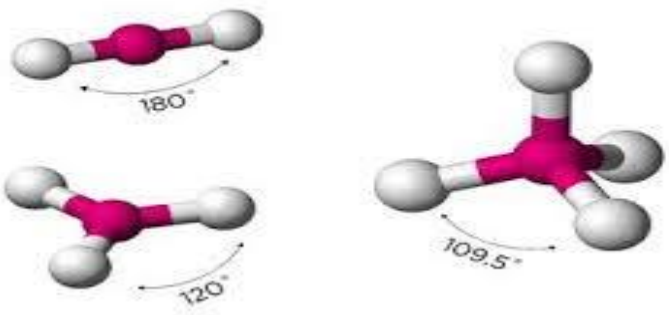
Biologically Important Molecules

Carbon

Cells contain many complex molecules called macromolecules. Carbohydrates, lipids, proteins, and nucleic acids are all examples of large molecules necessary for life. There has been some discussion on what constitutes a macromolecule. For example, carbohydrates, proteins, and nucleic acid are all significantly larger in molecular size when compared to lipids. Some suggest because of this they should not be called a macromolecule. On the other hand, lipids are made up of many atoms and are significantly larger than, for example, a molecule of water. Whether lipids are classified as a macromolecule or not, one fact holds true, lipids are important cell components that perform a wide array of functions allowing living organisms to maintain homeostasis. Carbohydrates, lipids, proteins, and nucleic acids are all organic molecules. Organic molecules generally refer to those molecules that have carbon as the principal element, bonded to hydrogen and other carbon atoms. Some carbon-containing compounds are not classified as organic, such as CO and CO2.

Molecules that do not contain carbon and hydrogen, such as water, are classified as inorganic. Carbon atoms are the fundamental components for all carbohydrates, lipids, proteins, and nucleic acids. Because carbon does not have a full valence electron shell, it is incredibly reactive. Carbon has an atomic number of 6 and is in group six on the periodic table. Therefore, elemental carbon has 6 protons and 6 electrons. Carbon atoms can form up to four covalent bonds with other atoms to satisfy the octet rule. The methane molecule provides an excellent example. In methane, the carbon atom forms four separate covalent bonds with four different hydrogen atoms. The valence shells for both hydrogen and carbon are now satisfied, thus creating a relatively stable molecule.



Carbon atoms

Hydrocarbons

Hydrocarbons are organic molecules consisting entirely of carbon and hydrogen, such as methane described above. We often use hydrocarbons in our daily lives. Fuels like the propane in a gas grill, or the butane in a lighter, are classified as hydrocarbons. The atoms in hydrocarbons form many covalent bonds which store large amounts of energy. This energy is released when these molecules burn (oxidize). For this reason, hydrocarbon molecules make excellent fuel sources. Hydrocarbons form the backbones of large macromolecules and may be linear chains, carbon rings, or a combination of both. Furthermore, carbon-carbon bonds may be single, double, or triple bonds, with each type of bond affecting the molecule's three-dimensional shape in a specific way . The three-dimensional shape or conformation of a molecule is critical to determining its function.

Functional groups are groups of atoms that are found within macromolecules and confer specific chemical properties to those molecules. The functional groups in a macromolecule are usually attached to the carbon backbone at one or several different places along its chain and or ring structure. Carbohydrates, lipids, proteins, and nucleic acids each have their own characteristic set of functional groups that contributes significantly to its differing chemical properties and its function in living organisms. For example, proteins are unique from other biologically important molecules in that their building blocks, amino acids, have both a carboxyl and amino functional group. Nucleic acids in comparison are made of building blocks called nucleotides, that always contain a phosphate functional group.

We usually classify functional groups as **hydrophobic** or **hydrophilic** depending on their charge or polarity. An example of a **hydrophobic** group is the nonpolar methyl molecule, which is hugely prevalent in lipids. The carboxyl group is hydrophilic and found in amino acids, the building blocks of proteins.

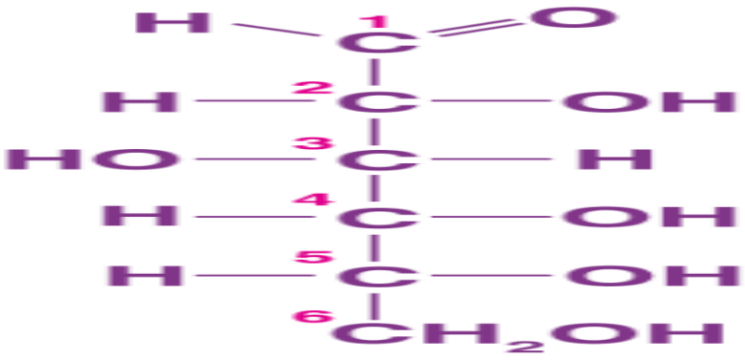
hydrophilic: describes a substance that dissolves in water; “water-loving" **hydrophobic**: describes a material that does not dissolve in water; “water-fearing"

Synthesis and Breakdown of Macromolecules

Each biological important molecule is built from smaller organic molecules. There are four major biological important molecule classes (carbohydrates, lipids, proteins, and nucleic acids). Each is an important cell component and performs a wide variety of functions. Biological important molecules are organic, meaning they contain carbon. They often also contain hydrogen, oxygen, nitrogen, and additional minor elements. Most biologically important molecules are made from single subunits, or

building blocks, called monomers. The monomers combine using covalent bonds to form larger molecules known as polymers. When monomers combine, water is released as a by-product. This type of reaction is called a dehydration synthesis, a condensation reaction, which means “to put together while losing water" (Figure 3.6a). Conversely, the covalent bonds that hold the polymer together can also be broken if need be. When a hydrolysis reaction occurs, a water molecule is used to break a chemical bond.

carbohydrate: a biological macromolecule in which the ratio of carbon to hydrogen to oxygen is 1:2:1; carbohydrates serve as energy sources and structural support in cells.



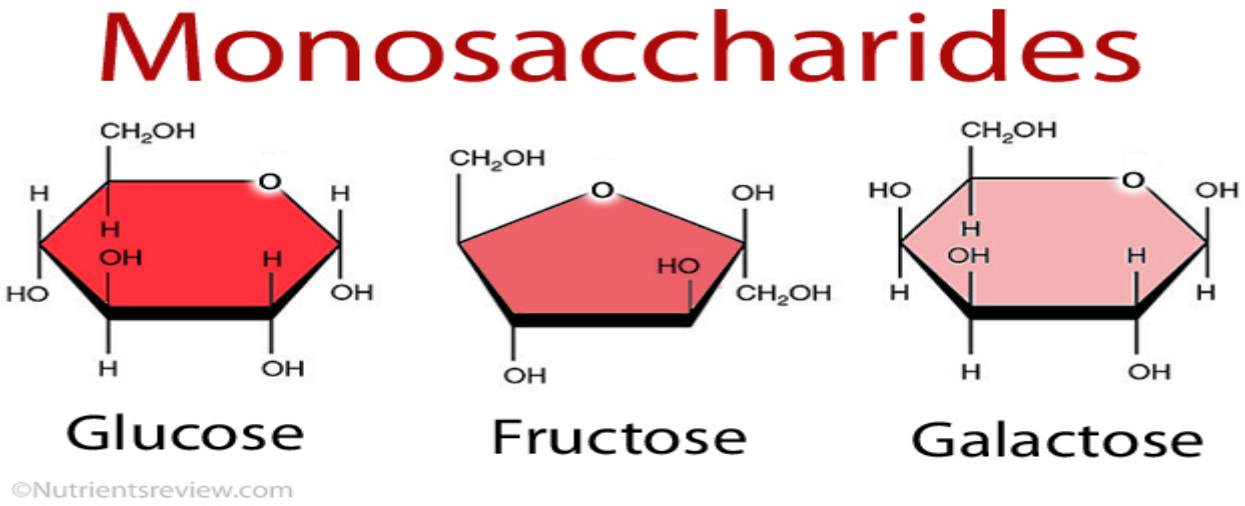
cellulose: a polysaccharide that makes up the cell walls of plants and provides structural support to the cell.

chitin: a type of carbohydrate that forms the outer skeleton of arthropods, such as insects and crustaceans, and the cell walls of fungi.

dehydration synthesis: a reaction where monomers combine with the help of water (and often an enzyme) to form polymers.

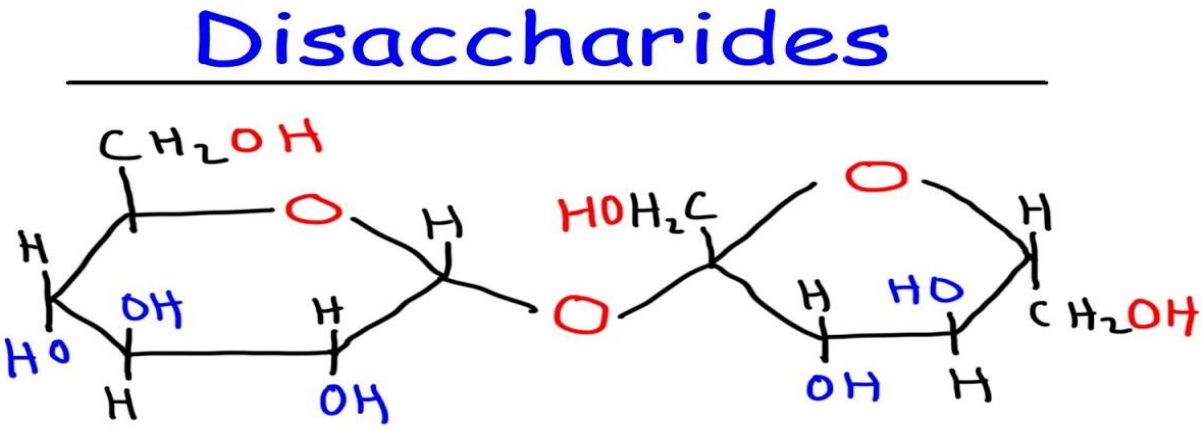
glycogen: a storage carbohydrate in animals

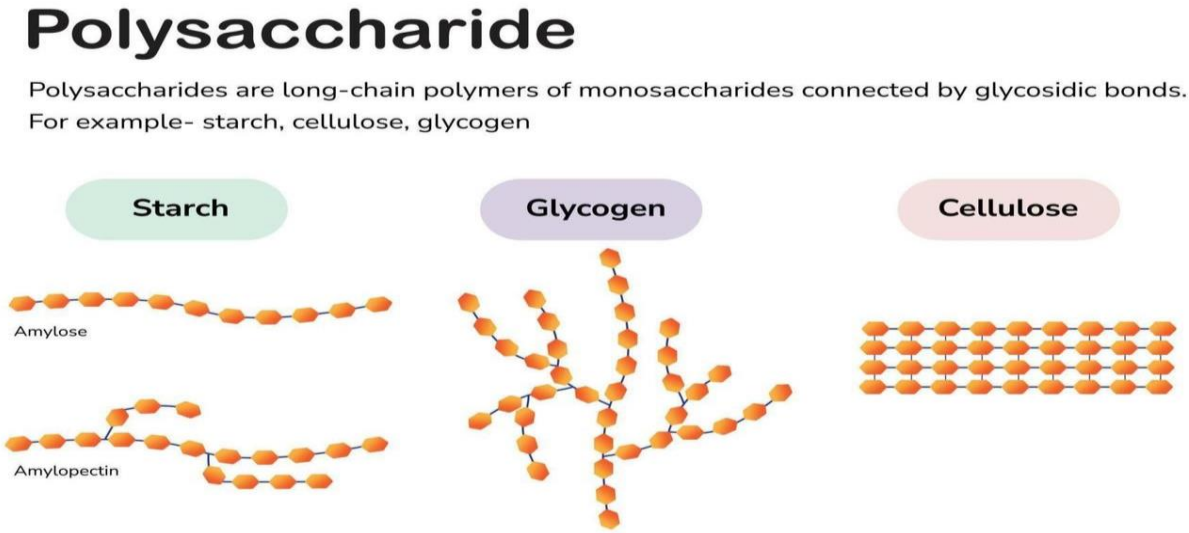
monosaccharide: a single unit or monomer of carbohydrates.



disaccharide: two sugar monomers that are linked together by a peptide bond

polysaccharide: a long chain of monosaccharides; may be branched or unbranched **starch**: a storage carbohydrate in plants.





Lipids are a class of biological molecules that are nonpolar and hydrophobic. Major types include fats, waxes, phospholipids, and steroids. Fats and oils are a stored form of energy. Phospholipids are the major component of the cell membrane. Steroids are the precursor molecules important in forming cholesterol and many required hormones. Waxes are generated by both plants and animals and are essential in both waterproofing and preventing organisms from drying out.

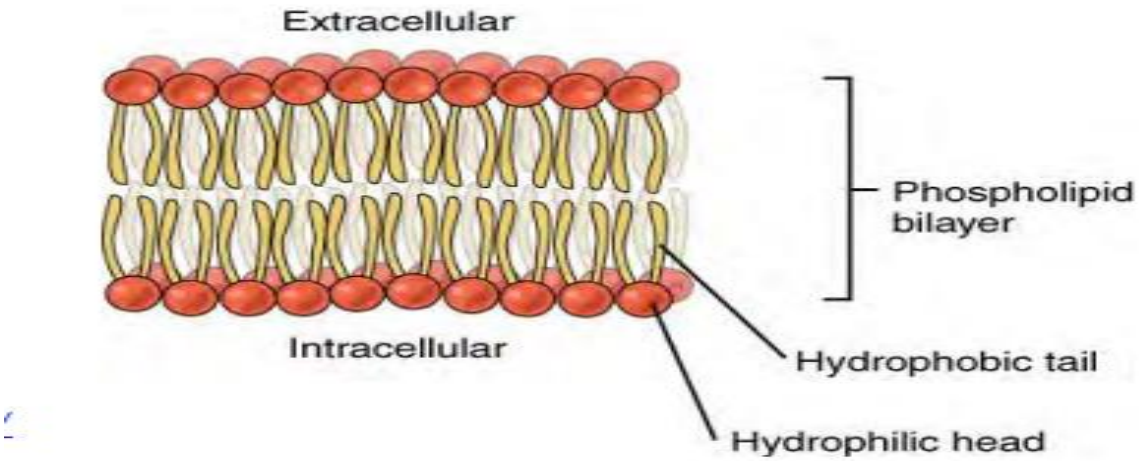


Figure represent: The cell membrane is composed in part of a phospholipid bilayer

fat: a lipid molecule composed of three fatty acids and glycerol (triglyceride) that typically exists in a solid form at room temperature

Hormone: a chemical signaling molecule, usually a protein or steroid, secreted by an endocrine gland or group of endocrine cells; acts to control or regulate specific physiological processes

hydrophilic: describes a substance that dissolves in water; water-loving

hydrophobic: describes a substance that does not dissolve in water; water-fearing

lipids: a class of macromolecules that are nonpolar and insoluble in water

oil: an unsaturated fat that is a liquid at room temperature

phospholipid: a major constituent of the membranes of cells; composed of two fatty acids and a phosphate group attached to the glycerol backbone

saturated fatty acid: a long-chain hydrocarbon with single covalent bonds in the carbon chain; the number of hydrogen atoms attached to the carbon skeleton is maximized

steroid: a type of lipid composed of four fused hydrocarbon rings

trans-fat: a form of unsaturated fat with the hydrogen atoms neighboring the double bond across from each other rather than on the same side of the double bond

triglyceride: a fat molecule; consists of three fatty acids linked to a glycerol molecule unsaturated fatty acid: a long-chain hydrocarbon that has one or more than one double bonds in the hydrocarbon chain

waxes: a type of lipid made up of a hydrocarbon chain with an alcohol (–OH) group and a fatty acid

Proteins are a class of macromolecules that can perform a diverse range of functions for the cell. They help in metabolism, provide structural support, speed up the rate of chemical reactions, transport materials, and function as hormones. The building blocks of proteins are amino acids. Proteins have four structures: primary, secondary, tertiary, and quaternary. Protein shape and function are intricately linked. Any change in shape caused by changes in temperature, pH, salinity, or chemical exposure may lead to protein denaturation and a loss of function.

amino acid: a monomer of a protein denaturation: loss of shape in a protein that may be a result of changes in temperature, pH, or chemical exposure enzyme: a catalyst in a biochemical reaction that is usually a complex or conjugated protein hormone: a chemical signaling molecule, usually a protein or steroid, secreted by an endocrine gland or group of endocrine cells; acts to control or regulate specific physiological processes hydrophilic: describes a substance that dissolves in water; water-loving **hydrophobic**: describes a substance that does not dissolve in water; water-fearing peptide bond: a covalent bond that forms between one amino acids carboxyl group and another amino acids amino group polypeptide chain: a long chain of amino acids linked by peptide bonds primary structure: a linear sequence of amino acids in a protein protein: a biological macromolecule composed of one or more chains of amino acids quaternary structure: association of different polypeptide chains in a protein secondary structure: structure that proteins form by hydrogen bonding between the oxygen atom of one amino acid and the hydrogen attached to the nitrogen atom of another amino acid substrate: a reactant that binds to a specific enzyme tertiary structure: a protein's three-dimensional conformation, including interactions between secondary structural elements

Nucleic acids are molecules made up of repeating units of nucleotides that direct cellular activities such as cell division and protein synthesis. Each nucleotide is made up of a pentose sugar, a nitrogenous

base, and a phosphate group. There are two types of nucleic acids: DNA and RNA. DNA and RNA have both similarities and differences. They both perform unique functions that allow cells to survive.

deoxyribonucleic acid (DNA): a double-stranded polymer of nucleotides that carries the hereditary information of the cell.

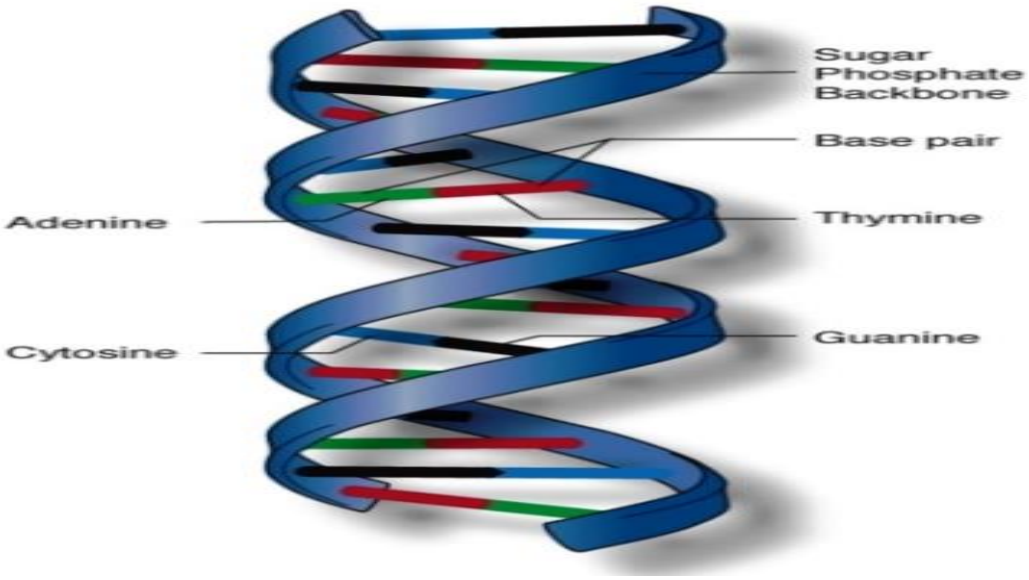
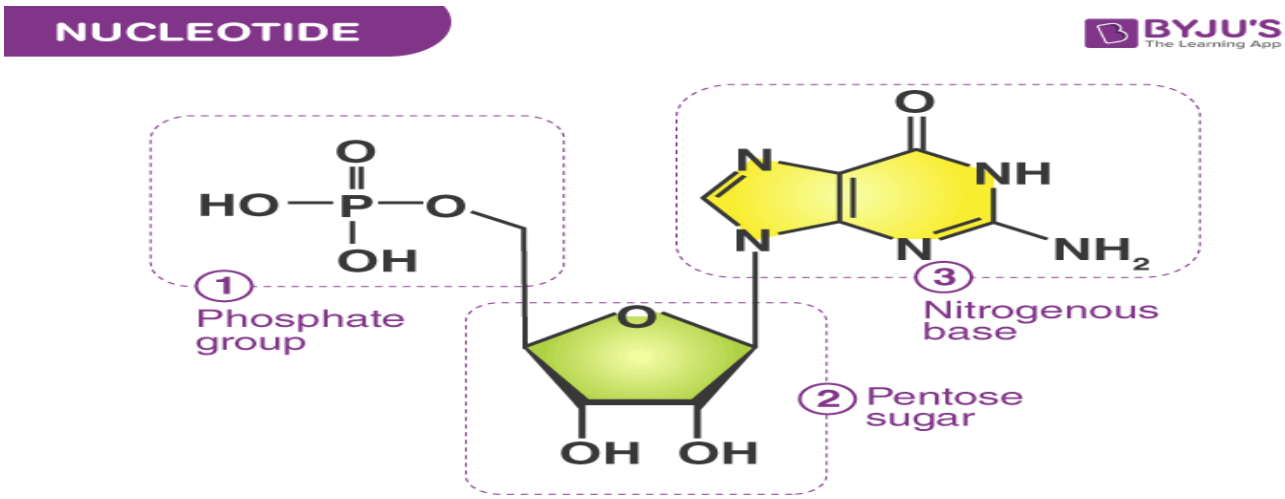


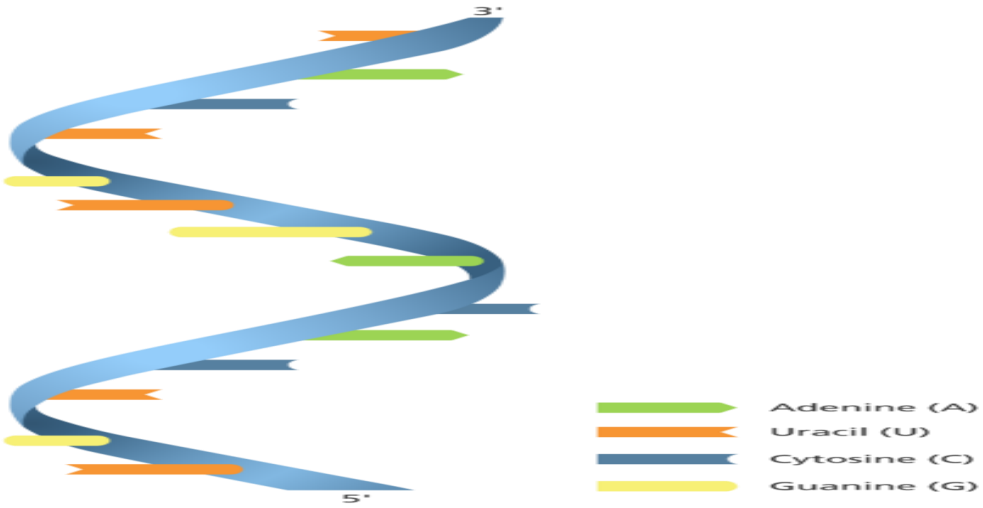
Figure of DNA

nucleic acid: a biological macromolecule that carries the genetic information of a cell and carries instructions for the functioning of the cell

nucleotide: a monomer of nucleic acids; contains a pentose sugar, a phosphate group, and a nitrogenous base.



Ribonucleic acid (RNA): a single-stranded polymer of nucleotides that are involved in protein synthesis.



transcription: the process of making RNA from DNA

translation: the process of making protein from mRNA

1. Which of the following is NOT a macromolecule?

a) Carbohydrate

b) Protein

c) Lipid

d) Water

e) Nucleic acid

2. Carbon can form how many covalent bonds?

a) 1

b) 2

c) 4

d) 6

e) 8

3. Which of the following is a hydrophobic molecule?

a) Water

b) Lipid

c) Protein

d) Nucleic acid

e) Carbohydrate

4. What type of reaction is responsible for forming polymers from monomers?

a) Hydrolysis

b) Dehydration synthesis

c) Combustion

d) Oxidation

e) Reduction

5. A monosaccharide is:

a) A single unit of carbohydrate

b) Two sugar molecules linked by a peptide bond

c) A storage form of fat

d) A protein monomer

e) A nucleic acid

6. Which of the following contains a phosphate group?

a) Amino acid

b) Fatty acid

c) Nucleotide

d) Triglyceride

e) Monosaccharide

7. What is the primary function of glycogen?

a) Structural support in plants

b) Hormone production

c) Energy storage in animals

d) Waterproofing

e) Genetic information

8. Proteins are made up of:

a) Fatty acids

b) Nucleotides

c) Monosaccharides

d) Amino acids

e) Phospholipids

9. What type of bond links amino acids together?

a) Hydrogen bond

b) Ionic bond

c) Peptide bond

d) Covalent bond

e) Disulfide bond

10. What is a saturated fatty acid?

a) A fatty acid with one or more double bonds

b) A fatty acid with single covalent bonds only

c) A fatty acid with no hydrogen atoms

d) A type of nucleotide

e) A carbohydrate

11. Which of the following is a function of lipids?

a) Catalyze chemical reactions

b) Store energy

c) Carry genetic information

d) Provide structural support to cells

e) Transport oxygen

12. DNA and RNA are classified as:

a) Proteins

b) Carbohydrates

c) Lipids

d) Nucleic acids

e) Enzymes

13. Which of the following is an example of a polysaccharide?

a) Glucose

b) Sucrose

c) Fructose

d) Glycerol

e) Starch

14. What is the main component of the cell membrane?

a) DNA

b) RNA

c) Phospholipids

d) Glycogen

e) Proteins

15. Which functional group is hydrophilic?

a) Methyl

b) Hydrocarbon

c) Carboxyl

d) Fatty acid

e) Steroid

16. What does denaturation affect in proteins?

a) Primary structure

b) Shape and function

c) Carbohydrate content

d) Number of hydrogen atoms

e) Fatty acid composition

17. Enzymes are classified as:

a) Carbohydrates

b) Proteins

c) Nucleic acids

d) Lipids

e) Steroids

18. What is the three-dimensional shape of a protein determined by?

a) Number of amino acids

b) Tertiary structure

c) Quaternary structure

d) Primary structure

e) pH levels

19. Which of the following is an unsaturated fat?

a) Butter

b) Olive oil

c) Wax

d) Cholesterol

e) Glycerol

20. A triglyceride is composed of:

a) Two fatty acids and one glycerol

b) Two phosphate groups

c) Three fatty acids and one glycerol

d) A nucleotide and a sugar

e) One fatty acid and three glycerol molecules

21. Which molecule is involved in waterproofing plants and animals?

a) Glycogen

b) Triglyceride

c) Wax

d) DNA

e) Starch

22. The quaternary structure of a protein involves:

a) Primary sequence

b) Hydrogen bonds

c) Association of different polypeptide chains

d) Amino acid folding

e) Protein denaturation

23. What molecule carries genetic information in cells?

a) RNA

b) Proteins

c) DNA

d) Lipids

e) Carbohydrates

24. The process of making RNA from DNA is called:

a) Transcription

b) Translation

c) Replication

d) Protein synthesis

e) Hydrolysis

25. Which of the following is a building block of proteins?

a) Glucose

b) Amino acid

c) Phosphate group

d) Fatty acid

e) Steroid

26. What molecule stores genetic information?

a) Protein

b) RNA

c) Phospholipid

d) DNA

e) Enzyme

27. A lipid with four fused hydrocarbon rings is:

a) Fat

b) Oil

c) Steroid

d) Wax

e) Triglyceride

28. Nucleotides are the building blocks of:

a) Proteins

b) Lipids

c) Carbohydrates

d) Nucleic acids

e) Enzymes

29. Which molecule helps in cell division and protein synthesis?

a) RNA

b) Phospholipids

c) Proteins

d) Carbohydrates

e) Steroids

30. Which molecule forms the outer skeleton of arthropods?

a) Glycogen

b) Starch

c) Chitin

d) Cellulose

e) Lipid

31. Which is the storage carbohydrate in plants?

a) Glucose

b) Starch

c) Glycogen

d) Chitin

e) Wax

32. What is an example of a disaccharide?

a) Glucose

b) Fructose

c) Sucrose

d) Starch

e) Cellulose

33. What is the primary source of energy for cells?

a) Carbohydrates

b) Lipids

c) Proteins

d) Nucleic acids

e) Steroids

34. The main function of cellulose is:

a) Provide structural support in plants

b) Energy storage in animals

c) Hormone production

d) Genetic information storage

e) Enzyme activity

35. Steroids are precursors for which molecule?

a) Glycogen

b) DNA

c) Cholesterol

d) RNA

e) Wax

36. Which of the following is an example of a hydrophilic molecule?

a) Water

b) Lipid

c) Wax

d) Fat

e) Oil

37. The building blocks of nucleic acids are:

a) Nucleotides

b) Amino acids

c) Monosaccharides

d) Fatty acids

e) Phospholipids

38. Which of the following is a storage form of carbohydrate in animals?

a) Starch

b) Glycogen

c) Cellulose

d) Chitin

e) Lipid

39. What is the name of the bond that forms between two sugar molecules?

a) Hydrogen bond

b) Peptide bond

c) Glycosidic bond

d) Ionic bond

e) Phosphodiester bond

40. What process breaks down polymers into monomers?

a) Dehydration synthesis

b) Translation

c) Transcription

d) Hydrolysis

e) Denaturation