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Unit 6

Energy transformation

Objectives; at the end of the lesson students will be able to:

- Describe how energy transformation occur in living things
- Differentiate aerobic from anaerobic respiration
- Explain the major features and sequence of the chemical events of cellular respiration

  (e.g major feature of glycolysis, krebs cycle , electron transport and chemiosmosis)
- Describe the role of oxygen in respiration

What is **energy** ?

Energy is the ability to do work . All living things require a constant supply of energy to survive. In plants and animals glucose is the main source of energy . If there is insufficient glucose available , fatty acid and amino acid can be used instead .

Energy transformation

- is the process of changing energy from one form to another .
- It studies how light energy is changed in to chemical energy then finally heat energy.
  E.g Light energy is converted in to chemical energy in photosynthesis and used ,together in the synthesis of organic material from inorganic material . This Chemical energy is present in the chemical bond, When the bond breaks energy is released(exergonic reaction) .
- Cells obtain energy for their metabolic reaction from the breaking of organic molecules with high energetic content. This energy is mostly stored as ATP molecule.

Exergonic reaction	Endergonic reaction
Release energy	Require energy
Cell respiration	Active transport
Catabolism	Anabolism

ATP (Adenosine triphosphate)

- Adenosine triphosphate(ATP) is found in all living cells
- known as the energy currency of a cell (universal energy carrier) because it is the immediate and the only source of energy that the cell can use directly for its various activities just like ready money in the pocket of someone .
- can release energy quickly,
- Move around the cell easly

ATP STRUCTURE

components of ATP contain

- Pentose sugar (ribose)
- A nitrogenouse base (Adenine)
- A chain of three phosphate

Example 1

ATP + H_2O _____ ADP + Pi + energy (30.6 KJ per mole of ATP)(this is a hydrolysis process , the third phosphate group is split from the ATP and this phosphate remain in the cell in inorganic form . the reaction release 30.6 KJ for every mole of ATP that is hydrolysed .

Note : . Immediate energy source lies in the energy rich bond holding the **third phosphate** to the rest of the molecules .

Example 2

30.6 KJ + ADP + Pi ATP + H_2O (This is condensation reaction which is used to form ATP)

ATP + H_2O Hydrolysis ADP + Pi + 30.6 KJ per mole of ATP

Condensation

Note ;

- adding phosphate to ADP is known as **phosphorylatiion** .the enzyme which is used to catalyses this reaction is known as **ATPase**.
- ATP combines an energy releasing reaction and an energy consuming reaction so that there is a continuous transfer of energy in cells. This is usually called **ADP – ATP cycle .**

Ways of ATP synthesis include :

- ✓ *Substrate level phosphorylatiion*
- ✓ *Oxidative phosphorylatiion in cellular respiration*

✓ *Photophosphorylation in photosynthesis*

Substrate level phosphorylatiion :

- is directly phosporylating ADP with a phosphate and energy provided from a coupled reaction.
- Will only occur if there is a reaction that release sufficient energy to allow the direct phosphorylatiion of ADP .

Oxidiative phosphorylatiion

- is when ATP is generated from the oxidation of NADH and $FADH_2$ and the subsequent transfer of electron and pumping of protons.
- This process generate an electrochemical gradient which is required to power the ATP synthase.

Substrate level phosphorylatiion	**Oxidative phosphorylatiion**
Synthesis of ATP when a phosphate group is transferred from a substrate directly to ADP .	Synthesis of ATP as electrons move down the electron transport system during oxidation in the presence of oxygen .
Occurs during glycolysis and the krebs cycle	Occurs in the electron transport system
Release small amount of energy from glucose	Release most of the energy from glucose

Photophosphorylation :

- is the synthesis of ATP by using light energy during **photosynthesis**.
- It is a light enhanced synthesis of ATP

Significance of ATP

In the cell may be used for :

- The synthesis of macromolecules e.g to synthesis proteins
- Chemical activation e.g to make glucose reactive at the beginning of respiration
- Active transport of substance
- Conduction of nerve impulses
- Movement

Cells make their own ATP in a cyclic process E.g When energy is used ATP is broken down in to adenosine diphosphate and inorganic phosphate with energy released. ATP is then reformed during cellular respiration .

Cellular respiration

- Is the process by which glucose is broken down (oxidized) to release energy for making ATP,another form of chemical energy
- Is the most important and common catabolic reaction to all living organism.

Types of cellular respiration

- Aerobic respiration
- Anaerobic respiration

Aerobic respiration	**Anaerobic respiration**
Respiration in the presence of oxygen	Respiration in the absence of oxygen
Complete breakdown of glucose	Incomplete breakdown of glucose
Give more energy (36 ATP per glucose)	Gives less energy (2 ATP per glucose)
Occurs mainly in the mitochondrion	Occurs in the cytoplasm

An overview of cell respiration

Note that there is one aerobic pathway and two anaerobic pathways. Note also that the first stage in all these pathways is glycolysis.

Aerobic respiration

Requirment

1, respiratory substrate

Are organic molecules that can be respired to supply energy

e.g glucose is the main respiratory substrate, lipids, protein

2, some key reaction

1, oxidation reduction process

e.g adding oxygen $A + O_2$ _____ AO_2

Removal of hydrogen (dehydrogenation)

Removal of electron

2, Decarboxylation removal of carbon from glucose

3, Hydrogen carriers e.g NAD and FAD

Stage of aerobic Respiration

1, Glycolysis

2, Link reaction (transition stage)

3, Krebs cycle (citric acid cycle)

4, Respiratory chain and Oxidative phosphorylatiion

1, Glycolysis(sugar splitting) is the oxidation of glucose to pyruvate

- It occurs in the cytoplasm of cells
- Does not require the presence of oxygen

Stage of glycolysis

1, **Phosphorylation of the sugar (activation energy)**

Glucose is phosphorylated by two molecules of ATP (two ATP molecules are used to make glucose reactive)

2, **Lysis (cleavage)**

The phosphorylated 6 carbon glucose split in to two molecules of 3 carbon sugar phosphate

3, **Oxidation by dehydrogenation and energy harvesting**

Each 3c sugar phosphate is converted to pyruvate .This involve a dehydrogenation making a reduced NAD molecule and production of two ATP molecule.

End product of glycolysis :

Input	Output
Glucose	2 Pyrovate
2NAD	2 NADH
2 ATP	4 ATP (net 2 ATP)

2, The link reaction involves

the link reaction of aerobic respiration involves the conversion of 2 molecules of pyruvate (3 carbon compound) in to 2 molecules of Acetyl Coenzyme A (2 carbon compound) .

It involves

- Decarboxylation (the removal of 2 molecules of carbon dioxide)
- Dehydrogenation (formation of 2 molecules of NADH)

- End product includes:

Input	Output
2 pyrovate	2 Acetyl
2NAD	2 NADH
Decarboxylase	2 CO_2

3, **Krebs cycle** (citric acid cycle)

- Developed by Cristian Hans Krebs
- is a reaction series involving the combining of acetyl CoA and Oxaloacetate to form citric acid.
- Takes place in the matrix of mitochondria.
- Each glucose molecule “cycles ” the Kerbs cycle twice because after glycolysis each used glucose has generated two pyruvic acid molecules and each pyruvic acid is converted in a 1:1 proportion into acetyl CoA then cycles the Kerbs cycle once.

Input	Output
2 Acetyl CoA	4 CO_2 removed by means of decarboxylation
6NAD	6NADH
2FAD	2 FADH
2 GDP + 2Pi	2 ATP

4, **Electron transport system (respiratory chain)**

- Energy carrier molecules produced during Glycolysis and the Krebs cycle enters the electron transport system.
- Occur in the folds of inner membrane of the mitochondria (Cristae)
- The electron is passed down a chain of proteins until they reach the final electron acceptor oxygen
- Electron transport system is a chain of electron carrier protein along the inner membranes of mitochondria to transfer electron from the $NADH_2$ and $FADH_2$ to the final electron acceptor molecule Oxygen (O_2). It produce 32 **ATP and H_2O Oxidatively.**
- It contains a coupled reaction which is

A. Electron transport chain and

B. Chemiosmosis

B. Chemiosmosis means diffusion of ions across a membrane .

- ✓ H+ ions diffuse from an area of high concentration to an area of low concentration
- ✓ Movement of H+ ions creats an electrochemical gradient of protons
- ✓ The energy from the H+ ions is used to make ATP
- ✓ ATP synthase makes ATP VIA chemiosmosis
- ✓ The energy from the H= ion is captured in ATP

Input	Out put
10 NADH	30 ATP
2 FAD	4 ATP
4 ATP	4 ATP
Total	38 ATP (2 ATP used during Chemiosmosis because of this net ATP will be 36)

Anaerobic respiration

Aso called fermentation or the process by which energy is released from glucose when oxygen is not available

This process allow organism to continue to produce energy until oxygen is available

However this process only release 2 ATP per molecule of glucose

Release less energy than aerobic respiration

Ccure in the cytoplasm

Types of Fermentation

- Alcoholic fermentation
- Lactic acid fermentation

Alcoholic fermentation

- Anaerobic way of converting energy for yeast ….
- Glucose broken down to produce alcohol, co2 and energy{ 2 ATP)
- C6h12o6 _____ Ethanol + co2 + 2 ATP

e.g baking bread with yeast, fermenting wine and beer

Lactic acid fermentation

- Anaerobic way of converting energy in animal cells and some microorganism
- Glucose break down to produce lactic acid and energy ATP

E,g $C_6H_{12}O_6$ _____ Lactic acid + 2 ATP

Muscle cell during strenuous exercise(rapid exercise), fermenting chesse, yogurt, sour cream(occur in bacteria) .

Photosynthesis

- Two main stages

Light dependent reaction

Light independent reaction

Light dependent reaction

- Occur on the thylakoid membranes of the chloroplast
- Chlorophyll absorbs light energy which is then used to produce ATP and split water molecule in to H+ ions and O_2 gas
- O_2 gas is a waste product
- ATP H ion and electron are used in the light independent reaction

Light independent reaction

- Also known as the calvin cycle
- Occurs in the stroma of the chloroplast
- Carbon dioxide is combined with the H ion using energy provided by ATP to form glucose and water.

Summary reaction of photosynthesis

$6CO_2 + 12H_2O$ _____ $C_6H_{12}O_6 + 6H_2O + 6O_2$

Factors that affect the rate of photosynthesis

- Light intensity
- CO_2 availability
- Temprature

Variation in photosynthesis

Plants adapt to their environment

C3 plant

C4 plant

CAM plant

C3 plant

- Called C3 because the CO2 is first incorporated in to a 3 carbon compound known as phosphoglycerate (PG)
- PG is the first stable product of carboxylation
- Rubisco is the enzyme that catalysed the carboxylation reaction
- Less efficient in carbon dioxide assimilation

Disadvantage

- Undergoes photorespiration
- Ribulose biphosphat (RUBP) is the initial acceptor of carbon dioxide
- Stomata are open during the day
- Photosynthesis takes place through out the leaf
- Adaptive value more efficient than C4 andCAM plants under cool and moist condition

C4 plant

- Called C4 because the CO2 is first incorporated in to a 4 carbon compound
- Phosphoenol pyrovate (PEP) is the initial acceptor of carbon dioxide
- Oxaloacetate is the first stable product of carboxylation
- PEPCO is the enzyme that catalyses the carboxylation reaction
- More efficient in carbondioxide assimilation

Advantage

- Does not undergo photorespiration in intense light

Photorespiration is respiration in the presense of light . It is a light enhanced respiration . Photorespiration occurs when the CO2 levels inside a leaf become low . This happens on hot dry days when a plant is forced to close its stomata to prevent excess water loss .

Use a different enzyme to capture and to convert CO2

Reduce the time the stomata are open and therefore reduce water loss

CAM plant (crassulacean Acid Metabolism)

- Can stan extremely arid environmental condition

- They open their stomata at night
- The CO_2 is converted to an acid and stored during the night ,
- During the day the acid is broken down and the CO_2 is released to RUBISCO for photosynthesis

Advantage

- They use water efficiently under arid condition due to closing their stomata during the day when transpiration rate are higher
- Open their stomata at night
- Convert the CO_2 to an acid that is stored
- During the day the acid is broken down back in to CO_2 and used during photosynthesis
- Stomata not open during day and therefore reduce water loss
- CAM plants include succulent

1, Glycolysis takes place in the cytoplasm because glucose molecule cannot diffuse through the mitochondrial membrane.

A, True B, False

2, Which process of respiration helps to release most of the energy stored in glucose

A, Oxidative phosphorylation C, Fermentation reaction

B, Glycolysis D, Anaerobic reaction

3, Which molecule will combine with the four carbon oxaloacetate in the krebs cycle to form the six carbon citrate ?

A, Two carbondioxide molecule C, NADH

B, Lactic Acide D, Acetyle CoA

4, All living cell respire all the time to produce

A, Organic molecule C, Food

B, Energy D, Glucose

5, Respiratory substrates are

A, Organic Molecule C, Light

B, ATP D ,Organism

6, Which is true about glycolysis

A, 2NADH produced C, 2 pyrovate produced

B, It take place in cytoplasm D, All

6, All nucleotide found in ATP contain the following except

A, Nitrogenous base C, Phosphate group

B, Ribose sugar D, Dioxiribose sugar

7, Identify the one which is different

A, adenine nucleotide with two extra phosphate group

B, Adenosine tri – phosphate

C, Phosphorylated nucleotide containing the nitrogenous base adenine

D, Polynucleotide chain

8,An example of respiration that require the presence of oxygen ?

A, Anaerobic respiration C, Aerobic respiration

B, Fermentation D, Substrate level phosphorylation

9, One is wrong about substrate level phosphorylation

A, does not require the intention of ATPsyntase

B, Small amount of ATP is produced

C, Formed when another molecule is able to transfer a phosphate group directly to ADP

D, Is a kind of phosphorylation depend on the presence of oxygen

10, How many carbon atom is present in two molecules of triose Phosphate?

A, One B, Two C, Three D, Six

11, Hans Krebs worked out the details of

A, oxidation of pyrovate C, Electron transport and chemiosmosis

B, Calivin cycle $NADH_2$ D, citric acid cycle

12, The Matrix of Mithochondria provides a fluid medium for the reaction of

A, Light dependent reaction C, Krebs cycle

B, Electron transport chain D, Photolysis

13, 10NADH plus 6FADH2 results in the formation of

A, 38 ATP B, 48 ATP C, 42 ATP D, 34

14, The following contain the main stage of aerobic respiration except

A, Glycolysis C, Chemiosmosis

B, link reaction D, Photorespiration

15, enzyme involved in the removal of CO2 during glucose

A ,RuBp C, Carboxylase

B, Decarboxyl D, Oxaloacetate

16, Which of the following stage of respiration does not yield ATP

A, Glycolysis C, Oxidative Phosphorylation

B, the Link reaction D, Krebs cycle

17, Which stage of respiration generate most ATP

A, Glycolysis C, Krebs cycle

B, Link reaction D, Oxidative phosphorylatiion

18, what happens to the hydrogen carried to the electron transport chain

A, It ends up as water C, It is recycled to Glycolysis

B, It forms Lactate D, It forms methane

19, Pyrovate is the end product of the _____ reaction

A, Krebs cyle C, Electron transport system

B, Glycolaysis D, Transition

20, How many times does the krebs cycle turn per glucose molecule

A, once C, four times

B, twice D, three times

21, which of the following process needs energy from respiration

A, movement of sugar in the phloem

B, Absorption of ions by plant roots

C, Absorption of water by plant roots

D, Uptake of carbondioxide by leaves

22, Where in a cell does aerobic respiration occur

A, Mithochondria C, Nucleus

B, Cytoplasm D, Chloroplast

23, The final electron acceptor in aerobic respiration is

A, Water C, NAD

B, carbondioxide D, Oxygen

24, where in a mithochondria does the electron transport chain take place

A, matrix C, Cytoplasm

B, Cristae of the inner membrane D, grana

25, Under normal condition as electron flow down the electron transport chain of the mitochondria all of the following events happen except

A, NADH and FADH2 are oxidized C, electrochemical gradient is formed

B, electron lose free energy D, NADH and FADH2 are reduced

26, Energy is released from ATP when

A, phosphate group is add C, ATP is exposed to sunlight

B, Adenosine bonds to ribose D, phosphate group is removed

27, All of the following is directly associated with photosystem II , except

A, Extraction of hydrogen electron from the splitting of water

B, Release of oxygen

C, Harvesting of light energy by chlorophyll

D, P680 is the only reaction center of chlorophyll

28, Assume a thylakoid is somehow punctured so that the interior of the thylakoid is no longer separated from the stroma. This damage will have the most direct effect on which of the following process

A, The splitting of water

B, absorption of light energy by chlorophyll

C, The flow of electron from photosystemI

D, the synthesis of ATP

29, Which one of the following is wrong about photorespiration

A, only one molecule of GP is produced from RUBP

B, Phosphoglycolate is produced which must be reconverted to RUBP using up ATP

C, increase the efficiency of photosynthesis

D, decrease the efficiency of photosynthesis

30, In C4 plants which one of the following molecule is used as Co2 acceptor

A, O2 B, PEP C, RUBP D, peroxisome

Short answer Questions

1, A total of how many ATP molecule is formed per glucose in the kreb citric acid cycle ?

2, What is the energy source for the production of ATP during oxidative phosphorylation ?

3, How many net ATP and NADH molecule are formed during the glycolysis of one glucose molecule ?

4, Match item below to one of the location in the key

Key- I, Matrix of mithochondria

Ii, Cristae of mithochondria

A, Electron transport chain D, Transition reaction

B, Krebs cycle E, Glycolysis

C, ATP syntase complex

5, A total of how many glucose molecule is produce if in the cell if 6 NADH and 6FADH are completely oxidized ?

6,Describe four major difference between aerobic and anaerobic respiration ?

7,Differentiate between cycle and non cyclic photophosphorylation ?

8, Choose one of the steps involved in aerobic respiration and write the major steps you selected for?

9, Draw the structure of ATP?

