Chapter 7 Carbohydrates and Glycobiology

Multiple Choice Questions

1. **Monosaccharides and disaccharides**
Page: 239 Difficulty: 1 Ans: C
To possess optical activity, a compound must be:

A) a carbohydrate.
B) a hexose.
C) asymmetric.
D) colored.
E) D-glucose.

2. **Monosaccharides and disaccharides**
Page: 239 Difficulty: 2 Ans: B
Which of the following monosaccharides is *not* an aldose?

A) erythrose
B) fructose
C) glucose
D) glyceraldehyde
E) ribose

3. **Monosaccharides and disaccharides**
Page: 240 Difficulty: 2 Ans: C
The reference compound for naming D and L isomers of sugars is:

A) fructose.
B) glucose.
C) glyceraldehyde.
D) ribose.
E) sucrose.

4. **Monosaccharides and disaccharides**
Page: 240 Difficulty: 2 Ans: D
When two carbohydrates are epimers:

A) one is a pyranose, the other a furanose.
B) one is an aldose, the other a ketose.
C) they differ in length by one carbon.
D) they differ only in the configuration around one carbon atom.
E) they rotate plane-polarized light in the same direction.

5. **Monosaccharides and disaccharides**
Pages: 240-241 Difficulty: 2 Ans: B
Which of the following is an epimeric pair?

A) D-glucose and D-glucosamine
B) D-glucose and D-mannose
C) D-glucose and L-glucose
D) D-lactose and D-sucrose
E) L-mannose and L-fructose

6. **Monosaccharides and disaccharides**
Page: 242 Difficulty: 2 Ans: D
Which of following is an anomeric pair?

A) D-glucose and D-fructose
B) D-glucose and L-fructose
C) D-glucose and L-glucose
D) α-D-glucose and β-D-glucose
E) α-D-glucose and β-L-glucose

7. **Monosaccharides and disaccharides**
Page: 242 Difficulty: 2 Ans: C
When the linear form of glucose cyclizes, the product is a(n):

A) anhydride.
B) glycoside.
C) hemiacetal.
D) lactone.
E) oligosaccharide.

8. **Monosaccharides and disaccharides**
Page: 242 Difficulty: 2 Ans: E
Which of the following pairs is interconverted in the process of mutarotation?

A) D-glucose and D-fructose
B) D-glucose and D-galactose
C) D-glucose and D-glucosamine
D) D-glucose and L-glucose
E) α-D-glucose and β-D-glucose

9. **Monosaccharides and disaccharides**
Pages: 243-246 Difficulty: 2 Ans: E
Which of the following is *not* a reducing sugar?

A) Fructose
B) Glucose
C) Glyceraldehyde
D) Ribose
E) Sucrose

10. Monosaccharides and disaccharides
Pages: 244-245 Difficulty: 1 Ans: C
Which of the following monosaccharides is *not* a carboxylic acid?

A) 6-phospho-gluconate
B) gluconate
C) glucose
D) glucuronate
E) muramic acid

11. Monosaccharides and disaccharides
Page: 245 Difficulty: 2 Ans: B
D-Glucose is called a reducing sugar because it undergoes an oxidation-reduction reaction at the anomeric carbon. One of the products of this reaction is:

A) D-galactose.
B) D-gluconate.
C) D-glucuronate.
D) D-ribose.
E) muramic acid.

12. Monosaccharides and disaccharides
Pages: 245-246 Difficulty: 2 Ans: A
From the abbreviated name of the compound Gal($\beta 1 \rightarrow 4$)Glc, we know that:

A) C-4 of glucose is joined to C-1 of galactose by a glycosidic bond.
B) the compound is a D-enantiomer.
C) the galactose residue is at the reducing end.
D) the glucose is in its pyranose form.
E) the glucose residue is the β anomer.

13. Polysaccharides
Page: 248 Difficulty: 1 Ans: D
Starch and glycogen are both polymers of:

A) fructose.
B) glucose1-phosphate.
C) sucrose.
D) α-D-glucose.
E) β-D-glucose.

14. Polysaccharides
Pages: 248-249 Difficulty: 2 Ans: C
Which of the following statements about starch and glycogen is *false*?

A) Amylose is unbranched; amylopectin and glycogen contain many ($\alpha 1 \rightarrow 6$) branches.
B) Both are homopolymers of glucose.
C) Both serve primarily as structural elements in cell walls.
D) Both starch and glycogen are stored intracellularly as insoluble granules.
E) Glycogen is more extensively branched than starch.

15. Polysaccharides
Pages: 248-253 Difficulty: 2 Ans: D
Which of the following is a heteropolysaccharide?

A) Cellulose
B) Chitin
C) Glycogen
D) Hyaluronate
E) Starch

16. Glycoconjugates: proteoglycans, glycoproteins, and glycolipids
Page: 256 Difficulty: 1 Ans: B
The basic structure of a proteoglycan consists of a core protein and a:

A) glycolipid.
B) glycosaminoglycan.
C) lectin.
D) lipopolysaccharide.
E) peptidoglycan.

17. Glycoconjugates: proteoglycans, glycoproteins, and glycolipids
Page: 258 Difficulty: 2 Ans: A
In glycoproteins, the carbohydrate moiety is always attached through the amino acid residues:

A) asparagine, serine, or threonine.
B) aspartate or glutamate.
C) glutamine or arginine.
D) glycine, alanine, or aspartate.
E) tryptophan, aspartate, or cysteine.

18. Glycoconjugates: proteoglycans, glycoproteins, and glycolipids
Page: 260 Difficulty: 1 Ans: D
Which of the following is a dominant feature of the outer membrane of the cell wall of gram negative bacteria?

A) Amylose
B) Cellulose
C) Glycoproteins
D) Lipopolysaccharides
E) Lipoproteins

19. Carbohydrates as informational molecules: the sugar code
Page: 262 Difficulty: 2 Ans: D
The biochemical property of lectins that is the basis for most of their biological effects is their ability to bind to:

A) amphipathic molecules.
B) hydrophobic molecules.
C) specific lipids.
D) specific oligosaccharides.
E) specific peptides.

Short Answer Questions

20. Monosaccharides and disaccharides
Page: 238 Difficulty: 1
Explain why all mono- and disaccharides are soluble in water.

Ans: These compounds have many hydroxyl groups, each of which can hydrogen bond with water. (See chapter 4.)

21. Monosaccharides and disaccharides
Pages: 239-240 Difficulty: 2
This compound is L-glyceraldehyde. Draw a stereochemically correct representation of C-1 and C-2 of D-glucose.

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      CHO
       |
 HO—C—H
       |
      CH2OH
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Ans: In D-glucose, the positions of the —H and —OH on C-2 are the reverse of those for C-2 of L-glyceraldehyde. (Compare Fig. 7-1, p. 239, with Fig. 7-2, p. 240.)

22. Monosaccharides and disaccharides
Pages: 239-245 Difficulty: 2
Define each in 20 words or less:

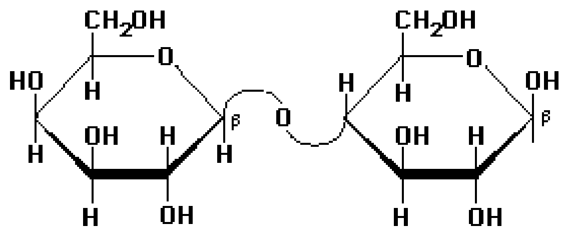
(a) anomeric carbon;
(b) enantiomers;
(c) furanose and pyranose;
(d) glycoside;
(e) epimers;
(f) aldose and ketose.

Ans: (a) The anomeric carbon is the carbonyl carbon atom of a sugar, which is involved in ring formation. (b) Enantiomers are stereoisomers that are nonsuperimposable mirror images of each other. (c) Furanose is a sugar with a five-membered ring; pyranose is a sugar with a six-membered ring. (d) A glycoside is an acetal formed between a sugar anomeric carbon hemi-acetal and an alcohol, which may be part of a second sugar. (e) Epimers are stereoisomers differing in configuration at only one asymmetric carbon. (f) An aldose is a sugar with an aldehyde carbonyl group; a ketose is a sugar with a ketone carbonyl group.

23. Monosaccharides and disaccharides
Pages: 240-243 Difficulty: 3
(a) Draw the structure of any aldohexose in the pyranose ring form. (b) Draw the structure of the anomer of the aldohexose you drew above. (c) How many asymmetric carbons (chiral centers) does each of these structures have? (d) How many stereoisomers of the aldohexoses you drew are theoretically possible?

Ans: (a) Any of the hexoses drawn with a six-membered ring, as shown in Fig. 7-7 on p. 243, is correct. The hydroxyls at C-2, C-3, and C-4 can point either up or down. (b) For the anomer, the structure should be identical to the first, except that the hydroxyl group at C-1 should point up if it pointed down in your first structure, and vice versa. (c) The number of chiral centers is 5; all are carbons except C-6. (d) The number of possible stereoisomers for a compound with *n* chiral centers is 2^n; in this case, 2^5, or 32 possible isomers.

24. Monosaccharides and disaccharides
Pages: 243-246 Difficulty: 2
In the following structure:



(a) How many of the monosaccharide units are furanoses and how may are pyranoses? (b) What is the linkage between the two monosaccharide units? (c) Is this a reducing sugar?
Explain.

Ans: (a) 2 pyranoses; (b) $\beta 1 \rightarrow 4$; (c) Yes. There is a free anomeric carbon on one of the monosaccharide units that can undergo oxidation.

25. Monosaccharides and disaccharides
Pages: 244-246 Difficulty: 3
(a) Define "reducing sugar." (b) Sucrose is a disaccharide composed of glucose and fructose (Glc($\alpha 1 \rightarrow 2$)Fru). Explain why sucrose is not a reducing sugar, even though both glucose and fructose are.

Ans: (a) A reducing sugar is one with a free carbonyl carbon that can be oxidized by Cu^{2+} or Fe^{3+}. (b) The carbonyl carbon is C-1 of glucose and C-2 of fructose. When the carbonyl carbon is involved in a glycosidic linkage, it is no longer accessible to oxidizing agents. In sucrose (Glc($\alpha 1 \rightarrow 2$)Fru), both oxidizable carbons are involved in the glycosidic linkage.

26. Polysaccharides
Pages: 245-255 Difficulty: 2
Match these molecules with their biological roles.

(a) glycogen	__ viscosity, lubrication of extracellular secretions
(b) starch	__ carbohydrate storage in plants
(c) trehalose	__ transport/storage in insects
(d) chitin	__ exoskeleton of insects
(e) cellulose	__ structural component of bacterial cell wall
(f) peptidoglycan	__ structural component of plant cell walls
(g) hyaluronate	__ extracellular matrix of animal tissues
(h) proteoglycan	__ carbohydrate storage in animal liver

Ans: g; b; c; d; f; e; h; a

27. Polysaccharides
Pages: 248-249 Difficulty: 2
The number of structurally different polysaccharides that can be made with 20 different monosaccharides is far greater than the number of different polypeptides that can be made with 20 different amino acids, if both polymers contain an equal number (say 100) of total residues. Explain why.

Ans: Because virtually all peptides are linear (i.e., are formed with peptide bonds between the α-carboxyl and α-amino groups), the variability of peptides is limited by the number of different subunits. Polysaccharides can be linear or branched, can be α- or β-linked, and can be joined $1 \rightarrow 4$, $1 \rightarrow 3$, $1 \rightarrow 6$, etc. The number of different ways to arrange 20 different sugars in a branched oligosaccharide is therefore much larger than the number of different ways a peptide could be made with an equal number of residues.

28. Polysaccharides
Page: 248 Difficulty: 2
Describe one biological advantage of storing glucose units in *branched* polymers (glycogen, amylopectin) rather than in linear polymers.

Ans: The enzymes that act on these polymers to mobilize glucose for metabolism act only on their nonreducing ends. With extensive branching, there are more such ends for enzymatic attack than would be present in the same quantity of glucose stored in a linear polymer. In effect, branched polymers increase the substrate concentration for these enzymes.

29. Polysaccharides
Pages: 248-249 Difficulty: 2
Explain how it is possible that a polysaccharide molecule, such as glycogen, may have only one reducing end, and yet have many nonreducing ends.

Ans: The molecule is branched, with each branch ending in a nonreducing end. (See Fig. 9-15c, p. 305.)

30. Polysaccharides
Page: 248 Difficulty: 2
What is the biological advantage to an organism that stores its carbohydrate reserves as starch or glycogen rather than as an equivalent amount of free glucose?

Ans: The polymers are essentially insoluble and contribute little to the osmolarity of the cell, thereby avoiding the influx of water that would occur with the glucose in solution. They also make the uptake of glucose energetically more feasible than it would be with free glucose in the cell.

31. Polysaccharides
Page: 249 Difficulty: 3
Draw the structure of the repeating basic unit of (a) amylose and (b) cellulose.

Ans: (a) For the structure of amylose, see Fig. 9-15a, p. 305. The repeating unit is α-D-glucose linked to α-D-glucose; the glycosidic bond is therefore ($\alpha 1 \rightarrow 4$). (b) Cellulose has the same structure as amylose, except that the repeating units are β-D-glucose and the glycosidic bond is ($\beta 1 \rightarrow 4$). (See Fig. 9-17a, p. 307.)

32. Polysaccharides
Page: 250 Difficulty: 2
Explain in molecular terms why humans cannot use cellulose as a nutrient, but goats and cattle can.

Ans: The ruminant animals have in their rumens microorganisms that produce the enzyme cellulase, which splits the ($\beta 1 \rightarrow 4$) linkages in cellulose, releasing glucose. Humans do not produce an enzyme with this activity; the human digestive enzyme α-amylase can split only ($\alpha 1 \rightarrow 4$) linkages (such as those in glycogen and starch).

33. Polysaccharides
Page: 253 Difficulty: 2
The glycosaminoglycans are negatively charged at neutral pH. What components of these polymers confer the negative charge?

Ans: Uronic acids such as glucuronic acid, and sulfated hydroxyl groups, such as GalNAc4SO_3^- and GlcNAc6SO_3^-. (See Fig. 7-24, p. 253.)

34. Glycoconjugates: proteoglycans, glycoproteins, and glycolipids
Page: 256 Difficulty: 3
Sketch the principal components of a typical proteoglycan, showing their relationships and connections to one another.

Ans: A typical proteoglycan consists of a core protein with covalently attached glycosaminoglycan polysaccharides, such as chondroitin sulfate and keratin sulfate. The polysaccharides generally attach to a serine residue in the protein via a trisaccharide (gal–gal–xyl). (See Fig. 7-26, p. 256.)

35. Glycoconjugates: proteoglycans, glycoproteins, and glycolipids
Page: 256 Difficulty: 3
Describe the differences between a proteoglycan and a glycoprotein.

Ans: Both are made up of proteins and polysaccharides. In proteoglycans, the carbohydrate moiety dominates, constituting 95% or more of the mass of the complex. In glycoproteins, the protein constitutes a larger fraction, generally 50% or more of the total mass.

36. Glycoconjugates: proteoglycans, glycoproteins, and glycolipids
Pages: 257-258 Difficulty: 2
Describe the structure of a proteoglycan aggregate such as is found in the extracellular matrix.

Ans: A proteoglycan aggregate is a supramolecular assembly of proteoglycan monomers. Each monomer consists of a core protein with multiple, covalently linked polysaccharide chains. Hundreds of these monomers can bind noncovalently to a single extended molecule of hyaluronic acid to form large structures.

37. Glycoconjugates: proteoglycans, glycoproteins, and glycolipids
Page: 259 Difficulty: 2
What are some of the biochemical effects of the oligosaccharide portions of glycoproteins?

Ans: Hydrophilic carbohydrates can alter the polarity and solubility of the proteins. Steric and charge interactions may influence the conformation of regions of the polypeptide and protect it from proteolysis.

38. Carbohydrates as informational molecules: the sugar code
Pages: 262-263 Difficulty: 3
Describe the process by which "old" serum glycoproteins are removed from the mammalian circulatory system.

Ans: Newly synthesized serum glycoproteins bear oligosaccharide chains that end in sialic acid. With time, the sialic acid is removed. Glycoproteins that lack the terminal sialic acid are recognized by asialoglycoprotein receptors in the liver, internalized, and destroyed.

39. Carbohydrates as informational molecules: the sugar code
Pages: 262-266 Difficulty: 2
What are lectins? What are some biological processes which involve lectins?

Ans: Lectins are proteins that bind to specific oligosaccharides. They interact with specific cell-surface glycoproteins thus mediating cell-cell recognition and adhesion. Several microbial toxins and viral capsid proteins, which interact with cell surface receptors, are lectins.