SCHOOL OF MARVEL-ASELLA

Subject: Bio Unit Five

Grade: 11

April 2020

UNIT -5
ENERGY TRANSFORMATION

- In a biological processes one of the most important is energy.
- energy is capacity do work.
- in biology energy expressed in unit called kilojoules (KJ)or kilocalories(kcal)
- N.B; **1Kcal =4.184KJ**

Energy and metabolism

- What is the ATP molecule like?
- The full name for ATP is **A**denosine **T**ri-**P**hosphate. The ATP molecule is composed of :
  - a nitrogenous base (this one contains adenine)
  - • a pentose sugar
  - • a phosphate group

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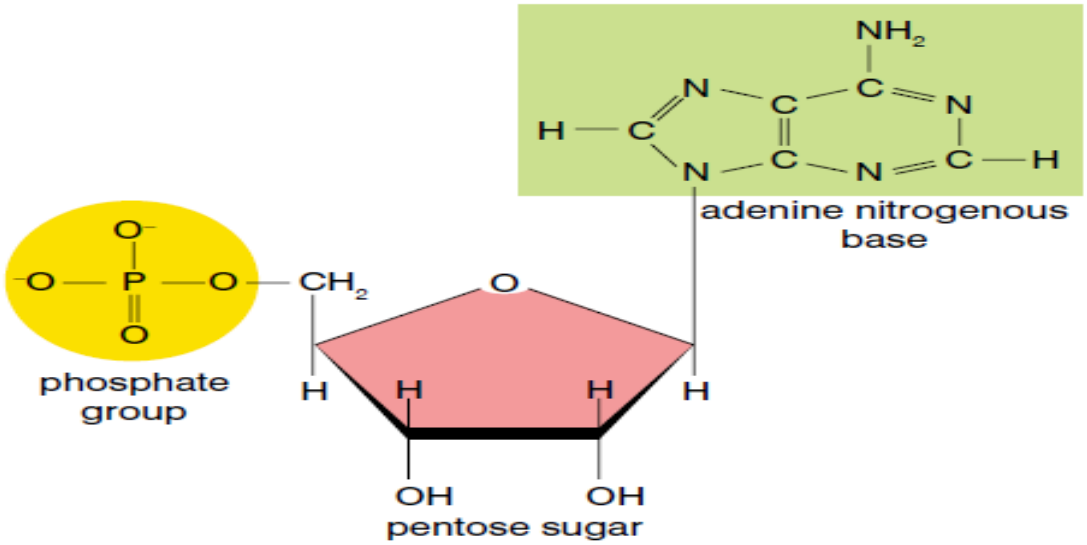

Figure 5.1 A nucleotide containing the nitrogenous base adenine

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- ATP is sometimes described as a **phosphorylated nucleotide**. Since it contains phosphate groups
- ATP is adenine nucleotide with three phosphate groups added on it to make it three phosphate.
- the bond b/n second and third phosphate contains energy w/c released.
- this splits ATP to ADP + pi +energy.

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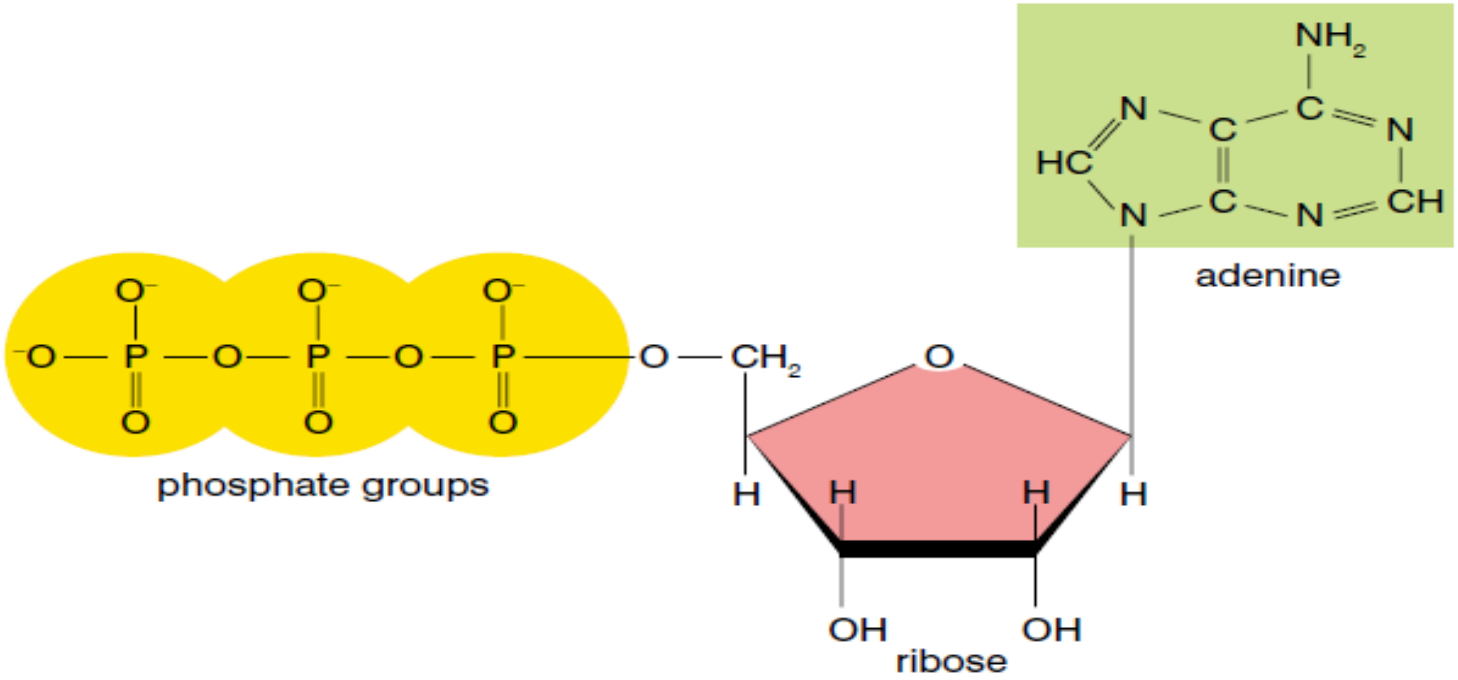

Figure 5.2 The structure of the ATP molecule

ATP AS ENERGY TRANSFER MOLECULE IN CELLS.

- Sunlight energy cannot be used directly by plants (and certainly not by other organisms) to 'drive' the synthesis of proteins – or any other molecules.
- The same applies to the energy held in a glucose molecule.
- These two energy sources must be used to produce ATP, which is used to transfer the energy to the relevant cellular process.
- We say that it is coupled to these processes.

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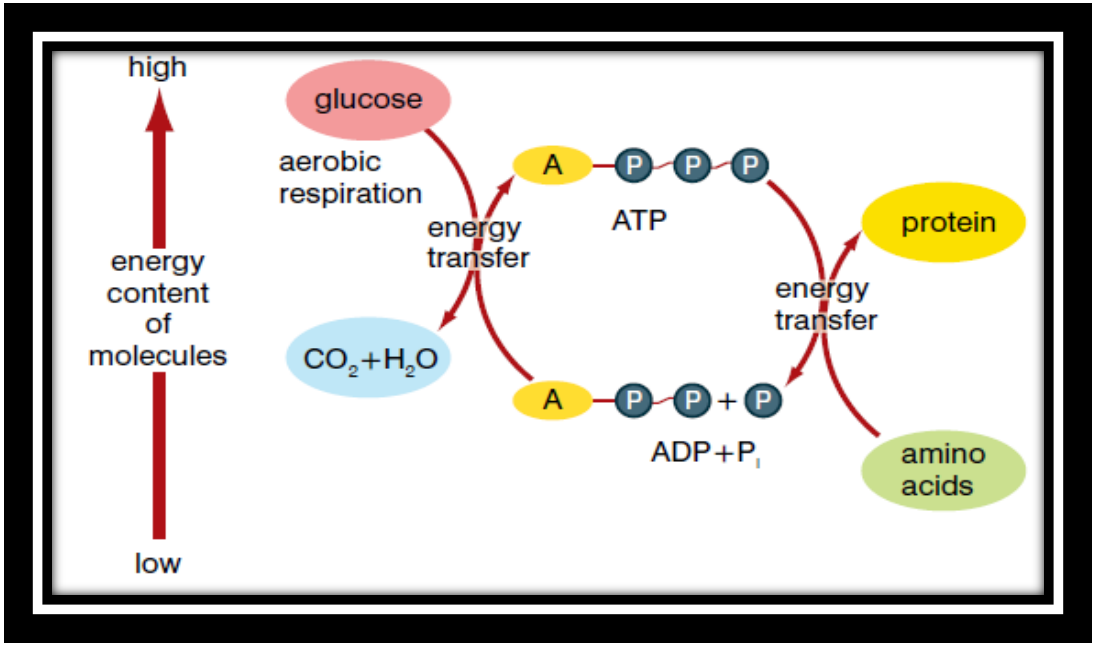

Figure 5.4 *Coupled reactions transfer energy in cells*

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- **ATP is adapted to this role because it:**
  - releases energy in relatively small amounts that are closely matched to the amounts of energy required in many biological processes occurring inside cells
  - releases energy in a single-step hydrolysis reaction, so the energy can be released quickly
  - is able to move around the cell easily, but cannot escape from the cell

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- **The following processes are examples of processes that require energy from ATP:**
  - ✓ The synthesis of macromolecules – such as proteins
  - ✓ Active transport across a plasma membrane.
  - ✓ Muscle contraction
  - ✓ Conduction of nerve impulses
  - ✓ The initial reactions of respiration (the later reactions release energy from glucose to form more ATP)

Production of ATP in the cell

- As it is described earlier the formation of ATP involves joining of ADP and pi which also requires an input of energy.
- ATP production is controlled by enzyme called ATP synthase.
- ATP synthase works within the membrane of mitochondria or chloroplast.

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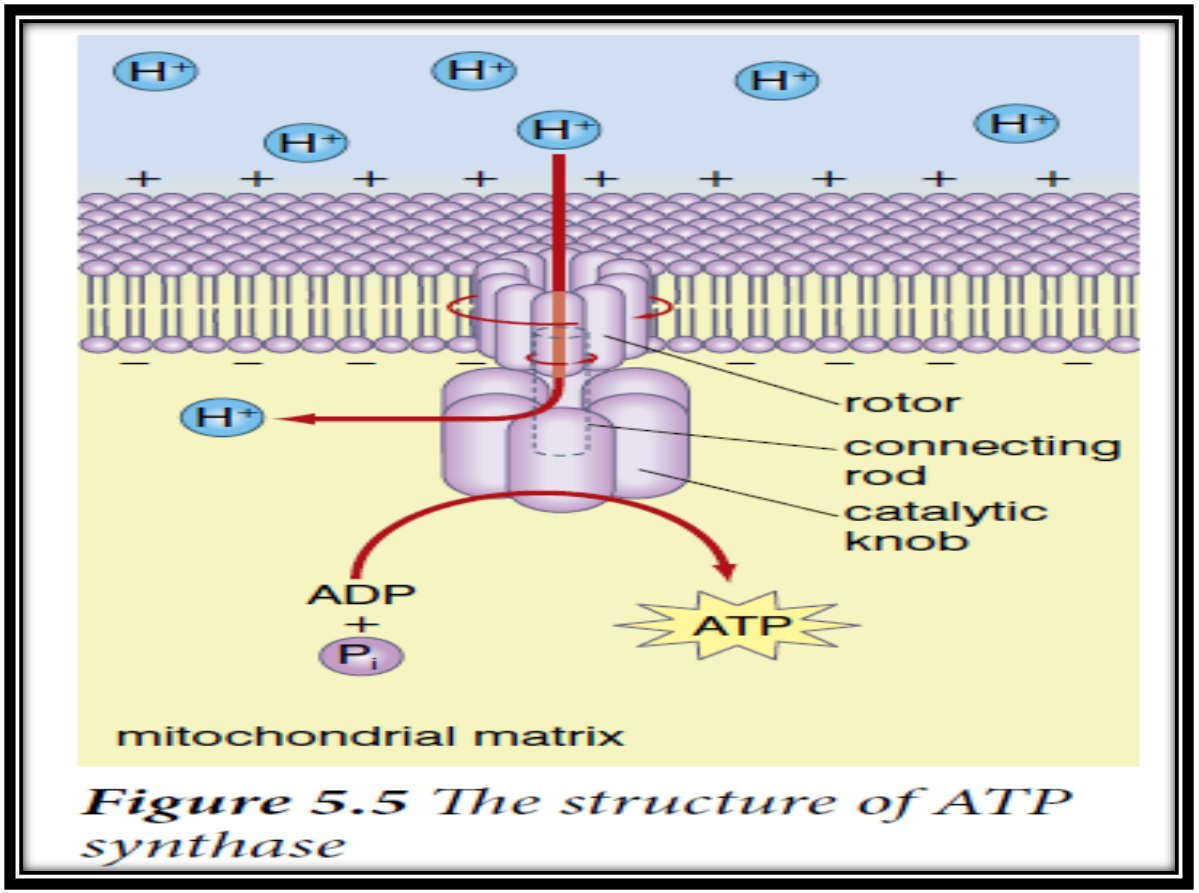

Figure 5.5 The structure of ATP synthase

PRODUCTION OF ATP IN THE RESPIRATION

- There are two main pathways by which ATP molecule can be produced in the process of respiration. This are:
  - **Aerobic pathways**(aerobic respiration) ,this requires the presence of oxygen**,**
  - **Anaerobic pathways**(anaerobic respiration and fermentation) this can take place in the absence of oxygen.

How is ATP produced in aerobic respiration?

- A small amount of ATP is produced in a way that does not involve the ATP synthase molecule; this method is called **substrate level phosphorylation.**
- In this process, another molecule such as phosphoenol pyruvate (the *substrate*) is able to transfer a phosphate group directly to ADP.
- There is no ATP synthase involved and no P_i. The process is still catalyzed by an enzyme, it is just not ATPsynthase.

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- Figure 5.6 shows how substrate level phosphorylation works.
- As already mentioned, this process only produces a relatively small amount of the ATP produced in aerobic respiration – in fact it produces about 10% of the total ATP produced in aerobic respiration.
- As about 90% of the ATP produced in aerobic respiration is produced by ATP synthase, many of the reactions of this process are geared to producing the hydrogen ions that will spin the rotor of the ATP synthase molecule.

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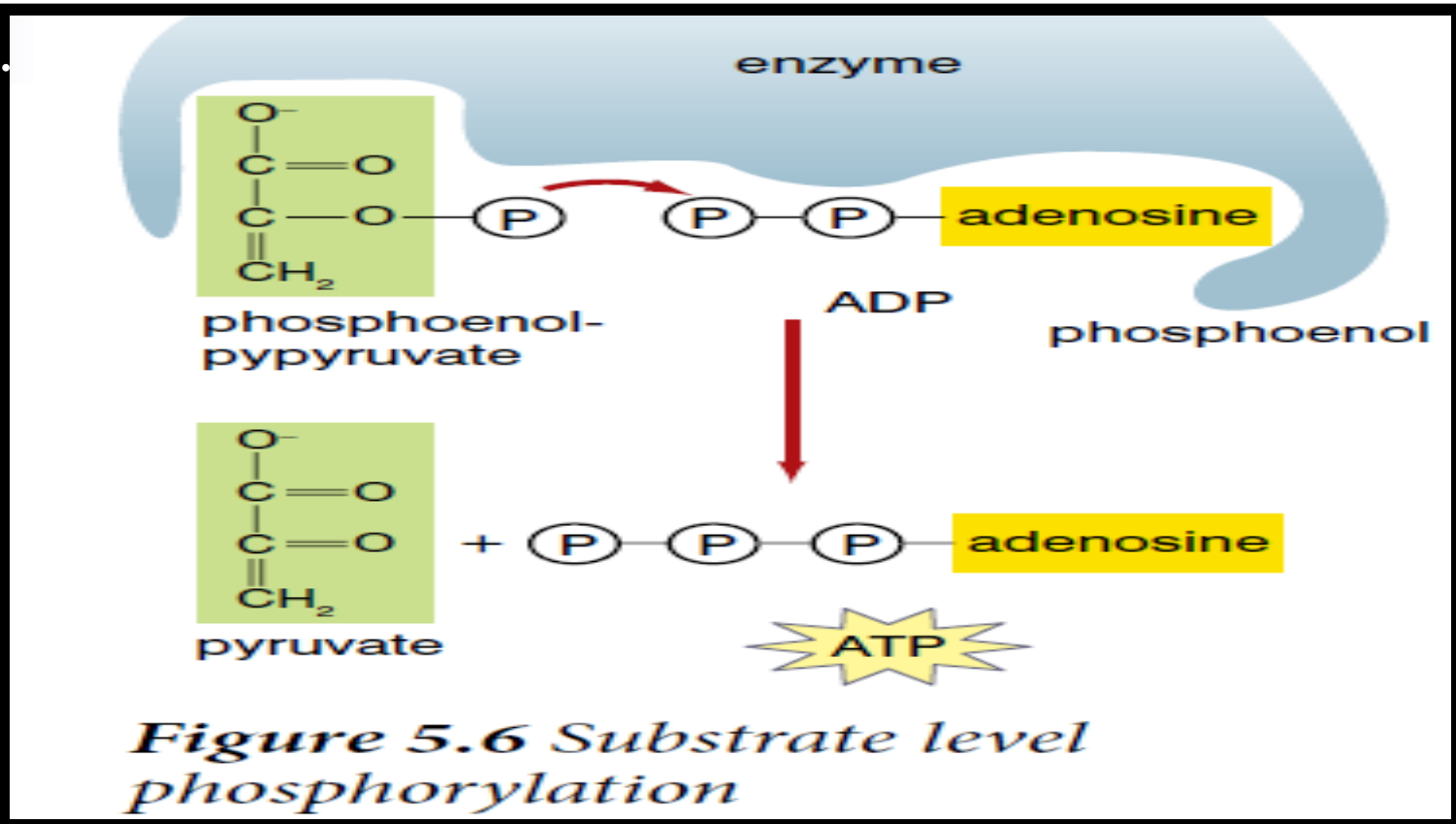

Figure 5.6 Substrate level phosphorylation

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- Many different organic molecules can be respired – they are called **Respiratory substrates**. However, glucose is the most commonly respired substrate.
- **How are hydrogen ions transferred from glucose to ATPsynthase?**
  - Two molecules are important in this transfer process:
    - ✓ Nicotinamide Adenine Dinucleotide (NAD)
    - ✓ Flavine Adenine Dinucleotide (FAD)
- Both are coenzymes and are capable of accepting hydrogen ions.
- When this happens, we say that the molecules have been **reduced**. (decrease the oxidation state of a substance).
- We write the reduced forms of the molecules as NADH and FADH or NAD(reduced) and FAD(reduced).

CONT. ..

- These molecules can release their hydrogen ions and become **oxidized** again.
- The hydrogen ions can then be used to turn the rotor of ATP synthase.

What are the stages of aerobic respiration of glucose?

There are four stages in the aerobic respiration of glucose.

These are:

- glycolysis
- the link reaction
- Krebs cycle
- electron transport and chemiosmosis

Oxidation and reduction

- Reduction is the opposite of oxidation, in which particles accept oxygen, lose hydrogen or lose electrons.
- In reduction, a particle loses oxygen, gains hydrogen or gains electrons.
- When a particle of compound A is oxidized by (say) losing electrons, the electrons have to go somewhere.
- A particle of compound B accepts the electrons and is reduced.
- The two processes always happen together and the reactions in which they are involved are called redox (reduction and oxidation) reactions. Figure 5.7 shows this.

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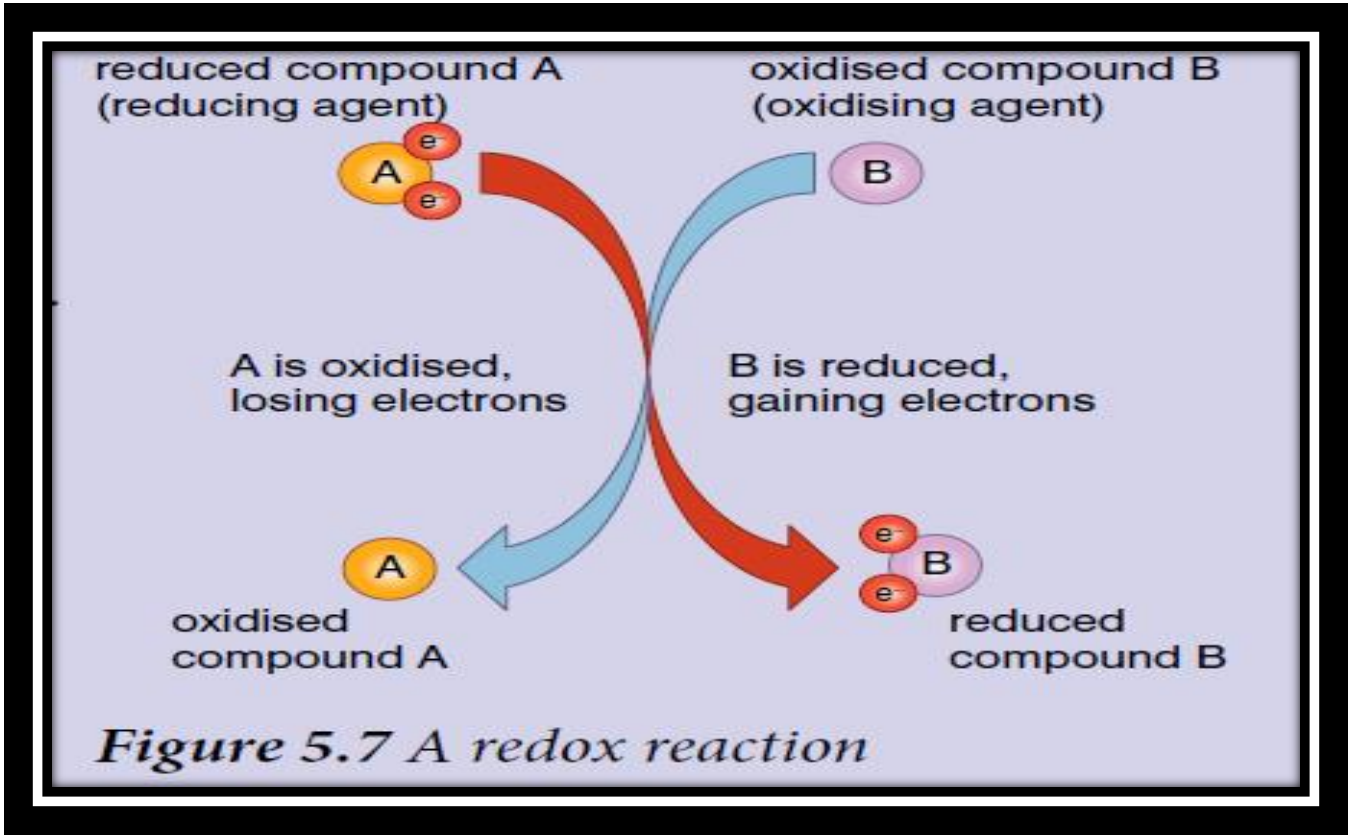

Figure 5.7 A redox reaction

GLYCOLYSIS

- The first stage, glycolysis, takes place in the cytoplasm. It does not take place inside the mitochondria because:
  - the glucose molecule cannot diffuse through the mitochondrial membranes (it is a medium-sized molecule and is not lipid soluble), and
  - there are no carrier proteins to transport the glucose molecule across the membranes.

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- Glycolysis (literally ‘glucose splitting’) results in glucose being converted into a smaller molecule containing only three carbon atoms – pyruvate. Pyruvate can enter the mitochondria and so all the other stages take place inside the mitochondrion. Figure 5.8 shows where the stages of aero

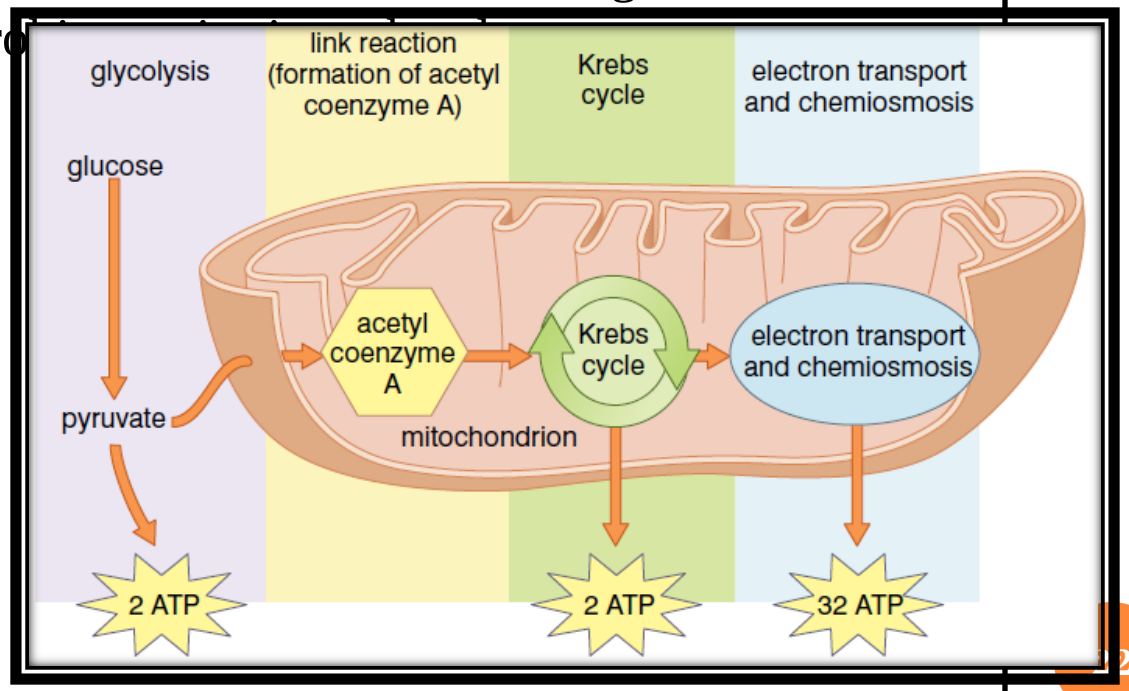

Figure 5.8 *The stages of aerobic respiration*

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- In the link reaction, pyruvate is then converted into a two-carbon compound that enters into a cycle of reactions.(Krebs cycle).
- **N.B** both link reaction and Krebs cycle are take place the fluid matrix of mitochondria.
- In all three stages (glycolysis, the link reaction and Krebs cycle), hydrogen atoms are transferred to NAD to produce reduced NAD.
- The Krebs cycle also produces reduced FAD.
- These molecules later release their hydrogen atoms as protons (hydrogen ions) and electrons in the final stage of aerobic respiration.

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- The electrons pass along a series of molecules called an **electron transport chain**.
- The protons are used in the chemiosmotic synthesis of ATP as they spin the rotor of the ATP synthase enzyme located in the inner membrane of the mitochondrion.
- Eventually, the protons (hydrogen ions) and electrons will combine with oxygen to form water.
- The electron transport chain grinds to a halt and so does the production of ATP by ATP synthase. Because it is oxygen-dependent, this method of production of ATP is called **oxidative phosphorylation**.

CONT. ..

- The link reaction, Krebs cycle and the reactions of the electron
- transport chain all depend on the presence of oxygen. None of
- these occurs in anaerobic respiration. Glycolysis can take place in the absence of oxygen and is the only energy-releasing process in **anaerobic respiration**.
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WHAT HAPPENS IN GLYCOLYSIS?

- The reactions of glycolysis take place in the cytoplasm. The following reactions take place in glycolysis:
  - Two molecules of ATP are used to ‘ phosphorylate’ each molecule of glucose. This makes the glucose more reactive
  - In the phosphorylation process, it is converted to another six carbon sugar (fructose 1,6-bisphosphate).
  - The fructose 1,6-bisphosphate is split into two molecules of the three-carbon sugar glyceraldehyde-3 phosphate (GP)
  - Each molecule of GP is then converted into pyruvate, with the production of two molecules of ATP (by substrate level phosphorylation) and one molecule of reduced NAD.

CONT. ..

- The main reactions of glycolysis are shown in figure 5.9. Note:
  - ✓ The figures in brackets give the number of carbon atoms in that molecule, so (6C) means six carbon atoms per molecule
  - ✓ Two molecules of pyruvate are produced from one molecule of glucose.

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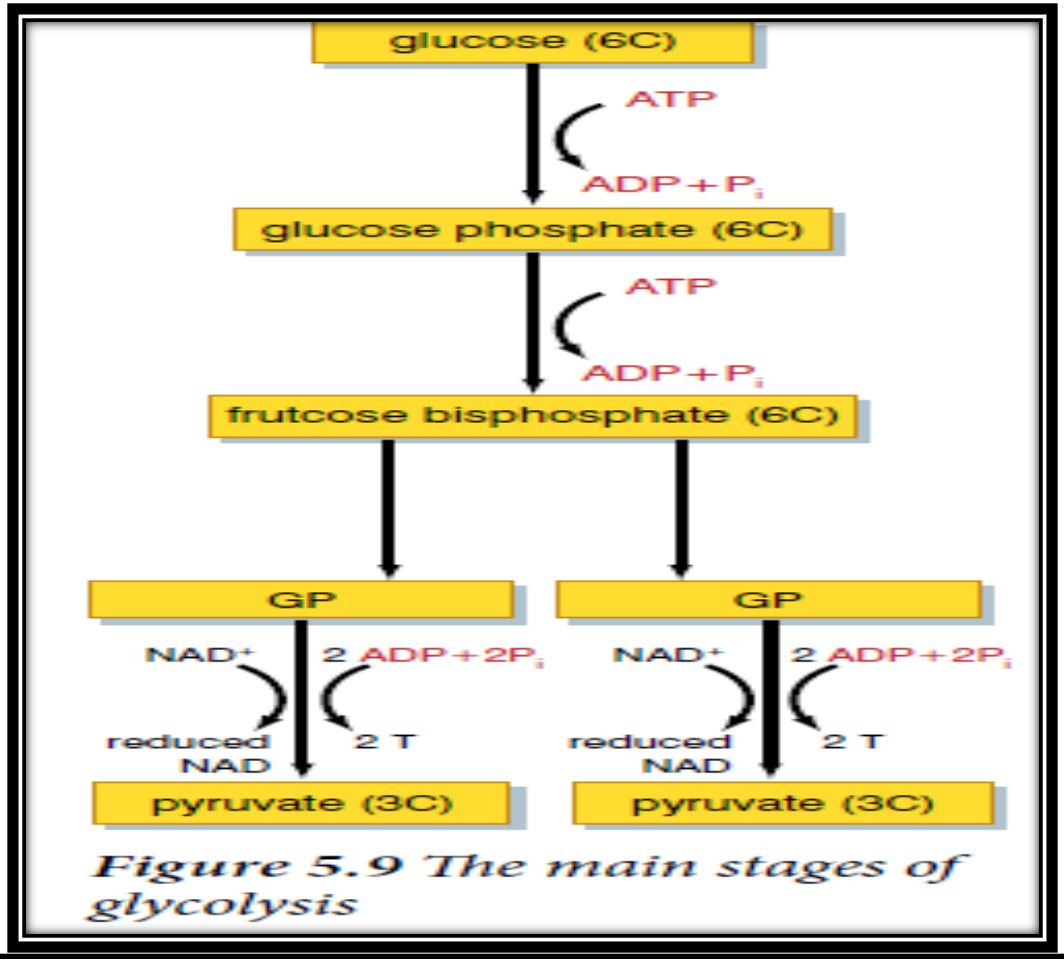

Figure 5.9 The main stages of glycolysis

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- At the end of glycolysis, there is a net gain of two ATP molecules per molecule of glucose (two molecules are used initially and then four are produced). Two molecules of reduced NAD are also produced (per molecule of glucose). The molecules of pyruvate pass into the mitochondria through carrier molecules in the mitochondrial membrane.

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- A summary of the overall reaction of glycolosis:
- C6H1206 + 2ATP + 4ADP + 2Pi +2NAD ➞ 2C3H603 + 2ADP + 4ATP +2NAD reduced + 2H+ +2H20
- In the link reaction, a molecule of pyruvate reacts with a molecule of coenzyme A (CoA) to form a molecule of acetyl coenzyme A (acetyl CoA). In the reaction:
  - hydrogen is lost and reduced NAD is formed; removing hydrogen from a molecule is **dehydrogenation.**
  - a carbon atom is lost to form carbon dioxide; removing carbon from a molecule is **decarboxylation**.

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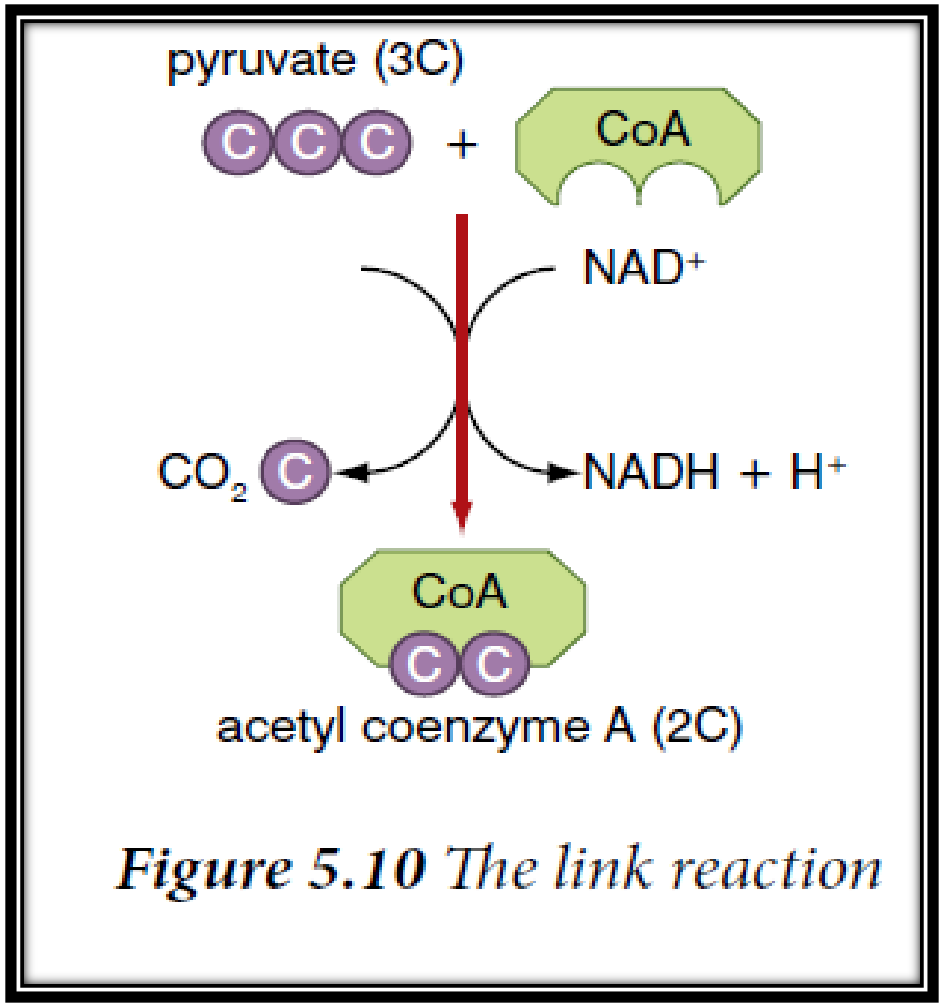

Figure 5.10 *The link reaction*

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- The acetyl coenzyme A then reacts with a C4 molecule (a molecule containing four carbon atoms) called oxaloacetate.
- In the reaction, acetyl CoA breaks down into:
  - a two-carbon ‘acetyl’ group, which reacts with the C4 compound oxaloacetate to form a C6 compound, and
  - the original coenzyme A molecule, which is reused in further reactions with other molecules of pyruvate.
- This is the first reaction of the Krebs cycle.

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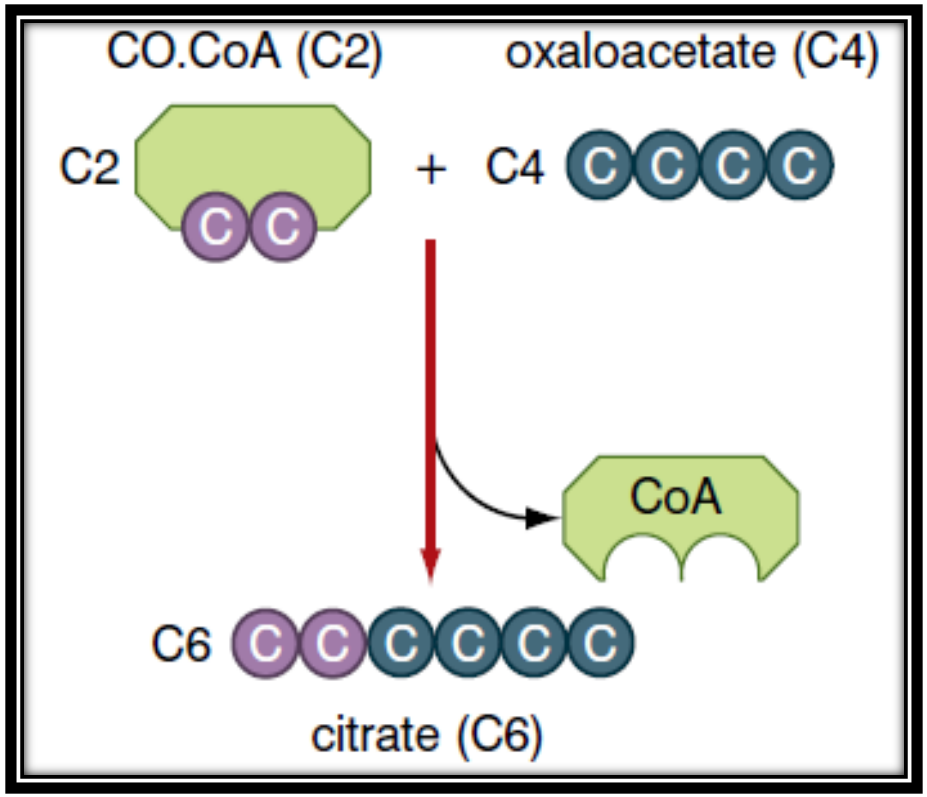

Figure 5.11 *The first reaction of the Krebs cycle*

What happens in the Krebs cycle?

- The two-carbon group from acetyl coenzyme A reacts with the four-carbon compound **oxaloacetate** to form a six-carbon compound called **citrate**
- Citrate then loses a carbon atom (is decarboxylated) to form a five-carbon compound and CO_2 is produced
- The five-carbon compound is then further decarboxylated to form a four-carbon compound and CO_2 is again produced; a molecule of ATP is also produced by substrate level phosphorylation

CONT. ..

- The four-carbon compound undergoes several molecular transformations to regenerate the original four-carbon compound (oxaloacetate) and the cycle is complete and can begin again with oxaloacetate reacting with another molecule of acetyl CoA.
- In several reactions in the cycle, reduced NAD is produced and, in just one reaction, reduced FAD is produced.

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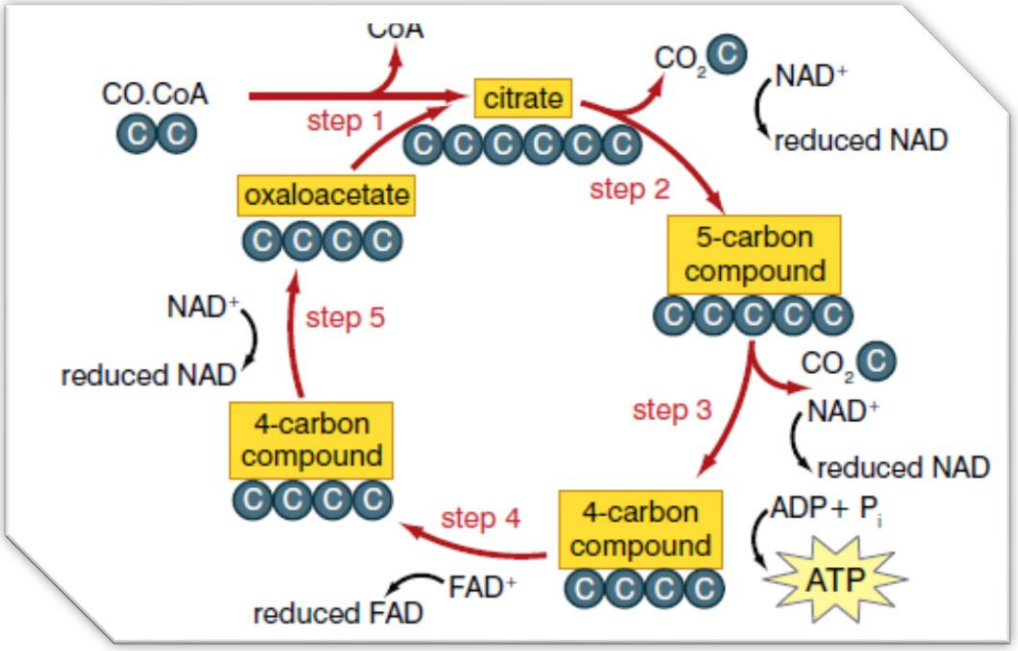

Figure 5.12 *The main stages of the Krebs cycle*

SECOND WORK SHEET

Answer the following question accordingly

1. What transformation of energy do organisms carry out?
2. why do living organisms need energy and where does this energy come from?
3. How ATP synthesized?
4. What are the products of the hydrolysis of ATP?
5. Where does ATP stored?

CONT. ..

. 1. What are the main events of glycolysis?

2. What does glycolysis produce?

3. Describe three ways in which the ATP molecule is suited to its function of energy carrier in a cell.

4. Describe how ATP is formed by:

(i) .substrate-level phosphorylation.

(ii) . chemiosmosis.

5. How are hydrogen ions transferred from glucose to ATPsynthase?

CONT. ..

1. what are the four stages of cellular respiration and where do they occur?
2. what is the stage of respiration?
3. what do you mean by oxidative phosphorylation and where does it occur?
4. what are the products of oxidative phosphorylation?
5. where does substrate level phosphorylation occur?