SIM – PHYSIOLOGY E-BOOK

(SIM LAB GUIDE for 2nd YEAR MEDICAL STUDENTS)

B1

- Introduction to Simulation Medicine in Physiology Course
- Primary Investigation and Evaluation

B2

- Handover (SBAR)
- Circulation, Blood Pressure, Determinants of Blood Pressure

B3

- Respiration
- Relationship between Respiration and Circulation
- Oxygen Supply (DO2)
- Determinants of Oxygen Delivery (DO2)

B4

- CO2 elimination
- Capnometry
- etCO2 variables
- Monitoring of the Organism during General Anesthesia
- Reaction to a Change in Condition

B5

- Invasive Blood Pressure Measurement
- Determinants of Glomerular Filtration

B6

- Consciousness (determinants and evaluation)
- Intrinsic Environment

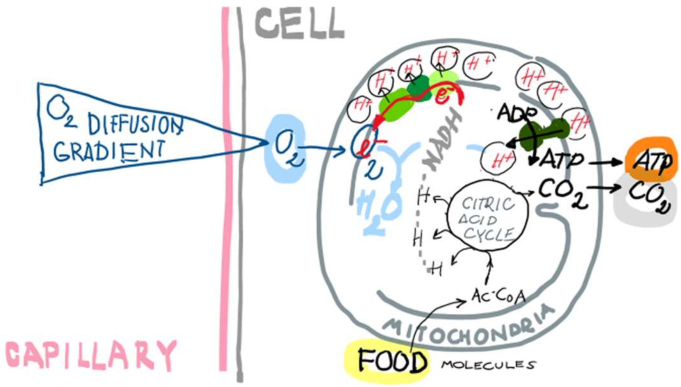
B4

CO2 ELIMINATION

- **CO2** is a metabolic by-product produced by the breakdown of energy substrates (carbohydrates, fats and proteins).
- **O2 is** a necessary prerequisite for aerobic metabolism, as it enables the continuous operation of the respiratory chain (it takes away electrons from carriers so that they can pump H+ protons between the walls of the mitochondrial membrane and thus create the H+ concentration gradient necessary for ATP synthesis).

Image: *Answer to the questions:*

What is the source of energy?
Where does CO2 come from?
How is ATP created?
What role does oxygen play in the release of energy and what is it used for?



The source of energy is food. Substrates enter the Krebs cycle, in which hydrogens are gradually taken away from them.

What is left is CO2. H^+ ions are transported to the inner mitochondrial membrane and pumped against the concentration gradient into the space between the membranes using the electron transport chain.

The generated H^+ gradient enables the formation of ATP from ADP by the enzyme ATP synthase.

Oxygen has a higher electronegativity than the other players in the electron transport chain in the inner mitochondrial membrane. Therefore, it is the final electron acceptor in this cycle. After binding electrons, it combines with H^+ in the mitochondrial matrix to form water, thereby causing O_2 consumption. Therefore, the O_2 decreases in the tissue. This causes the diffusion of additional O_2 molecules from the blood and the release of O_2 from hemoglobin.

RESPIRATORY QUOTIENT

- **The ratio** (molar ratio = also volume ratio) **of produced CO2 and consumed O2 is called the respiratory quotient**
- For carbohydrates it has a value of 1, for other substrates slightly lesser.
- This implies that we have to eliminate roughly the same amount of CO2 as we supply O2.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + 6O_2 \longrightarrow 6CO_2\uparrow + 6H_2O + \text{Energy}$$

$$\text{RQ of glucose} = \frac{6 \text{ molecules of } CO_2}{6 \text{ molecules of } O_2}$$

$$= 1 \text{ (unity)}$$

CO_2 TRANSPORT

- The vast majority (90%) of **CO_2 transport in the blood takes place in the form of bicarbonate.**
- Other methods are binding to the globin part of hemoglobin and the fraction dissolved in plasma.
- Bicarbonate is produced from CO_2 by the action of carbonic anhydrase in erythrocytes during tissue blood flow.

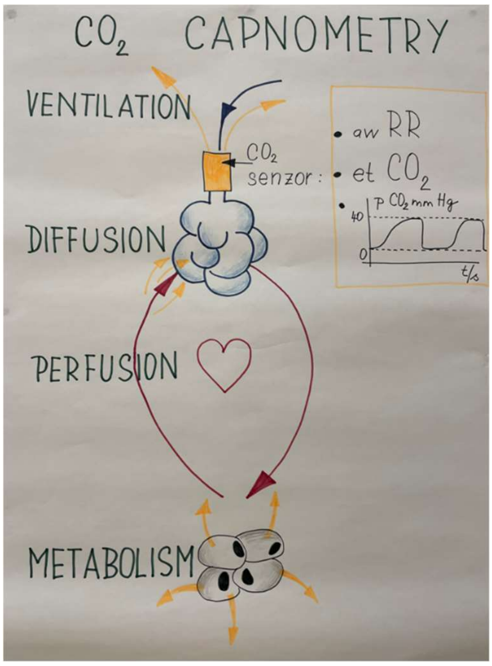
$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

- In the lungs, where the partial pressure of CO_2 is lower than in the tissues, the reaction takes place in the opposite direction, the released CO_2 diffuses into the alveolar space and is exhaled.

CO2 METABOLISM AND ITS EFFECT ON pH & MINUTE VENTILATION

- **The amount of CO_2 produced by metabolism and CO2 eliminated must be the same.**
- If this were not the case, the pH of the blood would change, an increase of CO2 in the body would lead to acidosis, and a decrease would lead to alkalosis.
- Since enzymes need an optimal pH for their function (proteins are only functional in certain conformations and changes in usual pH disturbs the protein conformation), therefore the organism would fail with fluctuating pH.
- The partial pressure of CO_2 is therefore very carefully detected by the central chemoreceptors and the amount of minute ventilation is adjusted according to its value.
- When the same amount of CO2 is produced and eliminated by the organism, the minute ventilation is optimum and is referred to as **normo-ventilation.**
- If we exhale **less than is produced,** this is **hypoventilation, and** if we exhale **more,** it is called **hyperventilation.**
- Such disturbance always have a corresponding consequence to the pH of the internal environment.

CAPNOMETRY, etCO2 VARIABLES



Principle: CO_2 is determined spectrophotometrically (in the infrared spectrum) in the air that flows through the breathing circuit. The sensor is positioned to continuously read (sample) inhaled and exhaled air. (That is, typically on an endotracheal tube or on a mask.) When inhaling, it calibrates to 0 (the CO_2 content in the atmosphere is negligible for these purposes), when exhaling, it plots the values in a graph (see picture).

etCO2: is the value obtained from the **exhaled air stream** at the end of exhalation (end tidal) and roughly corresponds to the partial pressure of CO_2 in the alveolar space and **in the arterial blood**. It is usually 5 mmHg lower due to the admixture of air from the dead spacex.

EtCO2 variables: the measured value depends on the intensity of metabolism, circulatory function, pulmonary diffusion and ventilation, (see figure.) Due to the highly sensitive regulation of pCO2 in the blood, it is quite constant physiologically. Given the possibility to freely influence ventilation, it is easy to demonstrate the effect of changes in this variable on etCO2. In various pathological conditions, $etCO_2$ is a source of information for other variables as well (see the simulated task.)

Respiration frequency/Respiratory Rate: by registering changes in the air flowing through the capnometric cuvette, we obtain **the number of breathing cycles per minute**. The abbreviation **awRR** on the monitor stands for **a** ir **w** ay **R** espiratory **R** ate and shows that the value was obtained directly by sensing the airflow in the airways. Although it is necessary to check the respiratory activity with one's own senses (as we have learnt earlier), the instrumental registration of the respiratory rate is very practical and useful in a clinical setting because it allows the healthcare professional to have continuing information and be oriented with the respiratory activity/effort of an unstable patient.

RESPIRATORY FREQUENCY, IMPEDANCE MEASUREMENT

The breathing frequency can also be determined by the fluctuation of the electrical resistance of the chest according to the phase of the breathing cycle (inspiration - increase in resistance, decrease in conductivity, exhalation - decrease in resistance, increase in conductivity).

If we connect the ECG cables to the chest, we can measure the resistance of the chest in addition to the ECG signal. The respiratory rate value will then be displayed next to the abbreviation RR on the monitor. The backlight color of the value usually matches the backlight color of the ECG recording to make it clear how the value was taken. Detecting respiratory rate from the exhaled air stream is more accurate than impedance measurement. For patients who do not have a sealing mask or a cannula in the airways (which are the conditions for using direct measurement of respiratory rate), this method is easy to perform and sufficient for orientation.

MONITORING THE ORGANISM DURING GENERAL ANESTHESIA

General anesthesia is pharmacologically induced unconsciousness, most often for the purpose of performing a painful procedure. Some anesthetics alone do not prevent pain management, and therefore it is necessary to combine them with analgesics. More demanding surgical procedures are carried out with securing the airways (intubation), simpler procedure only require short-term anesthesia without intubation after previous fasting (to prevent aspiration).

Because of the loss of consciousness, even an otherwise healthy individual is in danger of life for many reasons, his condition can change, hence it is necessary to identify the change, understand the mechanism of its development and react appropriately. Therefore, this task is suitable for students of physiology after proper simplification.

Risks of general anesthesia:

- Decreased muscle tone, Airway obstruction
- Attenuation of Reflexes:
    - defensive reflexes of the respiratory tract (risk of aspiration)
    - respiratory center (breath hold)
    - cardioinhibitory and excitatory center (bradycardia and hypotension)

Prevention:

- Preparation (anamnesis, preoperative examination including laboratory, fasting)
- A careful examination **before** the procedure serves as a comparative state (base line) for subsequent checks during the procedure.
- Anesthesiology Protocol: Repeated complete examination in short time intervals, with the aim of early detection of adverse developments (trends) and reaction to them (situational vigilance). At the same time, it also serves as medical documentation with forensic significance (protection of both the patient and the doctor).

Monitoring the patient's condition during general anesthesia

Consciousness + Overall status	• Monitoring the onset of the effect of the general anesthetic at the beginning of the procedure, the persistence of high-quality sedation during the entire procedure and the return of consciousness after its completion. • Control of effective suppression of the pain response. • Record of result: AVPU • + special items (presence of convulsions, description of pupils...more details B6) • General condition: body temperature, hydration
Respiration	• Manually (physical exam) and with equipment (SpO2, capnometry, impedance measurement of respiratory frequency). • Record of values, often also graphic display of trends for acute and timely recognition of changes. • Record of all interventions (e.g. airway, suction).
Circulation	• Manually (physical exam), and with equipment (EKG – before the procedure 12 leads, during the procedure permanently single-lead) • BP non-invasively repeatedly at 10 min intervals, if the values are stable), if not, more often.

	• Record of all values, graphical display of trends. • Record of interventions, e.g. insertion of vascular cannulas.
A record of times and doses of drugs administered	

The format of the anesthesia protocol, the list of monitored items, see protocol B4.