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Carbohydrates: Sugars as Macromolecules

Study Guide — Biochemistry

Pre-med/IB-style questions covering carbohydrate structure (mono/di/polysaccharides), glycosidic bonds, reducing sugars, alpha vs beta linkages, storage vs structural polysaccharides (starch, glycogen, cellulose, chitin), and cell biology roles (glycocalyx, glycoproteins/glycolipids, cell recognition, peptidoglycan).

40 items — Study Guide with Answers

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1 Why are large polysaccharides (e.g., glycogen, starch) better for intracellular glucose storage than storing the same number of glucose molecules as free monosaccharides?

- A Polysaccharides diffuse across membranes more easily than monosaccharides
- B **Polysaccharides create a much lower osmotic effect per glucose unit and can be stored compactly** ✓
- C Polysaccharides are more reactive and therefore easier to mobilize instantly
- D Polysaccharides are amphipathic and form bilayers around glucose
- E Polysaccharides cannot be broken down back into glucose

▶ **Explanation:** Many separate glucose molecules would strongly raise osmotic pressure (drawing in water). Linking glucose into a polymer drastically reduces the number of particles in solution, lowering osmotic stress, while still allowing rapid hydrolysis when needed. Polysaccharides do not diffuse across membranes as such, and they can be broken down enzymatically.

2 The formation of a glycosidic bond between two monosaccharides is best described as:

- A A hydrolysis reaction that consumes water
- B **A condensation (dehydration) reaction that releases water** ✓
- C A redox reaction that transfers electrons
- D A phosphorylation reaction that adds phosphate
- E A reaction that forms peptide bonds

▶ **Explanation:** Glycosidic bonds form when two sugars join and water is released (condensation). Hydrolysis is the reverse reaction (uses water to break the bond).

3 Which description best defines a glycosidic bond in carbohydrates?

A A covalent bond between two amino acids

B **A covalent bond between sugar units, typically involving the anomeric carbon of one sugar ✓**

C A hydrogen bond between parallel -sheets

D An ionic bond between fatty acid heads and tails

E A phosphodiester bond linking nucleotides

▶ **Explanation:** A glycosidic bond is the covalent linkage between sugars (e.g., in disaccharides and polysaccharides), often formed from the anomeric carbon of one monosaccharide to a hydroxyl of another. Peptide and phosphodiester bonds belong to proteins and nucleic acids, respectively.

4 Which disaccharide is NON-reducing (i.e., cannot act as a reducing sugar)?

A Maltose

B Lactose

C **Sucrose ✓**

D Cellobiose

E All disaccharides are reducing

▶ **Explanation:** Sucrose is non-reducing because its glycosidic bond involves both anomeric carbons, leaving no free anomeric carbon to open into a reactive carbonyl form. Maltose, lactose, and cellobiose each retain a free anomeric carbon and are reducing sugars.

5 A carbohydrate is called a "reducing sugar" mainly because it:

A **Has at least one free anomeric carbon that can open to a reactive aldehyde/ketone form ✓**

B Always contains a phosphate group

- C Is always a polysaccharide
- D Is always insoluble in water
- E Can only be digested by bacteria

▶ **Explanation:** Reducing sugars can donate electrons in oxidation reactions because they can form a free carbonyl (via ring opening) at an anomeric carbon. Phosphate groups and solubility are not the defining features, and reducing sugars can be mono- or disaccharides (and some polysaccharides have a reducing end).

6 Which disaccharide is composed of glucose + galactose and is typically a reducing sugar?

- A Sucrose
- B Maltose
- C **Lactose** ✓
- D Trehalose
- E Cellulose

▶ **Explanation:** Lactose is glucose + galactose and has a free anomeric carbon, making it reducing. Maltose is glucose + glucose. Sucrose is glucose + fructose and is non-reducing. Cellulose is a polysaccharide, not a disaccharide.

7 The "anomeric carbon" of a monosaccharide is best described as the carbon that:

- A Always carries the phosphate group in the cell
- B **Was the carbonyl carbon (aldehyde/ketone) in the linear form and becomes a new stereocenter in the ring form** ✓
- C Is always the terminal carbon farthest from oxygen
- D Forms peptide bonds with amino acids

E Is the only carbon present in carbohydrates

▶ **Explanation:** When a sugar cyclizes, the carbonyl carbon becomes the anomeric carbon. Its configuration (or) is crucial because it determines the type of glycosidic bonds and polymer structure.

8 When a glycosidic bond forms using a sugar's anomeric carbon, what happens to that anomeric carbon?

A **It becomes unable to participate in ring opening (it is "locked" as an acetal/ketal)** ✓

B It becomes a phosphate group

C It becomes an amino acid

D It is removed from the molecule

E It turns into a peptide bond

▶ **Explanation:** A glycosidic bond converts the anomeric carbon from a hemiacetal/hemiketal to an acetal/ketal, preventing ring opening at that carbon. This is why linking both anomeric carbons (as in sucrose) removes reducing ability.

9 Cellulose differs from starch mainly because cellulose contains:

A (1→4) glycosidic bonds that form a helix

B **(1→4) glycosidic bonds that create straight chains** ✓

C Peptide bonds between glucose units

D Phosphodiester bonds between glucose units

E Only fructose units

▶ **Explanation:** Cellulose is a glucose polymer with (1→4) links, producing straight chains that hydrogen-bond into strong fibers. Starch mainly has linkages (1→4 and 1→6), giving different shapes and digestibility.

10 Humans cannot digest cellulose efficiently because humans lack:

- A Enzymes that break (1→4) glycosidic bonds
- B **Enzymes that break (1→4) glycosidic bonds between glucose units (cellulase)** ✓
- C The ability to absorb glucose from the intestine
- D Hydrochloric acid in the stomach
- E Any enzymes that digest carbohydrates at all

▶ **Explanation:** Human enzymes (like amylase) digest linkages in starch, but humans lack cellulase to hydrolyze (1→4) bonds in cellulose. Therefore cellulose behaves as dietary fiber for humans.

11 Which statement best explains why cellulose fibers are mechanically strong?

- A Cellulose chains are highly branched, trapping large amounts of water
- B **Straight cellulose chains align and form extensive hydrogen bonds between chains** ✓
- C Cellulose contains many disulfide bonds between chains
- D Cellulose is made of lipid bilayers stacked together
- E Cellulose is a protein with -helices

▶ **Explanation:** (1→4) linkages yield straight chains that pack tightly and hydrogen-bond with neighboring chains, forming strong microfibrils. It is not branched, and it contains no disulfide bonds because it is not a protein.

12 **Which polysaccharide is the primary glucose storage polymer in animals?**

- A Cellulose
- B Chitin
- C **Glycogen** ✓
- D Amylose
- E Pectin

▶ **Explanation:** Animals store glucose mainly as glycogen, a highly branched polymer. Plants store glucose largely as starch (amylose/amylopectin). Cellulose and chitin are structural.

13 **Compared with amylopectin (starch), glycogen typically has:**

- A Fewer branches (fewer (1→6) linkages)
- B **More frequent branching (more (1→6) linkages)** ✓
- C (1→4) linkages instead of linkages
- D No glucose units
- E Only fructose units

▶ **Explanation:** Both glycogen and amylopectin contain (1→4) chains with (1→6) branch points, but glycogen is usually more highly branched. This increases the number of chain ends and supports faster mobilization of glucose.

14 **A key advantage of glycogen's branching for rapid energy release is that branching:**

- A Eliminates the need for enzymes

B **Creates many non-reducing ends where enzymes can add/remove glucose quickly** ✓

C Makes glycogen able to cross membranes directly

D Creates $(1 \to 4)$ bonds that are harder to break

E Turns glycogen into a lipid

▶ **Explanation:** Enzymes that build and break glycogen act at chain ends. More branching means more ends (especially non-reducing ends), increasing the rate at which glucose units can be released or added.

15 Which statement correctly matches amylose and amylopectin?

A Amylose is highly branched; amylopectin is unbranched

B **Amylose is mostly unbranched ($1 \to 4$); amylopectin is branched ($1 \to 4$ with $1 \to 6$)** ✓

C Amylose contains $(1 \to 4)$ bonds; amylopectin contains peptide bonds

D Amylose is made of fructose; amylopectin is made of galactose

E Both are structural components of insect exoskeleton

▶ **Explanation:** Amylose is largely linear ($1 \to 4$ glucose polymer) and can form helical structures; amylopectin has $1 \to 6$ branches. Chitin (not starch) is a major exoskeleton component.

16 Which pair of monosaccharides are epimers (differ at exactly one chiral carbon)?

A Glucose and fructose

B **Glucose and galactose** ✓

C Glucose and sucrose

D Starch and cellulose

E Glycine and alanine

▶ **Explanation:** Glucose and galactose are epimers (commonly at C-4). Glucose and fructose are structural isomers (aldose vs ketose), not epimers. The other pairs are not monosaccharide stereoisomers.

17 Which monosaccharide is a ketose (rather than an aldose)?

A Glucose

B Galactose

C **Fructose** ✓

D Ribose

E Deoxyribose

▶ **Explanation:** Fructose is a ketose (carbonyl as a ketone in the linear form). Glucose and galactose are aldoses, and ribose/deoxyribose are aldopentoses.

18 Most biologically common sugars are in the D-configuration. This statement refers primarily to:

A Whether the sugar can be digested by humans

B Whether the sugar is a reducing sugar

C **The stereochemistry around the chiral carbon farthest from the carbonyl group (relative to D-glyceraldehyde)** ✓

D Whether the sugar forms or anomers

E The number of carbons in the sugar

▶ **Explanation:** D/L describes stereochemistry relative to glyceraldehyde and is determined by the configuration at the highest-numbered chiral center (farthest from the carbonyl). It is not a statement about reducing ability, digestibility, or / anomers.

19 Chitin is best described as:

- A A branched (1→6) glucose polymer used for animal energy storage
- B **A (1→4) polymer of N-acetylglucosamine found in arthropod exoskeletons and fungal cell walls** ✓
- C A disaccharide of glucose + fructose
- D A lipid used to form membranes
- E A nucleic acid sugar found only in DNA

▶ **Explanation:** Chitin is a structural polysaccharide similar to cellulose in having (1→4) linkages, but its monomer is N-acetylglucosamine. It is not a storage polymer like glycogen.

20 In animal cells, carbohydrates on the external surface of the plasma membrane are most commonly found as part of:

- A Free polysaccharides floating in the cytosol
- B **Glycoproteins and glycolipids forming the glycocalyx** ✓
- C DNA and RNA projecting through the membrane
- D Triglycerides embedded as the main bilayer component
- E Cellulose microfibrils anchored in the membrane

▶ **Explanation:** Membrane carbohydrates are typically attached to proteins (glycoproteins) or lipids (glycolipids) and face the extracellular space, forming the glycocalyx. They are not free-floating polymers in the cytosol.

21 **Which is a key function of the glycocalyx on animal cells?**

- A ATP production via oxidative phosphorylation
- B **Cell–cell recognition and adhesion through specific carbohydrate patterns ✓**
- C DNA replication during S phase
- D Protein synthesis on ribosomes
- E Direct pumping of Na^+ out of the cell

▶ **Explanation:** Carbohydrate chains on glycoproteins and glycolipids serve as recognition labels and help with adhesion and protection. ATP production, replication, and translation are unrelated to the glycocalyx's main role.

22 **Glycolipids involved in cell recognition are most commonly oriented so that their carbohydrate chains face:**

- A The cytosol
- B The nucleus
- C **The extracellular space ✓**
- D The mitochondrial matrix
- E The inside of lysosomes

▶ **Explanation:** Membrane carbohydrate chains (in glycolipids and glycoproteins) are displayed on the extracellular side, forming part of the glycocalyx. This asymmetry is crucial for recognition and signaling.

23 **Which statement best distinguishes proteoglycans from typical glycoproteins?**

A Proteoglycans have short, branched oligosaccharides; glycoproteins have long unbranched chains

B Proteoglycans have long, often unbranched glycosaminoglycan chains and a high carbohydrate content ✓

C Proteoglycans are made entirely of lipids; glycoproteins are made entirely of sugars

D Proteoglycans are found only in the nucleus

E Glycoproteins cannot be part of membranes

▶ **Explanation:** Proteoglycans are protein cores with long glycosaminoglycan (GAG) chains and often extremely high carbohydrate mass. Many glycoproteins have shorter, branched oligosaccharides and diverse roles (including membrane proteins).

24 A major reason glycosaminoglycans (GAGs) attract water and resist compression in tissues is that they often:

A Contain many positively charged groups that repel water

B Are strongly negatively charged (e.g., sulfate/carboxyl groups), attracting cations and water ✓

C Are made only of hydrophobic amino acids

D Form peptide bonds with collagen

E Are stored inside mitochondria to regulate ATP

▶ **Explanation:** Many GAGs are highly negatively charged, which draws in ions and water, creating hydrated gels that resist compression—important in cartilage and connective tissue. This is not due to peptide bonding or mitochondrial storage.

25 Which statement about N-linked versus O-linked glycosylation is MOST accurate (basic cell biology level)?

A N-linked glycosylation attaches sugars to lysine in the nucleus; O-linked attaches to DNA in mitochondria

- **B** **N-linked glycosylation attaches to asparagine and begins in the ER; O-linked often attaches to serine/threonine and is commonly processed in the Golgi** ✓
- **C** Both occur only in the cytosol after translation
- **D** O-linked glycosylation always forms cellulose fibers
- **E** Glycosylation can only happen in prokaryotes

▶ **Explanation:** N-linked glycosylation (to Asn) begins in the ER, while O-linked (to Ser/Thr) is commonly added/modified in the Golgi. Glycosylation is a key eukaryotic secretory pathway modification, not a nucleus/mitochondria DNA process.

26 **ABO blood group differences are primarily determined by variation in:**

- **A** The amino acid sequence of hemoglobin
- **B** **Carbohydrate structures on glycoproteins/glycolipids at the red blood cell surface** ✓
- **C** The number of mitochondria in red blood cells
- **D** The length of DNA in the red blood cell nucleus
- **E** The fatty acid saturation level of red blood cell membranes

▶ **Explanation:** ABO antigens are carbohydrate modifications on surface molecules. Mature human red blood cells lack a nucleus and mitochondria, so options about RBC DNA/mitochondria are incorrect.

27 **Peptidoglycan in bacterial cell walls contains repeating units of:**

- **A** Glucose and fructose
- **B** **N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM)** ✓
- **C** Ribose and deoxyribose
- **D** Cellulose and chitin

E Amino acids only, no sugars

▶ **Explanation:** Bacterial peptidoglycan is a carbohydrate backbone of alternating NAG and NAM, cross-linked by short peptides. It is not made of glucose/fructose or nucleic acid sugars.

28 Lysozyme (found in tears and saliva) helps defend against bacteria by cleaving:

A Peptide bonds in bacterial enzymes

B **(1→4) glycosidic bonds between NAG and NAM in peptidoglycan** ✓

C (1→6) glycosidic bonds in glycogen

D Phosphodiester bonds in bacterial DNA

E Disulfide bonds in membrane proteins

▶ **Explanation:** Lysozyme targets the carbohydrate backbone of peptidoglycan by cleaving the (1→4) linkage between NAG and NAM, weakening the bacterial cell wall. It does not primarily act on DNA phosphodiester or protein disulfide bonds.

29 Which polysaccharide is a structural component of plant cell walls?

A Glycogen

B **Cellulose** ✓

C Amylopectin

D Sucrose

E Lactose

▶ **Explanation:** Cellulose is the major structural polysaccharide in plant cell walls. Glycogen is animal storage, amylopectin is plant storage (starch), and sucrose/lactose are disaccharides.

30 **If two glucose molecules form maltose, which type of bond is most characteristic of maltose?**

- A (1→4) glycosidic bond
- B **(1→4) glycosidic bond ✓**
- C (1→6) glycosidic bond
- D Peptide bond
- E Phosphodiester bond

▶ **Explanation:** Maltose is commonly glucose–glucose linked by an (1→4) bond (e.g., from starch breakdown). (1→4) is typical of cellobiose (from cellulose).

31 **Which polymer is a homopolysaccharide of glucose with (1→4) and (1→6) linkages and is typically MORE highly branched than plant starch?**

- A Cellulose
- B Chitin
- C **Glycogen ✓**
- D Pectin
- E Hyaluronan

▶ **Explanation:** Glycogen is a highly branched glucose polymer (1→4 chains with frequent 1→6 branches). Cellulose/chitin are (1→4) structural polymers, and pectin/hyaluronan are different polysaccharides.

32 **A student claims: "Starch and cellulose are both made of glucose, so they must have the same properties." What is the best rebuttal?**

A Correct—if monomers are the same, polymers must be identical

B Incorrect—different glycosidic bond geometry (vs) changes 3D structure and properties dramatically ✓

C Incorrect—cellulose is made of fructose, not glucose

D Correct—cellulose differs from starch only because it contains more water

E Correct—cellulose and starch are both proteins that fold differently

▶ **Explanation:** Same monomer does not guarantee same polymer properties. versus glycosidic linkages produce very different shapes (helical/branched vs straight fibers), which changes digestibility and mechanical strength.

33 A polymer has one reducing end and many non-reducing ends. Which polymer most fits this description and why?

A Cellulose, because it is highly branched

B Glycogen, because branching creates many non-reducing ends while the polymer still has only one reducing end ✓

C Sucrose, because it contains two reducing ends

D Lactose, because it contains no reducing end

E Triglyceride, because it is a carbohydrate polymer

▶ **Explanation:** A branched polysaccharide like glycogen has many chain ends for enzyme action (mostly non-reducing ends), but the entire molecule has only one reducing end. Cellulose is unbranched; sucrose is non-reducing; triglycerides are lipids.

34 A common lab test uses iodine to produce a blue-black color with certain carbohydrates. Which carbohydrate is most associated with this classic blue-black iodine reaction?

A Amylose (a component of starch) ✓

B Cellulose

C Glucose

D Sucrose

E Chitin

▶ **Explanation:** Iodine fits into the helical structure of amylose, producing the characteristic blue-black color. Cellulose lacks the same helical structure, and simple sugars like glucose/sucrose do not form that complex.

35 Many cell-surface carbohydrates serve as 'ID tags' for recognition. Which statement best explains why carbohydrate-based ID tags are so information-rich?

A **Carbohydrates can form many different branching patterns and linkage positions, increasing diversity** ✓

B Carbohydrates can only form one type of bond, making them easy to distinguish

C Carbohydrates have only one possible stereochemistry

D Carbohydrates always form double helices like DNA

E Carbohydrates cannot be modified after synthesis

▶ **Explanation:** Carbohydrates can vary in monomers, / configurations, linkage positions (e.g., 1→4, 1→6), and branching, allowing enormous structural diversity—ideal for recognition codes on cell surfaces.

36 A virus binds a specific carbohydrate residue on host cell glycoproteins to attach and enter. Where must that carbohydrate residue be located to allow binding?

A On the cytosolic side of the plasma membrane

B In the mitochondrial matrix

C **On the extracellular side of the plasma membrane** ✓

D Inside the nucleus

E Only on the inner leaflet of the Golgi membrane

▶ **Explanation:** To be recognized by an external virus, the carbohydrate must be exposed to the extracellular environment. Most glycoprotein and glycolipid carbohydrates are displayed on the outer leaflet (glycocalyx).

37 Which statement about monosaccharides in solution is most accurate?

A They exist only in the linear form

B They exist only in the cyclic form and can never open

C **They can interconvert between linear and cyclic forms, allowing and anomers to exist** ✓

D They are always non-reducing in water

E They form peptide bonds spontaneously

▶ **Explanation:** Many monosaccharides are mostly cyclic in water but can transiently open to the linear form, enabling interconversion between and anomers (mutarotation). This ring opening is also the basis for reducing sugar behavior.

38 A sugar is reducing even when most molecules are in the ring form because:

A The ring form contains a free aldehyde group

B **The ring can open to a linear form that contains a reactive carbonyl (aldehyde/ketone)** ✓

C All rings are nonpolar and donate electrons easily

D The sugar has a phosphate group that reduces other molecules

E Reducing sugars must be polysaccharides

▶ **Explanation:** Reducing behavior depends on access to a carbonyl form. Even if the cyclic form predominates, a small fraction opens to the linear carbonyl form, enabling redox reactions—unless the anomeric carbon is locked in a glycosidic bond.

39 Which sugar is the key pentose component of RNA (but not DNA)?

- A **Ribose** ✓
- B Deoxyribose
- C Glucose
- D Fructose
- E Galactose

▶ **Explanation:** RNA contains ribose, which has an -OH on the 2' carbon. DNA contains deoxyribose, which lacks that 2' -OH. Glucose/fructose/galactose are hexoses, not the nucleic-acid backbone sugars.

40 A lysosomal enzyme in an animal cell is tagged for delivery to lysosomes using a carbohydrate-based signal. Which signal is most associated with this targeting mechanism?

- A A cellulose microfibril attached to the enzyme
- B **Mannose-6-phosphate on an N-linked oligosaccharide** ✓
- C Sucrose attached to the enzyme's active site
- D Glycogen branching at $(1 \to 6)$ points
- E A phosphodiester bond added to serine

▶ **Explanation:** Many lysosomal enzymes are directed to lysosomes via mannose-6-phosphate tags on their N-linked oligosaccharides, recognized by sorting receptors in the Golgi/endomembrane pathway. The other options do not represent lysosomal targeting signals.