Respiration & Energy

All living organisms need a constant supply of energy to stay alive

Processes required for energy

- Substances must be moved across membranes across their concentration gradient, by active transport
- Movement requires energy such transporting a protein or contracting a muscle.
- Synthesising large molecules from smaller ones, known as an anabolic reaction.

★ Energy

→ ATP (Adenosine triphosphate is the universal energy currency of cells. Each cell makes ATP and releases energy from it.

→ ATP is a molecule made up of the base adenine, ribose sugar and three phosphate groups

→ When one phosphate group is removed from ATP, ADP (Adenosine diphosphate) is formed and 30.5 $kJ\,mol^{-1}$. Removal of another phosphate group produces AMP (Adenosine Monophosphate) and 30.5 $kJ\,mol^{-1}$. Removal of last phosphate leaving adenosine, releases only 14.2 $kJ\,mol^{-1}$.

* ATP is the most effecient energy currency as

- ATP is a small water soluble molecule so can move anywhere
- The hydrolysis of a molecule of ATP is quick and a very easy process. in the cell.

- The hydrolysis of one molecule of ATP releases a useful quantity of energy - enough to fuel any energy-requiring process

- ATP is a relatively stable molecule in the in the pH it normally occurs in, does not break down unless enzyme ATPase is present.

* ATP is made mainly in two reactions

- using energy provided directly by another chemical reaction - this is a substrate linked reaction.

- by chemiosmosis, a process that takes place across the inner membranes of mitochondria, using energy released by movement of hydrogen ions down their concentration gradient

* Aerobic respiration

→ Respiration is a process in which organic molecules are broken down in a series of stages to release chemical potential energy, which is used to synthesise ATP.

Glucose breakdown is in 4 stages; glycolysis, link reaction, Krebs cycle and oxidative phosphorylation.

★ Glycolysis

→ It is the splitting of glucose that takes place in the cytoplasm of the cell.

→ A series of reaction where glucose (6C) splits into two molecules of pyruvate (3C)

Glycolysis

glucose (6C)

ATP → ↓

fructose phosphate (6C)

ATP → ↓

fructose 1,6 bisphosphate

↓

2 molecules of triose phosphate (3C)

→ 2ATP

→ 2H (2NAD → 2 reduced NAD)

↓

intermediates

↓ → 2 ATP

2 molecules of pyruvate (3C)

2 ATP is used in adding Phosphate groups

First step is phosphorylation. Phosphate groups are transferred from ATP molecules to glucose. Raises the energy levels of the glucose molecules.

Hydrogen is transferred from the 2 molecules of triose phosphate to carrier molecule NAD. NAD is reduced and triose phosphate is oxidised.

End product is pyruvate

Link reaction

Pyruvate reaches the matrix of mitochondrion, enzyme decarboxyles and dehydrogenises Remainder of molecule reacts with coenzyme A to produce acetyl coenzyme A.

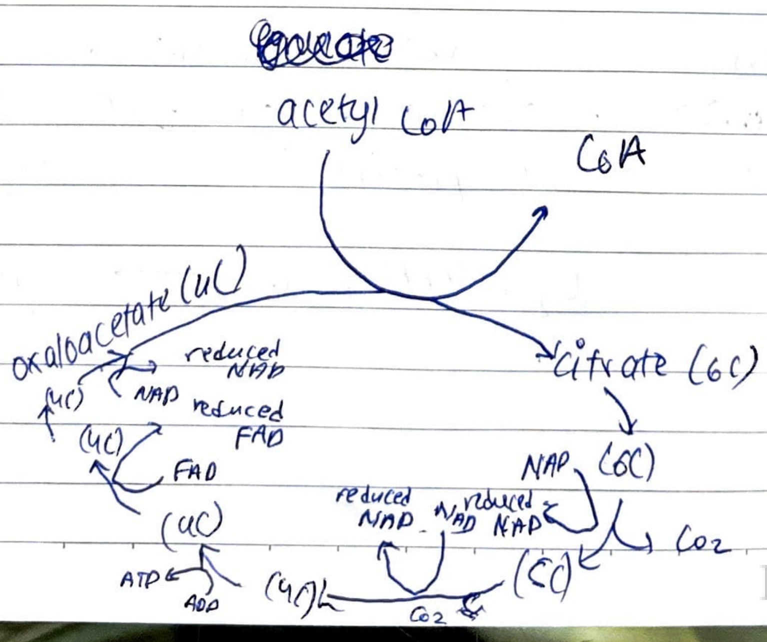
CoA is a complex molecule composed of a nucleotide (adenine + ribose) and a vitamin (vitamin B5) coenzyme A molecule made of CoA & 2C acetyl group.

pyruvate + CoA + NAD ⟶ acetyl CoA + CO_2 + reduced NAD

✲ Krebs cycle

Acetyl CoA (2C) combines with oxaloacetate (4C) to form citrate (6C)

citrate is decarboxylated and dehydrogenated in a series of steps releasing CO_2 as waste gas and H which are accepted by NAD & FAD)



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Oxidative phosphorylation and electron transport chain (ETC)

- Takes place in the inner mitochondrial membrane

→ ETC is a series of membrane proteins, called electron carriers. Electrons are passed from ~~to~~ the next with redox reactions

- Process

→ Electron has energy, as it moves from one carrier to the next, some energy is released.

→ Some energy is used to actively move protons from the matrix to the inner and outer membranes. This produces a high concentration of protons in the intermembrane space producing a concentration gradient. ~~protons pas~~

→ protons pass back using facilitated diffusion through passively by protein channels. Each channel is formed by a ~~class~~ large protein molecule, the enzyme, ATP synthase. As the protons pass through, their energy is used to synthesise ATP by chemiosmosis.

→ oxygen is required to accept electrons as they arrive at the end of ETC. 4 electrons recombine with 4 protons and an oxygen to make water.

$$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$$

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Respiration w/o oxygen

A cell can still produce small amout of ATP using anaerobic conditions. If reduced NAD can be oxidised glycolysis can take place

- Ethanol fermentation

Hydrogen from reduced NAD is passed to ethanal. Pyruvate is first decarboxylated to ethanal and reduced the ethanol by enzyme alcohol dehydrogenase.

- Lactate fermentation

In mammals and some micoorganisms, when deprived of oxygen, pyruvate acts as the hydrogen accepter. It is converted into lactate by enzyme lactate dehydrogenase. Lactate can be oxidised converting it back to pyruvate to generate ATP and can be stored by being converted to a polysaccharide glycogen.

Energy values for respiratory substrates

When lipids are respired, pair of carbon atoms are directly fed into the Krebs cycle. When amino acids are respired, they are first converted into into pyruvate or coenzyme A, and again move directly into the Krebs. Glucose is always the primary source of energy, and then lipids when glucose store is over.

Respiratory Substrate	Energy density / $kJ\,g^{-1}$
carbohydrate	15.8
lipid	39.4
protein	17.0

★ Respiratory Quotients

→ The ratio of carbon dioxide produced to oxygen used.

$$RQ = \frac{\text{volume of carbon dioxide given out in unit time}}{\text{volume of oxygen taken in unit time}}$$

Respiratory substrate	Respiratory Quotient
carbohydrate	1.0
lipid	0.7
protein	0.9

For anaerobic

$$C_6H_{12}O_6 \longrightarrow C_2H_5OH + 2CO_2 + \text{energy}$$

$$RQ = \frac{CO_2}{O_2} = \frac{2}{0} = \infty$$