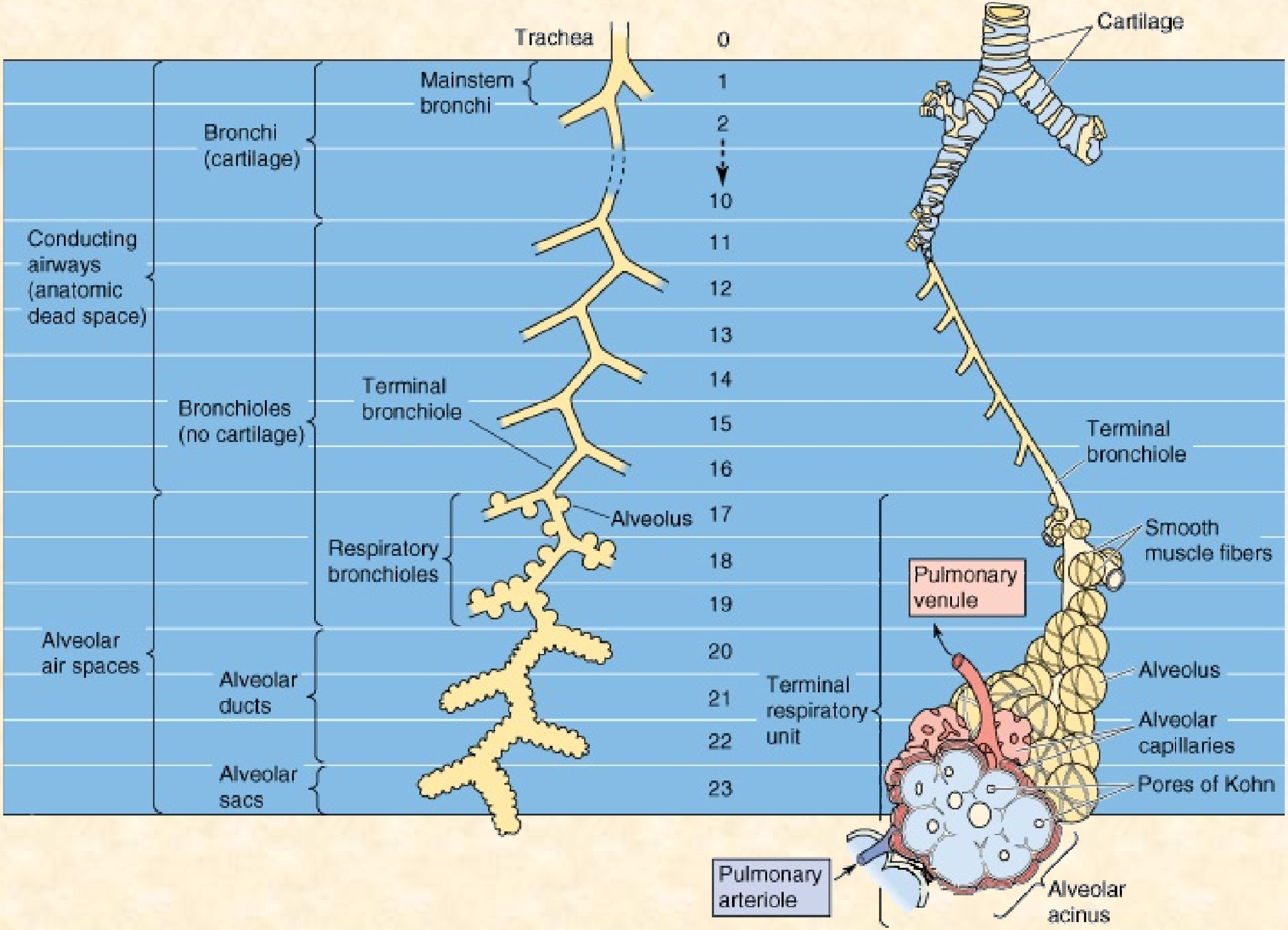
RESPIRATORY SYSTEM

RESPIRATORY FUNCTIONS
MECHANICS OF RESPIRATORY SYSTEM
GAS TRANSPORT



Trachea
0
Mainstem bronchi
1
2
10
Bronchi (cartilage)
Conducting airways (anatomic dead space)
11
12
13
14
15
16
Bronchioles (no cartilage)
Terminal bronchiole
Alveolus
17
18
19
Respiratory bronchioles
Alveolar air spaces
20
21
22
Alveolar ducts
23
Alveolar sacs
Terminal respiratory unit
Cartilage
Terminal bronchiole
Smooth muscle fibers
Pulmonary venule
Alveolus
Alveolar capillaries
Pores of Kohn
Pulmonary arteriole
Alveolar acinus

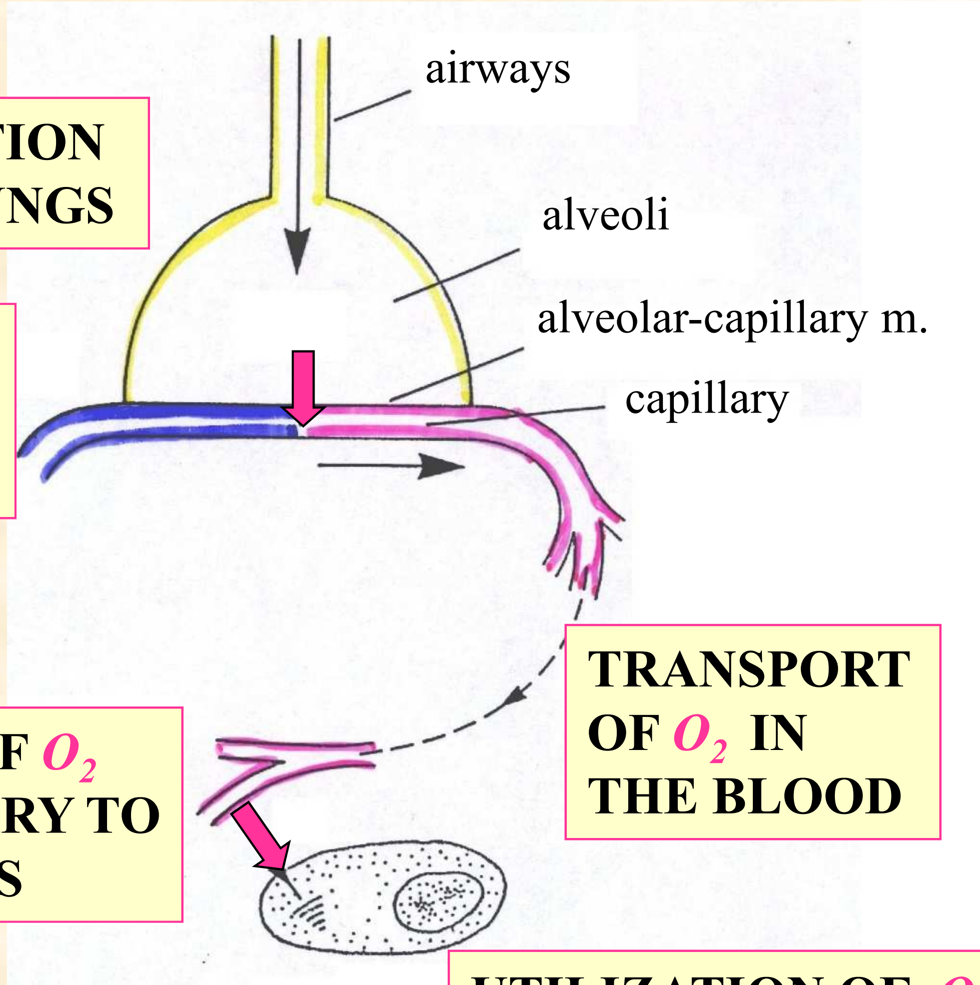
STEPS IN THE DELIVERY OF O_2 TO THE CELLS

VENTILATION OF THE LUNGS

Ventilation disorder: aspiration of a foreign body

DIFFUSION OF O_2 ACROSS ALVEOLAR-CAPILLARY MEMBRANE

diffuse disorder: emphysema, edema, fibrosis



TRANSPORT OF O_2 IN THE BLOOD

DIFFUSION OF O_2 FROM CAPILLARY TO THE CELLS

UTILIZATION OF O_2 BY MITOCHONDRIA

AT REST

O_2 UPTAKE ~300 ml / min

CO_2 OUTPUT ~250 ml / min

INTERNAL RESPIRATION

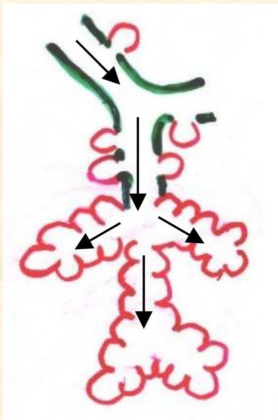
AIR PASSAGES

ANATOMICAL DEAD SPACE –CONDUCTING ZONE

- NASAL PASSAGES
- PHARYNX
- LARYNX
- TRACHEA
- BRONCHI
- BRONCHIOLES
- TERMINAL BRONCHIOLES

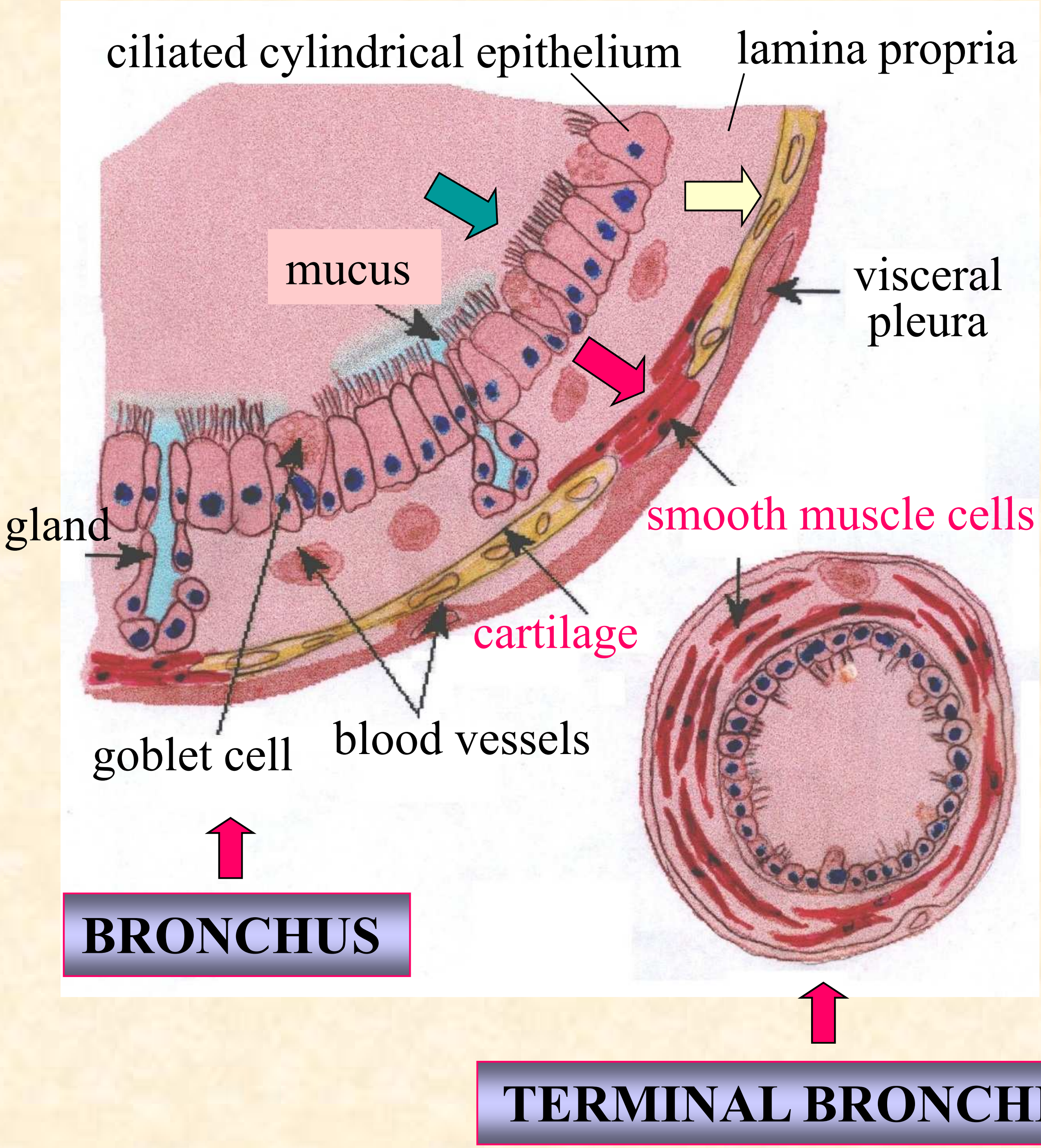
Other physiological functions:

- air is warmed, cleaned and takes up water vapour
- respiratory reflex responses to the irritants
- speech and singing (function of larynx –vocal corce)



RESPIRATORY ZONE
(GAS EXCHANGE)

Total alveolar area ~100 m^2



$\varnothing < 1$ mm

AUTONOMIC INNERVATION of smooth muscle cells

Muscarinic receptors:
Acetylcholine activates
bronchoconstriction

PARASYMPATHETIC NS

β-adrenergic receptors:
Noradrenaline activates
bronchodilatation

SYMPATHETIC NS

V_T tidal volume ~ **500 ml**

$V_T = V_A + V_D$

V_A part of tidal volume entering alveoli ~ **350 ml**

V_D part of tidal volume remaining in the dead space ~ **150 ml**

f = 12/min

$\dot{V} = V_T \times f$

PULMONARY MINUTE VENTILATION

6 l/min

$\dot{V}_A = V_A \times f$

ALVEOLAR VENTILATION

4.2 l/min

$\dot{V}_D = V_D \times f$

DEAD SPACE VENTILATION

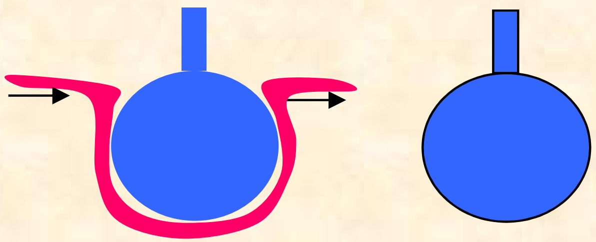
1.8 l/min

DEAD SPACE

TOTAL GAS VOLUME NOT EQUILIBRATED WITH BLOOD
(without exchange of gasses)

- **ANATOMICAL dead space - volume of air passages**
- **FUNCTIONAL (total) dead space =**

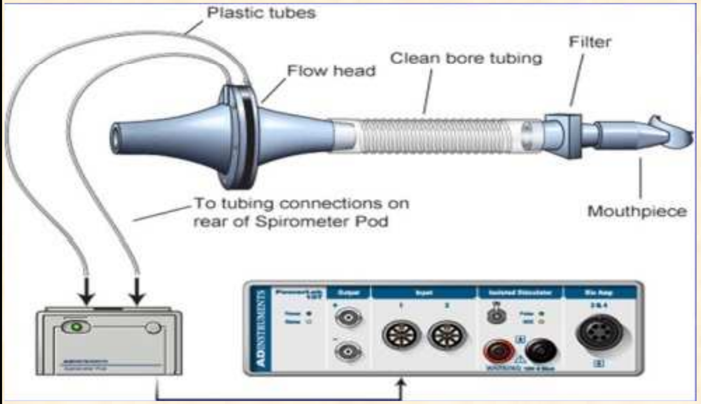
= ANATOMICAL dead space + total VOLUME of ALVEOLI without functional capillary bed

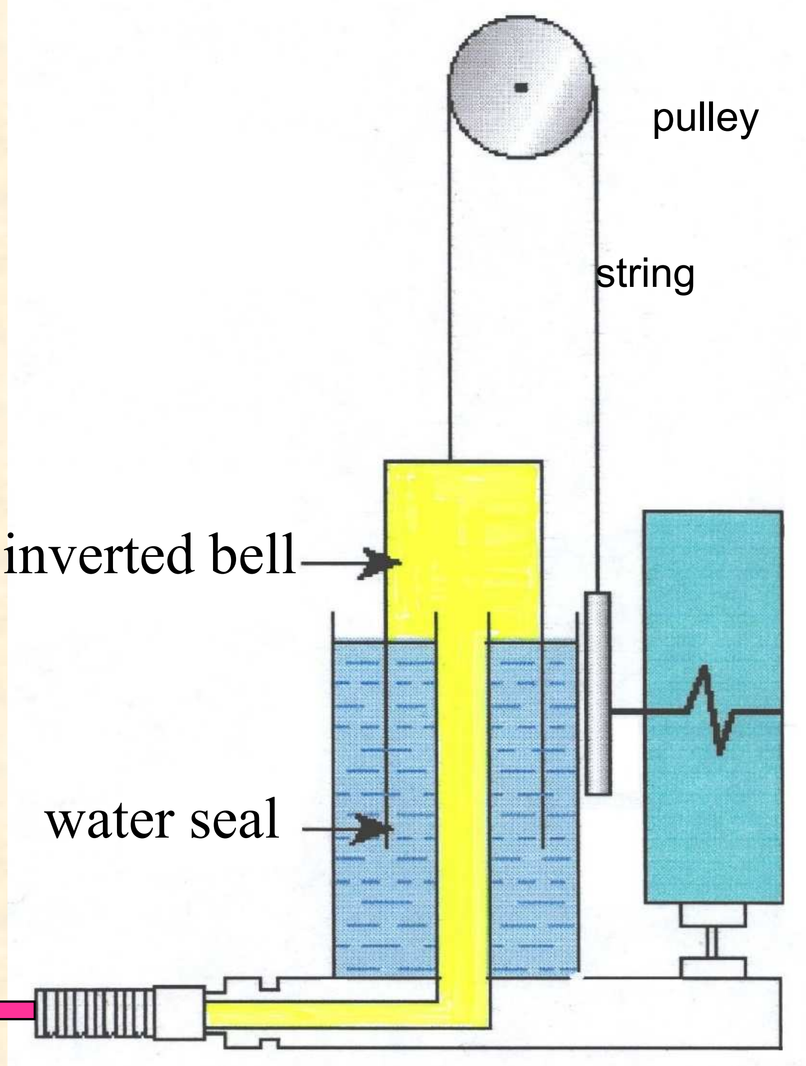


IN HEALTHY INDIVIDUALS
both spaces are practically identical

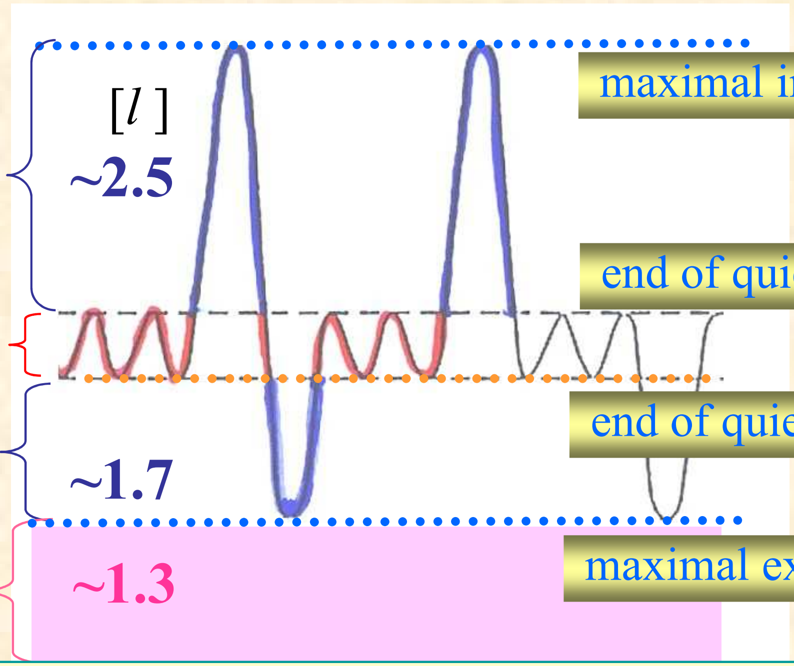
SPIROMETRY

(measurements of lung volumes, capacities, functional investigations, …)





LUNG VOLUMES



INSPIRATORY RESERVE VOLUME *IRV*

TIDAL VOLUME V_T

EXPIRATORY RESERVE VOLUME *ERV*

RESIDUAL VOLUME *RV*

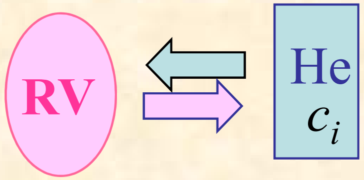
maximal inspiratory level

end of quiet inspiration

end of quiet expiration

maximal expiratory level

DILUTION METHOD
He

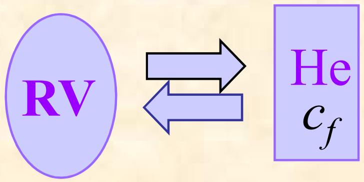


reservoir (V_r)

Principle of method: **1** Maximal expiration, **2** Repeated inspiration from and expiration into a reservoir (known **volume** V_r) with inert gas ***He*** (known concentration c_i)

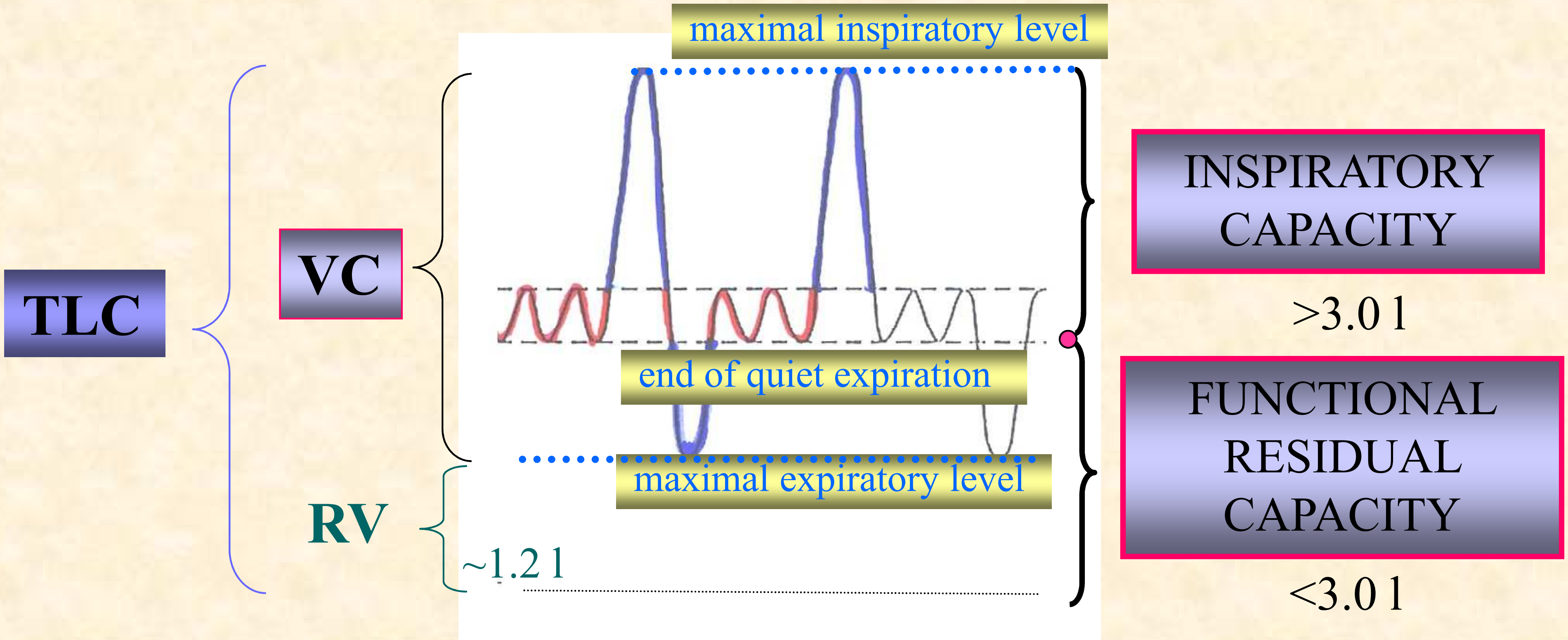
⇒ Equilibration of the air in the residual volume and reservoir

3 Calculation of **residual volume *RV*** from the initial and final *He* concentrations in reservoir (c_i , c_f).



reservoir (V)

$$RV = V_r \frac{c_{i\,He} - c_{f\,He}}{c_{f\,He}}$$



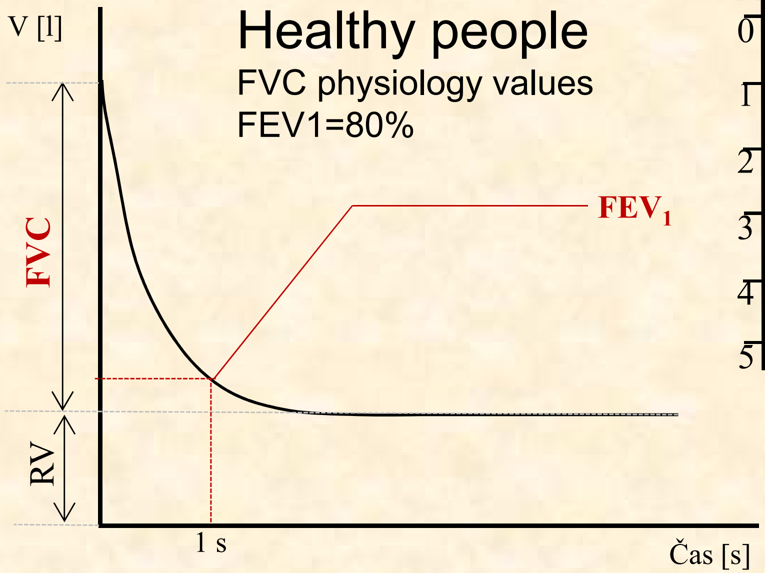
VC | **VITAL CAPACITY = V_T + IRV + ERV** ~ 4.7 l

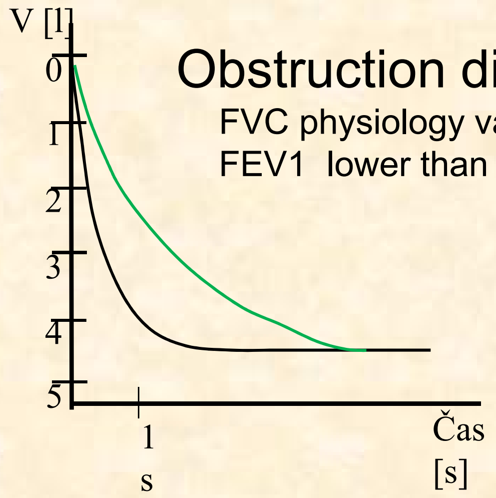
VC - the largest amount of air that can be expired after maximal inspiration

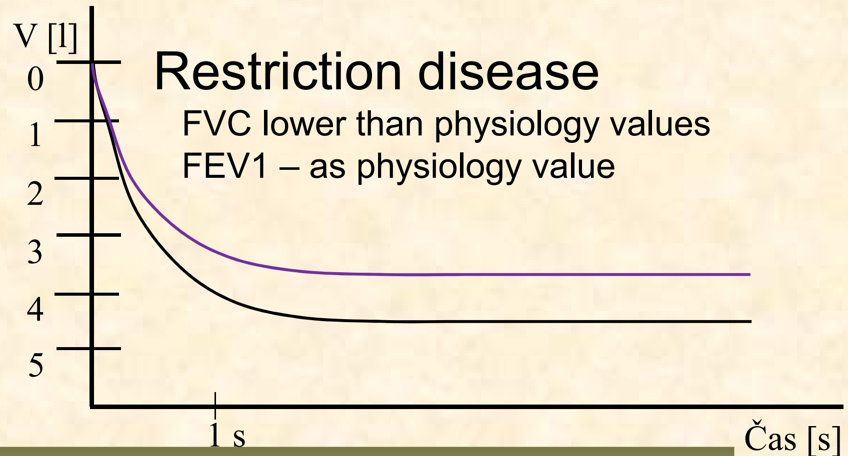
TLC | **TOTAL LUNG CAPACITY = VC + RV** ~ 6.0 l

FUNCTIONAL INVESTIGATION OF THE LUNGS

- **TIMED VITAL CAPACITY** (***FEV***$_1$ - forced expiratory volume per 1 s)



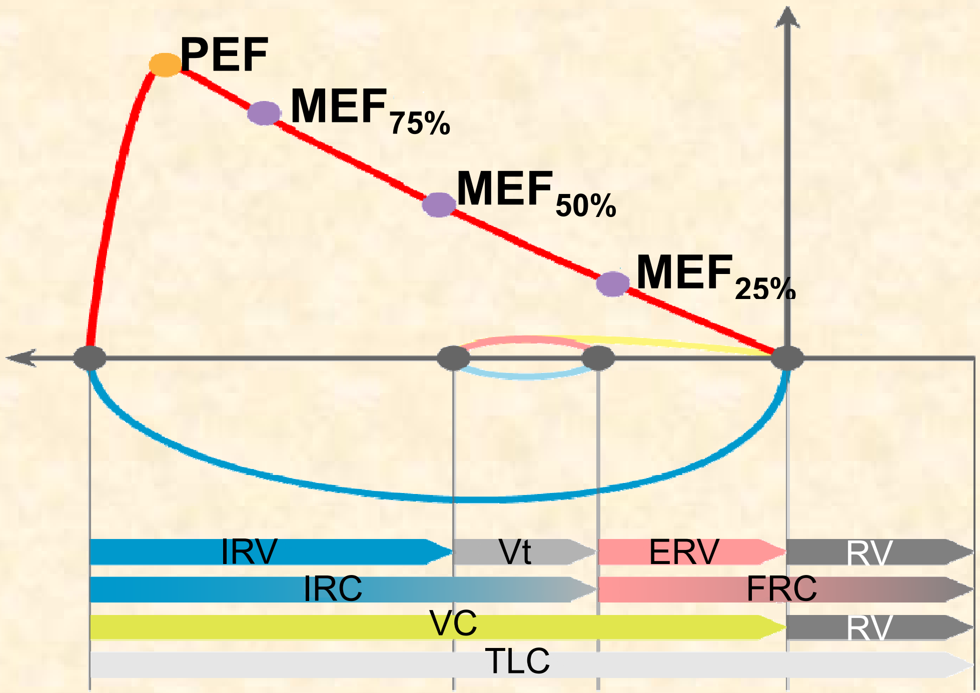


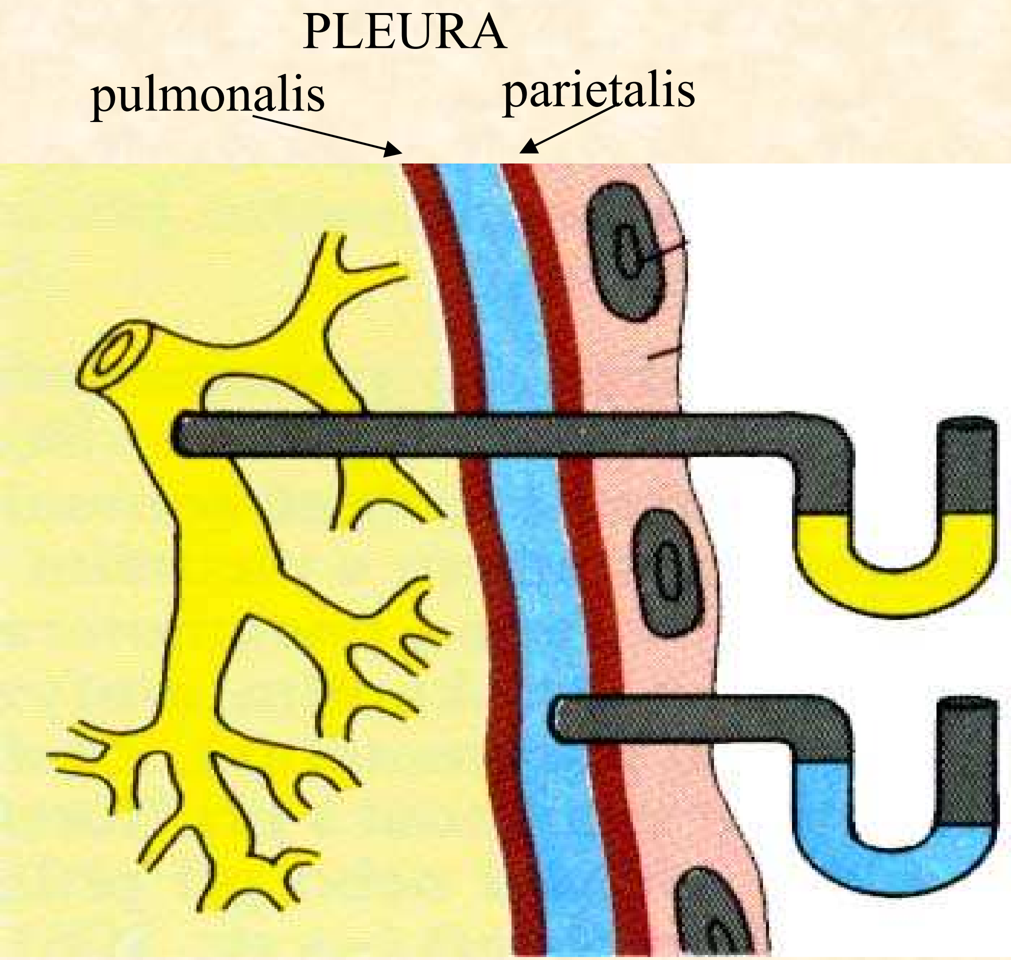


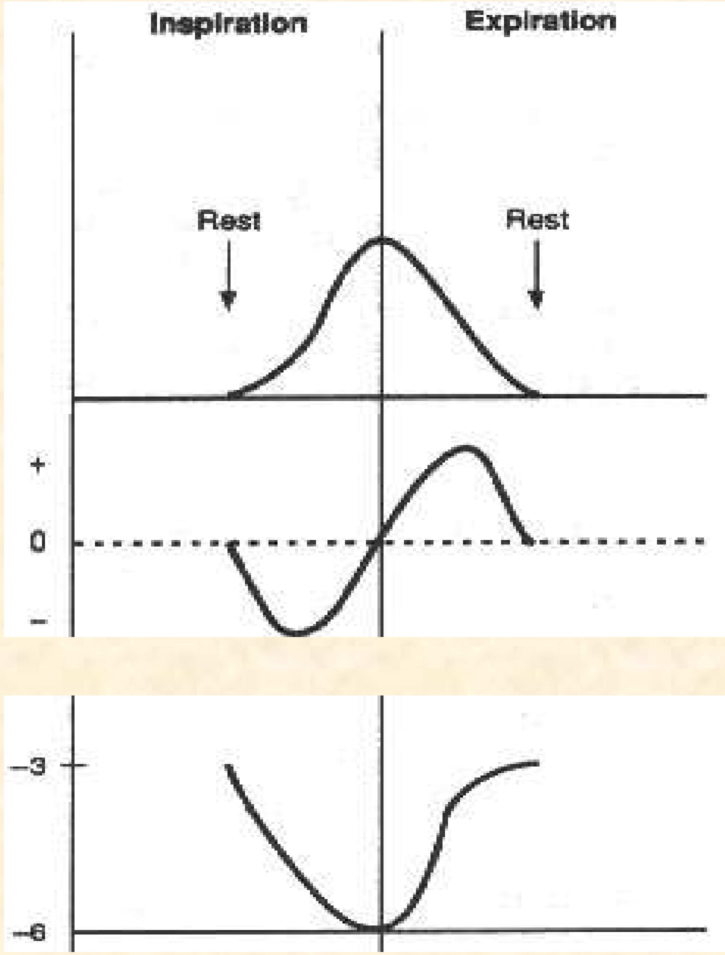
- **PULMONARY MINUTE VENTILATION** ***RMV*** **(respiratory minute volume) at rest** (0.5 l x 12 breathes/min = 6 l/min)
- **MAXIMAL VOLUNTARY VENTILATION (*MVV*)** (125-170 l/min)
- **PEAK EXPIRATORY FLOW RATE (*PEFR*)** (~10 l/s)

Flow – volume curve

- **PEF** – peak expiratory flow
- **MEF** – maximální maximal expiratory flow on the differential levels of FVC - 75 %, 50 % a 25 % FVC




PLEURA
pulmonalis
parietalis


Inspiration
Expiration
Rest
Rest
+
0
−
−3
−6

FORCES PARTICIPATING IN RESPIRATION

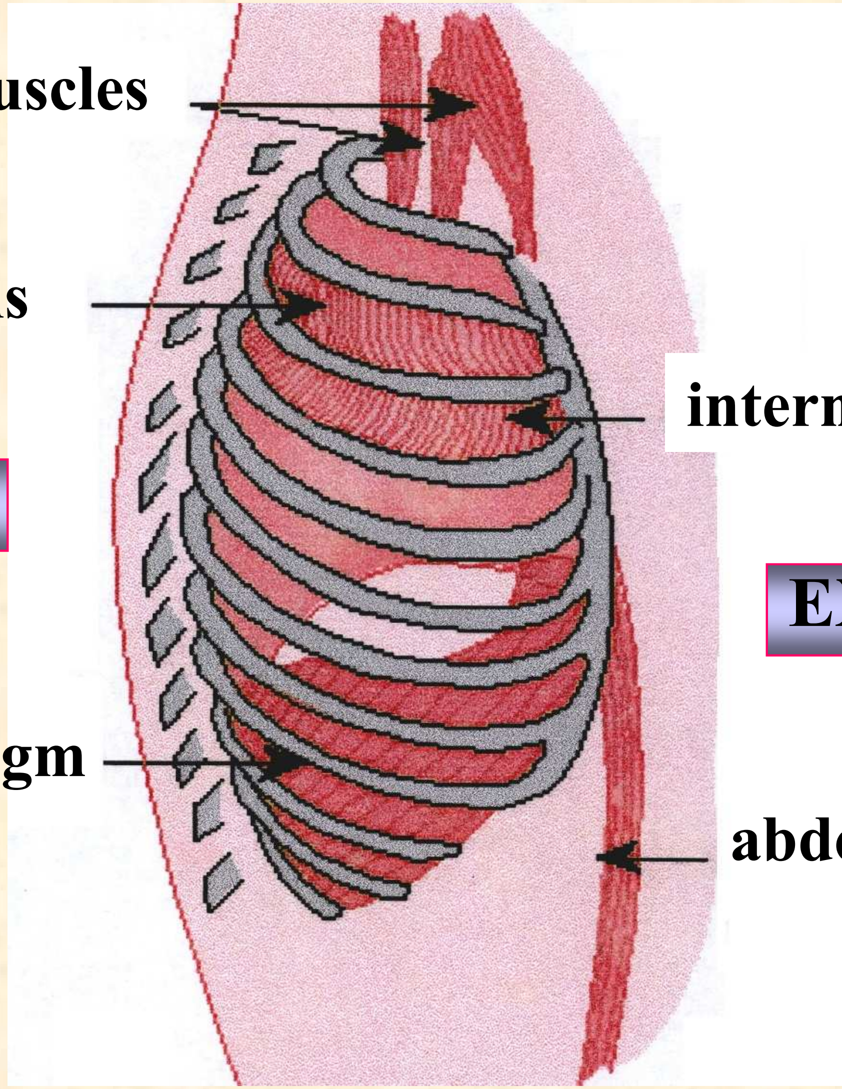
- **ACTIVE FORCES** performed by respiratory muscles
- **PASSIVE FORCES represented by:**
  - **lungs elasticity**
  - **chest elasticity**

QUIET RESPIRATION

INSPIRATION - active forces of inspiratory muscles prevail

EXPIRATION - only passive (elastic) forces are in action

RESPIRATORY MUSCLES



INSPIRATORY muscles

QUIET breathing

- ***diaphragm*** (> 80 %)
- ***external* intercostals** (< 20 %)

FORCED breathing

in addition

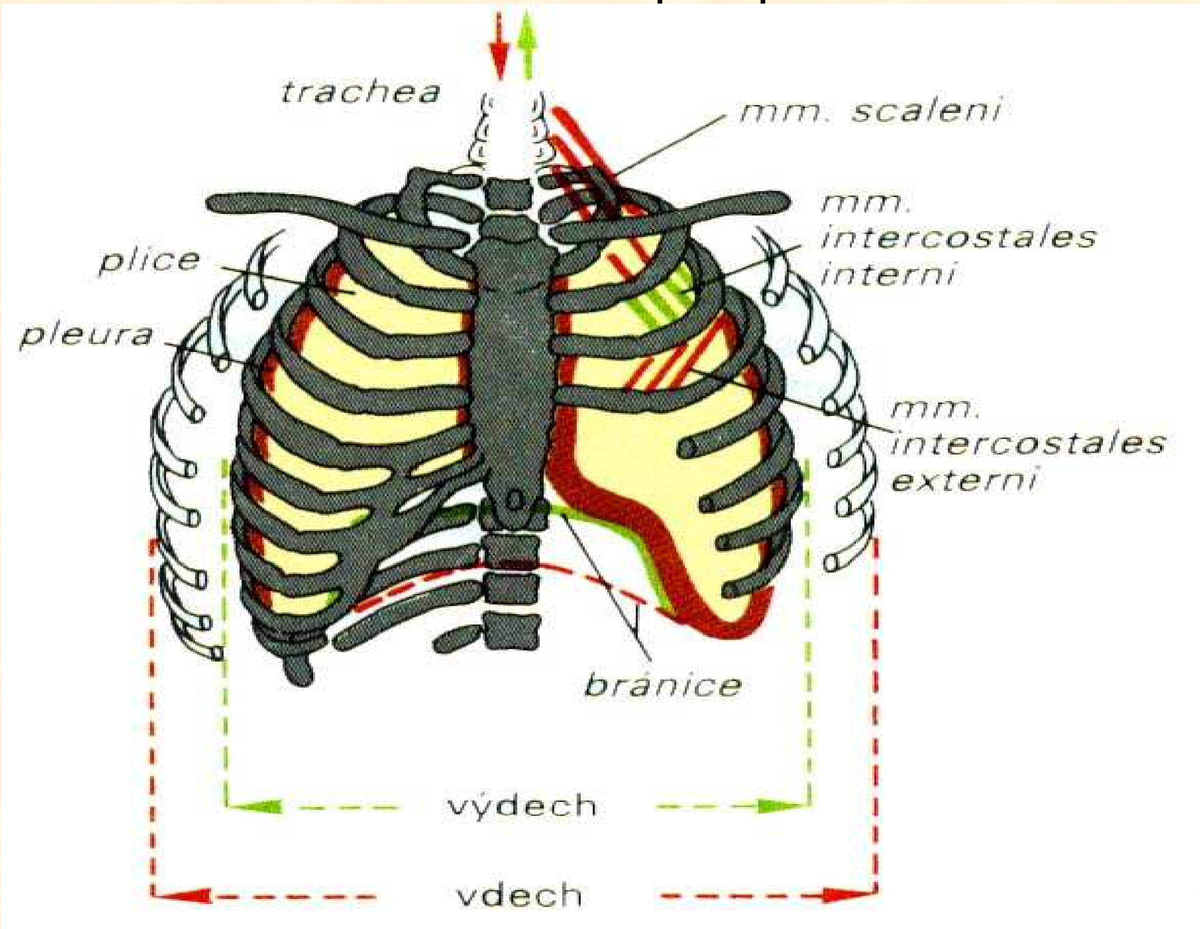
- ***accessory* inspiratory muscles** (mm. scalene)

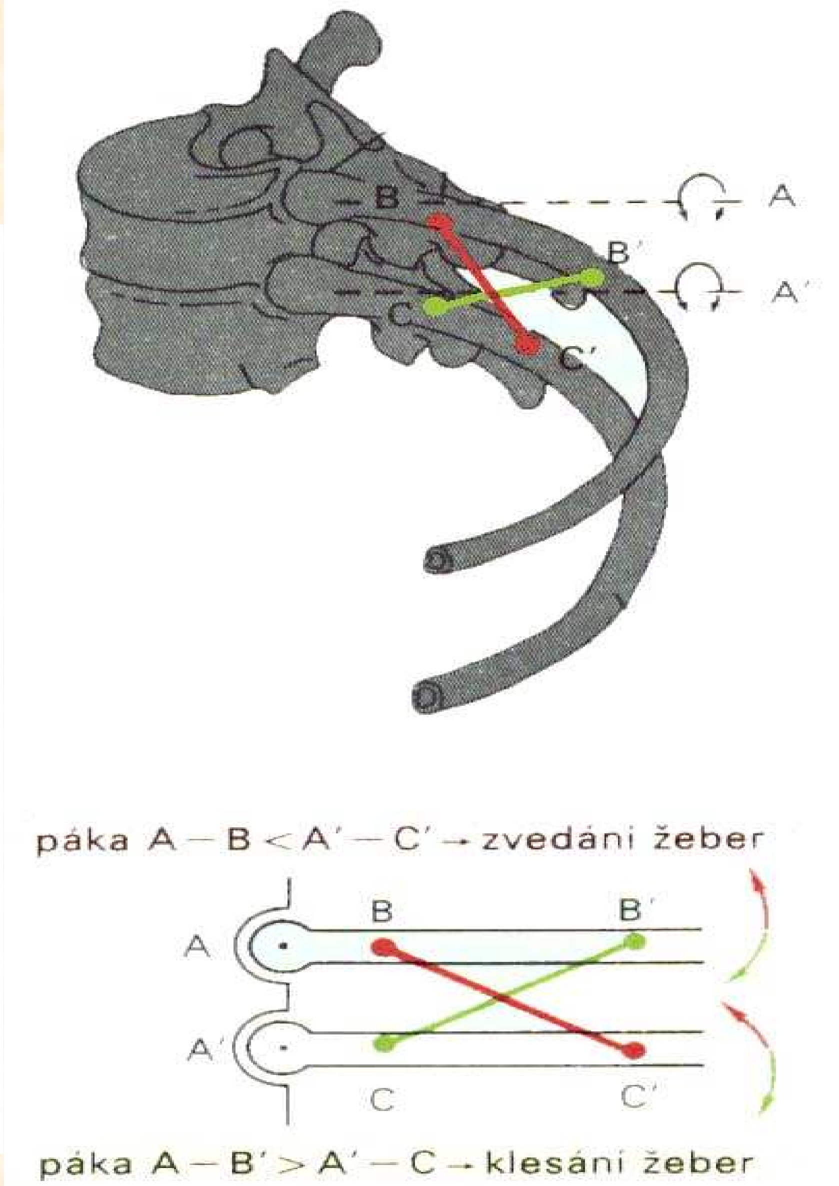
EXPIRATORY muscles

Only at FORCED breathing

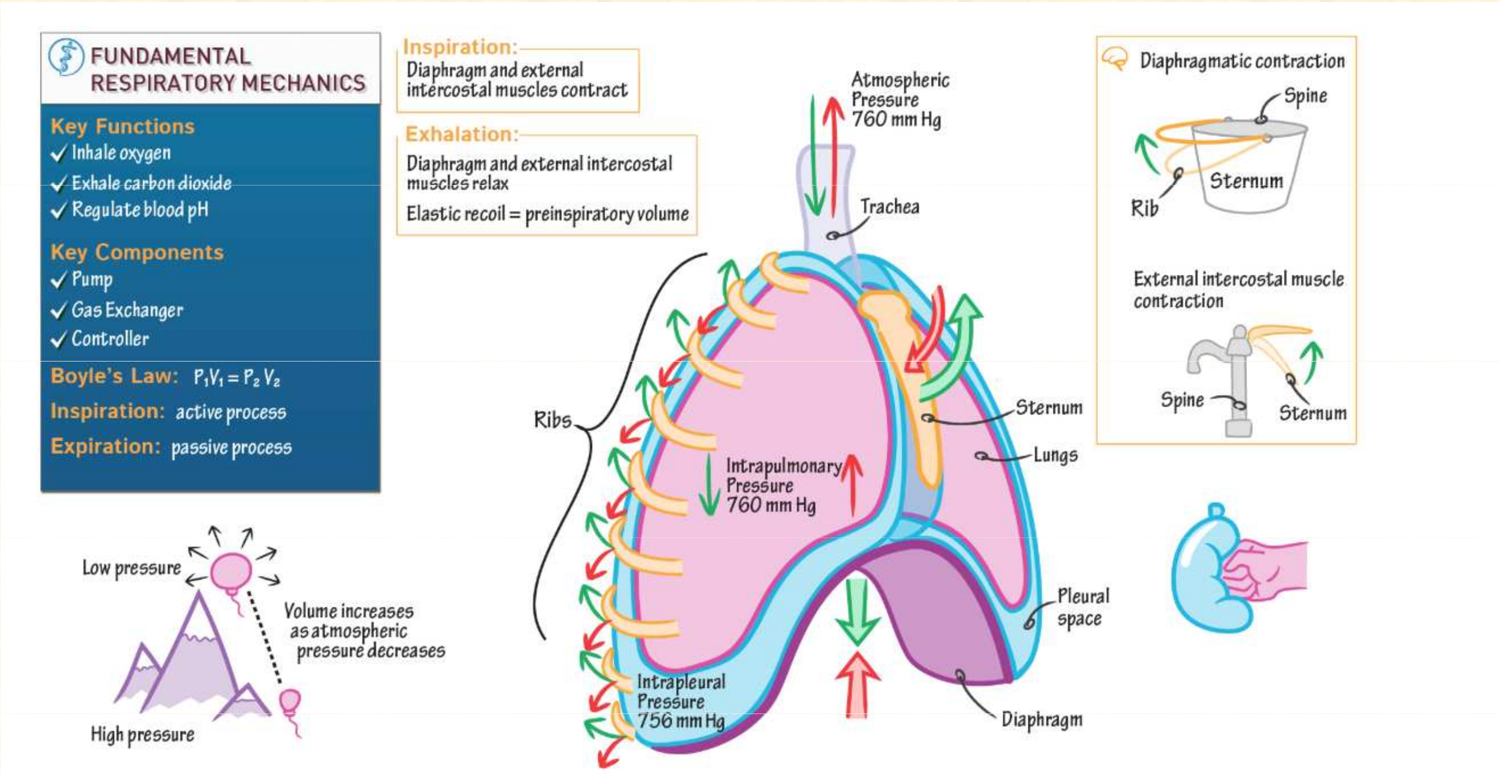
- ***internal* intercostals**
- **muscles of the anterior *abdominal* wall**
  (abdominal recti, …)

Bucket-handle and water-pump handle effects





Respiratory mechanics



COMPOSITION OF DRY ATMOSPHERIC AIR

O_2	20.98 %	$F_{O2} \cong 0.21$
N_2	78.06 %	$F_{N2} \cong 0.78$
CO_2	0.04 %	$F_{CO2} = 0.0004$

Other constituents

BAROMETRIC (ATMOSPHERIC) PRESSURE AT SEA LEVEL

1 atmosphere = 760 mm Hg

PARTIAL PRESSURES OF GASSES IN DRY AIR AT SEA LEVEL

P_{O2} = 760 x 0.21 = ~160 mm Hg

P_{N2} = 760 x 0.78 = ~593 mm Hg

P_{CO2} = 760 x 0.0004 = ~0.3 mm Hg

1 kPa = 7.5 mm Hg (torr)

COMPOSITION OF ALVEOLAR AIR

partial pressures in mm Hg

INSPIRED AIR

O_2 158.8
CO_2 0.3
N_2 601.0
…

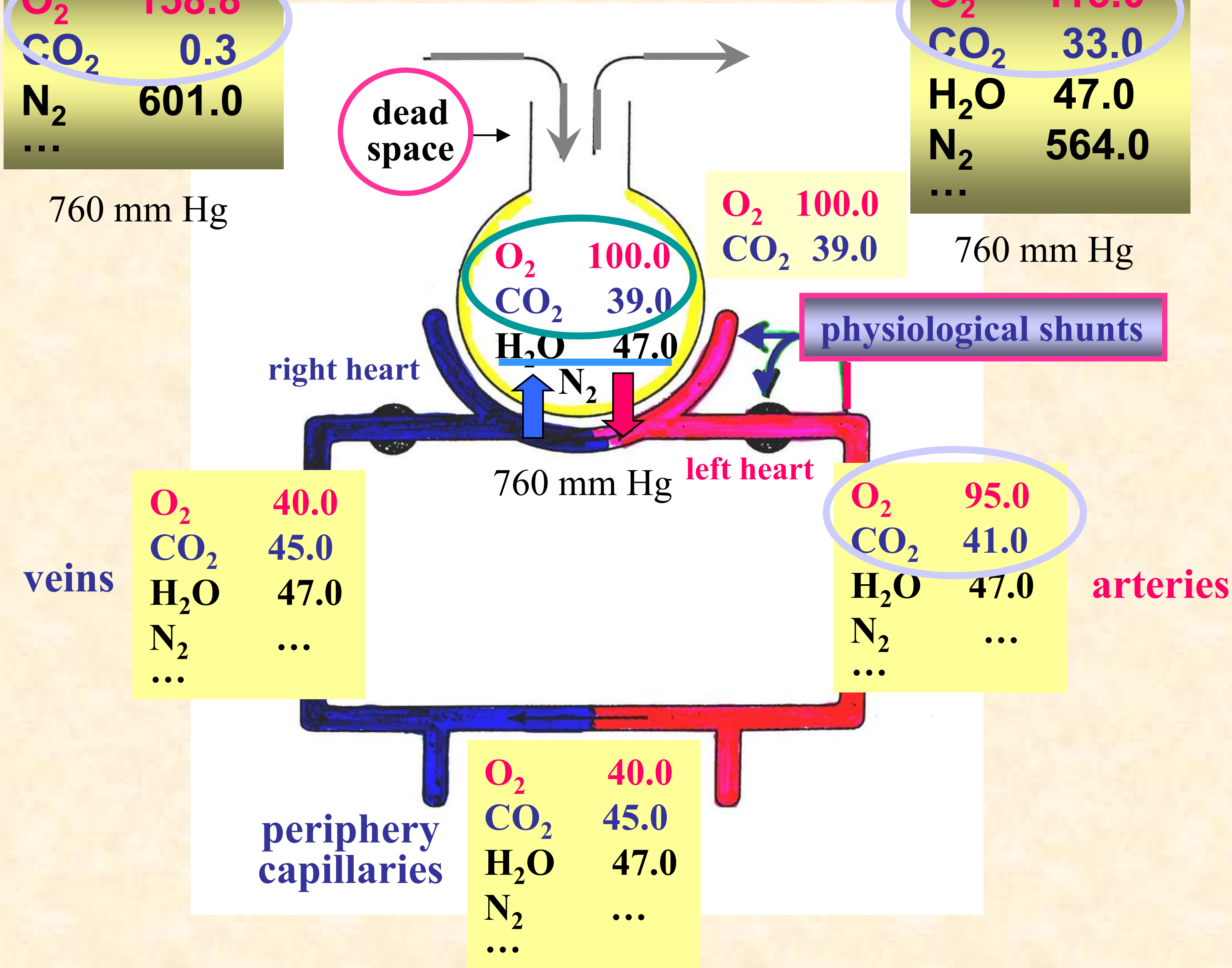
760 mm Hg

EXPIRED AIR

O_2 115.0
CO_2 33.0
H_2O 47.0
N_2 564.0
…

760 mm Hg

?

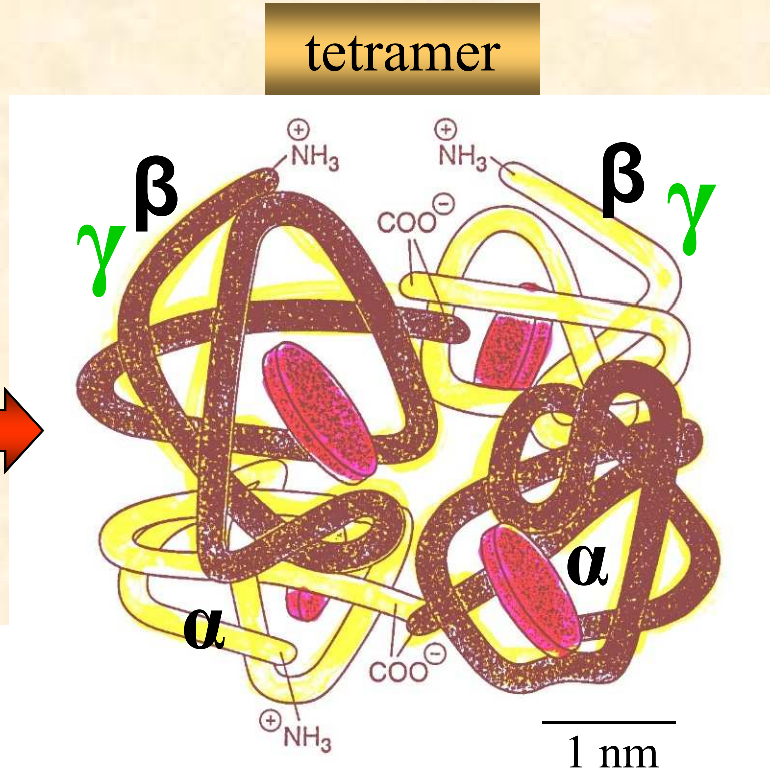


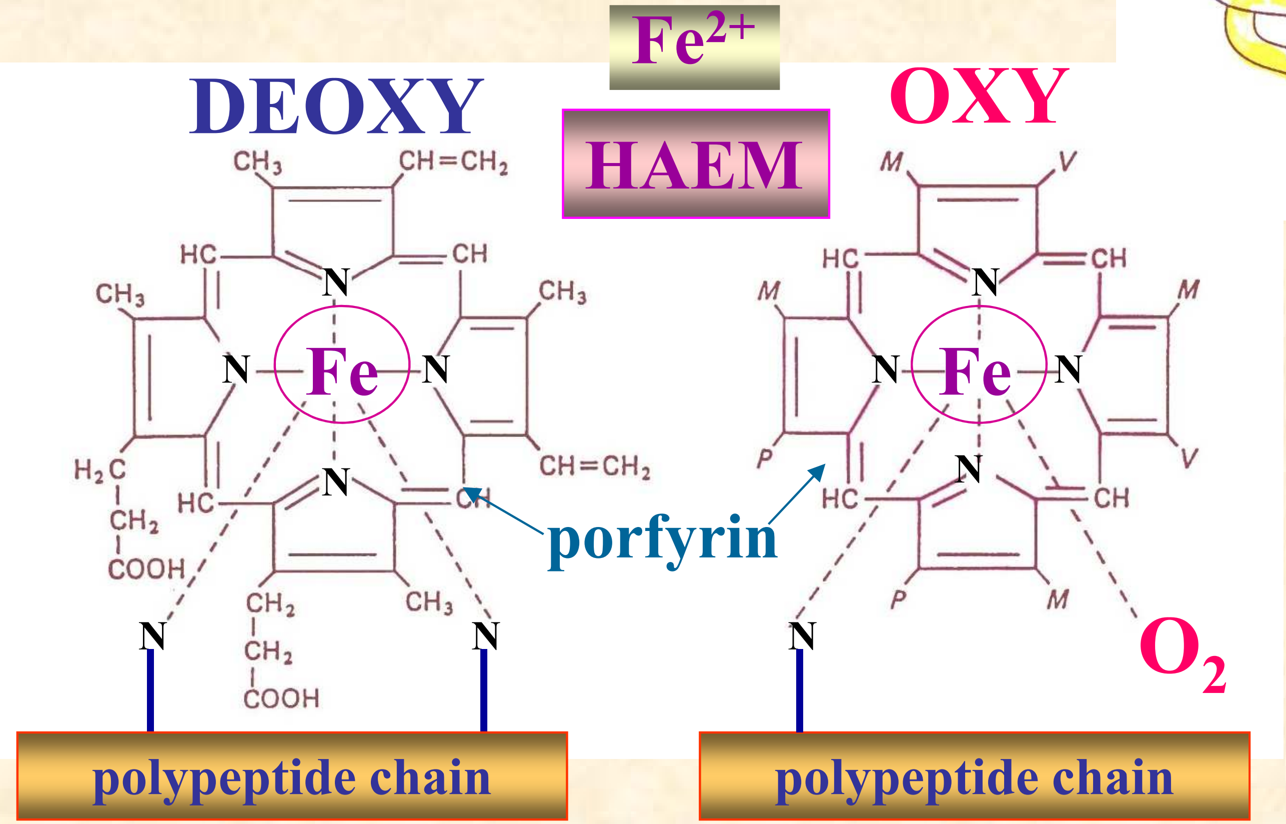
?

HAEMOGLOBIN

$Hb_4 + 4\ O_2 \leftrightarrow Hb_4O_8$

oxygenation

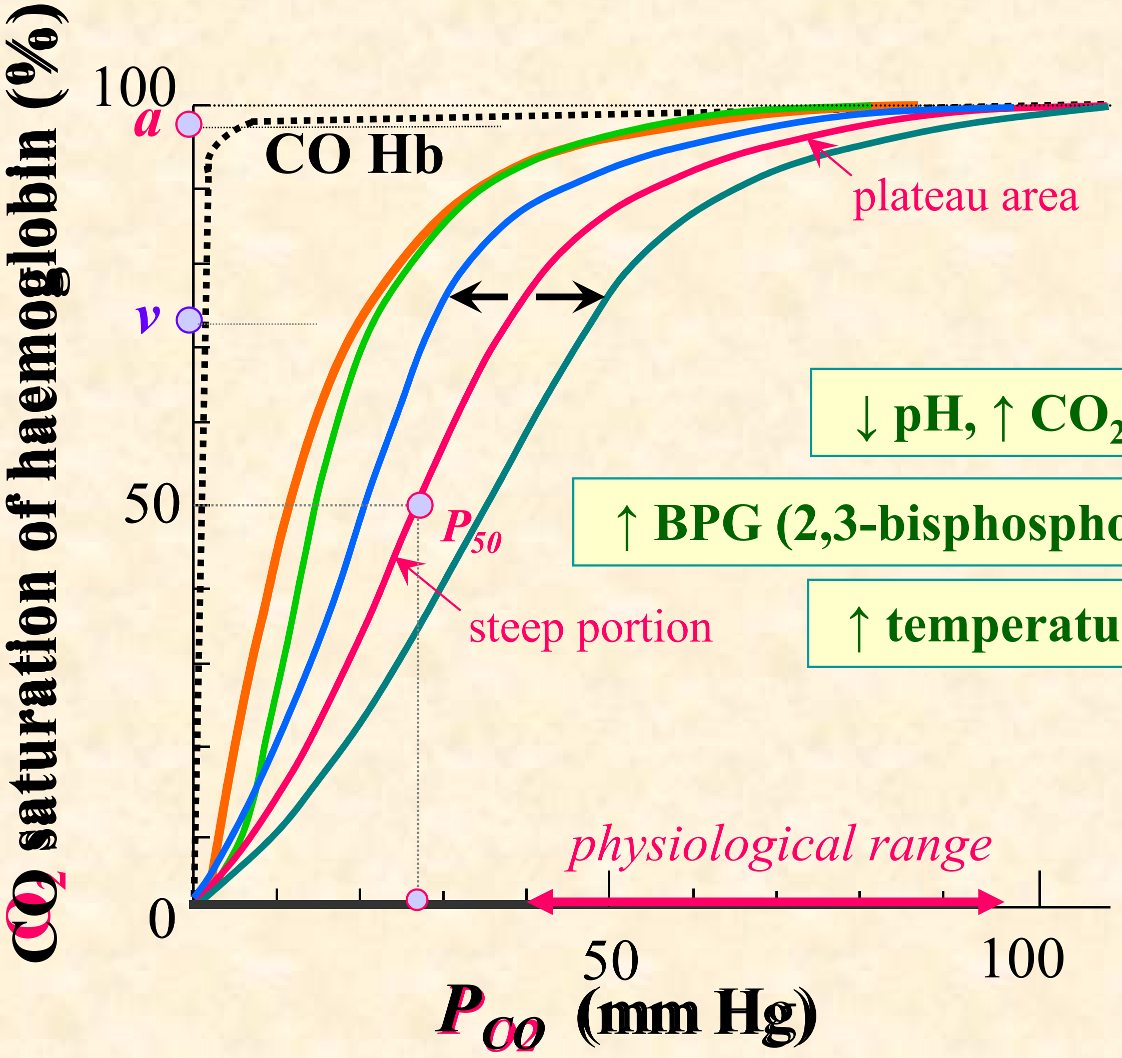




fetal Hb

Fe^{3+} (methaemoglobin)
oxidation

O_2–HAEMOGLOBIN DISSOCIATION CURVE



BOHR´S EFFECT
(↓ pH, ↑CO_2)

↓ pH, ↑ CO_2

↑ BPG (2,3-bisphosphoglycerate)

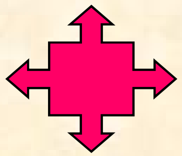
↑ temperature

fetal Hb

myoglobin

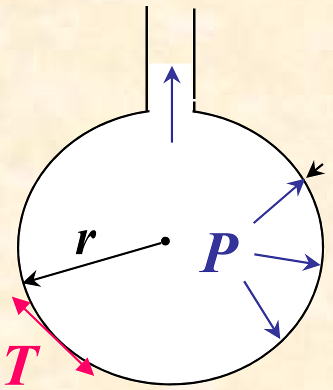
methaemoglobin

physically dissolved O_2 (1.4%)

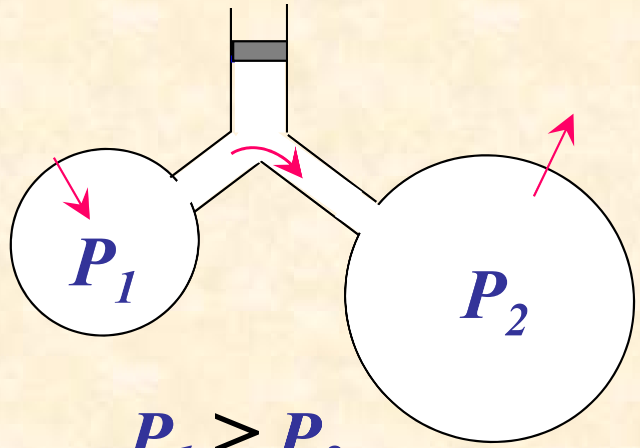


LAW OF LAPLACE

spherical structures



$$P = \frac{2T}{r}$$



$P_1 > P_2$

P pressure

r radius

T surface tension

PATHOLOGY

- COLLAPSE OF ALVEOLI - ATELECTASIS
- EXPANSION OF ALVEOLI

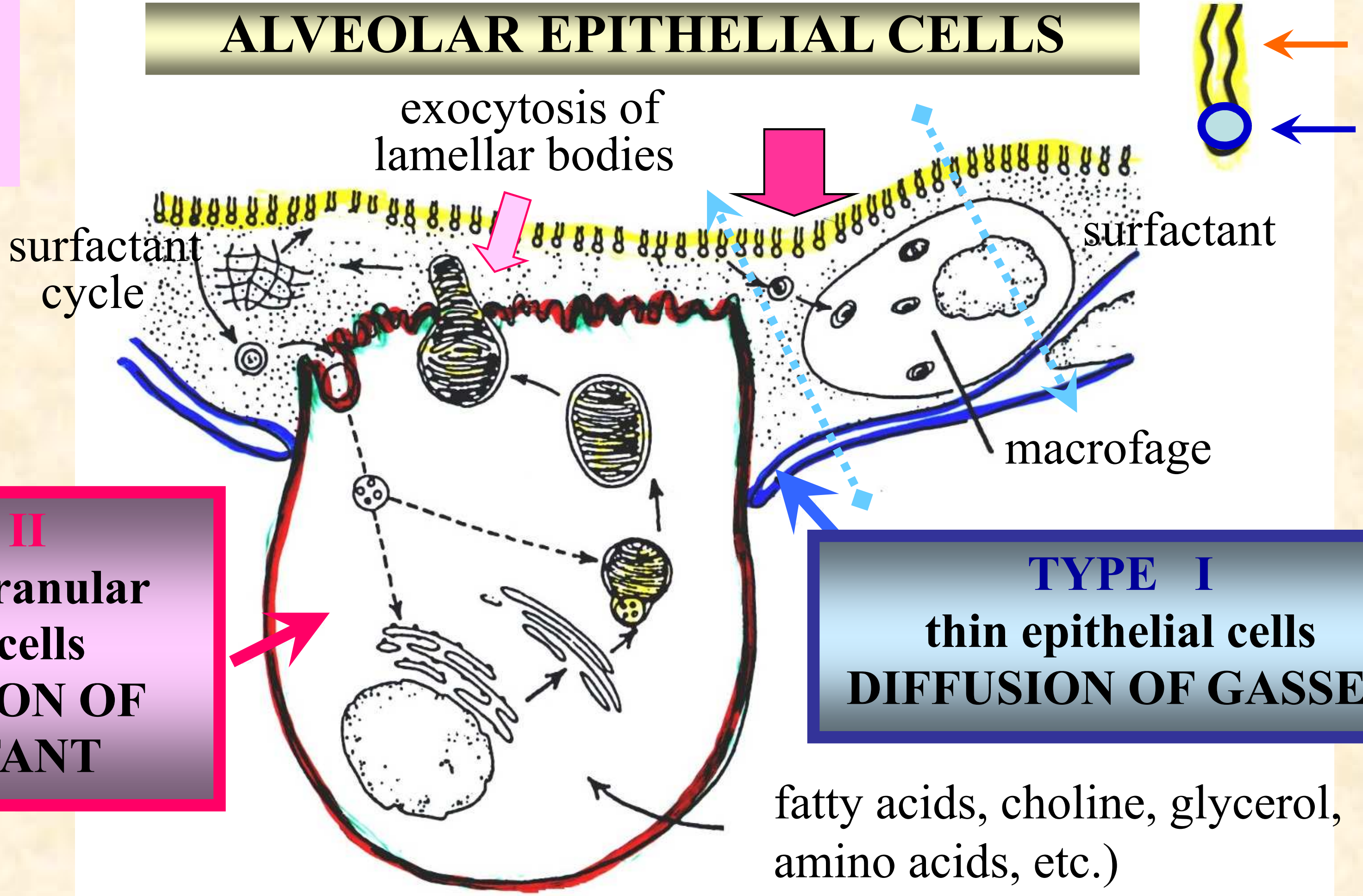
SURFACTANT

SURFACE TENSION LOWERING AGENT

EFFECT MAINLY IN THE EXPIRED POSITION

PHOSPHOLIPID
dipalmitoyl
fosfatidyl cholin

ALVEOLAR EPITHELIAL CELLS



TYPE II
specialized granular epithelial cells
PRODUCTION OF SURFACTANT

TYPE I
thin epithelial cells
DIFFUSION OF GASSES

Surface tension

- Water molecules are attracted to each other more strongly than gas molecules - there is a force acting inwards, towards the gaseous phase - in the case of a round alveolus to its center - tends to expel air from the alveoli - leading to its collapse

END