II. ELEMENTAL COMPOSITION OF LIVING MATTER

II.1. CONSTITUENTS OF MACROMOLECULES

A living cell is composed of a restricted set of elements, six of which (C, H, N, O, P, S) make up more than 99% of its weight, which represent the macroelements. This composition differs markedly from that of the Earth's crust and is evidence of a distinctive type of chemistry.

The most abundant substance of the living cell is not special at all, since it covers two-thirds of the Earth's surface. Water accounts for about 70% of the weight of cells, and most intracellular reactions occurs in an aqueous environment. Life in this planet began in the ocean, and the conditions in that primeval environment put a permanent stamp on the chemistry of living things. All organisms have been designed around the unique properties of water, such as its polar character and hydrogen bonds, its high melting and boiling points, and its high surface tension.

If we disregard water, all but a minor fraction of the molecules of a cell are carbon compounds, which are the subject matter of organic chemistry. Carbon is outstanding among all the elements on earth for its ability to form large molecules. The carbon atom, because of its small size and four outer-shell electrons, can form four strong covalent bonds with other atoms. Most important, it can join to other carbon atoms to form chains and rings and thereby generate large and complex molecules with no obvious upper limit to their size. Other abundant atoms in the cell are also small and able to make very strong covalent bonds.

In principle, the simple rules of covalent bonding between carbon and other elements permit an astronomically large number of compounds. The number of different carbon compounds in a cell is very large, but it is only a tiny subset of what is theoretically possible.

All the properties manifested by living cells ultimately reflect the characteristics of the organic molecules from which cells are constructed. In order to understand how cells carry out their essential functions, it is therefore necessary to describe the types of molecules inhabiting the cell. Of
the 92 natural elements potentially available for use in constructing these biological molecules, a relatively small number are of major importance (Table II, III and IV).

Table II – THE MACROELEMENTS' DISTRIBUTION AND ROLE

MACROELEMENTS	ROLE
CARBON (C)	forms backbone of all organic compounds
HYDROGEN (H)	constituent of water, all foods, and most organic molecules
OXYGEN (O)	constituent of water, organic compounds and all macromolecules; functions in cellular respiration
NITROGEN (N)	component of all protein molecules and nucleic acid molecules

PHOSPHORUS (P)	component of many proteins, nucleic acids, ATP and cyclic AMP; require for normal bone and tooth structure; found in nerve tissue; key role in energy transfer
SULPHUR (S)	component of many proteins, especially the contractile proteins of muscle

Carbon, hydrogen, oxygen, nitrogen, phosphorus and **sulphur** predominate in the large macromolecules that make up most of the cell's dry mass (Table II).

Table III - OTHER MAJOR ELEMENTS' (MICROELEMENTS) DISTRIBUTION AND ROLE

MICROELEMENTS	ROLE
SODIUM (Na)	Na^+ is a cation of NaCl; structural component of bone; essential in blood to maintain water balance; needed for conduction of nerve impulses
POTTASIUM (K)	require for growth and important in conduction of nerve impulses and muscle contraction
CHLORINE (Cl)	Cl^- is an anion of NaCl, a salt important in water movement between cells; principal cellular and extracellular anion
CALCIUM (Ca)	constituent of bone and teeth; required for blood clotting, intake (endocytosis) and output (exocytosis) of substances through plasma membranes, motility of cells, movement of chromosomes prior to cell division, glycogen metabolism, synthesis and release of neurotransmitters, and contraction of muscle
MAGNESIUM (Mg)	component of many enzymes
MANGANESE (Mn)	required for activity of several enzymes
ZINC (Zn)	required for activity of many enzymes
COPPER (Cu)	essential in some oxidations and enzymes
IRON (Fe)	essential component of hemoglobin and respiratory enzymes

Table IV – TRACE ELEMENTS' (OLIGOELEMENTS) DISTRIBUTION AND ROLE

OLIGOELEMENTS	ROLE
BORON (B)	essential in some plants; function unknown
IODINE (I)	essential for thyroid hormones
FLUORINE (F)	growth factor in rats; possible constituent of teeth and bone
SILICON (Si)	possible structural unit of diatoms; essential in chicks; function unknown
COBALT (Co)	required for activity of several enzymes
MOLYBDENUM (Mb)	required for activity of several enzymes

CHROMIUM (Cr)	essential in higher animals; required for insulin action
VANADIUM (Vn)	essential in lower plants, certain marine animals and rats
SELENIUM (Se)	essential for liver function
NICKEL (Ni)	required under study

II.2. INORGANICS COMPOUNDS

II.2.1. WATER

The most abundant compound in the cell is water, accounting for 75-90% of the total mass in most cells.

In fact, with a few exceptions, such as tooth enamel and bone tissue, water is by far the most abundant material in tissues. About 60% of red cells, 75% of muscle tissue, and 92% of blood plasma is water.

Hence life occurs in an aqueous environment, with the properties of water dictating to a large extent the activities that can take place. Water plays at least two critical roles. It is the medium in which all cellular reactions occur, as well as a direct reactant in the case of hydrolysis and dehydration reactions.

1. One of the key features determining the properties of water molecule is the fact that its electrons are not equally shared between the oxygen and the hydrogen, but are instead more closely associated with the oxygen.

One end of the molecule therefore exhibits a partial negative charge and the other a partial positive charge. This inherent **polarity** permits weak binding of water molecules to each other, as well as to any charged substance. The polarity of water also contributes to its great solvent power and its ability to dissociate other molecules into ions.

The solvating property of water is essential to health and survival. For example, if the surface of the air sacks in your lungs is not moist, oxygen cannot dissolve and therefore cannot move into your blood to be distributed throughout your body. Water, moreover, is the solvent that carries nutrients into and wastes out of your body cells.

As a suspending medium, water is also vital to your survival. Many large organic molecules are suspended in the water of your body cells. These molecules are consequently able to come in contact with other chemicals, allowing various essential chemical reactions to occur.

2. Water can participate in chemical reactions. During digestion, for example, water can be added to large nutrient molecules in order to break them down into smaller molecules. This kind of breakdown is necessary if the body is to utilize the energy in nutrients. Water molecules are also used in synthesis reactions. Such reactions occur in the production of hormones and enzymes.

3. Water absorbs and releases heat very slowly. In comparison to other substances, water requires a large amount of heat to increase its temperature and a great loss of heat to decrease it and so water moderates the effects of fluctuations in environmental temperature and thereby helps to maintain a homeostatic body temperature.

4. Water requires a large amount of heat to change from a liquid to gas. When water evaporates (perspiration) from the skin, it takes with it large quantities of heat and provides an excellent cooling mechanism.

5. Water serves as a lubricant in various regions of the body. It is a major part of mucus and other lubricating fluids. Lubrication is especially necessary in the chest and abdomen, where internal organs touch and slide over each other. It is also needed at joints, where bones, ligaments, and tendons rub against each other. In the gastrointestinal tract, water in mucus moistens foods to ensure their smooth passage.

The repartition of water in organism: -an adult about 70 kg, contains approx 40 kg of water, that means 60% from his weight. This water is divided in **intracellular environment** (40%) and in **extracellular environmen**t (20%). **Extracellular water** is distributed also to ***intravascular sector*** (plasma and limfa), which represents 15% and in ***extravascular sector*** (cerebrospinal liquid, interstitial liquid), which is 5 %.

Extracellular water forms the internal environment of the body. Its quantities must be constant for maintaining the homeostasis of the body.

Intracellular water - a cell is compounded of a watery phase and a nonwatery phase. Nonwatery phase is compounded from the membranes system (insoluble in water because of the lipid layer). The watery phase contains 2 forms: free water and bound water.

a) Free water represents 95% from the total intracellular water. It is the solvent of the metabolic processes;

b) Bound water represents 4.5% from intracellular water. It is bounded with proteins, lipids and other cellular compounds.

II.2.2. SALTS

A salt is an inorganic compound that consists of a cation that is not a hydrogen ion and an anion that is not a hydroxyl ion. Salts are held together by ionic bounds, and in water they dissociate, releasing cations and anions. For example, table salt (NaCl) in solution dissociates into Na and Cl ions; these are the most abundant ions in the body.

Salts are examples of electrolytes, compounds whose ions will conduct an electrical current in solution. For example, sodium ions (Na^+), potassium ions (K^+), calcium ions (Ca^{++})), and chloride ions (Cl^-) are released by the dissociation of electrolytes in blood and other body fluids. Alterations in the body fluid concentrations of these ions will disturb almost every vital function. For examples, declining potassium levels will lead to a general muscular paralysis, and rising concentrations will cause weak and irregular heartbeats.

In conclusion, many salts are found in the body. Some are in cells, whereas others are in the body fluids, such as lymph, blood, and the extracellular fluid of tissues. The ions of salts are the source of many essential chemical elements.

II.2.3. GASES

Carbon dioxide (CO_2) is produced by our cells in the course of normal metabolic activities. It is transported in the blood and released into the air in the lungs.

Oxygen (O_2), an atmospheric gas, is absorbed at the lung level, transported in the blood, and consumed by our cells.

II.3. ORGANIC COMPOUNDS

In addition with carbon, the most frequently found elements in organic compounds are hydrogen (which can form one bond), oxygen (two bonds), and nitrogen (three bonds). Sulphur (two bonds) and phosphorus (five bonds) appear less often. Other elements are found, but only in a relatively few organic compounds. Carbon has several properties that make it particularly useful to living organisms. For one thing, it can react with one to several hundred other carbon atoms to form large molecules of many different shapes. This means that the body can built many compounds out of carbon, hydrogen, and oxygen- Each compound can be especially suited for a particular structure or function. The relatively large size of most carbon containing molecules and the fact that some do not dissolve easily in water make them useful materials for building body structures. Carbon compounds are mostly or entirely held together by covalent bonds and tend to decompose easily. This means that organic compounds are also a good source of energy. Ionic compounds are not good energy sources because they form new ionic bonds as soon as the old ones are broken.

II.3.1. CARBOHYDRATES

A large and diverse group of organic compounds found in the body are the carbohydrates, also known as sugars and starches. The carbohydrates perform a number of major functions in living systems. A few even form structural units. For instance, one type of sugar (deoxyribose) is a building block of deoxyribonucleic acid (DNA), the molecules that carries hereditary information. Some carbohydrates are converted to other substances, which are used to build structures and provide an emergency source of energy. Other carbohydrates function as food reserves. One example is glycogen, which is stored in the liver and skeletal muscles. The principal function of carbohydrates, however, is to provide the most readily available source of energy to sustain life.

Carbon, hydrogen and oxygen are the elements found in carbohydrates, in a ratio near 1:2:1 .This ratio can be seen in the formulas for carbohydrates such as ribose ($C_5H_{10}O_5$), glucose ($C_6H_{12}O_6$), and sucrose ($C_{12}H_{22}O_{11}$). Although there are exceptions, the general formula for carbohydrates is $(CH_2O)_n$ where *n* symbolizes three or more CH_2O units. Carbohydrates can be divided into three major groups on the basis of size: monosaccharides, disaccharides, and polysaccharides.

II.3.1.1. **Monosaccharides** or the simplest sugars are compounds containing from three to seven carbon atoms. Simple sugars with three carbons in the molecule are called trioses. The number of carbon atoms in the molecule is indicated by the prefix *tri*. There are also tetroses (four-carbon sugars), pentoses (five-carbon sugars), hexoses (six-carbon sugars), and heptoses (seven-carbon sugars). Pentoses and hexoses are exeedingly important to the human organism. The pentose called deoxyribose is a component of genes. The hexose called ***glucose*** is the main energy-supplying molecule of the body.

II.3.1.2. Disaccharides the second group of carbohydrates, are also sugars and consist of two monosaccharides joined chemically. In the process of disaccharide formation, two monosaccharides combine to form a disaccharide molecule and a molecule of water is lost. This reaction is known as ***dehydration synthesis*** *(dehydration-loss of water)*. The following reaction shows disaccharide formation:

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{fructose}}{C_6H_{12}O_6} \rightarrow \underset{\text{sucrose}}{C_{12}H_{22}O_6} + \underset{\text{water}}{H_2O}$$

Molecules of the monosaccharide glucose and fructose combine to form a molecule of disaccharide sucrose. You may be puzzled to see that glucose and fructose have the same chemical formulas. Actually, they are different monosaccharides, since the relative positions of the oxygens and carbons vary in the two different molecules (Figure 6). In every dehydration synthesis, a molecule of water is lost. Along with this water loss, there is the synthesis of two small molecules, such as glucose and fructose, into one large, more complex molecule, such as sucrose (Figure 6). Similarly, the dehydration synthesis of two monosaccharides glucose and galactose forms the disaccharide lactose.

Disaccharides can also be broken down into smaller, simpler molecules by adding water. This reverse chemical reaction is called ***digestion*** *(hydrolysis)*, which means to split by using water. A molecule of sucrose, for example, may be digested into its components of glucose and fructose by the addition of water.

II.3.1.3. **Polysaccharides** have the formula $(C_6H_{10}O_5)_n$. The third major group of carbohydrates, the polysaccharides, consists of several monosaccharides joined together through dehydration synthesis. Like disaccharides, polysaccharides can be broken down into their constituent sugars through hydrolysis reaction. Unlike monosaccharides or disaccharides they usually lack the characteristic sweetness of sugar like fructose or sucrose and are usually not soluble in water. One of the chief polysaccharides is **glycogen.**

Glycogen, or animal starch, is a branched polysaccharide composed of interconnected glucose molecules. Like most other large polysaccharides, glycogen will not dissolve in water or other body fluids. Liver and muscle tissues manufacture and store significant amounts of glycogen. When these tissues have a high demand for energy, glycogen molecules are broken down into glucose; when demands are low, the tissues absorb or synthesize glucose and rebuild glycogen reserves.

Some people cannot tolerate sugar for medical reasons; others avoid it because they do no want to gain weight (excess sugars are stored as fat). Many of these people use artificial sweeteners in their foods and beverages. These compounds have a very sweet taste, but they either cannot be broken down in the body or they are used in such small amounts that their breakdown does not contribute to the overall energy balance of the body.

II.3.2. LIPIDS

A second group of organic compounds that is vital to the human organism is lipids. Like carbohydrates, lipids are composed of carbon, hydrogen, and oxygen, but they do not have a 2:1 ratio of hydrogen to oxygen. In fact the amount of oxygen in lipids is usually less than that in carbohydrates. In addition, lipids may contain small quantities of other elements, such as phosphorus, nitrogen, or sulphur. Familiar lipids include fats, oils, and waxes. Most lipids are insoluble in water, but special transport mechanisms carry them in the circulating blood.

Lipids form essential structural components of all cells. Lipid deposits also serve as energy sources and reserves. On average, lipids provide roughly twice as much energy as carbohydrates, gram for gram, when broken down in the body. For this reasons there has been great interest
in developing fat substitutes that that have the taste and texture of lipids, but without the calories.

All together, lipids normally account for roughly 12% of our total body weight. There are many different kinds of lipids in the body (Table V). The major types, presented are: fatty acids, glycerides, steroids, and phospholipids.

II.3.2.1 Fatty acids - are long carbon chains with hydrogen atoms attached. When placed in solution, only the carboxylic acid end (-COOH) of a fatty acid associates with water molecules. The rest of carbon chain is relatively insoluble.

In a saturated fatty acid each carbon atom has four single covalent bounds, allowing it to bond to a maximum number of hydrogen atoms. If any of the carbon - to - carbon bonds are double covalent bonds, then fewer hydrogen atoms are present and the fatty acid is unsaturated. Saturated and unsaturated fatty acids are shown in Figure 8. A polyunsaturated fatty acid contains multiple unsaturated bonds.

Both saturated and unsaturated fatty acids can be broken down for energy, but a diet containing large amounts of saturated fatty acids increases the risk of heart disease and other circulatory problems. Butter, fatty meat, and ice cream are popular dietary sources of saturated fatty acids. Vegetable oils such as olive oil or corn oil contain a mixture of unsaturated fatty acid.

II.3.2.2. Glycerides - Individual fatty acids cannot be strung together in a chain by dehydration synthesis, as simple as sugar can. But they can be attached to another compound, **glycerol**, through a similar reaction. In a **triglyceride**, a glycerol molecule is attached to three fatty acids. Triglycerides, otherwise known as neutral fats, are the most common fats in the body. In addition to serving as an energy reserve, fat deposits under the skin serve as insulation, and a mass of fat around a delicate organ, such as kidney, provides a protective cushion. Saturated fats, triglycerides containing saturated fatty acids, are usually solid at room temperature. Unsaturated fats, triglycerides containing unsaturated fatty acids, are usually liquid at room temperature.

II.3.2.3. Steroids are large lipid molecules composed of connected rings of carbon atoms, quite unlike the linear carbon chains of fatty acids. **Cholesterol** is probably the best-known steroid. All of our cells are surrounded by cell membranes that contain cholesterol, and some chemical messengers, or hormones, are derived from cholesterol. Examples include the sex hormones testosterone and estrogen.

The cholesterol needed to maintain cell membranes and manufacture steroid hormones comes from two sources. One source is the diet; meat, cream, and egg Yolks are especially rich in cholesterol. The second is the body itself, for the liver can synthesize large amounts of cholesterol. The ability of the body to synthesize the steroid can make it difficult to control blood cholesterol levels by dietary restriction alone. This difficulty can have serious repercussions because a strong link exists between high blood cholesterol concentrations and heart disease. Current nutritional advice suggests reducing cholesterol intake to fewer than 300 mg per day; this amount represents a 40% reduction for the average American adult.

II.3.2.4. Phospholipids consist of a diglyceride attached to molecule containing a phosphate group (PO_4^{3-}).The nonlipid portion is soluble in water, whereas the fatty acid portion is relatively insoluble. Phospholipids are the most abundant lipid components of cell membranes.

Table V - Relationships of representative lipids to the human organism

Lipids	
FATS	Protection, insulation, source of energy
PHOSPHOLIPIDS	
Lecithin	Major lipid component of cell membranes; constituent of plasma.

Cephalin and sphingomyelin	Found in high concentrations in nerves and brain tissue.
STEROIDS	
Cholesterol	Constituent of all animal cells, blood, and nervous tissue; suspected relation ship to heart disease and atherosclerosis; precursor of bile salts, vitamin D, and steroid hormones.
Bile salts	Substances that emulsify or suspend fats before their digestion and absorption of fat-soluble vitamins (A, D, E, K).
Vitamin D	Produced in skin on exposure to ultraviolet radiation; necessary for bone growth, development and repair.
Estrogens	Sex hormones produced in large quantities by females.
Androgenes	Sex hormones produced in large quantities by males.

II.3.3. PROTEINS

Proteins are the most abundant and diverse organic components of the human body. There are roughly 100,000 different kinds of proteins, and they account for about 20 % of the total body weight. All proteins contain carbon, hydrogen, oxygen, and nitrogen; smaller quantities of sulphur may also be present.

II.3.3.1. Protein function - Proteins perform a variety of essential functions. These fall into seven major categories:

1. *Support* - **Structural proteins** create a three-dimensional supporting framework for the body, providing strength, organization, and support for cells, tissues, and organs. Examples: keratin in the skin, hair, and fingernails; and collagen in connective tissue
2. *Movement* - **Contractile proteins** are responsible for muscular contraction; related proteins are responsible for the movement of individual cells .Examples: actin and myosin
3. *Transport* - Insoluble lipids, respiratory gases, special minerals, such as iron, and several hormones are carried in the blood attached to special **transport proteins.** Other specialized proteins transport materials from one part of a cell to another. Example: hemoglobin, which transports oxygen and carbon dioxide in the blood.
4. *Buffering* - Proteins provide a considerable buffering action, helping to restrict alterations in ph.
5. *Metabolic regulation* - **Enzymes** accelerate chemical reactions in living cells. The sensitivity of enzymes to environmental factors is extremely important in controlling the pace and direction of metabolic operations. Examples: salivary amylase, lipase and lactase.
6. *Coordination, communication, and control (regulatory)* - Protein hormones can influence the metabolic activities of every cell in the body or affect the function of specific organs or organ systems. Example: insulin, which regulates blood sugar level.
7. *Defense (immunological)* - Serve as **antibodies** to protect the body against invading microbes. Example: gamma globulin.

II.3.3.2. Protein structure Proteins are chains of small organic molecules called amino acids. The human body contains significant quantities of 20 different amino acids.

A typical protein contains 1000 amino acids, but the largest protein complexes may have 100,000 or more. The individual amino acids are strung together like beads on a string, with the carboxylic acid group of one amino acid attached to the amino group of another. This connection is called a peptide bond. If a molecule consists of two amino acids, it is called a dipeptide (Figure 11). The chain can be lengthened by the addition of more amino acids. Polypeptides are long chains of amino acids. Proteins are polypeptide chains containing over 100 amino acids.

Particularities of protein shape:

- The shape of a short peptide chain primarily depends on interactions between amino acids at different sites along the peptide chain.
- Large proteins can have complex three-dimensional shapes. In a *globular protein*, the peptide chain folds back on itself, creating a rounded mass such as *myoglobin.* Myoglobin is a protein found in muscle cells.
- Complex proteins may consist of several protein subunits. Examples include *hemoglobin*, a globular protein found inside red blood cells, and *keratin,* the tough, water-resistant protein found in skin, nails, and hair. Keratin is an example of a *fibrous protein*. In fibrous proteins the polypeptide strands are wound together as in a rope. Fibrous proteins are flexible but very strong.

The shape of a protein determines its functional properties, and the primary determinant of shape is the sequence of amino acids. Combining the 20 amino acids in various combinations creates an almost limitless variety of proteins. Small differences can have large effects; changing one amino acid in a protein containing 10,000 or more may make it incapable of performing its normal function.

The shape of a protein - and thus its function - can be altered by small changes in the ionic composition, temperature, or ph of its surroundings. For example, very high body temperatures (over 43^0C, or 110^0F) cause death because at these temperatures proteins undergo denaturation, a change in their three-dimensional shape. Denatured proteins are nonfunctional, and the loss of structural proteins and enzymes causes irreparable damage to organs and organ systems. You see denaturation in progress each time you fry an egg, for the clear egg white contains abundant dissolved proteins. As the temperature rises, the protein structure changes and eventually the egg proteins form an insoluble white mass.

II.3.3.3. Structural organisation levels of proteins

Proteins exhibit four levels of structural organisation:

a) **Primary structure** is a unique order (sequence) of amino acids making up the protein. Alteration in primary structure can have serious consequences. Example: a single substitution of an amino acid in a blood protein can result in a deformed hemoglobin molecule that produces sickle-cell anemia.

b) **Secondary structure** is the localized, repetitious twisting or folding of its polypeptide chain. Common secondary structures are clockwise spirals (helixes) and pleated sheets.

c) **Tertiary structure** refers to the overall three dimensional structure of a polypeptide chain. The folding is not repetitive or predictable as in secondary structures. Is very irregular, and it determines the particular function of a protein.

d) **Quaternary structure** refers to two or more individual polypeptide chains bounded to each other that function as a single unit.

II.3.4. NUCLEIC ACIDS: DEOXYRIBONUCLEIC ACID (DNA); RIBONUCLEIC ACID (RNA)

Nucleic acids, compounds first discovered in the nuclei of cells, are exceedingly large organic molecules containing carbon, hydrogen, oxygen, nitrogen, and phosphorus. They are divided into two principal kinds: **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)**.

Whereas the basic structural units of proteins are amino acids, the basic units of nucleic acids are **nucleotides.**

II.3.4.1. DNA - a molecule of DNA is a chain composed of repeating nucleotide units. Each nucleotide of DNA consists of 3 basic parts:

1. It contains one or four possible nitrogenous bases, which are ring-shaped structures containing atoms of C, H, O, and N. The nitrogenous bases found in DNA are adenine, thymine, cytosine,
   and guanine. Adenine and guanine are double-ring structures, collectively referred to as *purines.* Thymine and cytosine are smaller, single-ring structures called *pyrimidines.*
2. It contains a pentose sugar called *deoxyribose.*
3. It also contains *phosphate group.*

The chemical components of the DNA molecule were known before 1900, but it was not until 1953 that a model of the organization of the chemicals was constructed. This model was proposed by J.D. Watson and F.H. C. Crick on the basis of data from many investigations.

The structural characteristics of the DNA molecule:

- The molecule consists of two strands with crossbars. The strands twist about each other in the form of a ***double helix*** (Figure 16), so that the shape resembles a twisted ladder. For many years, it was assumes that all DNA was in the form of a double helix that twisted smoothly to the right (right-handed DNA). There are four varieties of right-handed DNA designated as A-DNA, B-DNA, C-DNA, and D-DNA. Watson and Crick's model, the one most commonly found in cells, is B-DNA. Also DNA can twist jaggedly to the left (Z-DNA or left-handed DNA). This alternate form of DNA is located near the ends of genes and may help to explain how genes turn on and off and how some cells may become malignant.
- The uprights of the DNA ladder consists of alternating phosphate groups and the deoxyribose portions of the nucleotides.
- The rungs of the ladder contain paired nitrogenous bases .As shown, adenine always pairs with thymine, and cytosine always pairs with guanine.

Cells contain hereditary material called **genes,** each of which is a segment of DNA molecule (Table VI). Our genes determine which traits we inherit, and they control all the activities that take place in our cells throughout a lifetime. When a cell divides, its hereditary information is passed on to the next generation of cells. The passing of information is possible because of DNA's unique structure.

The place of DNA:

- in eukariotes cells - in nucleus (double helix);
- in mitochondria (circular);
- in prokaryotes - circular molecules;
- viral DNA - circular molecule.

Each of the two strands in a circular DNA molecule forms a closed structure without free ends. Just as is the case for linear DNA, elevated temperatures or alkaline pH destroy the hydrogen bondes and otherinteractions that stabilize double-helical circular DNA molecules.

Unlike linear DNA, the two strands of circular DNA cannot unwind and separate, so they form an interlocked, tangled mass of single-stranded DNA under denaturing condition.

TABLE VI – THE DNA AND GENES

	Amount of DNA (bp)	**Estimated number of Genes**
PROKARYOTES		
E. coli	4.5×10^6	4,000
EUKARYOTES		
S. cerevisiae	1.5×10^7	5,000 to 10,000
Caernohabitis elegans	5.0×10^7	10,000
Drosophila melanogaster	1.5×10^8	20,000
Humans	4.0×10^9	100,000 to 500,000

II.3.4.2. RNA represents the second principal kind of nucleic acid with the following structural characteristics:

- is a single-stranded;
- the sugar is the pentose ribose:
- does not contain the nitrogen base thymine; instead of thymine, RNA has the nitrogen base uracil.

There are 3 kinds of RNA molecules that perform different but cooperative functions:

- ***Messenger RNA (mRNA)*** encodes the genetic information copied from DNA in the form of a sequence of bases that specifies a sequence of amino acids (Figure 15).
- ***Transfer RNA (tRNA)*** is the key to deciphering the code. The amino acids specified by the base sequence of an mRNA molecule are each attached to specific tRNAs, then carried to and deposited at the growing end of a polypeptide chain. The correct tRNA with its attached amino acid is selected at each step because each specific tRNA molecule can "read", by base pairing, its complementary base sequence in the mRNA.
- ***Ribosomal RNA** (rRNA)* has important functions by itself, including attracting the mRNA and very likely catalyzing peptide-bond formation. In addition, rRNA binds a set of proteins to form ribosomes; rRNA plus the associated ribosomal proteins provide binding sites for all the accessory molecules necessary for proteins synthesis. Ribosomes bearing bound tRNAs and special proteins can physically move along an mRNA molecule to translate its encoded genetic information into protein.

II.3.5. ENZYMES

Thousands of chemical reactions occur in the typical cell. These reactions underlie such diverse activities as synthesis and degradation of chemical building blocks, trapping and utilization of chemical energy, synthesis of macromolecules, transmission of genetic information, transport of materials across membranes, and motility. Thus every important cell function is dependent upon chemical reactions.

Most reactions upon which living organisms depend do not depend on, occur fast enough at moderate temperatures to sustain life without catalysts to speed these reactions.

Enzymes are specialized proteins that speed up the reactions that support life; belong to a class of substances called catalysts (compounds that accelerate chemical reactions without themselves being permanently changed). Enzymes are thousands and thousands of different kinds, each designed to enhance the rate of a specific reaction.

II.3.5.1. Structure and Function:

- The reactants in an enzymatic reaction ***(substrates)*** interact to form a specific ***product***.
- Substrate molecules bind to the ***enzyme*** at a particular location called ***active site.***
- This binding depends on the complementary shapes of the two molecules (as a key fits in a lock). The shape of the active site is determined by the three-dimensional shape of the enzyme molecule.
- When the reaction is completed, the products are released, and enzyme is free to catalyze another reaction.

In the years since the pioneering work of Summer and Northrop, over a thousand enzymes have been purified and identified as proteins. Though the number of different reactions catalysed by these enzymes is very large, one can subdivide this group into a relatively small number of categories (Table VIII).

All cellular reactions are catalysed by enzymes that fit into one of these categories.

Characteristics of enzymes:

1. modify the rates of chemical reactions;
2. are not consumed in the process;
3. are effective in extremely small quantities;
4. enzymes do not alter the equilibrium of the reaction being catalyzed.

Properties of enzymes:

- Enzymes are exceedingly efficient compared to other catalysts (a typical enzymatic reaction may proceed as much as 10^8-10^{11} times faster than the same reaction catalyzed by a nonenzymatic catalyst.

- The catalytic activity of enzymes can be regulated to suit specific cellular needs.
- The most striking properties of enzymes are their selectivity. Unlike other catalysts enzymes are highly specific, both in the types of reactions they catalyze and in the structures of the substances upon which they act. Example: the enzyme glucose oxydase is specific not just for the oxidation of glucose versus other six-carbon sugars but also for a particular three-dimensional form of the sugar, namely alfa-glucose.

The unique properties of enzymes (efficiency, regulation, and specificity) all stem from the fact that enzymes are protein molecules and therefore exhibit all remarkable characteristics of proteins.

TABLE VIII - CURRENT NOMENCLATURE OF 6 TYPES OF BIOCHEMICAL REACTIONS CATALYZED BY ENZYMES

Enzyme Class	Type of reaction catalyze	Examples
Oxidoreductases	Oxidation-reduction	Dehydrogenases, oxydases, peroxidases, hydroxylases, reductases, oxygenases
Transferases	Transfer of a functional group	Transaminases,

	from one molecule to another (AX+B=A+BX)	transmethylases
Hydrolases	Hydrolytic cleavage	Esterases, amidases, glycosidases, peptidases, phosphatases
Lyases	Cleavage of C-C , C-O, C-N, by elimination, leaving a double bond; or addition to double bonds	Aldolases, synthases hydrolases decarboxylases, nucleotide cyclases
Isomerases	Intramolecular rearrangements	Isomerases, racemases, mutases
Ligases	Joining together of two molecules coupled to the cleavage of a high-energy bond	Synthetases

II.3.6. HORMONES

Communication between non-contiguous cells involves a more elaborate signalling system based on diffusible chemical messengers. The molecules that make up this long-distance intercellular communication system are collectively known as horrmones.

In 1905 Starling introduced the term hormone (derived from a Greek word "horman", meaning - to arouse to activity). Hormones are produced by the cells of endocrine glands, such as the testis, ovary, kidney, pancreas, adrenal, thyroid, parathyroid, and pituitary. The term endocrine refers to cells that synthesize and release hormones directly into circulation.

Hormones can be classified into three major groups:

1. The **peptide hormones** - are composed of amino acid chains of varying lengths, from as few as 3 to as many as 200. A newly discovered class is the **neuropeptides** (small molecules localized within the nervous system and thought to exert their effects directly on other cells of the nervous system. Peptide hormones are water-soluble molecules stored in membrane-enclosed vesicles until the signal for hormone release is received.
2. **Steroid hormones -** are synthesized by enzymes of Smooth ER, utilising cholesterol as the parent molecule. The adrenal gland and gonads (testes and ovaries) are the principal sites of steroid hormone synthesis.
3. **Catecholamines and thyroid hormones** - are derivatives of the amino acid tyrosine. Catecholamines are synthesized in the adrenal gland as well as in certain cells of the nervous system. The thyroid hormones are synthesized first as a large precursor molecule called **thyroglobulin** in the cells lining the follicles of the thyroid gland. Thyroglobulin is iodinated and in this form is stored in the lumen of the follicle. On the appropriate signal it re-enters the cell and two hormones, triiodothyronine (T_3) and thyroxine (T_4), are cleaved from the larger molecule by intracellular enzymes.