Unit 2 Cell Compounds and Biological Molecules

Water is essential for life as we know it. Water makes up 70% to 99% of the weight of moving living organisms, including humans. This section explores not only the role of water in biological systems, but also the roles of acids, bases, and buffers in living systems. You will also analyze the structure and function of biological molecules in living systems. Understanding how carbohydrates “fuel” cellular activities, differentiating among carbohydrates, lipids, proteins, and nucleic acids, and describing the locations, structure, and function of neutral fats, steroids, and phospholipids are but a few of the outcomes you will be expected to learn in this section.

Cell Compounds – Water, Acids, Bases, and Buffers

Water is essential for life as we know it. Water makes up 70% to 99% of the weight of most living organisms, including humans.

Water is a polar molecule – it has a positive pole and a negative pole – and has many functions in our bodies. Did you know that water:

- Is a liquid at room temperature, which lets us drink it, cook with it, and bath in it?
- Is a universal solvent that facilitates reactions both inside and outside our bodies?
- Molecules are cohesive and therefore able to fill such things as blood vessels?
- Temperature rises and falls slowly, preventing sudden drastic changes in our bodies?
- Keeps our bodies from overheating due to its high heat of vaporization?

The hydrogen bonds in water attract water molecules to each other, causing them to hold on to each other. The properties of water makes it important to living organisms. In this lesson you will learn how the polarity of the water molecule results in hydrogen bonding. You will describe the role of water as a solvent, temperature regulator, and lubricant. You will also learn to distinguish among acids, bases and buffers, and understand the importance of pH to biological systems.

Properties of Water

Water molecules (H2O) are composed of two small hydrogen (H) atoms and one larger oxygen (O) atom. Each hydrogen atom is bonded to the oxygen atom by a covalent bond. Hydrogen atoms attract the electrons less than the oxygen atom, which causes the electrons to spend more time around the oxygen atom. This unequal sharing of electrons gives the oxygen atom a slightly negative charge (sigma -) and each hydrogen atom a slightly positive charge (sigma +).

Partial charges make the water molecule polar – the two hydrogen atoms act as positive poles and oxygen acts as a negative pole. The oppositely charged poles attract nearby water molecules and create weak bonds called hydrogen bonds, which are really hydrogen-oxygen bonds. Each water molecule can form up to four hydrogen bonds with neighboring molecules – one on each hydrogen atom and two on the oxygen atom. These bonds cause water to hold together to form water droplets. It also allows water to move to the tops of trees and organisms such as water striders to move on its surface.

Water as the Universal Solvent

Water is often referred to as the universal solvent because other polar (charged) molecules will dissolve in it. Therefore, when charged ions and molecules disperse in water, they move about, collide, and facilitate chemical reactions, both inside and outside our bodies.

For example, when sodium chloride (NaCl) is added to water, the positive hydrogen ions in the water are attracted to the negative chlorine ions of the salt. Similarly, the negatively charged oxygen ions in the water are attracted to the positively charged sodium ions of the salt. These attractions cause the sodium and chlorine ions to separate and dissociate into the water.

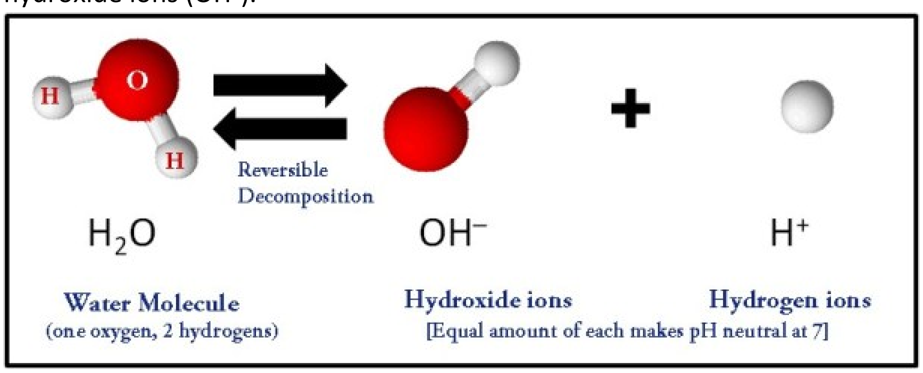
Sodium chloride and other molecules that interact this way with water are said to be hydrophilic. Non-polar molecules that cannot act this way are called hydrophobic.

Water as a Temperature Regulator

Water in our bodies helps to moderate temperature changes, just as ocean water heats or cools slowly. The numerous hydrogen bonds in water help it resist temperature changes because a great deal of energy must be added or lost to raise or decrease the temperature of water. If the body does overheat, such as during strenuous exercise, the excess heat causes the evaporation of sweat, which is mostly liquid water. Using up this heat energy cools the body.

Acids, Bases, and Buffers

When water molecule break up or dissociate, they release equal numbers of hydrogen ions (H+) and hydroxide ions (OH-).



http://hairmomentum.com/effects-of-ph-hair/

If the number of H+ ions is not equal to the number of OH-, then the solution has become either or basic.

Acids

Acids are molecules that dissociate in water and release hydrogen ions (H+). Acidic solutions have more H+ ions than OH- ions.

Strong acids, like the acids found in the stomach, release greater concentrations of H+ ions. An example of a strong acid is stomach acid – a highly concentrated solution of hydrochloric acid (HCl). The pH of stomach acid ranges from 1 to 3. A weak acid, such as acetic acid (vinegar) produces a lower concentration of H+ ions when added to water.

Acidic solutions have a sharp or sour taste. Examples of acids include vinegar, tomato juice, lemon juice and coffee. The acidity of these items is often associated with indigestion.

Bases

Bases are molecuels that either release hydroxide ions (OH-) or take up hydrogen ions (H+). If a strong base, such as sodium hydroxide (NaOH), is added to water, it dissociated in the following manner:

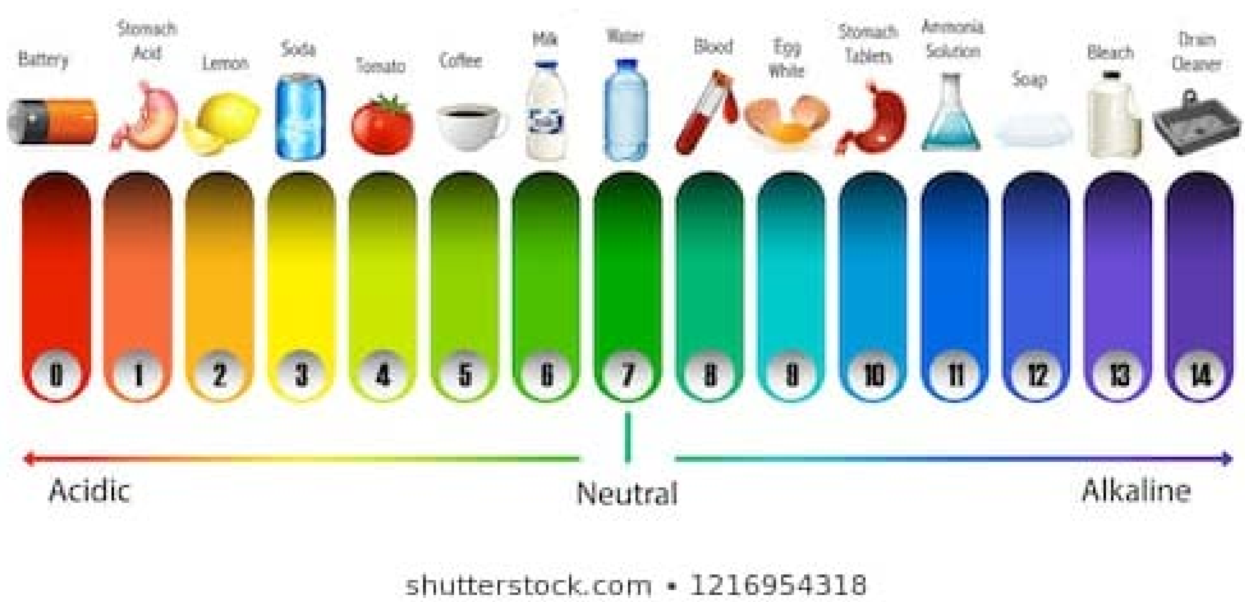
$NaOH \rightarrow Na^{+} + OH^{-}$

If sodium hydroxide is added to water, the number of hydroxide ions increases and the solution is said to be basic (or alkaline).

Bases are known for their bitter taste and feel slippery when in water. Examples include milk of magnesia, baking soda, and ammonia. Many household cleaning products are also strong bases. Human blood is also slightly basic.

The pH Scale

The pH scale ranges from 0 to 14 and is used to describe the relative acidity or alkalinity of solutions. A pH of 7 means the solution is neutral – it has the same concentration of H+ and OH-. Pure water has a pH of 7. Acids have a pH of less than 7. Stomach acid, with a pH of 1, is an extremely acidic solution. Saliva had a pH of 6.5 and is only slightly acidic.



https://www.shutterstock.com/search/ph+scale

Bases have a pH greater than 7. A pH of 14 represents an extremely basic solution, such as the concentrated sodium hydroxide found in oven cleaner. A pH of 7.4, such as human blood, represents a weak base.

If a solution has more OH- than H+, it will have a pH greater than 7 and will be considered alkaline or basic.

If a solution has more H+ than OH=, it will have a pH less than 7 and will be considered acidic.

If the concentrations of H+ and OH- are equal, the solution will have a pH of 7 and will be considered neutral.

As you move down the pH scale from 14 to 0, each unit has 10 times the [H+] of the previous unit. For example, black coffee (pH 5) has 1000 times less H+ than lemon juice (pH2).

Buffers

A buffer is a compound or combination of compounds, often a weak acid or base and a related salt that keeps the pH of a solution within tis normal limits. Buffers resist changes in pH because of their ability to take up excess hydroxide ions (OH-) or hydrogen ions (H+). Weak acids, such as carbonic acid (H_2CO_3) and bicarbonate ions (HCO_3^-), are part of the buffer system in our bodies that keep our blood pH at about 7.4, keeping the system in equilibrium.

The ability of carbonic acid to dissociate and re-form can be expressed this way:

$H_2CO_3 \rightarrow H^+ + HCO_3^-$

Carbonic acid → hydrogen ion + bicarbonate ion

When OH- ions are added to the blood, the following reaction occurs and counteracts any significant changes to the pH of the blood.

$OH^- + H_2CO_3 \rightarrow HCO_3^- + H_2O$

When H+ ions are added to blood, the following reaction prevents significant changes from taking place:

$H^+ + HCO_3 \rightarrow H_2CO_3$

Buffers combine with both hydroxide and hydrogen ions to resist pH changes. Our blood is buffered at a pH of 7.35 to 7.45.

Hemoglobin is another example of a buffer in the blood. During exercise, the muscles use up oxygen. This O2 comes from hemoglobin in the blood. During the breakdown of glucose, CO2 and H+ are produced and removed from the muscle via the blood. The production and removal of CO2 and H+, together with the use and transport of O2, cause the pH of the blood to drop. If the pH gets too low (below 7.4), then a condition known as acidosis results. This can be very serious because many chemical reactions that occur in the body are pH-dependent. If the pH drops below 6.8 or rises above 7.8, death may occur. Fortunately, buffers in the blood protect against large changes in pH.

Biological Molecules – Carbohydrates

Inorganic molecules (non-living) such as water (H2O) and certain salts (ex. NaCl) play important roles in all living things. However, organic molecules are considered the molecules of life. Organic molecules provide the energy we need to live. These molecules always contain carbon and hydrogen, an often oxygen. Carbon has the ability to bond to four different atoms, so the chemistry of carbon allows the formation of a wide variety of organic molecules.

In this lesson you will learn the process of dehydration synthesis (joining of compounds) and hydrolysis (degradation) as applied to organic macromolecules. You will learn the main functions of carbohydrates and be able to recognize the empirical formula of a carbohydrate. By the end of the lesson you will have also learned to differentiate monosaccharides, disaccharides, and polysaccharides, such as starch, cellulose, and glycogen.

Carbohydrates

Carbohydrates are produced by plants and provide the energy we need. They also made by animals for things like mucus and exoskeletons.

Carbohydrates primarily consist of carbon, hydrogen, and oxygen in a ratio of 1:2:1. The empirical or simplest formula of any carbohydrate is $(CH_2O)_n$.

The ratio of hydrogen to oxygen atoms is 2:1, which is the same as for water. Because of this, the term hydrates of carbon is used to distinguish carbohydrates.

In some instance, the ratio is only approximate. For example, the chemical equation for sucrose is $C_{12}H_{22}O_{11}$.

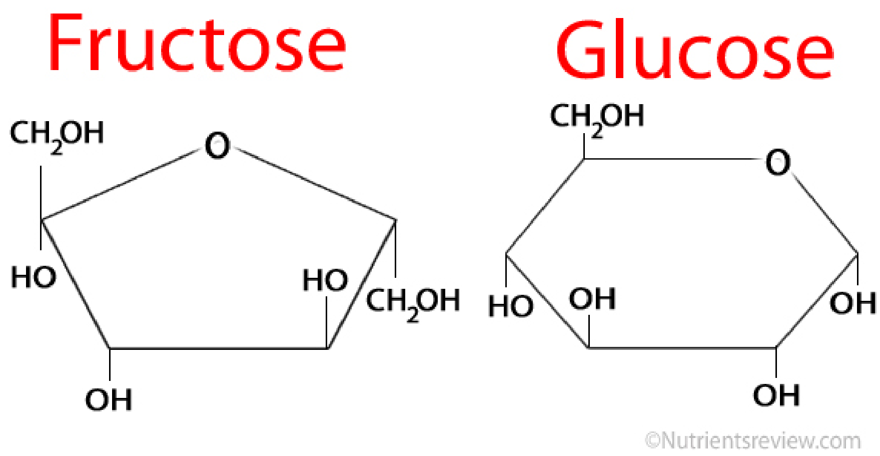
Occasionally, we'll use models to learn about different macromolecules and how to differentiate between them.

Monosaccharides

Monosaccharides, such as glucose and fructose, are simple sugars. These molecules are considered to be isomers of each other because they have the same formula $C_6H_{12}O_6$ but have different structural arrangements.

The number of carbon atoms in each of these molecules is low – from three to seven. The term pentose means a 5-carbon sugar and the term hexose refers to a 6-carbon sugar.

Blood sugar is glucose (a hexose) that has the molecular formula $C_6H_{12}O_6$. The following structural models are for the monosaccharide glucose and another common hexose, fructose, which is found in fruits.



http://www.nutrientsreview.com/carbs/monosaccharides-fructose.html

Each of these simple sugars has the same molecular formula of $C_6H_{12}O_6$, but the shape of the ring differs as does the arrangement of the hydrogen (-H) and the hydroxyl (-OH) groups attached to the ring.

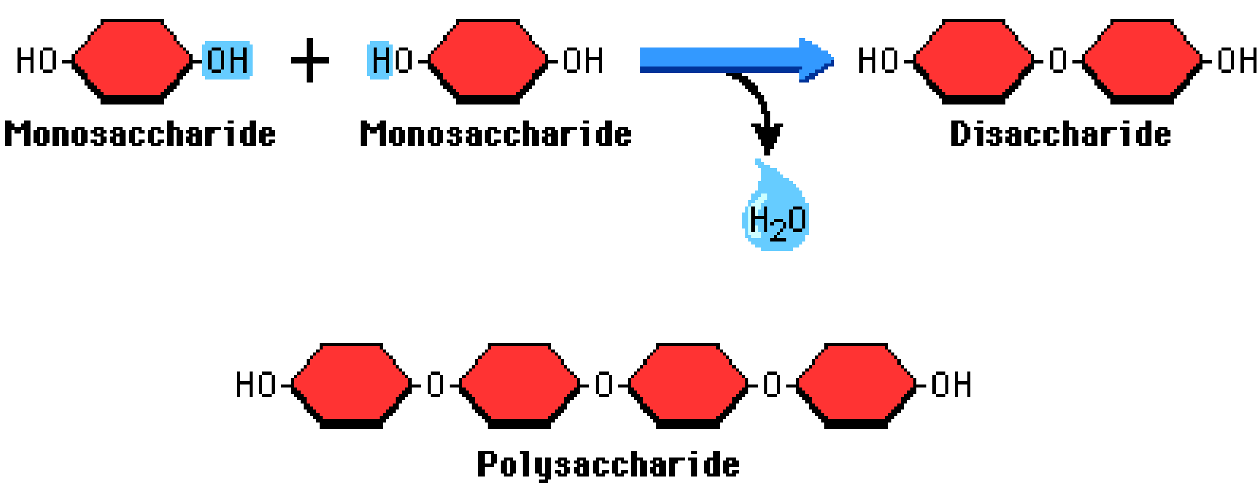
Disaccharides

Disaccharides (di, two; saccharide, sugar) are composed of two monosaccharides. For example:

- Sucrose (table sugar) is made of glucose bonding with fructose
- Glucose bonding with glucose gives us maltose (malt sugar)
- Lactose (milk sugar) is formed when glucose and galactose bond

Dehydration synthesis is the process that joins two monosaccharides to form a disaccharide. The two simple sugars join and a water molecule is released.

The following example shows how maltose, $C_6H_{22}O_{11}$, is formed. Maltose, or malt sugar, is a common disaccharide formed when two glucose monomers join to form a polymer, as shown here.



http://www.goldiesroom.org/Note%20Packets/04%20Biochemistry/02%20Biochemistry--Lesson%202.htm

Other common disaccharides include sucrose and lactose. The sucrose (table sugar) that we used to sweeten our food is formed when glucose and fructose join. Lactose, milk sugar, forms when glucose combines with galactose.

Polysaccharides

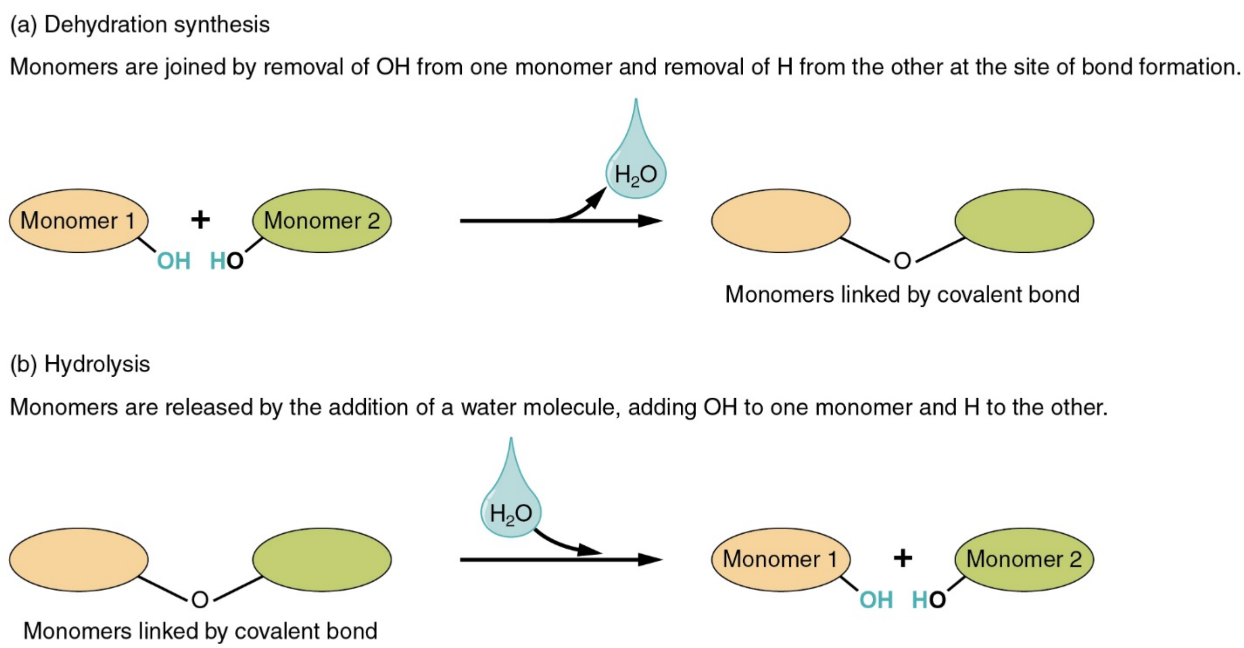
Polysaccharides are long chain molecules that contain many glucose subunits. Starch, glycogen, and cellulose are examples of polysaccharides.

Plants store glucose as starch. Starch molecules are composed of up to 4000 glucose units. Animals store glucose as glycogen.

Insulin, a hormone produced by the pancreas, stimulates the liver to absorb glucose and form glycogen when the glucose levels in the blood get too high. When glucose levels get too low, the liver breaks apart glucose and returns it to the blood.

To break down macromolecules, the cell used a hydrolysis reaction tin which the addition of water (H2O) causes the subunits of the macromolecule to separate and degradation to take place.

The following figure shows a general picture of the synthesis and degradation of macromolecules. Synthesis occurs when a dehydration reaction (removal of H20) causes monomers to bond. Degradation occur when the monomers in a macromolecule separate after the addition of water.



https://commons.wikimedia.org/wiki/File:213_Dehydration_Synthesis_and_Hydrolysis-01.jpg

The Main Functions of Carbohydrates

The primary function of carbohydrates is to provide a quick, short-term energy source for all living organisms. Carbohydrates also play an important role in the structure of plants. Plan cell walls contain cellulose, which makes the cell walls hard enough to permit non-woody plants to stand upright as long as they receive adequate supplies of water.

Animals, such as insects and crabs, require chitin, which is another structural polysaccharide, to produce their hard exoskeletons.

Carbohydrates on cell surfaces allow for cell-to-cell recognition. This will be covered in more detail in a later lesson.

In general, cells use monosaccharides, such as glucose, as a source of energy. Plants and animals use polysaccharides, such as starch and glycogen, as storage compounds. The cellulose in the cell walls of plants is also a polysaccharide.

Biological Molecules – Lipids, Proteins, and Nucleic Acids

Lipids

Compared to other biological molecules, lipids contain more energy per gram. Lipids include steroids, such as sex hormones and cholesterol, which serve important functions in the body. Fats and oils, which act as energy storage molecules, are also lipids.

Phospholipids are a key component of cell membranes. Lipids are diverse in structure and function, but they are unable to form in water because they lack a polar group and, as a result, have no attraction to the other groups.

Lipids will be covered in more detail in a future lesson, but the general structures of fats and oils, phospholipids, and steroids are examined here.

Fats and Oils

Fats and oils form when glycerol molecule reacts with three fatty acid molecules. Fatty acids can be unsaturated (have double bonds between carbon atoms) or saturated (have no double bonds between carbon atoms). Fatty acids are long chains of carbon atoms with hydrogen atoms attached to them.

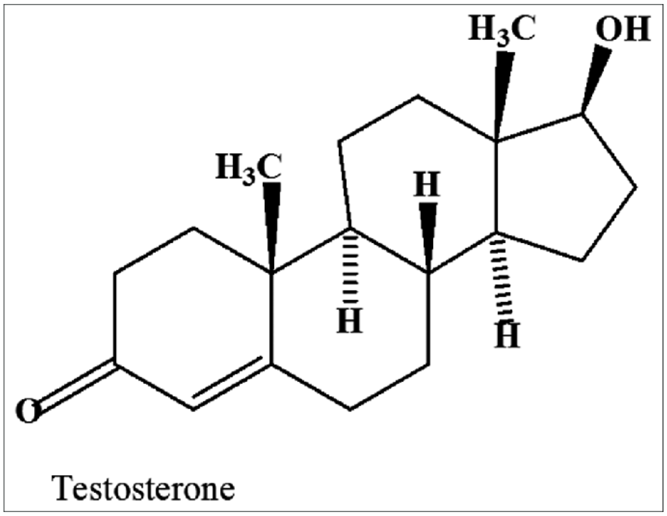
Phospholipids

Phospholipids make up most of a cell membrane. They are constructed like fats, except a phosphate group takes the place of one of the fatty acids. The glycerol end of the fat becomes polar and is able to dissolve in water. The fatty acid end does not dissolve in water.

Steroids

Steroids have characteristics similar to fats and are formed from cholesterol. Hormones such as estrogen, aldosterone, and testosterone are all steroids. The structure of a steroid is composed fo a backbone of four fused carbon rings. Each steroid differs by the arrangements in the rings and by functional group attached to it.

The following two models show examples of the structure of steroids, in this case, testosterone and estrogen.



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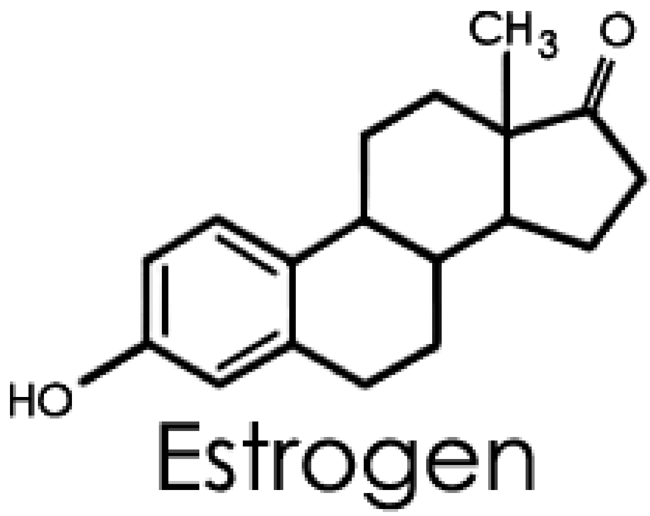

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Proteins

Protein have many functions and those will be discussed in more detail in a future lesson.

Proteins are polymers with amino acid monomers. They include all antibodies and enzymes, more hormones, and much of the structural support in the tissues of our bodies.

Proteins are composed of the elements carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur. Proteins are polypeptides or long, chained molecules composed of joined amino acids. An amino acid has a central carbon atom bonded to a hydrogen atom and three functional groups.

The following video illustrates the synthesis and degradation of a dipeptide.

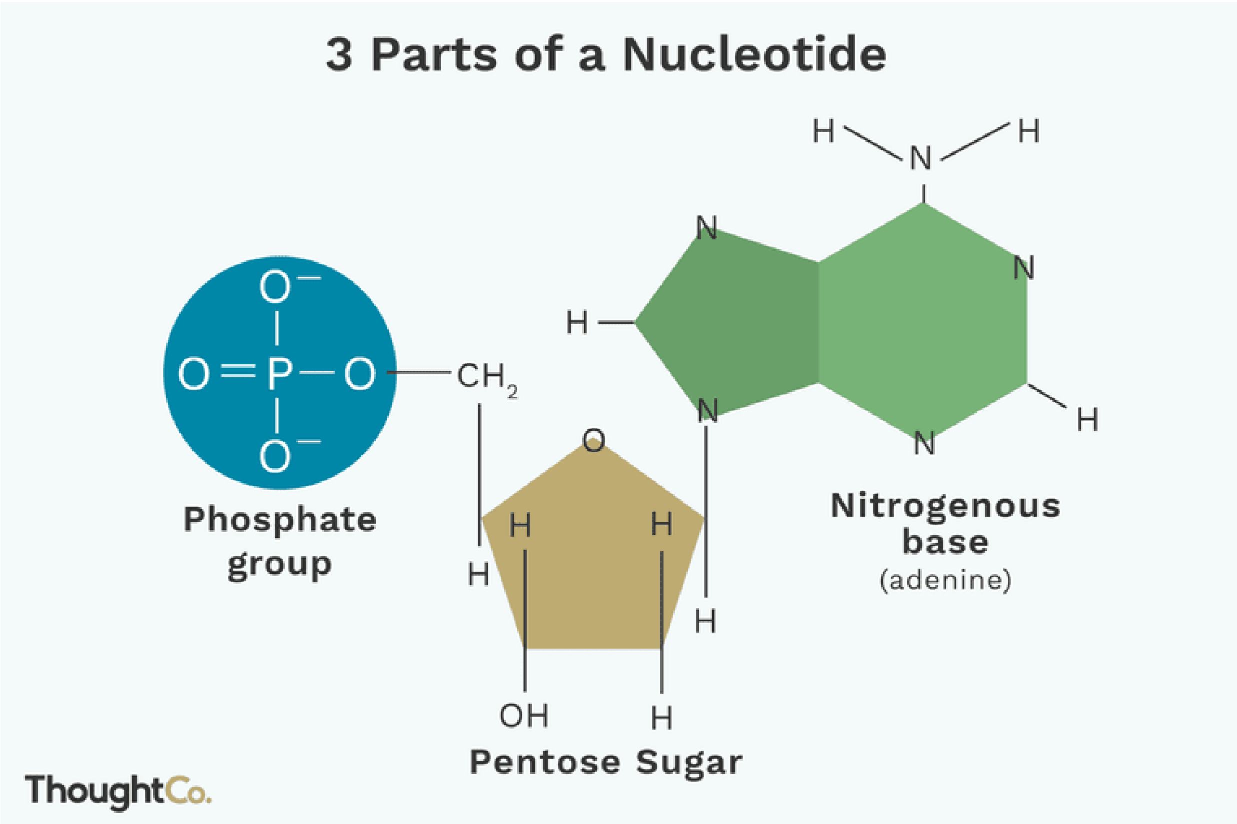
VIDEO: Dipeptides by WinstanleyBiology

LINK: https://youtu.be/6dcejnQfI9s

Nucleic Acids

There are two types of nucleic acids. The first is DNA (deoxyribonucleic acid) and the second is RNA (ribonucleic acid). The function of DNA and RNA will be discussed in greater detail in a later lesson.

The structure of both DNA and RNA consists of polymers of nucleotides. A nucleotide is made up of three molecules – a phosphate (phosphoric acid), a pentose sugar, and a nitrogen-containing base.



https://www.thoughtco.com/what-are-the-parts-of-nucleotide-606385

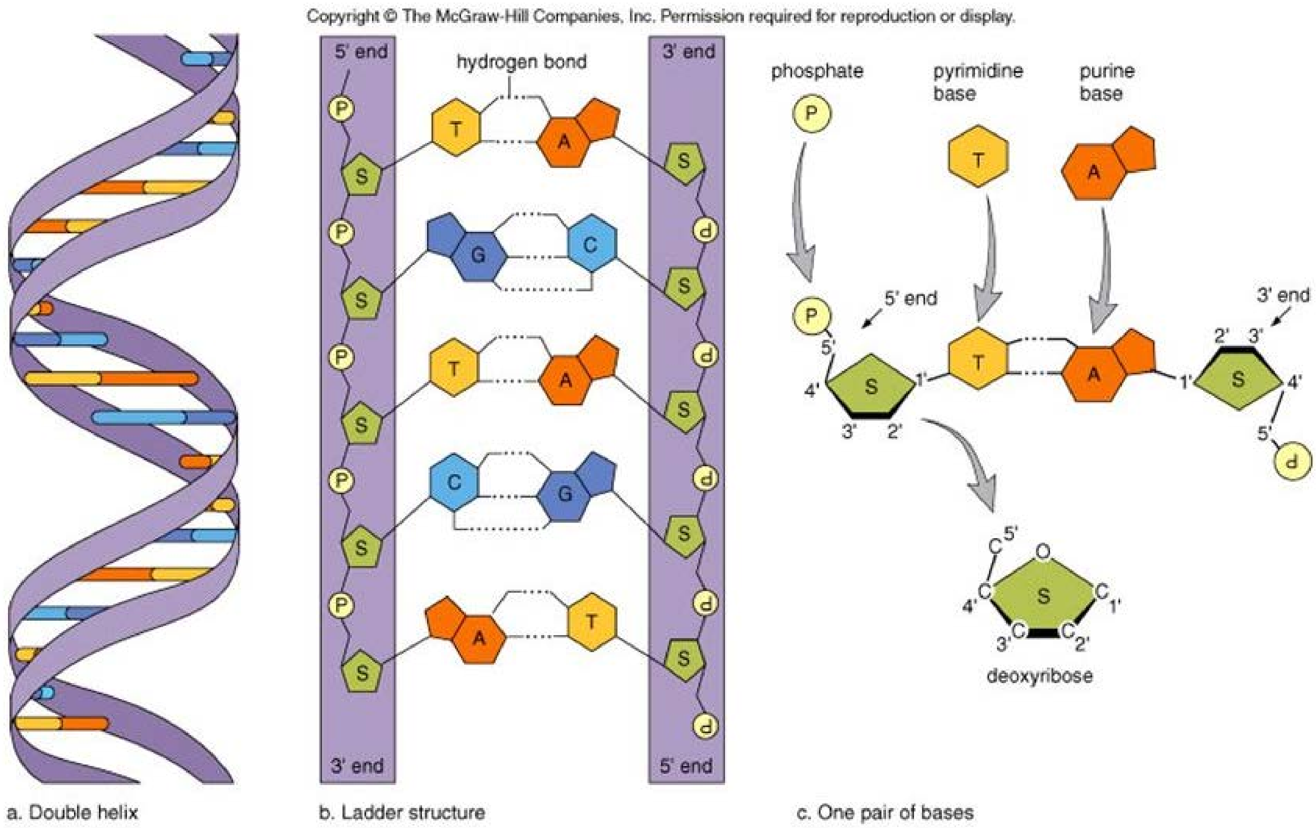
There are four types of nitrogen-containing bases: adenine (A), guanine (G), cytosine (C), and thymine (T).

DNA is thought to look like a twister ladder. The phosphates and the deoxyribose sugar make up the backbone or the uprights of the ladder, and pairs of bases form the ladder rungs. Adenine (A) will always bond with thymine (T), and guanine (G) will always bond with cytosine (C).

VIDEO: Structure Of Nucleic Acids - Structure Of DNA - Structure Of RNA - DNA Structure And RNA Structure by Whats Up Dude

LINK: https://youtu.be/apaP9a079po

Overview of DNA Structure



http://sgpaperfcdf.bellinghamfolkschool.com/structure-dna-overview-fucimytoq4873.html

Lipids

In the previous lesson you briefly learned about lipids, proteins, and nucleic acids. The next three lessons will revisit these biological molecules but provide further detailed instruction.

In this lesson you will compare and contrast the molecular structure of saturated fats and unsaturated fats and describe the location and explain the importance of neutral fats, steroids, and phospholipids in the human body.

Lipids

Lipids are diverse in structure and function, but they are unable to dissolve in water. Lipids are non-polar (lack polar groups), so they have no electrical attraction to polar solvents, such as water, because of this, lipids are insoluble.

Neutral Fats

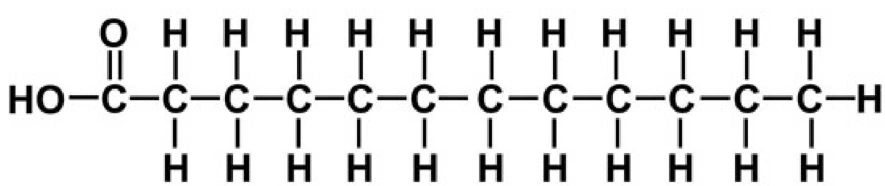
Fats are normally of animal origin (ex. Butter and lard). Oils are primarily of plant origin (ex. Soybean and corn oil). Fats and oils belong to the group of lipids called neutral fats. Fats and oils are considered neutral because they are non-polar molecules.

These types of molecules are called triglycerides because they are composed fo three fatty acid molecules. Fatty acids consist of long chains of carbon atoms with the hydrogen atoms attached, and end with the acidic group COOH. The glycerol molecule attaches to the fatty acid chains by dehydration synthesis.

Saturated fats, such as lard and butter, are solid at room temperature. They have the maximum number of hydrogen atoms on the fatty acid chains, which means there are no double bonds between the carbon atoms. These fats are saturated with all the hydrogen atoms they can hold.

This diagram shows a saturated fatty acid. Note there are no double bonds between carbon atoms.

Saturated Fatty Acid

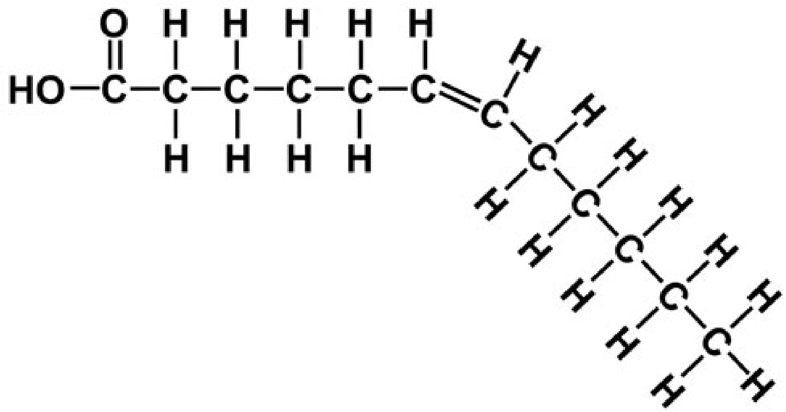


https://dlc.dcccd.edu/biology1-3/lipids

Unsaturated fats, such as olive and peanut oils, are liquids at room temperature. Their molecules have double bonds between any two carbon atoms with fewer than two hydrogen atoms attached to each. When the carbon atoms form double bonds, empty spaces are left around the carbon atoms. These spaces give the unsaturated fatty acids more freedom, which cause the oil to flow.

This diagram shows an example of an unsaturated fatty acid. There is at least one set of double bonds between any two carbon atoms.

Unsaturated Fatty Acid



https://dlc.dcccd.edu/biology1-3/lipids

Phospholipids

Phospholipids are special fat molecules that make up most of the cell membrane. Essentially, phospholipids are constructed similar to neutral fats (triglycerides), except a phosphate group takes the place of one of the fatty acids.

The phosphate end of the phospholipid becomes polar and is able to dissolve in water. The fatty acid end is non-polar and unable to dissolve in water. Because of this, phospholipids spontaneously form a bilayer in which the hydrophilic heads that can dissolve in water from the interior of the double-layer plasma membrane.

Steroids

Steroids are composed of a backbone of four fused carbon rings and are formed from a cholesterol precursor in body cells. Steroids have characteristics similar to fats. Some steroids differ from others by the arrangement of atoms in the carbon rings and the groups attached to the backbone. Testosterone (produced in the testes of males) and estrogen (produced in the ovaries of females) are synthesized from cholesterol.

Cholesterol is a component of an animal cell's plasma membrane and is a precursor for other steroids, such as bile salts. Steroid hormones can move about easily in the body due to their solubility in the phospholipid bilayer of the cell membrane.

Proteins

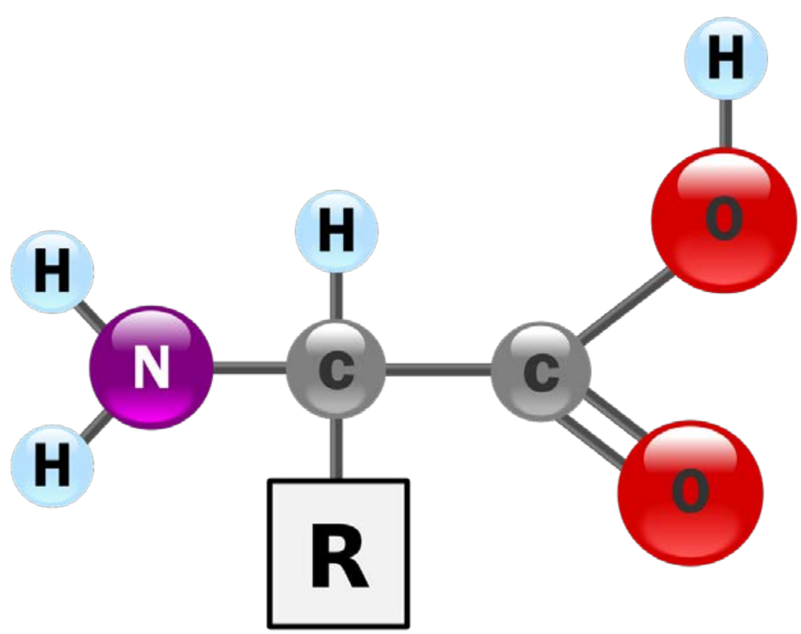
Proteins are an important group of cellular molecules that performs a variety of functions within the body. For example, hemoglobin is a protein in that transports oxygen in the blood. Antibodies are proteins that fight off foreign substances, such as disease and bacteria, and prevent them from destroying other cells. Many other proteins help with your exterior appearance. Keratin, for example, makes up your hair and nails, and collagen helps support your ligaments, tendons, and skin. Proteins are also responsible for forming enzymes.

Proteins are long chain molecules or polypeptides. They are composed of amino acids joined by peptide bonds that form by dehydration synthesis. There are twenty types of amino acids, which means there are many combinations and different type of proteins, each with a specific function.

In this lesson you will learn to draw a generalized amino acid and to identify the amine, acid (carboxyl), and R group. By the end of the lesson, you should be able to list the major functions of proteins and differentiate between the primary, secondary, tertiary, and quaternary structure of proteins.

Protein Structure

Protein include most hormones, antibodies, enzymes, and the majority of structural support tissues in the human body. Proteins are composed of the elements carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur.   Their structure consists of polymers made from the twenty different amino acids found in cells. Amino acids have a central carbon atom bonded to a hydrogen atom and three groups that include an amino group (-NH2), and acidic group (-COOH), and an R group. The R group is so named because it makes up the remainder of the molecule.



https://en.wikipedia.org/wiki/Amino_acid

Protein structure can be described in four levels – primary, secondary, tertiary, and quaternary.

Primary Structure of Proteins

Primary proteins are simply a linear sequence of amino acids linked by peptide bonds (C-N) that formed by dehydration synthesis. It is important that you understand the synthesis and degradation of a dipeptide. Following a dehydration reaction, water is given off as the peptide bonds joins two amino acids. Following a hydrolysis reaction, the addition of water causes the bond to break.

Secondary proteins look like primary proteins coiled into a slinky. The structure involves the twisting of the polypeptide chain into a helix or pleated sheet. These twisted structure are caused by hydrogen bonding between the H atoms in the amino groups and the O atoms of close range acidic groups.

Tertiary proteins are created by a secondary protein that has folded back upon itself and creating a three-dimensional structure. The globular shape of the tertiary protein often determines its function. The folding of this molecule is caused by covalent bonding between the R-groups in the structure.

Quaternary Proteins are made of two or more tertiary proteins joined together. The hemoglobin used to transport oxygen through the bloodstream is an example of a quaternary protein.

The functions of Proteins

Proteins function as enzymes, hormones, structural and plasma proteins, and a majority of the structural support tissue in the human body.

Enzymes

An enzyme is a biological catalyst that speeds up the chemical reaction taking place in the body. It does this by lowering the activation energy required for each chemical reaction to occur. Enzymes are involved in reactions such as blood clotting, synthesis and hydrolysis, DNA replication, and digestion. The function of the enzyme is determined by the tertiary structure of the protein. The names of enzymes have an –ase ending, for example, amylase, lipase, and carbonic anhydrase.

Structural Proteins

Structural proteins are found in many parts of the body. Keratin builds hair and nails; collagen gives strength to skin, cartilage, ligaments, tendons; and bone and muscle fibres are composed of actin and myosin proteins.

Membrane Proteins

AS you will learn about in a later section, a cell's plasma membrane has numerous proteins embedded in it. These proteins act as channels or pores, carriers, and pumps to move molecules into and out of the cell.

Hormones

Hormones are chemical messengers that travel throughout the body, influencing such cellular functions as metabolism, growth and development, and homeostasis (the internal maintenance of things like body temperature, blood sugar levels, etc.). Hormone regulate themselves by negative feedback mechanisms.

Plasma Proteins

Plasma is the liquid portion of the blood. It's mainly made up of water, but 7 to 8% of plasma consists of proteins. These proteins contribute to blood osmotic pressure by pulling water from the tissues. Albumin is an example of a plasma protein that helps maintain blood volume and pressure. Globulins help fight infection, and fibrinogen forms blood clots.

Nucleic Acids

Did you know that the DNA is one of your skin cells contains all the information needed to create you?

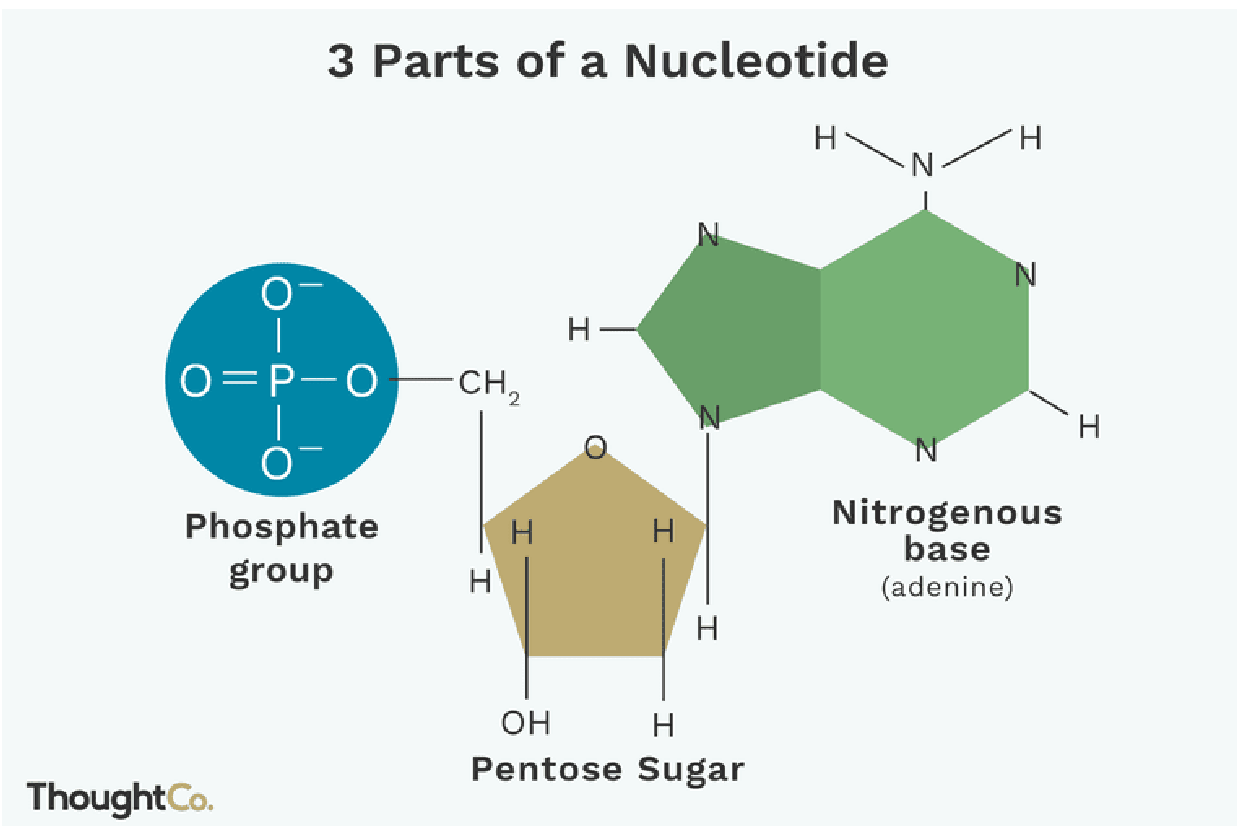
During the 1950s, Watson and Crick were the first scientists to describe DNA as a double helix structure. DNA, which is essentially the blue print for an organism, is made of many nucleotides. It is found in the nucleus of the cell and contains all the necessary instructions for creating an organism. However, without ATP energy created in the mitochondria, the nucleus would not have the energy to send the messages to the ribosomes to make proteins.

In this lesson you will review the basic structure and function of a nucleic acid, and you will also be able to relate the general structure of the ATP molecule to its role as the "energy currency" of cells.

The Structure of DNA

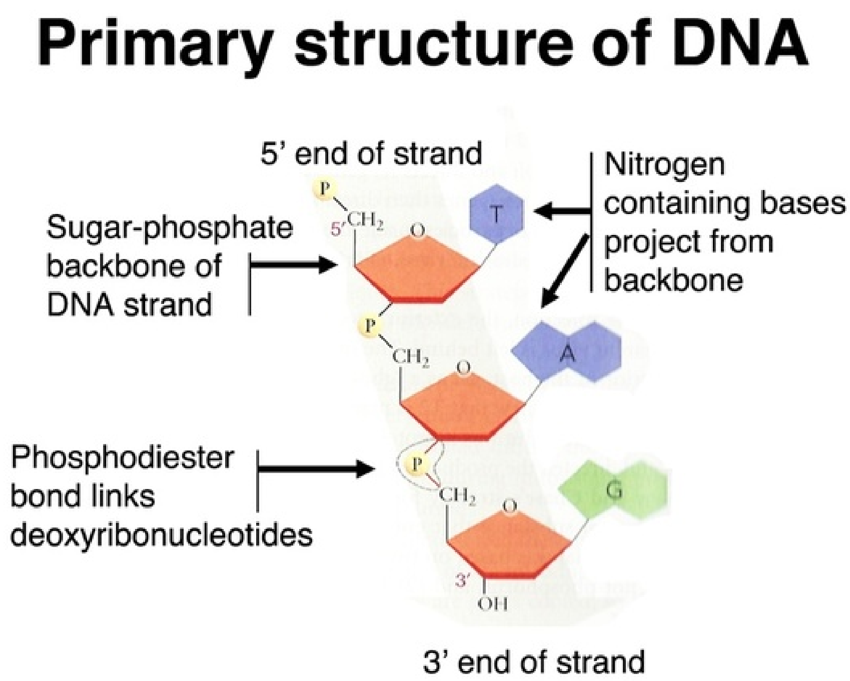
Both types of nucleic acids – DNA and RNA – are composed of many nucleotides. Nucleotides have three main parts:

1. A phosphate group (phosphoric acid)
2. A pentose (5 carbon) sugar (DNA contains the sugar deoxyribose and RNA contains the sugar ribose)
3. A nitrogen-containing base



https://www.thoughtco.com/what-are-the-parts-of-nucleotide-606385

DNA is a polymer of nucleotides. The sugars and phosphates form a linear sugar-phosphate-sugar backbone, and the bases project from the sides of the backbone.



https://www.quora.com/What-is-the-backbone-of-DNA-made-of

DNA has four different types of bases (named bases because their presence raises the pH of a solution):

1. Adenine (A)
2. Thymine (T) (in RNA, the base uracil (U) replaces the thymine)
3. Guanine (G)
4. Cytosine

DNA is double stranded, with two strands twisted around each other to form a double helix.

You will learn more about DNA/RNA structure, function, and replication in a later lesson.

ATP (Adenosine Triphosphate)

ATP (adenosine triphosphate) is a high-energy molecule that releases the energy required for all the metabolic work done in the cell. It is composed of adenine (a nitrogenous base), a ribose 5-sided sugar, and three phosphate groups.

ATP molecules must be created in a cell because a glucose molecule contains too much energy to be used as a direct source in cellular reactions.

ATP acts as the "energy currency" of the cell because the last two phosphate bonds are unstable and are easily broken. In most cases the last phosphate bond is hydrolyzed, leaving ADP (adenosine diphosphate) and an inorganic molecule of phosphate. ATP is another example of a nucleotide, but it has three phosphates as opposed to the one phosphate group (phosphoric acid) found in a nucleotide in DNA.

The energy released drives chemical reactions in cells. These molecules can be recycled and used to produce more ATP in the mitochondria. ATP is specifically used to synthesize polymers, to pump molecules across the cell membrane, for muscle contraction, and for the beating of cilia in the lungs.