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CORRECT ANSWERS ARE LOCATED IN THE 2ND HALF OF THIS DOC.

MULTIPLE CHOICE - Choose the one alternative that best completes the statement or answers the question.

1) If an element has an atomic number of 12, how many electrons are in its outermost shell?
   A) 1
   B) 10
   C) 8
   D) 2
   E) 12

2) The nucleus of an atom contains
   A) neutrons and electrons.
   B) electrons only.
   C) protons, neutrons, and electrons.
   D) protons and neutrons.
   E) neutrons only.

3) Which of the following subatomic particles will be found orbiting the nucleus of the atom?
   A) protons and neutrons
   B) only electrons
   C) electrons and neutrons
   D) only neutrons
   E) only protons

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4) If an element has an atomic number of 15, then
   A) the atomic mass must also be 15.
   B) the atom has 15 electrons.
   C) there are 7 electrons in the outermost shell.
   D) the atom has 15 neutrons.
   E) the atom must have only one orbital.

5) The chemical reactivity of an element is dependent on
   A) the number of protons.
   B) the arrangement of neutrons.
   C) the number of electrons in the outermost shell.
   D) the number of protons and neutrons.
   E) the number of electrons in the inner shell.

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6) The atomic mass of an element
   A) is determined by the number of protons and neutrons contained in the nucleus.
   B) equals the number of protons plus the number of electrons.
   C) equals the number of neutrons.
   D) changes after each reaction.
   E) depends on the number of electrons in the outermost shell.

7) Isotopes of a given element have
   A) the same number of protons but differ in atomic mass.
   B) the same atomic mass but a different number of protons.
   C) a different number of electrons.
   D) the same number of protons and atomic mass.
   E) the same number of neutrons.

8) The isotope shown below has
   $^{14}_{6}C$
   A) 14 electrons.
   B) 6 neutrons.
   C) 8 protons.
   D) 8 neutrons.
   E) 8 electrons.

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9) To measure the activity of the human brain during certain thought processes, a short-lived radioactive sugar is injected in the carotid artery and is utilized by those cells that are most active. This shows up on a PET scan and demonstrates the detection of
   A) ionic bonds.
   B) high levels of radiation.
   C) covalent bonds.
   D) neutrons.
   E) isotopes.

10) The two isotopes shown below differ in the number of
   $^{12}_{6}C$ $^{14}_{6}C$
   A) electrons.
   B) protons.
   C) neutrons.
   D) carbon atoms.
   E) ionic bonds.

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11) Which of the following is an example of a compound?
A) O_2
B) Cl
C) H_2
D) $C_6H_{12}O_6$
E) Na^+

12) Which of the following statements is true of chemical bonds?
A) Both ionic and covalent bonds involve electrons in the innermost shell.
B) Covalent bonds share electrons between two atoms.
C) An atom involved in an ionic bond has an equal number of electrons and protons.
D) Salts are covalently bonded.
E) The atoms in a molecule of water (H_2O) are bonded together with ionic bonds.

13) An ion is an atom that
A) exists in a gaseous state.
B) has a net charge.
C) does not have a net charge.
D) shares electrons with other atoms.
E) shares neutrons with other atoms.

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14) If neutral atoms become positive ions, they
A) gain electrons.
B) lose electrons.
C) gain protons.
D) lose protons.
E) do not change.

15) When an ionic bond forms, electrons are
A) lost from both atoms.
B) gained by both atoms.
C) shared equally by both atoms.
D) totally lost from the paired atoms.
E) transferred from one atom to another.

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16) Calcium chloride, $CaCl_2$, is an ionic compound in which
A) one chlorine atom transferred an electron to the other chlorine atom.
B) each chlorine atom has lost electrons.
C) calcium has two extra electrons in its innermost shell.
D) calcium has gained two electrons.
E) calcium has lost two electrons.

17) A covalent bond is
A) a type of bond that results in ionic compounds.
B) formed from the transfer of electrons from one atom to another.
C) a sharing of electrons between two atoms.
D) an attraction of charged atoms.
E) a sharing of protons between two atoms.

18) Potassium, a metal with one electron in the outermost shell, will react with how many chlorine atoms? (Chlorine is a nonmetal with seven electrons in the outermost shell.)
A) 5
B) 7
C) 1
D) 2
E) 3

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19) Polar covalent bonds result from
A) unequal sharing of electrons in a covalent bond.
B) equal sharing of electrons in a covalent bond.
C) equal sharing of electrons in an ionic bond.
D) unequal sharing of electrons in an ionic bond.
E) hydrogen bonding between molecules.

20) Which of the following statements about hydrogen bonding is correct?
A) Hydrogen bonding occurs only between water molecules.
B) Hydrogen bonds are difficult to break.
C) Hydrogen bonding can occur between different molecules or within the same molecule.
D) Hydrogen bonding is only common among small molecules.
E) Hydrogen bonding is usually represented by a solid line between atoms.

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21) Which of the following is a property of water that results from hydrogen bonding?
A) The temperature of water changes very quickly.
B) Many nonpolar substances dissolve in water.
C) Water molecules are cohesive.
D) Water is densest at 0°C.
E) Water has a low surface tension.

22) Water is a liquid at room temperature. This is due to
A) ionic bonding of the atoms in the water molecule.
B) covalent bonding in the water molecule.
C) covalent bonding between water molecules.
D) hydrogen bonding within the water molecule.
E) hydrogen bonding between water molecules.

23) The moon lacks life and varies dramatically in temperature. If we could keep a layer of water spread on the surface of the moon, what effect would it have?
A) Life would be possible but it would have to withstand these extremes in temperature.
B) Water would absorb and hold heat and moderate the temperature extremes.
C) The temperatures would drop to the lower extremes.
D) Because water has a high heat of vaporization, the temperatures would rise to the upper extremes.
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E) Physical conditions would remain the same.

24) In water, a weak hydrogen bond occurs between a hydrogen in one molecule and
A) an oxygen atom in the same molecule.
B) an oxygen atom in a different molecule.
C) a hydrogen atom in the same molecule.
D) a hydrogen atom in a different molecule.
E) either hydrogen and oxygen atoms of different molecules.

25) You notice that rain water forms "beads" on your car. This is an example of what property of water?
A) cohesion
B) dissociation
C) high heat of vaporization
D) adhesion
E) solvent

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26) Hydrogen bonding produces which of the following properties of water?
A) Water boils at a lower temperature than expected.
B) Ice is less dense than liquid water.
C) Water absorbs heat with a large change in temperature.
D) Water releases heat with a large change in temperature.
E) Land areas with an abundance of water have more extreme temperatures than land areas that are lacking water.

27) The water strider is an insect that skates across the water without sinking. The tips of its feet must be coated with molecules that are
A) ions.
B) hydrophilic.
C) hydrophobic.
D) basic.
E) acidic.

28) The lower the pH
A) the lower the hydrogen ion (H^+) concentration.
B) the more acidic the solution.
C) the higher the pH.
D) the greater the hydroxide ion (OH^-) concentration.
E) the closer the hydroxide ion (OH^-) concentration comes to equaling the hydrogen ion (H^+) concentration.

29) Since pure water is neutral in pH, it contains
A) no hydrogen ions (H^+).
B) no hydroxide ions (OH^-).
C) neither hydrogen ions (H^+) nor hydroxide ions (OH^-).
D) an equal number of hydrogen ions (H^+) and hydroxide ions (OH^-).
E) seven times more hydrogen ions (H^+) than hydroxide ions (OH^-).

30) The pH of blood is slightly alkaline. Which of the following would therefore be an expected pH for blood?
A) 6.4
B) 4.6
C) 4.7
D) 7.4
E) 13.8

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31) Potassium hydroxide (KOH) almost completely dissociates in aqueous solution into K^+ and OH^-, which means it is a(n)
A) acid.
B) base.
C) has no effect on pH.
D) polar covalent molecule.
E) nonpolar covalent molecule.

32) Which statement regarding acids and bases is correct?
A) Acids increase the pH, and bases decrease the pH.
B) Acids increase the proportion of hydrogen ions (H^+), and bases reduce the proportion of H^+.
C) Acids are harmful, but bases are not harmful.
D) Acids combine with bases to form buffers.
E) Acids combine with bases to form sugars.

33) Buffers
A) are strong acids or bases.
B) keep the pH within normal limits.
C) release large amounts of hydrogen ions (H^+).
D) will only lower the pH.
E) will only increase the pH.

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34) Aspirin is acetyl salicylic acid and can therefore pose a problem to people who have ulcers. Bufferin is an alternative to aspirin that uses a buffer to neutralize this effect by
A) substituting another ingredient for the acetyl salicylic acid.
B) adding a drug to stimulate the immune system.
C) adding salts to neutralize the acid.
D) adding an equal amount of hydroxide (OH^-) ions.
E) adding chemicals that take up excess hydrogen (H^+) or hydroxide (OH-) ions.

35) Rain falling in the northeastern United States has a pH between 5.0 and 4.0. Normally, rainwater has a pH of about 5.6. Which of the following statements is correct?
A) The pH of the rainwater has changed from neutral to acidic.
B) The pH of the rainwater has become more acidic.
C) The hydrogen ion (H^+) content of the rainwater has decreased.
D) The proportion of hydroxide ions (OH^-) in the rainwater has increased.
E) The rainwater with a pH of 4.0 is a thousand times more acidic than the rainwater with a pH of 5.0.

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36) Organic molecules
A) always contain carbon.
B) always contain hydrogen.
C) always contain carbon and hydrogen.
D) are found only in organisms, hence their name.
E) are always food molecules.

37) Which of the following molecules is inorganic?
A) CH_4
B) CO_2
C) $C_6H_{12}O_6$
D) $C_{12}H_{22}O_{12}$
E) C_6H_6

38) One carbon atom can form covalent bonds with up to___ other atoms to form an organic molecule.
A) 2
B) 3
C) 4
D) 6
E) 8

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39) Two molecules of glucose combine to form a disaccharide molecule during a(n)_____ reaction.
A) dehydration
B) hydrolysis
C) hydrogen bond
D) ionic bond
E) inert

40) A genetic mutation can cause a change in the sequence of the 20 amino acids used to build proteins. Such a change is a change to the protein's
A) primary structure only.
B) secondary structure only.
C) tertiary structure only.
D) primary structure, but this will likely alter higher levels of structure as well.
E) quaternary structure only.

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41) Glycogen is a
A) monosaccharide used for quick energy.
B) protein found in cell membranes.
C) polysaccharide used to store glucose/energy.
D) fat found in margarine.
E) nucleic acid found in the nucleus of a cell.

42) Why is maltose is classified as a disaccharide?
A) Maltose is classified as a disaccharide because it consists of just one single sugar molecule.
B) Maltose is classified as a disaccharide because it consists of two monosaccharides that were joined by a dehydration reaction.
C) Maltose is classified as a disaccharide because it consists of a long chain of glucose molecules bonded together by dehydration reactions.
D) Maltose is classified as a disaccharide because it forms the main structural framework of plant cell walls.

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43) All carbohydrate molecules
A) contain amino acids.
B) contain nitrogen and phosphate.
C) are organic acids.
D) are composed of atoms of C, H, and the functional group -OH.
E) are composed of atoms of C, H, O, and N.

44) When two glucose molecules combine, they form a disaccharide molecule and
A) another glucose molecule.
B) another disaccharide molecule.
C) a dipeptide molecule.
D) a lipid molecule.
E) a water molecule.

45) ____ is a polysaccharide that is found in plant cell walls and accounts for their strength.
A) Cellulose
B) Chitin
C) Glycogen
D) Starch
E) Cholesterol

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46) Hydrolysis of a fat results in
- A) glycerol only.
- B) fatty acids only.
- C) glucose only.
- D) two monosaccharides.
- E) both glycerol and fatty acids.

47) A long chain of carbon atoms with hydrogen atoms attached, ending in the acidic group -COOH would be a(n)
- A) triglyceride.
- B) amino acid.
- C) fatty acid.
- D) nucleic acid.
- E) monosaccharide.

48) Nucleic acids are polymers of
- A) amino acids.
- B) nucleotides.
- C) glycerol.
- D) monosaccharides.
- E) fatty acids.

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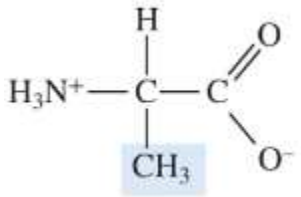
49) The molecular structure shown here is



- A) a glucose molecule.
- B) a fatty acid molecule.
- C) a glycerol molecule.
- D) a protein molecule.
- E) an amino acid.

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50) Enzymes are organic compounds classified as
A) nucleic acids.
B) carbohydrates.
C) lipids.
D) steroids.
E) proteins.

51) The_____ structure of a protein consists of a strand of amino acids forming an alpha helix or pleated sheet.
A) primary
B) secondary
C) tertiary
D) quaternary
E) molecular

52) Hemoglobin is a protein composed of two pairs of polypeptide chains. What is the highest level of protein structure represented by hemoglobin?
A) primary
B) secondary
C) tertiary
D) quaternary
E) molecular

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53) The proposed cause of CJD and kuru in humans, mad cow disease, and scrapie in sheep is a change in a brain protein. Disease victims appear to have a protein that should normally contain alpha helices but instead they have changed into a protein made of beta pleated sheets. The disease appears to spread when the abnormal protein comes into contact with the normal protein, causing it to become deformed. Which level of protein structure is associated with these diseases?
A) primary
B) secondary
C) tertiary
D) quaternary
E) molecular

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54) Which of these combinations would be found in a nucleotide?
A) base-acid-salt
B) adenine-thymine-uracil
C) base-sugar-phosphate
D) DNA-RNA-nucleus
E) sugar-protein-fat

55) The backbone of a nucleic acid strand is composed of
A) glycerol.
B) *R* groups.
C) nitrogenous bases.
D) alternating pentose sugars and phosphate groups.
E) alternating adenines and thymines.

56) In the search to discover the agents that cause mad cow disease, scrapie in sheep, and CJD and kuru in humans, diseased brain tissues were passed through a fine filter to remove bacteria. The filtrate was still infectious, indicating that something smaller than bacteria must be the causative agent. If a virus was responsible for these brain diseases, then the infectious agent would contain either RNA or DNA. Other possibilities were that the agent was a carbohydrate, fat, or protein. Tissue filtrates were treated with agents that destroyed just one of these chemicals and then injected into a healthy animal, with the results as follows. What is the infectious agent?

•Amylase digests carbohydrates; tissue filtrate still infects healthy test animal.
•Lipase digests fats; tissue filtrate still infects healthy test animal.
•Formaldehyde and/or heat denatures DNA and RNA; tissue filtrate still infects healthy test animal.
•Trypsin digests protein; tissue filtrate does not infect healthy test animal.
A) carbohydrate
B) fat
C) protein
D) DNA or RNA
E) carbohydrate, fat, or DNA or RNA; but not protein

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57) The final shape of a protein is very important to its function. When proteins undergo an irreversible change in shape called_____ they_____ perform their usual functions.
A) naturation; can
B) naturation; cannot
C) denaturation; can
D) denaturation; cannot
E) dehydration reaction; cannot

58) The primary function of carbohydrates is
A) quick fuel and short-term energy storage.
B) structural reinforcement of plant and fungal cell walls.
C) encoding the hereditary information.
D) to speed chemical reactions in cells.
E) to transport molecules across cell membranes.

59) Which of the following types of lipids is the most abundant constituent of cell membranes?
A) cholesterol
B) phospholipid
C) triglyceride
D) neutral fat
E) fat

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60) Which type of lipid molecule is characterized by a backbone of four fused rings?
A) DNA
B) phospholipid
C) triglyceride
D) steroid
E) amino acid

61) Which statement about DNA and RNA is correct?
A) DNA is single-stranded, and RNA is double-stranded.
B) The sugar in DNA is ribose, and in RNA the sugar is deoxyribose.
C) RNA has a helix shape; DNA does not.
D) The base uracil is unique to RNA and the base thymine unique to DNA.
E) DNA is a nucleotide polymer while RNA is a carbohydrate polymer.

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62) Which of the following radioactive isotopes are used to detect whether or not an individual has a healthy thyroid?
A) I^{131}
B) C^{14}
C) glucose
D) H_2

63) Which of the following radiation uses is the one that is most likely to have both beneficial and harmful consequences?
A) using radiation to treat a cancer patient
B) using radiation to sterilize mail
C) using radiation to sterilize surgical equipment prior to a surgery
D) radiating fruits and vegetables prior to storage

64) A hydrogen bond will form between two water molecules when
A) a slightly positive hydrogen on one water molecule becomes attracted to another slightly positive hydrogen on another water molecule.
B) a slightly negative oxygen on one water molecule becomes attracted to another slightly negative oxygen on another water molecule.
C) a water molecule transfers an electron to another water molecule.
D) a slightly positive hydrogen on one water molecule becomes attracted to a slightly negative oxygen on another water molecule.
E) a water molecule shares a pair of electrons with another water molecule.

65) Which of the following sequences correctly lists the bonds in order of strongest to weakest?
A) double covalent - single covalent - ionic - hydrogen
B) single covalent - double covalent - ionic - hydrogen
C) ionic - double covalent - single covalent - hydrogen
D) hydrogen - double covalent - single covalent - ionic
E) double covalent - single covalent - hydrogen - ionic

66) Which type of bond formation is responsible for the properties of lipids?
A) hydrogen
B) polar covalent
C) ionic
D) nonpolar covalent

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67) Which functional group(s) is/are associated with a dehydration reaction?
- A) OH
- B) SH
- C) OH and NH
- D) SH and OH
- E) COOH and SH

68) Which of the following functional groups is present in nucleic acids but not amino acids
- A) sulfhydryl
- B) amino
- C) carboxyl
- D) hydroxyl
- E) phosphate

69) Removal of the sulfhydryl functional group would disrupt the structure of
- A) sugars and some amino acids.
- B) sugars.
- C) fatty acids.
- D) proteins.
- E) nucleotides and fatty acids.

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70) Which of the following reactions is most likely to occur if an individual was to ingest a large dose of lemon juice?
- A) There would be an increase in the amount of carbonic acid within the bloodstream. If the carbonic acid did not form, then the pH of the individual's blood could shift toward 7.2.
- B) There would be an increase in the amount of carbonic acid within the bloodstream. If the carbonic acid did not form, then the pH of the individual's blood could shift toward 7.8.
- C) There would be a decrease in the amount of carbonic acid within the bloodstream. If the carbonic acid did not form, then the pH of the individual's blood could shift toward 7.2.
- D) There would be a decrease in the amount of carbonic acid within the bloodstream. If the carbonic acid did not form, then the pH of the individual's blood could shift toward 7.8.

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71) All of the following describe major functions of lipids except
A) fats function as energy storage molecules.
B) phospholipids form the cell membranes and inner compartments of cells.
C) steroids include the sex hormones.
D) oils function as enzymes, controlling most of the metabolic reactions in cells.

72) During the formation of a polymer, two monomers are joined by the removal of
A) OH and H.
B) OH and SH.
C) H and COH.
D) COOH and SH.
E) NHH and COOH.

73) Cholesterol is a component of cell membranes and is an example of which type of lipid?
A) steroids
B) phospholipids
C) fatty acids
D) triglycerides
E) oils

74) What type of reaction is necessary to produce a dipeptide from individual amino acids?
A) dehydration reaction
B) hydrolysis reaction
C) denaturation
D) Dipeptides are not formed from amino acids.

75) Determine what would happen to an individual's proteins if they developed a fever of 103° F for several days.
A) The proteins would denature due to the increase in body temperature and would become unable to function correctly.
B) The proteins would increase in their ability to perform their functions because of the increase in body temperature.
C) Nothing would happen to the proteins as a result of the increase in temperature.
D) The proteins would denature due to the increase in body temperature and would increase in their ability to function correctly.
E) One protein would alter in shape, which would then cause the next protein to alter in shape which would cause a third protein to alter in shape and so forth until all of the proteins were altered in shape.

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76) Which group of lipids forms a barrier around cells?
A) phospholipids
B) steroids
C) triglycerides
D) saturated acids
E) trans-fatty acids

77) Which nutrient source is the easiest one for humans to break down and form ATP?
A) glucose
B) protein
C) cellulose
D) phospholipids
E) chitin

78) All of the following are cellular functions of ATP except
A) conduction of nerve impulses.
B) contraction of muscle cells.
C) synthesis of macromolecules.
D) energy currency of the cell.
E) primary constituent of the cell membrane.

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79) When ATP is broken down into ADP:
A) Energy is consumed.
B) All three phosphate bonds are broken and energy is consumed.
C) All three phosphate bonds are broken and energy is released.
D) Two of the phosphate bonds are broken and energy is released.
E) The terminal phosphate bond is broken and energy is released.

80) What type of bond will connect the amino acids in a protein?
A) peptide
B) triple covalent
C) polar covalent
D) ionic
E) double covalent

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Answer Key

Test name: Chapter 02

1) D
Two electrons fill the innermost shell and eight fill the next, leaving two for the outermost shell.

2) D
The nucleus contains protons and neutrons; electrons orbit the nucleus.

3) B
The nucleus of an atom will contain the protons and neutrons. Electrons are found in the electron orbitals that orbit the nucleus.

4) B
In an electrically neutral atom, the number of protons (the atomic number) is the same as the number of electrons. The atom would need three orbitals to accommodate 15 electrons, and there would be 5 electrons in its outermost shell. The atomic mass includes the protons and the neutrons; the number of neutrons is not specified in this question.

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5) C
It is the outermost shell of an atom that can potentially react with electrons in the outermost shells of other atoms. The protons and neutrons remain in the nucleus and do not engage in chemical reactions.

6) A
The atomic mass is essentially the sum of protons and neutrons in the nucleus; it is not changed by chemical reactions. The mass of electrons is negligible.

7) A
Isotopes are atoms of the same element that differ in the number of neutrons only; thus, they have the same atomic number but different atomic masses.

8) D
Carbon 14 has 8 neutrons, 6 protons (and thus 6 electrons), and an atomic mass of 14.

9) E
The isotopes used in PET scans constitute a low level of radiation used for beneficial purposes. Types of chemical bonds are not registered by this procedure. Although isotopes of a given element differ in their numbers of neutrons, neutrons are not detected by PET.

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10) C
Carbon 12 and carbon 14 are different isotopes of the element carbon; this means they have the same number of protons and electrons, but they differ in the number of neutrons. The number of bonds an isotope can form is not determined by its neutrons.

11) D
A compound consists of atoms of two or more different elements bound together. $C_6H_{12}O_6$ (glucose) is the only answer given that contains two or more different elements.

12) B
Covalently bonded atoms share electrons. All the other answer choices are false statements.

13) B
An ion has more or less electrons than a neutral atom of the same element, so it has a net positive (fewer electrons) or negative charge (more electrons).

14) B
The electron transfer is what will determine if an atom becomes a positive or negative ion. To become a positive ion an atom will need to lose electrons so there are more protons than electrons.

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15) E
Ionic compounds form when one atom gives up an electron, which is accepted by the other member of the pair. Now that one atom is a positively charged ion and the other is a negatively charged ion, the two **ion**s are attracted to one other.

16) E
In the ionic compound $CaCl_2$, calcium has transferred two electrons from its outermost shell, becoming a calcium ion (Ca^{2+}). One of the electrons has been accepted by each chlorine atom, so they become chloride ions (Cl^-).

17) C
A covalent bond results when two atoms share electrons in such a way that each atom has eight electrons in its outermost shell. In contrast, ionic compounds result from the complete transfer of electrons between bonded atoms.

18) C

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Potassium will attain stability by transferring the one electron in its outermost shell to chlorine, which needs only one more electron in its outermost shell to become stable. The result will be a potassium ion (K^+) and a chloride ion (Cl^-). The two oppositely charged ions will be attracted to one another, thus forming an ionic compound.

19) A
Covalent bonds result from the sharing of electrons between bound atoms; when the sharing is unequal, it is a polar bond, and when the sharing is equal, it is a nonpolar bond. Ionic bonds are a different type of chemical bond from covalent bonds; in an ionic bond, one or more electrons are completely transferred from one member of the compound to the other(s). Hydrogen bonding is a relatively weak attraction between hydrogen in one molecule and a highly electronegative atom (such as O or N) in an adjacent molecule.

20) C
Hydrogen bonding is not limited to bonding between adjacent water molecules. For example, hydrogen bonds can form between hydrogen in water and nitrogen in ammonia, or between the two strands of a DNA molecule. Hydrogen bonds are important in determining the shape of large, complex molecules such as proteins. Even so, hydrogen bonds are relatively weak when compared to ionic or covalent bonds, and are easily broken. Because they are weak, they are represented by dotted lines between atoms.

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21) C
Since a water molecule is polar covalently bonded, it has partial charges. The oxygen atom has a partial negative charge and the hydrogen atoms have partial positive charges. When the partial charges in one water molecule become attracted to the partial charges in another water molecule, a hydrogen bond results. *This attraction of water molecules to one another is termed* cohesiveness. Because water molecules are charged, they are attracted to many substances with charges such as ionic and polar substances. This attraction gives water molecules the ability to dissolve these substances. Nonpolar substances lack charges, are not attractive to water and do not dissolve in water. The vast number of hydrogen bonds that form in a body of water impart many special properties such as high surface tension and the ability to resist temperature change. Hydrogen bonds also affect the density of water and it is most dense at 4°C.

22) E
Hydrogen bonding between water molecules keeps water in a liquid state at temperatures typically found on the earth's surface, including room temperature. Water molecules do not covalently bond to one another, and the water molecule is too small to permit intramolecular hydrogen bonds to form. Water molecules do ionize, but this does not influence the fluid nature of water.

23) B

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Water has a high heat capacity; this serves to moderate temperature changes. Although water does have a high heat of vaporization, this also has a moderating effect, and would prevent temperatures from rising to the highest extremes.

24) B
Because water molecules are polar, and each oxygen has slight negative charge and the hydrogen a slight positive charge, hydrogen bonding occurs between a hydrogen atom of one water molecule and the oxygen of another.

25) A
The formation of water beads on the surface of a car is due to the cohesiveness of water molecules for one another, thanks to hydrogen bonding. Adhesion is attraction of water molecules for a surface—a property that is not demonstrated here, since the surface of the car (especially a freshly waxed car) repels the water. The high heat of vaporization and solvent capabilities of water are not apparent in this example. Water does dissociate into ions, but this does not manifest in the formation of beads.

26) B
Due to the increased stability of hydrogen bonding at lower temperatures, water is less dense as ice than as liquid water. Because water can absorb and release heat with a relatively small change in temperature, it is a great moderator of temperature. This means that areas with an abundance of water have less extreme temperature shifts than areas lacking water. Water boils at 100°C; without hydrogen bonding, it would boil at -91°C.

27) C
The water strider's feet should be coated with hydrophobic molecules to repel water; a hydrophilic coating would cause the insect to stick to the surface of the water and sink. Ions, acids, and bases are hydrophilic.

28) B
The pH scale is based on hydrogen ion (H^+) concentration. The higher the concentration of H^+ (and the lower the concentration of OH^-, hydroxide), the lower the pH, and the more acidic the solution.

29) D
Pure water is neutral, with a pH of 7 (midway between 0 and 14 on the pH scale), meaning that it has equal concentrations of hydrogen ions (H^+) and hydroxide ions (OH^-).

30) D

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The pH scale ranges from 0 to 14, with 7 being neutral. Numbers lower than 7 are acidic, and those higher than 7 are basic. Thus, a pH of 7.4 would be slightly basic.

31) B
Because potassium hydroxide dissociates and adds hydroxide ions (OH^-) to an aqueous solution, it is a base. An acid would contribute hydrogen ions (H^+) to an aqueous solution. Potassium hydroxide is an ionic compound not a covalent molecule. A nonpolar covalent molecule would not dissociate or dissolve in an aqueous solution.

32) B
Acids raise the hydrogen ion (H^+) content of a solution, while bases reduce the proportion of H^+. The lower the pH, the more acidic the solution, and the higher the pH, the more basic the solution. Strong acids and bases are both harmful. When acids combine with bases, salts result.

33) B
Buffers are the chemicals or combinations of chemicals that keep pH within normal limits. Weak acids and bases may be used as buffers, not strong ones, which would greatly influence the H^+ concentration of the solution and thereby raise or lower the pH.

34) E
Bufferin contains a buffering system to bind the excess H^+ from the aspirin (acetyl salicylic acid). This would not be a salt; salts form when acids and bases react.

35) B
The pH of rainwater is normally acidic (5.6);, not neutral (7); and, therefore, rain with a pH between 5 and 4 is more acidic than normal rainwater. Since rain with a pH between 5 and 4 is more acidic, it contains more H^+ and fewer OH^-. Rain with a pH of 4 would be 10 times more acidic than rain with a pH of 5.

36) C
Organic molecules, by definition, must contain both carbon and hydrogen. They are found in organisms and in food, but can also be made in a laboratory.

37) B
Carbon dioxide (CO_2) is inorganic because, although it contains carbon, it does not contain hydrogen. All the other molecules contain both carbon and hydrogen and are therefore organic.

38) C
Carbon, with an atomic number of 6, has 4 electrons in its outermost shell. Thus, carbon can form 4 single covalent bonds with other atoms.

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39) A
The glucose molecules are monomers; forming a covalent bond between them requires a dehydration reaction. A hydrolysis reaction could be used to break the disaccharide apart into individual glucose monomers. An inert material would not react at all.

40) D
A mutation (a change in a DNA sequence) may directly alter the primary structure of a protein, since this is the sequence of amino acids in the chain. However, the primary level of structure dictates the higher levels of structure—secondary, tertiary, and even quaternary—so these may be indirectly affected as a result of the mutation.

41) C
Glycogen (a polysaccharide) is the storage form of glucose (a monosaccharide). It is rich in chemical bond energy, found in animal tissues such as liver and skeletal muscle. DNA would be a nucleic acid found in the nucleus of a cell, and trans fats are found in margarine.

42) B
Maltose is classified as a disaccharide because it consists of two monosaccharides that were joined by a dehydration reaction.

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43) D
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Carbohydrates are organic molecules, thus, they contain both carbon and hydrogen atoms. They are further characterized by the hydroxyl (-OH) functional group. Although some carbohydrates do contain nitrogen, this is not a requirement in order to be classified as a carbohydrate. Amino acids are the monomers of proteins, not carbohydrates. Carbohydrates do not release H^+ in aqueous solutions, so they are not organic acids.

44) E
Glucose is a monosaccharide (a carbohydrate monomer); two glucose molecules combine to form a disaccharide, not a dipeptide or a lipid. In the process, a water molecule is released, which is why this is called a dehydration reaction.

45) A
Cellulose is a structural polysaccharide found in plant cell walls. Starch and glycogen are storage forms of glucose found in plants and animals, respectively. Chitin is a polysaccharide found in the cell walls of fungi and the exoskeletons of arthropods. DNA is a nucleic acid, not a polysaccharide, and is found in cell nuclei.

46) E

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A triglyceride molecule (commonly known as a fat) is composed of three fatty acids covalently bonded to glycerol. No monosaccharides, including glucose, make up a triglyceride.

47) C
A fatty acid is a hydrocarbon chain ending with a -COOH group, which is acidic; a triglyceride is composed of three fatty acids bound to glycerol. Amino acids are the monomers of proteins, and monosaccharides are carbohydrates. Nucleic acids are polymers of nucleotides such as DNA and RNA.

48) B
Nucleic acids such as DNA and RNA are polymers of nucleotides. Polysaccharides are polymers of monosaccharides, triglycerides are made up of fatty acids bound to glycerol, and proteins are composed of amino acids.

49) E
An amino acid has a central carbon bonded to a hydrogen atom, an amino ($-NH_2$) group, a carboxyl (-COOH) group, and an *R* group where *R* stands for the remainder of the molecule. Amino acids are the monomers of proteins. Glucose is a monomer for certain polysaccharides, and a triglyceride is composed of fatty acids and a glycerol molecule.

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50) E
Enzymes are proteins that speed chemical reactions in living things. Their function is very dependent upon their structure. Steroids and other lipids do not function as enzymes, nor do carbohydrates. With a very few exceptions, neither do nucleic acids.

51) B
Amino acids joined together by peptide bonds constitute the primary level of protein structure. In secondary structure, hydrogen bonding between amino acids causes the polypeptide to form an alpha helix or a beta pleated sheet. In tertiary structure, interactions such as covalent bonds between *R* groups cause the polypeptide to fold and twist. When two or more polypeptides join together, this represents a quaternary level of structure. There is no level of protein structure termed the *molecular level*.

52) D
Amino acids joined together by peptide bonds constitute the primary level of protein structure. In secondary structure, hydrogen bonding between amino acids causes the polypeptide to form an alpha helix or a beta pleated sheet. In tertiary structure, interactions such as covalent bonds between *R* groups cause the polypeptide to fold and twist. When two or more polypeptides join together, this represents a quaternary level of structure. There is no level of protein structure termed the *molecular level*.

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53) B
Amino acids joined together by peptide bonds constitute the primary level of protein structure. In secondary structure, hydrogen bonding between amino acids causes the polypeptide to form an alpha helix or a beta pleated sheet—this is the level affected in CJD and similar brain diseases. In tertiary structure, interactions such as covalent bonds between *R* groups cause the polypeptide to fold and twist. When two or more polypeptides join together, this represents a quaternary level of structure. There is no level of protein structure termed the *molecular level*.

54) C
A nucleotide is composed of a nitrogenous base, a pentose sugar, and a phosphate group. Adenine, thymine, and uracil are bases. Combining an acid and a base yields a salt. Sugars, proteins, and fats are all biological organic molecules. DNA and RNA are nucleic acids composed of nucleotides. Both are made in the nucleus of a cell.

55) D
The backbone of a nucleic acid such as DNA is composed of alternating pentose sugars and phosphate groups. Glycerol is the backbone of a triglyceride. Although nitrogenous bases such as adenine and thymine are part of DNA, they do not make up the backbone. *R* groups are part of amino acids, not nucleotides.

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56) C
CJD, kuru, mad cow disease, and scrapie are caused by prions—infectious proteins. This was supported by the finding that only trypsin, which digests proteins, was able to deactivate the infectious agent.

57) D
Denaturation is when a protein loses its shape and cannot function. Although dehydration reactions do join amino acids together, this represents only the most basic (primary) level of protein structure.

58) A
Carbohydrates are primarily fuel and short-term energy storage molecules, although some polysaccharides do reinforce cell walls in certain organisms. DNA, a nucleic acid, encodes hereditary information. Proteins can function as enzymes to speed chemical reactions, or as transporters to move molecules across cell membranes.

59) B
Phospholipids are the most abundant type of lipids in cell membranes. Animal cells also have cholesterol in their membranes, but it is less abundant than phospholipids. Triglycerides, also known as neutral fats or simply fats, are energy-storage molecules, not structural molecules.

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60) D
Only steroids are characterized by their backbone of four fused rings. Phospholipids and triglycerides are lipids, but they do not share the same structure as steroids. Amino acids and DNA are not lipids.

61) D
In RNA, the base uracil replaces thymine. All the other answer choices are inaccurate statements.

62) A
I^{131} is a radioactive isotope that is used to detect whether the thyroid is healthy or not. C^{14} is used to date the age of fossils. Glucose is not taken up by the thyroid. H_2 is a gas commonly found in the atmosphere.

63) A
When using radiation on a person for cancer treatment, there is the possibility of destroying healthy cells along with the cancer cells. Sterilizing mail, surgical equipment, and fruits and vegetables tends not to have any type of consequence on people.

64) D
A hydrogen bond will form when a slightly positive hydrogen on one water molecule becomes attracted to a slightly negative oxygen on another water molecule.

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65) A
The strongest bond listed here is the double covalent followed by the single covalent, ionic, and then hydrogen bonds.

66) D
Lipids are characterized by their nonpolar covalent bonds. This type of bond makes lipids nonreactive with water.

67) A
The functional group OH is associated with the dehydration reactions.

68) E
Phosphate groups are found in nucleotides but not in amino acids.

69) D
Sulfhydryl is a functional group found within some amino acids and helps to stabilize protein structure. If it was removed it would disrupt the structure of the protein.

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70) A
Lemon juice is acidic so it contains large amounts H^+. When H^+ enters the bloodstream, it combines with HCO_3^- to form H_2CO_3 (carbonic acid). The carbonic acid prevents the blood pH from shifting toward a more acidic or basic range. If it did not form, in this case the individual's blood would become more acidic and shift toward 7.2.

71) D
Enzymes are composed of proteins, not lipids.

72) A
Polymers are formed when H and OH are removed from the monomers during a dehydration reaction. COH, SH, NHH, and COOH are all functional groups.

73) A
Due to the structure of cholesterol, it is classified as a steroid within the body.

74) A
Two amino acids are joined during a dehydration reaction to form a dipeptide. Hydrolysis reactions will break apart a dipeptide into individual amino acids. Denaturation is the change in shape of a protein. Dipeptides are formed from amino acids.

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75) A
An increase in body temperature for several days would cause the proteins to denature. Once they denatured, they would not be able to function correctly. Proteins would not increase in their ability to function due to an increase in body temperature.

76) A
Phospholipids have hydrophilic heads and hydrophobic tails that will form a barrier. Steroids have a backbone of four fused carbon rings. A triglyceride is formed from three fatty acids and a glycerol. Saturated acids and trans-fatty acids are both made from hydrocarbon chains with an acidic group on the end.

77) A
Glucose is the easiest substance to break down into ATP. Proteins, cellulose, phospholipids, and chitin are not easily broken down into ATP.

78) E
ATP has many important functions but it is not the primary constituent of cell membranes.

79) E

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When ATP (adenosine triphosphate) is broken down into ADP (adenosine diphosphate) the terminal phosphate bond is broken and energy is released.

80) A
A peptide bond will connect the amino acids together to form a protein.

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UNIT 1: CELL BIOLOGY
CHAPTER 2: THE MOLECULES OF CELLS

LEARNING OUTCOMES

2.1 Introduction to Chemistry

1. Describe how protons, neutrons, and electrons relate to atomic structure.
2. Understand how to interpret the periodic table of elements.
3. Explain what is meant by the term isotope
4. Identify the beneficial and harmful uses of radiation.

2.2 Molecules and Compounds

1. Describe how elements are combined into molecules and compounds.
2. List the different types of bonds that occur between elements.
3. Explain how hydrogen bonds are formed between molecules.

2.3 Chemistry of Water

1. Evaluate which properties of water are important for biological life.
2. Explain what values on a pH scale indicate about a solution
3. Describe how buffers are important to living organisms.

2.4 Organic Molecules

1. Compare inorganic molecules to organic molecules.
2. Identify the role of a functional group.
3. Recognize how monomers are joined to form polymers.

2.5 Carbohydrates

1. Describe the structure of the various classes of carbohydrates.
2. Explain the role of monosaccharides, disaccharides, and polysaccharides in biological organisms.

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2.6 Lipids

1. Compare the structures of fats, phospholipids, and steroids.
2. Identify the functions that lipids play in our bodies.

2.7 Proteins

1. Describe the functions of proteins in cells.
2. Explain how a polypeptide is constructed from amino acids.
3. Compare the four levels of protein structure.

2.8 Nucleic Acids

1. Compare the structure and function of DNA and RNA.
2. Explain the role of ATP in the cell.

LECTURE OUTLINE

2.1 Introduction to Chemistry

Matter refers to anything that takes up space and has mass. All matter, both nonliving and living, is composed of certain basic substances called **elements**.

Atomic Structure

Elements consist of tiny particles called **atoms**, which are the smallest part of an element that displays the properties of that element. Atoms are made up of positively charged **protons**, uncharged **neutrons**, and negatively charged **electrons**. All atoms of an element have the same number of protons. This number is called the **atomic number**. The **mass number** is the sum of an atom's protons and neutrons.

The Periodic Table

The periodic table was constructed as a way to group the elements according to certain similar chemical and physical characteristics.

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Radioactive Isotopes

Isotopes are atoms of the same element that differ in their number of neutrons; therefore, isotopes have the same number of protons, but their mass numbers are different.

Low Levels of Radiation

The chemical behavior of a radioactive isotope is essentially the same as that of the stable isotopes of an element, so you can use small amounts of radioactive isotopes as tracers to detect molecular changes.

High Levels of Radiation

Radioactive substances in the environment can harm cells, damage DNA, and cause cancer. Radiation is also used to sterilize items, treat cancer, and provide images (X-rays) of things we otherwise couldn't see directly.

Electrons

In an electrically neutral atom, the positive charges of the protons in the nucleus are balanced by the negative charges of electrons moving outside the nucleus in orbitals. The number of electrons in the outer orbital determines whether an atom reacts with other atoms. A common model of the atom, devised by Niels Bohr, shows electrons in concentric rings around the nucleus.

2.2 Molecules and Compounds

A **molecule** is formed when two or more atoms bond together. When the atoms of two or more different elements bond together, the product is called a **compound**.

Ionic Bonding

Ions form when electrons are transferred from one atom to another. Ionic compounds are held together by an attraction between negatively and positively charged **ions** called an **ionic bond**. An example is NaCl.

Covalent Bonding

A **covalent bond** results when two atoms share electrons in such a way that each atom has a complete outer orbital.

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The Shape of Molecules

Molecules have a three-dimensional shape that often determines their biological function. The shapes of molecules are necessary to the structural and functional role they play in living things.

Nonpolar and Polar Covalent Bonds

When the sharing of electrons between two atoms is fairly equal, the covalent bond is said to be nonpolar. The unequal sharing of electrons in a covalent bond results in slightly negative charge and a slightly positive charge, and the covalent bond is polar.

Hydrogen Bonding

Polarity within a water molecule causes the hydrogen atoms in one molecule to be attracted to the oxygen atoms in other water molecules, forming a **hydrogen bond**.

2.3 Chemistry of Water

The unique properties of water make it essential to the existence of life.

Properties of Water

Water Has a High Heat Capacity

The many hydrogen bonds that link water molecules help water absorb heat without a great change in temperature. Water has a high heat capacity because the main hydrogen bonds that link water molecules together help water absorb heat without a great change in temperature.

Water Has a High Heat of Vaporization

Water has a high heat of vaporization because hydrogen bonds must be broken before water boils and changes to a vaporized state.

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Water Is a Solvent
Water is a solvent, and due to its polarity, it facilitates chemical reactions inside and outside living organisms.
Water Molecules Are Cohesive and Adhesive
Cohesion refers to the ability of water molecules to cling to each other because of hydrogen bonding. **Adhesion** refers to the ability of water molecules to cling other polar surfaces which a function of water's polarity.
Frozen Water (Ice) Is Less Dense Than Liquid Water
Ice is less dense than liquid water because the water molecules form a regular crystal lattice with more open space, and, therefore, ice floats.

Acids and Bases
When water ionizes, it releases an equal number of hydrogen ions and hydroxide ions.

Acid Solutions (High H^+ Concentrations)
Acids are substances that release hydrogen ions (H^+) when they dissociate in water.
Basic Solutions (Low H^+ Concentration)
Bases are substances that either take up hydrogen ions (H^+) or release hydroxide ions (OH^-).
pH Scale
The **pH scale** is used to indicate the acidity or basicity (alkalinity) of solutions.
The pH scale ranges from 0 to 14.
Buffers and pH
A **buffer** is a substance that keeps pH within normal limits. In animals, the pH of body fluids is maintained within a narrow range or else health suffers.

2.4 Organic Molecules
Organic molecules always contain carbon (C) and hydrogen (H). To achieve eight electrons in its outer shell, a carbon atom shares electrons covalently with as many as four other atoms, including other carbon atoms.

Functional Groups
A **functional group** is a specific combination of bonded atoms that always react in the same way.
From Monomers to Polymers
A **monomer** is a simple organic molecule that exists individually or can link with other monomers to form a **polymer**. **Dehydration** and **hydrolysis reactions** join monomers and degrade polymers, respectively.

2.5 Carbohydrates
Carbohydrates function as quick fuel and short-term energy storage in all organisms and play a structural role in woody plants, bacteria, and insects. Carbohydrate molecules are characterized by the presence of the atomic grouping H–C–OH.

Monosaccharides – Simple Sugars
Monosaccharides consist of a single sugar molecule and are called simple sugars. They have a carbon backbone of three to six carbons. **Glucose** is a six-carbon monosaccharide found in our blood.
Disaccharides
A **disaccharide** contains two monosaccharides that have joined during a dehydration reaction.
Polysaccharides – Complex Carbohydrates
Long polymers such as starch, glycogen, and cellulose are **polysaccharides** that contain many glucose subunits.

Energy Storage Polysaccharides
Plants store large amounts of glucose as **starch**; animals store it as **glycogen**.
Structural Polysaccharides

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The polysaccharide **cellulose** is found in plant cell walls and makes them strong. **Chitin**, another structural polysaccharide, is found in the exoskeleton of crabs and related animals.

2.6 Lipids

Lipids function as energy storage molecules. Their structures vary, but all are hydrophobic molecules that are insoluble in water. Phospholipids form a membrane that separates the cell from its environment, and the steroids are a large class of lipids that includes, among others, the sex hormones.

Triglycerides: Fats and Oils

Fats are usually of animal origin and solid at room temperature while **oils** are of plant origin and liquid. In the body, fat is used for long-term energy storage, to insulate against heat loss, and to form a protective cushion around major organs. Fats and oils form when one glycerol molecule reacts with three fatty acid molecules. A fat molecule is sometimes called a **triglyceride**.

Saturated, Unsaturated, and Trans-Fatty Acids

A **fatty acid** is a hydrocarbon chain that ends with the acidic group –COOH.

Saturated fatty acids have no double covalent bonds between carbon atoms.

Unsaturated fatty acids have double bonds between carbon atoms.

Trans fats are often produced by hydrogenation or the chemical addition of hydrogen to vegetable oils.

Phospholipids

Phospholipids contain a phosphate group and have a hydrophobic end and a hydrophilic end. They are the primary components of cellular membranes.

Steroids

Steroids have a backbone of four fused carbon rings. Cholesterol is an important steroid because it is a component of a cell's plasma membrane and the precursor to other steroids.

2.7 Proteins

Proteins are of primary importance to the structure and function of cells. Proteins perform many functions in animals including metabolism, support, transport, defense, regulation, and motion.

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Amino Acids: The Building Blocks of Proteins

Proteins are polymers of amino acid monomers. An amino acid has a central carbon atom bonded to a hydrogen atom, an amino group ($–NH_2$), an acidic group (–COOH), and an *R* group. **Amino acids** differ by their *R* groups.

Levels of Protein Organization

Proteins have a *primary* (linear sequence of amino acids), *secondary* (alpha helices or beta pleated sheet), and *tertiary structure* (globular shape). Some proteins exhibit a *quaternary structure* (more than one polypeptide chain). The final shape of a protein is very important to its function.

2.8 Nucleic Acids

The two types of nucleic acids are **DNA** (**deoxyribonucleic acid**) and **RNA** (**ribonucleic acid**). DNA stores genetic information in the cell and in the organism.

Structure of DNA and RNA

Both DNA and RNA are polymers of nucleotides. Every **nucleotide** is composed of a phosphate, a pentose sugar, and a nitrogen-containing base. The nucleotides form a linear molecule. DNA is a **double helix**, while RNA is single stranded.

ATP (Adenosine Triphosphate)

ATP (**adenosine triphosphate**) is the energy carrier in cells, storing the energy in glucose and providing that energy to reactions in the cell.

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LECTURE ENRICHMENT IDEAS

1. The various organic molecules and types of bonds are easily visualized with models and remembered better than when presented on flat pictures in the textbook, videos, or computer screen.
2. Students should research the topic of acid rain on the Internet before coming to class. They should also collect and bring in water samples from their dorm faucets, drinking fountains, rainwater, snow, or a nearby pond or stream. Have pH paper or a pH meter available in class to determine the pH of these samples. Discuss the known or potential effects of acid rain in your particular geographic location, which might include effects on forests (including interruption of the symbiotic association between trees and their mycorrhizae), depletion of fisheries in lakes, or deterioration of car finishes and statues.
3. Bring in various types of colas and coffee. Have pH paper or a pH meter available in class to determine the pH of these beverages. How acidic are these? Discuss why you can drink such acidic beverages and not damage your stomach.
4. Have students read the Science in Your Life-Health "Japan's Nuclear Crisis" before coming to class. Discuss the answers to the discussion questions at the end of the reading.
5. Have students read the Science in Your Life-Health "A Balanced Diet" before coming to class. Discuss the answers to the discussion questions at the end of the reading.
6. Of the four organic molecules discussed in this section (carbohydrates, lipids, proteins, and nucleic acids), why are nucleic acids the best suited to store and transmit information? What properties of DNA allow these particular functions?

ESSAY QUESTIONS WITH ANSWERS

1. Name five characteristics of water and relate them to the structure of water.

Answer: Because electrons orbit around oxygen more than hydrogen, a slight positive charge is present on the hydrogen atoms and a slight negative charge on the oxygen atom, creating a polarity. Hydrogen bonds form between the water molecules, which leads to various characteristics of water: boils at 100 degrees C and freezes at 0 degrees C; absorbs large amounts of heat before it becomes warm and evaporates, which helps to maintain constant body temperature; excellent transport medium; ice floats in liquid water (less dense); and dissolves various chemical substances.

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2. All proteins have three basic structural levels. Describe those. Why does hemoglobin have a quaternary structure?

Answer: The primary structure of a protein consists of the linear sequence of amino acids joined by peptide bonds. The secondary structure comes about when the polypeptide chain takes a particular orientation in space (alpha helix or beta pleated sheet). The tertiary structure represents the final three-dimensional shape of the protein. When more than one polypeptide chain is present, a quaternary structure is formed, which is found in hemoglobin.

3. Explain how soaps, when added to oils, will cause the oil to mix with water.

Answer: Soaps have a polar and a nonpolar end. The nonpolar ends of the soap project into the nonpolar fat droplet while the polar ends of the soap project outward into the water, which is polar.

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