Atika School
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PRESENTS KCSE BIOLOGY NOTES

TOPIC 8: RESPIRATION

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Respiration Specific Objectives

By the end of the topic, the learner should be able to:

1. Explain the significance of respiration in living organisms
2. Distinguish between aerobic and anaerobic respiration
3. Describe the economic importance of anaerobic respiration in industry and at home
4. Describe experiments to show that respiration takes place in plants and animals.

Topics/Sub-Topics Outline

Meaning and significance of respiration

Tissue respiration

1. Mitochondrion - structure and function
2. Aerobic respiration (Details of kreb's cycle not required)
3. Anaerobic respiration in plants and animals, the products and byproducts
4. Application of anaerobic respiration in industry and at home
5. Compare the energy output of aerobic and anaerobic respiration78

Practical Activities

1. Carry out experiments to investigate
2. The gas produced when food is burnt
3. The gas produced during fermentation
4. Heat production by germinating seeds

Meaning and Significance of Respiration

Respiration is the process by which energy is liberated from organic compounds such as glucose.

It is one of the most important characteristics of living organisms.

Energy is expended (used) whenever an organism exhibits characteristics of life, such as feeding, excretion and movement.

Respiration occurs all the time and if it stops, cellular activities are disrupted due to lack of energy.

This may result in death e.g., if cells in brain lack oxygen that is needed for respiration for a short time, death may occur.

This is because living cells need energy in order to perform the numerous activities necessary to maintain life.

The energy is used in the cells and much of it is also lost as heat.

In humans it is used to maintain a constant body temperature.

Tissue Respiration

- ✓ Respiration takes place inside cells in all tissues.
- ✓ Every living cell requires energy to stay alive.
- ✓ Most organisms require oxygen of the air for respiration and this takes place in the mitochondria.

Mitochondrion Structure and Function

Structure

- ✓ Mitochondria are rod-shaped organelles found in the cytoplasm of cells.
- ✓ A mitochondrion has a smooth outer membrane and a folded inner membrane.
- ✓ The folding of the inner membrane is called cristae and the inner compartment is called the matrix.

Adaptations of Mitochondrion to its Function

- ✓ The matrix contains DNA ribosomes for making proteins and has enzymes for the breakdown of pyruvate to carbon (IV) oxide, hydrogen ions and electrons.
- ✓ Cristae increase surface area of mitochondrial inner membranes where attachment of enzymes needed for the transport of hydrogen ions and electrons are found.
- ✓ There are two types of respiration:
    - o Aerobic Respiration
    - o Anaerobic. Respiration

Aerobic Respiration

- ✓ This involves breakdown of organic substances in tissue cells in the presence of oxygen.
- ✓ All multicellular organisms and most unicellular organisms e.g. some bacteria respire aerobically.
- ✓ In the process, glucose is fully broken down to carbon (IV) oxide and hydrogen which forms water when it combines with the oxygen.
- ✓ Energy produced is used to make an energy rich compound known as adenosine triphosphate (ATP).
- ✓ It consists of adenine, an organic base, five carbon ribose-sugar and three phosphate groups.
- ✓ ATP is synthesised from adenosine diphosphate (ADP) and inorganic phosphate.
- ✓ The last bond connecting the phosphate group is a high-energy bond.
- ✓ Cellular activities depend directly on ATP as an energy source.
- ✓ When an ATP molecule is broken down, it yields energy.

Process of Respiration

- ✓ The breakdown of glucose takes place in many steps.
- ✓ Each step is catalysed by a specific enzyme.
- ✓ Energy is released in some of these steps and as a result molecules of ATP are synthesised.

- ✓ All the steps can be grouped into three main stages:

Glycolysis.

- ✓ The initial steps in the breakdown of glucose are referred to as glycolysis and they take place in the cytoplasm.
- ✓ Glycolysis consists of reactions in which glucose is gradually broken down into molecules of a carbon compound called pyruvic acid or pyruvate.
- ✓ Before glucose can be broken, it is first activated through addition of energy from ATP and phosphate groups.
- ✓ This is referred to as phosphorylation.
- ✓ The phosphorylated sugar is broken down into two molecules of a 3-carbon sugar (triose sugar) each of which is then converted into pyruvic acid.
- ✓ If oxygen is present, pyruvic acid is converted into a 2-carbon compound called acetyl coenzyme A (acetyl Co A).
- ✓ Glycolysis results in the net production of two molecules of ATP.
- ✓ The next series of reactions involve decarboxylation i.e. removal of carbon as carbon (IV) oxide and dehydrogenation, removal of hydrogen as hydrogen ions and electrons.
- ✓ These reactions occur in the mitochondria and constitute the Tri-carboxylic Acid Cycle (T.C.A.) or Kreb's citric acid cycle.
- ✓ The acetyl Co A combines with 4-carbon compound with oxalo-acetic acid to form citric acid - a 6 carbon compound.
- ✓ The citric acid is incorporated into a cyclical series of reactions that result in removal of carbon (IV) oxide molecules, four pairs of hydrogen, ions and electrons.
- ✓ Hydrogen ions and electrons are taken to the inner mitochondria membrane where enzymes and electron carriers effect release of a lot of energy.
- ✓ Hydrogen finally combines with oxygen to form water, and 36 molecules of ATP are synthesised.

Anaerobic Respiration

Anaerobic respiration involves breakdown of organic substances in the absence of oxygen.

It takes place in some bacteria and some fungi.

Organisms which obtain energy by anaerobic respiration are referred to as anaerobes.

Obligate anaerobes are those organisms which do not require oxygen at all and may even die if oxygen is present.

Facultative anaerobes are those organisms which survive either in the absence or in the presence of oxygen.

Such organisms tend to thrive better when oxygen is present e.g. yeast.

Products of Anaerobic Respiration

The products of anaerobic respiration differ according to whether the process is occurring in plants or animals.

Anaerobic Respiration in Plants

Glucose is broken down to an alcohol, (ethanol) and carbon (IV) oxide.

The breakdown is incomplete.

Ethanol is an organic compound, which can be broken down further in the presence of oxygen to provide energy, carbon (IV) oxide and water.

$$C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2 + Energy$$

(Glucose) (Ethanol) (Carbon (IV) oxide)

Fermentation

This is the term used to describe formation of ethanol and carbon (IV) oxide from grains

Yeast cells have enzymes that bring about anaerobic respiration.

Lactate Fermentation

This is the term given to anaerobic respiration in certain bacteria that results in formation of lactic acid

Anaerobic Respiration in Animals

Anaerobic respiration in animals produces lactic acid and energy.

$$C_6H_1P_6 = 2CH_3CHOH.COOH + energy$$

(Glucose) (Lactic acid) + Energy

When human muscles are involved in very vigorous activity, oxygen cannot be delivered as rapidly as it is required.

The muscle respire anaerobically and lactic acid accumulates.

A high level of lactic acid is toxic.

During the period of exercise, the body builds up an oxygen debt.

After vigorous activity, one has to breathe faster and deeper to take in more oxygen.

Rapid breathing occurs in order to break down lactic acid into carbon (IV) oxide and water and release more energy.

Oxygen debt therefore refers to the extra oxygen the body takes in after vigorous exercise.

Practical Activities

To Show the Gas Produced When the Food is burned

- ✓ A little food substance e.g., maize flour or meat is placed inside a boiling tube.
- ✓ The boiling tube is stoppered using a rubber bung connected to a delivery tube inserted into a test-tube with limewater.
- ✓ The food is heated strongly to bum.
- ✓ Observations are made on the changes in lime water (calcium hydroxide) as gas is produced.

- ✓ The clear lime water turns white due to formation of calcium carbonate precipitate proving that carbon (IV) oxide is produced.

Experiment to Show the Gas Produced During Fermentation

- ✓ Glucose solution is boiled and cooled. Boiling expels all air.
- ✓ A mixture of glucose and yeast is placed in a boiling tube, and covered with a layer of oil to prevent entry of air.
- ✓ A delivery tube is connected and directed into a test-tube containing lime water.
- ✓ The observations are made immediately and after three days the contents are tested for the presence of ethanol.
- ✓ A control experiment is set in the same way except that yeast which has been boiled and cooled is used.
- ✓ Boiling kills yeast cells.
- ✓ The limewater becomes cloudy within 20 minutes.
- ✓ This proves that carbon (IV) oxide gas is produced.
- ✓ The fermentation process is confirmed after three days when alcohol smell is detected in the mixture.

Experiment to Show Germinating Seeds Produce Heat

- ✓ Soaked bean seeds are placed in a vacuum flask on wet cotton wool.
- ✓ A thermometer is inserted and held in place with cotton wool.
- ✓ The initial temperature is taken and recorded.
- ✓ A control experiment is set in the same way using boiled and cooled bean seeds which have been washed in formalin to kill microorganisms.
- ✓ Observation is made within three days.
- ✓ Observations show that temperature in the flask with germinating seeds has risen.
- ✓ The one in the control has not risen.

Comparison between Aerobic and Anaerobic Respiration

	Aerobic Respiration	Anaerobic Respiration
1. Site	In the mitochondria.	In the cytoplasm.
2. Products	Carbon dioxide and water.	Ethanol in plants and lactic acid in animals.
3. Energy yield	38 molecules of ATP (2880 KJ) from each molecule of glucose.	2 molecules of ATP 210KJ from each molecule of glucose.
4. Further reaction	No further reactions on carbon dioxide and water.	Ethanol and lactic acid can be broken down further in the presence of oxygen.

Comparison between Energy Output in Aerobic and Anaerobic Respiration

- ✓ Aerobic respiration results in the formation of simple inorganic molecules, water and carbon (IV) oxide as the byproducts.
- ✓ These cannot be broken down further. A lot of energy is produced.
- ✓ When a molecule of glucose is broken down in the presence of oxygen, 2880 KJ of energy are produced (38 molecules of ATP).
- ✓ In anaerobic respiration the by products are organic compounds.
- ✓ These can be broken down further in the presence of oxygen to give more energy.
- ✓ Far less energy is thus produced.
- ✓ The process is not economical as far as energy production is concerned.
- ✓ When a molecule of glucose is broken down in the absence of oxygen in plants, 210 KJ are produced (2 molecule ATP).
- ✓ In animals, anaerobic respiration yields 150 kJ of energy.

Substrates for Respiration

Carbohydrate, mainly glucose is the main substrate inside cells.

Lipids i.e. fatty acids and glycerol are also used.

Fatty acids are used when the carbohydrates are exhausted.

A molecule of lipid yields much more energy than a molecule of glucose.

Proteins are not normally used for respiration.

However during starvation they are hydrolysed to amino acids, dearnination follows and the products enter Kreb's cycle as urea is formed.

Use of body protein in respiration result to body wasting, as observed during prolonged sickness or starvation.

The ratio of the amount of carbon (IV) oxide produced to the amount of oxygen used for each substrate is referred to as Respiratory Quotient (RQ) and is calculated as follows:

$$\text{R.Q.} = \frac{\text{Amount of carbon (IV) oxide produced}}{\text{Amount of oxygen used}}$$

Carbohydrates have a respiratory quotient of 1.0 lipids 0.7 and proteins 0.8.

Respiratory quotient value can thus give an indication of types of substrate used.

Besides values higher than one indicate that some anaerobic respiration is taking place.

Application of Anaerobic Respiration in Industry and at Home

Industry

- ✓ Making of beer and wines.
- ✓ Ethanol in beer comes from fermentation of sugar (maltose) in germinating barley seeds.
- ✓ Sugar in fruits is broken down anaerobically to produce ethanol in wines.
- ✓ In the dairy industry, bacterial fermentation occurs in the production of several dairy products such as cheese, butter and yoghurt.
- ✓ In production of organic acids e.g., acetic acid, that are used in industry e.g., in preservation of foods.

Home

- ✓ Fermentation of grains is used to produce all kinds of beverages e.g., traditional beer and sour porridge.
- ✓ Fermentation of milk.

Respiration Questions

1. Explain the roles of enzymes in respiration
2. What is aerobic respiration
3. Give a word equation for aerobic respiration
4. What are the end products of aerobic respiration?
5. What are obligate anaerobes?
6. What are facultative anaerobes?
7. State the word equation representing anaerobic respiration in plants
8. Name the end products of anaerobic respiration in plants
9. Give a word equation of anaerobic respiration in animals
10. Name the end products of respiration in animals when there is insufficient oxygen supply
11. Why is there a high rate of lactic acid production during exercise?
12. Why does lactic acid level reduce after exercise?
13. State why accumulation of lactic acid during vigorous exercise lead to an increase in heartbeat
14. State the economic importance of anaerobic respiration
15. What is oxygen debt?
16. What is respiratory quotient (RQ)?
17. Why are respiratory quotient important
18. Name the respiratory substrates
19. Why does anaerobic respiration of a given substrate yield a smaller amount of energy than aerobic respiration?
20. Explain the disadvantages of anaerobic respiration
21. Mention the types of experiments carried out for respiration
22. Define the following terms
    a. Excretion
    b. Secretion
    c. Egestion

d. Homeostasis

23. Explain why excretion is necessary in plants and animals
24. Describe how excretion takes place in green plants
25. Why do plants lack complex excretory structures like those of animals?
26. State the excretory products of plants and some of their uses to humans
27. Describe excretion in unicellular organisms
28. List excretory organs and products of mammals
29. Draw and label a mammalian skin
30. Explain how the mammalian skin is adapted to its functions
31. What is the role of lungs in excretion?
32. State the functions of the liver
33. Draw a labeled diagram of mammalian nephrone
34. Describe how the human kidney functions
35. Name the common kidney diseases
36. Why is homeostatic control necessary?
37. What is internal environment?
38. Why is constant body temperature maintained by mammals?
39. Explain the advantage gained by possessing a constant body temperature
40. How do mammals regulate body temperature?
41. Why does body temperature of a healthy person rise up to 37^{o}C on a hot humid day?
42. Name the structures in the human body that detect external temperature changes
43. State the advantages that organisms with small surface area to volume ratio experience over those with larger
44. Explain why individuals with smaller sizes require more energy per unit body weight than those with larger sizes.
45. What is the meaning of osmoregulation?
46. State the importance of osmoregulation

47. State the ways by which desert mammals conserve water
48. Explain why some desert animals excrete uric acid rather than water
49. Explain why eating a meal with too much salt leads to production of a small volume of concentrated urine
50. Explain how marine fish regulate their osmotic pressure
51. What is the biological significance of maintaining a relatively constant sugar level in a human body?
52. Discuss the role of the following hormones in blood sugar control
53. Explain the part played by antidiuretic hormone in homeostasis
54. What is the role of blood clotting in homeostasis?
55. Describe the role of the following hormones in homeostasis
56. Distinguish between diabetes mellitus and diabetes insipidus
57. How can high blood sugar level in a person be controlled?
58. Why does glucose not normally appear in urine even though it is filtered in the mammalian Bowman's capsule?
59. How would one find out from a sample of urine whether a person is suffering from diabetes mellitus?