CELLULAR RESPIRATION

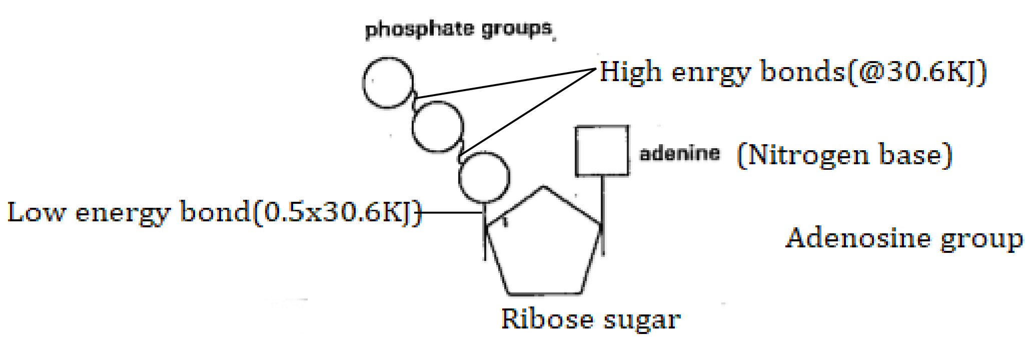
Defn: Is the breakdown of food substances within body cells to release energy

- It is also internal respiration or tissue respiration or cellular respiration.
- It is an example of a metabolic reaction. Metabolism refers to body reactions.
- It is controlled by enzymes; so any factor that affects enzymes also affects respiration.
- Substances that are broken-down to release energy within body cells are called **respiratory substrates**.
- The major respiratory substrate is a carbohydrate; glucose mainly.
- Other larger carbohydrates like starch, maltose, sucrose are also respiratory substrates but must be broken down first into glucose before are used.
- Lipids/fats are used as respiratory substrates when carbohydrates are used up but they are first broken down into fatty acids and glycerol before are used.
- Proteins are used as respiratory substrates only under extreme starvation. Proteins are broken down to amino acids which are then deaminated to a carbohydrate skeleton & ammonia. The carbohydrate skeleton is then used in respiration.
- During respiration, the energy released from food is stored in a chemical compound called **adenosine triphosphate (ATP).**

ATP & Energy from ATP

- **ATP** is the energy store within body cells. It is the immediate source of energy like cash at hand ready to be spent.
- It is made up of a chemical called Adenosine and 3 phosphates joined bonds thus tri=3.
- The energy is stored in these phosphate bonds.

Structure of ATP



- The heat energy produced during respiration is stored in the last bond in form of <u>chemical energy.</u>

- In order to store energy, adenosine diphosphate (ADP) with 2 phosphate groups is converted to ATP using heat energy released from respiration to add the 3rd phosphate group.
  i.e. $ADP + P + Energy \longrightarrow ATP$
- In order to release the energy from ATP for use; the ATP is split to ADP and a free phosphate in presence of ATPase enzyme.
  $ATP \longrightarrow ADP + P + Energy$ (Ready to be used by the body)

IMPORTANCE OF RESPIRATION

1. It produces energy in cells used for;
   - ✓ Nerve impulse transmission along nerves.
   - ✓ Muscular contraction; movement.
   - ✓ Cell division; growth.
   - ✓ Locomotion
   - ✓ DNA replication
   - ✓ Respiration
   - ✓ Active transport; phago/pinocytosis.
   - ✓ Secretion; hormones, enzymes etc
   - ✓ Excretion
   - ✓ Nutrition e.g. photosynthesis.
   - ✓ Reproduction.
   - ✓ Synthesis of proteins, fats etc
2. It produces heat energy to regulate the body temperature necessary for enzyme activity.

Types of respiration

1. Aerobic respiration
2. Anaerobic respiration

Aerobic respiration; is the oxidation of food substances in body cells to release energy.

OR

Is the breakdown of food substances within body cells to release energy in complete supply of oxygen.

- It involves chemical oxidation of food in cells to yield energy.
  $C_6H_{12}O_6 + 6O_2 \longrightarrow 6H_2O + 6CO_2 + Energy(About\ 2880KJ)$
  Glucose
- Aerobic respiration occurs in an organelle called **mitochondrion** (Plural: Mitochondria) found within a cell; part of the process occurs in the cytoplasm.

Anaerobic respiration; is the breakdown of food substances within body cells to release energy in absence of oxygen.

- Anaerobic respiration is also known as fermentation.
- It occurs only in the cytoplasm of the cell.
- In plants and fungi like yeast, ethanol (alcohol) and carbon dioxide are formed during anaerobic respiration. Thus also called alcoholic fermentation.
- In animals & certain bacteria, lactic acid/lactate is formed during anaerobic respiration but not ethanol. Thus also called lactic acid fermentation. Carbon dioxide is not formed.

Equations of anaerobic respiration

(a) In plant cells

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + Energy(About\ 210KJ)$$

Glucose Ethanol

(b) In animal cells

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + Energy(About\ 150KJ)$$

Glucose Lactic acid

NB:

- ✓ From the formulae, a molecule of lactic acid is half of the glucose molecule.
- ✓ Food is not completely broken down during anaerobic respiration; some energy remains locked up within the ethanol or lactic acid and thus produce less energy than aerobic respiration.

Summary of the major respiratory substrates and products of respiration

Type of respiration	Major substrate	Name(s) of products
1. Aerobic respiration in both plants & animals	Glucose	Energy, carbon dioxide & water.
2. Anaerobic respiration in plants(alcoholic fermentation)	Glucose	Energy, ethanol (alcohol) & carbon dioxide.
3. Anaerobic respiration in animals(lactic acid fermentation)	Glucose	Energy & lactic acid

COMPARISON BETWEEN AEROBIC AND ANAEROBIC RESPIRATION

SIMILARITIES

(i) Energy is produced in both.

(ii) Both are controlled by enzymes.
(iii) In both food/sugar in form of glucose is broken down.
(iv) In both carbon dioxide is formed except in lactic acid fermentation(anaerobic respiration in animals)
(v) Both occur inside living cells/tissues.

Differences

Aerobic respiration	**Anaerobic respiration**
Uses oxygen to breakdown glucose.	Doesn't use oxygen to breakdown glucose.
Glucose is completely broken down.	Glucose is incompletely broken down.
Water is produced	Water not produced
Neither alcohol/ethanol nor lactic acid is formed.	Produces ethanol in plants but lactic acid in animals.
Produces more energy for every glucose molecule.	Produces less energy for every glucose molecule.
Occurs in both cytoplasm and mitochondria	Occurs in only cytoplasm.
More carbon dioxide produced.	Less carbon dioxide produced.
Occurs at slower rate/releases energy slowly.	Occurs at faster rate/releases energy quickly.

Differences between anaerobic respiration in plants and in animals

In plants	**In animals**
• Ethanol is formed • Carbon dioxide is produced	• Lactic acid is produced • Carbon dioxide is not produced.

Examples of anaerobic respiration in nature.

In plants

1. Roots in water logged soils.

In fungi

2. Yeast; produces alcohol.

In microorganisms

3. In some bacteria like lactobacillus of genus; produces lactic acid.
4. Yeast.

In animals

5. In muscle cells during vigorous activity.
6. In earthworms in oxygen deficient mud.
7. In endoparasites like tapeworm in gut.

Classification of anaerobes

- **Anaerobes** are organisms that respire anaerobically.
- They are divided into 2 classes viz;
  1. Obligate anaerobes.
  2. Facultative anaerobes.

1. **Obligate anaerobes**; have to respire anaerobically for entire lives.

- Poisoned by oxygen like *Clostridium tetani*; which causes tetanus. i.e. oxygen is toxic to them & leads to their death.
- Thus, they never use oxygen at all to respire.

2. **Facultative anaerobes**; are aerobes but in oxygen absence, they respire anaerobically i.e. they are part-time anaerobes like;
   (i) Endoparasites such as gut/alimentary canal parasites like *Taenia solium/T. saginata* (tape worm).
   (ii) Muscle cells for humans & birds.
   (iii) Yeast.

Anaerobic respiration/lactic acid formation in human muscle cells

- Lactic acid is produced in vertebrate skeletal muscles when they are very active like in muscles of a sprinter in a race in man and in muscles of wings of a bird during very fast active flight.
- During a high rate of activity, the muscle cell respires faster than it can get oxygen.
- Blood cannot supply oxygen and glucose to cater for the highly respiring muscles at the same pace.
- The muscles of a sprinter respire aerobically in the first few minutes; then anaerobically for the rest of the race when there is no oxygen.
- Lactic acid is produced in the muscles and goes on accumulating; thus increasing its amount.
- The lactic acid is formed from glucose; obtained by conversion of glycogen stored in muscle cell into glucose.
- A lot of lactic acid is harmful because it causes <u>muscle fatigue</u> and <u>muscle cramps/pains(muscle pull)</u>.
- the lactic acid, therefore is carried by blood from the muscles at the end of the race; during the recovery period to the liver; where it is oxidized and converted to harmless glucose which can be used in respiration/stored as glycogen. This explains

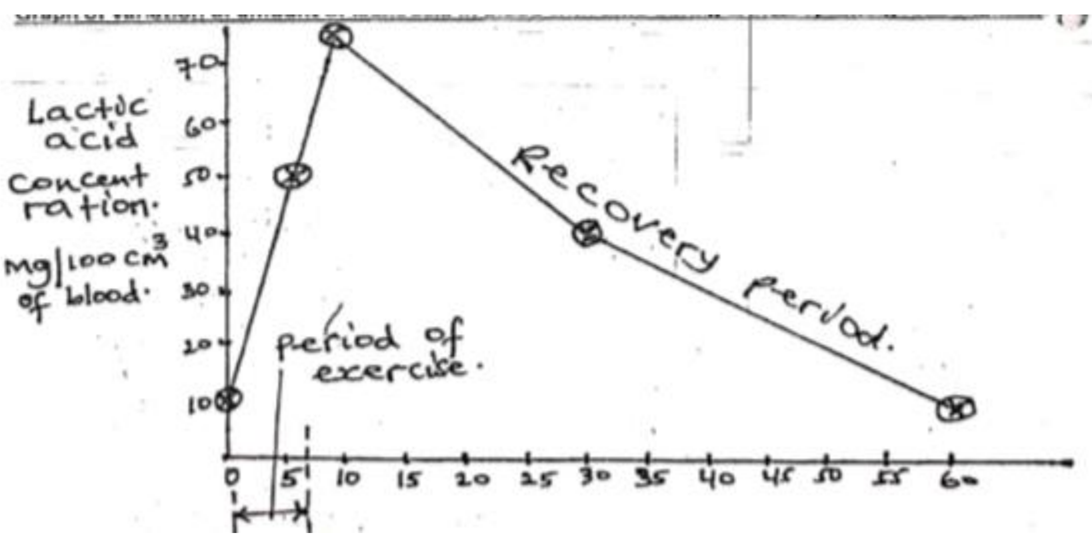
why the level of lactic acid reduces in the muscles at the end of the vigorous exercise.

- The level of lactic acid in blood continues to rise after the exercise, when anaerobic respiration has stopped, because lactic acid is being removed by the blood from the muscles and taken to the liver.
- The oxygen used to oxidize the lactic acid to glucose is known as the <u>oxygen debt/oxygen deficit</u>.
- **Oxygen debt** is the amount of oxygen required for oxidation of lactate.
- The oxygen needed to pay the oxygen debt at the end of the strenuous exercise/race is obtained by breathing deeply, increasing breathing rate, increasing the force & rate of heart beat.
- Thus anaerobic respiration in muscles is advantageous because;

(i) It enables animal tissues to obtain energy in absence of oxygen.

(ii) It supplements aerobic respiration in periods of very high demand for energy; otherwise the animal would not carry out vigorous and rapid activity like active flight, fight, vigorous exercise etc if it were not able to respire anaerobically.

A graph showing the variation of amount of lactic acid in blood with time during and after sprinting for 6 minutes



Questions:

1. A man performed a very vigorous exercise for 9 minutes and the concentration of lactic acid in his blood determined during and after the exercise up the 60th minute. The data below was obtained.

Time in minutes	0	5	10	15	20	25	30	35	40	45	50	55	60
Lactic acid concentration in	20	50	80	98	90	80	70	65	60	55	50	45	40

$mg/100cm^3$ of blood													

(a) Draw a graph to represent the above data.
(b) Describe the changes in the concentration of lactic acid in blood with time.
(c) By how much did the lactic acid increase at the end of the 12th minute?
(d) After how many minutes was the lactic acid concentration $72mg/100cm^3$ of blood?
(e) What would be the lactic acid concentration at the end of the 64th minute?
(f) During which process was lactic acid produced?
(g) Write down the word equation for the process.
(h) Which tissue is responsible for the production of lactic acid?
(i) Lactic acid is produced from glucose. What is the source of the glucose?
(j) Why does the concentration of lactic acid in blood increase further after the exercise upto the 15th minute?
(k) Which period on the graph represents the recovery period?
(l) What happens to the lactic acid during the recovery period?
(m) Why do the following occur the recovery period?
   (i) Breathing deeply and at a very high rate?
   (ii) High rate of heart beat?
(n) Of what advantage is the reaction which results in the production of lactic acid?
(o) How would the animals be handicapped if they could not be able to carry out this reaction?
(p) If the fall in lactic acid from the 30th to the 60th minute were to continue at the same rate, how long would it take to return to the original level/level of lactic acid at rest?

2.
(a) When you are walking or running, what forms of energy are being produced in your muscles?
(b) Why is it necessary to breathe faster when you are walking than when you are resting?
(c) Why must an athlete starting to run a thousand metres, not run as fast as he would if he were competing in a hundred metres race?

EXPERIMENTS ON ANAEROBIC RESPIRATION

AN EXPERIMENT TO SHOW THAT CARBON DIOXIDE IS PRODUCED DURING ANAEROBIC RESPIRATION (ALCOHOLIC FERMENTATION) OF GLUCOSE BY YEAST

Requirements

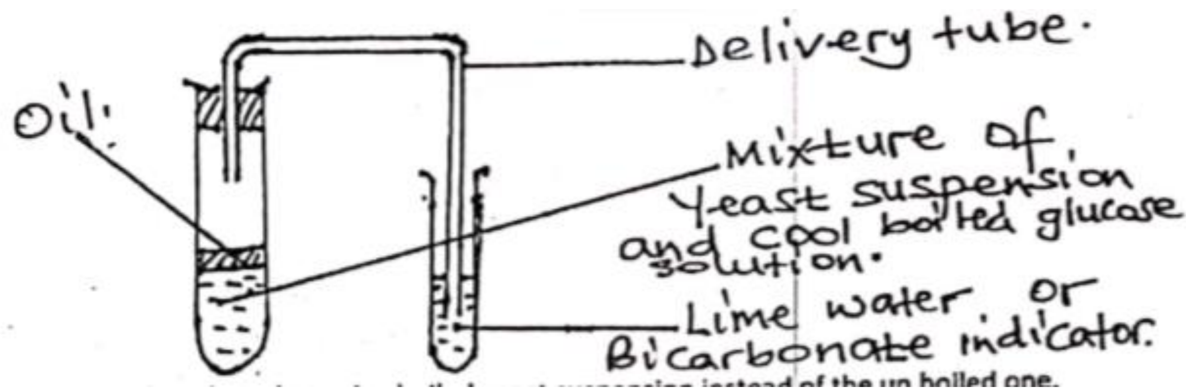
- Glucose solution

- Yeast solution
- Oil
- Lime water/bicarbonate indicator.
- Delivery tube
- Dropper
- 2 boiling tubes
- 2 test tubes

Procedure

- Boil glucose solution to drive out oxygen. Cool the solution.
- Pour the boiled glucose solution in a boiling tube.
- Add oil on top of the boiled glucose solution to prevent entry of oxygen.
- Add yeast solution to the glucose solution below the layer of oil using a dropper/ pipette.
- Add lime water/bicarbonate indicator in a test tube.
- Connect the boiling tube to the test tube using a delivery tube as shown in set up below.
- Set up a control experiment using boiled yeast suspension instead of the unboiled one.
- Leave the set up to stand for 20/30 minutes and observe what occurs in the boiling tube and the test tube.

Experimental set up



Observations

- Bubbles of a colourless gas are formed in the boiling tube that turn the lime water in the test tube milky [The bicarbonate indicator turns yellow if it is used instead of lime water].

- No bubbles of a colourless gas formed in the control experiment and the limewater remains colourless/bicarbonate indicator remains red.

Conclusion

- Carbon dioxide is produced anaerobic respiration (of yeast).

NB:

- ✓ The boiling tube feels warmer during the experiment due to the heat energy produced.
- ✓ The contents of the boiling tube smell strongly of alcohol because it's one of the products.

AN EXPERIMENT TO SHOW THAT HEAT ENERGY IS PRODUCED DURING ANAEROBIC RESPIRATION

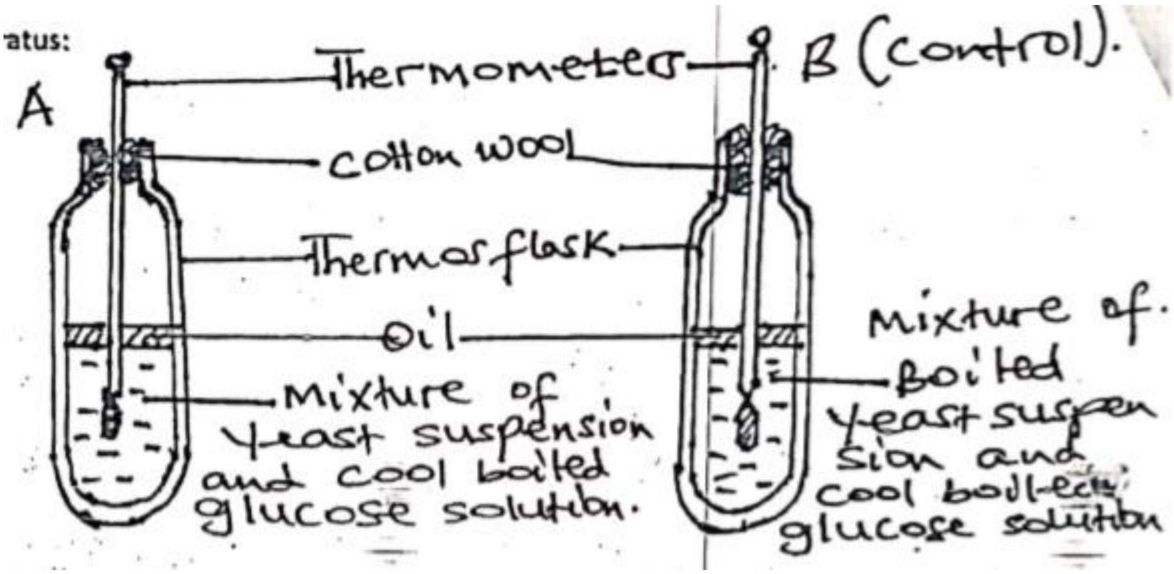
REQUIREMENTS

- Glucose solution
- Oil
- Dropper/pipette
- 2 Vacuum/thermos flasks
- Cotton wool
- Yeast suspension
- Water bath
- Thermometers

PROCEDURE

- Boil the glucose solution to drive off any dissolve oxygen.
- Cool the glucose solution.
- Divide the cool boiled glucose solution into 2 separate vacuum flasks.
- Add oil into each vacuum flask on top of the glucose solution to prevent entry of oxygen.
- Add yeast solution below the oil layer of one of the vacuum flasks using a dropper/pipette.
- Add boiled yeast/do not add any yeast to the other flask to serve as a control experiment.
- Place a thermometer in each of the flasks supported by cotton wool.
- Record the initial thermometer reading for each thermos flask.
- Record the thermometer readings every after 10 minutes for an hour.

EXPERIMENTAL SET UP



OBSERVATIONS

- The temperature rises for some time in the flask A; with unboiled yeast solution.
- The temperature remains the same in flask B; the control without yeast/with boiled yeast.

CONCLUSION

- Heat is produced during anaerobic respiration of glucose by yeast.

EXPLANATION

- Anaerobic respiration does not occur in the control experiment, in flask B; because the enzymes needed for respiration were denatured by boiling the yeast solution.

EXPERIMENT TO DEMONSTRATE THAT GERMINATING SEEDS CAN RESPIRE ANAEROBICALLY

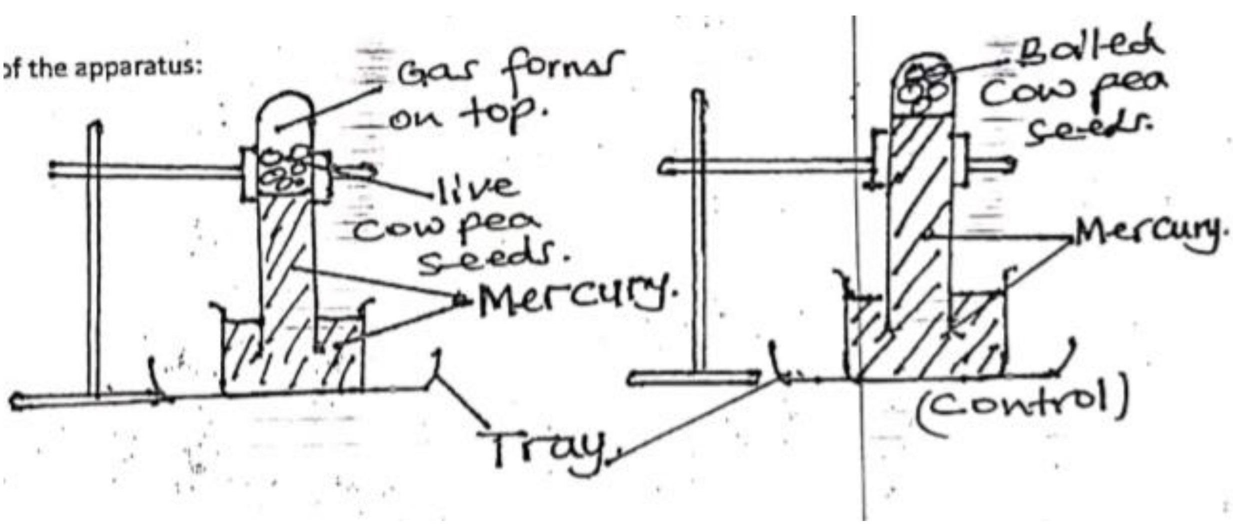
REQUIREMENTS

- 2 boiling tubes/test tubes
- Mercury
- Formalin
- 20 cow peas/other seeds.
- Lime water
- Clamp & stand.

PROCEDURE

- Soak 20 cow peas/other seed in water for 24 hours.
- Divide the soaked seeds into 2 groups.
- Boil one group of the soaked seeds in water for at least 5 minutes/ bake the seeds in an oven for the same period to kill the seeds.
- Soak the boiled/baked seeds in formalin to sterilize them and prevent growth of bacteria and fungi that would respire and affect the results.
- Completely fill 2 boiling tubes/test tubes with mercury.
- Invert each tube of mercury in a small dish of mercury in a tray. The tray prevents loss of spilled mercury.
- Clamp the tubes firmly.
- Place 10 unboiled/unbaked cowpeas/other seeds at the bottom of the test tube/boiling tube labeled A so that they rise to the top of the mercury.
- Similarly, place the 10 sterilized boiled/baked seeds in the other test tube labeled B, to serve as control experiment.
- Leave the set up to stand for 1/2 days.
- Observe if any gas is formed on top of the mercury and the mercury displaced downwards.
- Introduce limewater in the space created above the mercury using bent glass tubing.

EXPERIMENTAL SET UP



OBSERVATIONS

- A colourless gas that turns lime water milky is formed in test tube A with living seeds above the mercury with displaces the mercury downwards. The lime water dissolves the gas and the mercury fills up the test tube again.

- There is no change in the level of mercury in the test tube B with dead seeds.

CONCLUSION

- Germinating seeds can respire anaerobically to produce carbon dioxide.

IMPORTANCE/APPLICATION OF ANAEROBIC RESPIRATION IN EVERYDAY LIFE

1. Brewing of alcohol, wines and spirits using yeast in brewing industry.
2. Baking; where yeast added to the dough, respires anaerobically producing carbon dioxide that raises it.
3. Making dairy products like milk, cheese, butter, yoghurt etc using anaerobic bacteria. Souring of milk is done by lactic acid bacteria Lactobacillus.
4. Fermentation and curing of tea leaves or coffee by anaerobic bacteria.
5. Leather and skin tanning by anaerobic bacteria.
6. Production of biogas.
7. Sewage treatment using anaerobic bacteria.
8. Formation of fossil fuels.
9. Making and preservation of animal feeds like silage, hay etc.
10. Commercial production of organic acids like lactic acid, citric acid, oxalic acid etc.
11. Farm manure and composite manure formation.

Question:

(a) State the differences between aerobic and anaerobic respiration.
(b) In what ways is anaerobic respiration applied;
 (i) At home?
 (ii) In industries?

EXPERIMENTS ON AEROBIC RESPIRATION

EXPERIMENT TO SHOW THAT HEAT ENERGY IS PRODUCED BY GERMINATING SEED DURING AEROBIC RESPIRATION

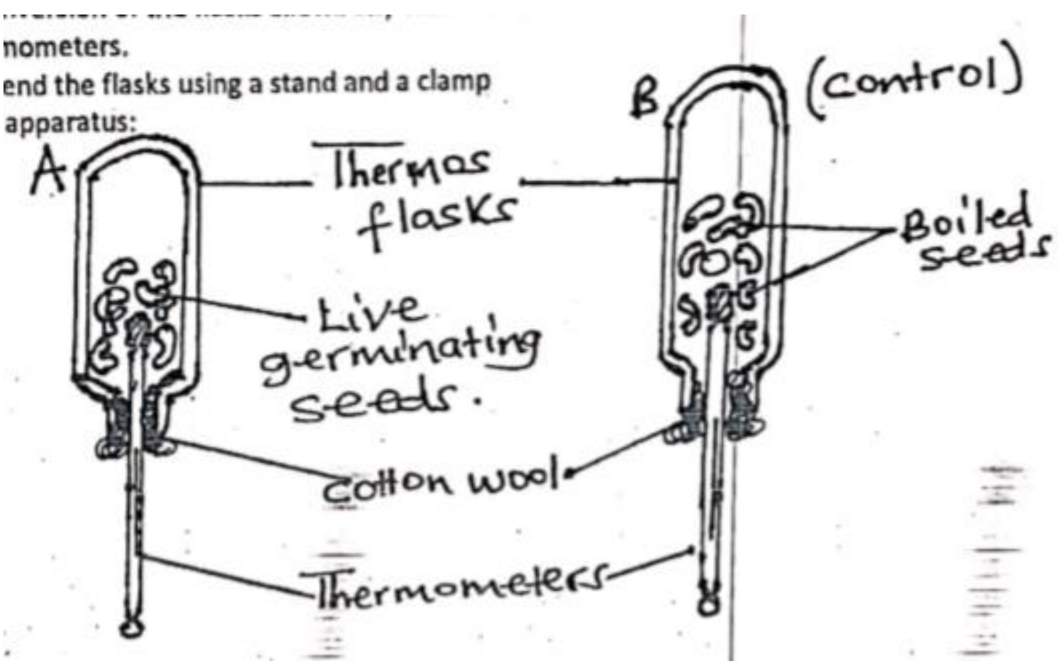
REQUIREMENTS

- 2 Thermos flasks
- 2 Thermometers
- Bean/pea seeds
- Formaldehyde /sodium hypochlorite solution
- Cotton wool

PROCEDURE

- Soak the seeds in water for 24 hours.
- Divide the seeds into 2 equal groups/sets.
- Boil one set of seeds to kill them.
- Soak both the boiled and unboiled seeds in formaldehyde/sodium hypochlorite that serves as disinfectant & prevents growth of bacteria & fungi that would respire and produce heat and affect the results.
- Rinse the seeds in water.
- Put the live/germinating seeds in flask labeled A and the boiled/killed seeds in another flask labeled B.
- Insert a thermometer into each of the flasks and support them using cotton wool plugged into their mouths.
- Invert the flasks upside down such that bulbs of the thermometers are covered by the seeds.
- The inversion of the flasks allows any water formed to flow out easily and eases reading of the thermometers.
- Suspend the flasks using a stand and a clamp.
- Record the initial thermometer readings.
- Leave the set up to stand for 2-3 days.
- Record the final thermometer readings.

EXPERIMENTAL SET UP



OBSERVATIONS

- Thermometer reading in flask A, containing germinating seeds rises rapidly.
- Thermometer reading in flask B is lower than for flask A. i.e. rises slightly or not at all.

CONCLUSION

- Heat energy is produced by germinating seeds when they respire aerobically (during aerobic respiration).

Questions:

1. Three thermos flasks A,B and C, containing equal quantity of peas, were taken. Moist germinating peas, were placed in flask A. boiled seeds were placed in flask B. boiled seeds soaked in formaldehyde were placed in flask C. thermometers were dipped into the peas; the flasks plugged with cotton wool and then placed upside down using stands. Thermometer readings were taken at the same time for 9 days. The following results were obtained.

Time in days		1	2	3	4	5	6	7	8	9
Temperature/°C	Flask A	20	22	25	30	35	38	37	33	26
	Flask B	20	20	20	22	25	30	33	39	45
	Flask C	20	20	19	20	20	19	20	20	19

(a) Using the same axes, represent the above information graphically.
(b) What was the aim of the experiment?
(c) What was the purpose of flask C?
(d) Account for the thermometer readings in flask;
  (i) A
  (ii) B
  (iii) C.
(e) Why are;
  (i) Vacuum thermos flasks used instead of glass flasks?
  (ii) Flasks plugged with cotton wool instead of rubber corks?
  (iii) Flasks kept upside down?
(f) Why were the peas used in flask B and C boiled?
(g) What changes in composition of air occurred in each flask from day 1 to day 6?

2. Attempt question 31 UCE/UNEB past paper 1 of 2008.

EXPERIMENT TO SHOW THAT CARBON DIOXIDE IS PRODUCED BY LIVING ORGANISMS DURING AEROBIC RESPIRATION

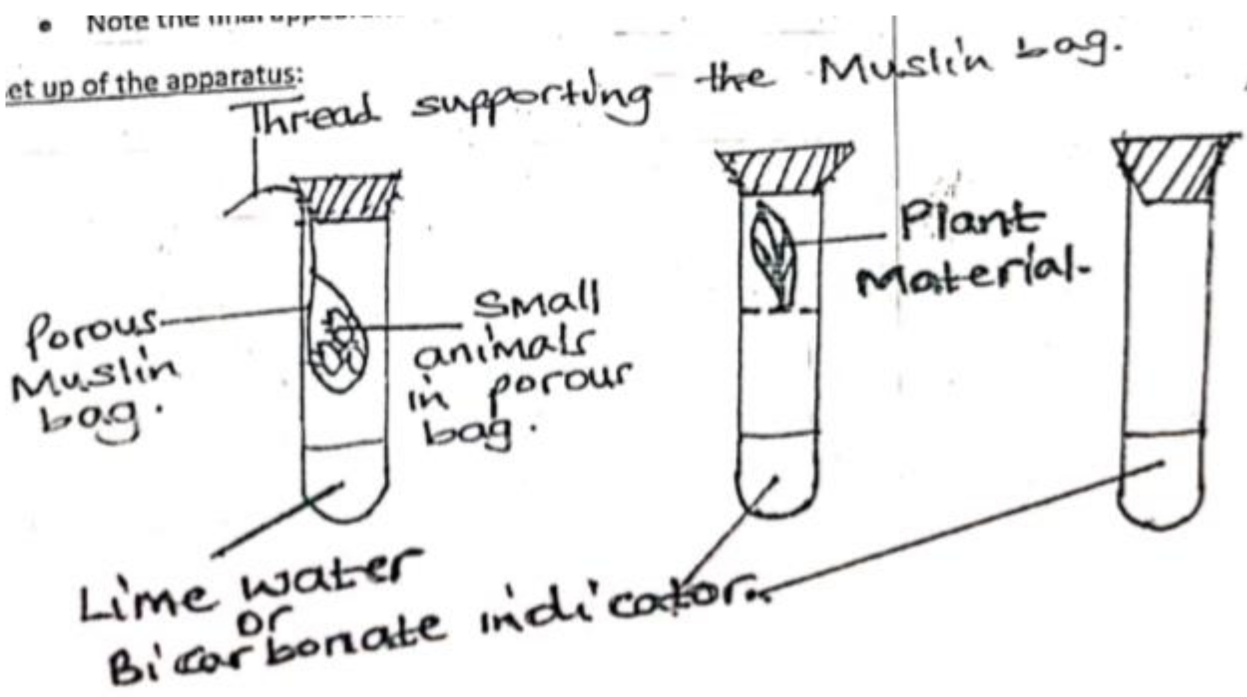
REQUIREMENTS

- 3 test tubes.
- 3 corks
- Wire gauze/muslin bag.
- Threads
- Lime water/ bicarbonate indicator.
- Living materials like cockroaches. Grasshoppers, green leaf/non green plant tissue.
- Black cloth/black polythene/dark card box/ darkroom.

PROCEDURE

- Pour about $3cm^3$ of limewater/bicarbonate indicator into 3 test tubes labeled A, Band C.
- Put some small animals like cockroaches in a muslin bag/on wire gauze in test tube A.
- Place no animal/plant material in test tube C, to serve as the control experiement.
- Fix tightly a cork in each of the test tubes.
- If the plant material used in B is green, then cover the test tube with black polythene/keep it in a dark place to avoid light and prevent photosynthesis that would use carbon dioxide and produce oxygen and affect the results.
- Note the appearance of the indicator in each of the test tubes.
- Leave the test tubes for one hour.
- Not the final appearance of the indicator in each of the test tubes.

EXPERIMENTAL SET UP



OBSERVATIONS

- The lime water in test tubes A and B turn milky / the bicarbonate indicator turns from red to yellow.
- The lime water in test tube C remains colourless/the bicarbonate indicator remains red.

CONCLUSION

- Carbon dioxide is produced by living organisms during aerobic respiration.

ALTERNATIVELY

EXPERIMENT TO SHOW THAT CARBON DIOXIDE IS PRODUCED BY LIVING ORGANISMS DURING AEROBIC RESPIRATION

REQUIREMENTS

- Filter pump/suction pump
- Glass wool
- Soda lime/sodium hydroxide solution
- Lime water/bicarbonate indicator
- Bell jar
- Conical flasks
- Delivery tubes
- Rat/potted plant
- .corks
- Vaseline

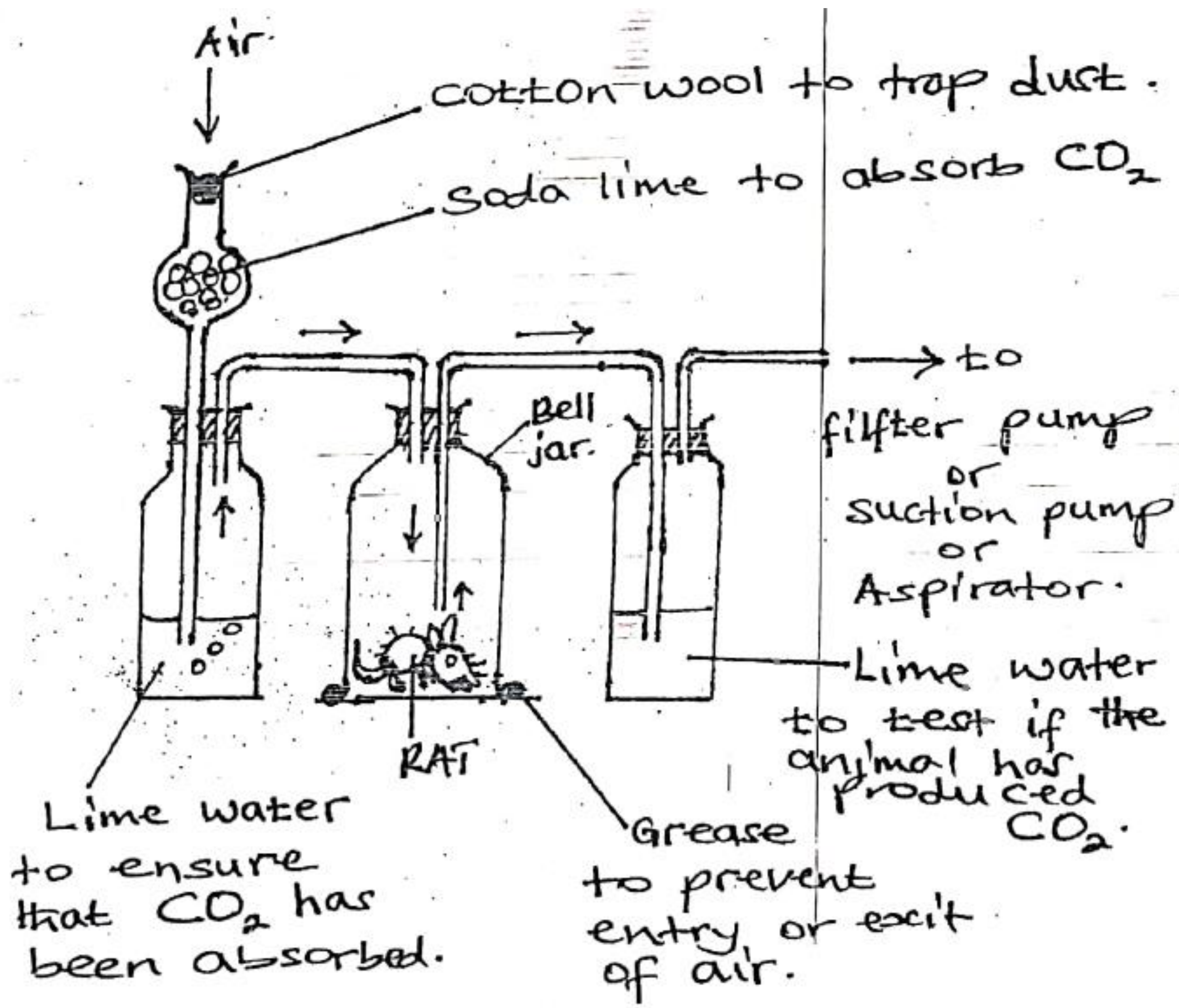
PROCEDURE

- Place a small animal like a rat/ a potted plant in the bell jar.
- If a plant is used, the pot must be enclosed in a polythene to;
  - ✓ Prevent carbon dioxide produced by soil microbes from interfering with the results.
  - ✓ Prevent evaporation of soil water into the ball jar.
- The ball jar must also be enclosed with a blackcloth/black polythene to avoid light and prevent photosynthesis that would use up the carbon dioxide produced by the plant.
- Smear Vaseline around the corks and the bottom of the bell jar at the junction with the glass plate to make it air tight; preventing entry or exit of air.

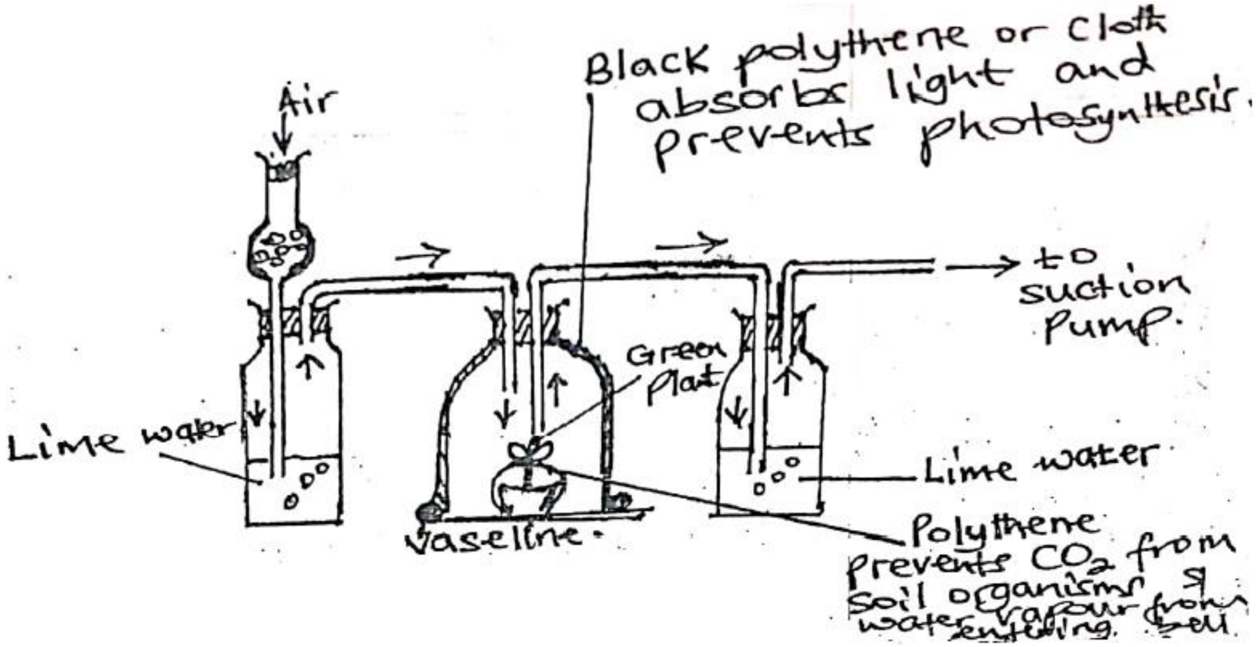
- Turn on the suction pump and draw air through the apparatus via the soda lime that absorbs carbon dioxide from the air entering the apparatus.
- The air is drawn through flask A on the left containing lime water/ bicarbonate indicator to test for carbon dioxide and ensure that it is not in the air.
- The lime water. Bicarbonate indicator in flask B, on the right is tested to find out whether the animal/plant has produced carbon dioxide.

EXPERIMENTAL SET UP

If animal used



If plant used



OBSERVATIONS

- Lime water in flask A, on the left remains colourless/bicarbonate indicator remains red/pink.
- Lime water in flask B, on the right turns milky/bicarbonate indicator turns yellow.

CONCLUSION

- Carbon dioxide is produced by organisms during aerobic respiration.

EXPERIMENT TO SHOW THAT OXYGEN IS USED UP DURING AEROBIC RESPIRATION USING A SIMPLE RESPIROMENTER

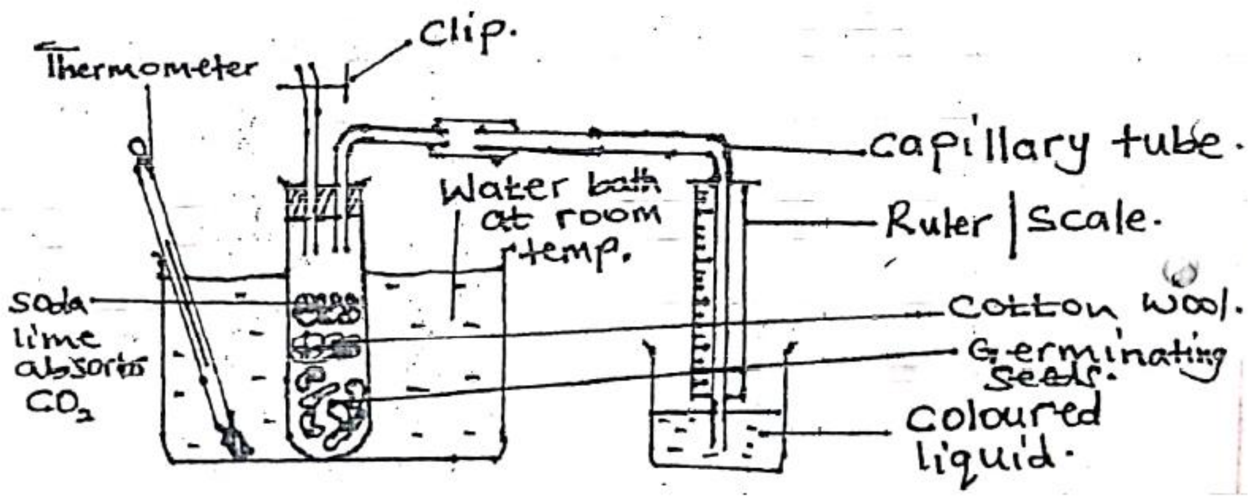
REQUIREMENTS

- 2 Thermometers
- Water bath
- Clips
- Capillary tube
- Ruler
- Coloured water
- Cotton wool
- Soda lime
- Germinating pea seeds
- Boiled/killed pea seeds

PROCEDURE

- The experiment is arranged as shown in the experimental set up below.
- Sodalime absorbs carbon dioxide from the apparatus and the respiring germinating seeds.
- The cotton wool holds the soda lime in position.
- The water bath is made of a beaker containing water maintained at room temperature using a thermometer. This ensures that the temperature of the test tube is kept constant as small changes in temperature cause large changes in the volumes of gases.
- The reservoir contains coloured water.
- The control experiment is set up in the same way but use the same number of boiled/killed peas instead of the germinating peas.
- Note the level of the coloured water in the capillary tubes every 10 minutes for the next one hour.

EXPERIMENTAL SET UP



OBSERVATIONS

- The level of the coloured water in the capillary tube connected to the germinating seeds rises up.
- The level of the coloured water in the control with boiled seeds does not change.

CONCLUSION

- Germinating seeds use up oxygen during aerobic respiration.

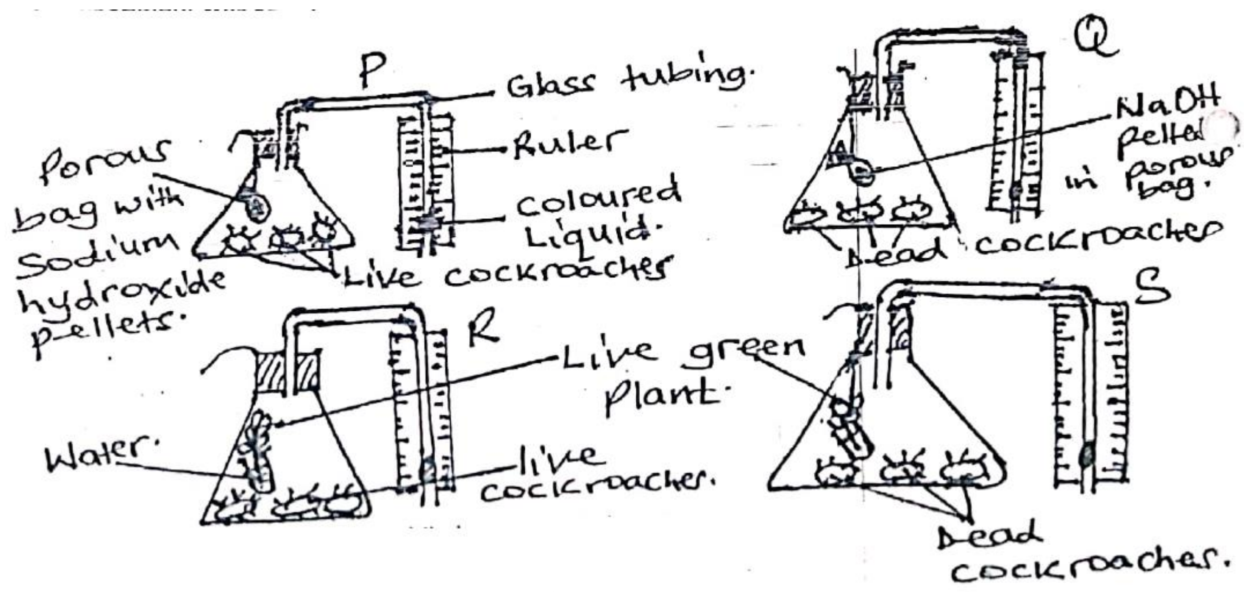
EXPLANATION

- Germinating seeds respire; using oxygen from the test tube; and produce carbon dioxide.
- The carbon dioxide is absorbed by the soda lime
- Thus the volume of the space in the test tube not occupied by gases increases while the pressure falls below atmospheric pressure.
- This causes the atmospheric pressure to act on the coloured liquid in the reservoir, rising it up the capillary tube.

NOTE: The same results are obtained if small animals like cockroaches, grasshoppers, beetles etc are used instead of germinating seeds using a similar set up as below.

Questions

1.
   (a) Differentiate between respiration and gaseous exchange.
   (b) What is the importance of respiration?
2. Describe an experiment to show that carbon dioxide is produced by germinating seeds during ;
   (a) Anaerobic respiration
   (b) Aerobic respiration
3. .
   (a) What is (i) ATP (ii) ADP in full?
   (b) What is the importance of ATP?
4. What is meant by the term;
   (i) Metabolism?
   (ii) Catabolism?
   (iii) Anabolism?
5. Describe an experiment to show that (i) oxygen is used (ii) carbon dioxide is produced (iii) energy is produced during aerobic respiration by;
   (a) Germinating seeds
   (b) A small animal
   (c) A green plant
6. An experiment was set up as shown in the diagram below and placed in sunlight for 10 minutes. The level of the coloured liquid rose to the top of the scale in P but remained the same in Q, R and S.
   Experimental set up



Explain why the liquid P rose while it remained the same in Q, R and S.

FACTORS AFFECTING THE RATE OF TISSUE RESPIRATION

1. **AGE**

- Young individuals are more active; thus require more energy; so have higher metabolism and respiration in their bodies than in the old ones to generate the required energy.
- Actively growing organisms like growing animals and germinating seeds respire fast to provide the energy needed for the cell division.

2. **HEALTH STATUS**

- During illness, the rate of metabolism and thus respiration increases to provide enough energy required to fight the disease/pathogens and to remove the toxic substances released by the pathogens.

3. **BODY SIZE**

- Small organisms have larger surface area to volume ratio than large ones.
- Thus small organisms like shrews lose heat energy faster than the bigger ones like elephants; so the rate of respiration and other metabolism is faster in smaller ones to replace the heat lost. This means that smaller organisms should have a higher rate of feeding to provide larger amount of food/glucose in proportion to the body mass;to be broken down to generate heat and replace the lost one. The large ones find it relatively difficult to lose heat; and have problems of keeping cool.

4. **LEVEL OF ACTIVITY**

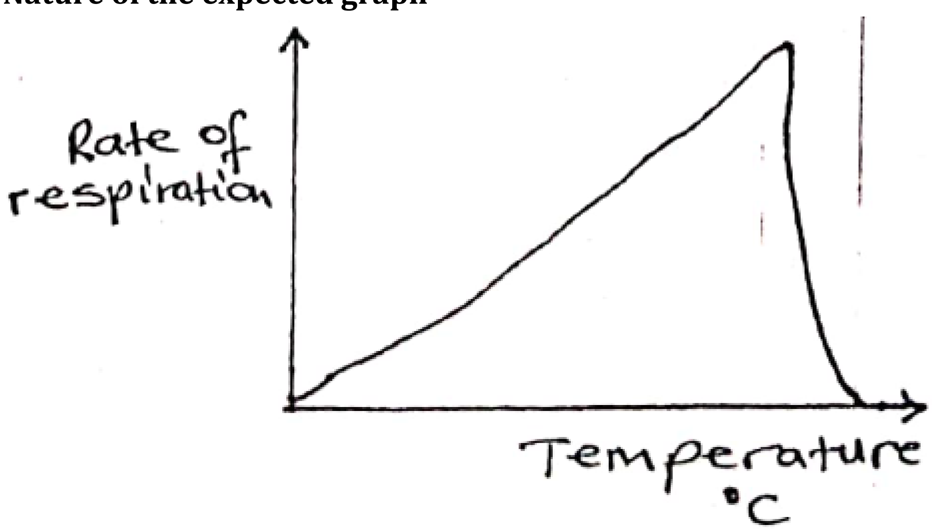
- An organism requires less energy at rest than when active.

- During a very vigorous activity like running in mammals or active flight in birds and insects; muscles contract at very fast rate thus need to respire fast to provide the necessary energy.
- The minimum energy required by an organism to sustain life while at rest per unit time is known as the basal metabolic rate (BMR).
- The BMR is higher for more active organisms.
- Males have higher BMR than females in humans.
- Respiration is slow in dormant animals/seeds to ensure that the stored food is used slowly, not to get exhausted during the dormancy period.

5. **TEMPERATURE**

- Respiration is controlled by enzymes.
- In germinating seeds and animals whose body temperature varies with that of the environment i.e. piokilotherms/ectotherms like amphibians, reptiles, insects; respiration is slow at low temperature due to inactivation of the respiratory enzymes. Respiration increases with increase in temperature due to activation of the respiratory enzymes up to the optimum temperature where the respiration/metabolism is highest. The respiration/metabolism decreases with increase in temperature beyond the optimum temperature due to denaturation of the respiratory enzymes.

  Nature of the expected graph



- Temperature does not affect respiration in homiotherms/endotherms –i.e. animals that maintain a constant body temperature in same way as for poilkilotherms/ectotherms; unless under very extreme conditions of cold/warmth when they can no longer maintain a constant body temperature.

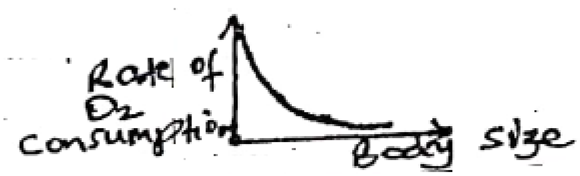
QUESTIONS

1. The table below shows the effect of temperature on the rate of respiration of a small animal determined using a respirometer. The rate respiration is expressed as the volume of oxygen consumed per kg of body mass per hour.

Rate of respiration(cm^3/kg)/hour	0	50	100	200	400	250
Temperature/°C	0	10	20	30	40	50

   (a) Draw a graph to represent the above information.
   (b) Describe the changes shown in the graph.
   (c) Explain the changes shown in the graph.

2. Below is a graph showing the relationship between metabolic rates determined by measuring the rate of oxygen consumption and body size in animals of the same species.



   (a) Describe the graph.
   (b) Explain the relationship as shown in the graph.

3. The table below shows 5 animals and their energy output per kg/day at rest.

Animal	Pig	Man	Dog	Chicken	Mouse
Body mass(kg)	128	64.3	15.2	2.0	0.02
Energy output(kg/day)	80.2	134.2	216.3	298.2	2746.8

   (a) Using the information in the table above, state the relationship between body mass and energy output.
   (b) Explain the relationship between body mass and energy ouput.
   (c) How does the relationship above affect the rate of respiration of the organisms?
   (d) If energy input must balance energy output; which one of the animals must feed almost continuously in order to keep alive? Explain your answer.

4.
   (a) Describe an experiment to show that;
      (i) Carbon dioxide is produced
      (ii) Heat is evolved during anaerobic respiration.
   (b) State the products of anaerobic respiration in;
      (i) Yeast
      (ii) Plants
      (iii) Animals

EXPERIMENT TO SHOW THAT SMALLER ORGANISMS LOSE HEAT FASTER THAN BIGGER ONES

REQUIREMENTS

- Boiling tube to represent a large organism
- A smaller test tube to represent a small organism
- Thermometer
- Stop clock
- Heat source
- Water
- Test tube holders

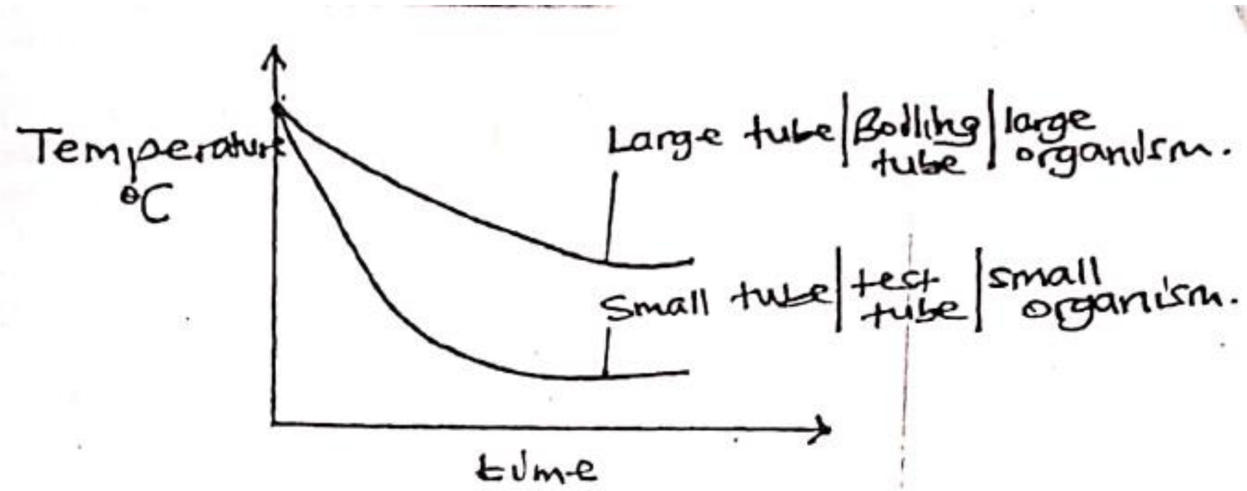
PROCEDURE

(i) Place a thermometer in a boiling tube.
(ii) Fill the boiling tube with water and leave a small space from its mouth.
(iii) Hold the boiling tube using a test tube holder and heat the water to a temperature that is slightly above 70°C but not beyond 80°C.
(iv) Place the boiling tube on a test tube rack as you read the temperature of the water.
(v) Start the stop clock as soon as the temperature of water is 70°C. Take this as the initial temperature of the water-i.e. the temperature at zero minutes.
(vi) Record the temperature of water after every one minute for 9 minutes; without removing the thermometer from the hot water.
(vii) Repeat the procedure (i) to (vii) above using a smaller test tube.
(viii) Fill the results in the table below.

<table>
<tr><td colspan="2">Time in minutes</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
<tr><td rowspan="2">Temperature of the water in °C in the</td><td>Boiling tube</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Test tube</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

(ix) Plot a graph of variation of temperature with time.

Nature of expected graph



Observation

- The temperature of the water in the small test tube decreases faster than the water in the big boiling tube.

Conclusion

- Smaller organisms lose heat faster than larger ones.

Question

A student performed an experiment to investigate the effect of size on the rate of heat loss in mammals using test tubes of different sizes A and B. The following results were obtained.

Time in minutes		0	1	2	3	4	5	6	7	8	9
Temperature of the water in °C in the	A	70	63	58	55	52	48	46	45	43	41
	B	70	68	66	60	57	55	53	52	51	48

(a) Using the same axes, represent the above results graphically.

(b) State with a reason, which of the 2 test tubes represents;

i) A larger mammal

ii) A smaller mammal?

(c) Explain why the respiratory rate and other metabolic reactions in a small mammal should be faster than for the larger one.

(d) Which of the 2 mammals

i) Eats more than its own body mass?

ii) Eats a small fraction of its mass in food?

(e) Using the above information, explain the disadvantage of (i) the small size (ii) large size in mammals.

COMPARISON BETWEEN AEROBIC RESPIRATION AND PHOTOSYNTHESIS

SIMILARITIES

i) Both occur in living cells.
ii) Both are controlled by enzymes
iii) In both exchange of carbon dioxide and oxygen is involved.
iv) Both involve energy conversions

DIFFERENCES

Aerobic respiration	Photosynthesis
• Occurs in all living cells of plants & animals.	• Occurs in cells with chlorophyll only.
• Uses oxygen as a raw material	• Oxygen is produced as a byproduct.
• Carbon dioxide and water are released as byproducts	• Carbon dioxide and water are used as raw materials.
• Food is broken down/is a catabolic process	• Food is synthesized/is anabolic process
• Energy is produced	• Energy in form of sun light is used.
• Occurs in cytoplasm and mitochondria of a cell.	• Occurs in chloroplasts of a cell.
• Occurs at all times since it's independent of light.	• Occurs in presence of light only.
• Decreases dry mass of the cell.	• Increases dry mass of the cell.
• Chemical energy in carbohydrates is converted into ATP and some is lost as heat.	• Light energy is converted into chemical energy which is stored in the bonds of the carbohydrates formed.
Equation $C_6H_{12}0_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + Energy$	$6H_2O + 6CO_2 \xrightarrow{Light,\ chlorophyll} C_6H_{12}0_6 + 6O_2$

- The equations show that respiration is the opposite of photosynthesis.

Question

State the differences between aerobic respiration and photosynthesis.

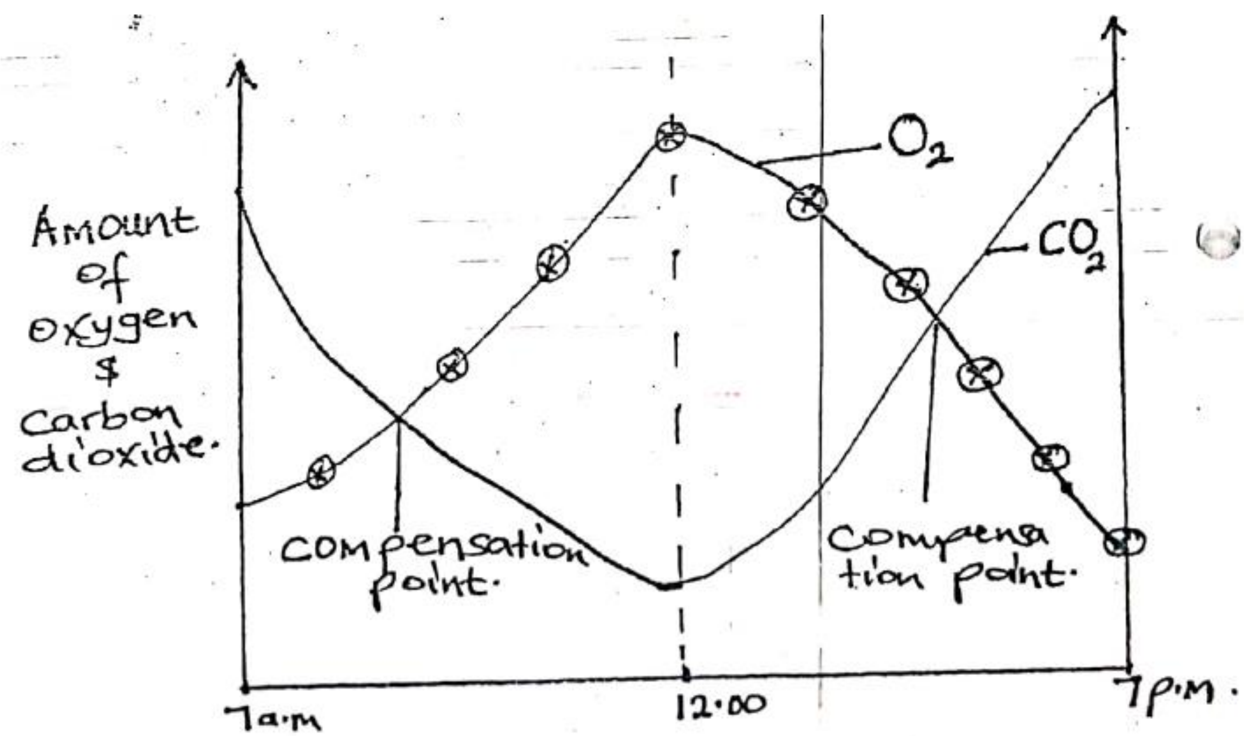
Compensation points and relationship between respiration and photosynthesis at different light intensities in green plants

- A green plant respires and photosynthesizes when light is available. Under low light intensity like at dawn, the rate of respiration is higher than the rate of photosynthesis.
- Under high light intensity, the rate of photosynthesis is faster than the rate of respiration.

  Compensation point:

- This is when the rate of photosynthesis is equal to the rate of respiration in green plants.
- At this point the amount of oxygen produced during photosynthesis is equal to the amount of oxygen used in respiration. So no oxygen is absorbed or released to the environment.
- Also the amount of carbon dioxide produced during respiration is equal to the amount utilized during photosynthesis. So no carbon dioxide is absorbed or released to the environment.
- The amount of carbon dioxide used in photosynthesis is equal to the amount of oxygen used in respiration.
- Thus compensation point is the light intensity at which there is no net exchange of gases between the plant and the environment.

A graph showing variation of amount of carbon dioxide and oxygen in a forest over a period of 12 hours



- At night, the plants respire but do not photosynthesize due to lack of sun light. So that carbon dioxide is high while the amount of oxygen is low.
- After dawn, the rate of photosynthesis increases with increase in light intensity which decreases the amount of carbon dioxide and increases the amount oxygen; until the compensation point where the rate of respiration is equal to the rate of photosynthesis.

- When the light intensity is high like at mid-day, the rate of photosynthesis is faster than the rate of respiration; thus the amount of oxygen is high while that of carbon dioxide is low.
- After mid-day, the amount of oxygen reduces due to decrease in light intensity which decreases the rate of photosynthesis.
- A second compensation point is obtained around dusk.
- The results are not accurate because not only plants respire; other organisms like animals also respire and affect the amount of oxygen and carbon dioxide in the forest.

Question

The data below the amount of carbon dioxide in a forest measured over a period of 24 hours.

	Mid night	Night		Dawn	Day		Mid-day	Day		Dusk	Night		Mid Night
Time in hours	12	02	04	06	08	10	12	14	16	18	20	22	24
Carbon dioxide concentration (%)	0.047	0.05	0.052	0.054	0.055	0.045	0.038	0.033	0.031	0.032	0.038	0.045	0.048

(a) Draw a graph of variation of the percentage of carbon dioxide in the air of the forest with time.
(b) Describe the changes as shown in the graph.
(c) Explain the major changes that occur over the 24 hours.
(d) At what time do you expect the concentration of oxygen to be highest? Explain your answer.
(e) At what time do you expect the concentration of oxygen to be lowest? Explain your answer.

Changes in a PH in a water body inhabited by green plants over a period of 24 hours.

- The changes in pH are due to production of absorption of carbon dioxide by the living organisms in the water body.
- The more the carbon dioxide produced; the more of it dissolves in water forming carbonic acid which lowers the pH [Note that high acidity leads to low pH].
- The more carbon dioxide is absorbed from the water body, the less the acidity, which increases the PH

- At night the plants respire without photosynthesizing. So a lot of carbon dioxide accumulates leading to decrease in pH of water with increase in duration of darkness.
- From dawn, the PH increases with increase in light intensity; due to increase in photosynthesis that uses up carbon dioxide; thus reduction in carbon dioxide; hence the pH is highest where light intensity is highest and photosynthesis is maximum.

Question

The data below shows how pH of an aquatic habitat varied within a period of 24 hours:

Time in hours	24(Mid-night)	06(dawn)	12(mid-day)	18(dusk)	24(mid-night)
PH	7.8	7.6	7.9	8.0	7.8

(a) Draw a graph of variation of pH with time of the day.
(b) Describe the variation of pH with time of the day.
(c) What causes the;
  i) Decrease in pH of the water from mid night to dawn?
  ii) Increase in pH of the water from dawn to dusk?
  iii) Decrease in pH of water from dusk to mid night?

END

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