Section 4.1 – Glycolysis

Cellular respiration

- Conversion of glucose to ATP
- Can occur in two different forms when O_2 is present and when O_2 is not present.
- **Aerobic respiration –** requires O_2.
- **Products of aerobic respiration –** CO_2, H_2O and lots of ATP
- **Anaerobic respiration** - O_2 Absent
- **Products of Anaerobic respiration –** In animals (lactate + small amounts of ATP), In plants (ethanol + CO_2 + small amounts of ATP)

Glycolysis

- Common to both aerobic and anaerobic respiration
- Occurs in the cytoplasm
- Glucose (6 Carbon) is split into pyruvate (3 Carbon)

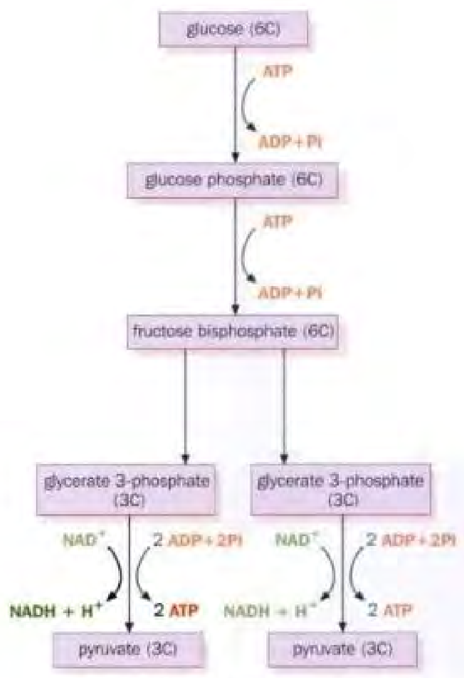
4Stages of Glycolysis

1. **Glucose is activated by phosphorylation - Two ATP** molecules are used so that two inorganic phosphate molecule can bind onto the glucose molecules making it more reactive, since its activation energy is lowered for the enzyme catalysed stage.

2. The phosphorylated glucose molecules split into two (3C) trios phosphate molecules.

3. **Triosphosphate is oxidised -** Hydrogen is removed from each triosphosphate molecules to the hydrogen carrier NAD to make NADH (reduced NAD)

4. **Production of ATP –** Triosphosphate is converted into Pyruvate (another 3 carbon molecule). As this occurs 2 molecules of ATP are regenerated from ADP and P_i.



two molecules of pyruvate are produced from **each** molecule of glucose

Energy yields from Glycolysis.

The conversion of triose phosphate to pyruvate produces 2 ATP molecules each. (**4** in total for the two molecules generated by splitting phosphorylated glucose. However to phosphorylated glucose (stage 1) two molecules of ATP are required, Making the total energy yield ***4ATP molecules – 2 ATP molecules = 2 ATP molecules***

Section 4.2 – Link reaction + Kreb cycle

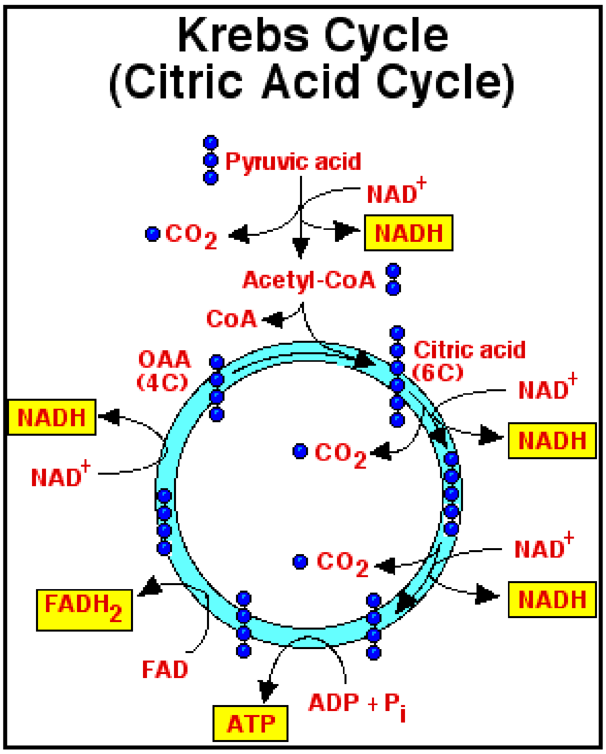
The link reaction

- Pyruvate from Glycolysis is actively transported into the matrix of the mitochondria
- Pyruvate undergoes a series of reactions
- Pyruvate is oxidised by removing hydrogen to from NADH, CO_2 and a two carbon molecule called an acetyl group.
- The acetyl group reacts with an enzyme called coenzyme A. (CoA)
- This forms acetyl coenzyme A. (acetyl CoA)

Pyruvate + NAD + CoA → Acetyl CoA + NADH + CO_2

The krebs Cycle

- A series of oxidation and reduction reaction
- Acetyl CoA (2C) reactions with a (4C) molecule to form a (6C) molecule
- The (6C) molecule loses CO_2 and Hydrogen to produce one ATP molecule as a result of substrate level phosphorylation.



Coenzymes – Hydrogen carriers

Coenzymes are molecules that some enzymes require in order to function. (e.g. NAD + dehydrogenase enzymes that catalyse the removal of hydrogen ions from substrate molecules.
The play a major role in photosynthesis and respiration

The significance of the krebs cycle

- It produces hydrogen atoms (NADH) → used in the electron transfer chain for oxidative phosphorylation

- Regenerates the (4C) molecule, preventing an accumulation of acetyl CoA

- A source of intermediate compounds used by cells to manufacture important substances such as fatty acids, amino acids and chlorophyll

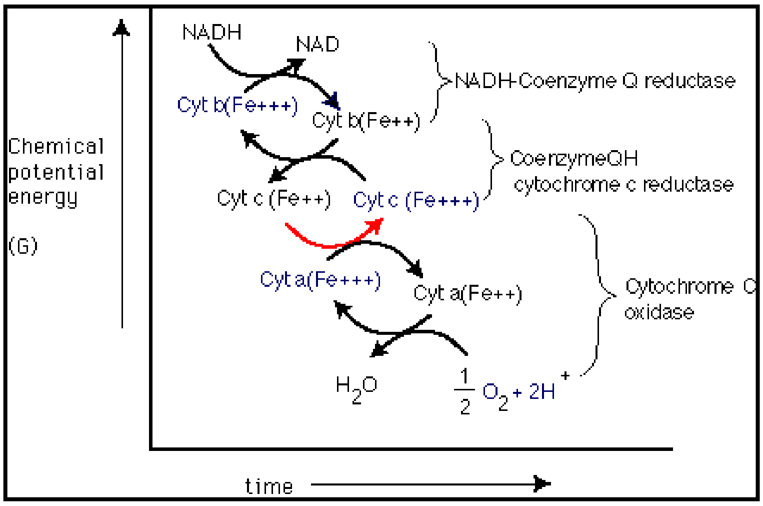
Section 4.3 – Electron transport chain

Takes place in the inner membrane of the mitochondria
NADH + $FADH_2$ from the Krebs cycle are needed by the electron transport chain for the production of ATP.
It is the electron associated with the proton that provides the energy to combine ADP with an inorganic phosphate molecule to form ATP.

Stages of the electron transport chain

1. NADH and $FADH_2$ are oxidised, thus releasing a proton and an electron.
2. The protons are actively transported into the intermembranous space. (between the inner and outer membrane)
3. The electron is taken up by an electron carrier
4. The electron-carrier is therefore reduced.
5. The electron from the reduced carrier is oxidised again by passing the electron to a new carrier which in turn also becomes reduced.
6. By passing the electron down a chain of electron carriers through oxidation/reduction reactions the electron loses energy in the process. It is this lost energy that is used to combine ADP with Pi to form ATP
7. Protons accumulate in the intermembranous space and so diffuse back into the cell through special protein channels
8. At the end of the chain, electrons combine with the proton as well as oxygen to form water.
9. Oxygen is therefore the final accepted of electrons in the electron transport chain.

Cyanide is a non-competitive inhibitor of the enzymes involved in the electron transport chain.
The enzyme catalyses the addition of electrons to the O_2
Cyanide causes an accumulation of H^+ and e^-, bringing cellular respiration to a halt



Section 4.4 – Anaerobic respiration

Since oxygen is the final acceptor of electrons in the electron transport chain, when it is not present, ATP cannot be produced in this way. Instead, ATP is produced anaerobically.
Ones produced in Glycolysis, products such as pyruvate and hydrogen must be constantly removed.
Furthermore, the hydrogen from NAD must be released so that it can be used again.
In order to do this the pyruvate with react with reduced NAD

In plants and some microorganisms, pyruvate is converted into ethanol and water, whereas in mammals and other organisms it is converted into lactate.

Production of ethanol in plants/some organisms

Occurs in organisms such as yeast and root hair cells for example that are in waterlogged soil
The reaction for the production of ethanol and CO_2 is as follows:

Pyruvate (3C) + reduced NAD → ethanol (2C) + carbon dioxide (1C) + NAD

Production of lactate in animals

Occurs most commonly when an animal is subject to physically demanding exercises that require large amounts of O_2 to release energy from respiration.
However, if oxygen cannot be supplied quickly enough, the cells producing ATP will temporarily respire anaerobically whilst producing lactate as a by-product.
As with any other form of anaerobic respiration, the reduced NAD must be converted back to NAD for the process to continue, and so it reacts with pyruvate.
The reaction is as follows

Pyruvate (3C) + reduced NAD →lactate (3C) + NAD

Lactate being acidic will cause pain and cramps to be experienced in muscle tissue.
It must therefore be removed quickly by oxidising it with O_2 to release more energy or taken to the liver by the blood to be stored as glycogen.