Control of Respiration

Input from \( P_{O_2}, P_{CO_2} \) and \( H^+ \)

**Sensors:**
1. Central chemoreceptors
   - Part of medulla oblongata respiratory centre,
   - Respond to changes in \([H^+]\) and \( P_{CO_2} \)
PO₂ and ventilation

A decrease in PO₂ stimulates an increase in ventilation

\[ \downarrow \text{Inspired PO}_2 \] 
\[ \downarrow \text{alveolar PO}_2 \] 
\[ \downarrow \text{arterial PO}_2 \] 
\[ \uparrow \text{Activity of peripheral chemoreceptor} \] 
\[ \uparrow \text{Contraction of respiratory muscles} \] 
\[ \uparrow \text{ventilation} \] 
\[ \uparrow \text{Alveolar & arterial PO}_2 \]

CO₂ and ventilation

\[ \text{CO}_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \]

If P₇CO₂ is high this reaction proceeds to the right

- increasing ventilation decreases P₇CO₂ & brings this reaction back to the left

CO₂ and ventilation

- Increased P₇CO₂ drives increased breathing
- Very sensitive – even small changes on CO₂ will effect breathing frequency
Activity of peripheral chemoreceptor

↑ Activity of central chemoreceptor

↑ Contraction of respiratory muscles

↑ ventilation

Return alveolar & arterial PCO2 to normal

Return arterial and brain [H+] to normal

This is important because CO2 can cross the blood-brain barrier, but H+ cannot.

H+ changes not related to CO2

- Metabolic acidosis/alkalosis
  - Ingestion of acid
  - Lactic acid production
  - Vomiting (loss of acid)
- Only through peripheral chemoreceptor

↑ Production of acid

↑ Arterial H+

↑ Activity of peripheral chemoreceptor

↑ Contraction of respiratory muscles

↑ ventilation

↓ alveolar PCO2

↓ arterial PCO2

Return H+ toward normal

How does central chemoreceptor work?

CO2 → CO2 + H2CO3

HCO3- + H+ → CO2 + H2O

Chemoreceptor neuron

Output to respiratory control centre, ↑ breathing

Calcium increases neurotransmission

Depolarization
• Exercise
  – The increase in ventilation during exercise is not easily explained by O₂, CO₂ regulation
  – Exercise
    • increased O₂ consumption and CO₂ production
    • But these changes are in the venous, not the arterial blood
    • During moderate exercise arterial PO2 and PCO2 are normal
    • Receptors are measuring arterial blood
  – Other factors:
    • Increase in H+ during strenuous exercise
    • Input from motor cortex of brain to respiratory centre
    • Receptors from muscles and joints
    • Epinephrine
    • Body temperature

• Longer term acclimatization:
  • eg high altitude is like chronic hypoxia

• Since \( P_{atm} \) goes down, \( P_{O2} \) goes down
  – Initial responses the same as acute hypoxia
  – Longer term changes include:
    1. Increased red blood cell production
    2. Shift in Hb saturation curve to unload more O₂
    3. Increased capillary density to increase delivery
    4. Decreased plasma volume (increases Hb concentration)

The End

Exam Structure

Saturday Dec 16, 4-7 pm CC1080

5 written questions
21 multiple choice
3 hour time slot
You do not need a calculator
• Office hours:
  – Thursday 1-2pm - class is cancelled
  – I am usually on campus
  – NOT here Friday Dec 10, or Friday Dec 15
  – If you want to make sure to see me, email for an appointment
  – Email questions

What you need to know for the final
Renal (5 lectures)
1. Basic fluid stuff – distribution of fluid in the body
2. Renal Processing
   a) Filtration
   b) Reabsorption
3. Formation of dilute and concentrated urine and regional differences in nephron tubules
4. Control of Renal blood flow and GFR
   a) autoregulation
   b) SNS
   c) Hormonal – AngII, ANP
5. Sodium and Water
   a) SNS – GFR & renin-secretion
   b) Renin, AngII, aldosterone system
   c) ANP – multiple effects
   d) ADH – aquaporin channels
6. Acid-Base
   a) Buffer systems: bicarbonate, phosphate, ammonia
   b) respiratory

What you need to know for the final
Respiratory (4 lectures)
1. Ventilation and mechanics of breathing
   a) compliance
   b) Surface tension
   c) Resistance
   d) Lung volumes
   e) Alveolar ventilation
2. Gas exchange
   a) Partial pressure of gas
   b) Driving pressures for gas exchange in alveoli and tissue
   c) Factors affecting alveolar gas pressure (Patm, ventilation, use/production by cells)
3. Gas Transport
   a) Hb and Oxygen, saturation
   b) Carbon dioxide
4. Controls
   a) P_{O2}
   b) P_{CO2}
   c) H+ (acid-base balance)

• What are the key variables?
  – Water
  – Na
  – Acid

• What are the sensors?
  – Atrial stretch receptors – blood volume
  – Osmoreceptors – blood osmolarity
  – Macula densa – tubular osmolarity
  – Acid – chemoreceptors (respiratory)
• What are the key variables?
  – \( P_{\text{O}_2} \)
  – \( P_{\text{CO}_2} \)
  – Acid
• What are the sensors?
  – Central Chemo – \( P_{\text{CO}_2}, H^+ \)
  – Peripheral Chem - \( P_{\text{O}_2}, P_{\text{CO}_2}, H^+ \)

• What is the challenge?

• Which sensors detect the challenge?

• How do the sensors respond to a challenge?

• Remember the physiology is always set up to bring the variables back toward normal

Questions you should know how to answer

1. How does the kidney produce concentrated (dilute) urine?
   1. What is important about the different regions of the nephron?
2. What is the relationship between sodium and water? How does the kidney handle sodium and water?
   1. How does the system respond to:
      1. Increased (decreased) water volume?
      2. Increased (decreased) sodium concentration
   3. How does the kidney contribute to acid balance?

Questions you should know how to answer

1. What is the relationship between compliance, surface tension, and ventilation?
   • What happens if compliance or surface tension go up (down)
2. What is the relationship between ventilation and alveolar gas pressure?
3. What is the relationship between blood flow and airflow in the alveoli?
4. How are gases transported in the blood
   • What is the role of hemoglobin?
5. How does the respiratory system respond to increased (decreased) \( P_{\text{O}_2}, P_{\text{CO}_2}, H^+ \)?