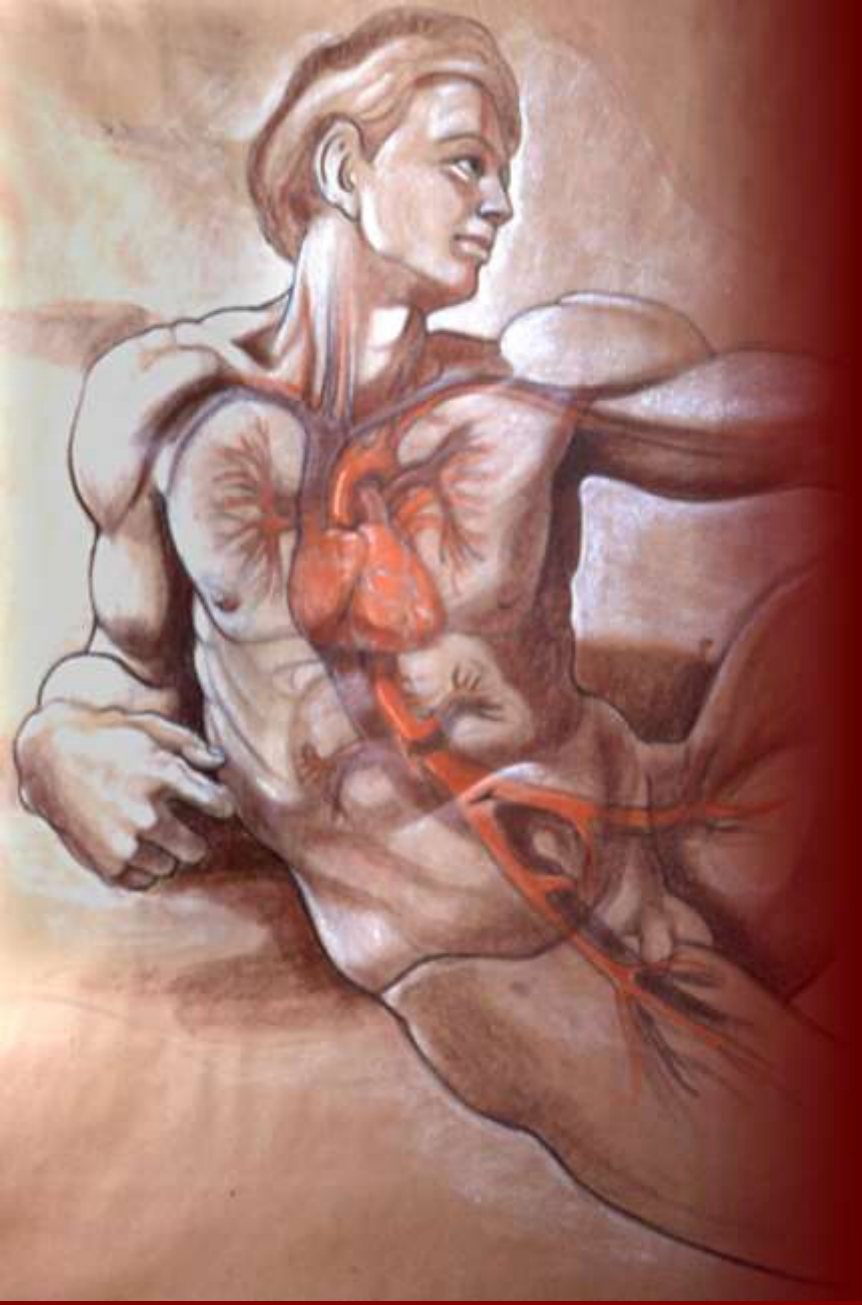


Cardiovascular Pathophysiology 4

Roman Benacka

Department of Pathophysioloy

Medical Faculty, Safarik University, Košice

Heart failure

Estimated volumetric data of the heart

Ventricular volumes		
Measure	**Right ventricle**	**Left ventricle**
Heart rate	60–100 beats/min	60–100 beats/min
Cardiac output	4.0–8.0 L /min	4.0–8.0 L/ min
Stroke volume	94 mL (± 15 mL)	95 mL (± 14 mL)
Stroke volume / body surface area	51 mL/m2 (± 7 mL/m2)	52 mL/m2 (± 6.2 mL/m2)
End-diastolic volume	144 mL(± 23mL)	142 mL (± 21 mL)[74]
End-diastolic volume / body surface area	78 mL/m2 (± 11 mL/m2)	78 mL/m2 (± 8.8 mL/m2)
End-systolic volume	50 mL (± 14 mL)	47 mL (± 10 mL)[74]
End-systolic volume / body surface area	27 mL/m2 (± 7 mL/m2)	26 mL/m2 (± 5.1 mL/m2)
Ejection fraction	66% (± 6%)	67% (± 4.6%)

Volumetric data of the heart workout

- **Stroke volume (SV) ~ 70ml;** is the volume of blood pumped from the left ventricle per beat. stroke volume itself correlates with cardiac function; is calculated using f ventricle volumes from an echocardiogram **SV = EDV-ESV**
- **End-diastolic volume (EDV) ~120ml;** the volme of blood filling the ventricles in the end of diastole; beggining of contraction (systole)
- **End-systolic volume (ESV) ~ 50 ml**; the volume of blood (residual) in a ventricle at the end of systole; the beginning of filling (diastole); part of EDV that is not ejected.
- **Cardiac output (CO)** is total amopunt blood pumped through the heart in minute ; the product of stroke volume and heart rate

  CO = HR x SV 70 ml x 80 bpm = 5600 ml = **5,6 litres**
- **Ejection fraction (EF) ,** which is stroke volume divided by end-diastolic volume
- Stroke volume is an important determinant of cardiac output, which is, and is also used to calculate. Because stroke volume decreases in certain conditions and disease states

A brief history in heart failure study

- 1628 William Harvey describes the circulation
- 1785 William Withering publishes an account of medical use of digitalis
- 1819 René Laennec invents the stethoscope
- 1895 Wilhelm Röntgen discovers x rays
- 1920 Organomercurial diuretics are first used
- 1954 Inge Edler and Hellmuth Hertz use ultrasound to image cardiac structures
- 1958 Thiazide diuretics are introduced
- 1967 Christiaan Barnard performs first human heart transplant
- 1987 CONSENSUS-I study shows unequivocal survival benefit of angiotensin converting enzyme inhibitors in severe heart failure
- 1995 European Society of Cardiology publishes guidelines for diagnosing heart failure

Epidemiology of heart failure in UK

Studies of the epidemiology of HF failure in United Kingdom	
Study	Diagnostic criteria
ECHOES study (West Midlands)	Clinical and echocardiographic (ejection fraction <40%)
Hillingdon heart failure study	Clinical (for example,shortness of (west London) breath,effort intolerance,fluid retention),radiographic,and echocardiographic
MONICA population	Clinical and echocardiographic (north Glasgow) (ejection fraction <30%)

Prevalence of heart failure (per 1000 population) Framingham heart study		
Age (years)	Women	Women
50-59	8	8
80-89	66	79
All ages	7.4	7.7

Annual incidence of heart failure (per 1000 population), Framingham heart study		
Age (years)	Women	Women
50-59	3	2
80-89	27	22
All ages	2.3	1.4

Heart failure

- **Def**: inability of the heart to filfil the neds of the body for delivery of blood, opxygen and nutrients in time; set of manifestation due to cummulation of the blood in trird spacw
- **Classification:**

(A) According to the course of disease: 1) Acute HF 2) Chronic

(B) According to the severity

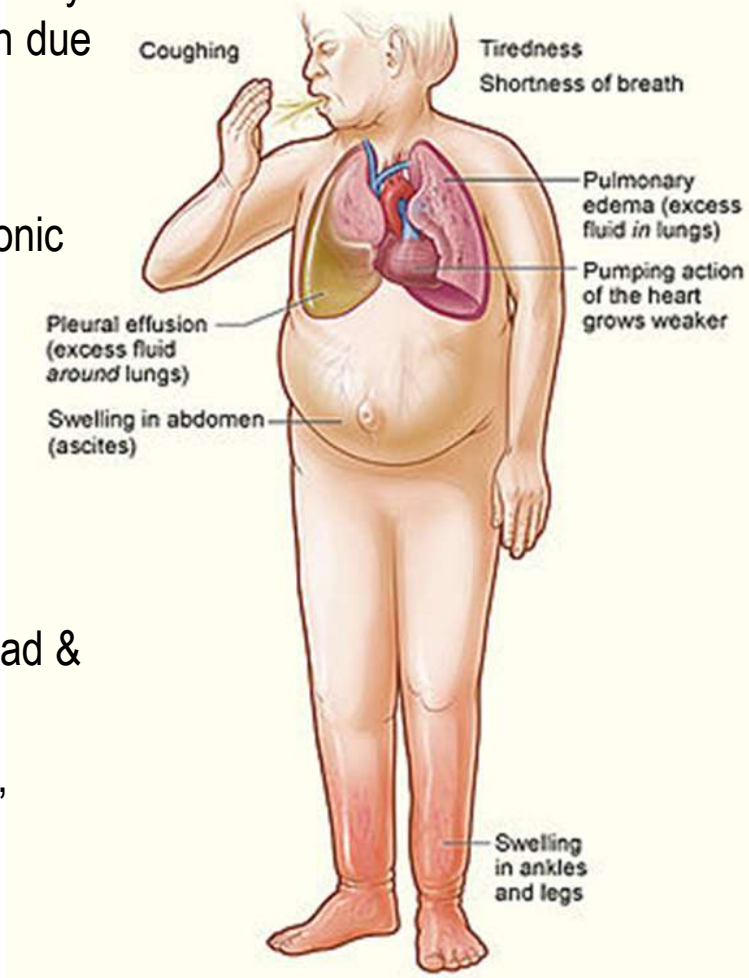
1) mild HF or complete compensation
2) middle HF or incomplete compensation
3) severe HF or decompensation

(C) According to the cardiac output (CO)

1) **Low-output HF:** due to volume overload, pressure overload & contractility problems.
2) **High-output HF:** Heart Rate is primarily affected; anemia, arrythmia, AV Fistula, fever, hyperthyroidism

(D) According to part of the heart: 1) **Right, 2) Left , 3) Biventricular (global)**

(E) According to effect of : **1) Systolic heart failure 2) Diastolic heart failure**



Causes of heart failure

1. Coronary artery disease
- Myocardial infarction
- Angina pectoris Ischaemia

2. Hypertension

3. Cardiomyopathy
- Dilated (congestive)
- Hypertrophic/obstructive
- Restrictive, e.g. amyloidosis, sarcoidosis, haemochromatosis
- Obliterative

4. Valvular and congenital heart disease
- Mitral & aortic valve disease
- Atrial & ventricular septal defect

5. Alcohol and drugs
- Alcohol
- Cardiac depressant drugs (blockers, calcium antagonists)

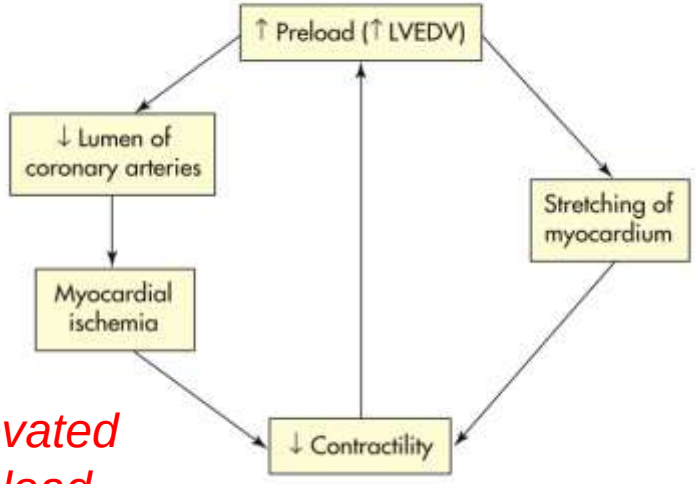
6. "High output"failure
- Anaemia,thyrotoxicosis,arteriovenous fistulae, Paget's disease
- Constrictive pericarditis
- Pericardial effusion

7. Primary right heart failure
- Pulmonary hypertension —e.g. pulmonary embolism,cor pulmonale
- Tricuspid incompetence

8. Arrhythmias
- Tachycardia, Bradycardia (AV complete block, sick sinus sy.)
- Loss of atrial transport, e.g. ,atrial fibrillation

Factors Affecting Cardiac Performance

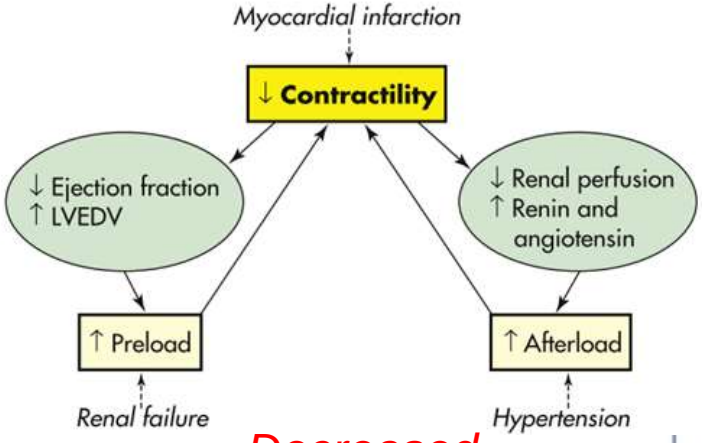
- **Preload:** volume overload, (End Diastolic Volume) amount of blood the heart must pump (such as in VSD, PDA, or valvular insufficiency).
- **Afterload**: the resistance (pressure) against which the heart must pump blood: e.g; systemic vascular resistance. (such as with aortic stenosis, pulmonary stenosis, or coarctation of the aorta)
- **Contractility:** cardiac performance independent of Preload or Afterload)



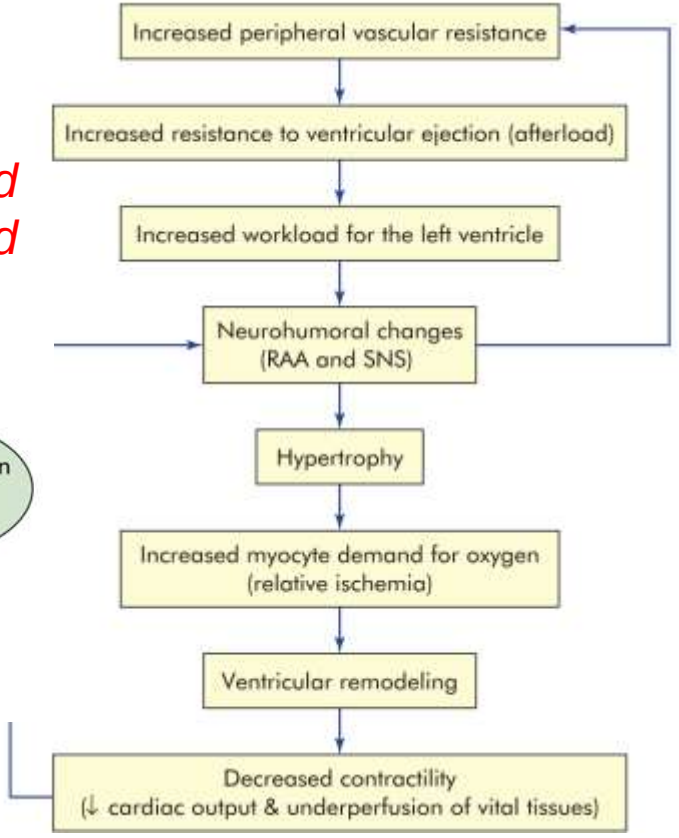
Elevated preload

Pathophysiological changes in heart failure

Ventricular dilatation
Myocyte hypertrophy
Increased collagen synth.
Altered myosin gene expres
Altered sarcoplasmic
Ca2+-ATPase
Increased ANP secretion
Salt and water retention
Sympathetic stimulation
Peripheral vasoconstriction

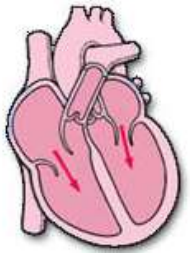
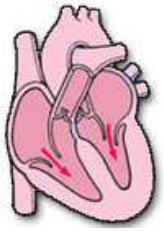


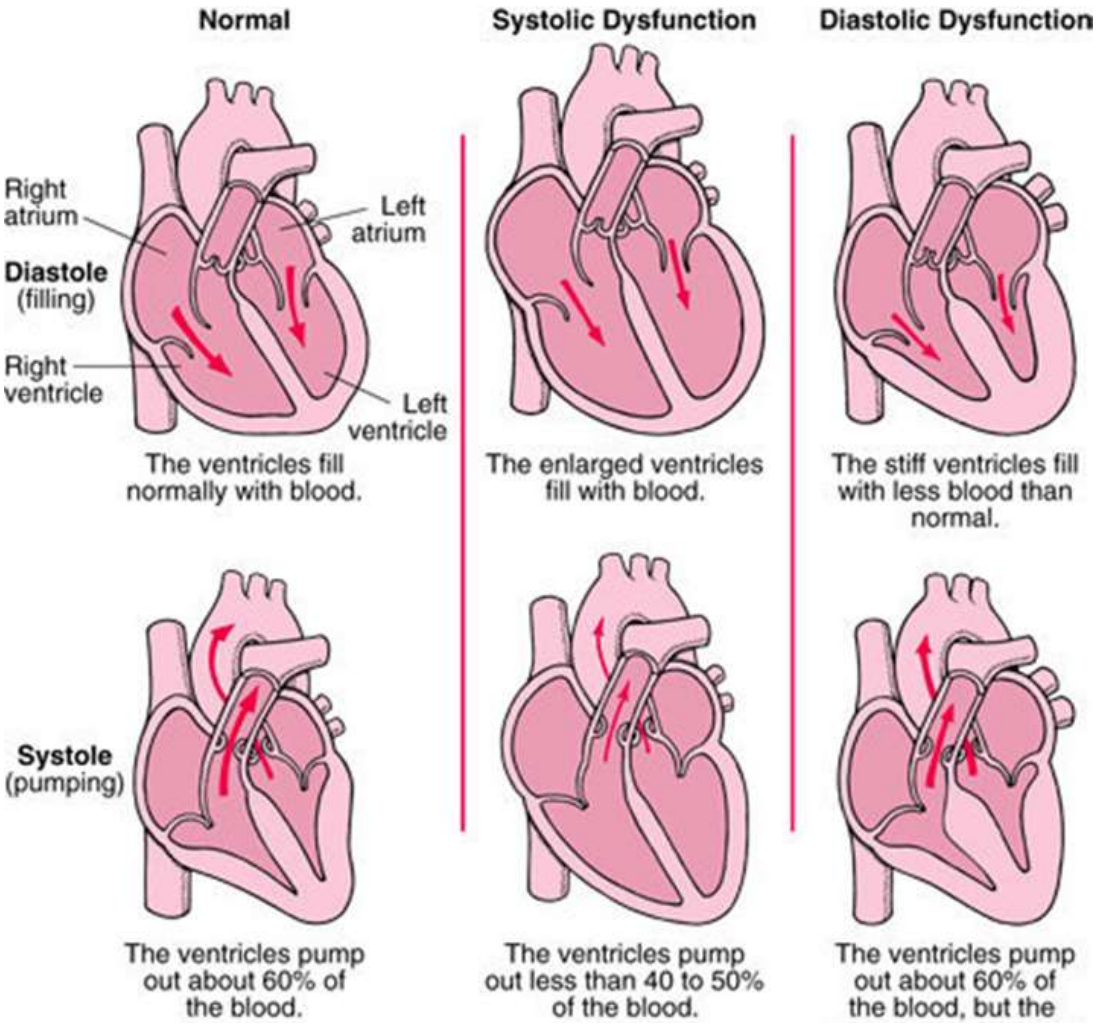
Decreased contractions



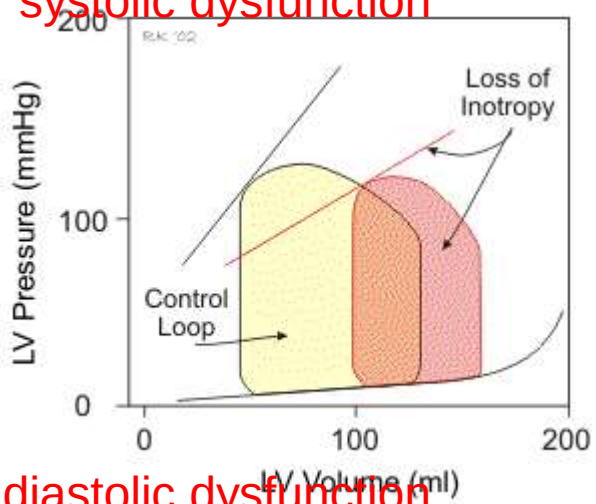
Elevated afterload

Comparing systolic and diastolic heart failure

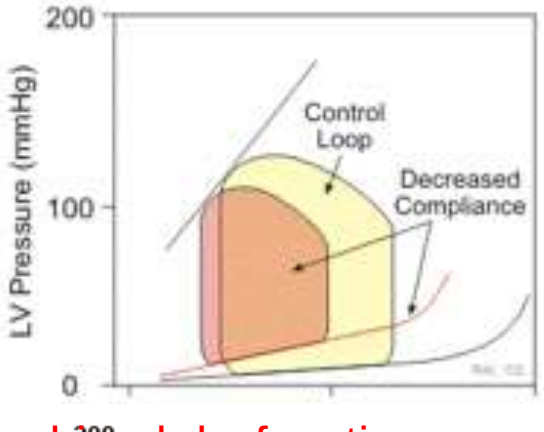
Characteristics	Systolic heart failure (dysfunction)	Diastolic heart failure (dysfunction)
Typical illustration		
Patients (age, sex)	All ages; prior myocardial infarction typically 50-70 yr; more often males;	Mostly elderly (> 70y), often females; hypertension atrial fibrilation
Left ventricular ejection fraction (LVEF)	Reduced <40-50 % of norm	Preserved or reduced but > 50-60%
Left ventricular cavity size	**Usually dilated; or excentric hypertrophy**	**Usually normal; or concentric hypertrophy**
Left ventricular mass	Increased	Increased
Relative left ventricular wall thickness	**Decreased**	**Increased**
Left atrial size	Increased	Increased
End diastolic pressure	Increased	Increased
End diastolic volume	**Increased**	**Normal**
BNP/NT-proBNP levels	↑↑More elevated	↑ Less elevated
Signs and symptoms	Dysponoea on exertion (96%) Cardiomegaly (96%) Pulmonary hypertension (80%)	Dysponoea on exertion (85%) Cardiomegaly (86%) Pulmonary hypertension (75%)
Gallop rhythm present	Third heart sound (S3) 55%	Forth heart sound
Chest radiography	Congestion and cardiomegaly	Congestion with or without cardiomegaly
Exercise capability	Decreased	Decreased



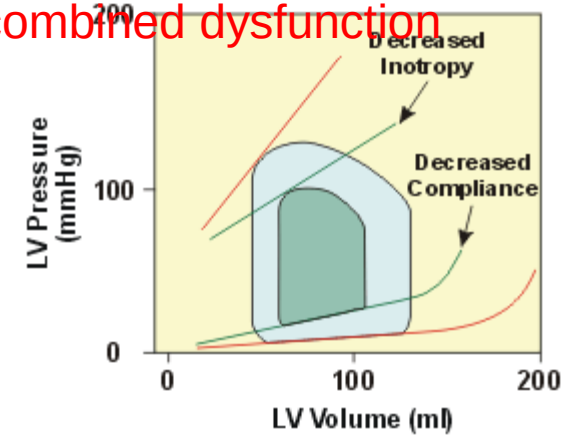
systolic dysfunction



diastolic dysfunction



combined dysfunction

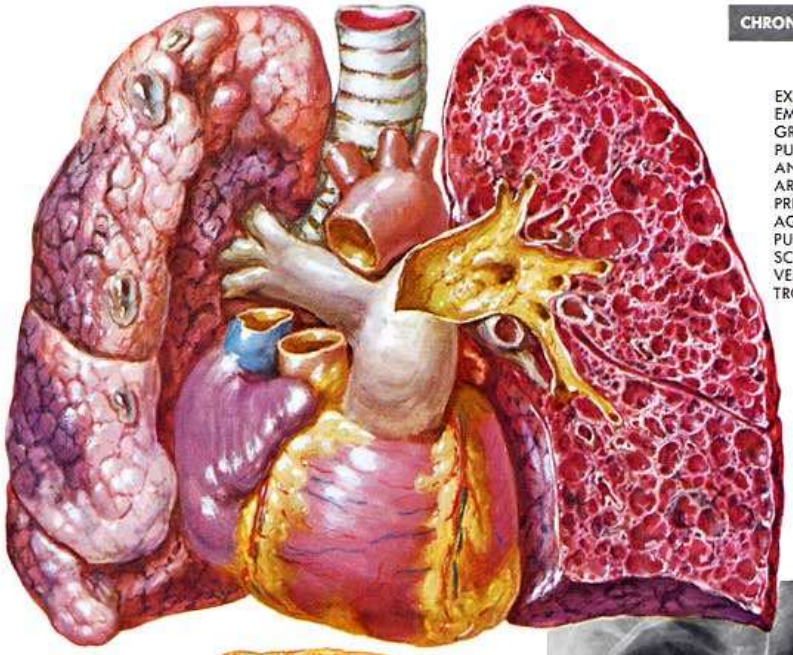


Gender	Male>female	Female>male
Left ventricular ejection fraction	Decreased	Normal
Left ventricular chamber size	Increased	Decreased
Left ventricular hypertrophy on electrocardiogram	Possible	Probable
Chest *radiography*	Pulmonary congestion with cardiomegaly	Pulmonary congestion without cardiomegaly
Gallop	S 3	S4

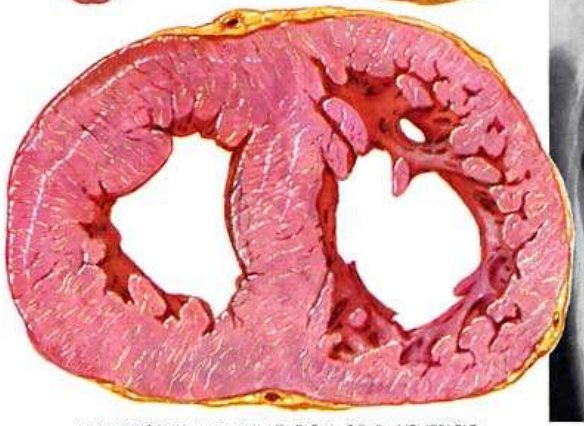
Right heart failure

- **Etio:** pulmonary heart disease (cor pulmonale) due to pulmonary hypertension, pulmonic stenosis.
- **Ptg:** right ventricular pressure is increased compensatory increase in contraction strength
- Backward failure of the right ventricle leads to congestion of systemic veins and capacitant system incl venules and capillaries. This generates excess fluid accumulation in the body with swelling (***peripheral edem***a) according to gravitational fall (***foot and ankle swelling*** when standing, sacral edema lying down). ***Nocturia*** (frequent nighttime urination) may occur when fluid from the legs is returned to the bloodstream while lying down at night. In progressively severe cases, ***ascites*** (fluid accumulation in the abdominal cavity causing swelling) and liver enlargement may develop. Significant liver congestion may result in ***congestive hepatopathy***, with functional impirment (***coagulopathy*** = problems of decreased or increased blood clotting) and ***jaundice.***
- **Sy:**
  - pitting peripheral edema, liver enlargement →portal hypertension → ascites,
  - Jugular venous pressure - a marker of fluid status accentuated by eliciting hepatojugular reflux. If the, a parasternal heave may be present

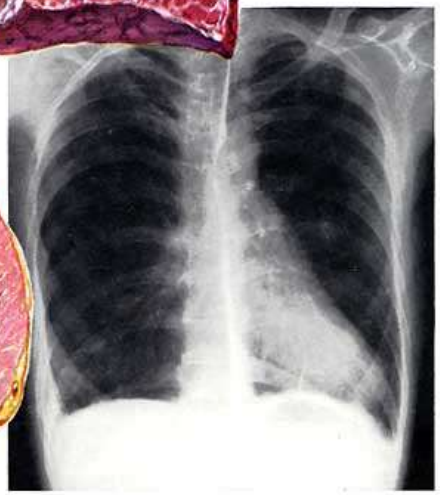
CHRONIC COR PULMONALE



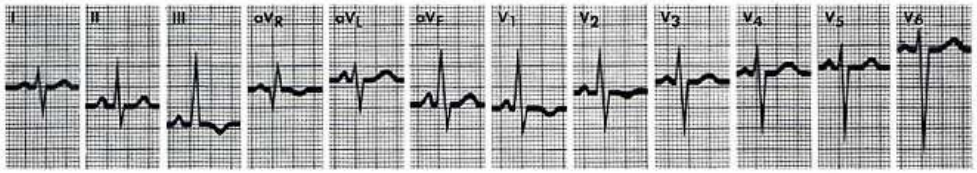
EXTENSIVE PULMONARY EMPHYSEMA WITH GREAT DISTENTION OF PULMONARY TRUNK AND MAIN PULMONARY ARTERIES WHICH HAVE PRESSED THE AORTA AGAINST THE TRACHEA: PULMONARY ARTERIOSCLEROSIS AND RIGHT VENTRICULAR HYPERTROPHY



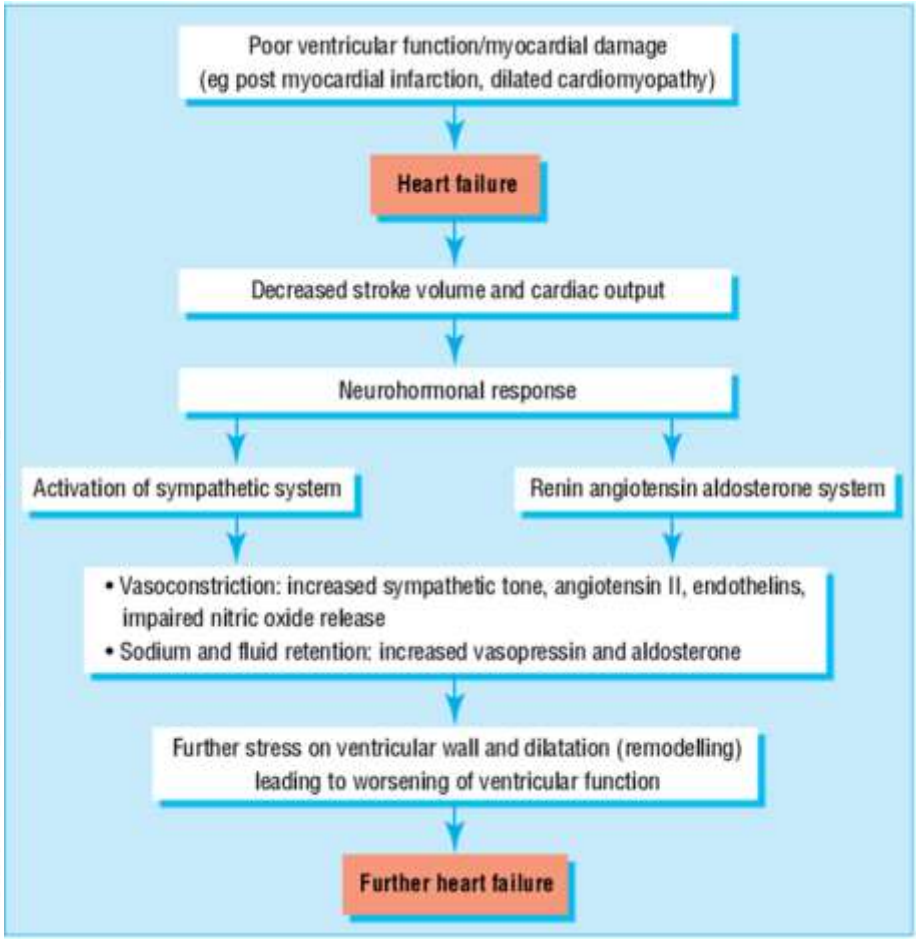
HYPERTROPHY AND DILATATION OF R. VENTRICLE



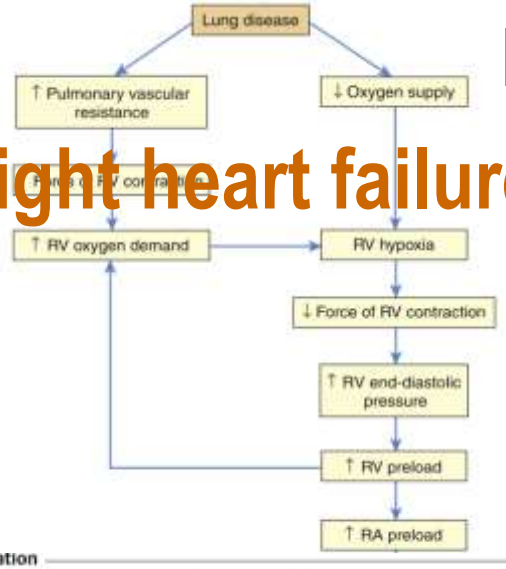
X-RAY: CHRONIC OBSTRUCTIVE EMPHYSEMA WITH COR PULMONALE

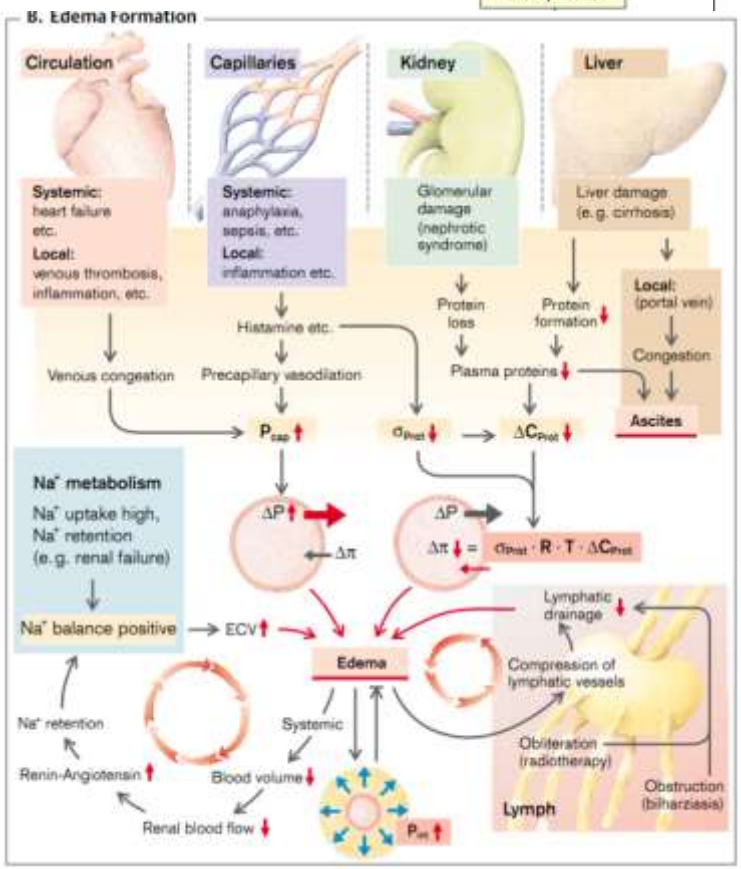


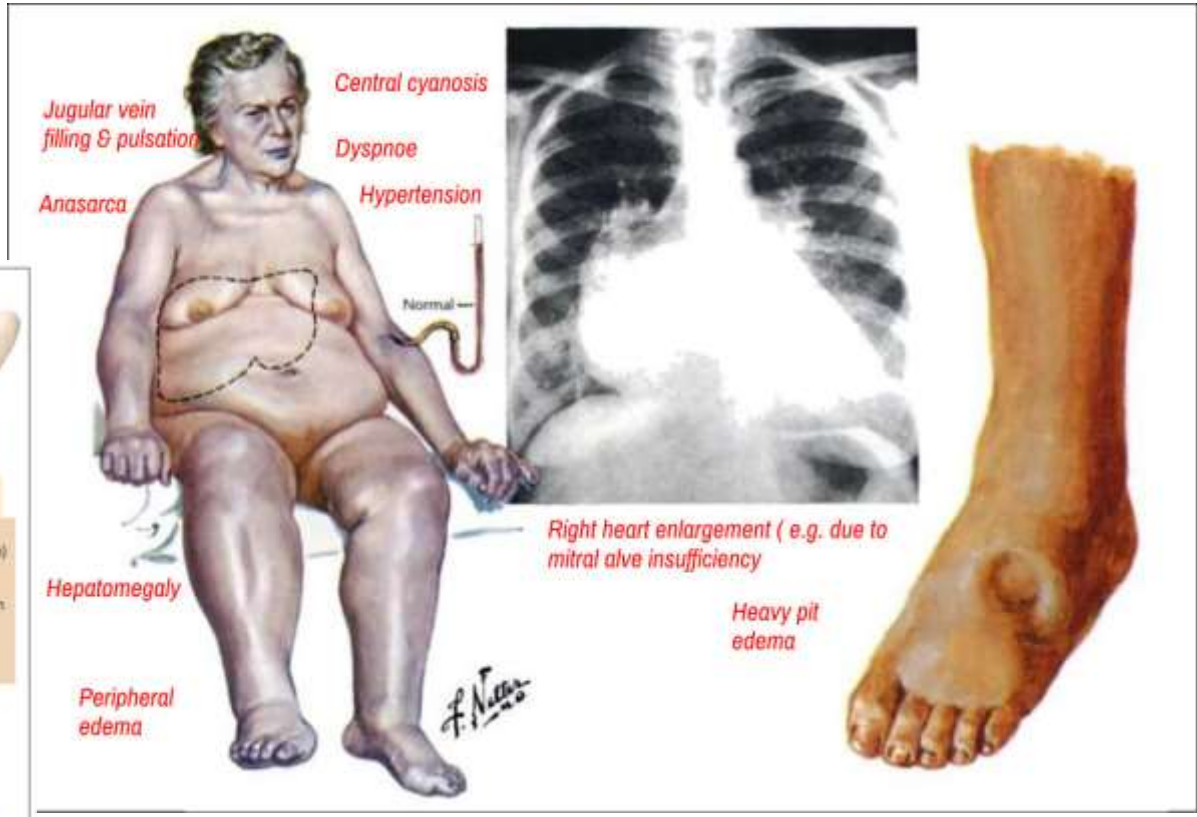
R WAVES IN LEADS V_1 AND V_2 AS WELL AS S WAVES IN LEADS I, V_4, V_5, AND V_6 ARE INDICATIVE OF RIGHT VENTRICULAR HYPERTROPHY; PROMINENT P WAVES IN LEADS II, III, aV_F, V_1, AND V_2 SUGGEST RIGHT ATRIAL ENLARGEMENT



Right heart failure







Left heart failure

- **Def:** inability of the heart to pump the blood into systemic circulation
- **Etio:** hypertension, valvular heart disease cause (e.g. aortic stenosis) or as a result (e.g. mitral regurgitation)
- **Ptg:** Failure of the left side of the heart causes blood to back up (be congested) into the lungs, causing respiratory symptoms as well as fatigue due to insufficient supply of oxygenated blood.
- **Sy:**
- increased rate of breathing ***(tachypnoea)*** and increased work of breathing ***dyspnea*** (shortness of breath) on exertion, exercise intolerance and in severe cases, dyspnea at rest. Increasing breathlessness on lying flat = ***orthopnea*** often measured in the number of pillows required to lie comfortably, the patient may resort to sleeping while sitting up
- paroxysmal nocturnal dyspnea: a sudden nighttime attack of severe breathlessness, usually several hours after going to sleep
- presence of pulmonary edema (fluid in the alveoli) → Rales or crackles, heard initially in the lung bases, and when severe, throughout the lung fields "Cardiac asthma" or wheezing may occur
- **Central cyanosis** - late sign of extremely severe pulmonary edema; laterally displaced apex beat (which occurs if the heart is enlarged)

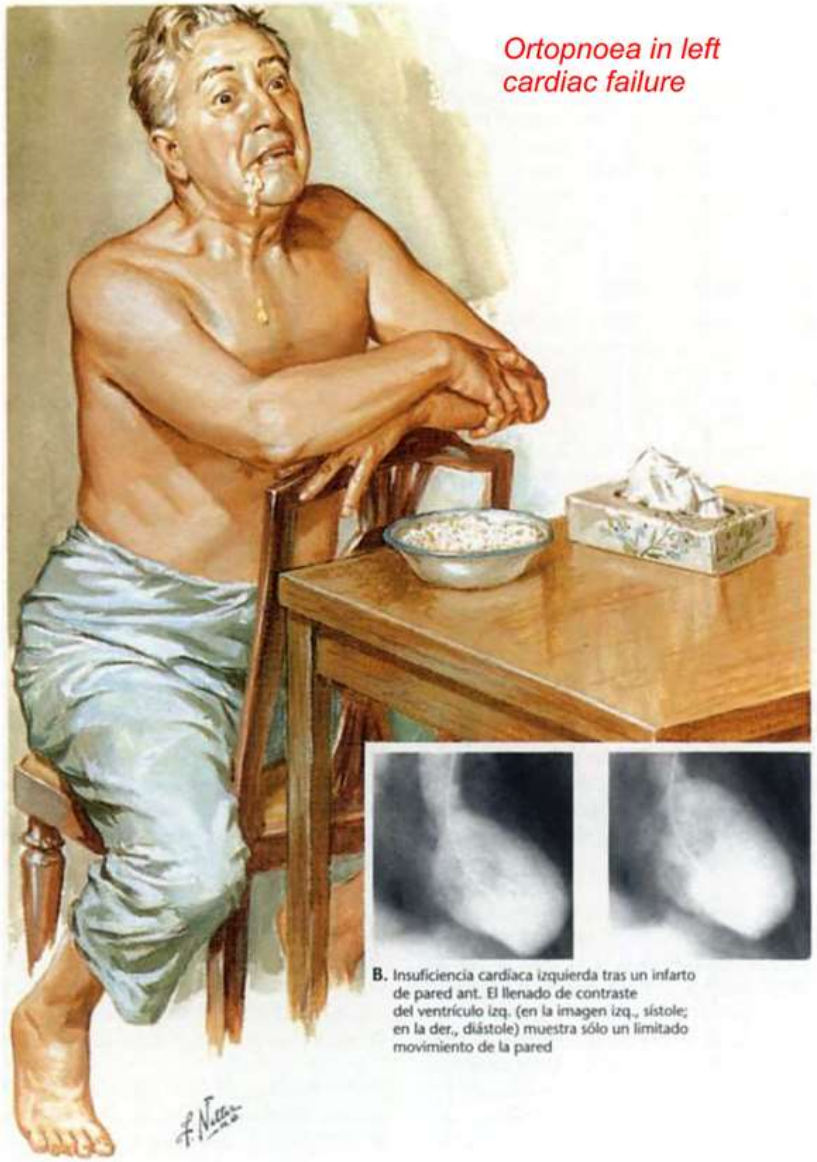
Left heart failure

- gallop rhythm (additional heart sounds) may be heard as a marker of increased blood flow, increased intra-cardiac pressure.
- Heart murmurs may indicate the presence of valvular heart disease, either as a cause (e.g. aortic stenosis) or as a result (e.g. mitral regurgitation) of the heart failure.
- Easy fatigability dizziness, confusion, cool extremities at rest = sy. of poor systemic circulation
- ***Backward failure can be subdivided***
  - failure of the left atrium,
  - the left ventricle
  - both within the left circuit. The patient will have

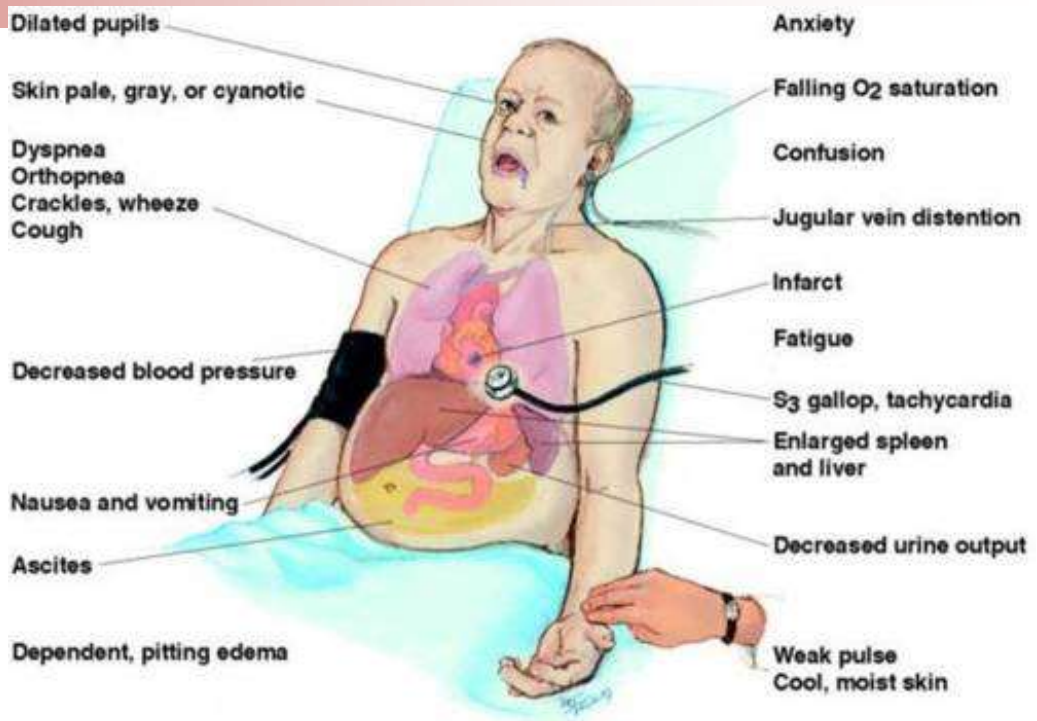
Biventricular failure

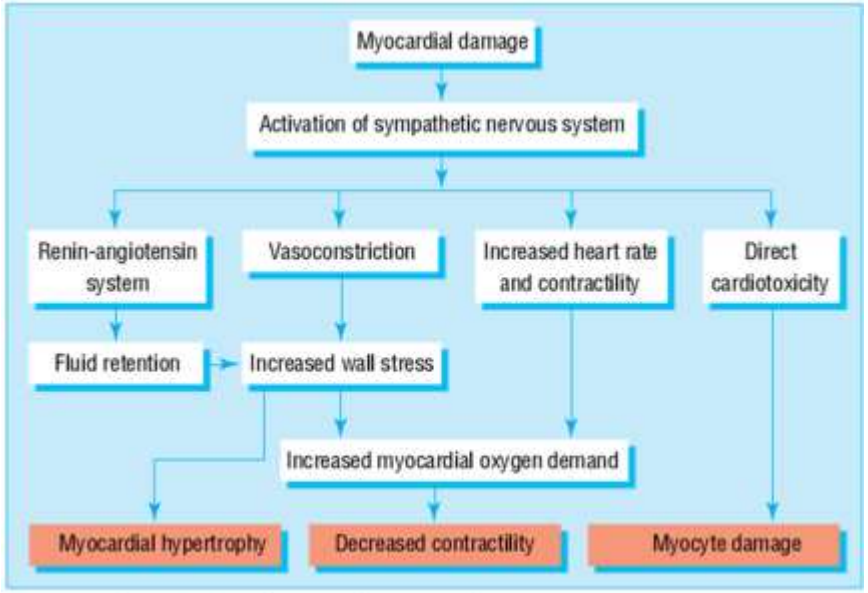
- failure of one ventricle after certain period tend to progress to failure of both ventricles (left ventricular failure → pulmonary edema and pulmonary hypertension → increase stress on the right ventricle.
- **Sy: pleural effusion** (fluid collection between the lung and the chest wall) → dullness of the lung fields to finger percussion and reduced breath sounds at the bases of the lung (common in biventricular failure) ← pleural veins drain into both the systemic and pulmonary venous systems.

Left heart failure



B. Insuficiencia cardíaca izquierda tras un infarto de pared ant. El llenado de contraste del ventrículo izq. (en la imagen izq., sístole; en la der., diástole) muestra sólo un limitado movimiento de la pared





Sympathetic activation in chronic heart failure

High-output heart failure

- **Def:** heart fails to supply system needs although cardiac output is higher than normal.
- **Etio**: situations with an **increased blood volume**
  - water and salt (kidney pathology, excess of fluid , treatment with retaining water steroids),
  - chronic and severe anemia, large arteriovenous fistula or multiple small arteriovenous shunts as in HHT or Paget's disease of bone,
  - severe liver or kidney disorders, hyperthyroidism, and wet beriberi.
  - acutely in high fever, septic shock (especially due to Gram-neg bacteria)
- **Ptg:** normal systolic function but symptoms are those of heart failure; circulatory overload may leac to pulmonary edema secondary to an elevated diastolic pressure in the left ventricle.. With time, this overload causes systolic failure. Ultimately cardiac output can be reduced to very low levels

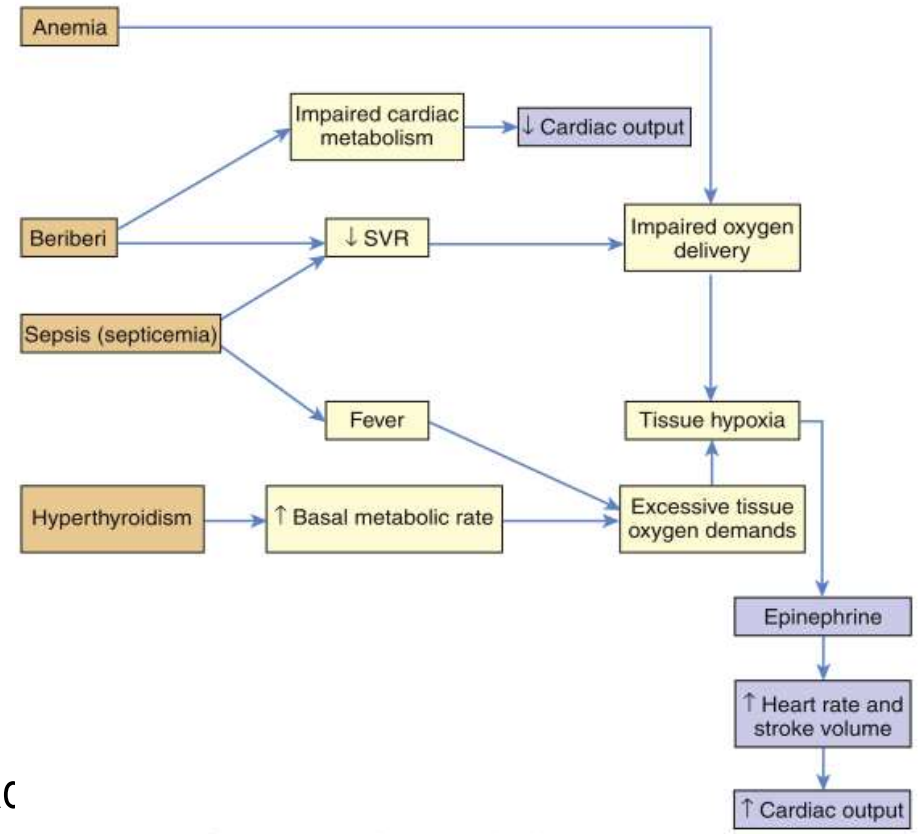
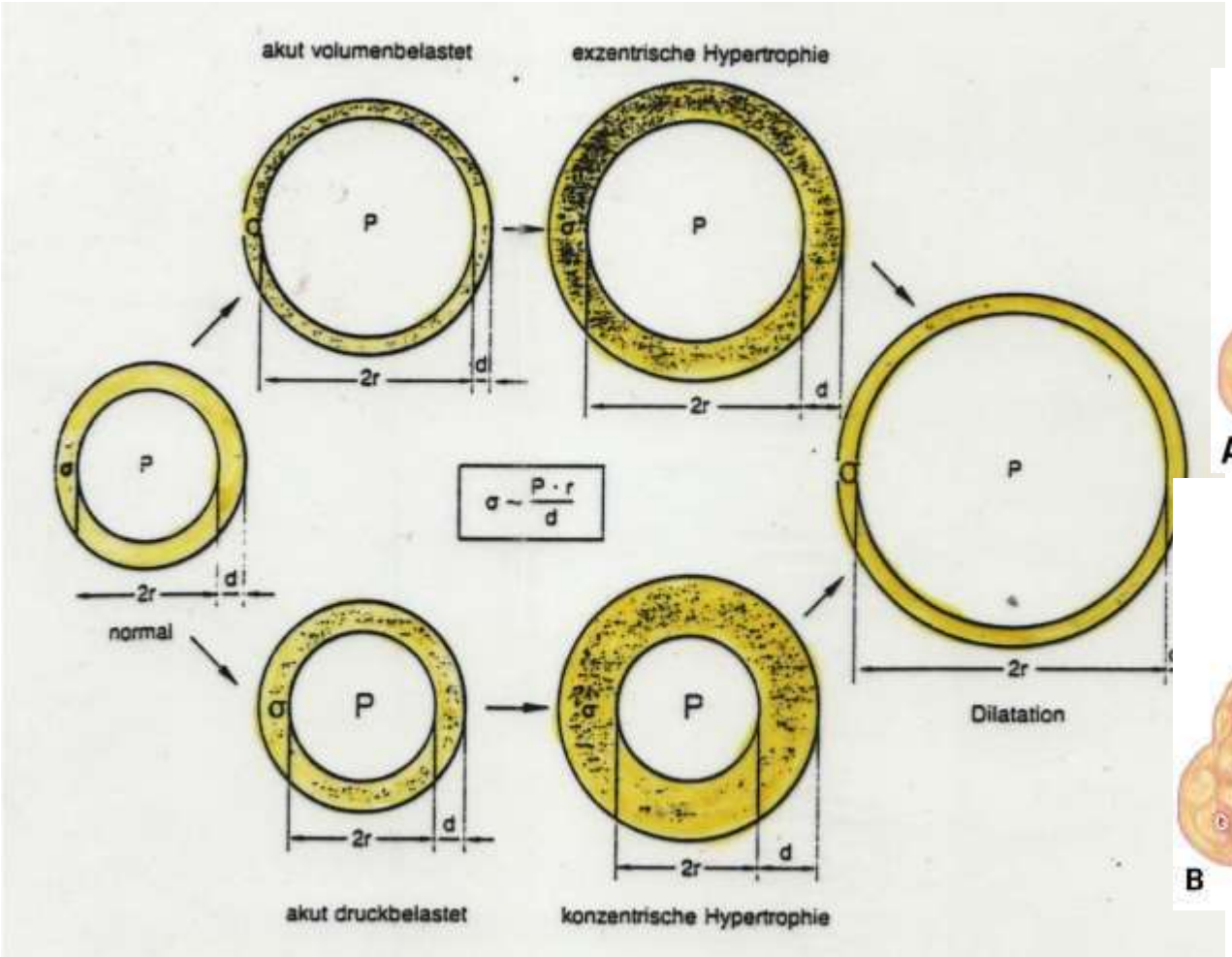


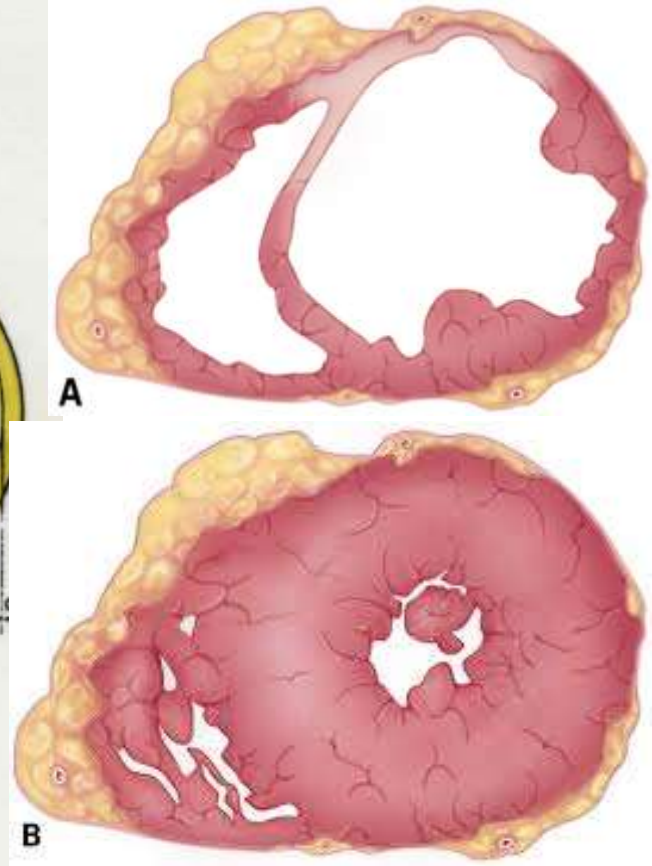
FIGURE 32-43 High-Output Failure. *SVR*, Systemic vascular resistance.

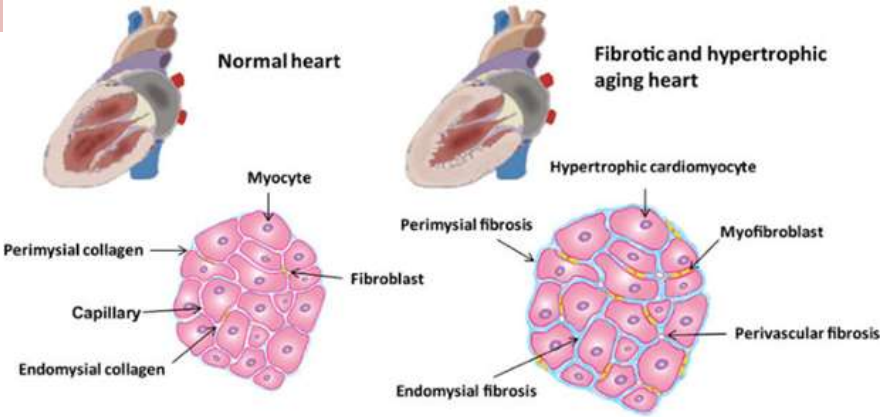
Remodelling

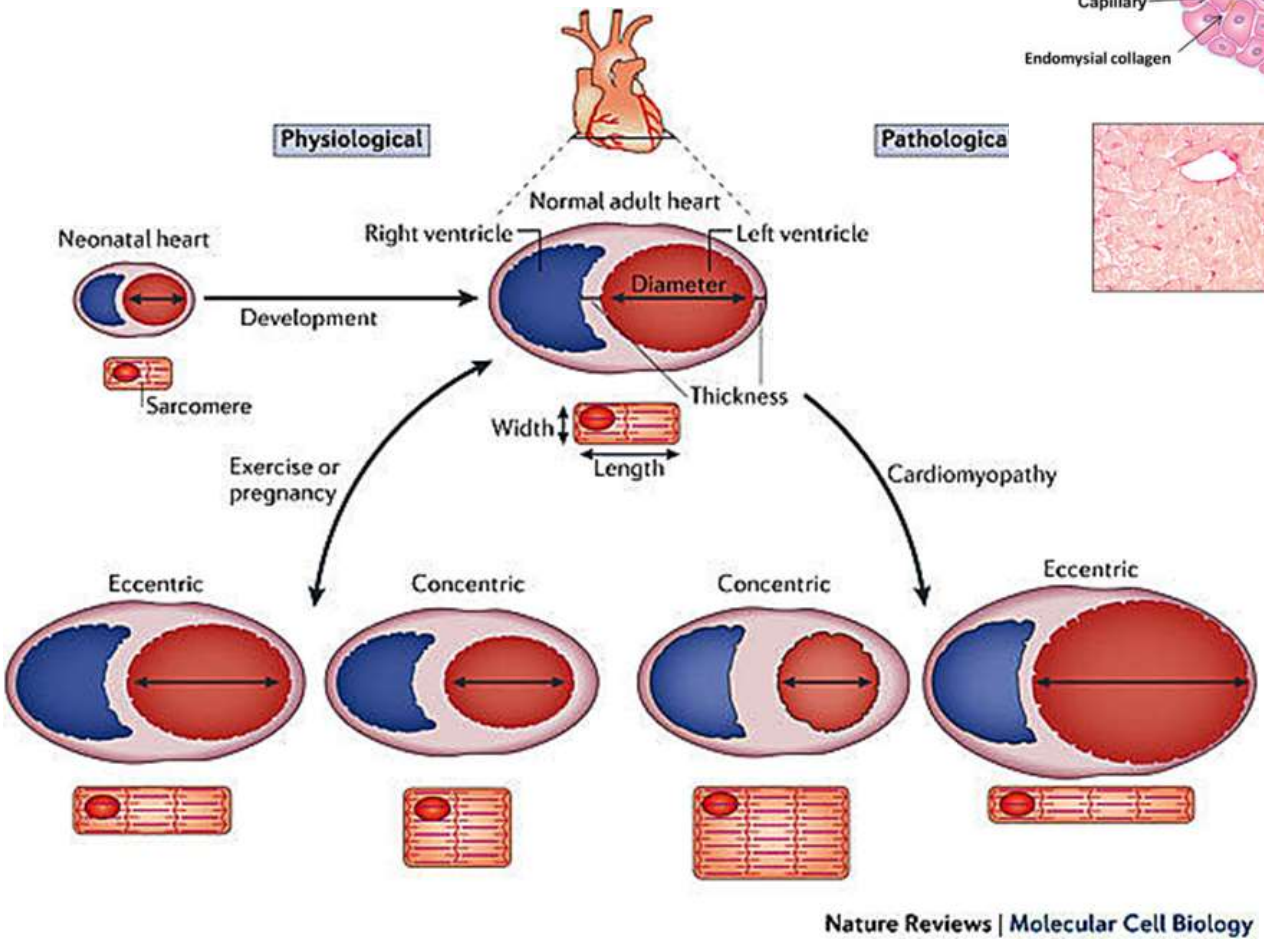
- Physiological or pathological hypertrophy. decreases ventricular wall stress by increasing the thickness of this wall.
- **Laplace's law = wall stress (or tension) is an inverse function of wall thickness (tension = (pressure × radius)/(2 × wall thickness))**. s =
- Cardiac hypertrophy can be classed based on the geometries of the heart and individual cardiomyocytes = **eccentric or concentric** growth,
- **Non-pathological eccentric hypertrophy** = increase in ventricular volume with a coordinated growth in wall and septal thicknesses, where individual cardiomyocytes grow in both length and width
- **Pathological eccentric hypertrophy** = under pathological conditions (myocardial infarction or dilated cardiomyopathy) can lead to wall dilation with preferential lengthening of cardiomyocytes.
- **Physiological hypertrophy =** less pronounced form of eccentric hypertrophy in pregnancy, endurance training
- **Concentric hypertrophy** = reduction in ventricular diameter with increase in free wall and septal thicknesses; individual ***cardiomyocytes increase in thickness more than in length*** (this results in a decreased length/width ratio)

Pathological concentric hypertrophy = chronic systemic (left heart) or pulmonary (right heart) hypertension or aortal valve stenosis; may be less reversible, produces heart failure .
Physiological concentric hypertrophy = can return to normal; isometric exercise training, wrestling or weight-lifting






Normal heart
Fibrotic and hypertrophic aging heart
Myocyte
Perimysial collagen
Fibroblast
Capillary
Endomysial collagen
Hypertrophic cardiomyocyte
Perimysial fibrosis
Myofibroblast
Perivascular fibrosis
Endomysial fibrosis


Physiological
Pathologica
Normal adult heart
Neonatal heart
Right ventricle
Left ventricle
Diameter
Development
Sarcomere
Thickness
Width
Length
Exercise or pregnancy
Cardiomyopathy
Eccentric
Concentric
Concentric
Eccentric
Nature Reviews | Molecular Cell Biology

NYHA classification of heart failure

Class I:asymptomatic

- No limitation in physical activity despite presence of heart disease.
- This can be suspected only if there is a history of heart disease which
- —for example,echocardiography is confirmed by investigations

Class II:mild

- Slight limitation in physical activity.
- More strenuous activity causes.e.g. walking on steep inclines and shortness of breath several flights of steps.
- Patients in this group can continue to have an almost normal lifestyle and employment

Class III:moderate

- More marked limitation of activity which interferes with work.
- Walkingon the flat produces symptoms

Class IV:severe

- Unable to carry out any physical activity without symptoms.Patients
- are breathless at rest and mostly housebound