STEM SMART Biology Week 32 - Respiration 1

Respiration Introduction

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

Part A

Respiration definition

Respiration is the process by which biological molecules (e.g. carbohydrates) are broken down into smaller molecules to produce energy. This energy is used to add a ______ group to ______, producing ______, which acts as an energy storage molecule. It can then transfer this energy to other molecules by ______ them.

Respiration can occur ______ (without oxygen) or ______ (with oxygen).

Items:

adenosine diphosphate (ADP) | phosphorylating | methylating | anaerobically | phosphate | aerobically | methyl | adenosine triphosphate (ATP)

Part B

Aerobic respiration equation

Complete the equation to give the correct (and balanced) general equation for aerobic respiration of one glucose molecule.

$$+ O_2 \longrightarrow 6\,CO_2 + 6$$

Part C

Aerobic vs anaerobic

Fill in the table below to identify which processes are part of aerobic respiration, which are part of anaerobic respiration, and which are part of both.

Process	Part of which type of respiration
Glycolysis	
Link reaction (oxidative decarboxylation)	
Krebs cycle (citric acid cycle)	
Oxidative phosphorylation	
Fermentation	

Items:

aerobic respiration | anaerobic respiration | both types

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Glycolysis

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

Glycolysis is the process by which glucose is broken down into pyruvate. This process is the first step of both anaerobic and aerobic respiration.

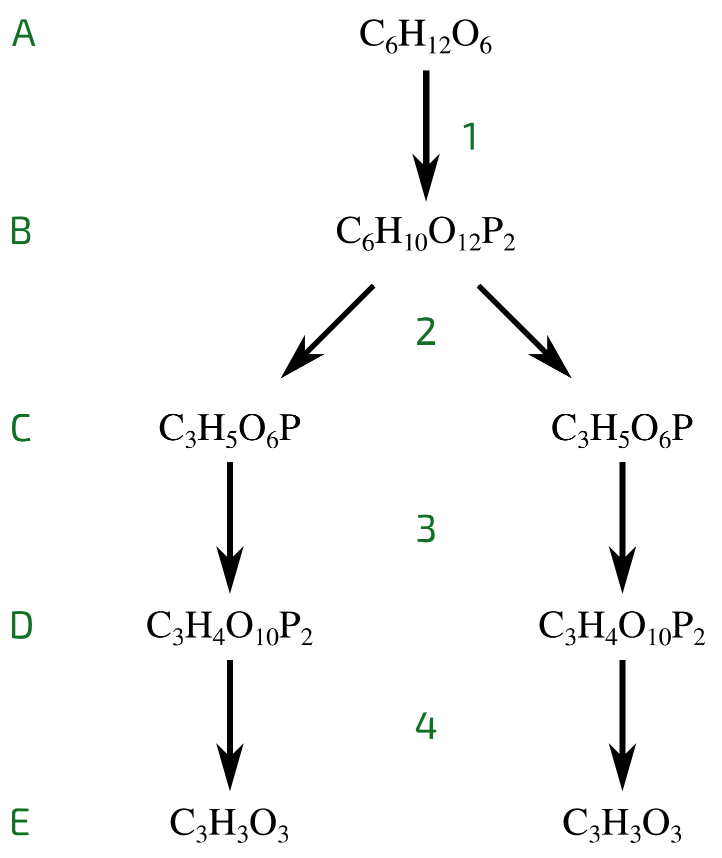

Figure 1: An overview of glycolysis. Molecules are labelled with letters (A-E), and individual steps (indicated by arrows) are labelled with numbers (1-4). Note that only some of the intermediate molecules/steps involved in glycolysis are shown.

Part A

Match the molecules

Match the molecule names to the letters in **Figure 1**.

Letter	Molecule name
A	
B	
C	
D	
E	

Items:

triose phosphate (glyceraldehyde-3-phosphate) | triose bisphosphate | glucose | pyruvate | hexose bisphosphate

Part B

Phosphorylation

What molecule is responsible for phosphorylating molecule A to help convert it into molecule B during step 1?

How many of these molecules are used up during step 1?

Part C

Oxidation and reduction

During step 3, molecule C gains another phosphate group via free phosphate ions in the cell. For this to happen, it has to be oxidised (i.e. lose electrons).

What molecule accepts these electrons (i.e. is reduced)?

How many of these molecules are used up during step 3?

Part D

Dephosphorylation

During step 4, molecule D is dephosphorylated to help convert it into molecule E.

These phosphate groups are used to produce which molecule?

How many of these molecules are produced during step 4?

Part E

Net results

Fill in the table below to give the net loss/gain of each molecule during glycolysis.

Molecule	Net result
glucose	-1
pyruvate	
ATP	
NAD^+	
NADH	

Items:

-2 -1 0 $+1$ $+2$ $+3$ $+4$

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The Link Reaction

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

The link reaction (also called pyruvate decarboxylation, or oxidative decarboxylation) is the stage of aerobic respiration that occurs after glycolysis.

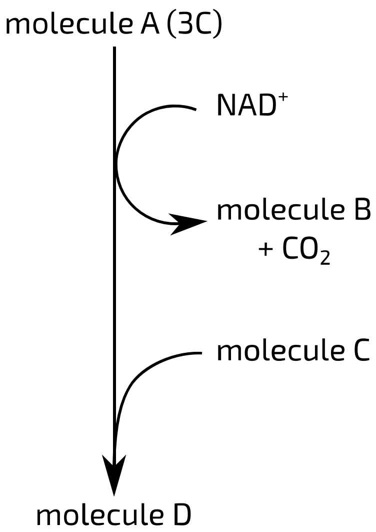

Figure 1: An overview of the link reaction. Certain molecules are labelled with letters (A-D). Molecule A is a three-carbon molecule.

Part A

Match the molecule

Match the names to the molecules in **Figure 1**.

Molecule	Name
A	
B	
C	
D	

Items:

pyruvate | coenzyme A (CoA) | acetyl coenzyme A (acetyl CoA) | NADH (reduced NAD)

Part B

Net results

Fill in the table below to give the net loss/gain of each molecule during this stage of respiration, **per molecule of glucose**.

Molecule	Net result
NAD^+	
NADH	
CO_2	

Items:

-2 | -1 | 0 | $+1$ | $+2$

Part C

Cell location

Where does the link reaction occur in eukaryotic cells?

- at the thylakoid membranes
- in the mitochondrial matrix
- in the cytoplasm
- in the chloroplast stroma
- at the outer mitochondrial membrane
- at the inner mitochondrial membrane

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Krebs Cycle

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

Krebs Cycle (also called the citric acid cycle, or the tricarboxylic acid (TCA) cycle) is the stage of aerobic respiration that occurs after the link reaction.

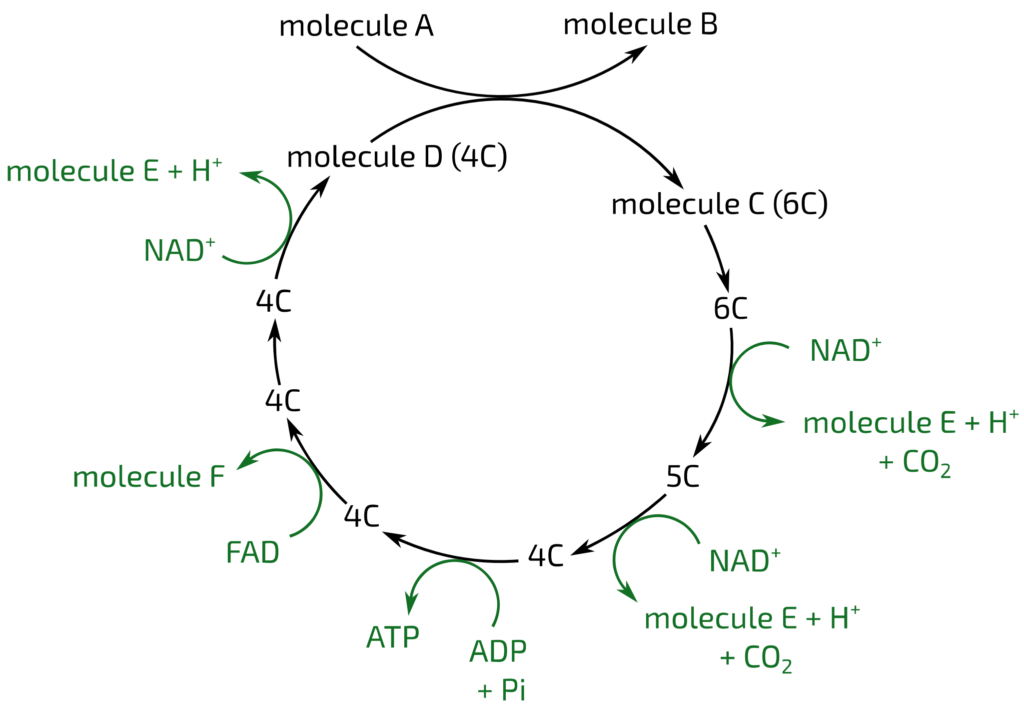

Figure 1: An overview of Krebs cycle. Certain molecules are labelled with letters (A-F). The number of carbons present in each intermediate molecule is shown e.g. 5C. Arrows represent the steps within Krebs cycle. Pi = inorganic phosphate.

Part A

Match the molecule

Match the names to the molecules in **Figure 1**.

Molecule	Name
A	
B	
C	
D	
E	
F	

Items:

FADH$_2$ (reduced FAD) | coenzyme A (CoA) | acetyl coenzyme A (acetyl CoA) | NADH (reduced NAD) | oxaloacetate | citrate

Part B

Net results

Fill in the table below to give the net loss/gain of each molecule during this stage of respiration, **per molecule of glucose.**

Molecule	Net result
ATP	
NAD^+	
NADH	
FAD	
$FADH_2$	
CO_2	

Items:

-6 -5 -4 -3 -2 -1 0 $+1$ $+2$ $+3$ $+4$ $+5$ $+6$

Part C

Cell location

Where does Krebs cycle occur in eukaryotic cells?

- at the outer mitochondrial membrane
- at the inner mitochondrial membrane
- in the cytoplasm
- in the mitochondrial matrix
- at the thylakoid membranes
- in the chloroplast stroma

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Fermentation

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

Aerobic respiration is the main form of respiration in eukaryotic cells. However, some eukaryotic cells can respire anaerobically. This requires a process called fermentation.

Part A

Why ferment?

Aerobic respiration is much more efficient at producing ______ than anaerobic respiration. However, aerobic respiration requires oxygen to act as the final electron acceptor during ______. Without oxygen, this process will stop working.

Importantly, this means that ______ will no longer be oxidised to regenerate ______, which is necessary for every other stage of aerobic respiration. Fermentation allows the cell to regenerate this molecule when there is not enough oxygen for aerobic respiration, which means the cell can keep respiring anaerobically (i.e. cycle between ______ and fermentation).

However, most cells cannot keep doing this indefinitely, as the products of fermentation are toxic at high levels.

Items:

ADP | NADH (reduced NAD) | NAD^+ | oxidative phosphorylation | Krebs cycle | ATP | the link reaction | glycolysis

Part B

Mammals

What is pyruvate reduced to in mammal cells during fermentation?

Part C

Plants and yeast

What is pyruvate reduced to in plant cells and yeast cells during fermentation?

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Aerobic vs Anaerobic Respiration

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

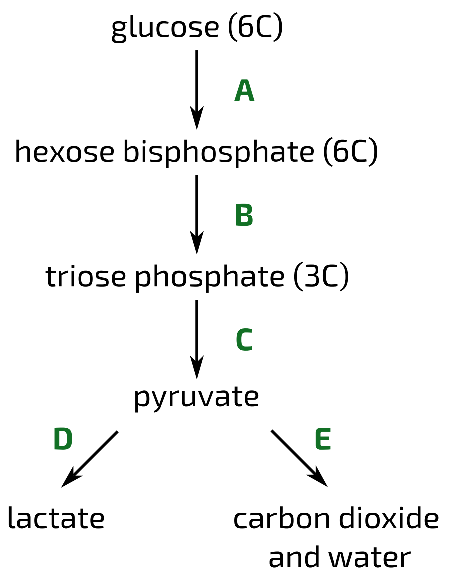

Figure 1: Two alternative pathways in mammalian respiration. Processes are shown as arrows and labelled A-E. Only some steps are shown in each process.

Part A

Process names

Processes A, B, and C make up one larger process. What is the name of this process?

What is the name of process D?

Part B

Using ATP

Select the process/processes in which ATP is used. Select all that apply.

- [ ] A
- [ ] B
- [ ] C
- [ ] D
- [ ] E

Part C

Oxidising NADH without ATP

Select the process/processes in which NADH (reduced NAD) is oxidised to NAD^+ **without** ATP formation. Select all that apply.

- [ ] A
- [ ] B
- [ ] C
- [ ] D
- [ ] E

Part D

Producing ATP

Select the process/processes in which ATP is produced **outside** the mitochondria. Select all that apply.

- [ ] A
- [ ] B
- [ ] C
- [ ] D
- [ ] E

Part E

Using oxygen

Select the process/processes for which oxygen is required. Select all that apply.

- [ ] A
- [ ] B
- [ ] C
- [ ] D
- [ ] E

Part F

Reducing NAD

Select the process/processes in which NAD^+ is reduced to form NADH (reduced NAD). Select all that apply.

- [ ] A
- [ ] B
- [ ] C
- [ ] D
- [ ] E

Adapted with permission from OCR A Level June 1999, Science Modular Central Concepts in Biology, Question 1

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Oxygen Debt and Recovery Period

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

In anaerobic respiration, glycolysis is followed by fermentation. In mammals, this means that each molecule of glucose is converted to two molecules of lactic acid, as is shown in a simplified form below.

$$\text{glucose} \rightarrow 2 \times \text{pyruvate} \rightarrow 2 \times \text{lactic acid}$$

This process is less efficient than aerobic respiration in terms of ATP production (producing 2 ATP molecules instead of ~ 30 ATP molecules per glucose molecule), but it is much faster and does not require oxygen.

During high-intensity exercise, muscle cells need ATP faster than aerobic respiration can provide, and so these cells carry out anaerobic respiration. However, lactic acid is toxic in high concentrations, and so the body must metabolise it by converting it back into pyruvate to be aerobically respired (broken down into $\mathrm{CO_2}$ and $\mathrm{H_2O}$), which requires oxygen. This is partly why, after high-intensity exercise, individuals have a period of increased oxygen consumption (compared to their oxygen consumption at rest). The excess oxygen consumed during this period is sometimes called the **oxygen debt** or excess post-exercise oxygen consumption (EPOC). The period itself is called the **recovery period.**

A particular individual undergoes $30\,\text{minutes}$ of high-intensity exercise. During this time, their muscles anaerobically respire glucose at an average rate of $0.010\,\text{mol min}^{-1}$.

Part A

Oxygen debt

How many moles of oxygen will be required to break down the lactic acid produced during this period?

Part B

Recovery period

Using the information below, and your answer to part A, calculate how long the recovery period will last.

- At rest, the individual consumes oxygen at an average rate of $0.011\,\mathrm{mol\,min^{-1}}$.
- During the recovery period, the individual consumes oxygen at an average rate of $0.070\,\mathrm{mol\,min^{-1}}$.
- 20% of the *excess* oxygen consumed during the recovery period is used for lactic acid metabolism.
- The recovery period ends when all lactic acid has been fully metabolised.

Assume that no lactic acid was metabolised during the exercise period.

Give your answer to 2 sf.

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