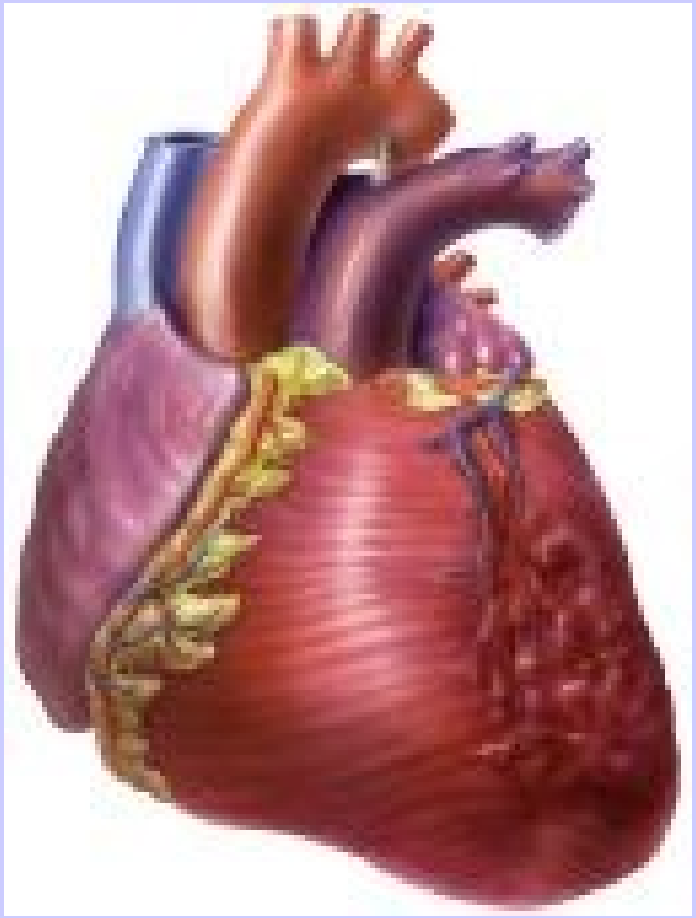

Institute of Pathological Physiology

Martin Vokurka
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HEART FAILURE

Case report A

68 year old patient, 10 years of hypertension history, low adherence to the treatment, 5 years ago had acute myocardial infarction

During the last month he complains of growing dyspnea, first exertional but later event at rest and even nocturnal. At acute deterioration he suffered from severe dyspnea, expectoration of watery and foamy fluid.

Case report B

73 year old patient with chronic obstructive pulmonary disease (COPD), heavy smoking from the youth.

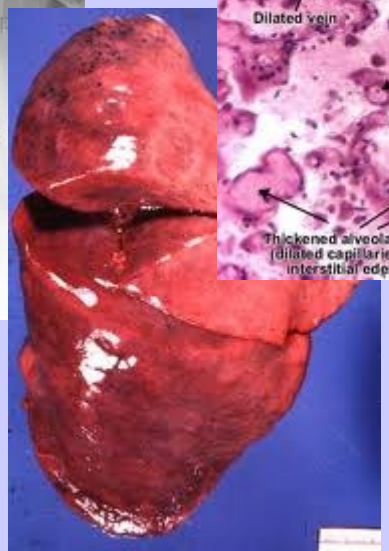
In several last weeks he observes intensive lower limb edemas, worsening during the day, improving at night. Mild pain in the right hypochondrium.

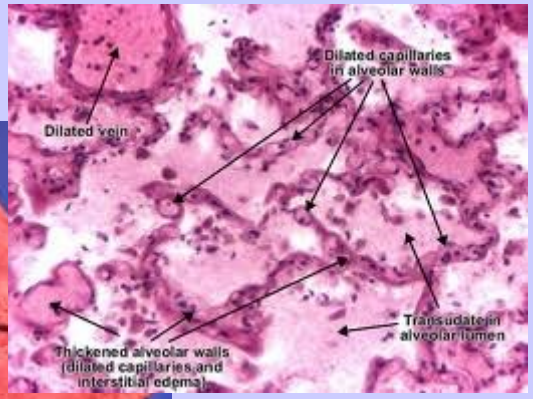
Case report A and B

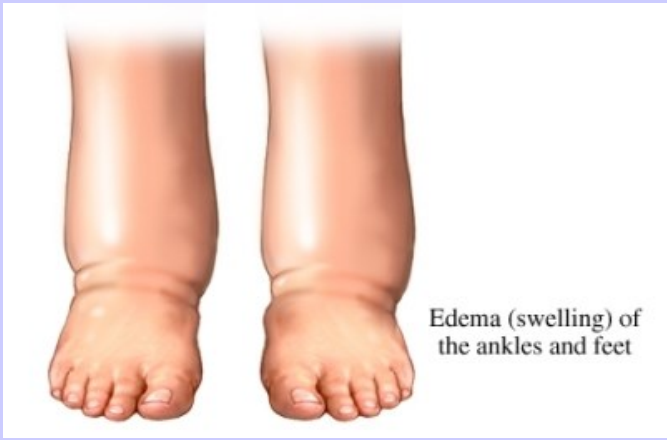
Both patients have edema (fluid and blood congestion).

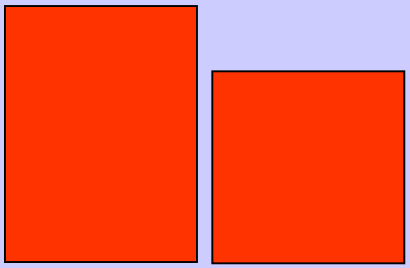
A – in the lungs

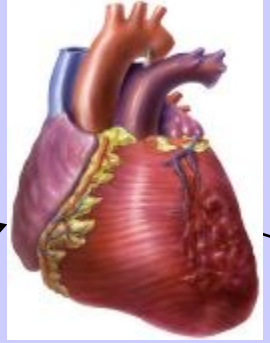
B – at the lower limbs, in the liver…

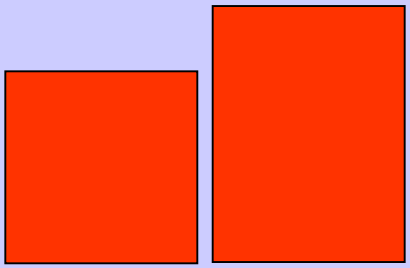




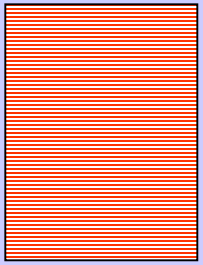








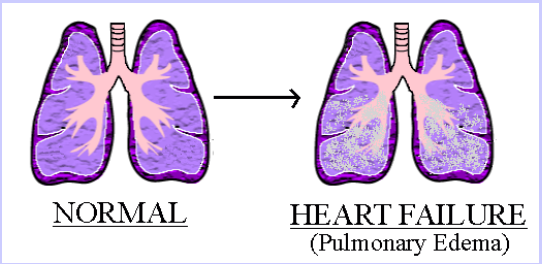
normal situation

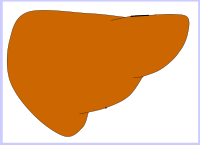


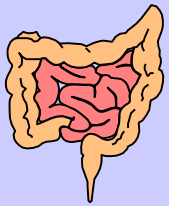
heart failure

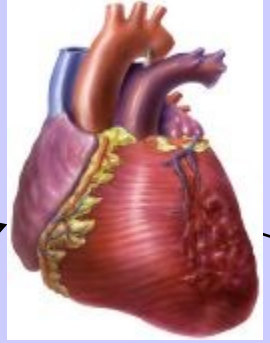
congestion

backward









normal situation

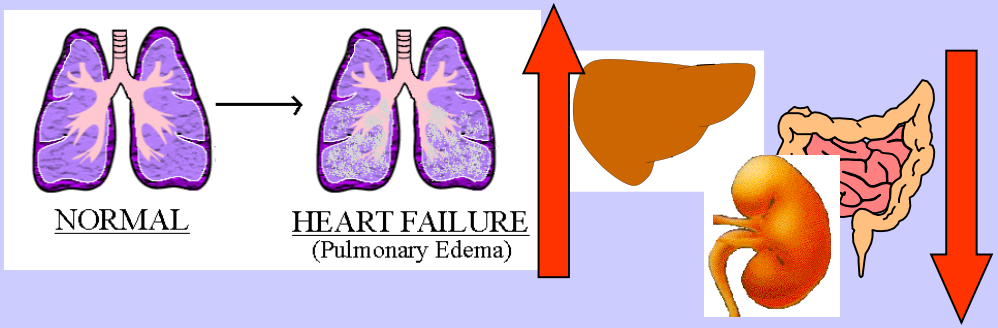
heart failure

congestion

backward

decreased cardiac output

forward



Insufficient organ perfusion – muscles, kidneys, skin, GIT…

- **Heart (ventricle) is not capable to pump the blood from one circulation to the other – basic hemodynamics**
- **The organs suffer from shortage of perfusion**

HEMODYNAMIC CONCEPT

- **Various compensatory mechanisms are activated**
- **The blood is not only redistributed but the fluid retention follows with edema development**
- **Changes in other organs and the whole organism**

SYSTEMIC CONCEPT

Case report A and B

The symptoms of BACKWARD failure with the congestion prior to the failing ventricle have been described

A – left ventricle
B – right ventricle

MAIN SYMPTOMES

1. *CONGESTION*

- left-sided - DYSPNEA, LUNG EDEMA

- right-sided - LOWER EXTREMITY EDEMAS, HEPATOMEGALY…

2. *DECREASED CARDIAC OUTPUT*

WEAKNESS, FATIGUE,
DECREASED ORGAN PERFUSION

Low CO consequences

- Decrease of peripheral perfusion
- Tiredness, weakness, paleness
- Decreased kidney perfusion
- In severe cases severe ischemisation, tissue hypoxia and ***microcirculation failure*** – SHOCK

Causes of heart failure

Myocardial failure

defect in myocardial contraction

Myocardial infarction myokardu (necrosis, scars)

ischemia (ischemic, coronary heart disease)

cardiomyopathy,

myocarditis

Causes of heart failure

Excessive, long-term hemodynamic burden

- **increased pressure burden**
  - hypertension systemic (LV)
  - hypertension pulmonary (RV)
  - valvular stenosis : Ao or P

- **increased volume burden**
  - valvular regurgitation
  - general volume overload

- **hyperkinetic cirkulation** (increased CO at rest)

In developed countries the most common cause in adults or seniors is a combination of

ischemic disease + arterial hypertension

Valvular diseases

(degerative origin)

CMP

Newborns and babies

myocarditis
arrhytmias
some inborn heart defects
CMP …

Children and adolescents

myocarditis incl. poststreptococcal
with valve damage
CMP
arrhytmias
systemic (juvenile) hypertension

Case report C

13 year old patient, so far healthy, following mild respirátory infect played football, the day after subfebrile, tired... X-ray suspicious pneumonia, enlarged heart shade, general worsening, heart sonography (ECHO) with importantly decreased myocardial contractility of both ventricles, mitral regurgitation.

Case report A

68 year old patient, 10 years of hypertension history, low adherence to the treatment, 5 years ago had acute myocardial infarction

During the last month he complains of growing dyspnea, first exertional but later event at rest and even nocturnal. At acute deterioration he suffered from severe dyspnea, expectoration of watery and foamy fluid.

Case report B

73 year old patient with chronic obstructive pulmonary disease (COPD), heavy smoking from the youth.

In several last weeks he observes intensive lower limb edemas, worsening during the day, improving at night. Mild pain in the right hypochondrium.

The most frequent causes of RV is ***pulmonary hypertension***

E.gl due to severe **pulmonary** disease (COPD, fibrosis) or due to the failure of **left ventricle**

Right sided heart failure in pediatrics

secondary pulmoary hypertension
acute pulmonary embolism

Case report D

Newborn in term, shortly after the birth circulatory and ventilátory failure, pulmonary hypertension, not well responding to the therapy, enlargement of right atrium and ventricle on ECHO, right-to-left shunt at atria, při dg. total anomaly in pulmonary veins

Case reports A and B

A – left-sided failure: hypertension (pressure damage to LV), myocardial infarction (ischemic damage of the myocardium, loss of the contractility)

B – right ventricle (pulmonary hypertension due to the lung disease)

Frequency of heart failure

In the Czech Rep. the prevalence is about 1-2 %
(i.e. 100 000 of patients)

The number of patients is increasing –
among others due to successful treatment of other heart diseases

Compensation of heart failure

- The effort to keep (i.e. again increase) cardiac output (CO) to maintain sufficient organ perfusion
- Physiological processes or the heart ana circulation regulation
- Long-term changes in the heart, its remodelation
- Involvement of other organs
- COMPENSATION IS NOT RECOVERY!

Cardiac output

- **volume of the blood pumped by the heart in 1 minute**

Cardiac output (CO) =

heart rate (HR) × stroke volume (SV)

70 /min **70 ml**

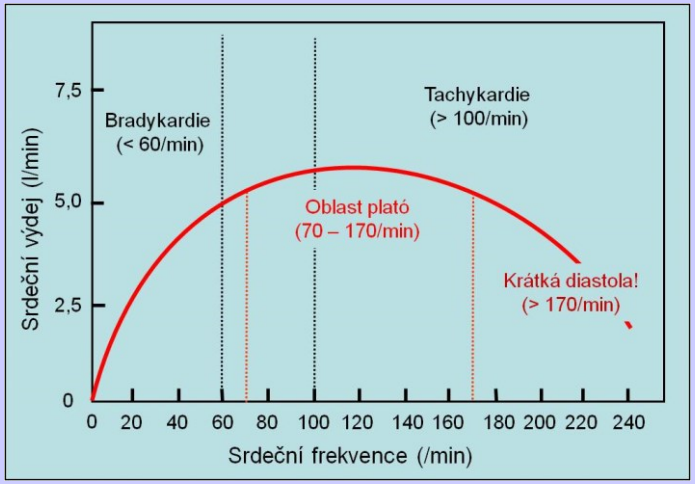
4 900 ml/min

Heart rate

- vegetative nerves
- (disturbances in) heart rhythm

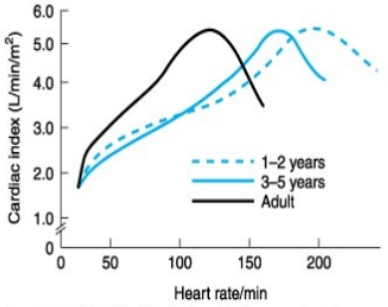
- has impact of heart cycle duration, mainly shortens diastole – when the heart is filling with blood

Increases CO but high rates decrease the ventricle filling and heart is easier exhausted



(1)HEART RATE :

- Cardiac output is generally directly proportional to heart rate.



http://pfyziollfup.upol.cz/castwiki2/?p=2293

http://www.slideshare.net/DRSHADABKAMAL/determinants-of-ventricular-performance

Cardiac output (CO) =

heart rate (HR) × stroke volume (SV)

70 /min **70 ml**

4 900 ml/min

Stroke volume

- preload
- contractility
- afterload

* How is the heart filled before the systole
* What is its „force“ of contraction
* What is resistance against the pumping

Contractility

- **„strenth“ of the contraction in <u>constant filling</u> (preload, i.e. independent of preload)**

- ***Increased*** (positive inotropy): sympathetic nerves, catecholamines (calcium)

Healthy heart
uses increased contractility
to increase SV and CO

The decrease of contractility
is a frequent cause
of heart failure

Causes of decreased contractility

- ischemia
- hypoxia
- acidosis
- inflammation, proinflammatory cytokines
- some drugs

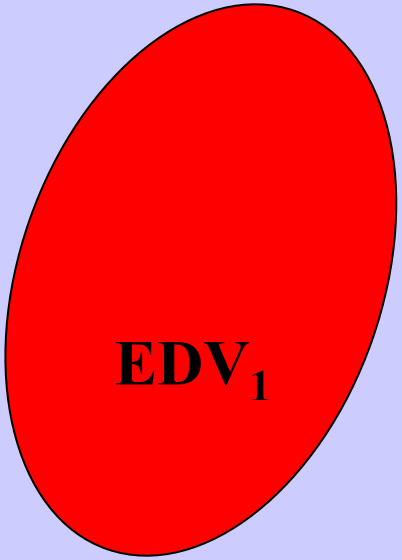
Ejection fraction

$EF = SV / EDV$

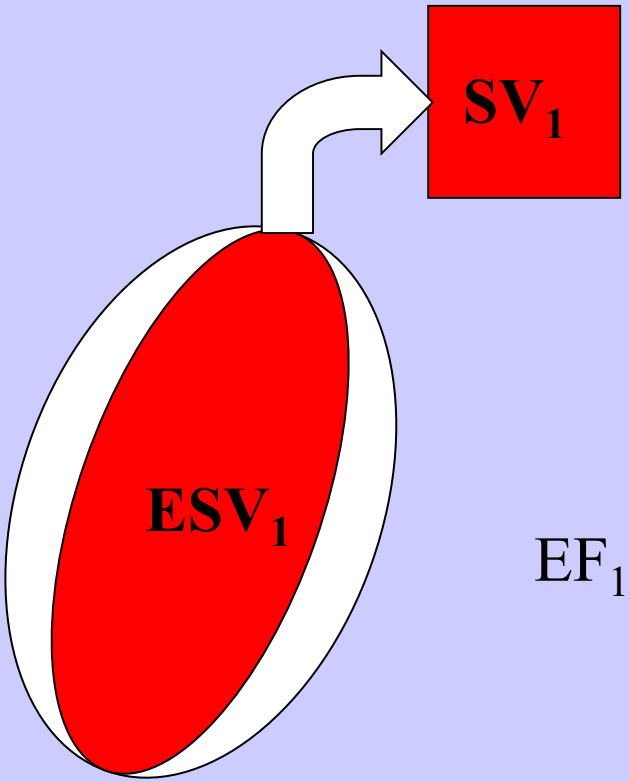
the ratio of stroke volume to end-diastolic volume
normal value = 67 ± 8 percent

$SV = 70\ ml,\ EDV = 120\ ml$

$EF = 70 / 120 = 58\ \%$



End of diastole 1



$EF_1 = SV_1/EDV_1$

End of systole 1

Stroke volume

- preload
- contractility
- afterload

* How is the heart filled before the systole
* What is its „force" of contraction
* What is resistance against the pumping

Preload

is the basic mechanism of the regulation of CO

Preload

Filling of the ventricle at the end of the diastoel

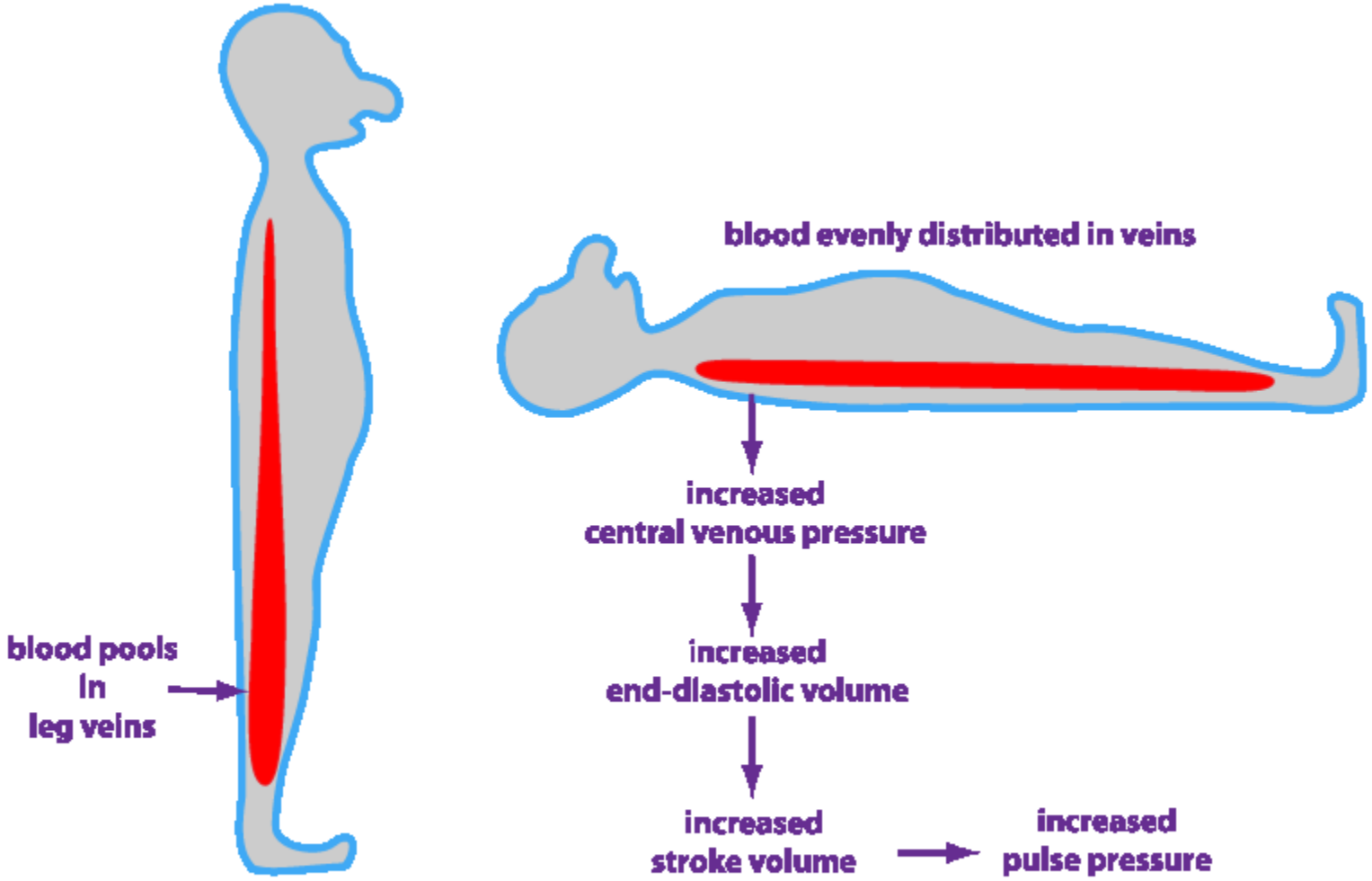
enddiastolic volume = EDV

Frank-Starling mechanism

Factors influencing preload

- ***Venous return***
total blood volume
blood distribution (position of the body, intrathoracic pressure, venous tonus…)
- ***atrial systole***
- ***size of ventricle cavity***
- ***intrapericardial pressure***

Low preload is the cause of the decreased CO in case of syncope and shock
In heart failure the preload is not decreased but it is ***increased*** as one of the the compensatory mechanisms



https://courses.washington.edu/conj/heart/cardiacoutput.htm

Low preload

- bleeding, strong vasodilation etc.
- shock, synkope
- THIS IS NOT HEART FAILURE

Failing heart
uses the increase of preload
to improve SV and CO

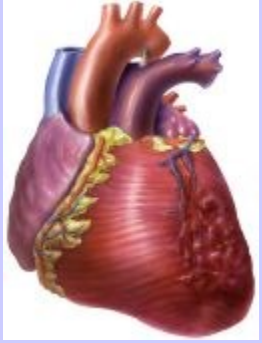
Healthy heart
uses increased contractility
to increase of SV and CO

Other causes of low CO

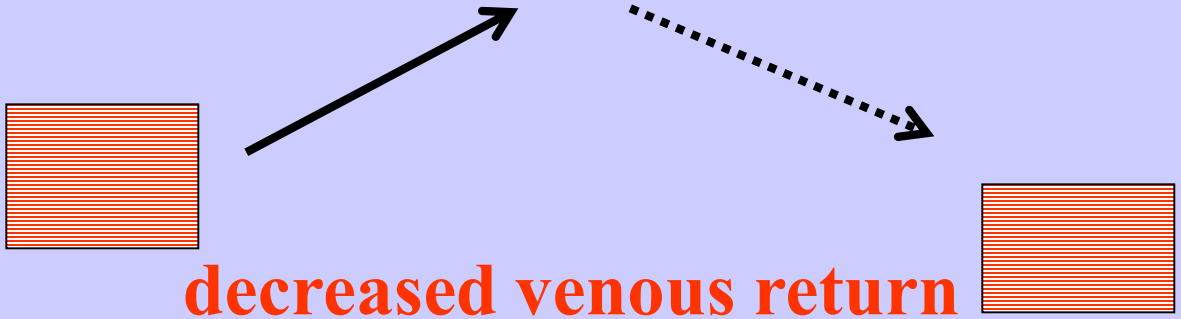
- Not caused directly by heart disturbances but by other parameters of the circulation

Situations with low CO

- Heart failure – high preload
- Impaired/limited filling of the ventricles (e.g. constrictive pericarditis) – high preload
- Blood loss, dehydratation – low preload



heart insufficiently filled



decreased venous return

e.g. shock

decreased cardiac output

bad filling of the ventricles
(e.g. constrictive pericarditis)

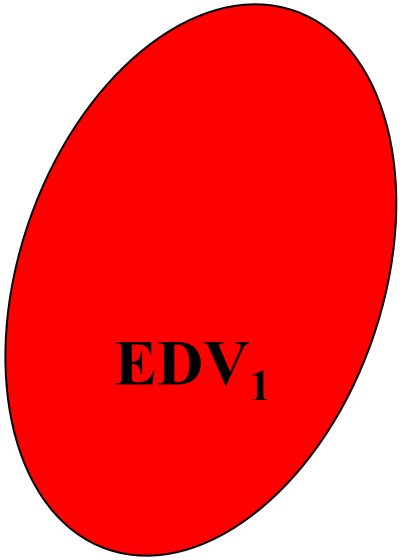
Failing heart:
uses increased preload
to improve SV and CO

This increase is efficient only partially

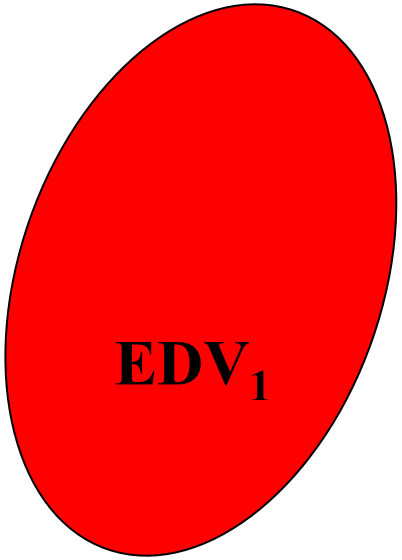
Non failing heart:
low CO is often the consequence of low preload

Preload and heart failure compensation

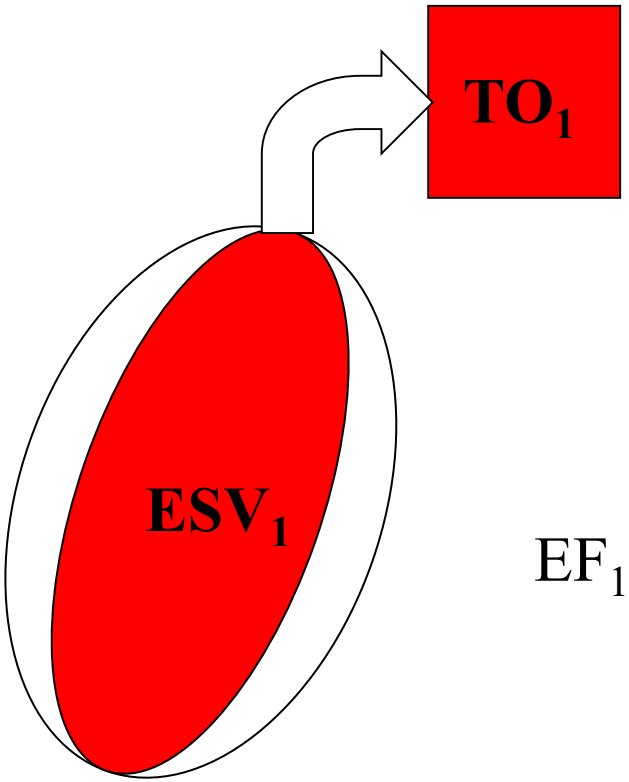
- If contractility decreases (EF decrease),
- the heart will start to use increased filling of the ventrikle to maintain SV and consequently CO



Konec diastoly 1

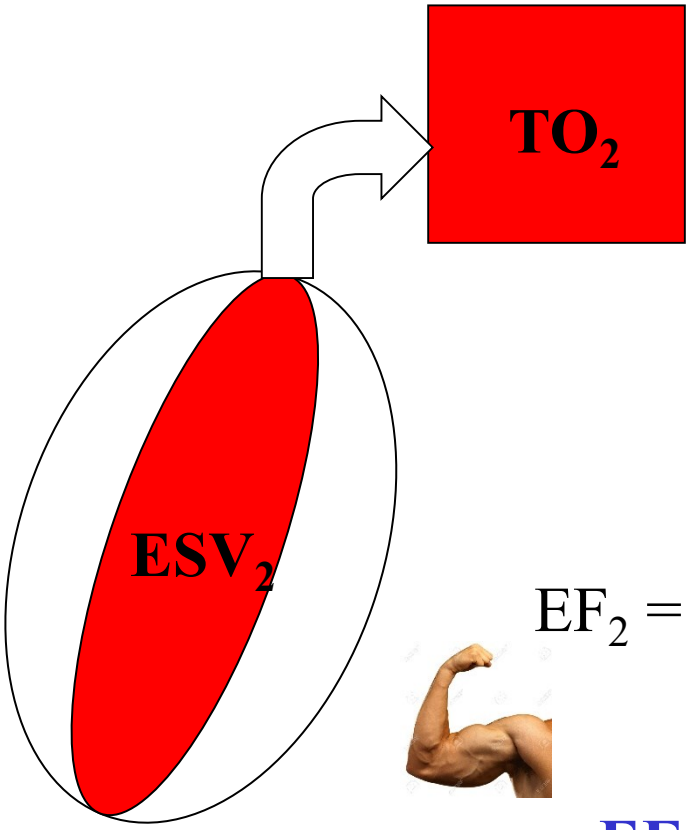


Konec diastoly 1



$$EF_1 = TO_1/EDV_1$$

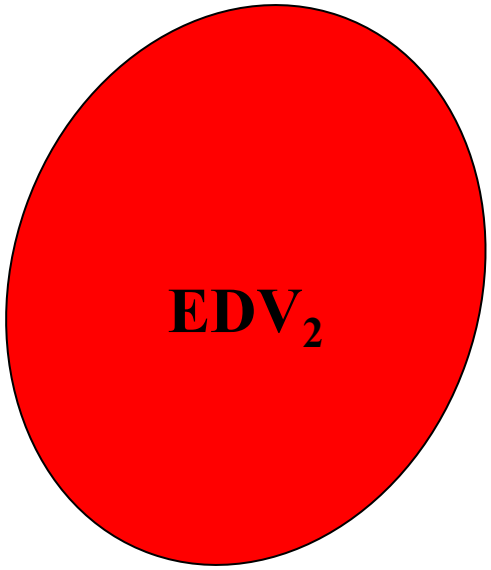
Konec systoly 1



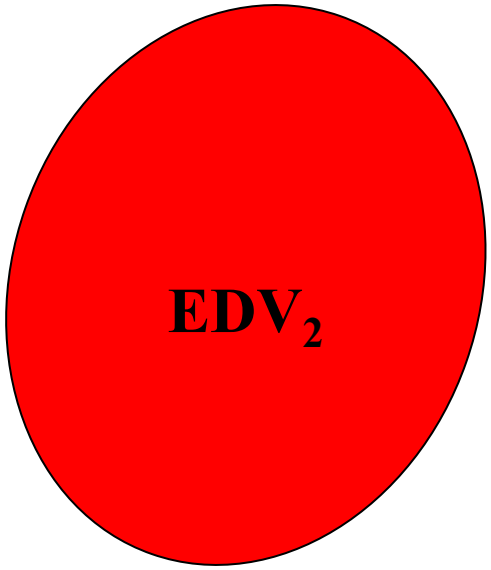
$EF_2 = TO_2/EDV_2$

$EF_2 > EF_1$

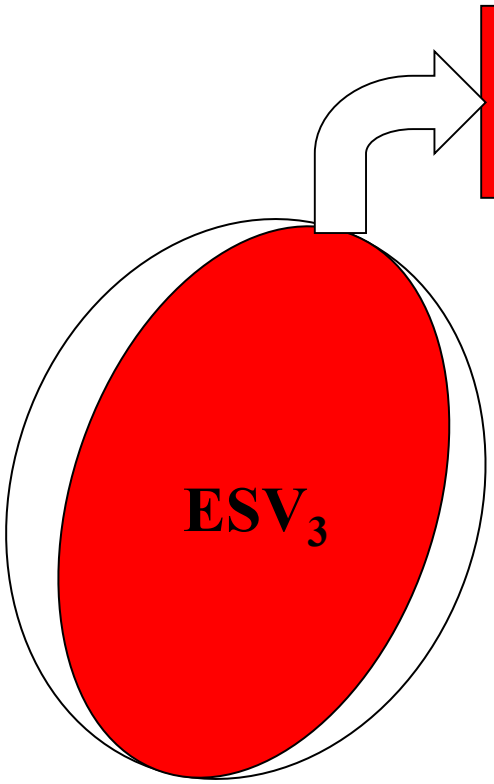
Konec systoly 2



Konec diastoly 2

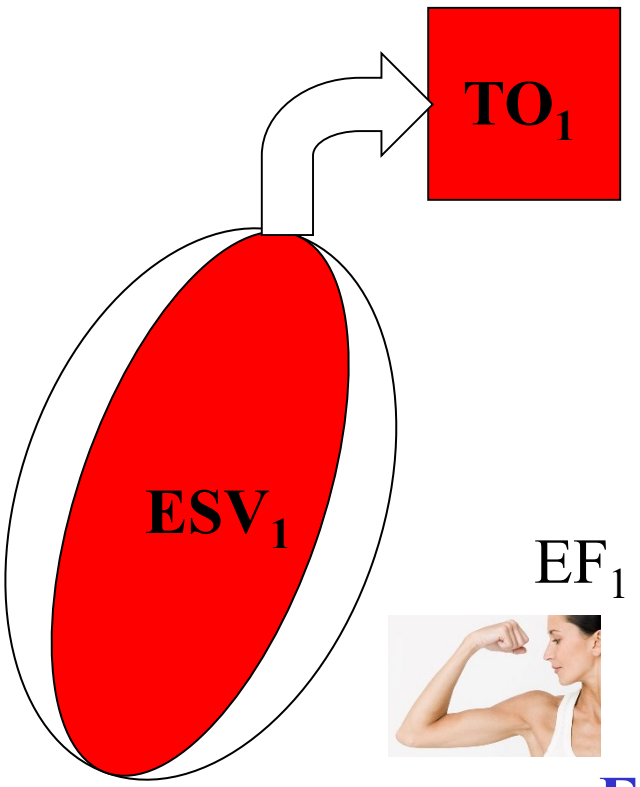


Konec diastoly 2



$EF_3 = TO_3/EDV_3$

Konec systoly 3



$EF_1 = TO_1/EDV_1$

$EF_1 > EF_3$

$TO_1 = TO_3$

Konec systoly 1

Consequences of increased preload

- Heart dilatation – RTG, ECHO
- Increased ventricular pressure – enddiastolic pressure (EDP)

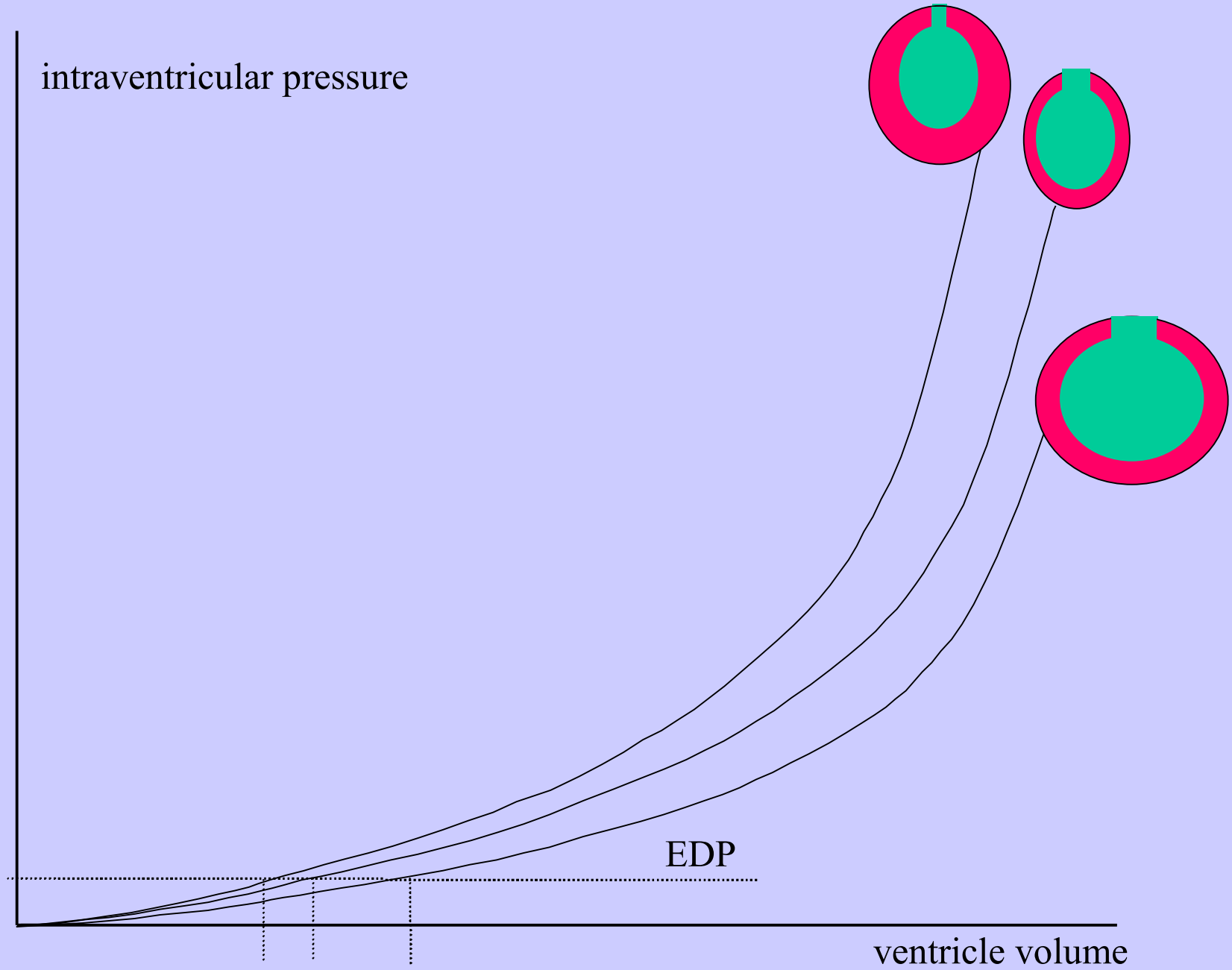
The relation between the filling of the ventricle and the intraventricular pressure

diastolic filling curve

volume: EDV - enddiastolic volume
pressure: EDP - enddiastolic pressure, filling pressure

- amount of the blood in the ventricle
- properties of the ventricle wall

J.Kofránek



preload → enddiastolic volume (EDV) → enddiastolic pressure (EDP)

enddiastolic volume (EDV) → changes in the ventricle geometry

changes in the ventricle geometry →

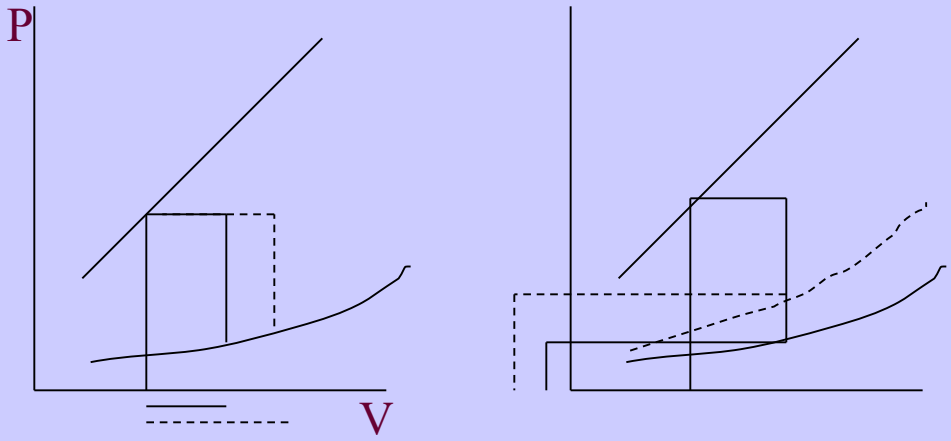
dilatation
increased wall tension
increased oxygen consumption
failure of Frank-Starling mech.

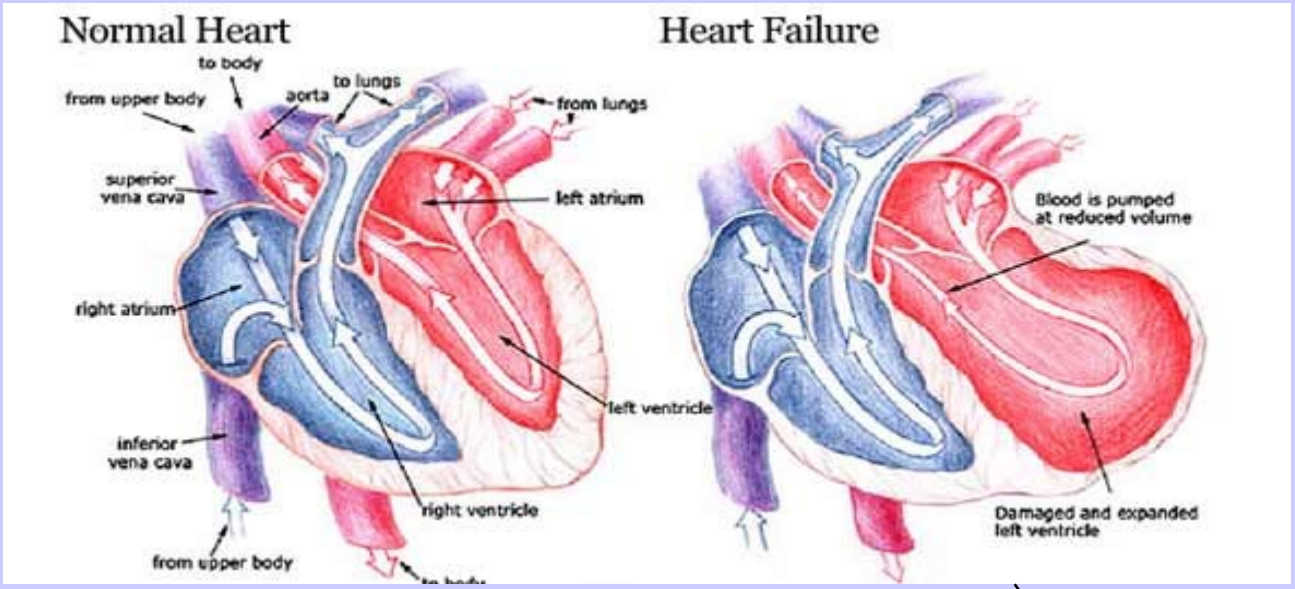
enddiastolic pressure (EDP) → pressure "transfer" to the regions „precceding the heart"

enddiastolic pressure (EDP) → **ventricle wall properties**
(compliance)
ischemia - impaired relaxation
fibrosis
hypertrophy/dilatation

pressure "transfer" to the regions „precceding the heart" →

L - lung edema
P - e.g. hepatomegaly

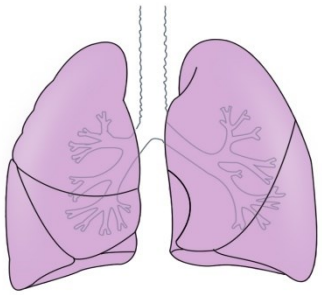


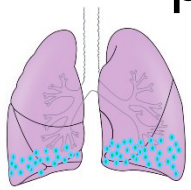


Normální EDV/EDP

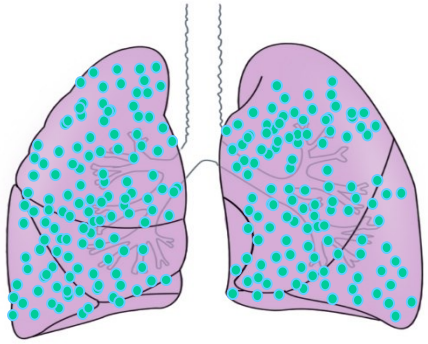
Vysoký EDV/EDP

Městnání na plicních bazích

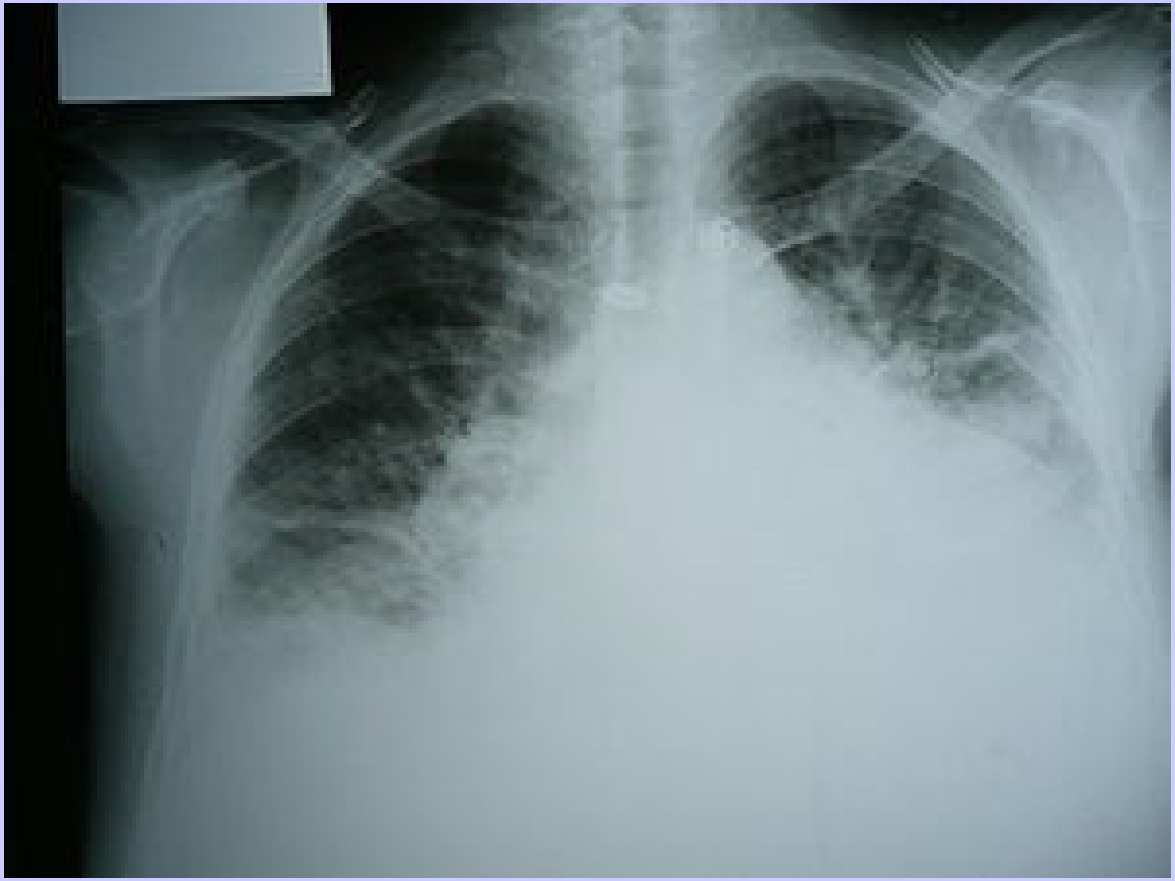




Otok plic



Městnání na plicích

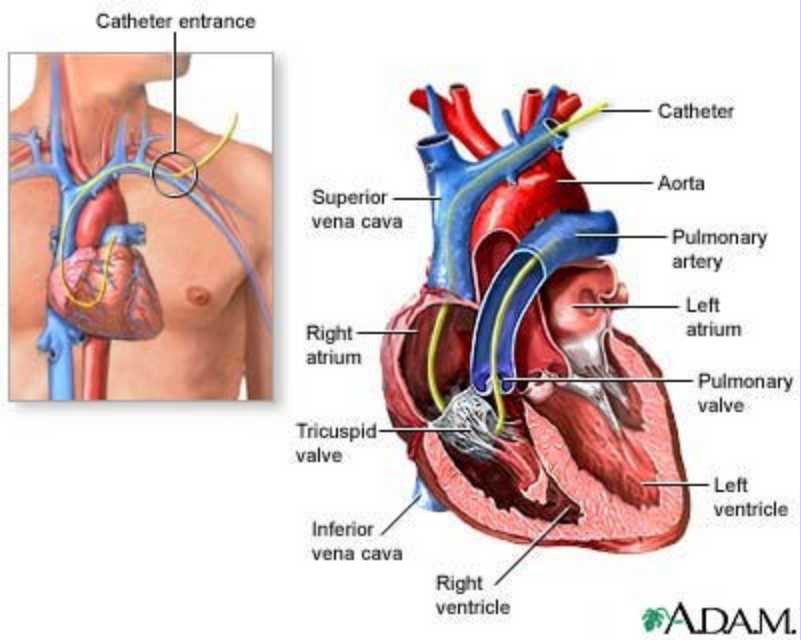


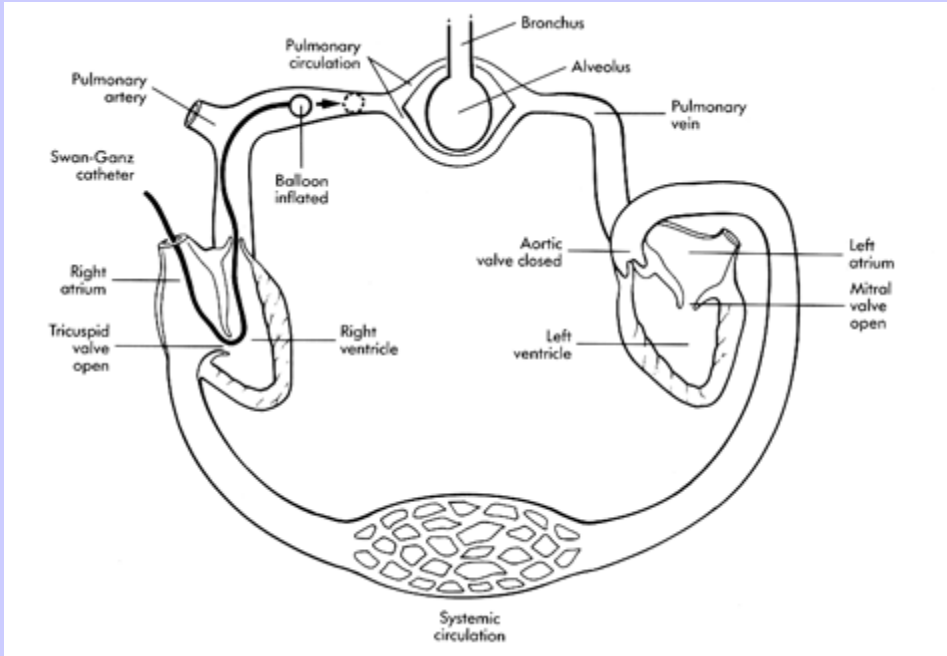
Zvětšení srdce (LK)

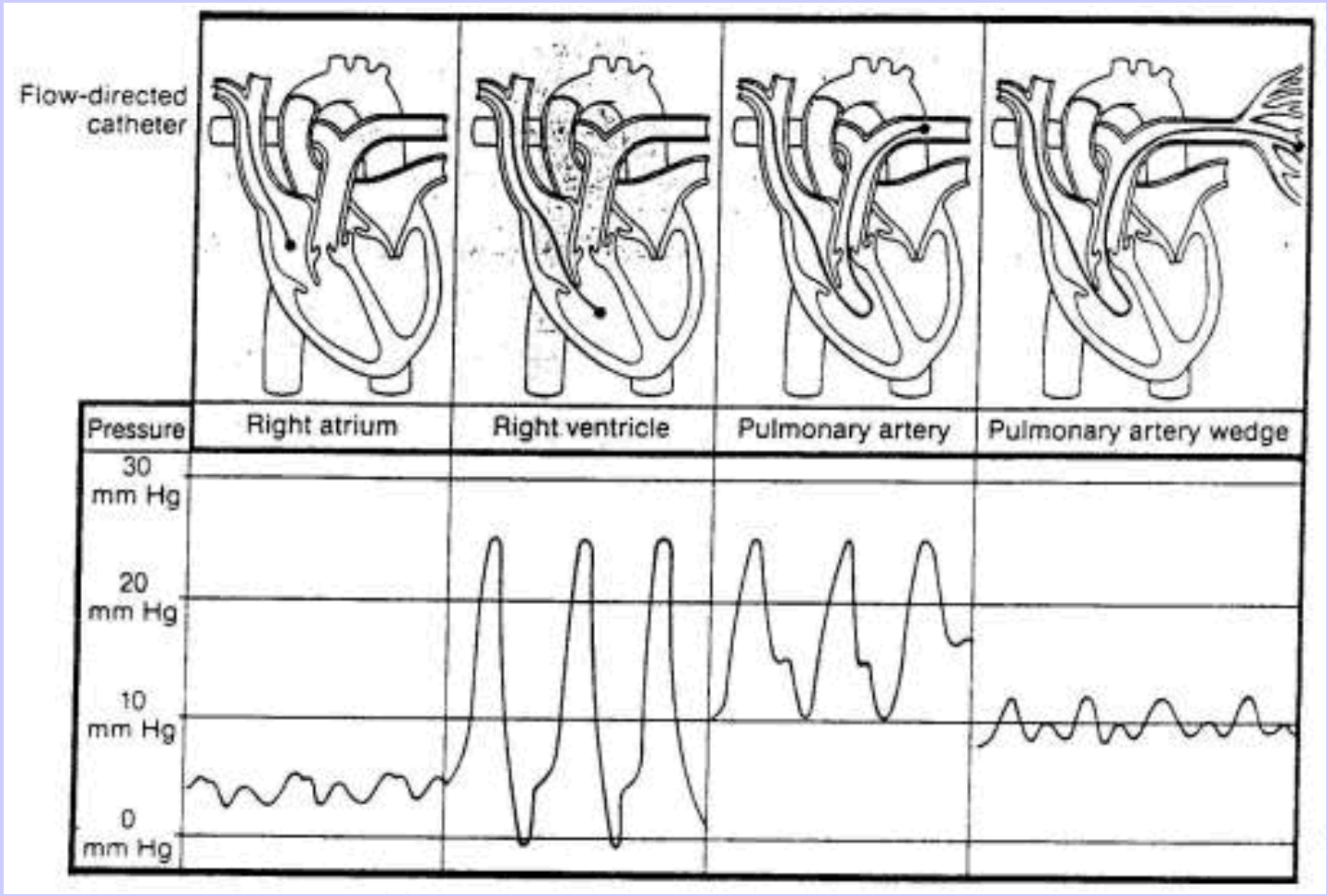
wikiskripta

EDP measurement

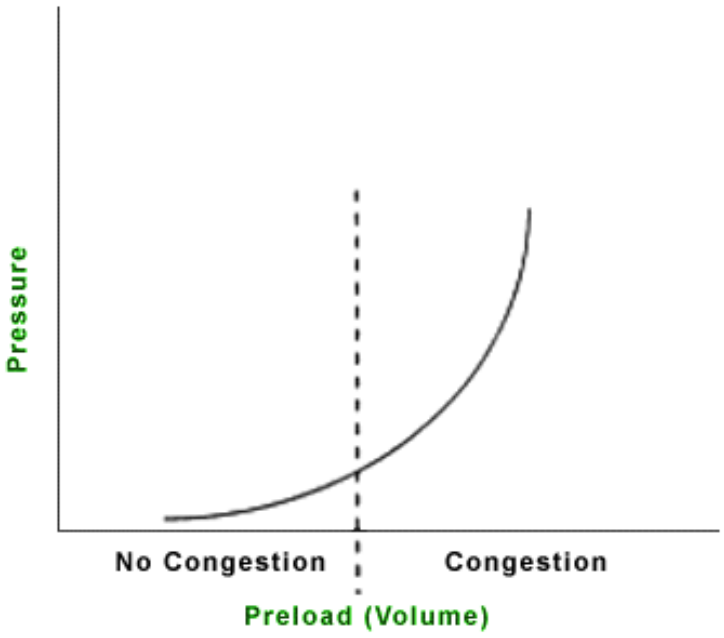
heart catheterization as a pulmonary wedge pressure

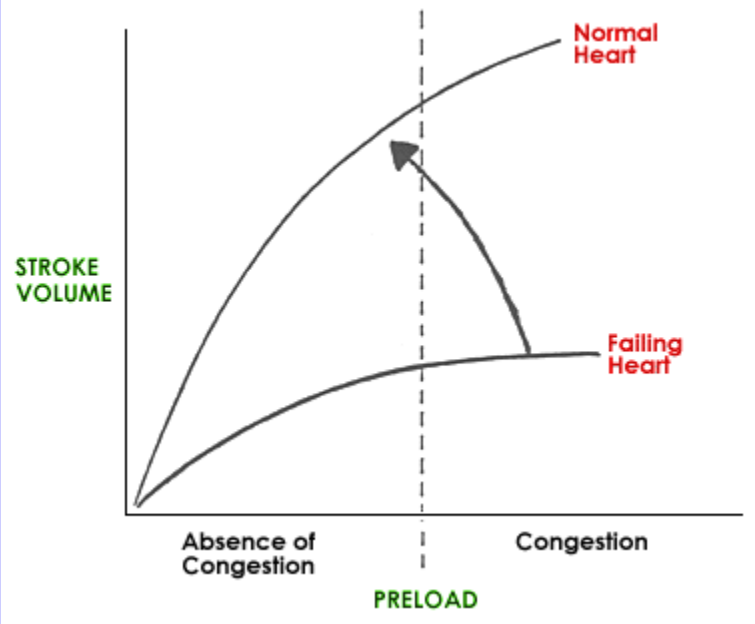





Flow-directed catheter
Pressure
Right atrium
Right ventricle
Pulmonary artery
Pulmonary artery wedge
30 mm Hg
20 mm Hg
10 mm Hg
0 mm Hg

The relation of EDP and congestion

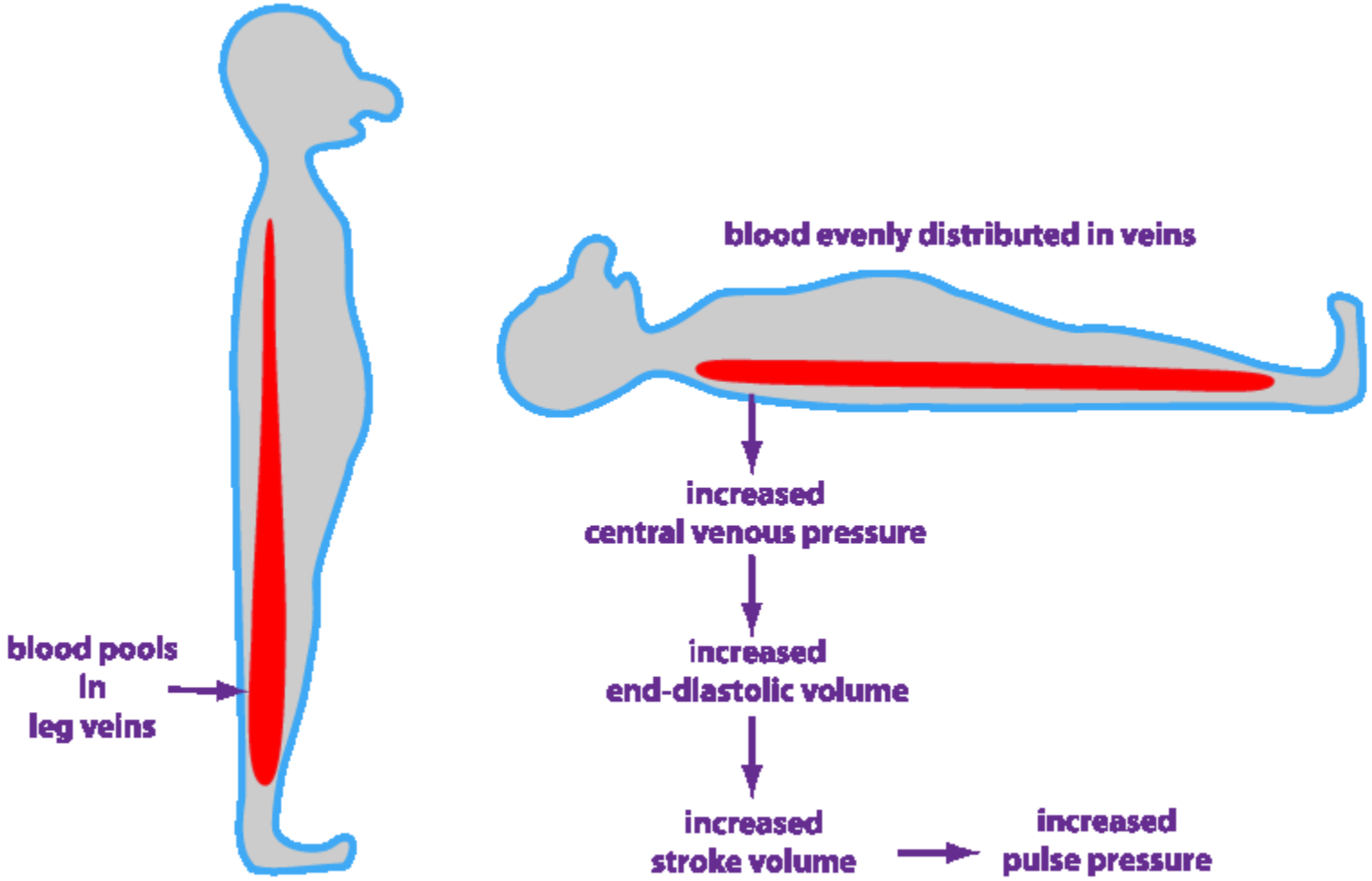




Case report A

Why is dyspnea present at night ??

In the supine position the venous return the failing heart increases and thus it accumulates in the lungs.



https://courses.washington.edu/conj/heart/cardiacoutput.htm

Stroke volume

- preload
- contractility
- afterload

* How is the heart filled before the systole
* What is its „force“ of contraction
* What is resistance against the pumping

Afterload

- arterial pressure
- systemic vascular resistence
- blood viscosity

Afterload

the force against which it contracts, the tension
or stress developed in the ventricular wall during ejection

- arterial pressure
- systemic vascular resistence
- blood viscosity

- geometry of the ventricle (***Laplace*** law)

$T = P \times r / d$

Increased volume of the ventricle and thiner wall (i.e. dilatation)
increase afterload
contribute to the decrease of CO
increase requirements for oxygen

High CO

- physiologically – effort, emotions
- Strong vasodilatation (decrease of afterload) – fever, sepsis, thyreotoxicosis
- HYPERKINETIC CIRKULATION

High CO can cause heart failure

Cardiac cycle

- **Systole** – contraction, ejection, high tension in the wall, energy requirement
- **Diastole** – filling, relaxation, rest, myocardium perfusion
- Both can be disturbed – **dysfunction**

Pumping disorders of the heart

Systolic failure (dysfunction)

The blood ejection from the ventricle is impaired due to the decrease of the contractility

Case report A

The patient has decreased contractility:
ischemia, part of the myocardium was replaced by fibrous tissue (scar) after the myocardial infarction;

Hypertension increases afterload

Case report A

The patient due to the decreased contractility has decreased EF < 35 %

The symptoms of systolic failure

Specificity of the regulation in children

- ***Higher heart and breath rate***
- ***Newborns – very high HR causes important decrease of ventricle filling time with decreased od CO. Because of high diastolic ventricle volume in this age the Frank-Starling law has only limited importance.***
- ***The increase of myocardium contractility is also limited due to the fact that myocardium contains less myofibrils and there are prevailing non-contractile elements.***

Diastolic failure – failure with normal EF

The ventricle filling during the diastole is accompanied by increased pressure

usually the decrease in the relaxation and later compliance of heart wall

EDP increases

- CHD
- Hypertension with hypertrophy
- Some cardiomyopathies etc.

- mainly the congestion symptoms

Causes of low compliance

- Hypertension with hypertrophy
- CHD
- Some cardiomyopathies (hypertrofic) etc.

Many patients have mainly diatolic failure

That means they have good contraction, the heart keeps normal CO but due to low compliance the EDP is high and leads to the lung congestion and dyspnea

Often in patients with LV hypertrophy due to previous (not treated) hypertension

Case report A

The patient has due to the hypertrophy (caused by systemic hypertension) of the LV decreased compliance, i.e. the increase of EDP is higher for the EDV

He has also the symptoms of diastolic failure

Case report A

The patient has dilated LV with increased enddiastolic pressure. This pressure propagates to the lungs to cause the congestion and dyspnea.

The ventrikle in hypertension is at the same time hypertrofized, i.e. less compliant

Evaluation / monitoring of hemodynamic heart function

- **EF** (ultrasound)

- **cardiac output** (ultrasound or catheterization)

- **EDP** (catheterization)

- **Heart rate (HR)**
- **Blood pressure (BP)**

HEART FAILURE

pathophysiologic state in which an abnormality of *cardiac* function is responsible for the failure of the heart to pump blood at a rate commensurate with the requirements of the metabolizing tissues

decrease of cardiac output

***and/or* can do so only from an abnormally elevated diastolic volume**

increase of the ventricular filling pressure (enddiastolic pressure, EDP)

Types of heart failure

According to the ventricle

- left-sided
- right-sided (cor pulmonale due to lung diseases, lung embolism etc.)
- both-sided

Acc. to the intensity

According to the course

- acute
- chronic (development of the compensatory mechanisms):

compensated

decompensated

According to the CO

- low-output (most)
- high-output (hyperkinetic cirkulation)

- **Heart (ventricle) is not capable to pump the blood from one circulation to the other – basic hemodynamics**
- **The organs suffer from shortage of perfusion**

HEMODYNAMIC CONCEPT

- **Various compensatory mechanisms are activated**
- **The blood is not only redistributed but the fluid retention follows with edema development**
- **Changes in other organs and the whole organism**

SYSTEMIC CONCEPT

Compensatory mechanisms

The aktivity and mechanisms of other organs and changes in heart morphology that tend to keep CO at sufficient level to maintain the tissue perfusion

Compensatory mechanisms

short-term action: can be positive (evolutionary are made to be active in acute situation, heart failure is somehow modern disease)

long-term action: have negative effects to further deterioration of heart failure

Heart failure is not only failing of the heart as a pump, but it is ***systemic disorder*** with activation of hormonal processes, with changed metabolism, changed regulation of water-mineral balance, with cytokines involved, heart changes, changes of gene expression etc.

HEMODYNAMIC ASPECTS
NEUROHUMORAL ASPECTS
CELLULAR AND GENE EXPECT

Main compensatory mechanisms in heart failure

They lead to incrase (maintain) CO

1. Sympathetic activity
2. Increase of preload
3. Salt and water retention
4. Myocardium changes

Short-term effective, long-term have deletirious effects themselves and contribute to the symptoms and progression of HF

Vitious circle

Case report

Why these patients have tachycardia?

Sympathetic activity in heart failure

↑ Heart rate
↑ Contractility
↑ Venous return

↑ CO

Negative consequences

Tachycardia:

Increase in oxygen consumption

shortening of the diastole (impairment of diastolic filling and myocardial blood flow)

Increased risk for arrhytmias

Norepinephrine cardiotoxicity (increase of calcium in myocardium)

Periphery vasoconstriction

increase of afterload

CO/blood flow redistribution

Metabolic action

hyperlipidemia, hyperglycemia

During the heart failure the β receptors in myocardium are down-regulated

Activation of sympathetic nerves improves CO only in short-term but is damaging and exhausting the heart

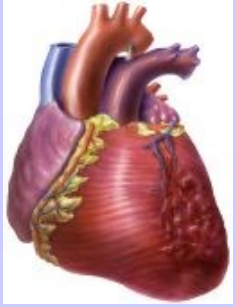
Low doses of betablockers are nowadays used to treat and improve the moderately severe heart failure.

Extremely activated sympatic activity is in SHOCK

Case report

Why do the patients have edemas?

Why patient A urinates often during the night?



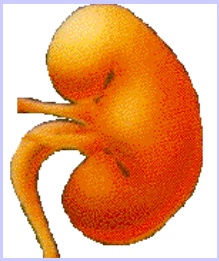
cardiac output - decrease in effective plasmatic volume

tissue perfusion

ADH

sympaticus

glomerular filtration



renin

angiotensin II

periphery vasoconstriction

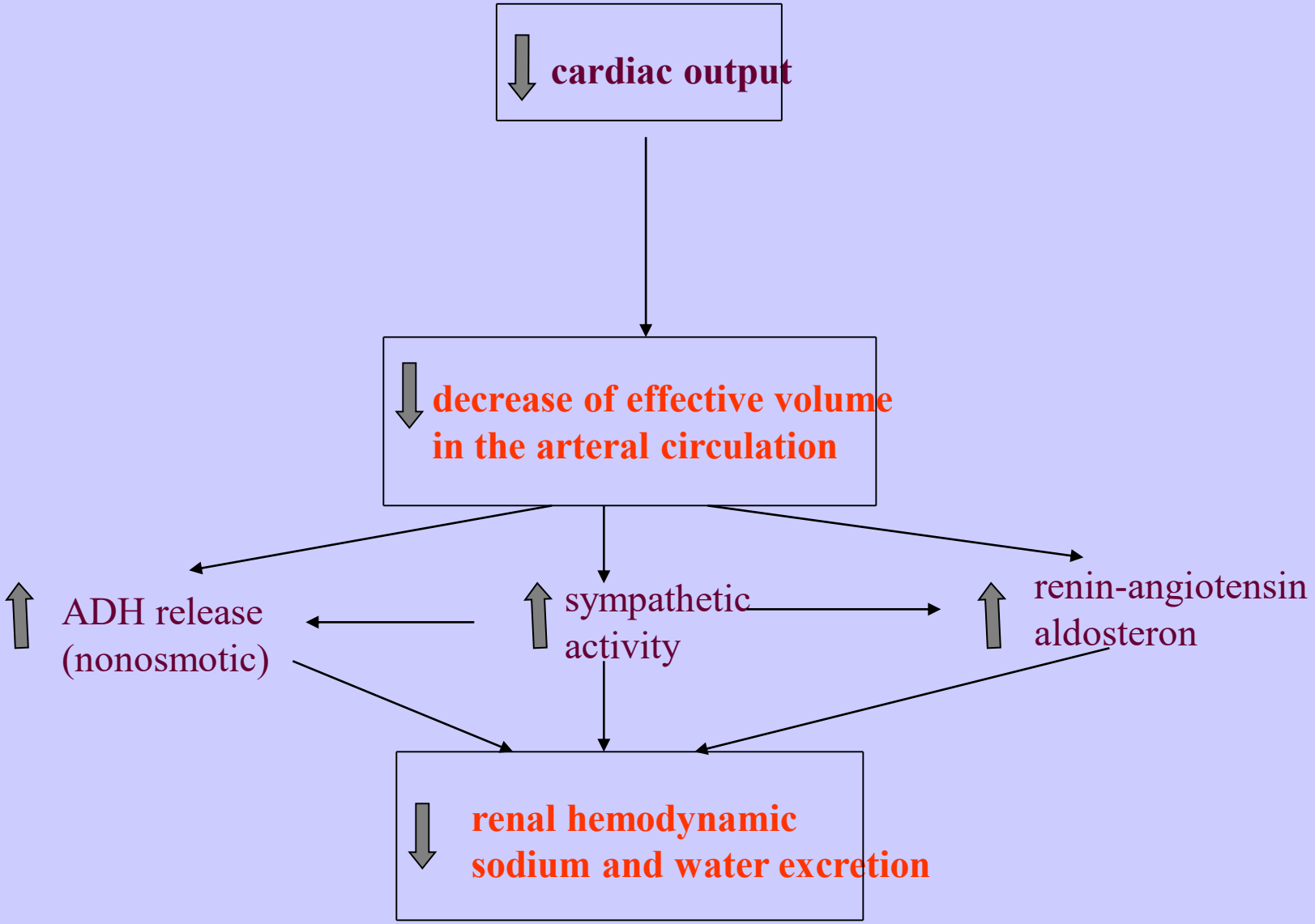
aldosterone
sec. hyperaldosteronisms

BP

ECT expansion

afterload

preload


cardiac output
decrease of effective volume
in the arteral circulation
ADH release
(nonosmotic)
sympathetic
activity
renin-angiotensin
aldosteron
renal hemodynamic
sodium and water excretion

Water retention and edema in heart failure are cause by the activation of renin-angiotensin-aldosteron

Prof. MUDr. J. Kvasnička, CSc.
Interní klinika KNP Pardubice, LFUK Hradec Králové

Chronic heart failure. What is it?

- **Heart failure is a pathophysiological error of the organism**:
- To the change of hemodynamic parameters which are under physiological conditions corrected by **short-term** activation of ***sympathetic nerves*** and ***renin-angiotensin-aldosteron*** system [RAAS] the organism reacts by ther **long-term and inadequate** activation**.**

- **Their long-term activation has devastating effects on the organims**.

Katz AM, In discussion, Am J Cardiol 1988;62:82A

Blocking of the RAAS is at present the main treatment of heart failure

-inhibitors of angiotensin converting enzyme (ACE inhibitors)

- angiotensin II receptor antagonists

- aldosterone antagonists

Natriuretic peptides
A (ANP) – 28 AA, mainly released in the dilated atria
B („braine“, **BNP**) – 32 AA, synthetized in the ventricles, *sensitive marker of heart failure*

Effects:
glomerulus – increse of GF
tubuli – decrease of sodium reabsorption
inhibiiton of the secretion of renin and aldosteron

Heart changes

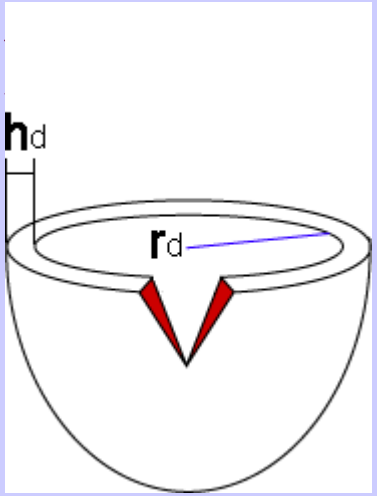
Reaction to ***biomechanical*** stress (tension in the wall)
and to ***neurohumoral*** stimuli

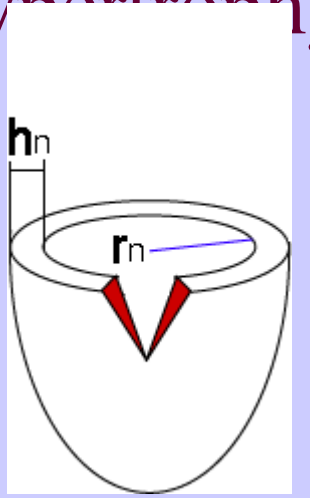
REMODELATION

important for further outcome of heart failure

* Dilatation

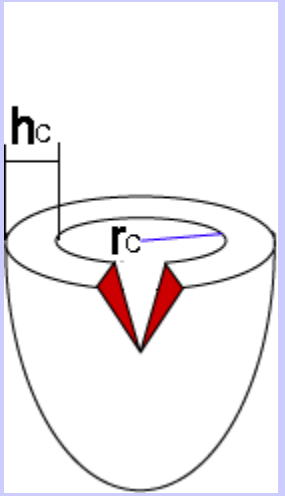
primary due to volume burden
thin wall – increased tension in the wal
(higher *r*, lower *h*)
secondary from previous hy rophy
(excentric hypertrophy)





* Hypertrophy

concentric in hypertension
excentric secund. in increased volume burden and increased preload



Consequences of heart changes

- increased ***wall tension*** in dilatation - increase in afterload and oxygen consumption

- ***impaired oxygen delivery*** in hypertrophy

- ***decrease of compliance*** - diastolic failure

- ***overstretched dilatation*** impairs contraction and leads to relative valvular insuficiency

- ***arrhytmias***

- ***prognostic*** factor

Heart changes – cellular and molecular level

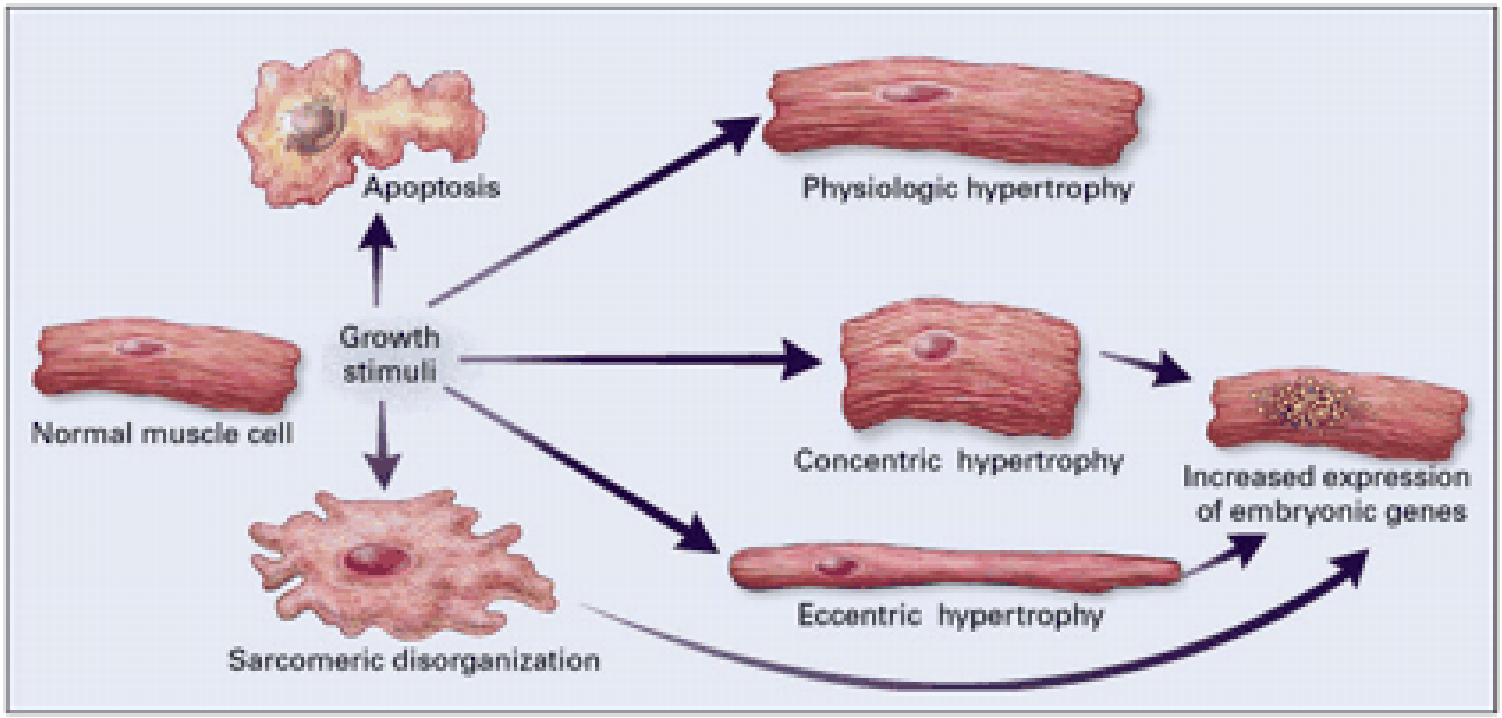
Severe heart failure is accompanied by cellular changes :

- deregulated myogenesis (abnormal, „embryonal“ growth)

-apoptosis

-Changes of gene expression

Further decrease of heart function


Apoptosis
Physiologic hypertrophy
Normal muscle cell
Growth stimuli
Concentric hypertrophy
Increased expression of embryonic genes
Eccentric hypertrophy
Sarcomeric disorganization

Cytokines in heart function / heart failure

Action:
negative inotropic
proapoptotic
fibroplastic
arrhytmogenic etc.

Mainly proinflammatory cytokines: TNFα, IL-1, IL-6

Originate in systemic inflammatory reaction (inflammation, tumor)
locally in heart failure as a response to hemodynamic changes

Further decrease of heart function

Neurohumoral adjustments

influence vasoconstriction, fluid retention, myocardium
- angiotensin II
- aldosterone
- natriuretic peptids
- norepinephrin
- ADH
- endotelin

- prostaglandins keeping the renal perfusion

Metabolic changes

In the myocardium
In peripheral tissues

Mainly catabolism

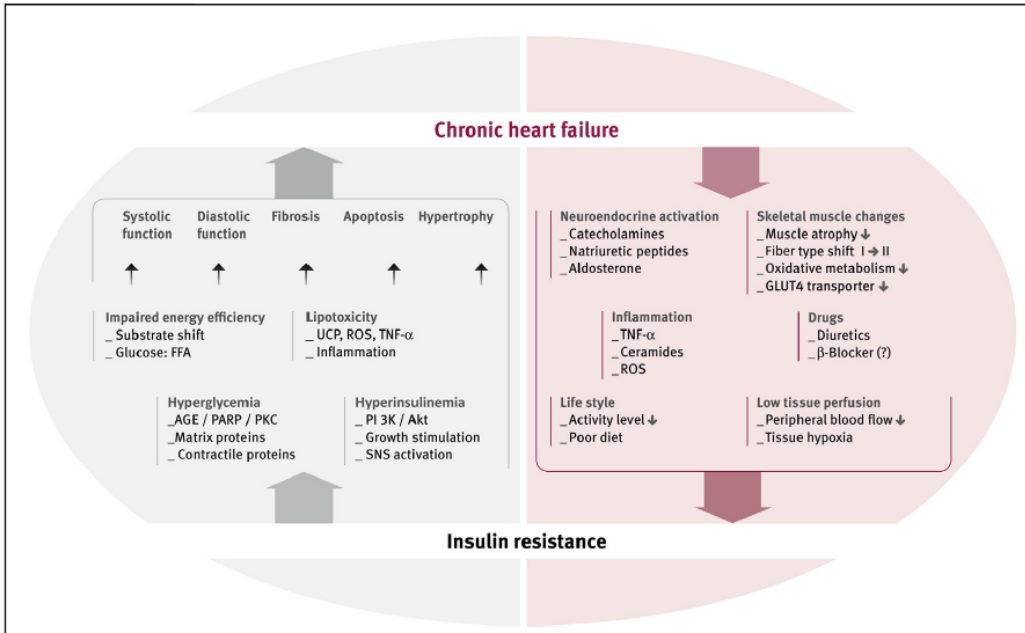


FIGURE 2 Insulin Resistance: Intrinsic Feature in HF Pathophysiology

The vicious cycle of insulin resistance as an intrinsic component of heart failure (HF) pathophysiology. Several features of HF trigger insulin resistance (right section in **red**). In turn, insulin resistance induces a range of signals responsible for HF progression. Accordingly, insulin resistance is a major underlying mechanism of the reciprocal interaction between congestive HF and diabetes mellitus, with hyperglycemia only exerting additive effects in overt DM. AGE = advanced glycation end products; PARP = poly(ADP-ribose) polymerase; PKC = protein kinase C; SNS = sympathetic nervous system; TNF = tumor necrosis factor; other abbreviations as in Figure 1.

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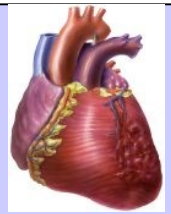
Metabolic Impairment in Heart Failure
The Myocardial and Systemic Perspective

Wolfram Doehner, MD, PhD,* Michael Frenneaux, MD,† Stefan D. Anker, MD, PhD‡

Overview of clinical symptoms

Right-sided failure



BACKWARD

FORWARD

decreased ejection from RV → decreased flow from RV to the lungs

↑ EDV, EDP in RV

↑ pressure in R atrium

↑ volume and pressure in large veins

↑ capillary pressure → edemas, transsudation (ascites, hydrothorax)

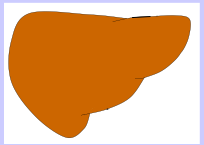
↑ volume in distensible organs (hepatosplenomegaly)

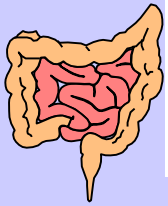
decreased flow to the left atrium

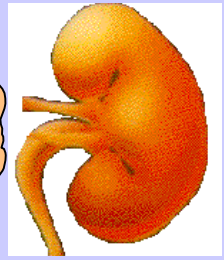
↓ cardiac output

fluid retention

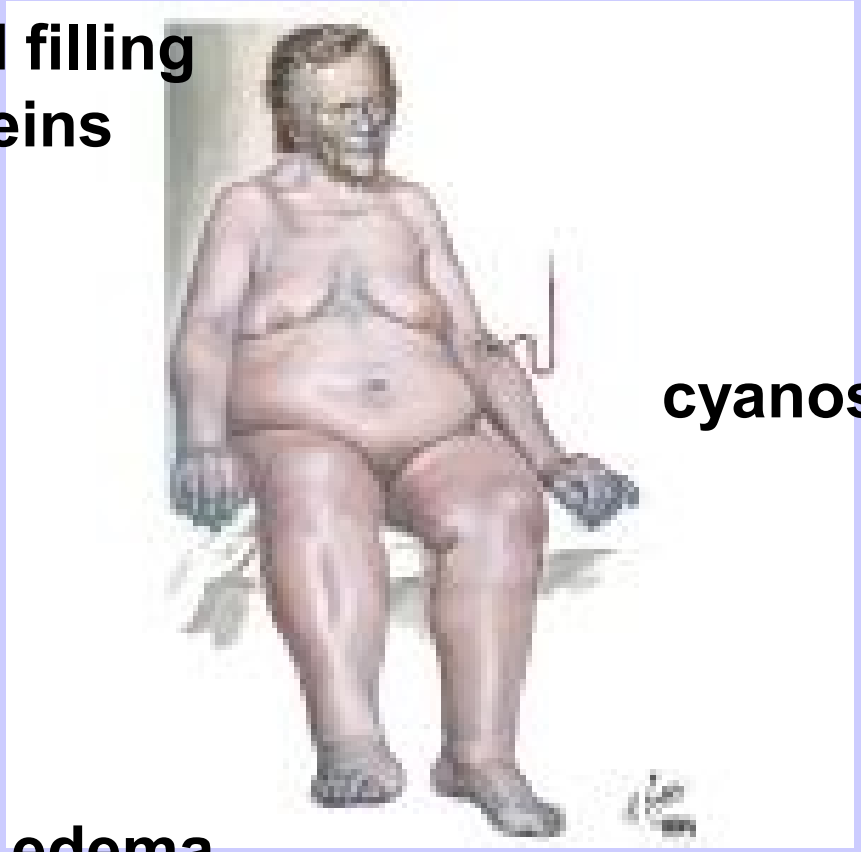
symptomes of decreased CO





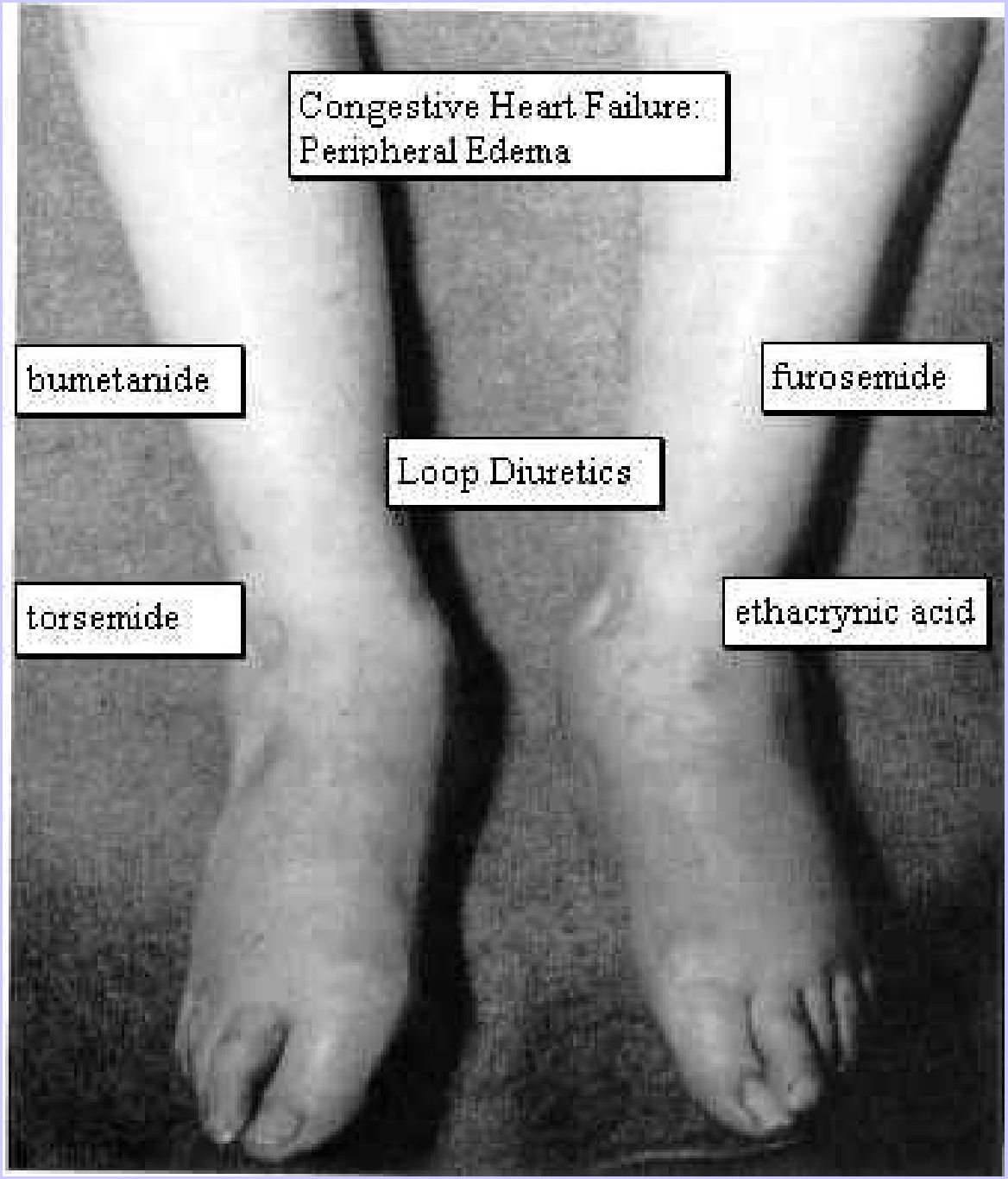


increased filling
of neck veins

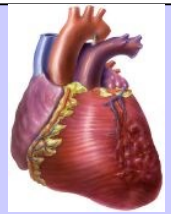


cyanosis

edema


Congestive Heart Failure:
Peripheral Edema
bumetanide
furosemide
Loop Diuretics
torsemide
ethacrynic acid

Left-sided failure



BACKWARD

decreased ejection from LV

↑ EDV, EDP in LV

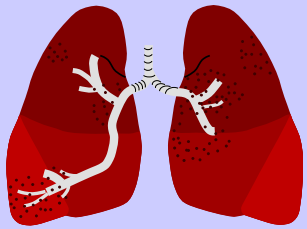
↑ pressure in L atrium

↑ volume and pressure in pulmonary veins

↑ capillary pressure

↑ fluid volume in the lung
fluid transsudation to the alveoli

pulmonary edema, dyspnea



FORWARD

↓ cardiac output

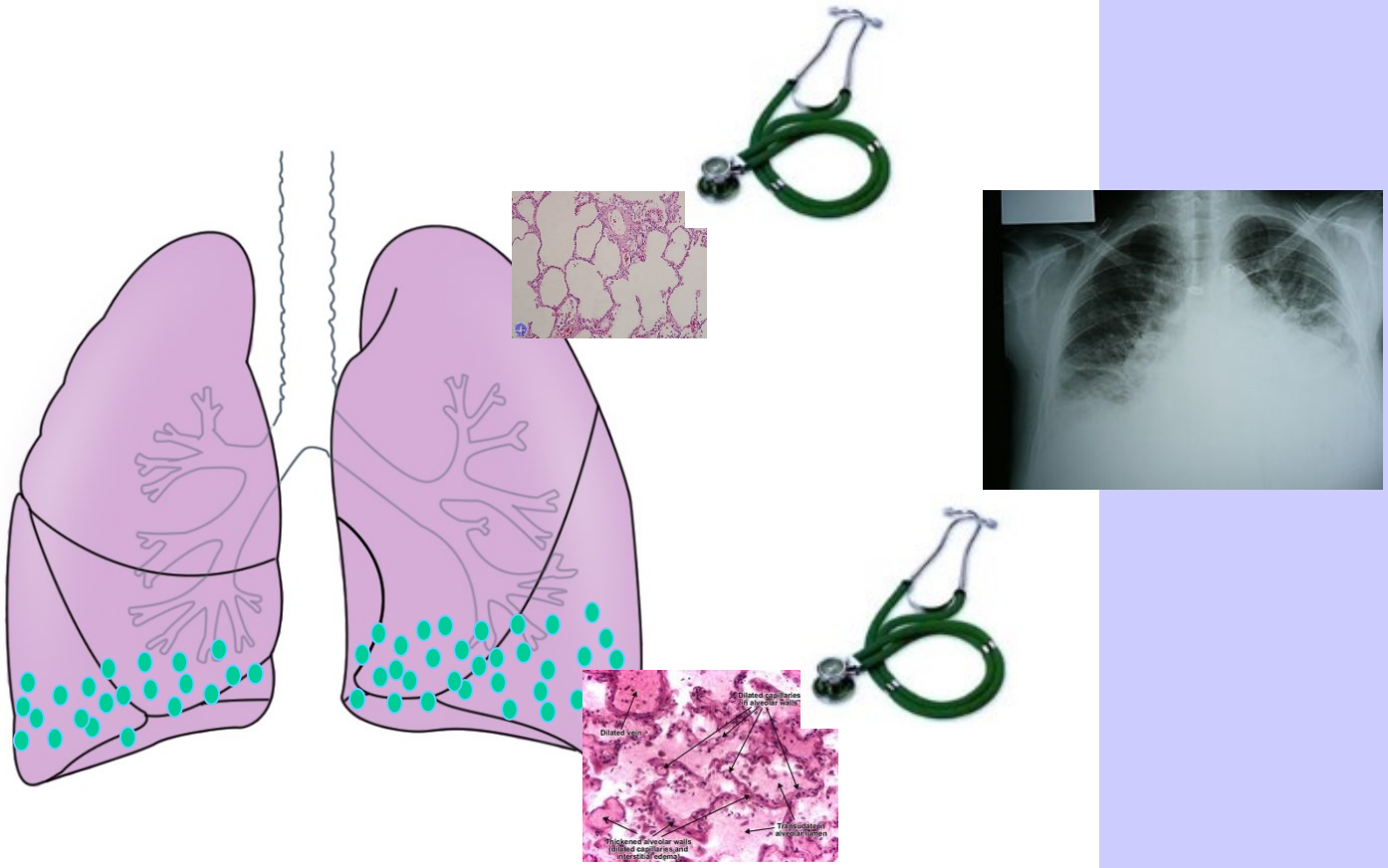
↓ kidney perfusion

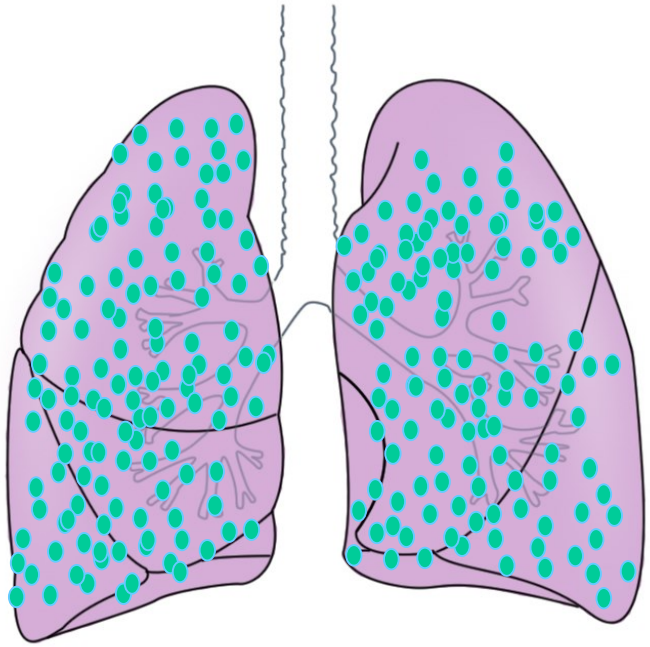
fluid retention

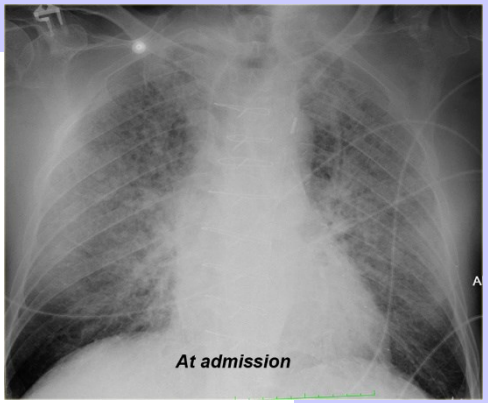
↓ tissue perfusion

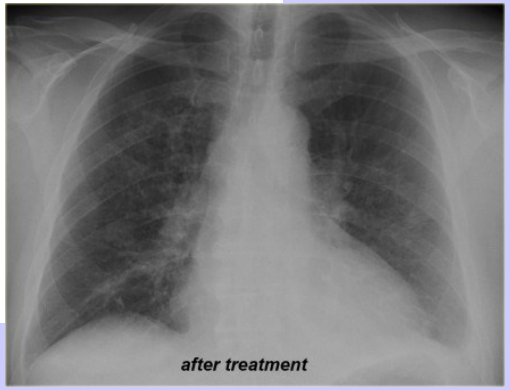
symptomes of decreased CO

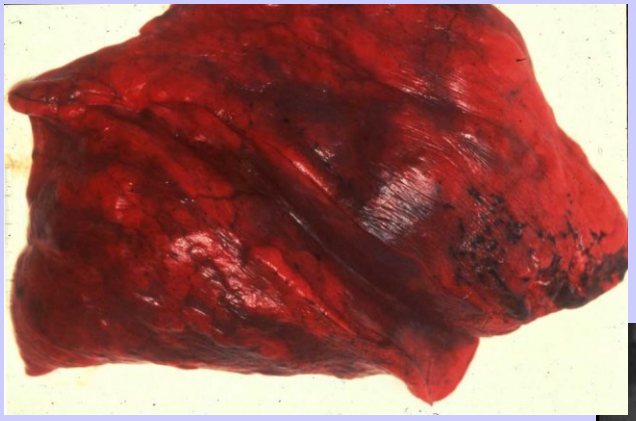
fatigue, weakness
pale skin
impairment of organ functions

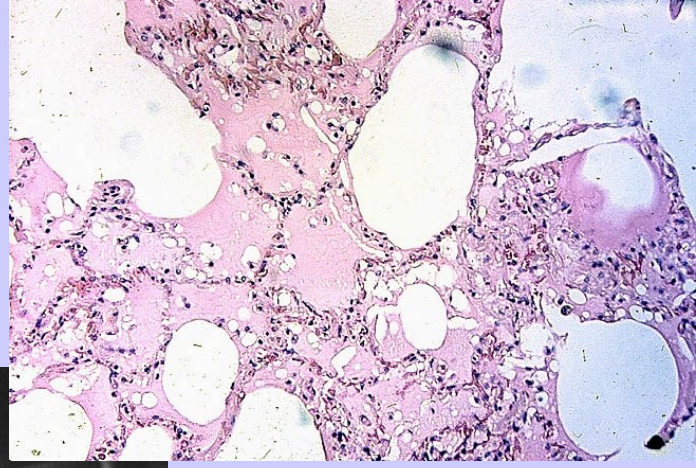

Dilated vein
Dilated capillaries
Thickened alveolar walls (dilated capillaries and interstitial edema)
Transudate in alveolar lumen

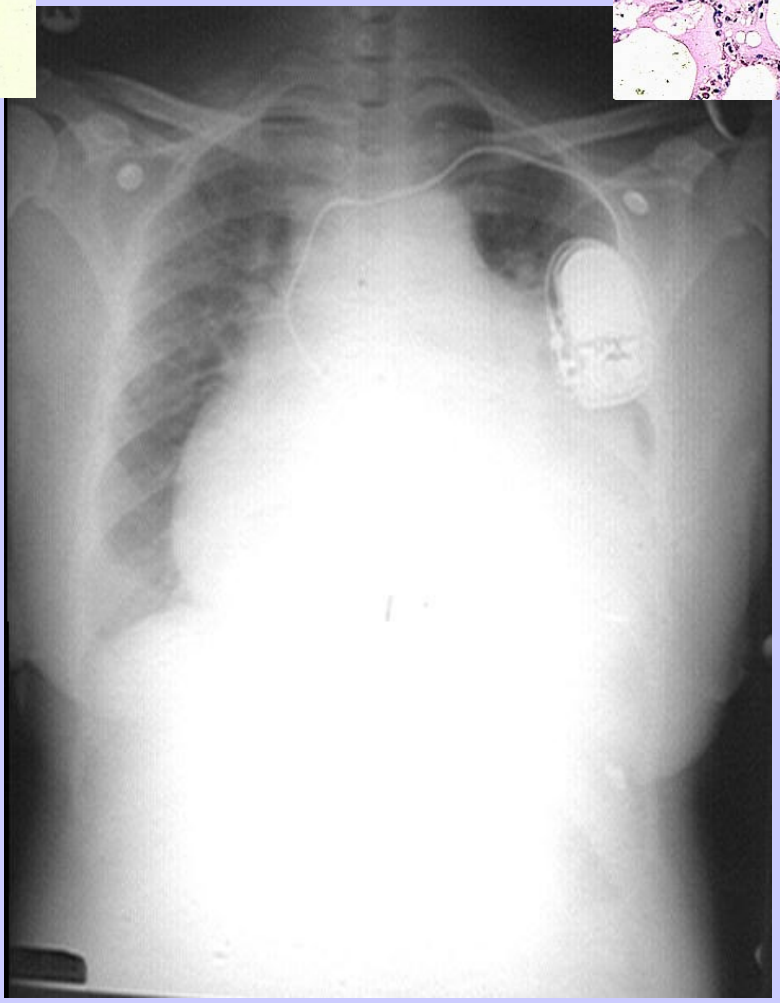



At admission


after treatment

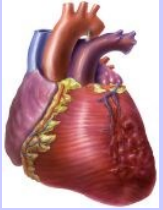






Pulmonary edema

- **Cardiac** – due to the high capillary pressure in the lung capillaries as a consequence of high EDP in LV in heart failure)
- **Non cardiac** – direct damage of pulmonary capillaries and tissue with increased permeability; LV functions and EDP are normal; mainly ARDS



left-sided failure

increase of filling pressure + fluid retention

pulmonary edema

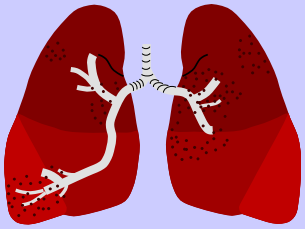
hypoxemia

dyspnea

myocardial hypoxia

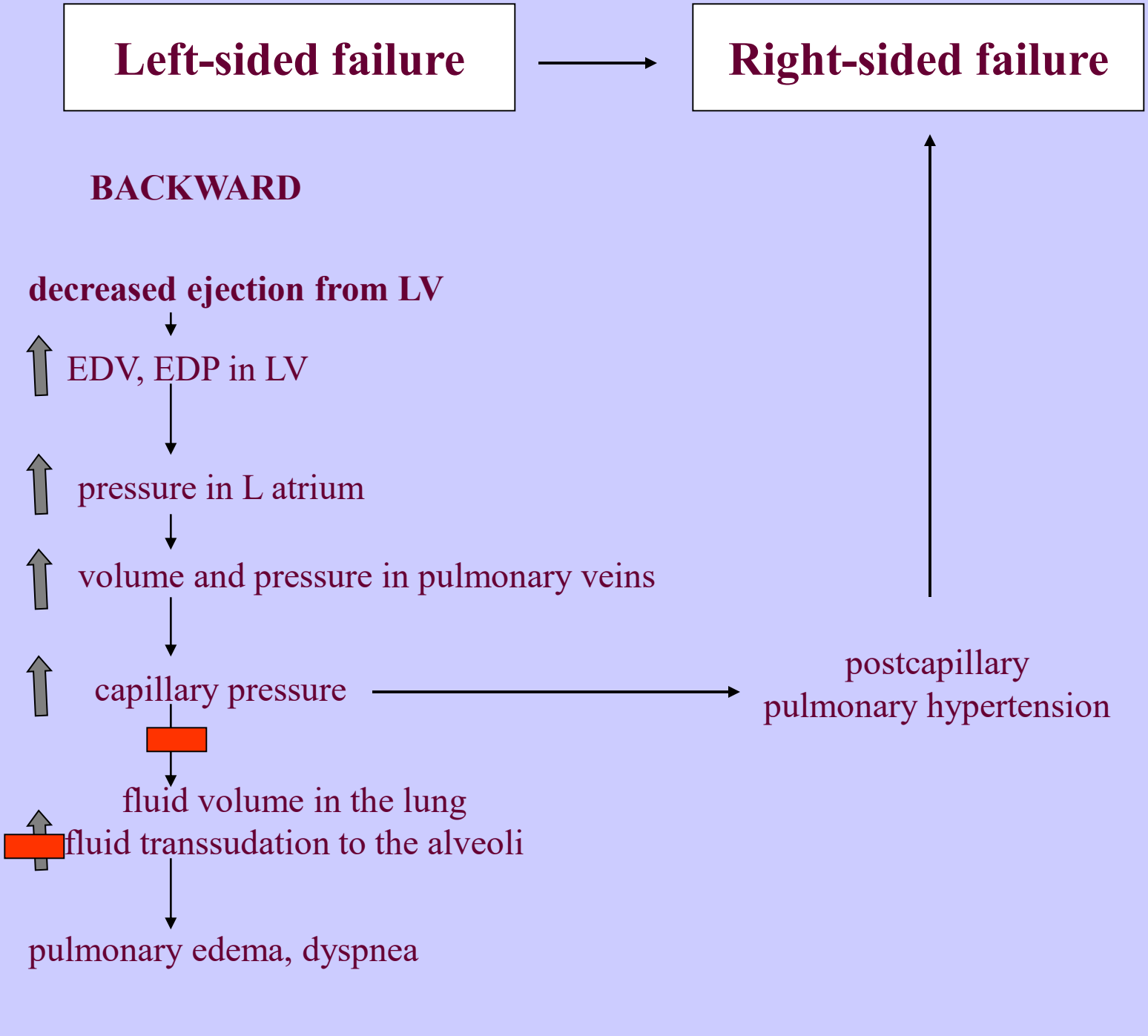
increase burden for respiratory muscles

impairment of myocardial contractility



Bilateral heart failure

- **Direct** damage of the myocardium of both ventricles (e.g. myocardium, cardiomyopathies)
- **Indirect** due to the left sided failure and postcapillary pulmonary hypertesion


Left-sided failure
Right-sided failure
BACKWARD
decreased ejection from LV
EDV, EDP in LV
pressure in L atrium
volume and pressure in pulmonary veins
capillary pressure
postcapillary
pulmonary hypertension
fluid volume in the lung
fluid transsudation to the alveoli
pulmonary edema, dyspnea

Typical features of the heart failure in pediatrics

- **Age dependent, depends on the cause, usually with the clinical pictureof general circulatory failure**
- ***Newborn, babies – fast development, tachycardia, hepatomegaly, systemic hypotenssion, severe course***
- ***Pre-school and school age – less urgent symptom onset***
- ***Adolescents – usually with non specific symptoms in the beginning – decreased performance, fatigue and gradual progression***

Basic evaluation of the heart failure

- BP, HR
- Skin color and temperature, neck veins, edema – CO, R
- Lung auscultation – L
- Heart auscultation (valves…)

- X-ray (shape and size of the heart, lung congestion)
- ultrasound (heart shape and size, valves, perikardium, contractility, ejection fraction…)
- BNP
- ECG (causes, ischemia, arrhytmias)

- catheterization– CO, EDP (pulmonary wedge pressure)

Heart failure classification

NYHA -New York Heart Association:
according to the dyspnea

- Class I: patients with no limitation of activities; they suffer no symptoms from ordinary activities.
- Class II: patients with slight, mild limitation of activity; they are comfortable with rest or with mild exertion.
- Class III: patients with marked limitation of activity; they are comfortable only at rest.
- Class IV: patients who should be at complete rest, confined to bed or chair; any physical activity brings on discomfort and symptoms occur at rest.

Principles of the treatment

- action against the negative effects of compensatory mechanism
  betablockers
  inhibitors of RAAS
- increase of the contractility – digitalis (only in some cases)
- reduction of cardiac work load
- control of excessive fluid retention - diuretics
- vasodilator therapy - improves (decreases) afterload
- perspective: natriuretic peptids, anticytokine treatment, antiendothelins…
- mechanical support
- transplantation

Conclusions I

- Hemodynamics: decrease of CO and congestion
- CO decrease: weakness, fatigue, cold skin, even deterioration of consciousness in worst cases. Decrease of kidney perfusion!
- Preload increase: high enddiastolic pressure and congestion –
  in the lungs or in the systemic circulation

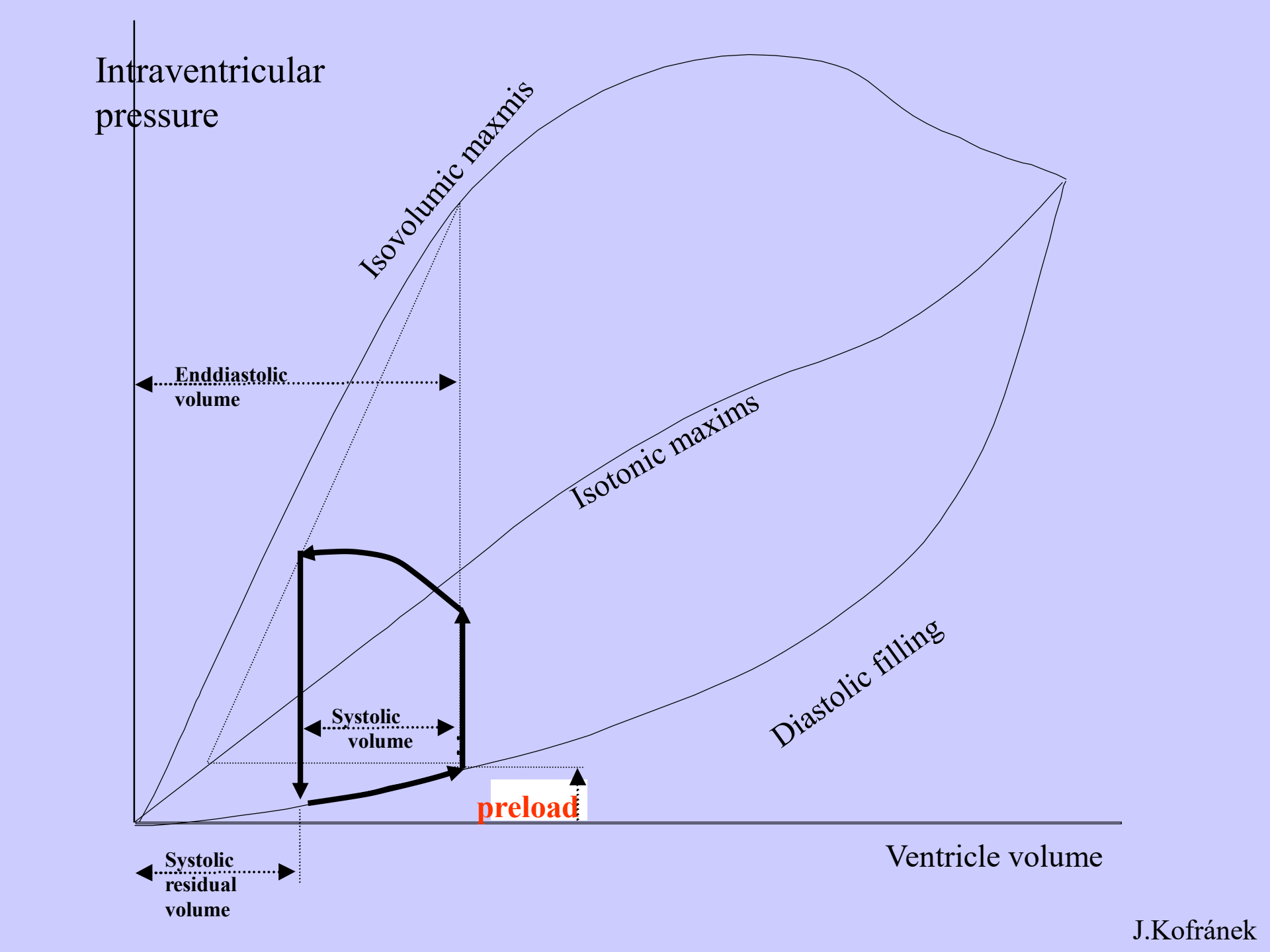
Conclusions II

- Failing heart works with low contractility, high enddiastolic pressure
- Systolic failure means low contractility, low ejection fraction
- Diastolic failure means low compliance komory, increase of enddiastolic

Conclusions III

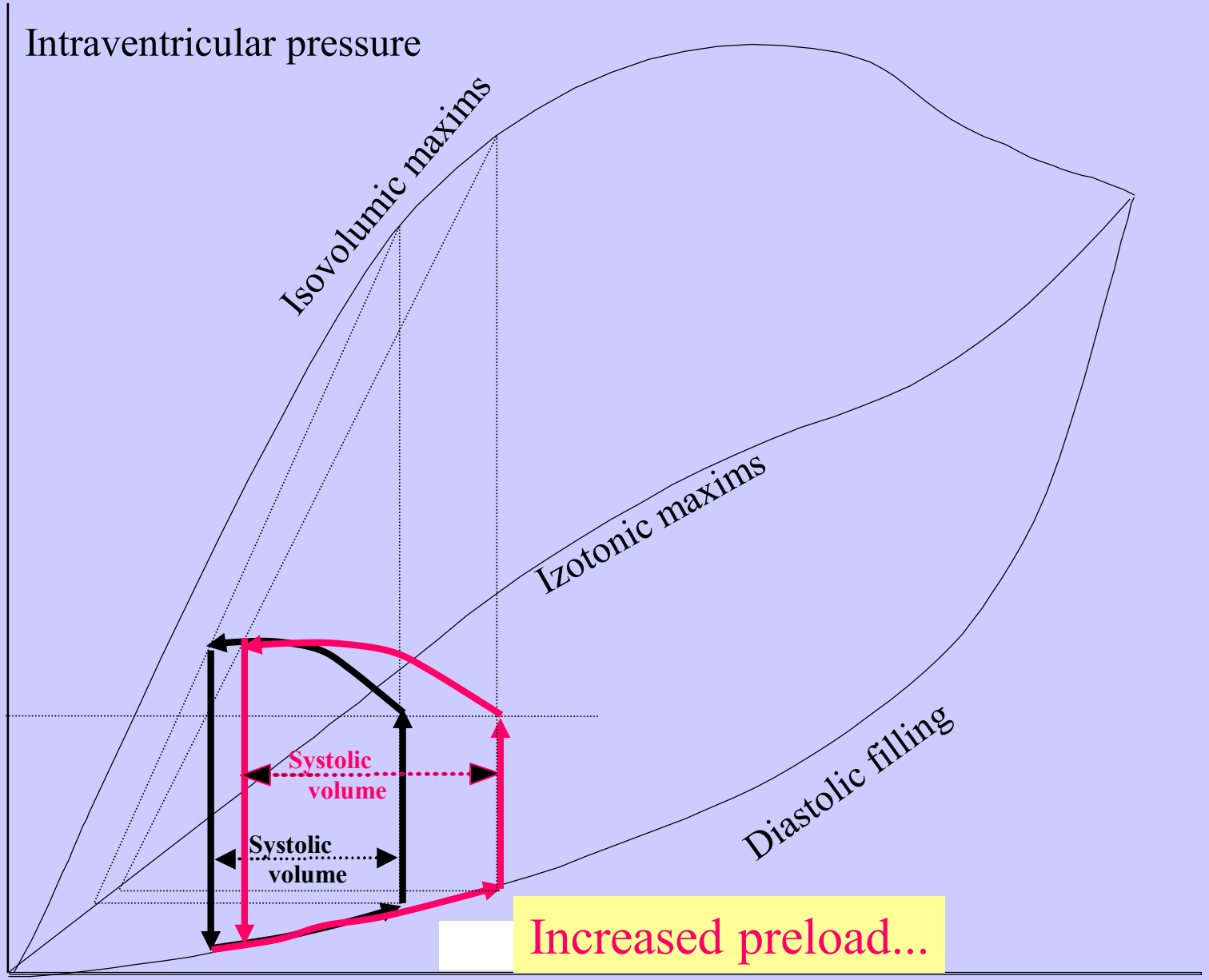
- HF is a systemic disease with changes in the heart but also other organs with strong neuroendocrine response and activation
- Compensatory mechanisms have short-term effect, later they contribute to the deterioration of the disease
- Important is mainly activation of sympathetic systém and RAAS. The modern treatment acts against them.

The End


Intraventricular pressure
Isovolumic maxmis
Enddiastolic volume
Isotonic maxims
Diastolic filling
Systolic volume
preload
Systolic residual volume
Ventricle volume

J.Kofránek

J.Kofránek



Increased preload...

…increases cardiac output.

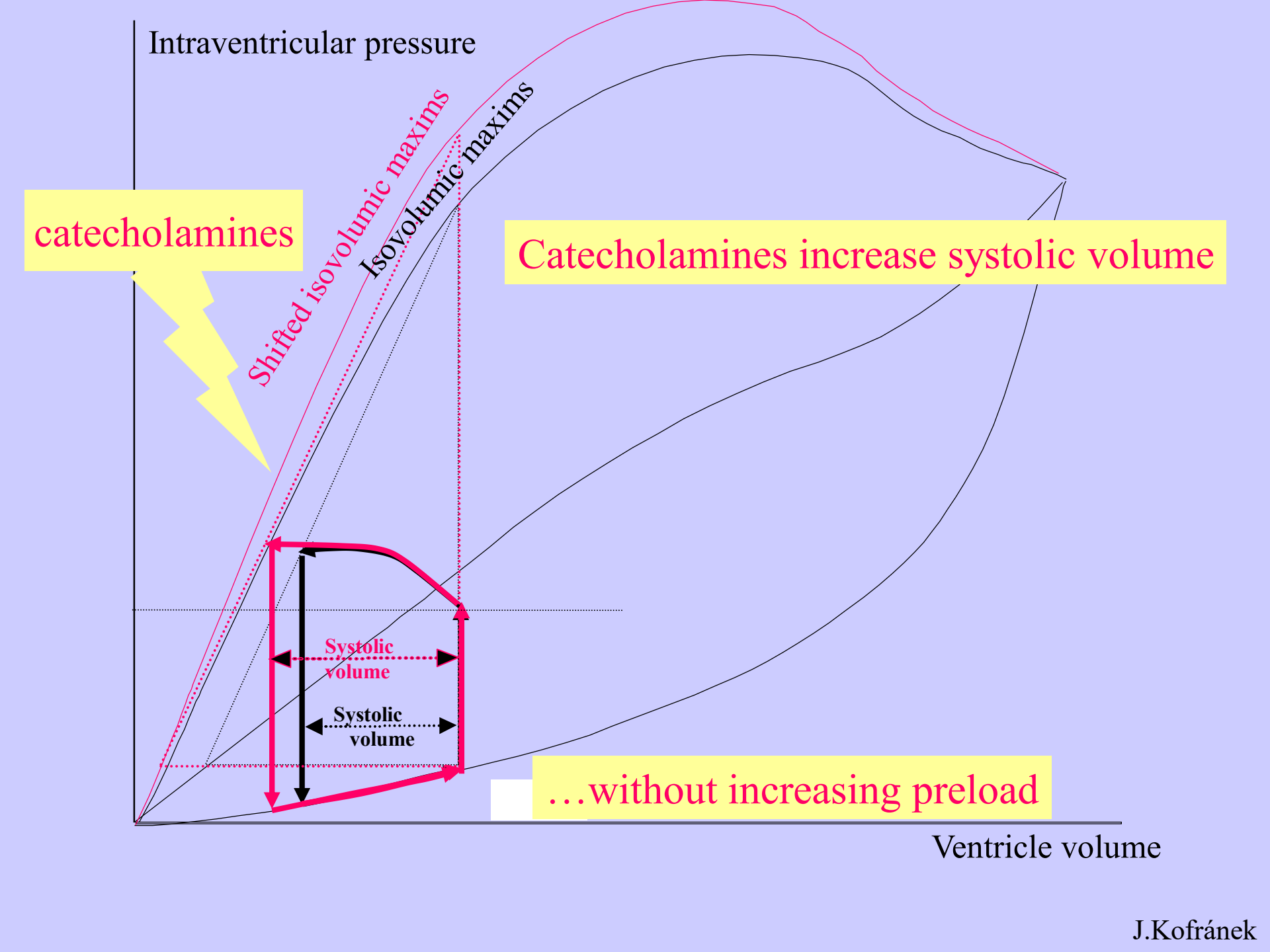
Stroke volume

- preload
- contractility
- afterload

* How is the heart filled before the systole
* What is its „force“ of contraction
* What is resistance against the pumping

Contractility

- **„force“ of the contraction in constant filling (preload, i.e. independent of preload)**


Intraventricular pressure
catecholamines
Shifted isovolumic maxims
Isovolumic maxims
Catecholamines increase systolic volume
Systolic volume
Systolic volume
…without increasing preload
Ventricle volume

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Děkuji za pozornost.

Symptoms of heart failure from the hemodynamic point of view

Low CO

Weakness, fatigue, decreased organ perfusion
incl. kidneys, muscles - ***redistribution of CO***
FORWARD

Blood congestion in organs from which blood is collected to the failing ventricle

Edemas etc.
BACKWARD

Water and salt retention

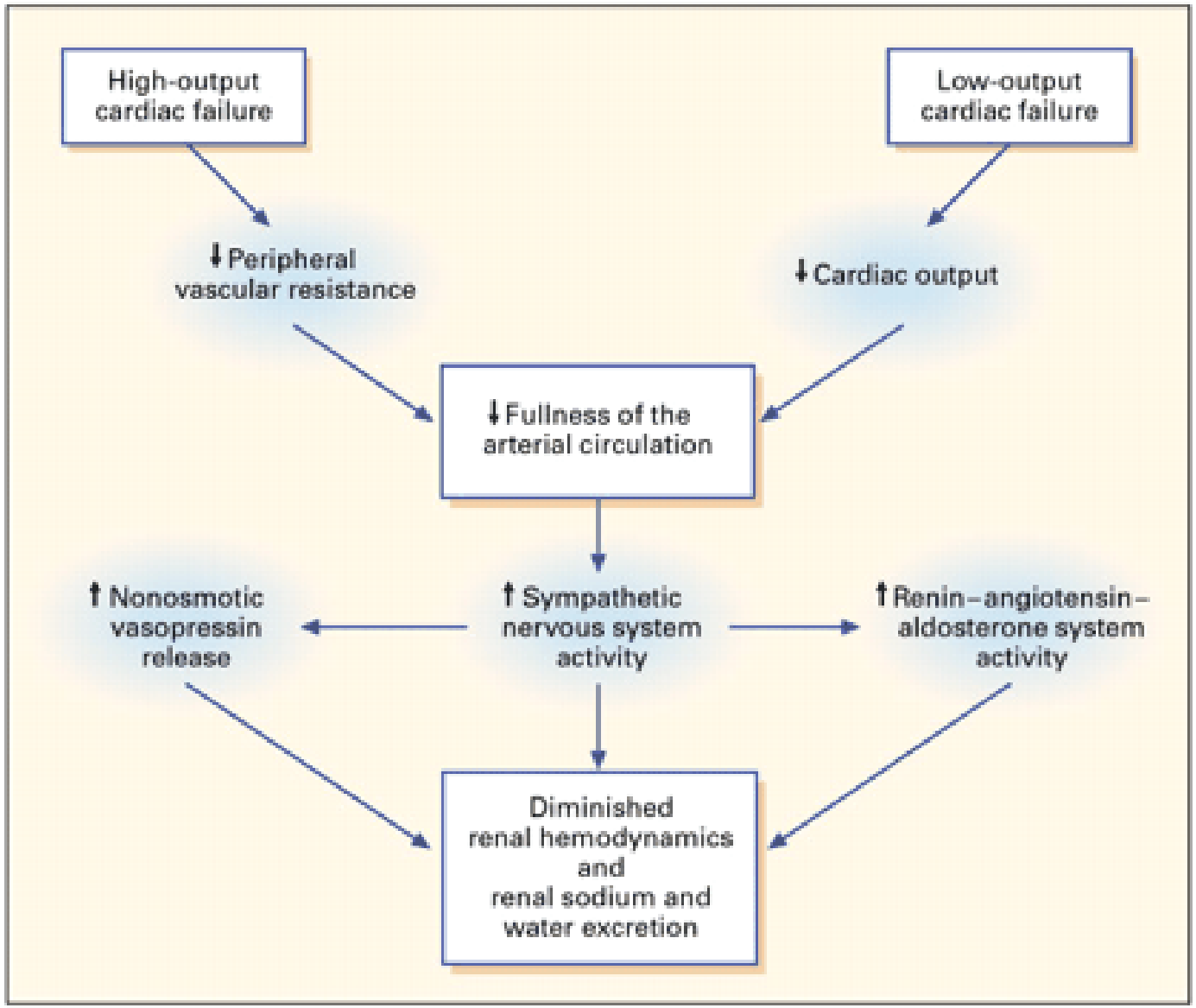
increase in preload

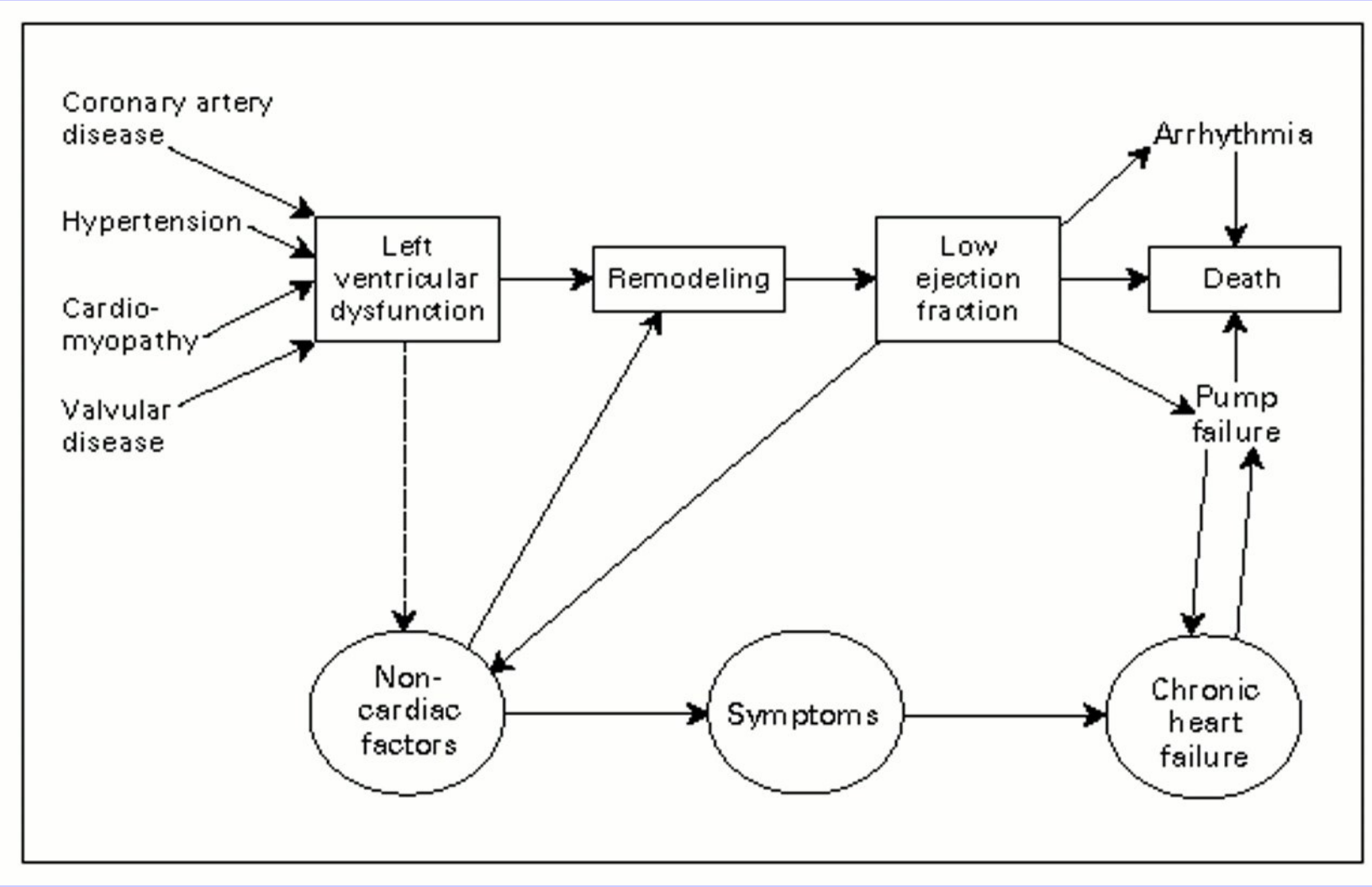
Negative consequences:

- heart dilatation

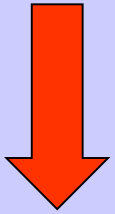
- congestion, edemas

- changes in water/mineral equilibrium, sodium retention and potassium depletion – contributes to electrical nestability of the myocardium

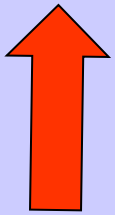

High-output cardiac failure
Low-output cardiac failure
↓ Peripheral vascular resistance
↓ Cardiac output
↓ Fullness of the arterial circulation
↑ Nonosmotic vasopressin release
↑ Sympathetic nervous system activity
↑ Renin–angiotensin–aldosterone system activity
Diminished renal hemodynamics and renal sodium and water excretion


Coronary artery disease
Hypertension
Cardio-myopathy
Valvular disease
Left ventricular dysfunction
Remodeling
Low ejection fraction
Arrhythmia
Death
Pump failure
Non-cardiac factors
Symptoms
Chronic heart failure

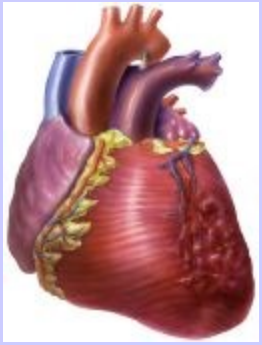
In heart failure CO decreases



Activation of compensatory mechanisms trying to increase CO back to normal values



How are the distinct mechanism influencing the CO regulated ?



heart changes

heart failure

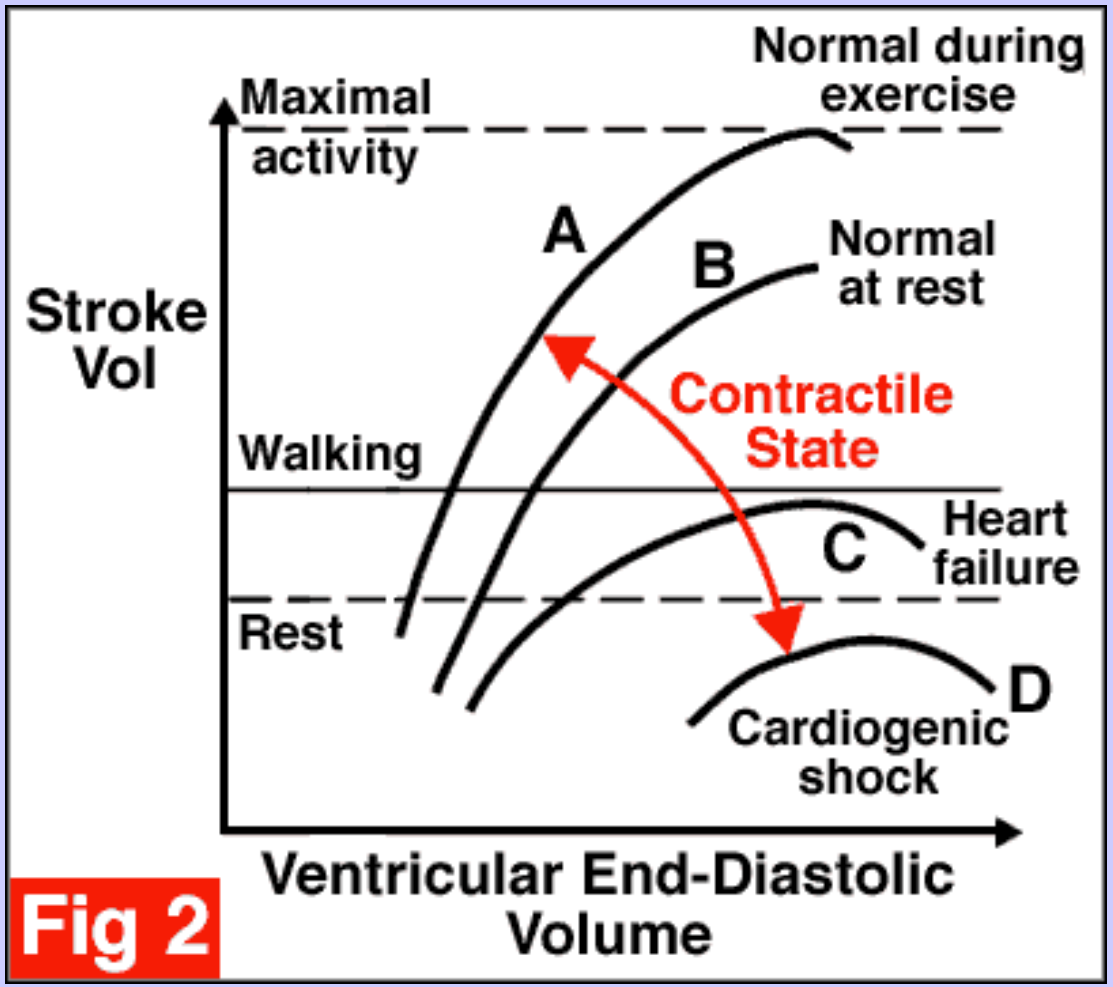
congestion

decreased cardiac output

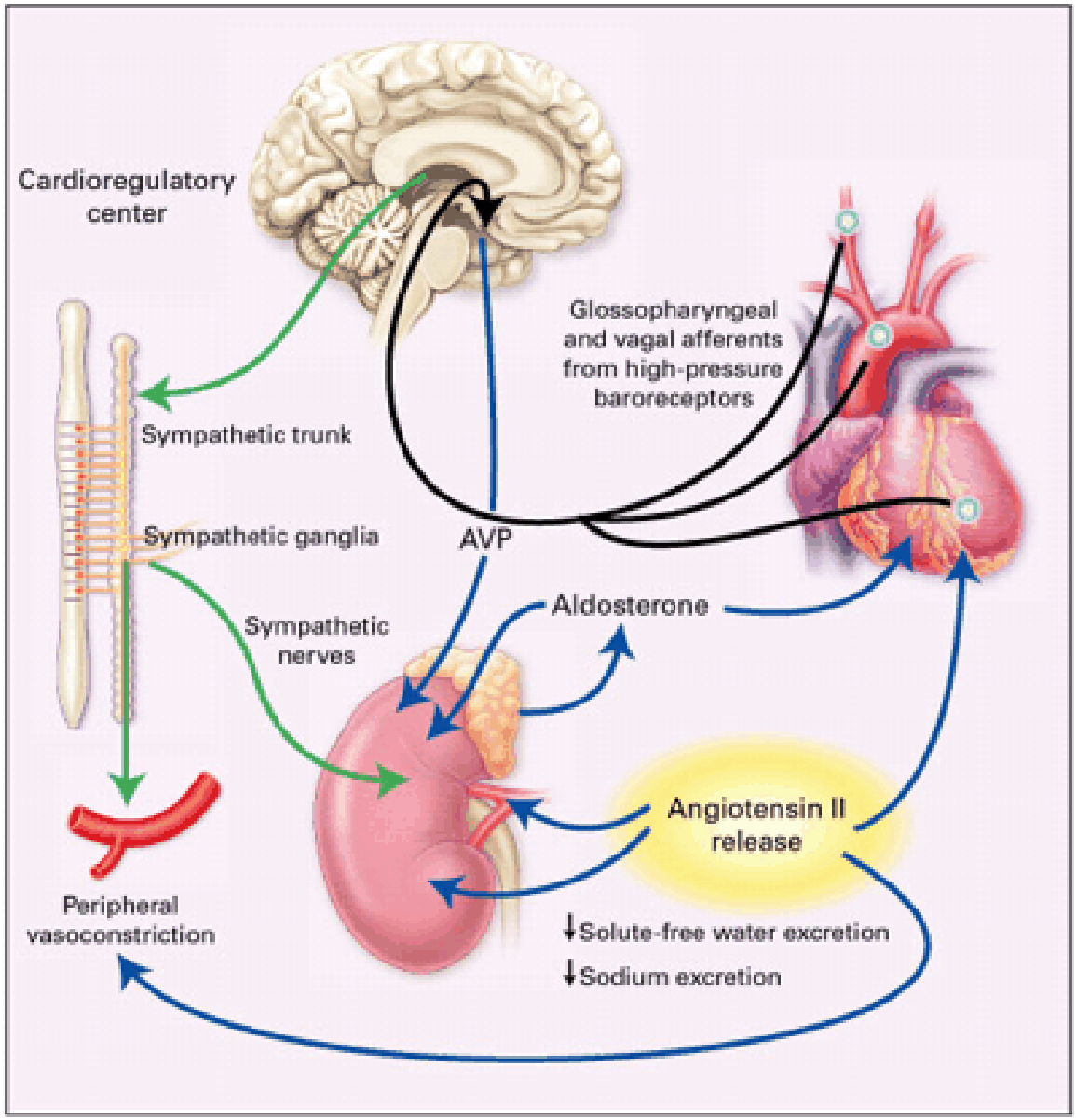
compensatory events

The relation of EDV and stroke volume (Starling curve)

TO (SV)



EDP


Cardioregulatory center
Glossopharyngeal and vagal afferents from high-pressure baroreceptors
Sympathetic trunk
Sympathetic ganglia
AVP
Aldosterone
Sympathetic nerves
Angiotensin II release
Peripheral vasoconstriction
↓Solute-free water excretion
↓Sodium excretion

Heart changes – cellular level

- dysregulated myogenesis (abnormal, „embryonal “ growth)

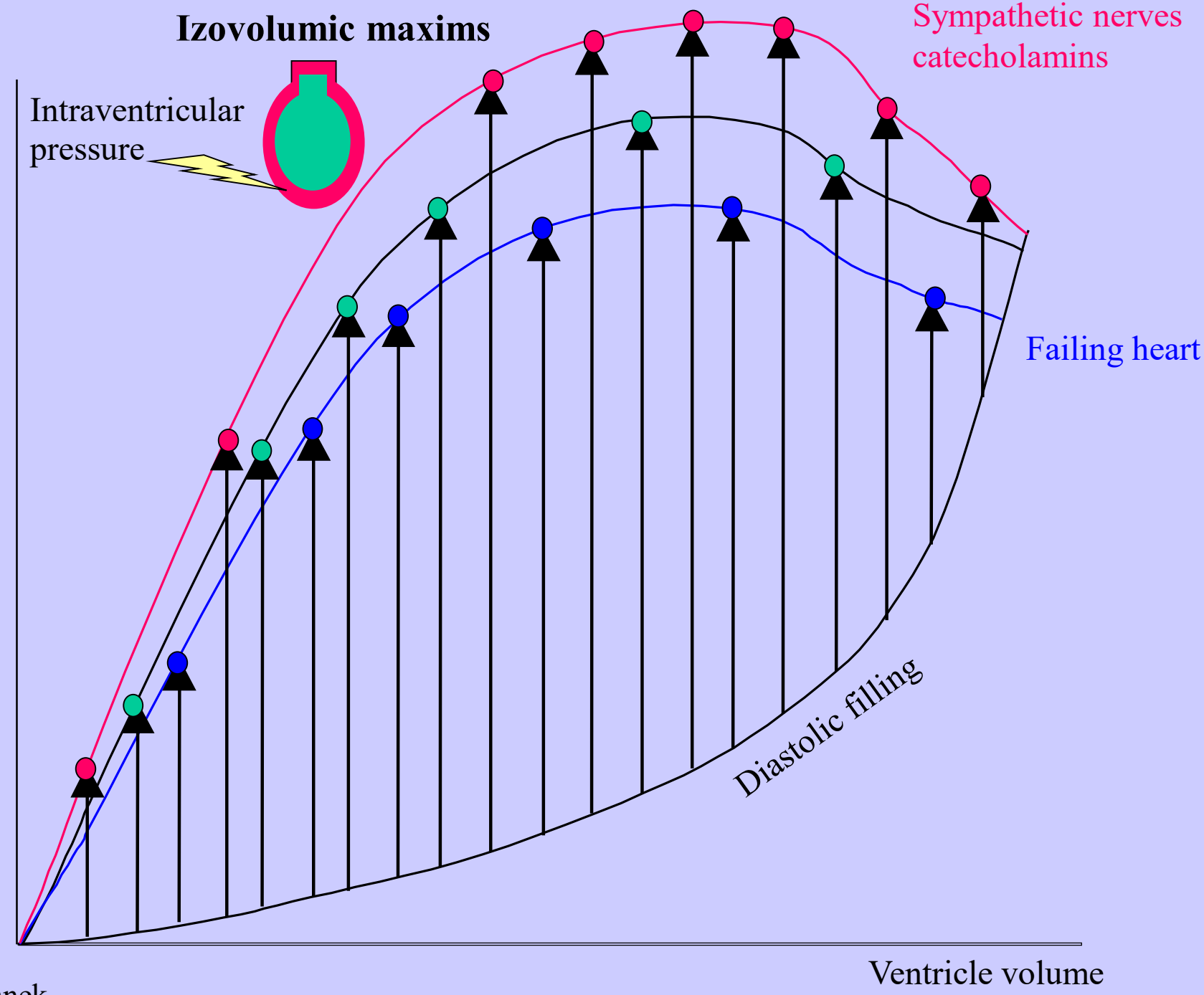
- apoptosis

Further worsening of heart function

Molecular and cellular changes

Angiotensin II
endotelin
IGF-I
growth factors
cytokins
IL-6
cardiotropin 1 etc.

Distension leads to gene expression, e.g. of the genes for natriuretic peptides and fetal genes


Izovolumic maxims
Intraventricular pressure
Sympathetic nerves catecholamins
Failing heart
Diastolic filling
Ventricle volume

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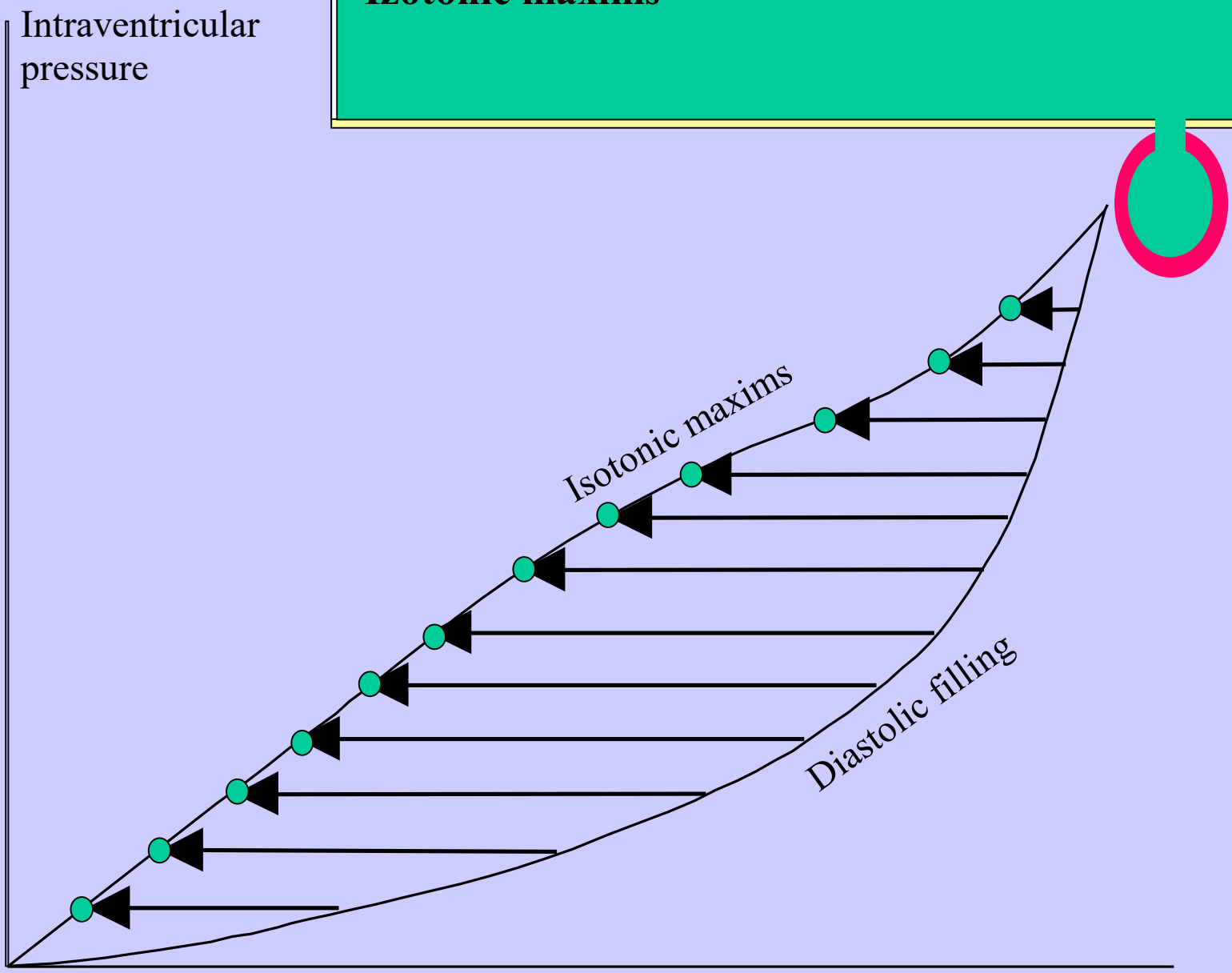
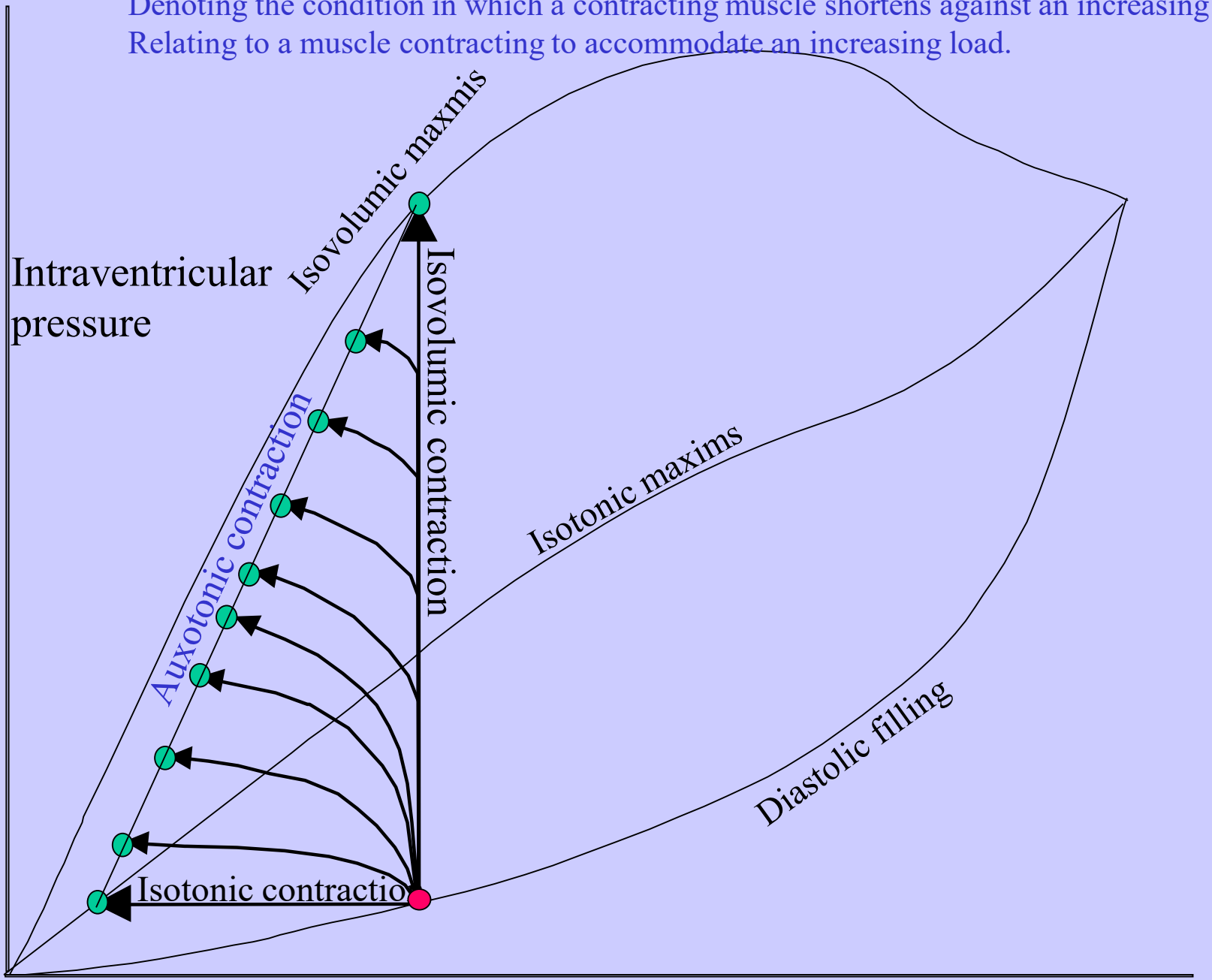
Izotonic maxims



Denoting the condition in which a contracting muscle shortens against an increasing load.
Relating to a muscle contracting to accommodate an increasing load.



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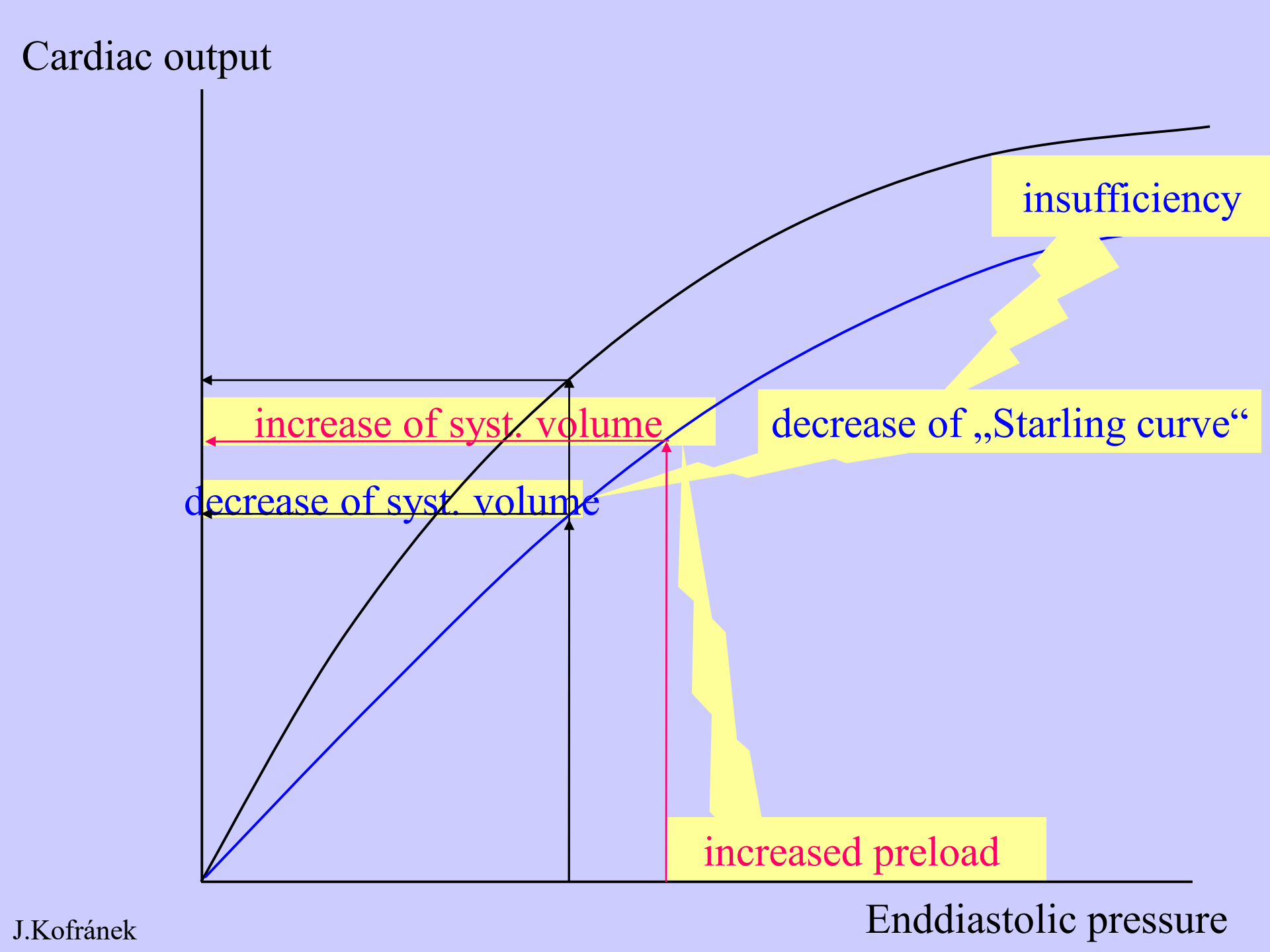
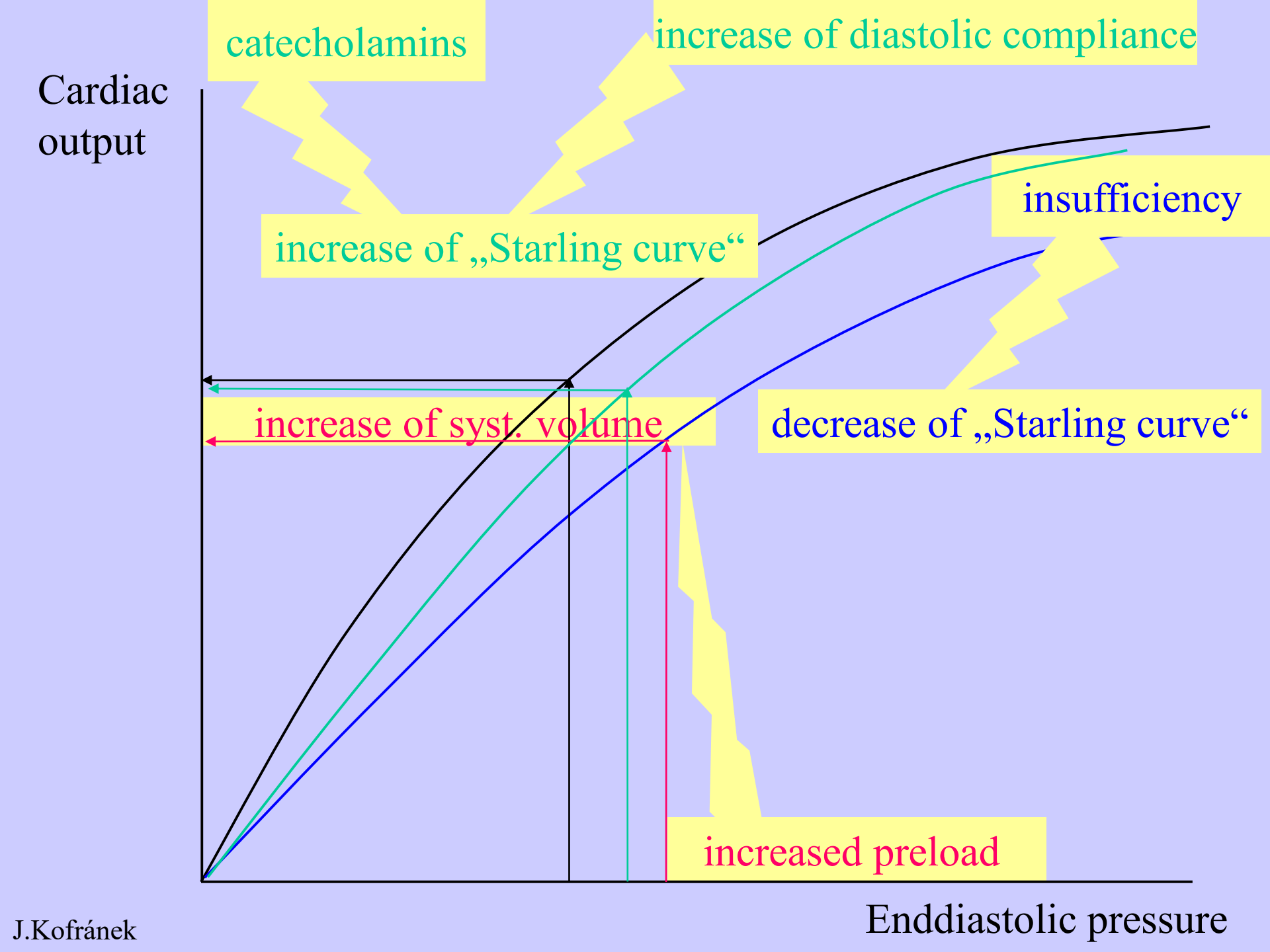

Cardiac output
insufficiency
increase of syst. volume
decrease of „Starling curve“
decrease of syst. volume
increased preload
Enddiastolic pressure


catecholamins
increase of diastolic compliance
Cardiac output
increase of „Starling curve“
insufficiency
increase of syst. volume
decrease of „Starling curve“
increased preload
Enddiastolic pressure

whether the principal abnormality is

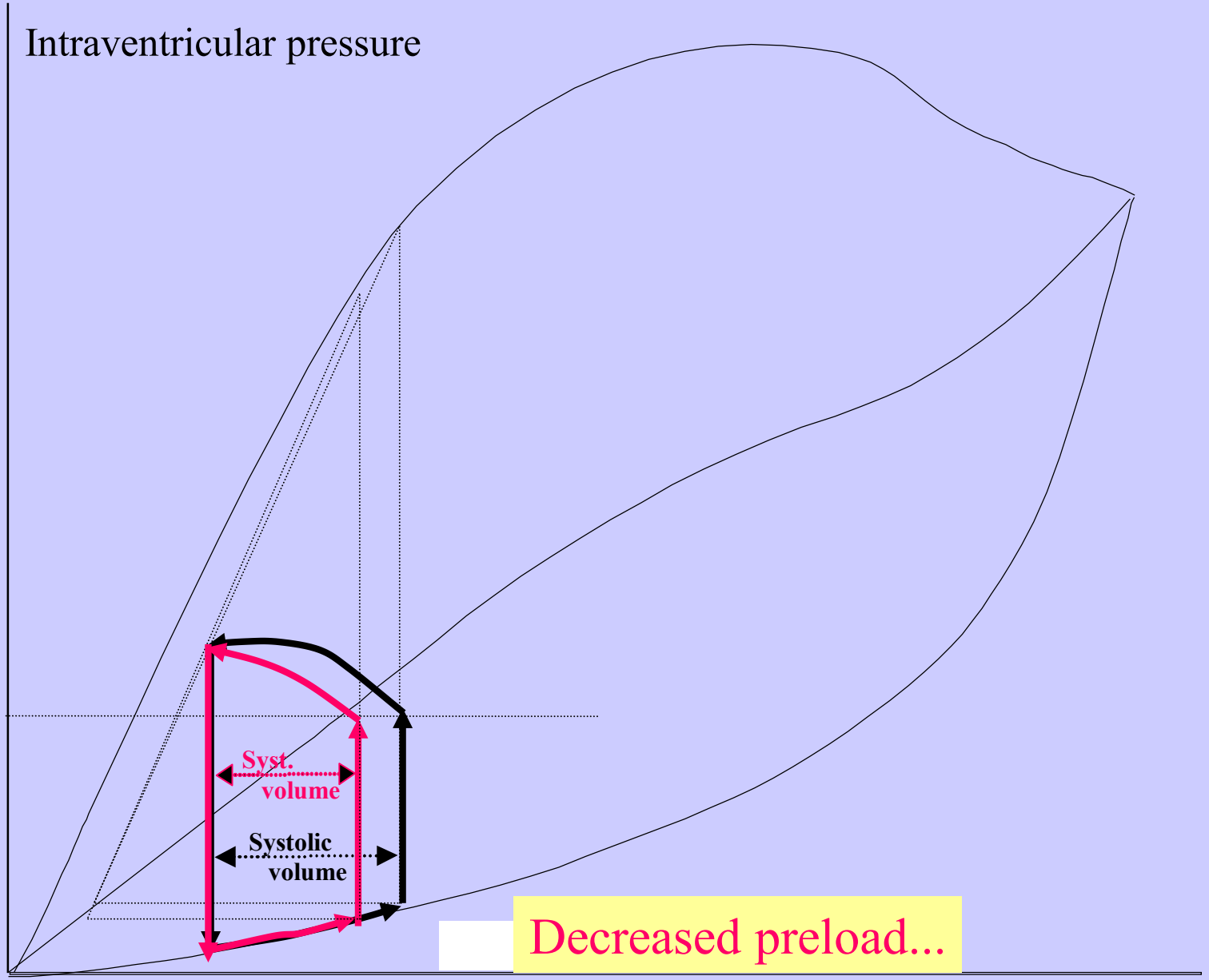
- the **inability to contract normally and expel sufficient blood** (systolic failure)

- or to **relax and fill normally** (diastolic failure)

Systolic failure

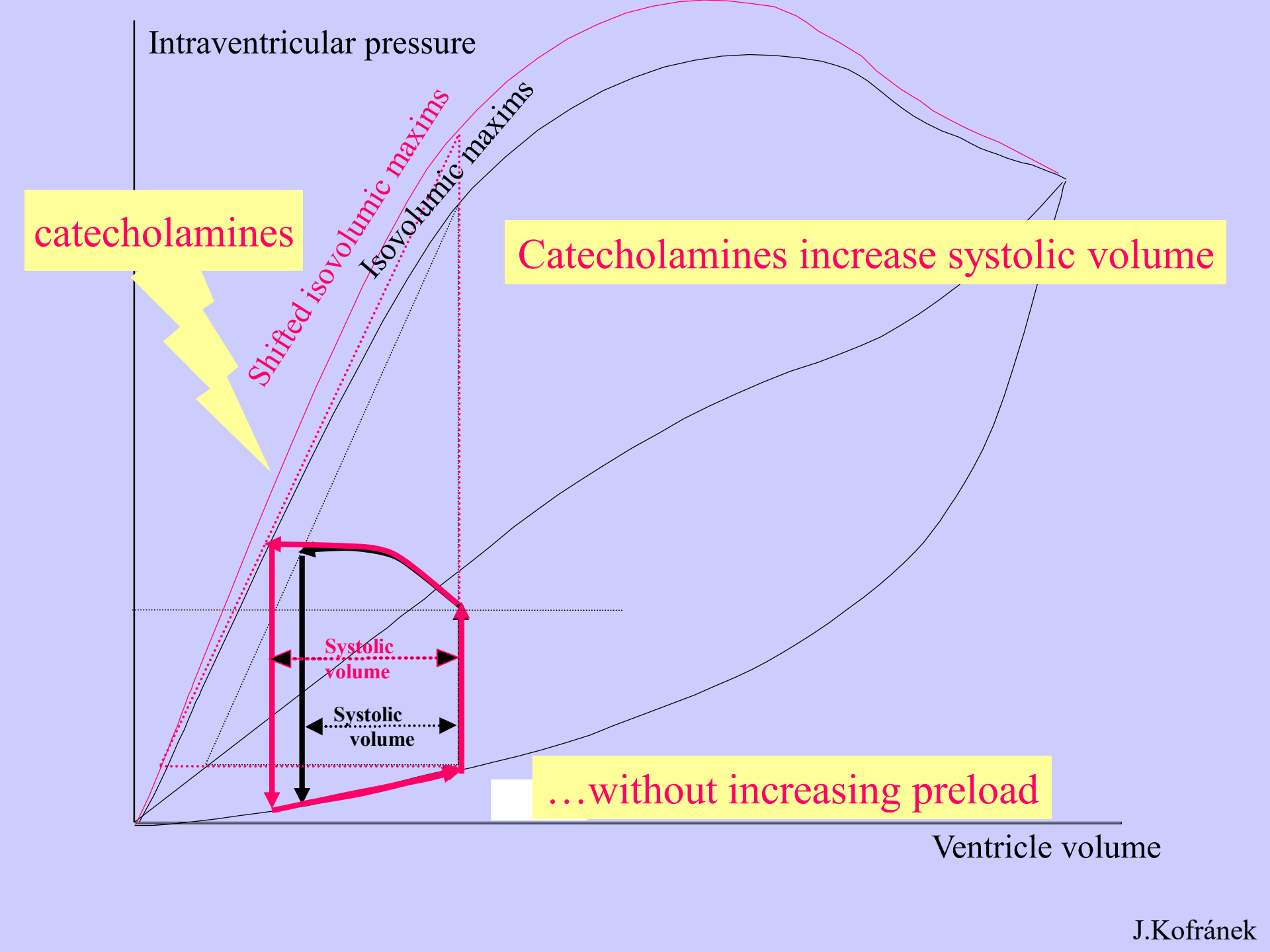
Blood ejection from the ventricle is disturbed

Stroke volume might be maintaind at the costs of increased EDV (and EDP)



Decreased preload...

…decreases cardiac output.


Intraventricular pressure
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Catecholamines increase systolic volume
Systolic volume
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…without increasing preload
Ventricle volume

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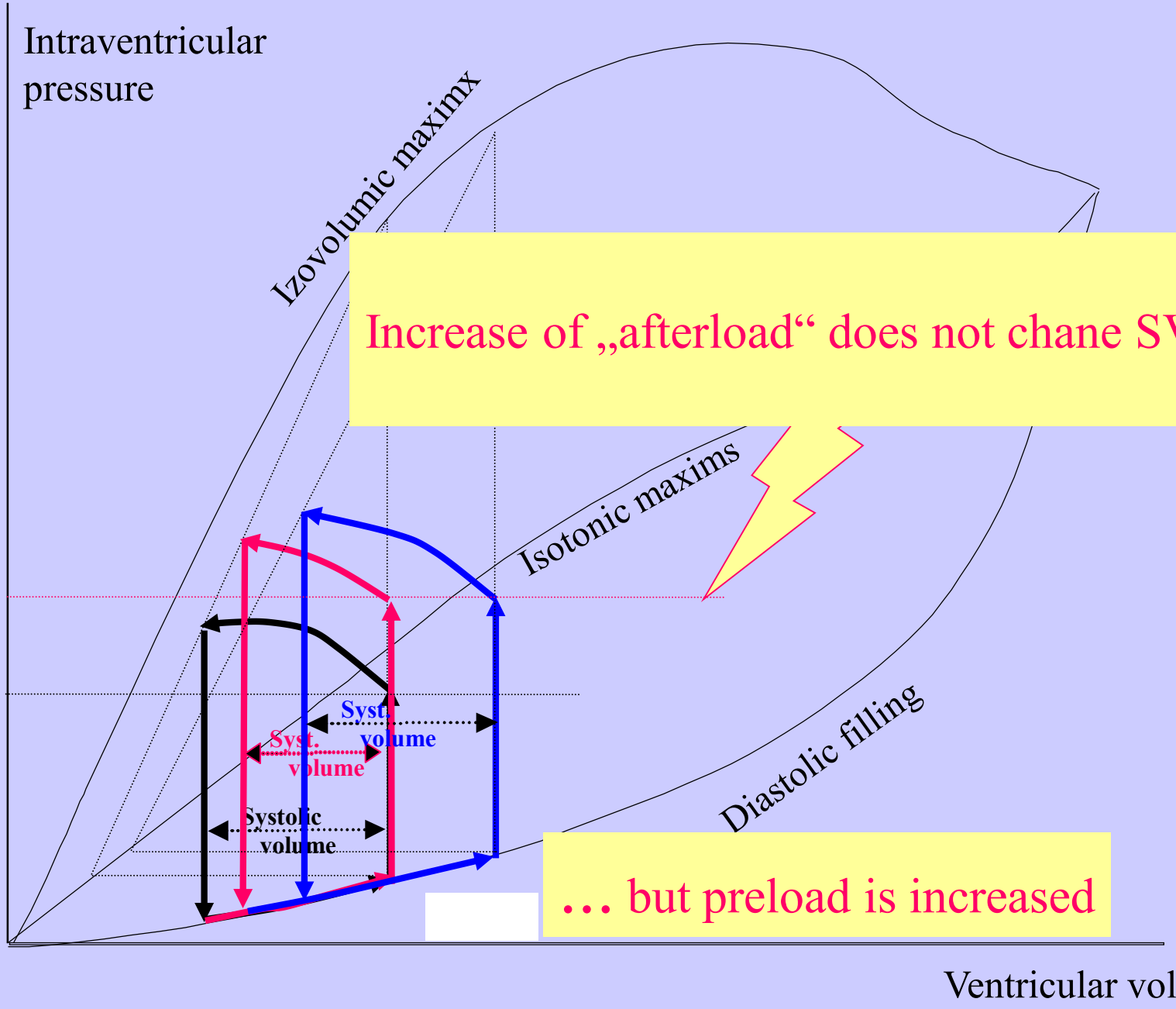

Increase of „afterload“ does not chane SV

… but preload is increased

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TYPES OF HEART FAILURE

- LEFT-SIDED

- RIGHT-SIDED

- BOTH-SIDED

according to the failing ventricle

Preload

filling of the heart at the end of the diastole
enddiastolic volume = EDV
Frank-Starling mechanisms

Volume in the ventricle corresponds to the pressure – ***enddiastolic pressure***, EDP, ***filling pressure***

The relation between the filling of the ventricle and the intraventricular pressure

diastolic filling curve

volume: EDV - enddiastolic volume
pressure: EDP - enddiastolic pressure, filling pressure

- amount of the blood in the ventricle
- properties of the ventricle wall

HEART FAILURE

pathophysiologic state in which an abnormality of *cardiac* function is responsible for the failure of the heart to pump blood at a rate commensurate with the requirements of the metabolizing tissues

decrease of cardiac output

***and/or* can do so only from an abnormally elevated diastolic volume**

increase of the ventricular filling pressure (enddiastolic pressure, EDP)

General symptoms of cardiac failure from the hemodynamic point of view

Low CO

Weakness, fatigue, decreased perfusion of the organs incl. the kidneys, muscles

- ***redistribution of CO***

FORWARD

Accumulation of blood/fluid prior to the failing ventricle

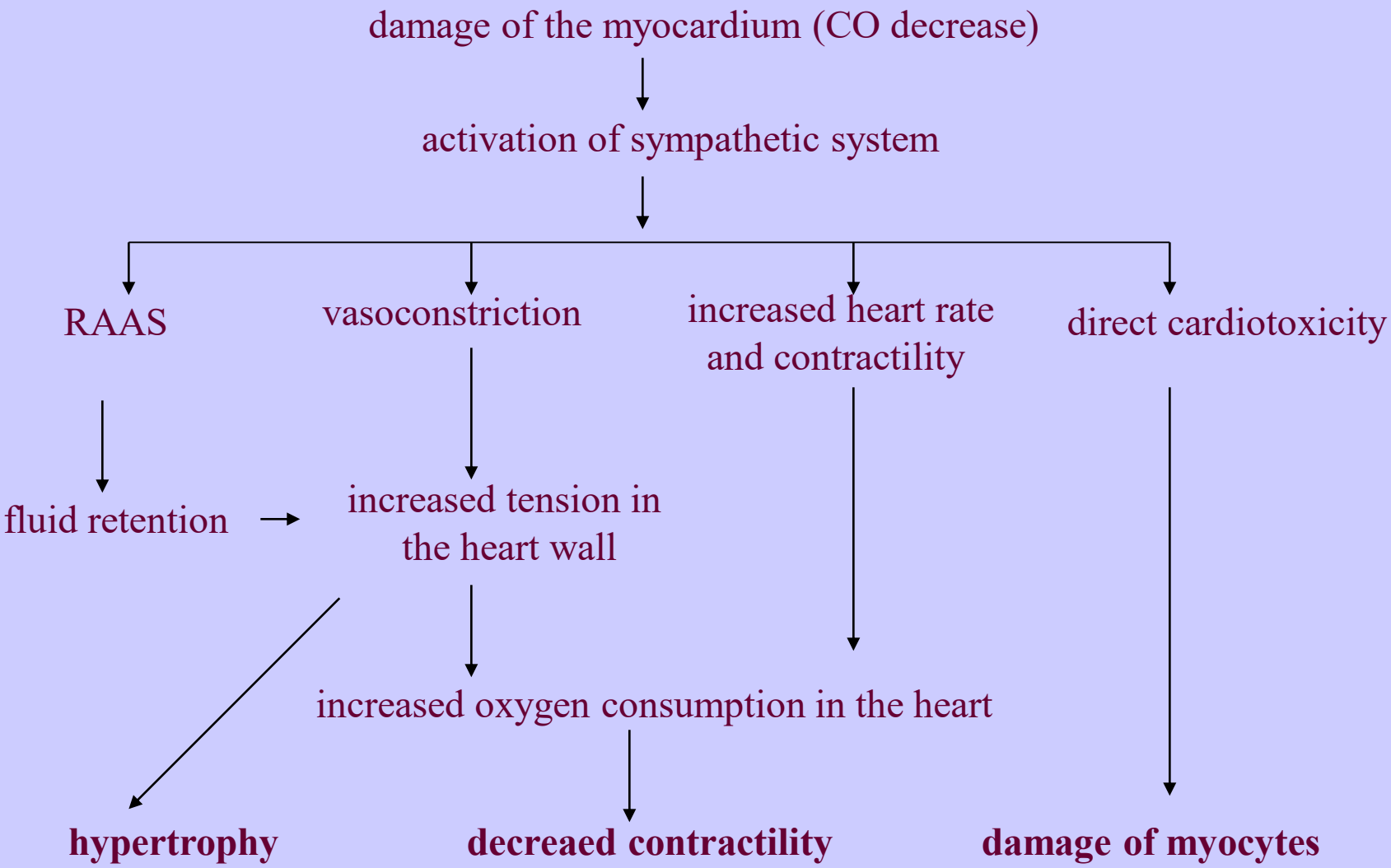
Congestion, edemas

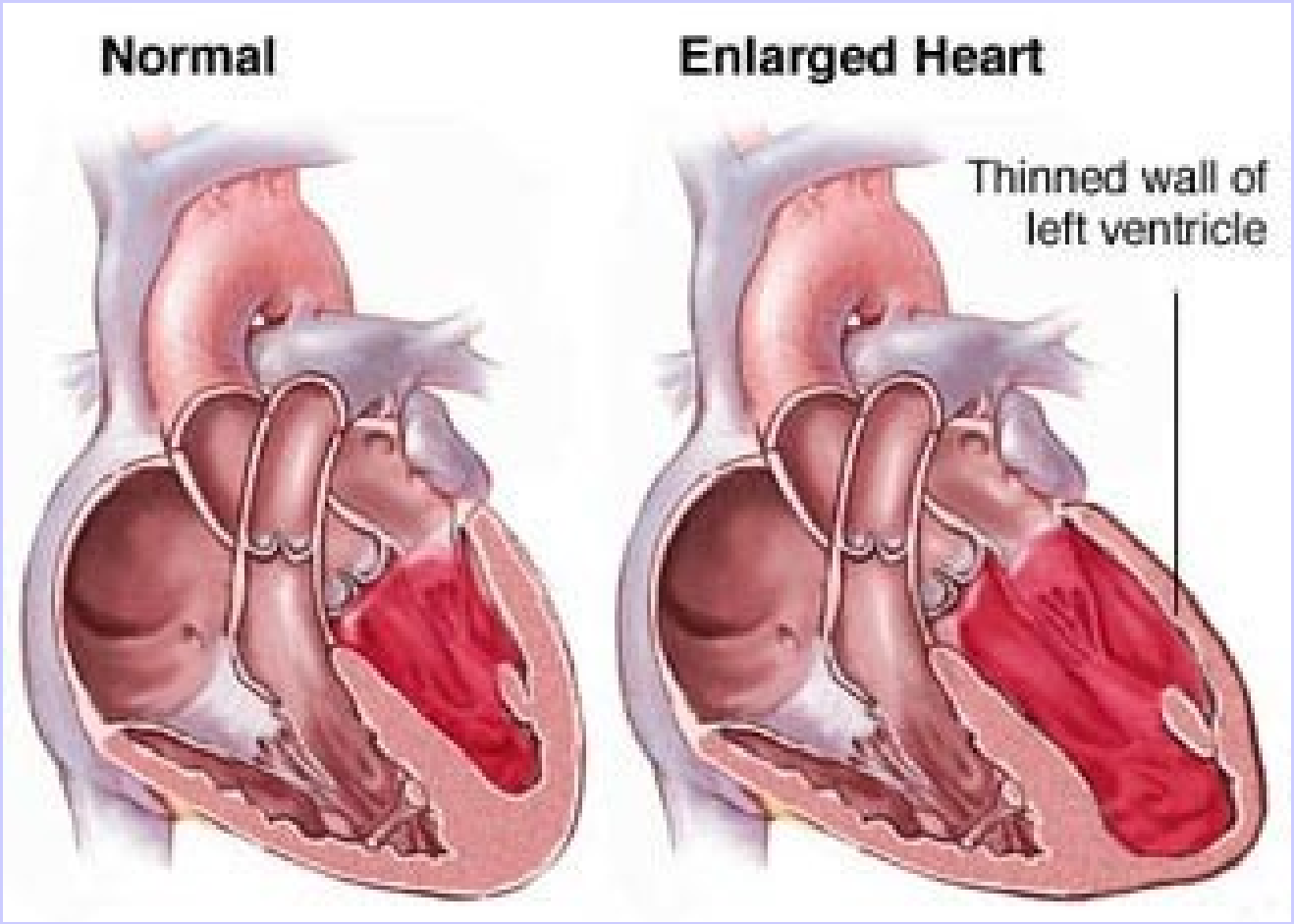
BACKWARD

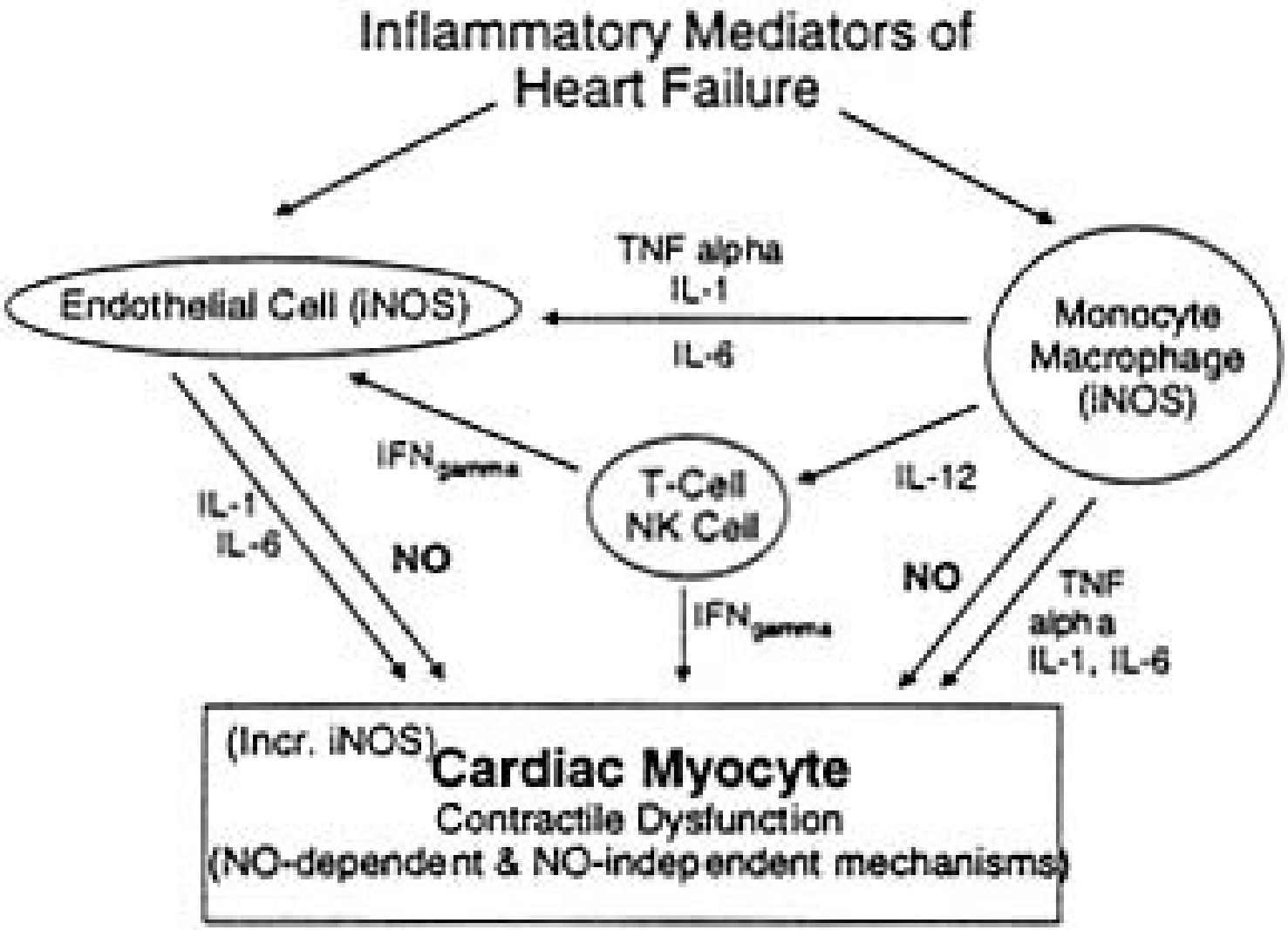
Systemic changes in heart failure

Apart from ***hemodynamic*** changes heart failure is characterized by important involvement of compensatory mechanisms, mainly ***neurohumoral***, which can, however, if persisting, lead to further progression of failure. Another changes involve the ***heart*** itself.

Compensatory mechanisms – can in ***short-term*** have a positive role, in ***long-term*** persistence contribute to the worsening of the failure.


damage of the myocardium (CO decrease)
activation of sympathetic system
RAAS
vasoconstriction
increased heart rate and contractility
direct cardiotoxicity
fluid retention
increased tension in the heart wall
increased oxygen consumption in the heart
hypertrophy
decreaed contractility
damage of myocytes


Normal
Enlarged Heart
Thinned wall of
left ventricle


Inflammatory Mediators of Heart Failure
Endothelial Cell (iNOS)
TNF alpha
IL-1
IL-6
Monocyte Macrophage (iNOS)
IFNgamma
T-Cell NK Cell
IL-12
IL-1
IL-6
NO
NO
IFNgamma
TNF alpha IL-1, IL-6
(Incr. iNOS)
Cardiac Myocyte
Contractile Dysfunction
(NO-dependent & NO-independent mechanisms)