For each step, the part of the molecule that undergoes a change is shadowed in blue, and the name of the enzyme that catalyzes the reaction is in a yellow box.

**STEP 1**  
Glucose is phosphorylated by ATP to form a sugar phosphate. The negative charge of the phosphate prevents passage of the sugar phosphate through the plasma membrane, trapping glucose inside the cell.

**STEP 2**  
A readily reversible rearrangement of the chemical structure (isomerization) moves the carbonyl oxygen from carbon 1 to carbon 2, forming a ketose from an aldose sugar. (See Panel 2–4.)

**STEP 3**  
The new hydroxyl group on carbon 1 is phosphorylated by ATP, in preparation for the formation of two three-carbon sugar phosphates. The entry of sugars into glycolysis is controlled at this step, through regulation of the enzyme phosphofructokinase.

**STEP 4**  
The six-carbon sugar is cleaved to produce two three-carbon molecules. Only the glyceraldehyde 3-phosphate can proceed immediately through glycolysis.

**STEP 5**  
The other product of step 4, dihydroxyacetone phosphate, is isomerized to form glyceraldehyde 3-phosphate.
The two molecules of glyceraldehyde 3-phosphate are oxidized. The energy generation phase of glycolysis begins, as NADH and a new high-energy anhydride linkage to phosphate are formed (see Figure 2–73).

\[
\text{glyceraldehyde 3-phosphate} + \text{NAD}^+ + \text{P} \rightarrow \text{1,3-bisphosphoglycerate} + \text{NADH} + \text{H}^+.
\]

The transfer to ADP of the high-energy phosphate group that was generated in step 6 forms ATP.

\[
\text{1,3-bisphosphoglycerate} + \text{ADP} \rightarrow \text{3-phosphoglycerate} + \text{ATP}.
\]

The remaining phosphate ester linkage in 3-phosphoglycerate, which has a relatively low free energy of hydrolysis, is moved from carbon 3 to carbon 2 to form 2-phosphoglycerate.

\[
\text{3-phosphoglycerate} \rightarrow \text{2-phosphoglycerate}.
\]

The removal of water from 2-phosphoglycerate creates a high-energy enol phosphate linkage.

\[
\text{2-phosphoglycerate} \rightarrow \text{phosphoenolpyruvate} + \text{H}_2\text{O}.
\]

The transfer to ADP of the high-energy phosphate group that was generated in step 9 forms ATP, completing glycolysis.

\[
\text{phosphoenolpyruvate} + \text{ADP} + \text{H}^+ \rightarrow \text{pyruvate} + \text{ATP}.
\]

In addition to the pyruvate, the net products are two molecules of ATP and two molecules of NADH.