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Modified session plan:

Fermentation: one part in a larger lesson on cellular respiration

what worked and didn't in previous lessons: Every time I was taught cellular respiration in the past, it was solely through lecture style transmission of information. This was not effective for me personally. I can't remember much about respiration at all now, so in spite of having been taught it at least three times, I never really learned it. I do remember drawing the different cycles (glycolysis, TCA, etc.) and how they related to each other, and thinking that it was useful at the time. I think that it would be additionally useful to incorporate some sort of lab work that demonstrates the principles and concepts of respiration. The greatest downfall I feel of all the sessions that I have had on respiration is that they were very one-dimensional in how they were presented. My high school, undergraduate, and graduate lessons about respiration all consisted of: 1) reading from the textbook, 2) listening to the professor lecture and taking notes on the various aspects of the different cycles involved in cellular respiration, and 3) homework or exams that required me to draw the cycles and list the components and equations that are most important. It would have been more effective, I feel, to incorporate some more exploratory/discovery type instruction. Also lacking was a good comparison of the different processes that would allow the student (in this case me) to better understand the relationship between all the different components and types of respiration. My modified session plan will focus on a lesson about fermentation. As I have found the format of the COSEE lessons to be helpful, I will utilize that in my session plan. This session is geared towards high school aged students.

modified session plan:

Key Concept: Sugars are broken down to provide energy for cellular and organismal activities.

assumptions:

students already know about photosynthesis, energy carrying molecules (ATP, NADH etc), and some about cell structure and have recently completed lectures on glycolysis

Session (should take approximately an hour)

invitation – talk about how photosynthesis has the end result of producing sugars. How do these get used? Have people ever thought about why athletes are often given oranges? What is similar/different about a yeast, an algae and a fish?

exploration – look at different foods, predict which you think will provide the most energy and why. What do they know about the foods? How were they produced? How are they similar/different? Do the saltine experiment (leave a saltine on your tongue until it tastes sweet) to demonstrate that carbohydrates are eventually broken down into sugars, the major substrate for production of energy.

concept introduction –review glycolysis (see below) having students give you key information regarding the pathway (enzymes, substrates, products etc.), discuss how

pyruvate (product of glycolysis) can be broken down to provide more energy, or can be used as terminal electron acceptor to regenerate NAD⁺ and produce waste, talk about aerobic vs. fermentation (differences in terminal electron acceptors, how respiration relates to photosynthesis), discuss fermentation products and substrates (lactic acid vs. alcoholic fermentation), where and why fermentation is used and how glycolysis fits in to fermentation (see diagrams below).

Lactic: pyruvate + NADH → lactic acid + NAD⁺

Alcoholic: pyruvate → acetaldehyde + CO₂ acetaldehyde + NADH → ethanol + NAD⁺

Application – guided Lab (1/2 hour) – provide students with different sources of sugars (orange juice, cider, sugar water, molasses, honey, bread), have them predict which will make the best substrate for fermentation. Pass out flasks, balloons, measuring spoons and yeast. Have each student (or pair) measure 1Tbs of yeast into their flask. Add ¾ cup of sugar source, mix it well, then put the balloon over the mouth of the flask and seal it well. Observe the mixture and have them note appearance and any other interesting features. Observe the experiment over three days, have them note any changes in the balloon or in the appearance of the liquid in the flask. Post experiment, discuss which source the yeast appeared able to use most efficiently and why they think so. Have them describe the processes they think were happening inside the flask.

Background Information:

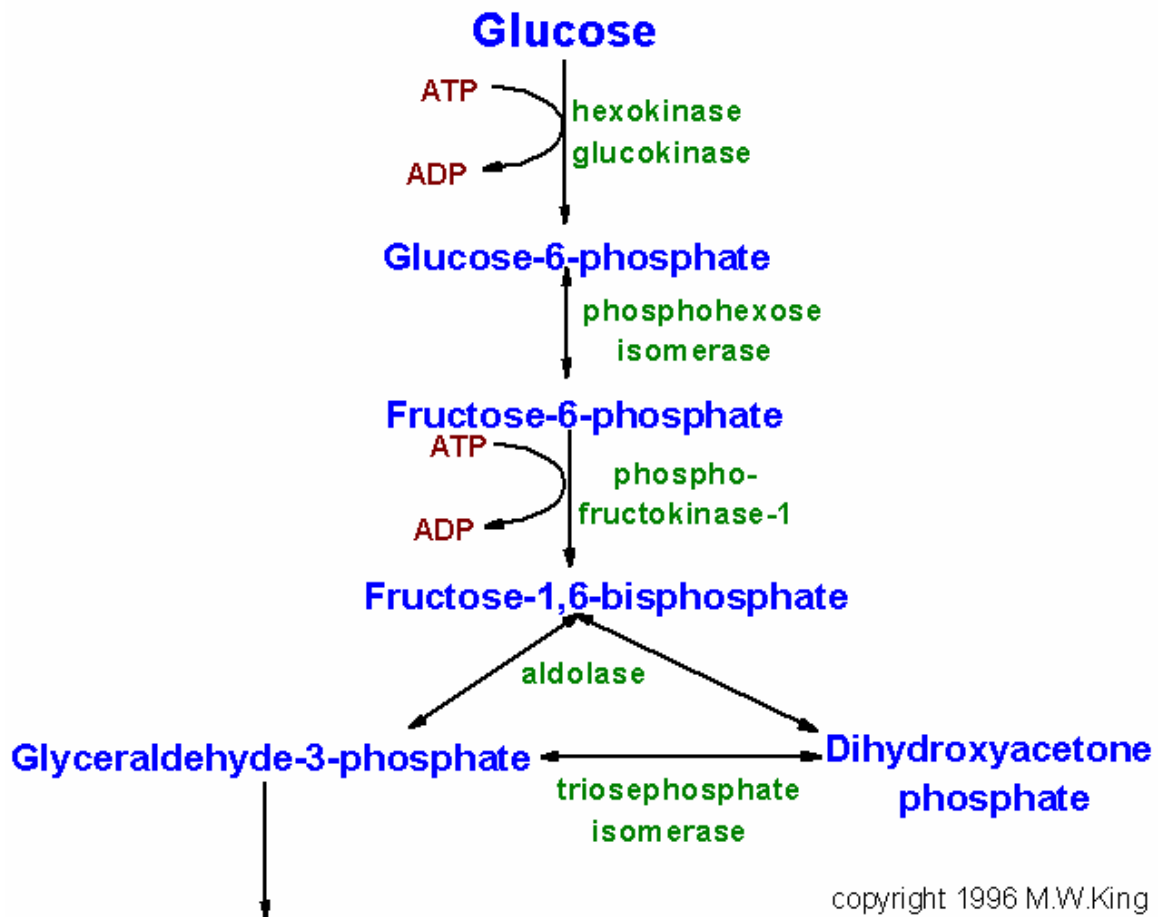
All organisms require energy to survive. This energy (in the form of chemical bonds in ATP and NADH) is utilized to run cellular and organismal processes. The breakdown of sugars and other foodstuffs is what provides this chemical energy. Plants are able to make sugars through photosynthesis, yet animals must obtain sugars by ingesting other organisms. The breakdown of the sugars to provide energy happens through similar processes in both plants and animals. Initially, through digestion, large molecules are broken down into monomers such as amino acids, sugars, fatty acids or glycerol. The sugars undergo glycolysis. The net result of this process is as follows:

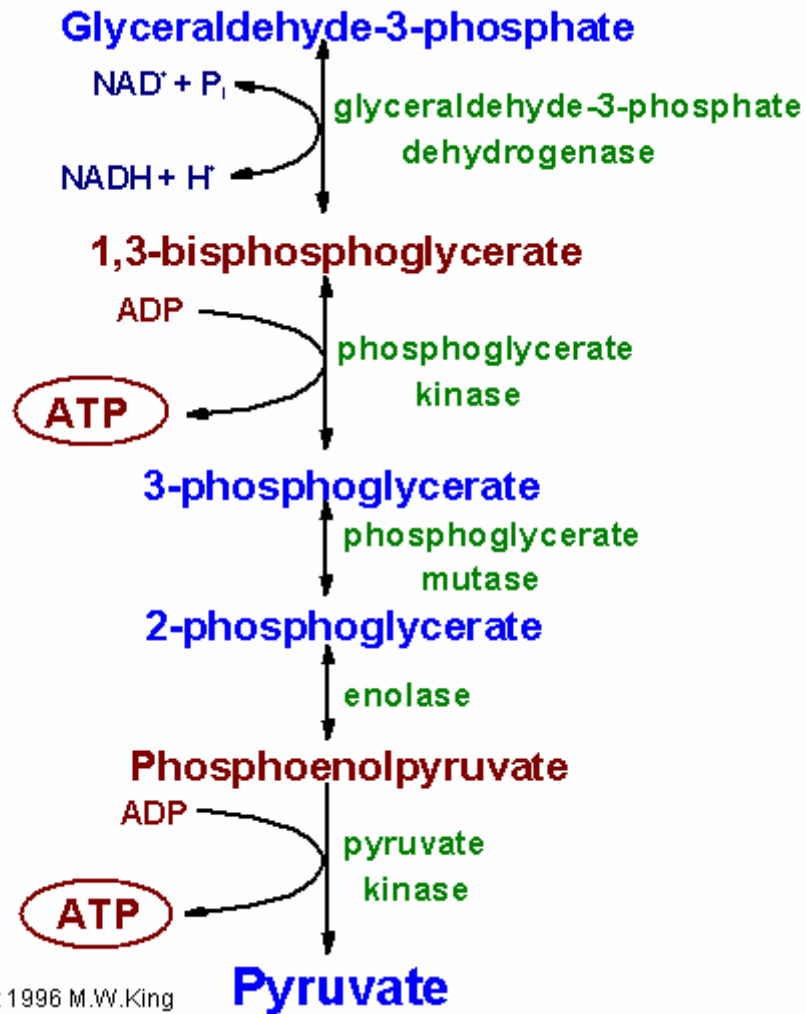
glucose + 2 ADP + 2 P_i + 2 NAD⁺ → 2 pyruvate + 2 ATP + 2 (NADH + H⁺)

Glycolysis results in the production of small amounts of ATP and NADH, and in some organisms this is the primary mechanism for generating chemical energy. In the majority of organisms, pyruvate is transported to the mitochondria where it is oxidized ultimately to carbon dioxide and water, producing additional ATP and NADH (respiration).

However in the absence of oxygen this pathway is not an option. As NADH is only present in small amounts, it must be oxidized back to NAD⁺ in order for ATP production to continue through glycolysis. Anaerobic organisms (like yeast) or cells functioning under insufficient oxygen conditions (such as heavily exercising skeletal muscle) utilize pyruvate as a terminal electron acceptor, converting it into waste products, thereby regenerating NAD⁺. This type of pathway is called fermentation. There are two major

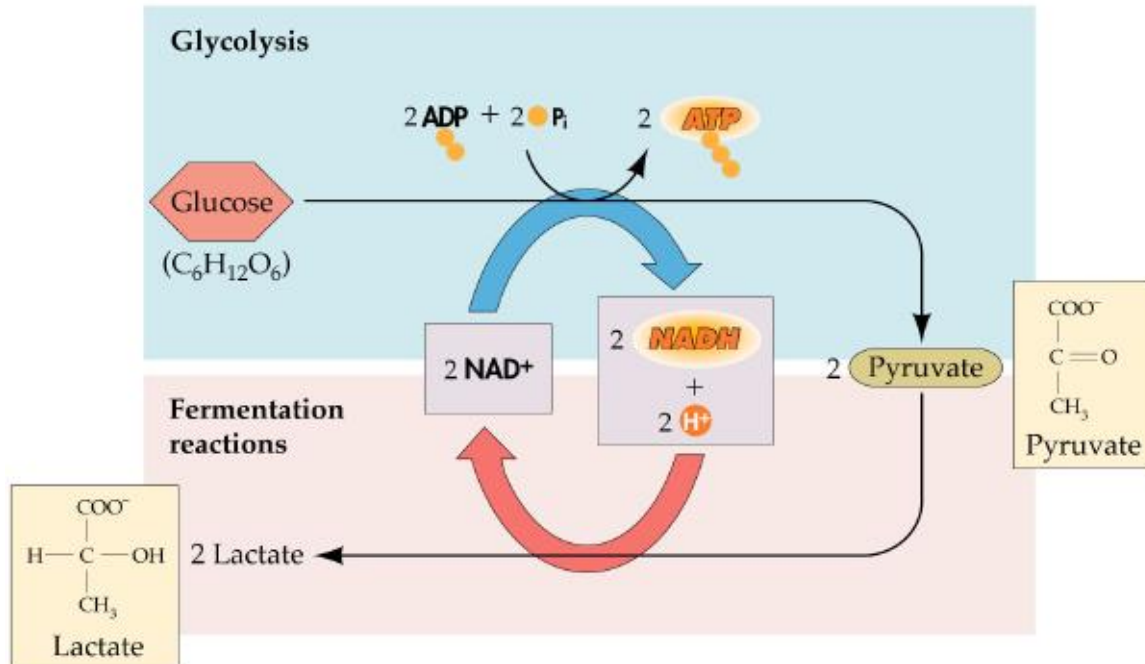
types of fermentation: lactic acid fermentation and alcoholic fermentation (see net processes above). Lactic acid fermentation is what causes muscles to “burn” under heavy exercise, as lactate builds up within the cell. It is also found in numerous bacteria, and is responsible for the souring of milk products. Fungi, yeast, and bacteria that undergo alcoholic fermentation are heavily exploited by humans for such processes as breadmaking and the production of alcoholic beverages. Though fermentation is not nearly as energy efficient as respiration, it still allows catabolism to occur in the absence of oxygen.





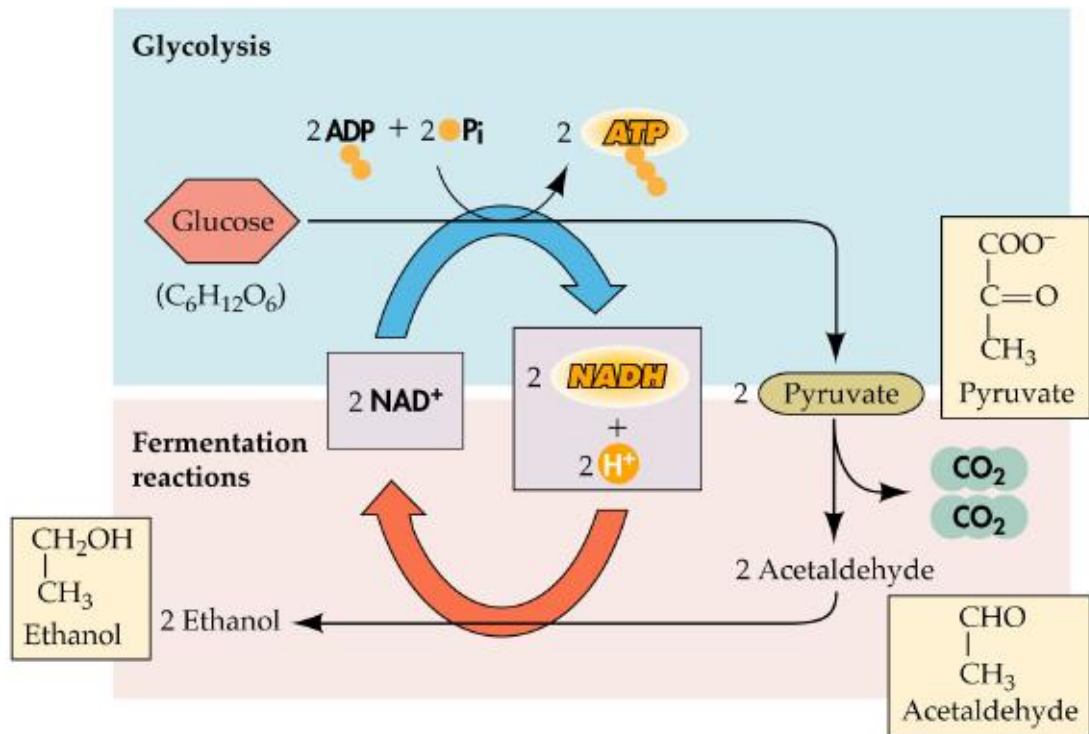
diagrams from: www.sp.uconn.edu/.../lectures/catabolism.html

Lactic acid fermentation:



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Alcoholic fermentation:



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above diagrams from: www.mie.utoronto.ca