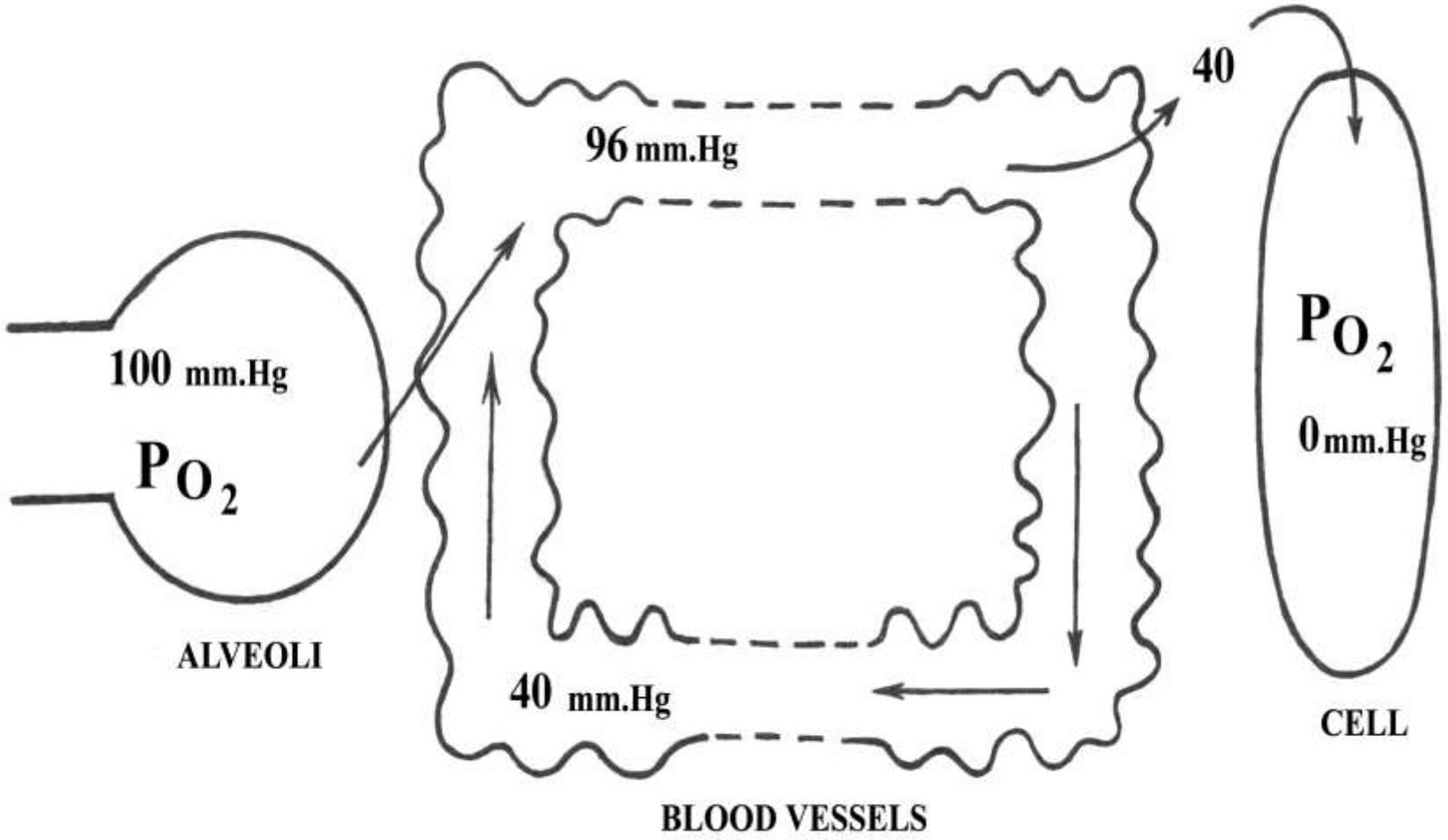
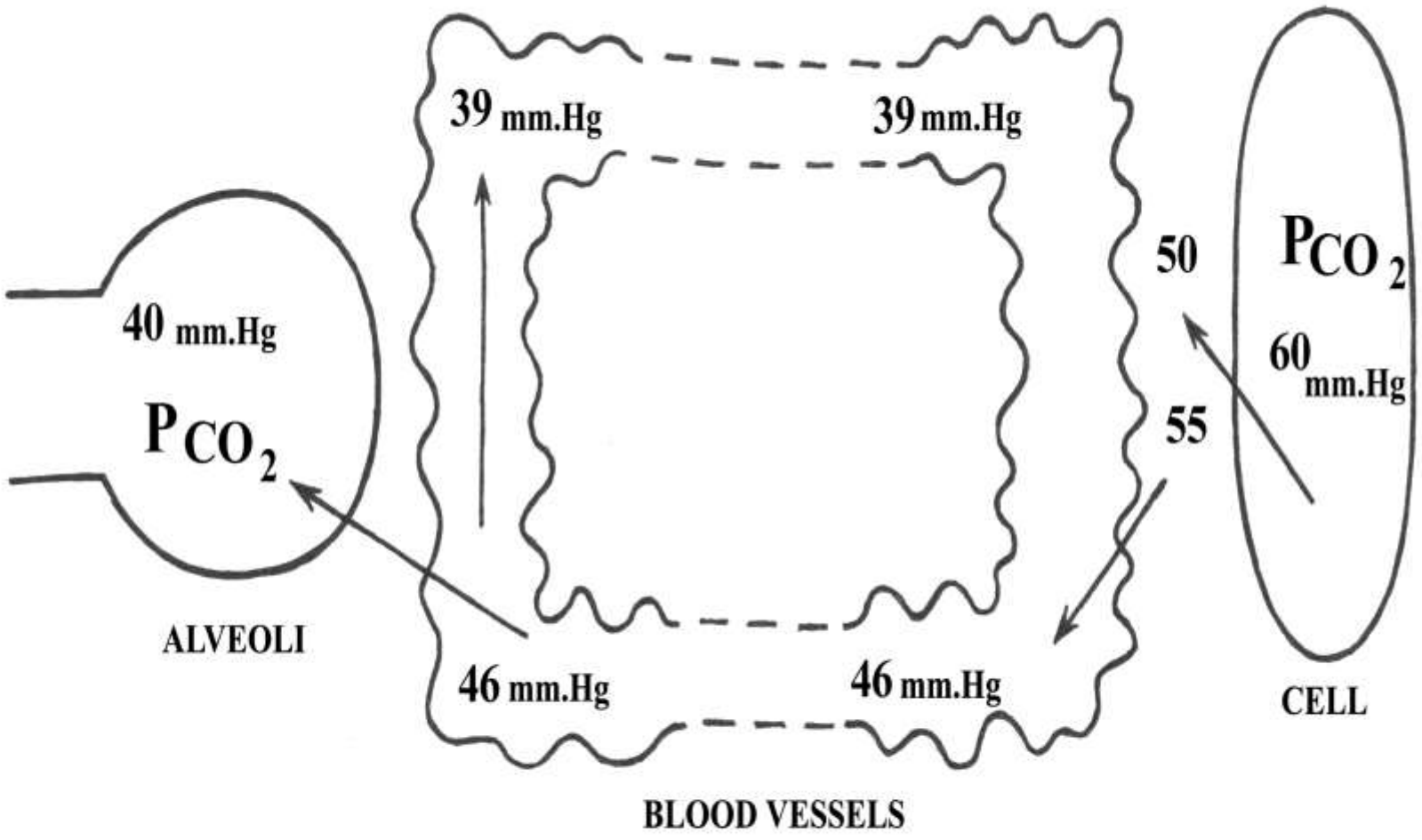
Lecture 19.

Gas exchange and gas transport in the blood. Regulation of respiration



OXYGEN TRANSPORT BY BLOOD



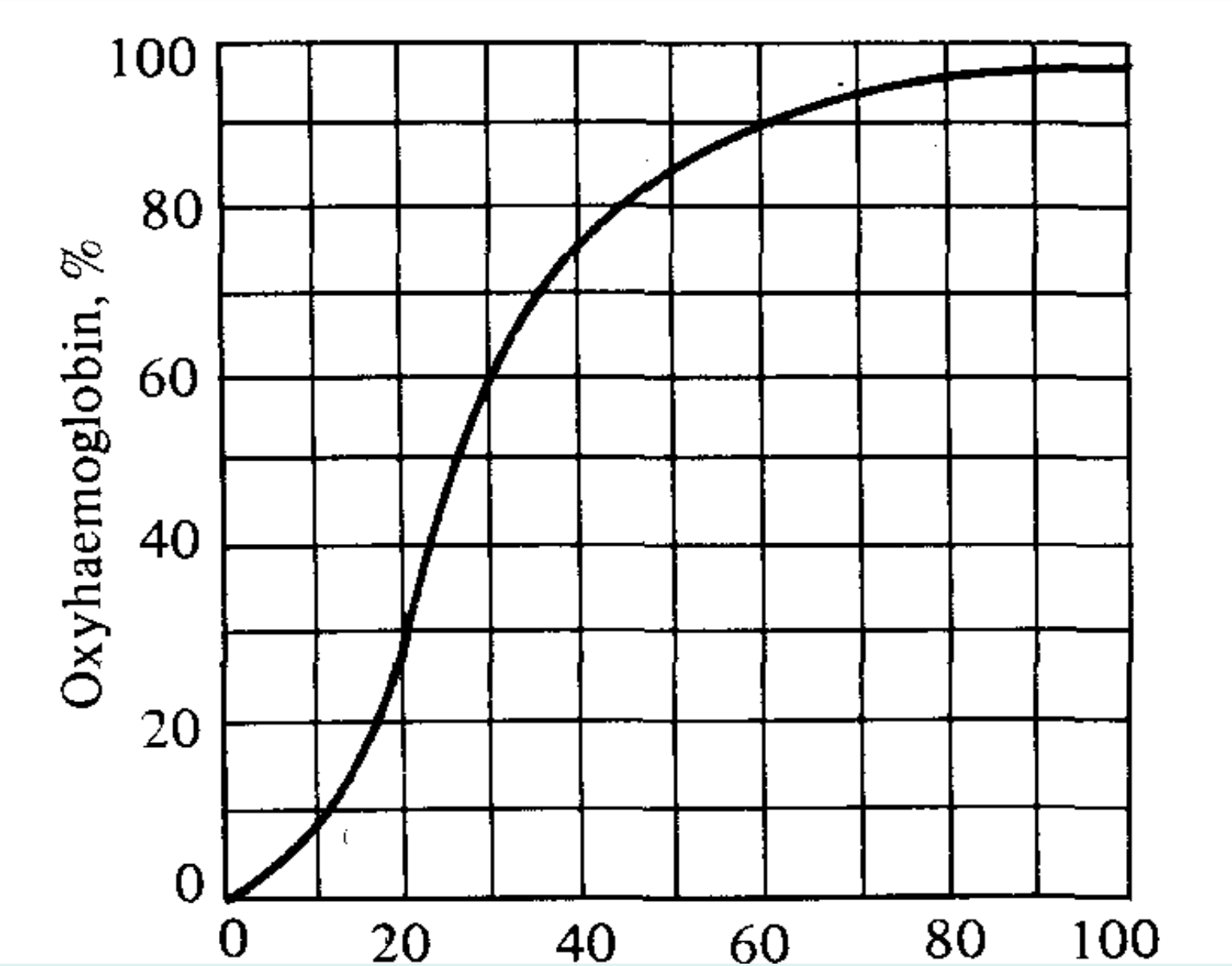
CARBON DIOXIDE TRANSPORT BY BLOOD

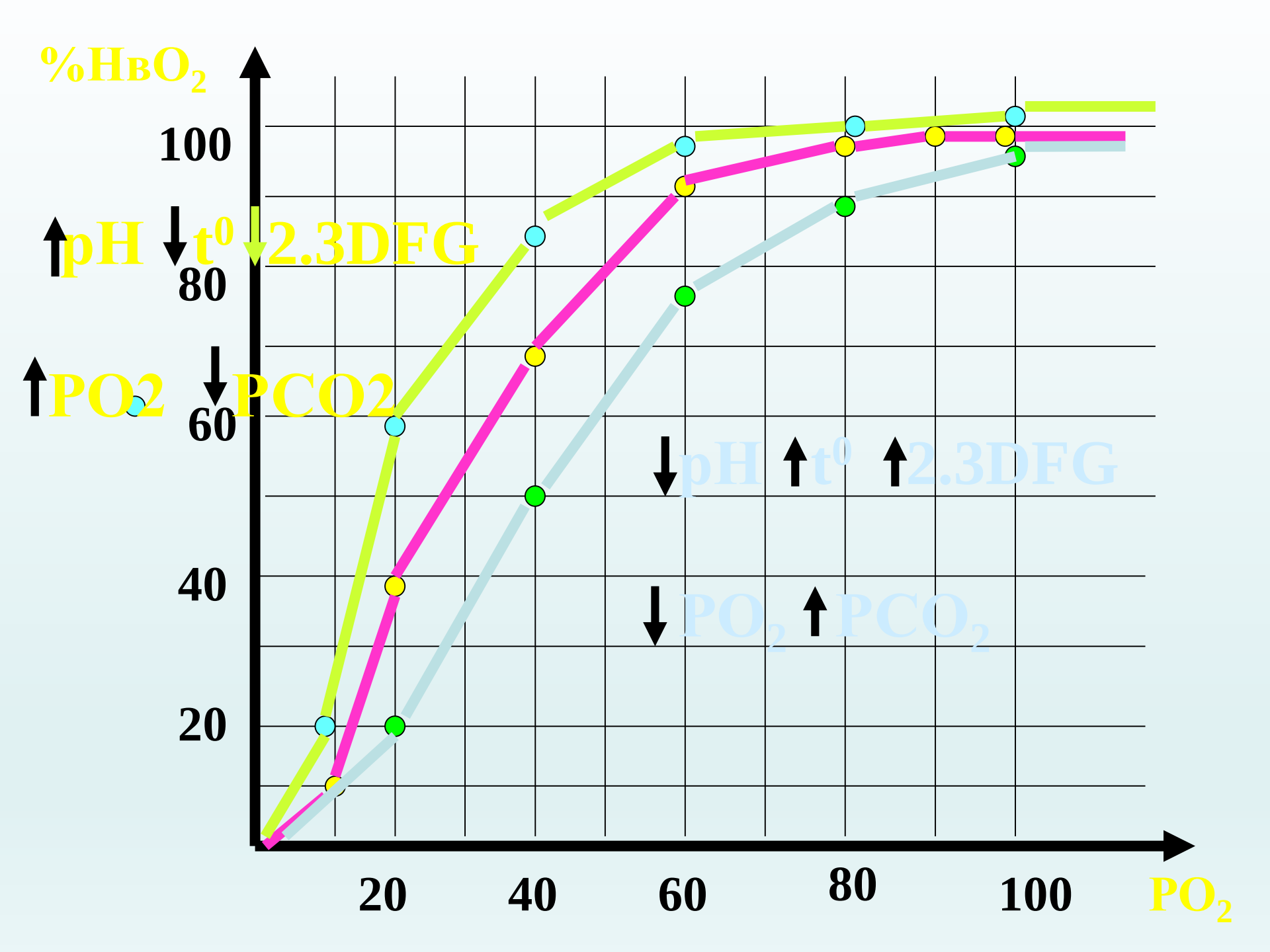
OXYGEN TRANSPORT BY THE BLOOD

- Oxygen is transported in the form of oxyhaemoglobin.
- Only 0,3 ml of oxygen is dissolved per 100 ml of blood at 37°C.

Oxyhaemoglobin dissociation curve

- Conversion of haemoglobin to oxyhaemoglobin is conditioned by the tension of dissolved O2.
- This dependence is expressed graphically by *the oxyhaemoglobin dissociation curve*


100
80
60
40
20
0
Oxyhaemoglobin, %
0
20
40
60
80
100
O2 tension, mm Hg


%HвO2
100
80
60
40
20
pH ↓ t0 ↓ 2.3DFG
↑PO2 ↓ PCO2
↓ pH ↑ t0 ↑ 2.3DFG
↓ PO2 ↑ PCO2
20
40
60
80
100
PO2

The sloping part of the curve

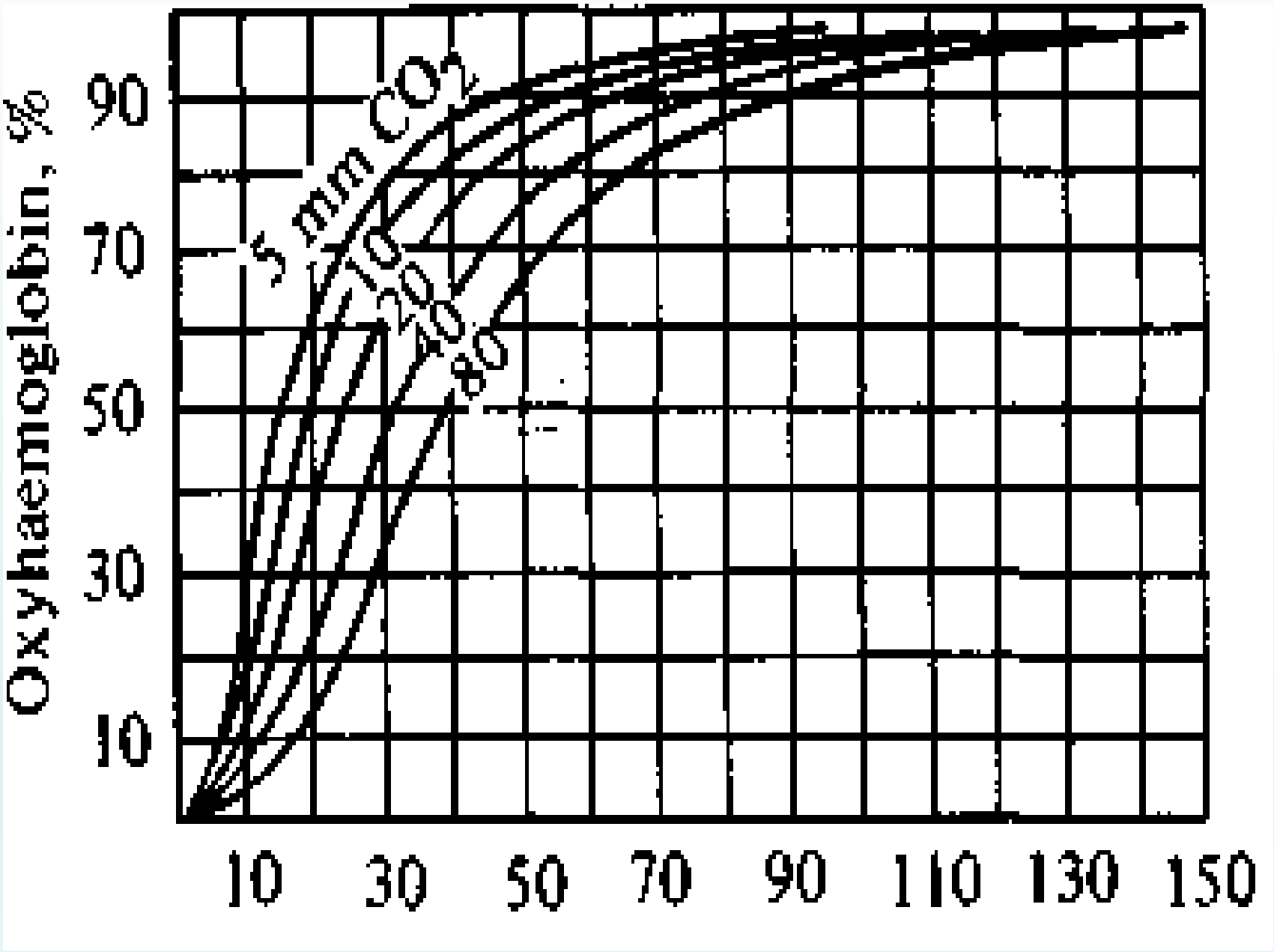
- corresponds to high O2 tension (more than 60 mm Hg)
- provides evidence that the level of oxyhaemoglobin under these conditions does not depend much on the O2 tension and partial pressure in inspired and alveolar air.

A steep part of the curve

- corresponds to O2 tension which is inherent in body tissues (35 mm Hg and lower).
- Dissociation or oxyhaemoglobin is higher and sometimes almost complete in tissues that consume much oxygen, e.g. working muscles, liver, kidneys.

Haemoglobin affinity for oxygen

- 2,3-disphosphoglycerate (2,3-DPG) content in erytrocytes
- the CO2 and H+ concentration (Bohr effect)
- *Temperature*


Oxyhaemoglobin, %
90
70
50
30
10
5 mm CO2
10
20
40
80
10
30
50
70
90
110
130
150

Shift of the curve to the right

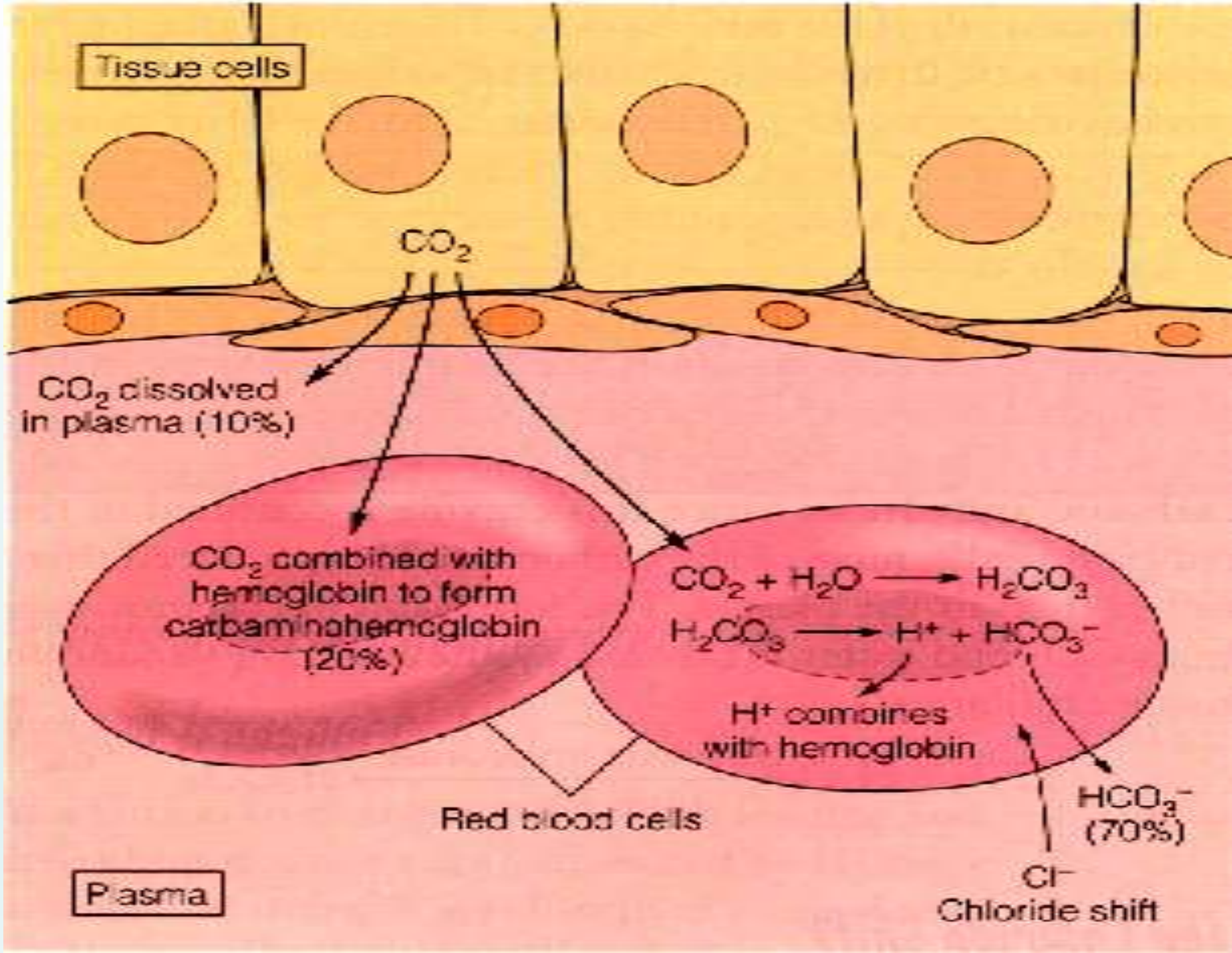
- oxygen enters tissues with more ease
- Increase in 2,3-disphosphoglycerate (2,3-DPG) content (when the blood O2 tension is reduced).
- increase in the CO2 and H+ concentration
- *Temperature rise*

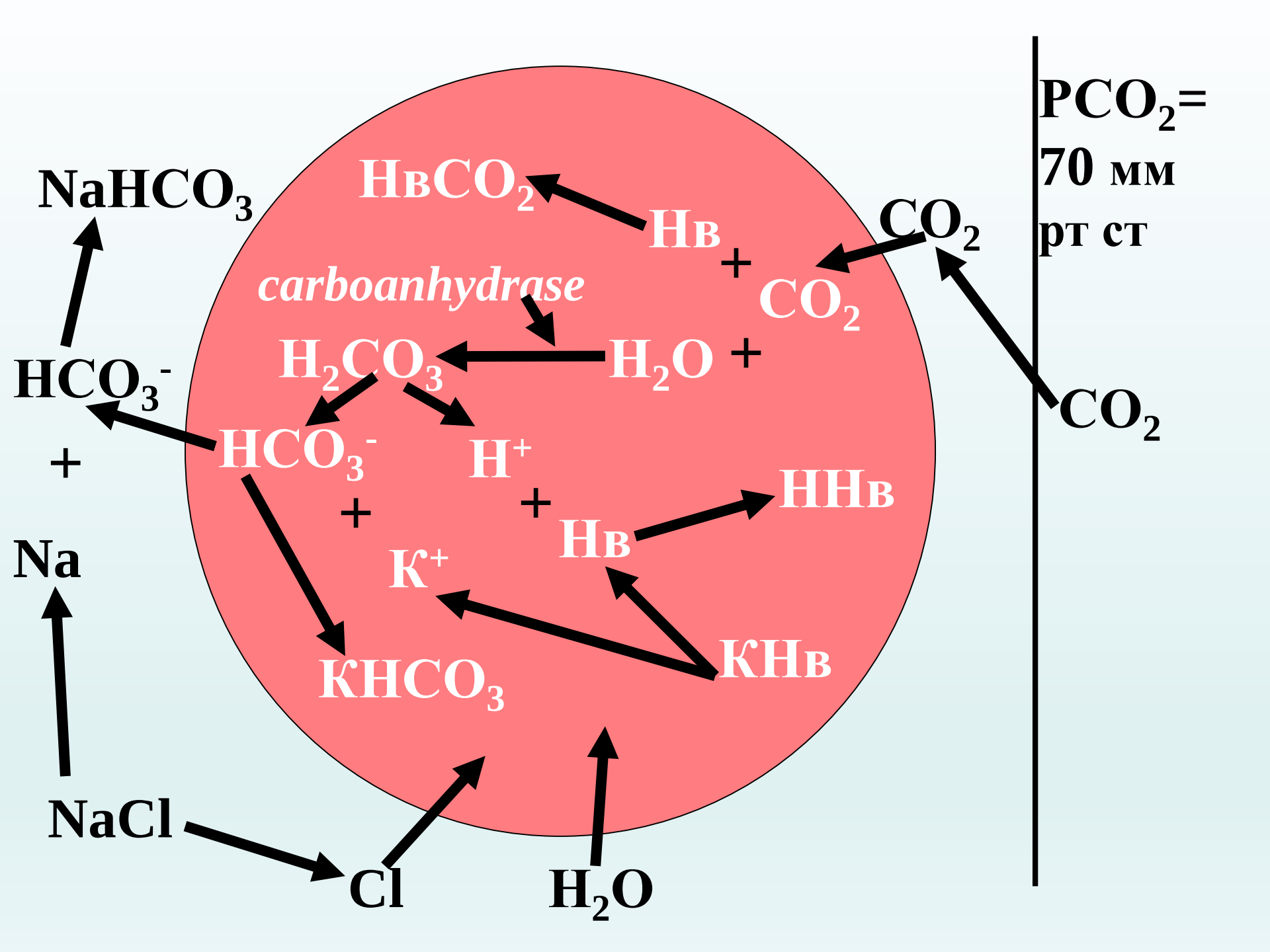
Oxygen capacity of the blood

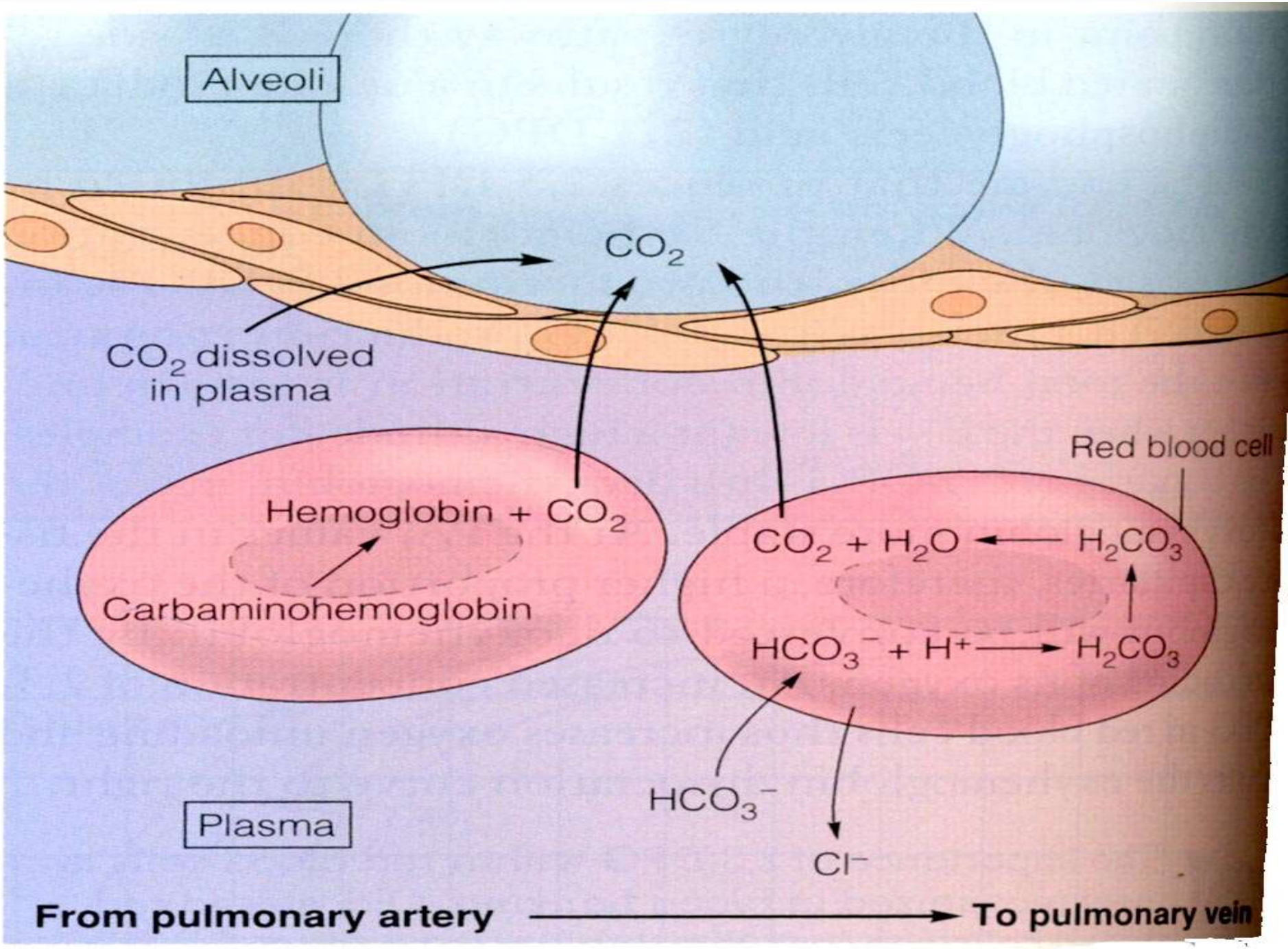
- The maximal amount of O2 that can be bound by blood in full saturation of haemoglobin with oxygen
- The oxygen capacity of the blood depends on its haemoglobin content.
- The volume of one mole of oxygen is 22.41. One Hb gram-molecule is capable of binding 22 400 x 4 = 89 600 ml of O2
- The molecular mass of Hb is 66 800, hence, 1 g of Hb is capable of binding 89600 : 66800 = 1.34 ml of O2.
- With 140 g/l of blood Hb, the O2 blood capacity is 1.34 x 140 = 187.6 ml or about 19 volume per cent

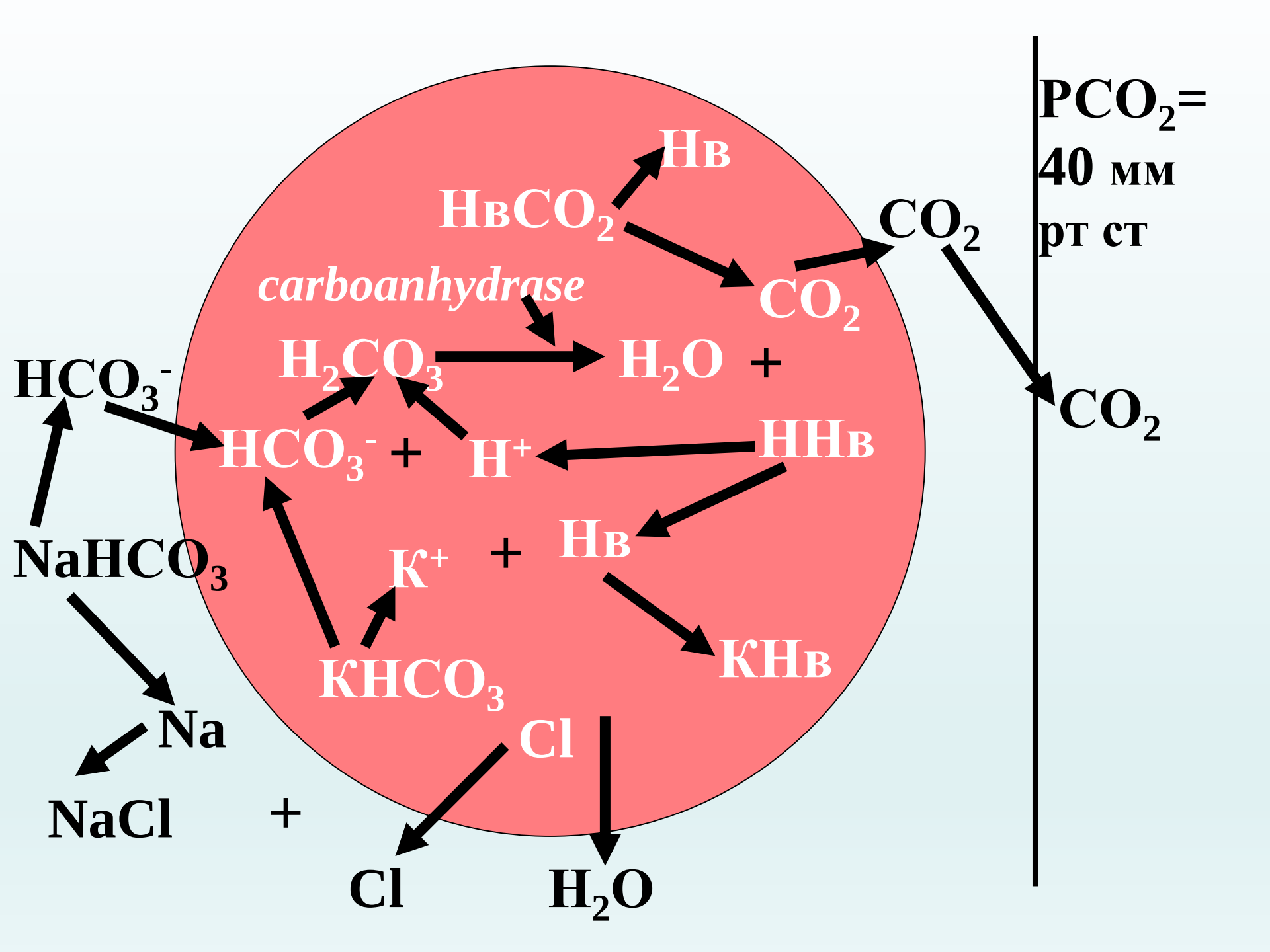
Forms of chemically bound CO_2

- **Carbonic acid H_2CO_3 – 7%**
- **Bicarbonate - HCO_3^- - 70%**
- **Carbaminohaemoglobin $HHbCO_2$ – 23%**


Tissue cells
CO_2
CO_2 dissolved in plasma (10%)
CO_2 combined with hemoglobin to form carbaminohemoglobin (20%)
$CO_2 + H_2O \rightarrow H_2CO_3$
$H_2CO_3 \rightarrow H^+ + HCO_3^-$
H^+ combines with hemoglobin
Red blood cells
HCO_3^- (70%)
Cl^-
Chloride shift
Plasma


NaHCO3
HCO3-
+
Na
NaCl
Cl
H2O
HвCO2
Нв
+
CO2
carboanhydrase
H2CO3
H2O +
HCO3-
+
H+
+
Нв
ННв
К+
КНв
КНСО3
CO2
CO2
PCO2=
70 мм
рт ст


Alveoli
CO_2
CO_2 dissolved in plasma
Red blood cell
Hemoglobin + CO_2
Carbaminohemoglobin
$CO_2 + H_2O$
H_2CO_3
$HCO_3^- + H^+$
H_2CO_3
HCO_3^-
Cl^-
Plasma
From pulmonary artery
To pulmonary vein


PCO2= 40 мм рт ст
Нв
НвCO2
CO2
CO2
carboanhydrase
H2CO3
H2O +
HCO3-
HCO3- + H+
ННв
CO2
NaHCO3
K+ +
Нв
КНв
КНCO3
Na
Cl
NaCl +
Cl
H2O

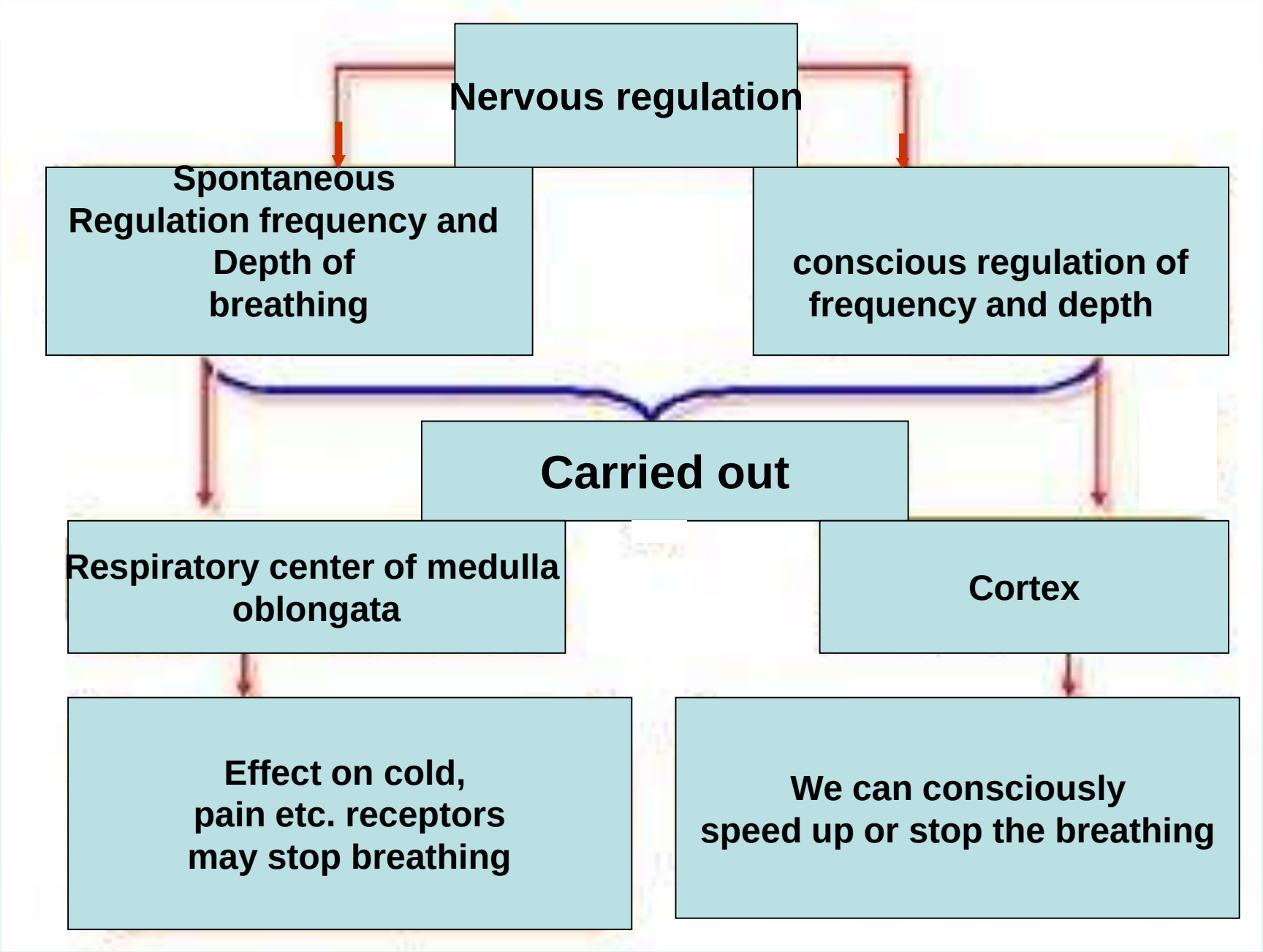
Regulation of respiration

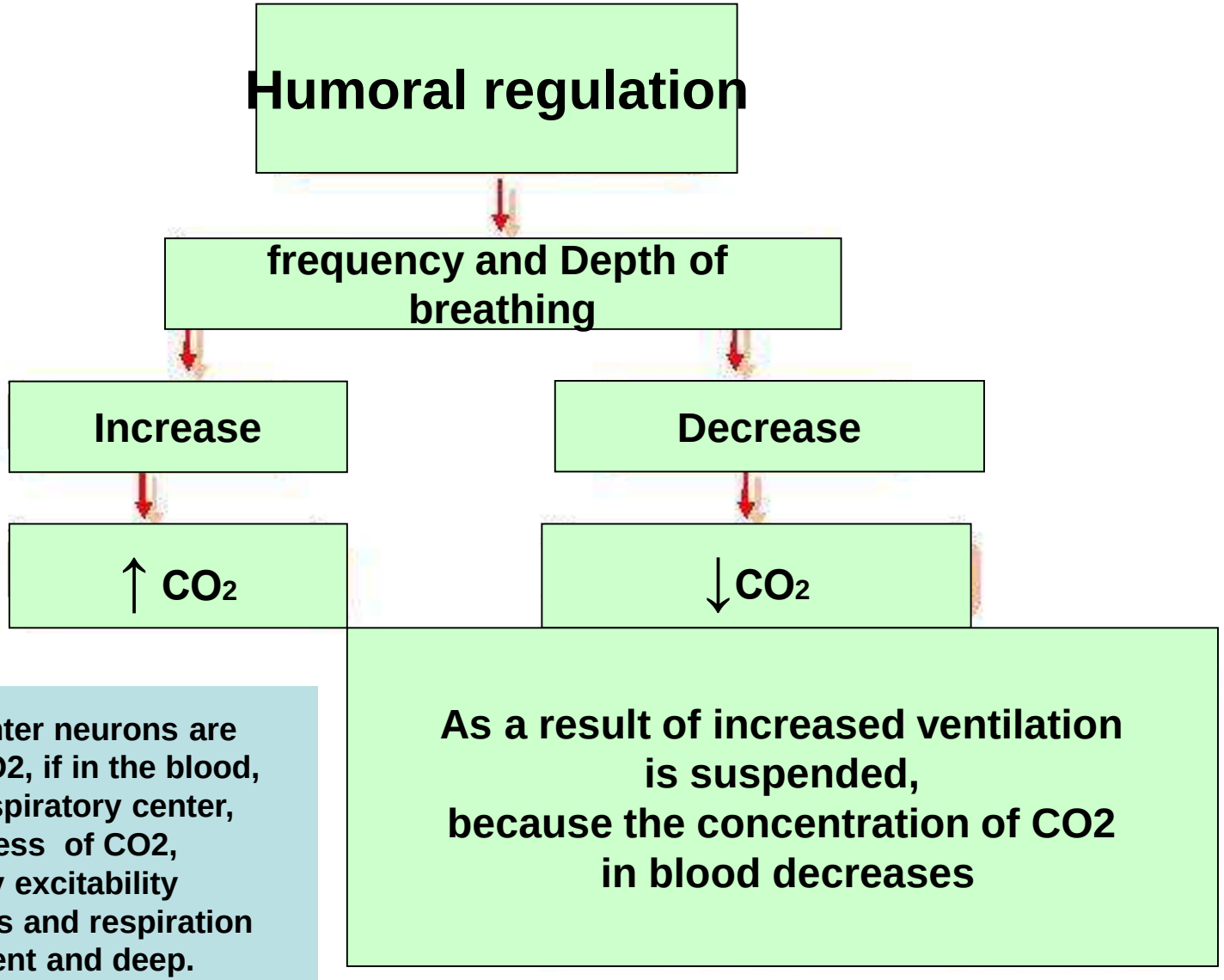
Nervous regulation

- In the medulla oblongata there is an unconditional reflex center of regulation of respiration - the respiratory center.
- It provides coordinated rhythmic activity of the respiratory muscles (contraction and relaxation), which causes alternating inhalation and exhalation, and adaptation of respiration to changes in the external and internal environment of the body.
- The automaticity of the respiratory center is caused by nerve impulses coming from the nerve endings of the lungs, blood vessels, muscles.
- Although the work of the respiratory center is automatic (it does not stop in a sleeping or unconscious person) - but it depends on the consciousness of man.
- A person can consciously slow down or speed up breathing (conditioned reflex regulation of breathing). This is due to the control of the respiratory center by the cortex.
- the respiratory reflexes: respiratory arrest duo to diving in cold water, protective reflexes of coughing and sneezing, regulation of laryngeal muscles, which coordinate swallowing with breathing.

Humoral regulation

- Humoral regulation of respiration occurs due to the content of carbon dioxide in the blood.
- Respiratory center neurons are sensitive to CO2, if there is an excess of CO2 in the blood that washes the respiratory center, then the excitability of the respiratory center increases and breathing becomes frequent and deep.
- If the CO2 in the blood is low, it causes respiratory arrest.
- During exercise, the muscles perform intensive work and the amount of CO2 in the blood increases, which becomes one of the reasons for the deepening and strengthening of respiratory movements.


Nervous regulation
Spontaneous Regulation frequency and Depth of breathing
conscious regulation of frequency and depth
Carried out
Respiratory center of medulla oblongata
Cortex
Effect on cold, pain etc. receptors may stop breathing
We can consciously speed up or stop the breathing



Respiratory center neurons are Sensitive to CO2, if in the blood, washing the respiratory center, there is an excess of CO2, then respiratory excitability center increases and respiration becomes frequent and deep. If the CO2 in the blood is low, then it causes respiratory arrest.

Regulation of the first breath of a newborn child

- lower skin temperature (increases lung ventilation by 30%)
- hypercapnia - breathing of a newborn baby with air containing 3% CO_2 increases lung ventilation by 15%;
- increasing the concentration of hydrogen ions;
- hypoxia, to which the respiratory center of the newborn is resistant;
- irritation of mechano-, nociceptors of the skin, vestibuloreceptors, receptors of other sensory systems;
- release of airways from the liquid - elimination of the "diver reflex".

Thank you for attention!