Regulation of Respiration

- Nervous system regulation
  - Various levels of activity produce different demands
  - Medulla
  - Regulation of respiratory rate
    - \(\text{PaCO}_2\) normal range 35-45 mmHg
Other receptors (e.g., pain) and emotional stimuli acting through the hypothalamus.

Peripheral chemoreceptors: \(O_2, CO_2, H^+\)

Central Chemoreceptors: \(CO_2, H^+\)

Receptors in muscles and joints

Respiratory centers (medulla and pons)

Stretch receptors in lungs

Irritant receptors

Higher brain centers (cerebral cortex—voluntary control over breathing)
Regulation of Respiration

• Nervous system regulation
  • **Hyperventilation:** increased depth and rate of breathing that exceeds the body’s need to remove CO\(_2\)
    • Causes CO\(_2\) levels to decline (hypocapnia)
    • pH increases
  • **Hypoventilation:** decreased rate and depth of breathing
    • Causes CO\(_2\) levels to increase (hypercapnia)
    • pH decreases
**Medullary Control Center in Brainstem**

**Pontine respiratory centers** interact with the medullary respiratory centers to smooth the respiratory pattern.

**Ventral respiratory group (VRG)** contains rhythm generators whose output drives respiration.

**Dorsal respiratory group (DRG)** integrates peripheral sensory input and modifies the rhythms generated by the VRG.
Regulation of Respiration

- Nervous system regulation
  - Medullary control center
  - Diffuse system of neurons
    - Separate pathways for inspiration and expiration
Regulation of Respiration

- Nervous system regulation
  - Higher brain centers
    - Cerebral cortex
      - Direct signals from the cerebral motor cortex bypass medullary controls
      - Example: voluntary breath holding
    - Hypothalamus
      - Limbic system can modify rate and depth of respiration
      - Examples: breath holding that occurs in anger or gasping with pain, laughing, crying
Regulation of Respiration

- **Chemoreceptors**
  - **Central**
    - $pCO_2$ most potent stimuli
    - $\uparrow pCO_2$ (hypercapnia) = $\uparrow pCO_2$ in the brain = central chemoreceptor in the medulla stimulated = $\uparrow$ respiratory rate
    - $pO_2$ has no effect here
Figure 22.25

Arterial $P_{CO_2}$ increases, leading to:

- $P_{CO_2}$ decreases pH in brain extracellular fluid (ECF)
- Central chemoreceptors in medulla respond to $H^+$ in brain ECF (mediate 70% of the $CO_2$ response)
- Peripheral chemoreceptors in carotid and aortic bodies (mediate 30% of the $CO_2$ response)

Afferent impulses:

- Medullary respiratory centers

Efferent impulses:

- Respiratory muscle
- $↑$ Ventilation (more $CO_2$ exhaled)

Result:

- Arterial $P_{CO_2}$ and pH return to normal

Initial stimulus

Physiological response

Result
Regulation of Respiration

- Nervous system control
  - Peripheral chemoreceptors
    - Carotid and aortic bodies
    - $\uparrow$ CO$_2$ levels are the most powerful respiratory stimulant
    - Also respond to $\downarrow$ pO$_2$ and pH
Peripheral Chemoreceptors

Brain

Sensory nerve fiber in cranial nerve IX
(pharyngeal branch of glossopharyngeal)
External carotid artery
Internal carotid artery
**Carotid body**
Common carotid artery
Cranial nerve X (vagus nerve)

Sensory nerve fiber in cranial nerve X
**Aortic bodies in aortic arch**
Aorta
Heart
Regulation of Respiration

• High altitude
  • Quick travel to altitudes above 8000 feet may produce symptoms of acute mountain sickness (AMS)
    o Headaches, shortness of breath, nausea and dizziness
    o In severe cases, lethal cerebral and pulmonary edema
Regulation of Respiration

- High altitude
  - \( \text{pO}_2 \leq 60 \text{ mm Hg} = \text{major stimulus for respiration} \)
    - Peripheral chemoreceptors
    - Hyperventilate \( \rightarrow \) respiratory alkalosis
Regulation of Respiration

- Chronic $\text{CO}_2$ retention disorders
  - CSF buffers reduce central chemoreceptor control
    - Rely on $\text{paO}_2$
    - Excessive $\text{O}_2$ administration = apnea!
  - Example: emphysema
Regulation of Respiration

- Baroreceptors
  - ↓ blood pressure = ↑ respiration
  - Relatively small influence and poorly understood
Higher brain centers (cerebral cortex—voluntary control over breathing)

Other receptors (e.g., pain) and emotional stimuli acting through the hypothalamus

Peripheral chemoreceptors: $\text{O}_2$, $\text{CO}_2$, $\text{H}^+$

Central Chemoreceptors: $\text{CO}_2$, $\text{H}^+$

Receptors in muscles and joints

Respiratory centers (medulla and pons)

Stretch receptors in lungs

Irritant receptors
Regulation of Respiration

- Exercise
  - Intensity and duration
  - Hyperpnea
    - Increase in ventilation (10 to 20 fold) in response to metabolic needs
    - Depth of respiration increases more than rate
    - $pCO_2$, $pO_2$, and pH remain surprisingly constant during exercise
      - $pCO_2$ may decrease
Regulation of Respiration

- Neural factors cause increase in ventilation as exercise begins
  - Psychological stimuli
    - Anticipation of exercise
  - Simultaneous cortical motor activation of skeletal muscles and respiratory centers
  - Excitatory impulses reaching respiratory centers from proprioceptors
Other receptors (e.g., pain) and emotional stimuli acting through the hypothalamus

Peripheral chemoreceptors
$O_2$, $CO_2$, $H^+$

Central Chemoreceptors
$CO_2$, $H^+$

Receptors in muscles and joints

Central Chemoreceptors

Respiratory centers (medulla and pons)

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