

Unit 1: Chemistry of Life

Unit 1 covers the chemistry that makes life possible: water and hydrogen bonding, the elements of life, and the structure and function of carbohydrates, lipids, nucleic acids, and proteins. CED topics 1.1 through 1.7.

AP Biology

Chemistry of Life

About 12 minutes to read

How to use this guide

Read it in order the first time because the topics build on each other. Water chemistry explains the environment that macromolecules work in, the elements of life become the monomers, monomers link into polymers, and then each of the four macromolecule families gets its own section. Exam questions usually give a scenario and ask which molecule or property is involved.

After the first read, use the trap boxes and the tables to review the distinctions that exam questions test most often. Finish with the practice questions, then complete the recall check on the last page out loud and note any items you cannot explain yet.

Why this unit comes first. Everything in this course is built from the molecules in this unit. Water is the medium every cell works in. Carbohydrates, lipids, nucleic acids, and proteins are the parts. When later units discuss membranes, enzymes, or DNA, they assume you already know these structures, so a weak Unit 1 follows you all year.

1.1 Structure of Water and Hydrogen Bonding

Water is polar because oxygen pulls the shared electrons in each O-H bond toward itself. That unequal sharing is a **polar covalent bond**, and it leaves the oxygen end of the molecule slightly negative and the hydrogen ends slightly positive. The positive hydrogen of one water molecule is then attracted to the negative oxygen of a neighbor. That attraction is a **hydrogen bond**. It is weak on its own, but water forms enormous numbers of them, and together they explain almost everything water does.

Cohesion is water sticking to itself through hydrogen bonds, which is why water beads into droplets.

Adhesion is water sticking to something else, which is why water climbs the walls of a narrow tube.

Surface tension is the tight skin on a water surface, caused by surface molecules pulling toward one another.

PROPERTY	WHAT IT MEANS FOR LIFE
High specific heat capacity	Water absorbs and releases large amounts of heat with only small temperature changes, so organisms keep a stable internal temperature.
High heat of vaporization	Turning liquid water into vapor takes a lot of energy, so evaporative cooling removes body heat effectively.
Cohesion and adhesion	Water moves as a continuous column, which matters for transport in plants and for droplets holding together.

Trap. A hydrogen bond is an attraction *between* molecules, not a covalent bond *within* one. Boiling water breaks hydrogen bonds between molecules. It does not split water into hydrogen and oxygen, which would mean breaking covalent bonds.

1.2 Elements of Life

Carbon, hydrogen, and oxygen are the most common elements in biological molecules. A few others appear in specific jobs. **Sulfur** is used to build proteins. **Phosphorus** shows up in phospholipids and nucleic acids. **Nitrogen** is found in nucleic acids. When a question asks why a molecule contains phosphorus, the answer is usually that it is a phospholipid or a nucleic acid.

1.3 Introduction to Macromolecules

Big molecules are built from small ones. A **monomer** is a single subunit. A **polymer** is a long chain of monomers joined by covalent bonds. **Polymerization** is the process of linking monomers into a polymer. Two reactions run this system in opposite directions.

REACTION	DIRECTION	WHAT WATER DOES
Dehydration synthesis	Builds. Joins two monomers with a covalent bond.	Water is removed. A hydrogen leaves one monomer and a hydroxyl group leaves the other.
Hydrolysis	Breaks down. Splits the bond between monomers.	Water is added. A hydrogen attaches to one monomer and a hydroxyl group to the other.

Trap. The names point in opposite directions from what many students guess. Dehydration synthesis *builds* polymers by removing water. Hydrolysis *breaks* polymers by adding water. If a question describes digestion or breakdown, the answer is hydrolysis.

1.4 Carbohydrates

Carbohydrates are built from **monosaccharides**, simple sugars that serve as the monomers. Linking monosaccharides by dehydration synthesis produces **polysaccharides**, which can be linear or branched. Three polysaccharides appear as illustrative examples. All three are built from glucose, so questions test whether you know them apart by job and organism, not by structure.

POLYSACCHARIDE	JOB	FOUND IN
Starch	Energy storage	Plants
Glycogen	Energy storage	Animals
Cellulose	Structural support	Plant cell walls

Trap. Starch and glycogen do the same job in different organisms. Cellulose is the odd one out because its job is structure, not storage. A question that mentions plant cell walls is pointing at cellulose, not starch.

1.5 Lipids

Lipids are a diverse family, and exam questions sort them by structure. A **saturated fatty acid** has only single bonds between its carbons, so the chain is straight. An **unsaturated fatty acid** has at least one carbon-carbon double bond, which kinks the chain. The straighter the chains, the tighter they pack, and the more solid the fat is at room temperature. More double bonds mean more kinks, looser packing, and a more liquid oil.

LIPID	STRUCTURE AND JOB
Fat	Energy storage and cell function. In mammals, fats also provide insulation that helps keep the body warm.
Phospholipid	Molecules group together to form the lipid bilayers of plasma membranes and organelle membranes.
Steroid	Includes cholesterol. Steroid hormones support growth and development, energy metabolism, and homeostasis.
Cholesterol	A steroid that gives animal cell membranes essential structural stability.

Trap. Saturated means saturated with hydrogen, which is only possible with single bonds. Students often flip this and pick unsaturated for the solid fat. Solid at room temperature means saturated. Liquid means unsaturated.

1.6 Nucleic Acids

A **nucleotide** has three parts: a five-carbon sugar, a phosphate group, and a **nitrogenous base**. DNA uses the sugar **deoxyribose**. RNA uses **ribose**. The bases are adenine, thymine, guanine, and cytosine in DNA, with **uracil** replacing thymine in RNA.

DNA is an **antiparallel double helix**. Two strands run in opposite directions and twist around each other. The strands are antiparallel because each has a **5' end** (phosphate) and a **3' end** (hydroxyl), and the two strands point opposite ways. When a new strand is synthesized, nucleotides are added to the 3' end of the growing strand. The strands are held together by **base pairing**. Adenine pairs with thymine and cytosine pairs with guanine in DNA, joined by hydrogen bonds. In RNA, adenine pairs with uracil.

FEATURE	DNA	RNA
Sugar	Deoxyribose	Ribose
Bases	A, T, C, G	A, U, C, G
Strands	Two, antiparallel, double helix	Uses uracil in place of thymine when pairing

Trap. Adenine pairs with thymine in DNA but with uracil in RNA. Questions that give a DNA sequence and ask for the RNA version are checking whether you swap in uracil. A second trap is direction. New nucleotides always add to the 3' end, never the 5' end.

1.7 Proteins

An **amino acid** has a central carbon bonded to a hydrogen atom, a carboxyl group, an amine group, and a variable **R group**. Amino acids link through **peptide bonds**, each formed between the carboxyl group of one amino acid and the amine group of the next, producing a **polypeptide** chain. The R group is what makes each amino acid different. Its chemistry, hydrophobic or nonpolar, hydrophilic or polar, or ionic, determines how that region of the protein folds and what it can do.

Protein structure has four levels, and each level builds on the one before. The **primary structure** is the amino acid sequence, and it determines the overall shape that follows.

LEVEL	WHAT IT IS	HELD TOGETHER BY
Secondary structure	Local folding of the backbone into alpha-helices and beta-pleated sheets	Hydrogen bonds between backbone atoms
Tertiary structure	The whole polypeptide folded into its three-dimensional shape	Hydrogen bonds, hydrophobic interactions, ionic interactions, and disulfide bridges
Quaternary structure	Interactions between multiple polypeptide chains	The same interactions, acting between chains

An **alpha-helix** is a coiled secondary structure. A **beta-pleated sheet** is a folded, sheet-like secondary structure. Both are held by hydrogen bonding within the backbone. A **disulfide bridge** is a covalent bond between sulfur atoms that helps lock the tertiary structure in place. All four levels together determine what the protein does.

Trap. Secondary structure is about the backbone, held by hydrogen bonds. Tertiary structure is about the R groups, held by hydrophobic interactions, ionic interactions, and disulfide bridges. A question that mentions R groups is asking about tertiary structure, not secondary.

Confusions That Cost Points

Most missed questions in this unit come from a short list of pairs that look alike under time pressure. Review each pair carefully so you can tell them apart when you see them in a question.

PAIR	HOW TO SEPARATE THEM
Cohesion vs adhesion	Cohesion is water sticking to water. Adhesion is water sticking to something else. Same substance versus different substance.
Hydrogen bond vs covalent bond	Hydrogen bonds attract separate molecules to each other. Covalent bonds hold atoms together inside one molecule. Boiling breaks the first, not the second.
Hydrolysis vs dehydration synthesis	Hydrolysis breaks polymers by adding water. Dehydration synthesis builds polymers by removing water. Digestion means hydrolysis.
Monomer vs polymer	Monomers are the subunits. Polymers are the chains. Monosaccharides and amino acids are monomers. Polysaccharides and polypeptides are polymers.
Starch vs glycogen vs cellulose	Starch stores energy in plants. Glycogen stores energy in animals. Cellulose gives structure to plant cell walls. Same glucose building block, three different jobs.
Saturated vs unsaturated fatty acid	Saturated has only single bonds, straight chains, and is solid at room temperature. Unsaturated has double bonds, kinked chains, and is liquid.
DNA bases vs RNA bases	DNA uses thymine. RNA uses uracil instead. Adenine pairs with T in DNA and with U in RNA. Cytosine always pairs with guanine.
Secondary vs tertiary structure	Secondary is local backbone folding, alpha-helices and beta-pleated sheets, held by hydrogen bonds. Tertiary is the whole chain folded in three dimensions, held by R-group interactions including disulfide bridges.
5' end vs 3' end	The 5' end carries the phosphate. The 3' end carries the hydroxyl. New nucleotides are added to the 3' end during synthesis.

Practice Questions

Original questions written for this guide in the style of the AP exam. Answers and explanations are on the next page, so complete the questions before checking them.

1. A coastal town and an inland town at the same latitude receive the same amount of sunlight, but the coastal town has much smaller daily temperature swings. Which property of water best explains this difference?

- A. High specific heat capacity
- B. Low heat of vaporization
- C. Water is nonpolar, so it resists temperature change
- D. Hydrogen bonds are strong covalent bonds that store heat

2. Water travels upward through the narrow xylem tubes of a plant, from the roots toward the leaves. Which pair of properties makes this movement possible?

- A. Cohesion and adhesion
- B. Cohesion alone, acting on the tube walls
- C. Surface tension and heat of vaporization
- D. High specific heat and cohesion

3. During digestion, a polysaccharide is broken down into monosaccharide monomers. This reaction is best described as

- A. hydrolysis, because a water molecule is added across each bond that breaks
- B. dehydration synthesis, because a water molecule is removed to break each bond
- C. polymerization, because monomers are being produced
- D. hydrolysis, because a water molecule is removed from each bond that breaks

4. A student examines cells from a potato tuber and finds a carbohydrate used for energy storage. Which molecule is it most likely to be?

- A. Starch
- B. Cellulose
- C. Glycogen
- D. A monosaccharide

- 5.** Butter is solid at room temperature, while olive oil is liquid. The best explanation is that butter contains a higher proportion of
- A. saturated fatty acids, whose straight chains pack tightly together
 - B. unsaturated fatty acids with more carbon-carbon double bonds
 - C. phospholipids, which form solid bilayers
 - D. steroids, which stiffen at room temperature
- 6.** One strand of a DNA molecule reads 5'-ATGCCG-3'. Which of the following could be the complementary strand, written in the 5' to 3' direction?
- A. 5'-CGGCAT-3'
 - B. 5'-TACGGC-3'
 - C. 5'-AUGCCG-3'
 - D. 5'-ATGCCG-3'
- 7.** When a new DNA strand is synthesized, nucleotides are added to which end of the growing strand?
- A. The 3' end
 - B. The 5' end
 - C. Both ends at equal rates
 - D. The nitrogenous base end
- 8.** Hemoglobin is made of four polypeptide chains that must associate correctly for the protein to carry oxygen. The interaction among the four chains is an example of
- A. quaternary structure
 - B. tertiary structure
 - C. primary structure
 - D. secondary structure

Answer Key

- 1. A.** High specific heat capacity means water absorbs and releases large amounts of heat with only small temperature changes, which steadies the coastal climate. B names the wrong property. C is the trap. Water is polar, not nonpolar, and polarity is not what steadies temperature. D confuses hydrogen bonds with covalent bonds. Hydrogen bonds are weak attractions between molecules, not strong bonds within one.
- 2. A.** Cohesion holds the water column together and adhesion grips the tube walls. Both are needed. B is the trap. Cohesion alone cannot explain climbing the walls, which is adhesion. C and D list real properties of water that do the wrong jobs here.
- 3. A.** Breaking a polymer into monomers is hydrolysis, and hydrolysis adds water across the bond. B reverses the reaction. Dehydration synthesis builds, and it removes water. C is the trap. Polymerization builds chains rather than breaking them. D is the subtler trap. It names the right reaction but describes the wrong water movement, which is what dehydration synthesis does.
- 4. A.** Starch is the storage polysaccharide in plants, and a potato tuber is plant tissue storing energy. B is the trap. Cellulose is also in plants, but its job is structure in cell walls, not storage. C stores energy but in animals, not plants. D is a monomer, not a storage polymer.
- 5. A.** Saturated fatty acids have only single bonds, so their chains are straight and pack tightly, making the fat solid. B reverses the relationship. More double bonds mean more kinks and a more liquid oil. C is the trap. Phospholipids build membranes. They do not explain solidity here. D names a different lipid class with different jobs.
- 6. A.** Pair each base (A with T, C with G) to get 3'-TACGGC-5', then flip it to read 5'-CGGCAT-3'. B is the trap. It pairs the bases correctly but keeps the wrong direction. The strands must run antiparallel. C puts uracil in DNA, which belongs in RNA. D copies the strand instead of complementing it.
- 7. A.** Nucleic acid synthesis adds new nucleotides to the 3' hydroxyl end of the growing strand. B reverses the direction. C invents a pattern the enzymes do not follow. D is the trap. It sounds technical but names a part, not an end. Strands have 5' and 3' ends defined by their sugars.
- 8. A.** Interactions between multiple polypeptide chains define quaternary structure. B is the trap. Tertiary structure is the three-dimensional folding of a single chain, not the association of several. C is the amino acid sequence of one chain. D covers local backbone shapes such as alpha-helices, which is a smaller scale than chain-to-chain association.

When you check your answers, note which distinction each miss came from. Make a flashcard for that distinction and drill it spaced out over the next few days instead of rereading the whole section. If you missed one of these questions, the same distinction is worth practicing again in Rycal, where the Chemistry of Life deck has flashcards for it and more practice questions use the same kinds of traps.

One-Page Recall Check

Say each answer out loud before you look back, and mark the ones you cannot finish. Anything you cannot say out loud yet belongs in your flashcard deck. In Rycal, add those items to the Chemistry of Life deck and let spaced review bring them back over the next few days.

- Explain why water is polar, and describe what a hydrogen bond is without calling it a covalent bond.
- Tell cohesion apart from adhesion, and give one example of each.
- Explain why sweating cools the body, using heat of vaporization.
- Explain why a coastal town has steadier temperatures than an inland town, using specific heat capacity.
- List the elements of life and say where sulfur, phosphorus, and nitrogen appear.
- Contrast hydrolysis and dehydration synthesis, naming what happens to water in each.
- Explain the monomer to polymer relationship using a carbohydrate example.
- Sort starch, glycogen, and cellulose by organism and job.
- Explain why butter is solid and olive oil is liquid at room temperature.
- Name the three parts of a nucleotide, then list every difference between a DNA nucleotide and an RNA nucleotide.
- Write the complementary DNA strand for 5'-ATGCCG-3', labeling the 5' and 3' ends correctly.
- State which end of a growing strand receives new nucleotides during synthesis.
- List the four levels of protein structure and say what holds each level together.
- Explain how an R group determines the structure and function of its region of a protein.
- Distinguish a disulfide bridge from a hydrogen bond in a folded protein.

Where to go next. Turn every missed item above into flashcards and drill them spaced out over several days rather than in one sitting. In Rycal, open the Chemistry of Life deck under AP Biology. The deck covers the terms in this guide, and its practice questions target the same traps named here. If you have a test date, add it in the Test Planner. You can also start your next review with a Brain Dump, then check what you missed against this guide.

Key terms for this unit

Hydrogen bond, Polar covalent bond, Cohesion, Adhesion, Surface tension, Specific heat capacity, Heat of vaporization, Elements of life, Hydrolysis, Dehydration synthesis, Polymer, Monomer, Polymerization, Monosaccharide, Polysaccharide, Starch, Glycogen, Cellulose, Saturated fatty acid, Unsaturated fatty acid, Fat, Steroid, Cholesterol, Phospholipid, Nucleotide, Deoxyribose, Ribose, Nitrogenous base, Antiparallel double helix, Base pairing, DNA and RNA strands, 5' and 3' ends, Amino acid, Peptide bond, Polypeptide, R group, Primary structure, Secondary structure, Alpha-helix, Beta-pleated sheet, Tertiary structure, Disulfide bridge, Quaternary structure.

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