Biomass – Biochemical Pathways

3.1 BIOCHEMICAL PATHWAYS

In a cell, the breaking down or building of compounds occurs via a series of smaller intermediate reactions. The series of reactions is known collectively as a **biochemical pathway**. Of course, both anabolic and catabolic biochemical pathways exist, however, only catabolic pathways will be dealt with in the following section. As discovered earlier, catabolic reactions can be divided up into those which occur aerobically (respiration) and those which occur anaerobically (fermentation and anaerobic respiration). The catabolism of glucose will be studied, as it is one of the most commonly studied and best known catabolic pathways.

3.1.1 Glycolysis

The first part of glucose degradation occurs via a pathway known as the glycolytic pathway, which is also sometimes referred to as the Embden Meyerhoff pathway. A schematic of this pathway is shown overleaf **Figure 1**.

This pathway is common to aerobic and anaerobic catabolism and yields a net energy gain of two molecules of ATP. Glycolysis can be divided into two main stages:

- In Stage One, energy is required to activate the glucose molecule before it can be oxidised. Two ATP molecules are utilised to provide activation energy. No O-R reactions are involved and, therefore, no energy is released.

- In Stage Two, O-R occurs in which the original glucose molecule (electron donor) is oxidised to two molecules of pyruvate, with the concomitant reduction of NAD^+ to NADH. Energy is released and stored as ATP. Four molecules of ATP are produced during this stage, resulting in a net gain of two ATP molecules per molecule of glucose.

Pyruvate then becomes the starting point of a number of different biochemical pathways.

Glycolysis - catabolic pathway

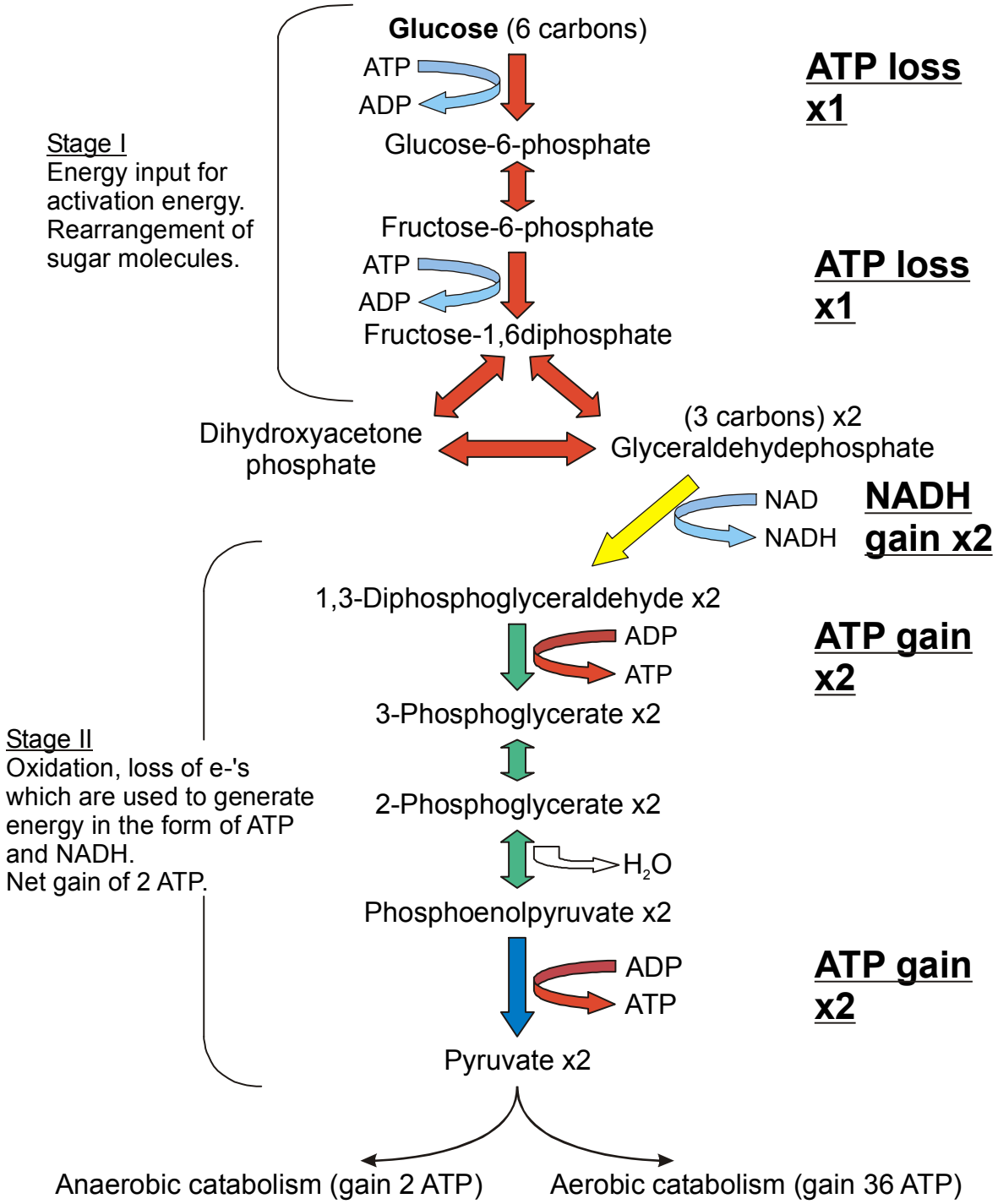

Figure 1. A simplified schematic of the Glycolytic Pathway.

3.1.2 Aerobic Respiration (Krebs Cycle)

When oxygen is available to a cell, the pyruvate (also known as pyruvic acid) molecules will be passed into the Krebs cycle (illustrated below in **Figure 2**) where it is oxidised completely to CO_2 and H_2O with the transfer of released energy to ADP molecules, which become energy-rich ATP **respiration**. As was saw when looking at the O-R Tower earlier (see Figure 4, Unit 2), the oxidation of glucose being linked to reduction of oxygen releases the maximum amount of energy possible.

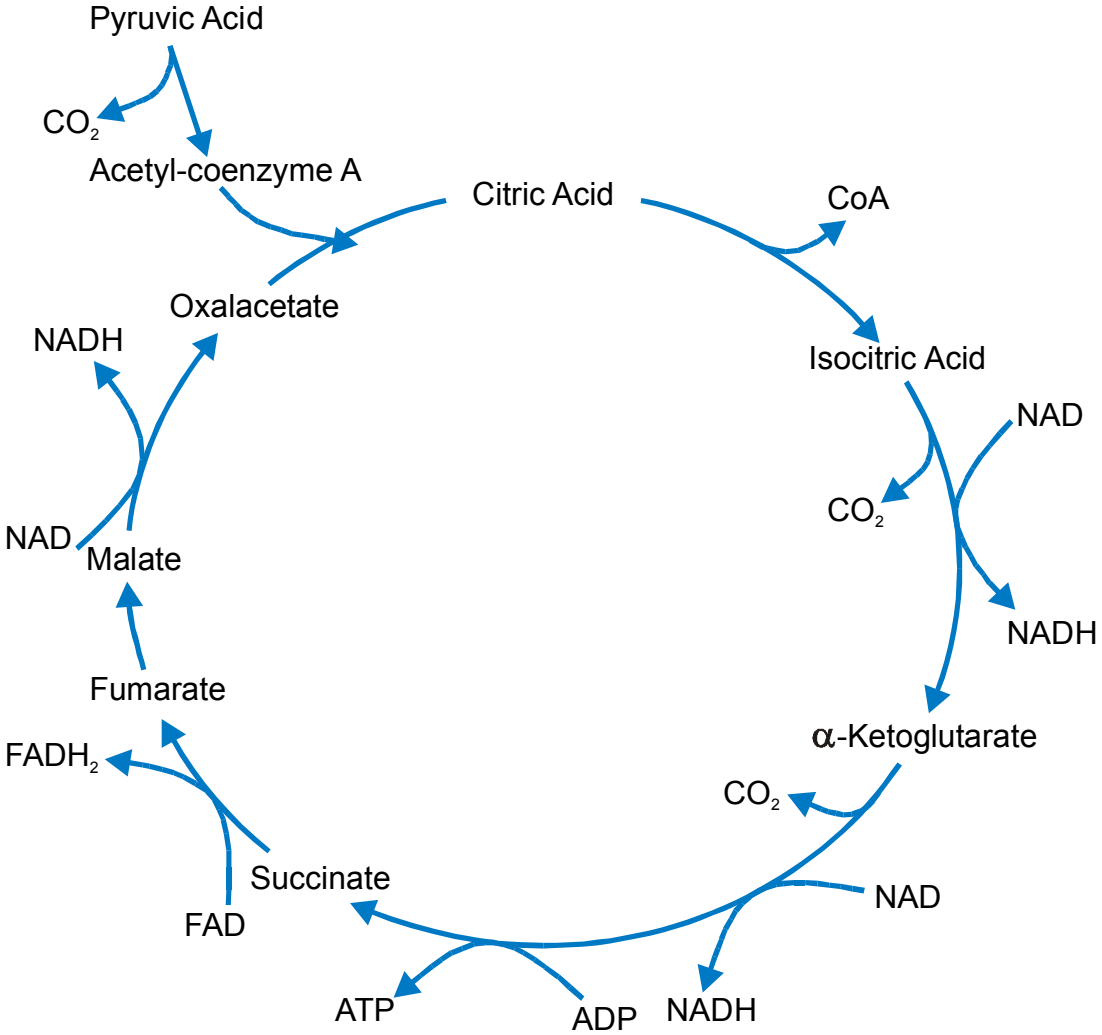

Figure 2. An illustration of the reactions occurring within the Krebs Cycle.

The essential feature of this cycle is that a 2-carbon acid (acetyl Co-A) combines with a 4-carbon acid (oxalacetate) to form the 6-carbon citric acid, which is highly reactive. The energy from pyruvate is then slowly released in a stepwise manner, the electrons being passed to electron carriers (NAD^+ and FAD^+) and finally to oxygen, resulting in the production of water. Energy generated the cascading of electrons from pyruvate to oxygen is stored as ATP. The carbon content of the 3-carbon pyruvate molecule is released as carbon dioxide, thus, the end-products of aerobic catabolism of glucose are only carbon dioxide and water. A net gain of 36 ATP molecules is achieved from the aerobic respiration of one molecule of glucose. This is, therefore, a highly efficient process, with over 35% of the available energy being returned to the cell.

3.1.3 Anaerobic Respiration (Fermentation and Anaerobic Digestion)

The previous section demonstrated that aerobic reactions are of no use as a source of bioenergy. Most of the available energy is conserved for use by the cell and results in high levels of growth and cell production. On the other hand, anaerobic reactions are relatively inefficient, resulting in a much lower release of energy, lower growth and cell production and a high-energy waste product, which can be utilised as a biofuel.

Taking the example of anaerobic fermentation, it can be seen that conversion of pyruvate to ethanol (or other organic acids such as lactic acid) (see **Figure 3** below) does not yield any further energy to the cell. The production of fermentation products is carried out only to balance the loss of electrons that occurred during Stage Two of the glycolytic pathway. These electrons were transferred to two NADH carriers (see **Figure 1**) and require a final electron acceptor. Rearrangement of the pyruvate molecules to form acetaldehyde (there is no loss of energy during this rearrangement, only loss of carbon atoms as CO_2) provides an electron acceptor for the above-mentioned electrons. Thus, acetaldehyde accepts the electrons and is reduced to ethanol (the biofuel) and NADH is re-oxidised to NAD^+. The net gain of ATP from the anaerobic fermentation of one molecule of glucose is **only two**, the rest of the potential energy being conserved in the waste product, ethanol.

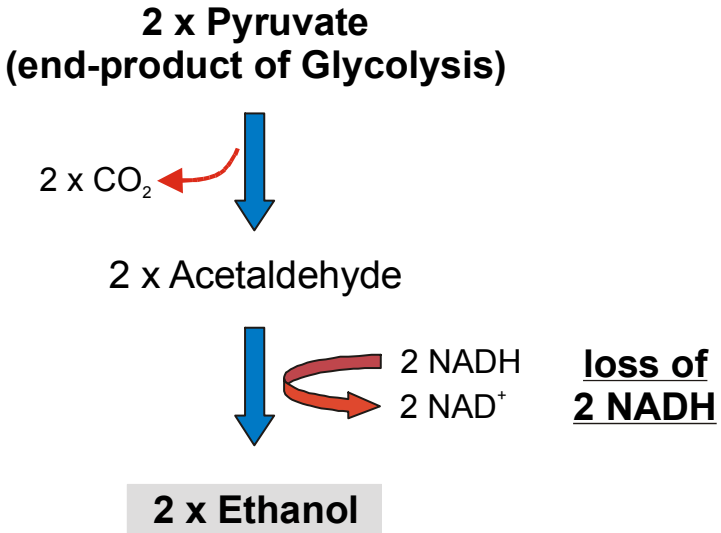

Figure 3. Anaerobic Fermentation of Pyruvate to form Ethanol.

The production of methane from ethanol during anaerobic digestion conforms to the same principles, i.e. energy released to be used by the cell is relatively low, with most of the energy being conserved in a high-energy end product, methane. However, the whole process of anaerobic digestion consists of a number of different steps, including anaerobic fermentation and anaerobic respiration, and will be explained in more detail in the main Biomass module.

Two on-line biology books can be found at the following Web Site addresses:

http://gened.emc.maricopa.edu/bio/BIO181/BIOBK/BioBookTOC.html

http://esg-www.mit.edu:8001/esgbio/chapters.html

Both sites are good for revision of cell bioenergetics, basic chemistry and photosynthesis, although I prefer the layout and information of the first site.

If you want to have a go at dissecting a cell, a *virtual cell* can be found at the following web site address:

http://www.life.uiuc.edu/plantbio/cell/

As well as being fun, this site gives good information on the structure and functions of all cell parts, and even includes animated clips on ATP generation and photosynthesis.