~ ACID-BASE BALANCE ~

LESSON 6

➤ Measures of „ABB":

① Actual pH: $-\log([H^+]) = pH$ Normal: arterial: 7,35-7,45; venous 7,26-7,36

② Partial pressure of CO_2 in blood

$pCO_{2\,arterial} = 4,7-6,0$ kPa $\quad pCO_{2\,venous} = 6,1-7,7$ kPa

③ Partial pressure of O_2 in blood.

NORM: $pO_{2\,art.} = 12,0-12,6$ kPa $\quad pO_{2\,ven.} = 4,6-6,0$ kPa.

④ Standart bicarbonate of blood serum. (SB)

in 37°C → NORM. 21,3-21,8 mmol/L

⑤ Buffer base of blood (BB) — sum of anions of blood.

NORM: 40-60 mmol/L

bicarbonate ions ⁓ protein anions.

⑥ Normal buffer base of blood (NBB)

measure delived when: pH = 7,38 ⁓ pCO_2 = 5,33 kPa.

⑦ ↑ or ↓ of bases (BE):

↳ measure of buffer forces: NORM: (+2,3) → (−2,3 mmol/L)

~ Buffer systems ~

① Bicarbonate buffer system: (10% of all buffers) → responsible for breathing regulation.

acid H_2CO_3 donor ⟷ ratio 1:20, work good at pH=7,4 ⟷ base acceptor $NaHCO_3$ outside / $KHCO_3$ in cell

↳ low amount in blood so it depends on pCO_2 in blood.

for this case we have ↳ equation of Henderson-Hasselbalch

$$pH = pK_a + \lg([HCO_3^-]/[CO_2])$$

② Phosphate buffer system (1%) ↓ → but important role in kidneys.

acid $H_2PO_4^-$ proton donor ⟷ ratio 1:4, work: pH: 6,1-7,7, norm. pH: 7,2 ⟷ base HPO_4^{2-} proton acceptor

③ Protein buffer system. (work at pH: 7,2-7,4)

↳ are amphoteric electrolytes. (with free acidic or base groups)

In acidic medium ↳ collects H^+ ions receive

In base medium ↳ gives H^+ ions.

4. Hb buffer system (70%) the most powerfull.

acid: $HHb : HHbO_2$ (proton donor) ⟷ base: $KHb : KHbO_2$ (proton acceptor)

↑ ventilation → ↓ pCO_2 in blood

or

↓ ventilation → ↑ pCO_2 in blood.

for maintenance of this process are responsible chemoreceptors. in carotid bodies and receptors sensitive to CO_2 in medulla oblongata, aorta and carotid b.

In lung

$Hb + O_2$

throw proton → to ↑pH in compensatory purposes.

In tissues

$Hb \rightarrow O_2$

+ proton → prevents ↓ of pH.

- Kidneys also regulate acid-base balance

↳ by ↑ of Na^+ and protons reabsorption → if ↑ amounts of acids (H_2CO_3; $H_2PO_4^-$)

ACIDOSIS → ↑ synthesis and excretion of NH_4^+ (this is base) in kidneys, reversible in alkalosis.

↑ CO_2 in arterial blood —(easy pass to renal tubules)→ tubules (causes ↓ of pH)

↓

↑ secretion of H^+

(activity carboanhydrase)
+
pH of arterial blood.
+
parathyroid hormone (which ↓ activity of Na^+/H^+ exchange)
+
aldosterone

Mineralcorticoids – ↑ Na^+ reabsorbtion
↳ better for proton synthesis.

Aldosterone activates H^+ATPase
↳ which transports H^+ into lumen of tubules.

they regulate proton secretion by kidneys.

~ Role of liver in A/B regulation ~

Synthesis of proteins for buffer.
Oxidation of organic acids to $CO_2 + H_2O$
Lactate to glucose → glycogen.
Excretion of bile with acids and bases.
Production of ketone bodies.

~ Role of GIT in A/B balance ~

→ release of HCl in stomach
→ Bicarbonate of Na^+ into pancreas duct.

~ Bone Marrow ~ Na^+, K^+, Ca^{2+}, Mg^{2+} in bone exchanged to H^+ ions. compensatory of acidosis.
↓
in severe conditions leads to bone decalcification.

~ Acid/Base balance violation: ~

1. Acute: regulated by buffer systems.
2. Chronic: regulated by lungs, kidneys, liver and organs.

- Acidosis or Alkalosis can be:
  - Compensated — Normal
  - Subcompensated — ← between two them →
  - Decompensated — pH < 7,24; pH > 7,55
- By mechanism of violation: 1. Gaseous ↳ respiratory 2. Nongaseous ↳ metabolic, exchange

~ Gaseous ~ acidosis ~

↑ CO_2 in blood

→ Acute respiratory acidosis: causes:

1. ↑ CO_2 concentration in breathing air.
2. ↑ resistance of respiratory (bronchospasm, aspiration, laryngospasm)
3. Respiration violation (pneumonia, lung swelling, pneumothorax)
4. ↓ of respiratory center (anesthetics, sedative drugs, brain damage)
5. Nerve-muscle violation. (toxins, miastenia)
6. Systemic violation of circulation (thromboembolia, heart failure)
7. Iatrogenic influence (mechanical lung ventilation, carbonarcosis)

→ Chronic respiratory acidosis (causes):

1. Oppression of resp. center. (brain tumor, chronic overdose of sedative)
2. Нервно-мышечная (Nerve-muscle) transmission violation: (sclerosis, polymyelit, dystrophy)
3. Chronic resp. diseases. (emphisema, chronic bronchitis)
4. Movement restriction (ограничение), lead to hypoventilation (kyphoscoliosis, obesity)

Kidneys: when ACIDOSIS and ↓ base
↑ secretion NH^{4+} & H^+ excr. (base)

also High excretion of H^+ (base) ↓
↑ HCO_3^- reabsorption. (acid?)

Respiratory acidosis → to compensate

to form bases

H^+ exchange

Na^+, Ca^{2+} of bone marrow

Hb function violation

↓

Hypoxia

↓

↑ underoxidized products

↓

Metabolic acidosis

gaseous alkalosis

Hypercapnia (↑CO_2)

↓

Сосудодвигательный центр.

↓

spasm of arteriols (mainly lung vessels)

↓

↑ BP

↓CO_2 in erythrocytes ← hyperventilation

↓

↑ сродство Hb to O_2 leads to ↓ transition of O_2 to tissues.

↓

Hypoxia

↓

compensatory metabolic acidosis

Hypercapnia (↑CO_2)

↓

bronchiola's spasm

↓

↑ synthesis of mucus in bronchi

↓

↑ upload on resp. muscles.

↓

More ↑CO_2 from muscles

Alkalosis → hypocalcemia → ↑ excitability of muscles.

~ Non-gaseous acidosis ~ metabolic.

causes:

1. Acidic metabolites accumulation. (aceto-acetic acid)
2. ↑ acid Retention or ↑ alkali removal on kidney diseases.
3. Bicarbonates loss with diarrhea
4. ↑ acid intake with food.

~ Non-gaseous alkalosis ~ metabolic.

causes: (выделения)

1. HCO_3^- allocation violation (молочно-щелочной синдром)
2. Introduction of large quantities of HCO_3^- (bicarbonate sol. therapy)
3. ↑ organic acid's salts oxidation metabolites (HCO_3^-)
4. Vomiting → loss of HCl
5. Diuretics → loss of protons.
6. Chloride-diarrhea (Хлорцирез) → loss of Cl^- & K^+
7. ↓ K^+ in organism. (H^+ into cell → excretion by kidney of H^+)

Main parameters: HbO_2 $HbCO_2$

1. pH — art. 7,35 - 7,45 ; venous: 7,26 - 7,36
2. pCO_2 — 40 ± 3 mm Hg.
3. HCO_3^-
   - BB = buffer base 40-60 mmol/L (all bases of bicarbonate system)
   - BE = base excess −2,3 ↔ +2,4
   - SB = Standard base (pCO_2 = 40 ± 3 mmHg, 37°C, Norm atmo. pressure) → 21-27 mm Hg.
   - AB = Actual base → individually (between 21-27 mmHg)

- **Bicarbonate buffer**

$\frac{H_2CO_3}{NaHCO_3} = \frac{1}{20}$ → the main buffer in our organism.
(in blood the main is Hb buffer system)

$$NaHCO_3 + H^+ \longrightarrow H_2CO_3 + Na^+$$
$$H_2CO_3 \rightarrow H_2O + CO_2$$
$$H_2CO_3 + OH^- \longrightarrow H_2O + HCO_3^- \leftarrow + Na^+$$

H_2CO_3 → not effective because (1)20

- **Phosphate buffer system (1%)** → main in kidneys

$\frac{NaH_2PO_4}{Na_2HPO_4} = \frac{1}{4}$

$$NaH_2PO_4 + NaOH \rightarrow Na_2HPO_4 + H_2O$$
$$Na_2HPO_4 + HCl \rightarrow NaH_2PO_4 + NaCl$$

- **Hb buffer system:**

HbO_2/Hb

I (in capillary): $Hb + CO_2 \rightleftarrows HbCO_2 \rightarrow$

$\rightarrow$ II (in lungs) $HbCO_2 \rightarrow Hb + CO_2$) this changes pH

- **Protein buffer:**

1. $R(NH_2)-COOH + OH^- \rightleftarrows R(NH_2)COO^- + H_2O$
2. $R(NH_2)-COOH + H^+ \rightarrow R(NH_3^+)-COOH$

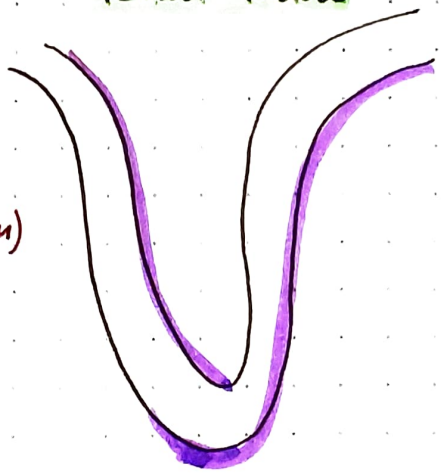
Kidney: for regulate of pH:

1. Acidogenesis: secretion of H^+
2. Ammoniogenesis: $HCl + NH_3 \rightarrow NH_4Cl$
   if found in urine (acidosis of organism)
3. Reabsorption: (of Na^+)
4. Phosphate synthesis:

pH↓ → Secretion of NaH_2PO_4 → ↑pH

pH↑ → Secretion of Na_2HPO_4 → ↓pH

renal tubule



Secretion (blood → to tubules)
Reabsorption (tubule → blood)

in blood	in blood
↓pH	↑pH
↑secretion	↓secretion
↓reabsorption	↑reabsorption
↑pH in blood	↓pH in blood

Digestive system:

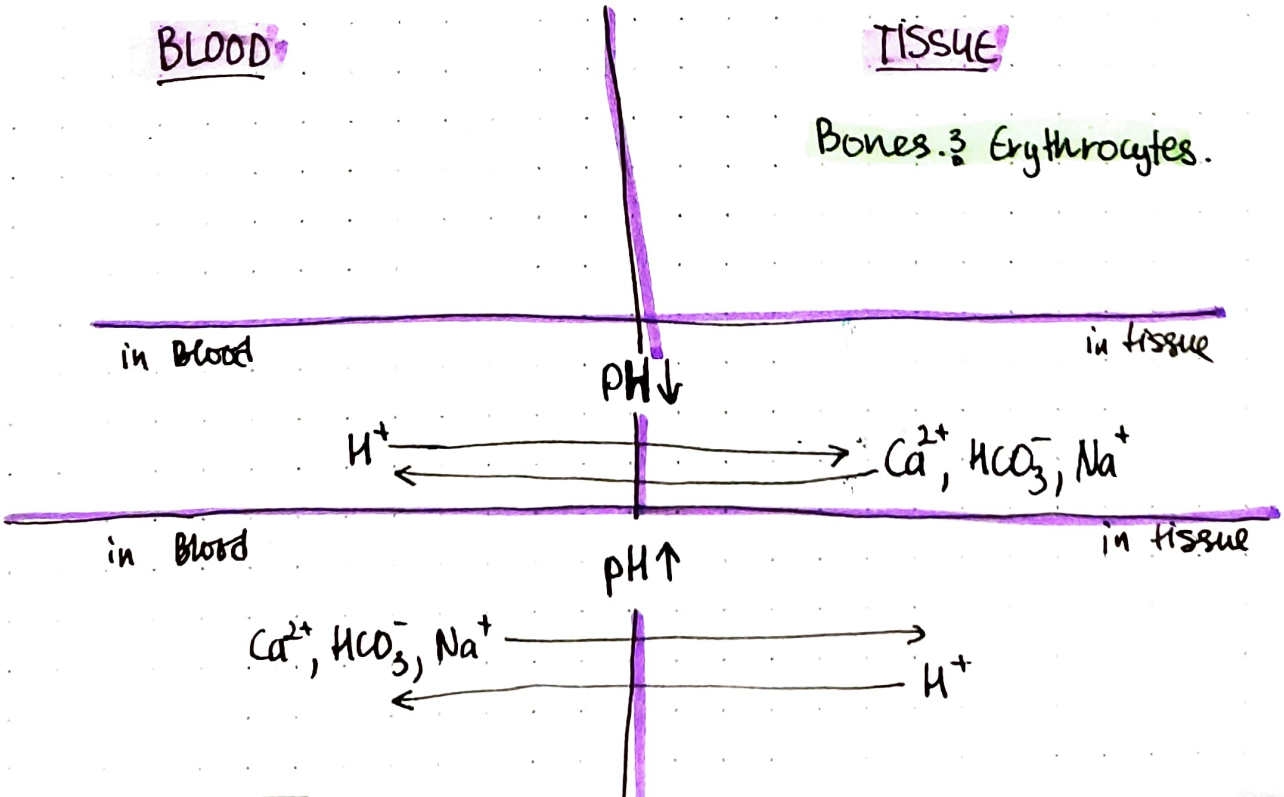
- intestine
  - reabsorption ($KHCO_3$, $NaHCO_3$)*
  - secretion of HCl
- liver
  - synthesis of proteins and etc (page 2.)

Diarhea → [redacted]
Vomitting → [redacted]

Ionic exchange

BLOOD | TISSUE

Bones.3 Erythrocytes.



Acidosis ↔ Alkalosis

1. Respiratory
2. Non-respiratory ↑ exc. of acids
   - ↳ metabolic
   - ↳ excretion
   - ↳ exogenic.

1. Compensatory
2. Decompensatory

7,35 – 7,45

decompens. acidosis	Compensatory acidosis	Compensatory alkalosis	decompens. alkalosis

Respiratory acidosis → compensatory

1. pH comp. ↓ — Blood
2. pCO_2 ↑
3. HCO_3^- ↑ (BB, BE, SB, AB) ↑

Urine:
1. pH ↓
2. am. salts ↑
3. titr. acidity ↑

Compensatory:
1. Hb buffer and Phosphate buffer.
2. Lungs – don't work.
3. Kidney
   - ↳ acidogenesis
   - ↳ ammoniogenesis
   - ↳ reabsorption
   - ↳ phosphate synthesis.
4. Ionic exchange – blood H^+
5. Digestive system → tissue Ca^{2+}

Respiratory alkalosis: → compensatory

1. pH ↑
2. pCO_2 ↓
3. HCO_3^- ↓

Blood

Urine:
1. pH ↑
2. am. salts ↓
3. titr. acidity ↓

Compensatory:
1. Hb buffer.
2. Lungs – don't work.
3. Kidney ↓ reabsorption, ↓ acidogenesis
4. Ionic exchange.

Metabolic acidosis: → compensatory

Blood: 1. ↓pH 2. pCO_2 ↓ 3. HCO_3^- ↓

Urine: 1. pH ↓ 2. ammon. salts ↑ 3. titr. acidity ↑

Compensatory:
1. 1. Bicarbonate buffer (main)
   2. Protein
   3. Phosphate
   4. Hb (rarely)
2. lungs → hyperventilation → hypocapnia
3. kidney – don't work. (diseases)
   - ↳ ↑ acidogenesis, ammoniagenesis reabs., phosphorylation.
4. Digestive → gastric, intestine, liver

Osteoporosis.

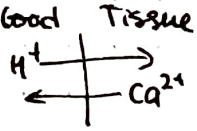
5. Ionic exchange: Blood | Bone — H^+ → ; Ca^{2+} ←

Metabolic alkalosis.

↳ exo
↳ endo (vomiting)

1. Buffer: Protein
2. lungs: hyperventilation ↓ hypocapnia
3. kidney: ↓ activity (acidogenesis, amm.genesis, reabsorption, phosphorylation)
4. digestive. HCl↑
5. Ionic exchange: rarely.

Blood	Urine
1. pH↑	1. pH↑
2. pCO_2↑	2. ammonia salts↓
3. HCO_3^-↑	3. titr. acidity↓



Type.	pH	pCO_2	HCO_3^-
resp. acidosis	↓	↑	↑
resp. alkalosis.	↑	↓	↓
met. acidosis	↓	↓	↓
met. alkalosis	↑	↑	↑

- **Decompensation** → combined (↓pH, ↑pCO_2 but ↓HCO_3^- → looks like resp. acidosis) but not → this is combined
  ↳ compensation of lungs → NO bad function of lungs.

NEXT LESSON

→ Violation in cells (gluconeogenesis)
→ Glycogenos diseases.
→ Diabetic and Metabolic syndrome.
→ 4 coma (hypo, hyperglycemia, keto, laeto).
→ 4 stages of atherosclerosis. (briefly)