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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Cells and Homeostasis Study Guide

Biology | ANSWER KEY

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

Key relationships	**Actual size** = image size ÷ magnification; 1 mm = 1,000 µm	**Cube**: SA = $6s^2$, V = s^3, SA:V = 6/s; sphere SA:V = 3/r	**Percent change** = (final − initial) ÷ initial × 100	**Pump**: 3 Na^+ out and 2 K^+ in per ATP	**Cardiac output** = heart rate × stroke volume

Part 1. Cell Theory

1. A student fills three tubes with boiled (sterile) nutrient broth and checks them after 3 days (sample data).

Tube	Treatment	Result	Cells per mL
1	Sealed, nothing added	Clear	0
2	Opened to room air for 5 minutes, then sealed	Cloudy	2,000,000
3	Sealed, then 1 drop of a yeast culture added	Cloudy	5,000,000

(a) Write a claim, evidence, and reasoning: did the broth make cells by itself? (b) Which part of cell theory does this support?

> (a) **Claim: no; the cells came from existing cells.** Evidence: sealed Tube 1 stayed clear with 0 cells/mL, while Tube 2 (open to air) and Tube 3 (yeast added) reached 2,000,000 and 5,000,000 cells/mL. Reasoning: the broth was the same in every tube; cells grew only where living cells could get in.
>
> (b) **New cells come only from existing cells.**

2. (a) A student says viruses are alive because they make copies of themselves inside cells. Use cell theory to evaluate this claim.

(b) A mature human red blood cell has no nucleus and no DNA. Does this mean cell theory is wrong? Explain.

(c) Name the four parts that a bacterium and a leaf cell share, and give the job of each.

> (a) **Viruses are not made of cells** and can copy themselves only by using a host cell, so most biologists do not count them as living.
>
> (b) **No.** It began as a cell from an existing cell and still has a membrane and cytoplasm; it lost its nucleus as it specialized to carry oxygen. (c) **Cell membrane** (controls what enters and leaves), **cytoplasm** (where reactions happen), **DNA** (instructions), **ribosomes** (build proteins).

Part 2. Prokaryotic and Eukaryotic Cells

3. (a) A micrograph at ×2,500 shows a yeast cell 15 mm wide. Find its actual width in mm and in µm.

(b) How many bacteria, each 1.5 µm long, would fit end to end across the yeast cell?

(c) A paramecium is 0.2 mm long. What is its length in µm? What magnification would make its image 50 mm long?

> (a) 15 mm ÷ 2,500 = **0.006 mm**; 0.006 mm × 1,000 = **6 µm**. (b) 6 µm ÷ 1.5 µm = **4 bacteria**.
>
> (c) 0.2 mm × 1,000 = **200 µm**. Magnification = image size ÷ actual size = 50 mm ÷ 0.2 mm = **×250**.

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4. The table describes four cells.

Cell	Nucleus	Mitochondria	Cell wall	Chloroplasts	Plasmids	Size	Type
P	No	No	Yes	No	Yes	3 µm	***Prokaryotic***
Q	Yes	Yes	No	No	No	15 µm	***Animal***
R	Yes	Yes	Yes	Yes	No	50 µm	***Plant***
S	Yes	Yes	Yes	No	No	8 µm	***Eukaryotic***

(a) Fill in the Type column. (b) Chloroplasts, like mitochondria, have their own circular DNA and a double membrane. What does this suggest about where chloroplasts came from?

> (a) P has no nucleus, so it is prokaryotic. Q has a nucleus but no wall, so it is an animal cell. R has a wall and chloroplasts, so it is a plant cell. S has a nucleus and a wall but no chloroplasts, so it is **eukaryotic** (a fungus such as yeast, or a plant cell that does not do photosynthesis).
>
> (b) **Chloroplasts probably began as photosynthetic bacteria that were taken into a larger cell** (endosymbiotic theory), the same way mitochondria did.

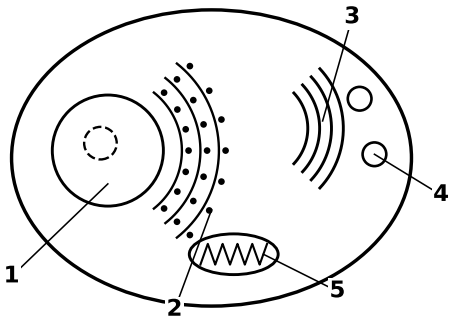
Part 3. Organelles

5. The model shows part of an animal cell.

(a) Name structures 1 to 5.

(b) A cell makes an antibody protein and releases it. List the numbered structures the protein passes through, in order.

(c) A white blood cell digests the bacteria it takes in. Which organelle, not shown, holds the digestive enzymes?



> (a) **1: nucleus. 2: rough ER. 3: Golgi apparatus. 4: vesicle. 5: mitochondrion.**
>
> (b) **2 (rough ER), 4 (vesicle), 3 (Golgi), 4 (vesicle), then the cell membrane**, where the vesicle fuses and releases it.
>
> (c) **Lysosome.**

6. Scientists added drug X to gland cells and measured a protein the cells release (sample data, arbitrary units).

Time (min)	0	30	60	90
Protein released, no drug	0	20	45	70
Protein released, drug X	0	2	3	3
Protein in rough ER, no drug	30	30	30	30
Protein in rough ER, drug X	30	55	80	100

(a) At 90 minutes, what percent of the no-drug amount was released with drug X?

(b) Which step of the protein pathway does drug X most likely block? Use both rows for drug X as evidence.

> (a) $3 \div 70 \times 100 \approx$ **4.3%**.
>
> (b) **Moving protein out of the rough ER to the Golgi.** With drug X, protein piles up in the rough ER (30 to 100) while almost none is released (3), so ribosomes still build it but it cannot leave the ER.

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Part 4. Cell Specialization

7. The table describes three cells from the same animal (sample values).

Cell	Mitochondria per cell	Rough ER and Golgi	Other features
W	About 3,000	Little	Long fibers that shorten
X	About 600	A lot	Many vesicles near the membrane
Y	0	None	No nucleus; packed with hemoglobin

(a) Which cell is a muscle cell, which releases digestive enzymes, and which is a red blood cell? Give a reason for each.

(b) Cell Y cannot make new proteins to repair itself. Explain why.

> (a) **W: muscle cell** (fibers shorten; many mitochondria for ATP). **X: enzyme-releasing cell** (rough ER, Golgi and vesicles make and ship proteins). **Y: red blood cell** (no nucleus; hemoglobin carries oxygen).
> (b) **It has no nucleus, so it has no DNA instructions for building new proteins.**

8. (a) Order from smallest to largest, and name the level of each: leaf, guard cell, sunflower plant, shoot system, epidermis tissue.

(b) A root cell and a leaf cell from the same sunflower have the same DNA, but only the leaf cell has chloroplasts. Explain how this happens, and name the process.

> (a) **Guard cell (cell), epidermis tissue (tissue), leaf (organ), shoot system (organ system), sunflower plant (organism).**
> (b) **The two cells switch on different genes, so they make different proteins and build different parts. This is differentiation.**

Part 5. The Cell Membrane

9. (a) Predict how each substance crosses a cell membrane: nitrogen gas (N_2), a chloride ion (Cl^-), fructose (a large polar sugar), and water.

(b) Insulin binds to a protein on the outside of a liver cell, and the cell responds. What kind of membrane protein is this?

(c) Immune cells recognize your cells as your own. What kind of membrane protein lets them do this?

> (a) **N_2: through the lipid bilayer** (small, nonpolar). **Cl^-: through a channel protein** (charged). **Fructose: by a carrier protein** (large, polar). **Water: slowly through the lipids, and faster through water channel proteins.**
> (b) **Receptor protein.** (c) **Identity marker** (a sugar chain on the cell surface).

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10. Scientists measured how much water crossed two membranes in 1 minute (sample values): a plain lipid bilayer, 4 units; the same bilayer with water channel proteins added, 96 units.

(a) How many times more water crossed with the channel proteins?

(b) Write a claim, evidence, and reasoning about how a cell can control how fast water enters.

(c) Why is the membrane described as a fluid mosaic?

> (a) 96 ÷ 4 = **24 times**.
>
> (b) **Claim: a cell controls water entry with water channel proteins.** Evidence: 96 units with channels vs 4 without. Reasoning: water is polar, so it crosses the hydrophobic middle slowly; adding or removing channels changes the rate. (c) **The parts can move (fluid), and many proteins sit in the bilayer (mosaic).**

Part 6. Passive Transport

11. (a) Two carrot sticks start at 4.00 g. After 1 day, the one in distilled water is 4.50 g and the one in a strong salt solution is 3.30 g. Find the percent change in each.

(b) Which solution was hypotonic to the carrot cells and which was hypertonic? Which way did water move in each?

(c) Why do the carrot cells in distilled water not burst?

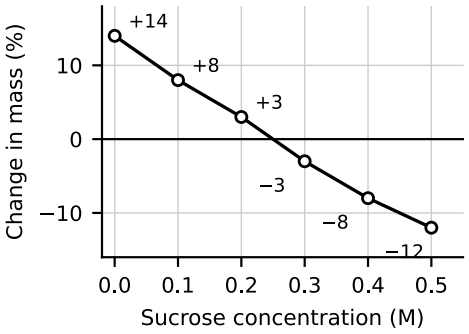
> (a) (4.50 − 4.00) ÷ 4.00 × 100 = **+12.5%**; (3.30 − 4.00) ÷ 4.00 × 100 = **−17.5%**.
>
> (b) **Distilled water: hypotonic, water moved in. Salt solution: hypertonic, water moved out.** (c) **The cell wall pushes back, so the cells become turgid instead of bursting.**

12. Equal beet cores were soaked in sucrose solutions for a day (sample data).

(a) Estimate the sucrose concentration where the mass would not change. What does it tell you about the beet cells?

(b) Explain why the cores in 0.5 M sucrose lost mass.

(c) Did the cells use ATP to move this water? Explain.



> (a) It crosses 0% between 0.2 M (+3%) and 0.3 M (−3%): 0.2 + 0.1 × (3 ÷ 6) = **about 0.25 M**. **The beet cells contain about 0.25 M solute** (isotonic point).
>
> (b) **0.5 M is hypertonic, so water left the cells by osmosis toward the side with more solute.** (c) **No; osmosis is passive**, water moving down its gradient.

Part 7. Active Transport

13. (a) A nerve cell's pumps move 1,800 Na^+ out. How many ATP are used, and how many K^+ enter?

(b) A cell has 12,000 ATP for its pumps. How many Na^+ can it move out, and how many K^+ in?

(c) Inside the cell, Na^+ is about 12 mM; outside, it is about 140 mM. Explain why moving Na^+ out needs ATP.

> (a) 1,800 ÷ 3 = **600 ATP**; 600 × 2 = **1,200 K^+**. (b) 12,000 × 3 = **36,000 Na^+ out**; 12,000 × 2 = **24,000 K^+ in**.
>
> (c) **Na^+ moves from low (12 mM) to high (140 mM), against its gradient, so it is active transport and needs energy from ATP.**

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14. The table shows four substances moving across membranes (sample values).

Substance	Outside (mM)	Inside (mM)	Moves	Passive or active?
Iodide ion (thyroid cell)	0.1	3	In	***Active***
Carbon dioxide (muscle cell)	1.2	1.5	Out	***Passive***
Amino acid (gut cell)	2	10	In	***Active***
Chloride ion, through a channel	110	10	In	***Passive***

(a) Fill in the last column. (b) A poison stops ATP production. Which of these would stop? (c) A white blood cell takes in a whole bacterium, and a gland cell releases enzymes in vesicles. Name each process.

> (a) **Iodide and amino acid: active** (low to high). **Carbon dioxide and chloride: passive** (high to low). (b) **Iodide and amino acid uptake**; the passive ones keep going.
> (c) **Taking in the bacterium: endocytosis. Releasing enzymes: exocytosis.** Both use ATP.

Part 8. Surface Area to Volume Ratio

15. (a) Two cells are modeled as cubes with sides of 4 μm and 12 μm. Find the SA, V, and SA:V of each.

(b) The side tripled. By what factor did SA and V each change? What happened to SA:V?

(c) A round cell has a radius of 15 μm. Find its SA:V.

> (a) 4 μm: SA = 6×4^2 = **96 μm^2**, V = 4^3 = **64 μm^3**, SA:V = **1.5:1**. 12 μm: SA = **864 μm^2**, V = **1,728 μm^3**, SA:V = **0.5:1**.
> (b) SA × **9** (864 ÷ 96), V × **27** (1,728 ÷ 64); **SA:V fell to one third**, because volume grows faster. (c) 3 ÷ 15 = **0.2:1**.

16. Use the simplified model time = distance^2 ÷ (2D), with D = 1,000 μm^2/s (typical for a small molecule in water; diffusion is slower inside a cell).

(a) Find the time to diffuse 20 μm, 200 μm, and 2,000 μm. Give the last one in minutes too.

(b) When the distance is 10 times longer, how many times longer is the time?

(c) A red blood cell is a thin, flat disk. How does this shape help oxygen reach every part of it?

> (a) $20^2 \div 2{,}000$ = **0.2 s**; $200^2 \div 2{,}000$ = **20 s**; $2{,}000^2 \div 2{,}000$ = **2,000 s ≈ 33 min**. (b) **100 times** (10^2).
> (c) **A thin, flat shape gives a large SA:V and keeps every part close to the surface, so diffusion distances are short and fast.**

Part 9. Organ Systems

17. (a) A trained athlete has a heart rate of 50 beats/min and a stroke volume of 100 mL/beat at rest, and 175 beats/min and 160 mL/beat in a race. Find the cardiac output for each in L/min. How many times greater is it in the race?

(b) The athlete has 7.0 L of blood. How many times per minute does all of it pass through the heart during the race?

(c) Name, in order, the systems a glucose molecule from lunch passes through to reach a leg muscle cell, and the structure where it enters the blood.

> (a) Rest: 50 × 100 = 5,000 mL/min = **5.0 L/min**. Race: 175 × 160 = 28,000 mL/min = **28.0 L/min**. 28.0 ÷ 5.0 = **5.6 times**.
> (b) 28.0 L/min ÷ 7.0 L = **4 times per minute**. (c) **Digestive system (absorbed through villi of the small intestine), then circulatory system, then the muscle cell.**

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18. A runner's body temperature and sweat rate were measured during a 40-minute run (sample data).

Time (min)	0	10	20	30	40
Body temperature (°C)	37.0	37.6	38.0	38.1	38.1
Sweat rate (mL/h)	0	300	700	800	800

(a) How much did body temperature rise? Write a claim, evidence, and reasoning: is sweating negative or positive feedback?

(b) A potato plant stores sugar in tubers underground. Which tissue carries the sugar down, and which carries water up?

> (a) 38.1 − 37.0 = **1.1 °C**. **Claim: negative feedback.** Evidence: sweat rose from 0 to 800 mL/h and temperature leveled off at 38.1 °C from minute 30. Reasoning: evaporating sweat cools the body, which reverses the rise in temperature.
> (b) **Phloem carries sugar down to the tubers; xylem carries water up from the roots.**

Part 10. Stimulus and Response

19. (a) Thirty mealworms are placed in a chamber with a dark half and a lit half. After 10 minutes, the number on the dark side in four trials is 22, 25, 21, and 24 (sample data). Find the mean and the percent on the dark side.

(b) Name the independent variable, the dependent variable, and one variable to keep the same.

(c) Why does the student repeat the trial and use the mean?

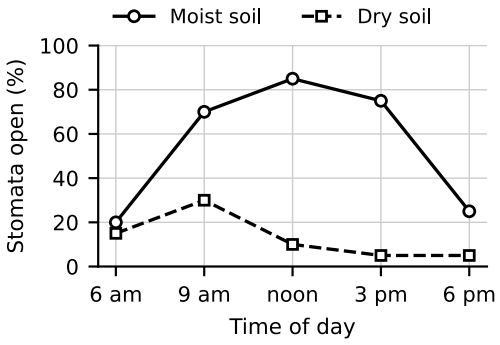
> (a) 22 + 25 + 21 + 24 = 92; 92 ÷ 4 = **23.0 mealworms**; 23.0 ÷ 30 × 100 ≈ **76.7%**. (b) **Independent: light or dark. Dependent: number on the dark side. Same: e.g. temperature, moisture, time, number of mealworms.**
> (c) **One trial can be off by chance; the mean of several trials is more reliable.**

20. The graph shows how many stomata were open on two bean plants during one day (sample data).

(a) What percent of stomata were open at noon on each plant?

(b) Explain how the plant in dry soil closes its stomata, and how this helps it.

(c) What is the cost of closing the stomata? Is this negative or positive feedback?



> (a) **Moist soil: 85%. Dry soil: 10%.**
> (b) **Guard cells close the stomata, so less water vapor escapes and the plant keeps its water.** (c) **Less carbon dioxide enters, so photosynthesis slows. Negative feedback** (it reverses the water loss).

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