How Your Body Obtains Energy

- 1. You eat food and the food passes through your digestive system.
- 2. The food is then broken down into small molecules.
- 3. These molecules then pass out of the digestive system and into your bloodstream.
- 4. The molecules travel through the bloodstream to the cells of your body.
- 5. Inside the cells, the energy in the molecules is released.

Cellular Respiration

The process in which sugars (glucose) are converted into usable energy (ATP).

Sugar + Oxygen → Carbon Dioxide + Water + Energy

What is respiration?

- Physiological definition:

The act of exchanging gasses with the environment

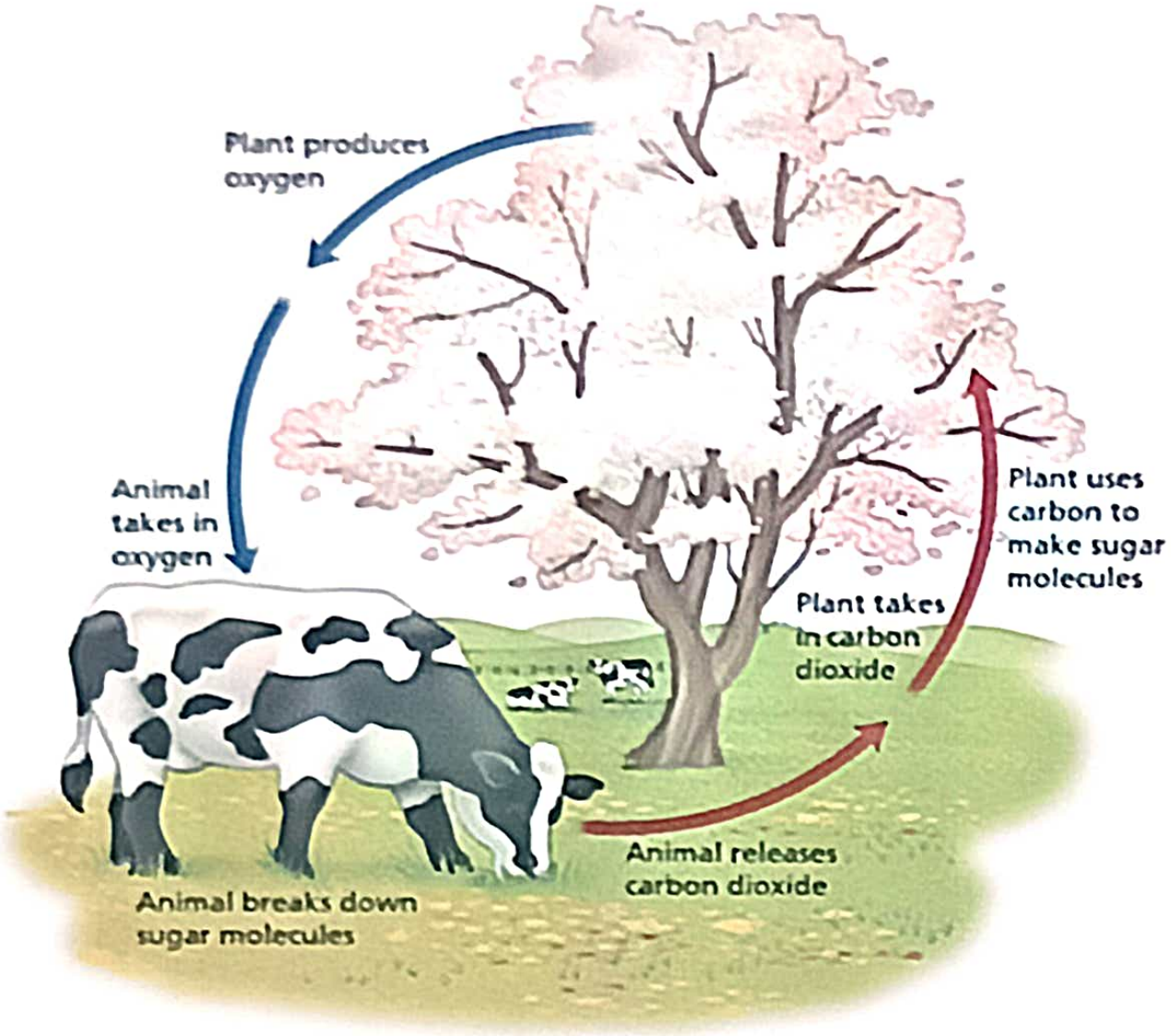
- mammals : inhale air, exhale CO_2

- Biochemical definition of cellular respiration:

A very complicated molecular mechanism of transferring energy from glucose to ATP

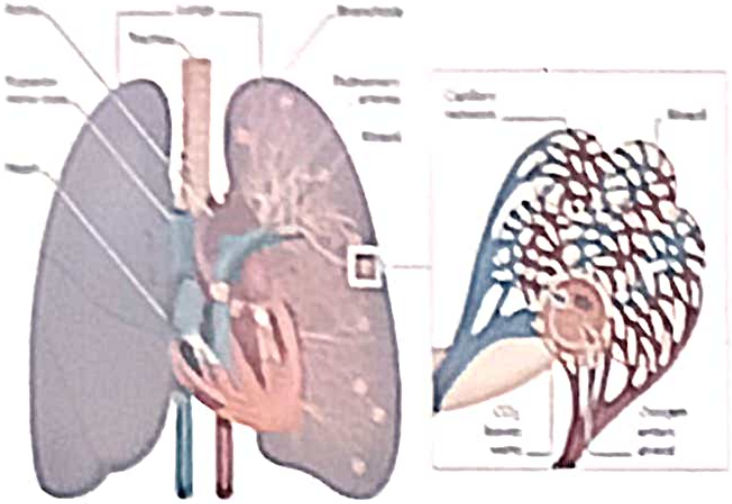
Respiration is the release of energy from fo

Cellular Respiration Diagram



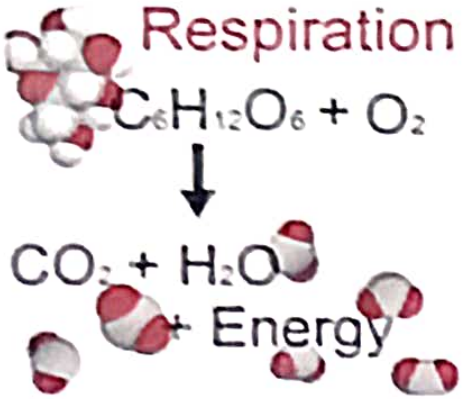
How do cells get O_2?

- Breathing brings oxygen to your lungs, and oxygen is necessary for cellular respiration to occur in most cells.



How do animal cells use O_2?

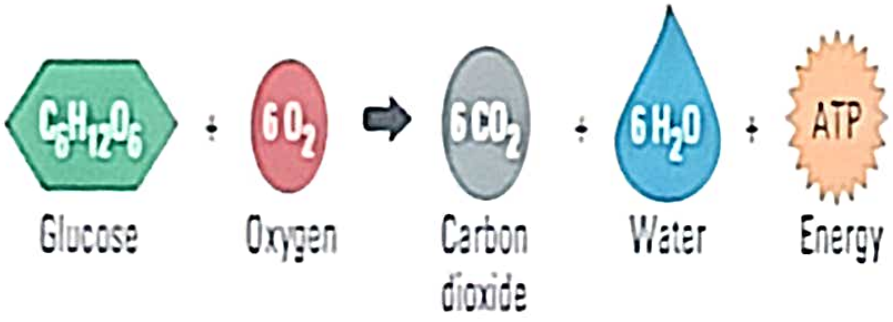
- Cells break down glucose molecules to create ATP, the energy storing molecule
- Aerobic respiration: O_2 is a crucial molecule in this process



Cellular Respiration

- Cellular respiration is the process which cells take the energy from glucose to function.

- During respiration, cells break down simple food molecules such as glucose and release the energy they contain.



- The food involved in respiration is usually glucose
- Internal respiration is controlled by enzymes which allow energy to be released in small amounts
- The energy is trapped in molecules called ATP

Steps of Cellular Respiration

1. Starts off in the cytoplasm of cells. Glucose is broken down into smaller molecules.

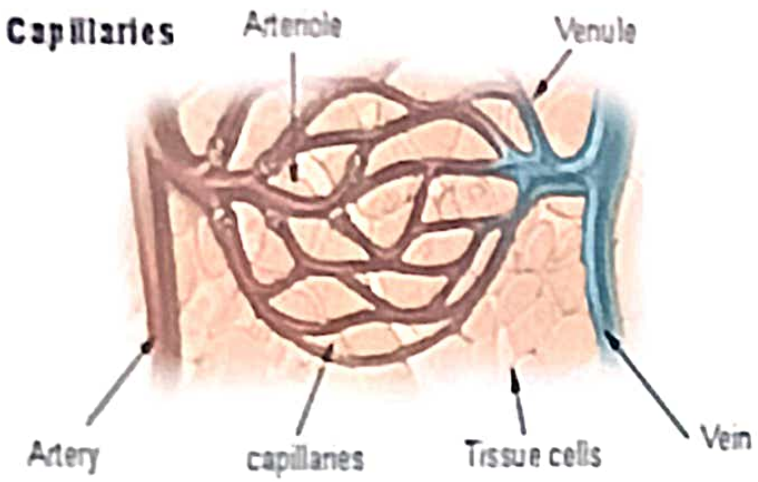
2. Next part takes place in the mitochondria. Molecules are broken down even smaller. This reaction requires oxygen, and a great deal of energy is released.

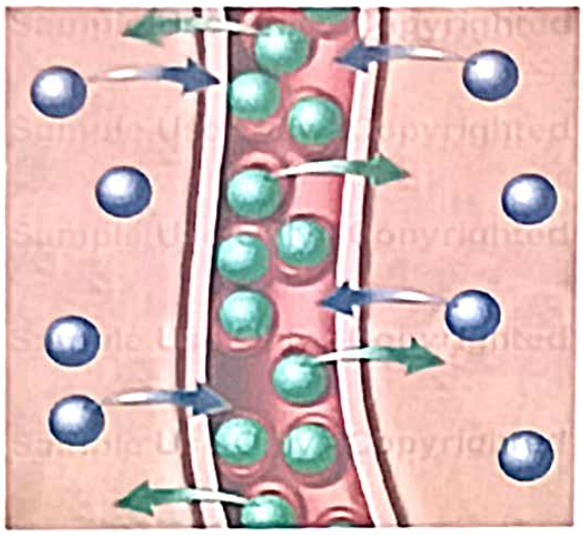
3. The end product is carbon dioxide and water. These products diffuse out of the cell.

4. This is why when you breathe in, you take in oxygen. When you breathe out, you release carbon dioxide and water.

Types of Respiration

- **Aerobic Respiration** – the release of energy from food in the presence of oxygen



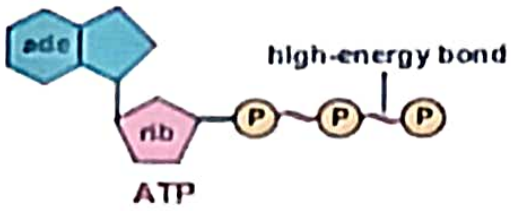


- **Anaerobic Respiration** The release of energy from food without requiring the presence of oxygen

Aerobic Respiration

- Most living things get energy from aerobic respiration and are called **AEROBES**

- The energy stored in bonds in glucose is released and used to make ATP



- When ATP breaks down it supplies energy for all the reactions in a cell, such as movement of muscles, growth of new cells etc.

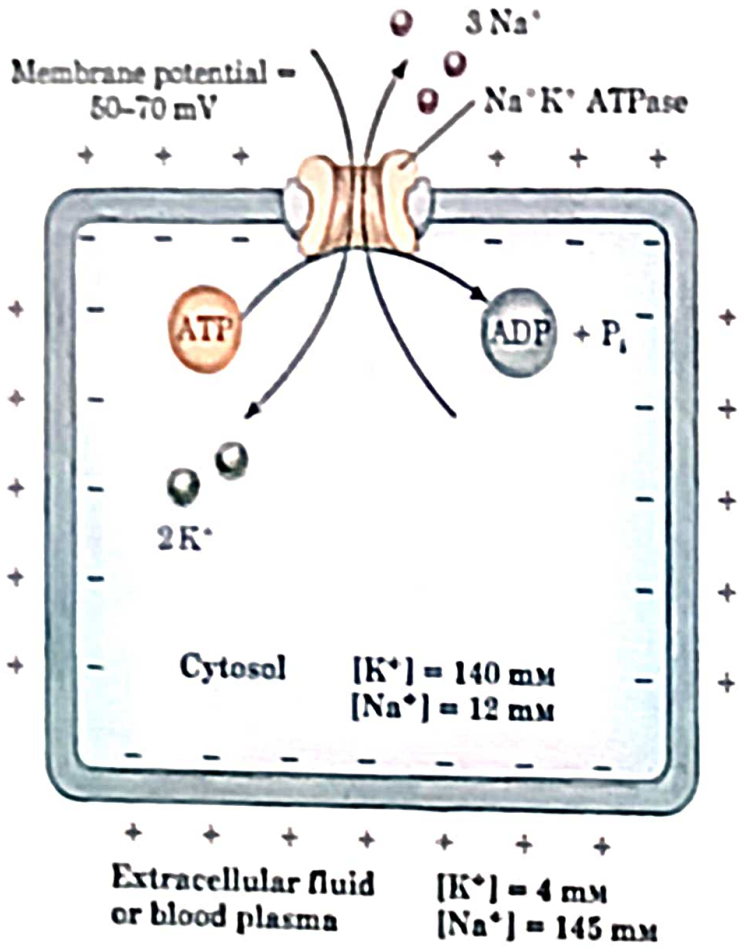
Equation for Aerobic Respiration

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + ATP\ (energy)$$

Glucose + Oxygen ⟶ Carbon dioxide + water + energy

- Aerobic respiration is relatively efficient, 40% of the energy in glucose is used to make ATP
- Any energy not used to produce ATP is lost as heat

Using ATP during active transport



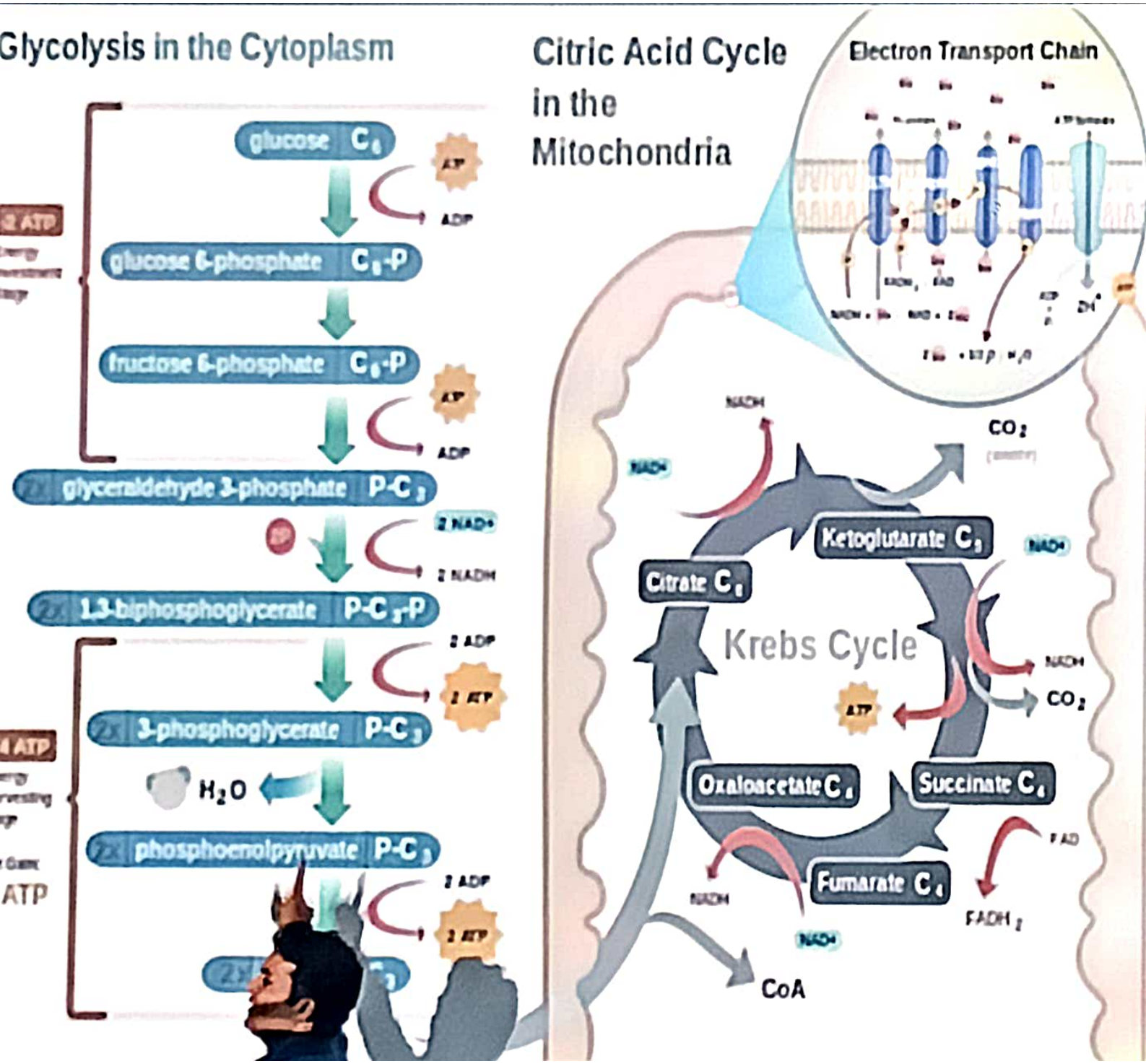
What happens without O_2

- Anaerobic respiration
  - _____
  - Much less efficient, takes place during emergencies when not enough O_2 is available
  - Produces alcohol in yeasts
  - _____

- EX: When running away from a tiger, your muscles need lots of ATP FAST, but your heart can't pump enough O_2 for aerobic respiration to produce enough ATP. Your muscles switch to anaerobic respiration, and the next day, all that lactic acid makes that tissue sore.

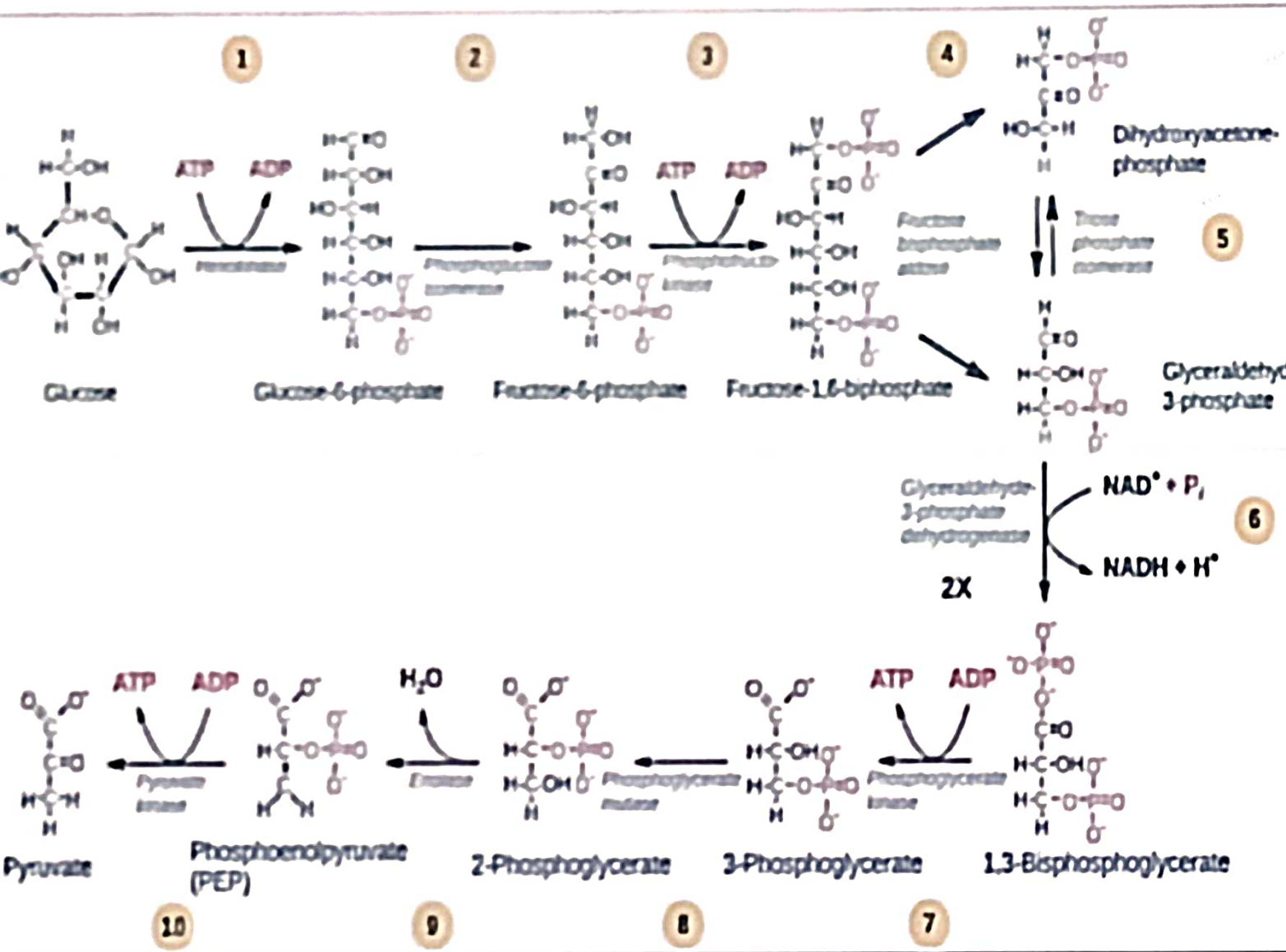
Aerobic Respiration occurs in multiple stages

- Stage 1 ---------- Glycolysis
- Stage 2 ---------- Kreb Cycle
- ---------- Electron transport chain


Glycolysis in the Cytoplasm
glucose C6
ATP
ADP
glucose 6-phosphate C6-P
fructose 6-phosphate C6-P
ATP
ADP
glyceraldehyde 3-phosphate P-C3
2 NAD+
2 NADH
1,3-biphosphoglycerate P-C3-P
2 ADP
2 ATP
3-phosphoglycerate P-C3
H2O
phosphoenolpyruvate P-C3
2 ADP
2 ATP
Citric Acid Cycle in the Mitochondria
Electron Transport Chain
NADH
CO2
Ketoglutarate C5
Citrate C6
Krebs Cycle
ATP
Oxaloacetate C4
Succinate C4
Fumarate C4
FADH2
CoA

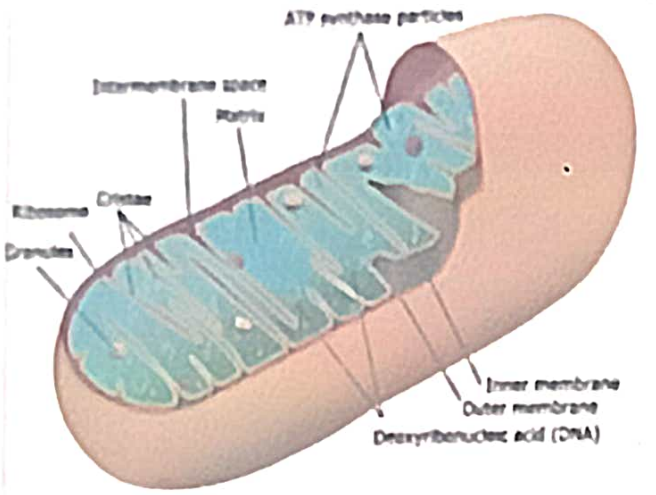
Satge 1: Glycolysis

- Takes place in the cytosol (the cytoplasm without the organelles) as enzymes are found here
- Does not require oxygen
- It only releases small amounts of energy
- Is the same for both aerobic and anaerobic respiration
- A 6 carbon carbohydrate (Glucose) is converted to two 3 carbon molecules with the release of a small amount of energy
- Most of the energy in the glucose molecule remains stored in each 3- carbon molecule


1
2
3
4
5
6
7
8
9
10
ATP
ADP
Hexokinase
Phosphoglucose isomerase
Phosphofructokinase
Fructose biphosphate aldose
Triose phosphate isomerase
Glucose
Glucose-6-phosphate
Fructose-6-phosphate
Fructose-1,6-biphosphate
Dihydroxyacetone-phosphate
Glyceraldehyde-3-phosphate
Glyceraldehyde-3-phosphate dehydrogenase
NAD⁺ + Pi
NADH + H⁺
2X
1,3-Bisphosphoglycerate
Phosphoglycerate kinase
3-Phosphoglycerate
Phosphoglycerate mutase
2-Phosphoglycerate
H2O
Enolase
Phosphoenolpyruvate (PEP)
Pyruvate kinase
Pyruvate

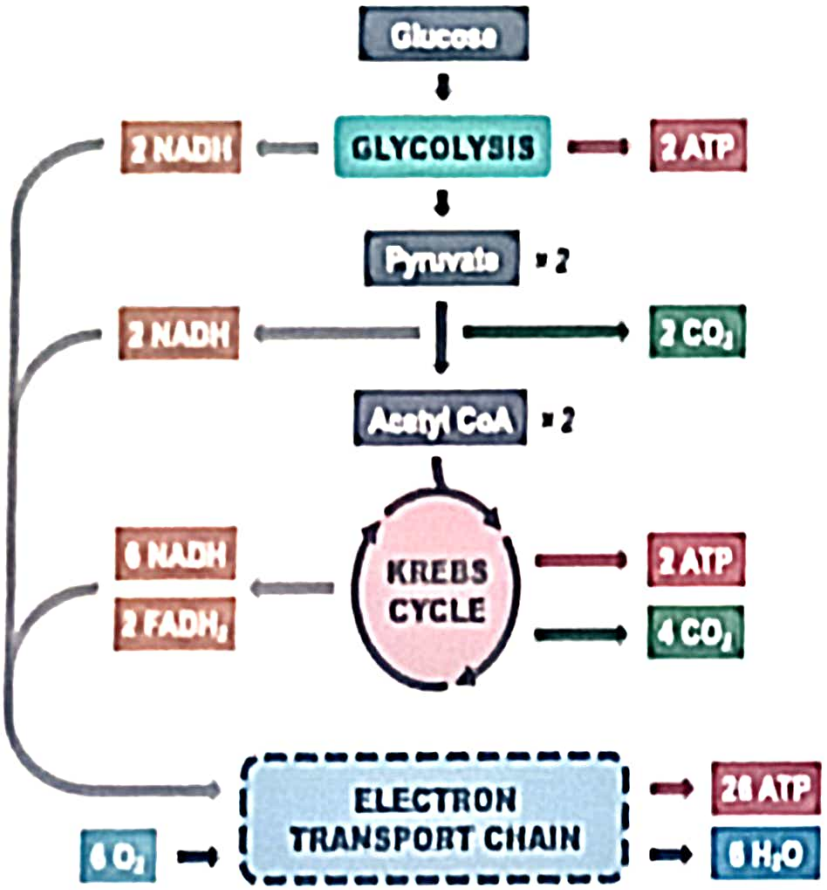
Stage 2

- This stage requires and uses oxygen
- It releases a large amount of energy
- It occurs in the mitochondria as the necessary enzymes are found here



- The 3- carbon molecules are broken down to Carbon Dioxide and Water
- The complete breakdown of the 3-carbon molecules releases a lot of energy
- There is very little energy left in Carbon Dioxide and Water

Overview of the Aerobic Reaction Process



Summary of the Molecular Conversions

STAGE	GLYCOLYSIS (anaerobic)	KREBS CYCLE (aerobic)	ETC (aerobic)
SITE	Cytosol	Matrix	Cristae
REACTION	Glucose → 2 Pyruvate	2 Pyruvate → 6 CO_2	6 O_2 → 6 H_2O
CARRIERS	2 NADH (small yield)	8 NADH, 2 $FADH_2$ (large yield)	All carriers are oxidised to make ATP
ATP	2 ATP Substrate level phosphorylation	2 ATP Substrate level phosphorylation	26 ATP Oxidative phosphorylation

ATP

NADH → 3x ATP

$FADH_2$ → 2x ATP

Glycolysis	2 ATP + 6 ATP = 8
Co-decarboxylation →	6 ATP = 6
Krebs →	6 ATP + 18 ATP = 24
	4 ATP

38 ATP

Glucose

↓

2 · Pyruvate

↓

Fatty Acid

Krebs Cycle

Anaerobic Respiration

- Anaerobic respiration can occur in the presence of oxygen, but it does not need to use it
- In anaerobic respiration, Glycolysis occurs this means glucose is broken into two 3-carbon molecules
- A small amount of energy is released this way
- There are different forms of anaerobic respiration where the 3 – carbon molecules are converted to different substances, but no extra energy is released
- Anaerobic respiration is said to be less efficient than aerobic respiration as less energy is released

Fermentation

- Anaerobic Respiration is also known as Fermentation

- 2 types of fermentation
  1. Lactic Acid Fermentation
  2. Alcohol Fermentation

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  1. Lactic Acid Fermentation
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Lactic Acid Fermentation

- This occurs in some anaerobic bacteria and fungi and in animal muscles when there is not enough oxygen

- In this fermentation Lactic acid is produced

- **Glucose ⟶ 2 Lactic Acid + small amount of energy**

- Lactic acid forms when bacteria cause milk to go sour, when bacteria respire on cabbage to form Sauerkraut, in silage production and in yoghurt production

- When we exercise and get out of breath not enough oxygen can reach our muscles and anaerobic respiration takes place in the muscle this forms lactic acid which causes cramps, when you rest the lactic acid is broken down by the liver.

Alcohol Fermentation

- Takes place in Bacteria and some fungi such as yeast and in plants when they are deprived of oxygen
- Involves the partial breakdown of glucose

- Glucose $\longrightarrow$ 2 Ethanol + 2 Carbon dioxide + small amount of energy

- The ethanol itself is high energy

- Alcohol fermentation has been used for centuries

- If baking yeast is used for alcohol fermentation, the alcohol evaporates but the carbon dioxide causes the dough to rise

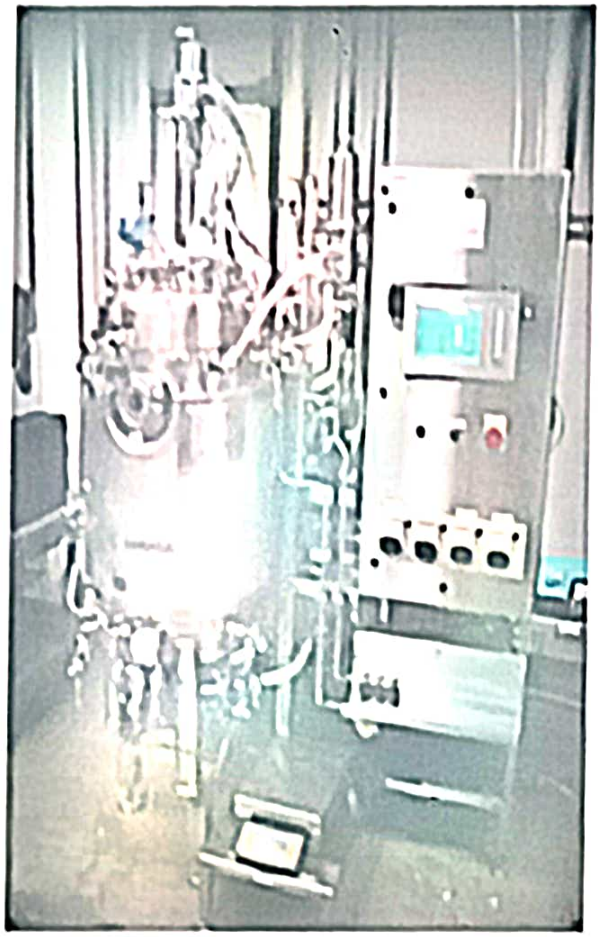
- Baking powder is used instead of yeast in very hot ovens

Industrial Fermentation

- **Biotechnology** refers to the use of living things (such as microorganisms and enzymes) to carry our useful reactions

- In industrial fermentation the microorganisms are placed in a container with a suitable substrate on which they can react

- The vessel in which biological reactions can take place is called a **Bioreactor**



A fermentation bioreactor