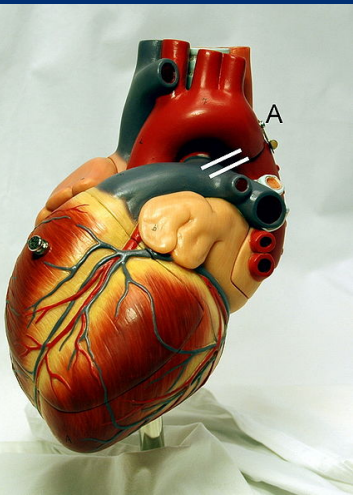


# Stroke volume

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## **Stroke volume**

**Is the volume of blood pumped by each ventricle per beat.**

**Normally it is about 70 ml/beat.**

## END-SYSTOLIC VOLUME (ESV) and END-DIASTOLIC VOLUME (EDV)

During ventricular diastole, filling of the ventricles with blood normally increases the volume of each ventricle to about **120-130 ml.**

The volume of blood present in each ventricle at the end of ventricular diastole is called end-diastolic volume (EDV) or **preload**, which is about **120-130 ml.**

The volume of blood ejected by each ventricle during each ventricular systole is called stroke volume (**=70-80 ml**).

The volume of blood present in each ventricle at the end of ventricular systole is called end-systolic volume (ESV) and it is **about 50-60 ml.**

# Factors Affecting the Stroke Volume

**1- The end diastolic volume (EDV) or preload**

**Is the amount of blood a ventricle contains at the end of diastole, depends on:**

**1- Filling time:**

**Which is the duration of ventricular diastole**

**2- Venous return:**

**The rate of blood flow during ventricular diastole**

# The Frank–Starling Principle (Starling's law of the heart)

- The Frank Starling principle is based on the **length-tension** relationship within the ventricle.
- If ventricular end diastolic volume (**preload**) is increased, it follows that the ventricular fiber length is also increased, resulting in an increased 'tension' of the muscle.
- Cardiac output is directly related to venous return, the most important determining factor is preload.
- The contraction and therefore stroke volume in response to changes in venous return is called the **Frank-Starling mechanism** (or Starling's Law of the heart).

# Factors Affecting the Stroke Volume

## 2- End-Systolic Volume (ESV)

- The amount of blood that remains in the ventricle at the end of ventricular systole is the ESV.

↑ End-Systolic Volume (ESV) → ↓ stroke volume

↓ End-Systolic Volume (ESV) → ↑ stroke volume

## Afterload

It is expressed as **tension** which must be developed in the wall of ventricles during systole to **open** the semilunar valves and eject blood to aorta /pulmonary artery.

**Is increased by any factor that restricts arterial blood flow like:**

1- Increased arterial blood pressure.

2- Vasoconstriction.

As afterload **increases**, stroke volume **decreases**.

# Stroke Volume Control Factors

## 1- End-Diastolic Volume (EDV) or Preload

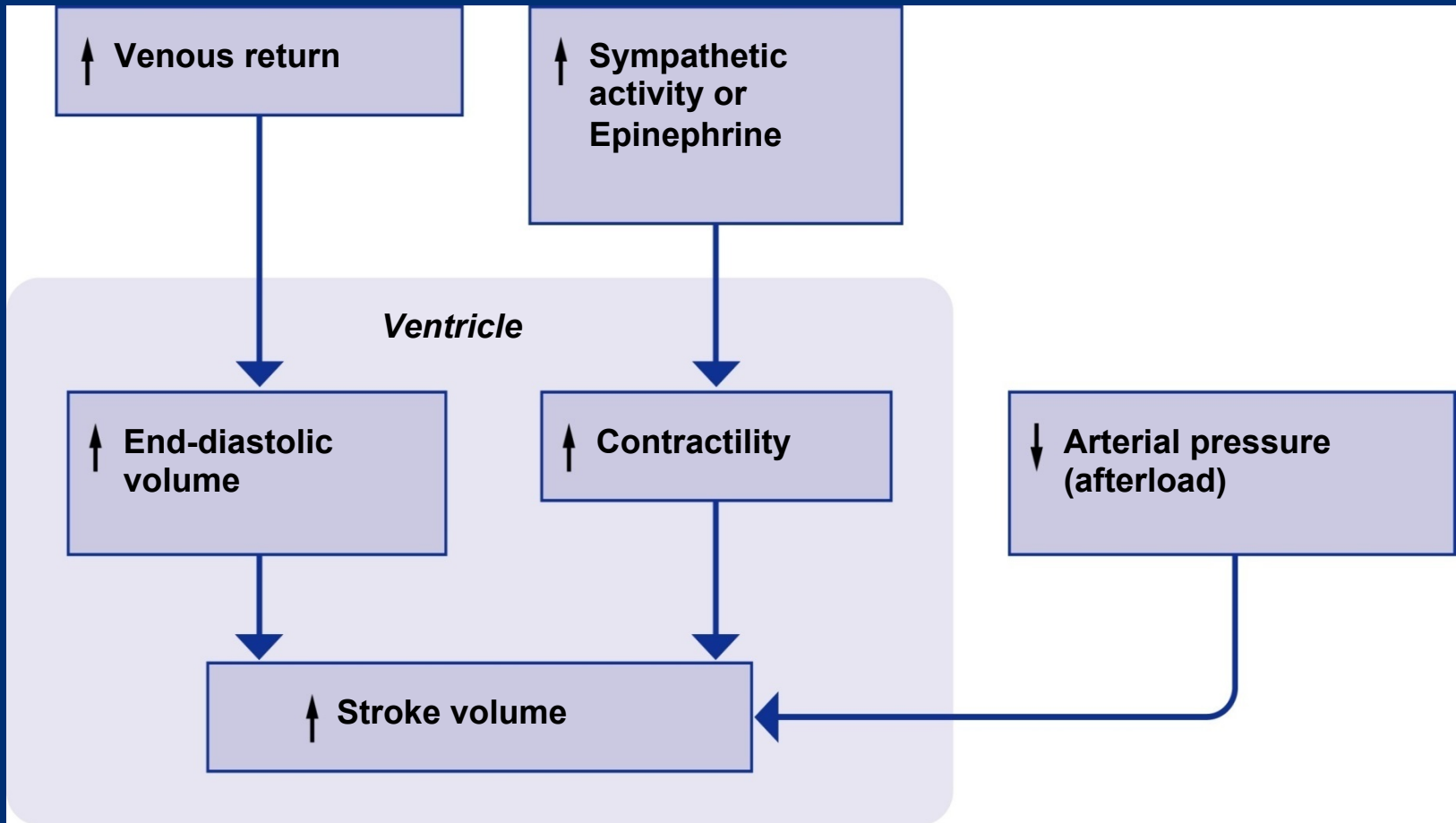
- Filling time
- Rate of venous return

## 2- End-Systolic Volume (ESV)

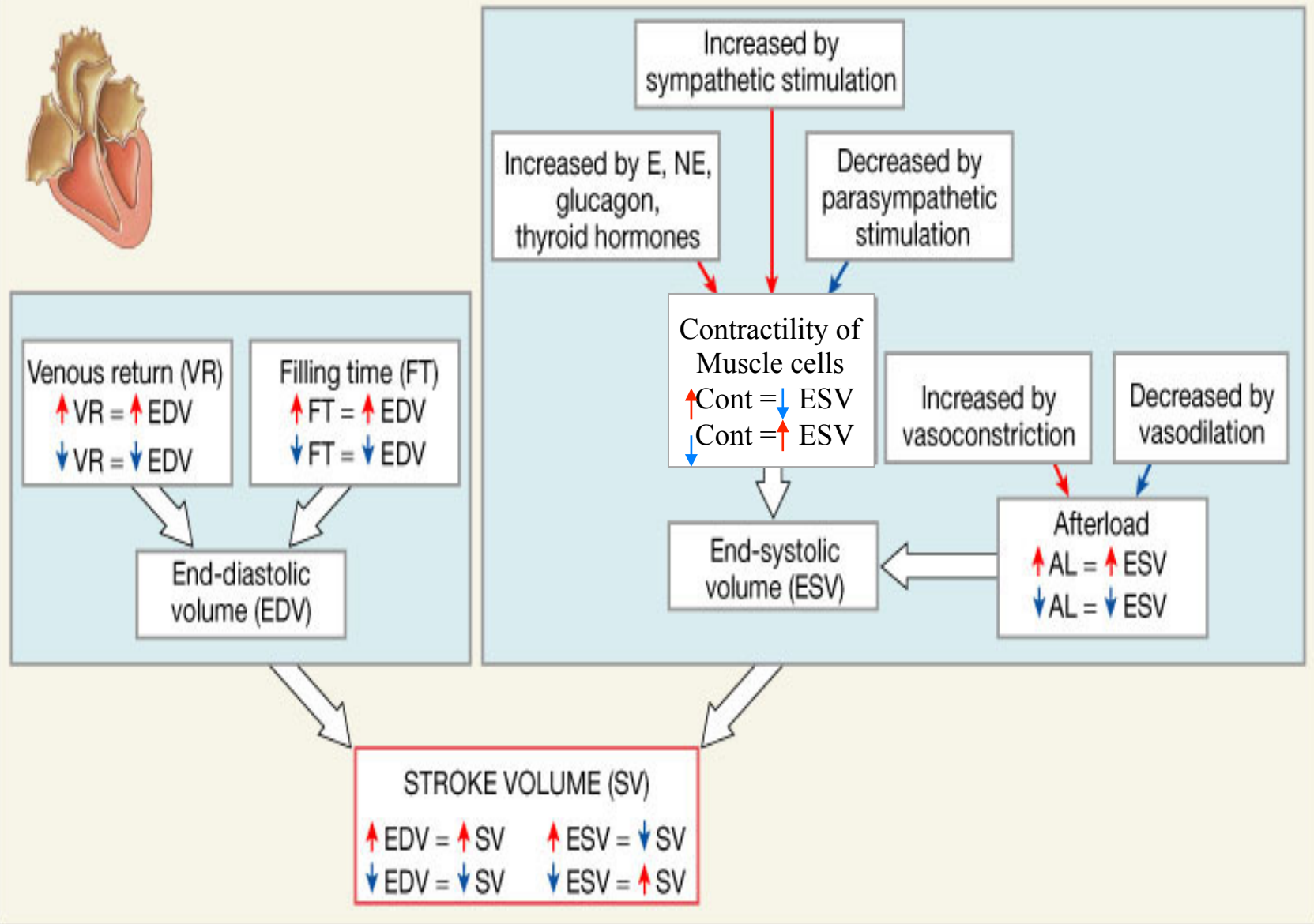
- Preload             $\uparrow$  preload  $\rightarrow$   $\downarrow$  ESV
- Contractility     $\uparrow$  Contractility  $\rightarrow$   $\downarrow$  ESV
- Afterload         $\uparrow$  Afterload  $\rightarrow$   $\uparrow$  ESV



# Factors Influencing Stroke Volume



# Factors Affecting Stroke Volume



## Ejection Fraction

Fraction of end-diastolic volume ejected during a heart beat.

$$\begin{aligned}\text{Ejection fraction} &= \\ \text{stroke volume} / \text{end diastolic volume} \\ &= 70 \text{ mL} / 130 \text{ mL} = 0.54\end{aligned}$$

## **Factors affecting myocardial contractility: (Inotropic effectors)**

- 1. End-Diastolic Volume (Starling' s law of the heart).**
- 2. Cardiac innervation.**
- 3. Oxygen supply.**
- 4. Calcium & potassium ions concentration in ECF.**
- 5. Physical factors.**
- 6. Hormonal & chemical factors (drugs).**
- 7. Mechanical factors.**

## **1- Starling's law of the heart:**

**“Length-tension relationship”**

**Within limits, the power of contraction is directly proportional to the initial length of The muscle fiber.**

**Overstretching the fiber as in heart failure its power of contractility decreases.**

## 2- Cardiac Innervation

Sympathetic NS → ↑ force of contraction.

Parasympathetic NS (vagus) → ↓ atrial force of contraction with **no significant** effect on Ventricular contraction.

### **3- Oxygen supply:**

Hypoxia → ↓ contractility.

### **4- Calcium & potassium ions concentration in ECF:**

↑  $\text{Ca}^{2+}$  → ↑ contractility.

↑  $\text{K}^{+}$  → ↓ contractility.

### **5- Physical factors:**

Warming → ↑ contractility.

Cooling → ↓ contractility.

## **6- Hormonal & chemical factors (drugs):**

**Positive inotropics:**

**(Adrenaline, noradrenaline, alkalosis, digitalis,  $\text{Ca}^{2+}$  and caffeine)**

**Negative inotropics:**

**(Acetylcholine, acidosis, ether, chloroform, some bacterial toxins (e.g. diphtheria toxins),  $\text{K}^+$ , ...)**



## 7- Mechanical factors:

a. Cardiac muscle obeys 'all or none law:

Minimal or threshold stimuli lead to **maximal** cardiac contraction, because cardiac muscle behaves as a **syncytium**.

b. Cardiac muscle can't be stimulated while it is contracted,

Because its **excitability** during contraction is **zero** due to **Long** absolute refractory period, so it **can't be tetanized**.

c. Cardiac muscle can perform both **isometric** & **isotonic** types of contractions.

# Heart failure

## Definition

**It is the pathophysiological process in which the heart as a pump is unable to meet the metabolic requirements of the tissue for oxygen and substrates despite the venous return to heart is either normal or increased.**

# Heart Failure

Heart failure can involve the left or right side of the heart or both.

Usually the **left side** is affected first.

Heart failure occurs when either side of the heart cannot keep up with the flow of blood.

# Heart Failure

## Systolic failure

The heart loses its ability to contract or pump blood into the circulation

## Diastolic failure

The heart loses its ability to relax because it becomes stiff

Heart cannot fill properly between each beat

# Congestive Heart Failure

## Symptoms:

- Shortness of breath
- Leg swelling (edema)
- Breathing worsens with lying flat (orthopnea)
- Fatigue

# Heart Failure

## What is Left Heart Failure?

Systolic and diastolic heart failure are treated with different types of medications

In both types, blood may “**back up**” in the lungs causing fluid to leak into the lungs (**pulmonary edema**)

Fluid may also build up in tissues throughout the body (edema)

# Heart Failure

## What is Right Heart Failure?

Usually occurs as a result of left heart failure.

Occasionally isolated right heart failure can occur due to **lung disease** or blood clots to the lung (**pulmonary embolism**).

# Heart Failure

How fast does heart failure develop?

Usually a **chronic** disease

The heart tries to compensate for the loss in pumping function by:

- **Developing more muscle mass**
- **Enlarging**
- **Pumping faster**



# Causes of Heart Failure

## 1- Impaired cardiac function

- Coronary heart disease
- Cardiomyopathies (muscle disease)
- Rheumatic fever
- Endocarditis

## 2- Increased cardiac workload

- Hypertension
- Valvular disorders
- Anemias
- Congenital heart defects

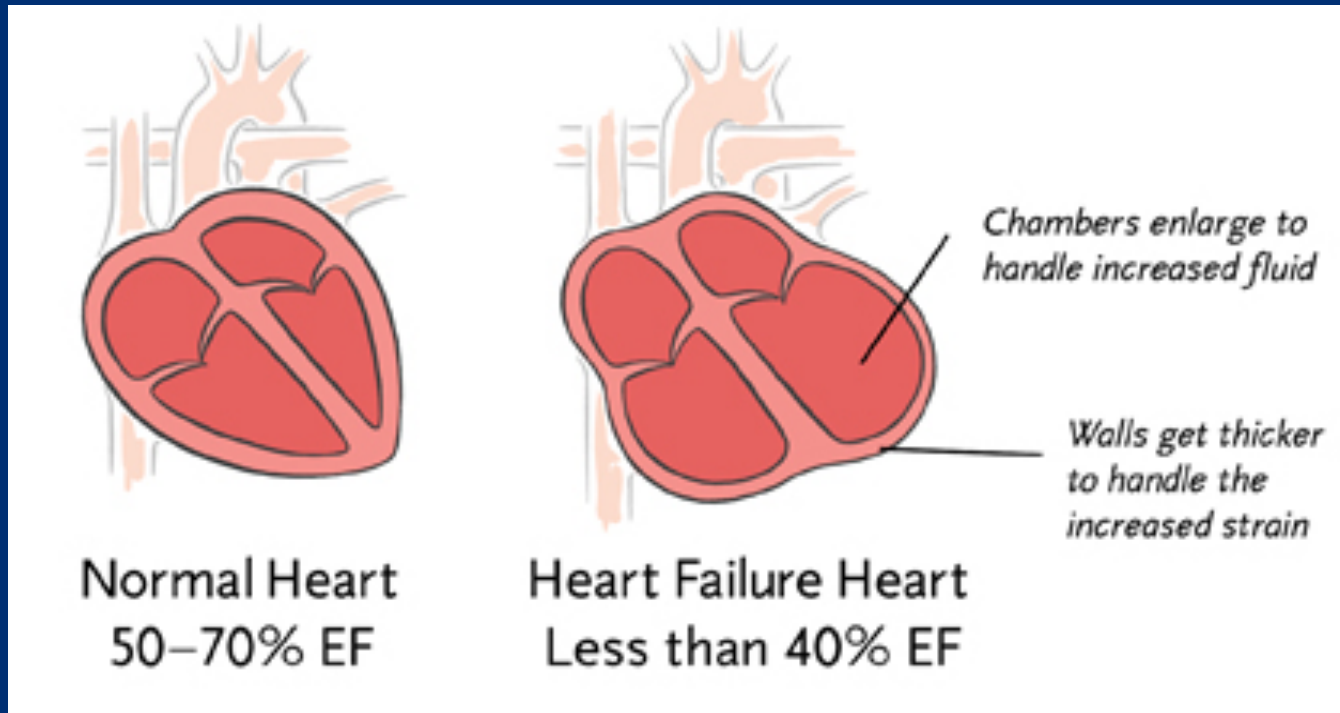
## 3- Acute non-cardiac conditions

- Volume overload
- Hyperthyroidism, Fever, Infection

# Indicator for Diagnosing Heart Failure

## Ejection Fraction (EF)

- Ejection Fraction (EF) is the percentage of blood that is pumped out of your heart during each beat



# How Heart Failure Is Diagnosed

- **Medical history is taken to reveal symptoms**
- **Physical exam is done**
- **Tests**
  - **Chest X-ray**
  - **Blood tests**
  - **Electrical tracing of heart (Electrocardiogram or “ECG”)**
  - **Ultrasound of heart (Echocardiogram or “Echo”)**
  - **X-ray of the inside of blood vessels (Angiogram)**

# Heart Failure

## Signs and Symptoms of Heart Failure

### Persistent Cough or Wheezing

#### WHY?

Fluid “backs up” in the lungs

#### SYMPTOMS

Coughing that produces white or pink blood-tinged sputum

# Heart Failure

## Signs and Symptoms of Heart Failure

### Edema

#### WHY?

Decreased blood flow out of the weak heart  
Blood returning to the heart from the veins  
“backs up” causing fluid to build up in  
tissues

#### SYMPTOMS

Swelling in feet, ankles, legs or abdomen  
Weight gain

# Heart Failure

## Signs and Symptoms of Heart Failure

Tiredness, fatigue

### WHY?

Heart can't pump enough blood to meet needs of bodies tissues

Body diverts blood away from less vital organs (muscles in limbs) and sends it to the heart and brain

### SYMPTOMS

Constant tired feeling

Difficulty with everyday activities

# Heart Failure

## Signs and Symptoms of Heart Failure

**Lack of appetite/ Nausea**

**WHY?**

**The digestive system receives less blood  
causing problems with digestion**

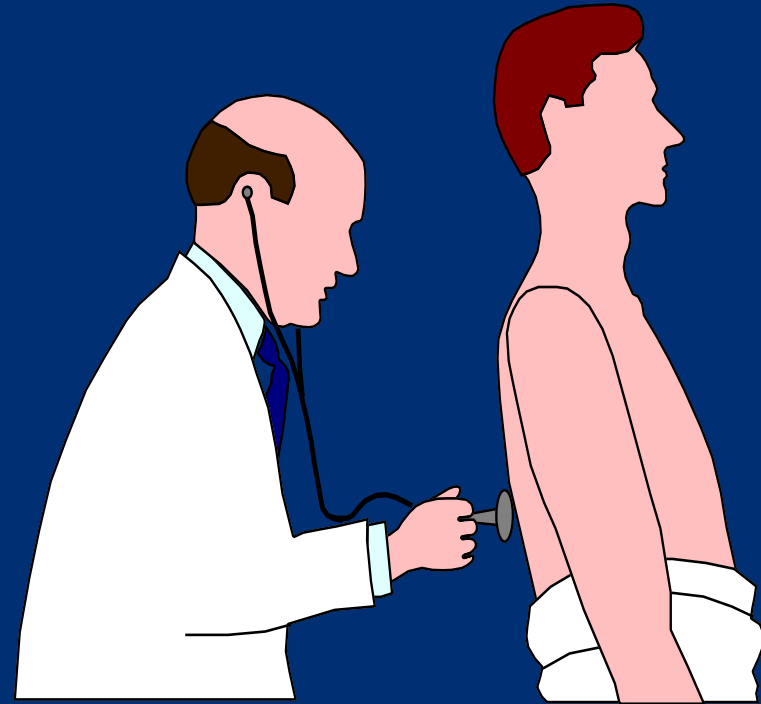
**SYMPTOMS**

**Feeling of being full or sick to your stomach**

# Left Ventricular Failure

## Signs and symptoms

- Dyspnea
- Orthopnea and paroxysmal nocturnal dyspnoea
- Cheyne Stokes breathing
- fatigue
- Anxiety
- Rales
- pallor, cyanosis
- Increased HR and BP

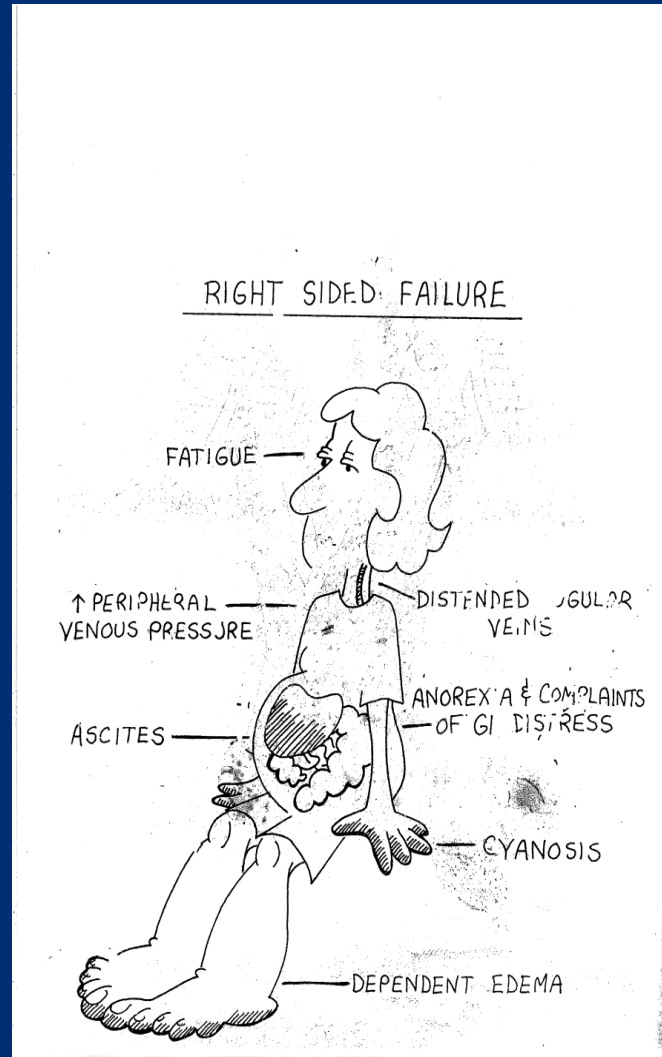




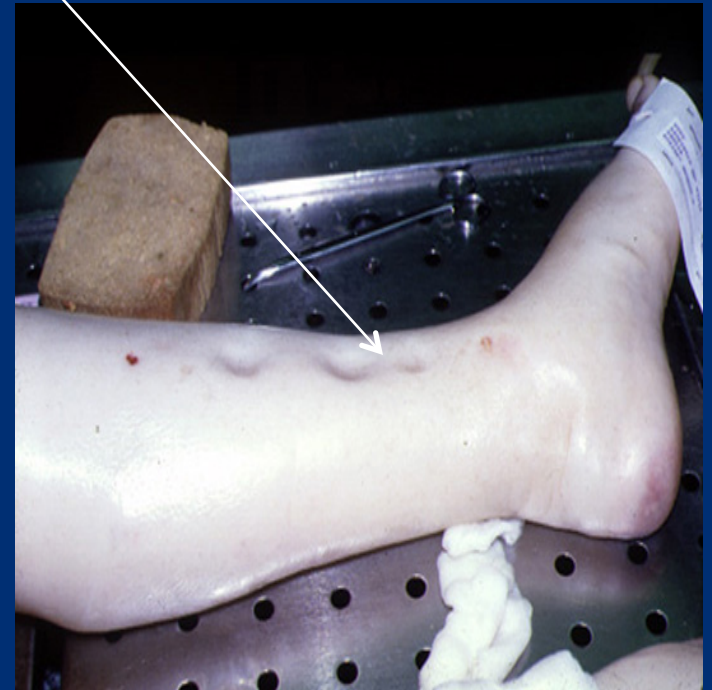
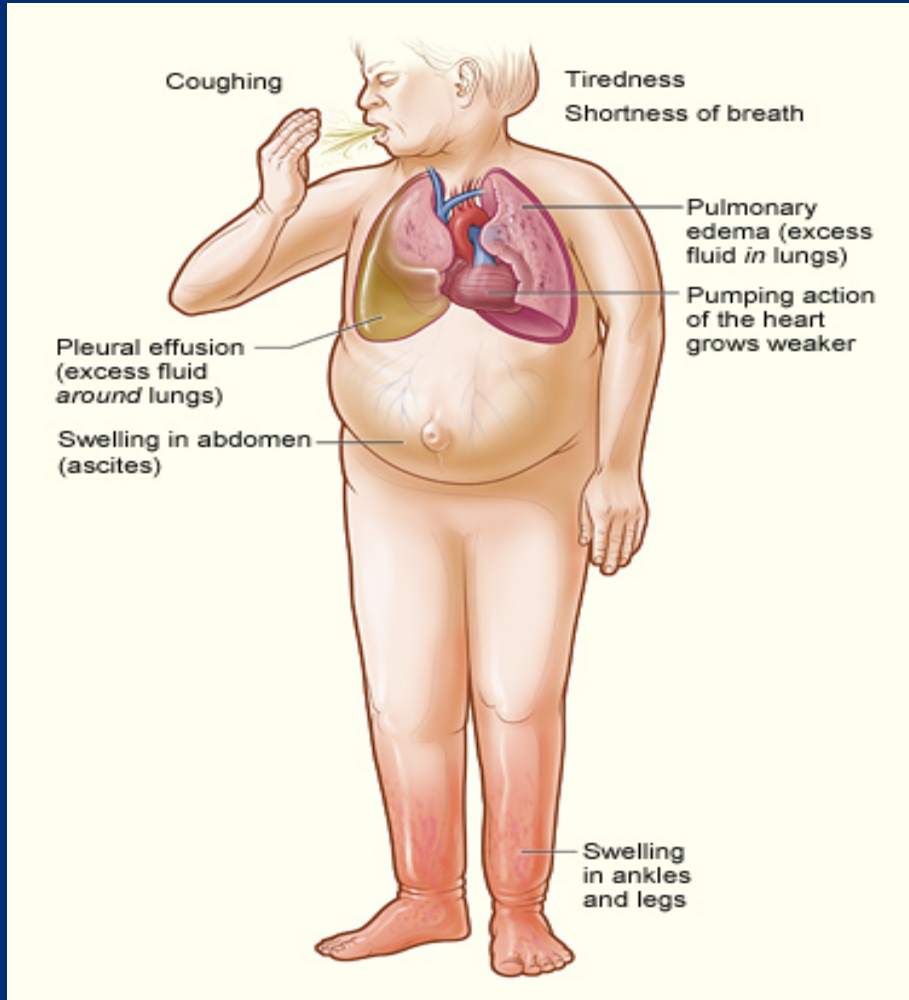
# Right Heart Failure

## Signs and Symptoms

- Fatigue
- Weakness
- Lethargy
- Weight gain, including abdominal girth
- Anorexia
- Elevated neck veins
- Hepatomegaly



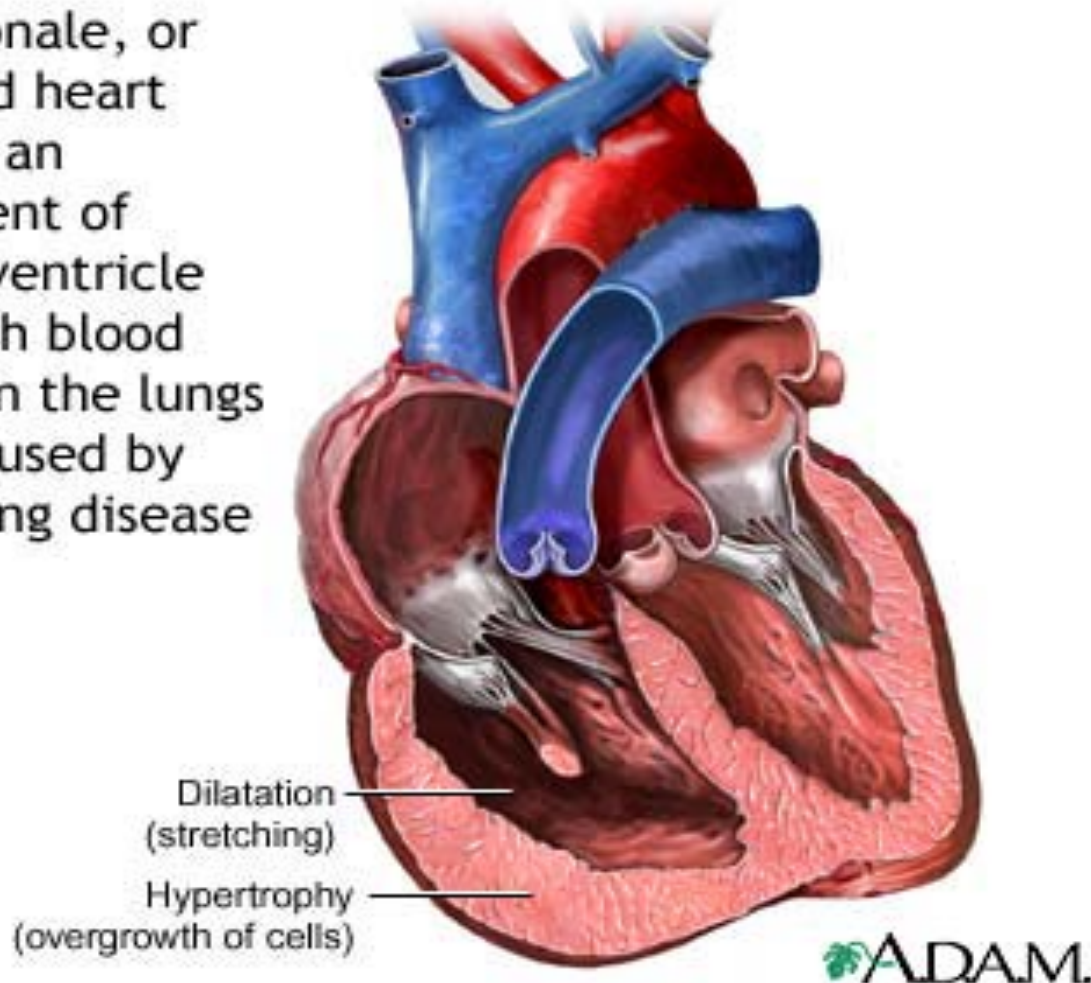
# What is present in this extremity, common to right sided HF?



# Can You Have RVF without LVF?

## This is called **COR PULMONALE**

Cor pulmonale, or right-sided heart failure, is an enlargement of the right ventricle due to high blood pressure in the lungs usually caused by chronic lung disease



For further readings and diagrams:

Textbook of Medical Physiology by Guyton & Hall

Chapter 19 (Cardiac Failure)