NOTES: CH 42, part 2 - Gas Exchange in Animals
Functions of the Respiratory System:

1) **Air distribution / gaseous exchange**;
2) Filter, warm & humidify air we breathe;
3) Influence speech;
4) Help maintain body’s pH;
5) Make sense of smell possible.
Gas exchange supplies $O_2$ for cellular respiration and disposes of $CO_2$. 
ORGANS OF THE RESPIRATORY SYSTEM

*The organs of the respiratory system can be divided into two groups:

1) **Upper Respiratory Tract:** nose, nasal cavity, sinuses, pharynx

2) **Lower Respiratory Tract:** larynx, trachea, bronchial tree, lungs, alveoli
SUMMARY OF PATHWAY OF AIR (OXYGEN) IN THE RESPIRATORY SYSTEM:

Nostrils
↓
Nasal cavity
↓
Pharynx
↓
Glottis/epiglottis
↓
Larynx
Trachea

Bronchi

Bronchioles

Alveoli

Blood (capillaries)

Body cells
• **NOSE**

- supported by bone and cartilage

- openings for air: **NOSTRILS**
NASAL CAVITY

- lined with mucous membrane to filter, warm, and moisten incoming air

- CILIA carry particles trapped in the mucus to the pharynx, where they are swallowed
SINUSES

spaces in the bones of the skull that open into the nasal cavity

lined with mucous membranes
PHARYNX

→ behind the oral cavity; between the nasal cavity and the larynx

→ a.k.a. the “throat”
LARYNX

- conducts air and prevents foreign particles from entering trachea
- composed of muscles and cartilage; lined with mucous membrane
- the **GLOTTIS** and **EPIGLOTTIS** help prevent foods and liquids from entering the trachea
- contains the **VOCAL CORDS**
**VOCAL CORDS** vibrate from side to side and produce sounds when air passes between them.
• TRACHEA

→ extends into the thoracic cavity; in front of the esophagus

→ divides into R and L BRONCHI
• **BRONCHIAL TREE**

- consists of branched air passages that lead from the **trachea** to the **air sacs**

- **ALVEOLI** are at the distal ends of the narrowest tubes, the **ALVEOLAR DUCTS**
**ALVEOLI**: humans have approx. 300,000,000 of these microscopic air sacs; walls are only 1-2 cells thick.
ALVEOLI

- $\text{O}_2$ dissolves in moist film covering epithelium & diffuses across to the capillaries covering each alveolus;
- $\text{CO}_2$ moves in opposite direction
- LUNGS

- enclosed by the **DIAPHRAGM** and the thoracic cage

- closely surrounded by the **PLEURAE**
- **VISCERAL PLEURA**: attaches to the surface of the lungs

- **PARIETAL PLEURA**: lines the thoracic cavity

- **PLEURAL CAVITY**: the space between the two pleurae; contains fluid to lubricate and cushion lungs during breathing; fluid also holds the two pleurae together which aids in breathing
COMPONENTS OF THE PULMONARY / RESPIRATORY SYSTEM (Source: http://webschoolsolutions.com/patts/systems/lungs.htm)
Gas Exchange and Transport

Atmosphere

Alveoli

De-oxygenated blood

Pulmonary circulation
ALVEOLAR GAS EXCHANGES

*Gas exchange between air and blood occurs in the alveoli.
ALVEOLAR GAS EXCHANGES

- Gases ($O_2$ and $CO_2$) diffuse from regions of **HIGH concentration** (and partial pressure) to regions of **LOW concentration** (partial pressure)

- **OXYGEN** diffuses from alveolar air into blood

- **CARBON DIOXIDE** diffuses from blood into alveolar air
<table>
<thead>
<tr>
<th>Gas</th>
<th>Partial Pressure in Blood</th>
<th>Action</th>
<th>Partial Pressure in Alveolar Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>45 mm Hg</td>
<td>exit</td>
<td>40 mm Hg</td>
</tr>
<tr>
<td>Oxygen</td>
<td>40 mm Hg</td>
<td>enter blood</td>
<td>104 mm Hg</td>
</tr>
</tbody>
</table>
GAS TRANSPORT IN THE BLOOD / BODY

*Blood transports gases between the lungs and body cells.
OXYGEN TRANSPORT:

- oxygen binds to the protein **hemoglobin** in the blood (RBCs)

- the resulting molecule, oxyhemoglobin, is unstable and readily releases oxygen in regions where $P_{O_2}$ is low
more oxygen will be released from oxyhemoglobin when:

- CO₂ levels in the blood increase
- blood becomes more acidic
- blood temperature increases
CARBON DIOXIDE TRANSPORT:

- Carbon dioxide may be carried:
  - In solution
  - Bound to hemoglobin (different spot on molecule than where oxygen binds)

**As a bicarbonate ion \((HCO_3^-)\) … Most \(CO_2\) is in this form!
CARBON DIOXIDE TRANSPORT:

- Carbon dioxide reacts with water to form carbonic acid:

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \]
CARBON DIOXIDE TRANSPORT:

- carbonic acid dissociates to release hydrogen ions and bicarbonate ions:

\[ \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^- \]
Aqueous phase of blood cells passing through capillaries in lung

Air space in lung
Control of Breathing:
*Normal breathing is rhythmic and involuntary.*
Respiratory Center:

- the respiratory center is in the **brain stem** and includes portions of the **pons** and **medulla oblongata**
FACTORS AFFECTING BREATHING:

1) respiratory center in the brain
2) chemical concentrations (gases, ions, pH, etc.)
3) stretching of lung tissue
4) emotional state
EXAMPLES:

*when chemoreceptors in the walls of certain large arteries detect low O$_2$ levels (or high CO$_2$ levels), breathing rate increases

*fear and pain typically increase the normal breathing pattern
CONTROL OF BREATHING

-medulla control center also monitors blood biochemistry & pH of the spinal fluid;

-as blood CO\textsubscript{2} concentrations increase, the pH drops (CO\textsubscript{2} combines with water to form carbonic acid);

-when the medulla senses the drop in pH, the rate & depth of breathing are increased & excess CO\textsubscript{2} is removed in the exhaled air
CONTROL OF BREATHING

-when oxygen concentration in blood becomes very low, oxygen sensors in aorta and carotid arteries send signals to the medulla and pons, which respond by increasing the breathing rate.
CONTROL OF BREATHING

-breathing is an automatic action
-we inhale when nerves in the “breathing centers” of the medulla oblongata & pons send impulses to the rib muscles or diaphragm stimulating the muscles to contract
-when muscles contract, the volume of the chest cavity expands, pressure decreases, air from outside rushes in
-this happens approx. 10-14 times per minute

“Negative Pressure Breathing”
Breathing Mechanism
*Changes in the size of the thoracic cavity accompany **INSPIRATION** (inhaling) and **EXPIRATION** (exhaling).
Pressure...

* **ATMOSPHERIC PRESSURE** (the “weight” of the air) is the force that moves air into the lungs.

* Air (gases) move from regions of **HIGH PRESSURE** to regions of **LOW PRESSURE**
INSPIRATION:

• if the pressure inside the lungs/alveoli decreases, atmospheric pressure will force air into the lungs
INSPIRATION:

How does the pressure inside the lungs decrease???

> Diaphragm contracts (moves downward)

> Thoracic cage moves upward and outward (external intercostal muscles contract)
The diaphragm is shaped like a parachute.
INSPIRATION:

→ the **INCREASE IN VOLUME** of the thoracic cavity causes a **DECREASE IN PRESSURE**
INSPIRATION:

• as the walls of the thoracic cavity expand, they pull on the parietal pleura
• the serous fluid in the pleural cavity holds the pleural membranes tightly together (*much like a wet microscope slide will stick to another microscope slide*)
• as the parietal pleura is pulled outward, the visceral pleura follows…
INSPIRATION:

- the lungs expand in all directions and air is pulled inward!!

**for a deeper breath, the diaphragm and intercostals muscles contract with more force**
EXPIRATION:

• the forces for normal exhalation come from **ELASTIC RECOIL** of tissues

• the opposite pressure and volume changes occur...pressure inside the lungs increases and forces air out
EXPIRATION:

How does the pressure inside the lungs increase???

> Diaphragm relaxes (moves upward)

> External intercostals muscles relax; thoracic cage moves downward and inward
EXPIRATION:

- Lungs and thoracic cage recoil and return to their original shape.

- the **DECREASE IN VOLUME** of the thoracic cavity causes an **INCREASE IN PRESSURE**.

- *air is forced out!!*
RESPIRATORY AIR VOLUMES AND CAPACITIES:

*the amount of air inhaled and exhaled depends upon size, activity level and state of health.
TIDAL VOLUME = volume of air an animal inhales & exhales with each breath during normal, quiet breathing
(Average = 500 mL in humans)
RESPIRATORY AIR VOLUMES AND CAPACITIES:

• even after forceful expiration, some air remains in the lungs (RESIDUAL VOLUME) …why?

-so that lungs don’t collapse! (alveoli always stay partially inflated)

-prevents the O₂ and CO₂ levels from fluctuating greatly (“new” air always mixes with “old” air)
RESPIRATORY AIR VOLUMES AND CAPACITIES:

- **VITAL CAPACITY** = maximum air volume that can be inhaled & exhaled during forced breathing

  (Average = 3400-4800 mL in humans)

- loss of lung elasticity may result in collapse of bronchioles during exhalation

- emphysema causes a decrease in vital capacity
TOTAL LUNG CAPACITY = VITAL CAPACITY + RESIDUAL VOLUME

**all of these volumes/capacities vary with age, sex, and body size**
Vital capacity
NONRESPIRATORY MOVEMENTS: used to clear passageways, or to express emotion

• COUGH -
  -may be produced through conscious effort
  -may be triggered by the presence of a foreign object
  -clears the object from the lower respiratory tract
• **SNEEZE** -
-cleans the **upper respiratory tract**
-a reflex triggered by a mild irritation in the lining of the nasal cavity
-can propel a particle at 200 miles per hour!
• **LAUGHING** - involves taking a breath and releasing it in a series of short expirations

• **CRYING** - similar to laughing in terms of mechanism

• **HICCUP** - a sudden inspiration to a spasmodic contraction of the diaphragm

• **YAWN** - may aid respiration by providing an occasional deep breath
Disorders and Diseases of the Respiratory System:

• **Asthma**

• **Emphysema**
Disorders and Diseases of the Respiratory System:

- **Cancer**

- **Cystic fibrosis**

  Cystic fibrosis is a hereditary disorder characterized by lung congestion and infection and malabsorption of nutrients by the pancreas.
Disorders and Diseases of the Respiratory System:

- Tuberculosis (TB)
- Pneumonia
- Common cold
Disorders and Diseases of the Respiratory System:

- **Flu**

- **Whooping cough**

- **Plague**
Disorders and Diseases of the Respiratory System:

• Strep throat
Disorders and Diseases of the Respiratory System:

- **Bronchitis / laryngitis**

  ![Normal bronchi](image1.png) ![Bronchitis](image2.png)  
  ![Normal vocal chords](image3.png) ![Inflamed vocal chords](image4.png)