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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Molecules of Life Study Guide

Biology | ANSWER KEY

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

Key relationships	**Chain of n monomers**: n − 1 bonds; 1 water released per bond formed, 1 used per bond broken	**Food energy**: fat about 9 kcal/g; carbohydrate and protein about 4 kcal/g	**DNA base pairing**: A = T and G = C; A + T + G + C = 100%	**Rate** = amount of product ÷ time	**Percent change** = (new − old) ÷ old × 100

Part 1. Monomers and Polymers

1. (a) A cell builds one nucleic acid strand of 1,500 nucleotides. How many bonds join the nucleotides, and how many water molecules are released? What is this kind of reaction called?

(b) A short starch chain of 25 glucose units is broken completely into glucose. How many water molecules are used? What is this kind of reaction called?

(c) A plant makes sugar from CO_2 and water. Which two elements must it take in from the soil to build proteins and nucleic acids?

> (a) 1,500 − 1 = **1,499 bonds and 1,499 water molecules released; dehydration synthesis.** (b) 25 − 1 = **24 water molecules used; hydrolysis.**
> (c) **Nitrogen** (proteins and nucleic acids) and **phosphorus** (nucleic acids).

2. The table shows the mass of a leaf cell by type of molecule (sample data).

Part of the cell	Percent of mass
Water	80%
Carbohydrates	9%
Proteins	6%
Lipids	2%
Nucleic acids	1%
Other small molecules and ions	2%

(a) What percent of the cell's mass is not water? What percent of that non-water mass is carbohydrate?

(b) A molecule from the cell contains C, H, O, N, and P and is a chain of nucleotides. Which class is it? Why would a plant cell have so much more carbohydrate than a bacterial cell?

> (a) 100% − 80% = **20%**. 9 ÷ 20 × 100 = **45%** of the non-water mass.
> (b) **Nucleic acid. Plant cell walls are made of cellulose, a carbohydrate, and plants also store starch.**

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Part 2. Carbohydrates

3. (a) Raffinose, a sugar in beans, forms when three monosaccharides (each $C_6H_{12}O_6$) join by dehydration synthesis. What is the formula of raffinose? Show how you found it.

(b) Is raffinose a monosaccharide, disaccharide, or something else? A glycogen molecule has 2,000 glucose units. How many water molecules are released when it is built?

(c) Starch, glycogen, and cellulose are all made only of glucose. Why can people digest starch but not cellulose?

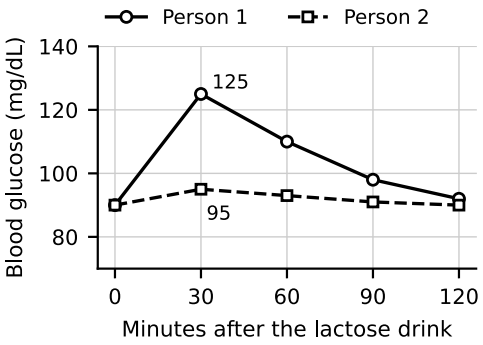
> (a) $3 \times C_6H_{12}O_6 = C_{18}H_{36}O_{18}$; two bonds release 2 H_2O; **$C_{18}H_{32}O_{16}$**.
> (b) **A trisaccharide** (three sugar units; not a mono- or disaccharide). 2,000 − 1 = **1,999 water molecules**. (c) **Cellulose has different bonds and a different shape, so human enzymes cannot break it into glucose.**

4. Two people drink the same lactose drink. Lactose is a disaccharide of glucose and galactose (sample data).

(a) How much did each person's blood glucose rise at its peak?

(b) Person 2 makes very little lactase, the enzyme that splits lactose. Use hydrolysis to explain the difference.

(c) Predict what would happen if both drank plain glucose instead. Explain.



> (a) Person 1: 125 − 90 = **35 mg/dL**. Person 2: 95 − 90 = **5 mg/dL**.
> (b) **Lactase splits lactose into glucose and galactose by hydrolysis. Without it, little lactose is broken down, so little glucose enters the blood.** (c) **Both would rise about the same**, because glucose is already a monosaccharide and does not need to be split.

Part 3. Lipids

5. (a) A granola bar has 12 g of fat, 30 g of carbohydrate, and 6 g of protein. Find the energy from each and the total energy in kcal.

(b) What percent of the bar's energy comes from fat? Why does fat give more energy per gram even though the bar has more carbohydrate?

> (a) Fat: 12 g × 9 kcal/g = 108 kcal. Carbohydrate: 30 g × 4 kcal/g = 120 kcal. Protein: 6 g × 4 kcal/g = 24 kcal. **Total: 252 kcal**.
> (b) 108 ÷ 252 × 100 ≈ **42.9%**. **Fat stores about 9 kcal/g, more than twice the 4 kcal/g of carbohydrate, because it is made mostly of carbon and hydrogen.**

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6. The table shows approximate values for four fats.

Fat	Saturated fatty acids (% of fat)	State at about 20 °C
Coconut oil	87%	Solid
Butter	63%	Solid
Olive oil	14%	Liquid
Canola oil	7%	Liquid

(a) Describe the pattern. (b) Use the shape of fatty acid tails to explain it.

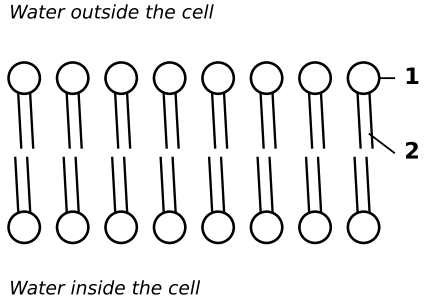
> (a) **Fats with a high share of saturated fatty acids (87%, 63%) are solid; fats with a low share (14%, 7%) are liquid.**
> (b) **Saturated tails have no double bonds and are straight, so they pack tightly and stay solid. Unsaturated tails have double bonds that bend them, so they pack loosely and melt at lower temperatures.**

7. The model shows part of a cell membrane.

(a) Name parts 1 and 2. Which part is hydrophilic, and which is hydrophobic?

(b) Explain why the molecules form two layers with the heads facing out on both sides.

(c) A molecule in animal membranes has four connected carbon rings. Which group of lipids is it in? Name it.



> (a) **1: phosphate head (hydrophilic). 2: fatty acid tails (hydrophobic).**
> (b) **There is water inside and outside the cell. The heads are attracted to water and the tails avoid it, so the tails point toward each other in the middle.** (c) **Steroids; cholesterol.**

Part 4. Proteins

8. (a) A protein is made of two chains, one of 21 amino acids and one of 30, and each chain is built separately. How many peptide bonds are in the two chains? How many water molecules were released to build them?

(b) How many different dipeptides (chains of 2 amino acids) can be made from the 20 kinds of amino acids?

(c) Collagen is made of three chains wound together like a rope. Which level of protein structure describes how the three chains join?

> (a) $(21 - 1) + (30 - 1) = 20 + 29 =$ **49 peptide bonds; 49 water molecules**. (b) $20 \times 20 =$ **400**. (c) **Quaternary structure.**

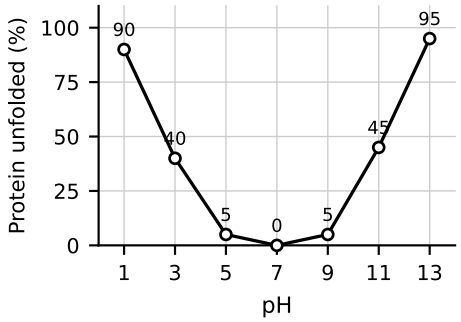
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9. A protein was kept for 10 minutes at different pH values at room temperature (sample data).

(a) In which pH range does the protein keep its shape best?

(b) Explain why strong acid or base makes the protein unfold. What is this called?

(c) Are the peptide bonds broken at pH 1? Explain what happens to the protein's job.



(a) **About pH 5 to 9** (0 to 5% unfolded).

(b) **Acid and base change the charges on R groups, which breaks the weak bonds holding the folded shape. This is denaturation.** (c) **No**, the primary sequence stays the same, but the unfolded protein usually cannot do its job.

10. The first six amino acids of a normal protein and a mutant protein are shown.

Position	**1**	**2**	**3**	**4**	**5**	**6**
Normal	Met	Gly	Lys	Asp	Leu	Phe
Mutant	Met	Gly	Lys	Val	Leu	Phe

(a) At which position do they differ? Which level of protein structure changed directly?

(b) Asp has a charged R group, and Val has an uncharged R group. Explain how this one change could stop the protein from working.

(a) **Position 4 (Asp to Val). Primary structure** (the order of amino acids).

(b) **The R group affects how the chain folds. A different R group can change the tertiary shape, so the protein may no longer fit its target, and shape decides function.**

Part 5. Nucleic Acids

11. (a) A double-stranded DNA sample is 26% cytosine. Find the percent of G, A, and T.

(b) A DNA molecule has 2,400 base pairs, and 30% of its bases are adenine. How many nucleotides does it have? How many of each base?

(c) The genome of a virus is 22% uracil. Is it DNA or RNA? Explain.

(a) **G = 26%**; A + T = 100% − 52% = 48%, so **A = 24% and T = 24%**.

(b) 2 × 2,400 = **4,800 nucleotides**. A = T = 0.30 × 4,800 = **1,440 each**; G = C = 0.20 × 4,800 = **960 each**. (c) **RNA**: uracil is found in RNA, and DNA has thymine instead.

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12. One strand of DNA reads G C G T A C G A.

(a) Write the complementary strand.

(b) How many hydrogen bonds hold this section of the double helix together?

(c) Name the three parts of one nucleotide. Explain why the order of bases matters to the cell.

> (a) **C G C A T G C T**. (b) 5 G-C pairs × 3 + 3 A-T pairs × 2 = 15 + 6 = **21 hydrogen bonds**.
>
> (c) **Phosphate group, five-carbon sugar, nitrogen base. The order of bases is the information: it sets the order of amino acids in a protein, which decides its shape and function.**

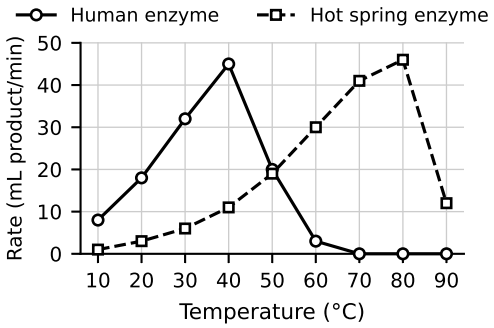
Part 6. Enzymes

13. The graph compares an enzyme from humans with one from bacteria that live in a hot spring (sample data).

(a) What is the optimum temperature of each enzyme?

(b) Explain why the human enzyme's rate drops above its optimum.

(c) Why would the hot spring enzyme be useful in a factory process that runs at 70 °C?



> (a) **Human: about 40 °C. Hot spring: about 80 °C.**
>
> (b) **Above the optimum, heat breaks the weak bonds that hold the enzyme's shape, so the active site changes (denaturation) and the substrate no longer fits.** (c) **It still works fast at 70 °C (41 mL/min), while the human enzyme has stopped (0 mL/min).**

14. (a) An enzyme makes 45 mL of gas in 6 minutes. Find the rate. At this rate, how much gas forms in 10 minutes?

Substrate concentration	0	2	4	6	8	10
Rate with 1 unit of enzyme	0	18	28	33	35	35
Rate with 2 units of enzyme	0	30	50	62	68	70

(b) The table shows sample data (rates in arbitrary units). Why does the rate stop rising with 1 unit of enzyme? What does doubling the enzyme do to the highest rate, and why?

> (a) 45 mL ÷ 6 min = **7.5 mL/min**; 7.5 mL/min × 10 min = **75 mL**.
>
> (b) **All the active sites are busy, so extra substrate cannot speed it up. Doubling the enzyme doubles the highest rate (35 to 70 units), because there are twice as many active sites.**

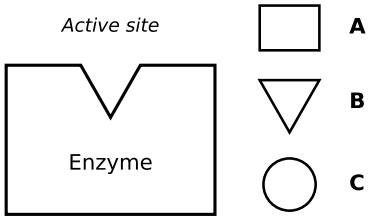
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15. The model shows an enzyme and three molecules.

(a) Which molecule is most likely the enzyme's substrate? Explain.

(b) What happens to the enzyme after the products leave?

(c) Use the model to explain why each enzyme usually works on only one substrate or a few similar ones.



> (a) **B**: its shape fits the active site. (b) **The enzyme is not used up; it can bind another substrate.**
> (c) **The active site has a specific shape, so only molecules with a matching shape can fit and react.**

Part 7. ATP and Energy Needs

16. (a) A cyclist uses about 650 kcal per hour. How much energy does a 1.5-hour ride use? How many grams of carbohydrate, or of fat, would supply that energy?

(b) A model cell holds 3,000,000 ATP molecules and uses 75,000 per second. If no ATP were remade, how long would the supply last? What process keeps the supply going?

> (a) 650 kcal/h × 1.5 h = **975 kcal**. Carbohydrate: 975 ÷ 4 ≈ **244 g**. Fat: 975 ÷ 9 ≈ **108 g**.
> (b) 3,000,000 ÷ 75,000 = **40 seconds**. **Cellular respiration breaks down food molecules and uses the energy to add a phosphate back to ADP, remaking ATP.**

17. (a) Name the three parts of an ATP molecule. Which bond is broken to release energy for cell work, and what are the products?

(b) Muscle cells in a sprinter's legs need far more ATP during a race than at rest. Explain how the cells meet this need, and why the sprinter breathes faster.

> (a) **Adenine, ribose, three phosphate groups. The bond to the third (end) phosphate is broken by hydrolysis, giving ADP + P.**
> (b) **The cells break down food molecules faster in cellular respiration to remake ATP from ADP and phosphate. Faster respiration needs more oxygen, so the sprinter breathes faster.**

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