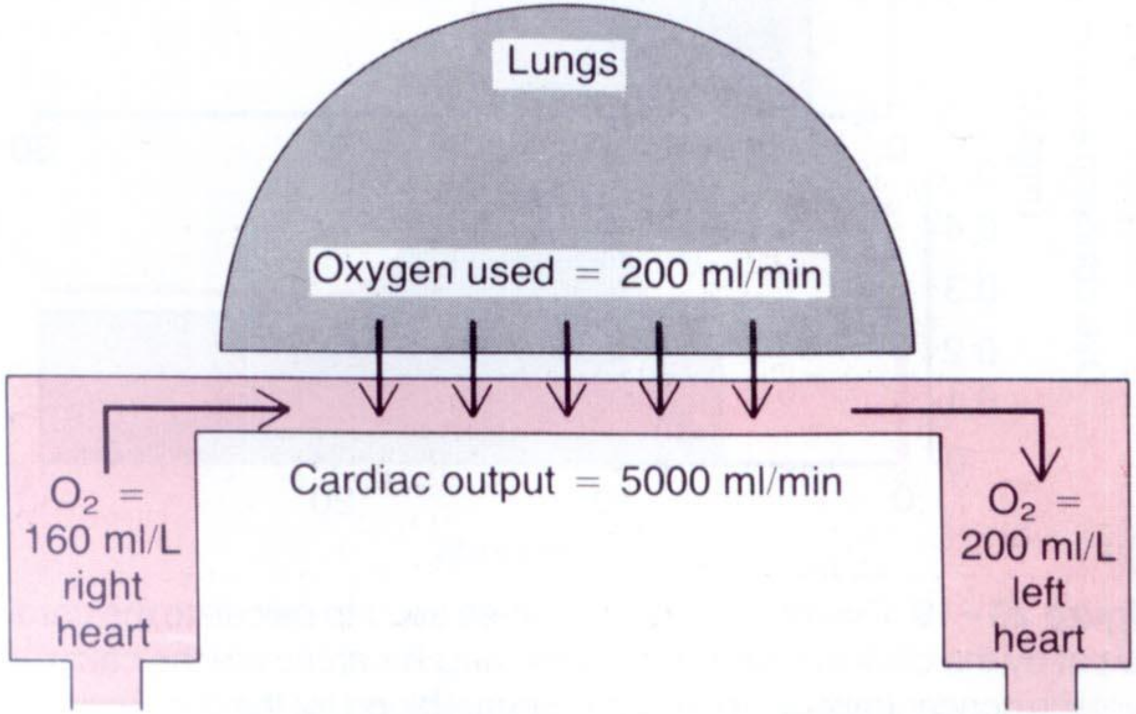


Figure 20–18. The Fick principle for determining cardiac output.

Methods for measuring cardiac output

- Cardiac output can be *measured* using the Fick principle, whose fundamental assumption is that, in the steady state, the cardiac output of the left and right ventricles is equal.
- The Fick principle states that in the steady state, the rate of O2 consumption by the body must equal the amount of O2 leaving the lungs in the pulmonary vein minus the amount of O2 returning to the lungs in the pulmonary artery.
- Total O2 consumption or the rate of oxygen absorption by the lungs can be measured by the rate of disappearance of oxygen from respired air, using any oxygen meter.
- The amount of O2 in the pulmonary veins is pulmonary blood flow multiplied by the O2 content of pulmonary venous blood. Likewise, the amount of O2 returned to the lungs via the pulmonary artery is

  pulmonary blood flow multiplied by the O2 content of pulmonary arterial blood.
- O2 consumption = cardiac output × [O2] pulmonary vein – cardiac output × [O2] pulmonary artery
- **Cardiac output = O2 absorbed by the lungs per minute/arteriovenous O2 difference**