Disorders of the mechanical function of the lung

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creative connections
charles multimedia education

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Pulmonary alveolus

Lecture structure

- **Context** of disorders of ventilation = i.e. mechanical function
- **Static characteristics** of the lung – **restrictive** disease
- **Dynamic** characteristics of the lung – **obstructive** disease
- **Typical obstructive** diseases
- **Typical restrictive** disease – **lung fibrosis**
- **Assesment** of ventilatory // = **spirometry** etc.

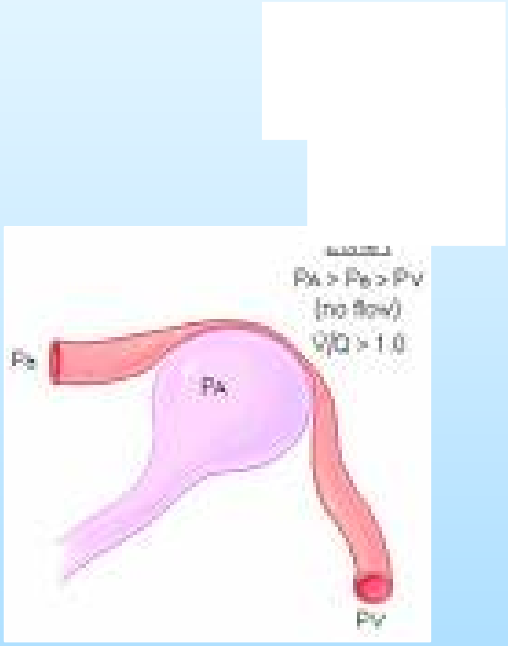
Context of ventilatory disorders

Possible respiratory system disturbances

- // **ventilation**
- // **perfusion**
- // **distribution** of ventilation and perfusion

= ventilation perfusion mismatch

- // **diffusion**



The „most important“ measure of respiratory system function

- pO2 & pCO2 in arterial blood - („Astrup“)
- O2 solubility in water is low => need of Hemoglobin
- **pO2** = 13,3 kPa = **100 Torr**
- Conversion: 1 Atm = 10 m H2O = 100 kPa = 760 Torr = 760 mmHg

..... 1 kPa = 10 cm H2O = 7,6 Torr

- **pCO2** = **40 Torr** = 5,3 kPa

Respiratory insufficiency

- **Respiratory insufficiency type I** (partial, hypoxemic)
  - pO2 is ↓ low, but pCO2 is normal or even also ↓ lower
- **Respiratory insufficiency type II** (global, hypoventilation)
  - pO2 is ↓ low and pCO2 is ↑ high (respiratory a....)

Partial respiratory insufficiency (Type I)

- Impaired // **distribution**
  - Ventilation perfusion mismatch - uneven V_A/Q in different lung regions
  - True shunting (right-left)
- Impaired **// diffusion**
  - Through water O2 diffuses about 20x slower than CO2

Global respiratory insufficiency (type II)

- **Impaired // ventilation -** overall alveolar hypoventilation

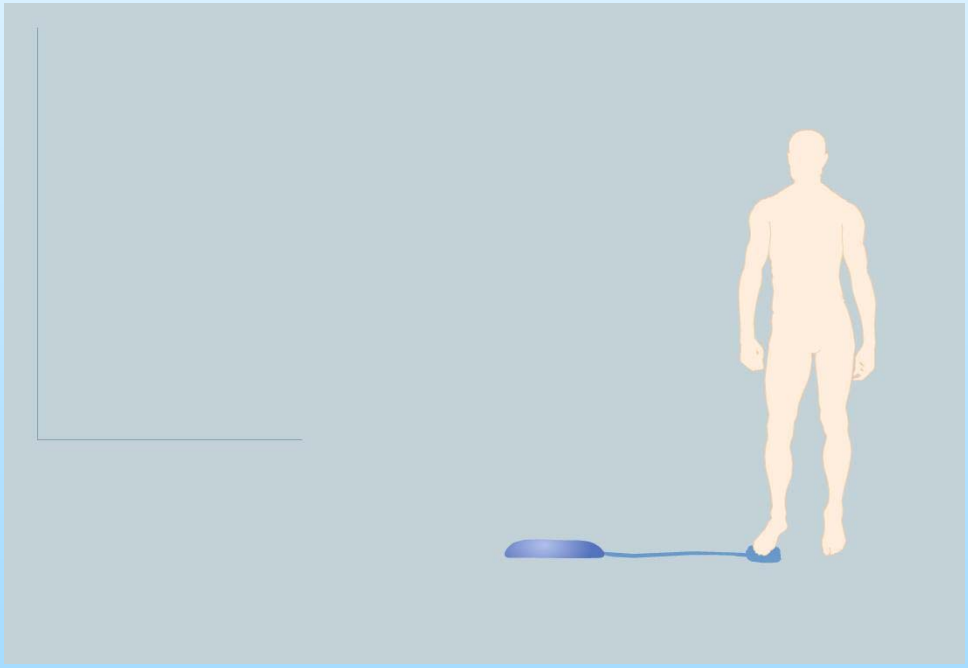
Ventilation

- Is carried out by respiratory muscles, that change volume of thorax.
- Volume changes cause changes of pressures
- Changes of pressure in alveoli cause air flow (↑ pressure – expiration; ↓ pressure – inspiration) flow behaves according to Ohm's law

Static characteristics of the lung

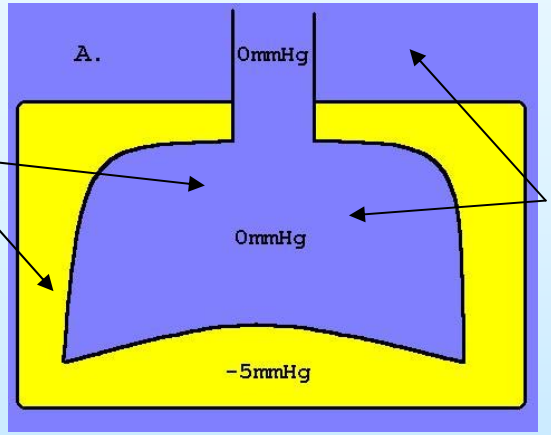
Static ventilatory parameters

- Inflating baloon

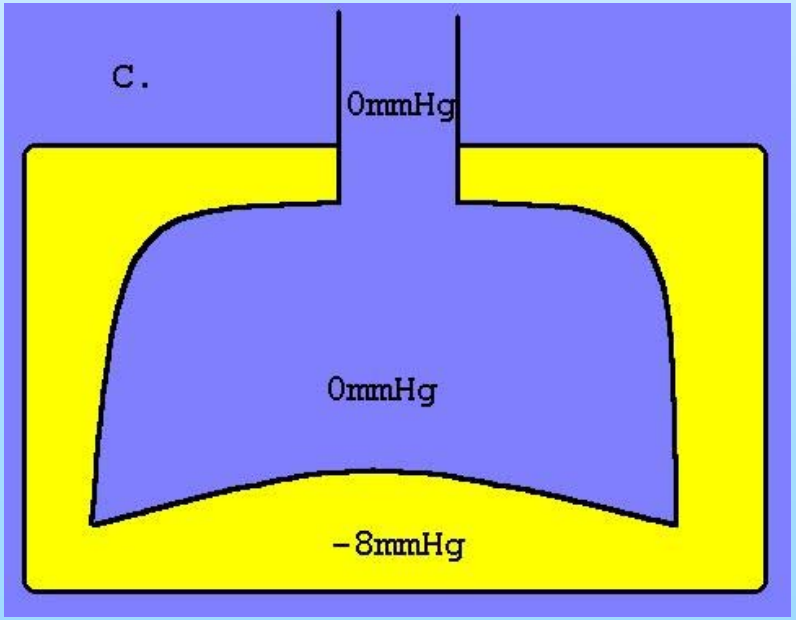


Pressures in the lungs

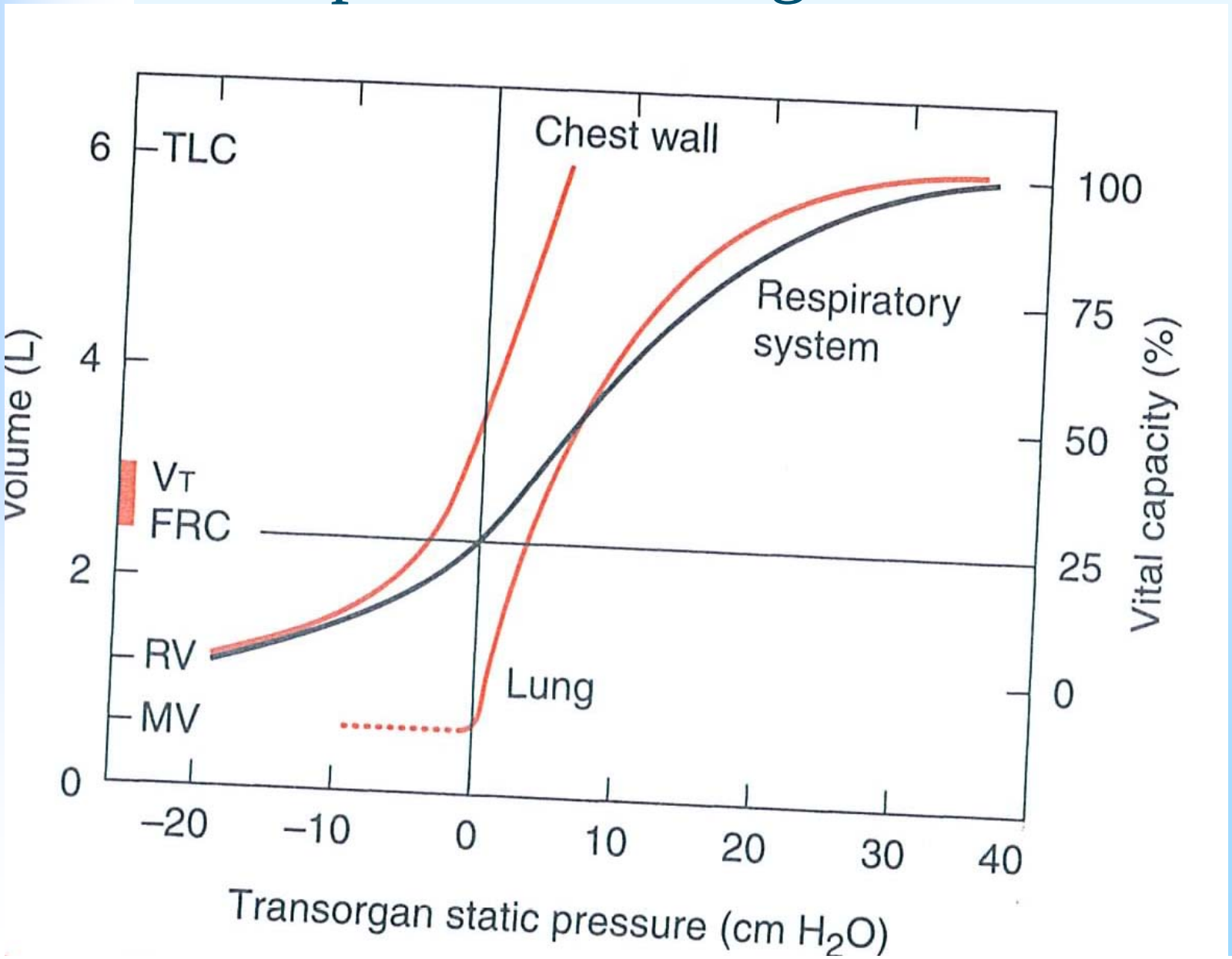
Transpulmo-
nary
pressure

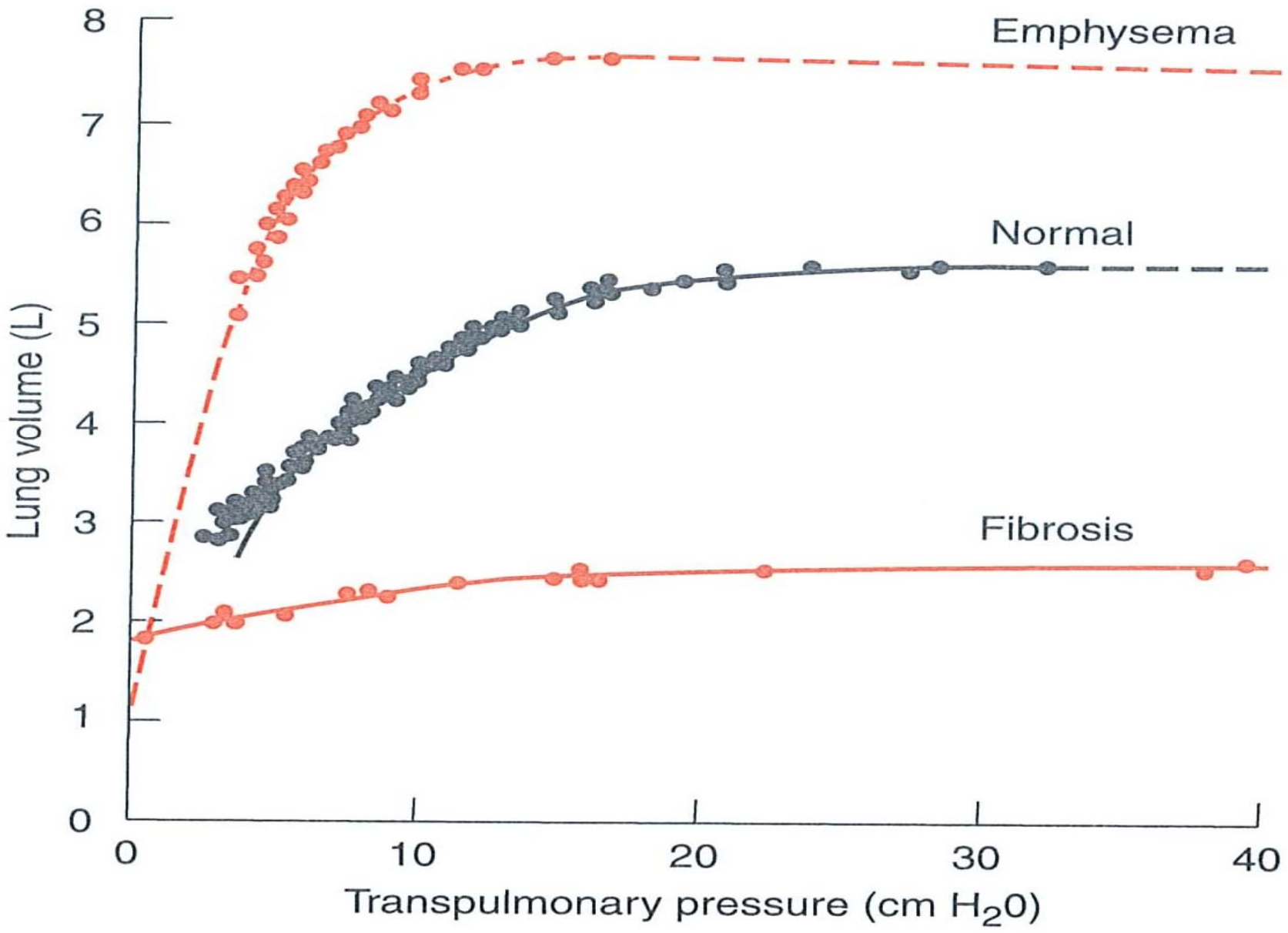


Transthoracic
pressure

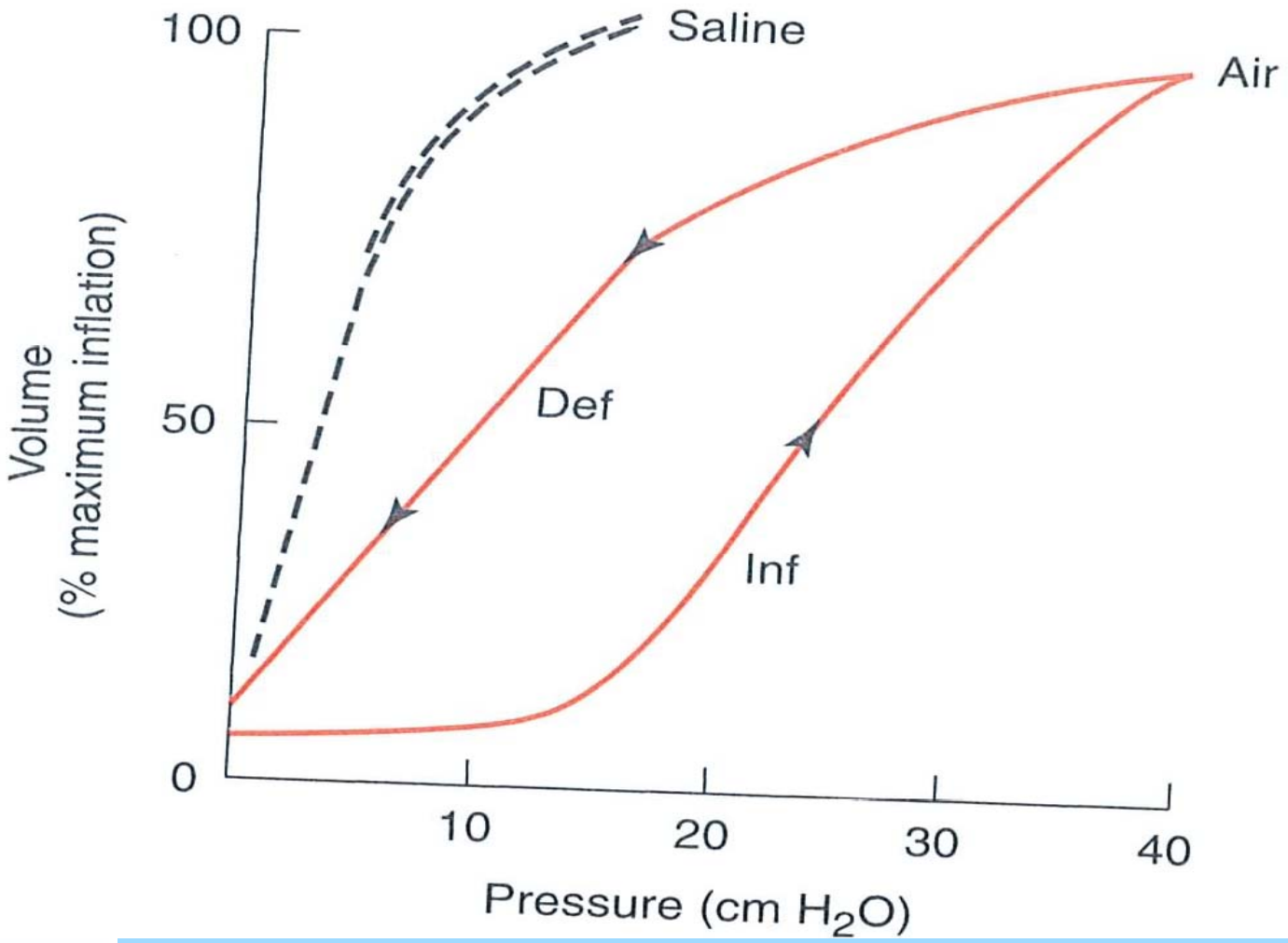


Compliance of lung and chest



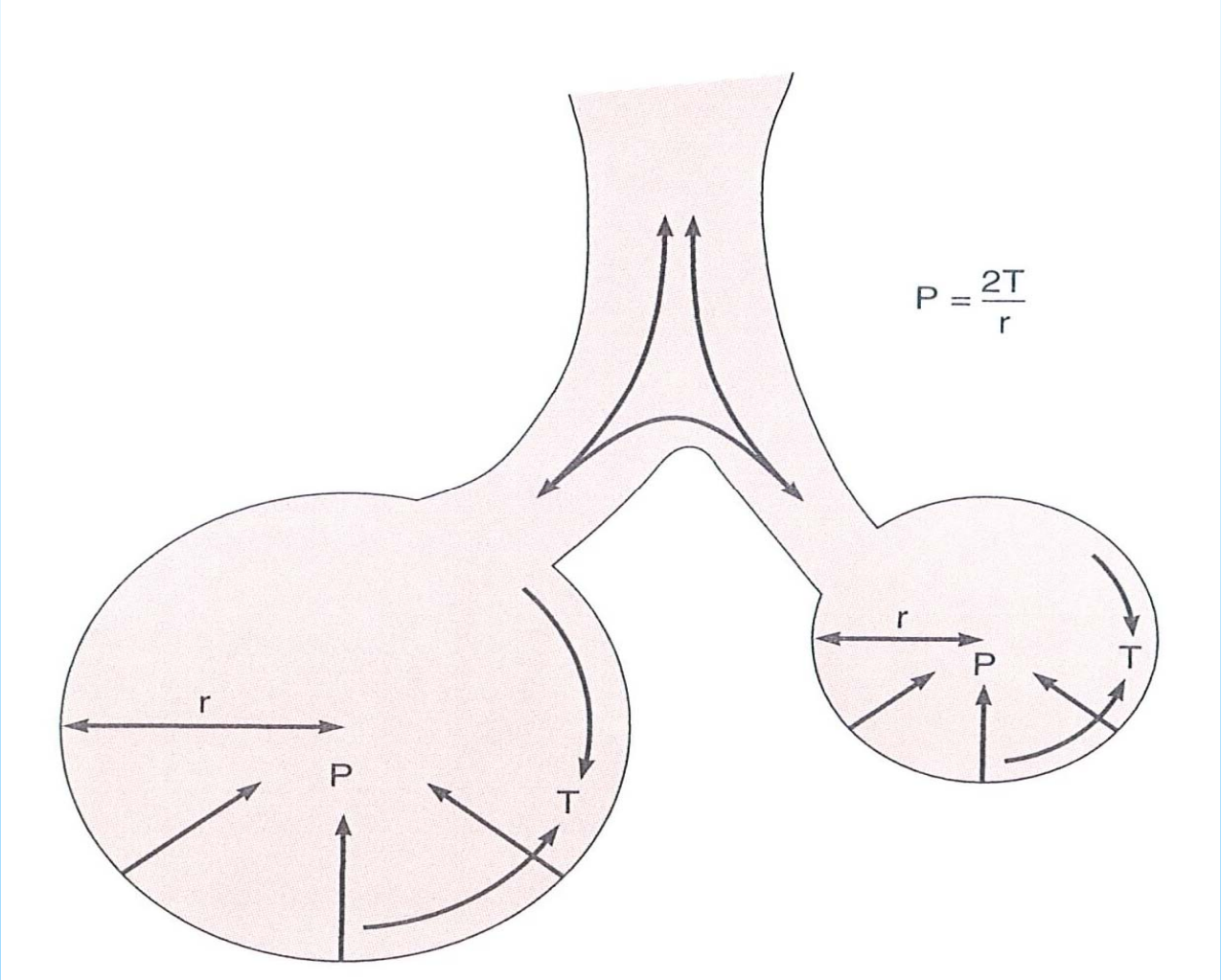

Emphysema
Normal
Fibrosis
Lung volume (L)
0
1
2
3
4
5
6
7
8
0
10
20
30
40
Transpulmonary pressure (cm H_20)

Compliance – effect of surfactant



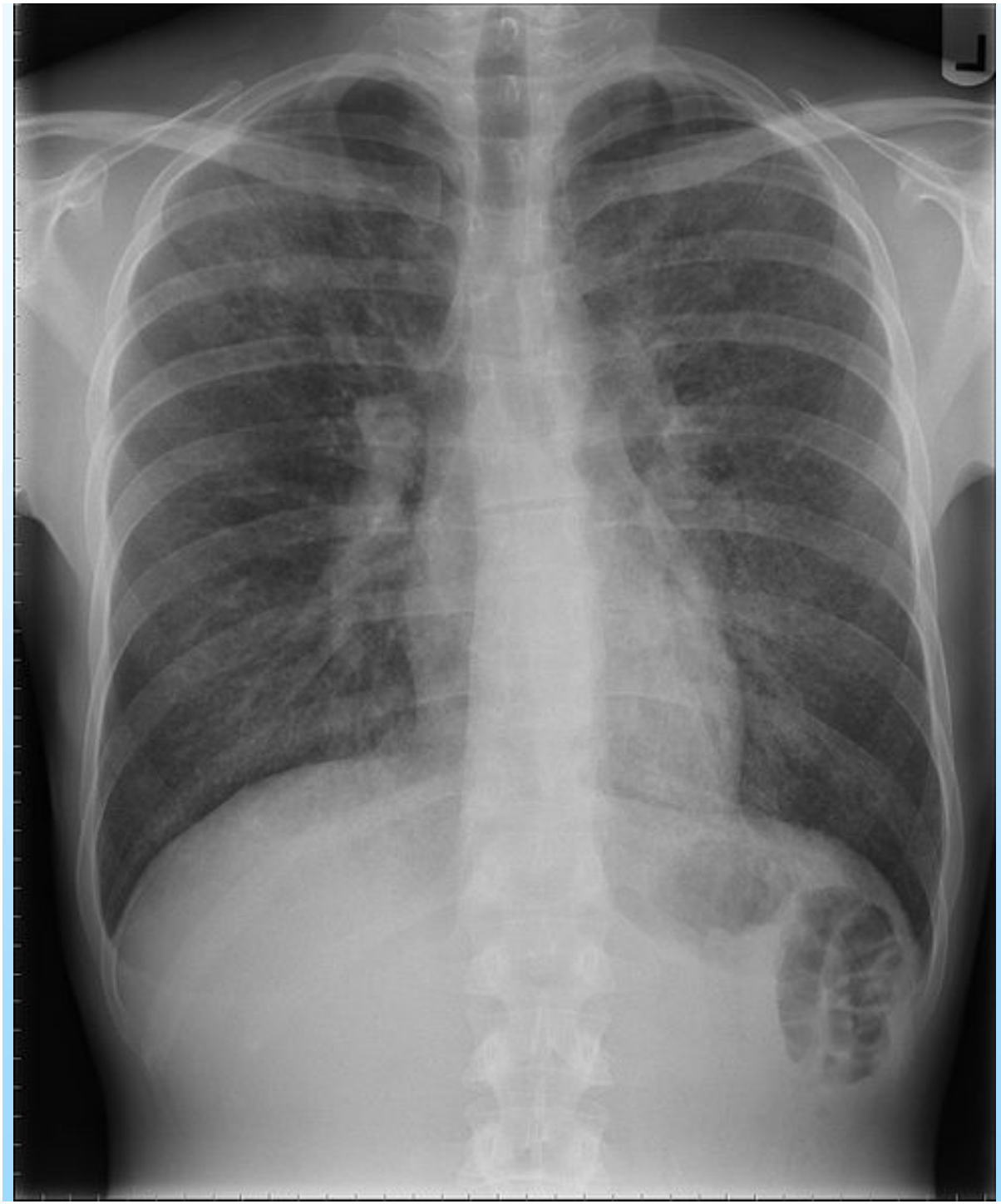
Surfactant

Stability of alveoli



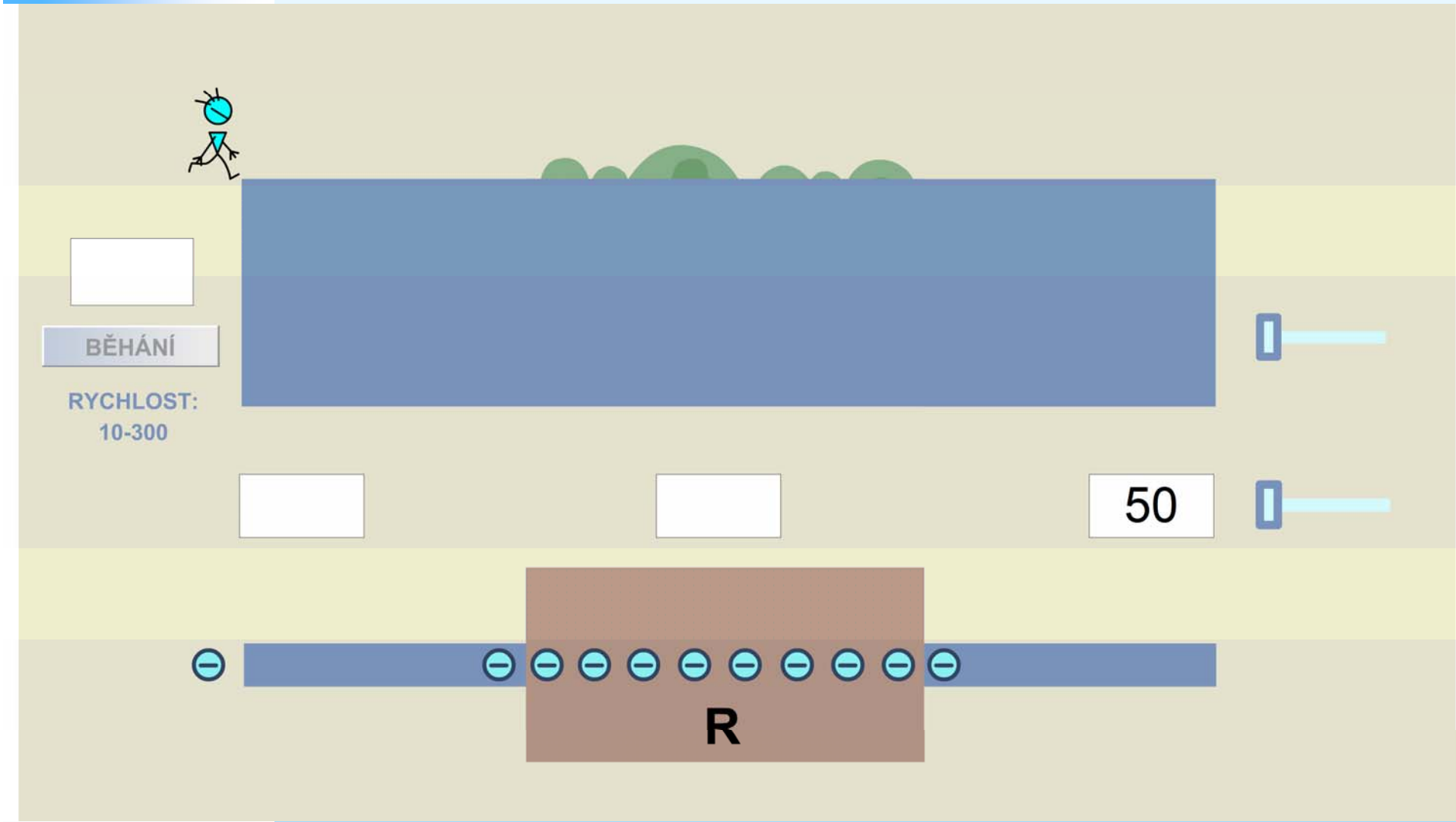
Lung fibrosis = Interstitial lung disease (ILD)

- = diffuse parenchymal lung disease
- Inflamation in alveolar wall leads to scarring and collagen deposition
- Chest X-ray, pulmonary function testing, (lung biopsy)
- Affect the alveolar wall or the interstice of the lung (alveolar epithelium, capillary endothelium, basal membrane, interstice and perilymphatic tissue)
- Fibrosis may be a late sign

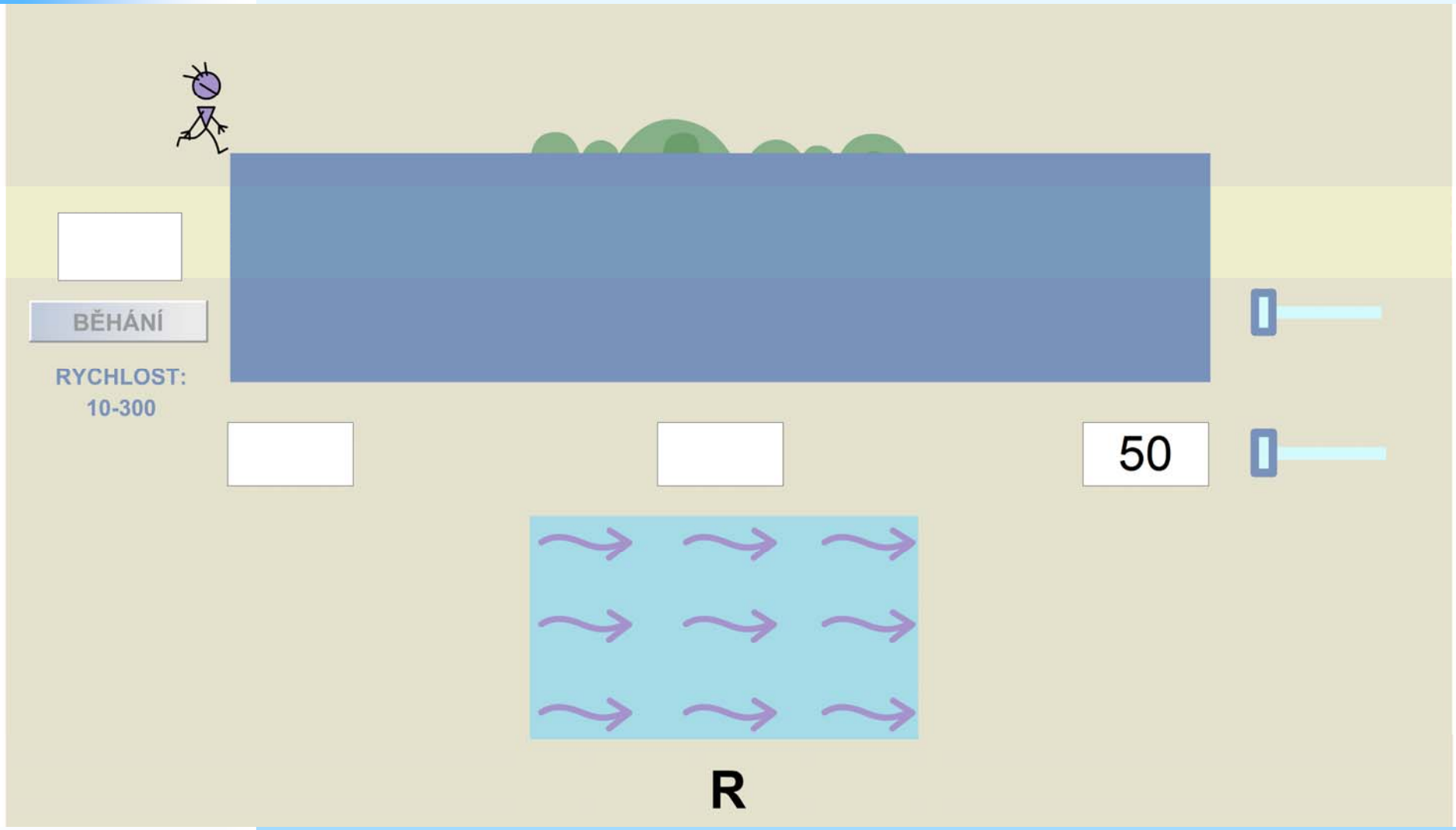


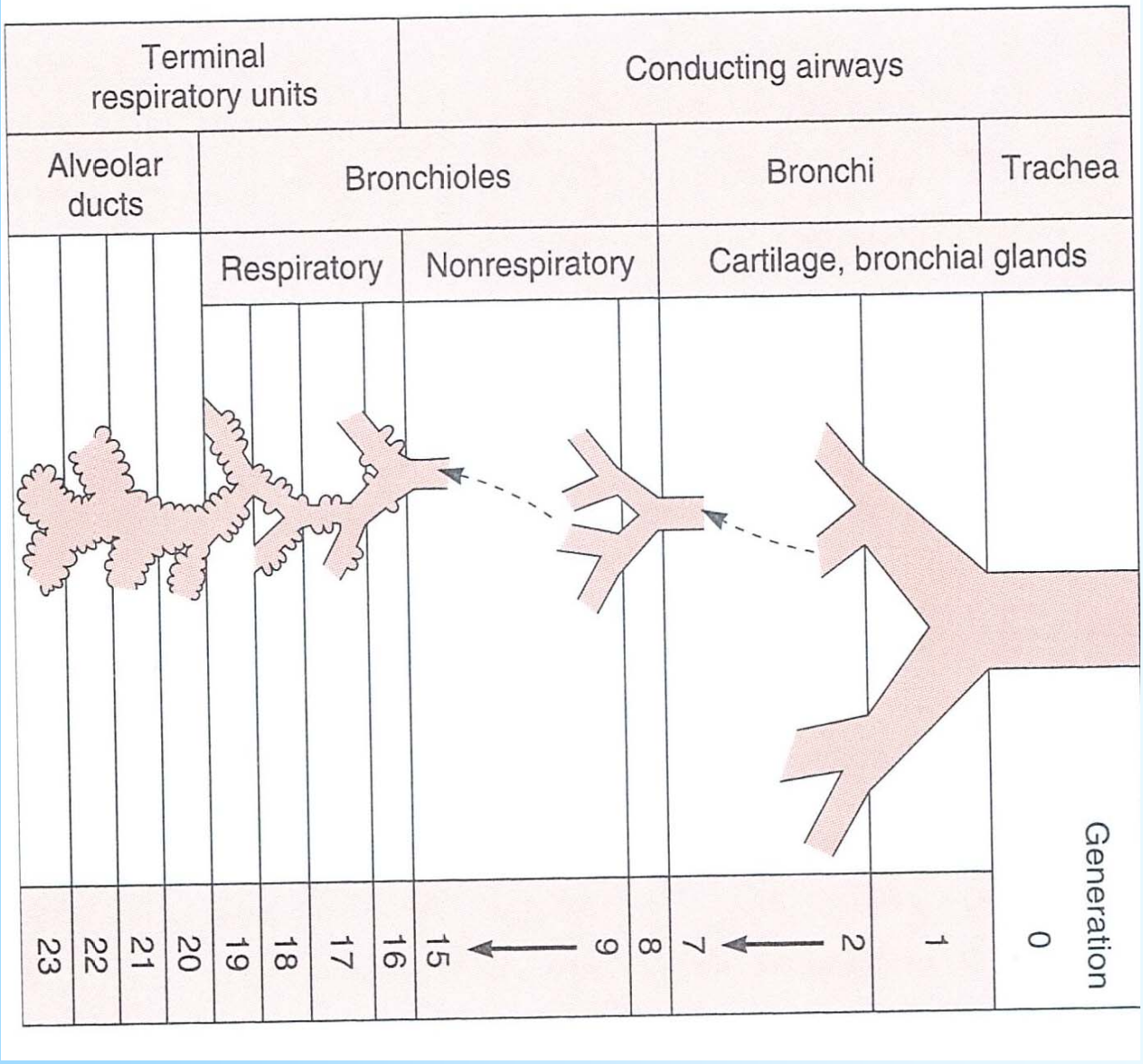
Dynamic characteristics of the lung

Ohm's law

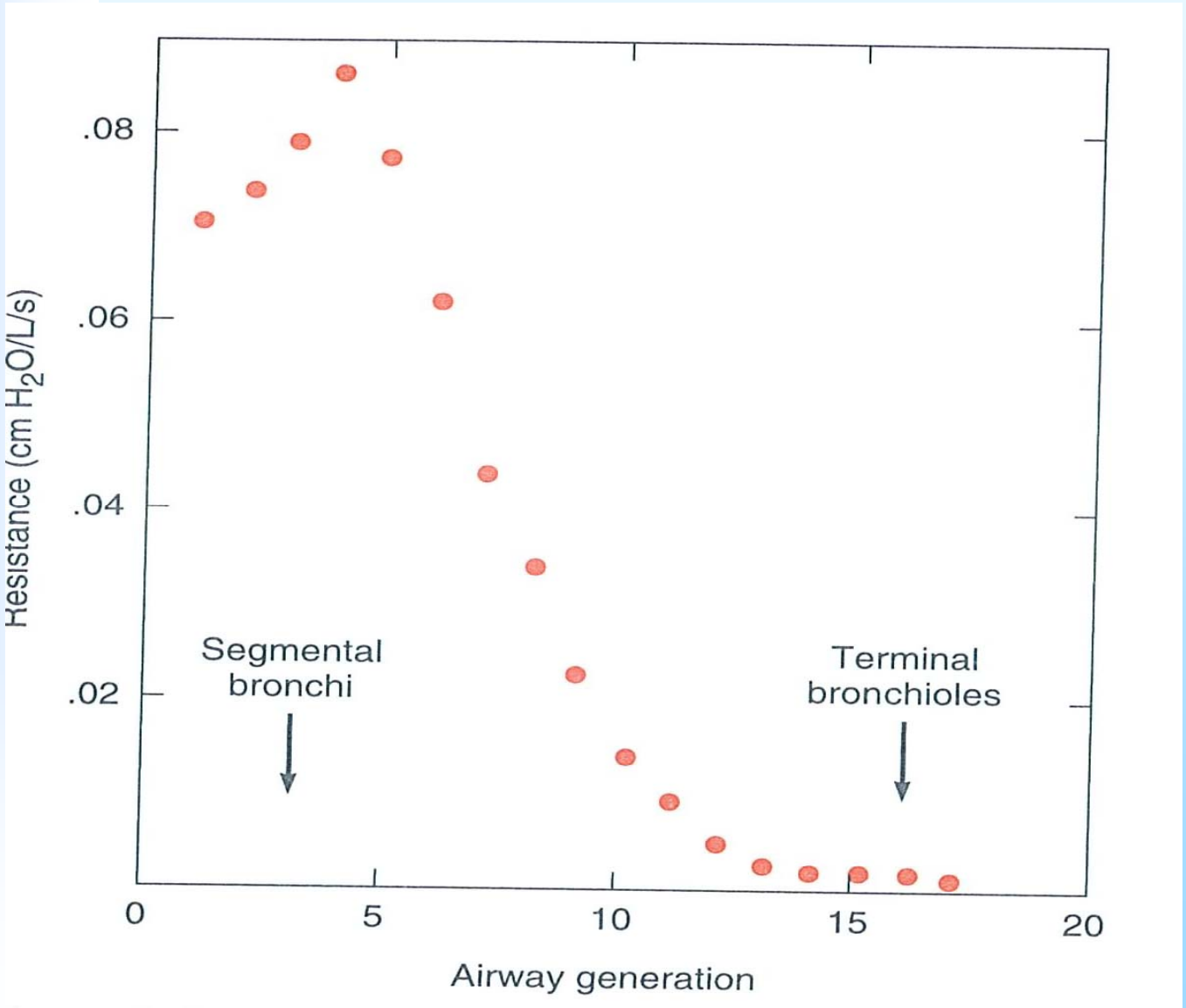


Ohm's law

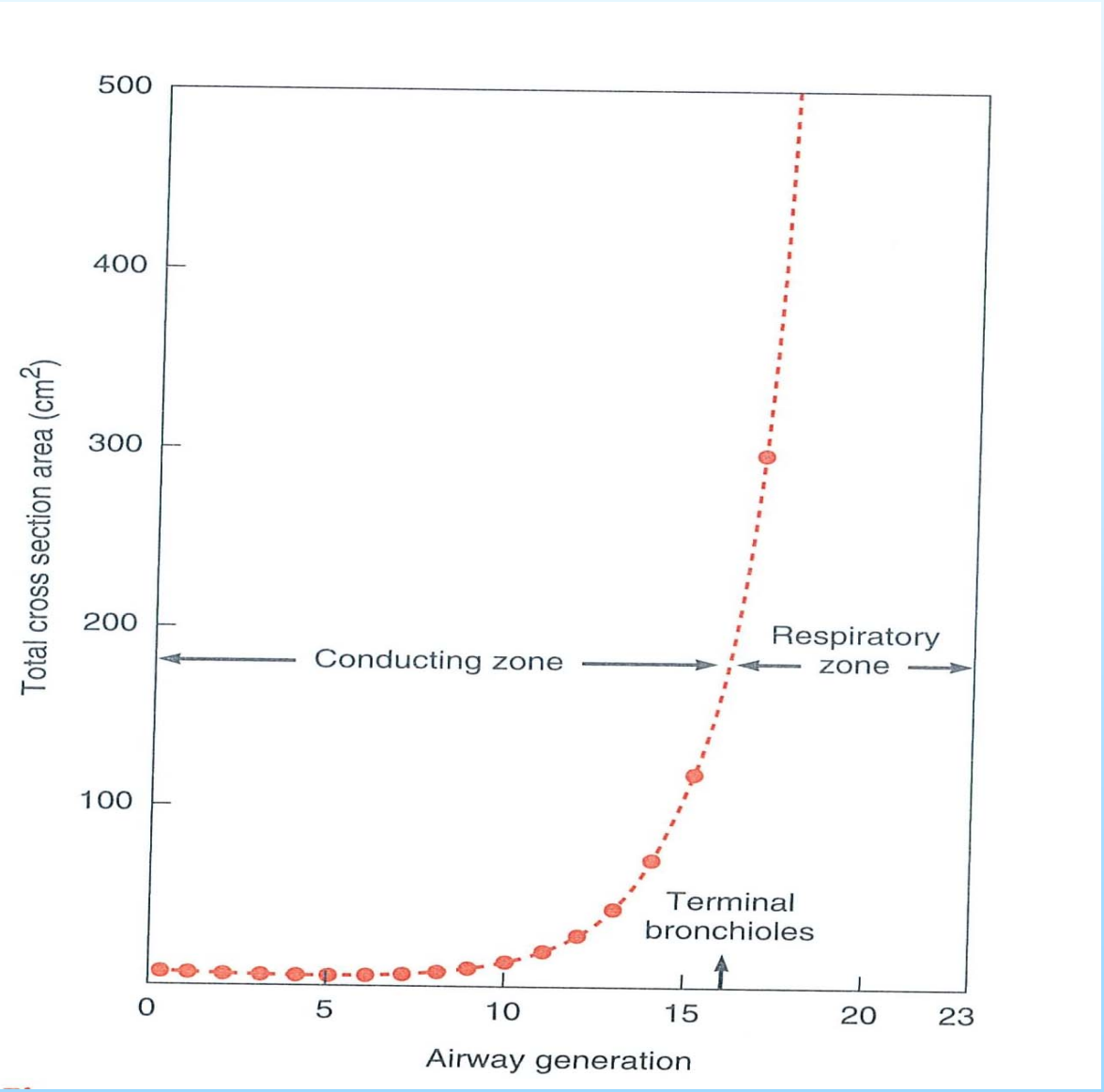



Terminal respiratory units
Conducting airways
Alveolar ducts
Bronchioles
Bronchi
Trachea
Respiratory
Nonrespiratory
Cartilage, bronchial glands
Generation
0
1
2
7
8
9
15
16
17
18
19
20
21
22
23

Resistence along the blonchial tree

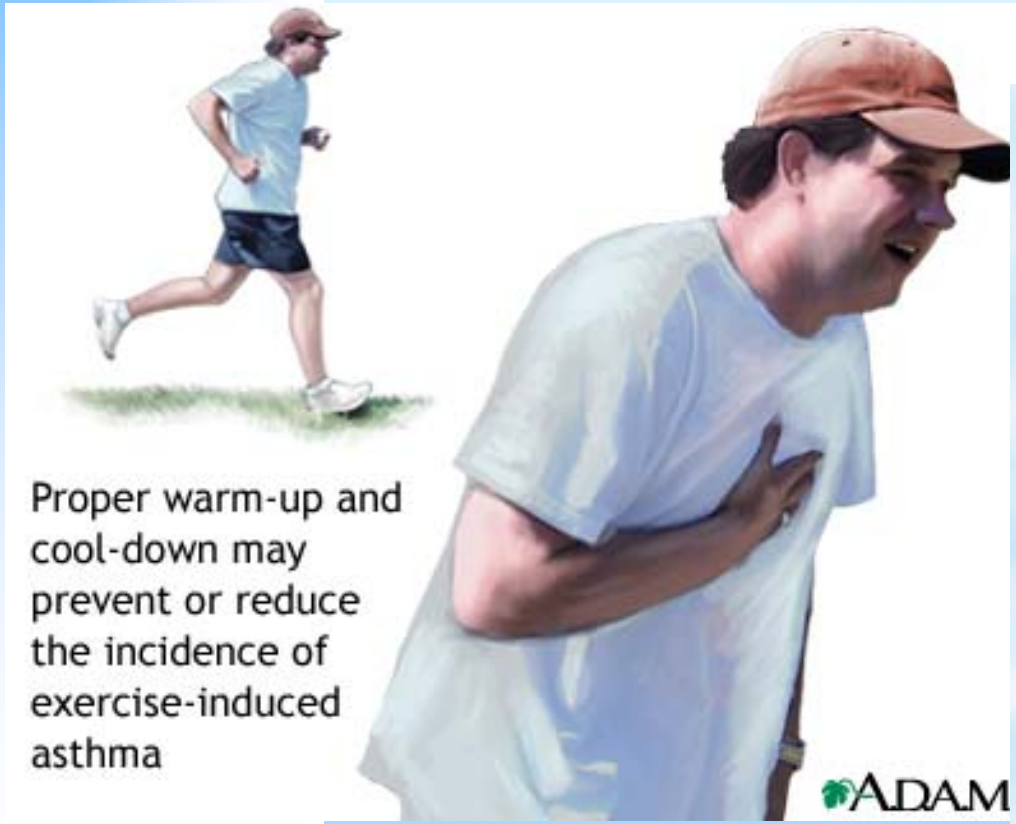


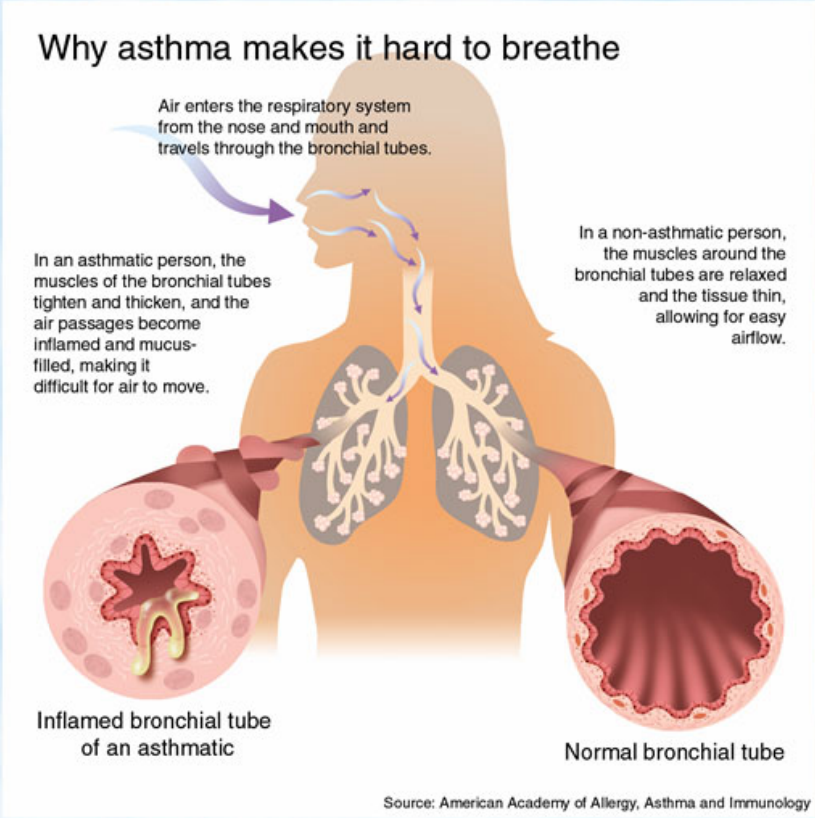
Airway diameter



Asthma

chronic inflammation of the airways, which causes an associated airway hyperreactivity





Overview

Normal lung

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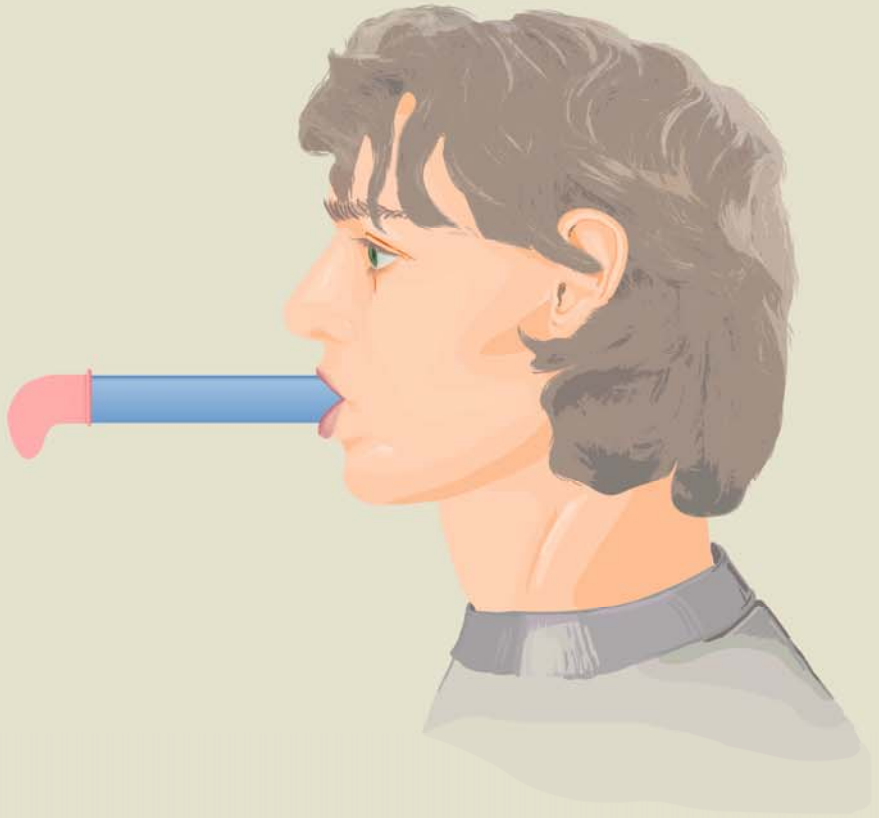
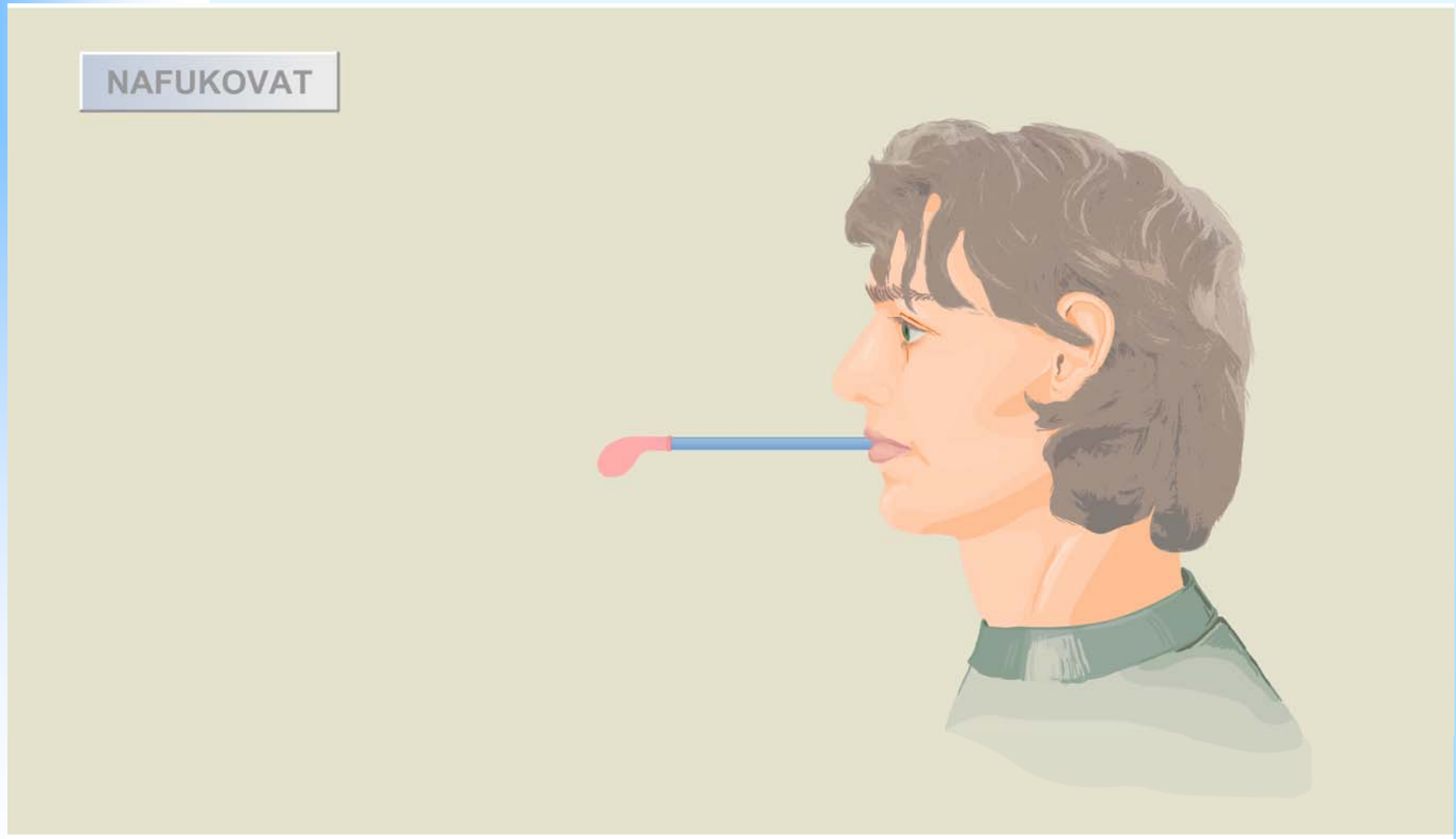
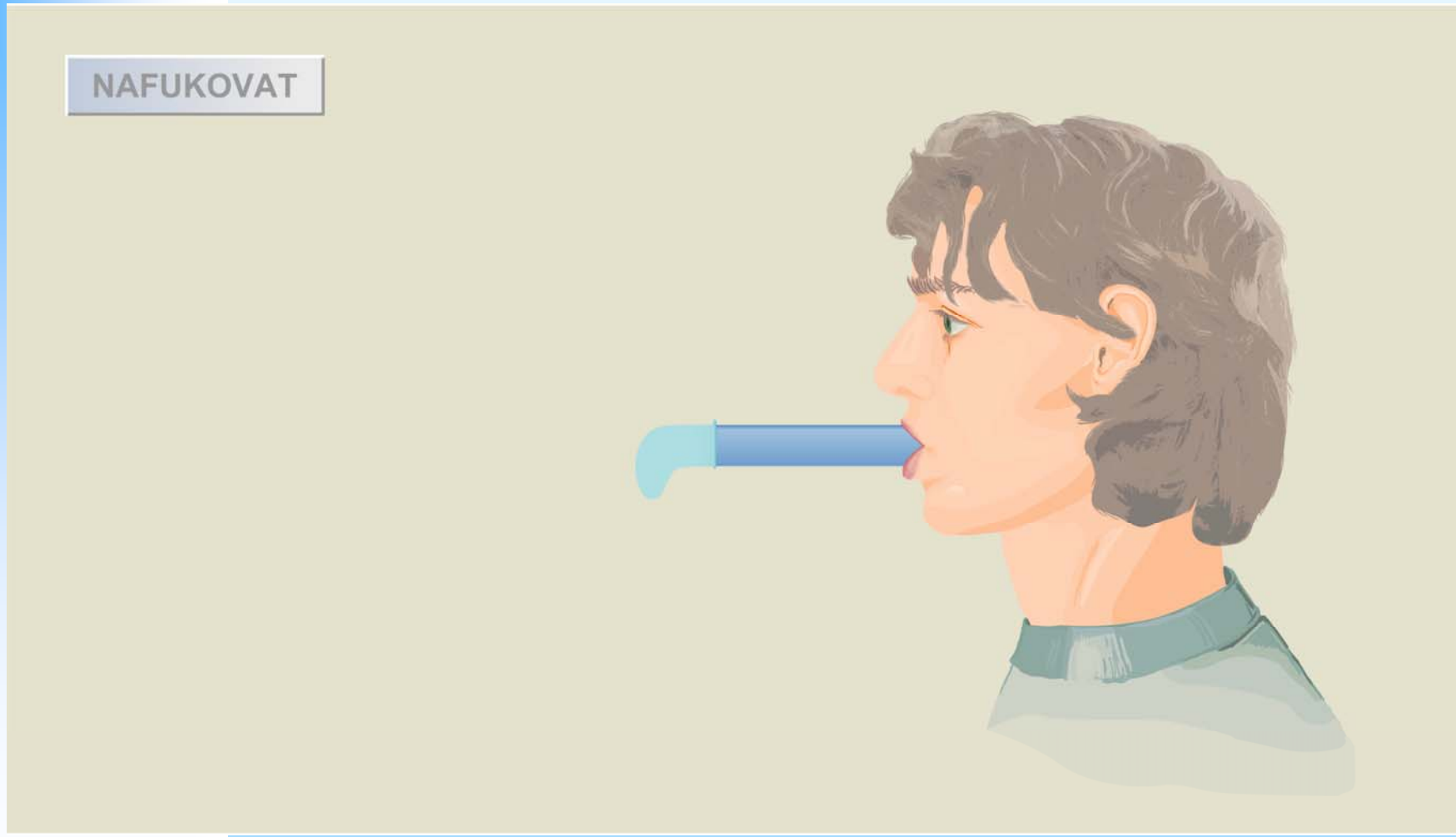


Obstructive disease



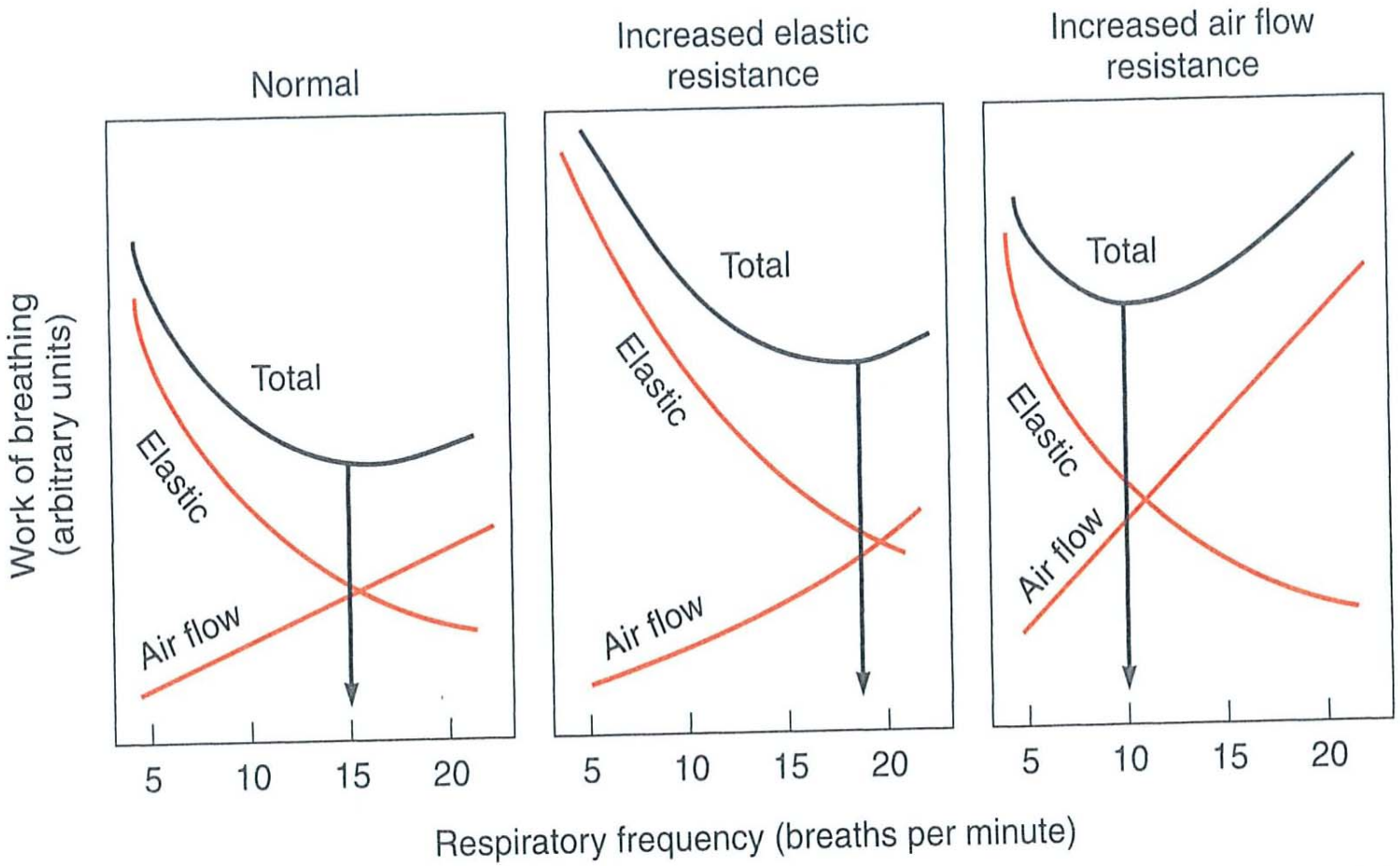
Restrictive disease



Ventilation disorders

- **Lung impairment (mechanical properties change)**
  - **Obstructive disease -** ↑ increased resistance R of airways (R = "dynamic lung resistance")
  - **Restrictive disease** – ↓decreased lung compliance C ('↑ static resistance" `; C = 1/ static lung resistance)
- **Chest wall impairment**
  - ↓ decreased C of chest wall – severe scoliosis, extensive fibrosis, serial fractures
- **Insufficient activity of respiratory muscles** (// innervation or // muscle strength , // of CNS) – E.g.. Respiratory centre suppression in barbiturate poisoning, myasthenia gravis

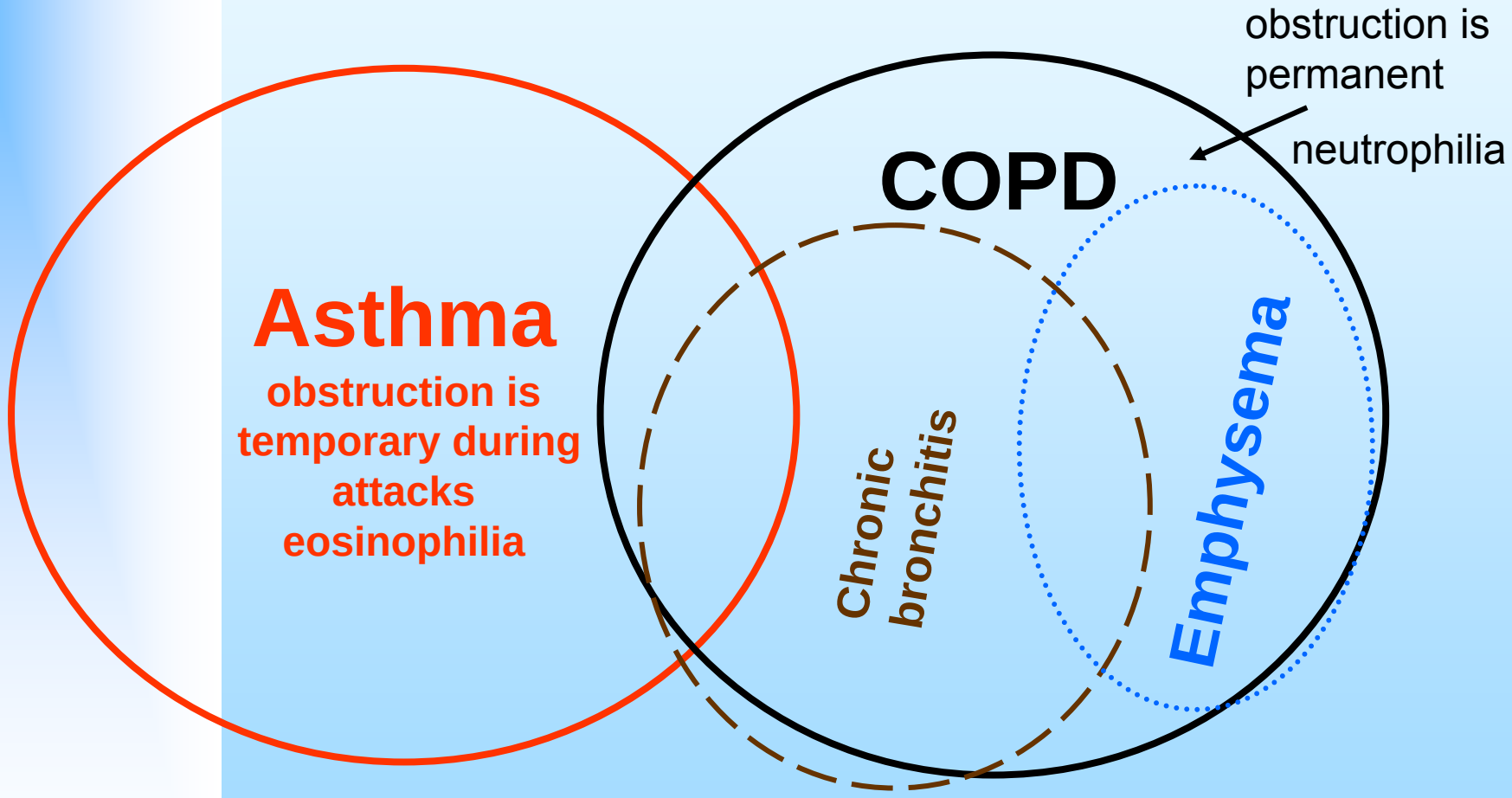
Restrictive Obstructive



Ventilation perfusion mismatch

Obstructive disease – Asthma and COPD

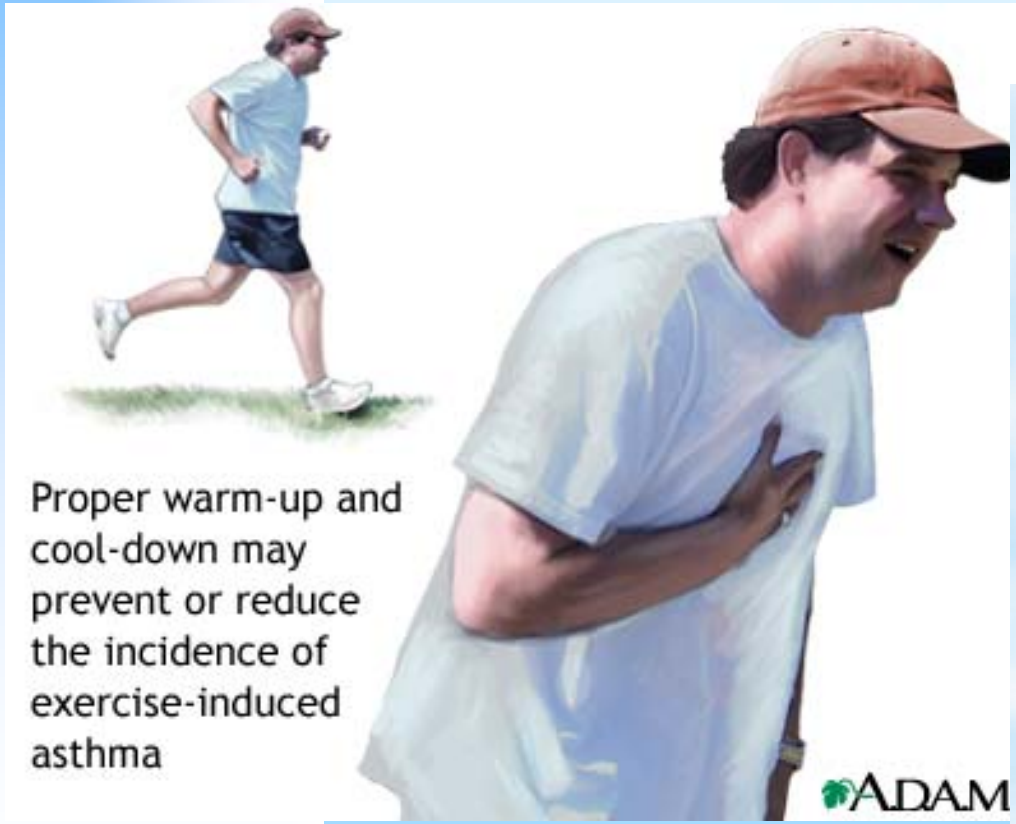
Various obstructive syndromes

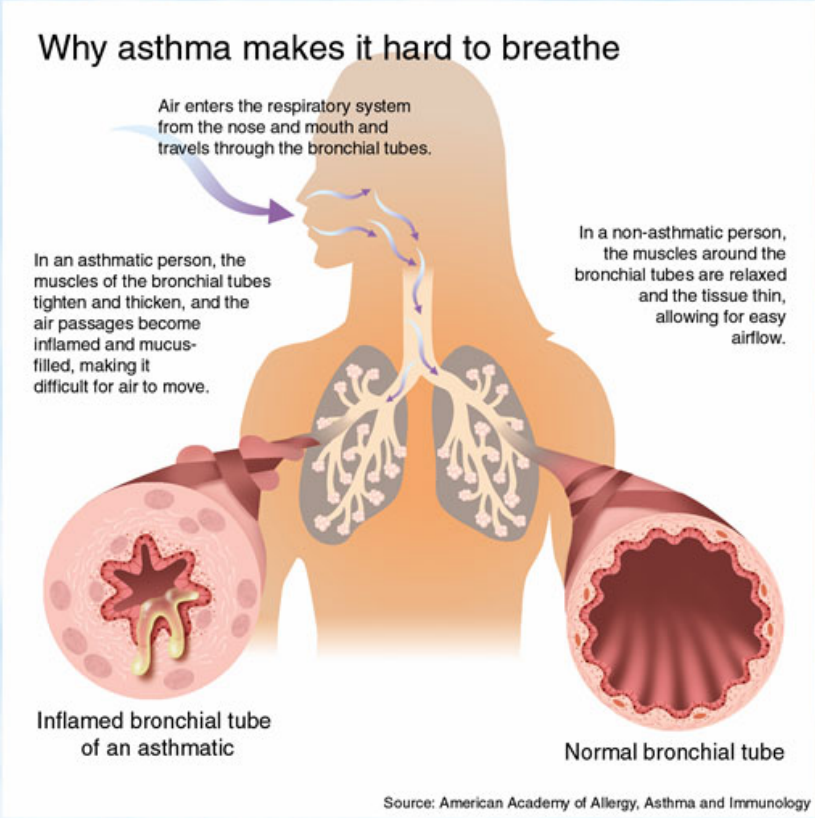


Causes of obstruction

Asthma

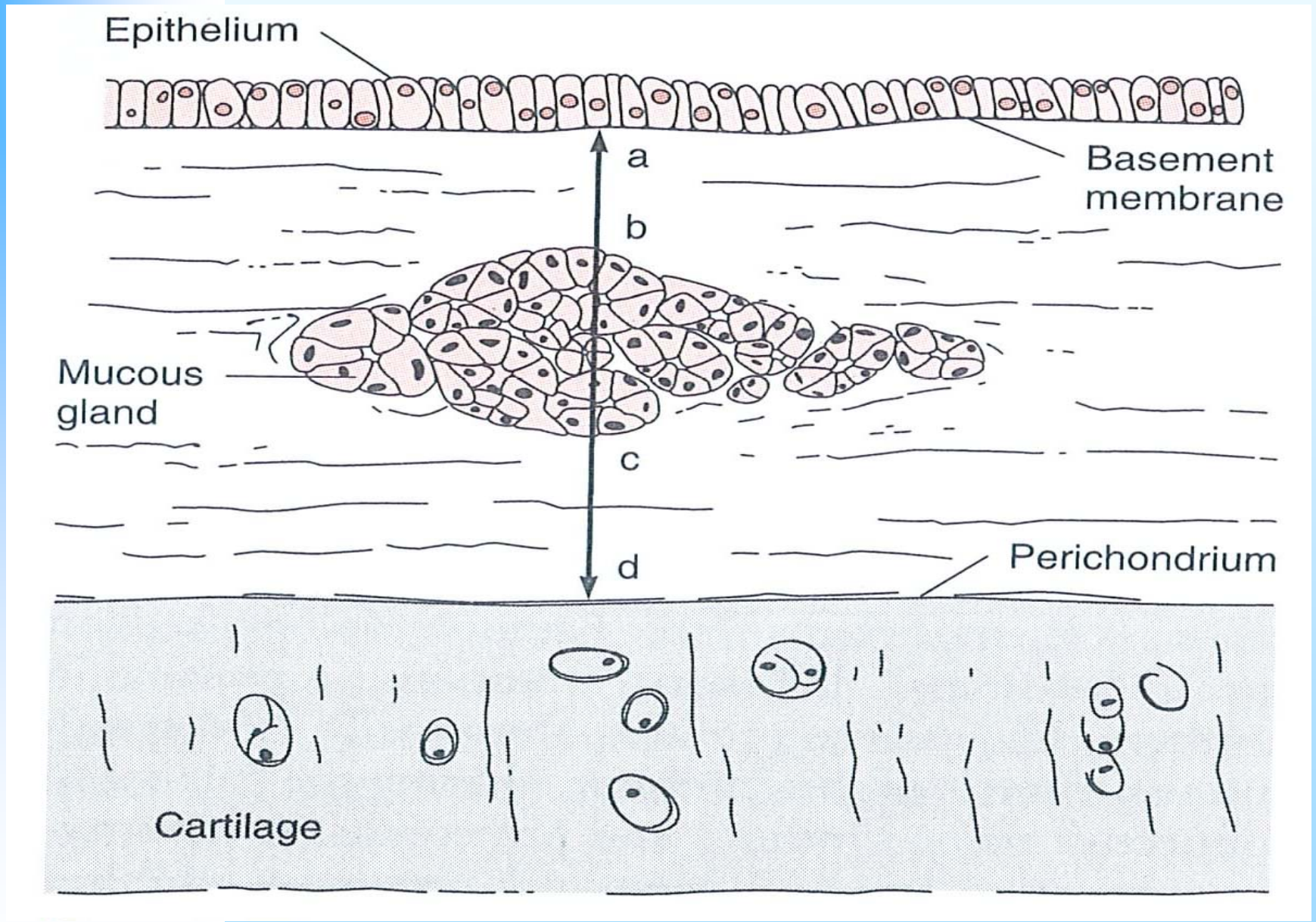
chronic inflammation of the airways, which causes an associated airway hyperreactivity





Asthma features

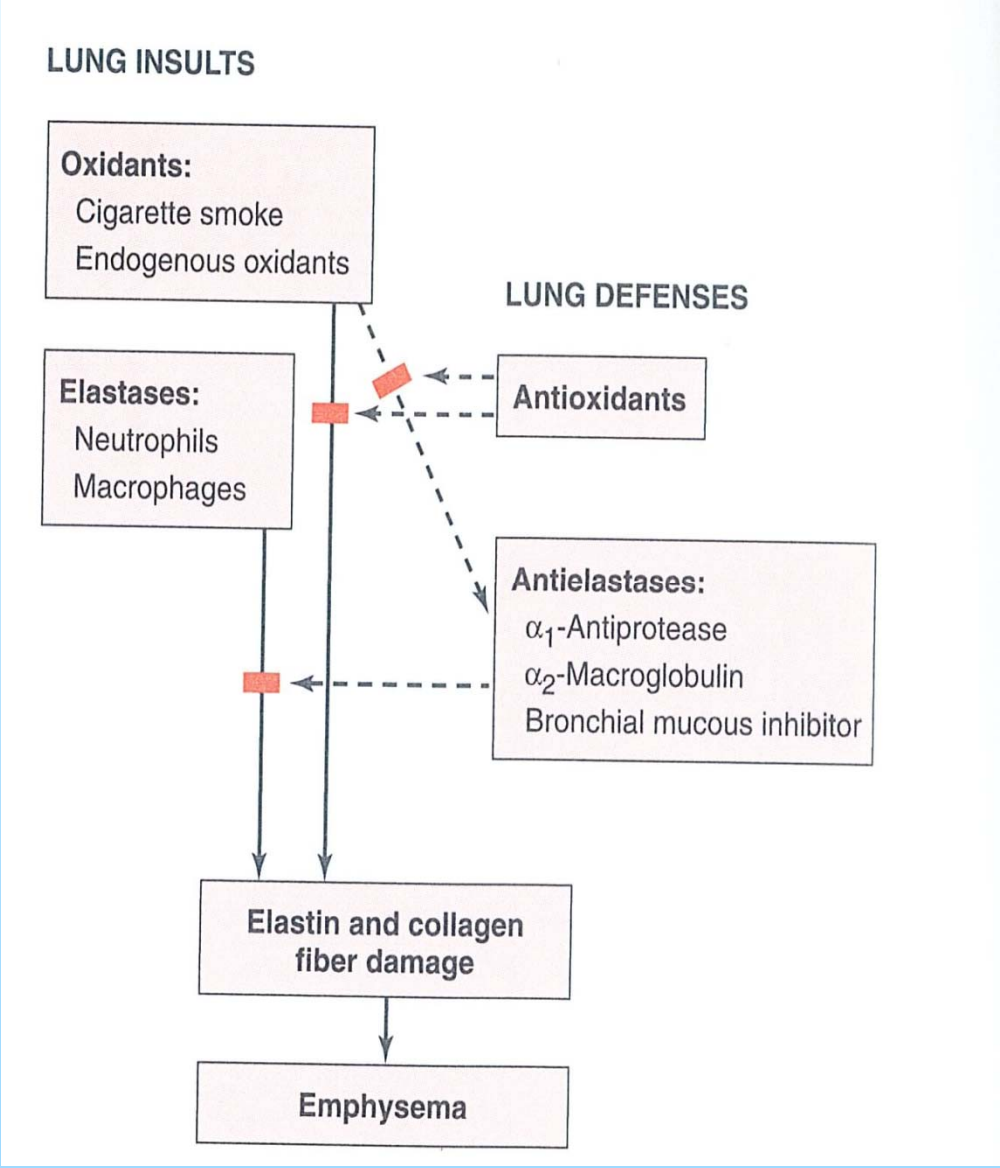
- inflammation of bronchi
  - early and late phase response
- bronchial hyperreactivity
- hypertrophy of airway smooth muscle cells
- Inflammatory swelling
- Increased secretion of mucus.
- Mucous plugs


Epithelium
Basement membrane
a
b
Mucous gland
c
d
Perichondrium
Cartilage

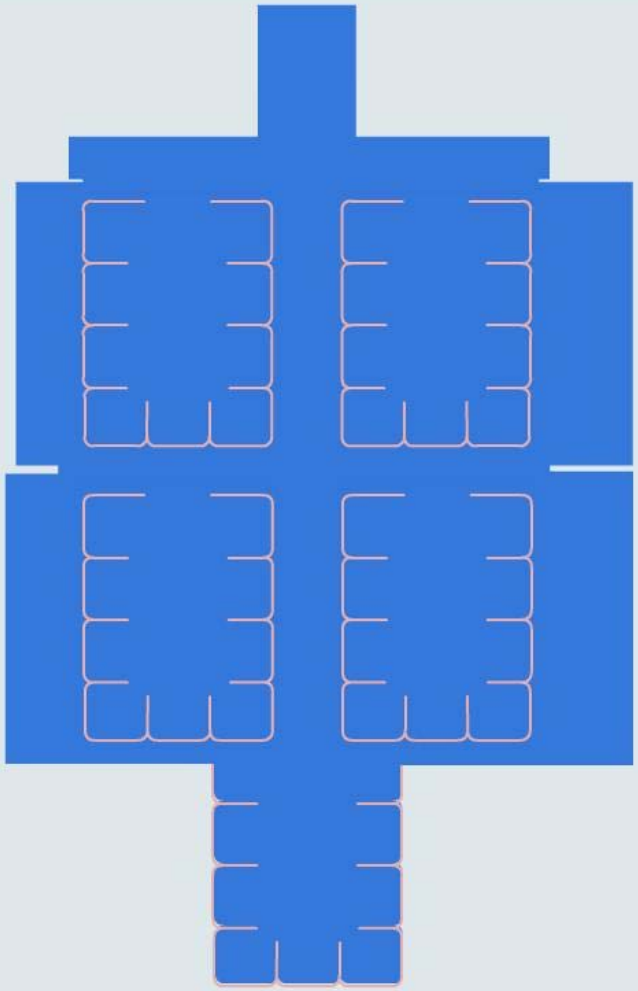
COPD

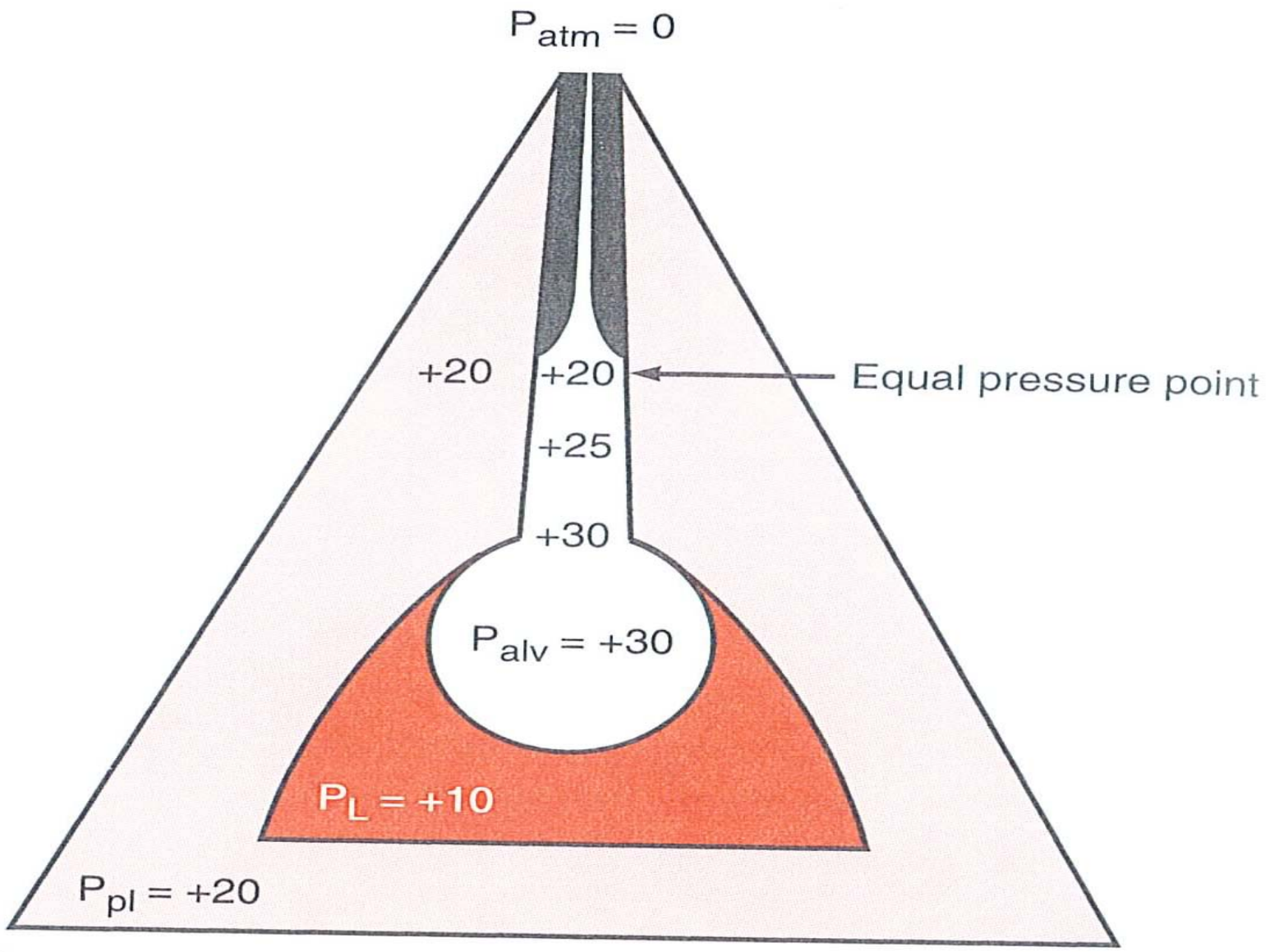
- Caused 90% by smoking
- Emphysema and chronic bronchitis
- Expiratory obstruction

Development of emphysema

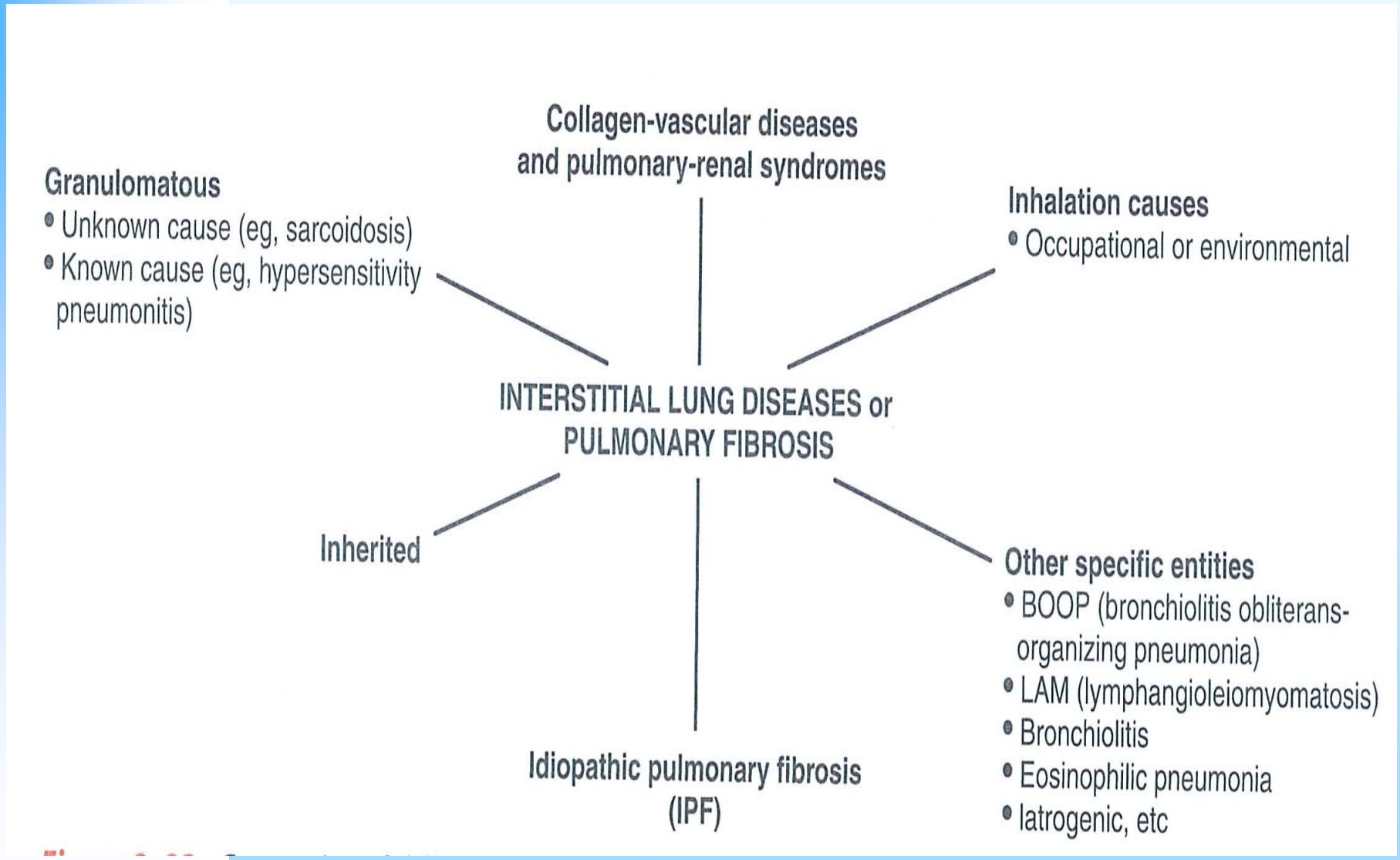


Obstruction in emphysema



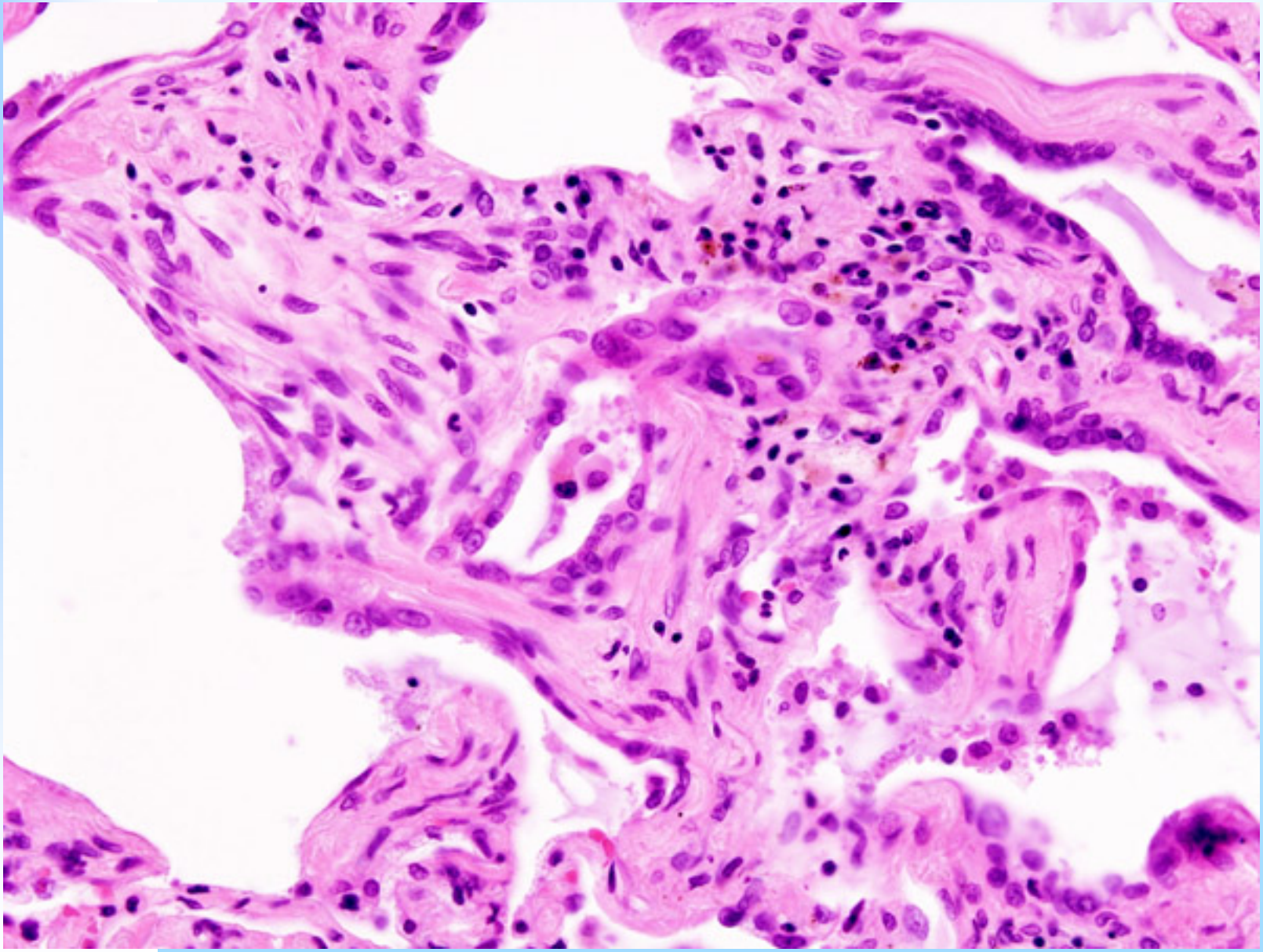

$P_{atm} = 0$
+20
+20
Equal pressure point
+25
+30
$P_{alv} = +30$
$P_L = +10$
$P_{pl} = +20$

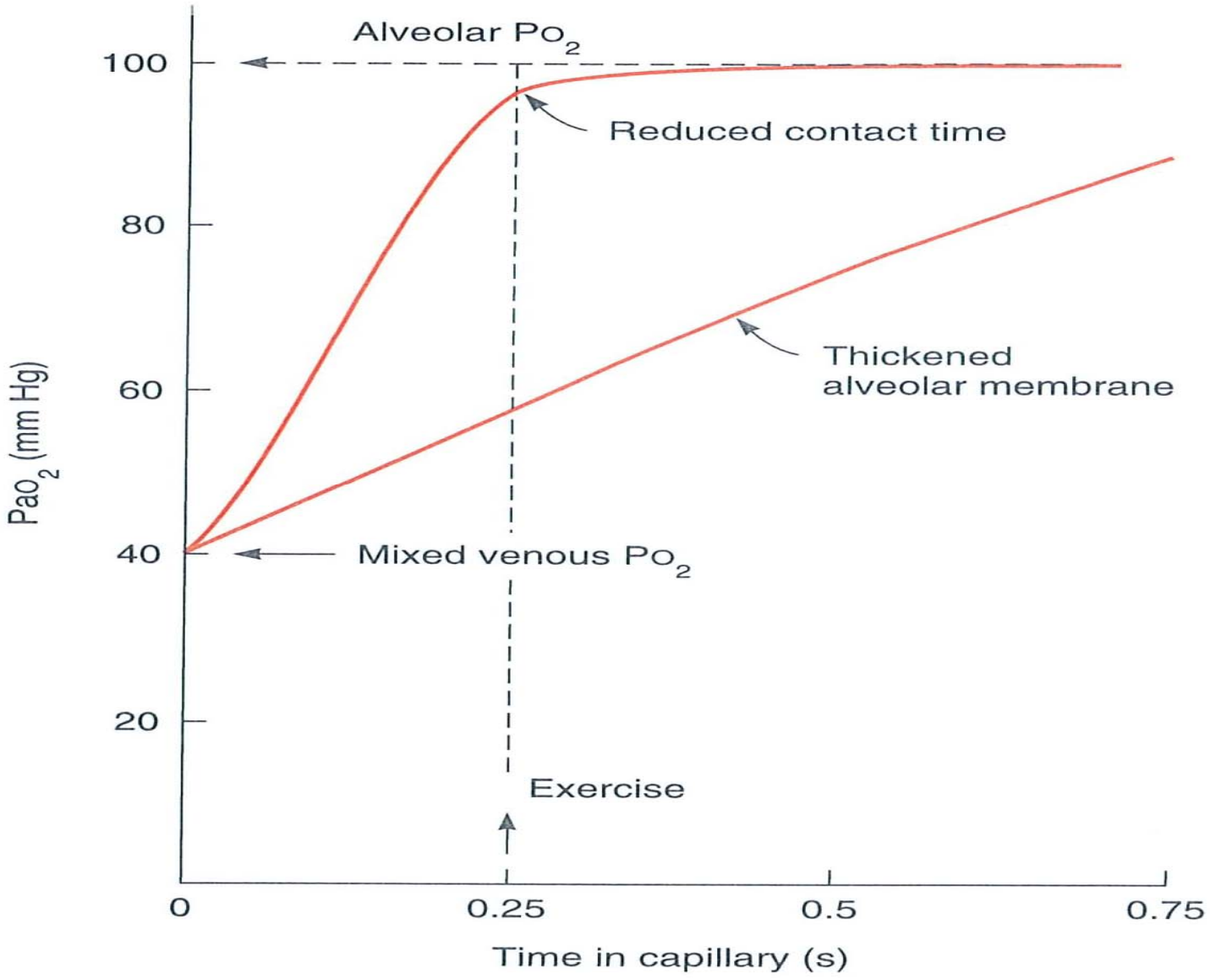
Restrictive disease – Lung fibroses


Collagen-vascular diseases
and pulmonary-renal syndromes
Granulomatous
• Unknown cause (eg, sarcoidosis)
• Known cause (eg, hypersensitivity pneumonitis)
Inhalation causes
• Occupational or environmental
INTERSTITIAL LUNG DISEASES or
PULMONARY FIBROSIS
Inherited
Other specific entities
• BOOP (bronchiolitis obliterans-organizing pneumonia)
• LAM (lymphangioleiomyomatosis)
• Bronchiolitis
• Eosinophilic pneumonia
• Iatrogenic, etc
Idiopathic pulmonary fibrosis
(IPF)

Causes of lung fibrosis/ ILD

- Inhalation of particles
  - 3. Azbestosis, silicosis, pneumoconiosis, = Pneumokonioser
  - 2. hypersensitivity (farmer's lung) = Alveolitis allergica
- 6. Drug induced (Abio, chemo, Antiarrhythmic) = Cytotoksiske og allergiske reaktioner
- 5. Connective tissue disease: Systemic sclerosis, Dermatomyositis, SLE, RA = Systemsygdomme
- 7.Infection: Atypical pneumonia, pneumocystis, TBC
- 8. Lymphangitic carcinoma = maligne sygdomme
- 4. Idiopatic: Sarcoidosis
- 1. Idiopathic pulmonary fibrosis = Alveolitis fibrosa




Alveolar Po_2
100
80
60
40
20
Pao_2 (mm Hg)
Reduced contact time
Thickened
alveolar membrane
Mixed venous Po_2
Exercise
0
0.25
0.5
0.75
Time in capillary (s)

Fibrosing alveolitis= Idiopathic pulmonary fibrosis

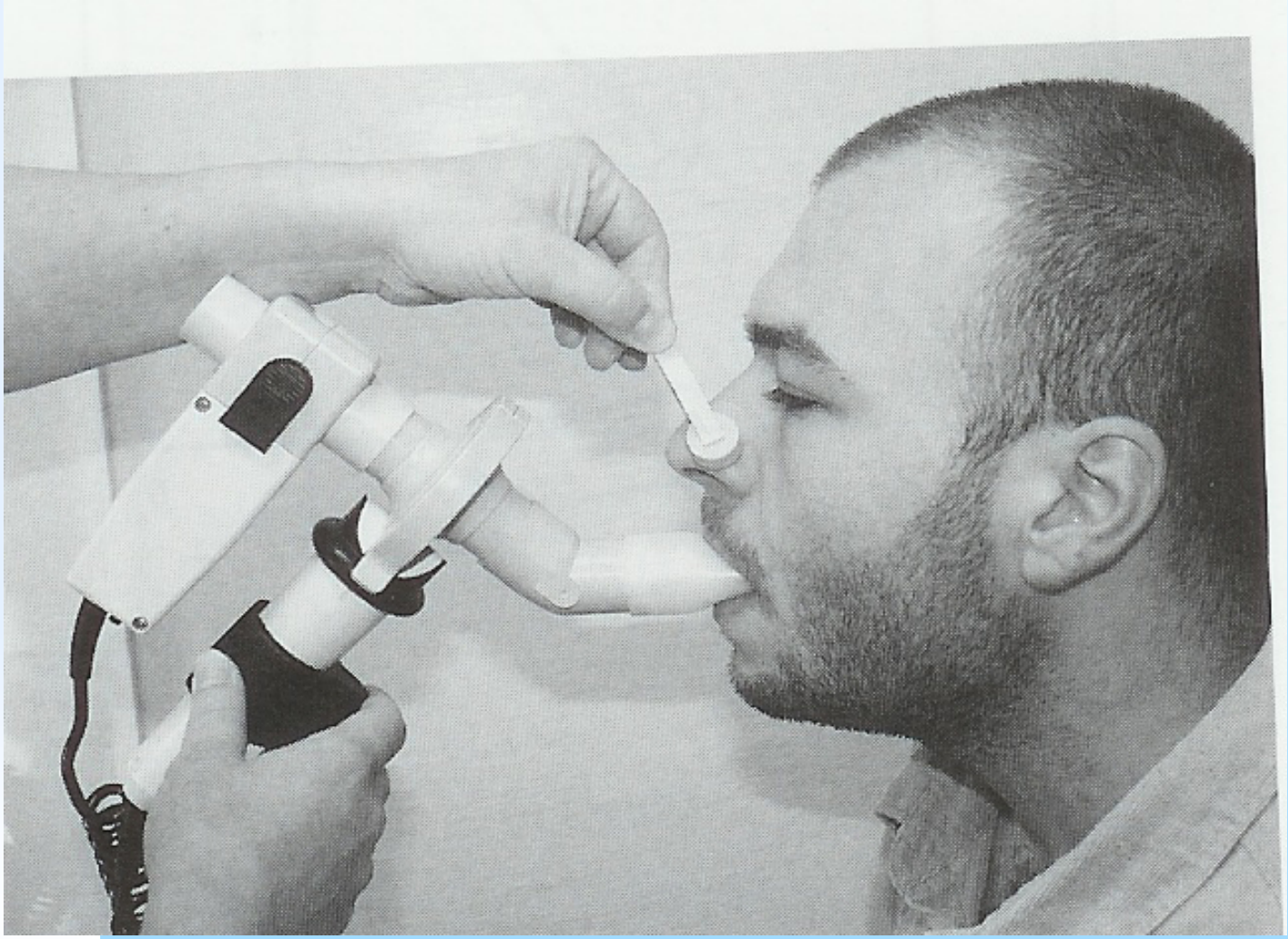
- Unknown cause – Autoimmunity?
- People after 50 / 3 years life expectancy
- Symptoms:
  - Tachypnoe, cyanosis, finger clubbing
- Dg:
  - Chest X-ray
  - HRCT
  - Spirometry/whole body pletysmography
  - Blood gas analysis
  - Inflamatory and autoimmunity testing
- Biopsy and histology: Histology: Usual interstitial pneumonia

Other fibroses/ occupational medicine

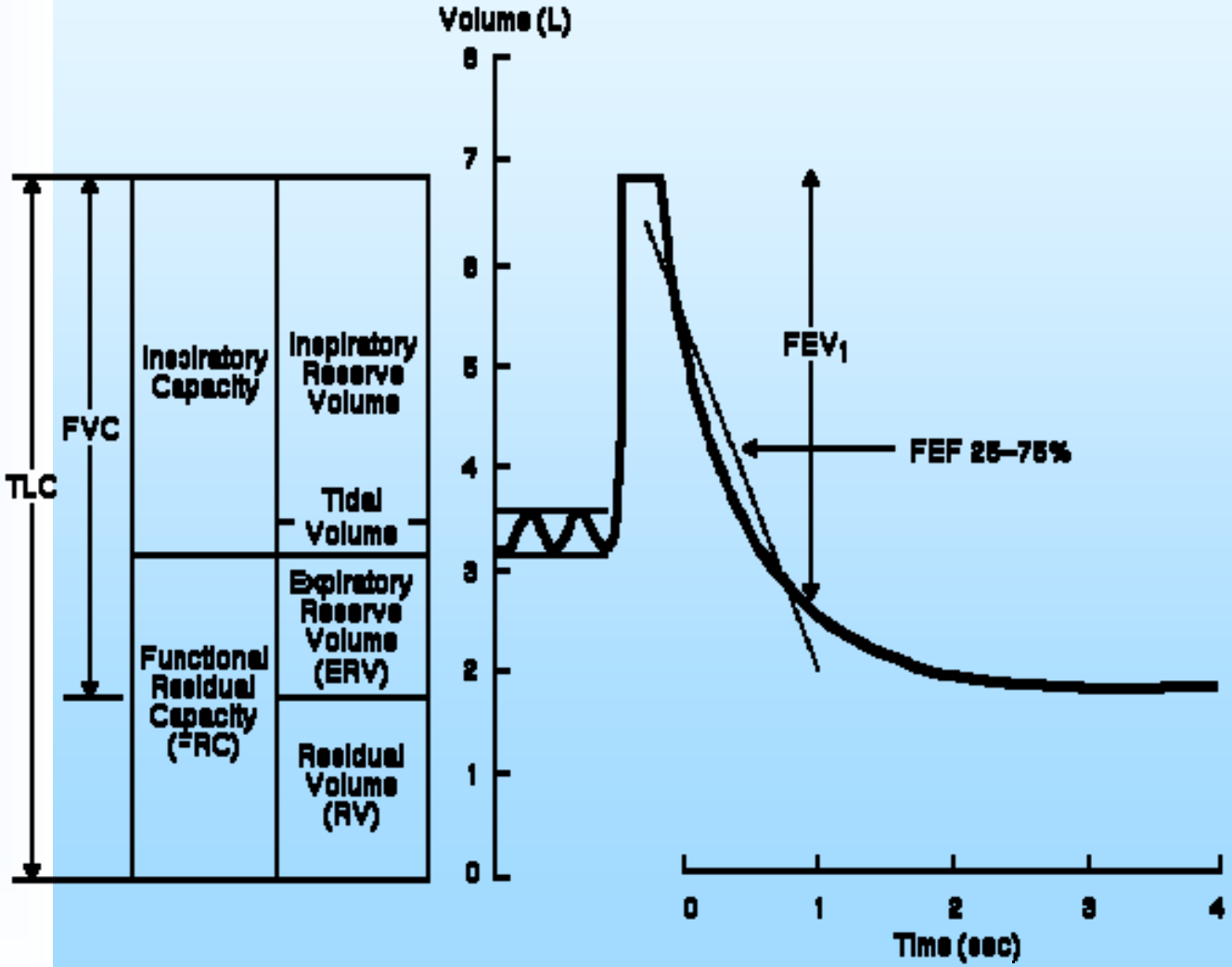
- Pneumoconioses
- Asbestosis
- Silicosis

Assessment of ventilation = spirometry

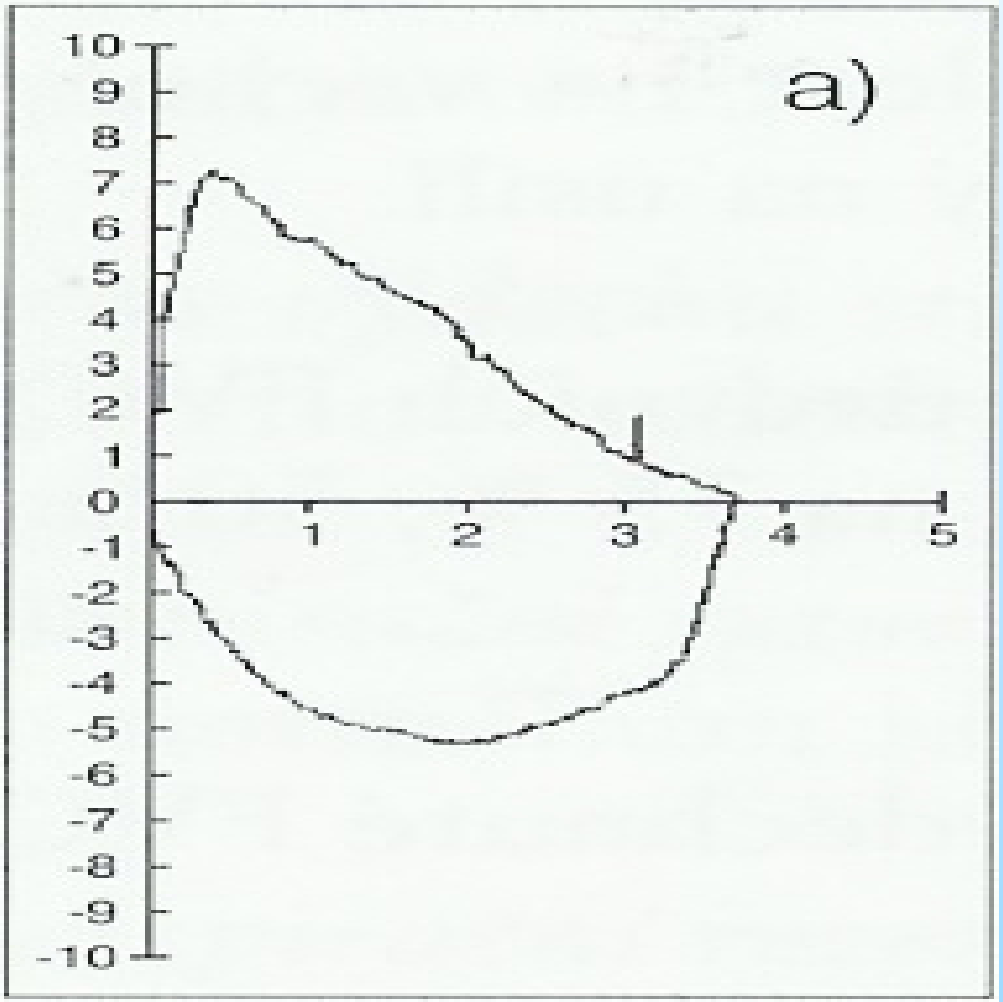
Spirometry - Measure of ventilation volumes (and air flow)



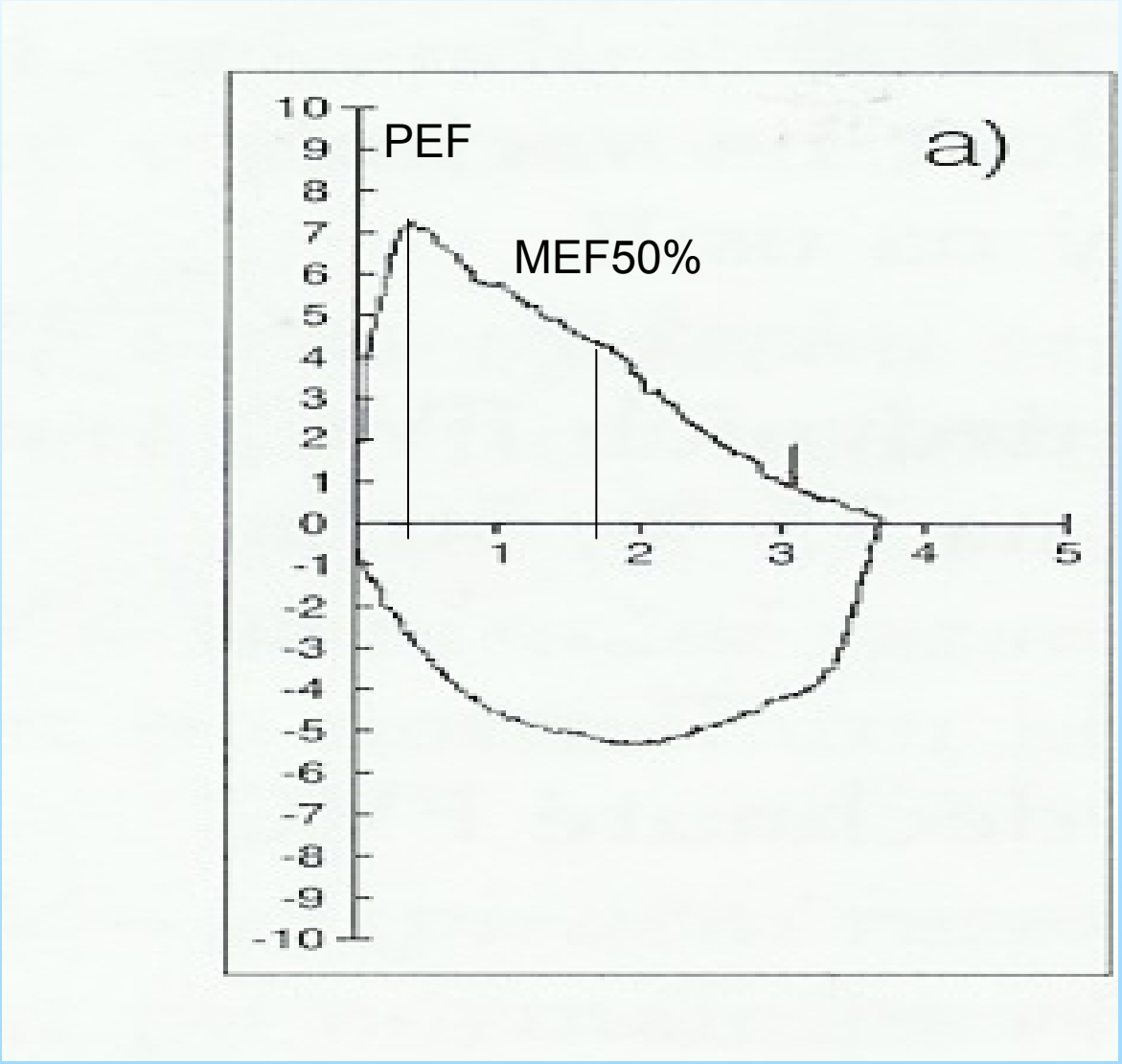
Spirometry


Volume (L)
8
7
6
5
4
3
2
1
0
TLC
FVC
Inspiratory Capacity
Inspiratory Reserve Volume
Tidal Volume
Expiratory Reserve Volume (ERV)
Functional Residual Capacity (=RC)
Residual Volume (RV)
FEV1
FEF 25–75%
0
1
2
3
4
Time (sec)

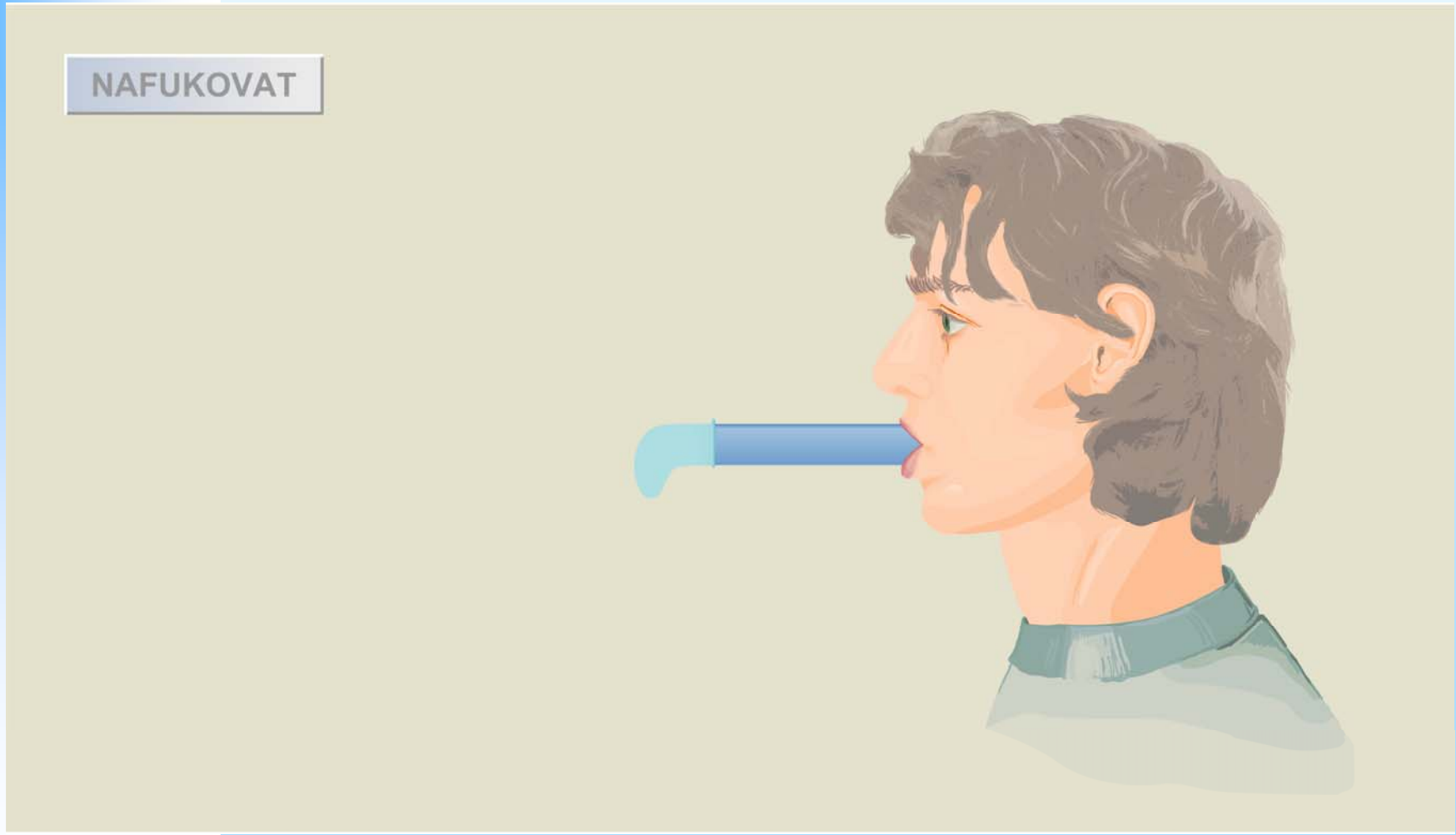
Spirometry – Volume-flow loop



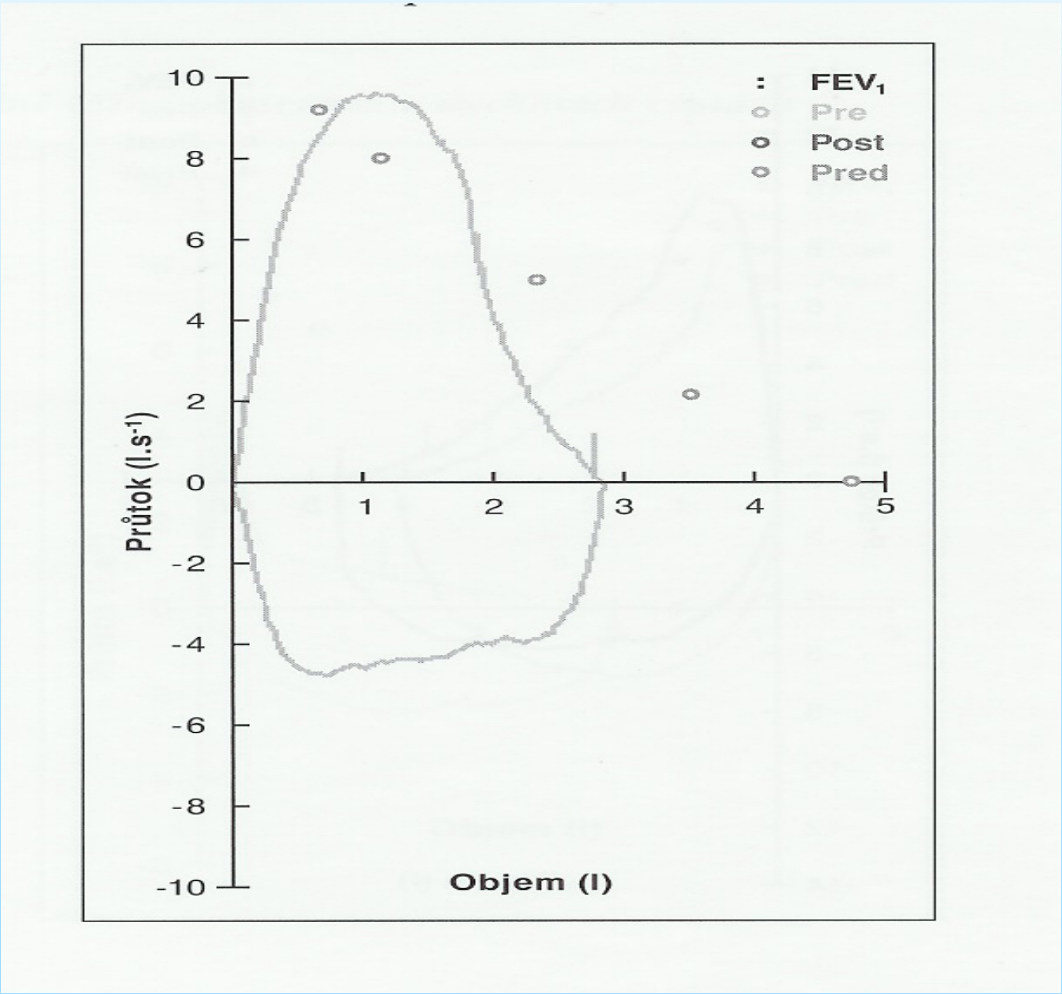
Normal spirogram



Restrictive disease



Restrictive disease



Obstructive disease

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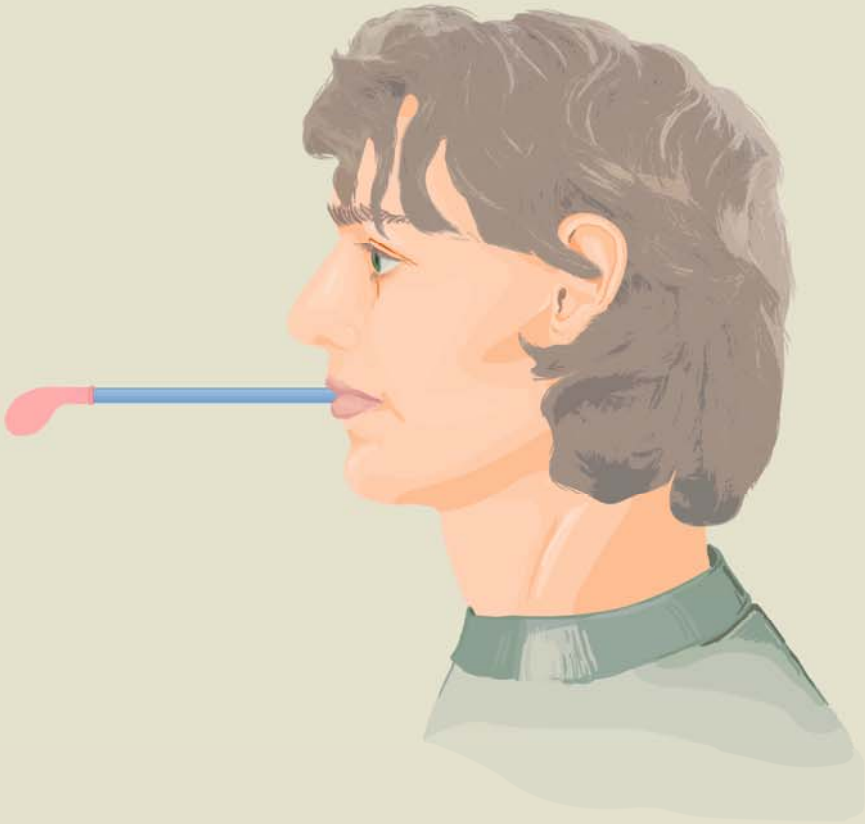
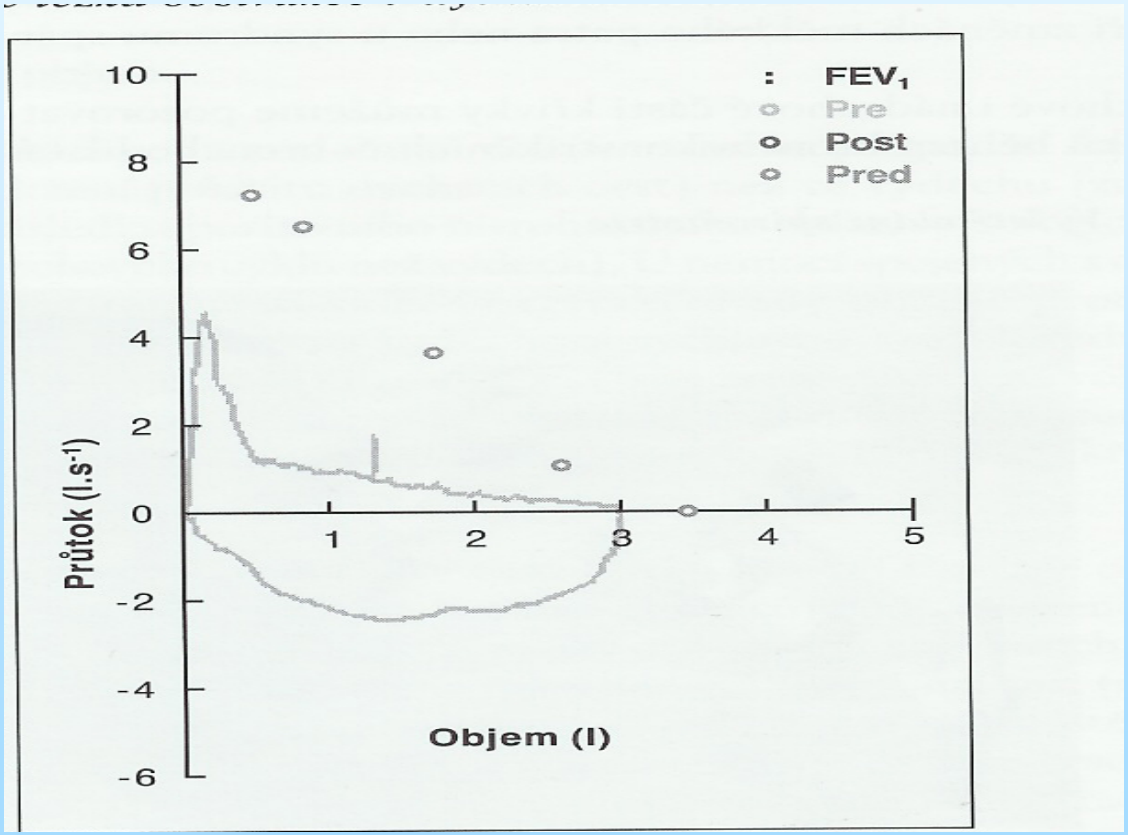
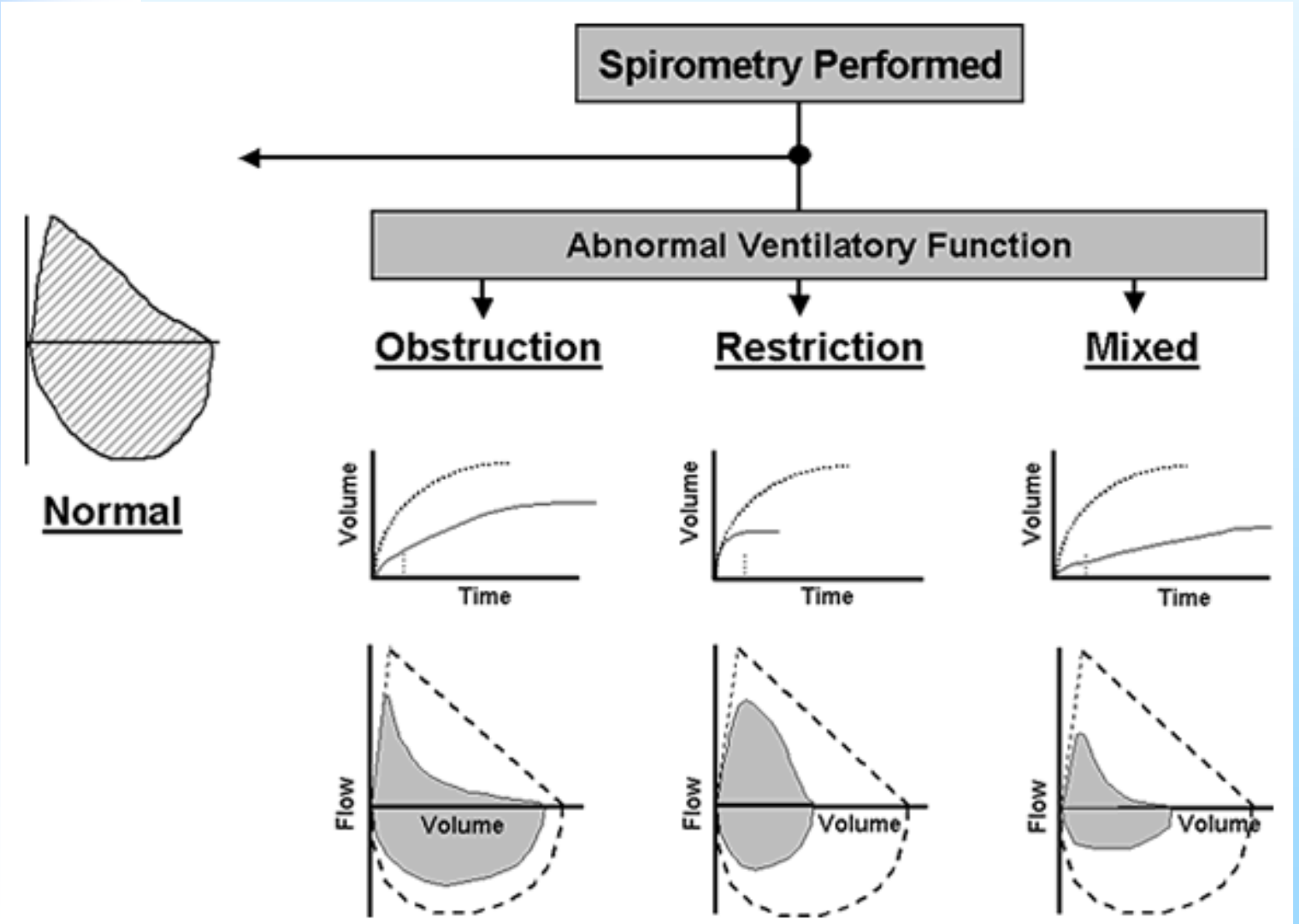


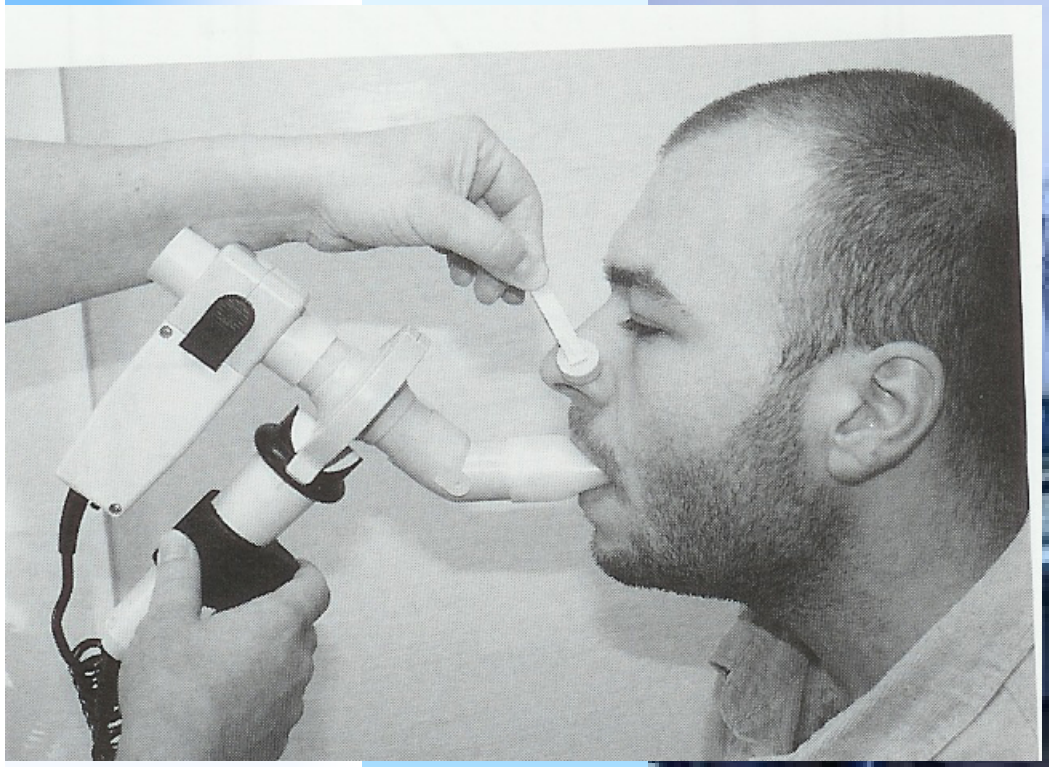
Obstruction- medium degree



Overview


Spirometry Performed
Abnormal Ventilatory Function
Obstruction
Restriction
Mixed
Normal
Volume
Time
Flow
Volume

Spirometry/ Whole body pletysmography



Obstructive vs. Restrictive

Obstructive

Low FEV1

Low FEV1%FVC (index Tiffeneau)

Low PEF, MEF50%, MEF25%, MEF75%

High RV, ERV, low IRV

Restrictive

Low FVC, VC (EVC, IVC)

Low RV, ERV

Division in clinical practice – index Tiffeneau

- Restriction:
  - FEV1%FVC ≥ 55% (should be normal)
  - FVC%pred < 85%
- Obstruction:
  - A low FEV1/FVC ratio (forced expiratory ratio, FER)
  - Or low FEV1/IVC ratio (Tiffeneau index)
- Degree of obstruction:

Obstruction	FEV1%FVC	FEV1%predicted
None	>LLN	
Mild	< LLN	> 60%
Moderate	< LLN	40-59 %
Severe	< LLN	< 40%

The lecture

What did we cover

- **Context –** four possible disturbances of pulmonary function; insufficienly
- **Static characteristics** of the lung – intrapleural pressure, surfactant, **restrictive** disease
- **Dynamic** characteristics of the lung – **obstructive** disease
- **Typical obstructive** diseases
- **Typical restrictive** disease – **lung fibrosis**
- **Assesment** of ventilatory // = **spirometry** etc.