Chapter 12 – Respiration

2.2 Cell Metabolism	Learning Objectives
2.2.5 Respiration	1. Define, give the role and balanced equation for "aerobic respiration". 2. Explain the stages and molecules involved in the process of respiration. 3. Cellular location of the first and second stage of the process. 4. Define "anaerobic respiration" and explain with reference to fermentation. 5. Examine the role of microorganisms in industrial fermentation, including bioprocessing with immobilised cells: procedure, advantages, and use in bioreactors. 6. Prepare and show the production of alcohol by yeast.
H.2.2.10 Respiration (Extended Study)	7. *First-stage process: Glycolysis – the conversion of a six-carbon carbohydrate to pyruvate with the generation of ATP. 8. *Fermentation option – ethanol or lactic acid production. 9. *Second-stage process: Production of Acetyl Co. A and one molecule of carbon dioxide. 10. *Krebs Cycle and the electron transport system, which produce more carbon dioxide, water, and ATP molecules.

External respiration → process by which organisms exchange gas with their environment.

Internal respiration → controlled release of energy from food (glucose).

→ Aerobic or Anaerobic

ENERGY CARRIERS INVOLVED

ATP/ADP

- ADP – Adenosine DiPhosphate
- ATP – Adenosine TriPhosphate
- They are energy molecules found in all the cells of all living things.
- They involve high levels of energy.
- ATP is formed when high energy electrons combine with a phosphate molecule and ADP.

NADH

- NAD - Nicotinamide Adenine Dinucleotide
- NAD+ gains a H (Hydrogen atom) and 2 electrons to form NADH
- An electron carrier molecule, carries electrons to Electron Transport System and transfers them for ATP formation.

- **Aerobic respiration** → controlled release of energy from food using oxygen
  Equation for aerobic respiration

Glucose (Food) + **Oxygen** (Breathing in) → **Energy** (Heat, ATP) + **Carbon Dioxide** + **Water** (Breathing out)

$$C_6H_{12}O_6 + 6O_2 \longrightarrow \text{Energy} + 6CO_2 + 6H_2O$$

- The energy formed is in a molecule in the form of ATP.
- 40% of the energy in Glucose is converted to ATP, other 60% is last as heat.
- The 6 carbons in Glucose ($C_6H_{12}O_6$) are separated, releasing 6 molecules of Carbon Dioxide ($6CO_2$)

Aerobic respiration (Ordinary Level):

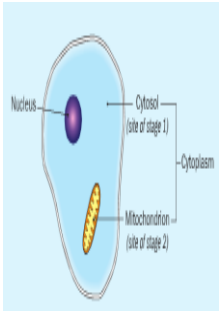
Stage 1 – glycolysis

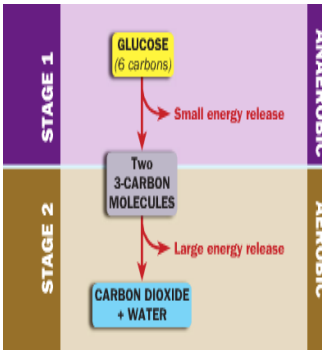
- This stage does not require oxygen (**Anaerobic**).
- It only releases a small amount of energy.
- It takes place in the **cytosol** (cytoplasm less organelles).
- Glucose is broken down into two 3-carbon molecules (called **Pyruvate**)

Glucose → two 3-carbon molecules + a small amount of energy

Stage 2:

- This stage requires oxygen (**Aerobic**).
- A large amount of energy is released
- It takes place in the **mitochondria**
- Two 3-C molecules → **carbon dioxide** + **wat**

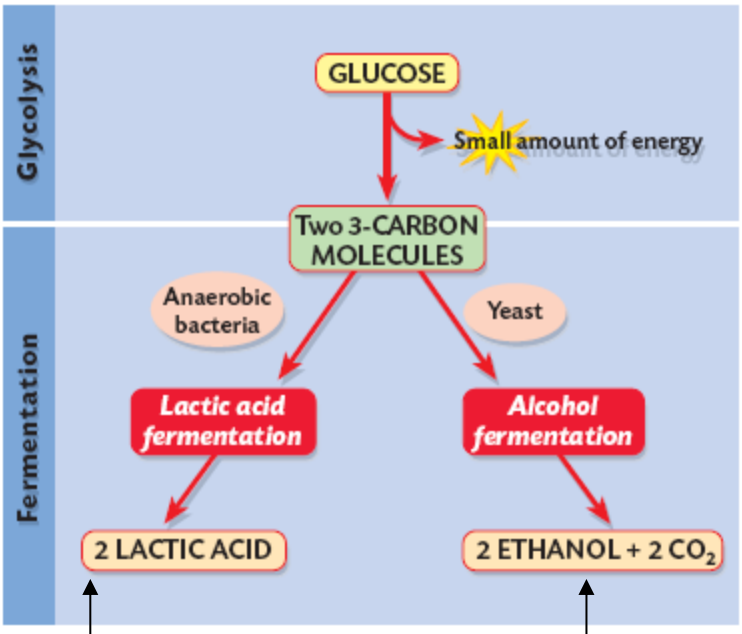




	Stage 1	Stage 2
Location	Cytosol	Mitochondria
Oxygen Requirements	Anaerobic	Aerobic
End Products	Two 3-carbon molecules	Carbon Dioxide & Water
Energy Produced	Small amounts of ATP	Large Amounts of ATP

Anaerobic respiration (Ordinary level):

- ***Anaerobic respiration → controlled release of energy from food without the use of oxygen***
- Can also be called **fermentation**
- Does not require oxygen
- It is a 1 stage process
- There are 2 common types of fermentation – lactic acid fermentation & alcohol fermentation



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Causes cramp and muscular stiffness

Broken down in the liver

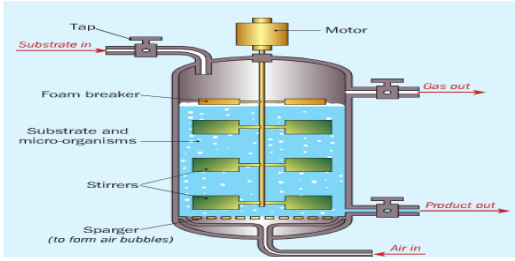
Generally involves Yeast

Industrial fermentation:

- ***Biotechnology refers to the use of living things or their components to manufacture useful products.***
- Micro-organisms are placed in a container along with a suitable substrate.
- The vessel in which the biological reactions take place is called a ***bioreactor***.
- ***Bio-processing – use of enzyme controlled reactions to produce a product***.

Examples:

Micro-organisms	Product	Use
Bacteria	- Ethanol - Antibiotics - Hormones - Yoghurt etc	- Beer, wine, solvent for paints - Kill other bacteria - e.g insulin - Food
Yeast	- Ethanol - Carbon dioxide	- Beer, wine etc - Causes dough to rise (bread)

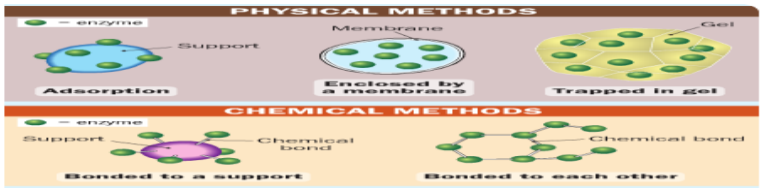


Bioreactor

- The **stirrers** mix the micro-organisms with the subtrate.
- To reduce foam production there is a **foam breaker** at the top of the bioreactor.
- The micro-organisms are in a liquid **nutrient medium**.
- Many bioreactors have oxygen pumped in through a **sparger**, which forms easily dissolvable air bubbles.

Immobilised Cells

- Immobilised cells may be used in bioprocessing
- Cells are immobilised in the same way as enzymes. They may be bonded to each other, attached to a support or enclosed in a gel.



Advantages of immobilised cells:

- Immobilised cells can be easily recovered at the end of the reaction (No need for purification)
- They can be reused.
- Efficiency is not affected by the immobilisation.

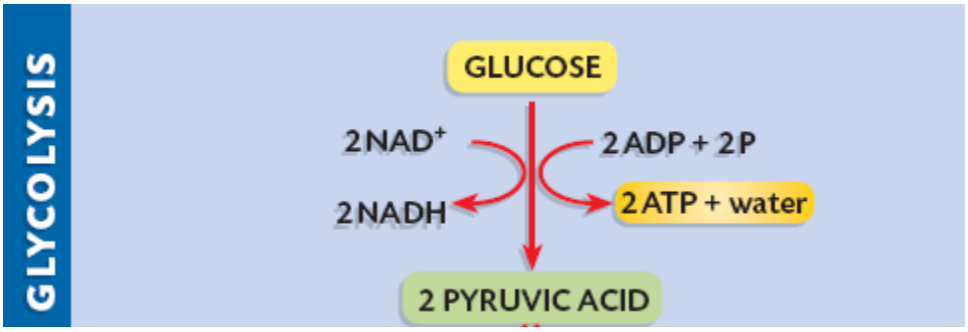
Uses of immobilised cells:

- In alcohol production, Yeast cells are trapped in sodium alginate.
- In vinegar production, bacteria are fixed to wood shavings.
- In sewage treatment micro-organisms are trapped on grains of sand or gravel, to decompose waste.

<u>Aerobic Respiration – HL only</u>

Stage 1 – glycolysis

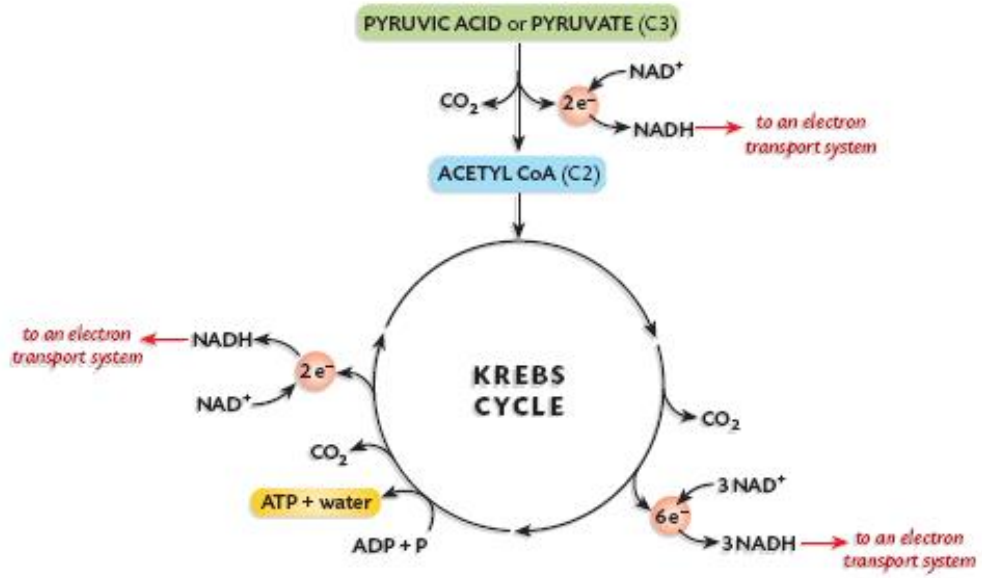
- Takes place in the **cytosol** of the cell
- It is **anaerobic**



- Glucose is broken down into **pyruvic acid/pyruvate** (two 3-carbon molecules)
- Some of the energy is used to form ATP
- More of the energy is used to form NADH (electron carrier)

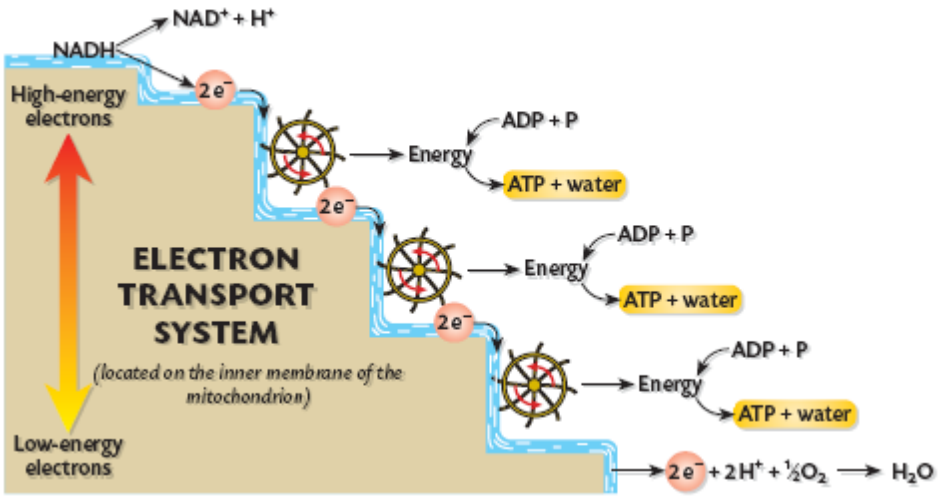
Stage 2:

- **<u>If</u>** oxygen is present, pyruvic acid enters the mitochondria.
- Pyruvic acid loses a carbon dioxide molecule to form **Acetyl-co-enzyme A(C_2).** It also loses 2 high energy electrons. These combine with NAD^+ and H^+ to form NADH.
- NADH will enter the electron transport chain.
- Acetyl co-A now enters into a series of reactions known as **Krebs cycle**.



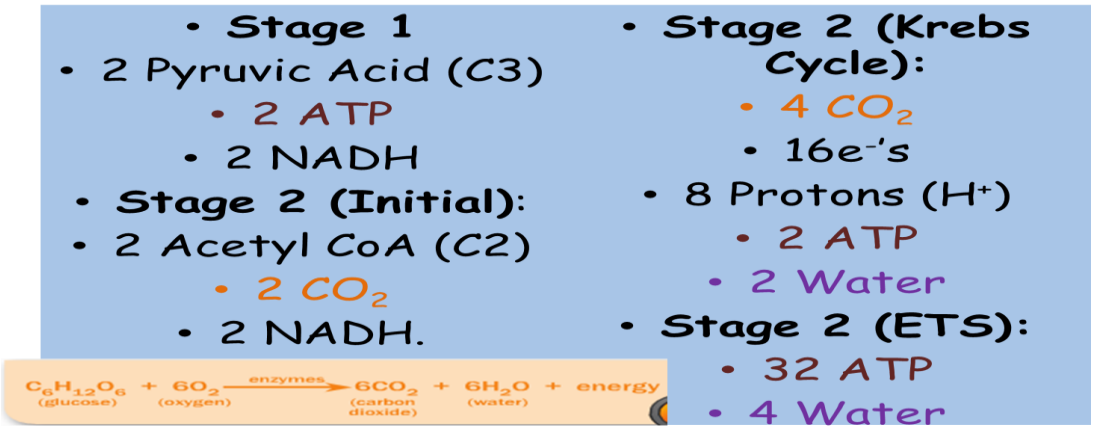
- Acetyl co-A is broken down releasing 2 carbon dioxide and protons.
- Energy is released in the form of high energy electrons
- These electrons along with the protons join with NAD^+ to from NADH. The NADH molecule enters the electron transport system.
- Some energy is also trapped by ADP to form ATP + water.

Electron transport system:



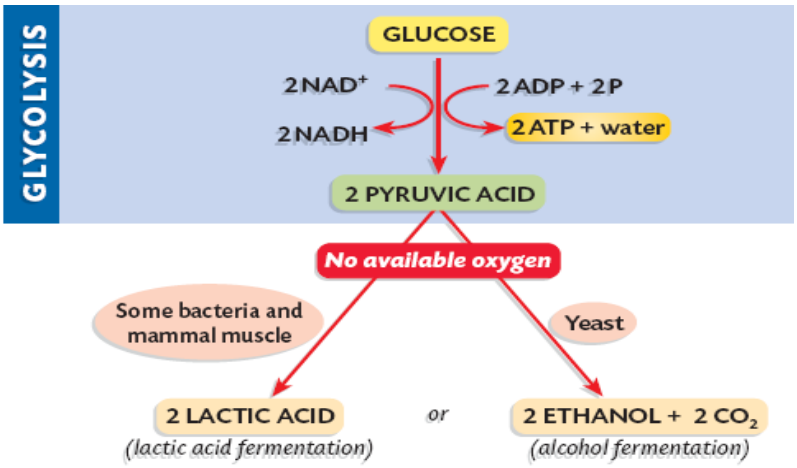
- NADH releases high energy electrons.

- The electrons are passed from molecule to molecule along the system. As they pass they lose energy. Some of this energy is used to form 32 ATP.
- At ***the end of the system*** low energy electrons combine with oxygen and protons to form **water**.



Anaerobic Respiration:

If no oxygen is present the Pyruvic Acid remains in the cytosol and is reduced (due to gaining of electrons, to either Lactic Acid OR Ethanol and Carbon Dioxide.



Overview of Aerobic & Anaerobic Respiration