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Determination of the sensitivity of the respiratory center to hypercapnia

Physiology I – practice

Autumn, weeks 7–9

Regulation of breathing

Cerebral cortex
Voluntary breathing, conditioned reflexes

Subcortical structures
Emotions, changes in central temperature, reactions of autonomic nervous system

Respiratory centre
Central chemoreceptors, automatic breathing

Peripheral chemoreceptors

Receptors in lung and airways

Receptors in breathing muscles

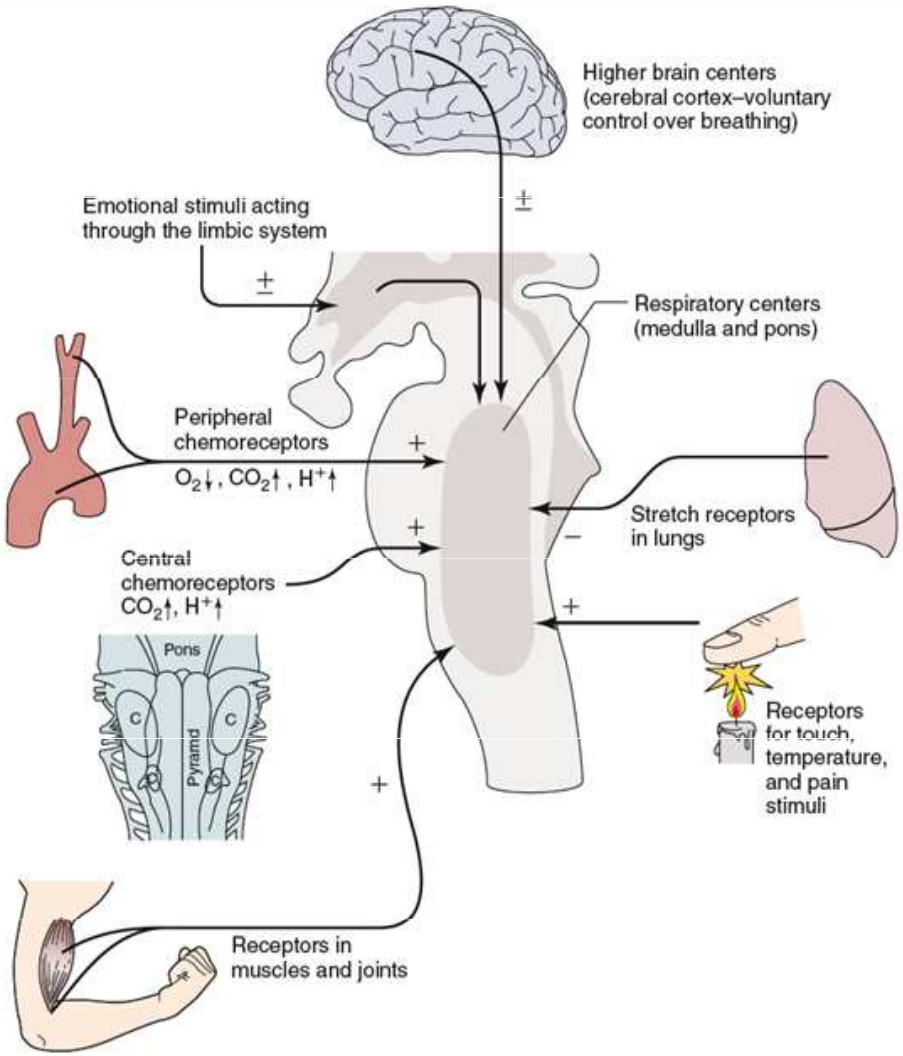
Receptors in skin, muscles, tendons and joints

Nespecific mechanoreceptors

Baroreceptors

Hormones
(epinephrine, steroid hormones)

Direct effect of environment

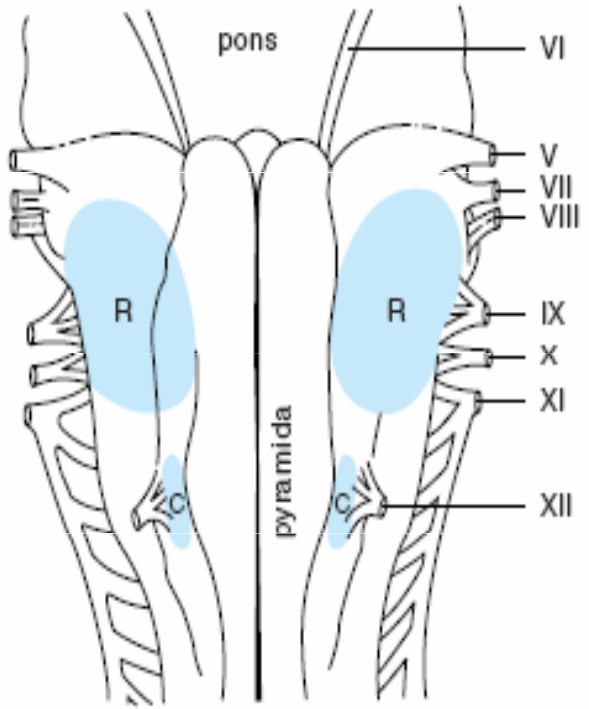


Breathing centres in the medulla

- Breathing is an automatic process that takes place unconsciously.
- Automaticity of breathing comes from regular (rhythmic) activity of groups of neurons anatomically localized in the medulla and its vicinity. They can be divided into three main groups:
  - **Dorsal respiratory group** – only inspiratory neurons, their axons go to the motoneurons of the inspiratory muscles (diaphragm, external intercostal muscles; their activation = inspiration, during their relaxation = expiration), they participate in inspiration at rest and also during exercise
  - **Ventral respiratory group** – located on the ventrolateral part of the medulla, the upper part: neurons whose axons activate the motoneurons of the primary and accessory inspiratory muscles; the lower part: expiratory neurons with innervation of expiratory muscles. Neurons of this group are active only during forced inhalation and exhalation
  - **Pontine respiratory group (pneumotaxic centre)** – participates in the control of the frequency and depth of breathing; it affects the activity of respiratory neurons in the medulla

Central chemoreceptors

- on the front side of the medulla
- CO_2 can cross the hematoencephalic barrier to the cerebrospinal and intercellular fluid
  - $CO_2 + H_2O \rightarrow CHO_3^- + H^+$
- Higher H^+ concentration of H^+ in cerebrospinal fluid stimulates central chemoreceptors → increased ventilation
  - central chemoreceptor are stimulated also by other types of acidosis (lactate acidosis, ketoacidosis)
  - a sudden change of pCO_2 does not have an immediate effect, the changes in ventilation through central chemoreceptors occur after 20-30 s



Obr. 36-7. Rostrální (R) a kaudální (C) chemosenzitivní oblasti ventrálního povrchu prodloužené míchy

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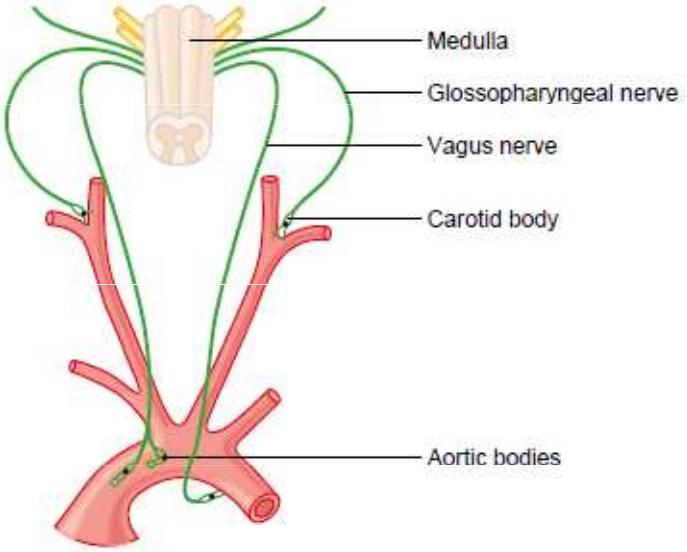
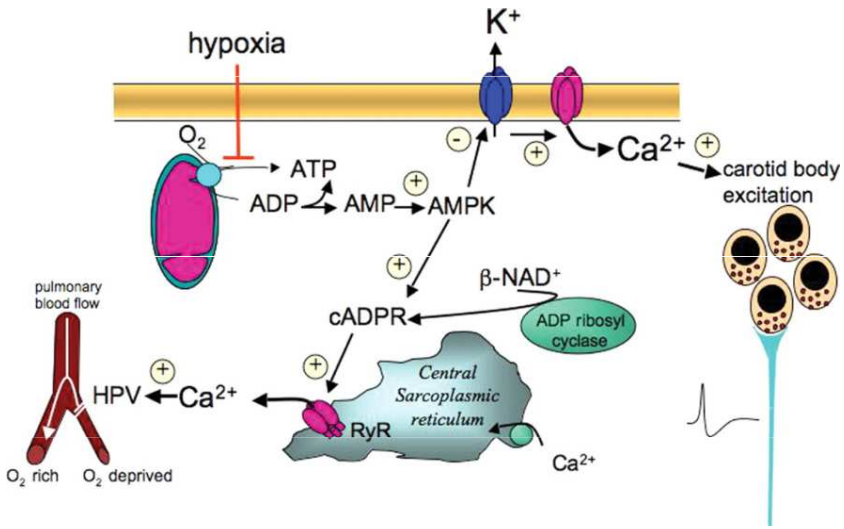
Peripheral chemoreceptors

- Located in the aortic and carotid bodies
  - glomus caroticum, glomus aorticum
  - They convey their sensory information to the medulla via the vagus nerve and glossopharyngeal nerve.
- Sensitive to a decrease in arterial pH and pO_2 and an increase in arterial pCO_2
  - The **most important reaction is to decrease in arterial pO_2**, particularly to decrease of O_2 under 10-13 kPa in the arterial blood (caused mainly by a general decrease of pO_2 or impaired flow of the blood)
  - Mechanism: decreased pO_2 leads to the decrease of ATP synthesis in mitochondria resulting in membrane depolarization





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Hypoxia, hypoxemia (norm. 11-16 kPa)

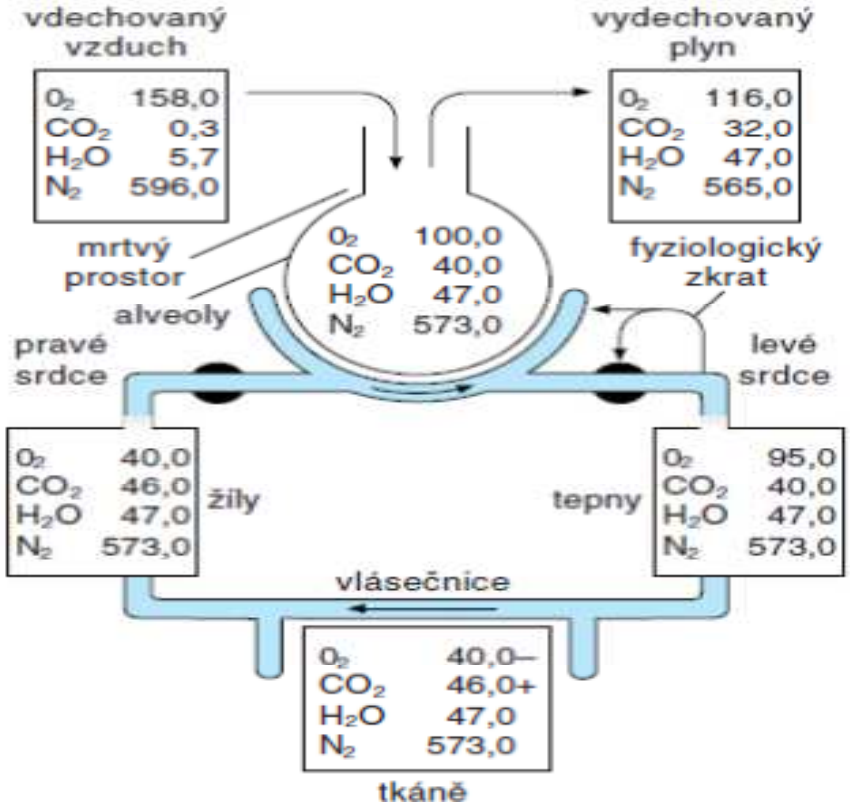
- **Hypoxia** is a general name for a lack of oxygen in the body or certain tissues.
- **Hypoxemia** is a lack of oxygen in arterial blood.
- A complete lack of oxygen is known as **anoxia**.
- The most common types of hypoxia:
  - **Hypoxic** – physiological: stay at higher altitudes, pathological: hypoventilation during lung or neuromuscular diseases, thorax injuries, opioid overdose, …
  - **Transport (anemic)** – reduced transport capacity of blood for oxygen (anemia, blood loss, CO poisoning)
  - **Ischemic (stagnation)** – restricted blood flow to tissues (heart failure, shock, obstruction of an artery)
  - **Histotoxic** – cells are unable to utilize oxygen (cyanide poisoning – disruption of the respiratory chain)

Hypercapnia (norm. 5.3-6.65 kPa)

- An increase in the concentration of carbon dioxide in the blood or tissues caused by the retention of CO_2 in the body
  - Possible causes: total alveolar hypoventilation – decreased respiration or extension of dead space
  - Mild hypercapnia (5-7 kPa) causes stimulation of the respiratory center (therapeutic use: pneumoxid = mixture of oxygen + 2-5% CO_2)
  - Hypercapnia around 10 kPa – CO_2 narcosis – respiratory depression (preceded by headache, confusion, disorientation, a feeling of breathlessness)
  - Hypercapnia over 12 kPa – significant respiratory depression – coma and death.

The partial pressure of gases (mmHg)

– In different parts of the respiratory and circulatory system



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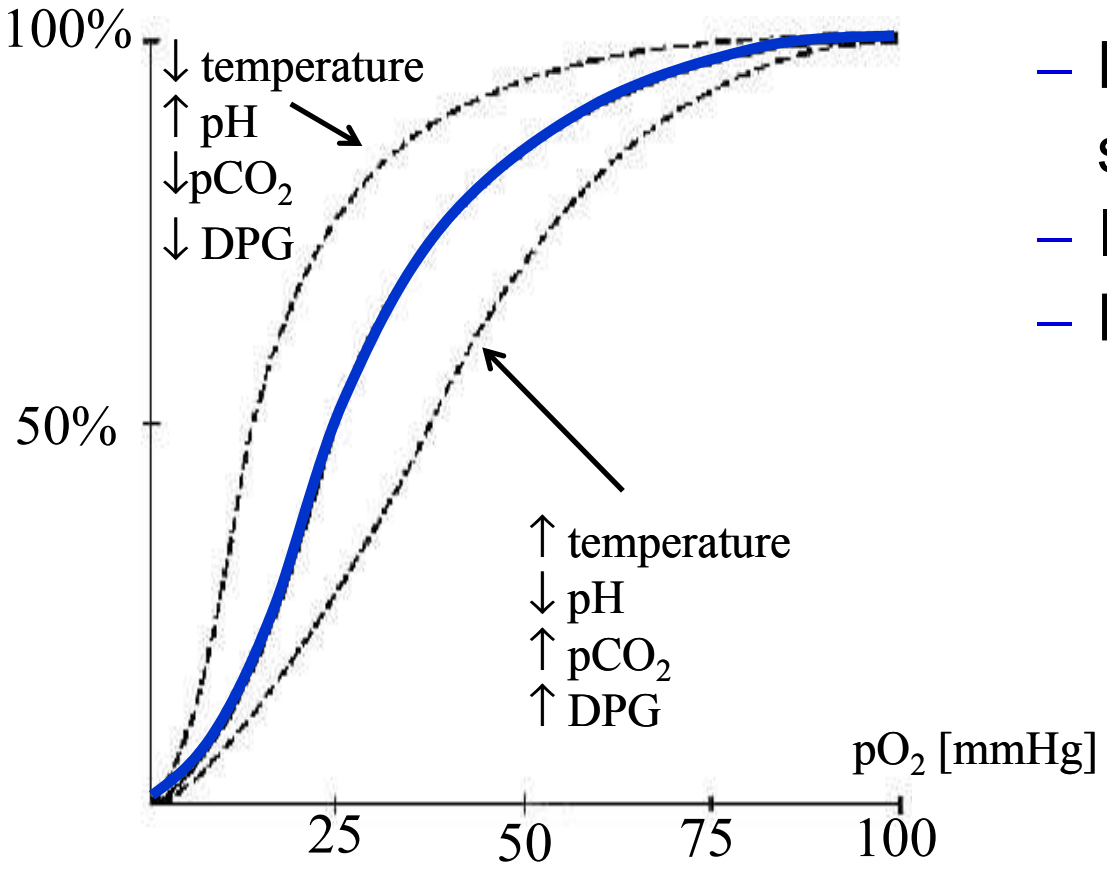
Saturation of hemoglobin with oxygen



- Percentage of hemoglobin saturated with oxygen
- In arterial blood around 95-98%
- Hypoxia <85%

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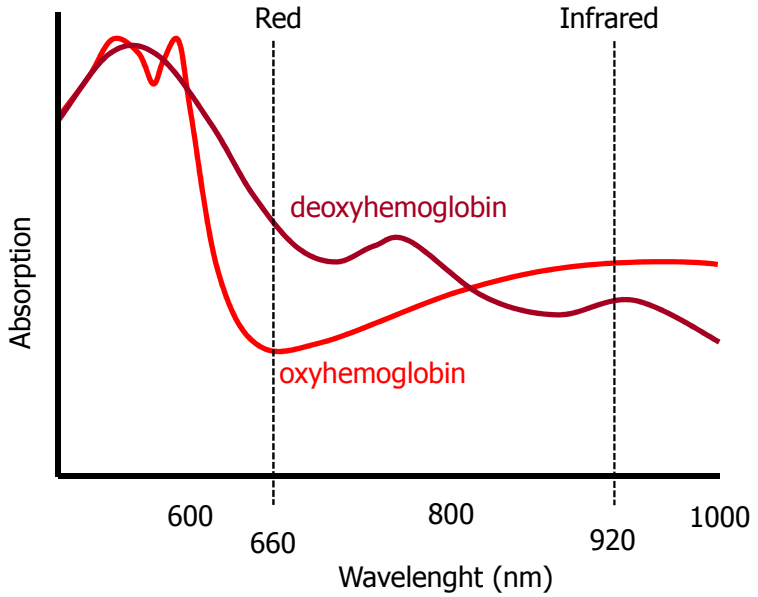
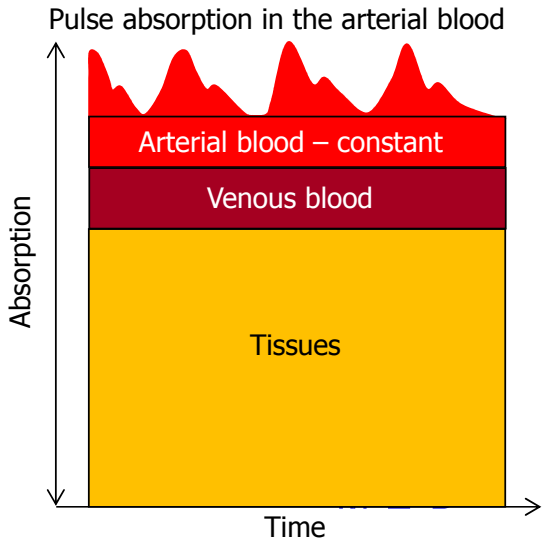
Pulse oximetry

- Is a photometric method of non-invasive measurement of hemoglobin saturation with oxygen in the arterial blood.
- The method is based on the evaluation of the absorption of transmitted light of two different wavelengths after passing through tissues.
- How to get saturation only in the arterial blood: subtract the value between individual heartbeats from the value at the peak of the pulse wave. The component calculated in this way is then equal to the absorption of the variable component, which is the arterial blood (the representation of other tissue is stable).



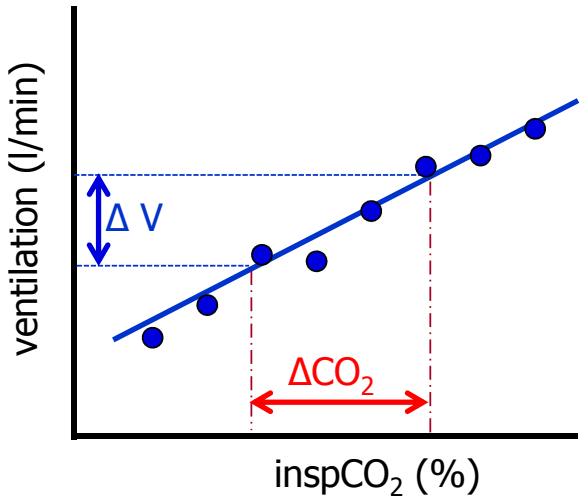


Sensitivity of the respiratory centre to hypercapnia

- **Aim**: to demonstrate the changes in ventilation during induced hypercapnia and to compare the sensitivity of the respiratory centre to hypercapnia in several subjects
- **Method**: Hypercapnia is induced by re-breathing of air expired into Krogh respirometer with a closed circuit (Krogh respirometer with oxygen, without the soda lime – the CO_2 concentration naturally increases)
- **Interpretation**: The slope of the curve shows the sensitivity of the respiratory centre to hypercapnia

$$\frac{\Delta \dot{V}}{\Delta CO_2} \; [\mathrm{l/min \cdot \%}]$$

Clinical note: the sensitivity of the respiratory centre to change of partial pressure of CO_2 is reduced in patients with chronic end-stage lung disease, in patients with heart failure as well as in subjects training breath holding (e.g. divers without oxygen tanks)



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