Regulation of respiration

Breathing is controlled by the central neuronal network to meet the metabolic demands of the body

- Neural regulation
- Chemical regulation
Respiratory center

Definition:

- A collection of functionally similar neurons that help to regulate the respiratory movement
Respiratory center

- **Medulla**: Basic respiratory center: produce and control the respiratory rhythm
- **Pons**: Higher respiratory center: cerebral cortex, hypothalamus & limbic system
- **Spinal cord**: respiratory motor neurons
Neural regulation of respiration

- **Voluntary breathing center**
  - Cerebral cortex

- **Automatic (involuntary) breathing center**
  - Medulla
  - Pons
Neural generation of rhythmical breathing

The discharge of medullary inspiratory neurons provides rhythmic input to the motor neurons innervating the inspiratory muscles. Then the action potential cease, the inspiratory muscles relax, and expiration occurs as the elastic lungs recoil.
- Inspiratory neurons
- Expiratory neurons
Respiratory center

- **Dorsal respiratory group** (medulla) – mainly causes inspiration

- **Ventral respiratory group** (medulla) – causes either expiration or inspiration

- **Pneumotaxic center** (upper pons) – inhibits apneustic center & inhibits inspiration, helps control the rate and pattern of breathing

- **Apneustic center** (lower pons) – to promote inspiration
Hering-Breuer inflation reflex (Pulmonary stretch reflex)

- The reflex is originated in the lungs and mediated by the fibers of the vagus nerve:
  - **Pulmonary inflation reflex:**
    - inflation of the lungs, eliciting expiration.
  - **Pulmonary deflation reflex:**
    - deflation, stimulating inspiration.
Pulmonary inflation reflex

- Inflation of the lungs $\rightarrow$ +pulmonary stretch receptor $\rightarrow$ +vagus nerve $\rightarrow$ - medially inspiratory neurons $\rightarrow$ +eliciting expiration
THE MEDULLA'S CONTROL OF THE RESPIRATORY CYCLE

Inspiration Center

Expiration Center

Stretch receptors in trachea, bronchi and bronchioles inhibit inspiration center

Motor neurons of phrenic nerve

Motor neurons to intercostal muscles

Contraction of diaphragm

Typical Cross Section of Spinal Cord
Thoracic Level T1-T12

Lower motor neurons

Upper motor neurons

Inspiration center inhibits expiration center
Chemical control of respiration

- **Chemoreceptors**
  - **Central chemoreceptors**: medulla
    - Stimulated by $[H^+]\uparrow$ in the CSF
  - **Peripheral chemoreceptors**
    - Carotid body
      - Stimulated by arterial $PO_2\downarrow$ or $[H^+]\uparrow$
    - Aortic body
Central chemoreceptors
Chemosensory neurons that respond to changes in blood pH and gas content are located in the aorta and in the carotid sinuses; these sensory afferent neurons alter CNS regulation of the rate of ventilation.
Glossopharyngeal nerve (IX)

Carotid bodies

Vagus nerve (X)

Common carotid artery

Aortic bodies in aortic arch
**Peripheral chemoreceptors**—that is, carotid bodies and aortic bodies—respond to changes in the *arterial blood*. They are stimulated by:

1. Decreased $P_{O_2}$ (hypoxia)
2. Increased hydrogen ion concentration (metabolic acidosis)
3. Increased $P_{CO_2}$ (respiratory acidosis)

**Central chemoreceptors**—that is, located in the medulla oblongata—respond to changes in the *brain extracellular fluid*. They are stimulated by increased $P_{CO_2}$ via associated changes in hydrogen ion concentration. (See Equation 13–11.)
Small changes in the carbon dioxide content of the blood quickly trigger changes in ventilation rate.

\[ \text{CO}_2 \uparrow \rightarrow \uparrow \text{respiratory activity} \]
Central and peripheral chemosensory neurons that respond to increased carbon dioxide levels in the blood are also stimulated by the acidity from carbonic acid, so they “inform” the ventilation control center in the medulla to increase the rate of ventilation.

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^- \]
Regardless of the source, increases in the acidity of the blood cause hyperventilation.
Regardless of the source, increases in the acidity of the blood cause hyperventilation, even if carbon dioxide levels are driven to abnormally low levels.
A severe reduction in the arterial concentration of oxygen in the blood can stimulate hyperventilation.

**Effect of low arterial $P_{O_2}$ on pulmonary ventilation**

$P_{O_2} \downarrow \rightarrow \uparrow$ respiratory activity

Normal resting level

A severe reduction in the arterial concentration of oxygen in the blood can stimulate hyperventilation.
Chemosensory neurons that respond to decreased oxygen levels in the blood “inform” the ventilation control center in the medulla to increase the rate of ventilation.
The levels of oxygen, carbon dioxide, and hydrogen ions in blood and CSF provide information that alters the rate of ventilation.

In summary:
Regulation of respiration

- Normal respiration
- Maximal increase in hydrogen ions
- Maximal oxygen lack
- Maximal excess of CO₂
- Maximal exercise
Questions

1. Why is increased depth of breathing far more effective in evaluating alveolar ventilation than is an equivalent increase in breathing rate?

<table>
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<th>SUBJECT</th>
<th>TIDAL VOLUME (ML/BREATH)</th>
<th>×</th>
<th>FREQUENCY (BREATHS/MIN)</th>
<th>=</th>
<th>MINUTE VENTILATION (ML/MIN)</th>
<th>ANATOMIC DEAD-SPACE VENTILATION (ML/MIN)</th>
<th>ALVEOLAR VENTILATION (ML/MIN)</th>
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<td>40</td>
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<td>12</td>
<td></td>
<td>6000</td>
<td>150 × 12 = 1800</td>
<td>4200</td>
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<tr>
<td>C</td>
<td>1000</td>
<td></td>
<td>6</td>
<td></td>
<td>6000</td>
<td>150 × 6 = 900</td>
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2. Describes the effects of PCO2, [H+] and PO2 on alveolar ventilation and their mechanisms.

- CO2↑ --- ↑ respiratory activity; Peripheral mechanism and central mechanism, the latter is the main one.
- [H+]↑ --- ↑ respiratory activity; Peripheral mechanism and central mechanism, the former is the main one.
- PO2↓ --- ↑ respiratory activity; Peripheral mechanism is excitatory.
Questions

- 3. What is the major result of the ventilation-perfusion inequalities throughout the lungs?
- 4. Describe the factors that influence gas exchange in the lungs.
- 5. If an experimental rabbit’s vagi were obstructed to prevent them from sending action potential, what will happen to respiration?