5.1 Respiration, glycolysis to oxidative phosphorylation

Name: _____ Class: _____ Date: _____ **Total: 23 marks**

KEY WORDS glycolysis • Krebs cycle • oxidative phosphorylation • lactate • respiratory quotient

Objective

Practise statements 7.1-7.8 with Core Practicals 15-16: the four stages of respiration, where each happens and what each yields, anaerobic lactate metabolism, and the respiratory quotient.

1 Key knowledge and worked examples

■ The four stages in one table

Stage	Where	Carbon products	Hydrogen carriers	ATP
Glycolysis	cytoplasm	none (pyruvate made)	2 reduced NAD	2 (substrate-level)
Link reaction	matrix	1 CO2 per pyruvate	1 reduced NAD	0
Krebs cycle	matrix	2 CO2 per acetyl	3 reduced NAD + 1 reduced FAD	1
Oxidative phosphorylation	cristae	none	carriers reoxidised	most (chemiosmosis)

Electrons from reduced NAD and FAD pass down the transport chain; released energy pumps H+ into the intermembrane space; H+ flows back through ATP synthase; oxygen accepts the electrons and forms water.

Anaerobic and after

No oxygen, no chain: reduced NAD cannot be reoxidised, so pyruvate accepts its hydrogen and becomes lactate. After exercise the lactate travels to the liver and is rebuilt to glucose – that reconstruction costs oxygen (the oxygen debt).

Respiratory quotient (RQ)

RQ = CO2 produced / O2 consumed: carbohydrate 1.0, protein 0.9, lipid about 0.7.

Worked example: RQ from a respirometer

Germinating seeds release 42 cm3 CO2 and consume 60 cm3 O2 per hour. RQ = 42/60 = 0.70 - lipid is the substrate. An RQ above 1.0 means some anaerobic respiration is present, since CO2 is released without matching O2 use.

2 Practice

2.1 Name the stage of respiration that occurs in the cytoplasm and state its carbon-containing product. [2]

2.2 State the final electron acceptor of the electron transport chain and the molecule formed. [2]

2.3 Explain why the rate of respiration of a mammal falls sharply above 45 degrees Celsius. [2]

3 Exam-style questions

3.1 A student uses a respirometer with hydrogencarbonate indicator to follow respiration of three organisms. The table shows gas exchange per hour.

Organism	CO2 produced / mm3	O2 consumed / mm3
A	60	60
B	36	60
C	72	60

Calculate the RQ of each organism, identify the likely substrate in each case, and suggest what organism C's value above 1.0 indicates. [6]

3.2 Cyanide blocks the final electron carrier of the transport chain. Explain why cyanide poisoning stops ATP production by oxidative phosphorylation AND stops the Krebs cycle soon afterwards. [5]

3.3 During intense exercise a muscle cell's ATP demand rises tenfold while its oxygen supply rises only threefold. Explain how the cell keeps respiring, what accumulates, and why the muscle aches and recovers hours later. [6]

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 Glycolysis; pyruvate.

2.2 Oxygen; water.

2.3 Above the enzymes' optimum, tertiary structure breaks down (denaturation); the enzymes of glycolysis, link reaction and Krebs no longer fit their substrates, so rate collapses.

3.1 A: 60/60 = 1.0, carbohydrate. B: 36/60 = 0.6, close to the lipid value 0.7 – lipid substrate. C: 72/60 = 1.2, above 1.0: some anaerobic respiration is releasing extra CO2 without oxygen consumption.

3.2 With the final carrier blocked, electrons cannot leave the chain; reduced NAD and FAD cannot be reoxidised; without oxidised carriers there is no H+ gradient and no chemiosmosis, so ATP synthesis stops. The Krebs cycle halts because its reduced NAD cannot be handed on – the carriers stay fully reduced.

3.3 Oxygen too low for full aerobic respiration, glycolysis continues and pyruvate is reduced to lactate, regenerating NAD so glycolysis keeps making ATP. Lactate accumulates in the muscle; afterwards blood carries it to the liver where it is converted back to glucose, consuming oxygen – repaying the oxygen debt.