isaac You work it out.

STEM SMART Biology Week 33 - Respiration 2

Oxidative Phosphorylation

Subject & topics: Biology | Biochemistry | Respiration **Stage & difficulty:** A Level P3

Oxidative phosphorylation is the final stage of aerobic respiration.

Part A

The process

During oxidative phosphorylation, NADH (reduced NAD) and $FADH_2$ (reduced FAD) are ______, releasing H^+ ions and electrons, and regenerating NAD^+ and FAD. The electrons move along a series of protein complexes embedded in the ______ called the ______. The energy released during this allows these protein complexes to actively transport H^+ ions from the mitochondrial matrix to the ______.

These H^+ ions then flow back into the mitochondrial matrix down their electrochemical gradient through a transmembrane protein called ______, providing the energy needed to synthesise ATP from ADP & Pi (inorganic phosphate). The maximum number of ATP molecules produced during this stage (per molecule of glucose) is ≈ 34, but the actual number varies depending on how much of the energy produced is used to make ATP, and how much is lost in the form of ______.

After reaching the final part of the electron transport chain, the electrons react with oxygen (the ______) and the H^+ ions to form water (H_2O).

Items:

oxidised | intermembrane space | inner mitochondrial membrane | cytoplasm | final electron acceptor | heat | ATP synthase | reduced | outer mitochondrial membrane | electron transport chain

Part B

Reactants

Which of the following molecules are **used up** during oxidative phosphorylation?

- [ ] oxygen
- [ ] water
- [ ] NAD^+
- [ ] NADH (reduced NAD)
- [ ] FAD
- [ ] $FADH_2$ (reduced FAD)
- [ ] ADP
- [ ] ATP
- [ ] carbon dioxide

Part C

Products

Which of the following molecules are **produced** during oxidative phosphorylation?

- [ ] oxygen
- [ ] water
- [ ] NAD^+
- [ ] NADH (reduced NAD)
- [ ] FAD
- [ ] $FADH_2$ (reduced FAD)
- [ ] ADP
- [ ] ATP
- [ ] carbon dioxide

Created for isaacphysics.org by Lewis Thomson

Adenosine Triphosphate (ATP)

Subject & topics: Biology | Biochemistry | Respiration **Stage & difficulty:** A Level P3

Adenosine triphosphate (ATP) is the main "energy transfer" molecule used in cells. Energy (from organic molecules in respiration, or from sunlight in photosynthesis) is used to synthesise ATP from adenosine diphosphate (ADP) and inorganic phosphate (P_i). This energy is stored within the ATP molecule and can then be released during ATP hydrolysis.

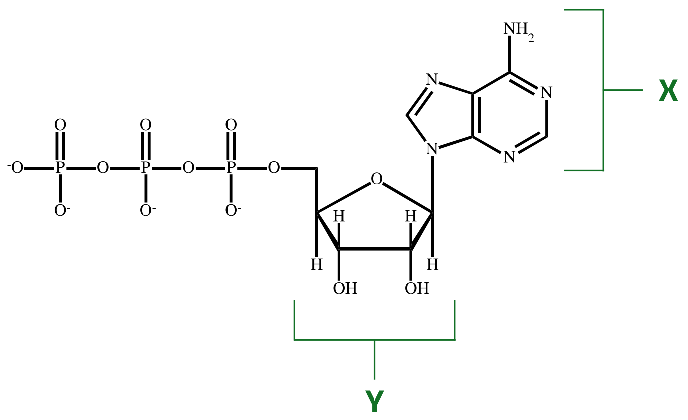

Figure 1: The molecular structure of adenosine triphosphate (ATP).

Part A
X and Y

What is the name of the nitrogenous base labelled **X** in **Figure 1**?

What is the name of the sugar labelled **Y** in **Figure 1**?

Part B

Inorganic phosphate

During respiration and photosynthesis, ATP is synthesised from ADP (adenosine diphosphate) and P_i (inorganic phosphate).

What is meant by "inorganic phosphate"?

- a single phosphate ion (PO_4^{3-}) which is not bound to anything else
- a compound consisting of one or more phosphate groups but which is not bound to anything else
- any compound that contains one or more phosphate groups
- any compound that contains one or more phosphate groups but does not contain any carbon atoms

Part C

Chemical energy

Why does the hydrolysis of ATP to ADP and P_i release energy?

- ATP is much more stable than ADP, which means that energy will be released when ATP is converted to ADP.
- The bonds between phosphate groups within ATP are relatively weak. The new bonds that form after hydrolysis are much stronger, which means that the reaction will release energy.
- The bonds between phosphate groups within ATP are "high-energy" bonds, which means they are very strong and therefore release a lot of energy when they are broken.
- During hydrolysis, water is split apart into hydrogen and oxygen. This process releases energy.
- Breaking chemical bonds is exothermic, whereas forming chemical bonds is endothermic.
- ATP hydrolysis is a spontaneous reaction that requires no energy input.

Adapted with permission from OCR A Level June 2002, Science Modular Central Concepts in Biology, Question 1

Question deck:

STEM SMART Biology Week 33 - Respiration 2

STEM SMART Biology Week 33 - Respiration 2

NAD and FAD

Subject & topics: Biology | Biochemistry | Respiration **Stage & difficulty:** A Level P3

Part A

Function of NAD and FAD

What is the main function of NAD^+ and FAD in aerobic respiration?

- To act as energy transfer molecules which transfer energy by donating a phosphate group.
- To be transported across the inner mitochondrial membrane, driving an electrochemical gradient that is then used to synthesise ATP.
- To act as the final electron acceptors during oxidative phosphorylation.
- To be broken down into smaller organic molecules in order to provide the energy needed for other reactions.
- To react with coenzyme A (CoA) to form acetyl CoA.
- To accept electrons from organic molecules and transfer them to the electron transport chain - where they are used to synthesise ATP.

Part B

Oxidation and reduction

In the table below, match the reaction type to the equation.

Equation	Reaction type
$NAD^{+} + H^{+} + 2\,e^{-} \longrightarrow NADH$	
$NADH \longrightarrow NAD^{+} + H^{+} + 2\,e^{-}$	
$FAD + 2\,H^{+} + 2\,e^{-} \longrightarrow FADH$	
$FADH \longrightarrow FAD + 2\,H^{+} + 2\,e^{-}$	

Items:

oxidation reduction

Part C

NADH and FADH2 production

Fill in the table below to give the number of molecules produced during each stage of aerobic respiration **per molecule of glucose**.

Stage	**Molecule**	
	NADH	**$FADH_2$**
Glycolysis		
Link reaction		
Krebs cycle		
Oxidative phosphorylation		

Items:

0 1 2 3 4 5 6

Created for isaacphysics.org by Lewis Thomson

Question deck:

STEM SMART Biology Week 33 - Respiration 2

STEM SMART Biology Week 33 - Respiration 2 >

Oxygen Levels

Subject & topics: Biology | Biochemistry | Respiration **Stage & difficulty:** A Level C3

Liver cells are frequently used as a source of mitochondria. These cells are homogenised in a sucrose solution and the mitochondria isolated. The suspended mitochondria are then placed in an oxygen electrode where the oxygen uptake of these organelles can be measured over a given time period.

The results of one of these experiments are shown in **Figure 1**.

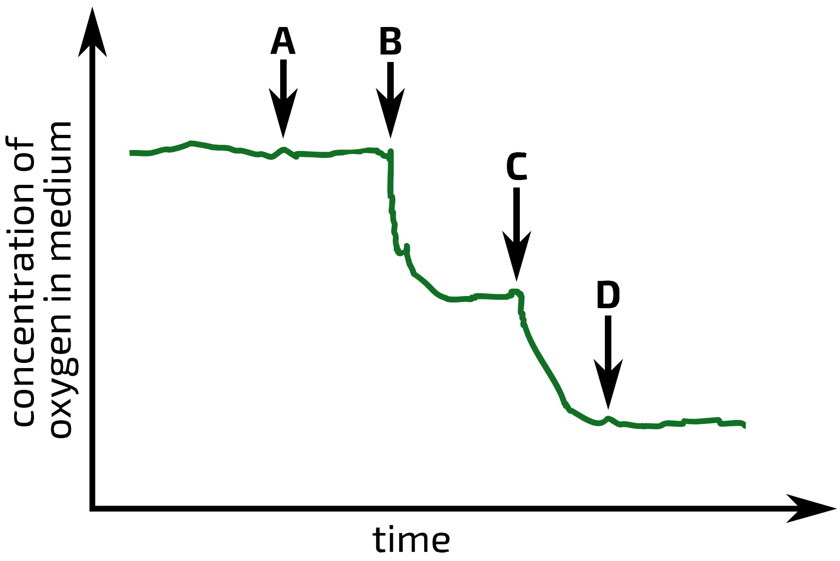

Figure 1: Oxygen concentration over time in a medium containing isolated mitochondria. At point A, glucose was added. At points B, C, and D, equal quantities of ADP were added.

Part A

A to B

Which of the following explains the results between points A and B? Select all that apply.

- [ ] The mitochondria are carrying out the process of fermentation, so the oxygen concentration remains constant during this period.
- [ ] There is not enough glucose present for aerobic respiration to occur.
- [ ] Photosynthesis and respiration are occurring at equal rates, so the oxygen concentration remains constant during this period.
- [ ] The earlier stages of aerobic respiration do not use up oxygen, so the oxygen concentration remains constant during this period.
- [ ] There is not enough oxygen present for aerobic respiration to occur.
- [ ] Not enough ADP is present for the later stages of aerobic respiration to occur.

Part B

B to C

Which of the following explains the results between points B and C? Select all that apply.

- [ ] The decrease in oxygen concentration slows down as ADP is used up (in making ATP).
- [ ] The rate of aerobic respiration slows down as oxygen begins to run out.
- [ ] The rate of photosynthesis increases until the rate of oxygen production is equal to the rate of oxygen loss.
- [ ] Glycolysis is occurring during this period, so the oxygen concentration decreases.
- [ ] The decrease in oxygen concentration slows down as glucose is used up.
- [ ] Oxidative phosphorylation is occurring during this period, so the oxygen concentration decreases.

Part C

D onwards

Which of the following explains the results from point D onwards? Select all that apply.

- [ ] Only glycolysis is occurring from point D onwards, so the oxygen concentration remains constant.
- [ ] All of the respiratory substrate has been used up, so respiration cannot proceed.
- [ ] All of the oxygen has been used up, so aerobic respiration cannot proceed.
- [ ] Not enough ADP is present for respiration to occur.
- [ ] The lactic acid produced by the mitochondria has changed the pH of the solution such that the respiratory enzymes can no longer function.
- [ ] The rate of photosynthesis increased between points C and D, resulting in oxygen levels being kept constant.

Adapted with permission from OCR A Level June 2003, Science Modular Central Concepts in Biology, Question 3

Question deck:
STEM SMART Biology Week 33 - Respiration 2

STEM SMART Biology Week 33 - Respiration 2

Respiratory Quotients

Subject & topics: Biology | Biochemistry | Respiration **Stage & difficulty:** A Level P2

The respiratory quotient (RQ) of a respiratory substrate is the number of $\mathrm{CO_2}$ molecules produced divided by the number of $\mathrm{O_2}$ molecules consumed during the aerobic respiration of one molecule of substrate, i.e.

$$\text{RQ} = \frac{\mathrm{CO_2}\,\text{produced}}{\mathrm{O_2}\,\text{consumed}}$$

Because the respiratory quotient differs between different respiratory substrates, it is possible to estimate the relative proportions of macronutrients being metabolised by measuring an individual's $\mathrm{CO_2}$ production and $\mathrm{O_2}$ consumption.

Part A

Carbohydrates

Carbohydrates are the main type of respiratory substrate. Larger carbohydrates (polysaccharides) are broken down into glucose, which can then enter the glycolysis pathway.

Balance the equation below to calculate the respiratory quotient of glucose.

$$\mathrm{C_6H_{12}O_6} + \mathrm{O_2} \longrightarrow \mathrm{CO_2} + \mathrm{H_2O}$$

What is the respiratory quotient of glucose?

Part B

Fats

Carbohydrates are not the only type of respiratory substrate. Fats (triglycerides) are also used in aerobic respiration, after being broken down into glycerol and fatty acids. Glycerol can then enter the glycolysis pathway (after being converted into one of the intermediate molecules), and fatty acids can enter Krebs cycle (after being converted into acetyl CoA).

Balance the equation below to calculate the respiratory quotient of a particular fatty acid.

$$C_{18}H_{36}O_2 + O_2 \longrightarrow CO_2 + H_2O$$

What is the respiratory quotient of this fatty acid? Give your answer to 2 decimal places.

Part C

Energy storage

Cells store energy in the form of triglycerides and polysaccharide carbohydrates.

What is the name of the energy-storage carbohydrate found in plant cells?

What is the name of the energy-storage carbohydrate in animal cells?

Adapted with permission from CIE, A Level, November 2005, Paper 4, Question 3

Question deck:

STEM SMART Biology Week 33 - Respiration 2

isaac You work it out.

Energy Released by a Teaspoon of Sugar

Subject & topics: Biology | Biochemistry | Respiration **Stage & difficulty:** A Level C3, Further A C1

*This question involves using **moles**, which is part of GCSE and A Level Chemistry. For more information please check with your teacher.*

During aerobic respiration, respiratory substrates such as carbohydrates and lipids are broken down in a process that generates ATP. One monosaccharide molecule (e.g. glucose, fructose, galactose) generates ~ 30 ATP molecules by aerobic respiration.

An individual consumes a teaspoon $(4\ \mathrm{g})$ of table sugar (sucrose).

Part A

ATP molecules

How many molecules of ATP will this individual generate as a result of this? Assume that all sucrose molecules are absorbed and broken down and that all products are aerobically respired.

Give your answer to 2 sf.

Part B

ATP hydrolysis ›

For each **mole** of ATP that is hydrolysed (to ADP $+$ P_i), $\sim 30.5\ \mathrm{kJ}$ of energy are released.

How much energy will be released by the hydrolysis of the ATP molecules that were generated from the teaspoon of sucrose? Assume that all ATP molecules are hydrolysed.

Give your answer to 2 sf.

Created for isaacscience.org by Lewis Thomson

Question deck:

STEM SMART Biology Week 33 - Respiration 2

Respiration Summary

Subject & topics: Biology | Biochemistry | Respiration **Stage & difficulty:** A Level P3

Part A

Respiration processes

Match the processes and cellular locations to the descriptions in the table below.

Process	Description	Location
	NADH and $FADH_2$ are oxidised and the energy released is used to produce ATP. Water is also produced.	
	Pyruvate is reduced to lactate or ethanol in order to regenerate NAD^+ from NADH.	
	Pyruvate is used to make acetyl CoA. NADH and CO_2 are produced.	
	Glucose is broken down into two pyruvate molecules. NADH and ATP are produced.	
	Acetyl CoA goes through a series of reactions. NADH, $FADH_2$, ATP, and CO_2 are produced	

Items:

the link reaction | Krebs cycle | fermentation | cytoplasm | oxidative phosphorylation | glycolysis | inner mitochondrial membrane | mitochondrial matrix

Part B

Molecule functions in aerobic respiration

Match the molecules to the functions in the table below.

Molecule	Function
	respiratory substrates
	electron carriers (accept electrons from organic molecules and donate them to the electron transport chain)
	final electron acceptor (accepts electrons from the electron transport chain)
	primary energy transfer molecule
	reacts with oxaloacetate (4C) to form citrate (6C) and restart the Krebs cycle

Items:

ATP | NAD^+ and FAD | carbohydrates | oxygen | acetyl CoA

Part C

Aerobic and anaerobic respiration

Which of the following processes are involved in **aerobic** respiration of glucose?

- [ ] glycolysis
- [ ] fermentation
- [ ] the link reaction
- [ ] Krebs cycle
- [ ] oxidative phosphorylation

Which of the following processes are involved in **anaerobic** respiration of glucose?

- [ ] glycolysis
- [ ] fermentation
- [ ] the link reaction
- [ ] Krebs cycle
- [ ] oxidative phosphorylation

Created for isaacphysics.org by Lewis Thomson