Online Physiology 2130 – The Respiratory System

Introduction

Hey! Thanks for opening up this Physiology 2130 resource, and welcome. The education team at WebStraw has put together comprehensive review sheets for you that cover all the major learning outcomes for the **Respiratory System of Physiology 2130**.

Members of our team have taken the course in previous years, and we understand better than anyone else what specific ideas and concepts tend to trip students up throughout the course. **We are able to essentially offer you the key takeaways from the course after having completed the course ourselves**. We also have representatives currently enrolled in the course as well to keep us up to date on specific topic coverage.

Before you read further, also keep in mind that **these resources are not meant to be a tool for you to learn the course from scratch**. The content presented below was designed with the assumption that you already have a preliminary understanding of the course content. Our goal is to provide you with **a resource in order to quickly review key concepts and easily refer to course content**. We have added a few questions for each module in order to give you some practice and a feel for exam type questions. Please refer to the course material provided by your instructors if there are any discrepancies between the content found in these review sheets and the course content.

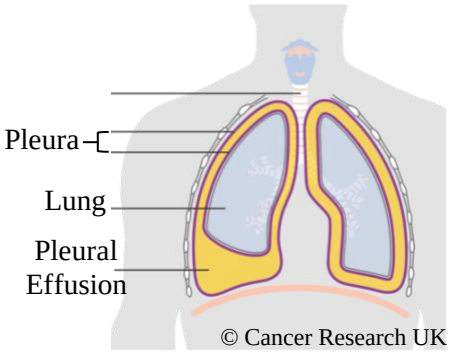
With that said, best of luck in your studying! Remember to make good use of your time, but to also take breaks as well.

The WebStraw Education Team

Module 10 – The Respiratory System

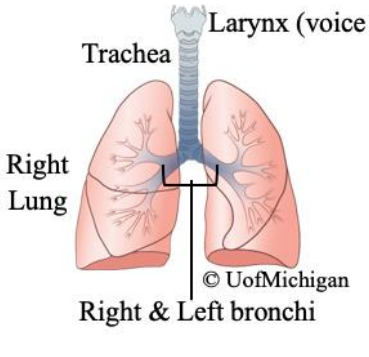
Principle Functions

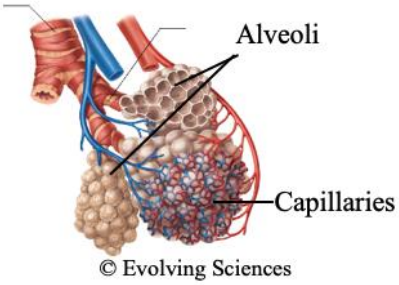
1. Transports oxygen from air into blood
2. Removes CO_2 from blood
3. Controls blood acidity (pH)
4. Regulates temperature
5. Forms line of defense against airborne particles



Anatomy

- Located in thoracic cavity – surrounded by rib cage and diaphragm
- Bronchi → bronchioles → alveoli
- Pleural membranes (parietal sticks to ribs and visceral lines lungs) – secrete lubricating fluid





Pressures of the Lungs

1. **Alveolar (intrapulmonary) Pressure (AP)** – inside lungs
2. **Intrapleural Pressure (IP)** – in intrapleural space (756 mmHg)
   - Between breaths, atmospheric pressure = alveolar pressure = 760 mmHg
   - Chest wall & lungs moving in opposite directions causes lower intrapleural pressure

Transpulmonary Pressure – holds the lungs open

$$TP = AP - IP$$

Pneumothorax

- No pressure holding lungs open → collapse
- Occurs when intrapleural space is punctured
  - AP = IP = 760 mmHg
- Only one lung collapses because intrapleural spaces of lungs are isolated from each other

	Inspiration	Expiration (at rest)	Expiration (during exercise)
Muscles involved	Diaphragm contracts downwards External intercostal muscles of rib contract, lift ribcage up and out	Diaphragm and external intercostal muscles relax (lungs recoil to orig. size)	Abdominal and internal intercostal muscles contract
Pressure gradient	Alveolar < Atmospheric (lung volume increases)	Alveolar > Atmospheric (lung volume decreases)	Alveolar > Atmospheric (lung volume decreases more)

Boyle's Law – important for pulmonary ventilation

$$\text{Pressure} \propto \frac{1}{\text{Volume}}$$

Pulmonary Compliance – stretchability of lungs

$$\text{Compliance} = \frac{\text{Volume Change}}{\text{Pressure Change}}$$

*determines the ease of breathing

Surface Tension Explained

- Force developed at the surface of a liquid due to attractive forces between water molecules
- Tends to collapse the alveoli, decreasing compliance and making inflation difficult
- Contributes to ***2/3*** of total compliance

Factors influencing Compliance of the lung

1. Amount of elastic tissue found in walls of alveoli, blood vessels and bronchi
   a. Elastin fibers easily stretched but collagen fibers are not
   b. Contributes to ***1/3*** of total compliance
2. Surface tension of the film of liquid that lines all the alveoli

*Both decrease compliance

Pulmonary Surfactant

- Lipoprotein substance produced by type II (or great) alveolar cells
- Consist mostly of phospholipids (hydrophilic head and hydrophobic tail)
- Balances attractive forces at air-water interface and reduces surface tension

	Tidal Volume (TV)	Inspiratory Reserve Volume (IV)	Expiratory Reserve Volume (EV)	Residual Volume (RV)	Inspiratory Capacity (IC)	Functional Residual Capacity (FC)	Vital Capacity (VC)	Total Lung Capacity
Definition	Volume of air entering/ leaving lungs during one breath at rest	Maximum amount of air that can enter the lungs in addition to the tidal volume	Maximum amount of air that can be exhaled beyond the tidal volume	Remaining air in the lungs after a maximal expiration	Maximum amount of air that can be inhaled after exhaling the tidal volume	Maximum amount of air that can be exhaled after a maximal inhalation	Maximum amount of air that can be exhaled after a maximal inhalation	Max amount of air that the lungs can hold
Quantity	500 ml	2500 ml	1000 ml	1200 ml	TV + IV	EV + RV	IV + TV + EV	VC + RV

Pulmonary Ventilation (VE)

- Amount of air that enters all of the conducting & respiratory zones in one minute

VE = tidal volume (ml) x respiratory rate (breaths/min)

Alveolar Ventilation (VA)

- Volume of air entering only the respiratory zone per minute
- Represents the volume of fresh air available for gas exchange

VA = VE - VD

Conducting Zone (VD) aka anatomical dead space

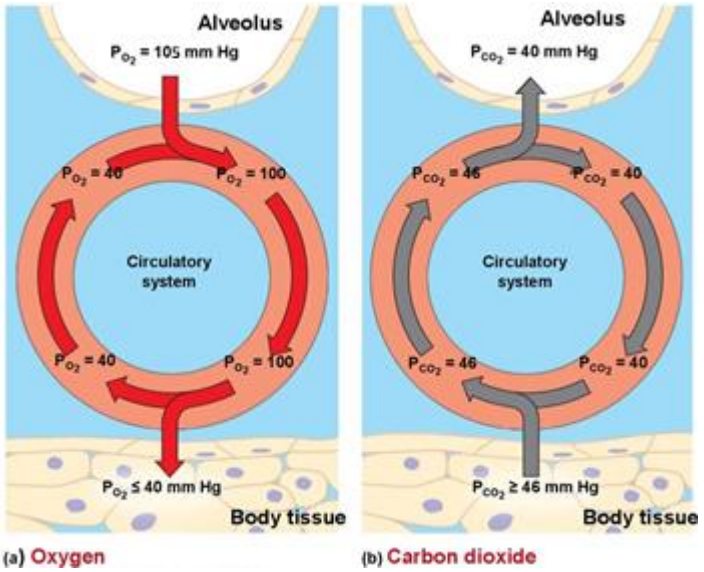
- Area of lungs where no gas exchange takes place due to lack of alveoli
- Volume (ml) approximately equal to person's body weight (lbs)

Partial Pressures

- The pressure exerted by one gas in a mixture of gases
- Partial pressure of O_2 or CO_2 in blood refers to the amount of these gases dissolved in the plasma

Partial pressure of A (mmHg) = $P_{total\ (gas\ mixture)}$ x X_A (fractional concentration of A)

Partial Pressures Throughout Circulatory System



Erythropoietin (EPO)

- A hormone that stimulates bone marrow to produce red blood cells (RBCs)
- Secreted by kidneys & liver (90% & 10%)
- Usually secreted in low amounts to account for RBCs lost daily
- When levels of O_2 to kidneys drop, EPO secretion increases
- Testosterone stimulates EPO secretion; males have more RBCs per cubic millimeter than females

Red Blood Cell Production (Erythropoiesis)

- Erythropoiesis takes place in bone marrow
- Requires:
  - ***Amino acids and iron*** – important components of hemoglobin
  - ***Folic acid*** – needed for formation of new DNA and normal cell division
  - ***Vitamin B12*** – small amount needed to allow folic acid to function

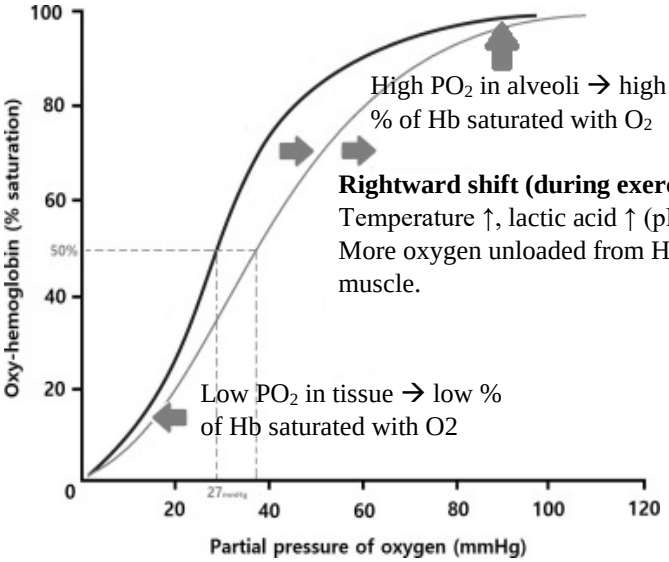
Hemoglobin (Hb)

- Each Hb molecule has 4 subunits
- Each subunit has 1 heme molecule attached to a polypeptide
- Each heme molecule can carry 1 O_2 attached to the central iron (Fe) atom
  - Iron gives blood its red colour

Transport of O_2 in Blood

- Small amount (1.5%) of O_2 dissolved in plasma
- 98.5% of O_2 carried in red blood cells is attached to hemoglobin
- Each hemoglobin molecule can carry 4 O_2 molecules
- Oxygen binds with hemoglobin in a reversible reaction to produce oxyhemoglobin: $Hb + O_2 \rightleftharpoons HbO_2$
- PO_2 high in lungs → O_2 will bind Hb
- PO_2 low in tissue → O_2 will unload from HbO_2

Oxyhemoglobin Dissociation Curve



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Carbon Dioxide Transport

- 7-10% of CO_2 can be dissolved & carried directly in plasma (PCO_2)
- 70% of CO_2 can be carried as a bicarbonate ion (HCO_3^-)
  - The H^+ binds Hb inside RBCs (would otherwise make blood too acidic)
    - HCO_3^- diffuses out of RBCs into the plasma to act as a buffer to stabilize blood pH
    - Cl^- diffuses into RBCs to balance the positive charge → **chloride shift**

$$CO_2 + H_2O \xrightleftharpoons{\text{Carbonic anhydrase}} H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

- 20-23% of CO_2 can be attached to proteins in blood, forming carbamino compounds
  - CO_2 attaches with the globin portion of hemoglobin → **carbamino hemoglobin**
    - $Hb + CO_2 \rightleftharpoons HbCO_2$ (reversible reaction)
  - $HbCO_2$ returns to lungs via RBCs, CO_2 detaches from Hb & diffuses out into alveolar space

Medullary Respiratory Center

- Spontaneous respiration originates in medullary respiratory center of medulla oblongata in brainstem
- **Inspiratory center:**
  - Active process → contraction of diaphragm and external intercostal muscles
  - Inhibits expiratory center
- **Expiratory center:**
  - Quiet exhalation is passive → relaxation of inspiratory muscles
  - Forceful exhalation is active → contraction of abdominal muscles & internal intercostal muscles
    - Inhibits inspiratory center

Apneustic and Pneumotaxic Centers

- Special regions in the pons able to modify spontaneous signals from medullary centers
- **Pneumotaxic center** – regulates rate of breathing
- **Apneustic center** – controls depth of inhalation/exhalation
- Pons centers work together to ensure ventilation is smooth and coordinated
- **Cerebral cortex** – site of voluntary ventilation. Affects signals from apneustic & pneumotaxic centers to modify ventilation

Peripheral Chemoreceptors	Central Chemoreceptors
• Located in aortic arch and carotid sinus • Primarily sensitive to O_2 concentrations & slightly sensitive to CO_2 concentrations in blood • Send signals to the brain when there are small drops in O_2 or large increases in CO_2 • Respiratory center will initiate increase in ventilation (negative feedback loop)	• Located in medulla • Sensitive to H^+ levels in interstitial space of brain • H^+ cannot diffuse past blood brain barrier, CO_2 can • CO_2 then reacts with water to produce H^+, which can be detected ($CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$) • Increase in CO_2 will increase H^+ → chemoreceptors will send signals to respiratory center to increase ventilation

Review Questions

1. Which of the following is FALSE regarding respiration?
   a. It can be spontaneous.
   b. It is controlled by the medulla oblongata.
   c. It can be voluntary.
   d. It can be controlled by the cerebral cortex.
   e. The inspiration area signals to the diaphragm to relax.

2. Which of the following is FALSE regarding Boyle's Law?
   a. It is important for ventilation.
   b. If pressure increases, then volume also increases.
   c. If the volume of a container increases, then the pressure decreases.
   d. As the lungs inflate, the pressure decreases.
   e. During exhalation, the pressure in the lungs is relatively high compared to atmospheric pressure

3. Which of the following scenarios promote inspiration?
   a. Atmospheric pressure = 760 mmHg; intrapleural pressure = 757 mmHg
   b. Atmospheric pressure = 760 mmHg; intrapleural pressure = 763 mmHg
   c. Relaxed Diaphragm
   d. Relaxed external intercostal muscles

4. A baby was born premature and is having difficulty breathing, due to decreased compliance of the lungs. Which of the following treatments will NOT help promote breathing for the baby?
   a. A safe drug that will reduce the number of collagen molecules in the alveoli
   b. Artificial surfactant
   c. A safe drug that will reduce the number of elastin molecules in the alveoli
   d. Moving the baby to an area with low atmospheric pressure
   e. Moving the baby to an area with high atmospheric pressure

5. Which of the following is TRUE regarding erythropoietin (EPO)?
   a. The liver secretes the majority of EPO
   b. EPO is only secreted when O_2 levels drop
   c. EPO secretion is halted when O_2 levels drop
   d. Testosterone stimulates EPO secretion
   e. Estrogen stimulates EPO secretion

6. Which of the following is FALSE regarding chemoreceptors?
   a. Peripheral chemoreceptors are located in the aortic arch and carotid sinus
   b. Central chemoreceptors are located in the medulla
   c. Central chemoreceptors sense H^+ ions that diffuse across the blood brain barrier
   d. Peripheral chemoreceptors are primarily sensitive to O_2
   e. Both peripheral and central chemoreceptors can send signals to increase ventilation

7. What is the approximate alveolar ventilation of an individual who has a tidal volume of 500 ml, a respiratory rate of 15 breaths/min, and weighs 190 lbs?
   a. 94985 ml
   b. 7310 ml
   c. 705 ml
   d. 2350 ml
   e. 7690 ml

Answer Key:
1. E 2. B 3. A 4. D 5. D 6. C 7. B