Glycolysis

Glycolysis is the first metabolic pathway used to catabolize glucose. Glycolysis is thought to be the oldest energy-harvesting pathway since nearly all living organisms carry out this process. Scientific evidence suggests that atmospheric oxygen levels were very low, if not nonexistent, when life first evolved on the planet. The earliest living cells would have needed to be able to generate energy in the absence of oxygen. Glycolysis is **anaerobic,** meaning it does not require oxygen. As a result, glycolysis could have been used by the first living cells to produce energy. Also, glycolysis takes place in the cytoplasm of both prokaryotic and eukaryotic cells. Membrane-bound organelles are not necessary to carry out this metabolic pathway. Glycolysis consists of distinct phases. In the first phase, the energy-consuming phase, two ATP molecules are used to alter one six-carbon glucose molecule. In the next phase, the six-carbon sugar is split evenly into two three-carbon sugar molecules which are then oxidized. Two molecules of NAD^+ accept the electrons and are reduced to NADH. In the last phase, four ATP and two three-carbon sugars, called pyruvate or pyruvic acid, are produced (Figure 6.11). Note, some biochemists use the words pyruvate and pyruvic acid interchangeably. Recall that two ATP molecules were invested in the first phase of glycolysis, therefore one glucose molecule results in a *net production* of two ATP molecules.

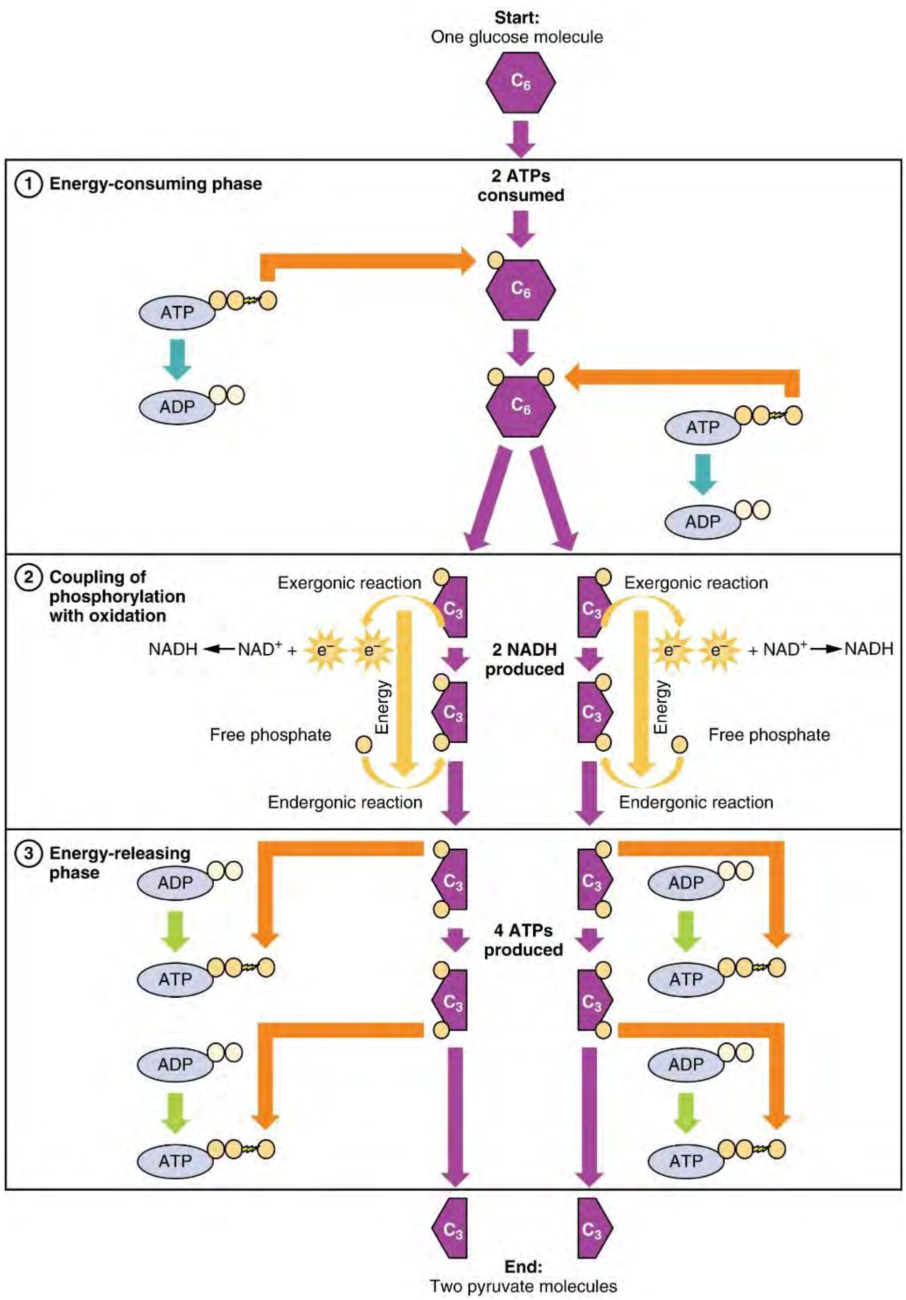

Figure 6.11 shows an overview of glycolysis. (credit: Betts et al. / Anatomy and Physiology OpenStax)

Glycolysis is a much more extensive metabolic pathway than that which is shown in Figure 6.11. Figure 6.12 provides a more accurate picture of glycolysis. Students are not responsible for learning the intermediates or the enzymes used to catalyze each reaction.

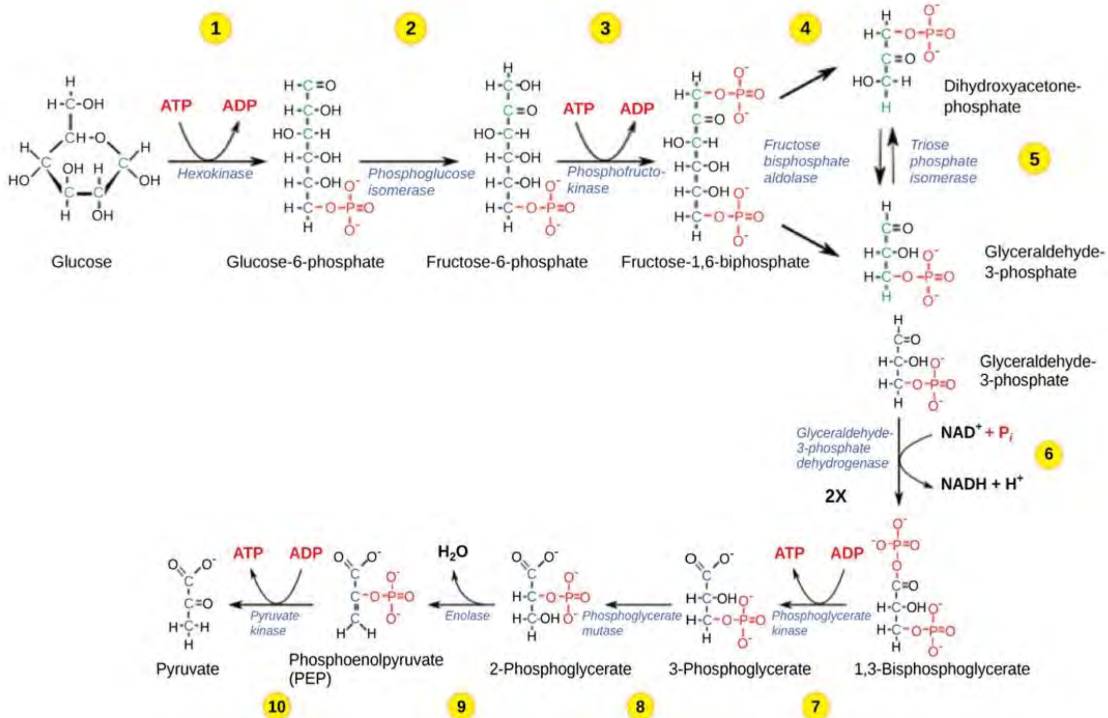

Figure 6.12 shows the glycolysis pathway in detail. (credit: Clark et al./ Biology 2E OpenStax)

The two ATP molecules that are netted during the process of glycolysis are made through **substrate-level phosphorylation**. Remember that during substrate phosphorylation, a phosphate group is removed from an intermediate substrate and attached directly to ADP producing ATP (Figure 6.13). This process does not require oxygen.

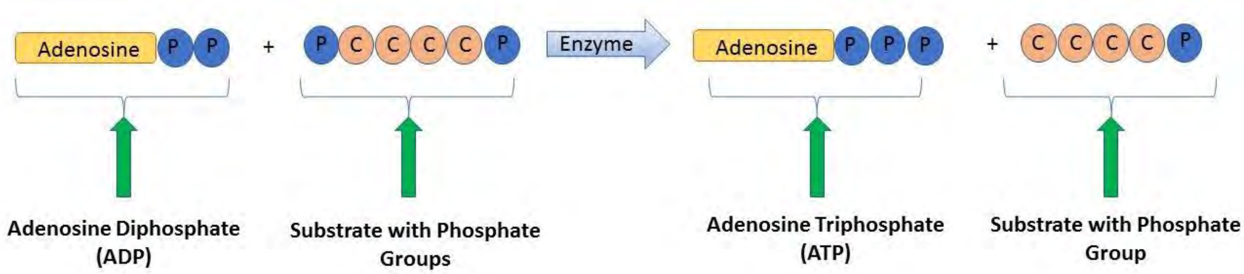

Figure 6.13 In substrate-level phosphorylation, an intermediate organic substrate provides the third phosphate of ATP with the help of an enzyme. (credit: Elizabeth O'Grady)

If oxygen is present, pyruvate will enter the mitochondria, where it will be oxidized and a large amount of ATP will be produced. If the cell cannot oxidize the pyruvate, it will only be able to generate two molecules of ATP from one molecule of glucose. For example, mature mammalian red blood cells are only capable of glycolysis. Glycolysis is their sole source of ATP, and if this pathway is interrupted, these cells will die.

CONCEPTS IN ACTION - Gain a better understanding of the breakdown of glucose by glycolysis by visiting this site to see the process in action Also view the video - *Glycolysis: An Overview*

Outcomes of Glycolysis

Glycolysis begins with one molecule of glucose, two molecules of ATP, and two molecules of NAD^+. The outputs of glycolysis are two molecules of pyruvate, four molecules of ATP, and two molecules of NADH (Figure 6.14). Note: because four new ATP molecules are generated during glycolysis but two molecules of ATP are used in the first half of the pathway, the cell has a *net gain of two ATP molecules*.

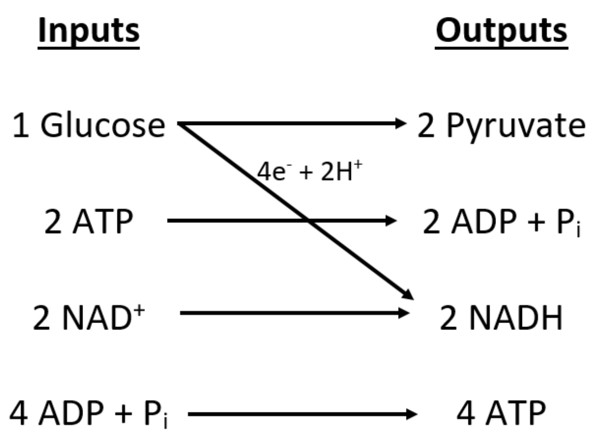

Figure 6.14 shows the inputs and outputs of glycolysis. (credit: Jason Cashmore)

Check your knowledge

If a bacteria has 4 glucose molecules, how many net ATP can it produce during glycolysis?

Answer: 8