Glycolysis

Slide 2 Glycolysis, the first step in glucose metabolism, is a fundamental pathway by which virtually all cells can produce energy. Why are we always so concerned with metabolizing glucose when everyone is telling us not to eat so much sugar? In fact many different metabolic pathways can feed into glycolysis. First of all, glucose may result directly from the breakdown of other complex carbohydrates. Products from the breakdown of proteins and lipids can participate in some of the different reactions of glycolysis and the other steps of glucose metabolism as this slide illustrates. So as we talk about glycolysis and the other parts of glucose metabolism, it is important to remember that other compounds (such as many of the 12 key intermediates) are integral to the process. In our specific discussion of glycolysis, however, we will be focusing on glucose.

Slide 3 The process of glycolysis consists of 10 enzyme-catalyzed reactions during which one molecule of the 6-carbon sugar glucose is converted to two molecules of the 3-carbon compound pyruvate. Overall, this is an energy producing process because it involves the partial oxidation of the glucose molecule. We can see this by comparing the amount of energy that goes into the process with the amount of energy that comes out. During glycolysis 2 molecules of ATP are invested and 4 molecules of ATP as well as 2 molecules of NADH + H^+ are produced. Remember that the energy that is contained in glucose is potential energy stored in the chemical bonds of the molecule. Glycolysis represents a controlled release of some of the energy in those bonds. Pyruvate, the product of glycolysis, still contains a large amount of potential energy in its bonds. That energy is tapped in other metabolic pathways such as aerobic respiration and fermentation. Finally, it is important to note that because oxygen is not required for any of its steps, glycolysis can be performed by organisms under both aerobic and anaerobic conditions.

Slide 4 Before we get into some of the details of glycolysis, it might be helpful to look at enzyme names. Although at this point it is not necessary to memorize the names of each of the enzymes involved in glycolysis, understanding what each of the names means will help elucidate the steps in the process.

First of all, when you see the suffix “-ase” on a chemical name, that chemical is an enzyme. For example a kinase is an enzyme that transfers a phosphate from ATP to another molecule. Some of the other common enzyme names that you will encounter are as follows:
An isomerase is an enzyme that rearranges the structure of a molecule without changing the numbers and kinds of atoms in that molecule. A dehydrogenase oxidizes a molecule by transferring a hydrogen to an acceptor such as NAD^+. A hydrolase catalyzes the hydrolysis of covalent bonds. A ligase catalyzes the formation of covalent bonds. A polymerase catalyzes the formation of a polymer. Descriptive words preceding the actual enzyme name tell what the enzyme does. For instance phosphohexose isomerase

catalyzes the rearranging of glucose 6-phosphate to form its isomer, fructose 6-phosphate.

Slide 5 Now let's look at what actually happens in glycolysis. Glycolysis begins with glucose. The first step of glycolysis requires the investment of one ATP, which transfers a phosphate to the glucose to form glucose 6-phosphate. The second step rearranges the structure of glucose to form its isomer, fructose 6-phosphate. In the third step another ATP must be invested to add another phosphate group to form fructose 1,6-bisphosphate. At this point a very symmetrical sugar molecule has been formed, and in the fourth step of glycolysis this sugar is cleaved down the middle to form 2 3-carbon sugar molecules. After rearrangement of one of these 3-carbon sugar molecules by an isomerase, we have 2 molecules of glyceraldehyde 3-phosphate (G3P). Note at this point that although a lot of rearranging has been done and a small amount of energy and phosphate has been added, we still have the same 6 carbons that we started out with. These first 5 steps are the "energy-investing" steps of glycolysis. In the next step we start to get some return on our investment.

Slide 6 In step 6 of glycolysis the two molecules of G3P are oxidized, yielding 2 NADH + H^+ in a highly exergonic reaction. During the final four steps of glycolysis, 4 ATP molecules are formed as phosphate groups are transferred from the sugar phosphates to ADP. This transfer of phosphate groups is called substrate-level phosphorylation. In the end 2 molecules of the 3-carbon compound pyruvate have been formed. In addition the carefully controlled reactions have yielded 2 NADH + H^+ and a net of 2 ATP, which act as molecular energy shuttles that can supply energy to other cellular processes.

Slide 7 All types of organisms can perform glycolysis. For this reason it is considered to be an ancient metabolic pathway that has been conserved throughout the evolution of life. Glycolysis occurs in the cytoplasm of both prokaryotic and eukaryotic cells. If oxygen is present, the pyruvate that is formed during glycolysis may diffuse into the mitochondria of eukaryotic cells or move to the inner face of the plasma membrane of prokaryotic cells to be oxidized. In the absence of oxygen, pyruvate remains in the cytoplasm where it undergoes fermentation. In the following lessons, the fate of pyruvate will be followed as we discuss the pathways of aerobic respiration and fermentation.