# Hemodynamic Disorders, Thromboembolic Disease and Shock (Part 1)

Lilla Madaras

250 years of EXCELLENCE in medical education, research & innovation and healthcare

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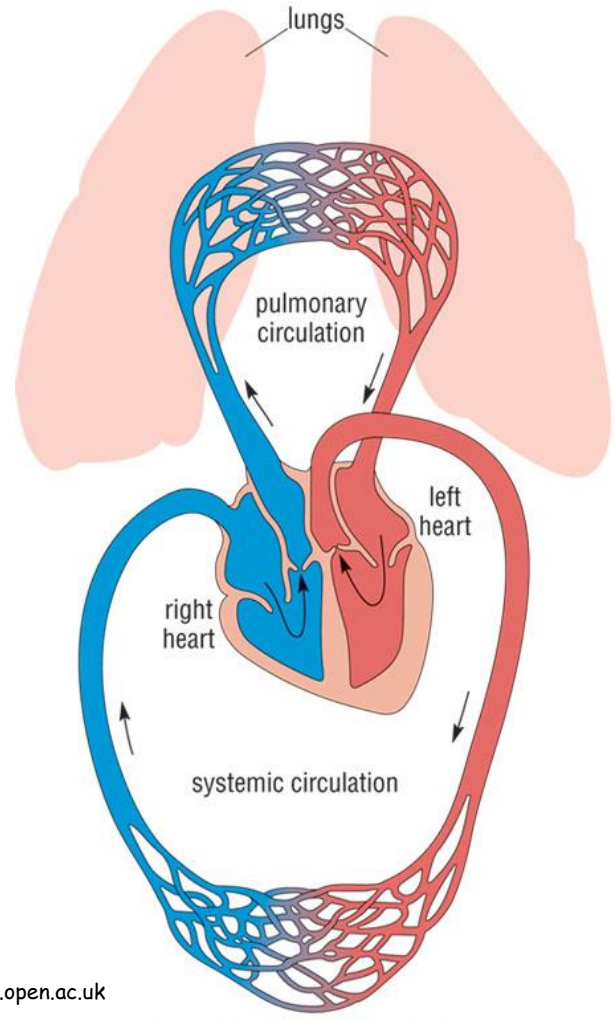
Semmelweis University
http://semmelweis.hu
2nd Department of Pathology

# Normal fluid homeostasis

- Vessel wall integrity
- Intravascular pressure and osmolarity in physiologic ranges
- Maintaining blood as a liquid

# Protagonists

- Heart
- Blood vessels and lymphatic vessels
- Blood

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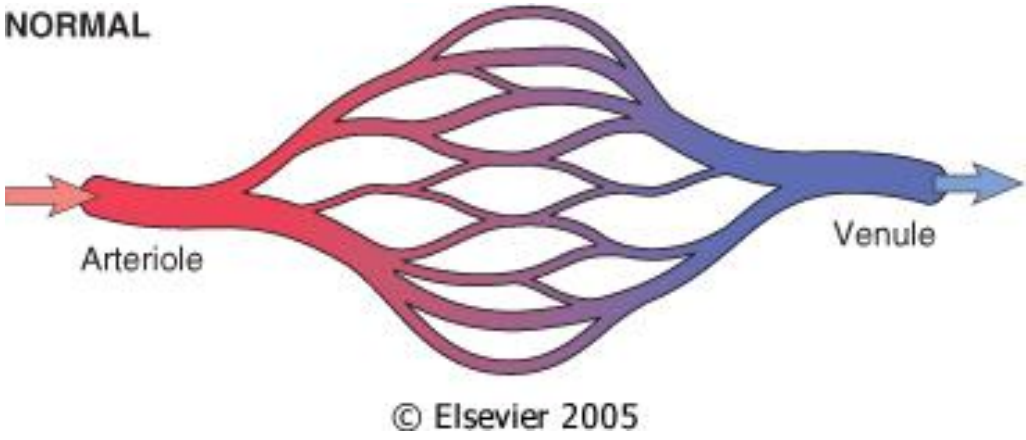
# Hemodynamic disorders

- Hyperemia (active and passive)
- Edema
- Hemorrhage
- Thrombosis
- Embolism
- Infarction
- Shock

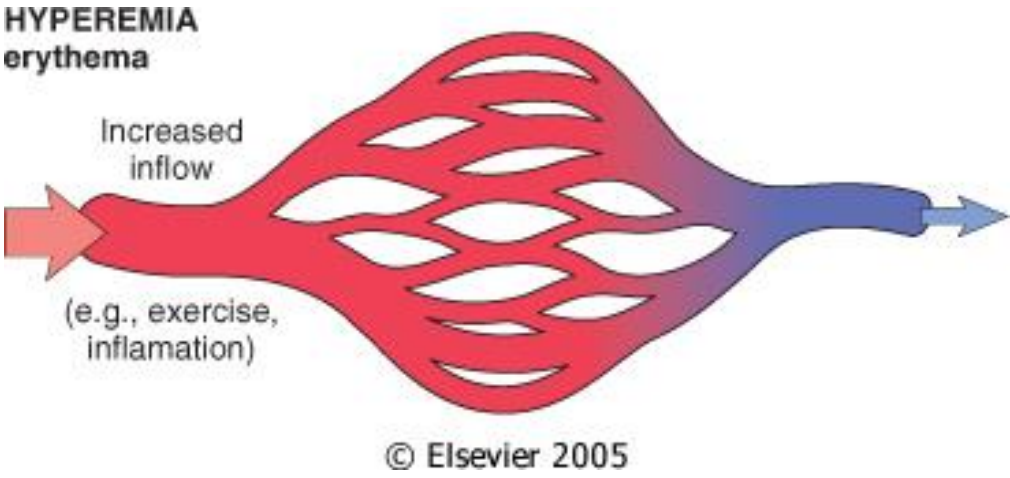
# HYPERAEMIA

# HYPEREMIA I.

- **Definition:** locally increased blood volume
- **Forms**:
  - active,
  - passive/congestion

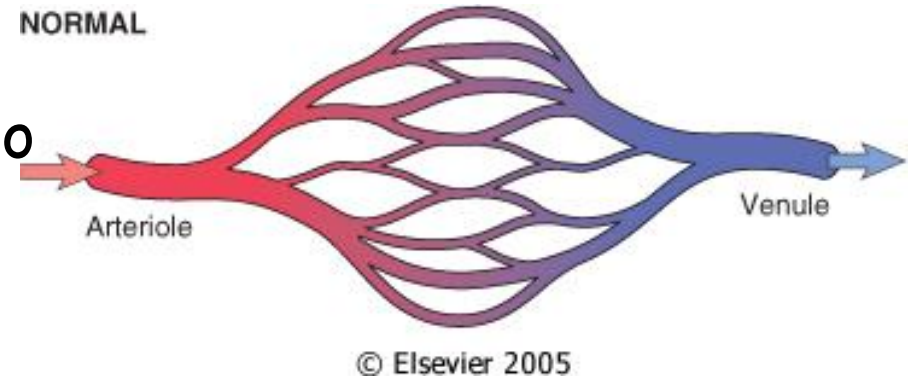


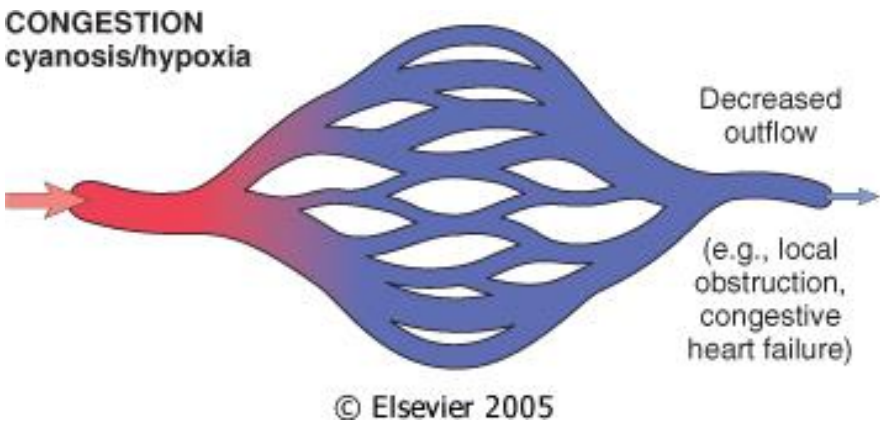

- **ACTIVE HYPEREMIA**
  - Active dilation of arteriae, arterioles, capillaries
  - erythema
  - Forms: physiological, pathologic (inflammation, fever, chemical and physical injury)



# HYPEREMIA II.

- **PASSIVE HYPEREMIA** (congestion)
  - dilation of venous side due to decreased outflow
  - cyanosis, hypoxia
  - **Causes**:
    - **Local**: thrombosis, obstruction
      - Deep venous thrombosis-legs
      - Pylethrombosis- portal congestion
      - V.cava sup. syndrome
    - **Systemic**: congestive heart failure



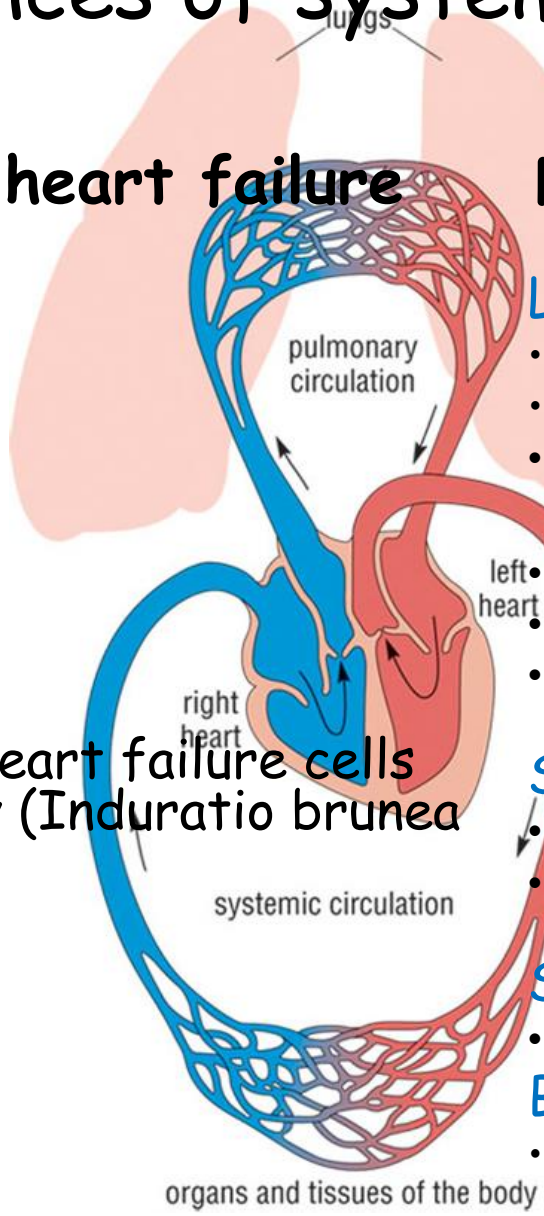



# Consequences of systemic chronic congestion

## Left sided heart failure

### Lungs

heavy, firm, heart failure cells on microscopy (Induratio brunea pulmonum)




## Right sided heart failure

### Liver

- nutmeg liver (hepar moschatum)
- centrilobular necrosis
- cardiac fibrosis (cirrhosis-misnomer!)

### Kidneys

- stellate veins accentuated
- cortex widened
- sharp separation of medulla and cortex

### Spleen

- enlarged, livid
- fibrosis with time (Induratio cyanotica lienis)

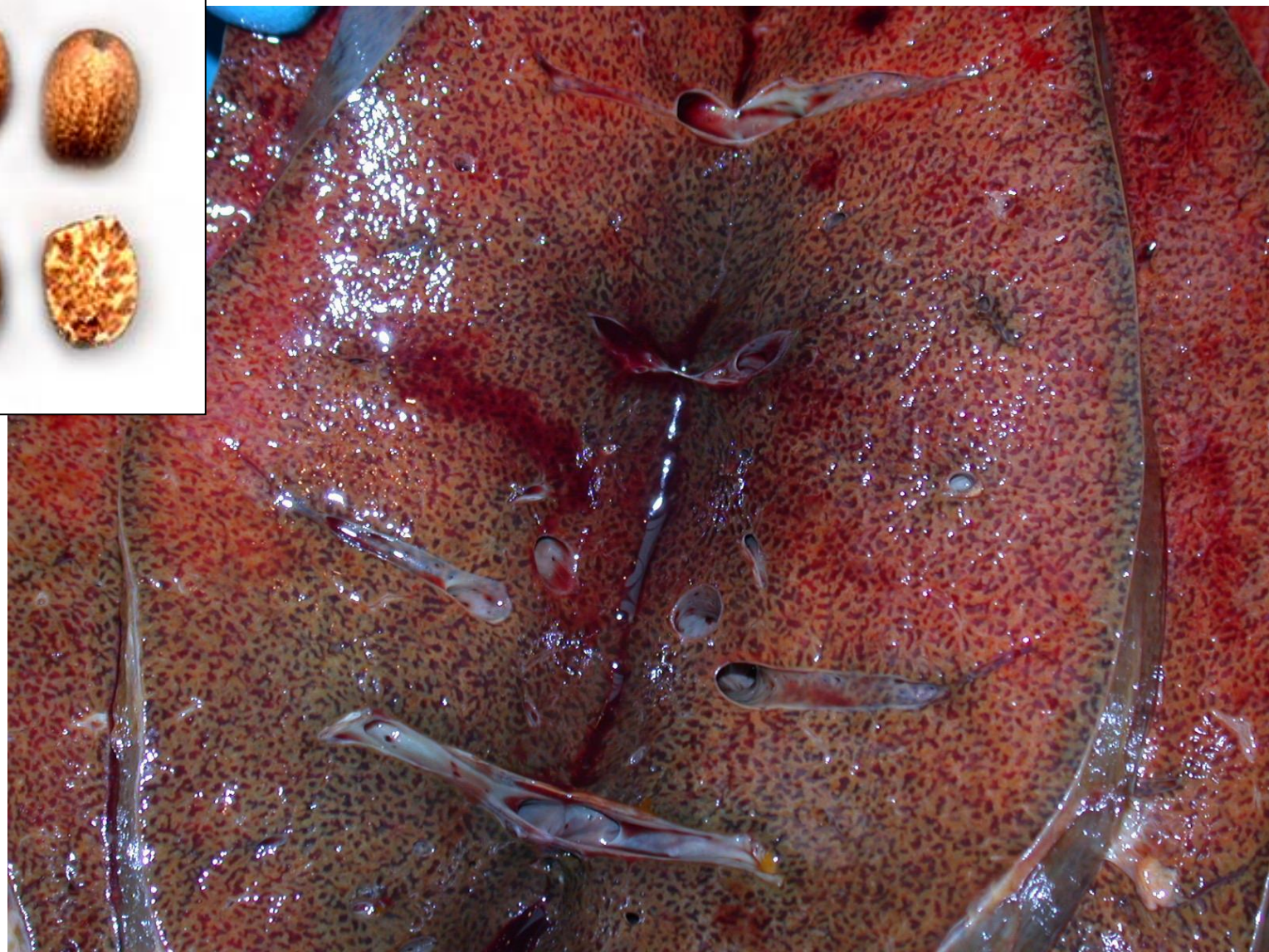
### Skin

- cyanosis, anasarca

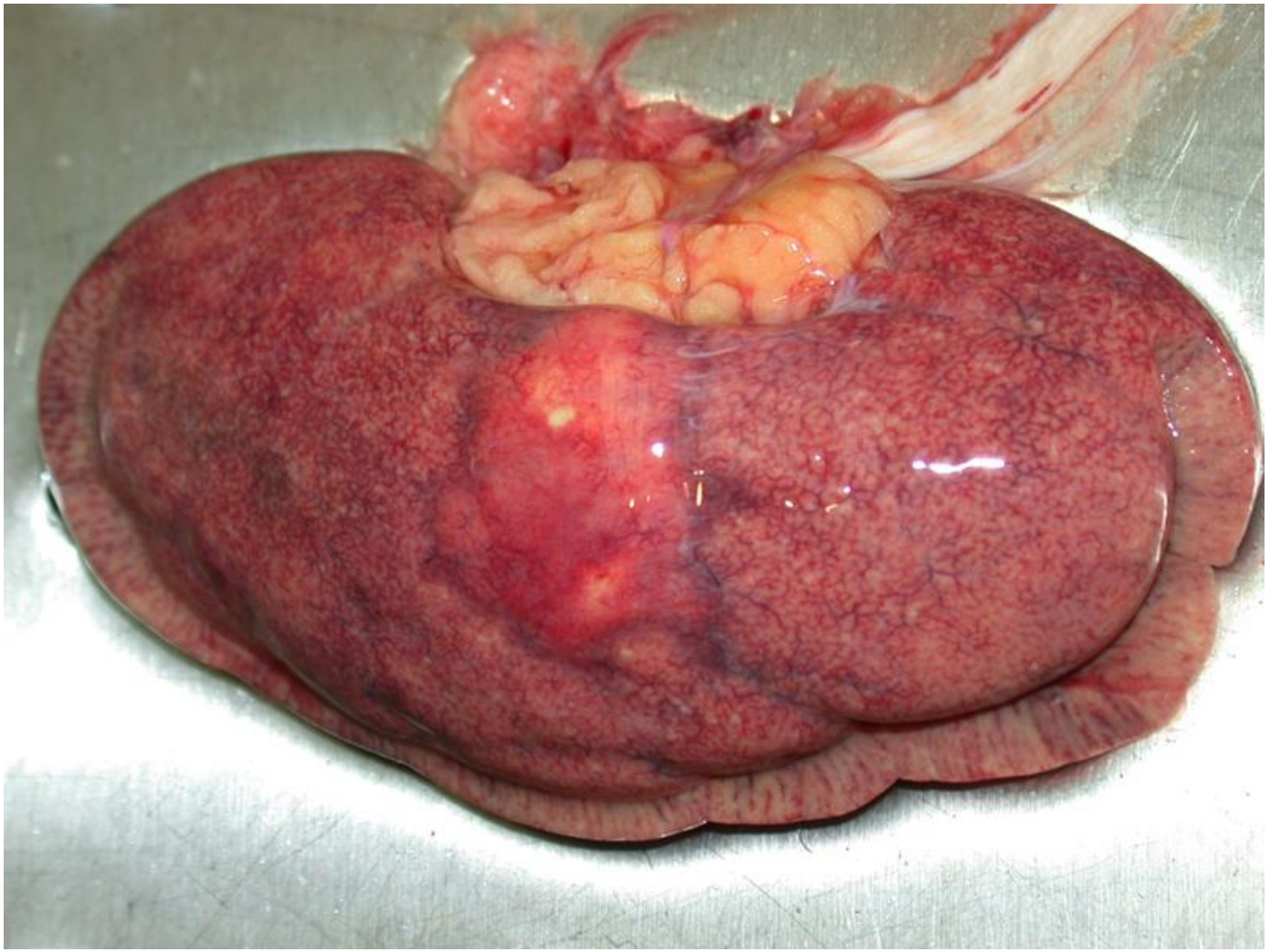
### Body cavities

- Ascites, hydrothorax

# Systemic congestion-Nutmeg liver

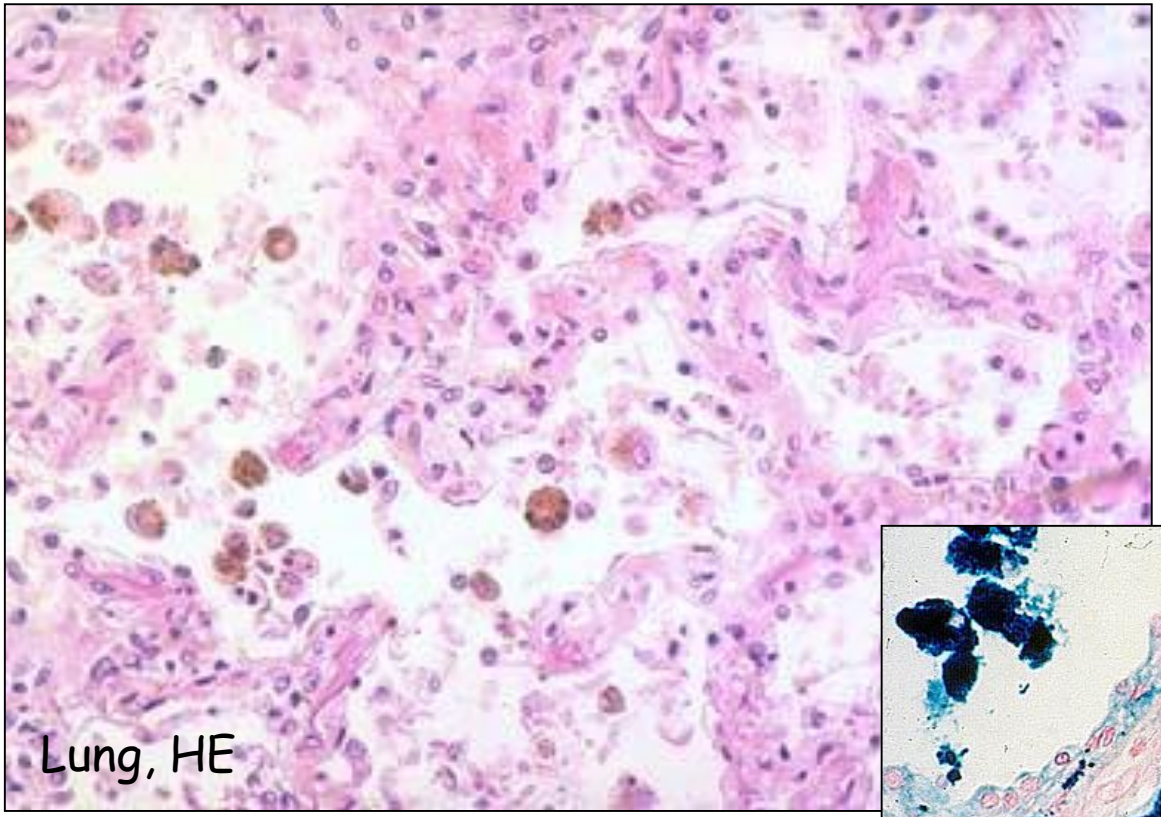


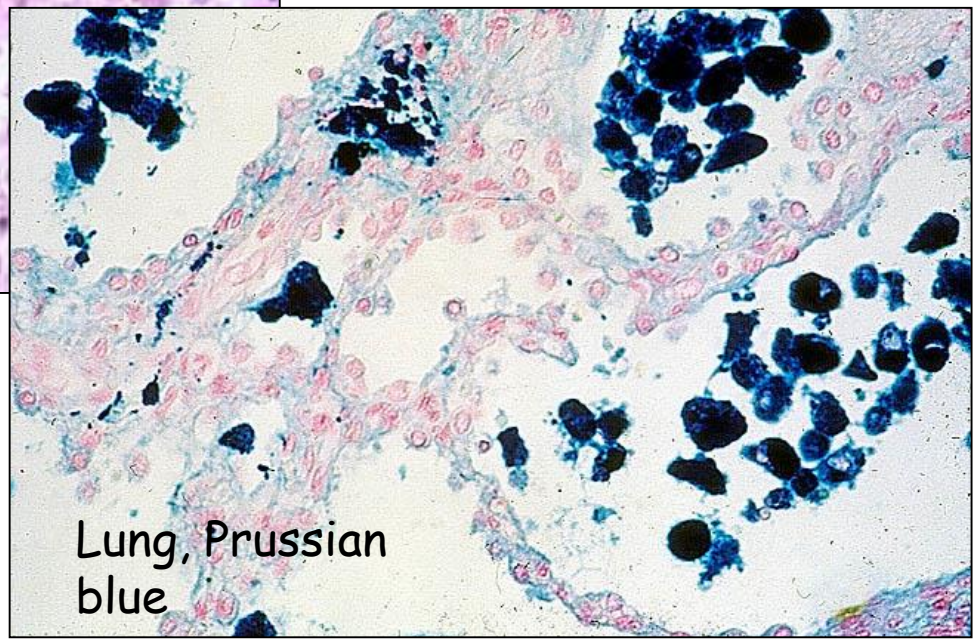
# Systemic congestion (+?) - kidney



# Lung, chronic passive hyperemia/ congestion

# Hemosiderin in heart failure cells

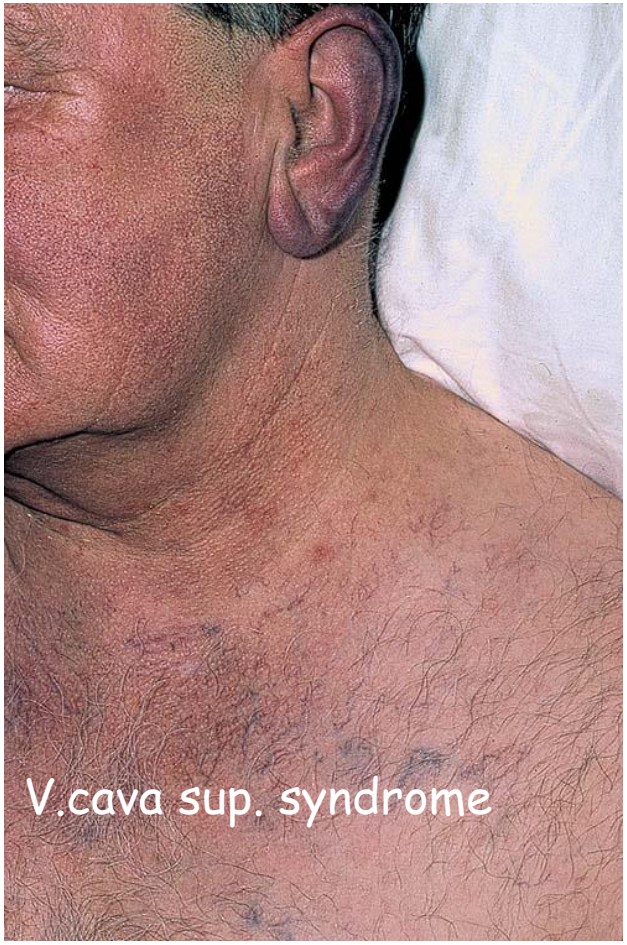


# Local chronic congestion

- May occur in every organ
  - E.g. vena cava superior syndrome,
  - Budd-Chiari sy (hepatic vein thrombosis),
  - extremities etc.

# Local congestion




# EDEMA

# EDEMA

- Definition: increased fluid content in the interstitium

(transudate or exudate)

- Causes:
  - **INCREASED INTRAVASCULAR HYDROSTATIC PRESSURE**

    (arteriolar dilation or impaired venous return)

    (**LOCAL**- eg. Deep venous thrombosis of the legs,

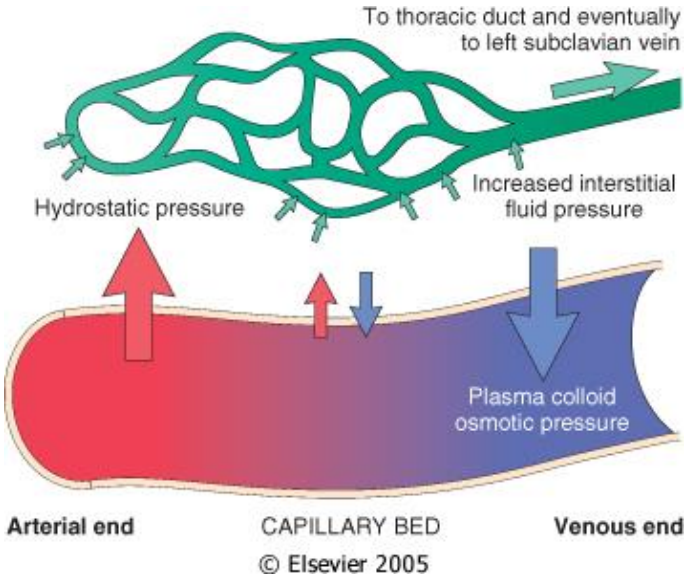
    **SYSTEMIC**- eg. Congestive heart failure)
  - **DECREASED PLASMA COLLOID OSMOTIC PRESSURE**

    (eg. nephrosis sy, cirrhosis, protein malnutrition)
  - **LYMPHATIC OBSTRUCTION** (lymphedema, elephantiasis)
  - **SALT AND WATER RETENTION** (GN, Acute renal failure)
  - **INFLAMMATION** (EXUDATE)

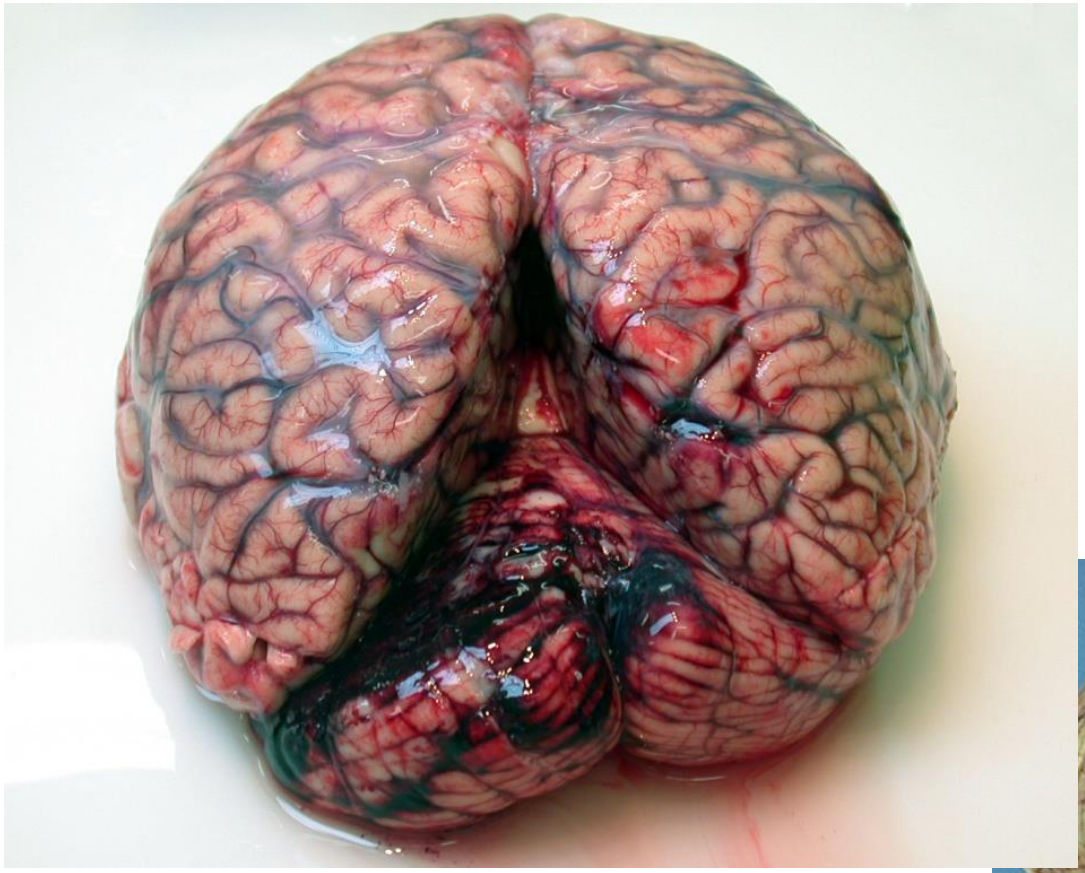
**Normal fluid homeostasis:**

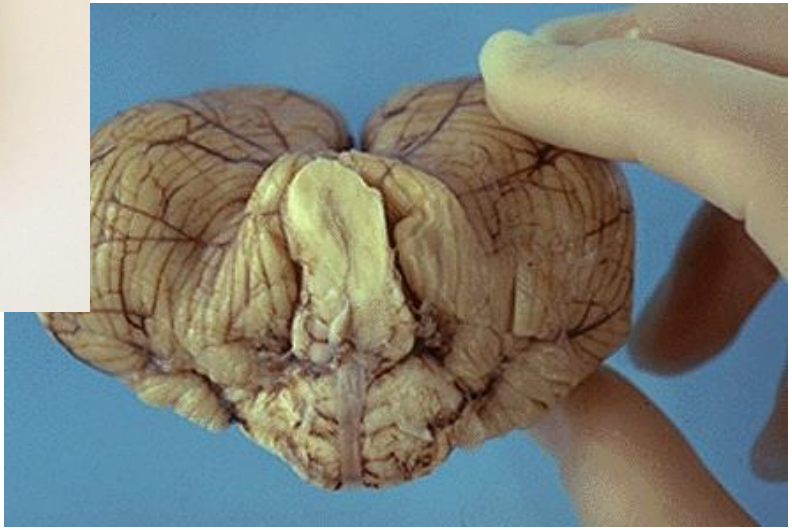
60% of body weight is water

2/3 intracellular, 5% blood, remainder within interstitium

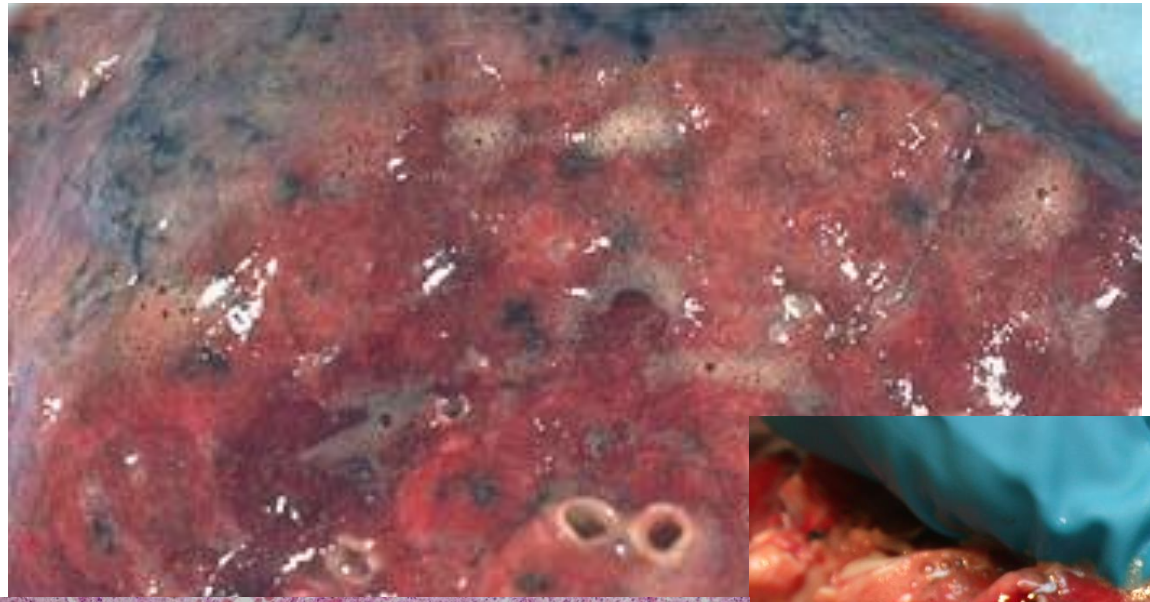


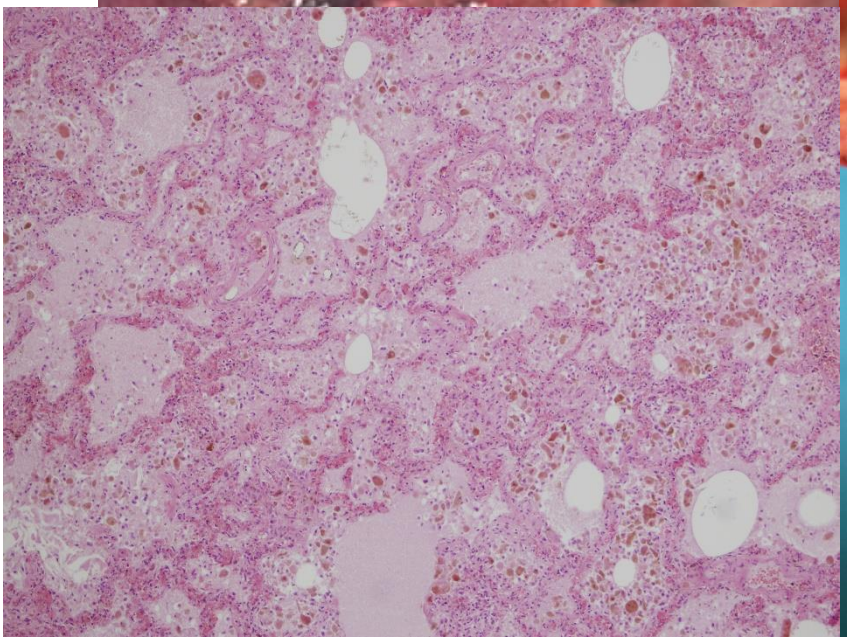
# Cerebral edema- tonsillar herniation

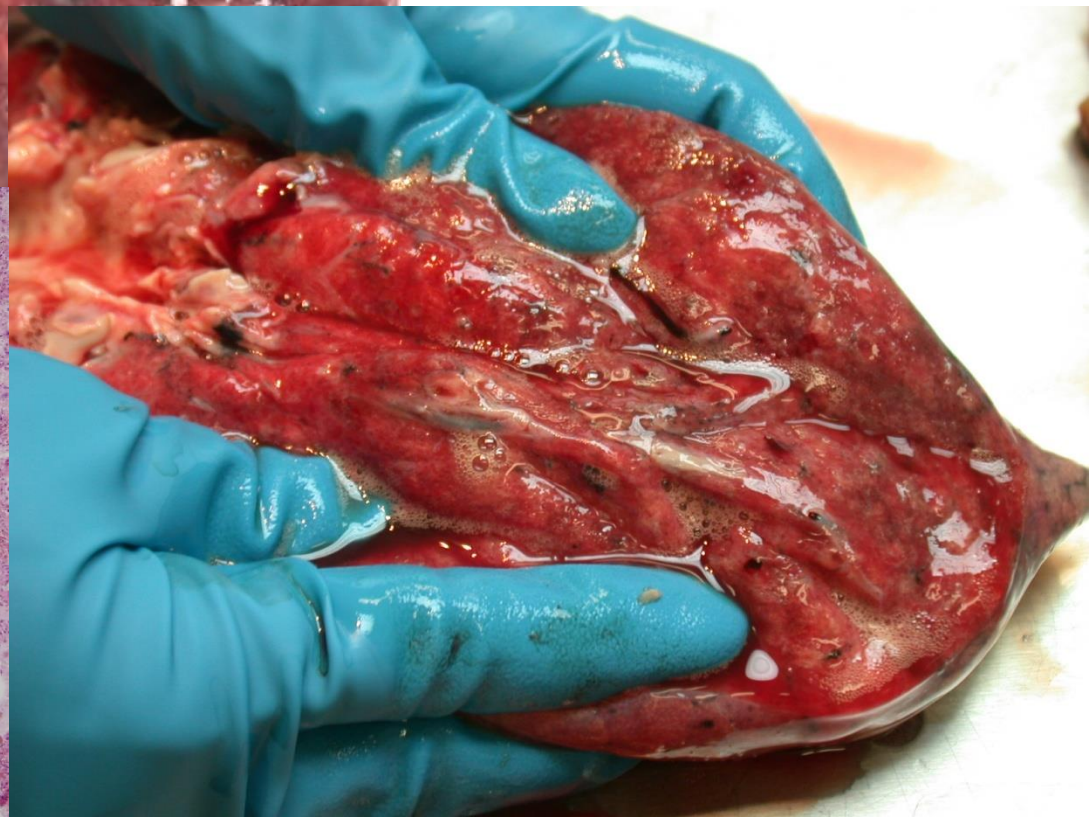


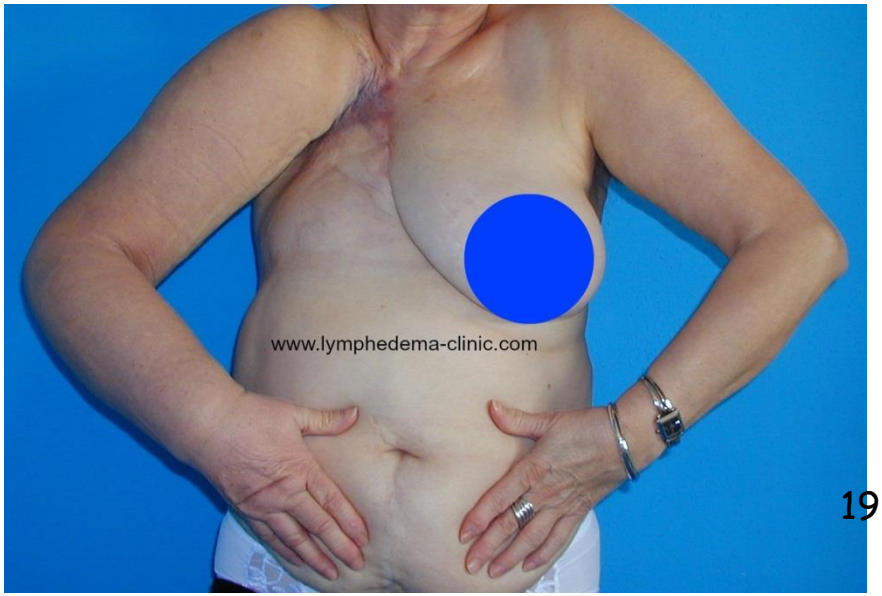


# Pulmonary edema





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# HEMORRHAGE

# Hemostasis-protagonists

- Vascular wall (endothelium)
- Platelets
- Coagulation cascade

# Normal hemostasis–sequence of events

- **Arteriolar vasoconstriction** (major regulator: endothelin)
- Platelet adherence, activation and aggregation ⇒ **Primary hemostasis** (major regulator: ECM)
- Fibrin meshwork creation, additional platelet recruitment ⇒ **Secondary hemostasis** (major regulator:Tissue factor)

# Hemorrhage

- **Definition:** Extravasation of blood
- **Pathogenesis:**
  - Rupture of vessel wall **(haemorrhagia per rhexim)**
  - Erosion of vessel wall **(haemorrhagia per arrosionem**)
  - Vascular wall disturbances and other hemorrhagic diatheses **(haemorrhagia per diapedesim)**
    - **Vessel wall abnormalities**: due to – hypoxia, infections, drugs, impaired collagen synthesis, Henoch-Schönlein purpura, Hereditary hemorrhagic teleangiectasia etc.
    - **Other hemorrhagic diatheses**

**-Thrombocytopenia** (low platelet count)

Decreased platelet production

Bone marrow diseases, bone marrow infiltration, drug induced (Heparin-induced thrombocytopenia), infections (HIV associated!) etc.

Decreased platelet survival

- Immune thrombocytopenic purpura ( ITP, autoimmune)
- Thrombotic microangiopathies (TTP: thrombotic thrombocytopenic purpura, HUS: Hemolytic- uremic syndrome)

**-Thrombasthenia (defective platelet function):** primary, secondary (aspirin!!!)

**-Abnormalities in clotting factors**

- Primary, or Secondary ( acquired – eg. In hepatic diseases!)
- Von Willebrand disease
- Hemophilia A (factor VIII deficiency)
- Hemophilia B ( Factor IX deficiency- Christmas disease)
- Hemophilia C (Factor XI deficiency)

**Disseminated intravascular coagulation (DIC**, consumption coagulopathy)

» Causes: obstetric complications, infections, neoplasms, excessive tissue injury

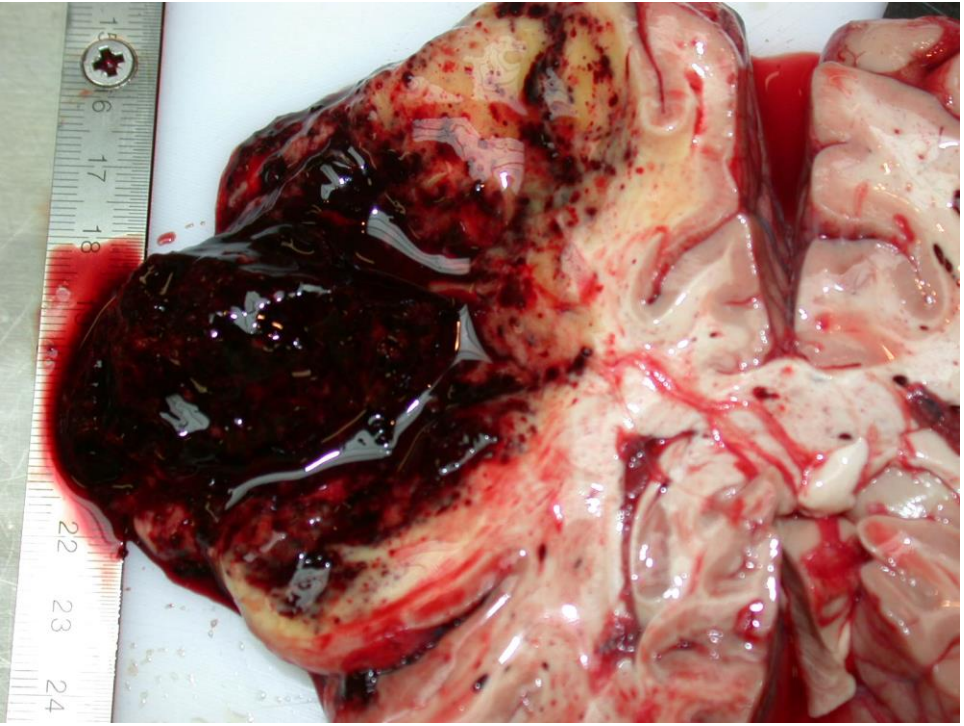
» Hemorrhage and thrombosis

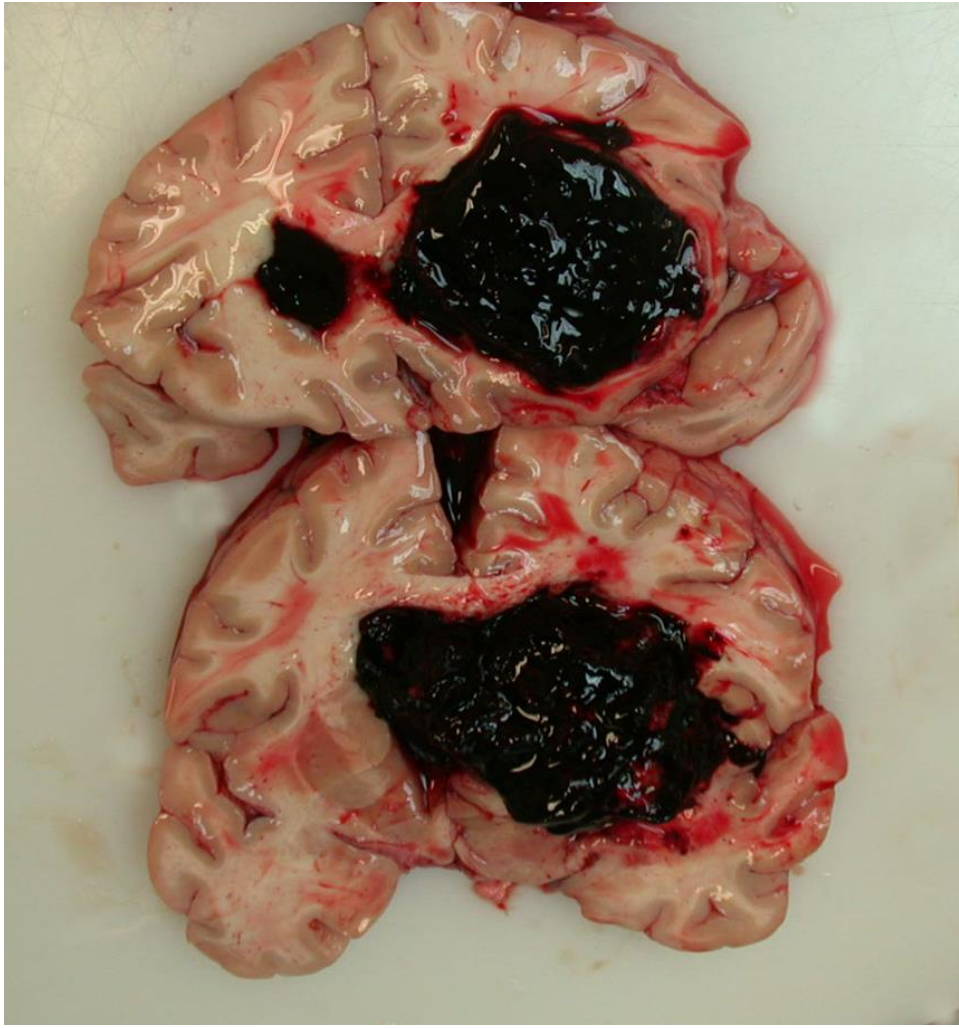
# Categories

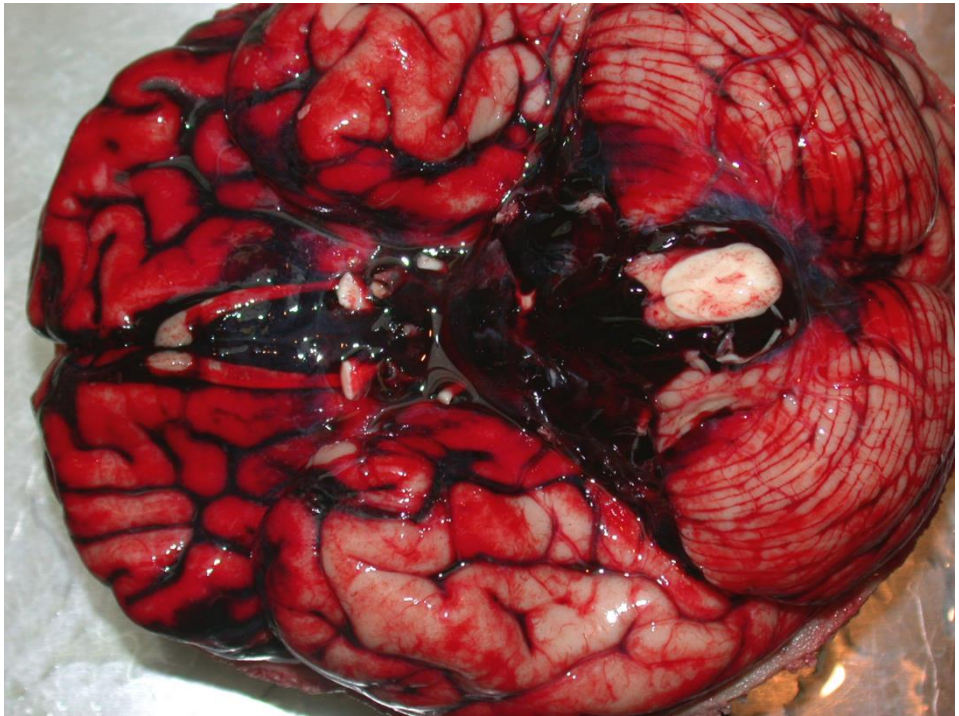
- By extent
  - Exsanguination, hematoma, suffusion, ecchymosis, purpura, petechia
- By localization

  eg: hemothorax, hemopericardium, hemascos, hemarthrosis, epistaxis, hematemesis, melena, hematochesia…

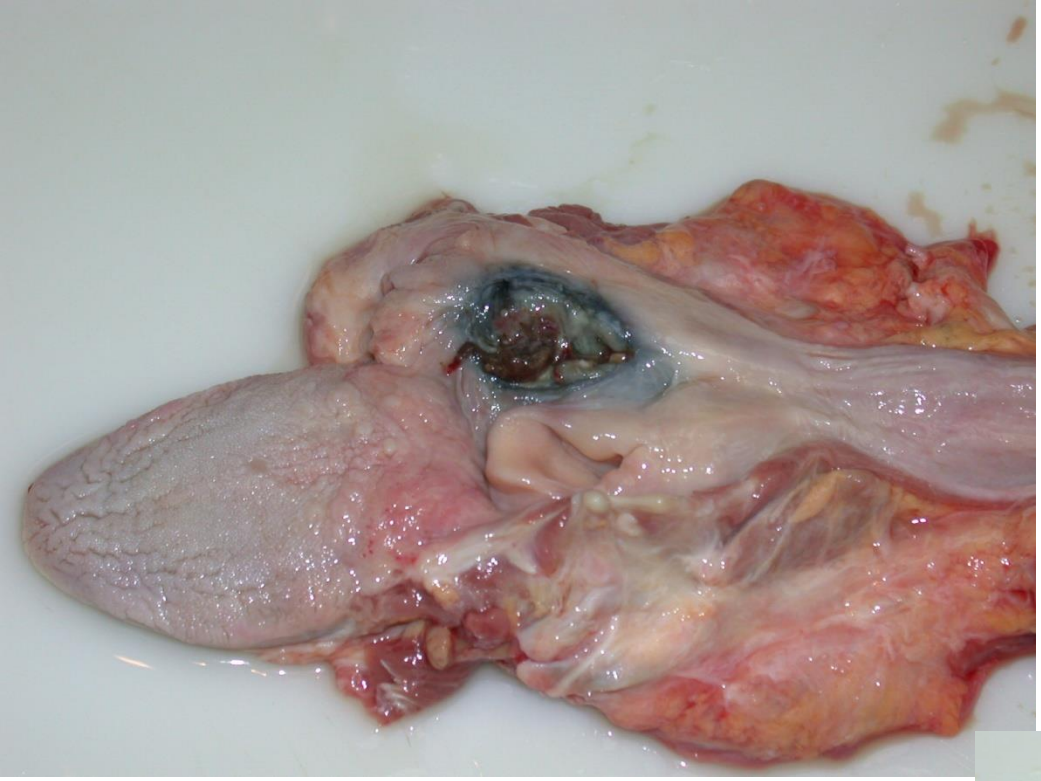
# By pathomechanism…

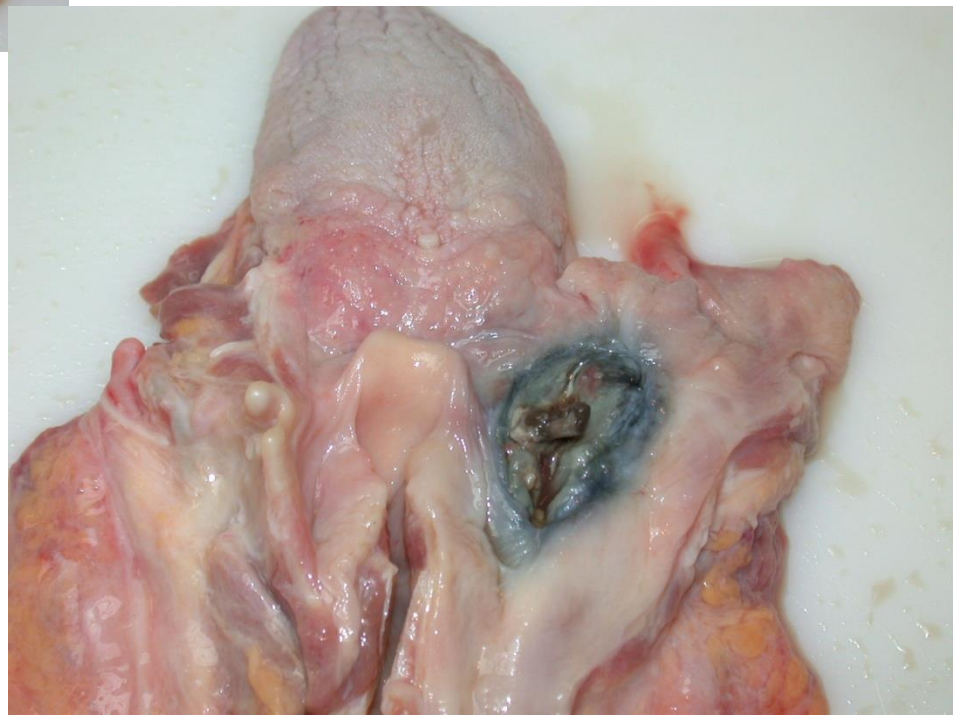






Haemorrhagia per rhexim (by rupture)- cerebral





Haemorrhagia per arrosionem
(by erosion)

(hypopharynx tumor)

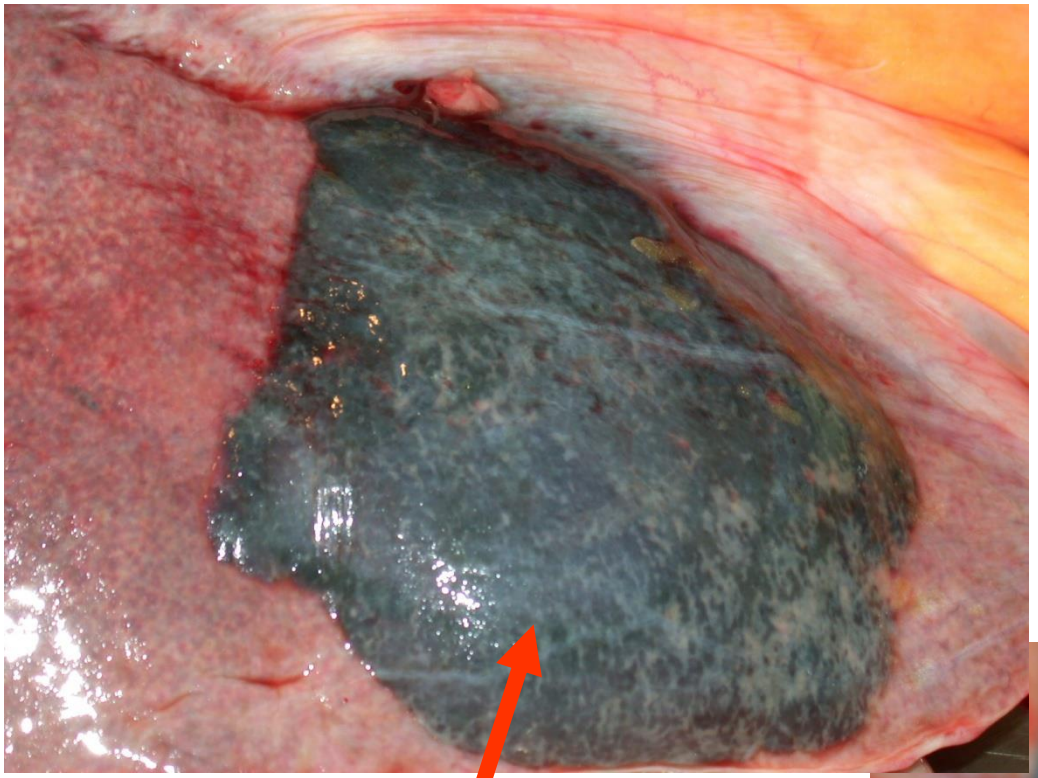
Petechiae- pericardium
( thrombocytopenia)

Petechiae- fat embolism due to trauma

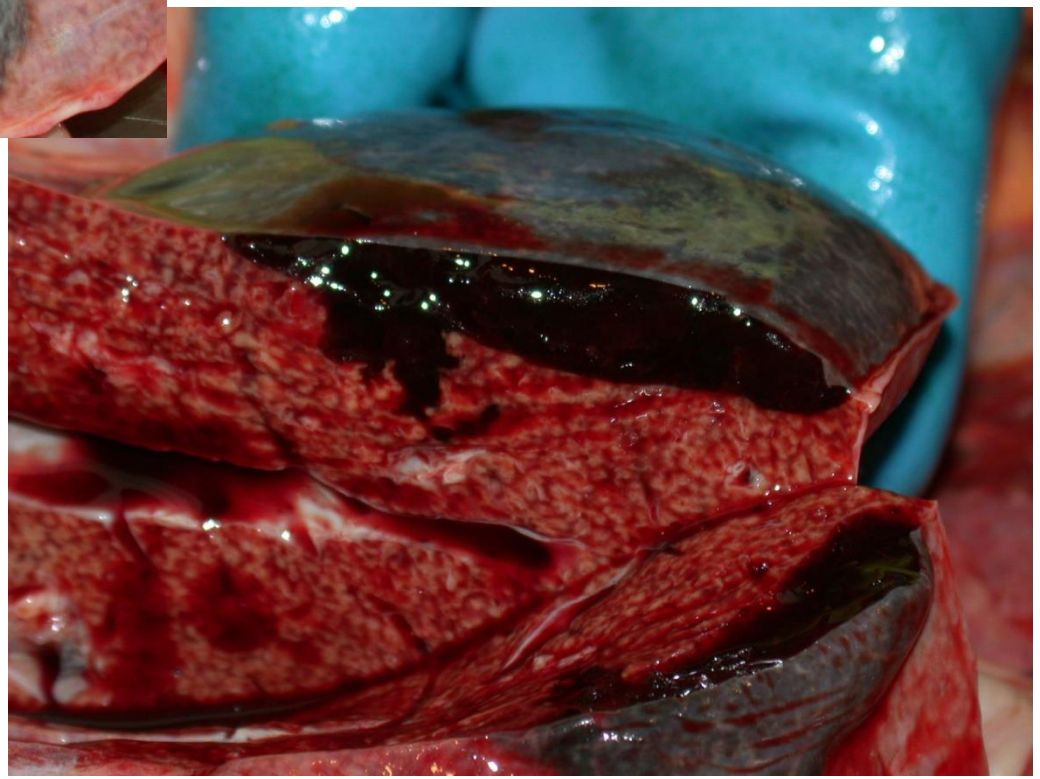
**Haemorrhagia per diapedesim (by diffusion)**

# Categories by extent…

# Subcapsular hematoma - liver

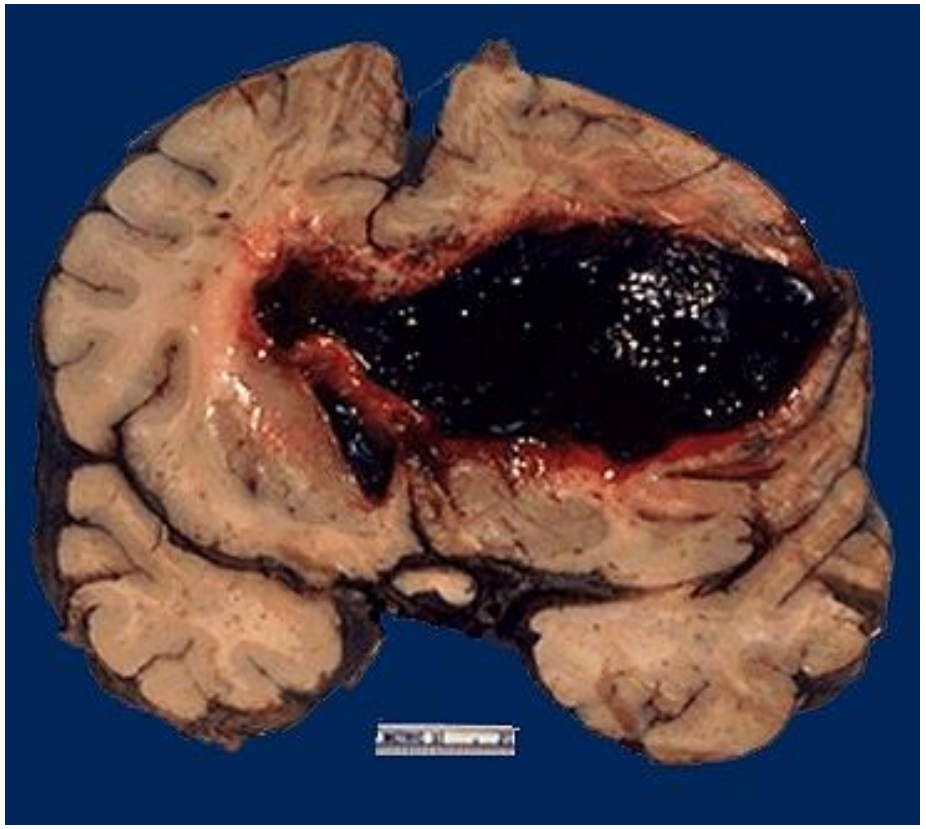


hematoma

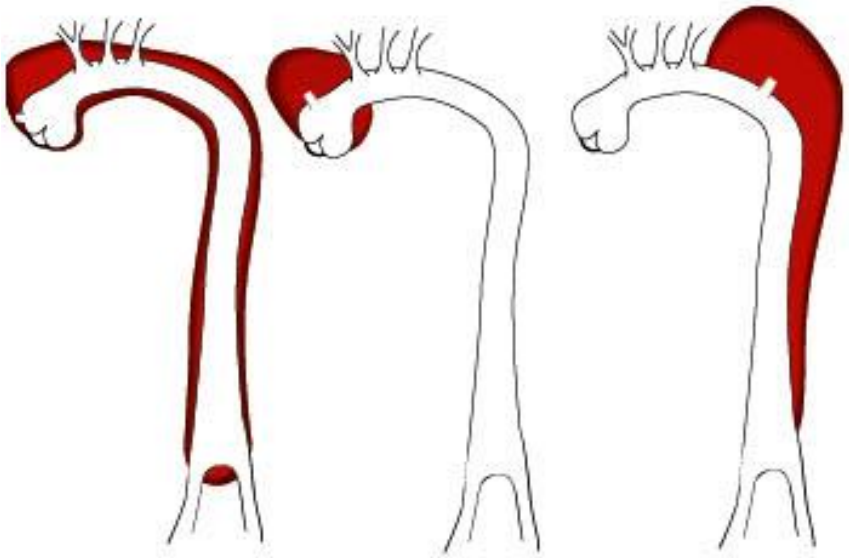


# Suffusion, hematoma

Thalamus -
hemorrhage-
hypertension



Apoplexia cerebri-
hypertension



Hemopericardium- due to aortic dissection

# THROMBOSIS

# THROMBOSIS

- **Definition**: coagulation of blood within vessels or heart chambers

- **Pathogenesis** (Virchow's triad)
  1. **Endothelial injury** (inflammation, hypertension, atherosclerosis etc.)
  2. **Stasis or turbulence** of blood flow
  3. **Hypercoagulability**
     - **Primary** (Genetic predisposition) (e.g. Leyden-mutation in factor V. (resistant to cleavage by protein C)
     - **Secondary (Acquired)**: smoking, obesity, drugs, pregnancy, malignant tumors (e.g. pancreas cc- Trousseau phenomenon), antiphospholipid antibody syndrome

# Classification by localization I.

## Arterial thrombosis

**Pathogenesis**: endothelial injury, turbulent blood flow (due to atherosclerosis, vasculitis)

**Complications**:

- **Ischemia** (non occlusive thrombus)
- **Infarction** (occlusive thrombus)

a.coron.-AMI, angina pectoris
Cerebral arteries- TIA, stroke, status lacunaris
a. mesenterica sup. or inf.- bowel infarction

# Classification by localization II.

**Venous thrombosis** (phlebothrombosis)

**Pathogenesis**: stasis (varicositas, immobilization), thrombophlebitis

**Localization**: 90% legs

Periprostatic, parametrial plexus, dura sinuses, v. portae, vv.hepaticae, Trousseau phenomenon: migratory thrombophlebitis

**Complications:** Ulcus cruris

Postthrombotic sy

Vena cava superior sy

Vena cava inferior sy- congestion in lower extremities, pelvis

# Classification by localization III.

**Thrombosis in heart chambers** (like arterial thrombosis)

**Pathogenesis**: endothelial injury (eg. AMI), turbulent blood flow (dilatation, AMI)

**Complications**: atrial, ventricular, valvular (endocarditis maranthica) thrombi may be the source of **embolism**

## Fibrin (Hyalin) thrombi

- In arterioles, capillaries, venules (disordered microcirculation)
- Composed of platelets, fibrin
- DIC

# Secondary hypercoagulable states

## High risk for thrombosis

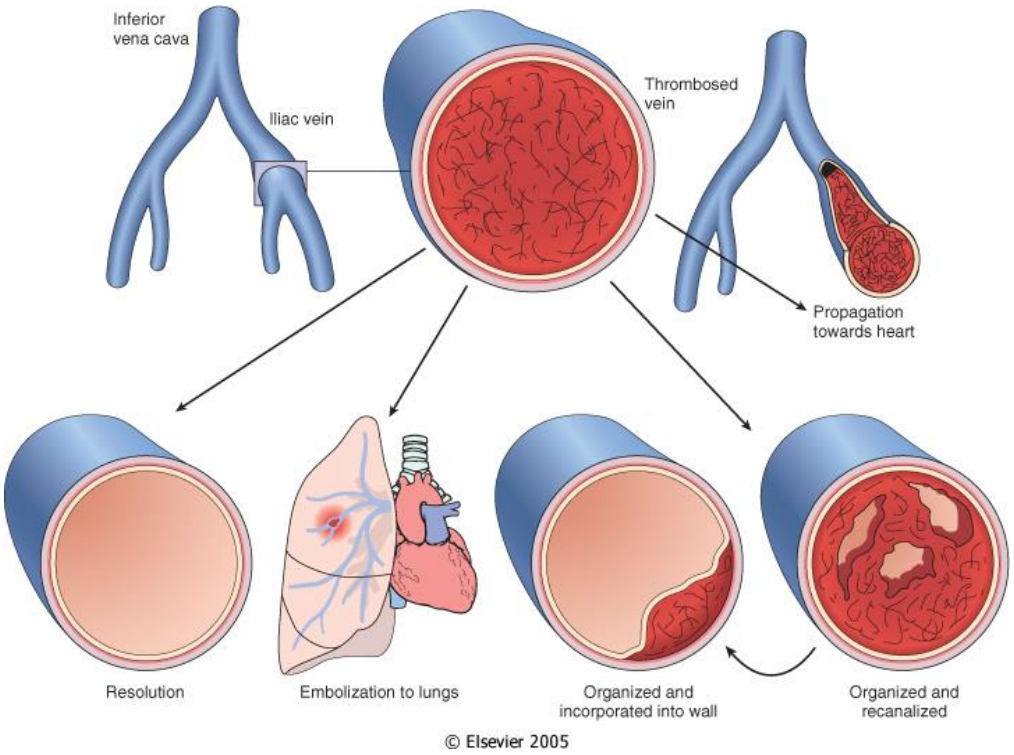
- Prolonged bed rest or immobilization
- Myocardial infarction
- Atrial fibrillation
- Tissue damage
  - (including surgery fractures, burns etc)
- Prosthetic cardiac valves
- Disseminated intravascular coagulation
- Heparin-induced thrombocytopenia
  - HIT (unfractionated heparin)
- Cancer
- Antiphospholipid antibody syndrome
  - („lupus anticoag.sy")

# Secondary hypercoagulable states

## Lower risk for thrombosis

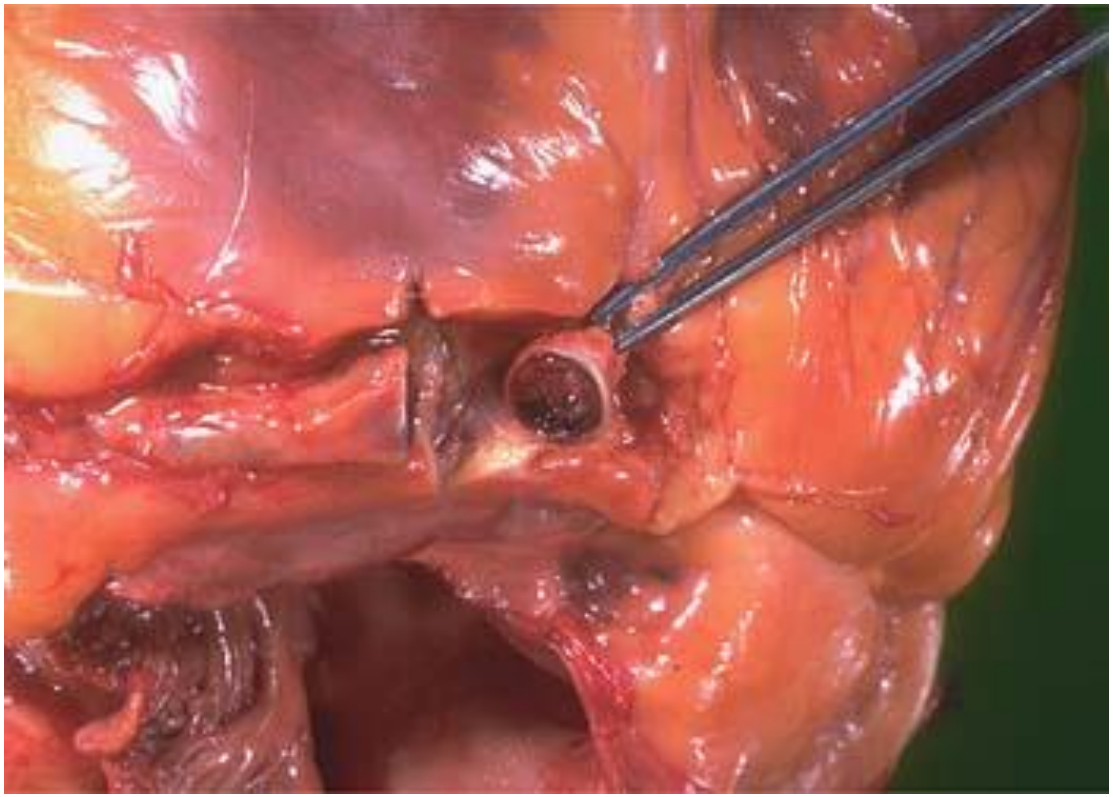
- Cardiomyopathy
- Nephrotic syndrome
- Hyperestrogenic states
  (Pregnancy,postpartum)
- Oral contraceptives
- Hyperlipidaemia
- Sickle cell anaemia
- Smoking

# FATE OF THROMBI



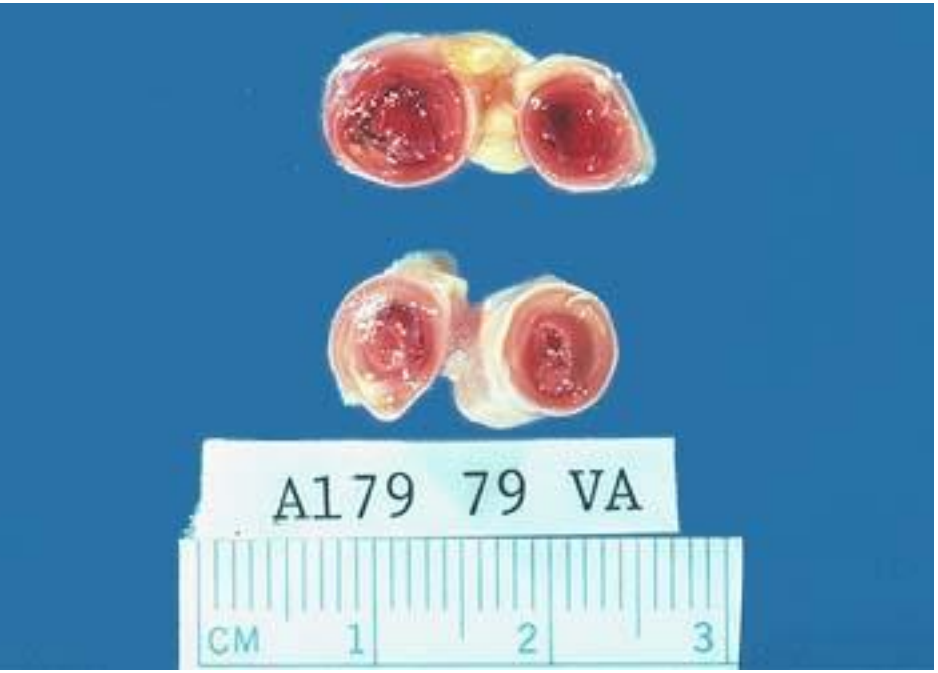

- Resolution
- Propagation
- Embolization
- Organization, recanalization

# Arterial thrombus



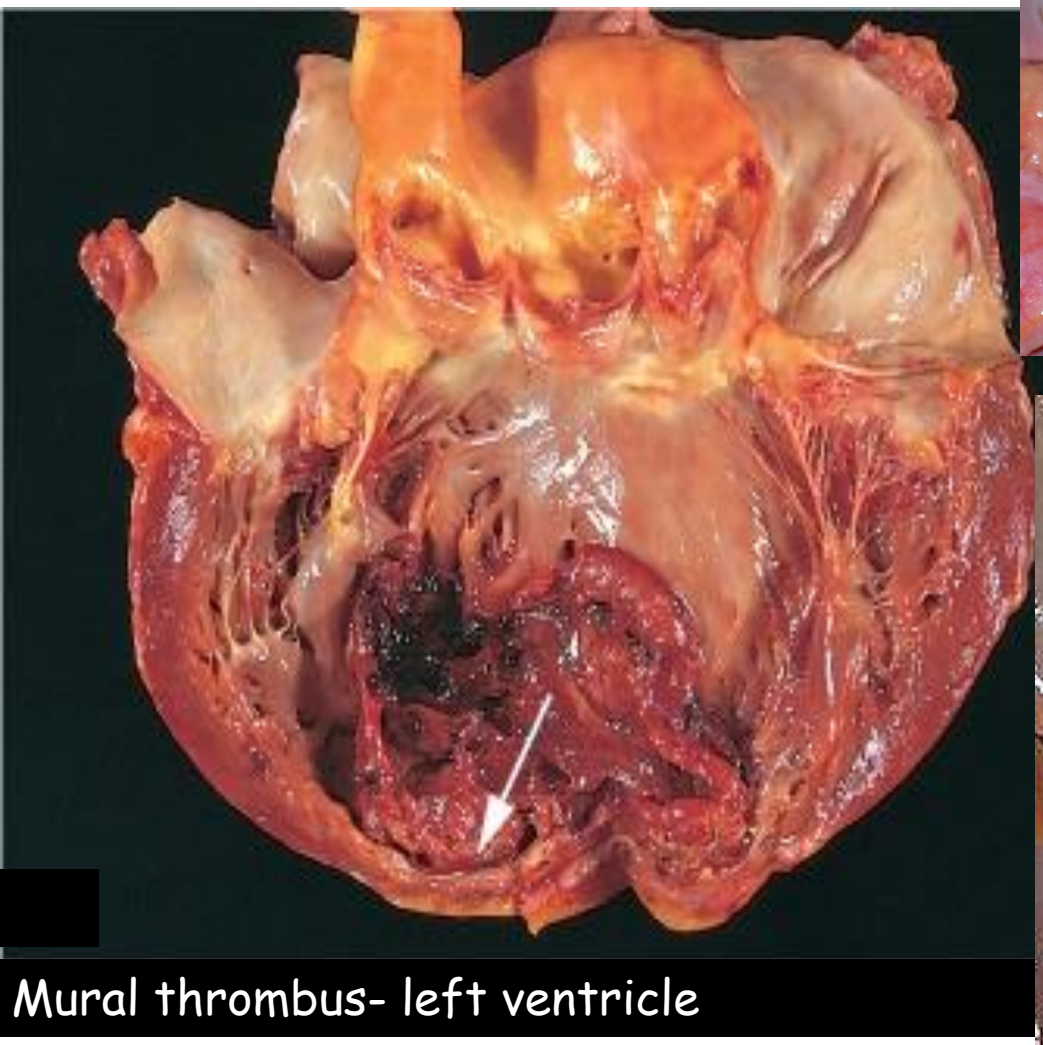
Coronary artery thrombosis

# Venous thrombosis

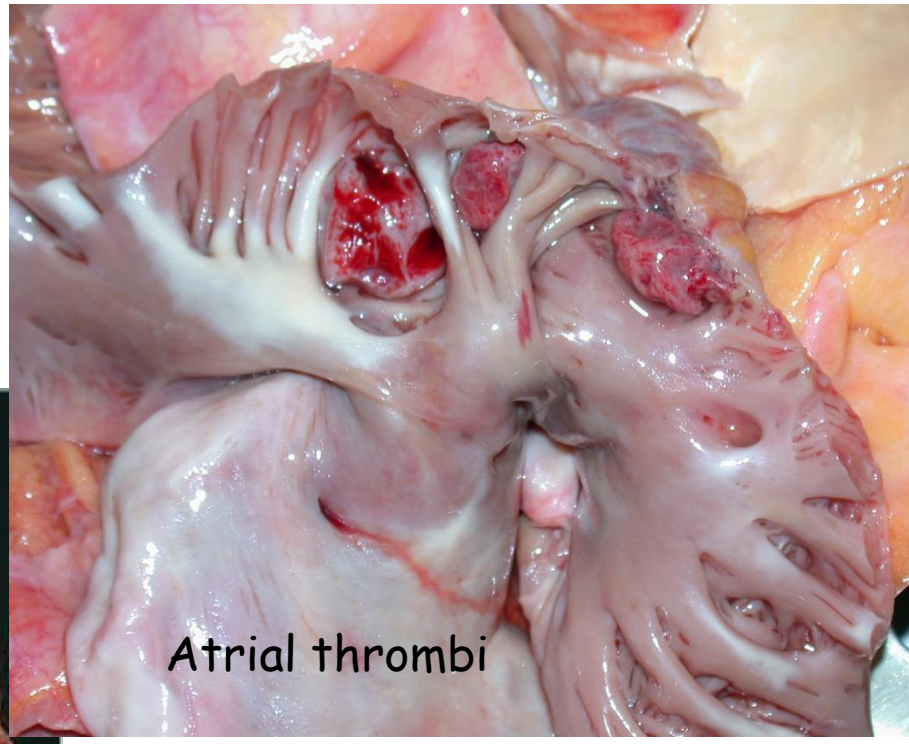



Thrombus in iliac vein

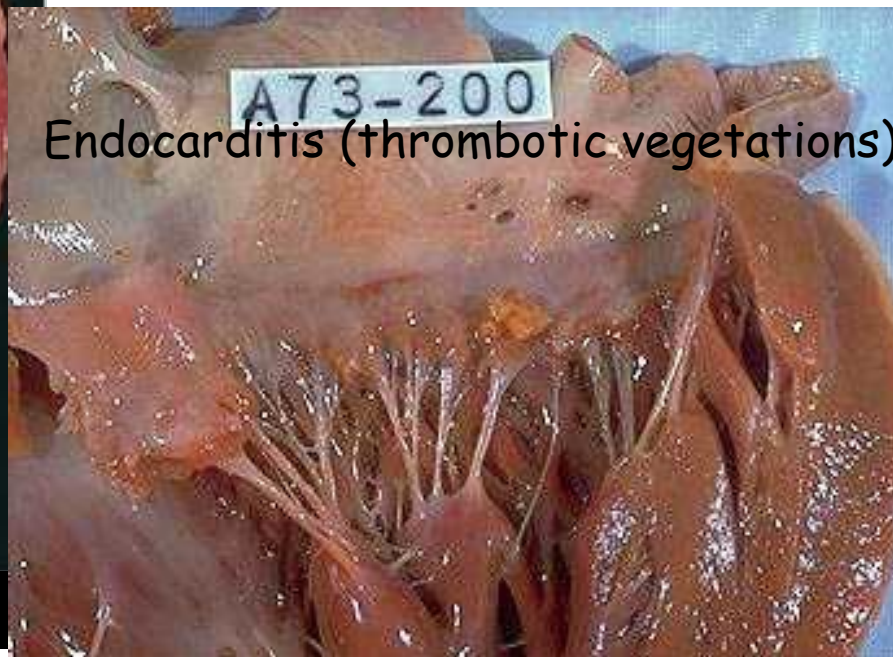
# Cardiac thrombi



Mural thrombus- left ventricle



Atrial thrombi




Endocarditis (thrombotic vegetations)

# EMBOLISM

- **Embolus**: detached intravascular gaseous, liquid or solid mass carried by the bloodstream from its site of origin to another site where it causes vascular obstruction and subsequent tissue damage (necrosis)
- **Forms**:
  - **Thromboembolism**
  - **Fat embolism**
  - **Air embolism**
  - **Amniotic fluid embolism-**pulmonary edema, ARDS, DIC
  - Cholesterol embolism- kidney
  - Bacterial embolism- e.g. infective endocarditis
  - Foreign body embolism- i.v. drug abusers

# Thromboembolism I.

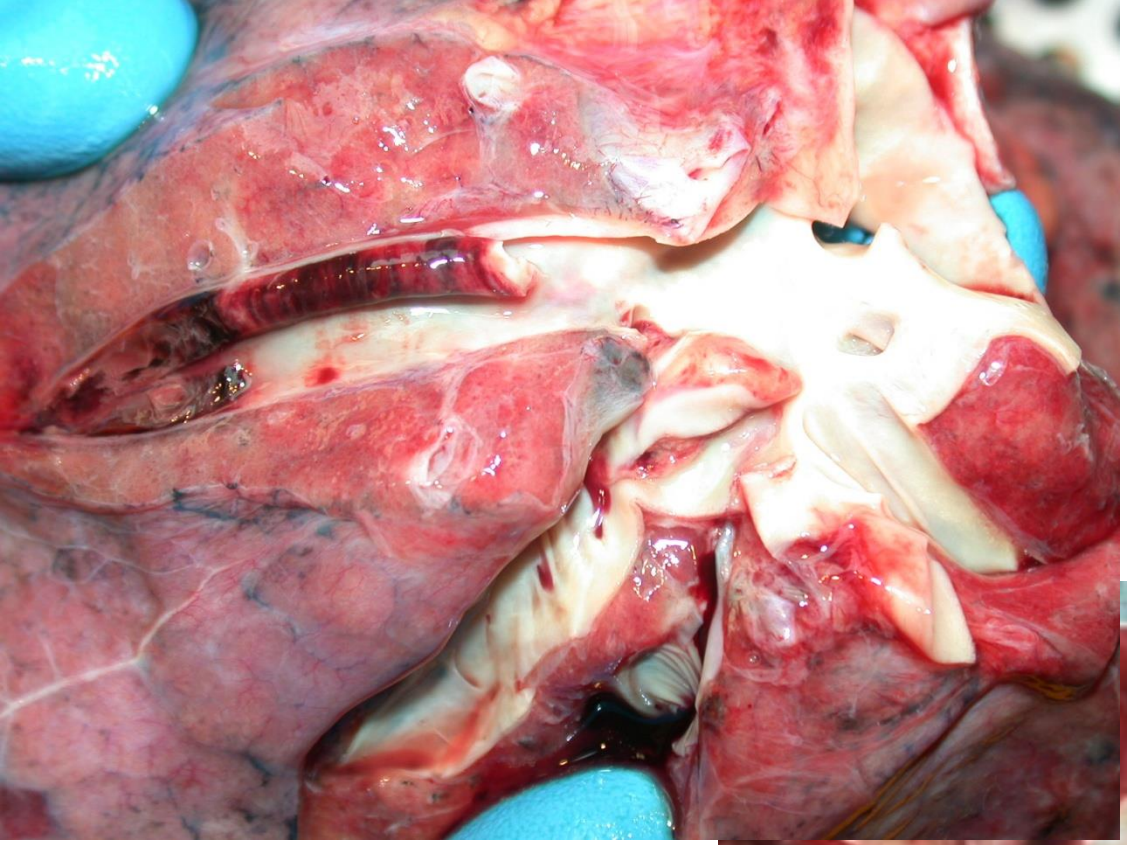
## Pulmonary thromboembolism

**Source**: deep venous thrombosis of lower extremities

**Possible complications**: - sudden death (saddle embolus)

- pulmonary hypertension, cor pulmonale
- hemorrhage, hemorrhagic infarction

# Pulmonary embolism



# Thromboembolism II.

## Systemic thromboembolism

**Source**: -80% mural thrombi within heart chambers (AMI, left atrial thrombi)

-others: aortic atherosclerosis, aortic aneurysm, vegetations (in endocarditis), unknown origin

**Paradoxical embolism**!

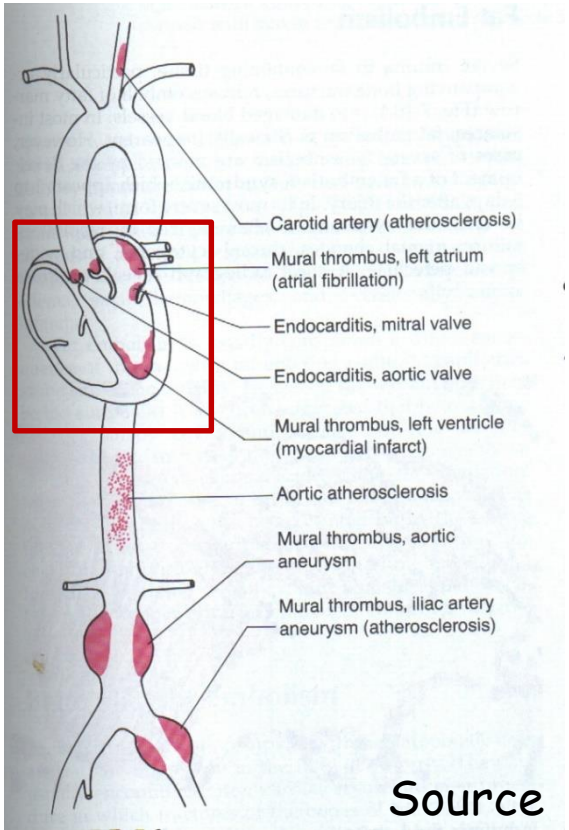
**Complications**: arterial embolization

-in lower extremities (75%)

-in the brain (10%),

-in arteries of bowel, kidney, spleen, upper extremities

→INFARCTION

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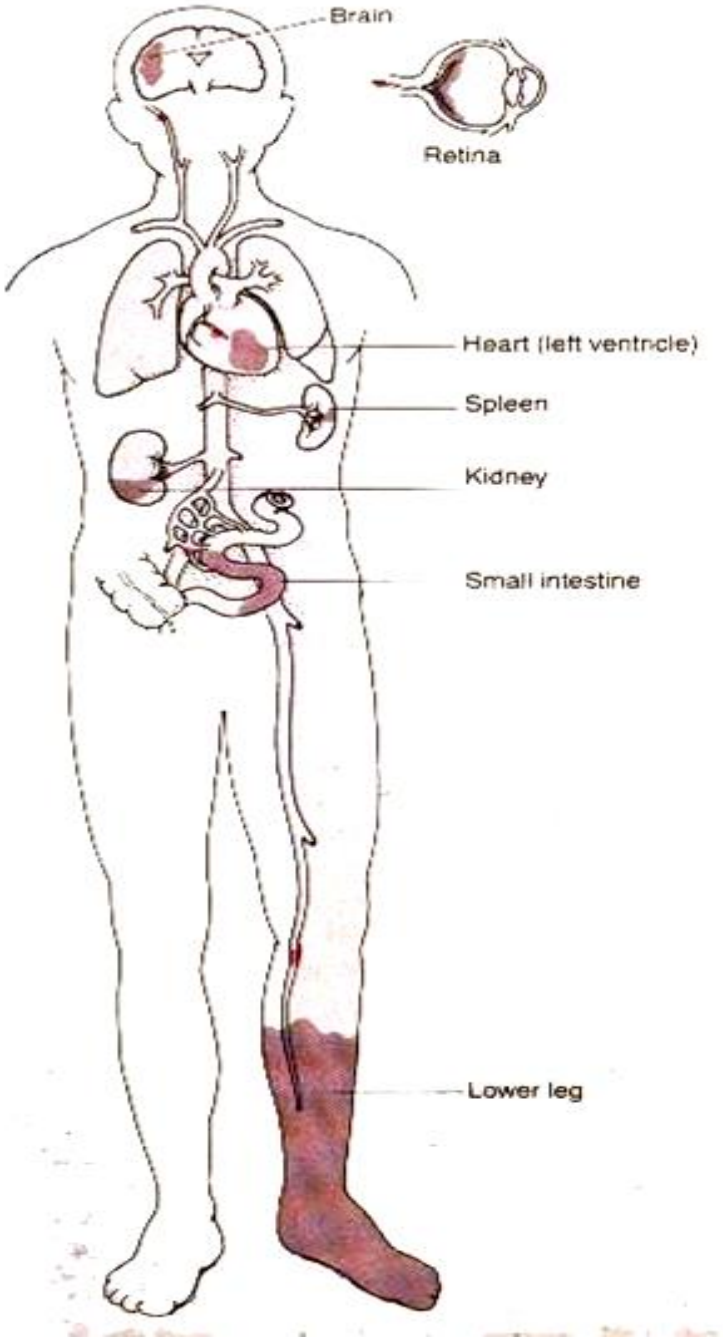


# Systemic arterial embolization

lower extremities
brain
retina
heart
spleen
kidney
small bowel

# Fat embolism

- After fractures of long bones
- **Clinical signs**: respiratory distress, neurologic symptoms (restlessness, irritability, delirium, coma), anemia, thrombocytopenia
- Mechanic and toxic injury

# Air embolism

**Causes**:-Trauma (chest wall injury)

-obstetric complications

-decompression disease (eg. scuba divers)

-caisson's disease

**Complications**: neurological symptoms, pulmonary hemorrhage and edema, atelectasis, epiphyseal necrosis of long bones