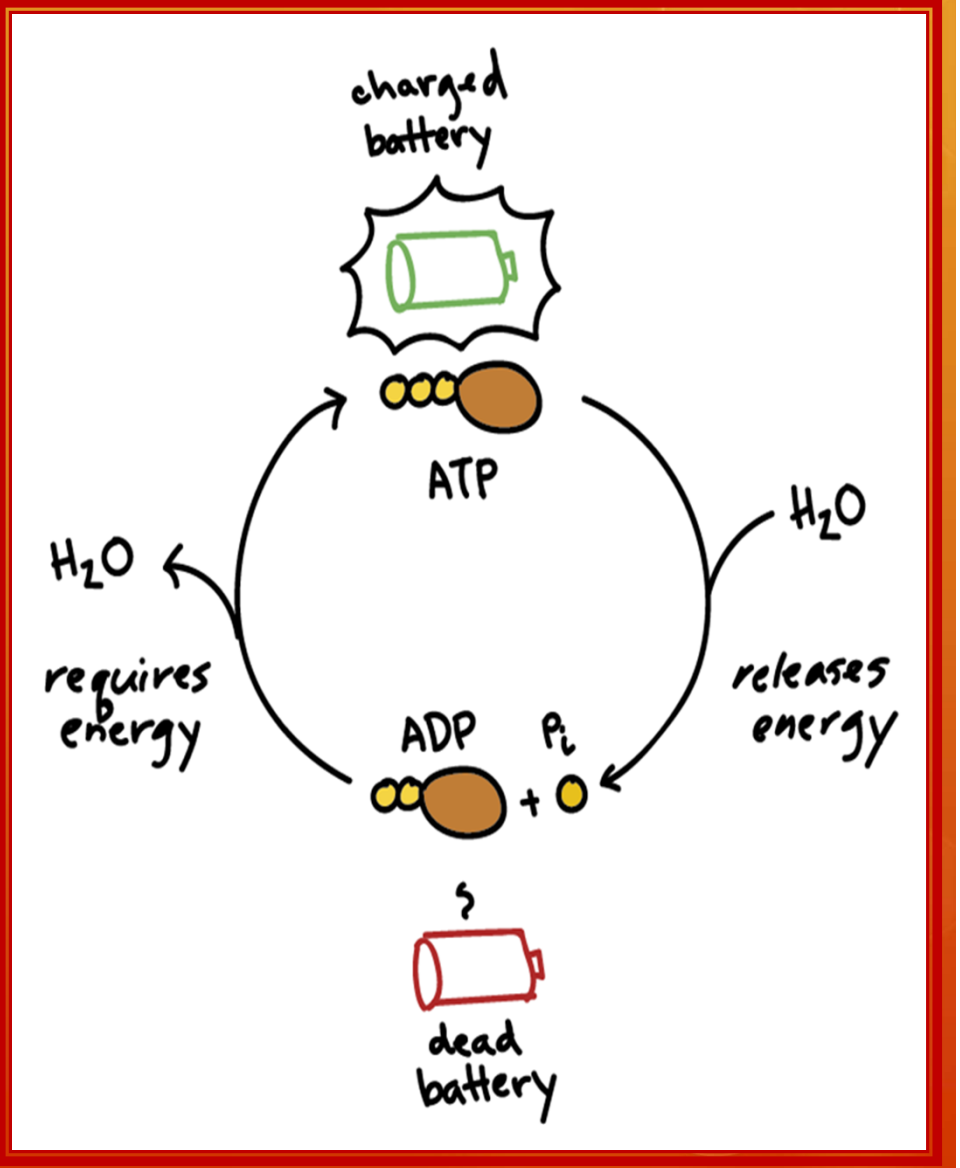
Cellular Respiration and the Human Respiratory System

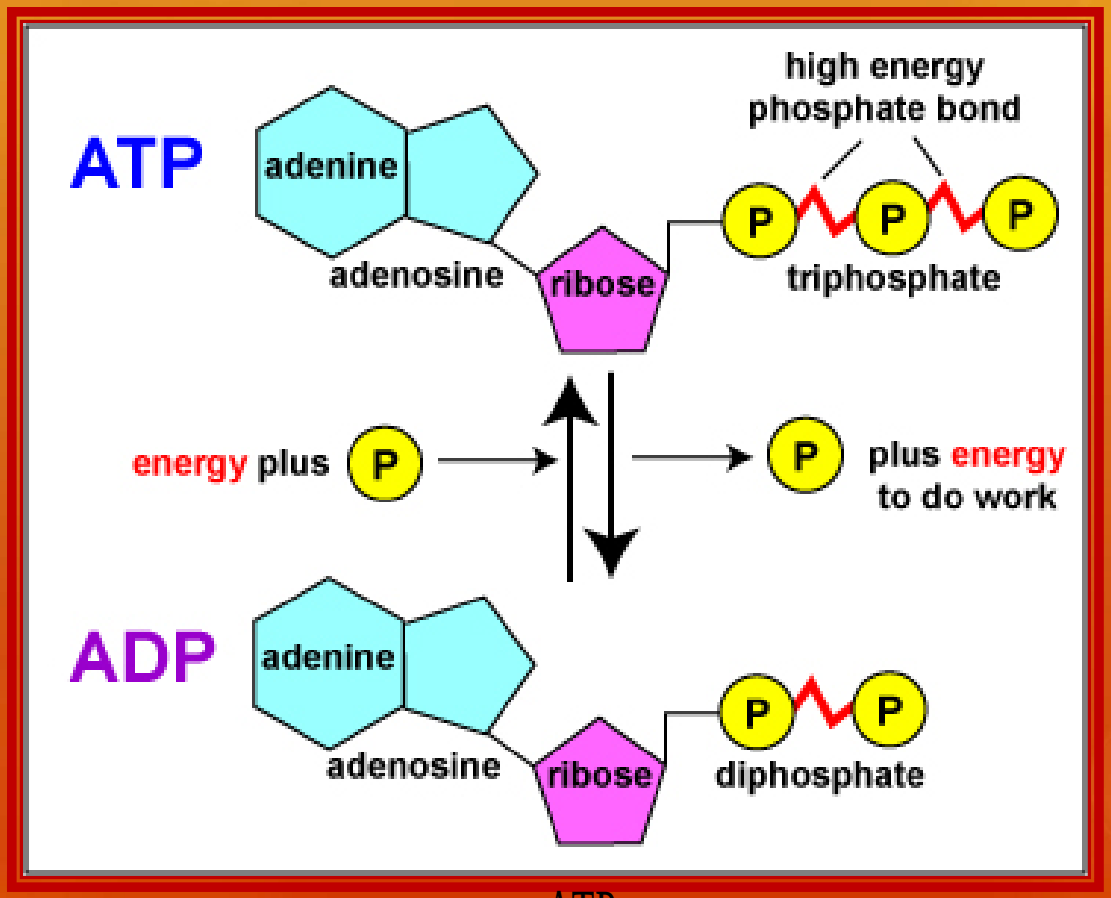
What is Cellular Respiration?

- Enzyme controlled process that transfers chemical bond energy of food molecules such as glucose to a more available form of energy for the cell.
- Energy is stored in the bonds of the glucose molecules. When these bonds are broken, energy is released. This energy is then transferred onto energy carrying molecules called ***ATP*** *(Adenosine Tri-Phosphate).*
- The role of ATP can be compared to that of a "battery".



Adenosine Tri Phosphate (ATP)

- The key to ATP's usefulness is in high energy bonds that attach to the three phosphate groups

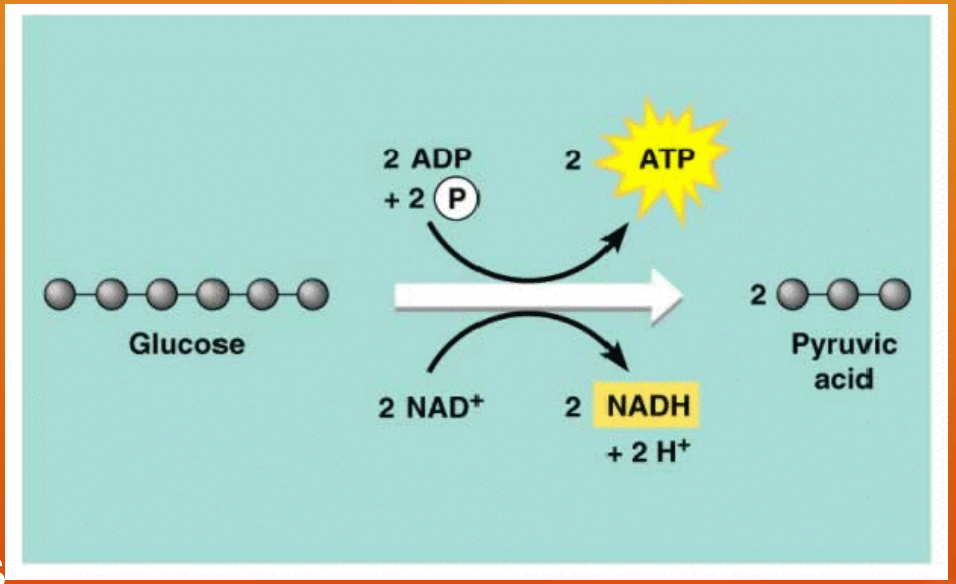


ATP-ase

$$ADP + P + energy \rightleftharpoons ATP + H_2O$$

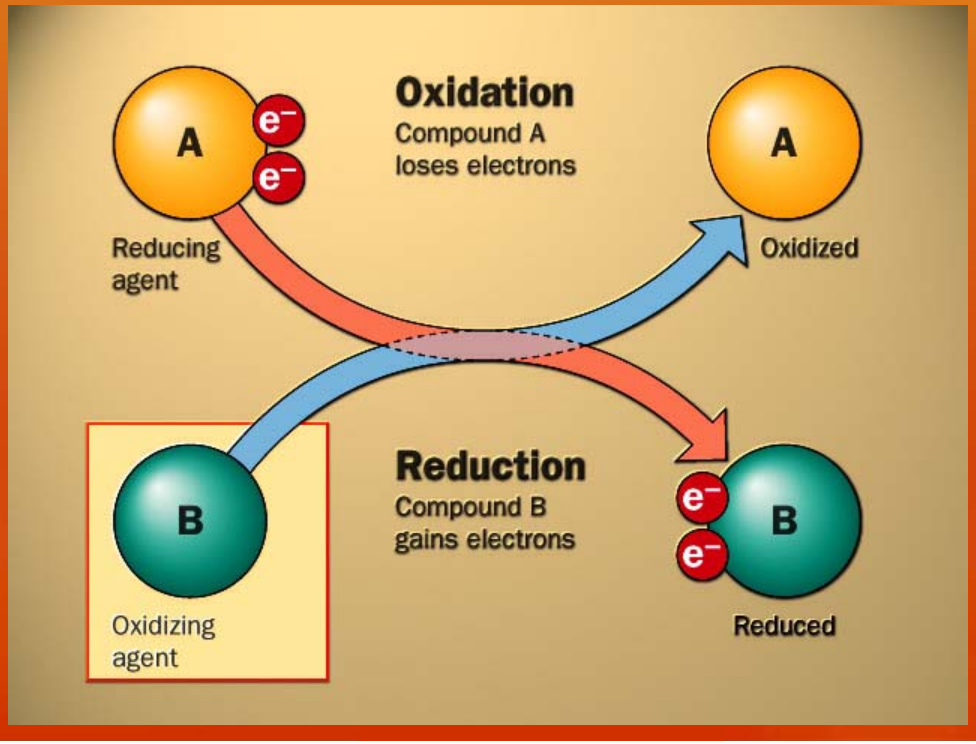
Glycolysis

- Cell respiration begins with **GLYCOLYSIS,** the process by which one molecule of glucose is broken in half to produce two molecules of **pyruvic acid**, a 3 carbon compound.
- Takes place in the **cytoplasm** of the cell
- **2 ATP** are required to get the reaction started
- End products are 2 molecules of pyruvic acid and **4 ATP.**
- Produces a net of 2 **ATP** molecules from the breakdown of 1 glucose molecule.
- Although the energy yield is small, the process of glycolysis is very fast. Thousands of ATP molecules can be produced by cells in a few milliseconds.
- This process **DOES NOT** require oxygen.



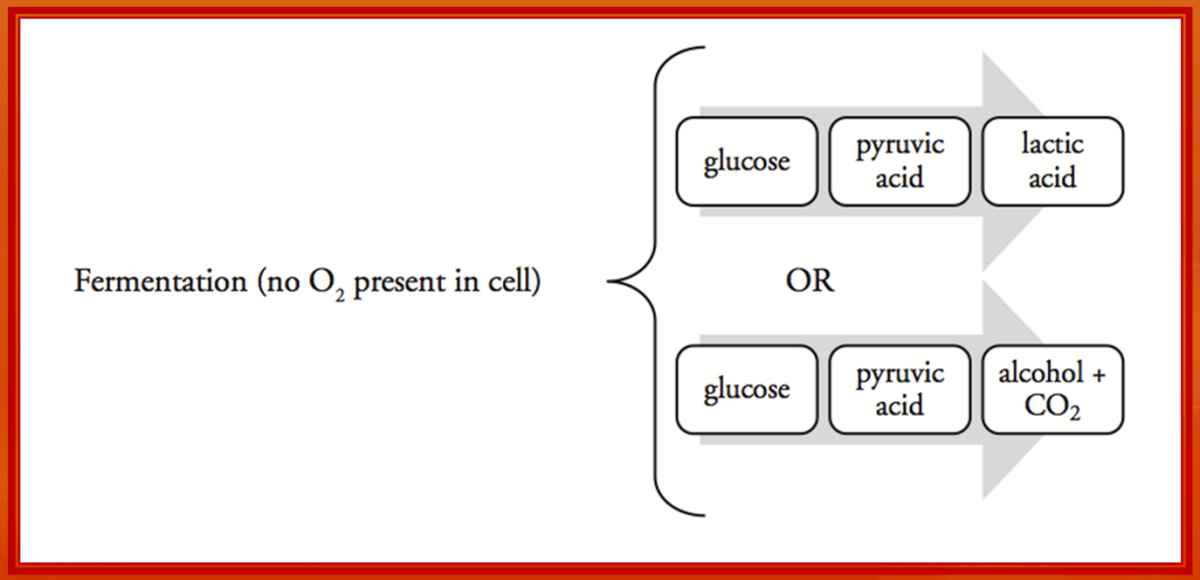
REDOX Reactions

- Oxidation: whenever you remove a hydrogen atom and/or its electron from a substance you are **oxidizing** that substance.
- Reduction: whenever you add a hydrogen atom and/or its electron to a substance you are **reducing** that substance.
- Memory devices: **OIL RIG** or **LEO says GER**



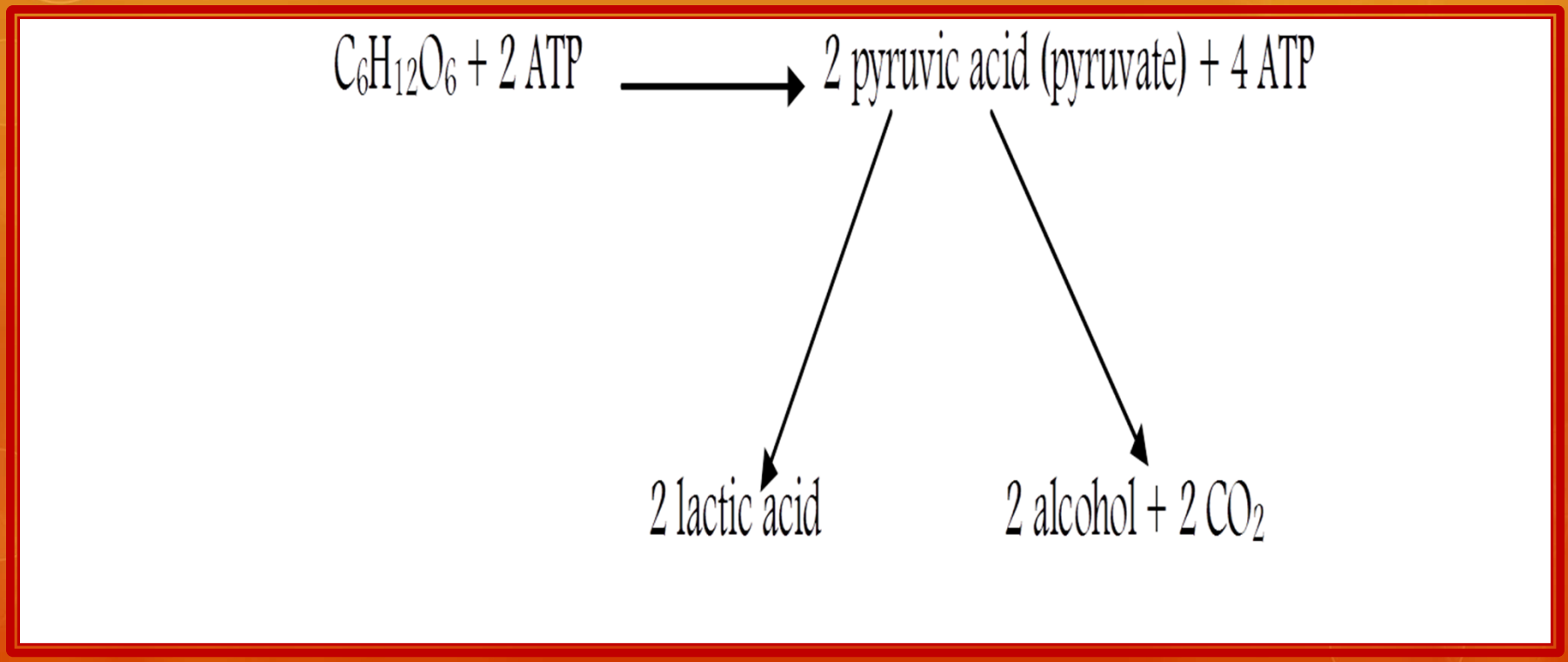
Anaerobic Respiration

- Follows glycolysis when there is **NO** oxygen
- Often referred to as **FERMENTATION**
- Takes place in the cytoplasm of the cell
- Fermentation further breaks down pyruvic acid (pyruvate) **WITHOUT** making any additional ATP
- **There are two main types of fermentation: lactic acid fermentation and alcoholic fermentation.**



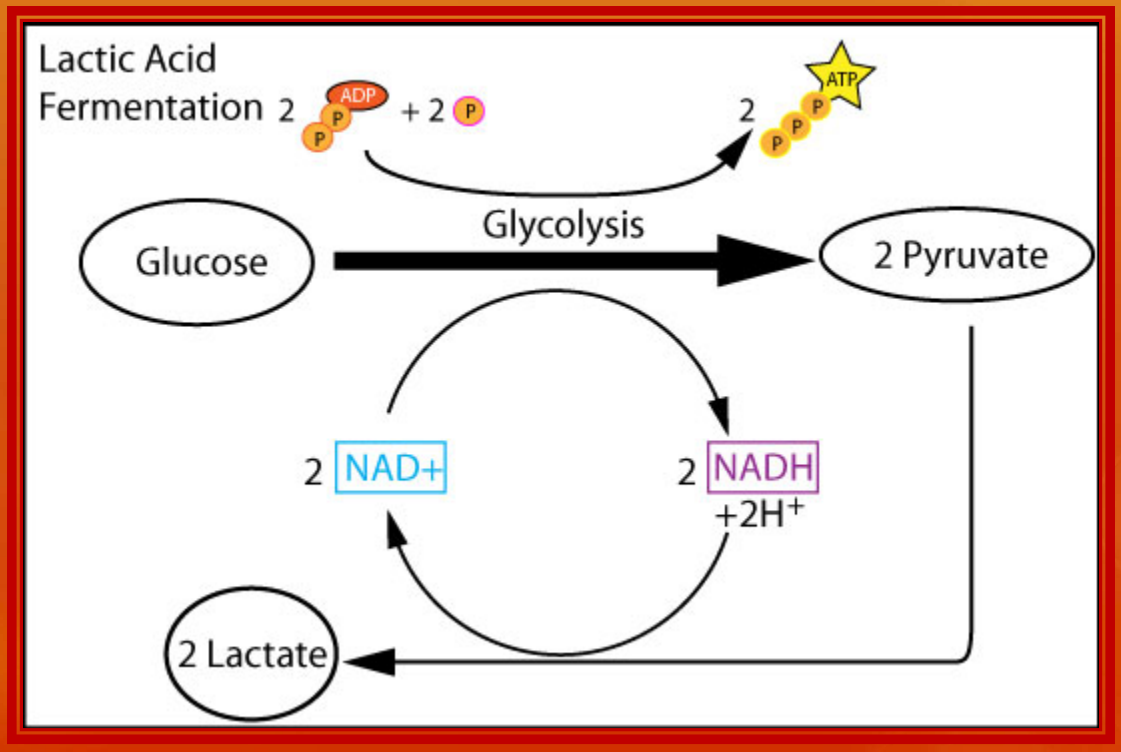
Glycolysis and Fermentation

- General Equation for glycolysis and fermentation. Otherwise known as anaerobic respiration



Lactic Acid Fermentation

- **Lactic Acid Fermentation and Bacteria**
  - -- Some bacteria use lactic acid fermentation to obtain their energy.
  - -- The dairy industry uses the lactic acid produced by bacteria during fermentation to make yogurt, buttermilk, and cheeses (this gives these foods their familiar "sour" taste).



Lactic Acid Fermentation

- **Muscle Fatigue (Oxygen Debt)**

--Lactic acid is produced in your muscle cells during rapid exercise when the body cannot supply enough oxygen to all the tissues.

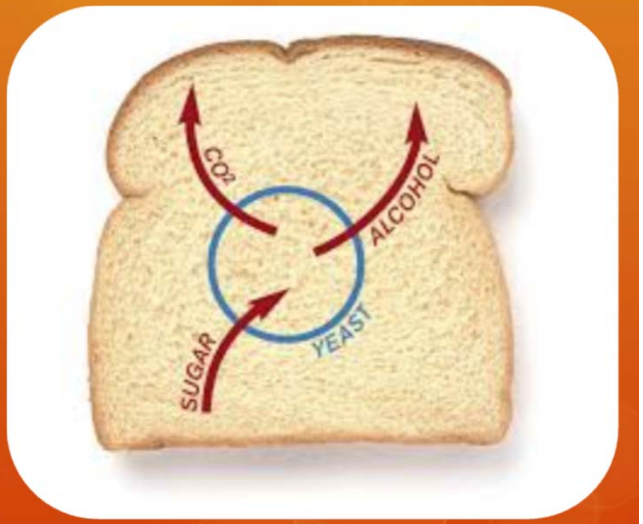
--When you exercise vigorously, the large muscles of your arms and legs run out of oxygen quickly.

--Without oxygen, your muscle cells continue to produce ATP through lactic acid fermentation, resulting in an excess build-up of lactic acid, quickly tiring the muscles and causing a painful, burning sensation.

--Once our muscles form lactic acid, it is gradually released to the bloodstream and carried to the liver be disposed of.

Alcohol Fermentation

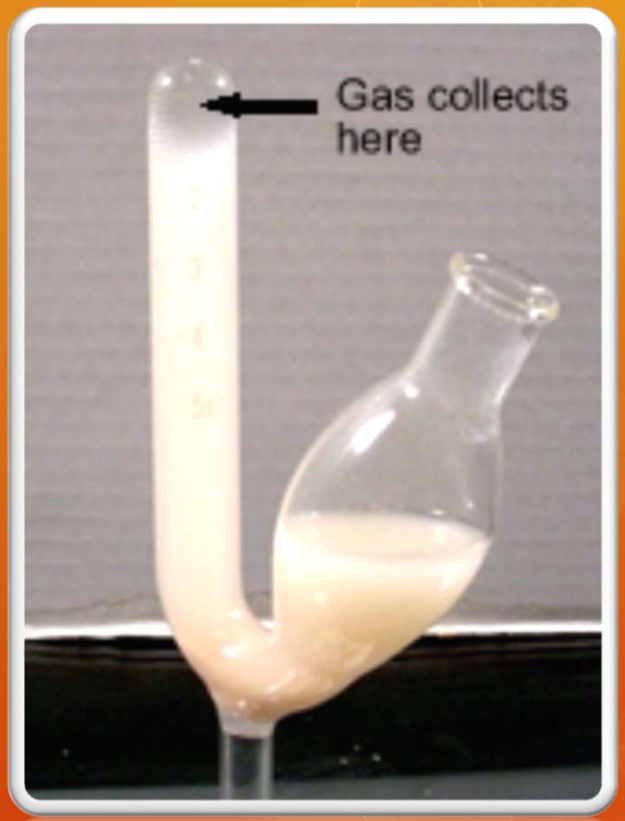
- Yeast and a few other microorganisms use a different pathway to break down pyruvic acid into ethyl alcohol and CO_2 (metabolic wastes) with no further production of ATP
- The baking industry takes advantage of the fact that yeast, although it is an aerobic organism, can revert to fermentation if oxygen is not present.
- When the yeast in the dough runs out of oxygen, it begins to ferment the glucose, producing CO_2 bubbles which pop, forming the air spaces you see in bread and muffins. The small amount of alcohol that is made during this process evaporates when the bread is baked.



- The beer and wine-making industries also use yeast to obtain the alcohol content of their drinks and bubbly or fizz, which come from the bubbles of CO_2.

Fermentation Experiments in lab

- A fermentation tube is often used to observe the process of alcohol fermentation by various organisms such as yeast.
- In such an experiment, the fermentation tube would be loaded with a mixture of water, glucose (usually brown sugar or molasses), and yeast.
- After stoppering the tube and mixing the contents for a few minutes, the tube is tilted so that the mixture moves into the blind end of the apparatus.
- A vacuum is created that will initially hold the mixture up in the blind end of the tube.
- Eventually the yeast cells begin to "burn" the sugar and produce a gas which pushes the mixture back down the tube into the bulb. As fermentation continues, the gas collects in the blind part of the tube



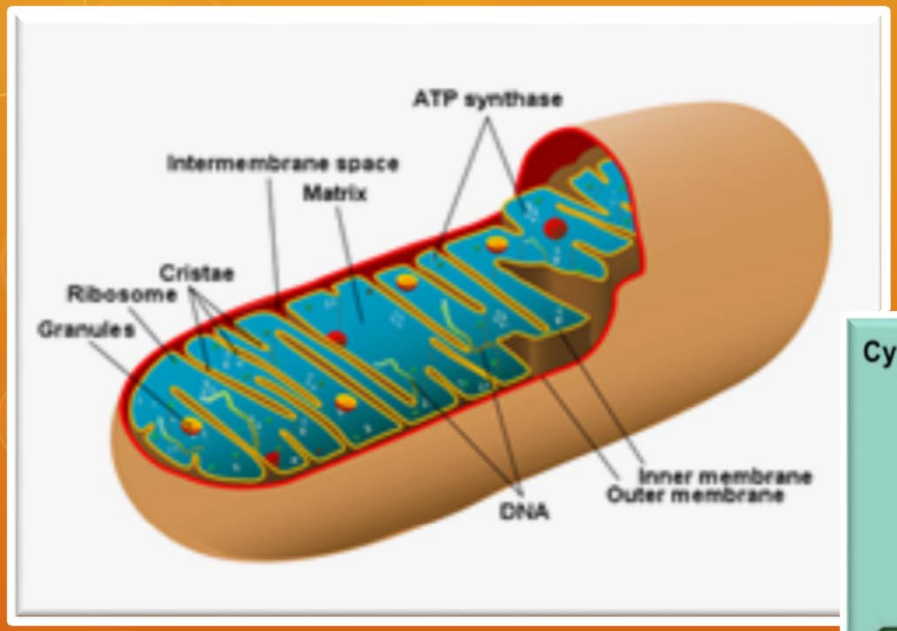
Aerobic Respiration

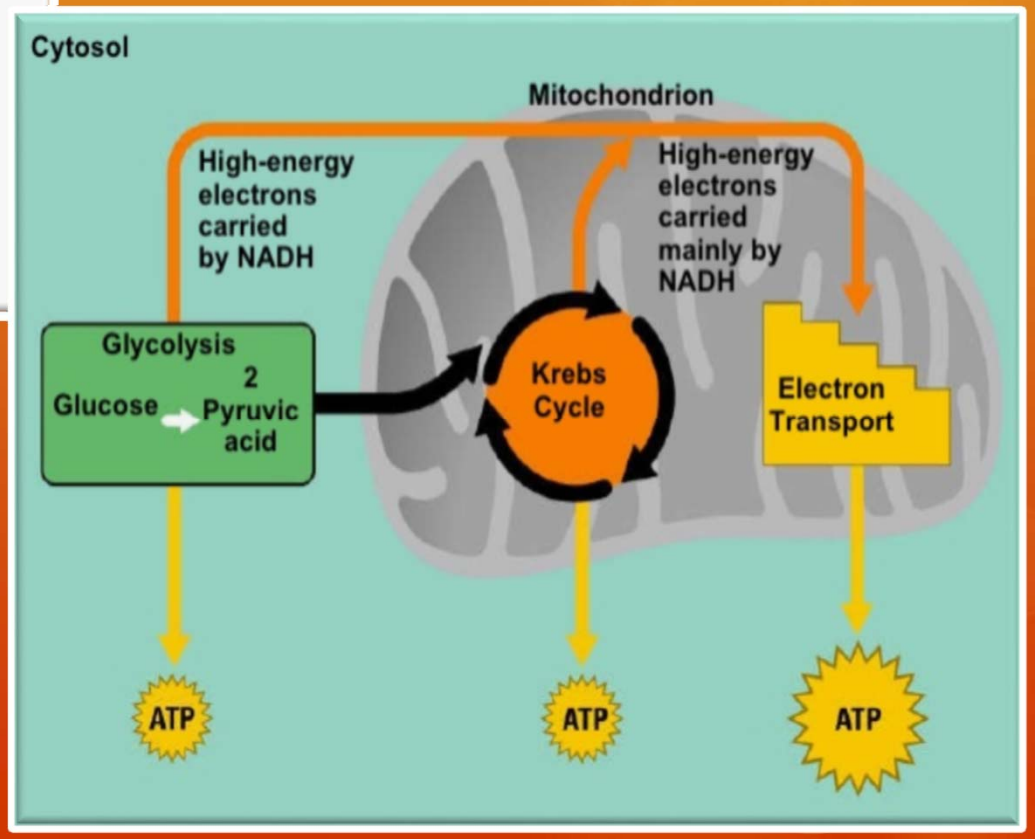
- **Pyruvic Acid ….Chock full of Potential Energy!**
- At the end of glycolysis, pyruvic acid still has about 90% available unused energy locked in its high energy electrons that bond this molecule together.
- To unleash this energy, the cell uses oxygen, one of the most powerful electron acceptors.
- Once glycolysis is completed, there are two additional stages of aerobic respiration: The Kreb's Cycle and the Electron Transport Chain, both which take place in the mitochondria.

Overall Summary Equation of Aerobic Respiration:

$$C_6H_{12}O_6 + 6O_2 + 2\ ATP \longrightarrow 36\ ATP + 6\ CO2 + 6\ H_2O$$

Aerobic Respiration: the Mitochondrion

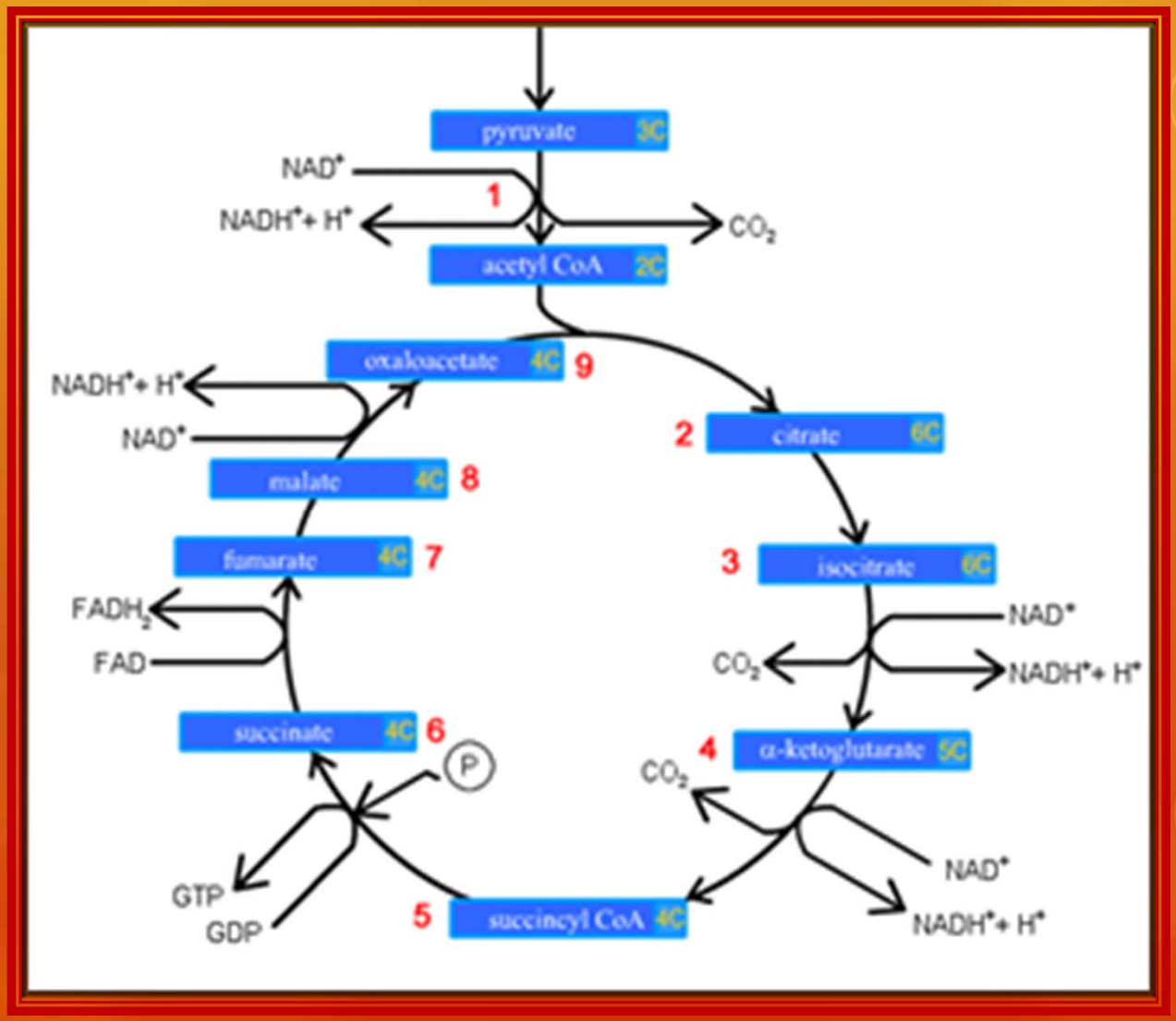




Aerobic Respiration: the Kreb's Cycle

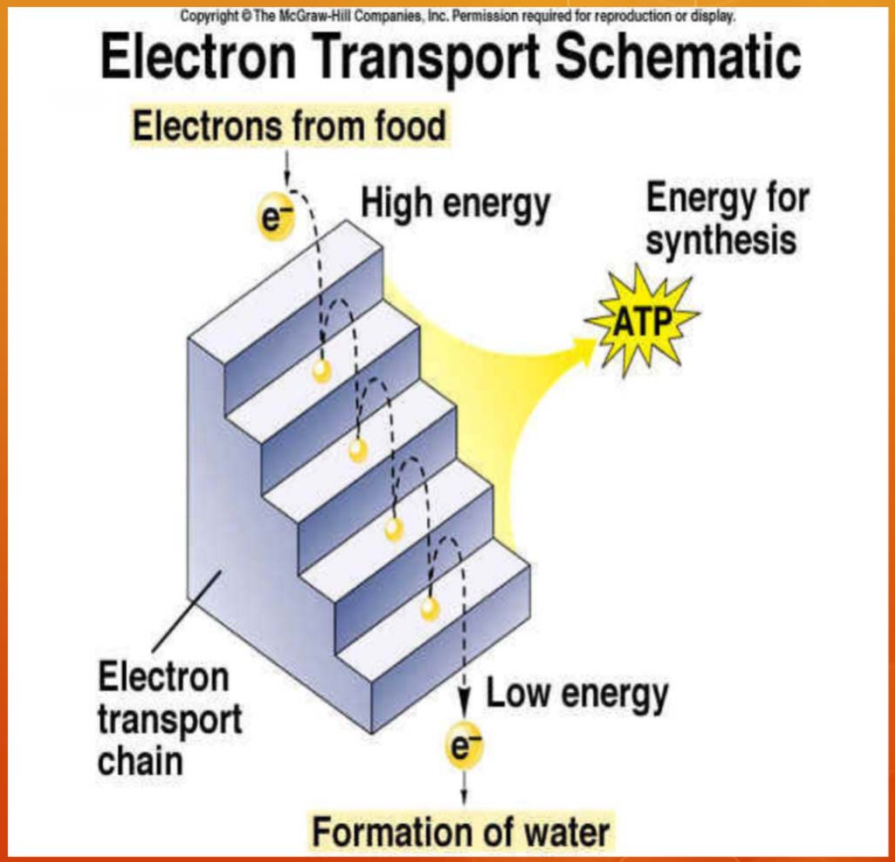
- Takes place in the matrix of the mitochondria
- Pyruvic acid, produced by glycolysis passes to the mitochondria where it is broken down into CO_2 in a series of energy extracting reactions.
- Since citric acid is the first compound formed in this series of reactions, the Krebs Cycle is also known as the Citric Acid Cycle.
- **For each turn of the Kreb's cycle, 2 CO_2 are released, 5 pairs of high energy electrons are captured by carrier molecules (4 NADH and 1 $FADH_2$), and 1 ATP molecule is formed.**
- The carrier molecules NADH and FADH2 carry the high energy electrons to the electron transport chain found in the inner membrane of the mitochondria.
- The Kreb's Cycle turns once for each molecule of pyruvic acid. Since glucose is converted into 2 pyruvic acid molecules, the Kreb's cycle must turn twice for each molecule of glucose that is **oxidized**

The Kreb's Cycle



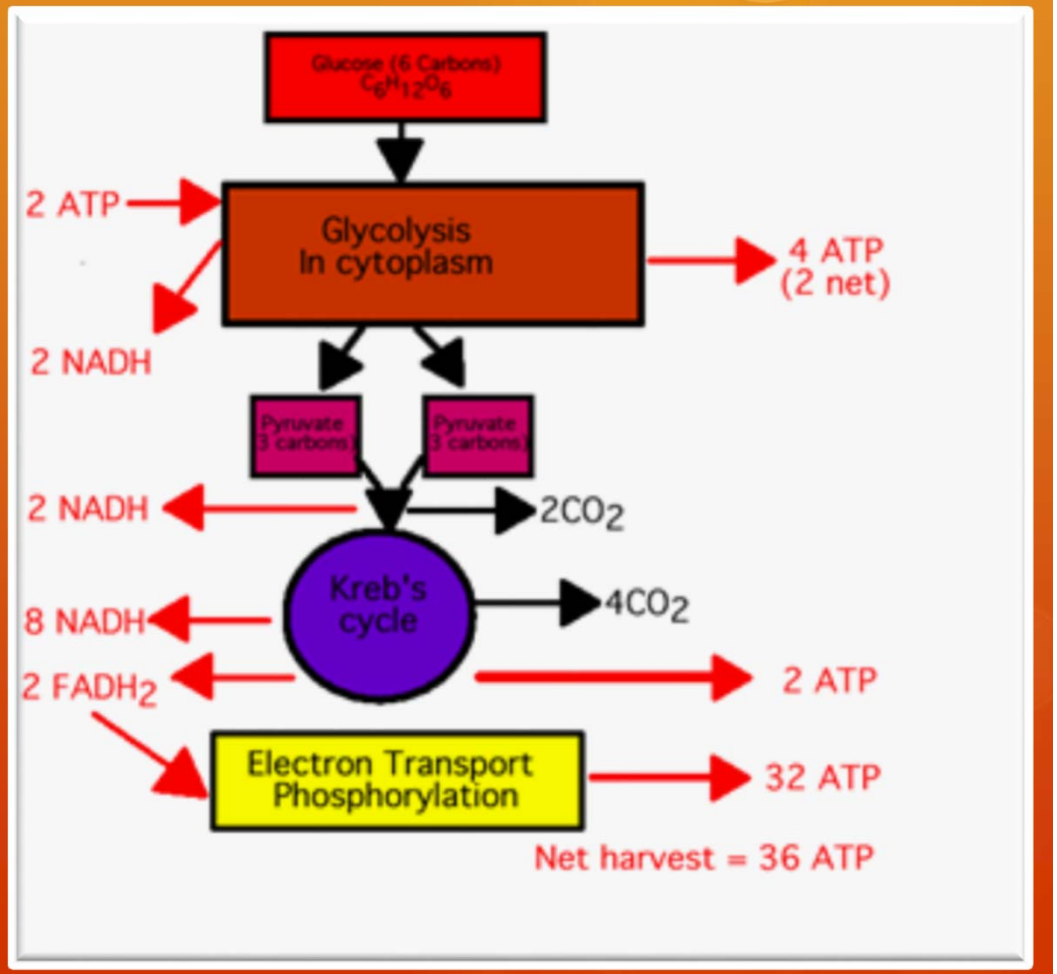
Aerobic Respiration: Electron Transport Chain

- The electron transport system is a chain of electron acceptors embedded in the inner membrane of the mitochondrion.
- Hydrogens are passed from NADH and FADH2 to a chain of electron acceptors.
- The electrons entering the electron transport system have relatively high energy content.
- As they pass along the chain of electron acceptors they lose much of their energy in a enzyme controlled set of reactions.
- The electrons reunite with protons to form hydrogen, and the chemical union of the hydrogen and oxygen produces water.
- **Oxygen, which is reduced, is the final acceptor of the hydrogen ions and their electrons.**



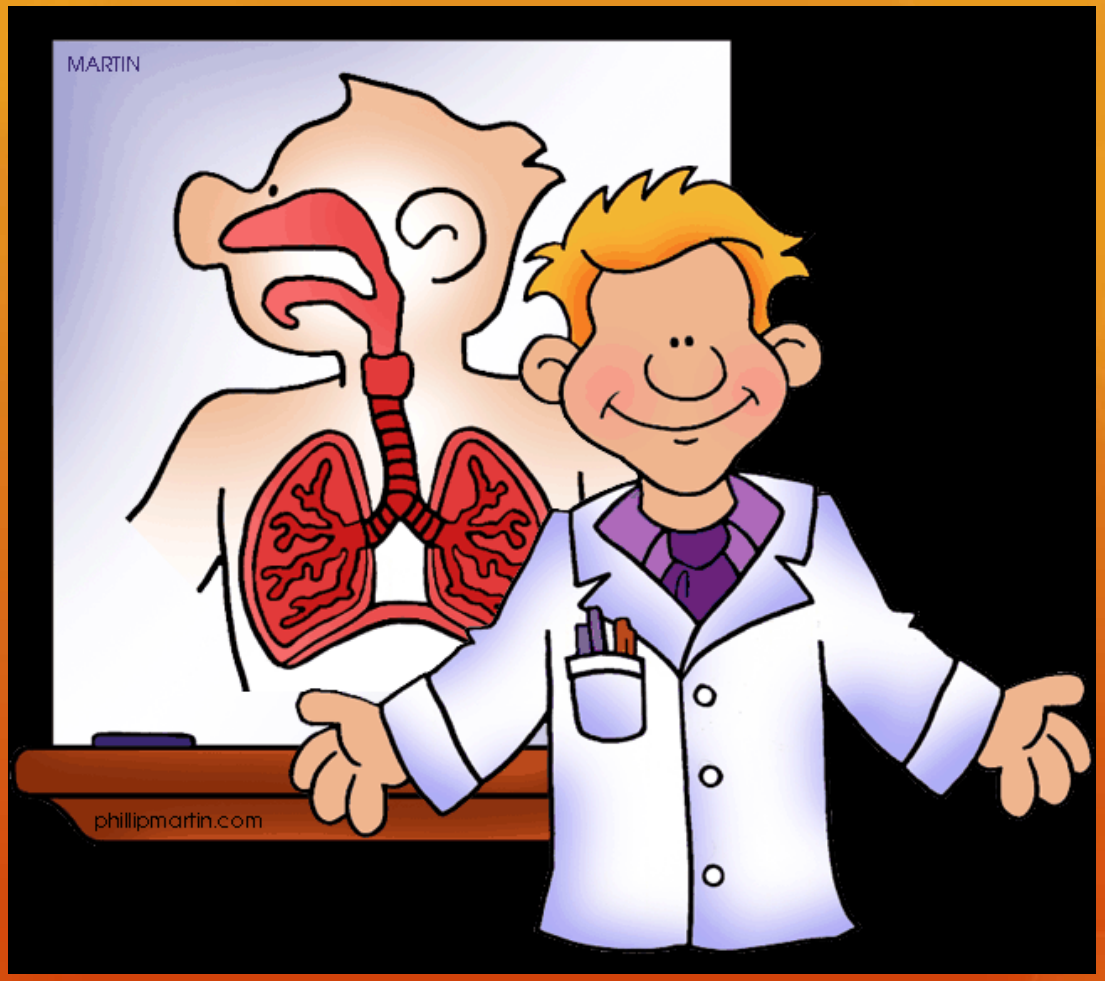
Aerobic Respiration: Yield of ATP

- In addition to 4 ATP synthesized during glycolysis, the Kreb's cycle makes 2 ATP and the electron transport chain adds another 32 ATP.
- Grand total is 38 ATP – 2 ATP to start the process of glycolysis.
- Net ATP for eukaryotes = **36 ATP per molecule of glucose**



Comparison: Cellular Respiration

Lactic Acid Fermentation	Alcoholic Fermentation	Aerobic Respiration
Glucose	Glucose	Glucose
Glycolysis	Glycolysis	Glycolysis
(pyruvic acid)	(pyruvic acid)	(pyruvic acid)
Lactic Acid	CO_2 + Alcohol	CO_2 + H_2O
2 ATP	2 ATP	36 ATP



Human Respiratory System

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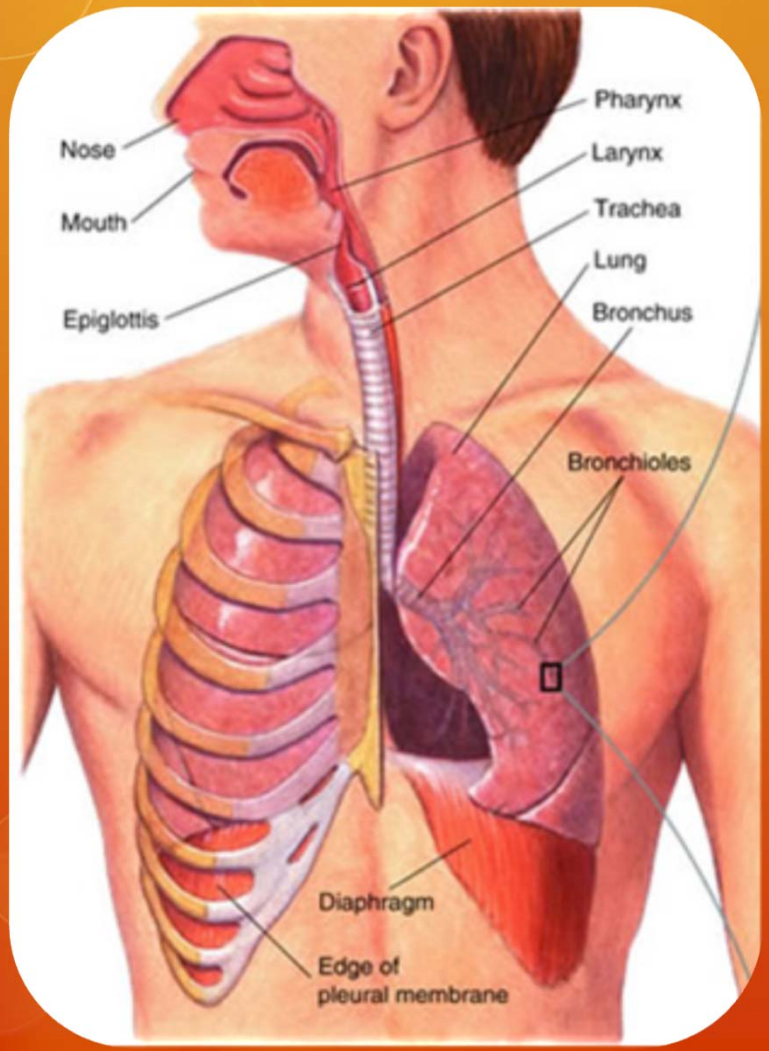
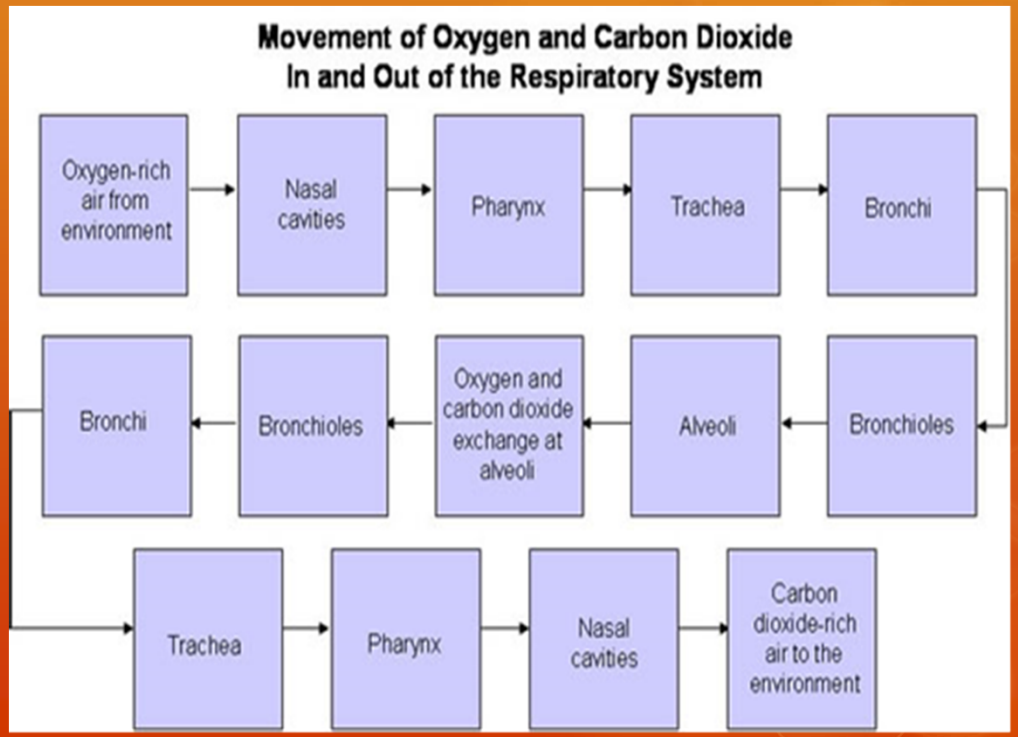




Parts of the Human Respiratory System

NASAL CAVITY **(NOSE)**

- Air enters the nasal cavity which is lined with moist ciliated mucus membranes which warms, moistens, and filters the air

PHARYNX

- Air then travels past the pharynx, the place were the oral and nasal cavities meet. Air can also enter through the oral cavity (mouth) as well

EPIGLOTTIS

- A flap of tissue at the opening of the TRACHEA.
- When swallowing food or drink, the epiglottis covers the TRACHEA to prevent choking

TRACHEA **(WINDPIPE)**

- The air passes from the pharynx to the ***TRACHEA***, which leads to the lungs
- The walls of the trachea contain rings of ***CARTILAGE***, which keep the trachea open yet flexible.
- As the air passes into the trachea, it passes the ***LARYNX*** or ***VOICE BOX***
- The trachea is lined with **CILIA**, which filters out particles and sweeps them upward toward the pharynx

Parts of the Human Respiratory System

BRONCHI

- The lower end of the trachea branches into 2 tubes called the ***BRONCHI*** (singular - ***BRONCHUS***) which lead directly into the lungs
- The bronchi are also kept open by rings of cartilage and lines with mucus membranes (no cilia)

BRONCHIOLES

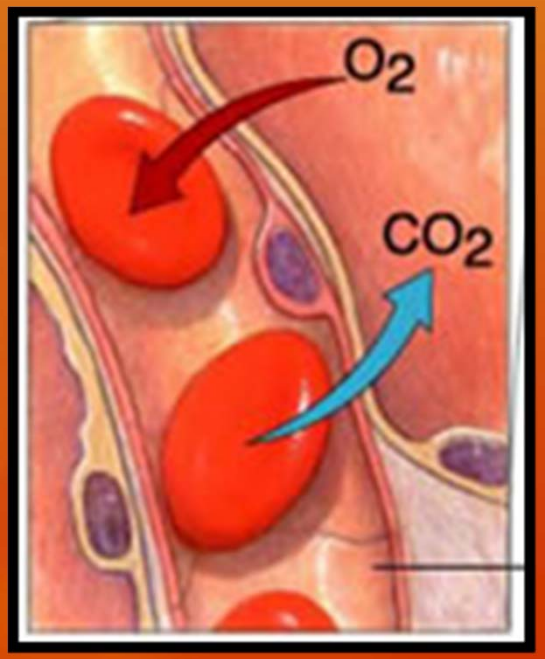
- The bronchi extend into the lungs, branching into smaller and smaller tubes called ***BRONCHIOLES***
- The bronchioles are lined with mucus membranes but lack cartilage rings
- At the end of each bronchiole there is a cluster of tiny, hollow air sacs called ***ALVEOLI***

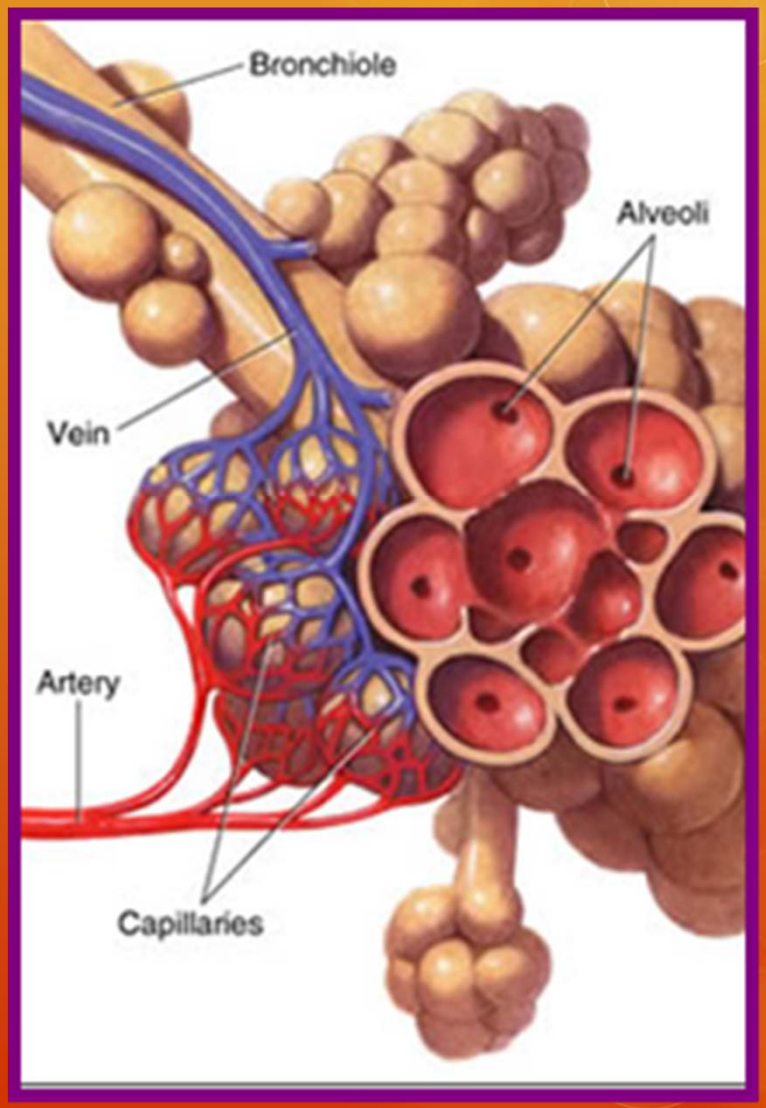
ALVEOLI

- The lungs contain millions of **ALVEOLI,** which are the sites for gas exchange
- The walls of the alveoli are thin and moist and are surrounded by capillaries

Gas Exchange at the Alveoli

- Oxygen diffuses out of the alveoli and into the surrounding capillaries
- carbon dioxide and water vapor diffuse out of the blood and into the alveoli, to be released to the outside

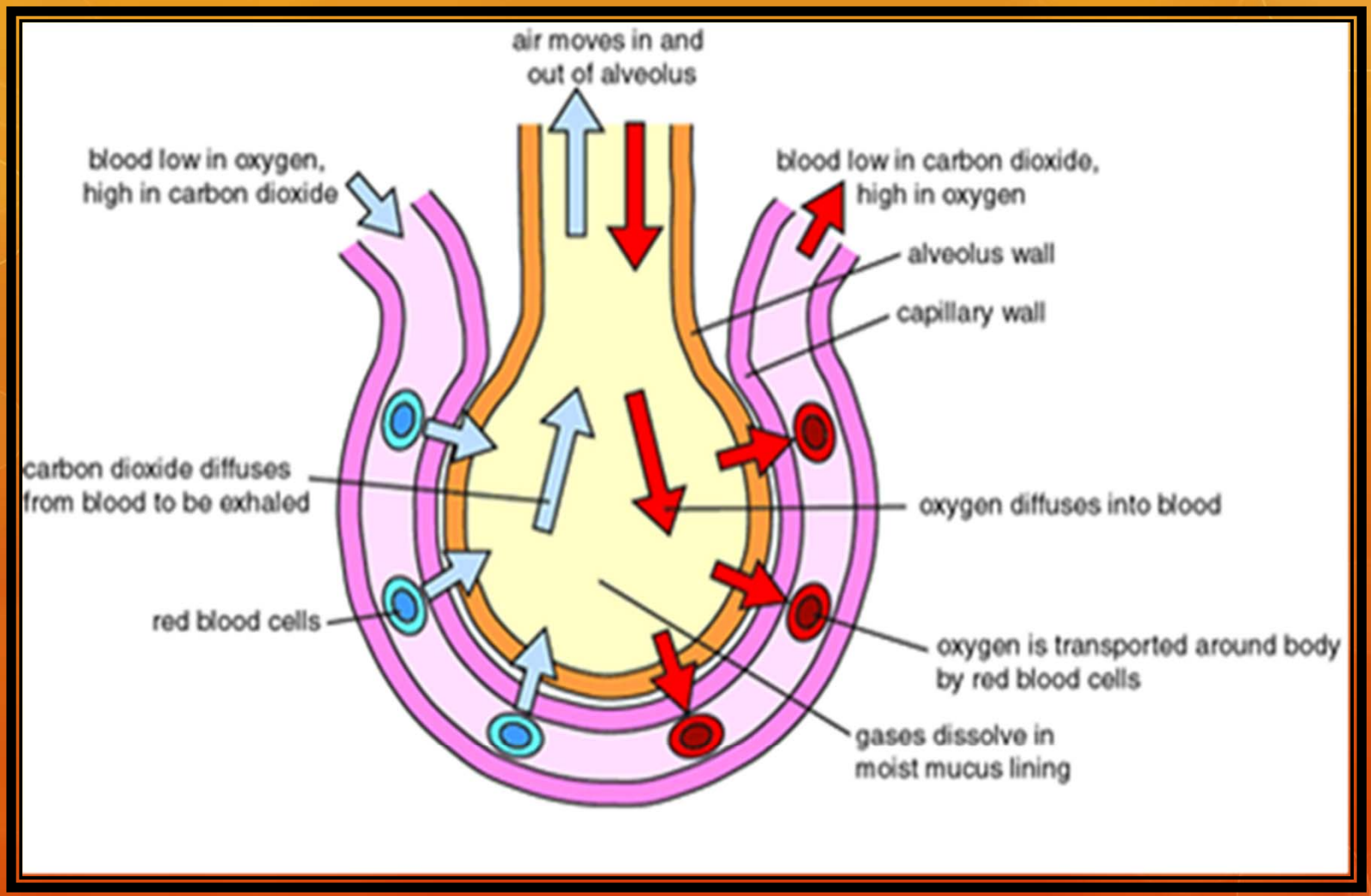




How Gas Exchange Occurs

- Oxygen from the alveoli diffuses into the blood and combines with the hemoglobin on the RBC to form a compound called ***OXYHEMOGLOBIN***
- At the body cells, the oxygen and hemoglobin separate and the oxygen diffuses into the cells for aerobic respiration.
- Carbon dioxide and water (waste products of aerobic respiration) diffuse from the body cells into the blood and carried to back to lungs.
- A majority of the carbon dioxide combines with the water in the blood and is carried in the form of ***BICARBONATE IONS (HCO_3^-)***. When the blood gets to the lungs, the bicarbonate ions break down into carbon dioxide and water, which diffuses into the alveoli and released to the outside**.**
- Some of the carbon dioxide combines with hemoglobin on the RBC to form ***CARBOXYHEMOGLOBIN*** which is then carried to the alveoli for gas exchange.
- A little of the carbon dioxide is dissolves directly into the blood and is carried back to the lungs to be excreted.

Gas Exchange in an Alveolus



How Do We Breathe?

- ***BREATHING***: movement of air in/out of the lungs
- Lungs are ***ELASTIC*** similar to balloons, but contain **NO** muscle.
- The lungs expand and contract in response to pressure changes in the chest cavity which is brought about by the rib cage and the diaphragm
- ***INHALATION***

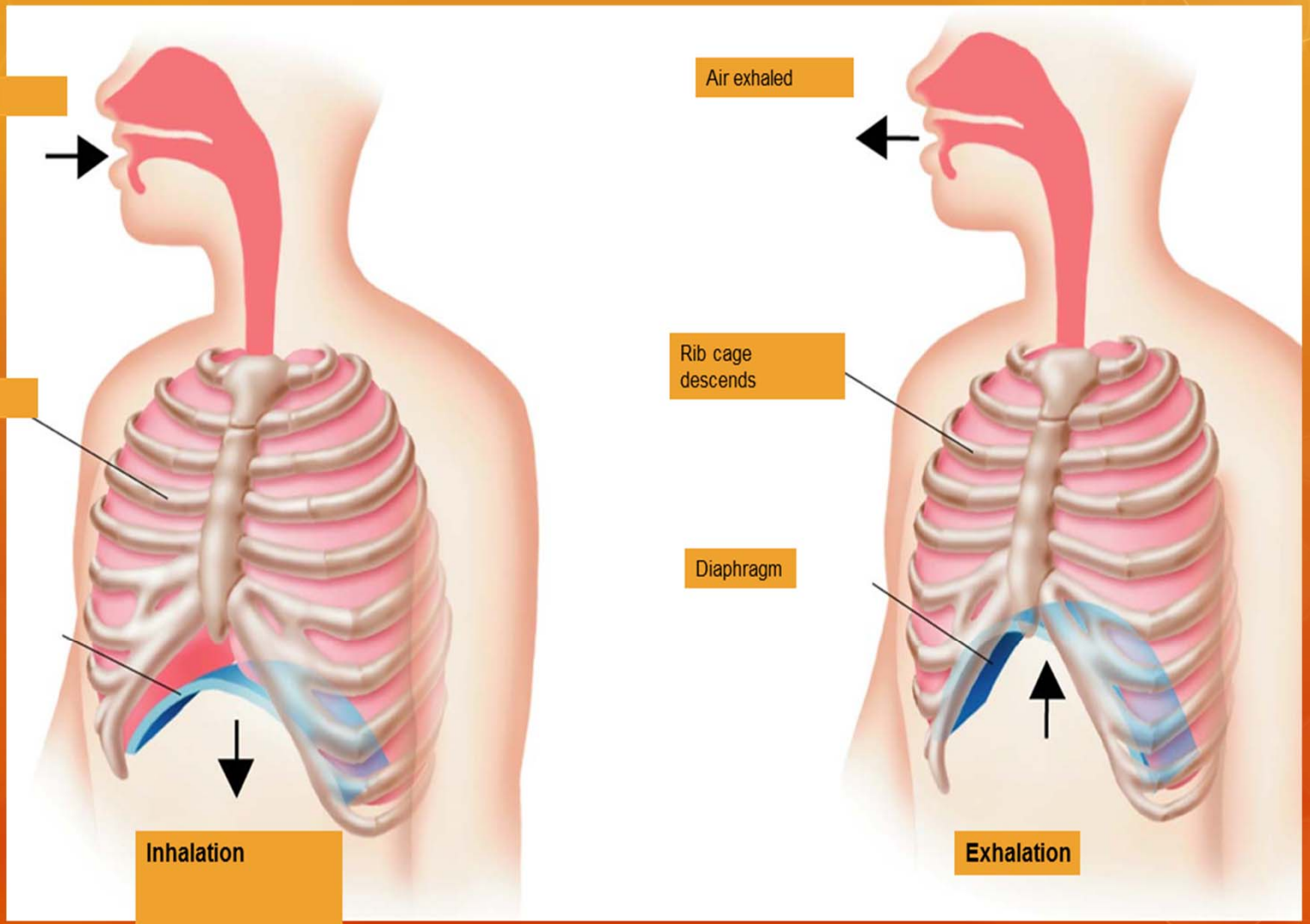
  --the ribs push upward and outward and the diaphragm moves downward, ENLARGING the chest cavity, REDUCING the pressure around the lungs.

  --the lungs expand and air rushes in
- ***EXHALATION***

  --the ribs move in and down and the diaphragm moves up making the chest cavity smaller, INCREASING pressure on the lungs

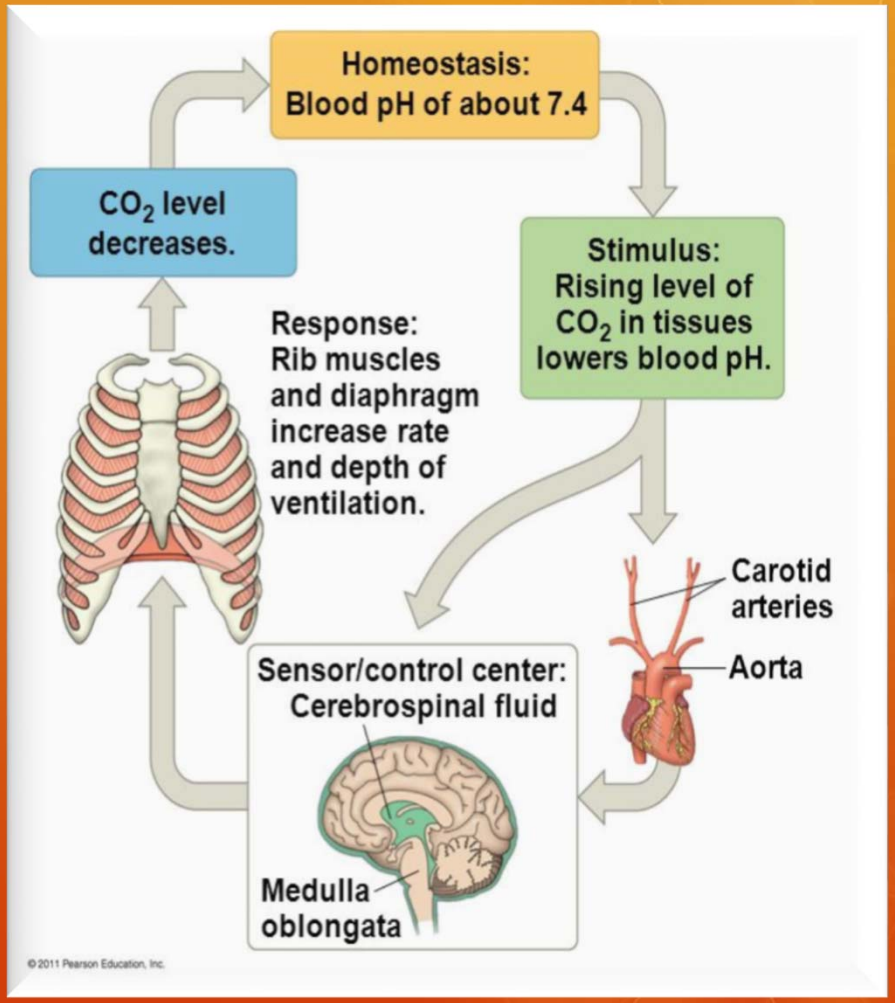
  --the pressure pushes against the lungs, forcing the air up and out of the body.

The Mechanics of Breathing



Rate of Breathing

- The breathing rate is controlled by the **MEDULLA OBLONGATA** of the brain
- The medulla monitors the levels of **CARBON DIOXIDE** in the blood
- When CO_2 is high, messages are sent to the rib cage muscles and the diaphragm to **INCREASE** the breathing rate
- When the CO_2 blood levels decrease, the breathing rate slows down.
- Regulation of breathing rate is an example of a ***FEEDBACK MECHANISM*** that helps the body maintain homeostasis



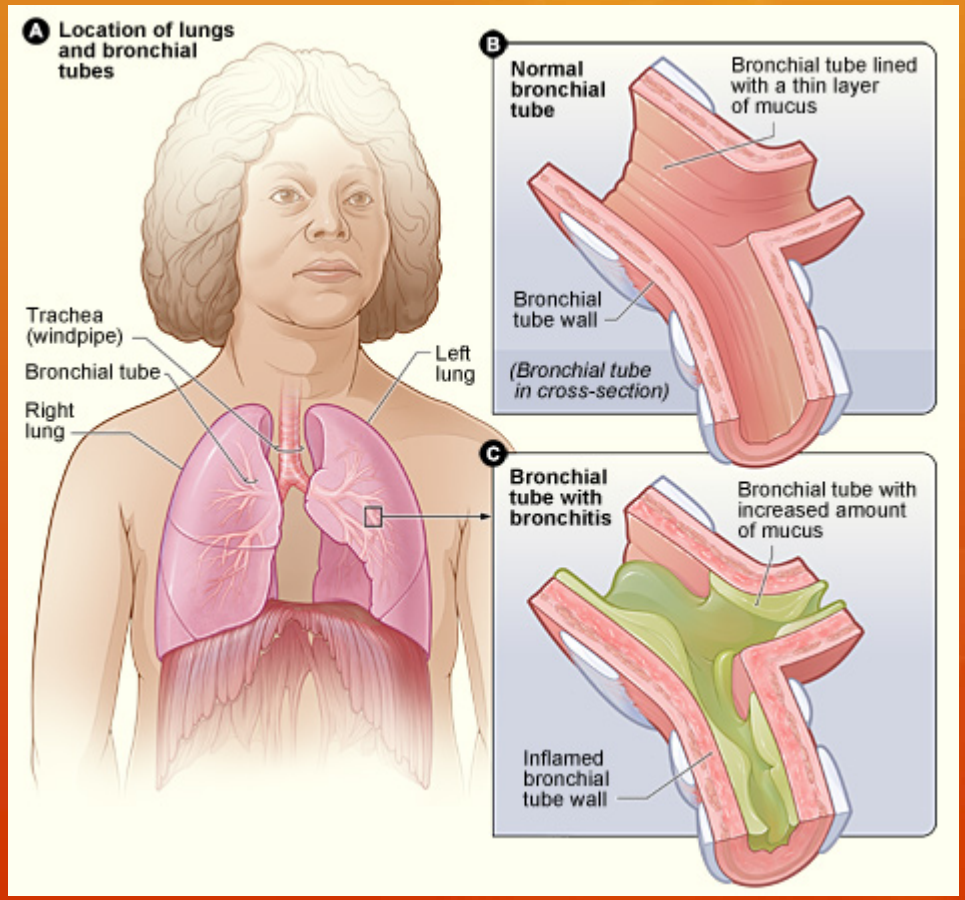
Disorders of the Respiratory System

- ***BRONCHITIS***

--inflammation of the linings of the bronchial tubes, usually from a bacterial infection

--due to the swelling, the air passages become narrowed and filled with mucus causing coughing & breathing difficulties

--usually treated with antibiotics

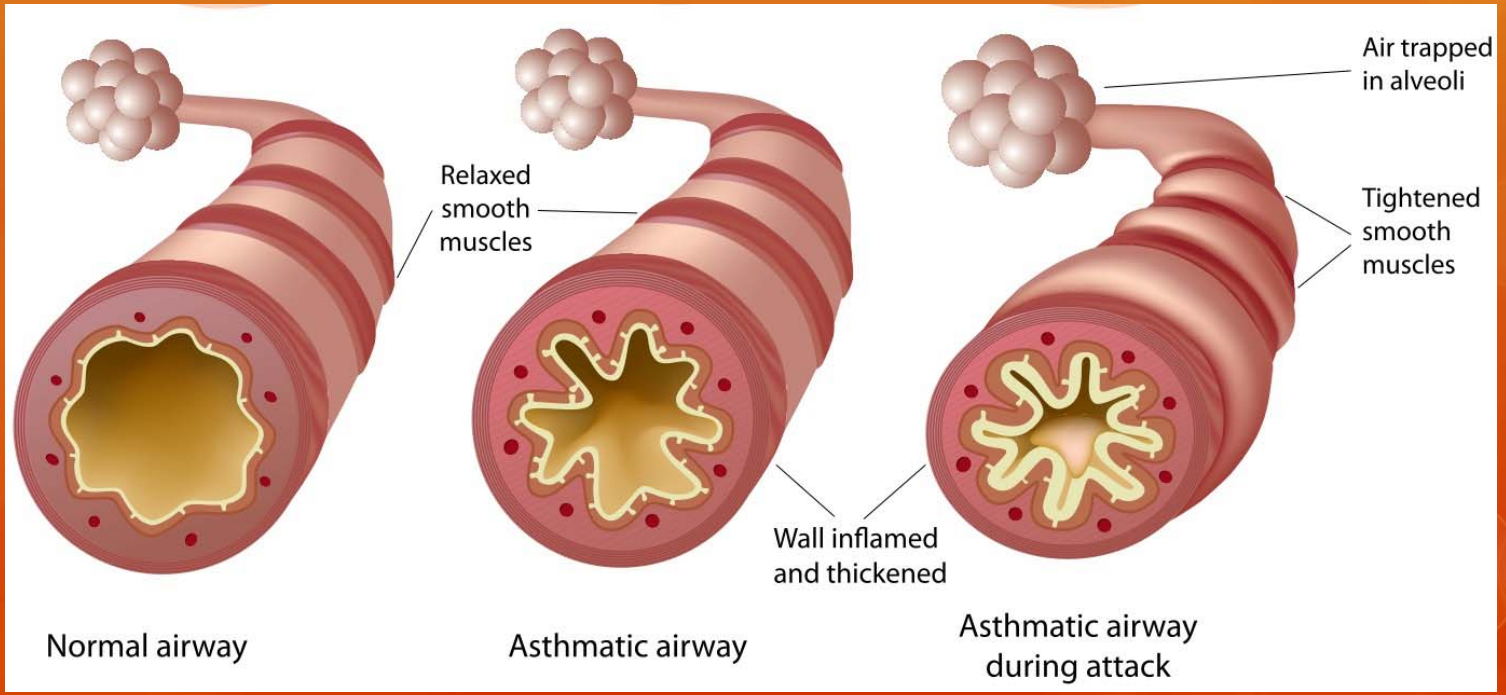


Disorders of the Respiratory System

- ***ASTHMA***

  --an allergic reaction characterized by a narrowing of the bronchial tubes, resulting in difficulty breathing.

  --asthma medications and inhalers are often used to open up the airways



Disorders fo the Respiratory System

- ***EMPHYSEMA***

  --disease often caused by cigarette smoking

  --walls of the alveoli break down and lose their elasticity, making it more difficult for gas exchange to occur

  --symptoms include difficulty in breathing, decreased lung capacity, and a shortness of breath