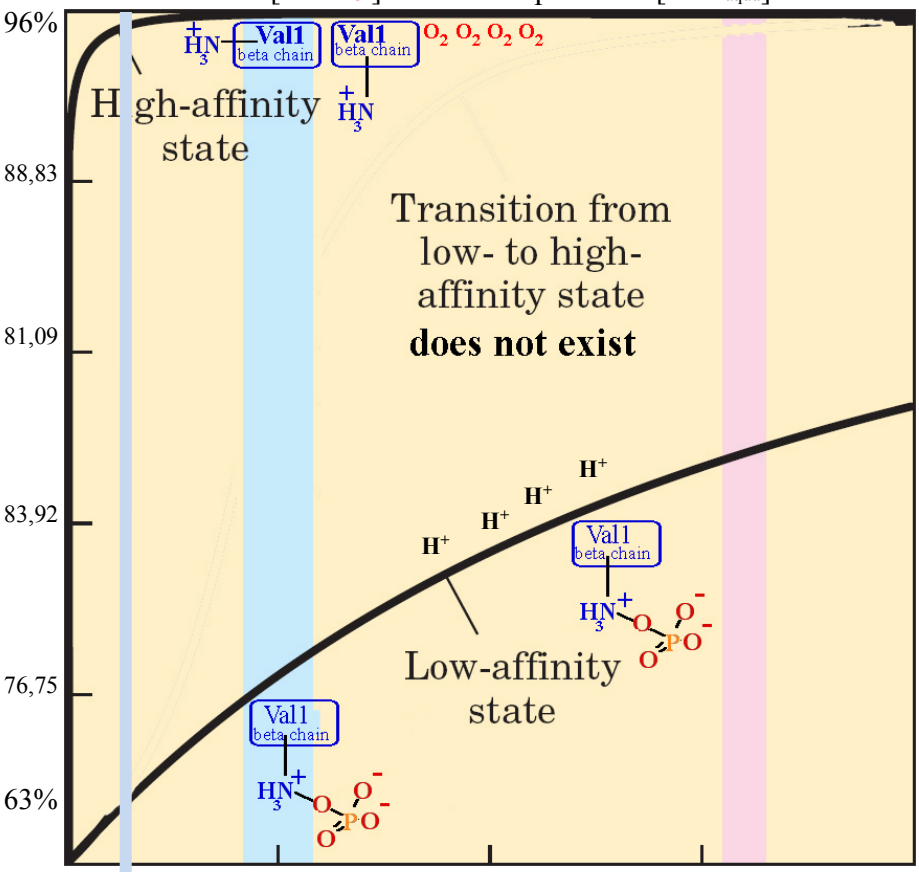
Aris Kaksis, 2020, Riga Stradin`s University
http://aris.gusc.lv/ChemFiles/ChromoHem/HbOxDeoxCO/HumanMeasure/O2Solutions.pdf

O_2 and CO_2 human blood water solutions

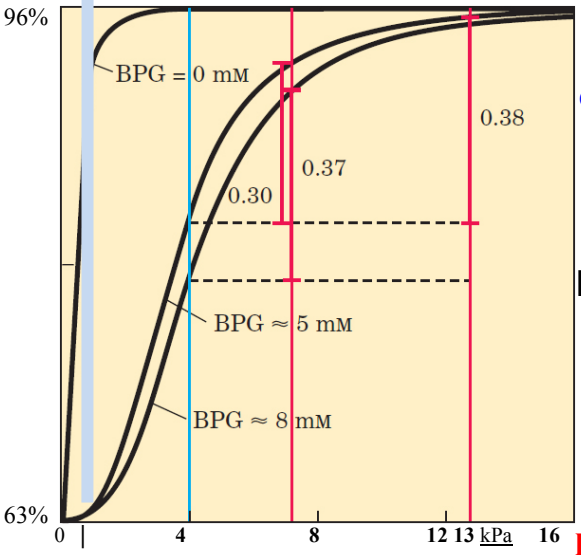
Blood plasma, saliva, tears, sweat $[O_{2aqua}] = 6 \cdot 10^{-5}$ **M = 0.00006 M** to air contact V_{O2}%=20,95%. Blood hemoglobin accumulate maximal $[O_{2Hb}] = 82{,}6 \cdot 10^{-3}$ **M = 0.0826 M** times x1377 as solute in plasma. Bicarbonate concentration gas volume **CO258.5 mL** in 100 mL of blood 0,02393 M relates to concentration $[HCO_3^-]$=**0.0154 M** pH=7.36 $[CO_{2aqua}]$=**0.0076M** and sum is $[HCO_3^-]+[CO_{2aqua}]$=**0.023 M**;



Blood volume 5 L in human body. Red blood cell-total erythrocytes account $2.5 \cdot 10^{14}$. In each erythrocyte hemoglobin two hundred seventy million $2.7 \cdot 10^8$ molecules. Oxygen O_2 molecules in each erythrocyte of arterial blood $1.04 \cdot 10^9$ one billion if saturated 96%. 5L of blood 0.413 mols, 10.507L O_2 or 13.22g. Arterial oxygen concentration $[O_{2aqua}] = 6 \cdot 10^{-5}$ **M** 37°C gas amount 1,53 mL/L but $C_{O2} = 2{,}556 \cdot 10^{-4}$ M in **water** is (25°C 5,822 mL/L H_2O), absorbing from air. Volume fraction **20.95%** oxygen make pressure pO_2=21,12 **kPa**. Venous $[O_{2aqua}] = 0{,}426 \cdot 10^{-5}$ **M**; pO_2=1,0 **kPa** units and arterial $[O_{2aqua}] = 6 \cdot 10^{-5}$ **M**; pO_2=12,9 **kPa** units.

0 | venouse 4 kPa 8 kPa=$3{,}7 \cdot 10^{-5}$ M 12 kPa=$5{,}55 \cdot 10^{-5}$ M 16 kPa => 16 kPa (15,96%) 21,12 kPa AIR
1,0 kPa $[O_{2aqua}] = 0{,}426 \cdot 10^{-5}$ M arterial $[O_{2aqua}] = 6 \cdot 10^{-5}$ **M | 12,9** kPa $7{,}442 \cdot 10^{-5}$ M $= [O_{2plasma}] = 9{,}768 \cdot 10^{-5}$ M

Oxy Hemoglobin High affinity **Relax** form four oxygen molecules 4 O_2 are adsorbed **Deoxy** hemoglobin low affinity **Tense** form are protonate with four 4 H^+. BPG^{3-}-PO_4^{2-} are attached to ammonium cat ions $\mathbb{H}_3N^+$ in cavity on two beta chains **N**-terminal **Val 1**



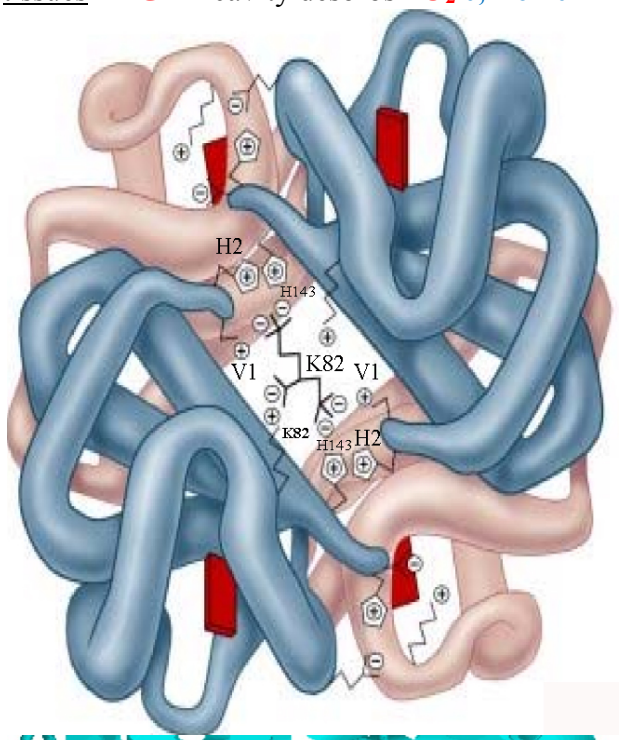
Cavity entrance of BPG^{5-} to desorbs of four oxygen 4 O_2 molecules turning **oxy Relax** state high affinity hemoglobin to **deoxy Tense** state low affinity hemoglobin. 33% of 96% adsorbed oxygen O_2 in hemoglobin used in tissue. Compare 5 L medium blood solution 7,63 mL O_2 with blood 96% saturated **arterial** hemoglobin adsorbed oxygen O_2 content 10,507 L to release 33%=>3,612 L O_2. Active 33% reserve is 3612/7,63=473 times $[O_{2aqua}] = 6 \cdot 10^{-5}$ **M** grater. At high 4.5 km mountains area bisphospho glyceride **BPG** concentration increases from 5 mM to 8 mM slightly shifts about 15% increase $[O_2]$ response level. That improve reserve extent to 33%+15%=48% as well mountain one week accommodate active reserve is 5253,5/7,63=688,5 times greater, that increase per 10% oxygen $[O_2]$ supply to tissues for human body. Accommodation time 5 mM to 8 mM is week. pO_2. Increasing supplay from $[O_2]$=$0{,}426 \cdot 10^{-5}$ M to $[O_2]$=$0{,}433 \cdot 10^{-5}$ M

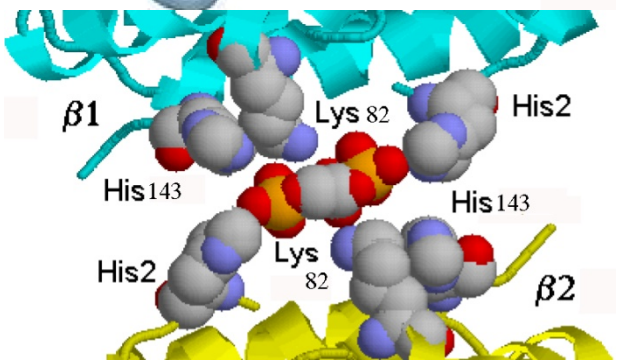
7 days acclimatization on high mountains area elevate 2,3 bisphosphate glycerate concentration from 5 mM to 8 mM. 1,0 kPa $[O_2]$=$0{,}433 \cdot 10^{-5}$ M , arterial $4 \cdot 10^{-5}$ **M** 12,9kPa , 21,12 kPa $[O_2]$=$9{,}75 \cdot 10^{-5}$ M contact to air. HIF (hypoxy induced factor) factor release in cells increase erytrocite amount in blood.

$H_2COPO_3^{2-}$-$HCOPO_3^{2-}$-COO^-->BPG^{5-} is glyceride dihydroxy acid salt G^- of two phosphate 2,3-esters with **homeostasis** concentration [BPG^{5-}]= 5 mM and is glycolysis metabolite in erythrocytes which stabilize [O_{2aqua}]=**6•10^{-5}M** concentration by shift **oxy R=>deoxy T** in **blood** plasma because of BPG^{5-} squeeze in to cavity desorbs stored reserves of oxygen 4 O_2 , adsorbing 4 H^+ on distal histidines 2*His63,58 and four bicarbonate ions 4 . As well carbonic anhydrase **CA** equilibrium: Q_{aqua}+ CO_{2aqua}+2H_2O <$\overset{CA}{}$>H_3O^++HCO_3^- stabilizes physiologic pH value **7.36** as concentration [H_3O^+]=$10^{-7.36}$ **M**=10^{-pH} **M**.

$4O_2$+(H^+His63,58)$_4$betaVal1($NH_4^+PO_4^{2-}$)$_2$$HbTG^-$<=>(His63,58)$_4Arg^+His^+$betaVal1($NH_4^+$)$_2$$HbR(O_2)_4$+4$H^+$+$BPG^{5-}$

tissues BPG^{5-}in cavity desorbs $4O_2$ 0,426•10^{-5} M<[O_{2aqua}]< **6•10^{-5}** M reach arterial concentration in lungs.





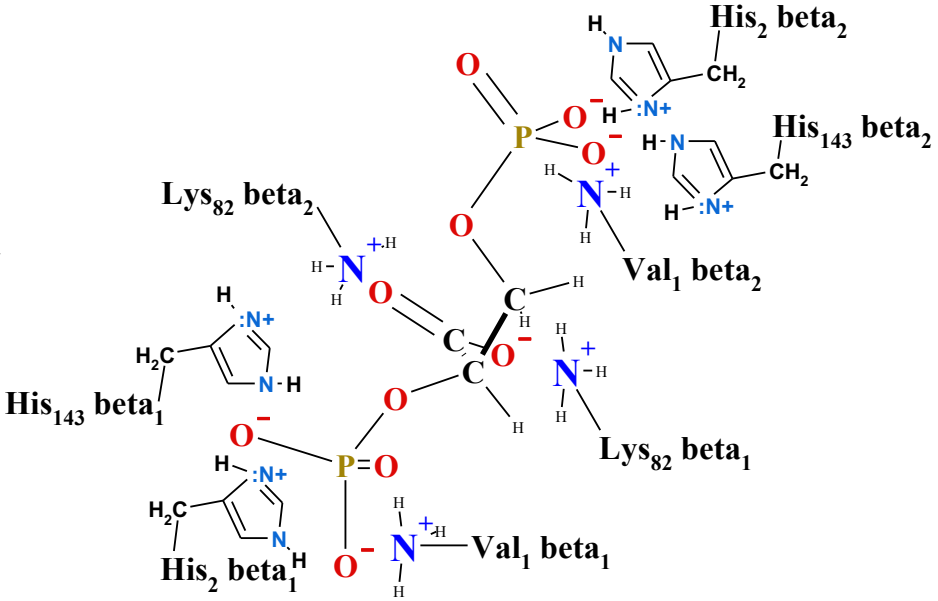
Try animating in **View$_2$** (choose from the "**Views**" pull down menu), which looks down the exact crystallographic 2-fold axis from the Beta^1-Beta$_2$ end. The **yellow** tint crosses **x** are **phosphates** -OPO_3^{2-}sites present in **deoxy** but not **oxy** Hb. In **oxy** Hb, the beta subunits move closer together, squeezing out **phosphates** -OPO_3^{2-} (such as **2,3-BPG^{5-}**), and allowing the **N**$^-$ and **C**-termini to interact. **BPG** and other **inositol 4,5-phosphates (birds** erythrocytes**)** bind very much more strongly to the **deoxy** quaternary structure; therefore they necessarily push the equilibrium toward **deoxy** Hb, and they decrease O_2 affinity. Such regulatory **phosphate** -OPO_3^{2-} groups let maintain [O_{2aqua}]=**6•10^{-5}M** concentration in **blood** stabile to shift the HbO_2^-binding curve, which is working across the steepest and most efficient part in the **lungs**, to **deoxy venous blood** Hb in **tissues** when oxygen is desorbed to maintain stabile concentration in water [O_{2aqua}]=**6•10^{-5}M**.

In cavity squeezes **2,3-BPG^{5-}** negative charged five units -5 molecule and electro statically connects to eight positively charged amino acid residues :

a) ^+H_3N- two **Lys82** in subunit **beta1** and **Lys82** in subunit **beta2** ;

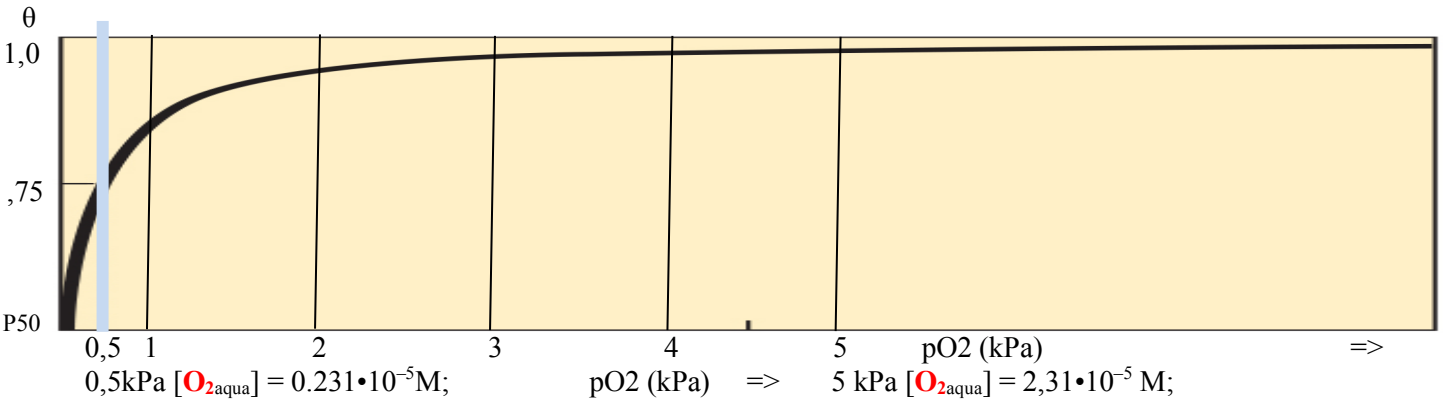
b) four amino acids **His2;His143** positively $^+$**H–N–** charged residues **His2;His143** from subunit **beta1** and **His2;His143** from subunit **beta2**

c) two **N**-terminus amino acids **Val 1** in subunit **beta1** and **Val 1** in subunit **beta2** with positively charged amino groups ^+H_3N- as **blood** pH=7.36.



Myoglobin oxy – deoxy joined (tandem) equilibrium with oxidation in mitochondria drive enzymes governed processes of Krebs cycle or/and of fatty acid beta oxidation consuming desorbed oxygen O_{2aqua} and releasing the products of protons and of bicarbonate $H^+ + HCO_3^-$ particles:

$$O_{2aqua}+(H^+His64)salt...bridge(HCO_3^-)Mb_T <=> (His64)Mb_R(O_2)_4+H^+ + HCO_3^-$$



0,5kPa $[O_{2aqua}] = 0.231 \cdot 10^{-5}$M; pO2 (kPa) => 5 kPa $[O_{2aqua}] = 2{,}31 \cdot 10^{-5}$ M;

Myoglobin homeostasis and dynamic physiologic stress by Krebs cycle consumed oxygen O_{2aqua} concentration decrease and produced protons and bicarbonate amount $H^+ + HCO_3^-$ shifts equilibrium on the left deoxy state as well as fresh supplied oxygen adsorbtion shifts equilibrium to the right releasing $H^+ + HCO_3^-$:

$$O_{2aqua}+(H^+His64)salt...bridge(HCO_3^-)Mb_T <=> (His64)Mb_R(O_2)_4+H^+ + HCO_3^-$$

$$\theta = \frac{[O_{2aqua}]}{[O_{2aqua}] + 0{,}231*10^{-5}\,M}$$

myoglobin physiologic active ligand binding fraction from 75% to 96% with concentrations 0,5 units $[O_{2aqua}] = 0.231 \cdot 10^{-5}$M; and 5 kPa $[O_{2aqua}] = 2{,}31 \cdot 10^{-5}$ M ;

Physiologic limited myoglobin ligand binding fraction θ=0,75 (theoretic θ=0) maintain the concentration in cytosole $[O_{2aqua}] = 0{,}231 \cdot 10^{-5}$ M that refers to limiting physiologic activity (stress) state of cell. Homeostasis, when oxygen consumption is minimal, myoglobin ligand binding fraction 96% with oxygen , that maintain cytosole saturation concentration $[O_{2aqua}] = 2{,}31 \cdot 10^{-5}$ M 96% of theoretic 100% possible.

Hemoglobin – myoglobin $O_2 <=> H^+ + HCO_3^-$ shuttle equilibrium reaction complex joined in tandem with Krebs cycle or/and beta oxidation reactions as well with carbonic anhydrase Brensted protolytic equilibrium and membranes crossing protons, bicarbonate channeling equilibria processes and, without doubts, with oxygen and water osmosis through aquaporin channels stabilising homeostasis physiologic parameters:

pH = 7,36;

arterial $[O_{2aqua}] = 6 \cdot 10^{-5}$M | concentration;

venous $[O_{2aqua}] = 0{,}426 \cdot 10^{-5}$ M concentration;

cytosolic concentration in stress $[O_{2aqua}] = 0{,}231 \cdot 10^{-5}$ M and in homeostasis $[O_{2aqua}] = 2{,}316 \cdot 10^{-5}$ M; $[HCO_3^-]+[CO_{2aqua}] = 0.023$ M; $[CO_{2aqua}] = 0.0076$M physiologic homeostasis concentration in cells: one blood circulation produced amount of $[HCO_3^-]+[CO_2]=0{,}05054$ M=[Hb_Tsalt bridges$(HCO_3^-)_{Hb}$] and consuming the $[O_{2Hb}] = 0{,}05054$ M amount;

One day consumption in human body is 500 g O_2 amount 15,6 moles of oxygen;

What is one day carbon dioxide amount breathed out of human body?

20,95	21,12	0,991951	3,25	1,503125	-5 M
	16	15,87121	%		
0,23125	1,503125	1,734375	0,866667	1 vienība	0,4625
	16	7,4	-5 M		
20,95	21,12	0,991951	4	1,85	-5 M
	16	15,87121	%		
0,23125	1,85	2,08125	0,888889		
	16	7,4	-5 M		
20,95	21,12	0,991951	5	2,3125	-5 M
	16	15,87121	%		
0,23125	2,3125	2,54375	0,909091		
	16	7,4	-5 M		
20,95	21,12	0,991951	8	3,7	-5 M
	16	15,87121	%		
0,23125	3,7	3,93125	0,941176		
	16	7,4	-5 M		
20,95	21,12	0,991951	12	5,55	-5 M
	16	15,87121	%		
0,23125	5,55	5,78125	0,960000		
	16	7,4	-5 M		
20,95	21,12	0,991951	13	6,0125	-5 M
	16	15,87121	%		
0,23125	6,0125	6,24375	0,962963		
	16	7,4	-5 M		
20,95	21,12	0,991951	12	5,55	-5 M
	16	15,87121	%		
0,4625	5,55	6,0125	0,923077		
	16	7,4	-5 M