The major classes of macromolecules are carbohydrates, lipids, nucleic acids, and proteins. Nucleic acids and proteins play very active roles in the structure and function of cells. Both types of molecules are polymers made up of similar, but not identical, monomers.

Some macromolecules are polymers made up of repeating subunits called monomers.

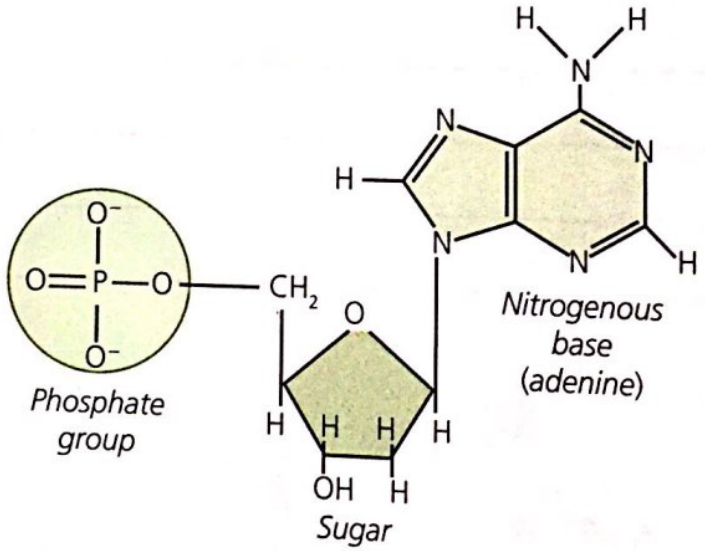
Nucleic Acids: DNA and RNA

Some of the most important polymers in living cells are the **nucleic acids,** DNA and RNA. These polymers are made up of monomers called *nucleotides.* Each nucleotide consists of three parts: a phosphate group, a 5-carbon sugar, and a variable nitrogenous base. As a result, instead of being exactly identical, the nucleotides come in four different varieties or "flavors": adenine (A), cytosine (C), guanine (G), and thymine (T). (RNA has uracil, U, instead of thymine.) Like letters of an alphabet making up a story, the four nucleotides allow RNA and DNA to encode information—genetic information.

A **nucleic acid,** DNA or RNA, is a macromolecule that carries genetic information.

DNA is deoxyribonucleic acid and **RNA** is ribonucleic acid.

Nucleotides are the building blocks, or monomers, of nucleic acids. They are composed of carbon, hydrogen, nitrogen, oxygen, and phosphorus.



Nucleotides all have three similar components: a sugar, a phosphate group, and a variable nitrogenous base.

The nucleotides that make up DNA differ slightly from those in RNA in several ways:

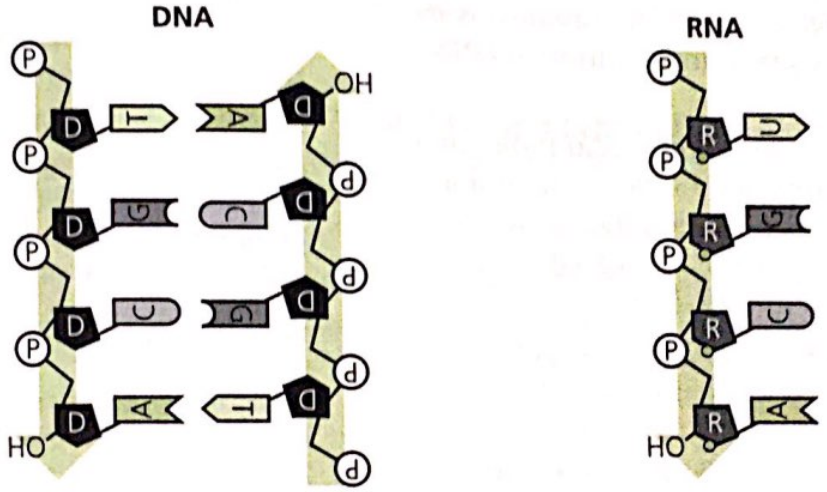
- **5-carbon sugar**—RNA nucleotides contain ribose instead of deoxyribose.
- **Uracil**—This nucleotide is used in RNA instead of thymine.
- **Double vs. single strand**—While DNA is usually found as a double-stranded molecule, RNA is usually a single strand.

The nitrogenous bases of nucleotides vary. They determine whether each nucleotide is an A, T, C, or G.

Deoxyribose and ribose are 5-carbon sugars, or monosaccharides.

A nucleic acid polymer is made by joining the phosphate group of one nucleotide to the sugar of a second nucleotide, through a dehydration synthesis reaction. This forms a chain of repeating phosphate groups and 5-carbon sugars. The nitrogenous bases are not involved in forming the chain, but simply jut out from one side of it.

The bases do, however, participate in another, critical type of bonding: nucleotides form hydrogen bonds with other nucleotides. Hydrogen bonding between two DNA strands forms the DNA double strand. However, for this to occur, the two strands must be *complementary*. That is, each type of nucleotide must pair with its "partner" type on the other strand: A with T and G with C. The same type of hydrogen bonding allows RNA to pair with DNA. In this case, uracil (U) bonds with adenine (A). Hydrogen bond interactions between the complementary bases bind the nucleic acid strands together.



Both DNA and RNA share a phosphate-sugar backbone. DNA is usually found as a double strand. Its nitrogenous bases pair with complementary bases on the partner strand.

Nucleic acids have a phosphate-sugar backbone. The nucleotide monomers are joined by dehydration synthesis.

In *complementary* DNA strands, the A of one strand forms a hydrogen bond with the T of the opposite strand. C and G also pair in this way. In RNA, U takes the place of T.

Hydrogen bond interactions hold the two strands of DNA together to form the double strand. These bonds are easily broken and reformed, allowing the DNA strands to be easily separated whenever necessary.

Nucleic acids have the following functions:

- **Encoding genetic information**—DNA encodes the genetic information of the cell. It makes up the chromosomes found in the nucleus. Genes provide specific instructions for making the proteins the organisms need to carry out all of life's chemical reactions and cellular functions.
- **Protein synthesis**—RNA transports genetic information to ribosomes for the production of proteins.
- **Composing ribosomes**—These organelles are made up of RNA and proteins.

Which is **not** found in both RNA and DNA?

A ribose sugar

B phosphate group

C nitrogenous base

D guanine nucleotide

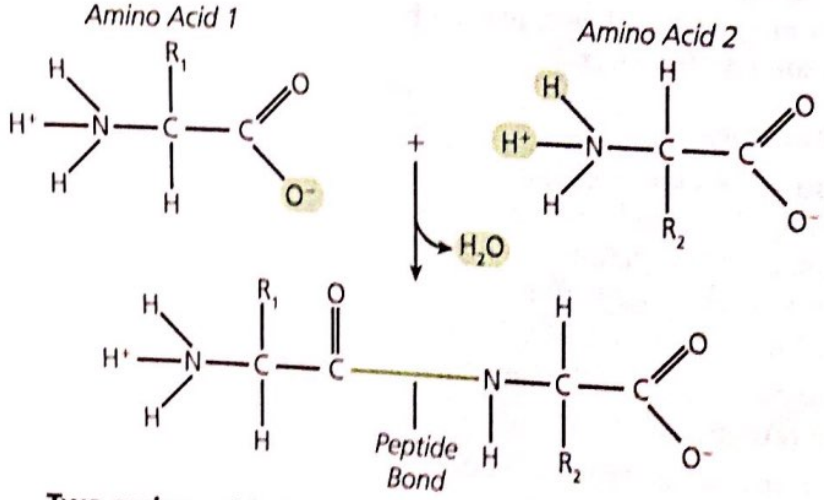
Both DNA and RNA contain phosphate groups, nitrogenous bases, and guanine nucleotides; choices B, C, and D are incorrect. Choice A is correct because the ribose sugar is found only in RNA molecules.

Proteins

Proteins are important polymers that perform a variety of functions within living organisms. Proteins help living organisms to catalyze reactions, transport molecules, copy and synthesize DNA, and communicate between cells.

Proteins consist of long, straight chains of *amino acid* molecules linked together. Amino acids are all composed of the same amino, carboxyl, and central carbon structure. Like nucleotides, however, amino acids are not all identical. The R group is the variable part of the monomer. Most cells use 20 different amino acids.

Peptide bonds join amino acids through dehydration synthesis reactions. Notice how a water molecule is formed from the –OH group of one monomer and the hydrogen atom of the next monomer. A single *polypeptide* chain can be many hundreds of amino acids in length.



Two amino acids join to form a peptide bond through dehydration synthesis. A water molecule is a by-product.

Proteins are macromolecules that perform structural and regulatory functions for cells.

Amino acids are the building blocks, or monomers, of proteins. Amino acids contain nitrogen, as well as carbo hydrogen, and oxygen.

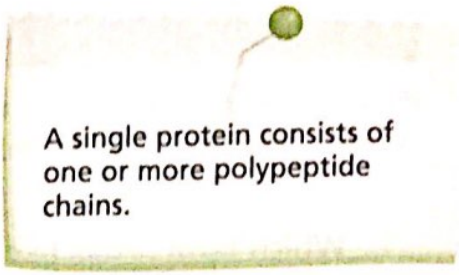
Some R groups are polar; others are nonpolar.

A *peptide bond* joins amino acids.

Dehydration synthesis reactions join amino acids to make peptides.

Dehydration reactions break down peptides into amino acids.

However, polypeptide chains do not branch; they are single lines of amino acids, similar to a necklace made of beads. In order to give proteins the three-dimensional structure needed to function, polypeptide chains must bend and fold in various ways. One or more polypeptides, folded into a specific three-dimensional structure, make up the protein.



A single protein consists of one or more polypeptide chains.

Proteins have important roles in the following:

- **Cell structures**—Proteins provide much of the structure of the cell, making up the cytoskeleton of eukaryotic cells.
- **Animal structures**—Proteins make up hair, nails, and muscles.
- **Cell function**—Proteins in the cell membrane help determine which substances enter or exit the cell.
- **Enzymes**—Some proteins are enzymes, which help carry out specific chemical reactions. Without enzymes, many of the reactions within the cell would not occur quickly enough to support life.

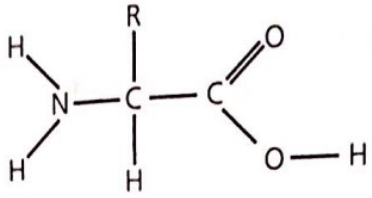
Explain how many thousands of different types of proteins, with diverse structures and functions, can be assembled from just 20 types of amino acids.

Amino acids are building blocks that can be joined together in many different combinations and sequences to make up polypeptide chains of different lengths. These polypeptides can join together in different ways and take on different three-dimensional structures to form proteins. Therefore, a great variety of proteins can be assembled from just 20 types of amino acids.

IT'S YOUR TURN

Please read each question carefully. For a multiple-choice question, circle the letter of the correct response. For a constructed-response question, write your answers on the lines.

1 Which term refers to the molecule shown?



A nucleotide

B amino acid

C polypeptide

D nitrogen base

2 Which pair of terms is **not** correctly matched?

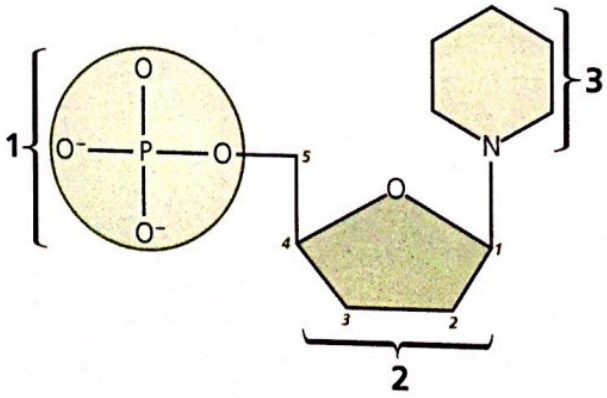
A deoxyribose: RNA

B polypeptide: protein

C nitrogenous base: DNA

D amino acid: polypeptide

Use the diagram below to answer question 3.



3 Which statement about the part of the molecule labeled 3 is correct?

A It comes in twenty different varieties.

B It is the same for all monomers of this type.

C It participates in hydrogen bond interactions.

D It forms the backbone of a nucleic acid strand.

4 Which does **not** describe a function of proteins?

A They encode genetic information.

B They allow muscle cells to contract.

C They help to carry out chemical reactions.

D They make up structures that support the cell.

5 Proteins and nucleic acids play important roles in the cell.

A Compare the structure of proteins with the structure of nucleic acids.

B Describe how the monomers that make up nucleic acids contribute to their function.

C Describe how the monomers that make up proteins contribute to their function.