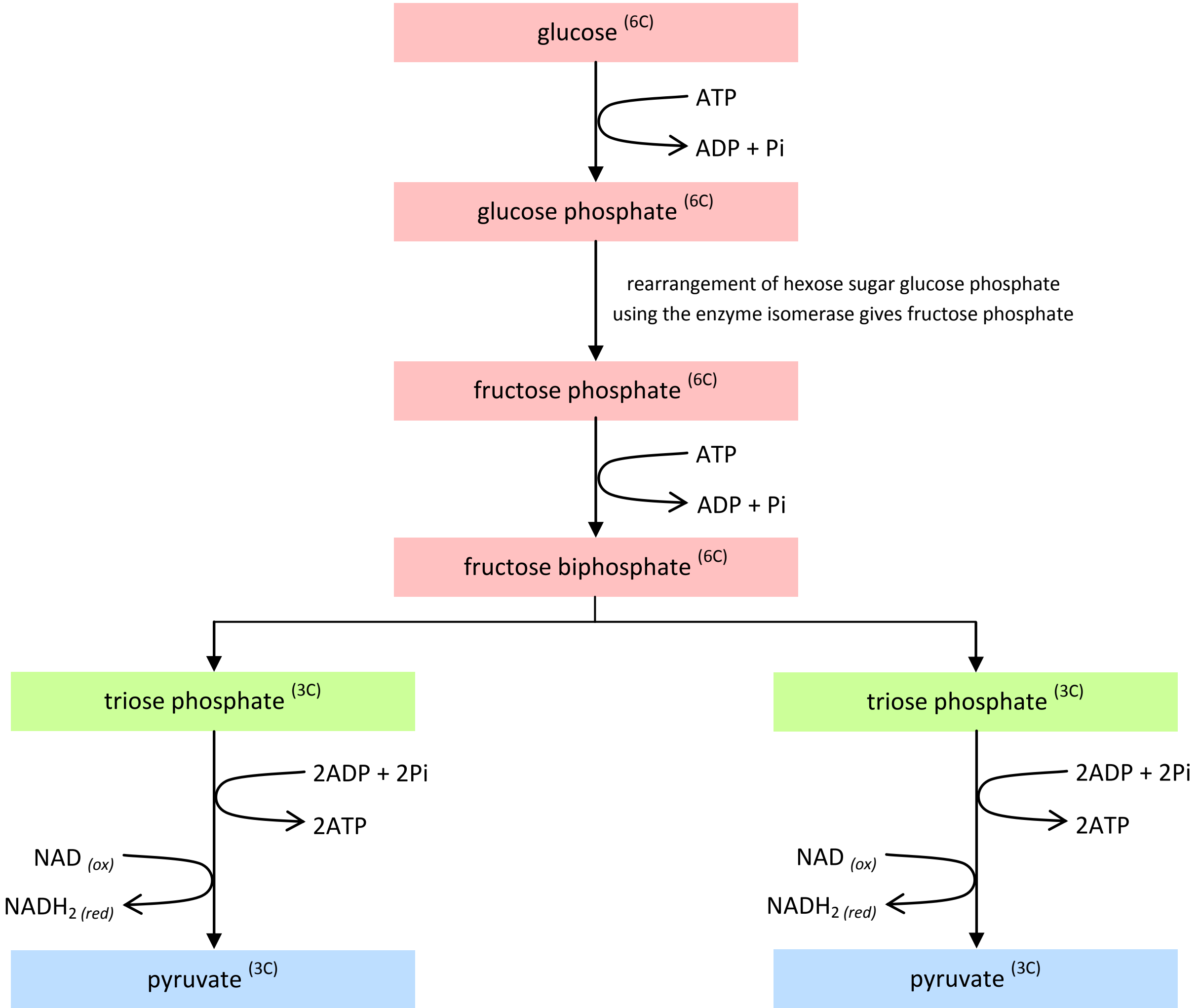
4.2 Glycolysis

The first stage of respiration of glucose, occurring in cellular cytoplasm

There are two variations of the respiration of glucose: *aerobic* and *anaerobic*. Each of these types of respiration has only one ‘stage’ in common, and that is **glycolysis**. This is a metabolic pathway which is the first stage in cellular respiration, occurring in both eukaryotic and prokaryotic cells. The chains of reactions which are known collectively as glycolysis take place in the cytoplasm, not the mitochondrion. The entire process consists of ten unique reactions, but it can be simplified to a simple three stage process.



Phosphorylation

The first few steps are collectively known as **phosphorylation**. The process begins with glucose, a *hexose* sugar (or six-carbon sugar). One molecule of ATP is **hydrolysed**, which releases one phosphate group, which attaches to the glucose molecule. The molecule then becomes glucose phosphate (still a 6-carbon sugar). This molecule is then rearranged to give fructose phosphate (which has the same chemical formula, but a slightly different biochemical structure). This happens using the enzyme **isomerase**. Next, another molecule of ATP is hydrolysed, and the phosphate group released attaches to the fructose at carbon-1 to become fructose biphosphate.

Splitting of fructose biphosphate

Note that, at this point, the process has *used up* two molecules of ATP, but none have been produced. Therefore, there is an energy deficit by the end of the phosphorylation stage. However, by the end of the glycolysis process, there will be an energy surplus (and further energy is released in the various other stages of respiration). The second stage of glycolysis involves splitting the fructose biphosphate into two separate molecules. Two triose phosphate molecules are produced (triose as they are a 3-carbon sugar, and they each get one phosphate group from the two accumulated so far).

Forming the pyruvate

Next, two hydrogen atoms are removed from each triose phosphate using dehydrogenase enzymes, which are aided by **NAD** (nicotinamide adenine dinucleotide), a hydrogen acceptor, so one molecule of NAD combines with the two hydrogen atoms from each triose phosphate molecule, resulting in one reduced NAD molecule for each triose phosphate (reduced NAD is $NADH_2$). At this stage, two molecules of ADP are phosphorylated (one for each triose phosphate molecule), so two molecules of ATP are produced.

Finally, a series of micro-reactions, catalysed by enzymes, converts each triose phosphate molecule into a **pyruvate** molecule (also a 3-carbon compound). At this stage, two more molecules of ADP are phosphorylated, again one on each side, so another two molecules of ATP are produced.

The products of glycolysis

Whilst it may seem a rather complicated process, this long chain of reactions actually only produces the following:

- two molecules of pyruvate (this compound is actively transported into the mitochondrion for the next process)
- two molecules of reduced $NADH_2$ which carry hydrogen atoms which will be used in the process later on
- two molecules of ATP (whilst you can clearly see that during the final few stages of glycolysis *four* molecules of ATP were produced, it is important to not forget that two ATP molecules are used up during the initial phosphorylation)

It should be noted that the events which make up glycolysis occur entirely in the cellular cytoplasm, and not in the mitochondrion. The stage of aerobic respiration which follows glycolysis is the 'link reaction', which takes place in the mitochondria. The basis of this reaction is the pyruvate produced from glycolysis, and in order for the pyruvate molecules to reach the mitochondrial matrix, they are actively transported there.