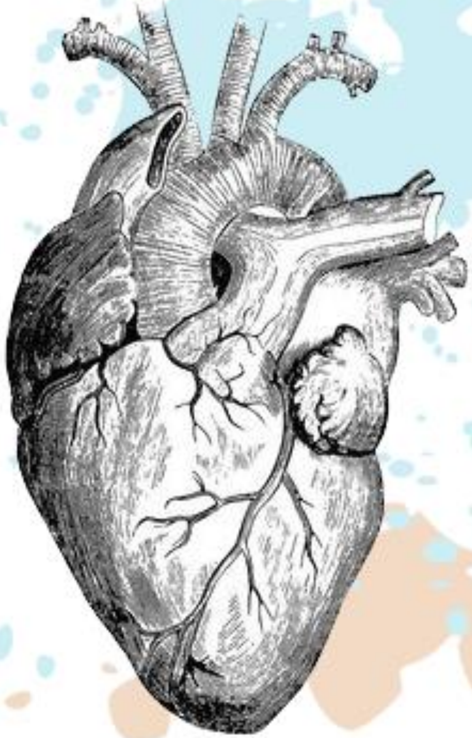


Physiology
OF THE CARDIOVASCULAR SYSTEM

Very important

Extra information

* Guyton corners, anything that is colored with grey is EXTRA explanation

PHYSIOLOGY TEAM435

Venous return and cardiac output

Objectives :

- Define cardiac output, stroke volume, end-diastolic and end-systolic volumes.
- Define physiological conditions affecting CO
- List causes of high and low output pathological states.
- Define venous return and describe factors controlling venous return..

Contact us : Physiology435@gmail.com

Venous Return

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

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.

Venous Return *“extra”*

- During inspiration, the pressure in the chest becomes negative , so the blood will flow from the lower limb towards the chest which means that the venous return is increased.

-How can the changes in blood volume affect the venous return? - They are directly proportional . So when blood volume increases the venous return increases also

- Gravity is inversely proportional to venous return *(it carries the blood away from the heart so venous return decreases.)*

- **Guyton corner:**

- 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. Page 245

Cardiac output = Total tissue blood flow

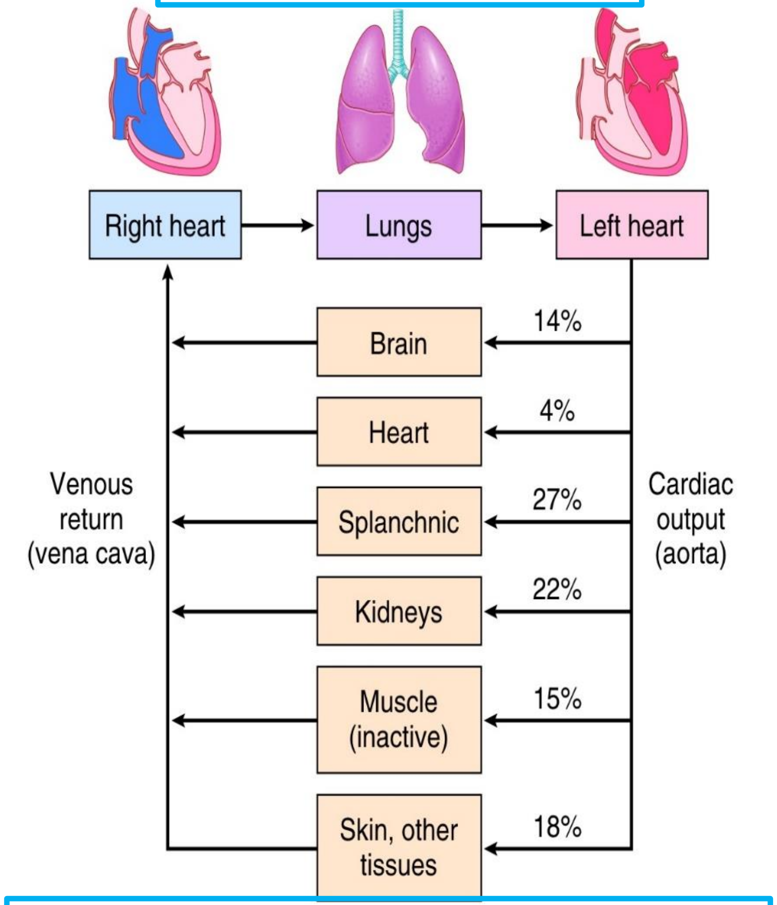
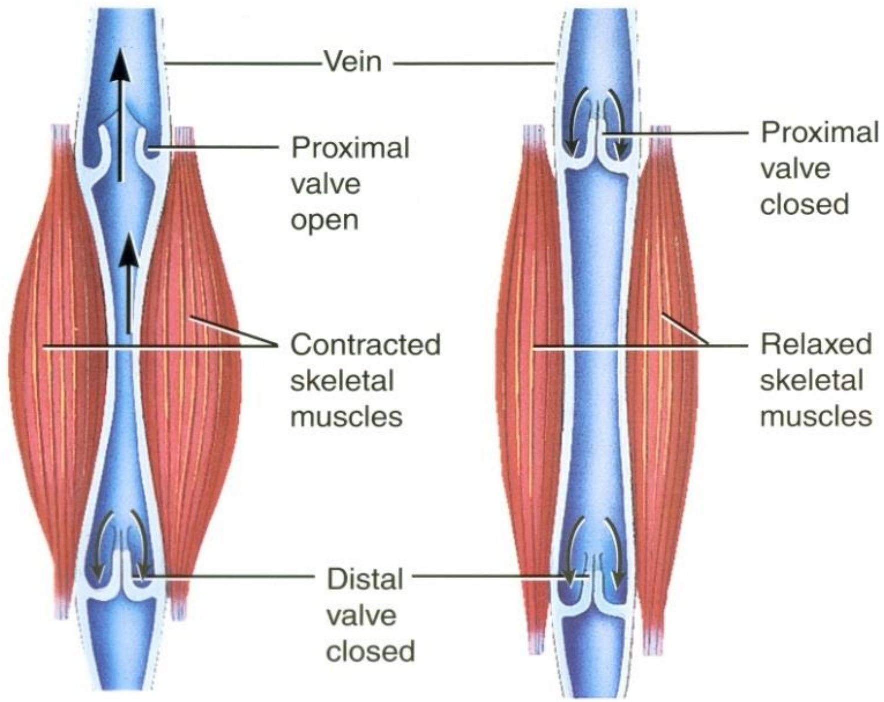


Figure 20-2. Cardiac output is equal to venous return and is the sum of tissue and organ blood flows. Except when the heart is severely weakened and unable to adequately pump the venous return, cardiac output (total tissue blood flow) is determined mainly by the metabolic needs of the tissues and organs of the body.

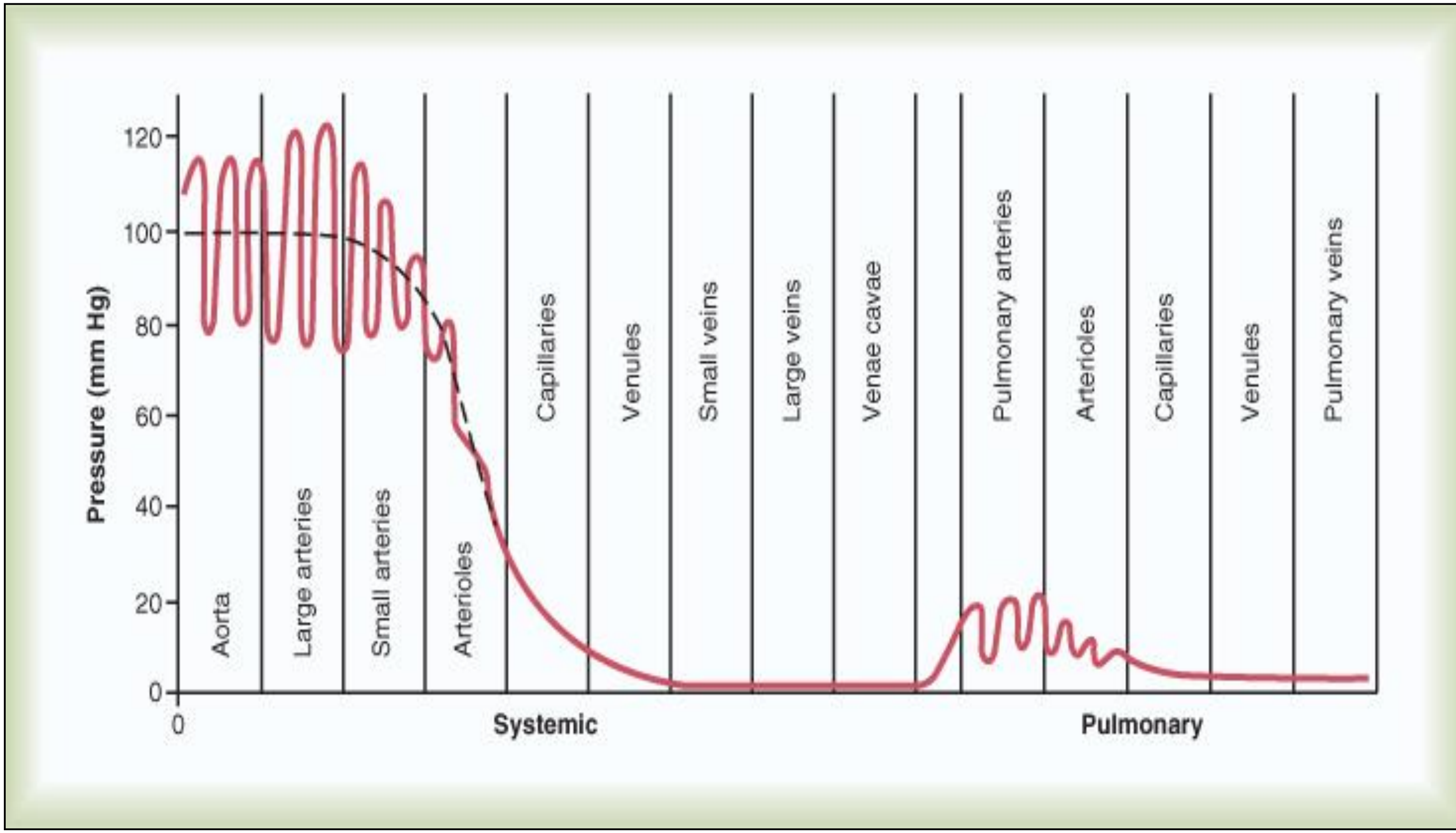
Effect of Venous Valves



(a) Contracted skeletal muscles (b) Relaxed skeletal muscles

- Veins are surrounded by muscles; when these muscles contract, the valves act as pumps so the flow of blood is facilitated by muscle contraction.
- **(a)** Muscle contraction= opening of valves = push of blood towards the heart *(muscle contraction increase the venous return)*
- **(b)** When the muscle is relaxed the valves will be closed.

Effect of Venous Valves



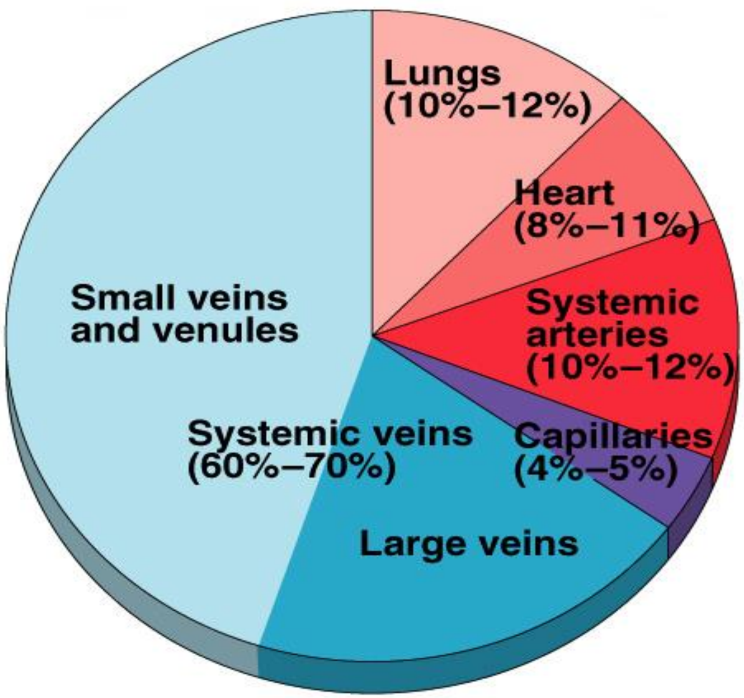
* Notice the **very low** pressure in veins compared to arteries.

Venous Return

Veins hold most of blood in body (70 %),
Thus it is called **capacitance vessels.**

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

Have only 0 -10 mm Hg Pressure.

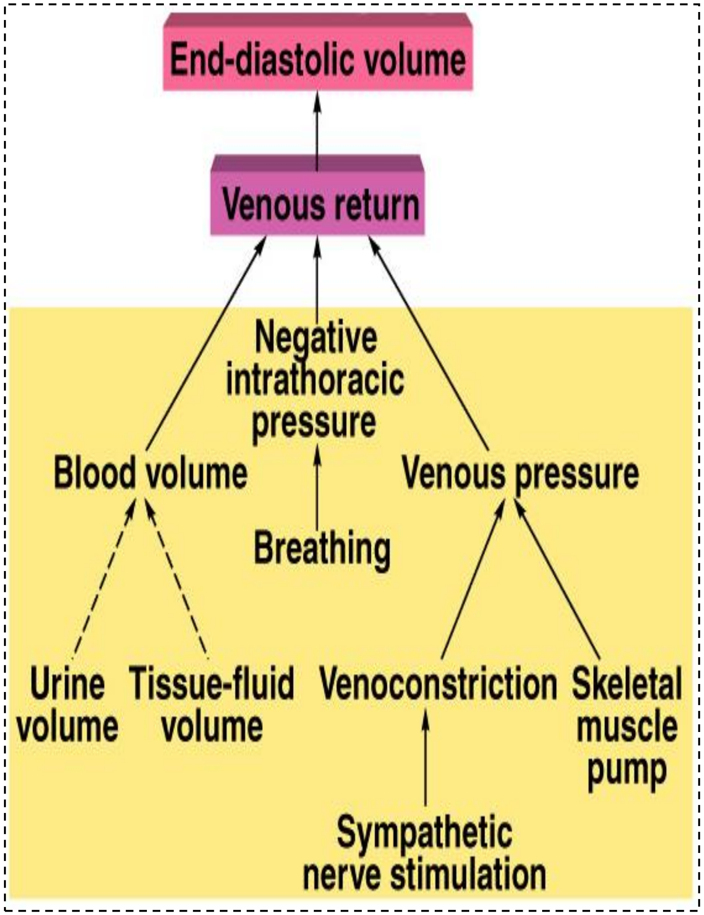


The compliance is inversely proportional to pressure:
high compliance= low pressure (as in veins)
Low compliance= high pressure (as in arteries)

Venous Return

Depends on:

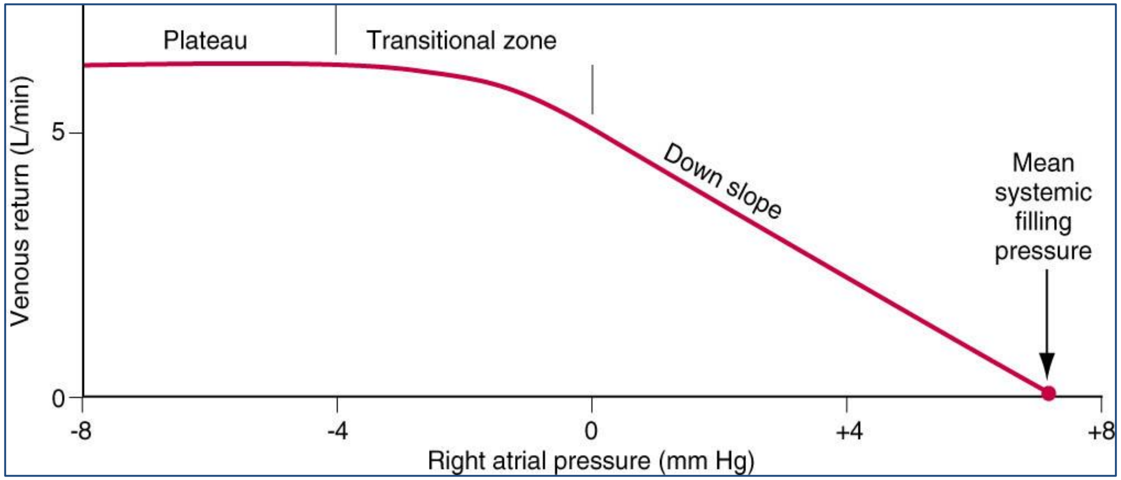
- Blood volume &venous pressure.
- Pressure drop during inhalation
- Venoconstriction caused by Sympathetic
- Skeletal muscle pumps



-Sympathetic stimulation will cause vasoconstriction, and vasoconstriction will increase venous return.

Venous return curve

- **Venous return (VR) curve relates VR to right atrial pressure**



-This curve shows Y axis (The venous return) and the X axis (the right atrial pressure)
- Mean systemic filling pressure:
The point at which the venous return drops to zero (this happens when right atrial pressure increase)

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

- **Guyton corner** : This curve shows that1- when heart pumping capability becomes diminished and **causes** the right atrial pressure to rise, the backward force of the rising atrial pressure on the veins of the systemic circulation decreases venous return of blood to the heart. If all nervous circulatory reflexes are prevented from acting venous return decreases to zero when the right atrial pressure rises to about +7 mm Hg. Such a slight rise in right atrial pressure causes a drastic decrease in venous return because the systemic circulation is a distensible bag, so any increase in back pressure causes blood to dam up in this bag instead of returning to the heart.

Venous return curve

- **Plateau** in the venous return curve at *[2]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.

- *[1]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

Guyton corner : *[1]the right atrial pressure is rising and causing venous stasis, pumping by the heart also approaches zero because of decreasing venous return. Both the arterial and the venous pressures come to equilibrium when all flow in the systemic circulation ceases at a pres sure of 7 mm Hg, which, by definition, is the mean systemic filling pressure (Psf).
*[2]Negative pressure in the right atrium sucks the walls of the veins together where they enter the chest, which prevents any additional flow of blood from the peripheral veins. Consequently, even very negative pressures in the right atrium cannot increase venous return significantly above that which exists at a nor mal atrial pressure of 0 mm Hg.

Jugular vein

Definitions:

- 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.

How to measure the jugular venous pressure?

- I'll ask the patient to sit at 45 degree
- Then the neck muscles will be flexed
- The internal jugular vein pass through the two heads of sternocleidomastoid muscle

.

Why are we asking the patient to sit at **45** degrees?

- For the jugular vein to be straight with the right atrium
- Good reflection of any changes in pressure surrounding it

Why internal jugular vein(IJV)?

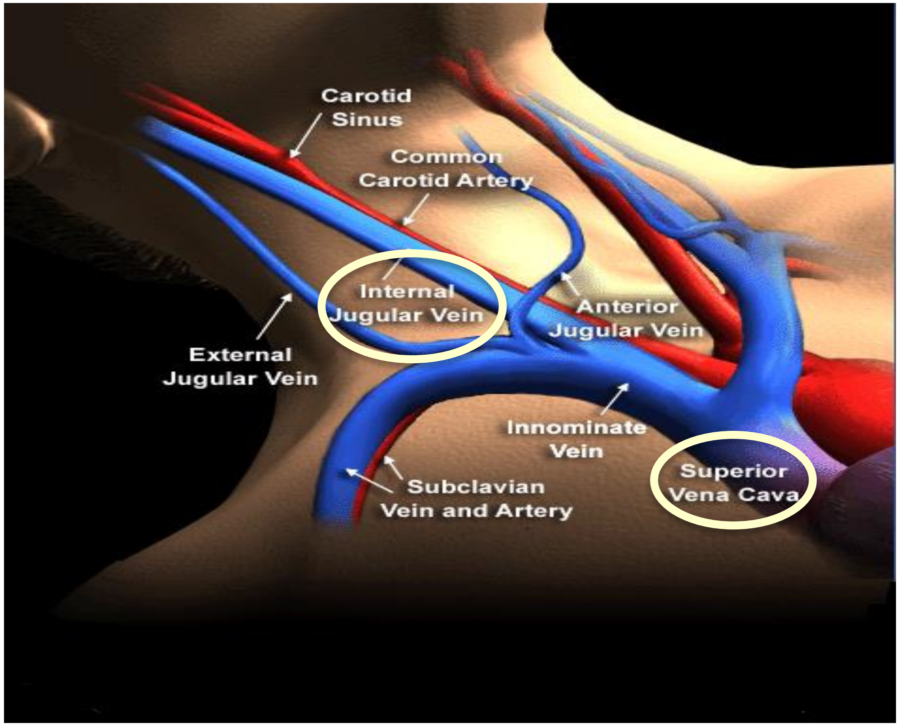
- IJV has a direct course to RA.
- IJV is anatomically closer to RA.
- IJV has no valves (Valves in EJV prevent transmission of RA pressure)

Jugular Vein..cont

Why right internal jugular vein

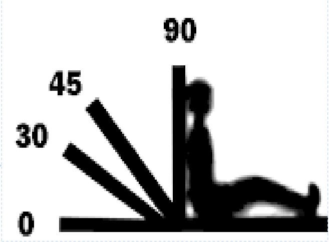
1. Right jugular veins extend in an almost straight line to superior vena cava, thus favoring transmission of the haemodynamic changes from the right atrium.

2. 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 <u>light</u> 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.

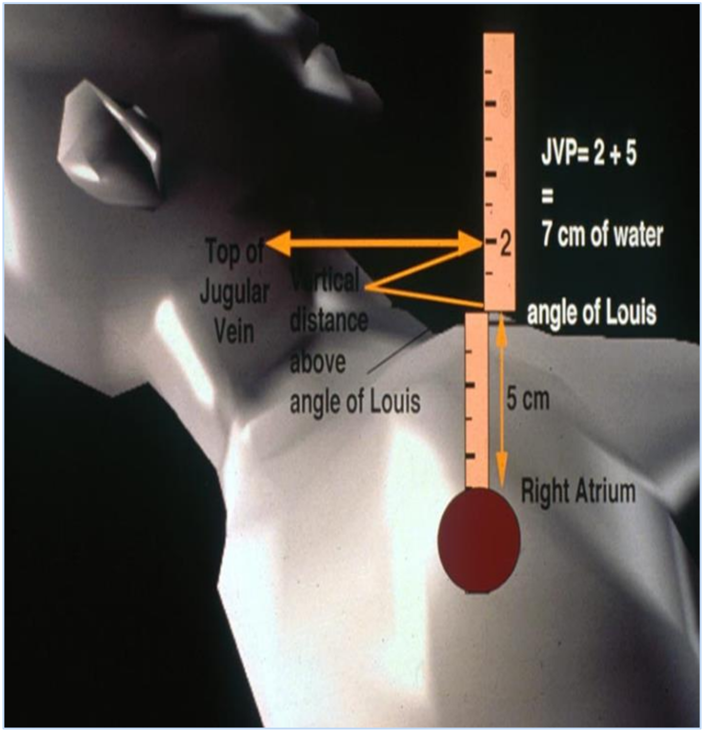
- The upper limit of normal is 3 cm *above the sternal angle*.

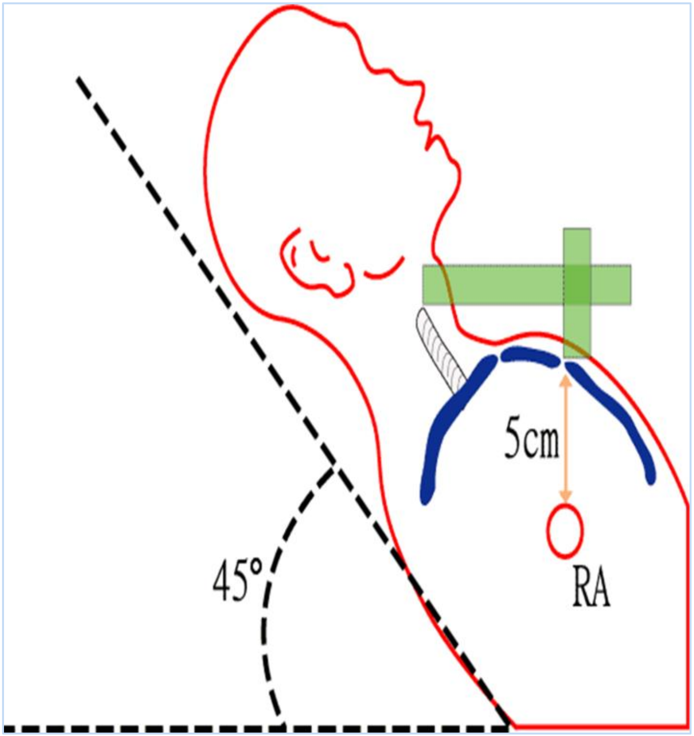
- Add 5 cm to measure central venous pressure since right atrium is 5 cm *below the sternal angle*.

- **Normal** CVP is < 8 cm H2O

-normal jugular venous pressure is below 8
- If it's above 8 this indicate high pressure in the right atrium

The level of venous pressure





video

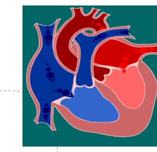
jugular venous pulse

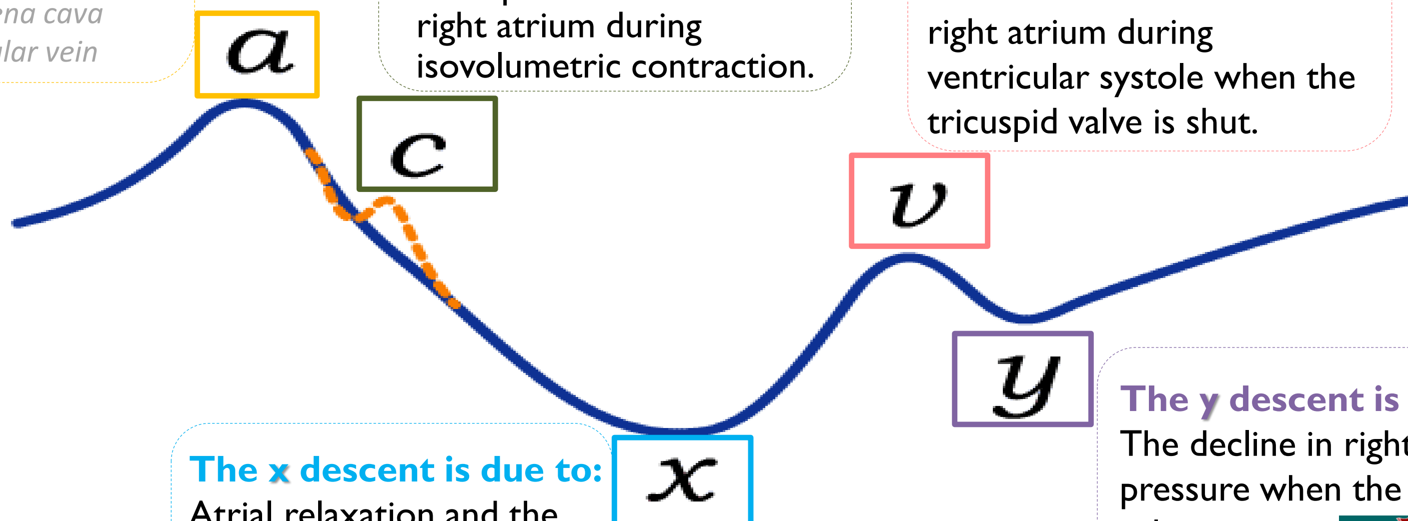
- The normal JVP reflects phasic pressure changes in the right atrium and consists of three positive waves and two negative descents.

a wave:
Venous distension due to right atrium contraction
Retrograde blood flow into SVC* and IJV*.
**SVC= Superior vena cava*
**IJV=internal jugular vein*

The c wave is due to:
Ventricular contraction and resulting bulging of tricuspid valve into the right atrium during isovolumetric contraction.

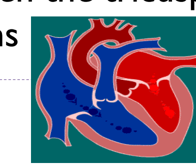
The v wave: is due to:
Rising right atrial pressure when blood flows into the right atrium during ventricular systole when the tricuspid valve is shut.





The x descent is due to:
Atrial relaxation and the tricuspid valve moves downward.

The y descent is due to:
The decline in right atrial pressure when the tricuspid valve reopens

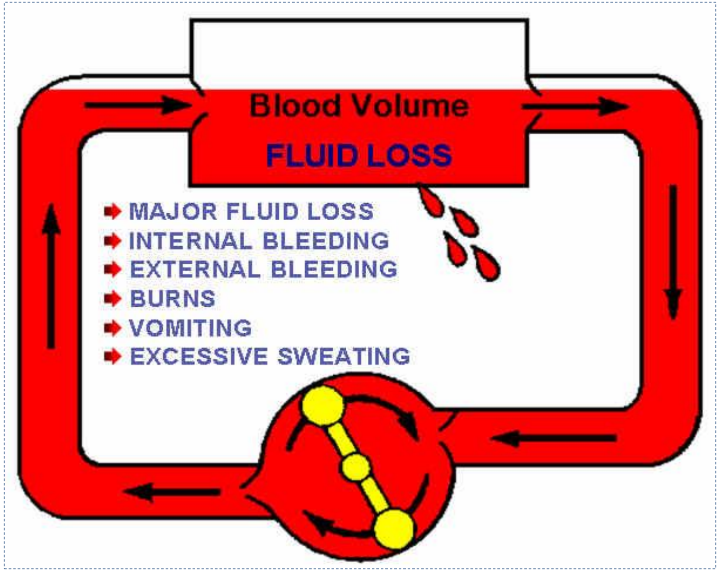


Abnormalities of jugular venous pulse

Low jugular venous pressure

- Hypovolemia

causes of hypovolemia:
- Sweating
- Dehydrating
- Hemorrhage
- Diarrhea

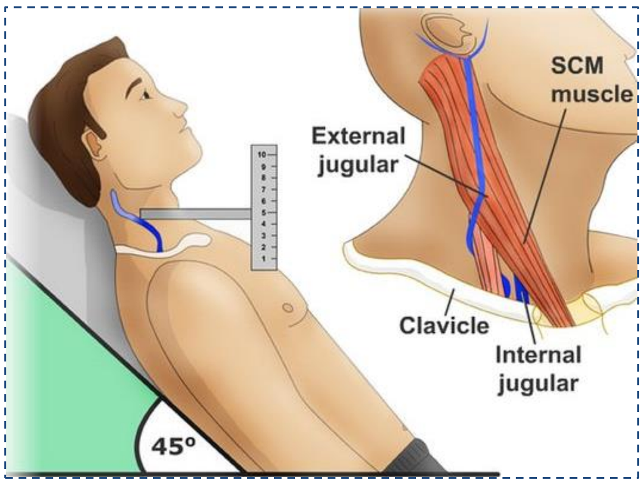


- **Guyton corner : P 274 12TH EDITION** Hypovolemia means diminished blood volume. Hemorrhage is the most common cause of hypovolemic shock. Hemorrhage decreases the filling pressure of the circulation and, as a consequence, decreases venous return. As a result, the cardiac output falls below normal and shock may ensue.

video

Raised jugular venous pressure

Causes of raised JVP			
1- increased right ventricular filling pressure. e.g.: in heart failure, fluid overload.	**2-Obstruction of blood flow from right atrium to 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 most important cause of raised jugular venous pressure is Right sided heart failure.

Cardiac Output (C.O.)

- **Cardiac output** is the volume of blood ejected from the right or left ventricle **per minute** = 5 L/min (at rest)(*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 **MINUTE**

C.O. = Heart Rate x Stroke Volume

Heart rate at rest is approximately equal to 72 **beats/min**

Stroke volume is the volume of blood ejected from each ventricle per bet = 70 **ml/beat** at rest

*Cardiac output is the amount of blood pumped per **MINUTE**, while the stroke volume is the amount of blood pumped per **BEAT**

- **Guyton corner :**

Minute work output is the total amount of energy of heart converted to work in 1 minute; this is equal to the stroke work output times the heart rate per minute.

Normal values of C.O.

During Activity	At Rest
It varies widely with the level of activity. And it depends on: 1- body metabolism. 2- exercise. 3- hyperthyroidism 4- age 5- pregnancy 6- increased body temperature.	Resting cardiac output: For men = 5.6 L/min For women = 4.9 L/min So, the average for a resting adult is **5 L/min**.

[extra]

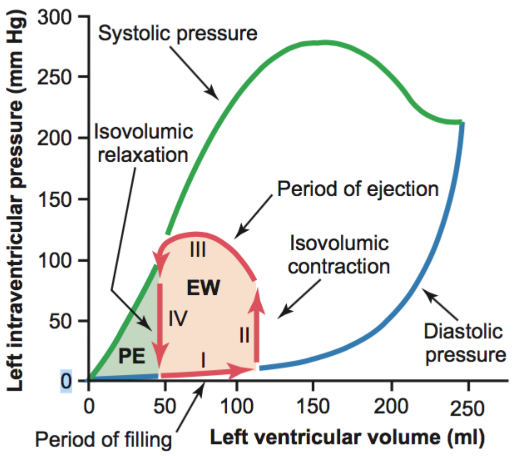
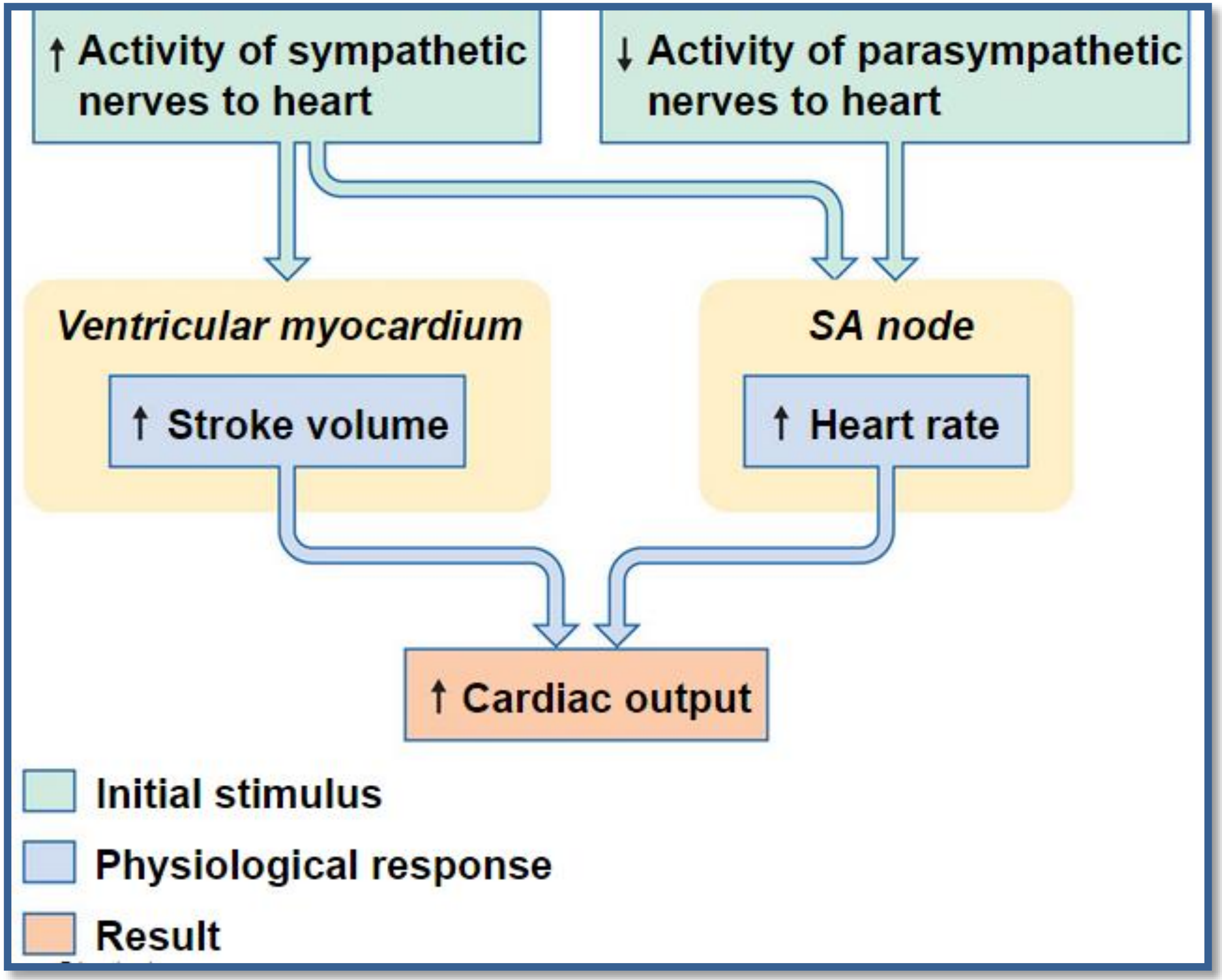


Figure 9-9. Relationship between left ventricular volume and intraventricular pressure during diastole and systole. Also shown by the red lines is the "volume-pressure diagram," demonstrating changes in intraventricular volume and pressure during the normal cardiac cycle. EW, net external work; PE, potential energy.

- **Guyton corner :** When the heart pumps large quantities of blood, the area of the work diagram becomes much larger. That is, it extends far to the right because the ventricle fills with more blood during diastole, it rises much higher because the ventricle contracts with greater pressure, and it usually extends farther to the left because the ventricle contracts to a smaller volume—especially if the ventricle is stimulated to increased activity by the sympathetic nervous system.

Regulation of cardiac output



PHYSIOLOGY TEAM 435

Regulation of heart rate

Increased by:

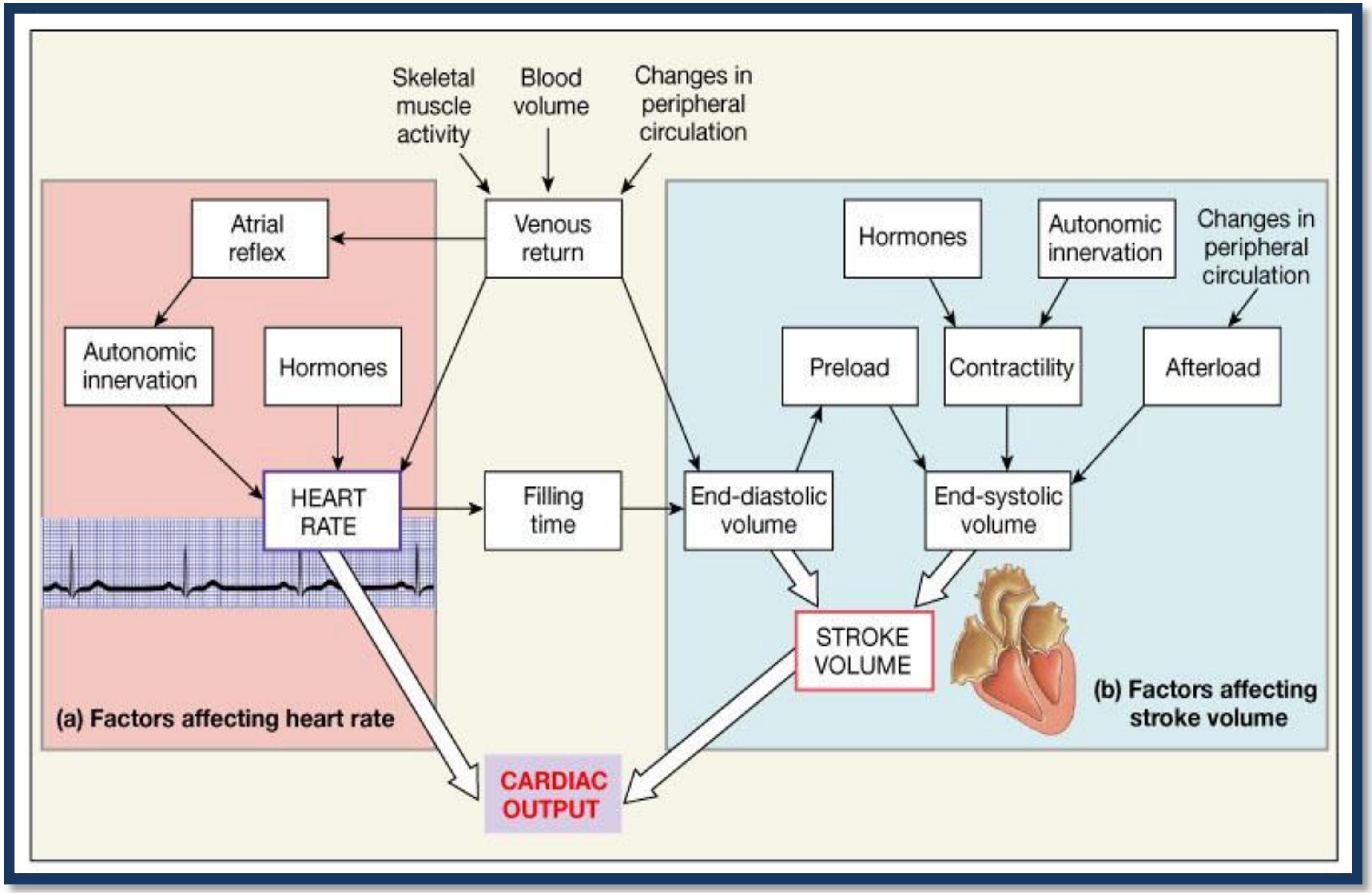
- Sympathetic nervous system due to crisis or low blood pressure
- Hormones
Thyroxine & Epinephrine
- Exercise
- Decreased blood volume
- Atrial reflex also known as **Bainbridge reflex,** adjust heart rate due to venous return
- Stretch receptors in the right atrium trigger the increase in heart rate through increased sympathetic activity.

Decreased by:

- Parasympathetic nervous system
- High blood pressure or blood volume

- The **Bainbridge reflex**, also called the atrial **reflex**, is an increase in heart rate due to an increase in central venous pressure. Increased blood volume is detected by stretch receptors (baroreceptors) located in both atria at the venoatrial junctions.
- The stretch receptors are sensitive to venous return.
- volume of blood entering the right atrium will cause stretching in the receptors.
- when the receptors are stretched, they will send signals to the brain which will increase the heart rate.

Factors Affecting Cardiac Output



Cardiac index

Definition	Benefit	Unit
It relates the cardiac output to body surface area.	Thus relating heart performance to the size of the individual.	liter per minute per square meter of body surface area ($L/min/m^2$). *Cardiac output=L/min while the surface area= m^2*

- **Guyton corner :** Experiments have shown that the cardiac output increases approximately in proportion to the surface area of the body. Therefore, cardiac output is frequently stated in terms of the cardiac index, which is the cardiac output per square meter of body surface area. The average human being who weighs 70 kilograms has a body surface area of about 1.7 square meters, which means that the normal average cardiac index for adults is about 3 L/min/m2 of body surface area.

Cardiac index for the human being at different ages

- **Guyton corner :**

Figure 20-1 shows the cardiac output, expressed as cardiac index, at different ages. The cardiac index rises rapidly to a level greater than 4 L/min/m2 at age 10 years and declines to about 2.4 L/min/m2 at age 80 years. We explain later in the chapter that the cardiac output is regulated throughout life almost directly in proportion to overall metabolic activity. Therefore, the declining cardiac index is indicative of declining activity or declining muscle mass with age.

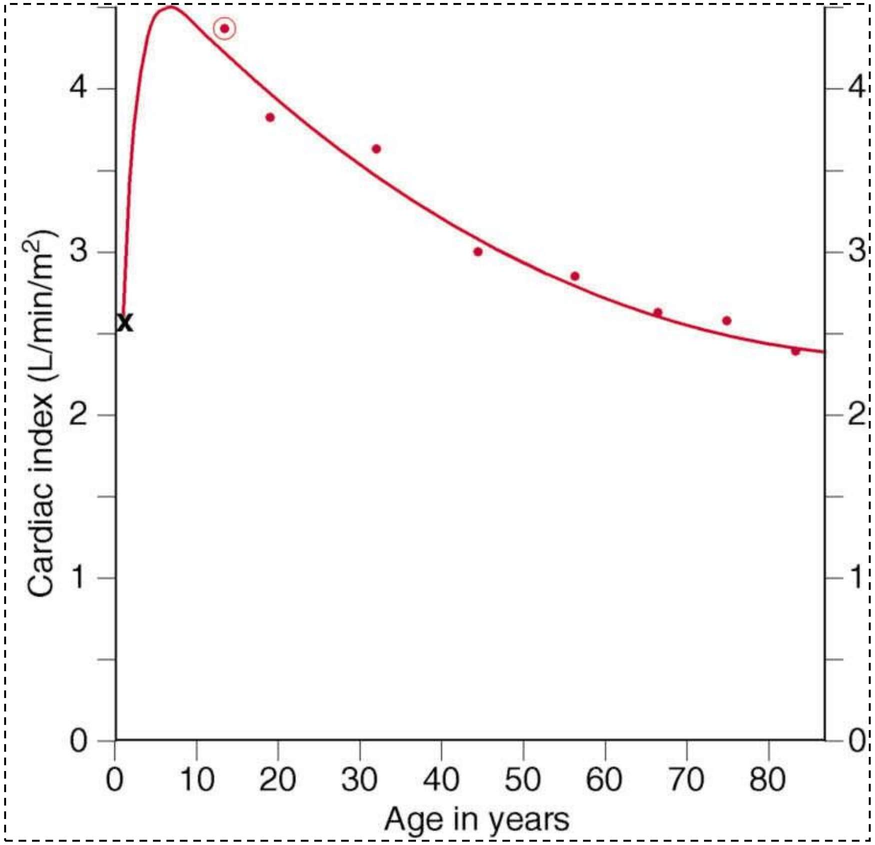


Figure 20-1

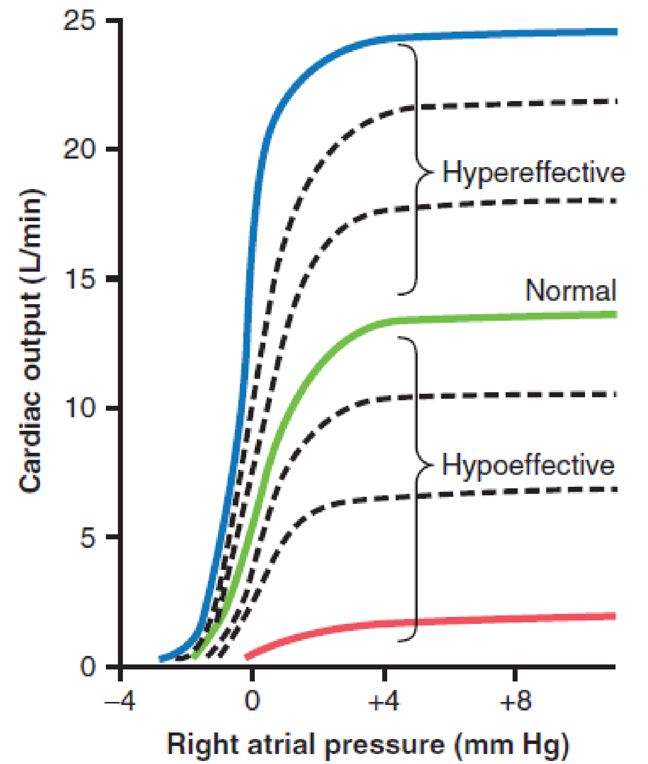
How does the cardiac index change with age? Cardiac index decrease with age

The heart has limits for cardiac output that can achieve

- Factors that can cause hypereffective heart:
  1.Nervous stimulation
  2.Hypertrophy of the heart muscle.

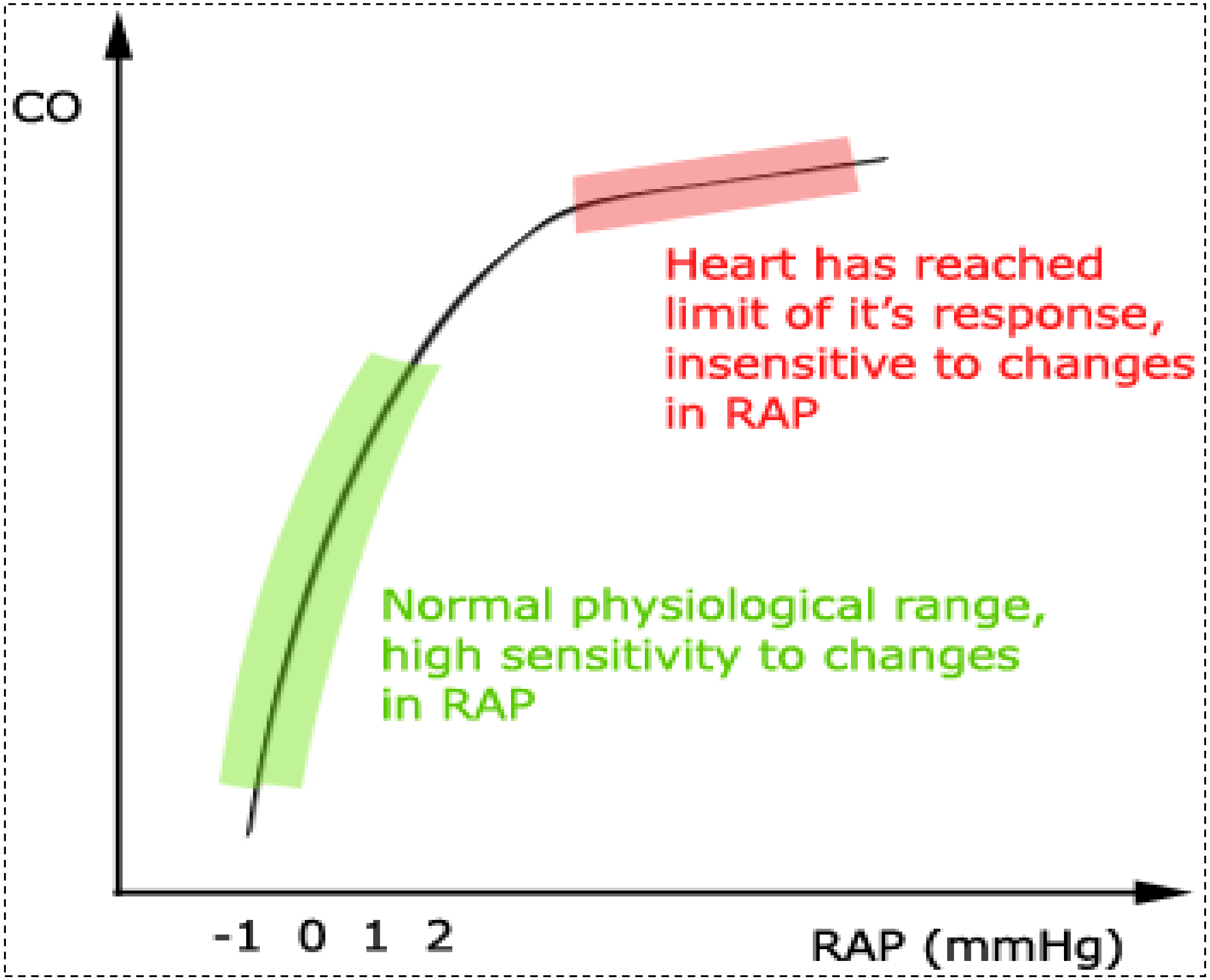
- Sympathetic stimulation and parasympathetic inhibition can increase the effectiveness of the heart via:
  1.increasing the heart rate
  2.increasing the strength of heart contraction.

- 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%.



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.

Measurement Of C.O



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.

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

Thus :

$$\left[\{ Arterial\ level\ of\ the\ substance - The\ venous\ level \} \text{ X } \{ \frac{Amount\ of\ substance}{Artirial\ level\ Venous\ level} \} \right]$$

- **Guyton corner :**

In animal experiments, one can cannulate the aorta, pulmonary artery, or great veins entering the heart and measure the cardiac output using a flowmeter. An electromagnetic or ultrasonic flowmeter can also be placed on the aorta or pulmonary artery to measure cardiac output.
In humans, except in rare instances, cardiac output is measured by indirect methods that do not require surgery. Two of the methods that have been used for experimental studies are the *oxygen Fick method* and the *indicator dilution method.*

Methods for measuring C.O

" not that important"

- Cardiac output can be measured using the Fick principle, whose fundamental assumption is that, in the steady state, the CO of the left and right ventricles is equal.
- The Fick principle states that in the steady state, the rate of O_2 consumption by the body must equal the amount of O_2 leaving the lungs in the pulmonary vein minus the amount of O_2 returning to the lungs in the pulmonary artery.
- Total O_2 consumption or the rate of oxygen absorption by the lungs can be measured by the rate of disappearance of O_2 from respired air, using any oxygen meter.
- The amount of O_2 in the pulmonary veins is pulmonary blood flow multiplied by the O_2 content of pulmonary venous blood. Likewise, the amount of O_2 returned to the lungs via the pulmonary artery is pulmonary blood flow multiplied by the O_2 content of pulmonary arterial blood.
- O_2 consumption = cardiac output × $[O_2]$ pulmonary vein – cardiac output × $[O_2]$ pulmonary artery
- Cardiac output = O_2 absorbed by the lungs per minute/arteriovenous O_2 difference

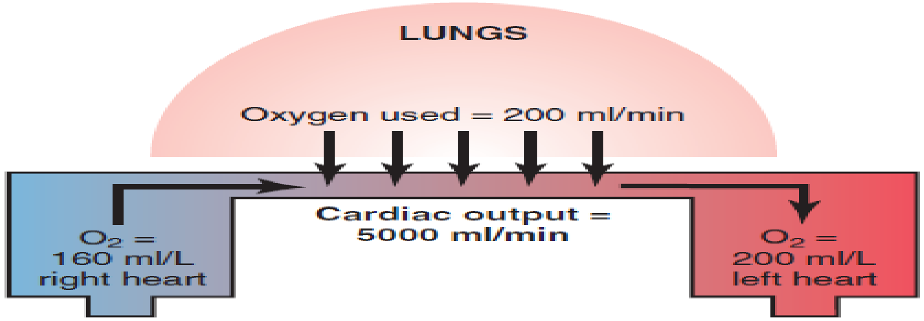
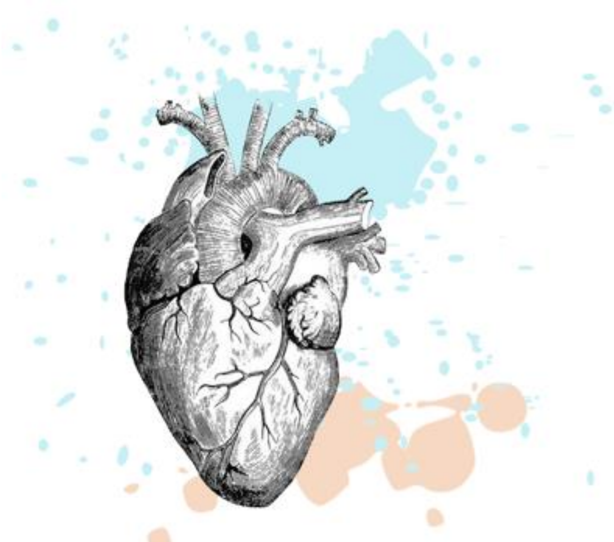


Figure 20-19. Fick principle for determining cardiac output.

Physiology
OF THE CARDIOVASCULAR SYSTEM

Physiology Leaders :

Khawla Alammari
Nojood Alhaidri
Rawaf Alrawaf



Girls team :

- Atheer Alnashwan
- Asrar Batarfi
- Afnan Almalki
- Alhanouf Aljlaoud
- Deema AlFaris
- Elham Alzahrani
- Johara Almalki
- Lojain alsiwat
- Malak Alsharif
- Monirah Alsalouli
- Nora AlRomaih
- Nurah Alqahtani
- Nouf Alabdulkarim
- Nora Albusayes
- Nora Alsomali
- Norah Alakeel
- Reem Alageel
- Rawan Aldhuwayhi
- Reham Al-Obaidan
- Samar AlOtaibi
- Shamma Alsaad

Boys team :

- Abdullah Aljaafar
- Omar Alotaibi
- Abdulrahman Albarakah
- Adel Alshehri
- Abdulaziz Alghanaym
- Abdulmajeed Alotaibi
- Khalil Alduraibi
- Hassan Albeladi
- Omar Alshehri
- Saleh Alshawi
- Abdulaziz Alhammad
- Faisal Alabdulatif
- Abdulnasser Alwabel
- Saad Almutairy