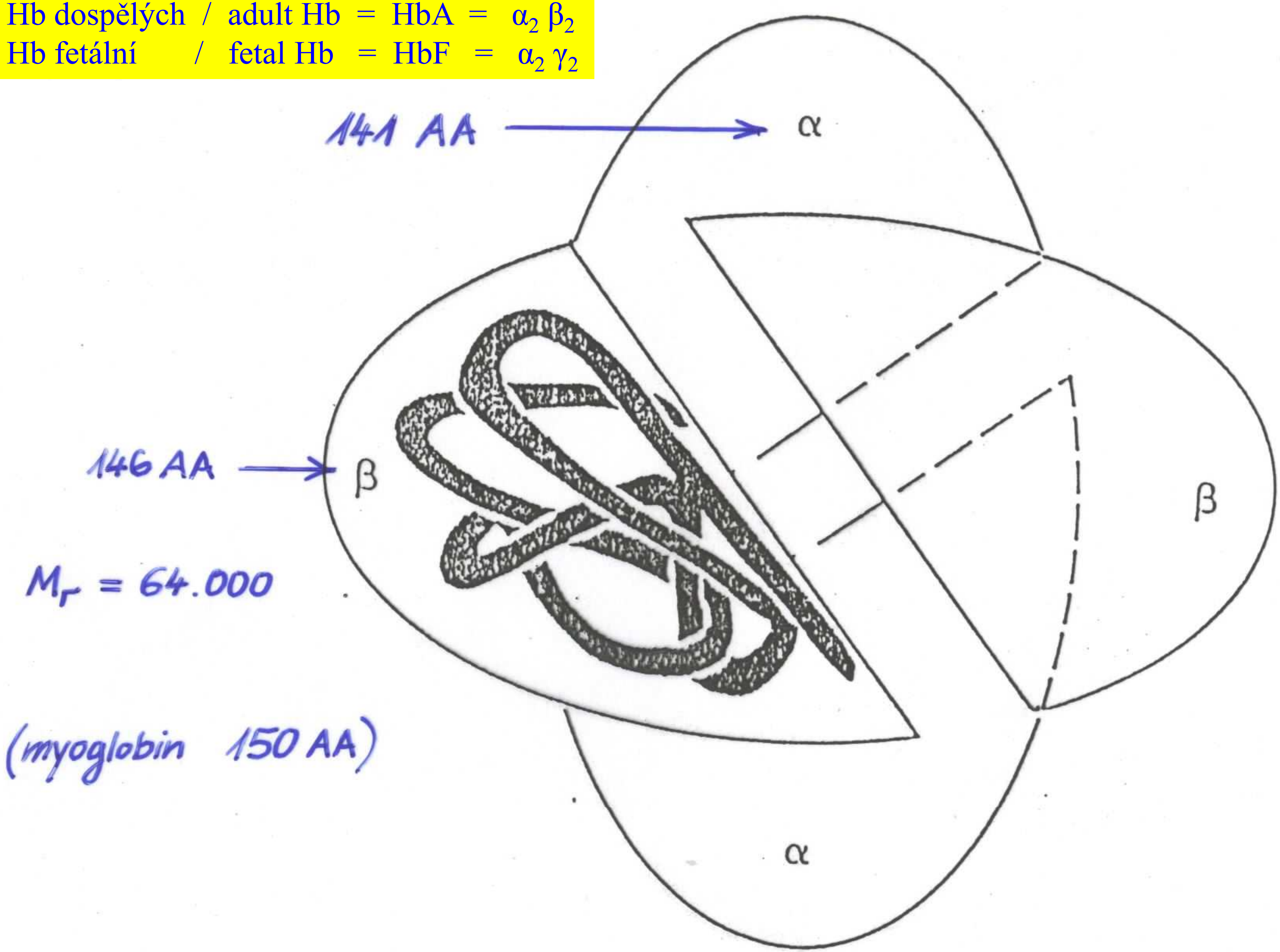
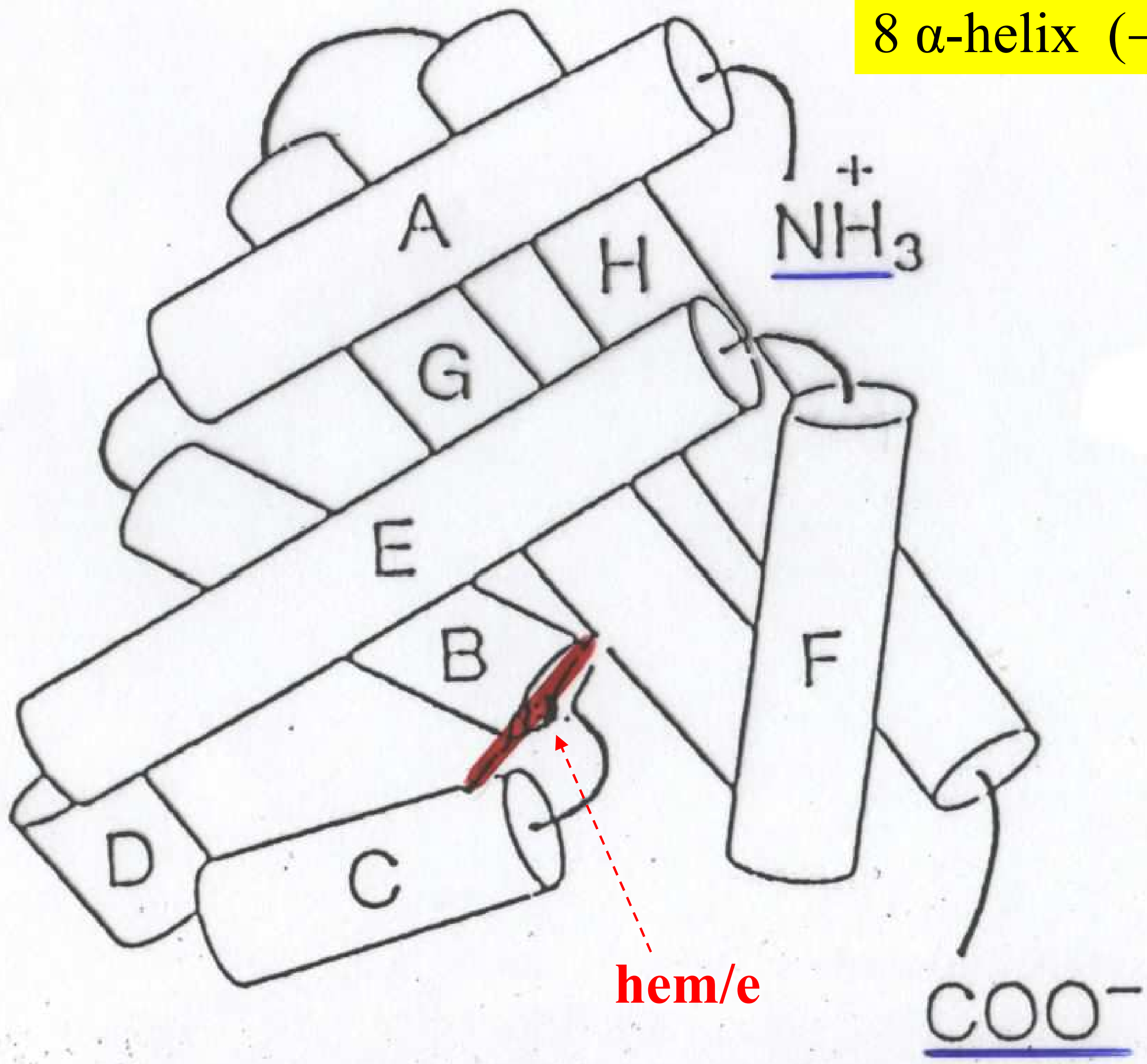
$\approx$

H b
structure, function

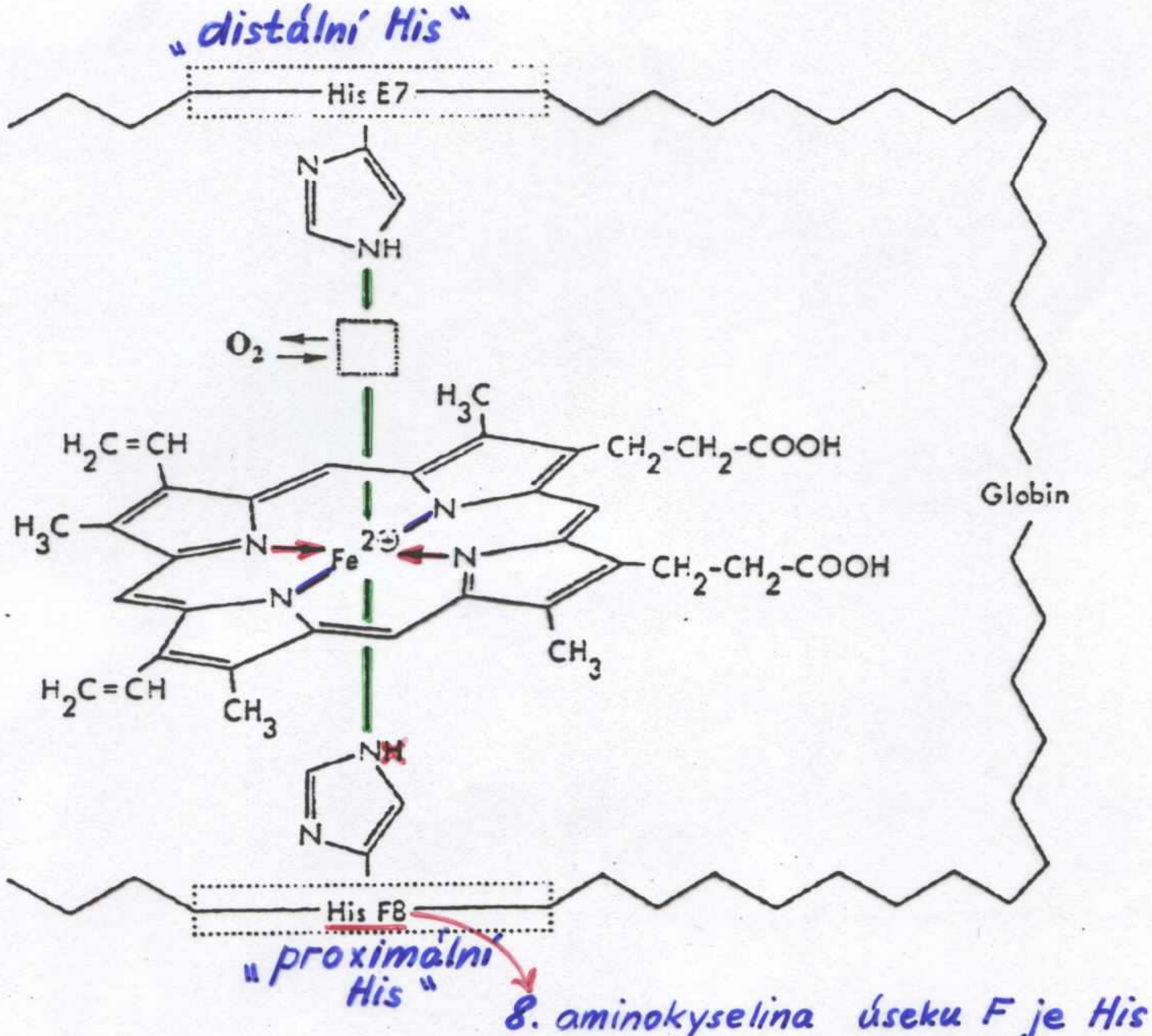
Hb dospělých / adult Hb = HbA = $\alpha_2 \beta_2$
Hb fetální / fetal Hb = HbF = $\alpha_2 \gamma_2$



8 α-helix (→ A, … H)



Struktura hemu



Fe (n-1)d VIII → 8 valenčních e^-

Fe^{2+}

High-spin Fe(II) (larger radius, lose O_2)

~~$4s^2$~~ $3d^6$ [↑↓] [↑] [↑] [↑] [↑]

„vysokospinový stav"

(součet spinů je vysoký)

větší objem Fe

Low-spin Fe(II) (smaller radius, gain O_2)

$3d^6$ [↑↓] [↑↓] [↑↓] [ ] [ ]

„nízkospinový stav"

$$\overset{III}{HNO_2} + Fe^{2+} + H^+ \longrightarrow \overset{II}{NO} + Fe^{3+} + H_2O$$

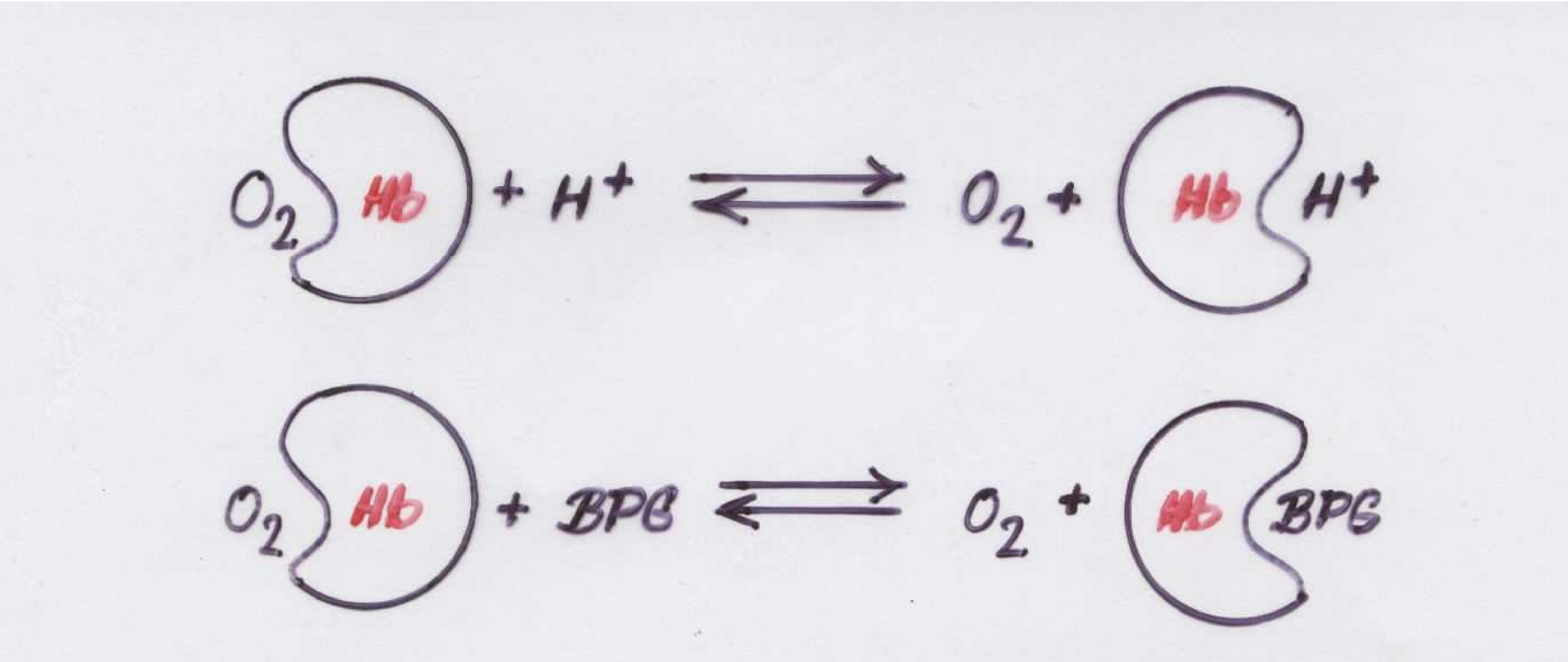
Fe^{2+} ↓ hemoglobin (~ferro-) Hb

Fe^{3+} ↓ hemiglobin (~ferri-) MetHb

ferr**o**si-   ferr**i**-

Iron in hem - remark

Iron is bonded to the cyclic tetrapyrrole so, that formal two pyrrole nuclei lost H^+ from their nitrogens.
This way free electrone pair was formed on every from two nitrogens. The pair of electrons creates dative covalent bond with Fe^{2+} (on every from two nuclei). Fe^{2+} brings in the molecule of heme 2 positive charges, „lost“ as 2 H^+.
Heme in hemoglobin is now electric neutral and bonds also electric neutral moleculs (O_2 , CO) too.
The oxidation of iron on Fe^{3+} (→ hemiglobin, methemoglobin) leads to gain of one positive charge in molecule of heme.
Then heme is a cation and bonds anionts (e.g. CN^-, however it is not able to bond electric neutral molecules – so it cannot transfer oxygen).
The facts are important among others for toxicology.

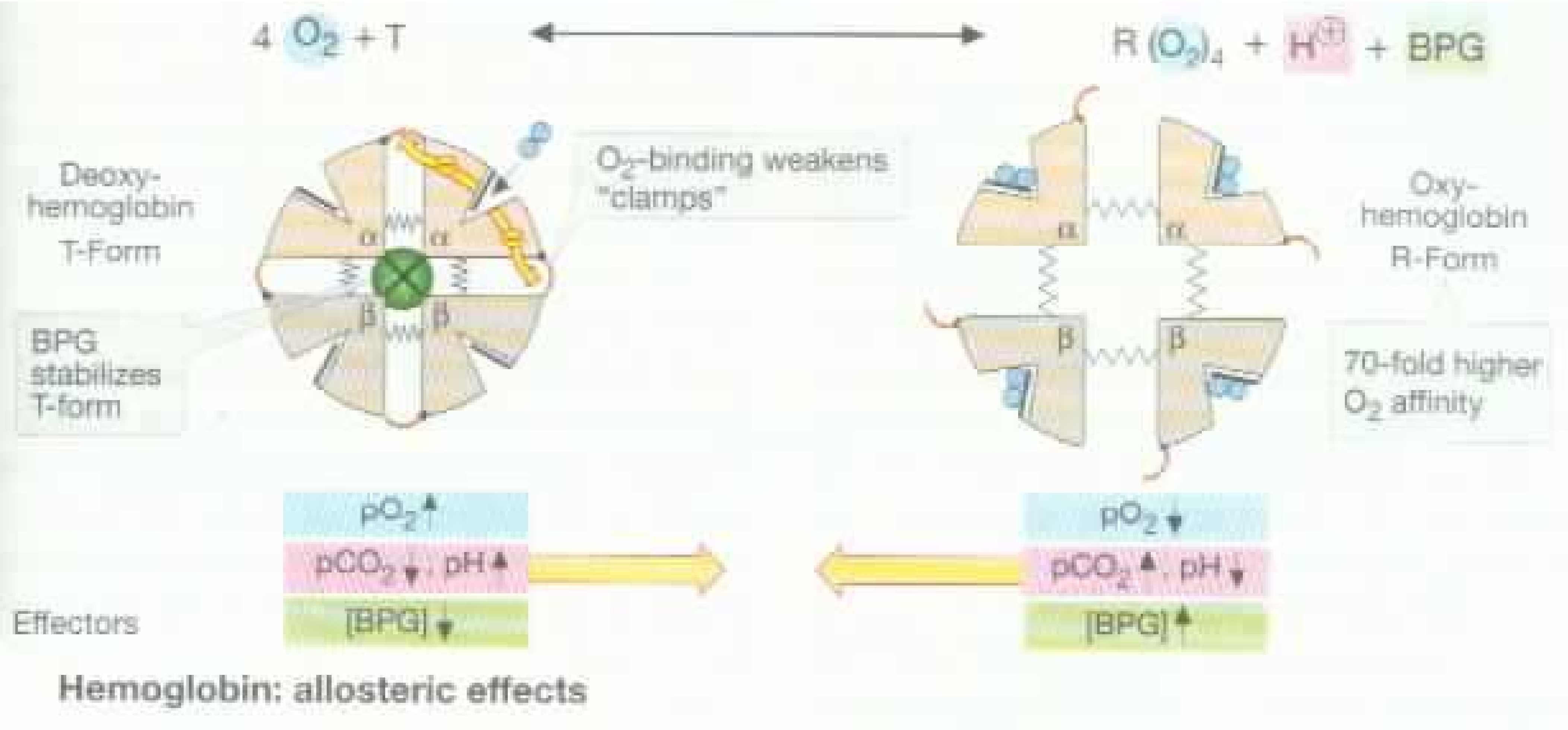


Bohrův efekt: snížení afinity kyslíku k Hb při nízkém pH
Bohr effect : decrease of affinity of oxygen to Hb at low pH

BPG = 2,3-bisphosphoglycerate

model: neúplně nafouknutý míč / model: not fully blow up ball

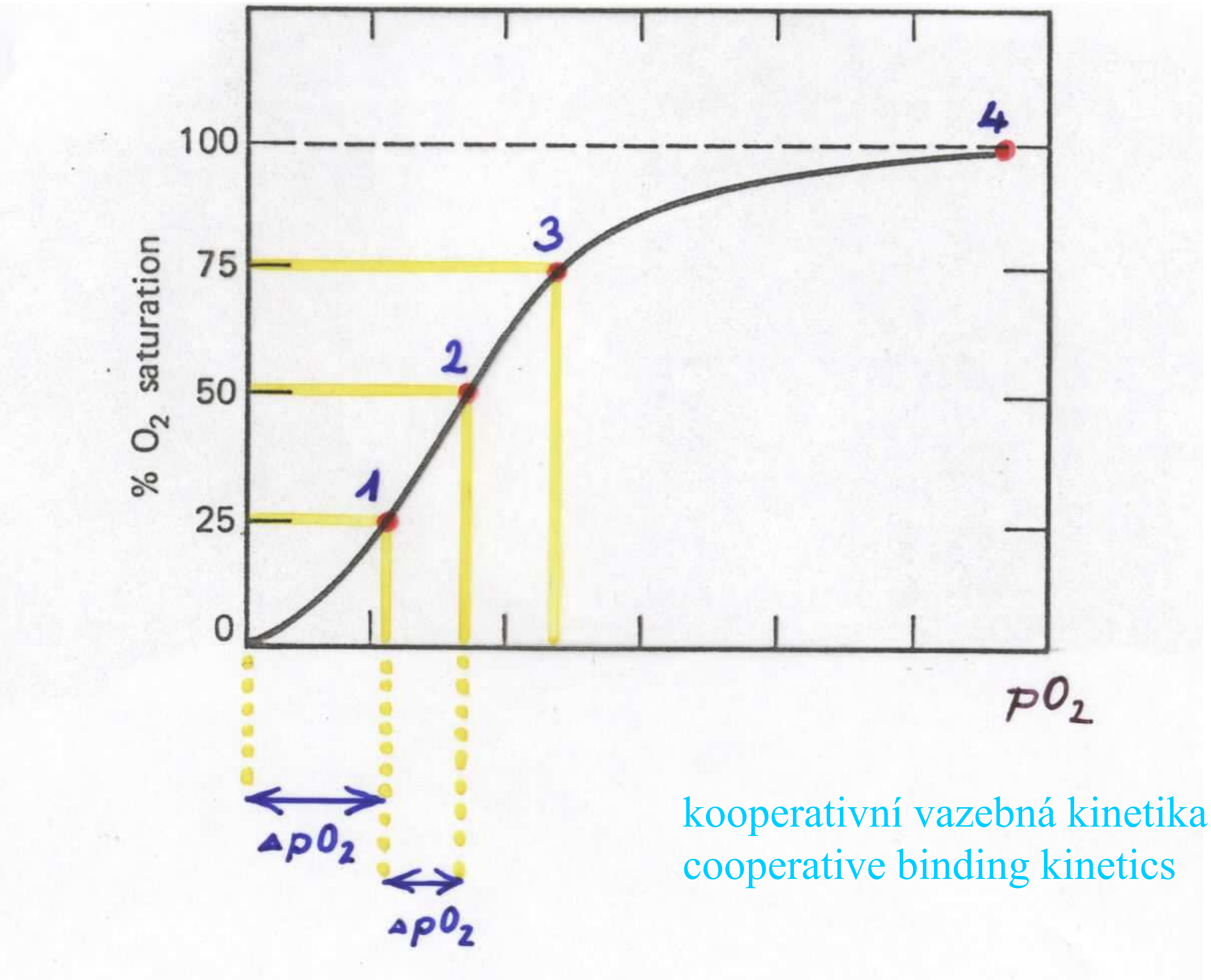
T-forma Hb (BPG) a R-forma Hb (O_2) :



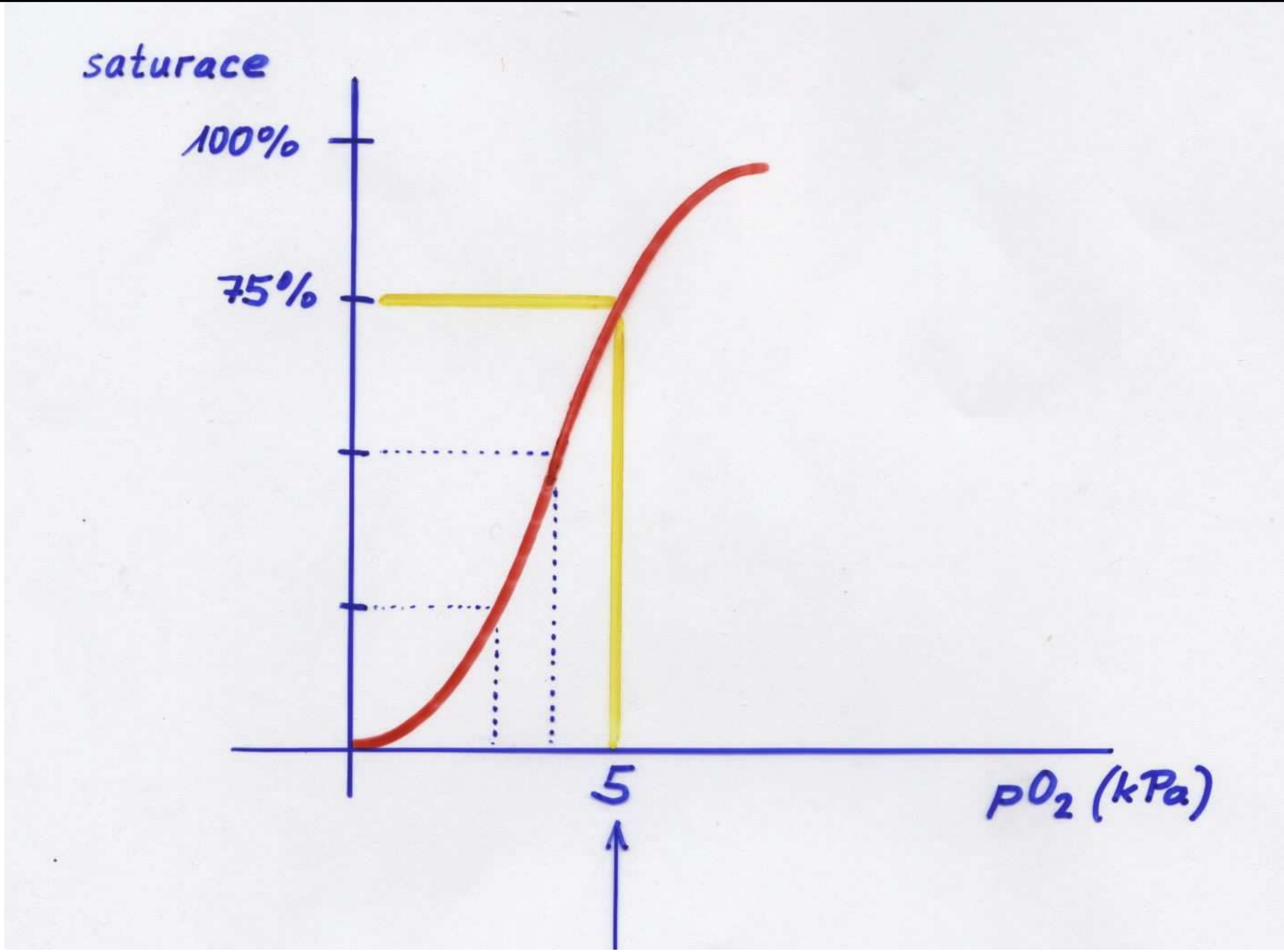
tense [tens] napjatý

release [ri'li:s] uvolnění

Vazba kyslíku na hemoglobin / saturační křivka (esovitá !)
Oxygen binding to hemoglobin / saturation curve (sigmoidal !)



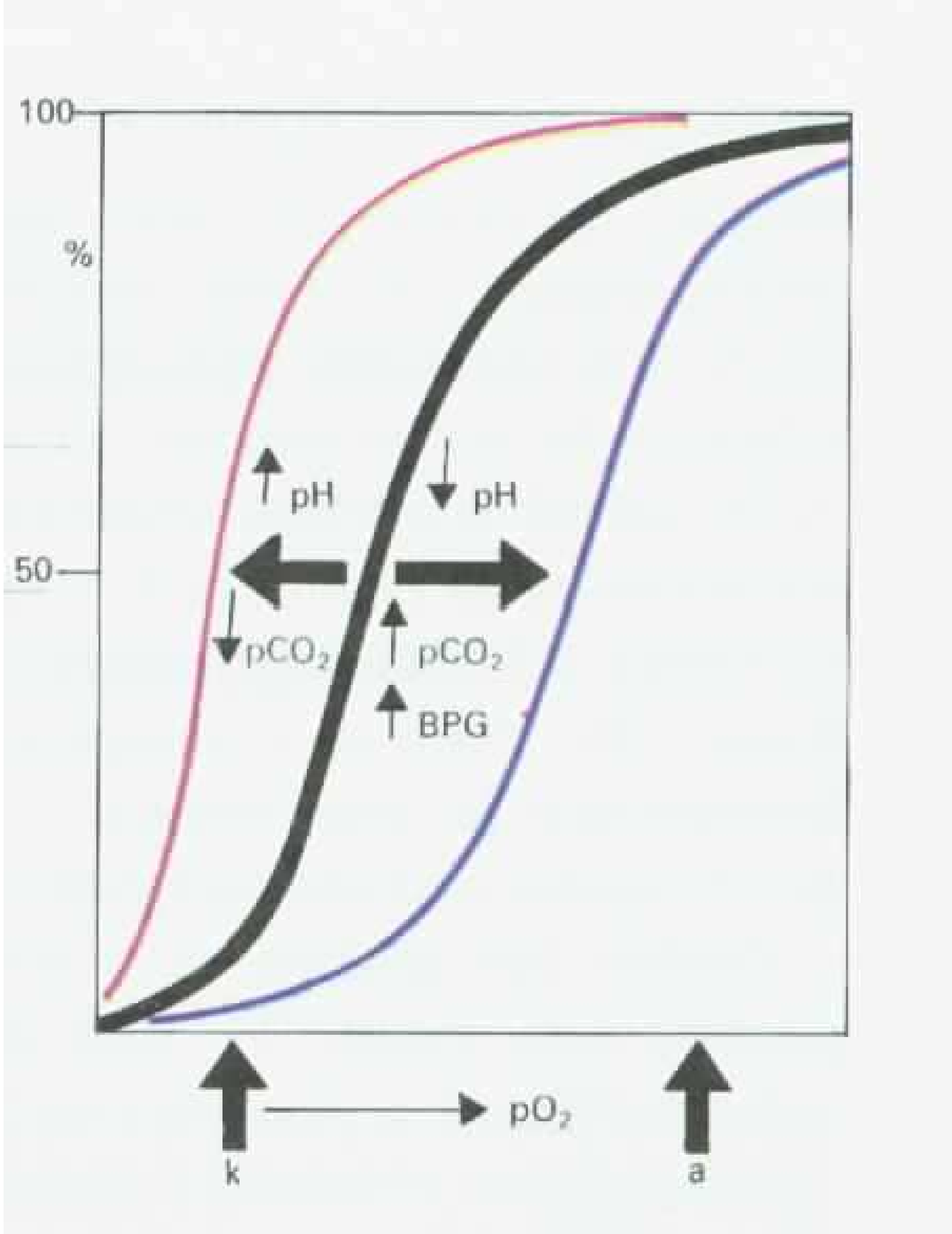
kooperativní vazebná kinetika
cooperative binding kinetics



smíšená venózní krev
mixed venous blood

jen 1 O_2 z tetrameru ! / 1 O_2 from tetramer only !

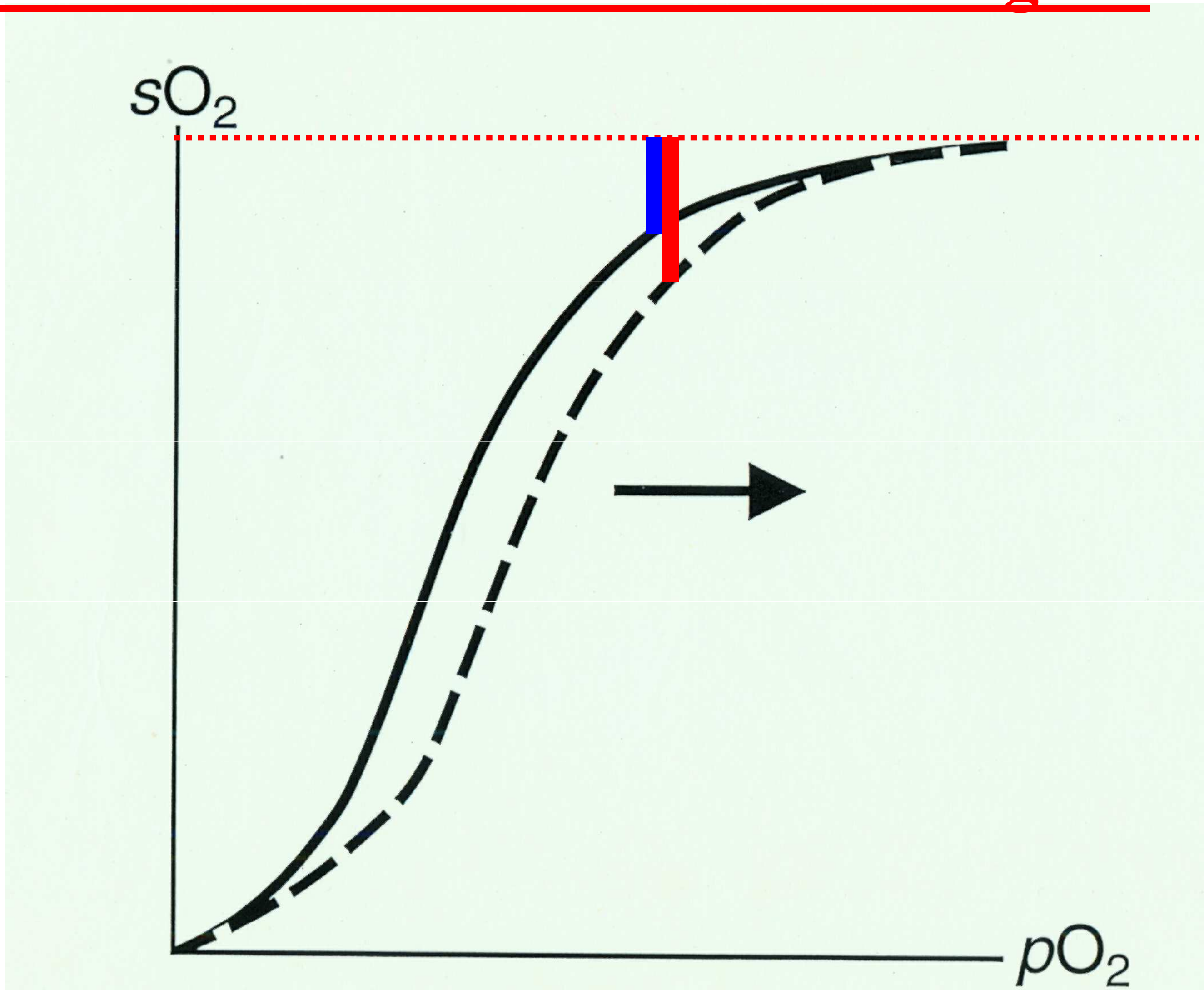
Conditions affecting the shift of dissociation curve :



CO Hb
Met Hb
HbF
↓ temperature
↓ BPG

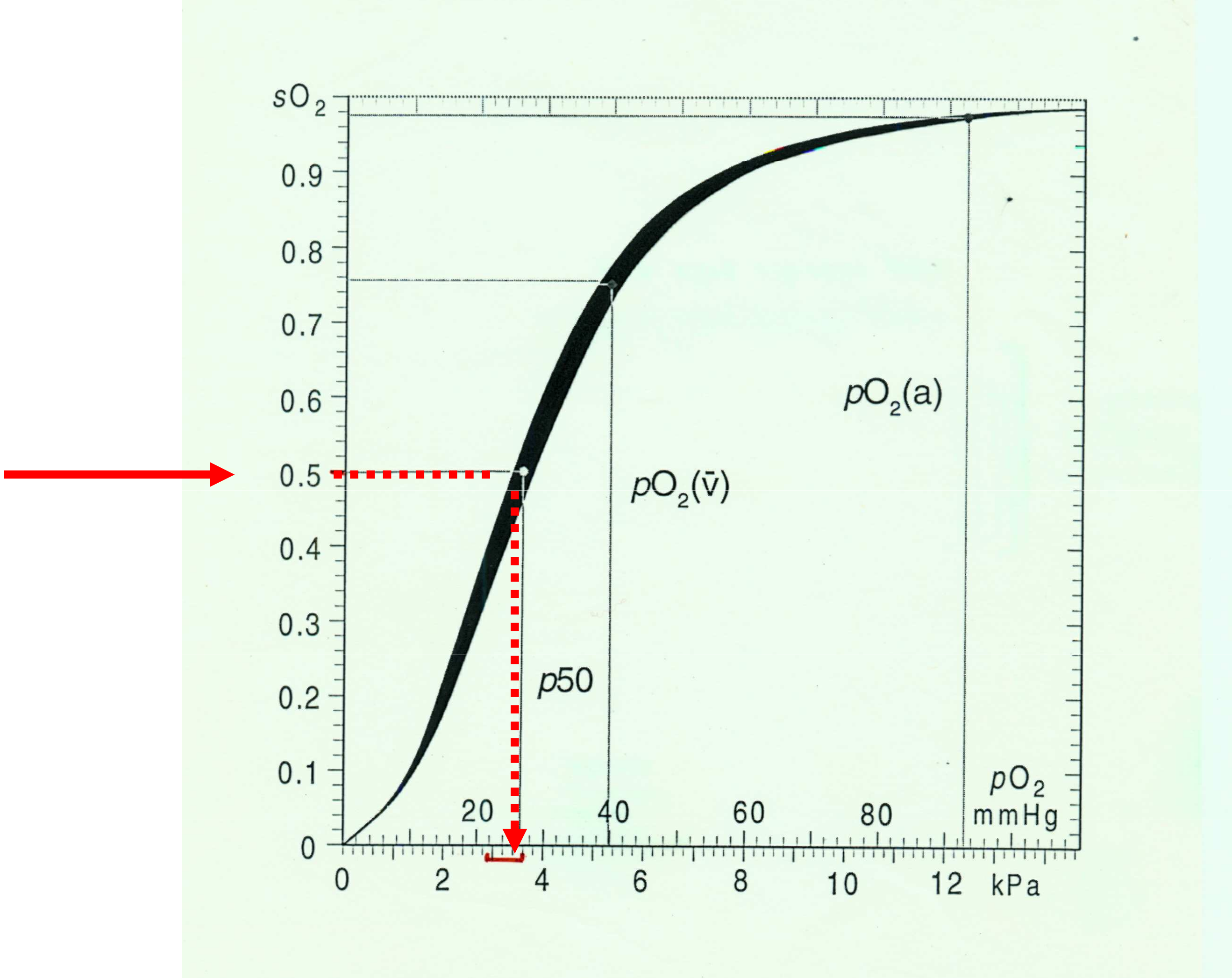
Sulf Hb
↑ temperature

Increased quantity of released oxygen by shift of the saturation curve to the right :



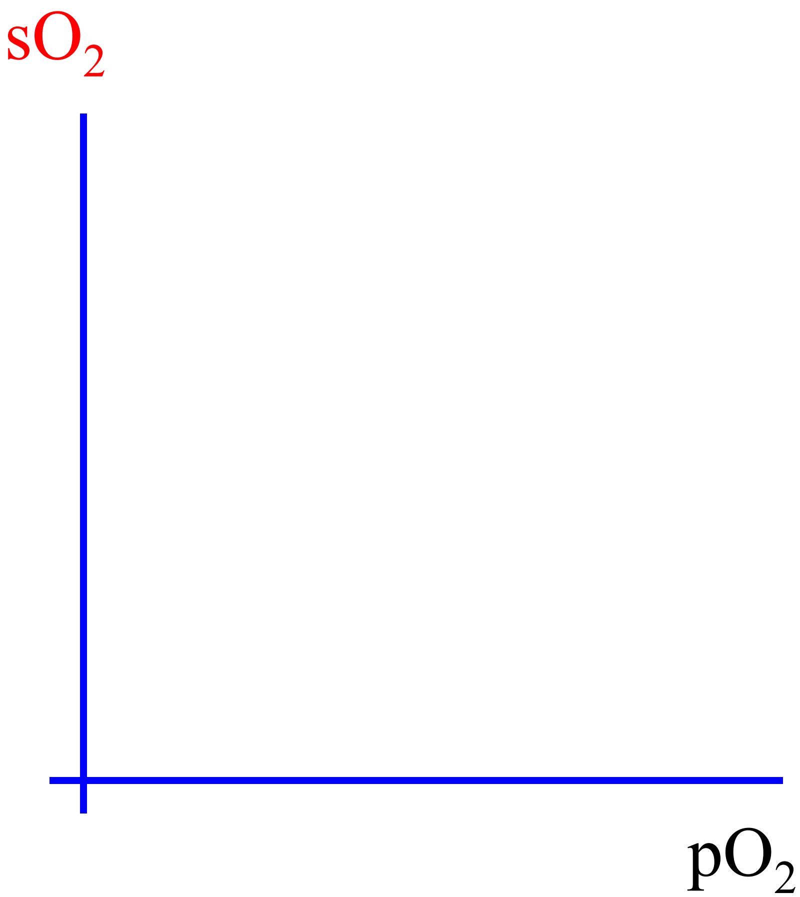
In the original position the curve allowes to release the quantum of oxygen comlaying with the blue line segment at the given pO_2 . By the shift of the curve to the right is the quantum of accesible oxygen increased to the value given the red line segment.

The expression of position of saturation curve :

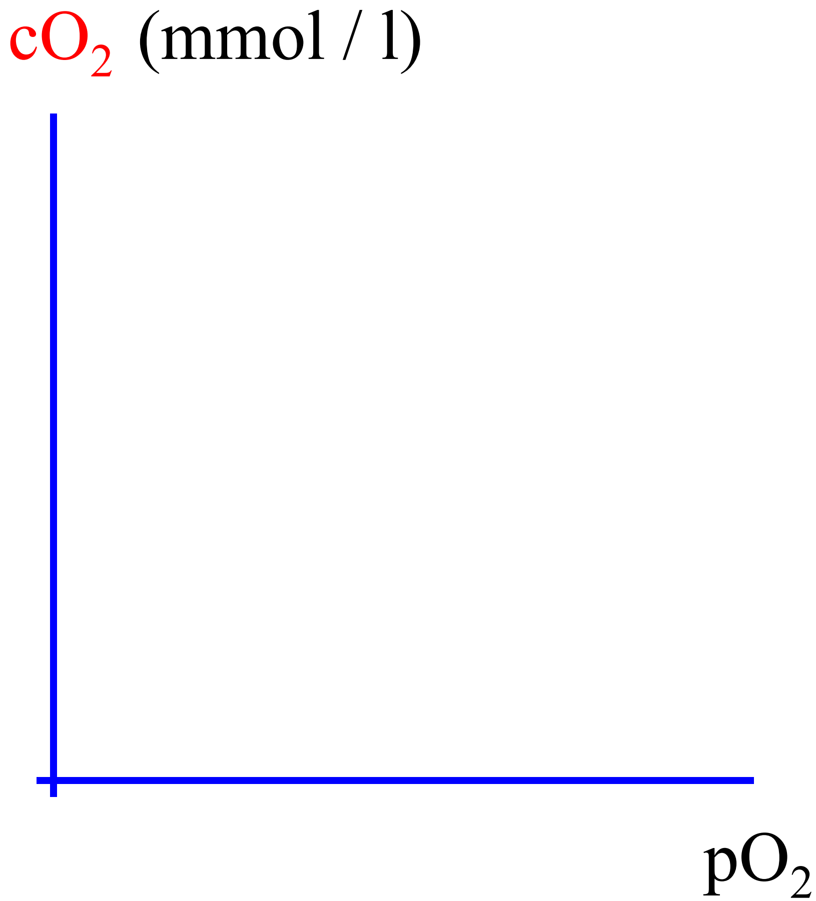


The position/shift of saturation curve is expressed parcial pressure of oxygen by 50 % saturation of Hb **(„the value p50“)**, it is the position of inflex point of the curve.

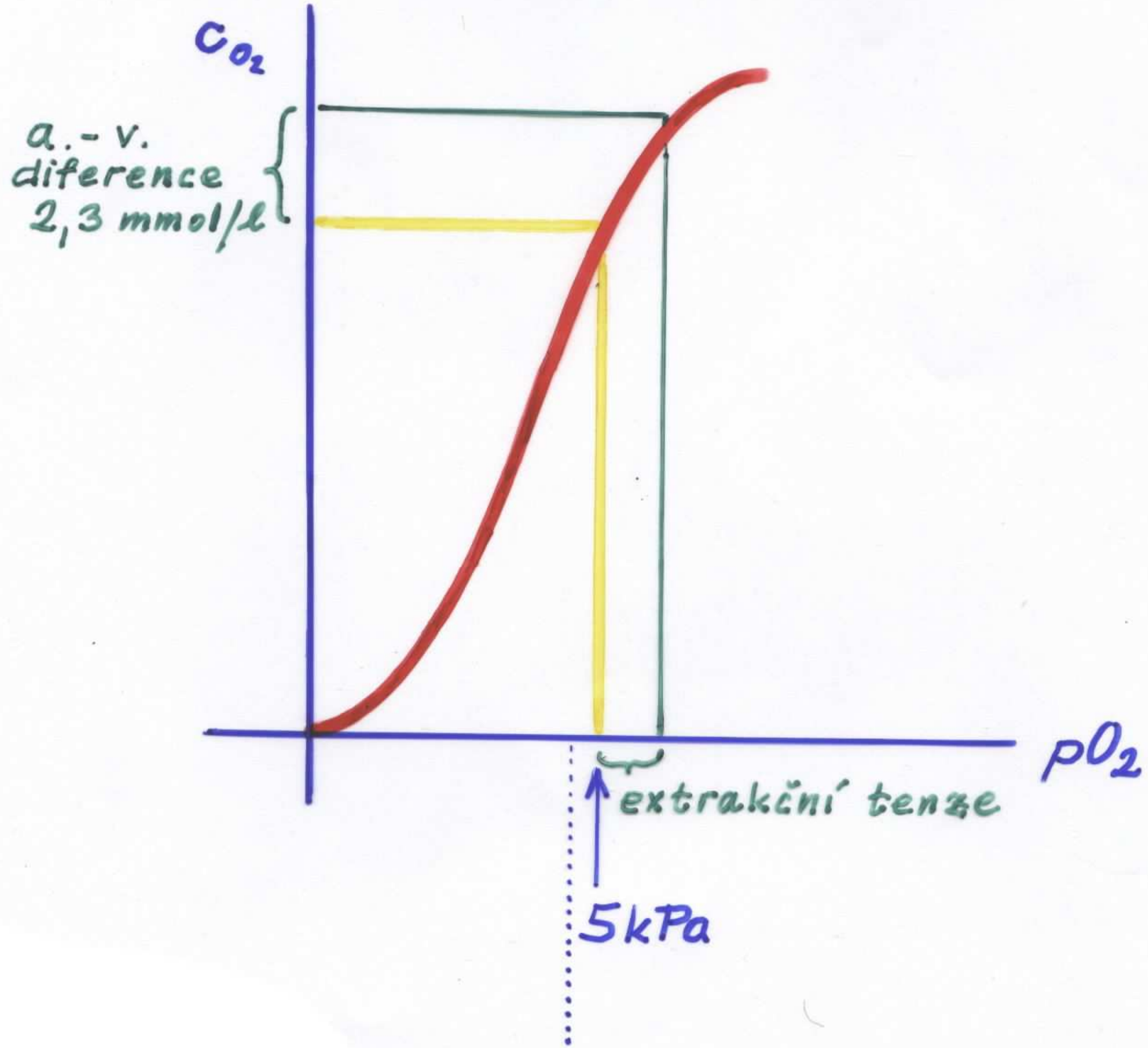
[The normal value of p50 is ~ 3,25 kPa (2,9 - 3,6 kPa)]



saturační křivka
saturation curve



absorpční křivka
absoption curve



< 4,5 kPa znesnadněné uvolňování O_2

impeded release of oxygen

hrozí tkáňová hypoxie !

Transport of CO_2 in blood :

1/ 85 % HCO_3^-

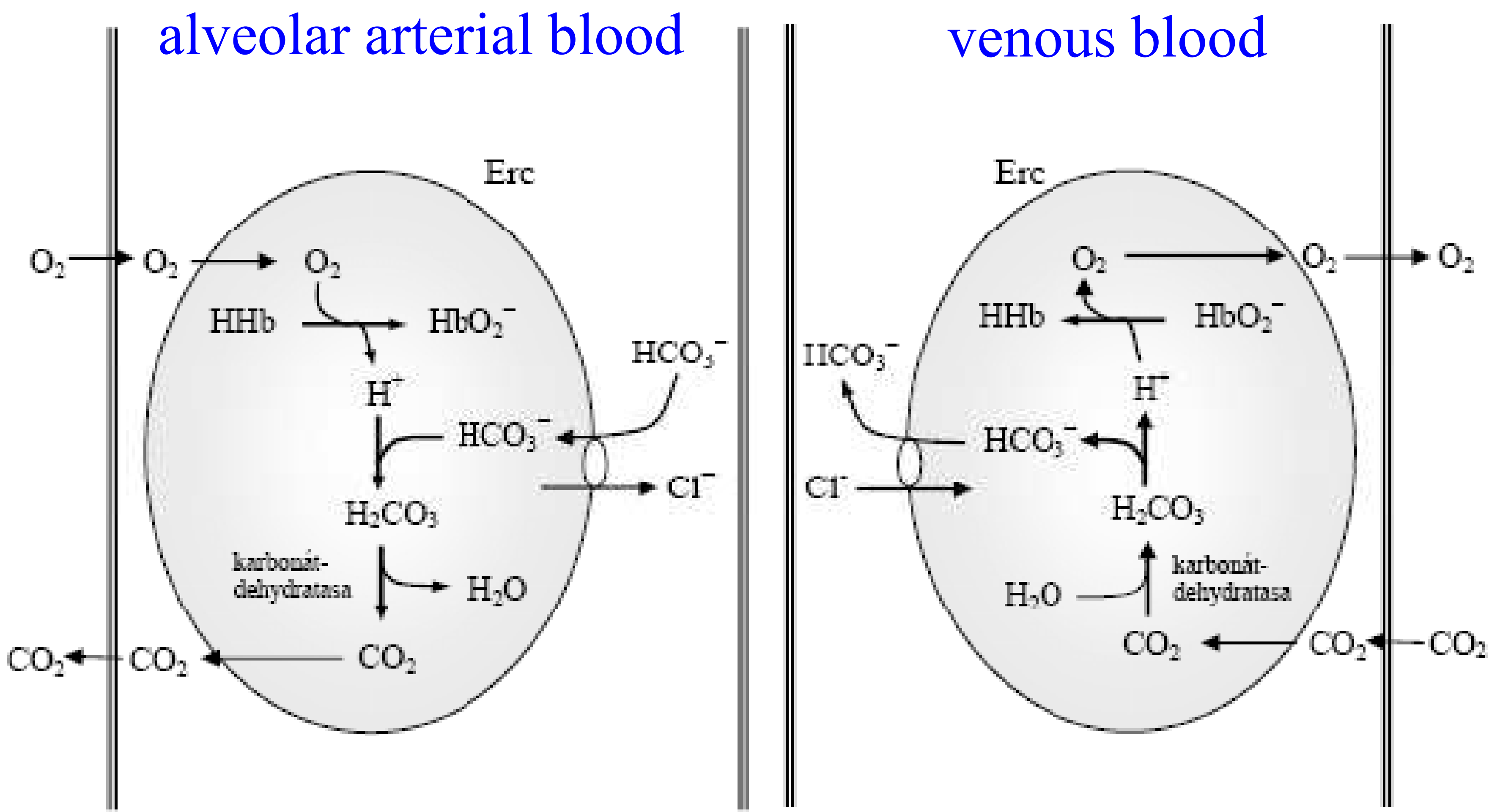
2/ 10 % carbamate (carbamino compouds)

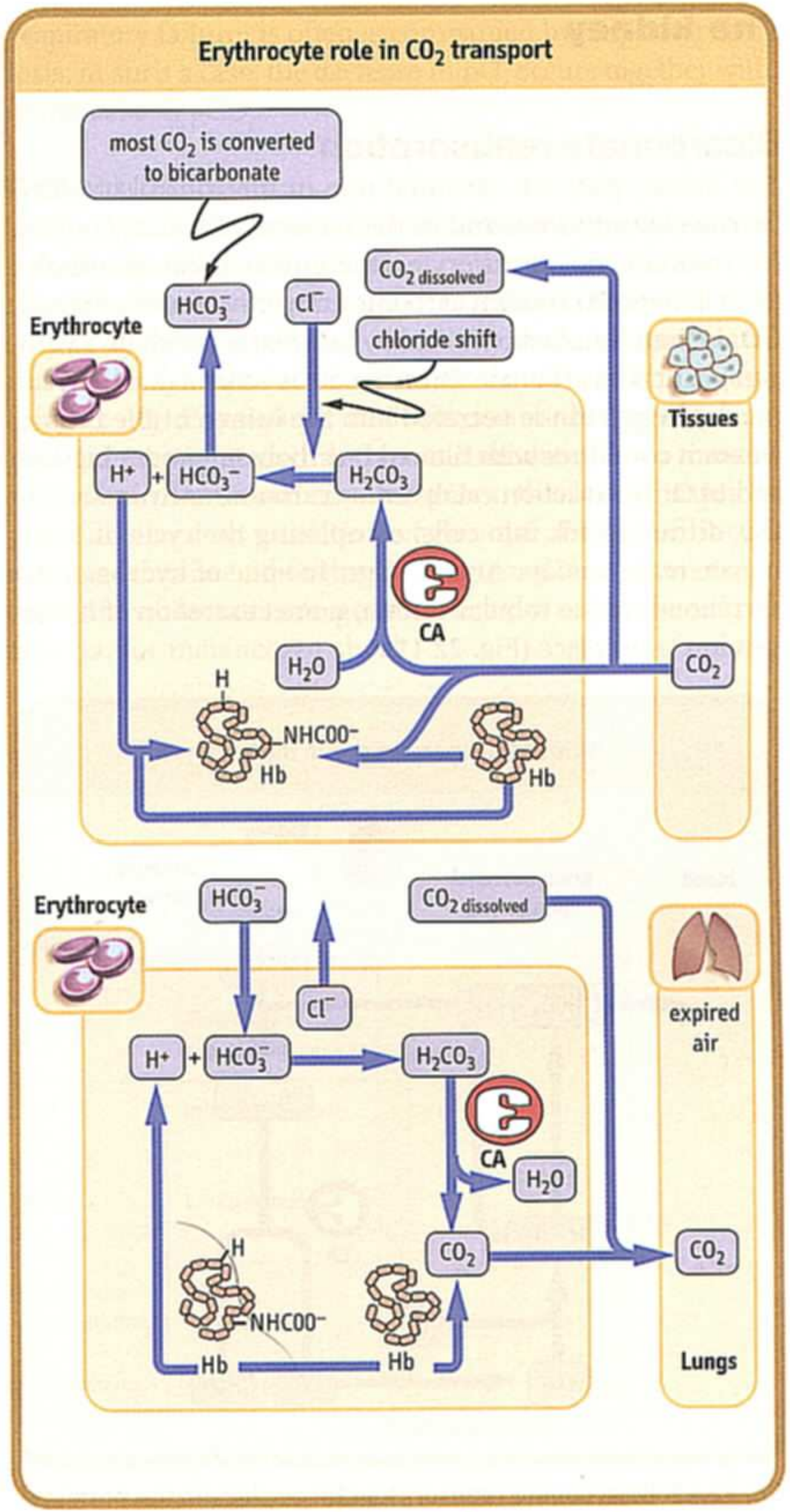
3/ 5 % physically dissolved (chemically not affected CO_2)

$$Hb - NH_2 + CO_2 \rightarrow Hb - NH - COOH$$

carbamic acid = aminoformic acid $H_2N - COOH$

Transfer of O_2 and CO_2 :





karbonátdehydratasa
(karboanhydratasa)

(carbonic anhydrase, carbonate hydro-lyase EC 4.2.1.1)

pO_2 of arterial blood (aB-pO_2) :

age	average	range
20 - 29	12,66 kPa	10,66 – 14,66
30 - 39	12 kPa	10,4 – 14,4
40 - 49	11,46 kPa	10 – 13,86
50 - 59	10,93 kPa	9,46 – 13,33
60 - 69	10,4 kPa	8,66 – 12,66

pO_2 of arterial blood ($aB\text{-}pO_2$) :

$aB\text{-}pO_2$ is decreased with increasing age

$cB\text{-}pO_2$ values are approximately by 10-20 % lower

$aB\text{-}pO_2$ values *in lying* patients are lower about 1,33 kPa in comparison with described

symbolic:
a = arterial [a:'tiəriəl]
B = blood [blad]
c = capillary [kə'piləri]
p = partial pressure [pa:šl prešə]
v = venous [vi:nəs]

Representation of constituent forms of Hb :

So called oxymeters measure at wavelength which are absoption maxima: (- see next)

H Hb = reduced hemoglobin

O_2 Hb = oxyhemoglobin

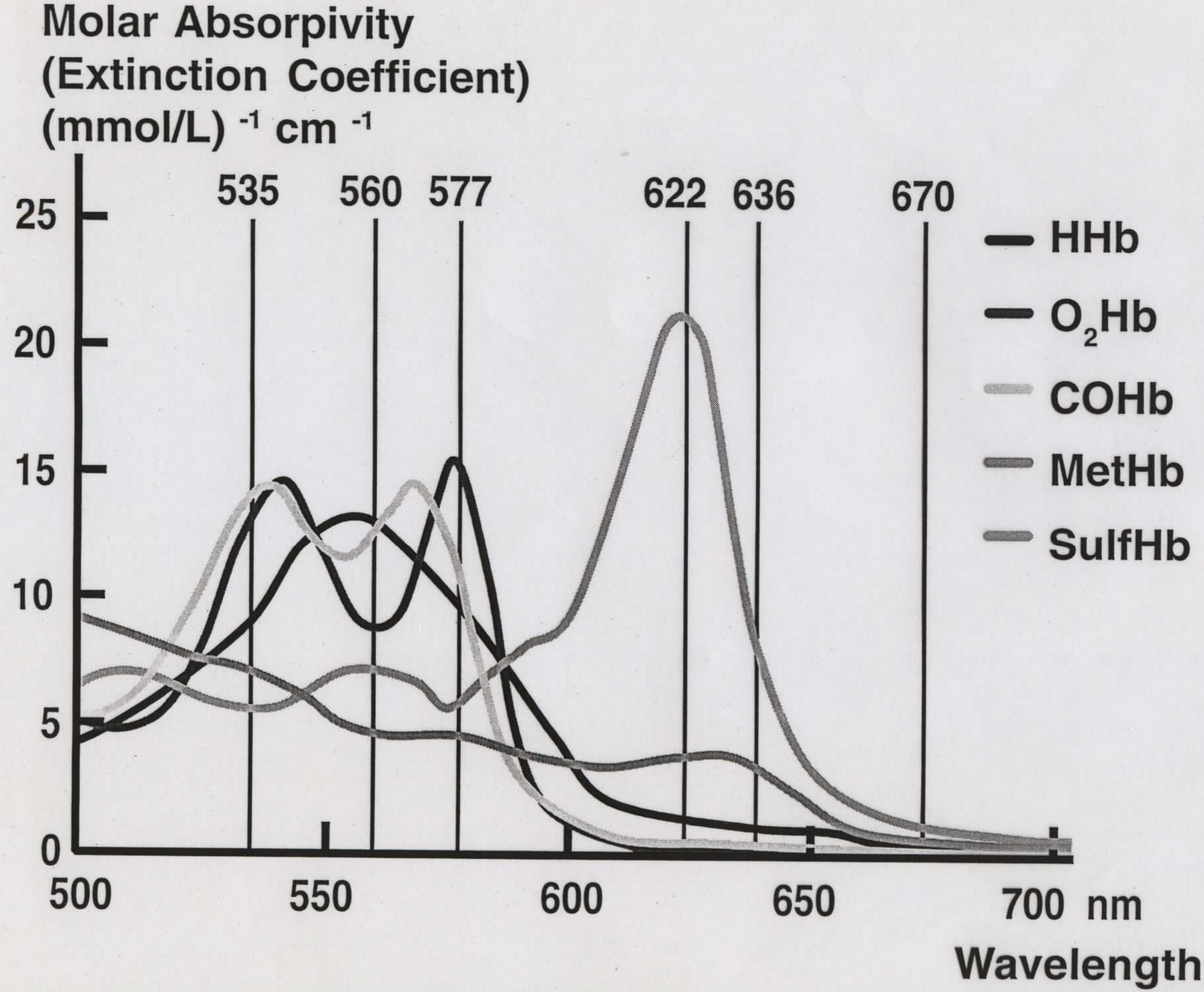
CO Hb = carbonylhemoglobin

Met Hb = methemoglobin

Sulf Hb = sulfhemoglobin

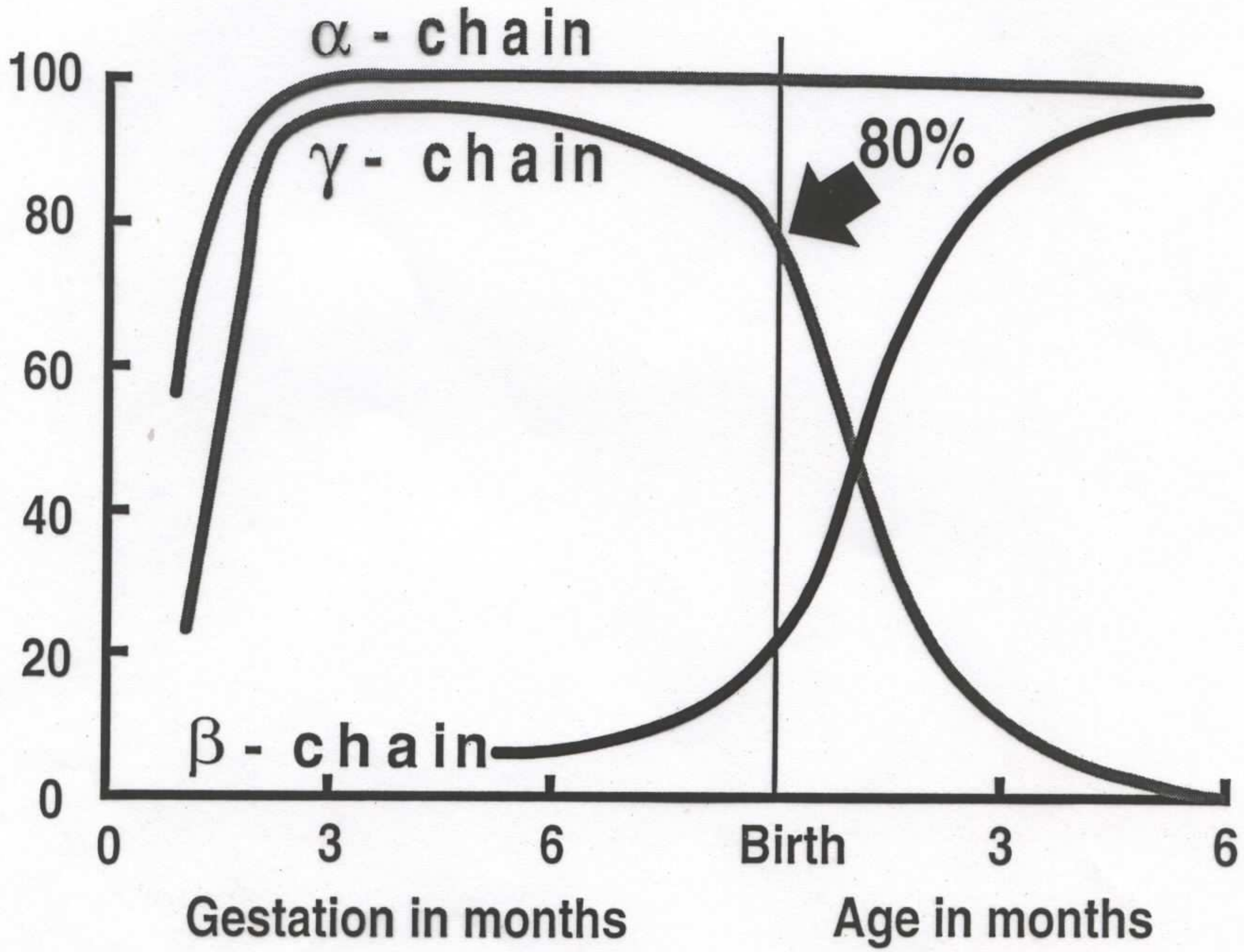
From the concentration of the whole Hb are subtracted all forms of Hb, which are not able to transfer oxygen (CO Hb + Met Hb + Sulf Hb).

The sum (O_2Hb + H Hb) is then Hb utilizable for transfer of oxygen = „active (effective) Hb“



Molar Absorpivity
(Extinction Coefficient)
(mmol/L) -1 cm -1
25
20
15
10
5
0
535
560
577
622
636
670
HHb
O2Hb
COHb
MetHb
SulfHb
500
550
600
650
700 nm
Wavelength

Hb dospělých / adult Hb = HbA = $\alpha_2 \beta_2$
Hb fetální / fetal Hb = HbF = $\alpha_2 \gamma_2$



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Air composition (1) :

	volume %
O_2	20,9
CO_2	0,03
N_2	78,1
inert gases	0,9

Air composition (2) :

	inspired	expired
pO_2	21 kPa	15,33 kPa
pCO_2	0,03 kPa	4,4 kPa
$p(N_2 + \text{inert gases})$	79,4 kPa	75,33 kPa
pH_2O	0,76 kPa	6,27 kPa

The sum of partial pressures is 101,3 kPa in both cases.
Expired air is fully saturated with water vapour (data pH_2O for alveoli and 37°C).