

12.1 Energy

Name: _____ Class: _____ Date: _____

Total: 24 marks

KEY WORDS energy • respirometer • respiratory quotient
 • respiratory substrate • chemiosmosis

Objective

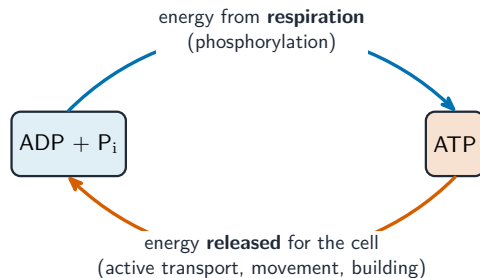
Build the skills to answer exam questions on **energy** – why cells need it, **ATP** as the energy currency, respiratory substrates, and the **respiratory quotient** (RQ).

You must be able to:

- state why living organisms need energy and the features that suit ATP as the energy currency
- compare the energy values of carbohydrates, lipids and proteins
- calculate RQ values from respiration equations and use a **respirometer**

1 Key knowledge and worked examples

■ ATP – the energy currency



Respiration adds a phosphate to make ATP; the cell breaks it off to release energy

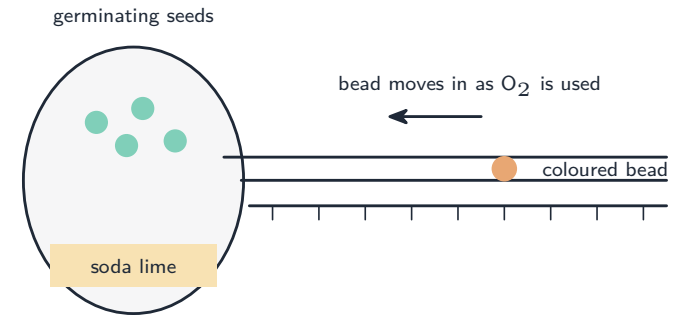
Cells need energy for **active transport**, movement and **anabolic** reactions. ATP suits the job: it releases energy in small usable amounts, is quickly re-made, and is small and soluble. It is made by **phosphorylation** (direct transfer) and **chemiosmosis**.

■ Respiratory quotient (RQ)

$$\text{RQ} = \frac{\text{molecules of CO}_2 \text{ produced}}{\text{molecules of O}_2 \text{ taken in}}$$

For glucose: $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$, so $\text{RQ} = \frac{6}{6} = 1.0$. Carbohydrates give ≈ 1.0 , lipids ≈ 0.7 , proteins ≈ 0.9 (lipids release the most energy per gram).

■ The respirometer



Soda lime absorbs the CO₂, so the bead moves in by the volume of oxygen used

2 Practice

2.1 State **two** features of ATP that make it a good energy currency. [2]

2.2 State which respiratory substrate releases the most energy per gram. [1]

3 Exam-style questions

3.1 What is the RQ of a substrate that produces 8 molecules of CO₂ and uses 10 molecules of O₂? [1]

- ☐ A 0.6
☐ B 0.8
☐ C 1.0
☐ D 1.25

3.2 Why is the soda lime needed in a respirometer that measures oxygen uptake? [1]

- ☐ A to release oxygen
B to absorb the carbon dioxide produced
C to keep the seeds warm
D to colour the liquid

3.3 A lipid respire according to: $2C_{51}H_{98}O_6 + 145O_2 \rightarrow 102CO_2 + 98H_2O$.

(a) Calculate the RQ for this lipid. Give your answer to 2 significant figures. [2]

(b) State what this RQ value tells you about the substrate being respired. [1]

3.4 In a respirometer, the coloured bead moves 45 mm in 15 minutes. The capillary tube has a cross-sectional area of 1.0 mm^2 .

(a) Calculate the rate of oxygen uptake, in mm^3 per minute. [2]

(b) Explain why this apparatus measures oxygen uptake rather than the total gas change. [2]

3.5 A student measured the oxygen used and the carbon dioxide produced by germinating seeds in a respirometer.

	Oxygen used / $\text{cm}^3 \text{ h}^{-1}$	Carbon dioxide produced / $\text{cm}^3 \text{ h}^{-1}$
Seed batch A	12.0	12.0
Seed batch B	12.0	8.4

(a) Calculate the respiratory quotient for each batch, and state which respiratory substrate each is using. [4]

(b) Explain why the RQ differs between the two substrates. [2]

(c) Explain why cells use ATP as an energy currency rather than releasing energy directly from glucose. [4]

(d) State **two** variables that must be controlled in this experiment, and why each matters. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- any two: releases energy in small usable amounts; quickly made and re-made; small and soluble (moves easily)

2.2

- lipids

3.1 B

- $RQ = 8/10 = 0.8$

3.2 B

- Soda lime absorbs the CO_2 , so the gas volume falls only by the oxygen used

3.3

(a)

- $RQ = \frac{102}{145} = 0.70$

(b)

- it shows a lipid is being respired

3.4

(a)

- volume $V = l \times A = 45 \text{ mm} \times 1.0 \text{ mm}^2 = 45 \text{ mm}^3$; rate $= \frac{V}{t} = 45/15 = 3.0 \text{ mm}^3 \text{ min}^{-1}$

(b)

- the soda lime absorbs all the CO_2 released, so the only change in gas volume is the oxygen taken in

3.5

(a)

- $RQ = \frac{\text{CO}_2 \text{ produced}}{\text{O}_2 \text{ used}}$; $A = \frac{12.0}{12.0} = 1.0$, so A is respiring **carbohydrate**; $B = \frac{8.4}{12.0} = 0.7$, so B is respiring **lipid**

(b)

- A lipid molecule contains proportionally far less oxygen than a carbohydrate, so more oxygen must be taken from the air for each carbon dioxide released – giving a lower RQ

(c)

- Glucose holds a large amount of energy, and releasing it all at once would waste most of it as heat and damage the cell; ATP releases a small, usable amount from one bond, so energy can be delivered in the size the reaction needs; it is soluble and moves easily within the cell; and it is quickly re-formed from ADP and phosphate, so it is recycled rather than stored

(d)

- Temperature – it changes the rate of respiration and also the volume of the gas being measured; the mass or number of seeds, and their stage of germination, so the rates compared are per equivalent amount of tissue