Business

- Optional midterm review Tuesday 5-6pm
- Bring your Physio EX CD to lab this week
- Homework #6 and 7 due in lab this week
  - Additional respiratory questions need to be completed for HW #7…

Midterm #1 is Monday, study hard!
Respiratory System

Part 4
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
- \( \text{O}_2 \downarrow, \text{CO}_2 \uparrow, \text{H}^+ \uparrow \)

Central Chemoreceptors
- \( \text{CO}_2 \uparrow, \text{H}^+ \uparrow \)

Respiratory centers (medulla and pons)

Irritant receptors

Stretch receptors in lungs

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 CO₂
    - Causes CO₂ levels to decline (hypocapnia)
    - pH increases

  - **Hypoventilation**: decreased rate and depth of breathing
    - Causes CO₂ levels to increase (hypercapnia)
    - pH decreases

  What circumstances might cause these conditions?
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.

**Medullary Control Center in Brainstem**

External intercostal muscles

To inspiratory muscles
Regulation of Respiration

• Nervous system regulation
  • Medullary control center
  • Diffuse system of neurons
    o 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
    • $P_{\text{CO}_2}$ most potent stimuli
    • $\uparrow P_{\text{CO}_2}$ (hypercapnia) = $\uparrow P_{\text{CO}_2}$ in the brain = central chemoreceptor in the medulla stimulated = $\uparrow$ respiratory rate
    • $P_{\text{O}_2}$ has no effect here
Figure 22.25

Initial stimulus:

- $\uparrow \text{Arterial } P_{\text{CO}_2}$

Result:

- $\uparrow P_{\text{CO}_2}$ decreases pH in brain extracellular fluid (ECF)

Physiological response:

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
- $\uparrow$ Ventilation (more CO$_2$ exhaled)

Arterial $P_{\text{CO}_2}$ and pH return to normal
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)
    - Headaches, shortness of breath, nausea, and dizziness
    - 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 CO$_2$ retention disorders
  - CSF buffers reduce central chemoreceptor control
    - Rely on PaO$_2$
    - Excessive O$_2$ administration = apnea!
- Example: emphysema
Regulation of Respiration

- Baroreceptors
  - ↓ blood pressure = ↑ respiration
  - Relatively small influence and poorly understood
Figure 22.24

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

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
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
  - $P_{co_2}$, $P_{o_2}$, and pH remain surprisingly constant during exercise
    - $P_{co_2}$ 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
Higher brain centers (cerebral cortex—voluntary control over breathing)

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Questions?