1 introduction, respiratory insufficiency
2 spirometric classification, restrictive
3 and obstructive diseases
4 ventilation/ to perfusion ratio and other amendments

Outline …

- **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.

Selected spirometric parameters and tests

-Breathing in rest: ventilatory rate (f/min) (~ 12 breaths / min)

-Minute ventilaton (volume/min) 6-8 L/min

- **FVC - Forced vital capacity**

Total volume exhaled during the forced expiration

f: [21.7 – (0.101 x age[y])] × (cm) = (mL)

m: [27.63 – (0.112 x age[y])] × (cm) = (mL)

Values between 80 to 120 % of predicted are considered to be normal

-MVV (Vmax) = Maximal voluntary ventilation

maximal tidal volume (TV) and maximal ventilatory rate measured for 10 – 30 sec

> 40 L/min

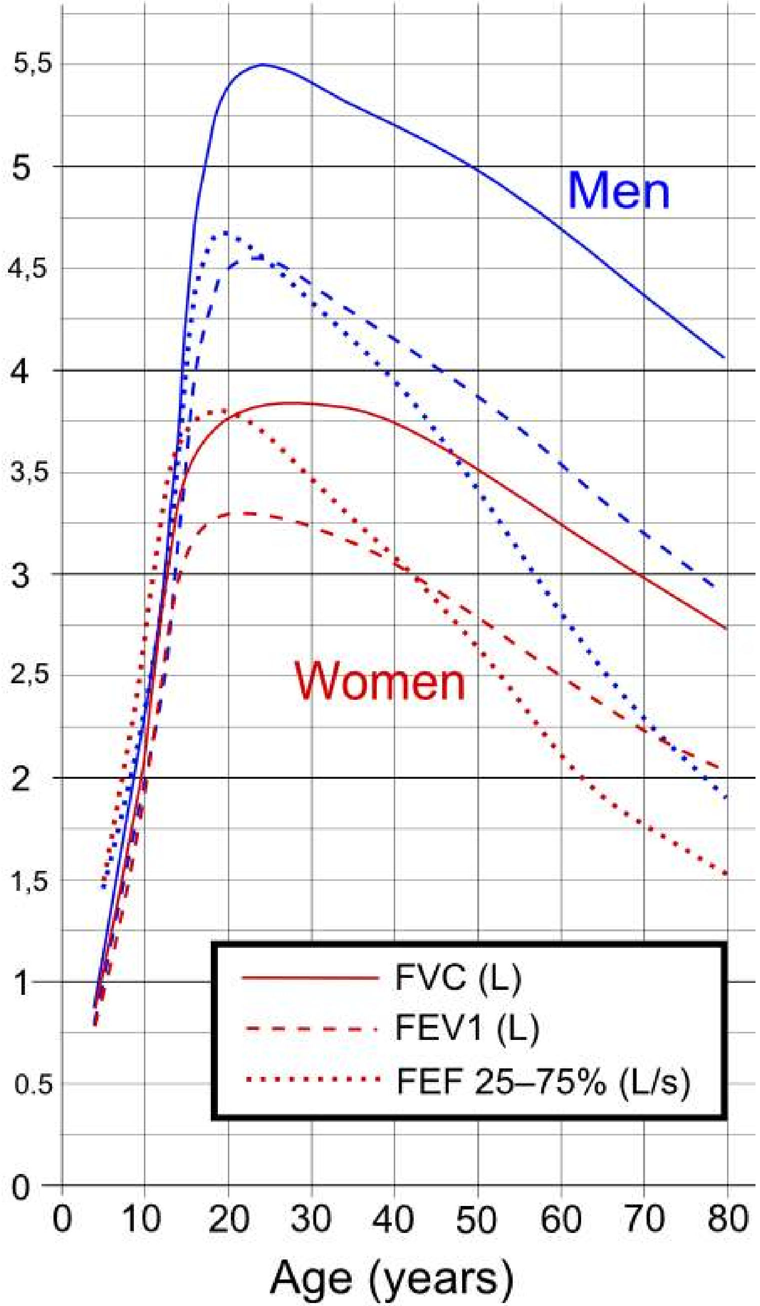
- **Ventilatory reserve**:

minute ventilation / MVV

$> 1 : 5$

$= 1 : 2$

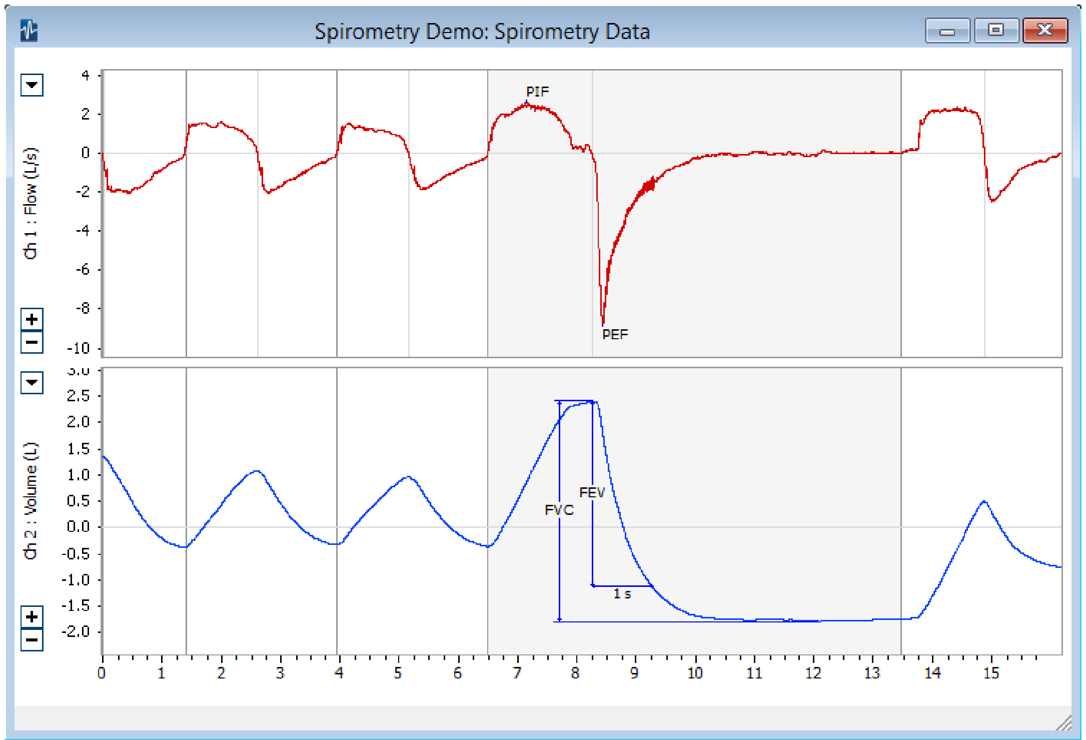
Normal values for FVC, FEV1 and FEV 25-75%



Regression equation for vital capacity:

Women: [21.7 – (0.101 x age[y])] ×h (cm) = (mL)

Men: [27.63 – (0.112 x age[y])] × h (cm) = (mL)



Restrictive diseases

anatomical and/or functional loss of surface for gas exchange

resection
atelectasis
lung edema
lung fibrosis
thoracic deformities / impaired breathing movements
pneumonia
pneumothorax

Characteristics

- decreased vital capacity (VC)
- decreased function residual capacity (FRC)/

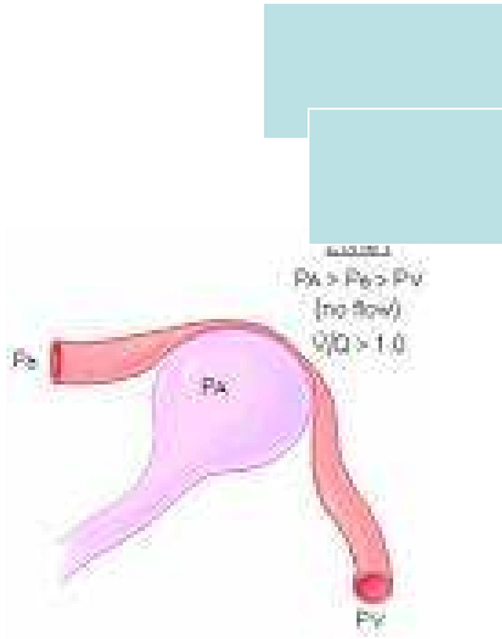
  =exspiratory reserve vol. + residual vol.
- decreased compliance
- normal shape of flow volume loops
- more negative intrapleural pressure during inspiration
- increased in pulmonary vascular resistance
- hypoxemia

Possible respiratory system disturbances

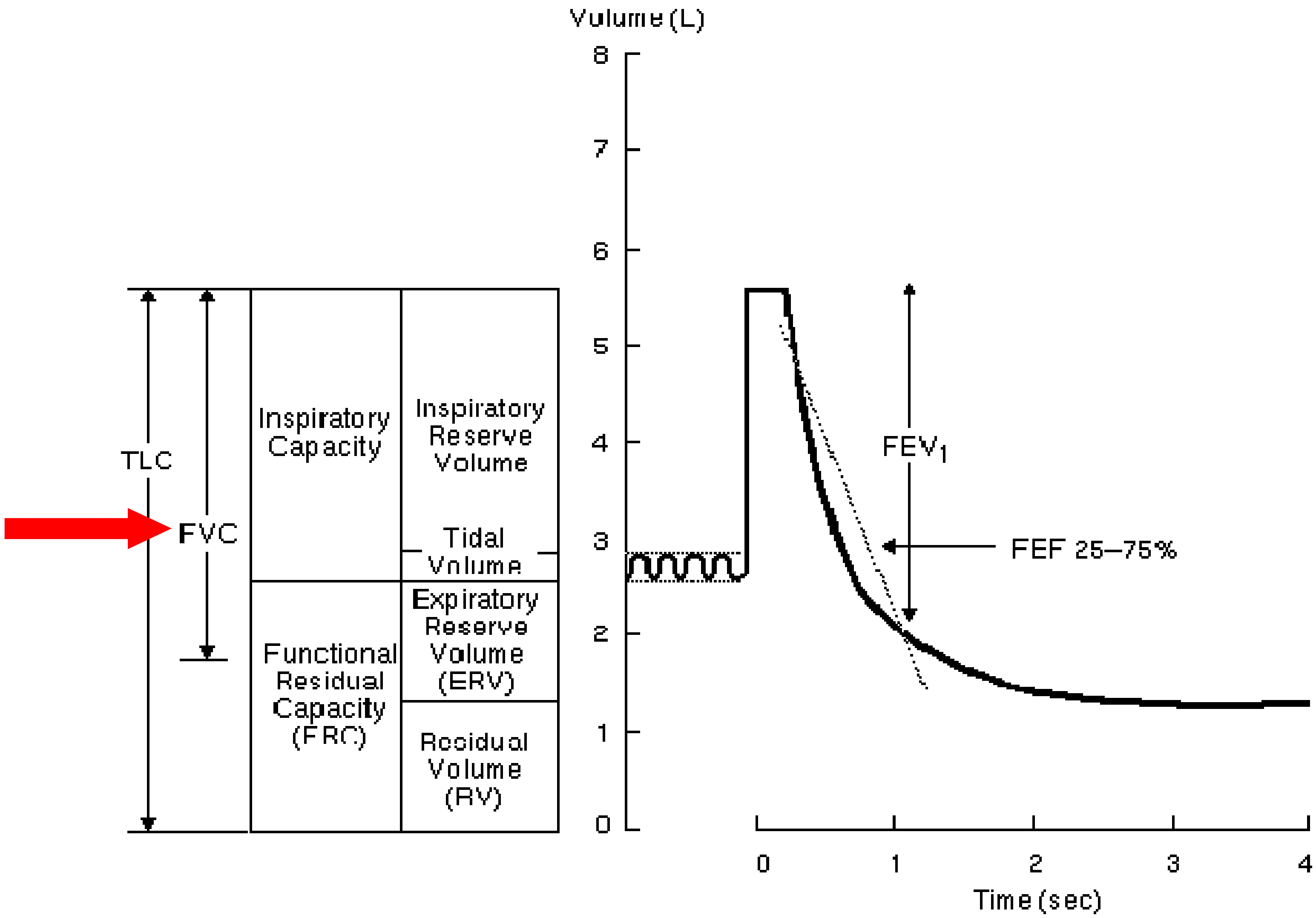
- // **ventilation**
- // **perfusion**
- // **distribution** of ventilation and per-fusion

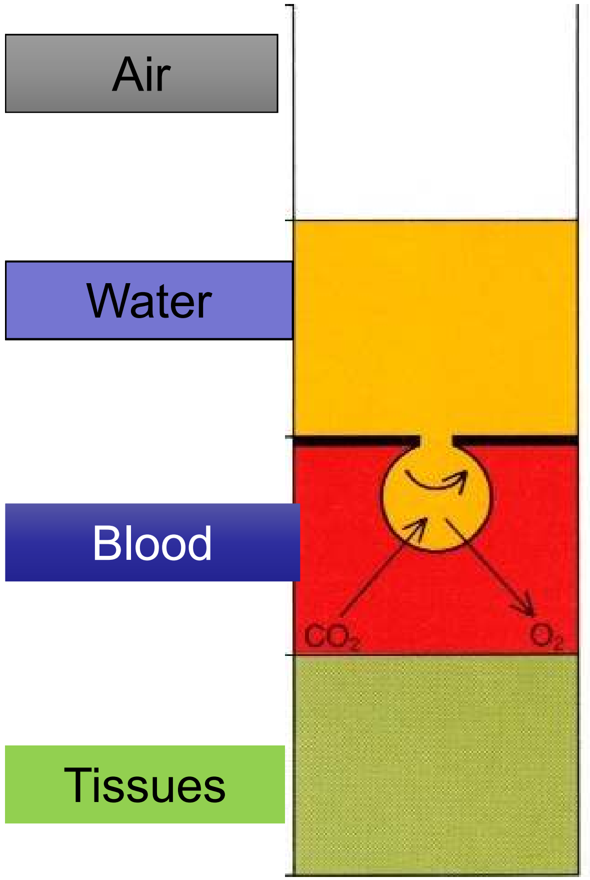
 = ventilation perfusion <u>mismatch</u>

- // **diffusion**

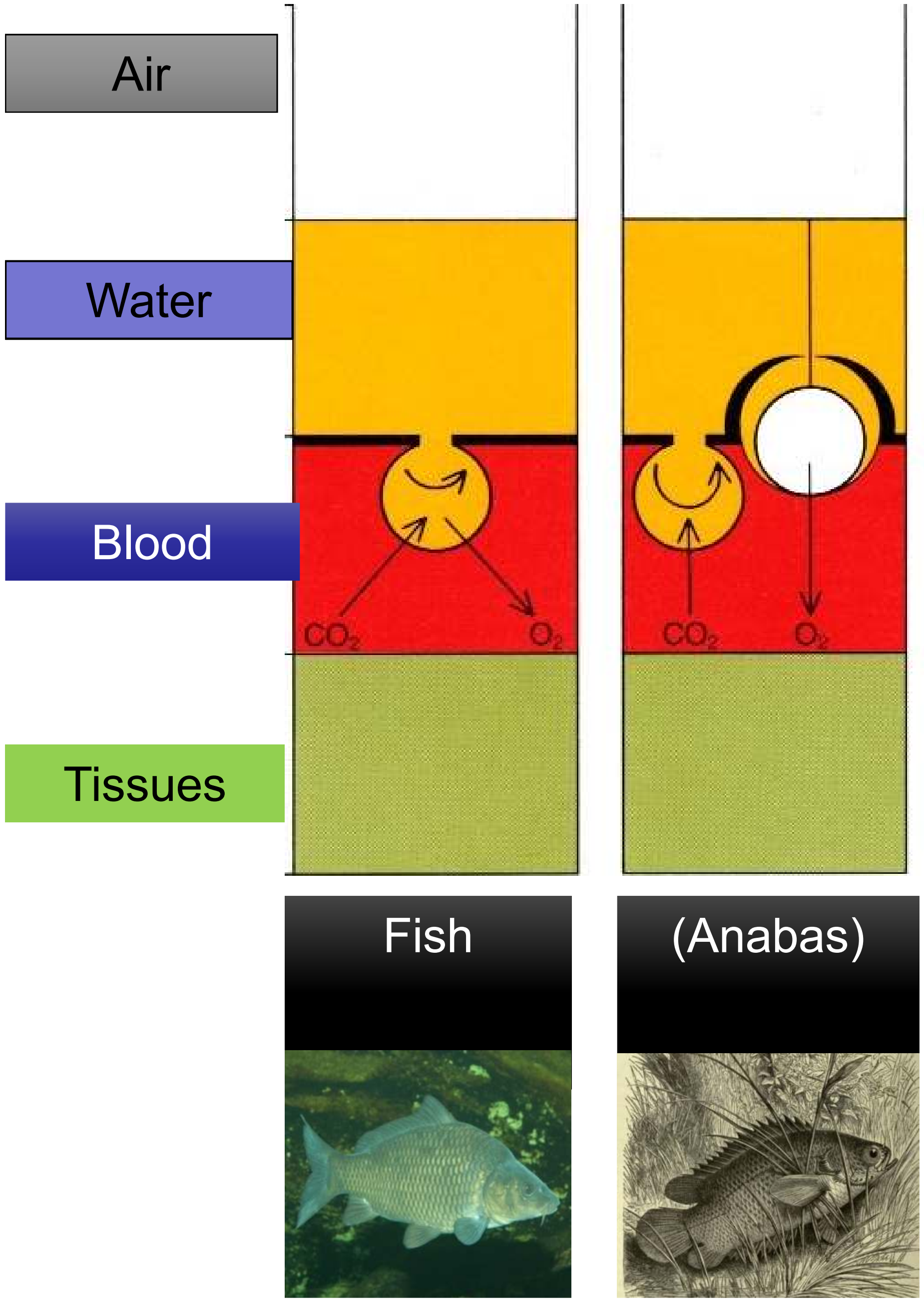


Spirogram - **restrictive** disease

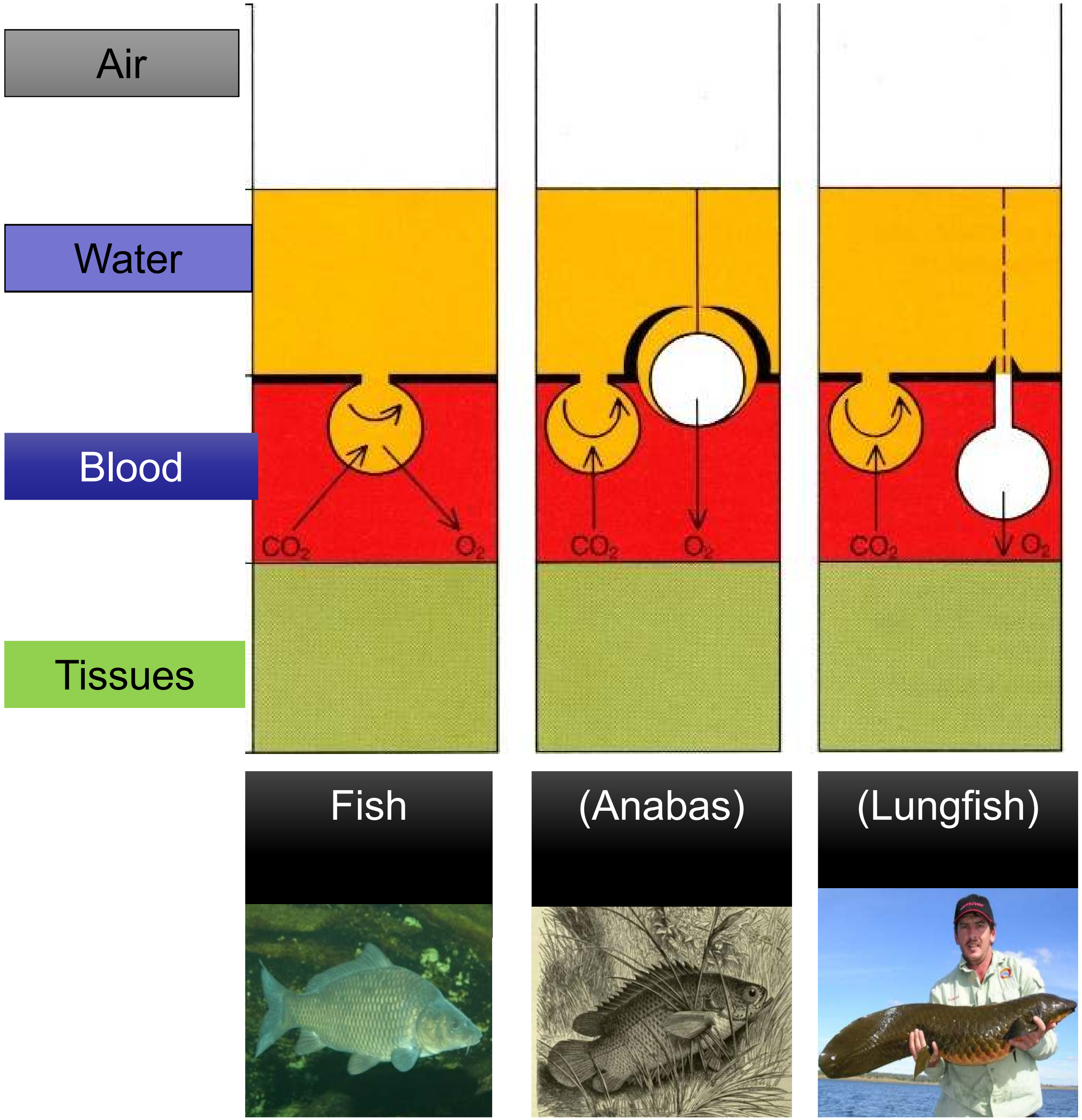




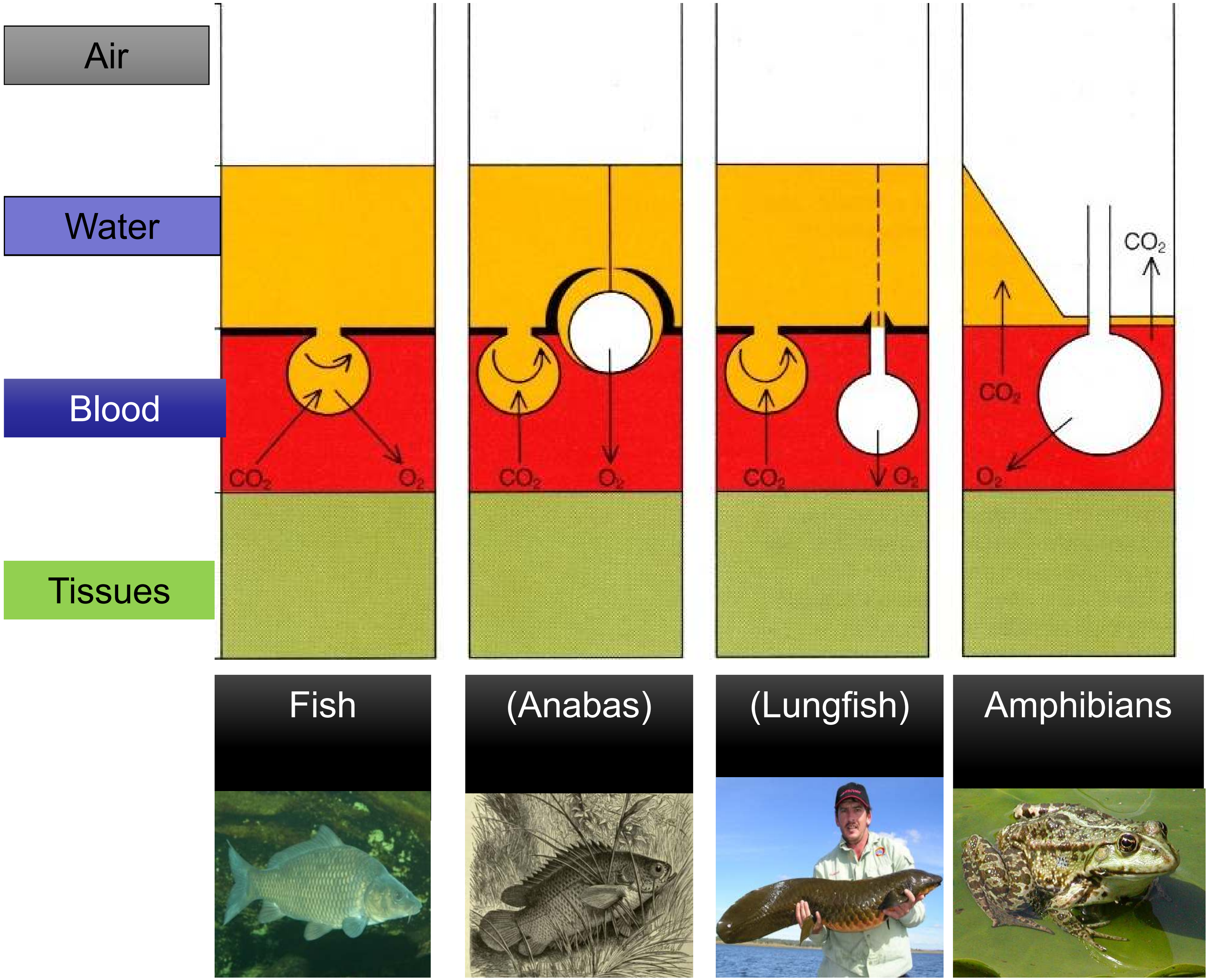
Fish

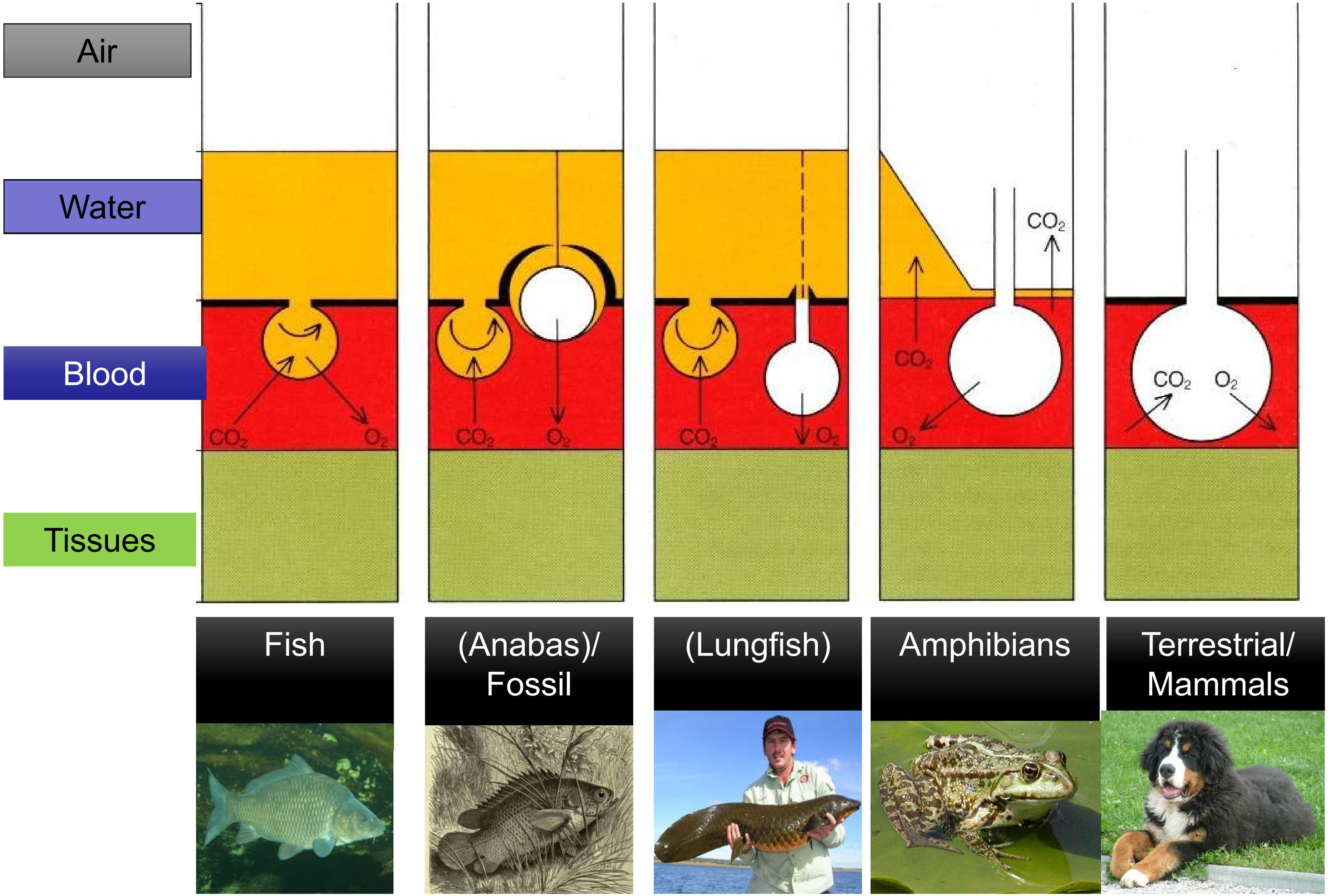


Air
Water
Blood
Tissues
CO2
O2
CO2
O2
Fish
(Anabas)

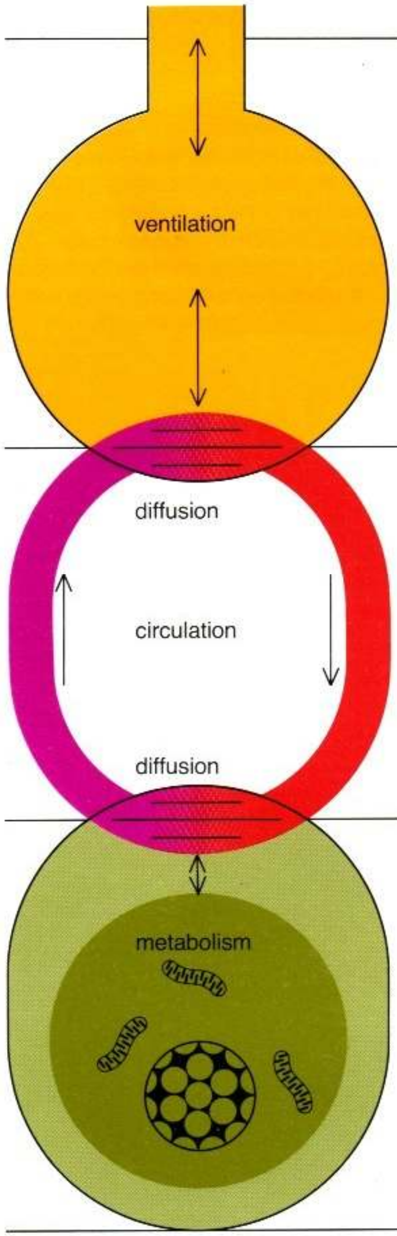


Air
Water
Blood
Tissues
CO2
O2
CO2
O2
CO2
O2
Fish
(Anabas)
(Lungfish)

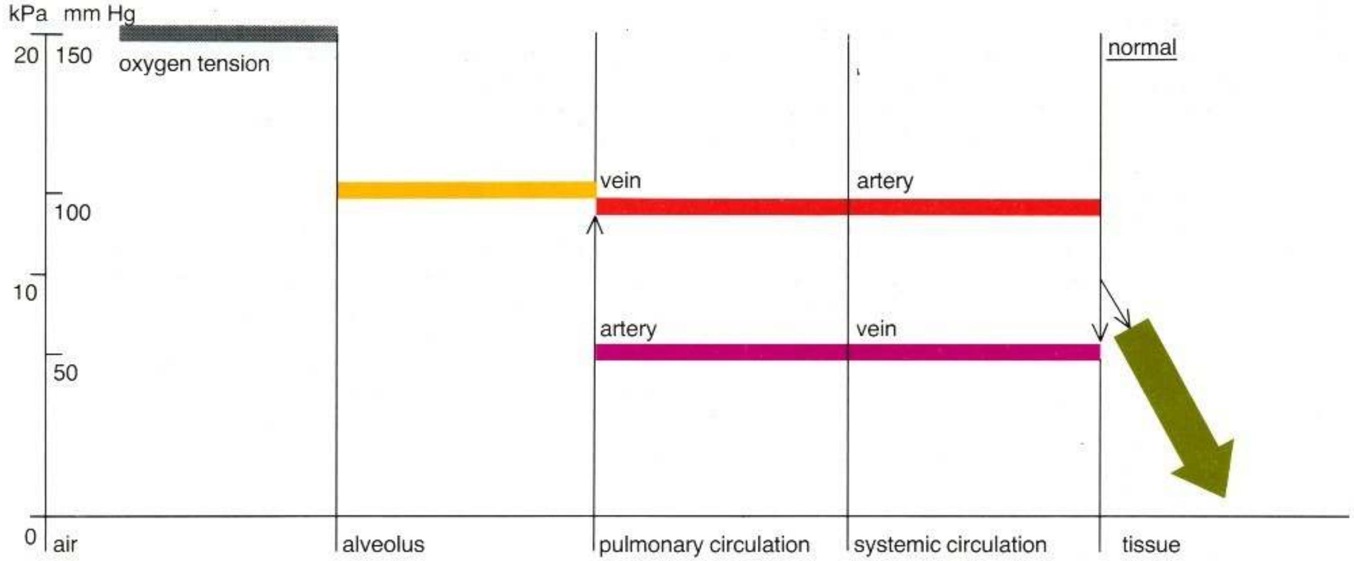

Air
Water
Blood
Tissues
CO2
O2
CO2
O2
CO2
O2
CO2
CO2
O2
Fish
(Anabas)
(Lungfish)
Amphibians

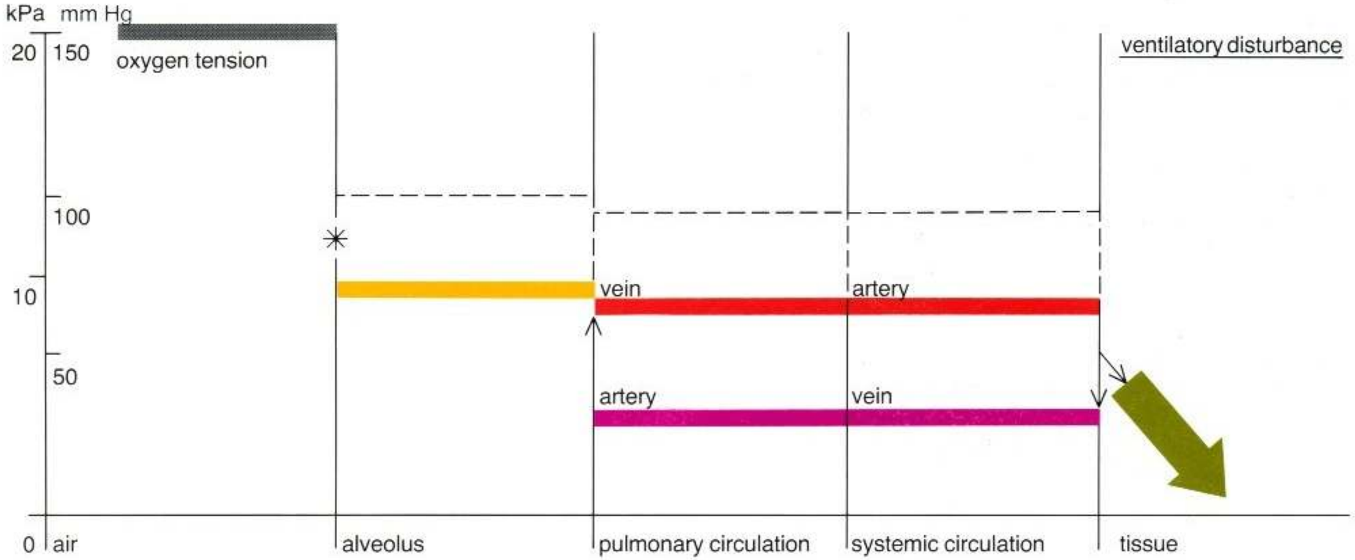


Air
Water
Blood
Tissues
CO_2
O_2
Fish
(Anabas)/ Fossil
(Lungfish)
Amphibians
Terrestrial/ Mammals

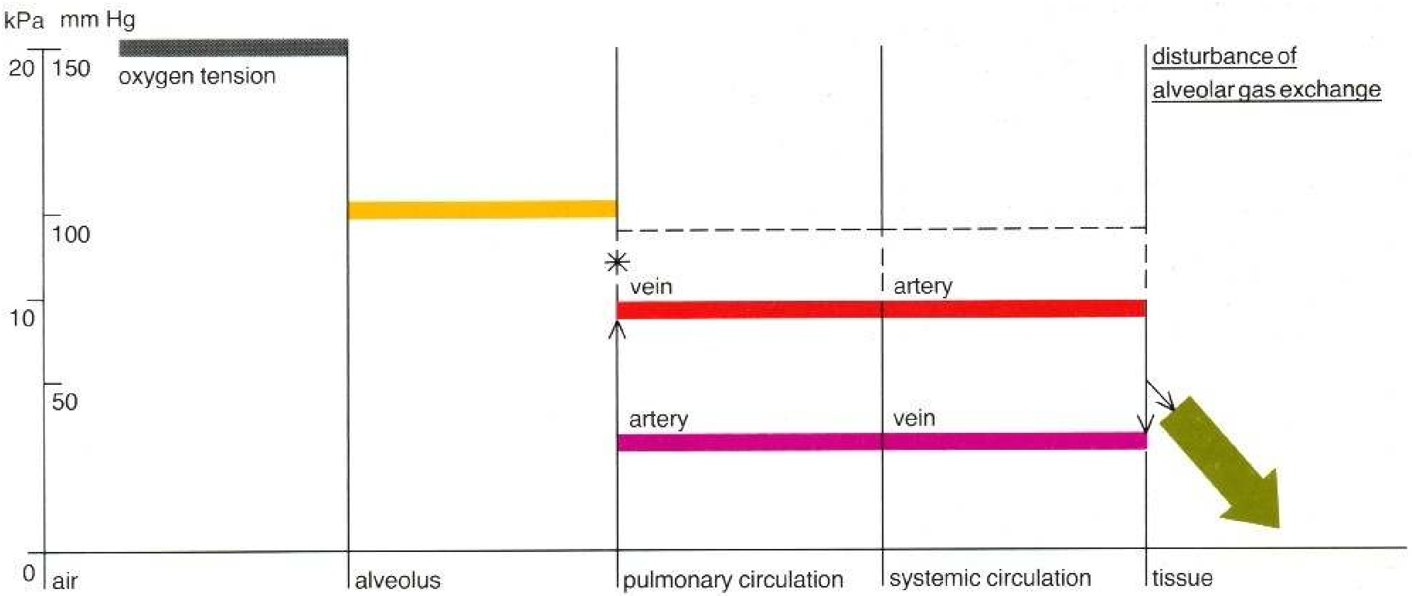


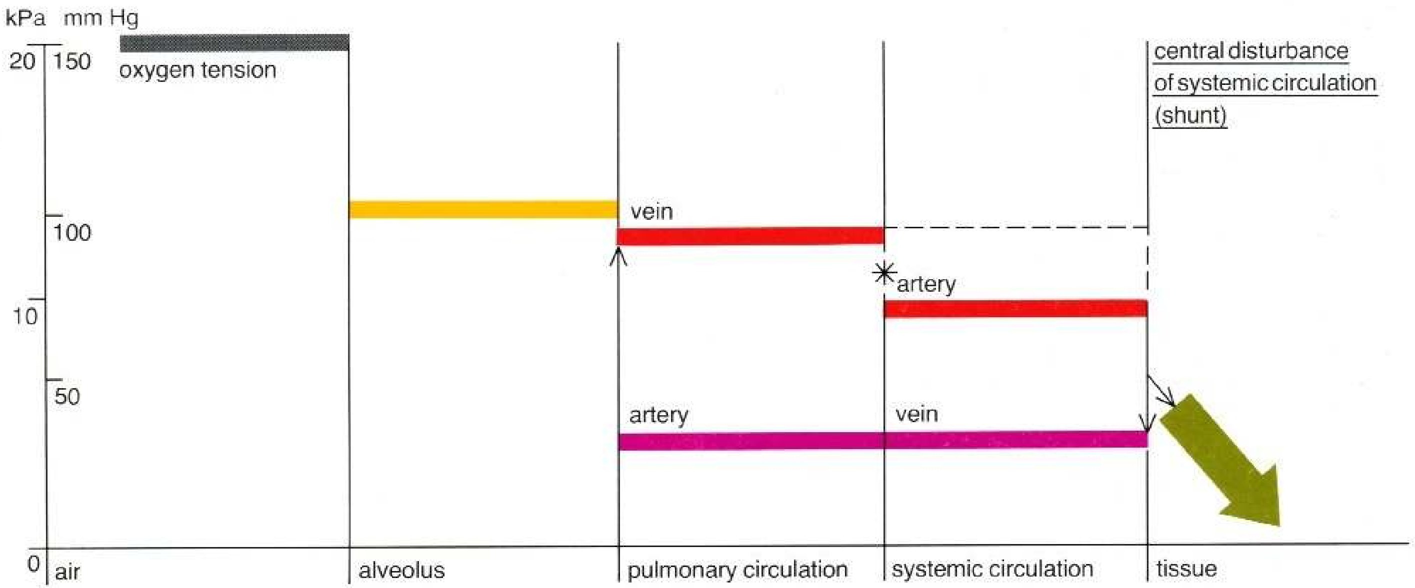
compartment		$\dot{V}_{O_2}$ l/min	V_{O_2} l	P_{O_2} mm Hg	$\dot{V}_{CO_2}$ l/min	V_{CO_2} l	P_{CO_2} mm Hg
air		0.25	∞	150	0.20	≃ 0	≃ 0
airway	lung		0.03	–		0.02	–
alveolus	lung		0.40	100		0.17	40
arterial	blood			90–100			40
capillary	blood		0.80			2.70	
venous	blood			35–45			45
extracellular	tissue			40			45
intracellular	tissue		0.30			3.30	
mitochondria	tissue			<5			>45
		0.25	1.53		0.20	6.19	





* disturbance
1 mm Hg = 0.133 kPa (see A3)





* disturbance
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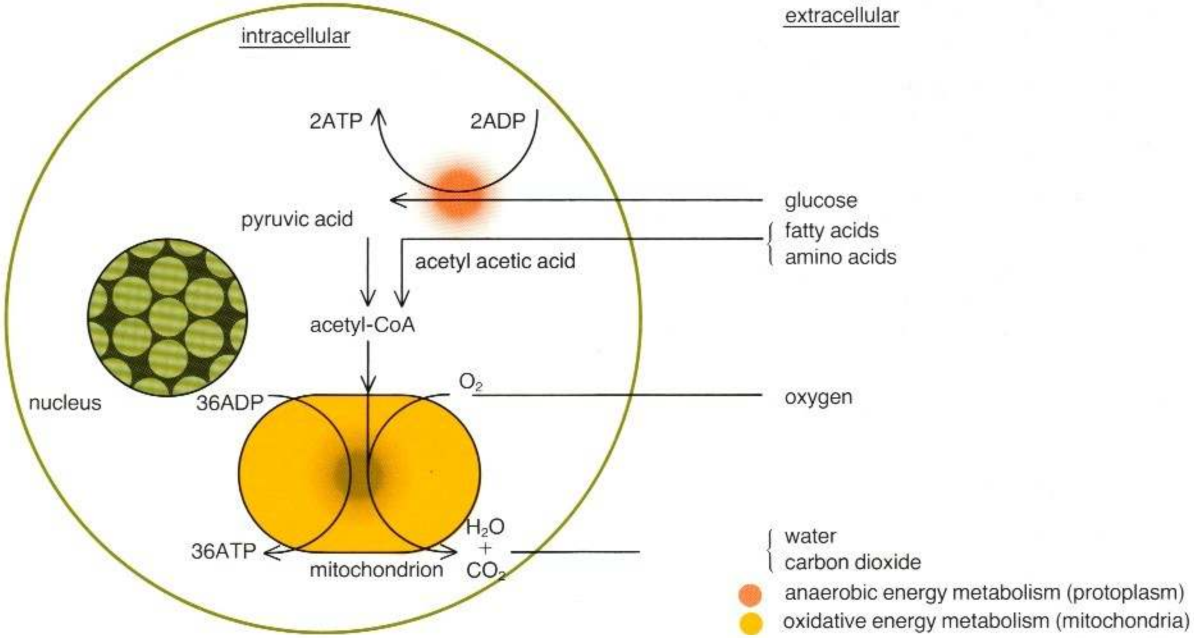
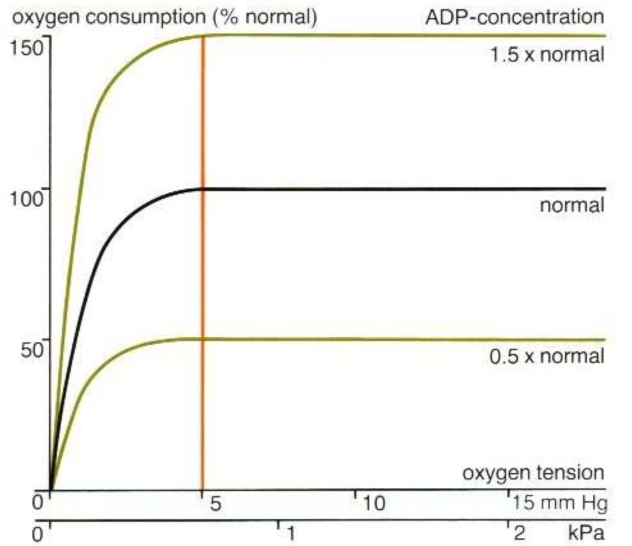
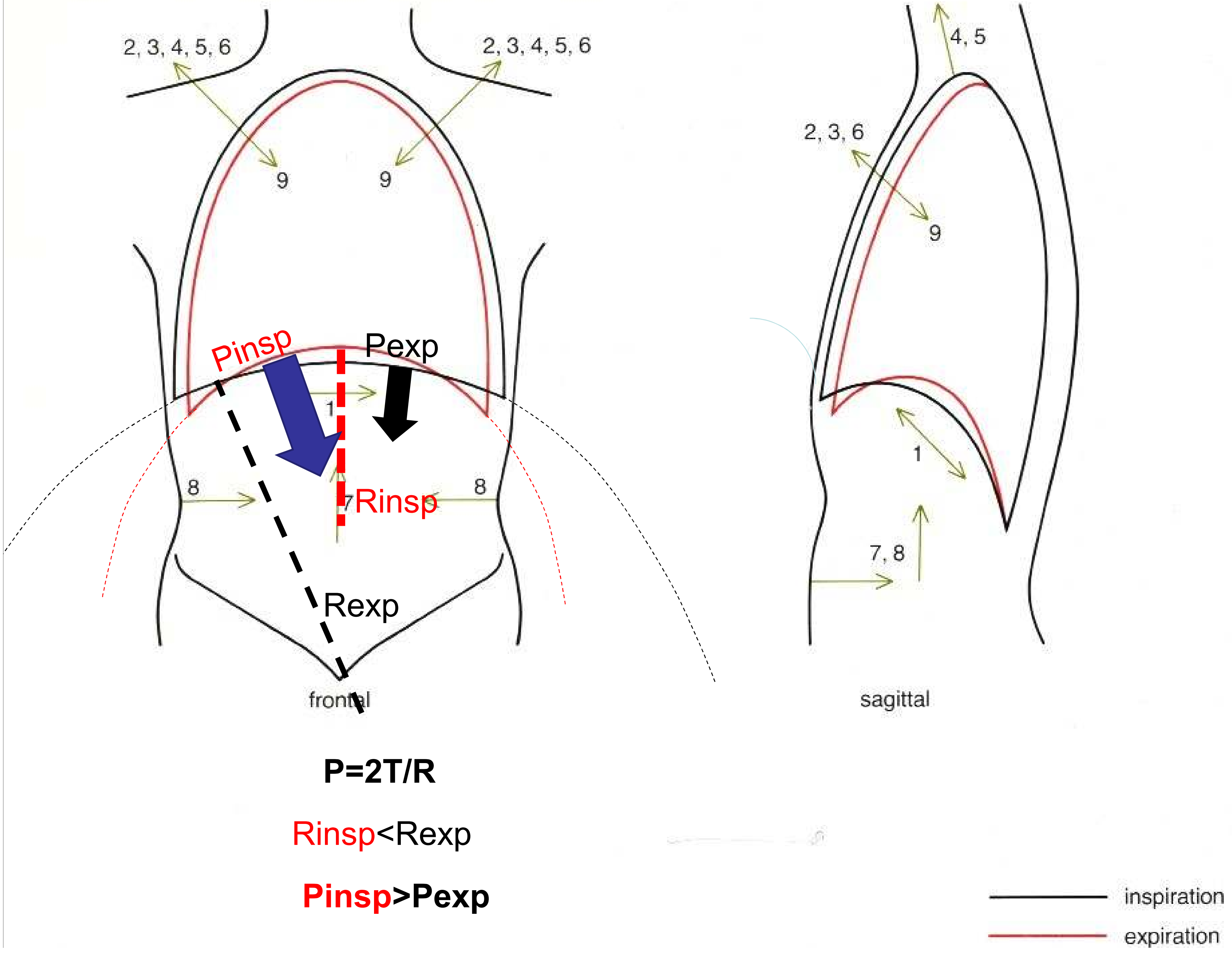




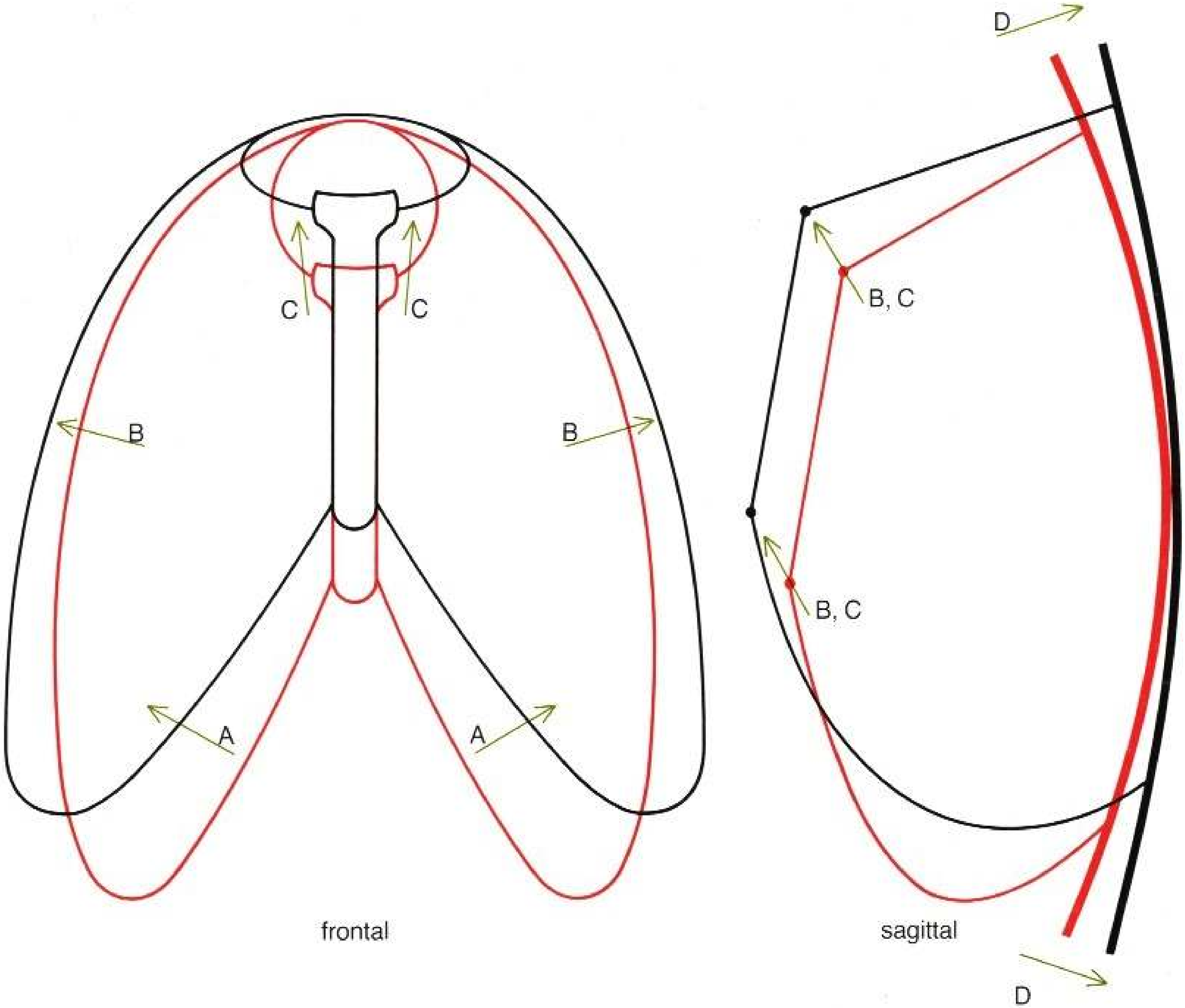
ADP = adenosine diphosphate
ATP = adenosine triphosphate

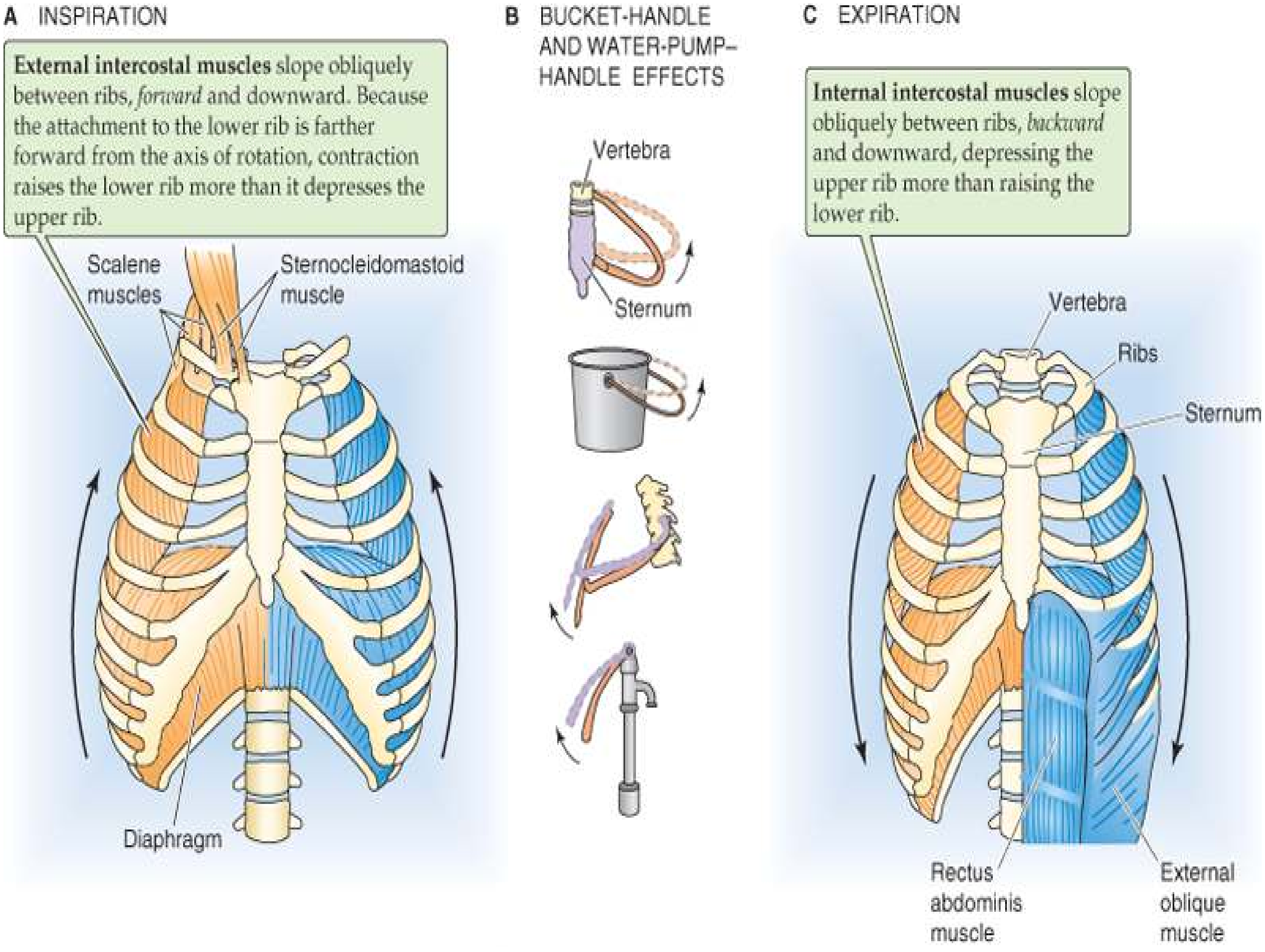


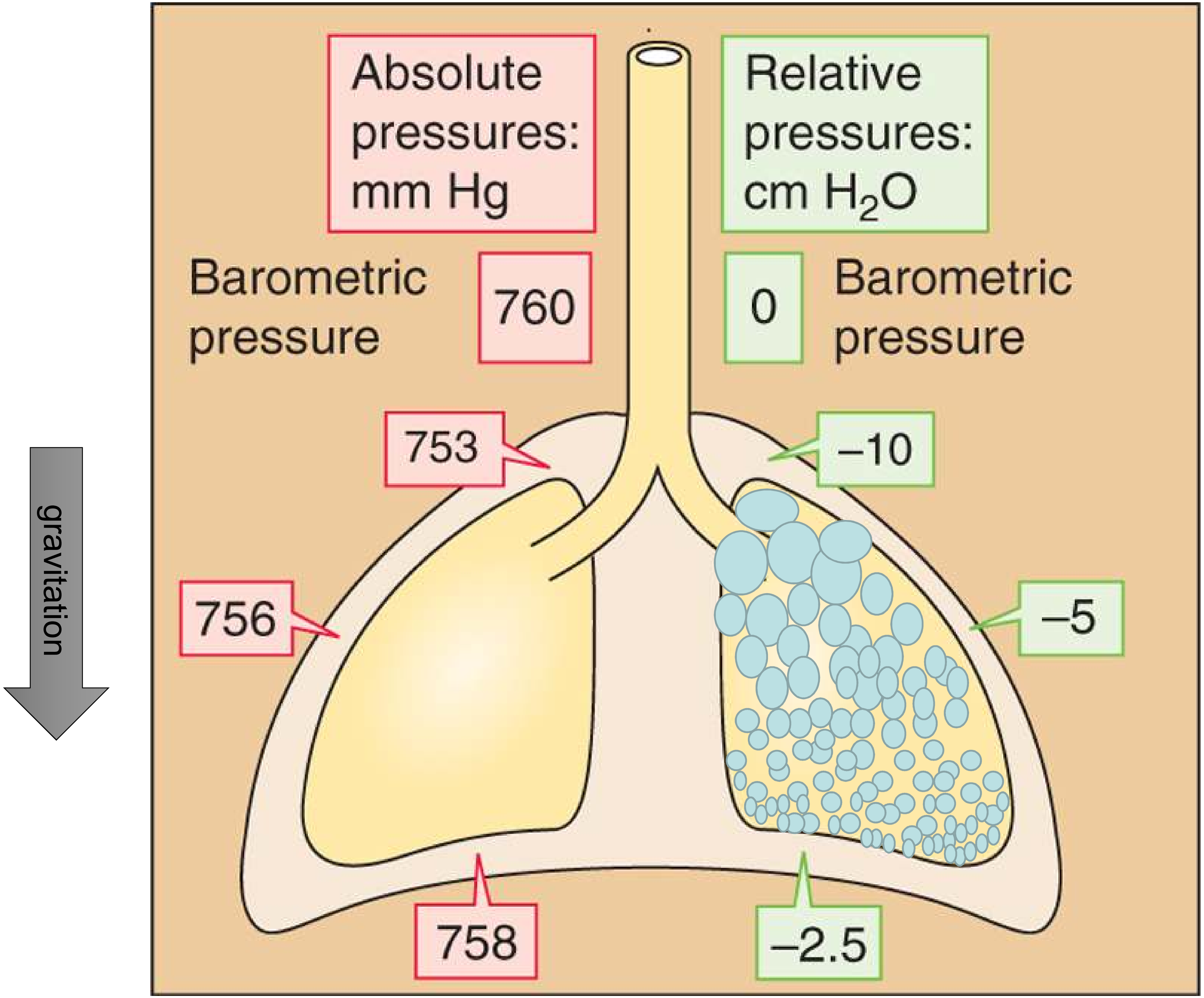
P=2T/R

Rinsp<Rexp

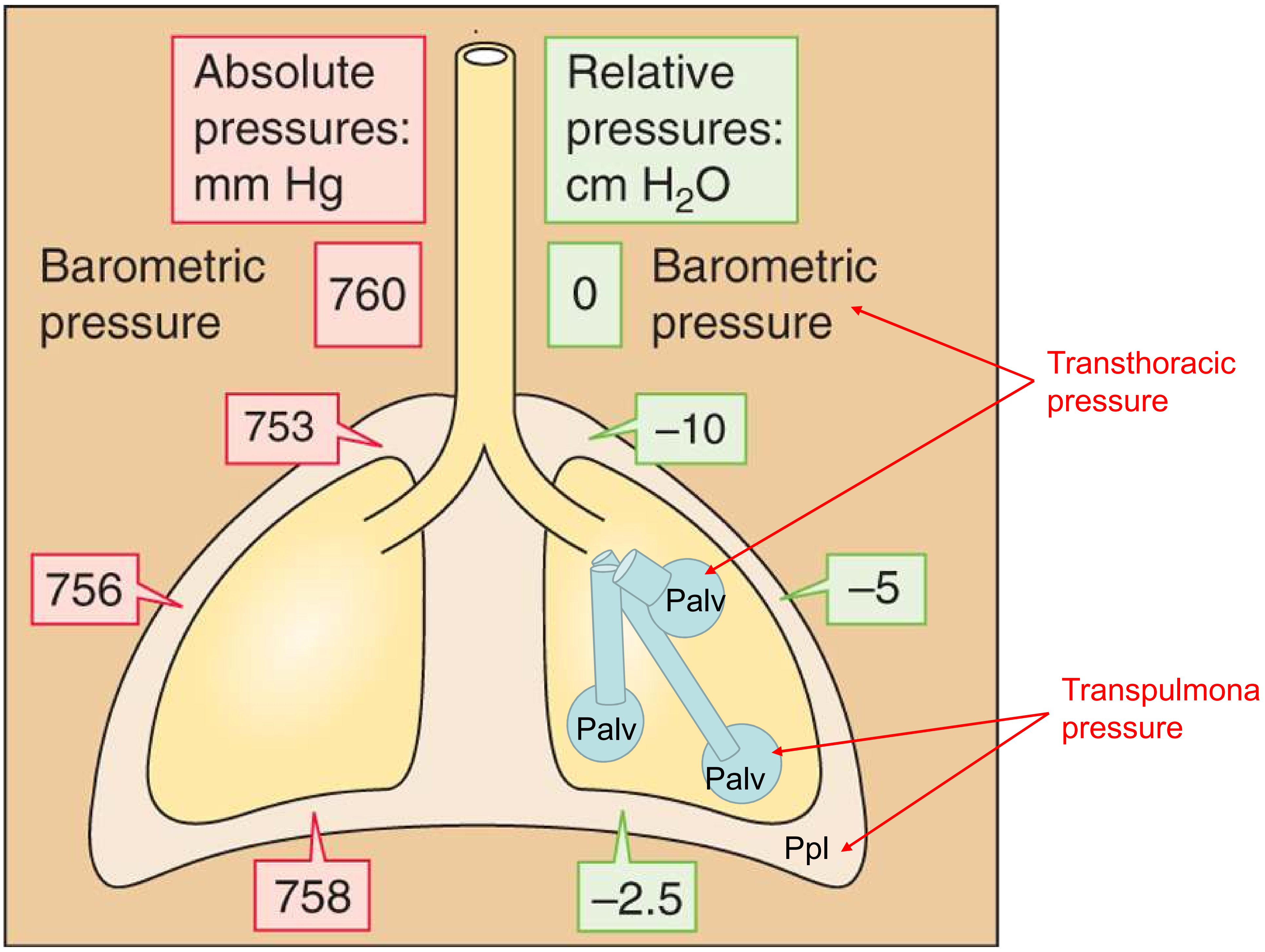
Pinsp>Pexp


C
C
B
B
A
A
frontal
D
B, C
B, C
sagittal
D

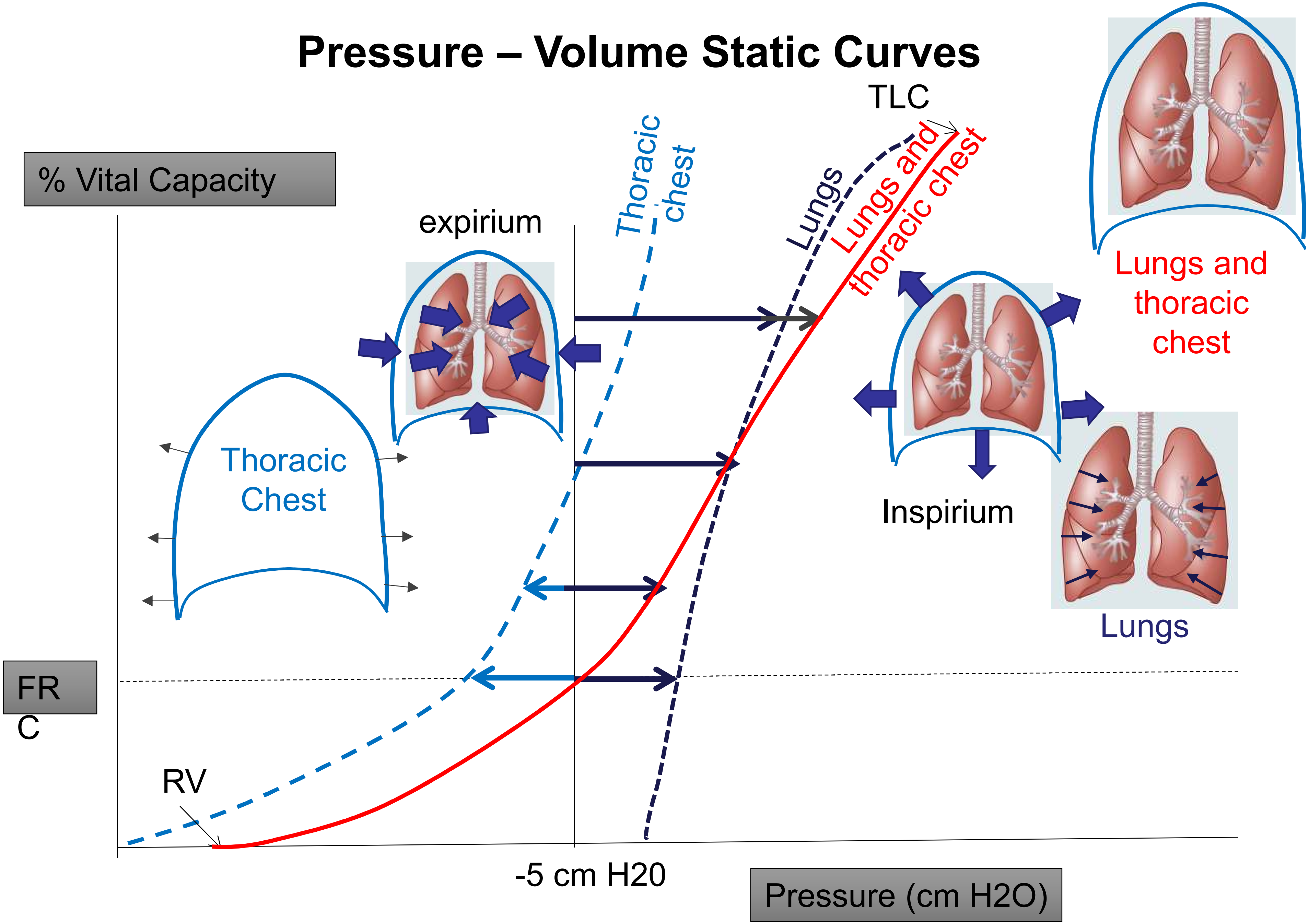

A INSPIRATION
External intercostal muscles slope obliquely between ribs, forward and downward. Because the attachment to the lower rib is farther forward from the axis of rotation, contraction raises the lower rib more than it depresses the upper rib.
Scalene muscles
Sternocleidomastoid muscle
Diaphragm
B BUCKET-HANDLE AND WATER-PUMP–HANDLE EFFECTS
Vertebra
Sternum
C EXPIRATION
Internal intercostal muscles slope obliquely between ribs, backward and downward, depressing the upper rib more than raising the lower rib.
Vertebra
Ribs
Sternum
Rectus abdominis muscle
External oblique muscle



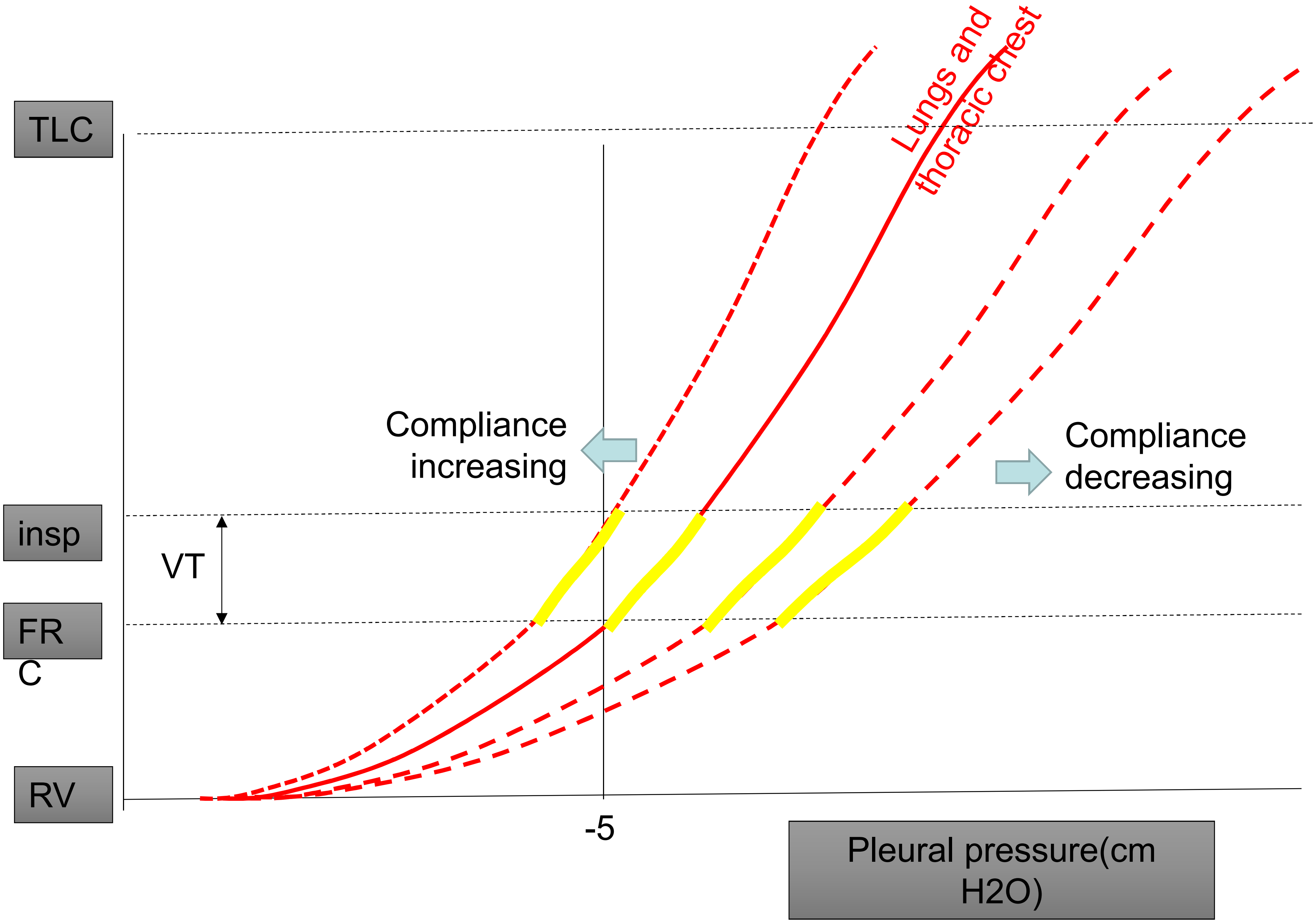
gravitation
Absolute pressures: mm Hg
Relative pressures: cm H_2O
Barometric pressure
760
0
Barometric pressure
753
–10
756
–5
758
–2.5

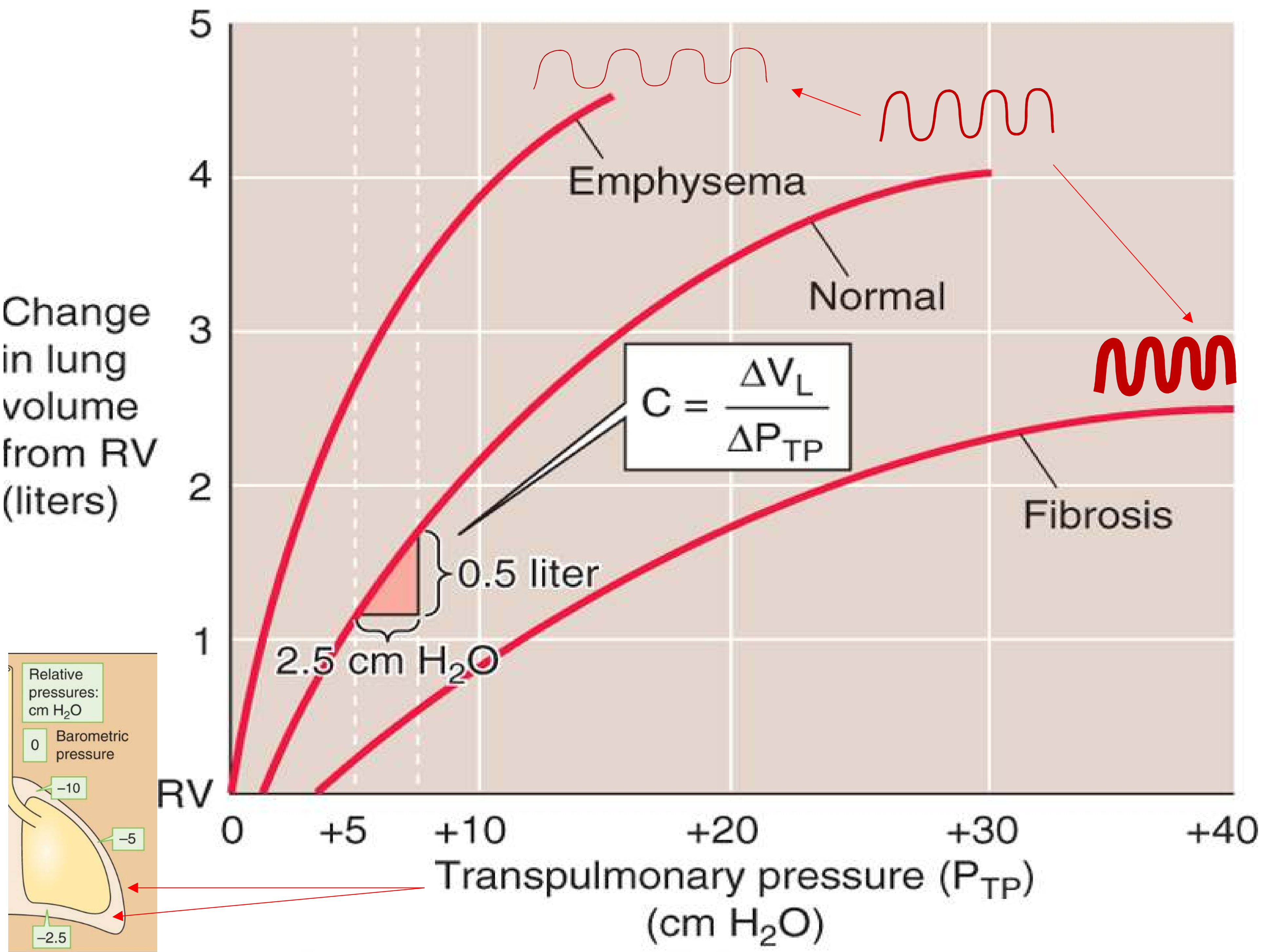

Absolute pressures: mm Hg
Relative pressures: cm H_2O
Barometric pressure
760
0
Barometric pressure
Transthoracic pressure
753
–10
756
–5
Palv
Palv
Palv
Transpulmona pressure
Ppl
758
–2.5

Pressure – Volume Static Curves

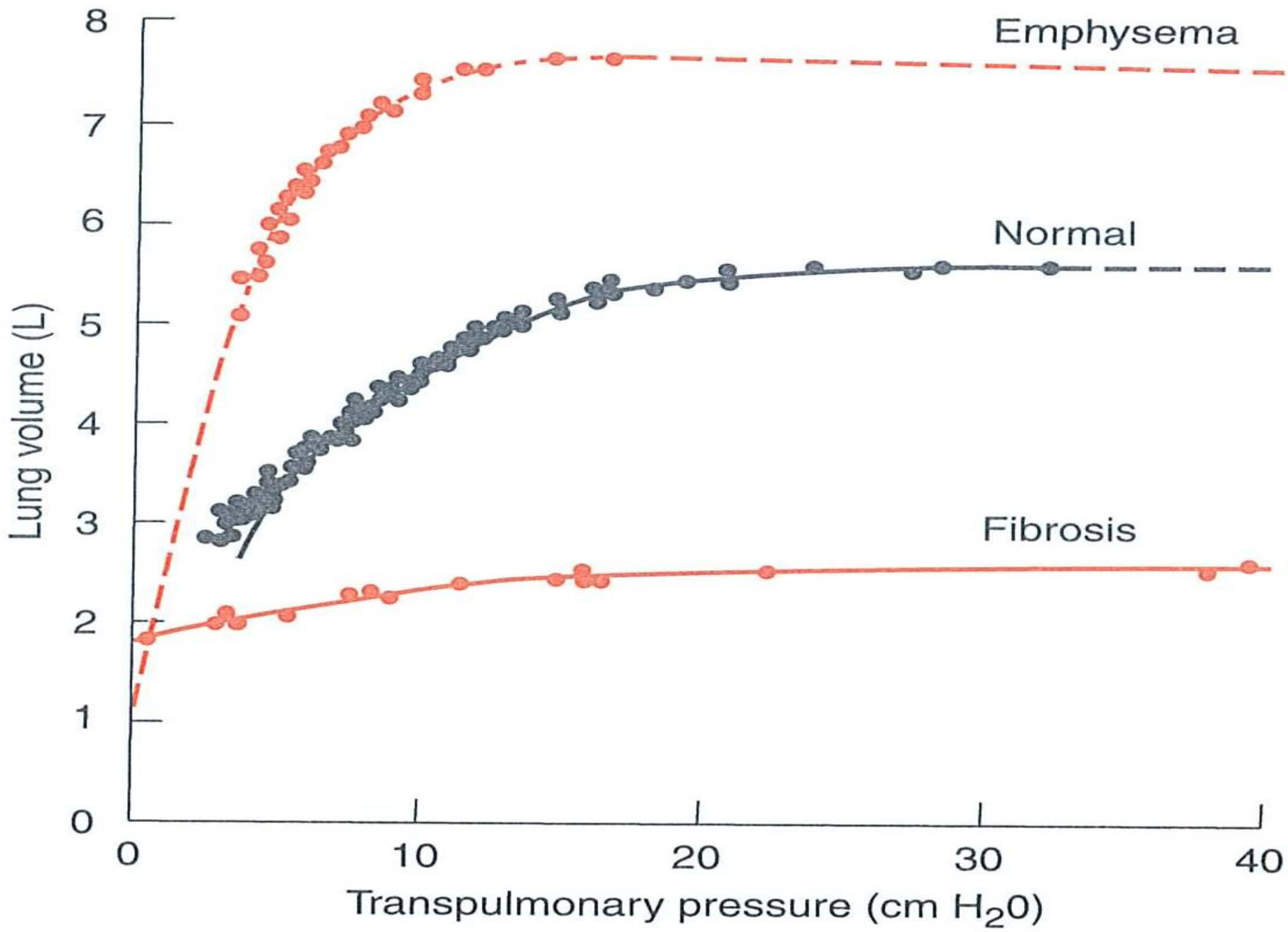


Pressure – Volume Static Curves

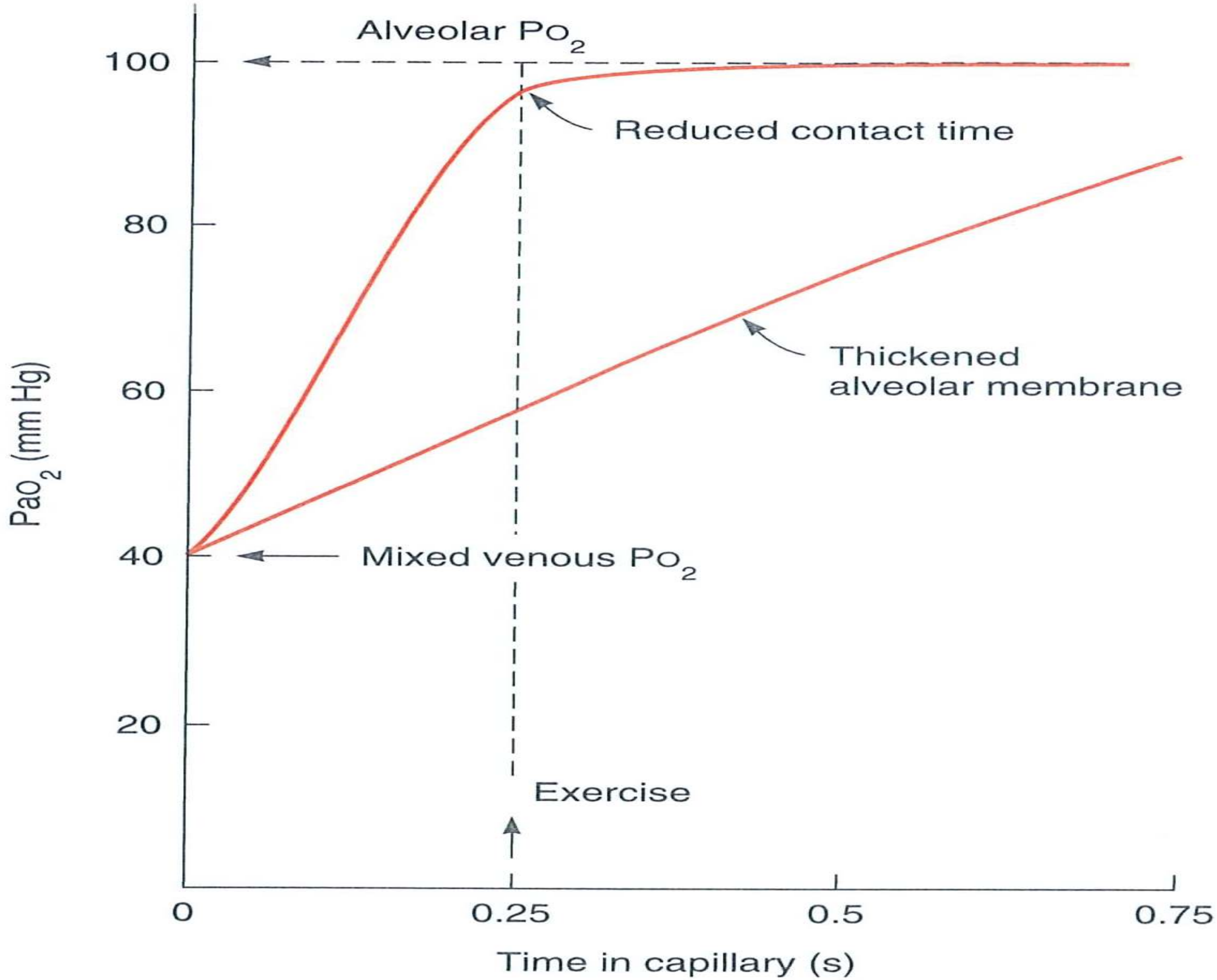




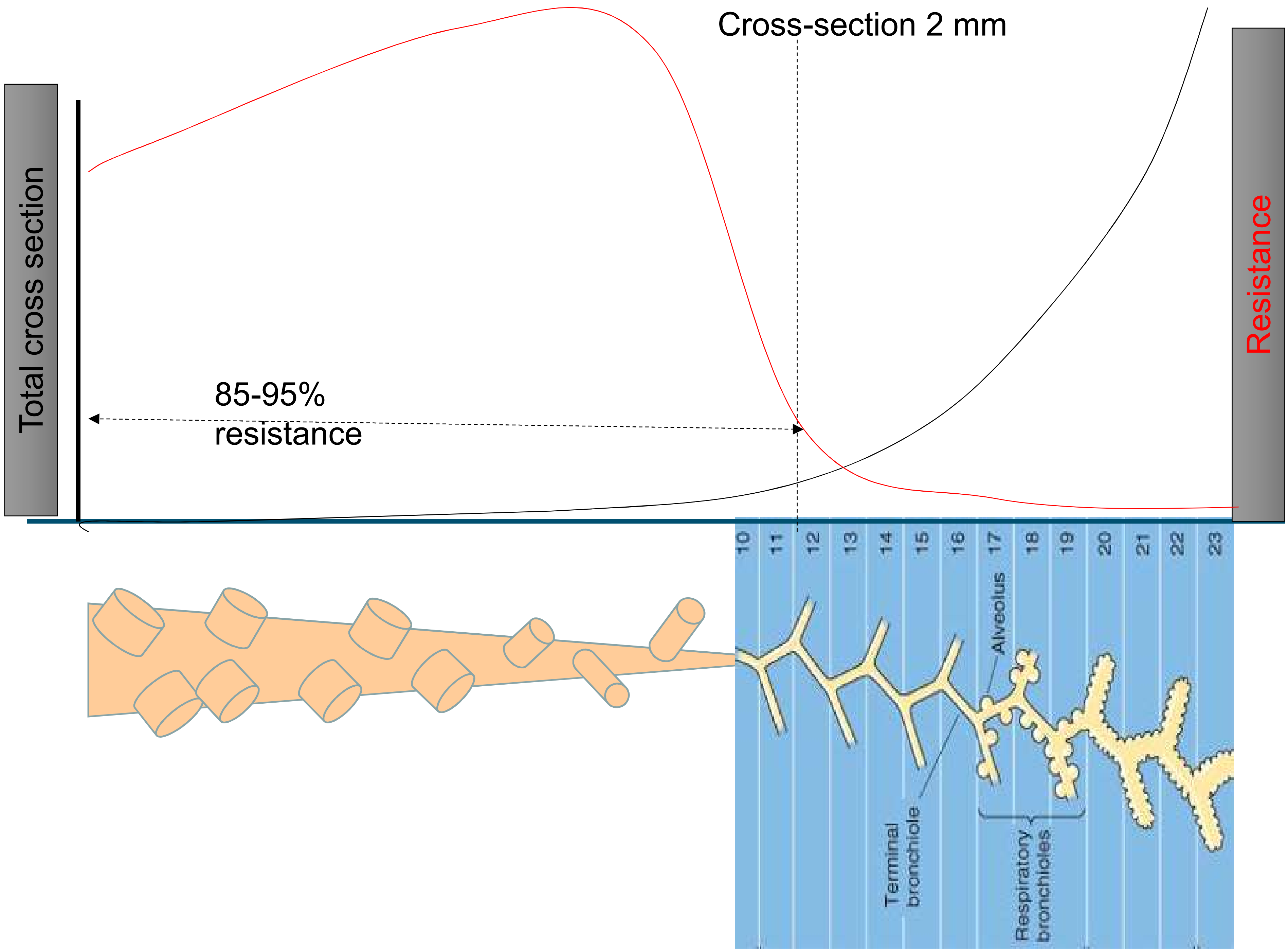
Change in lung volume from RV (liters)
5
4
3
2
1
RV
0
+5
+10
+20
+30
+40
Transpulmonary pressure (P_{TP}) (cm H_2O)
Emphysema
Normal
Fibrosis
$C = \frac{\Delta V_L}{\Delta P_{TP}}$
0.5 liter
2.5 cm H_2O
Relative pressures: cm H_2O
0
Barometric pressure
–10
–5
–2.5



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)



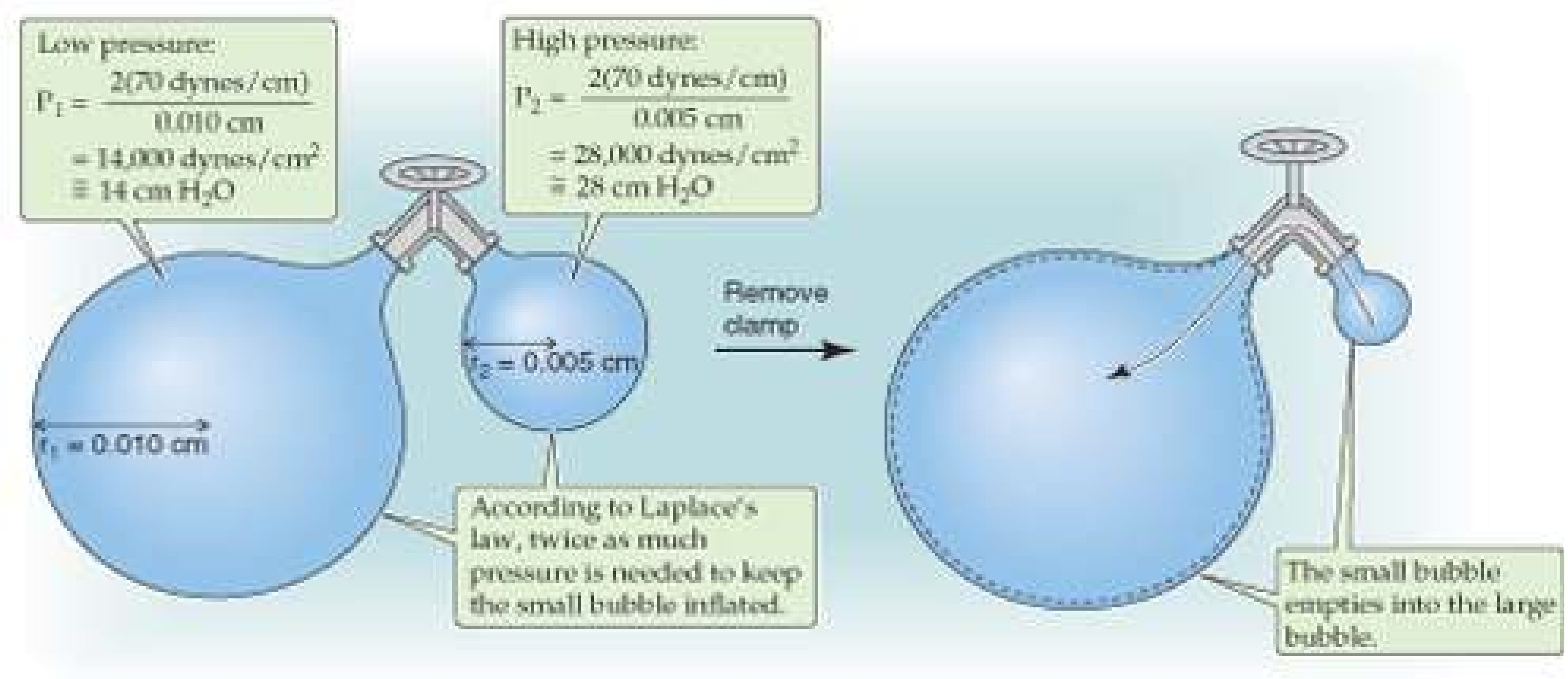
Alveolar Po2
100
80
60
40
20
Reduced contact time
Thickened
alveolar membrane
Mixed venous Po2
Exercise
Pao2 (mm Hg)
0
0.25
0.5
0.75
Time in capillary (s)



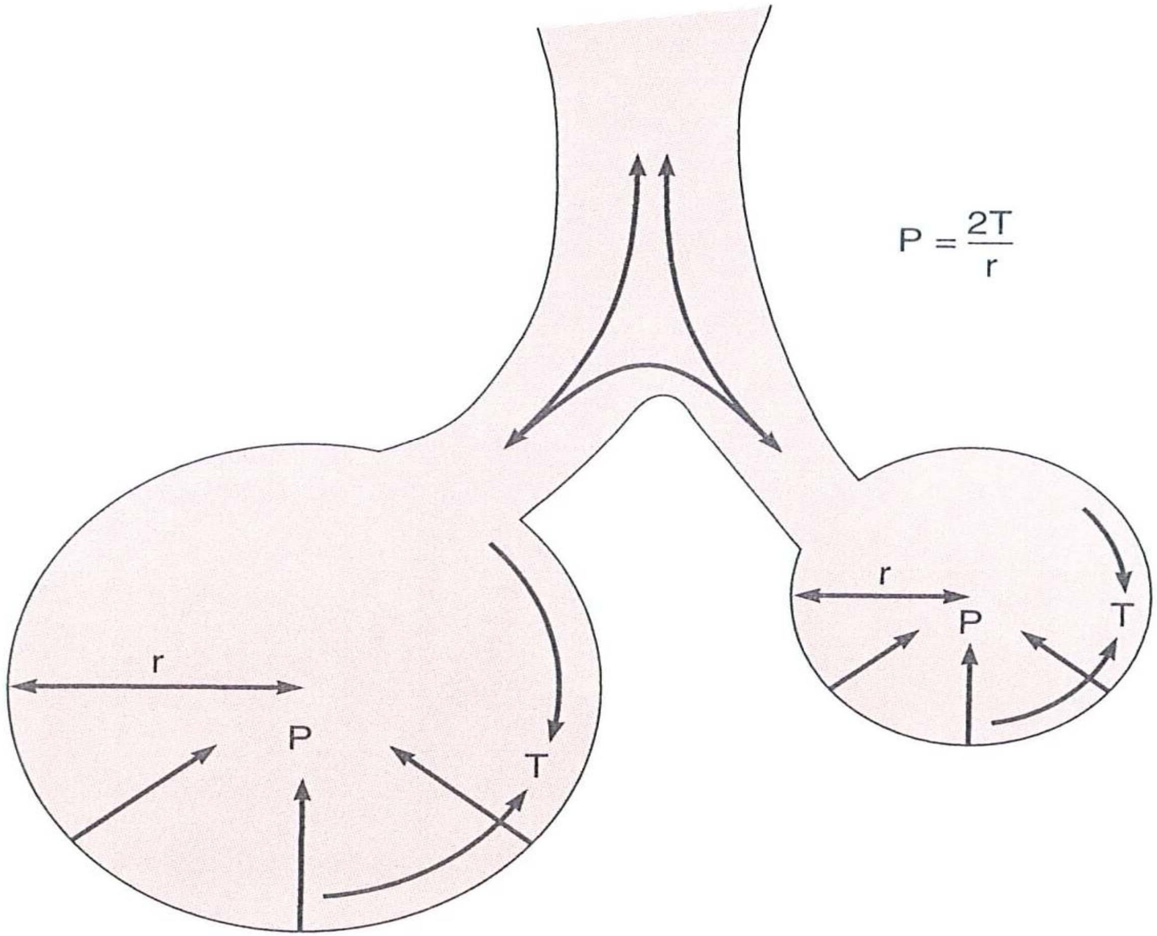
Cross-section 2 mm
Total cross section
Resistance
85-95%
resistance
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Alveolus
Terminal bronchiole
Respiratory bronchioles

760 mmHg = 1 atm = **1000 cmH2O** = 101 kPa =~100 %

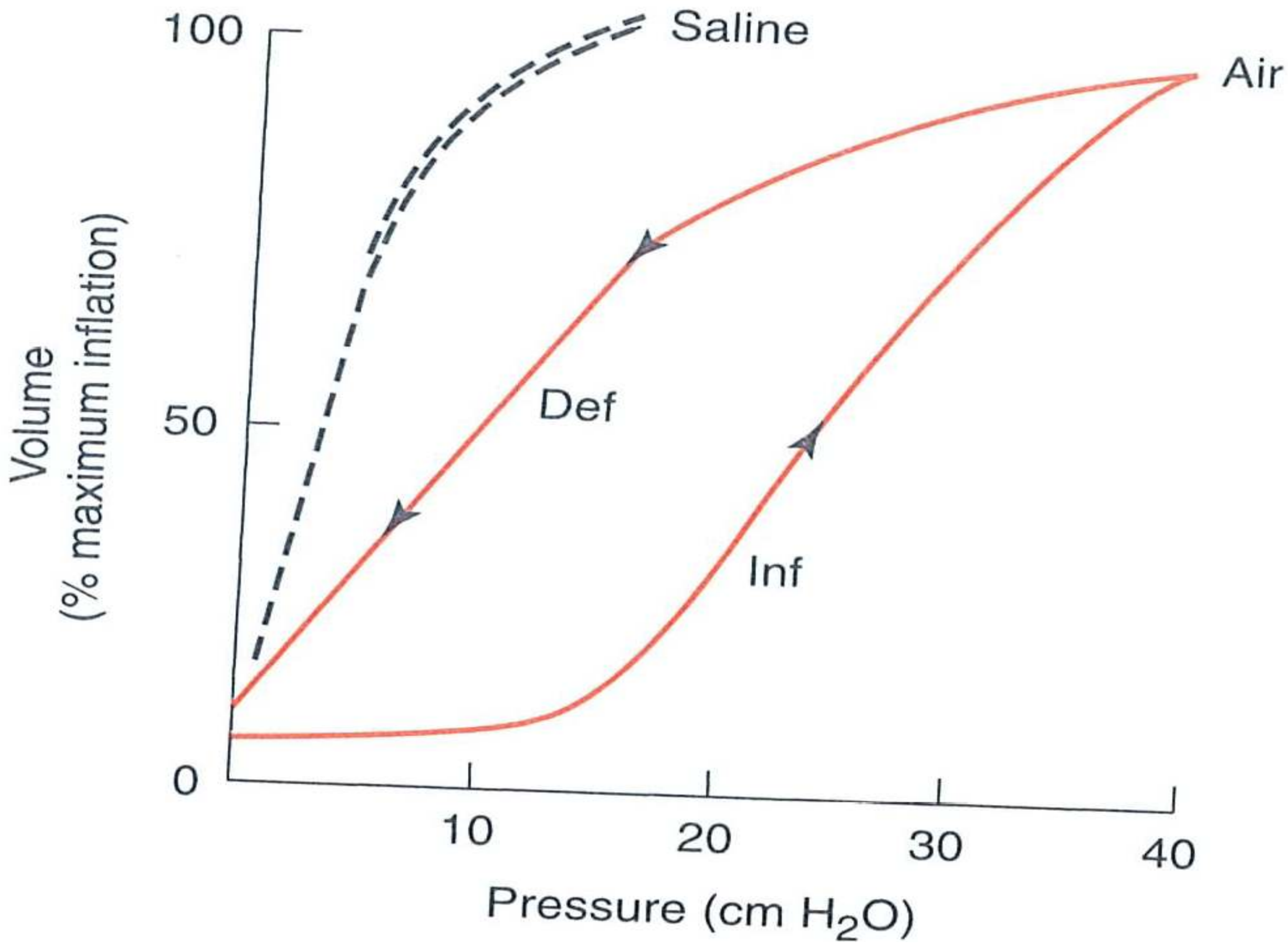
1 dyne = 10 uN,   1 Pa = 1 N/m2

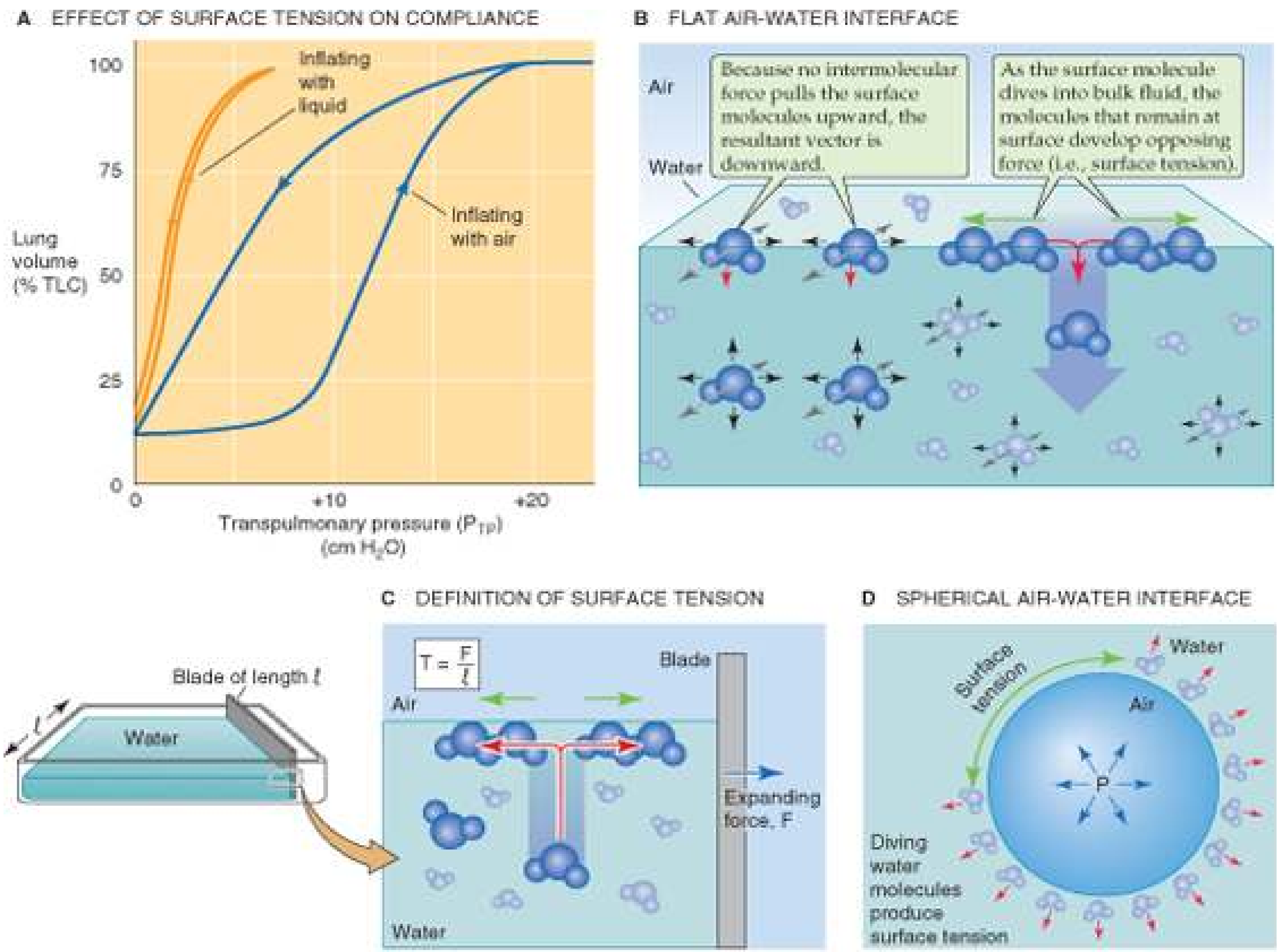


Stability of alveoli



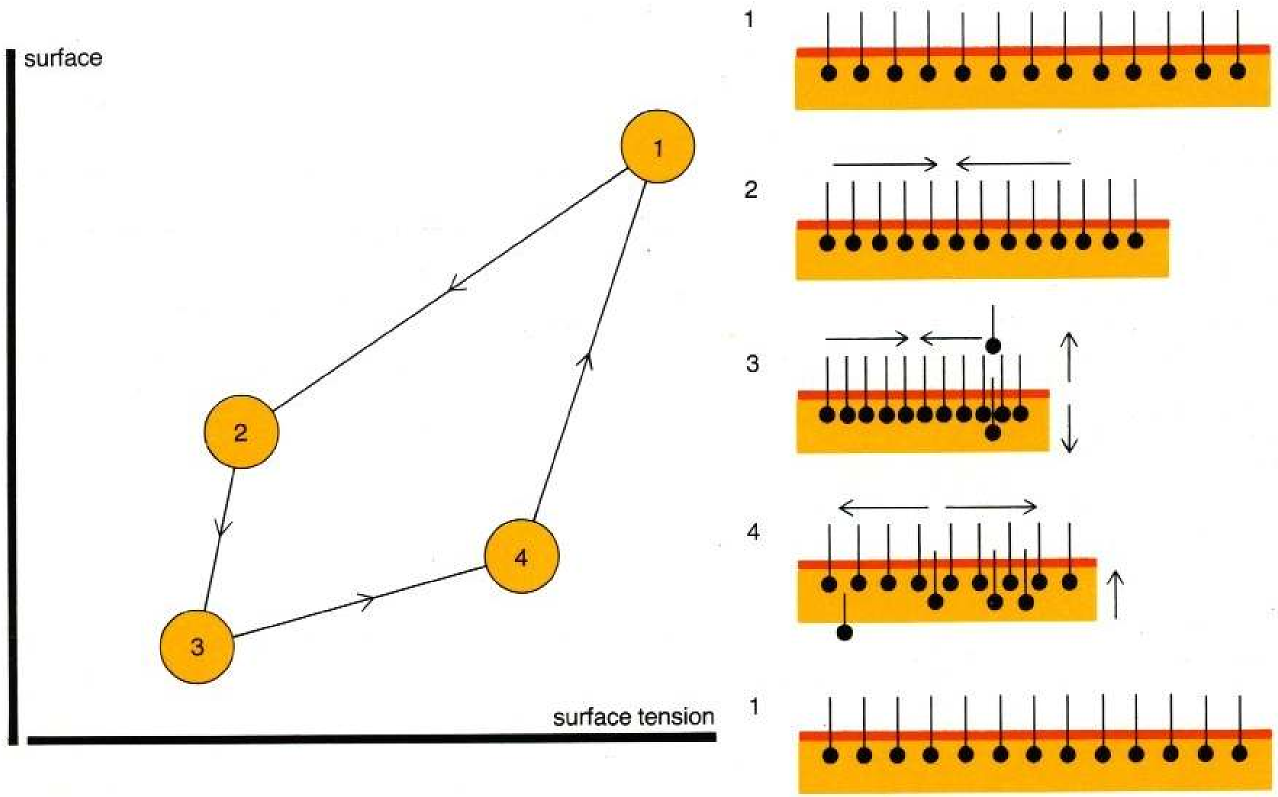
Compliance – effect of surfactant




A EFFECT OF SURFACE TENSION ON COMPLIANCE
100
75
50
25
0
Lung volume (% TLC)
Inflating with liquid
Inflating with air
0
+10
+20
Transpulmonary pressure (P_{TP}) (cm H_2O)
B FLAT AIR-WATER INTERFACE
Air
Water
Because no intermolecular force pulls the surface molecules upward, the resultant vector is downward.
As the surface molecule dives into bulk fluid, the molecules that remain at surface develop opposing force (i.e., surface tension).
Blade of length ℓ
Water
C DEFINITION OF SURFACE TENSION
$T = \frac{F}{\ell}$
Air
Blade
Expanding force, F
Water
D SPHERICAL AIR-WATER INTERFACE
Surface tension
Water
Air
P
Diving water molecules produce surface tension

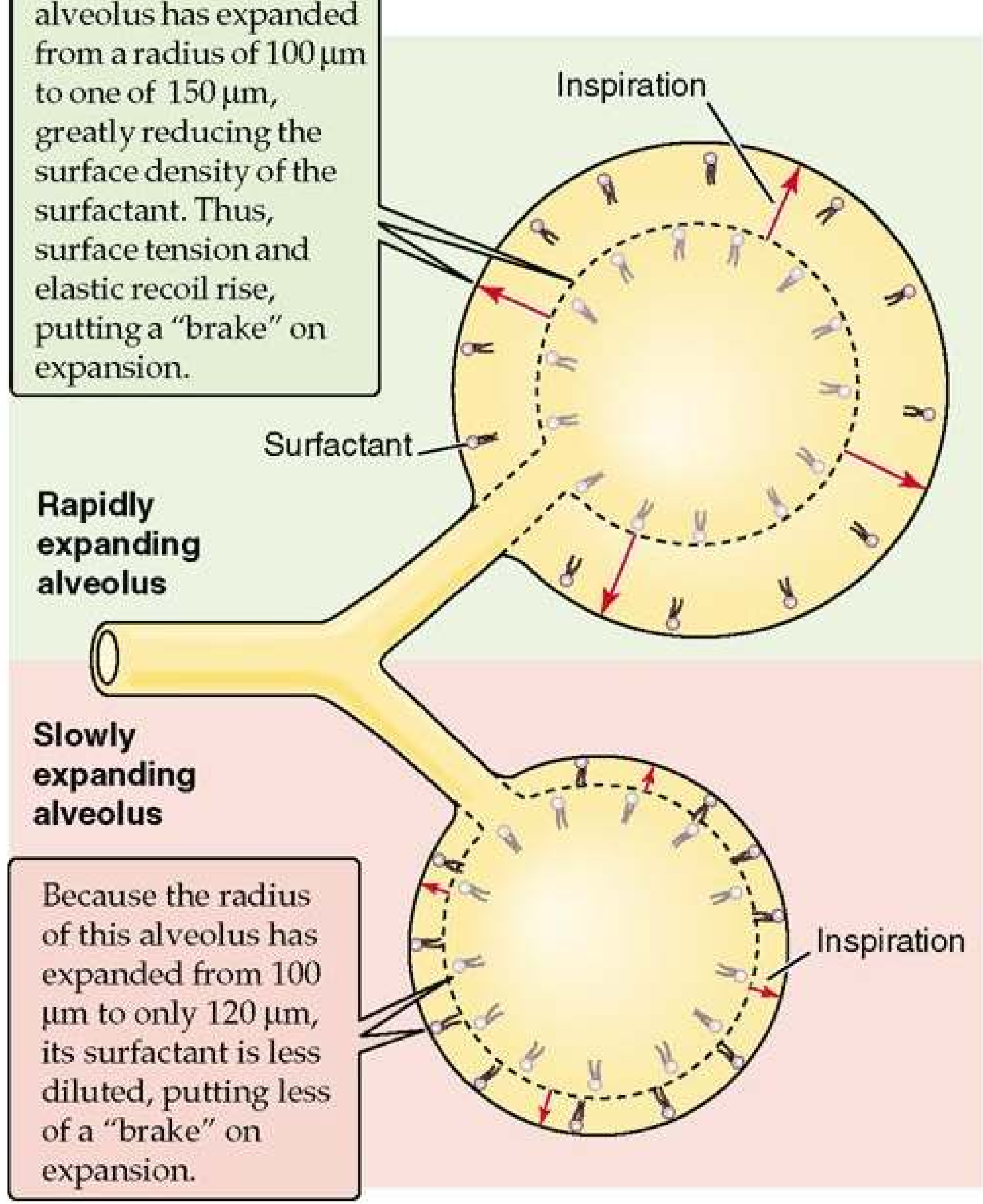
Surfactant

alveolar space
alveolar surface
hypophase
granular pneumocyte
alveolar interstitium
endothelial cell
blood capillary
surfactant
counter-ion



surface
surface tension
1
2
3
4
1

$$P = T / (2R)$$



bez surfaktantu:

$\uparrow R$

$P = T / (2R)$

se surfaktantem:

$\uparrow T \quad \uparrow R$

$P = T / (2R)$

bez surfaktantu:

$\downarrow R$

$P = T / (2R)$

se surfaktantem:

$\downarrow T \quad \downarrow R$

$P = T / (2R)$

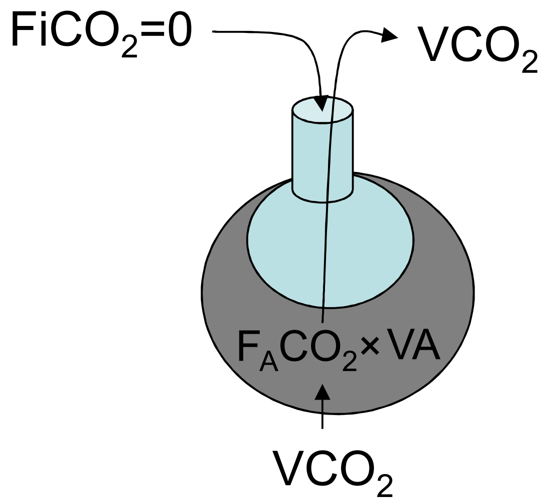
The „most important“ measure of respiratory system function

- pO_2 & pCO_2 in arterial blood - („Astrup“)
- O_2 solubility in water is low => need of Hemoglobin
- **pO_2** = 13,3 kPa = **100 Torr**
- Conversion: 1 Atm = 10 m H_2O = 100 kPa = 760 Torr = 760 mmHg

…….. 1 kPa = 10 cm H_2O = 7,6 Torr

- **pCO_2** = **40 Torr** = 5,3 kPa

Alveolar ventilation



$$VCO2 = F_ACO2 * VA$$

$$VA = VCO2/F_ACO2$$

$$P_ACO2 = F_ACO2 \times \text{Barometric pressure}$$

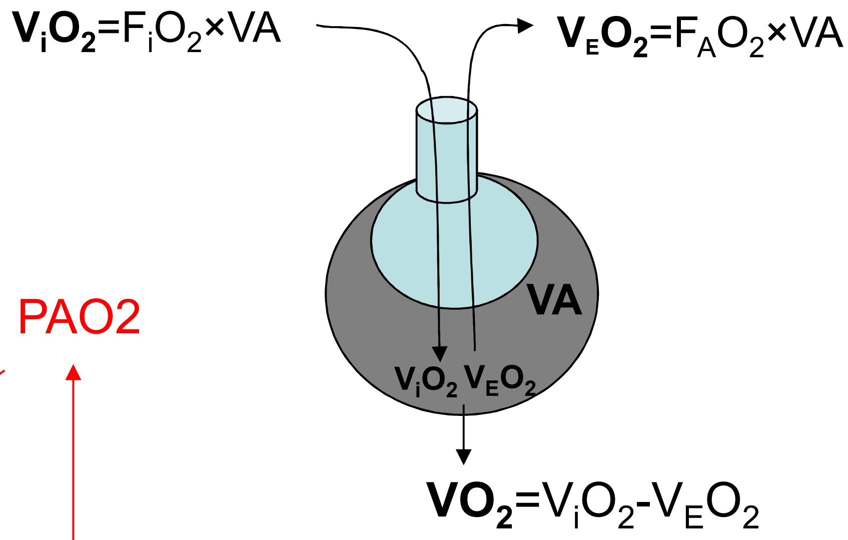
$$VA = k_1 \times VCO2/P_ACO2$$

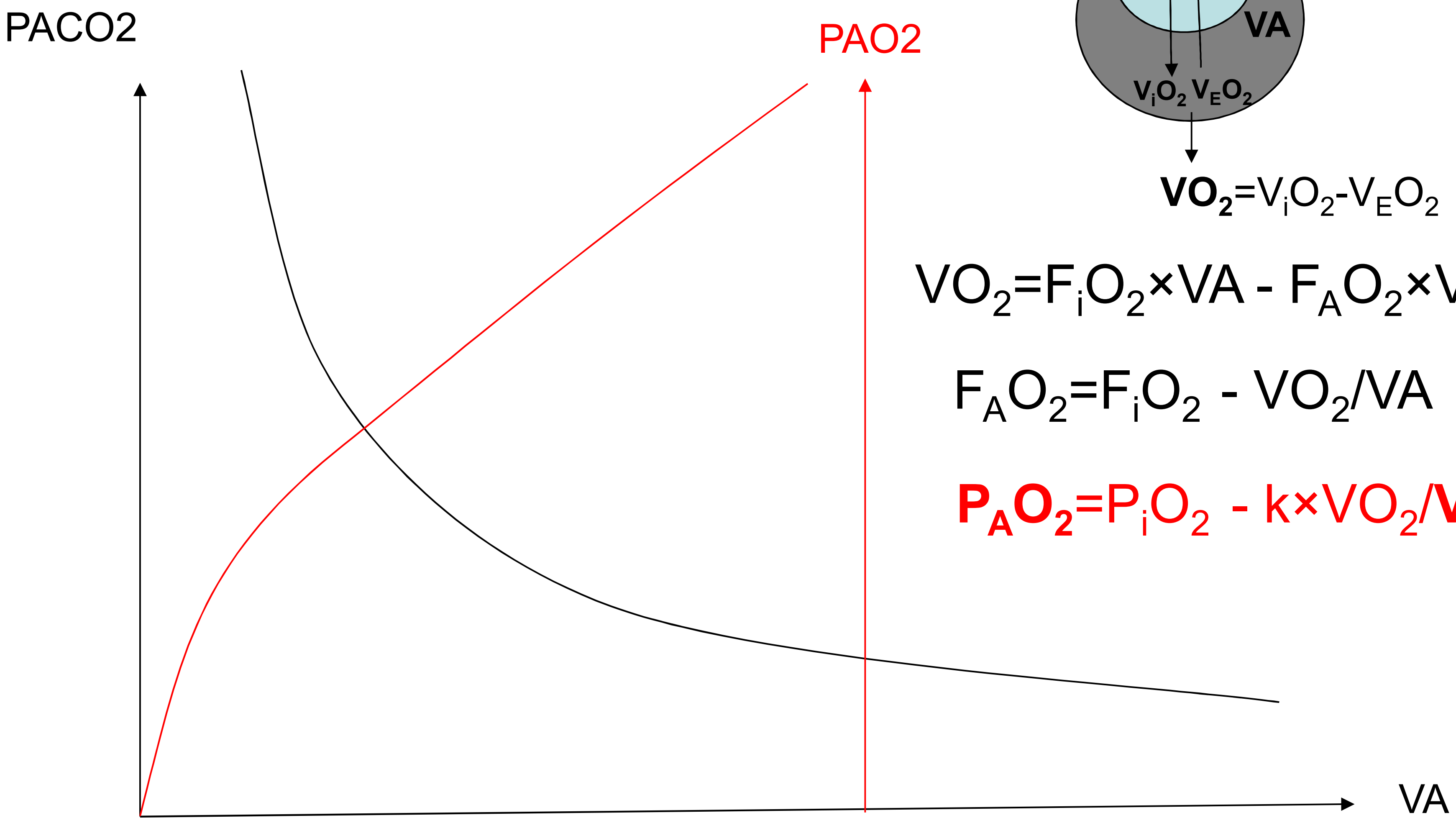
$$P_ACO2 = k_2 \times VCO2/VA$$

VCO2 → STPD; VA → BTPS

$$\frac{P \times V}{T} = R \qquad \frac{(P-P_{H_2O}) \times V_{BTPS}}{273 + t°_{patient}} = \frac{760 \times V_{BTPS}}{273}$$

$$P_ACO2_{[torr]} = 0{,}863 * VCO2_{[ml/min\ STPD]}/VA_{[l/min\ BTPS]}$$





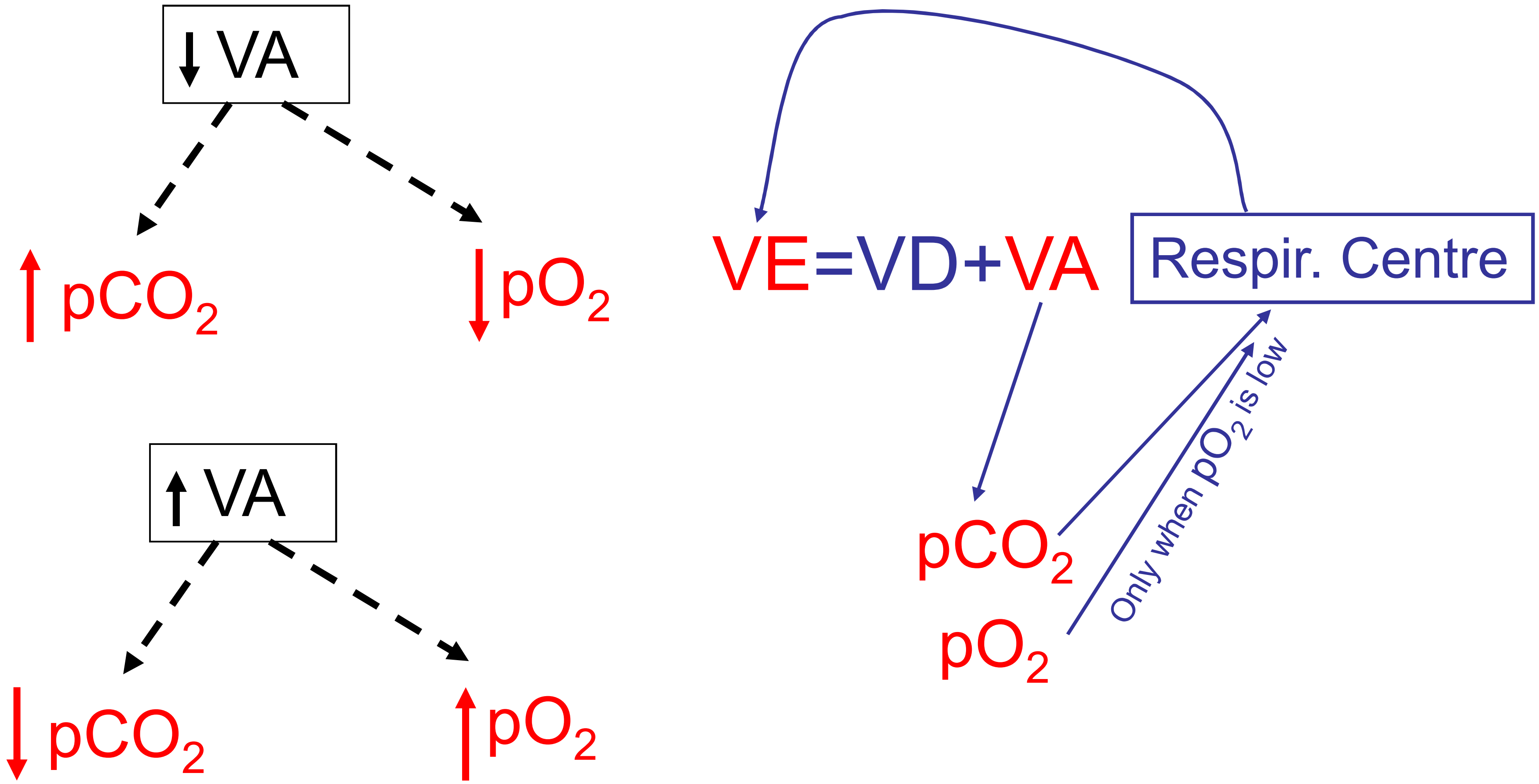
$$VO_2=F_iO_2 \times VA - F_AO_2 \times VA$$

$$F_AO_2=F_iO_2 - VO_2/VA$$

$$\mathbf{P_AO_2}=P_iO_2 - k \times VO_2/\mathbf{VA}$$

$$P_ACO2_{[torr]} = 0{,}863 * VCO2_{[ml/min\ STPD]}/VA_{[l/min\ BTPS]}$$

Alveolar Ventilation Controls Rate of Breathing by Influencing pCO2 and pO2



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

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

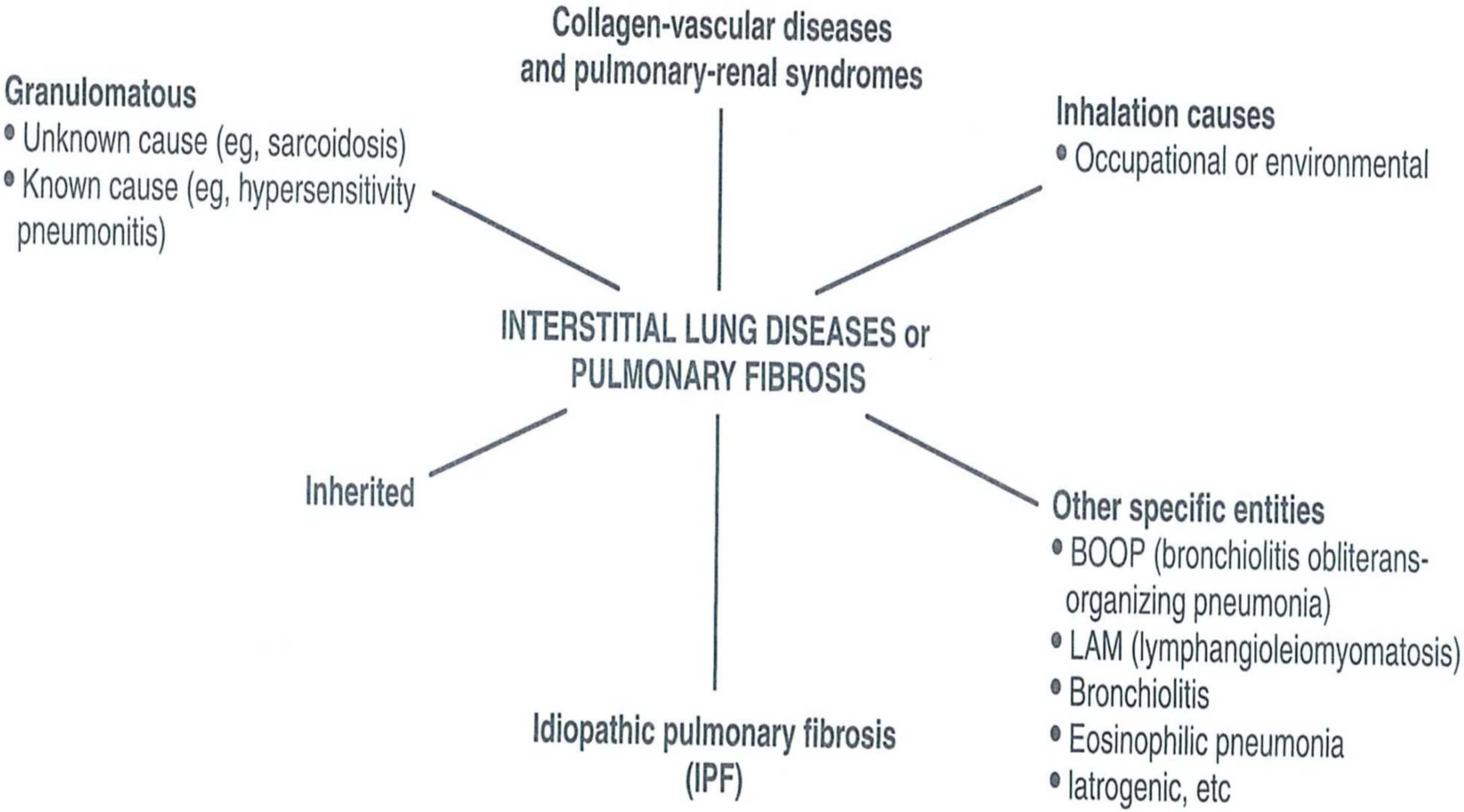
Causes of lung fibrosis/ ILD

- Inhalation of particles
  - 1. Azbestosis, silicosis, pneumoconiosis, = Pneumokonioser
  - 2. hypersensitivity (farmer's lung) = Alveolitis allergica
- Drug induced (Abio, chemo, Antiarrhythmic) =
- Connective tissue disease: Systemic sclerosis, Dermatomyositis, SLE, RA
- Infection: Atypical pneumonia, pneumocystis, TBC
- Lymphangitic carcinoma = maligne sygdromme

  Idiopatic: Sarcoidosis
- Idiopathic pulmonary fibrosis = Alveolitis fibrosa

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



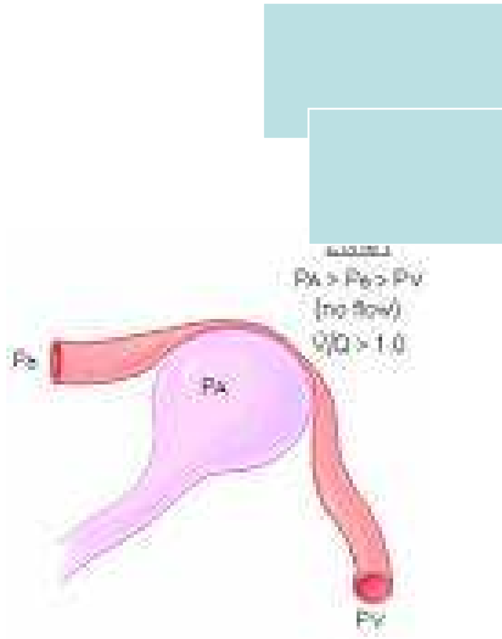
Collagen-vascular diseases and pulmonary-renal syndromes
Granulomatous
• Unknown cause (eg, sarcoidosis)
• Known cause (eg, hypersensitivity pneumonitis)
Inhalation causes
• Occupational or environmental
INTERSTITIAL LUNG DISEASES or PULMONARY FIBROSIS
Inherited
Other specific entities
• BOOP (bronchiolitis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

Possible respiratory system disturbances

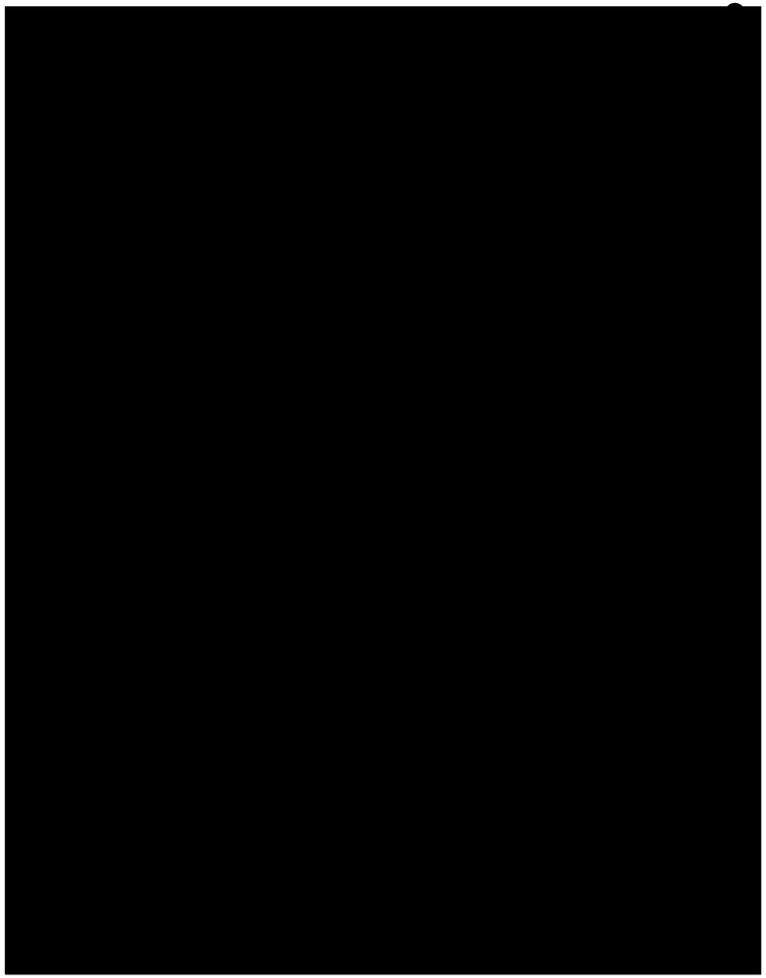
- // **ventilation**
- // **perfusion**
- // **distribution** of ventilation and per-fusion

= ventilation perfusion <u>mismatch</u>

- // **diffusion**



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

Ventilation disorders

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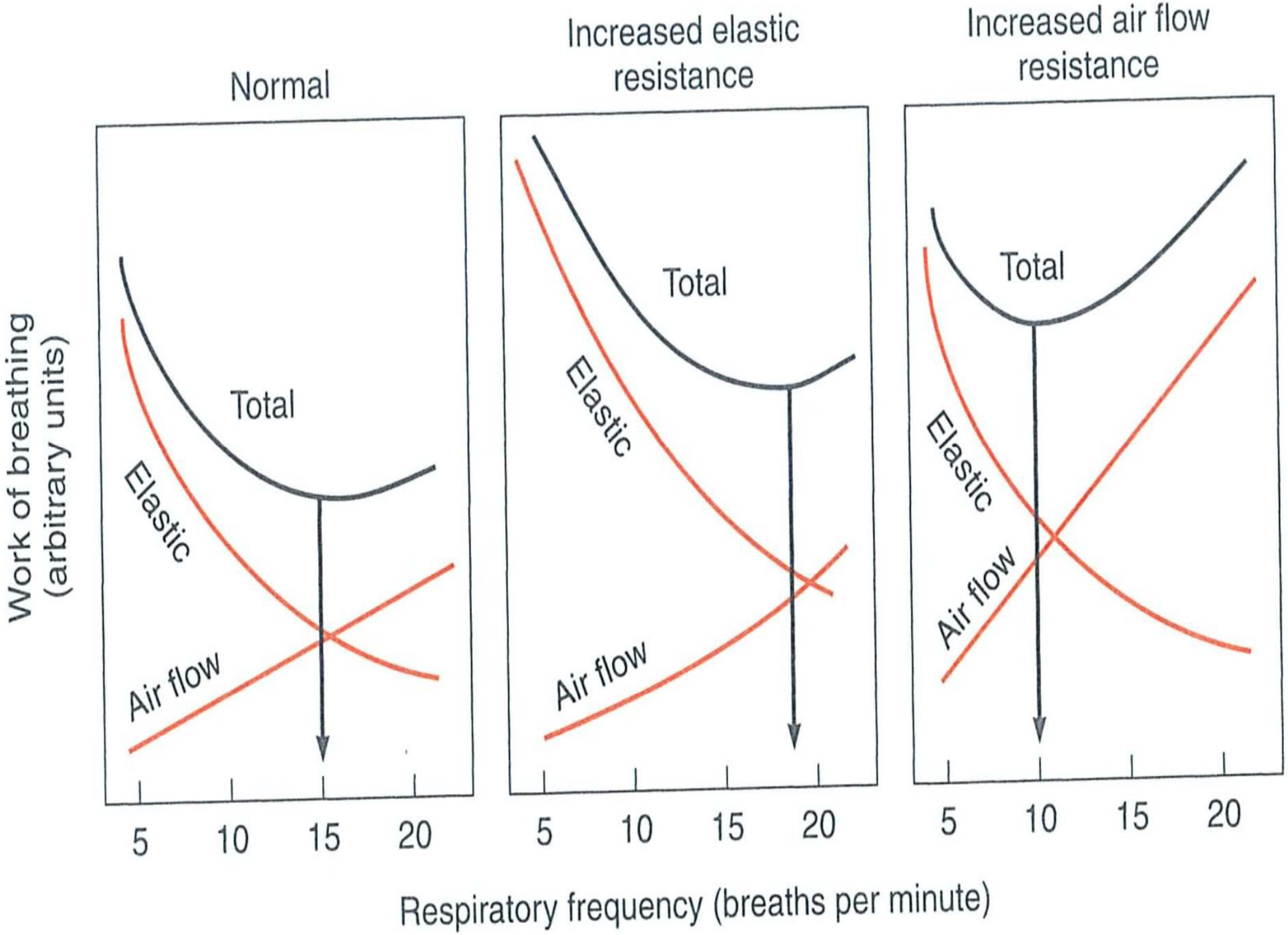
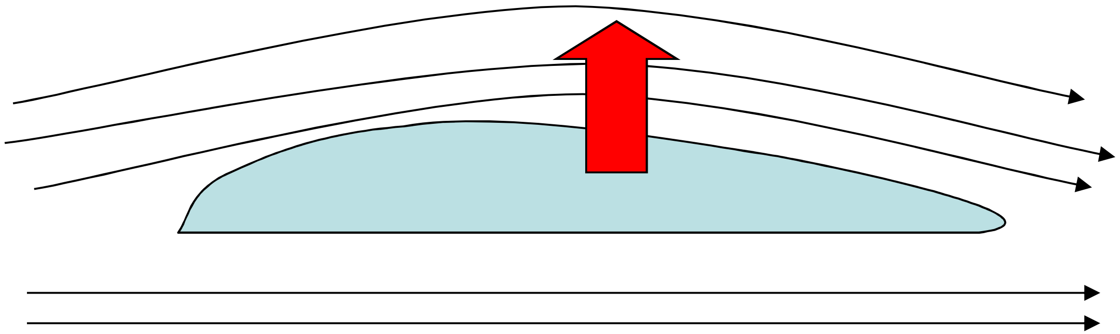
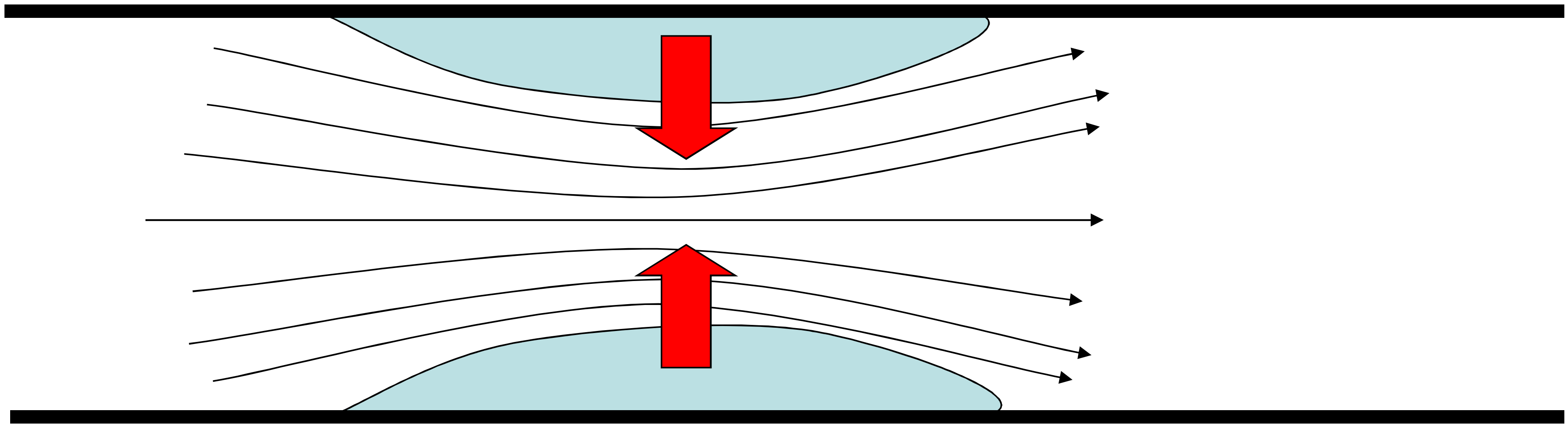
Normal/ Restrictive/ Obstructive



Why the airplane flies?



Bronchiolus narrows
(broncho-constriction, mucus…)



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.

END
OF THE LECTURE

Thanks for your attention

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