Transport of gases in the blood

- Gas exchange between the alveolar air and the blood in pulmonary capillaries results in an increased oxygen concentration and a decreased carbon dioxide concentration in the blood leaving the lungs. This blood enters the systemic arteries, where blood gas measurements are taken to assess the effectiveness of lung function.

Composition of respired air

in QUIET BREATING (of the 500 ml atmospheric air)

- **INSPIRED** **in a single inspiration**

OXYGEN makes up about 21%

NITROGEN about 79%

CARBON DIOXIDE about 0.04%

In most climates, water vapour in air will reduce these percentages slightly. There are also very small amounts of inert gases.

150 ml occupy the conducting passages – "dead space" air.
This remains unchanged in composition since it is not in contact with respiratory surfaces.

350 ml reach the respiratory units and mix with 2.4 liters alveolar air (Functional Residual Capacity).

Alveolar air is saturated with WATER VAPOUR. It constantly gives up OXYGEN to the blood, and constantly takes up CARBON DIOXIDE from the blood.

- **EXSPIRED in a single expiration**

OXYGEN makes up	15.7%
NITROGEN	74.5%
CARBON DIOXIDE	3.6%
WATER VAPOUR	6.2%

[NB: The percentage of nitrogen is changed because it is diluted by the addition of other gases, especially water vapour. Air is saturated with water vapour by the time it reaches the lungs.]

This represents a mixture of: "dead space" air – air which has moved out unchanged from the conducting passages **And**

Alveolar air - air which has been in contact with respiratory surfaces and has given up some oxygen to the blood and taken up carbon dioxide from it.

OXYGEN	13.6%
NITROGEN	74.9%
CARBON DIOXIDE	5.3%
WATER VAPOUR	6.2%

In **VOLUNTARY DEEP BREATHING** at rest (hyperventilating) more new air exchanges with the alveolar air. Thus O_2 content of alveolar air will increase and the CO_2 content will decrease.

MOVEMENT OF RESPIRATORY GASES

- A gas moves from an area where it is present at higher pressure to an area where it is present at lower pressure. The movement of gas molecules continues till pressure exerted by them is the same throughout both area. Dry atmospheric air (at sea level) has a pressure of 1 atmosphere = 760 mmHg = 101.3 kilopascals (kPa).

EXPIRED AIR
is saturated with water

H_2O = 47 mmHg (6.2 kPa)
O_2 = 119.3 mmHg (15.8 kPa)
CO_2 = 27.4 mmHg (3.6 kPa)
N_2 = 566 mmHg (74.5 kPa)

EXTERNAL
RESPIRATION
in the ALVEOLI
CO_2 pressure is low;
CO_2 moves from blood to air;
4ml/100 ml (4 vol. %) given
up by blood

INTERNAL
RESPIRATION
In the TISSUES
CO_2 pressure is high;
CO_2 moves from tissues
to blood:
4 ml/100 ml (4 vol %)
taken up by blood.

Pressure is the force
per unit area. In
Standard International
Units it is defined in
newtons per square metre.
The unit is the pascal (Pa)
1 kPa = 1000 Pa.

INSPIRED AIR

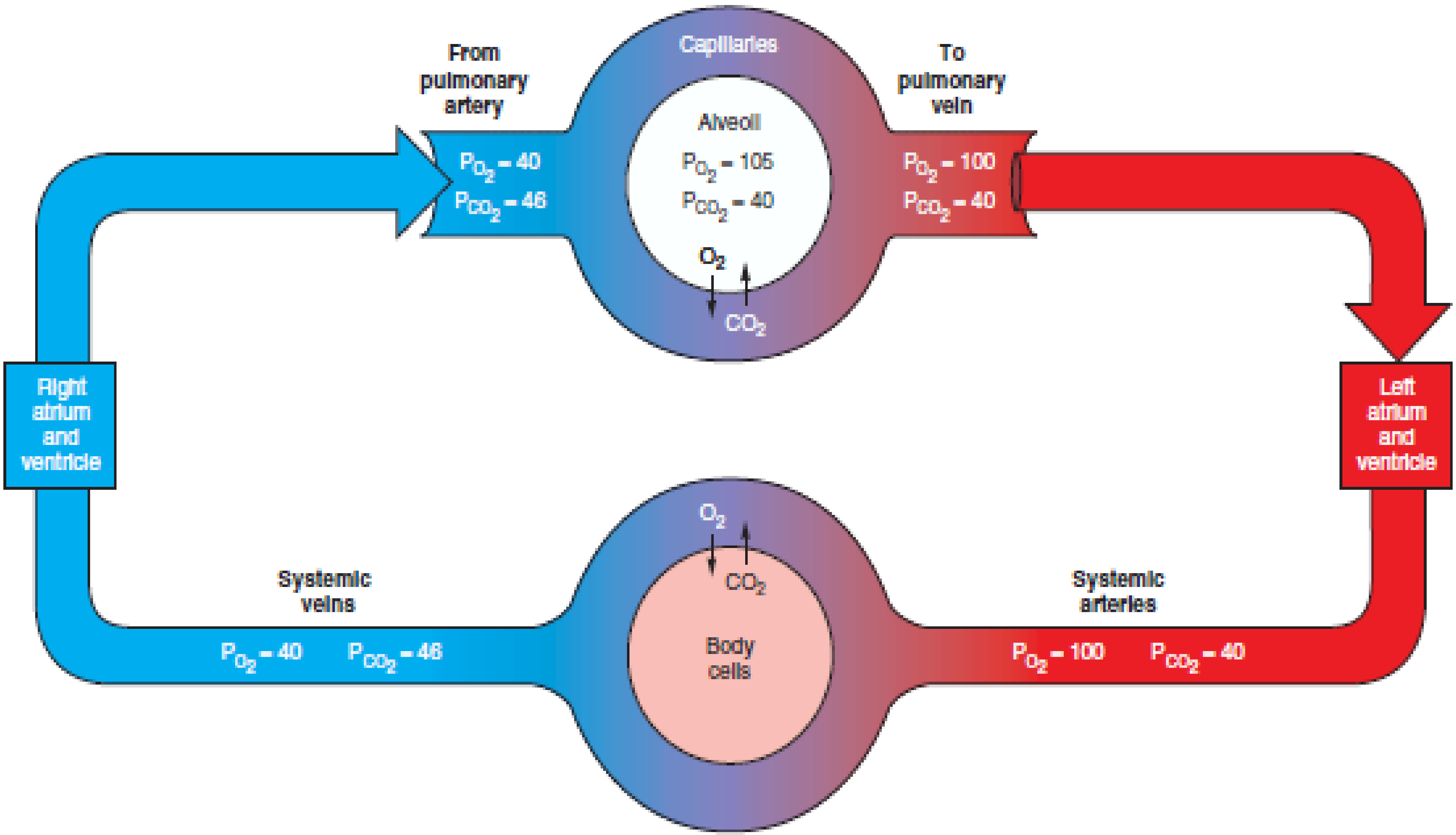
O_2 = 160 mmHg (21 kPa)
CO_2 = 0.3 mmHg (0.04 kPa)
N_2 = 600 mmHg (79 kPa)

In the ALVEOLI
O_2 pressure is high;
O_2 moves from air to blood;
5 ml/100 ml (5 vol %)
taken up by blood

In the TISSUES
O_2 Pressure is low:
O_2 moves from blood
to tissues:
5 ml/100 ml (5 vol %)
given up by blood.

Concentrations of the gases, and therefore the pressures exerted by them, vary in the tissues depending on the metabolic activity of the particular tissue at any one time.

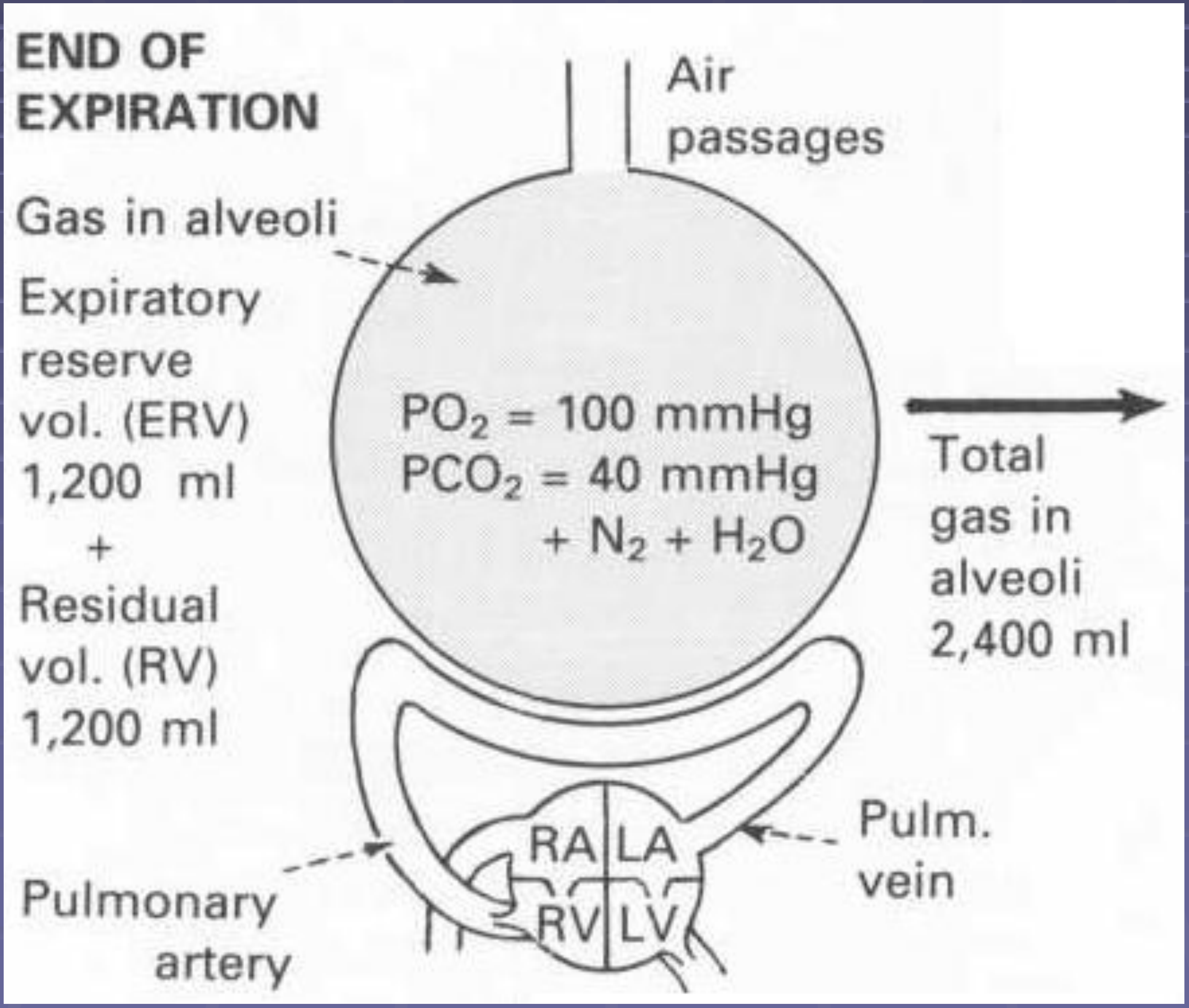
Partial pressures of gases in blood



ALVEOLAR VENTILATION and DEAD SPACE

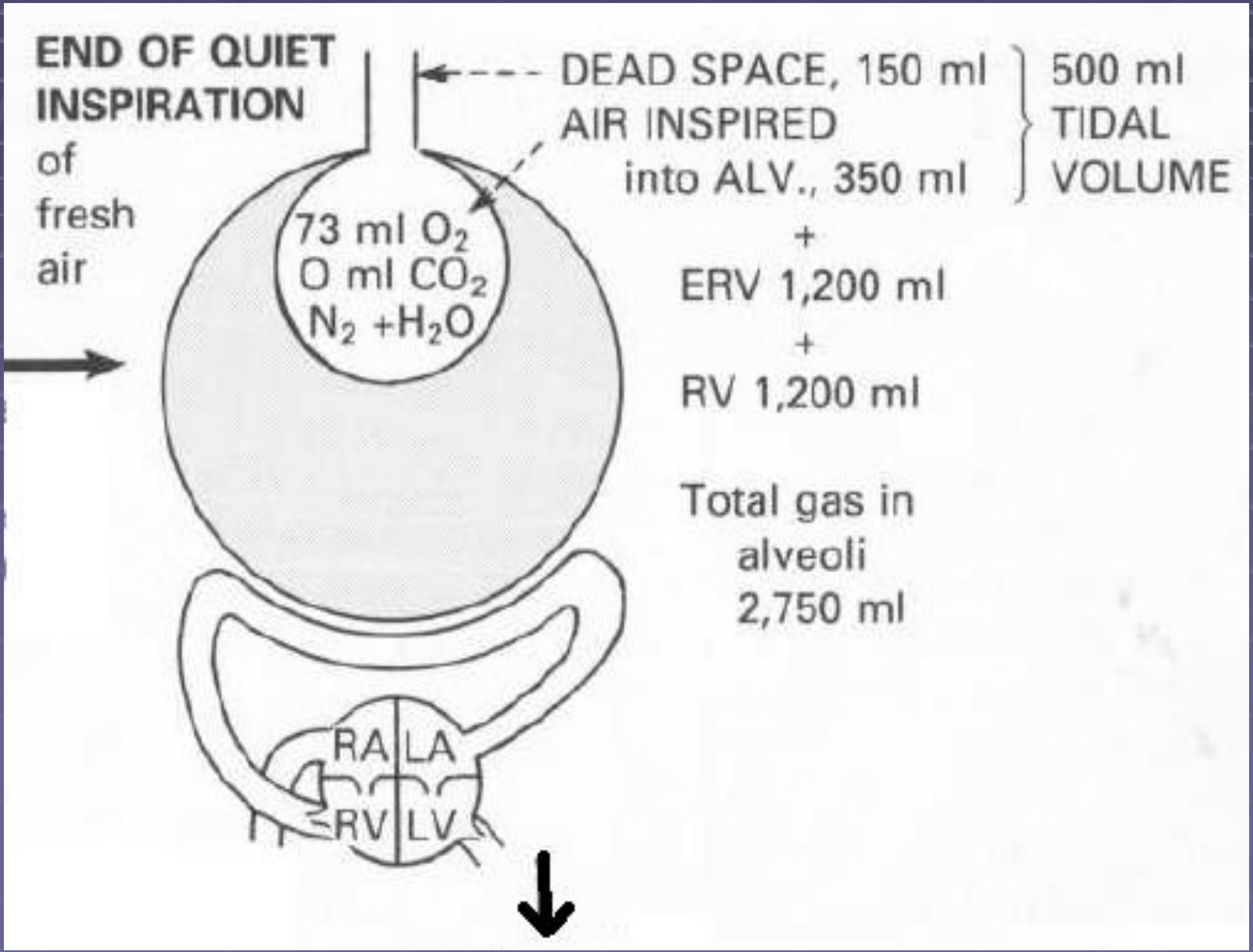
- At rest, with each breath, we breathe in about 500 ml of fresh atmospheric air (the TIDAL volume). Of this volume 350 ml mix with air already in the lung alveoli and 150 ml occupy the air passages (anatomical dead space) and do not take part in exchange with gases in the blood. It is instructive to consider the fate of one breath of dry air at rest. For simplicity, consider the rate of breathing to be 10 breaths per minute.

Stage 1

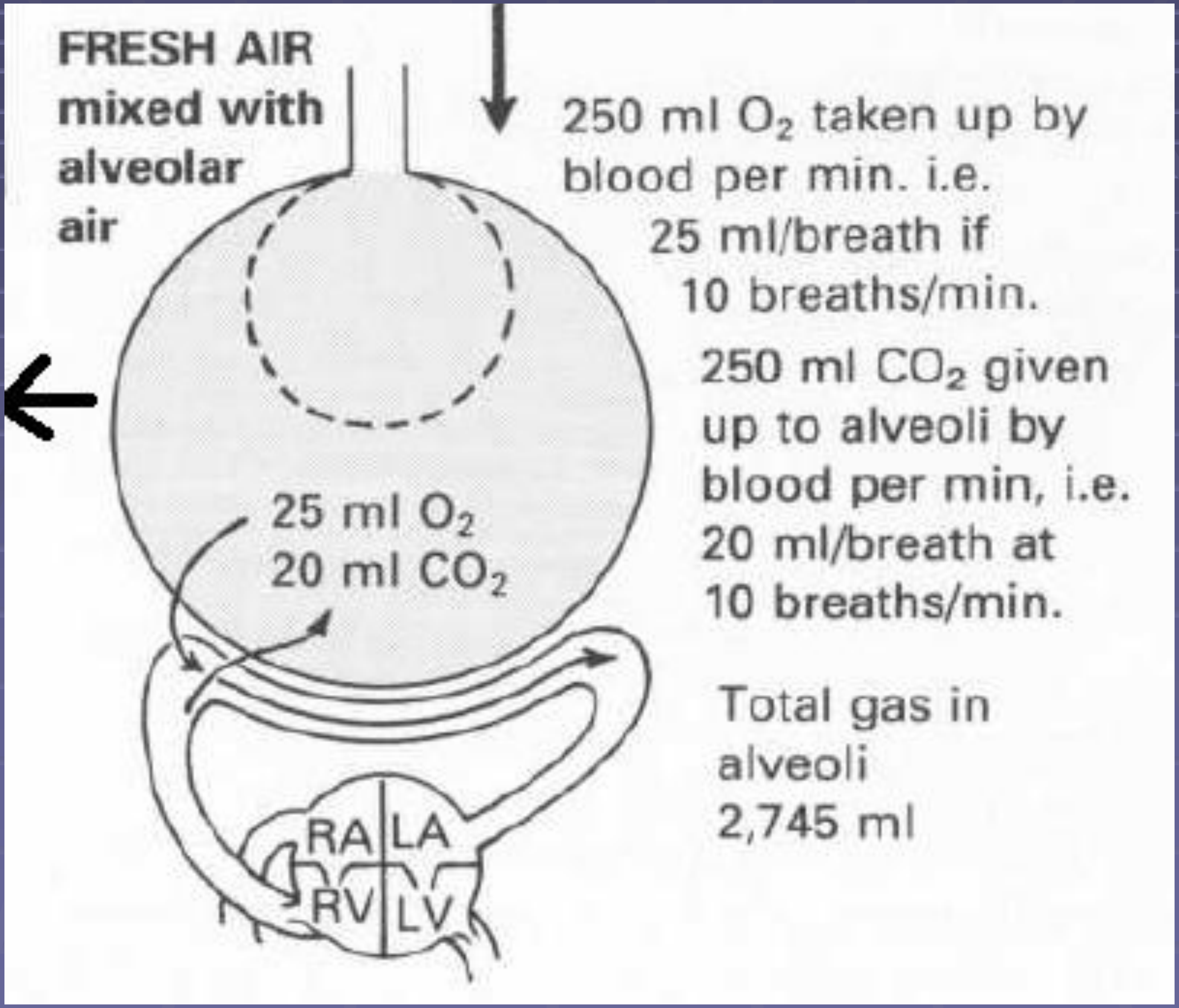


END OF
EXPIRATION
Air
passages
Gas in alveoli
Expiratory
reserve
vol. (ERV)
1,200 ml
+
Residual
vol. (RV)
1,200 ml
PO2 = 100 mmHg
PCO2 = 40 mmHg
+ N2 + H2O
Total
gas in
alveoli
2,400 ml
RA
LA
RV
LV
Pulm.
vein
Pulmonary
artery

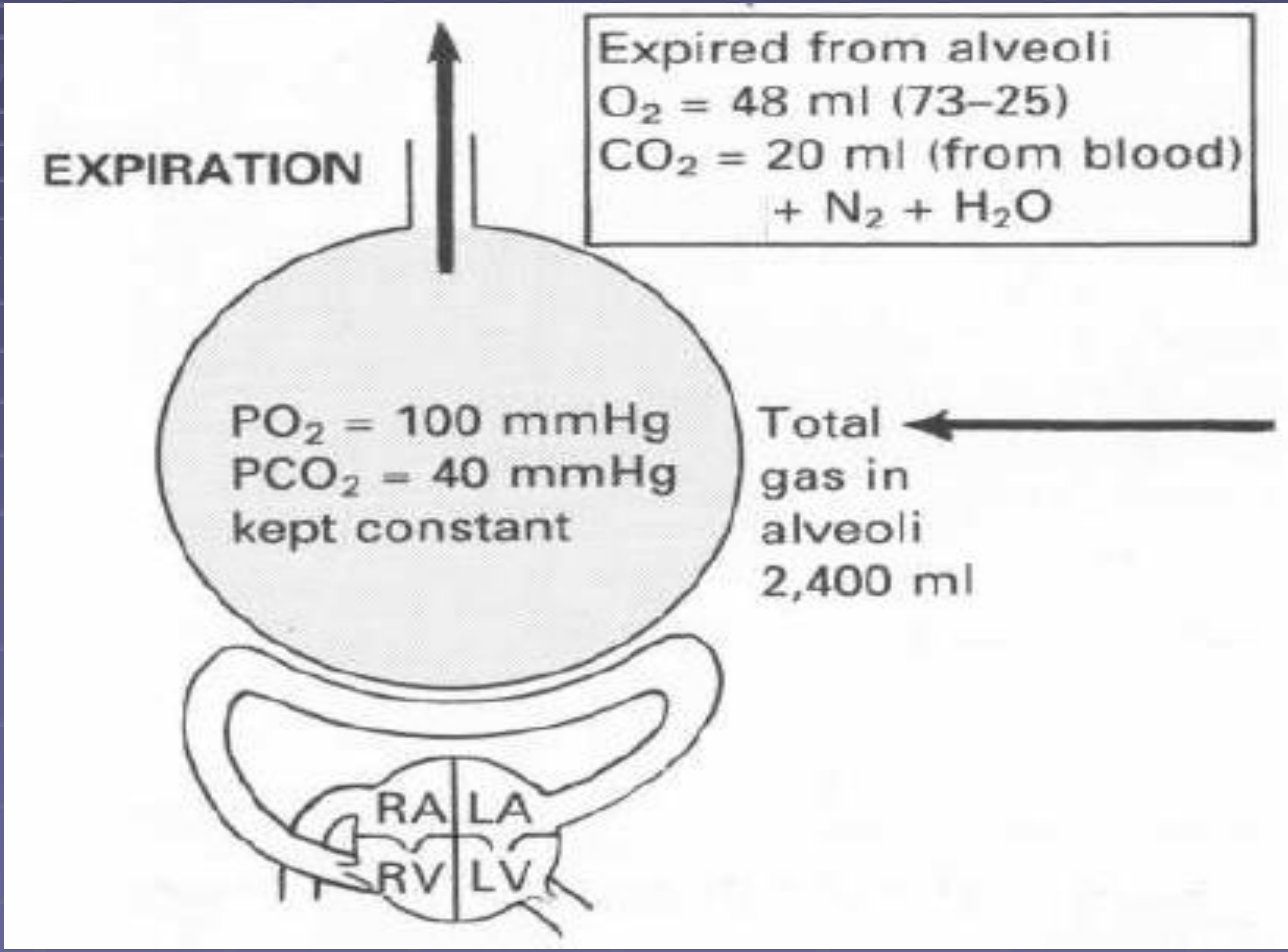
Stage 2


END OF QUIET INSPIRATION
of
fresh
air
DEAD SPACE, 150 ml
AIR INSPIRED
into ALV., 350 ml
500 ml
TIDAL
VOLUME
73 ml O_2
0 ml CO_2
N_2 +H_2O
+
ERV 1,200 ml
+
RV 1,200 ml
Total gas in
alveoli
2,750 ml
RA
LA
RV
LV

Stage 3


FRESH AIR mixed with alveolar air
250 ml O_2 taken up by blood per min. i.e. 25 ml/breath if 10 breaths/min.
250 ml CO_2 given up to alveoli by blood per min, i.e. 20 ml/breath at 10 breaths/min.
25 ml O_2
20 ml CO_2
Total gas in alveoli 2,745 ml
RA
LA
RV
LV

Stage 4



Although shown in stages, the process is continuous.

In this case,

- Dead space ventilation = **150 x 10 =1,500 ml/min.**
- Alveolar ventivation = **350 x 10 = 3,500 ml/min.**
- Total ventilation = **500 x 10 = 5,000 ml/min.**

- For simplicity, the CO_2 in 350 ml of atmospheric air which would be 0.14 ml has been called 0 ml and N_2 which would be approximately 276 ml has not been quantified, not has the water output.

Forms of oxygen transport

- Physically dissolved in plasma
- Chemically bound to hemoglobin

Physically dissolved oxygen

Henry-Dalton law

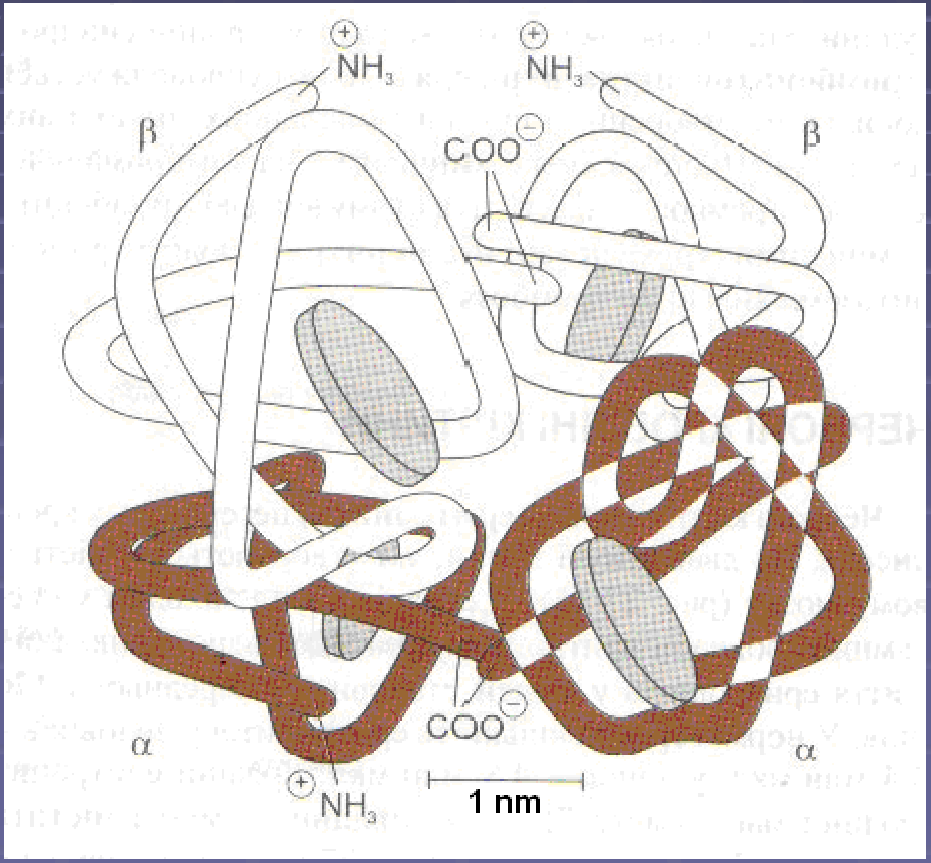
$$[газ] = \frac{\alpha}{760} * P_2$$

$$[O_2] = \frac{0{,}024}{760} * 95 = 0{,}003 \ \textit{мл на } 1 \textit{ мл крові}$$

The value of physically dissolved oxygen

- provides diffusion of O2 (the transition into the blood or from the blood O2 must go in physically dissolved state and only in this form can diffuse);
- physically dissolved oxygen significantly affects the properties of hemoglobin

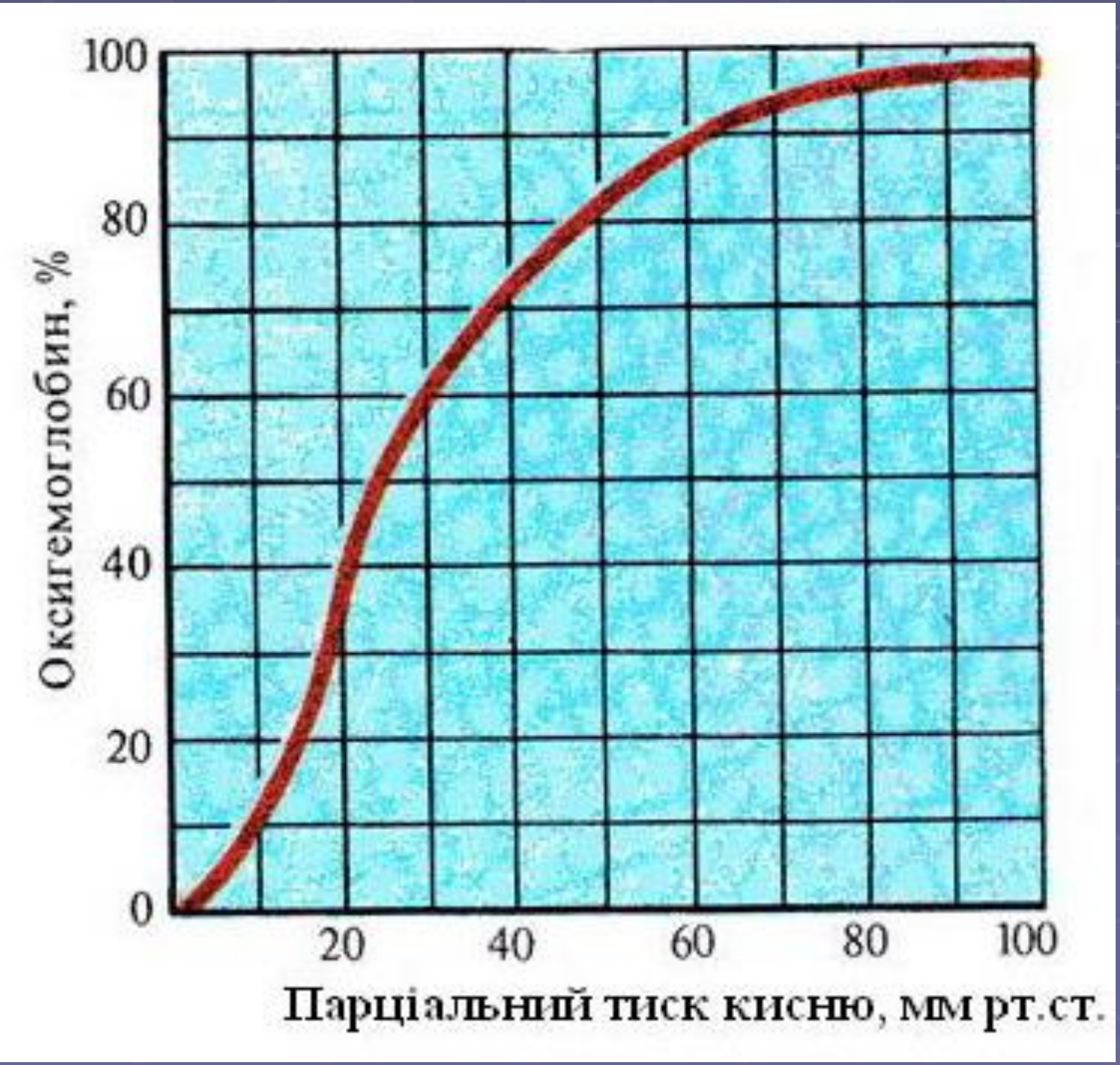
Chemically bound to hemoglobin



Oxyhemoglobin dissociation curve

- The curve describes the dependence of the degree of hemoglobin oxygen saturation from O2 tension in the blood.
- Hemoglobin oxygen saturation (SO2) - the percentage between oxyhemoglobin and total hemoglobin content.

$$SO_2 = \frac{[HbO_2]}{[HbO_2]+[Hb]} * 100\%$$



100
80
60
40
20
0
Оксигемоглобин, %
20
40
60
80
100
Парціальний тиск кисню, мм рт.ст.