Cellular Metabolism Lesson Plan

Saturday, February 7, 2008

Aim: To understand the aerobic and anaerobic metabolic pathways in the cell.

Materials:

Clean, empty plastic bottles + caps
Large Bowl, funnel, mixing spoon
Water (preferably spring water)
Bakers' yeast (the dry kind)
Root beer extract
Sugar, Measuring spoons and cups

Slide 1: Metabolic pathway. The diagram shows all of the metabolic pathways in the body. The dark blue one, carbohydrate metabolism, is the one we will be going through today. Even in college level biochemistry you only learn about half of the pathways.

Slide 2: Catabolism vs. Anabolism

Catabolism is the breakdown of molecules.

Anabolism is building molecules.

Slide 3: Anabolic steroids

Remember the difference between anabolic and catabolic. Anabolic steroids are "building up" steroids. They stimulate protein synthesis to grow muscles.

Slide 4: Cellular metabolism: chemical reactions that occur in living organisms in order to maintain life

These processes allow organisms to grow and reproduce, maintain their structures, and respond to their environments.

Autotrophs: organisms that convert sunlight into bond energy stored in the bonds of organic compounds (glucose) in the process of photosynthesis.

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + O_2$

Examples of autotrophs:

- Plants
- Algae
- Some bacteria

Heterotrophs: organisms that obtain their energy through the breakdown of organic nutrients that must be ingested.

$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$

Examples of heterotrophs:

- Humans
- Animals
- Almost everything else

Slide 5: Carnivorous plants

Plants such as venous fly traps "eat" insects and other live organisms. However, in laboratories, they can be grown successfully without feeding them live insects. Technically, they are heterotrophic, but can survive as autotrophs.

Plants on slide: venous fly trap (left) and California pitcher plant (right)

Slide 6: Adenosine triphosphate (ATP) is the molecular unit of energy currency. ATP is used as the energy source for almost every process in your body. In the cell, it is used for DNA, RNA, and protein synthesis. It is also used to transport molecules across cellular membranes. It is the energy source for muscle contractions, including those involved in respiration and locomotion. The energy in ATP is stored in the high energy phosphate groups.

Slide 7: Analogy to remember what ATP is. ATP is readily available energy. It is like the cash in your wallet. Energy stored in the form of carbohydrates and fats are like money in the bank. They take longer to get but can be converted to cash (ATP) and then spent.

Slide 8: Glycolysis is the first stage of glucose catabolism

Overall reaction: Glucose + 2ADP + 2Pi → 2Pyruvate + 2ATP + 2H+ + 2H20 + electrons

Glycolysis produces 2 net ATP molecules. The electrons are carried into the mitochondria by electron carriers and will be used to make more ATP, in a process that will be described later.

Slide 9: Simple picture of glycolysis

Slide 10: Glycolysis takes place in the cytoplasm of the cell.

Slide 11: No Slide: Blob tag!

Get the students running around and show them why they need oxygen.

Two students holding hands run, trying to tag other students. If a student is tagged, he or she must attach to the Blob by joining hands to the person who tagged him or her. The only two people who can tag are the two people on each end of the Blob. The Blob continues to grow as more students are tagged. The Blob must stay connected at all times and work together.

Slide 12: Aerobic vs. Anaerobic

Aerobic respiration occurs when oxygen is present. Think of aerobic exercise. Anaerobic respiration occurs in the absence of oxygen. Glycolysis alone is anaerobic, but the products are used differently under aerobic and anaerobic conditions.

Slide 13: Fermation

Fermentation is the process undergone by pyruvate (the product of glycolysis) in the absence of oxygen. Lactic acid fermentation or ethanol fermentation occurs depending on the organism.

Slide 14: Lactic acid fermentation: occurs in animal cells and some bacteria cells. The buildup of lactic acid is what makes your muscles sore while you are exercising when the muscle cells do not get enough oxygen. It is found in foods: sour milk products (yogurt, cottage cheese), or various processed foods as a preservative. The overall reaction is:

2Pyruvate + electrons → 2Lactic acid

This process does not make any more ATP (energy), but is necessary to free the electrons from the electron carriers. After glycolysis, the electrons are attached to electron carriers. If the electrons are not used up somehow, the electron carriers won't be able to accept any more electrons and glycolysis will stop.

Slide 15: Wall-sit: Demonstration of lactic acid buildup. Have students sit against wall for as long as they can. They will feel the lactic acid building up in their legs.

Slide 16: Alcohol fermentation: occurs in yeast and some bacteria in the absence of oxygen. Alcohol fermentation is used in the production of the ethanol in alcoholic beverages. The overall reaction is:

2Pyruvate + electrons → 2Ethanol + CO_2

Slide 17: Make Root Beer!

1. Dissolve 1/8 teaspoon of yeast in ½ cup of very warm water. Let stand for 5 minutes.

2. Combine 1 1/2 - 2 tablespoons of Root beer extract with 1 1/8 cups of sugar in warm water.

3. Add the two mixtures to the bottle and add warm water to bring the level of the liquid up to two liters.

4. Fill sterilized bottles within 1 ½ to 2 inches to the top.

Slide 18: Citric acid cycle

The citric acid cycle occurs in the mitochondrial matrix. The pyruvate does not go into the cycle, but is first converted to citrate. The overall reaction is:

2Pyruvate → 2ATP + electrons + 6CO_2

Again, not much ATP is produced, but this process produced a lot of electrons.

Slide 19: Oxidative Phosphorylation

This is where all the electrons go! Oxidative phosphorylation occurs in the inner mitochondrial membrane. The electrons are transported here and are used to produce ATP. Oxygen is the final electron accepter, which is why the citric acid cycle and oxidative phosphorylation require oxygen (they are aerobic processes). The electrons from glycolysis produce 2 ATP and the electrons from the citric acid cycle produce 30 ATP. This is why aerobic respiration is so much better. Without aerobic respiration, you can produce 2 ATP from glycolysis alone, but through oxidative phosphorylation, 34 additional ATP are produced.

Slide 20: Slow twitch vs. Fast twitch muscles

<u>Slow Twitch</u>
The slow muscles are more efficient at using oxygen to generate more fuel (known as ATP) for continuous, extended muscle contractions over a long time. They fire more slowly than fast twitch fibers and can go for a long time before they fatigue. Therefore, slow twitch fibers are great at helping athletes run marathons and bicycle for hours. In the body, they are darker because they have more mitochondria. This is where dark meat on a chicken comes from.

<u>Fast Twitch</u>
Because fast twitch fibers use anaerobic metabolism to create fuel, they are much better at generating short bursts of strength or speed than slow muscles. However, they fatigue more quickly. Fast twitch fibers generally produce the same amount of force per contraction as slow muscles, but they get their name because they are able to fire more rapidly. Having more fast twitch fibers can be an asset to a sprinter since she needs to quickly generate a lot of force. Fast twitch fibers are lighter, and this is where light meat comes from.

Slide 21: Cell metabolism is not just used to produce energy (although that is all we talked about here). Other metabolic processes involve breaking down lipids, proteins, amino acids, and nucleotides.