Unit 4 · Plant Respiration

ANSWER KEY · FOR TEACHERS

Full marks 32

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. catabolic
2. ATP
3. cytoplasm
4. acetyl CoA
5. citric acid
6. oxygen
7. ATP synthase
8. lactic acid

Each carries 0.5 mark. **K · 4**

2 Label the diagram

1. oxaloacetic acid
2. fumaric acid
3. succinic acid
4. acetyl CoA
5. citric acid
6. α-ketoglutaric acid

Each carries 0.5 mark. **K · 3**

3 Multiple choice

i. **a.** 2 **K · 1**

Glycolysis makes **4** ATP (steps 7 and 10) but uses **2** (steps 1 and 3): a net gain of **2**. (Counting its 2 $NADH_2$ too, at 3 ATP each in the electron transport chain, it gives 8, but those aren't made by glycolysis itself.)

ii. **b.** the link reaction and the Krebs cycle **U · 1**

Glycolysis gives off **no** CO_2. One carbon of each pyruvic acid leaves as CO_2 in the **link reaction**, and the other two in the **Krebs cycle** (steps 5 and 6). The oxygen taken in ends up in **water**, at the end of the electron transport chain, not in CO_2.

iii. **b.** from the intermembrane space into the matrix **U · 1**

The complexes **pump** H^+ ions out of the matrix into the intermembrane space; there they build up. They return **into the matrix** through ATP synthase, and that flow powers ATP-making. (In a chloroplast, H^+ ions flow from the thylakoid space into the stroma: the same idea in another organelle, but not respiration.)

iv. **c.** a little ATP, from glycolysis **A · 1**

Without oxygen the electron transport chain stops (oxygen is the last acceptor of its electrons), and with it the Krebs cycle, which needs the chain to take back its NAD. **Glycolysis** needs no oxygen, so it goes on, giving **2 ATP** per glucose, and the seeds switch to fermentation: they make ethanol and carbon dioxide, which is why seeds sown too deep in waterlogged soil rot.

v. **b.** their cells respire very slowly in the cold, so they use up little of their sugar and age slowly **A · 1**

Respiration is a set of enzyme reactions, and cold slows enzymes. A cabbage at 4 °C respires several times more slowly than at 25 °C (about half for every 10 °C), so it keeps its sugar and water and wilts and yellows far later. Cold slows bacteria and molds too, but doesn't kill them; and respiration doesn't need light.

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4 Short answers

a. MARKING SCHEME — K · 2

- ✓ One correct difference (e.g. oxygen needed / not needed).
- ✓ A second (e.g. 38 ATP against 2, or complete against partial breakdown).

b. MARKING SCHEME — U · 2

- ✓ Without oxygen $NADH_2$ can't be unloaded, so glycolysis would stop for lack of NAD.
- ✓ Fermentation regenerates NAD, so glycolysis goes on making its 2 ATP.

c. MARKING SCHEME — A · 2

- ✓ Damp grain respires fast; the heat it releases is trapped and speeds respiration further.
- ✓ The middle runs out of oxygen, and anaerobic respiration makes alcohol and acids (sour).

d. MARKING SCHEME — U · 3

- ✓ Electrons pass along the carriers of the inner membrane to oxygen, forming water.
- ✓ The energy pumps H^+ ions from the matrix into the intermembrane space.
- ✓ H^+ ions flow back into the matrix through ATP synthase, which makes ATP.

5 Numerical problem

ANSWER — A · 4

One pyruvic acid:

- link reaction: 1 $NADH_2$; Krebs cycle (one turn): 3 $NADH_2$, 1 $FADH_2$, 1 GTP (= 1 ATP).
- 4 $NADH_2 \times 3 = 12$ ATP; 1 $FADH_2 \times 2 = 2$ ATP; + 1 ATP = **15 ATP**.

One glucose gives 2 pyruvic acid: $2 \times 15 = 30$ ATP. Glycolysis adds 2 ATP (net) and 2 $NADH_2$ ($2 \times 3 = 6$ ATP): 8 ATP.
Total = 30 + 8 = **38 ATP**.

MARKING SCHEME

- ✓ Carriers from one pyruvic acid: 4 $NADH_2$, 1 $FADH_2$, 1 GTP.
- ✓ 12 + 2 + 1 = 15 ATP.
- ✓ Two pyruvic acid per glucose: 30 ATP.
- ✓ Glycolysis 2 + 6 = 8 ATP; total 38.

6 Long answer

ANSWER — U · 4

Glycolysis (the EMP pathway) is the breakdown of one **glucose** (6 C) into **two pyruvic acid** (3 C each) in ten enzyme steps in the **cytoplasm**, with **no oxygen** used and no CO_2 given off.

- **Investment phase** (steps 1–5): the cell **spends 2 ATP**, adding a phosphate at each end of the sugar (hexokinase, step 1; phosphofructokinase, step 3), and **splits** fructose 1,6-bisphosphate into two 3-carbon sugars (aldolase), both turned into glyceraldehyde 3-phosphate.
- **Pay-off phase** (steps 6–10): each glyceraldehyde 3-phosphate is **oxidized**, loading NAD as **$NADH_2$** (step 6), and gives **2 ATP** by substrate-level phosphorylation (steps 7 and 10), ending as pyruvic acid.

Net gain per glucose: 4 ATP made − 2 used = **2 ATP**, with **2 $NADH_2$** and **2 pyruvic acid**.

MARKING SCHEME

- ✓ Glucose → 2 pyruvic acid, in the cytoplasm, without oxygen (EMP pathway).
- ✓ Investment phase: 2 ATP spent and the sugar split into two 3-carbon halves.
- ✓ Pay-off phase: oxidation makes $NADH_2$ and substrate-level phosphorylation makes 4 ATP.
- ✓ Net: 2 ATP, 2 $NADH_2$, 2 pyruvic acid.

7 Think

ANSWER

Bread is raised by **yeast**, which carries out **alcoholic fermentation**: pyruvic acid loses a carbon as **CO_2** (pyruvate decarboxylase) and becomes acetaldehyde, then ethanol. The CO_2 gas is trapped in the

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dough and makes it rise.

Lactobacillus carries out **lactic acid fermentation**: pyruvic acid (3 C) is reduced **straight to lactic acid** (3 C), so **no carbon is lost as CO_2**; there is no gas, only acid, which sets the milk proteins into curd.

MARKING SCHEME

- ✓ Yeast: alcoholic fermentation releases CO_2, which raises the dough.
- ✓ *Lactobacillus*: pyruvic acid reduced directly to lactic acid, with no CO_2.
- ✓ So curd gets acid (which sets the milk) but no gas.

8 Activity: Yeast blows up a balloon

(not marked)

WHAT STUDENTS SHOULD FIND

The balloon on the warm bottle with sugar fills with **carbon dioxide** from alcoholic fermentation, and the bottle smells of **alcohol**. The cold bottle fills far more slowly (enzymes work slowly in the cold), and the one without sugar hardly at all (no food to ferment).

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	10	11	8	3	**32**

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