ANSWER KEY. Answers and explanations appear after each question, marked by a bar at the left. Answers written in table cells are in italics.

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Photosynthesis and Respiration Study Guide

Biology | ANSWER KEY

Show your work with units. Use complete sentences when a question asks you to explain.

Key relationships	**Photosynthesis**: $6CO_2 + 6H_2O$ + light energy → $C_6H_{12}O_6 + 6O_2$	**Respiration**: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy	**ATP per glucose** (model): about 30 aerobic (2 + 2 + 26); 2 by fermentation	**Net O_2** = gross O_2 − O_2 used in respiration	**Percent change** = (new − old) ÷ old × 100

Part 1. Photosynthesis

1. (a) A leaf makes 5 glucose molecules by photosynthesis. How many CO_2 and H_2O molecules does it use, and how many O_2 does it release? Show that the oxygen atoms balance.

(b) Which input supplies the carbon in glucose? Name two things a potato plant does with glucose besides cellular respiration.

> (a) **30 CO_2, 30 H_2O, 30 O_2** (6 × 5 each). O atoms in: 30 × 2 + 30 × 1 = **90**; out: 5 × 6 + 30 × 2 = **90**.
> (b) **Carbon dioxide.** Any two: **stores it as starch** (for example in the potato), **builds cellulose** for cell walls, **makes amino acids, lipids and other molecules**.

2. Identical water plants were lit through colored filters, and their O_2 output was measured (sample data).

Light color	Blue	Red	Green	White (all colors)
O_2 made (mL/h)	30	26	4	34

(a) Use what chlorophyll absorbs to explain why green light gave the lowest rate. Why did white light give the highest?

(b) How does CO_2 get into a leaf cell, and how does water get there?

> (a) **Chlorophyll absorbs blue and red light strongly but reflects most green light, so little green light energy is captured (4 mL/h). White light holds blue and red together, so the most light is absorbed (34 mL/h).**
> (b) **CO_2 enters through the stomata and diffuses through air spaces; water travels up from the roots in the xylem.**

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Part 2. Stages of Photosynthesis

3. (a) Sort each statement into the light-dependent or light-independent reactions.

Statement	Stage
Splits water and releases O_2	***Light-dependent***
Builds carbon from CO_2 into sugar	***Light-independent***
Makes ATP and NADPH	***Light-dependent***
Takes place in the stroma	***Light-independent***
Takes place in the thylakoid membranes	***Light-dependent***

(b) A plant is moved from bright light into darkness. Explain why the light-independent reactions also stop soon after, even though they do not use light.

> (b) **Without light, no new ATP and NADPH are made. The light-independent reactions use up what is left, then stop, because they need ATP and NADPH to make glucose.**

4. (a) Model values: 2,000 J of sunlight strikes a leaf; 500 J is reflected or passes through and 1,440 J is lost as heat. How much is stored in sugar, and what percent is that?

(b) At this efficiency, how much sunlight is needed to store 900 J?

(c) In a tracer test, only the water contains heavy oxygen (0.60% of its oxygen atoms). Predict the percent of heavy oxygen in the O_2 released, and explain.

> (a) 2,000 − 500 − 1,440 = **60 J**; 60 ÷ 2,000 × 100 = **3%**. (b) 900 ÷ 60 = 15; 15 × 2,000 J = **30,000 J**.
>
> (c) **About 0.60%. The O_2 comes from water split in the light-dependent reactions, so it carries the same label as the water.**

Part 3. Rates of Photosynthesis

5. (a) A water plant gives off 5.2 mL of O_2 in 8 minutes. Find the rate.

(b) When the lamp is moved closer, the bubble count rises from 12 to 33 bubbles per minute. Find the percent change, and explain why moving the lamp changes the rate.

> (a) 5.2 mL ÷ 8 min = **0.65 mL/min**.
>
> (b) (33 − 12) ÷ 12 × 100 = **175% increase**. **Closer means brighter light, so more ATP and NADPH are made and O_2 is released faster.**

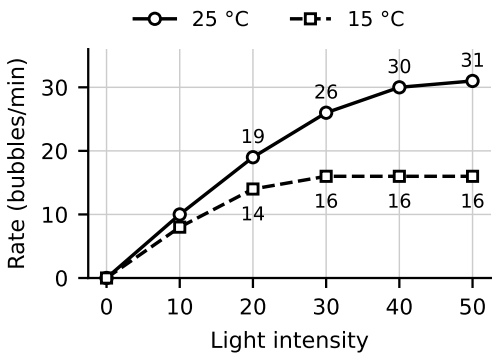
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6. The graph shows the rate of photosynthesis of a water plant at two temperatures (sample data).

(a) At light intensity 10, which factor limits the rate? Use the graph.

(b) What limits the 15 °C plant at intensity 50? How do you know?

(c) Find the percent increase from 15 °C to 25 °C at intensity 50.



(a) **Light.** Both lines are close (8 and 10) and still rising, so more light raises the rate and temperature makes little difference.

(b) **Temperature**: the 15 °C line levels off at 16 from intensity 30, while at 25 °C the rate keeps rising, so more light no longer helps at 15 °C. (c) (31 − 16) ÷ 16 × 100 ≈ **93.8%**.

7. A student will test how the amount of CO_2 affects photosynthesis by adding different amounts of sodium bicarbonate (a CO_2 source) to the water around a water plant.

(a) Name the independent variable, the dependent variable, and two variables to keep the same.

(b) Predict the shape of the graph of rate against CO_2, and explain it. Why should the lamp be bright?

(a) **Independent: amount of sodium bicarbonate (CO_2). Dependent: rate (bubbles or mL O_2 per minute). Same: e.g. light intensity, temperature, the plant, time.**

(b) **The rate rises, then levels off**, when another factor (light, temperature) becomes limiting. **In dim light, light would be limiting and extra CO_2 could not be used.**

Part 4. Cellular Respiration

8. (a) A cell respires 8 glucose molecules. How many O_2 are used, how many CO_2 and H_2O are made, and about how many ATP (model value)? Show that the oxygen atoms balance.

(b) Breathing and cellular respiration are linked, but they are not the same. Explain the difference.

(a) **48 O_2; 48 CO_2; 48 H_2O** (6 × 8 each); **about 240 ATP** (8 × 30). O atoms in: 8 × 6 + 48 × 2 = **144**; out: 48 × 2 + 48 × 1 = **144**.

(b) **Breathing moves air in and out of the lungs. Cellular respiration is the chemical process inside cells that uses O_2 and glucose and makes CO_2, H_2O and ATP.**

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9. One mole of glucose releases about 2,870 kJ, and one mole of ATP stores about 30.5 kJ.

(a) Suppose a cell makes only 28 ATP per glucose. What percent of the energy is captured in ATP?

(b) Using the model value of 32% captured, how much heat is released by 0.5 mole of glucose? What does the body do with this heat?

> (a) 28 × 30.5 = **854 kJ**; 854 ÷ 2,870 × 100 ≈ **29.8%**.
>
> (b) 0.5 × 2,870 kJ × 0.68 ≈ **976 kJ**. **In warm-blooded animals, it helps keep body temperature steady; the rest spreads into the surroundings.**

10. A respirometer measured O_2 used by germinating corn seeds and by boiled corn seeds at 25 °C (sample data).

Time (min)	**0**	**5**	**10**	**15**
Germinating seeds (mL O_2)	0	0.9	1.8	2.7
Boiled seeds (mL O_2)	0	0.05	0.05	0.05

(a) Find the rate of O_2 use by the germinating seeds.

(b) Write a claim, evidence, and reasoning about the boiled seeds. Why are they a useful control?

> (a) 2.7 mL ÷ 15 min = **0.18 mL/min**.
>
> (b) **Claim: boiled seeds do not respire.** Evidence: they used only 0.05 mL in 15 min vs 2.7 mL. Reasoning: boiling killed the cells and destroyed their enzymes. **As a control, they show the change in the germinating tube is caused by living cells, not by the equipment or temperature.**

Part 5. Stages of Cellular Respiration

11. (a) A cell fully respires 3 glucose molecules. How many pyruvate molecules does glycolysis make? How many CO_2 are released in total? Use the model to find the total ATP and the ATP from the electron transport chain.

(b) What percent of the ATP comes from the electron transport chain? Why is so much made at the inner membrane?

> (a) **6 pyruvate** (2 per glucose); **18 CO_2** (6 per glucose). Total: 3 × 30 = **90 ATP**; electron transport chain: 3 × 26 = **78 ATP**.
>
> (b) 78 ÷ 90 × 100 ≈ **86.7%**. **The inner membrane is folded into cristae, so its large surface area holds many copies of the chain.**

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12. (a) A poison stops the Krebs cycle. Which stages keep working and which stop? About how many ATP per glucose can the cell still make? Explain.

(b) The leg muscle cells of a trained runner have more mitochondria with more cristae than an untrained person's. Explain how this helps.

> (a) **Glycolysis keeps working** in the cytoplasm, so the cell makes **about 2 ATP**, as in fermentation. **The Krebs cycle stops, and the electron transport chain stops too**, because it gets most of its NADH and $FADH_2$ from the Krebs cycle.
> (b) **More mitochondria and more cristae mean more electron transport chains, so the cells can make more ATP aerobically for running.**

Part 6. Fermentation

13. (a) Find the ATP made from 9 glucose by aerobic respiration and by fermentation. How many glucose does each need to make 450 ATP?

(b) Yeast ferments 5 glucose by alcoholic fermentation. How many ethanol and CO_2 molecules form? Which kind of fermentation happens in a sprinter's muscles?

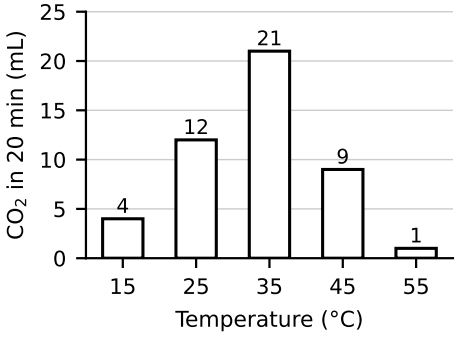
> (a) Aerobic: 9 × 30 = **270 ATP**; fermentation: 9 × 2 = **18 ATP**. For 450 ATP: fermentation 450 ÷ 2 = **225 glucose**; aerobic 450 ÷ 30 = **15 glucose**.
> (b) **10 ethanol and 10 CO_2** (2 of each per glucose). **Lactic acid fermentation** (no CO_2).

14. Equal amounts of yeast and sugar water were kept at different temperatures, and the CO_2 made in 20 minutes was measured (sample data).

(a) At which temperature is fermentation fastest?

(b) Explain the drop above that temperature.

(c) Fermentation makes no ATP of its own. Why does the yeast need it?



> (a) **35 °C** (21 mL). (b) **Above the optimum, heat changes the shape of the enzymes, so they work slowly or stop (9 mL at 45 °C, 1 mL at 55 °C).**
> (c) **It turns NADH back into NAD^+, so glycolysis can keep making 2 ATP per glucose without oxygen.**

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Part 7. Linking Photosynthesis and Respiration

15. The table shows the net O_2 output of a plant at different light intensities (sample data).

Light intensity	0	10	20	40
Net O_2 (mL/h)	−3	−1	+2	+7

(a) How fast does the plant use O_2 in respiration? Find the gross O_2 at intensities 20 and 40.

(b) Estimate the compensation point. What does it mean for the plant?

> (a) **3 mL/h** (net in the dark). Gross = net + respiration: 2 + 3 = **5 mL/h**; 7 + 3 = **10 mL/h**.
>
> (b) Net crosses 0 between 10 (−1) and 20 (+2): 10 + 10 × (1 ÷ 3) ≈ **13**. **Here photosynthesis just balances respiration; below it the plant uses more glucose than it makes.**

16. Four sealed tubes were set up, and the change in CO_2 after 4 hours was measured (sample data).

Tube	Contents	CO_2 change (ppm)
A	Water plant, light	−80
B	Water plant, dark	+40
C	Snail, light	+60
D	Water plant and snail, light	−20

(a) In which tubes is respiration faster than photosynthesis? Find the rate of change in Tube B in ppm/h.

(b) Explain the result in Tube D, using Tubes A and C as evidence.

> (a) **B and C** (CO_2 rose). Tube B: 40 ÷ 4 = **+10 ppm/h**.
>
> (b) **The plant removes CO_2 by photosynthesis (A: −80) while the snail adds it by respiration (C: +60). Together, photosynthesis is still faster, so CO_2 falls a little (−20).**

17. (a) Over one day, a plant makes 48 units of glucose by photosynthesis and uses 30 units in respiration (sample values). Find its net gain. Why would the plant die if it were kept in darkness for weeks?

(b) A carbon atom moves from the air into grass, into a cow, and back to the air. Name the process at each step. Why does the cow keep needing food, even though carbon can be reused?

> (a) 48 − 30 = **18 units**. **In darkness, photosynthesis stops but respiration goes on, so the plant uses up its stored glucose.**
>
> (b) **Photosynthesis, eating, cellular respiration. Matter cycles, but energy flows one way: the cow uses energy for cell work and loses it as heat, so it needs new energy from food.**

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