

Venous Return

Dr. Mona Soliman, MBBS, MSc, PhD
Head, Medical Education Department
Associate Professor of Physiology
Chair of Cardiovascular Block
College of Medicine
King Saud University

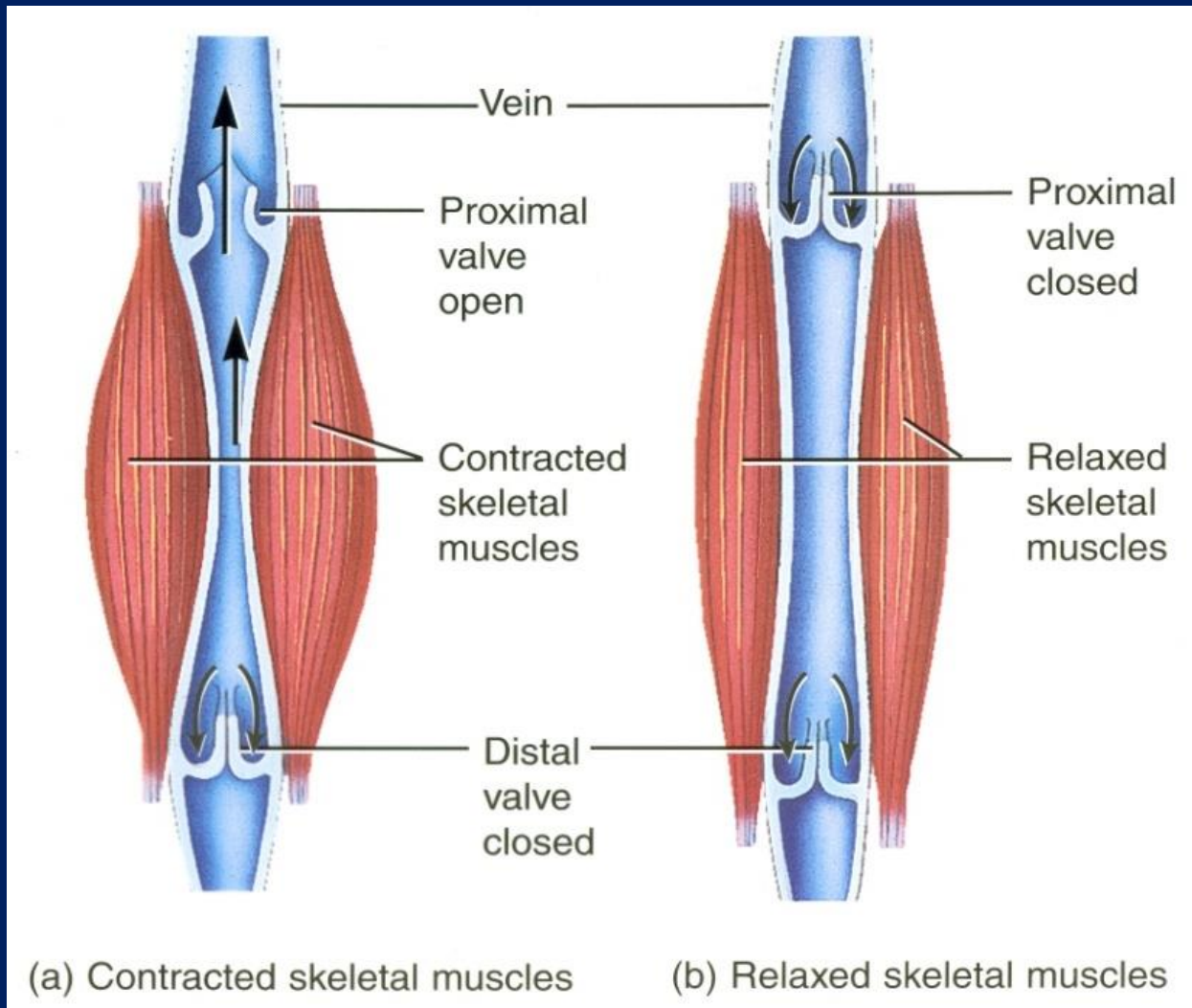
Venous Return

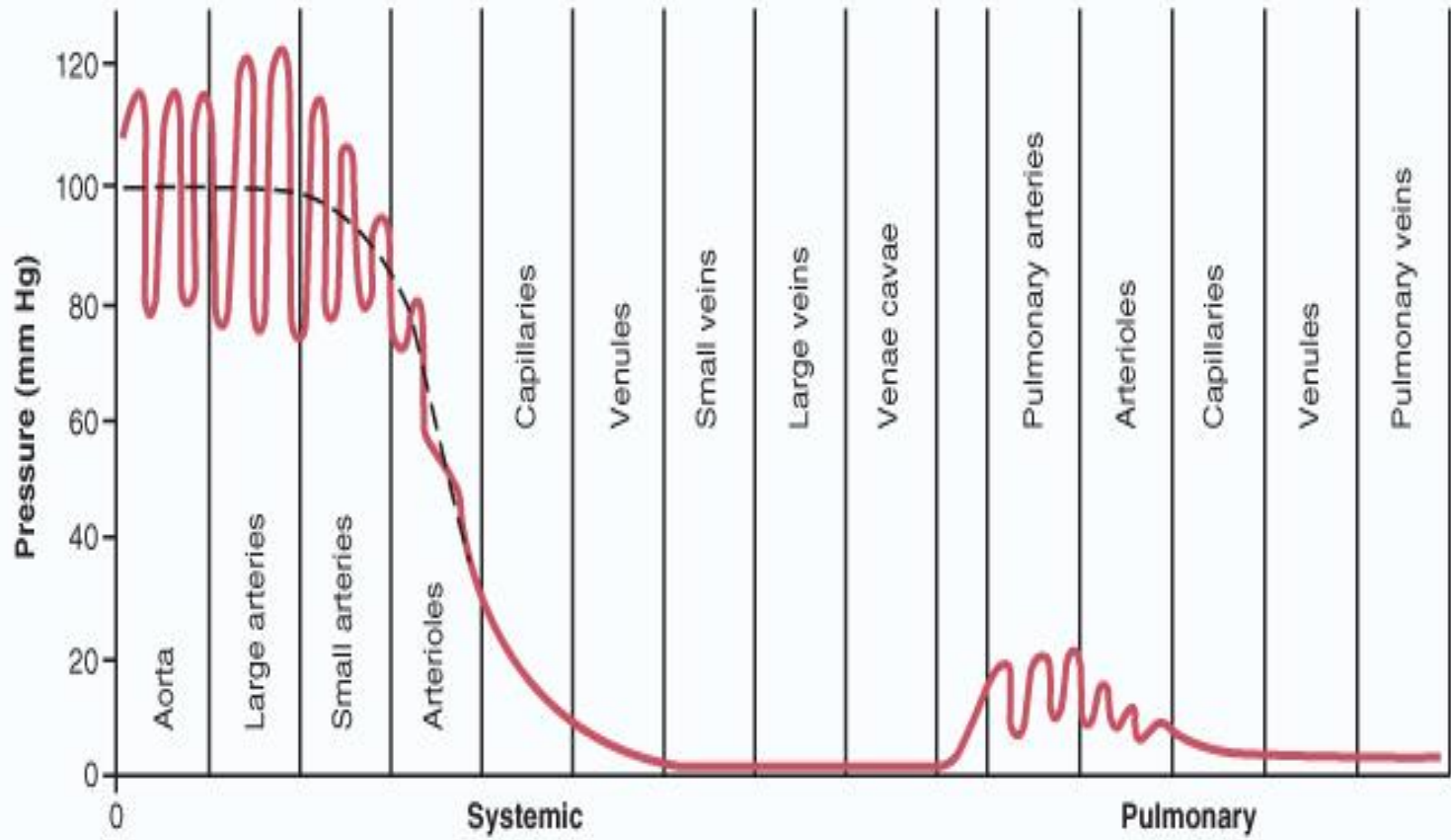
Venous return is the quantity of blood flowing from large veins into the right atrium **each min.**

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.

Effect of Venous Valves



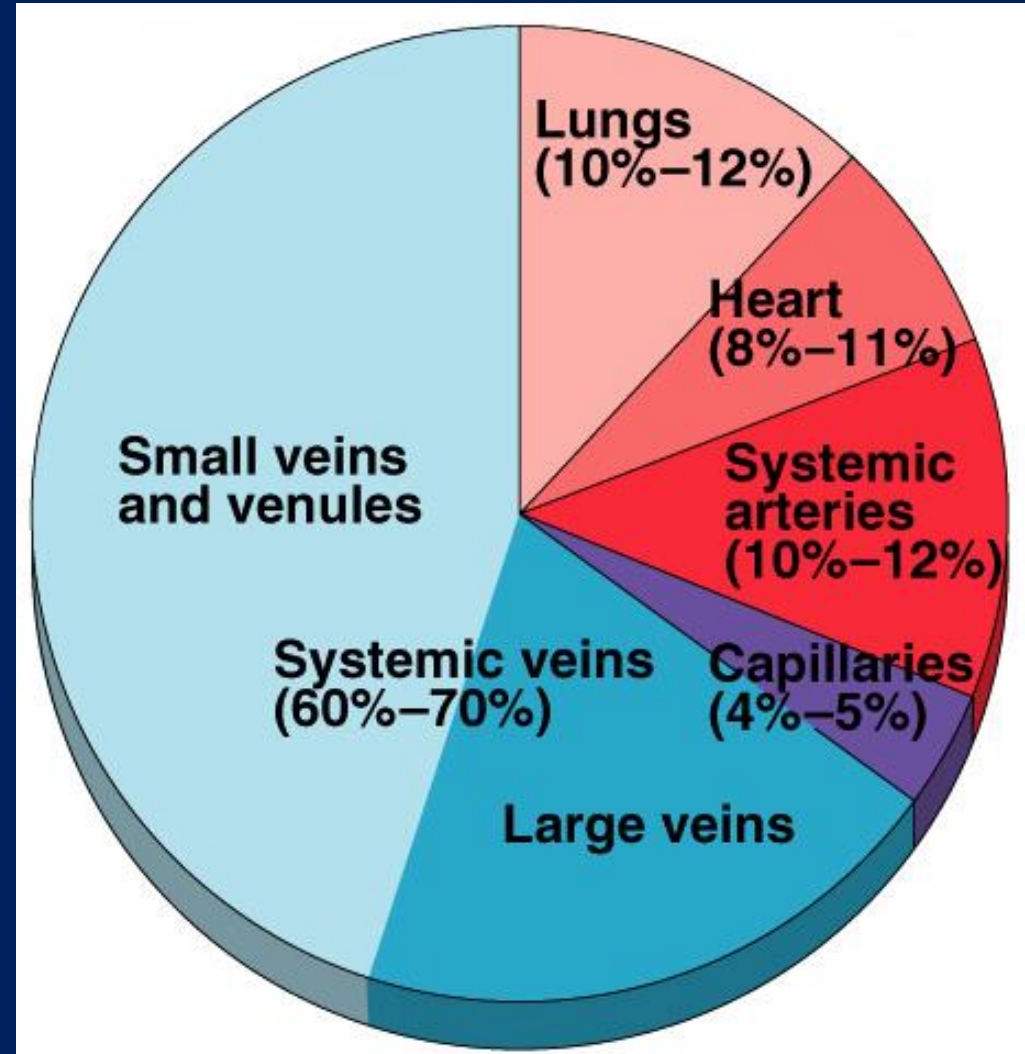


Venous Return

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)**

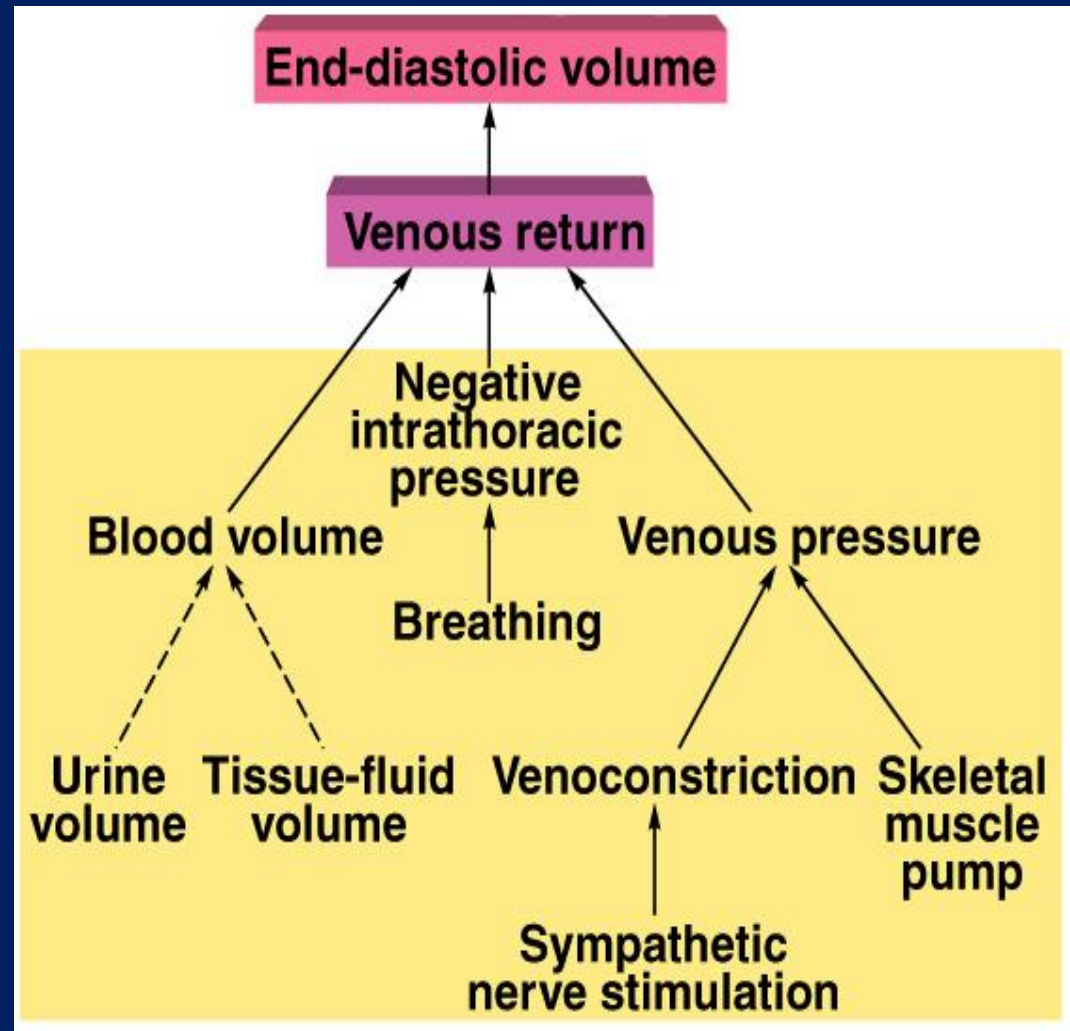
Have only 0 -10 mm Hg Pressure.



Venous Return

Depends on:-

- 1- Blood volume & venous pressure.
- 2- Venoconstriction caused by Sympathetic
- 3- Skeletal muscle pumps.
- 4- Pressure drop during inhalation.

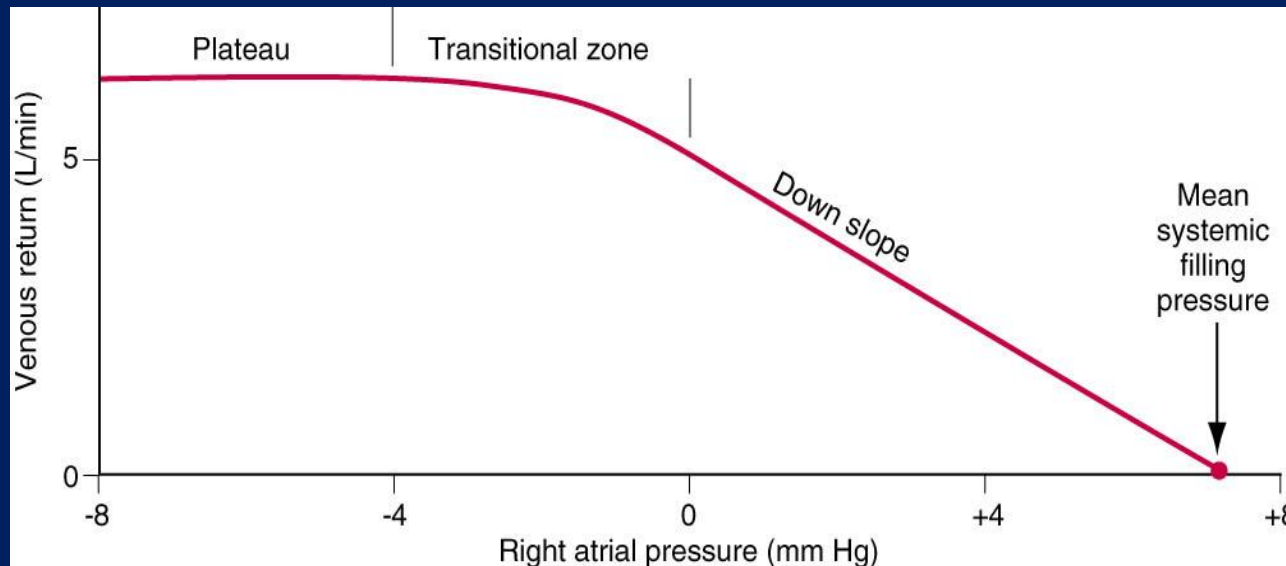


Venous return curve

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 manoeuvre (forceful expiration against a closed glottis) the intrapleural pressure becomes 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**.

Definition of:

- **Jugular Venous Pulse:**

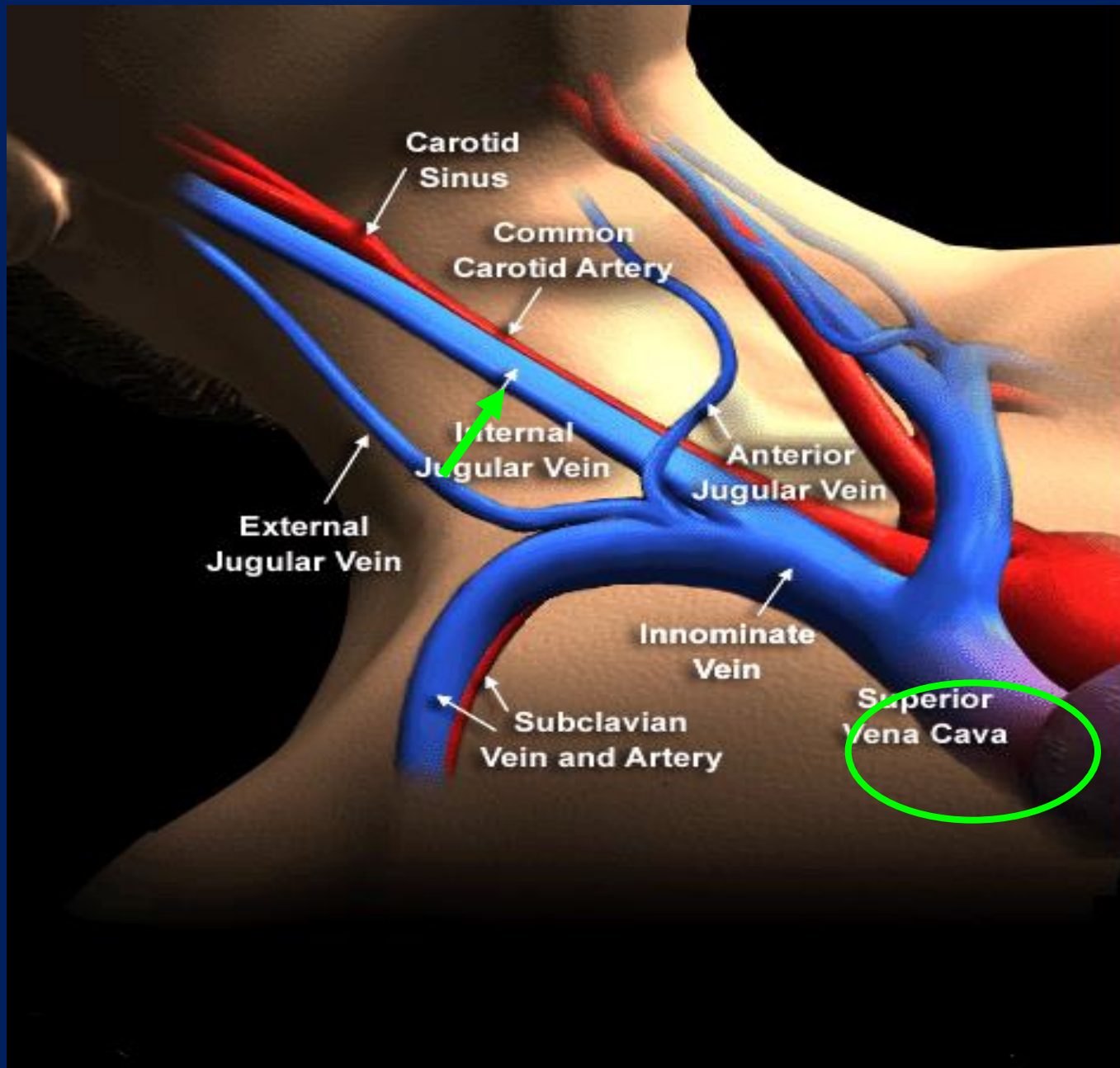
Defined as the oscillating top of vertical column of blood in **right internal jugular vein** that reflects pressure **changes** in right atrium in cardiac cycle.

- **Jugular Venous Pressure:**

Vertical height of oscillating column of blood.

Why Internal Jugular Vein (IJF)?

- IJV has a direct course to RA.
- IJV is anatomically closer to RA.
- IJV has no valves (Valves in EJV prevent transmission of RA pressure)



Why Right Internal Jugular Vein?

- Right jugular veins extend in an almost straight line to superior vena cava, thus favoring transmission of the haemodynamic changes from the right atrium.
- The left innominate vein is not in a straight line and may be kinked or compressed between Aortic Arch and sternum, by a dilated aorta, or by an aneurysm.

Method Of Examination

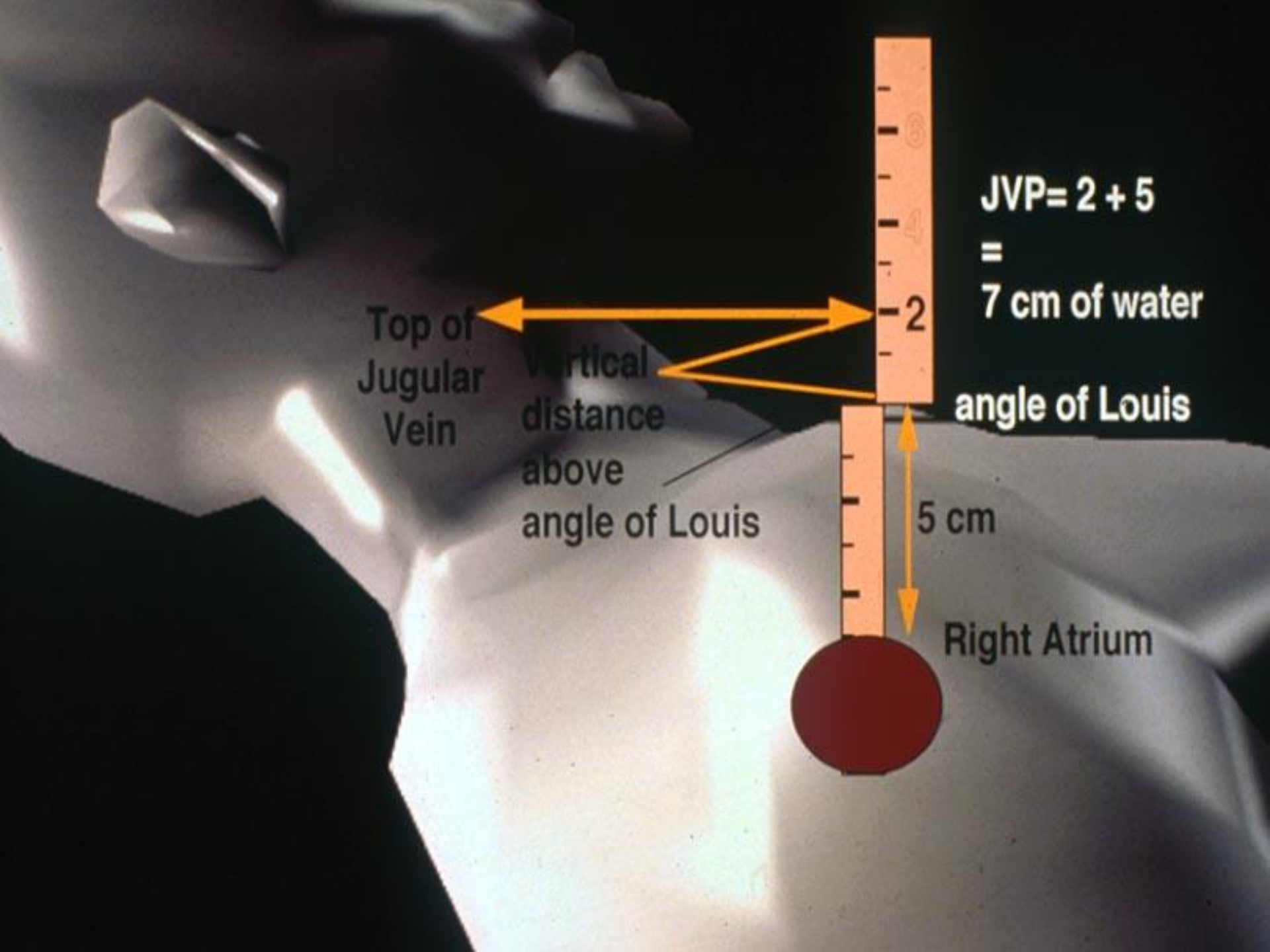
- The patient should lie comfortable during the examination.
- Clothing should be removed from the neck and upper thorax.
- Patient reclining with head elevated 45 °
- Neck should not be sharply flexed.
- Examined effectively by shining a light across the neck.
- There should not be any tight bands around abdomen

Observations Made

- the level of venous pressure.
- the type of venous wave pattern.

The level of venous pressure

- Using a centimeter ruler, measure the vertical distance between the angle of Louis and the highest level of jugular vein pulsation.
- The upper limit of normal is 3 cm above the sternal angle.
- Add 5 cm to measure central venous pressure since right atrium is 5 cm below the sternal angle.
- Normal CVP is < 8 cm H₂O



Top of
Jugular
Vein

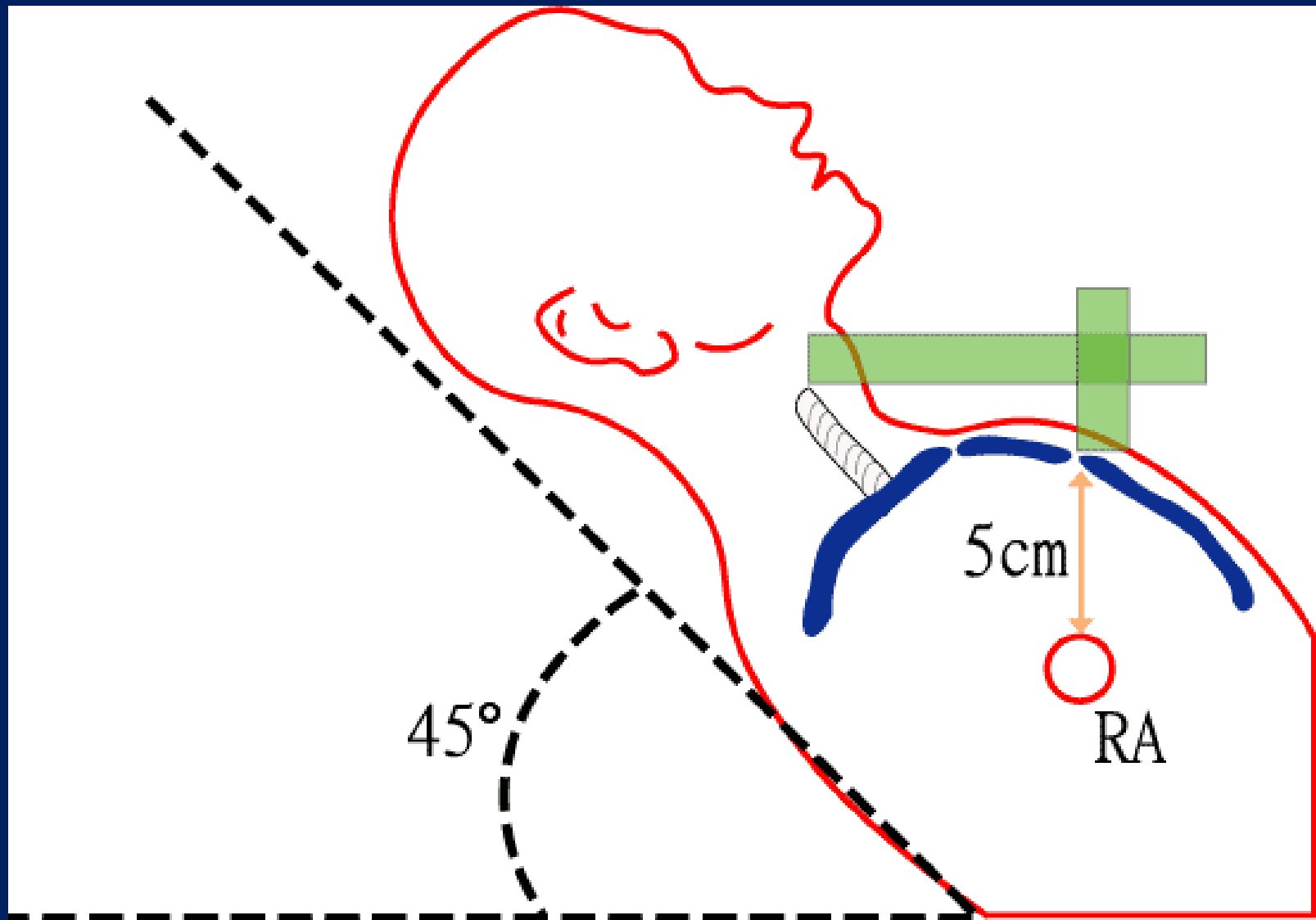
Vertical
distance
above
angle of Louis

$JVP = 2 + 5$
 $=$
7 cm of water

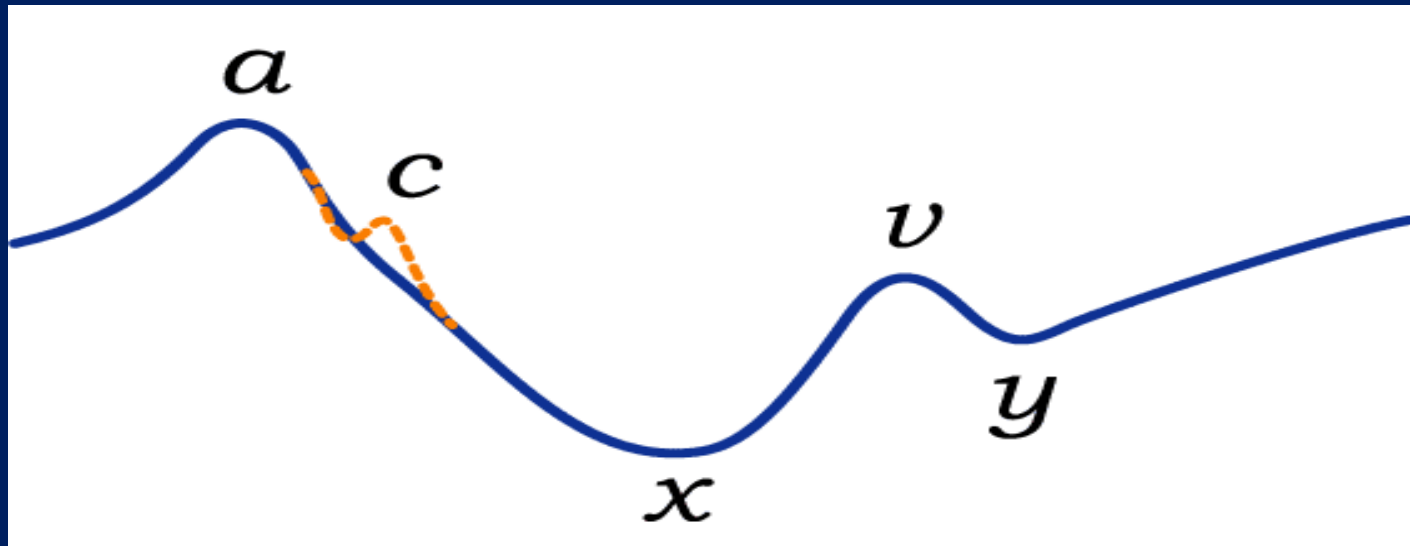
angle of Louis

5 cm

Right Atrium



Normal pattern of the jugular venous pulse



- The normal JVP reflects phasic pressure changes in the right atrium and consists of **three positive** waves
- and **two negative** descents.

a WAVE



- Venous distension due to **RA contraction**
Retrograde blood flow into SVC and IJV

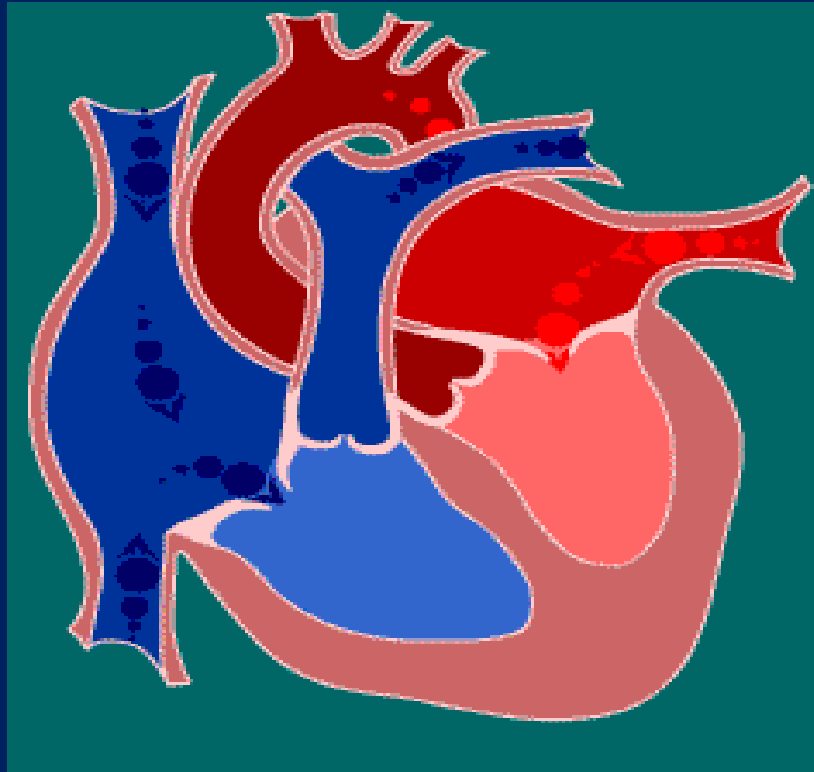
The x descent: is due to

Atrial relaxation and the tricuspid valve moves downward.

The c wave: is due to:

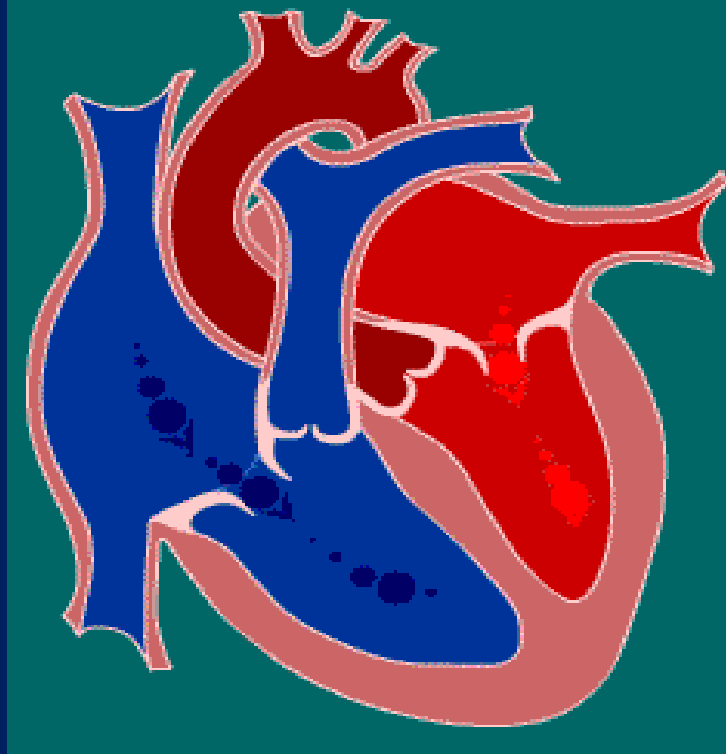
Ventricular contraction and resulting bulging of tricuspid valve into the right atrium during isovolumetric contraction.

v WAVE: is due to



- **Rising** right atrial pressure when blood flows into the right atrium during ventricular systole when the tricuspid valve is shut.

y DESCENT is due to



The **decline** in right atrial pressure when the tricuspid valve reopens

Abnormalities of jugular venous pulse

A- Low jugular venous pressure

1. Hypovolemia.

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.

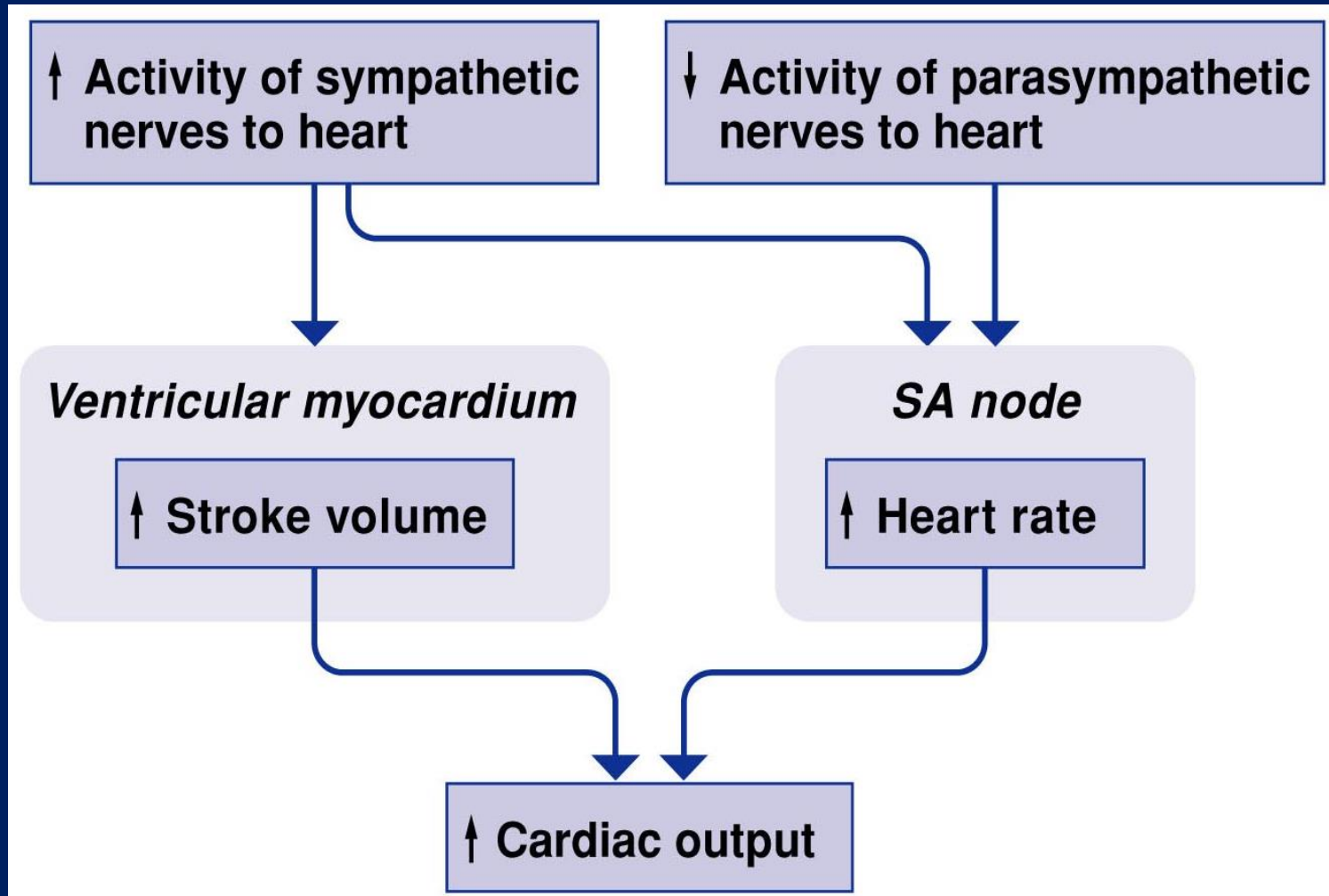
Stroke volume is the volume of blood ejected from each ventricle per beat = 70 mls /beat at rest.

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

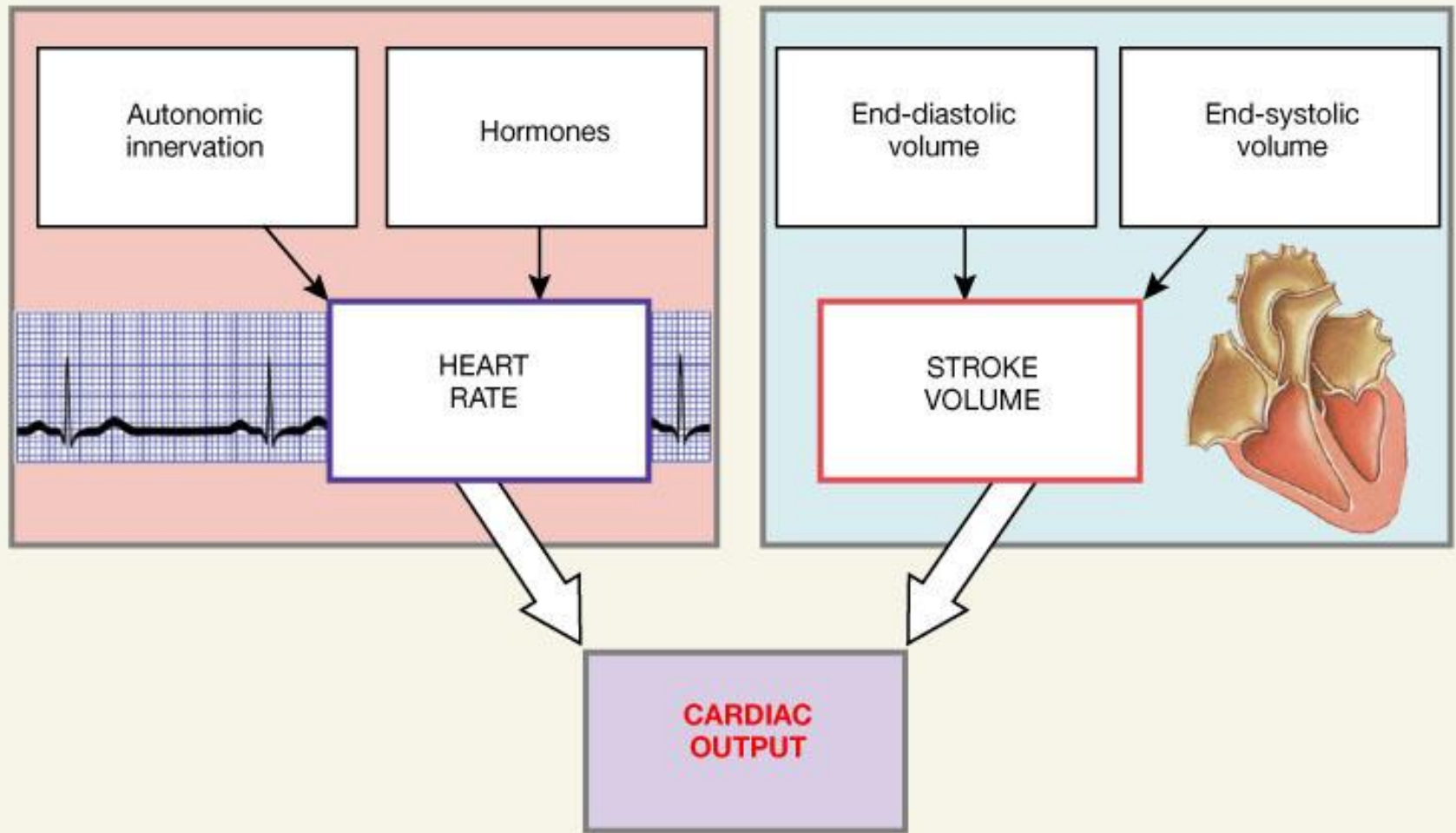
Adjusts heart rate in response to venous return

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

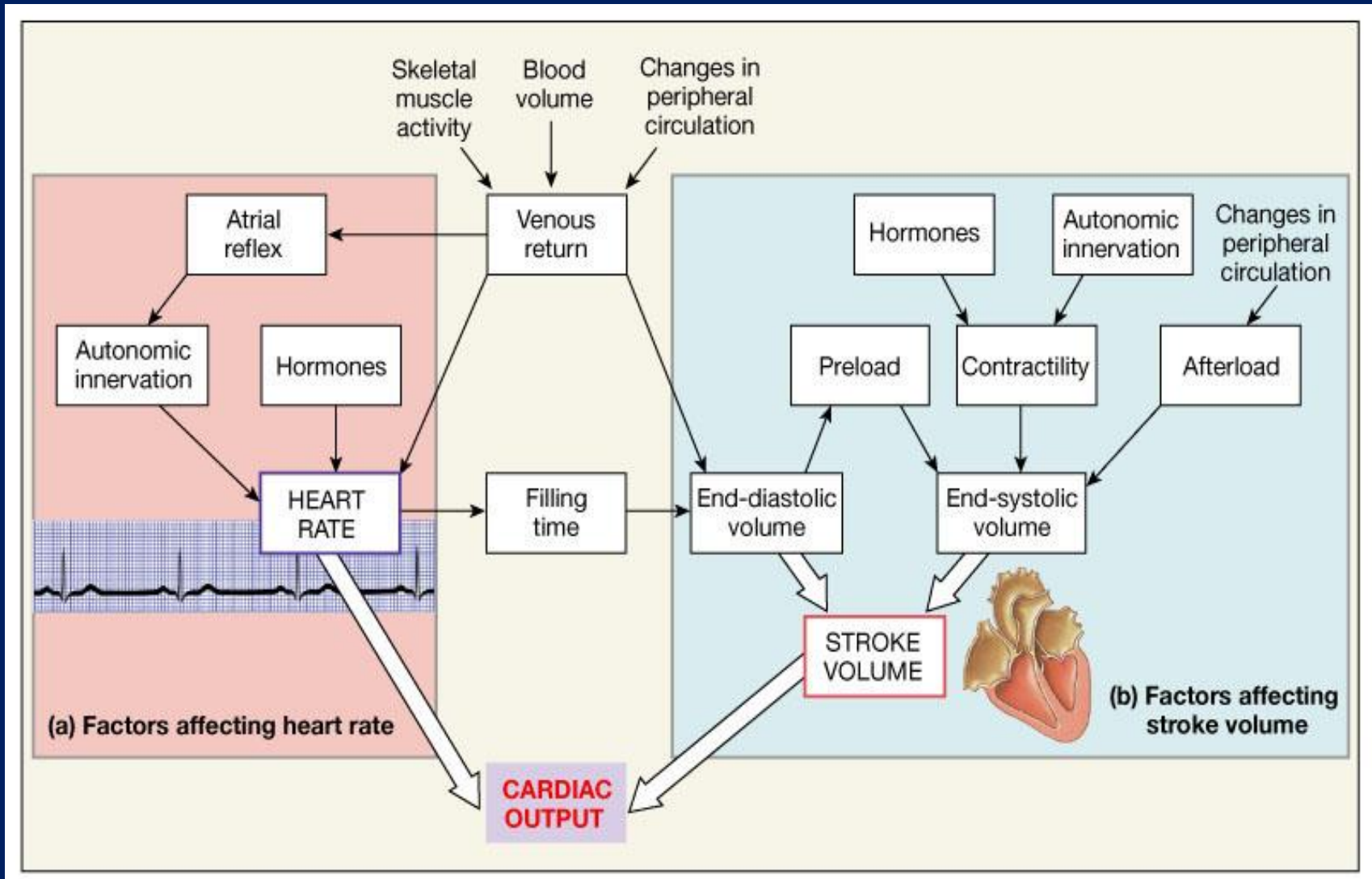
Regulation of Heart Rate

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

Factors Affecting Cardiac Output



Summary of the Factors Affecting Cardiac Output



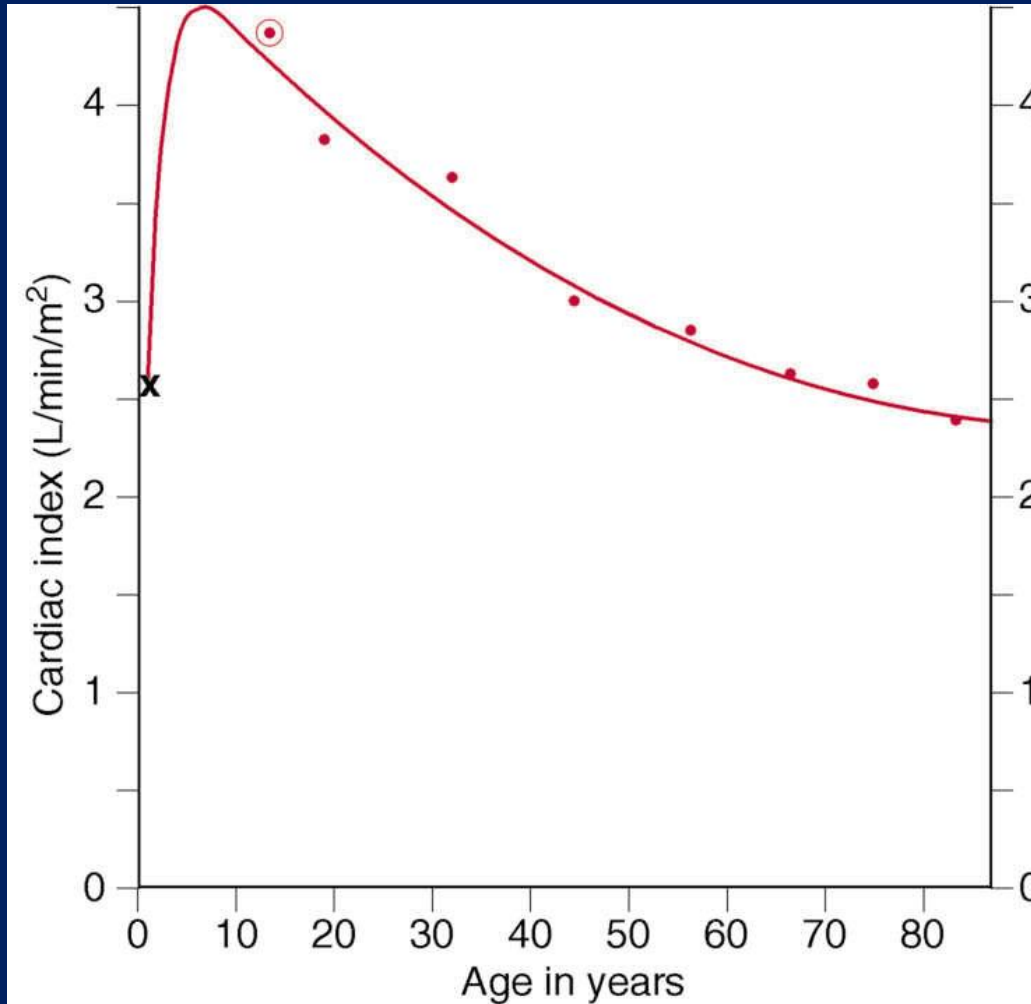
Cardiac index:

It relates the **cardiac output** to body surface area.

Thus relating heart performance to the size of the individual.

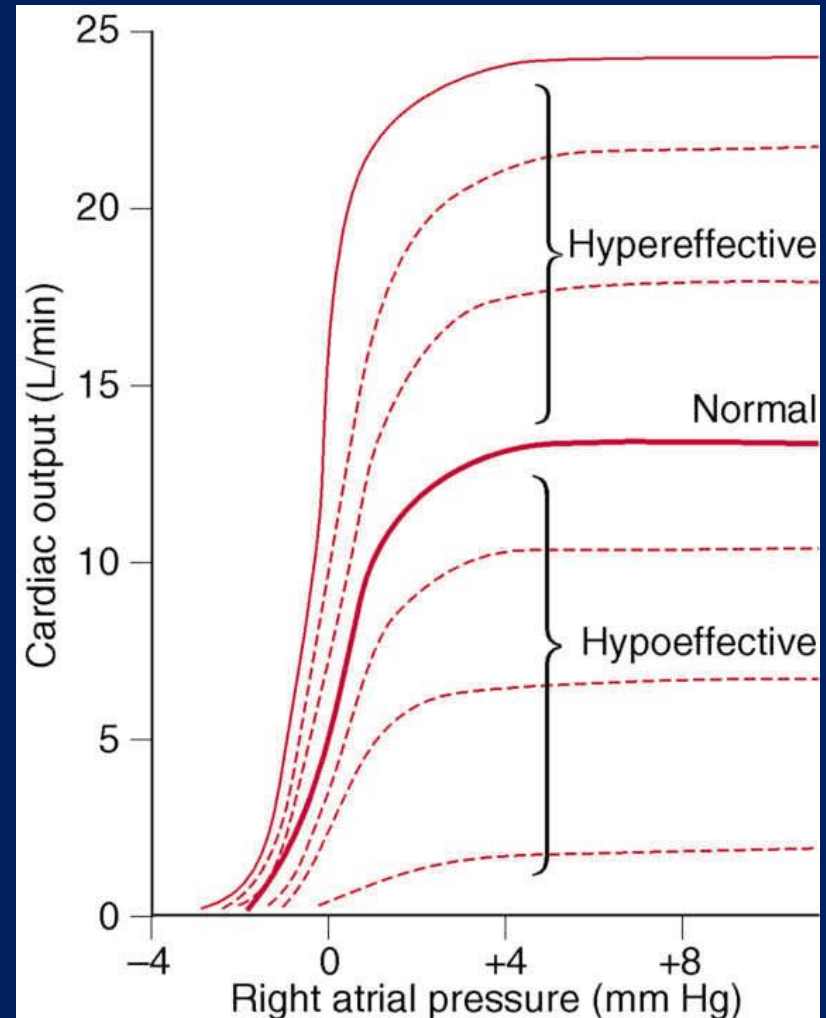
The unit of measurement is **liter** per **minute** per square meter of body surface area (**L/min/m²**).

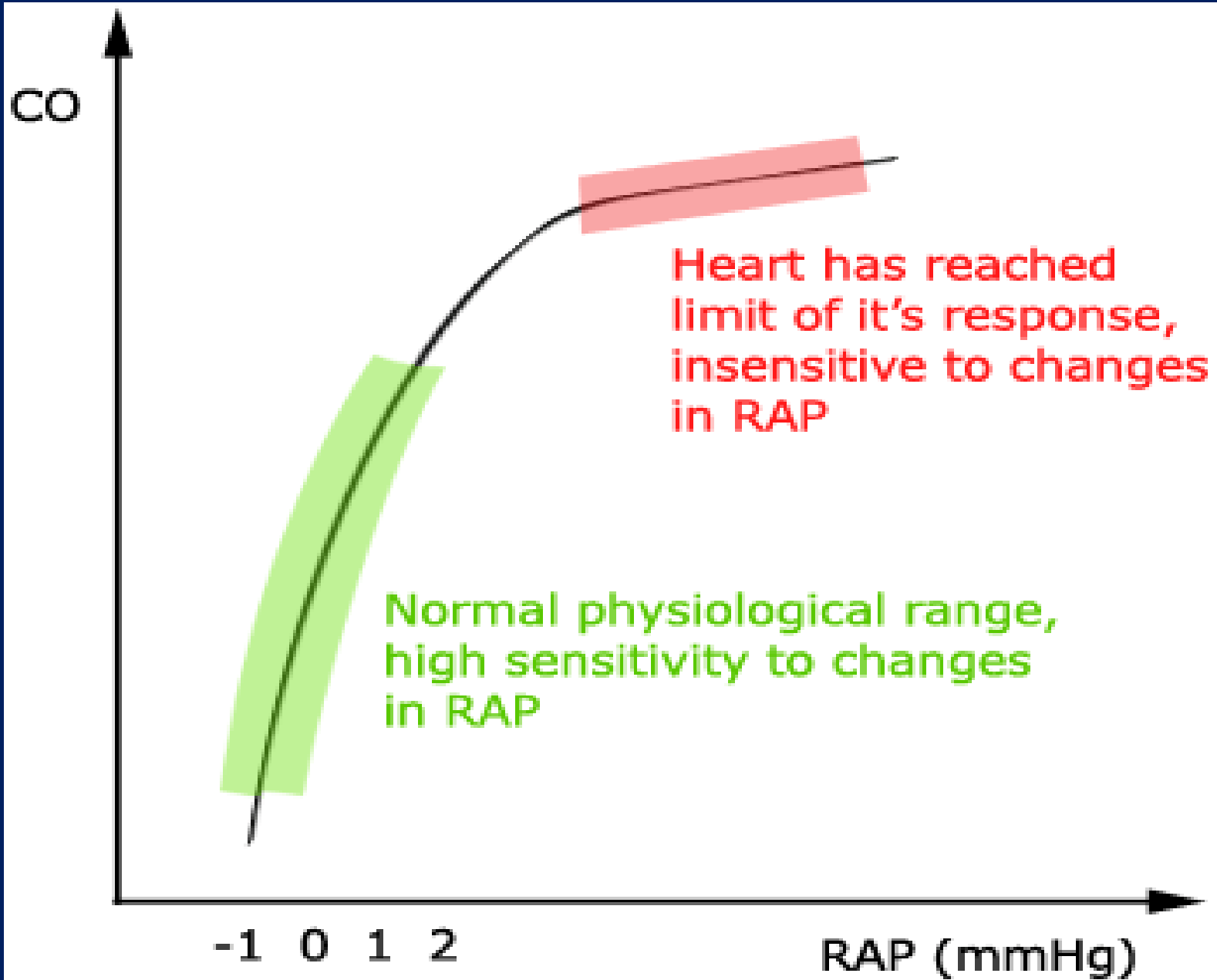
Cardiac index for the human being at different ages.



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%**.





Measurement Of C.O.

The Direct Fick's Method:

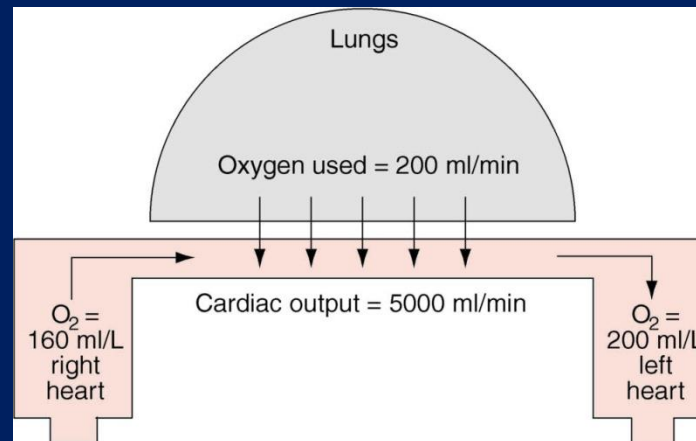
It states that, the **amount** or **volume** of any substance taken up by an organ or by the whole body is equal to:

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

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

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.
- $\text{O}_2 \text{ consumption} = \text{cardiac output} \times [\text{O}_2] \text{ pulmonary vein} - \text{cardiac output} \times [\text{O}_2] \text{ pulmonary artery}$
- **Cardiac output = O₂ absorbed by the lungs per minute/arteriovenous O₂ difference**



For further readings and diagrams:

Textbook of Medical Physiology by Guyton & Hall

Chapter 17 (Cardiac Output)

