Uttar Pradesh Tandon
Open University

UGHN-103
Fundamentals of Nutritional Biochemistry

Block-1 Introduction to Biochemistry: Carbohydrates and Lipids

Unit 1: Introduction to Biochemistry

Unit 2: Carbohydrates

Unit 3: Types of Carbohydrates

Unit 4: Lipids

Block- 2 Introduction to proteins and enzymes

Unit 5: Proteins

Unit 6: Essential and Non-essential amino acids

Unit 7: Elementary knowledge & Structure

Unit 8: Enzymes

Block-3: Introduction to vitamins and enzymes

Unit 9: Industrial Enzymes

Unit 10:Water soluble vitamins

Unit 11: Minerals (Group I)

Unit 12: Minerals (Group I)

COURSE INTRODUCTION

The objective of this course deals basic introduction to carbohydrates, proteins lipids vitamins, minerals etc. in concerned to their nutritional value. The aim is to provide brief introduction to nutritional values of different food materials. This course is organized into following three blocks. These are as under:

Block 1 It covers the introduction of Biochemistry, carbohydrates and lipids
Block 2 It deals the introduction to proteins and enzymes
Block 3 It describes the introduction to vitamins and minerals

Rajarshi Tandon Open
University, Prayagraj

UGHN-103
Fundamental of Nutritional
Biochemistry

BLOCK

1

Block-1 Introduction to Biochemistry: Carbohydrates and Lipids

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Unit 1: Introduction to Biochemistry

Unit 2: Carbohydrates

Unit 3: Types of Carbohydrates

Unit 4: Lipids

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UGHN 103- Fundamental of NutritionalBiochemistry

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Introduction

This is the first block (Introduction to Biochemistry; Carbohydrates and Lipids) of fundamentals of nutritional biochemistry. It consists of four units. The first unit is as under:

Unit 1: Biochemistry is the study of chemical processes in living organisms, including, but not limited to, living matter. Biochemistry governs all living organisms and living processes. By controlling information flow through biochemical signaling and the flow of chemical energy through metabolism, biochemical processes give rise to the incredible complexity of life. Over the last decades of the 20th century, biochemistry become so successful at explaining living processes that now almost all areas of the life sciences from botany to medicine to genetics are engaged in biochemical research. Today, the main focus of pure biochemistry is in understanding how biological molecules give rise to the processes that occur within living cells, which in turn relates greatly to the study and understanding of whole organisms. Biochemistry is closely related to molecular biology, the study of the molecular mechanisms by which genetic information encoded in DNA is able to result in the processes of life.

Unit- 1: Introduction to Biochemistry

Structure

1.1 Introduction

Biochemistry is a discipline of Chemistry that deals with the chemical composition of living organisms. It deals with interactions between living organic cells and their surrounding fluids/matter and is the study of important chemical processes occurring within living organisms. Biochemistry is the subdivision of Biology and chemistry that can further be divided into three segments, namely, metabolism, structural Biology and enzymology. By the end of the 20th century, these three variants together have been able to successfully explain the process of living. It is the study of how living things are made, how they work, and what chemicals they have. It also looks at the human body's muscles and bones. In a Biochemistry Class, students can learn how cells are made or how blood works.

Thus Biochemistry helps in understanding the chemical basis that gives rise to the process through biological molecules that are occurring between the living cells and within the cells. This, in turn, relates to the understanding of tissues and organs as well as the structure of the organisms and their functions. Therefore, Biochemistry can alternatively be defined as the study of molecular Biology that relates to the molecular mechanisms of biological phenomena.

Objectives

This is the first block on introduction to biochemistry; carbohydrates and lipids..It consists of following four units. Under first unit (Introduction to biochemistry) we have following objectives. These are as under:

- To know the introduction of Biochemistry.
- To know the definition and objectives of Biochemistry.
- To discuss the inter-relationship between Biochemistry and Biological Sciences
- To discuss the different scopes of Biochemistry

1.2 Brief History of Biochemistry

Biochemistry is the study of structures and the interactions of biological macromolecules. These macromolecules include protein, nucleic acids, lipids, and carbohydrates present in your body. As a result, Biochemistry is being used in research related to botany, medicine, and gene enhancement. Biochemistry is now working on finding the secret of life and how biological molecules boost the processes that occur within the living cells. This study will help in understanding the whole working organism. Teaching, Science, researchers, analytical Chemist, and forensic scientist are all options for BioChemists.

Biochemistry or biological chemistry is the study of chemical processes within and relating to living organisms. A sub-discipline of both chemistry and biology, biochemistry may be divided into three fields: structural biology, enzymology and metabolism. Over the last decades of the 20th century, biochemistry has become successful at explaining living processes through these three disciplines. Almost all areas of the life sciences are being uncovered and developed through biochemical methodology and research. Biochemistry focuses on understanding the chemical basis which allows biological molecules to give rise to the processes that occur within living cells and between cells, in turn relating greatly to the understanding of tissues and organs, as well as organism structure and function. Biochemistry is closely related to molecular biology, which is the study of the molecular mechanisms of biological phenomena.

Depending on the exact definition of the terms used, molecular biology can be thought of as a branch of biochemistry, or biochemistry as a tool with which to investigate and study molecular biology. Much of biochemistry deals with the structures, functions and interactions of biological macromolecules, such as proteins, nucleic acids, carbohydrates and lipids, which provide the structure of cells and perform many of the functions associated with life. The chemistry of the cell also depends on the reactions of smaller molecules and ions.

These can be inorganic, for example water and metal ions, or organic, for example the amino acids which are used to synthesize proteins. The mechanisms by which cells harness energy from their environment via chemical reactions are known as metabolism. The findings of biochemistry are applied primarily in medicine, nutrition, and agriculture. In medicine, biochemists investigate the causes and cures of disease. In nutrition, they study how to maintain health and study the effects of nutritional deficiencies. In agriculture, biochemists investigate soil and fertilizers, and try to discover ways to improve crop cultivation, crop storage and pest control. Much of biochemistry deals with the structures and functions of cellular components such as proteins, carbohydrates, lipids, nucleic acids and other biomolecules; although increasingly processes rather than individual molecules are the main focus.

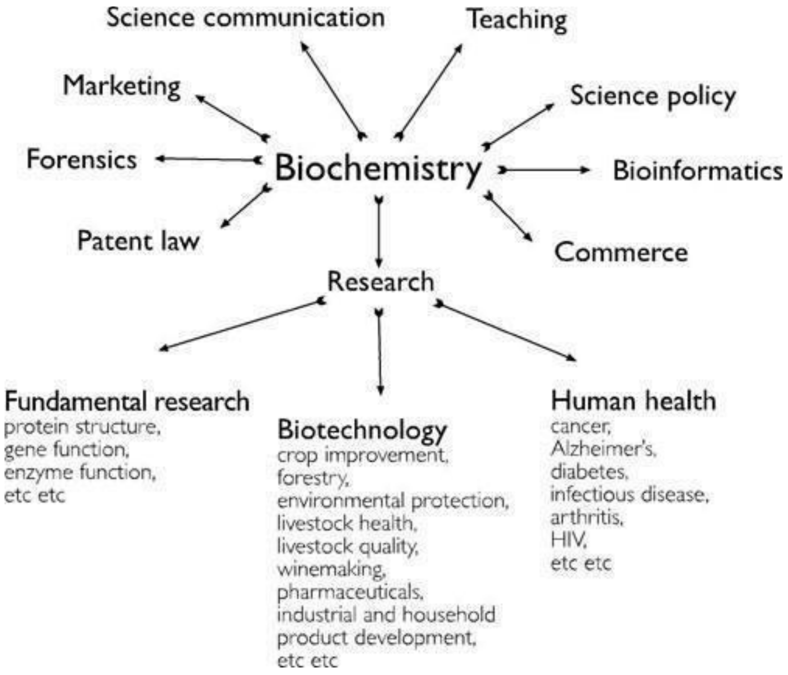

Fig. 1 Scope and Applications of Biochemistry

The study of Biochemistry is of immense importance in our daily life since it helps us develop and improve clinical diagnosis, treatment of disease, or agricultural aspects. Biochemistry plays an essential role in Medicine, Pharmacy, Agriculture, Nutrition, and Engineering. For that reason, Biochemical concepts are applied to various sub-disciplines identified within the areas mentioned above.

Different biochemical concepts

Nutrition

Biochemists have long been interested in the chemical composition of the food of animals. All animals require organic material in their diet, in addition to water and minerals. This organic matter must be sufficient in quantity to satisfy the caloric, or energy, requirements of the animals. Within certain limits, carbohydrate, fat, and protein may be used interchangeably for this purpose. In addition, however, animals have nutritional requirements for specific organic compounds. Certain essential fatty acids, about ten different amino acids (the so-called essential amino acids), and vitamins are required by many higher animals. The nutritional requirements of various species are similar but not necessarily identical; thus man and the guinea pig require vitamin C, or ascorbic acid, whereas the rat does not.

That plants differ from animals in requiring no preformed organic material was appreciated soon after the plant studies of the late 1700s. The ability of green plants to make all their cellular material from simple substances—carbon dioxide, water, salts, and a source of nitrogen such as ammonia or nitrate—was termed photosynthesis. As the name implies, light is required as an energy source, and it is generally furnished by sunlight. The process itself is primarily concerned with the manufacture of carbohydrate, from which fat can be made by animals that eat plant carbohydrates. Protein can also be formed from carbohydrate, provided ammonia is furnished.

In spite of the large apparent differences in nutritional requirements of plants and animals, the patterns of chemical change within the cell are the same. The plant manufactures all the materials it needs, but these materials are essentially similar to those that the animal cell uses and are often handled in the same way once they are formed. Plants could not furnish animals with their nutritional requirements if the cellular constituents in the two forms were not basically similar.

Digestion

The organic food of animals, including man, consists in part of large molecules. In the digestive tracts of higher animals, these molecules are hydrolyzed, or broken down, to their component building blocks. Proteins are converted to mixtures of amino acids, and polysaccharides are converted to monosaccharides. In general, all living forms use the same small molecules, but many of the large complex molecules are different in each species. An animal, therefore, cannot use the protein of a plant or of another animal directly but must first break it down to amino acids and then recombine the amino acids into its own characteristic proteins. The hydrolysis of food material is necessary also to convert solid material into soluble substances suitable for absorption. The liquefaction of stomach contents aroused the early interest of observers, long before the birth of modern chemistry, and the hydrolytic enzymes secreted into the digestive tract were among the first enzymes to be studied in detail. Pepsin and trypsin, the proteolytic enzymes of gastric and pancreatic juice, respectively, continue to be intensively investigated.

The products of enzymatic action on the food of an animal are absorbed through the walls of the intestines and distributed to the body by blood and lymph. In organisms without digestive tracts, substances must also be absorbed in some way from the environment. In some instances simple diffusion appears to be sufficient to explain the transfer of a substance across a cell membrane. In other cases, however (e.g., in the case of the transfer of glucose from the lumen of the intestine to the blood), transfer occurs against a concentration gradient. That is, the glucose may move from a place of lower concentration to a place of higher concentration.

In the case of the secretion of hydrochloric acid into gastric juice, it has been shown that active secretion is dependent on an adequate oxygen supply (i.e., on the respiratory metabolism of the tissue), and the same holds for absorption of salts by plant roots. The energy released during the tissue oxidation must be harnessed in some way to provide the energy necessary for the absorption or secretion. This harnessing is achieved by a special chemical coupling system. The elucidation of the nature of such coupling systems has been an objective of the biochemist.

Blood

One of the animal tissues that has always excited special curiosity is blood. Blood has been investigated intensively from the early days of biochemistry, and its chemical composition is known with greater accuracy and in more detail than that of any other tissue in the body. The physician takes blood samples to determine such things as the sugar content, the urea content, or the inorganic-ion composition of the blood, since these show characteristic changes in disease.

The blood pigment hemoglobin has been intensively studied. Hemoglobin is confined within the blood corpuscles and carries oxygen from the lungs to the tissues. It combines with oxygen in the lungs, where the oxygen concentration is high, and releases the oxygen in the tissues, where the oxygen concentration is low. The hemoglobins of higher animals are related but not identical. In invertebrates, other pigments may take the place and function of hemoglobin. The comparative study of these compounds constitutes a fascinating chapter in biochemical investigation.

The proteins of blood plasma also have been extensively investigated. The gamma-globulin fraction of the plasma proteins contains the antibodies of the blood and is of practical value as an immunizing agent. An animal develops resistance to disease largely by antibody production. Antibodies are proteins with the ability to combine with an antigen (i.e., an agent that induces their formation). When this agent is a component of a disease-causing bacterium, the antibody can protect an organism from infection by that bacterium. The chemical study of antigens and antibodies and their interrelationship is known as immunochemistry.

Metabolism and hormones

The cell is the site of a constant, complex, and orderly set of chemical changes collectively called metabolism. Metabolism is associated with a release of heat. The heat released is the same as that obtained if the same chemical change is brought about outside the living organism. This confirms the fact that the laws of thermodynamics apply to living systems just as they apply to the inanimate world. The pattern of chemical change in a living cell, however, is distinctive and different from anything encountered in nonliving systems. This difference does not mean that any chemical laws are invalidated. It instead reflects the extraordinary complexity of the interrelations of cellular reactions.

Hormones, which may be regarded as regulators of metabolism, are investigated at three levels, to determine

- Their physiological effects,
- Their chemical structure, and
- The chemical mechanisms whereby they operate.

The study of the physiological effects of hormones is properly regarded as the province of the physiologist. Such investigations obviously had to precede the more analytical chemical studies. The chemical structures of thyroxine and adrenaline are known. The chemistry of the sex and adrenal hormones, which are steroids, has also been thoroughly investigated. The hormones of the pancreas—insulin and glucagon—and the hormones of the hypophysis (pituitary gland) are peptides (i.e., compounds composed of chains of amino acids). The structures of most of these hormones have been determined. The chemical structures of the plant hormones, auxin and gibberellic acid, which act as growth-controlling agents in plants, are also known.

The first and second phases of the hormone problem thus have been well, though not completely, explored, but the third phase is still in its infancy. It seems likely that different hormones exert their effects in different ways. Some may act by affecting the permeability of membranes; others appear to control the synthesis of certain enzymes. Evidently some hormones also control the activity of certain genes.

Genes

Genetic studies have shown that the hereditary characteristics of a species are maintained and transmitted by the self-duplicating units known as genes, which are composed of nucleic acids and located in the chromosomes of the nucleus. One of the most fascinating chapters in the history of the biological sciences contains the story of the elucidation, in the mid-20th century, of the chemical structure of the genes, their mode of self-duplication, and the manner in which the deoxyribonucleic acid (DNA) of the nucleus causes the synthesis of ribonucleic acid (RNA), which, among its other activites, causes the synthesis of protein. Thus, the capacity of a protein to behave as an enzyme is determined by the chemical constitution of the gene (DNA) that directs the synthesis of the protein. The relationship of genes to enzymes has been demonstrated in several ways.

The first successful experiments, devised by the Nobel Prize winners George W. Beadle and Edward L. Tatum, involved the bread mold Neurospora crassa; the two men were able to collect a variety of strains that differed from the parent strain in nutritional requirements. Such strains had undergone a mutation (change) in the genetic makeup of the parent strain. The mutant strains required a particular amino acid not required for growth by the parent strain. It was then shown that such a mutant had lost an enzyme essential for the synthesis of the amino acid in question. The subsequent development of techniques for the isolation of mutants with specific nutritional requirements led to a special procedure for studying intermediary metabolism.

Animal Biochemistry

Animal Biochemistry is a branch of Biochemistry which studies various chemical reactions going on in the body of an animal. Moreover, it examines the structure and function of animal cellular components (e.g., proteins, lipids, carbohydrates, nucleic acids, etc.).Animal Biochemistry also contributes to research and veterinary education in animal metabolism and function of animals in health issues and various disease pathways.The study of Animal Biochemistry is a significant field not only for the development of veterinary aspects but also for a better understanding of chemistry in living organisms.

Plant Biochemistry

Plants are eukaryotic organisms, which dominate the terrestrial world. They are one of the principal components of the living organisms on Earth. Plants are responsible for fresh oxygen supply and reduction of pollution level on Earth by taking in carbon dioxide and producing oxygen. Furthermore, plants are also essential for human nutrition, production of industrial materials, formulation and manufacture of medicine, biofuels, or pesticides. For that reason, it is of immense importance to study Plant Biochemistry before applying it to so many areas which affect the quality of our lives.

Plant Biochemistry is not only fundamental for the explanation of the molecular function of a plant but is also an applied science that plays a primary role in understanding various issues related to agricultural or pharmaceutical problems. Plants are considered to be raw materials for the current production of drugs and other agricultural materials. More importantly, it is hypothesized that the development of gene technology might lead to the substantial use of plants in the production of raw materials for industrial purposes.

Molecular Biology

Molecular Biology is a field of science which studies Biology at a molecular level. Molecular Biology interconnects Biology and Chemistry, more specifically, Genetics and Biochemistry through which Molecular Biologists implement biological techniques combined with ideas from Genetics and Biochemistry.Moreover, Molecular Biology studies the composition, structure, function, and interactions of cellular components responsible for carrying out biological processes such as proteins, carbohydrates, lipids, and nucleic acids. Molecular Biology is mainly concerned with the study of particularly nucleic acids (DNA and RNA) and the proteins which are constructed using the genetic information encoded in DNA and RNA.

Reproductive Biochemistry

Reproduction (sexual and asexual) is the biological process, a fundamental feature of all known life, through which new individual organisms are produced. Reproduction is essential for increasing the individuals in a population and creating variations in particular species through genetic recombination. Reproductive Biochemistry is the study Biochemistry, Cell Biology, Molecular Biology, Genetics, Physiology, and Endocrinology connected to human, animal, and plant reproduction. The study of Reproductive Biochemistry is a vital area since it develops and enhances concepts, ideas, and techniques related to various reproductive health issues, including diseases, dysfunctions, syndromes, etc.

Cell Biology

Cell Biology is the branch of Biology which studies cell structure and function. Cell Biology is concerned with all the properties and processes involving cells, which means that it is an inclusive discipline since cells are the basic units of life. Examples are physiological properties, metabolic processes, signaling pathways, life cycle, chemical composition, and interactions of cells with their corresponding environment. For a better understanding of growth and development of the cells, it is of enormous importance to study Biology at the cellular level. Cell Biology covers various topics related to cellular processes such as cell division, transcription, translation, cell death, glycolysis, respiration, photosynthesis, chemosynthesis, signaling, transcript, etc.

Neurobiology

Neurobiology is a sub-discipline of Cell Biology and Neuroscience which studies the cells of the nervous system explicitly. The study of Neurobiology is concerned with the examination of neurons which are diverse concerning morphology and function. They are generally specialized to receive, propagate, and transmit electrochemical impulses. Nervous system is an essential part of the organism since it not only produces emotions or behavior but also controls and regulates vital body functions such as the rate of breathing, blood pressure, body temperature, etc. Neurobiology is a vital field which provides an in-depth scientific understanding of the human mind employing observation of various biological and chemical processes essential for the proper functioning of the brain and nervous system.

Metabolomics

Metabolism is the set of chemical reactions occurring within a living organism to sustain life. There are three major purposes of metabolism which are the following: conversion of food to energy, conversion of food to building blocks for biomolecules, and elimination of wastes. The study of these processes is called metabolomics, which is an essential branch of Biochemistry. Metabolomics is a comprehensive qualitative and quantitative analysis of metabolites (intermediate end products of metabolism) along with, the examination of detailed reaction mechanisms and cycles occurring in living organisms. The study of metabolic reactions and processes is essential for detection and treatment of metabolic disorders which happen when abnormal chemical reactions occur in an organism which alter the normal metabolic processes.

Immunology

Immunology is a very important sub-discipline of Medical and Biological Sciences which studies the immune system. The immune system consists of organs and processes occurring in the body which are responsible for protection from infections and toxins. There are various sub-branches of Immunology which study specific defense systems in living organisms. Here are several examples of such branches:

- Clinical Immunology – the study of diseases caused by immune system disorders. Developmental Immunology – the study of factors responsible for the development of immune cells and organs.
- Ecoimmunology – the study of the relationship between the immune system of an organism and its environment.
- Diagnostic Immunology – the study of tests and techniques for immune system-mediated diseases.
- Reproductive Immunology – the study of immunological concepts related to reproductive processes.
- Cancer Immunology – the study of the relation of the immune system to cancer cells.

Enzymology

Enzymology is the branch of Biochemistry which studies structure, function, and kinetics of enzymes. Enzymes are typically proteins that speed up the rate of biological-chemical reactions. Enzymes are essential for the processes occurring in living organisms since, without enzymes, these reactions would have happened too slowly to keep bodies alive. Metabolic reactions are enzyme-catalyzed reactions which are vital for the proper functioning of an organism. The study of enzymes is significant for the understanding and treatment of various diseases.

Pharmaceutical Biochemistry

Pharmacy is the field which studies the techniques of preparation of drugs and provides additional clinical services. The area of pharmacy is generally divided into three major disciplines, one of which is Pharmaceutics. Pharmaceutics is the discipline that studies the effective use of new chemical entities of old drugs into a medication. Various drugs are related to the Biochemistry and Metabolism of human health and diseases which is studied by the branch called Pharmaceutical Biochemistry. Pharmaceutical Biochemistry studies the clinical uses of drugs and their effects on living organisms. It examines chemical processes associated with drug activity occurring in living cells at the molecular level.

Genetic Engineering

Genetic Engineering, also referred to as Genetic Modification or Genetic Manipulation, is the study of the manipulation of genes using Biotechnology. The product of Genetic Engineering is a genetically modified organism, the DNA of which was altered or modified. Recombinant DNA technology is used to introduce foreign genes into microbes, plants, or animals to convey new desirable characteristics. Generic Engineers modify food, medicines, or organisms to produce more efficient means of nutrition, tastier food, disease- and drought-resistant plants requiring fewer resources, etc.

Biotechnology

Biotechnology is a broad discipline which studies the implementation of biological processes and living organisms for industrial or other purposes, including genetic engineering, production of antibiotics or hormones, etc. Biotechnology is responsible for providing products and technologies for the treatment of various diseases, reduction of environmental footprint, providing nutritious food for hungry, use of less and cleaner energy (production of biofuels from biomass), manufacture of safer and more efficient industrial products.

Scope of Biochemistry

Biochemistry is the amalgamation of chemistry and biological sciences. It brings together all of the sciences to study the chemical and physical processes that occur in living organisms. It truly is the science of life. Also, the course provides an introduction to several important metabolic pathways and bioenergetics, including state of the art modern techniques relevant to present-day research in academia and industry.

Scope of the Course:

In the present scenario study of Biochemistry is highly relevant, biochemistry students can aspire for bigger roles in industry as well as academia. Some of its scope in medical sciences and other fields is given as follows:

Medical Sciences

- Thorough knowledge in biochemistry is essential in understanding different aspects of medical sciences like drug development, immunology, pathology, pharmacy, vaccine development, etc. After BSc. One can find jobs as marketing executives in different Pharmaceutical companies, as a lab assistant in different govt. and private organizations, clinical co-ordinators for big pathology chains and medical transcriptionists for different healthcare groups.
- The most important use of medical biochemistry, however, is biochemical tests done in the clinical laboratory. In a diagnostic center, one can get jobs as pathologists related to diagnostics, monitoring, and screening of patients.
- Genetic Engineering or Recombinant DNA Technology is another advanced part of biochemistry which has immense scope in vaccine development. After post-graduation in Biochemistry, one can pursue a research career and work as a research scientist in R&D sections of big pharmaceutical companies.

Agriculture

- Knowledge of biochemistry is very important for understanding the biochemistry of crops and medicinal plants. Plant biochemistry studies can help students to become agricultural scientists in the future. Agricultural scientists work on developing high yielding crops, disease-resistant crops, isolating medicinal compounds from plants.
- Gaining knowledge in plant tissue culture techniques students can set up their own farms and nurseries.

Food Industry

- Biochemists can help nutritionists, as they can describe different aspects of health-related to food consumption; the nutrients value of food material can also be determined by biochemical tests. Proper measurement of carbohydrates, proteins, and fats can be done by
- Food Analyst jobs are now available in different private sectors. They can find out adulterants mixed in diverse types of food items.
- A food security officer is a very important job prospect for present biochemistry students.

The evolution of life that took us from the small microorganism to apes, to the humans which we have now become. All that study falls under one of the branches of Biochemistry. Besides, it is a study that is said to be the language of nature. All the tools that you see in the field of medical science are biochemical. Biotechnology is using genetic engineering, which is one of the most sophisticated branches of chemistry. The use of biotechnology can be seen in the field of medical science, animal farming, pathological research, etc.

Lastly, one more branch we would like to mention is the medical Biochemistry, and this is one of the essential branches of the whole science as it deals with both the health and the disease of the human body. Every condition which the human body faces is biochemical because of every form of illness due to the abnormal behavior of chemicals and molecules present in the human body. A BioChemist can work well for both the government and the private sector. They can even set up their labs with help from doctors who know what they're doing. Today, Biochemistry is very popular in research fields, so BioChemists can work on hot topics to write about and publish later. They can also choose to be scientists or to be a member of a scientific group.

Academician

After the masters, one can apply for B.Ed to become a teacher of the subject or can further pursue a PhD to become a professor in colleges and universities. Different govt. jobs like a Patent officer, Scientific Officer (BARC, DRDO, and ISRO), Epidemiologist, Forest officer, Food security officer can be a very good option for the student currently pursuing masters in Biochemistry.

Molecular Biochemistry

This branch of biochemistry deals with the study of structures and functions of proteins, carbohydrates, DNA, and other biomolecules. It covers a detailed study of how the different biomolecules interact with one another and carry out biochemical reactions.

Cellular Biochemistry

This branch of biochemistry deals with the study of chemical processes occurring within the cells of organisms. It covers a detailed study of how energy is produced in the cells, how the structure of cells is maintained, how the nutrients are synthesised, stored, and used in the cells, and other cellular chemical processes.

Biochemical Genetics

This branch of biochemistry discusses the role of genes in the biochemical processes of various organisms. It provides a detailed study of how genes play a role in synthesising biomolecules like proteins and how they function.

Major Areas of Biochemistry

Some major areas into which biochemistry can be classified for the convenience of students are discussed below.

Structural Biochemistry

Structural biochemistry involves the study of macromolecules and their chemical architecture. Being a major area of biochemistry, it also covers a detailed study of DNA, RNA, and proteins.

Xenobiotics

This major area of biochemistry involves the study of the metabolic behaviour of certain compounds. The chemical structure of these compounds is improper in the usual metabolism for a particular organism. While entering the human body, these compounds are likely to be secondary metabolites of some other organisms, non-existent in nature, or infrequent compounds.

Bio-Organic Chemistry

This area of biochemistry involves the study of organic compounds derived from living organisms. These compounds are identified by their carbon-hydrogen and carbon-carbon covalent bonds. Most of the carbon biological compounds are studied in bio-organic chemistry. This area of biochemistry integrates a sense of reaction mechanisms, organic synthesis, analytical methods, and structural analysis, with primary and secondary metabolic reactions, cell recognition, biosynthesis, and chemical diversity of organisms.

Metabolic Biochemistry

This is an area of biochemistry that involves the study of different types of metabolic pathways from an organic and cellular level. Bioenergetics, nutritional biochemistry and clinical biochemistry are the disciplines that arise from metabolic biochemistry. The organic biochemical indices, cellular biochemical reactions, the molecular basis of metabolic diseases, or intermediate metabolic flows are studied in this branch of biochemistry.

Importance of Biochemistry

Biochemistry knowledge is essential in our daily lives. Agriculture, medicine, and medical treatment all benefit from it. Below is the importance of Biochemistry:

- Biochemistry can help you increase your crop productivity.
- It is critical for enhancing land quality by preserving vegetables and flowers, as well as assisting in the preparation and preservation of food materials.
- It is necessary to understand the actions of numerous genes as well as their interactions with enzymes.
- It is useful in determining the nutritional requirements of animals. It aids in the provision of adequate nutrition and the elimination of malnutrition.
- To understand heredity in plants and animals, geneticists rely on metabolic reactions.
- It aids in the discovery of new drugs in the pharmaceutical industry.
- It explains how to use medications properly.
- It is beneficial in the treatment of sick people and animals.
- It aids in the improvement of beneficial animal breeds and nutrition, as well as the study of herbicide and pesticide activity.

Applications of Biochemistry

Applications in Agriculture:

- **Increase Fertility:** The fertility of the crop can be increased with the help of the study of Biochemistry. The agriculturist uses the Biochemistry tools to find out the conditions of the plants and experiment accordingly to improve their fertility.
- **Increase Growth:** The reaction between the pesticides and the crops in the cell is analysed by the biochemist and does it contribute to rising plant growth.
- **Disease Control:** The study of Biochemistry because of its versatility provides a large number of treatments to help control plant diseases. Exclusion and eradication of disease plants falls under few of such techniques that are used in Biochemistry.

- **Animal Husbandry:** Appropriate cultivation and growth of domestic animals falls under the animal husbandry. Various Biochemistry tools are used by the experts to diagnose disease in such animals and provide control accordingly.
- **Soil Conditions:** The soil condition, its composition and its deficiency is comprehended with the help of Biochemistry tools. Therefore this focuses primarily on enhancing the soil condition and work on it.

Applications in Medicine:-

Blood Test:

Blood test suggests serum test for diagnosing hepatitis falls under few of the crucial blood tests where Biochemistry plays a crucial role. Biochemistry tools are mostly used for the qualitative and quantitative analysis of liver functioning. Moreover it also analyses the blood sugar level in human blood. It also helps in performing the urine test to find out the kittens where the complete blood count indicates the overall health of a patient. All these tests are related to the study of Biochemistry.

Liver Test:

In order to understand and assist the liver condition of a patient it is important to know a few Biochemistry tools. For qualitative and quantitative analysis the same PCR test is used. Also the Biochemistry techniques are used for diagnosis of HCC.

Pregnancy Test:

Biochemistry test and techniques are also used to find out about the pregnancy. Urine test is required to find out about the gonadotropin hormone that a body produces. A particular blood test which is also known as HCG test is done to find out about the pregnancy. It indicates the initial level of human gonadotropin which rises during the pregnancy.

Kidney Function:

A lot of Biochemistry tools are used for a simple urine test that checks the pH and the colour of the urine that changes during the kidney issues.

AFP Test:

Alpha-fetoprotein is used as a marker to test the poor liver function of the patient and to know whether the patient has liver dysfunction on liver cancer.

Methods in biochemistry

Like other sciences, biochemistry aims at quantifying, or measuring, results, sometimes with sophisticated instrumentation. The earliest approach to a study of the events in a living organism was an analysis of the materials entering an organism (foods, oxygen) and those leaving (excretion products, carbon dioxide). This is still the basis of so-called balance experiments conducted on animals, in which, for example, both foods and excreta are thoroughly analyzed. For this purpose many chemical methods involving specific colour reactions have been developed, requiring spectrum-analyzing instruments (spectrophotometers) for quantitative measurement.

Gasometric techniques are those commonly used for measurements of oxygen and carbon dioxide, yielding respiratory quotients (the ratio of carbon dioxide to oxygen). Somewhat more detail has been gained by determining the quantities of substances entering and leaving a given organ and also by incubating slices of a tissue in a physiological medium outside the body and analyzing the changes that occur in the medium. Because these techniques yield an overall picture of metabolic capacities, it became necessary to disrupt cellular structure (homogenization) and to isolate the individual parts of the cell—nuclei, mitochondria, lysosomes, ribosomes, membranes—and finally the various enzymes and discrete chemical substances of the cell in an attempt to understand the chemistry of life more fully.

Centrifugation and electrophoresis

An important tool in biochemical research is the centrifuge, which through rapid spinning imposes high centrifugal forces on suspended particles, or even molecules in solution, and causes separations of such matter on the basis of differences in weight. Thus, red cells may be separated from plasma of blood, nuclei from mitochondria in cell homogenates, and one protein from another in complex mixtures. Proteins are separated by ultracentrifugation—very high speed spinning; with appropriate photography of the protein layers as they form in the centrifugal field, it is possible to determine the molecular weights of proteins.

Another property of biological molecules that has been exploited for separation and analysis is their electrical charge. Amino acids and proteins possess net positive or negative charges according to the acidity of the solution in which they are dissolved. In an electric field, such molecules adopt different rates of migration toward positively (anode) or negatively (cathode) charged poles and permit separation.

Such separations can be effected in solutions or when the proteins saturate a stationary medium such as cellulose (filter paper), starch, or acrylamide gels. By appropriate colour reactions of the proteins and scanning of colour intensities, a number of proteins in a mixture may be measured. Separate proteins may be isolated and identified by electrophoresis, and the purity of a given protein may be determined. (Electrophoresis of human hemoglobin revealed the abnormal hemoglobin in sickle-cell anemia, the first definitive example of a “molecular disease).

Chromatography and isotopes

The different solubilities of substances in aqueous and organic solvents provide another basis for analysis. In its earlier form, a separation was conducted in complex apparatus by partition of substances in various solvents. A simplified form of the same principle evolved as ‘‘paper chromatography,” in which small amounts of substances could be separated on filter paper and identified by appropriate colour reactions. In contrast to electrophoresis, this method has been applied to a wide variety of biological compounds and has contributed enormously to research in biochemistry.

The general principle has been extended from filter paper strips to columns of other relatively inert media, permitting larger scale separation and identification of closely related biological substances. Particularly noteworthy has been the separation of amino acids by chromatography in columns of ion-exchange resins, permitting the determination of exact amino acid composition of proteins. Following such determination, other techniques of organic chemistry have been used to elucidate the actual sequence of amino acids in complex proteins.

Another technique of column chromatography is based on the relative rates of penetration of molecules into beads of a complex carbohydrate according to size of the molecules. Larger molecules are excluded relative to smaller molecules and emerge first from a column of such beads. This technique not only permits separation of biological substances but also provides estimates of molecular weights. Perhaps the single most important technique in unravelling the complexities of metabolism has been the use of isotopes (heavy or radioactive elements) in labelling biological compounds and “tracing” their fate in metabolism. Measurement of the isotope-labelled compounds has required considerable technology in mass spectroscopy and radioactive detection devices. A variety of other physical techniques, such as nuclear magnetic resonance, electron spin spectroscopy, circular dichroism, and X-ray crystallography, have become prominent tools in revealing the relation of chemical structure to biological function.

Similarities between Biochemistry and Biology

We know what the difference between biochemistry and biology is. However, there are certain similarities discovered between the two disciplines.

- Biology is the core subject and biochemistry is the branch or sub-division of the same.
- Research in both subjects can help to identify the life functions of the living organism.

Both these subjects have some common topics to cover in its curriculum like ecology, genetics, cell biology, organic chemistry, etc. Some of the departments have even included subjects like molecular biology, microbiology, physics, and chemistry. In the work field also, there are related job roles. As there are many familiar concepts, many professionals work and share their responsibilities and split the research work. Students of both disciplines can get a job in departments like pharmaceutical companies, biotechnology companies, hospitals, etc.

1.13 Summary

Under this unit we have discussed biochemistry and its introduction. It has various objectives and scope. Much of biochemistry deals with the structures, functions and interactions of biological macromolecules, such as proteins, nucleic acids, carbohydrates and lipids, which provide the structure of cells and perform many of the functions associated with life. The chemistry of the cell also depends on the reactions of smaller molecules and ions. These can be inorganic, for example water and metal ions, or organic, for example the amino acids which are used to synthesize proteins. The mechanisms by which cells harness energy from their environment via chemical reactions are known as metabolism. The findings of biochemistry are applied primarily in medicine, nutrition, and agriculture. In medicine, biochemists investigate the causes and cures of disease. In nutrition, they study how to maintain health and study the effects of nutritional deficiencies. In agriculture, biochemists investigate soil and fertilizers, and try to discover ways to improve crop cultivation, crop storage and pest control. Much of biochemistry deals with the structures and functions of cellular components such as proteins, carbohydrates, lipids, nucleic acids and other biomolecules—although increasingly processes rather than individual molecules are the main focus.

1.14 Terminal questions

Q.1 What do you mean by biochemistry? Define it with examples.

Answer:---
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Q.2 Explain the scope of biochemistry.

Answer:---
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Q.3 Explain the role of my biochemistry our life.

Answer:---
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Q.4 Write short notes on the followings.

(i) Scope of biochemistry
(ii) Nutritional biochemistry

Answer:---
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Q. 5 Explain the inter-relationship between biochemistry and biological sciences.

Answer:---
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Further readings

1. Biochemistry- Lehninger A.L.
2. Textbook of Nutrition and Dietetics Ranjana Mahna
3. Biochemistry fourth edition-David Hames and Nigel Hooper.
4. Textbook of Biochemistry for Undergraduates - Rafi, M.D.
5. Textbook of Nutrition and Dietetics- Monika Sharma

Unit: 2 Carbohydrates

Structure

2.1. Introduction

Carbohydrates or carbs are the sugars, starches, and dietary fiber that occur in plant foods and dairy products. The body breaks them down into glucose, which provides energy. Carbohydrates are mainly found in plant foods. They also occur in dairy products in the form of a milk sugar called lactose. Foods high in carbohydrates include bread, pasta, beans, potatoes, rice, and cereals. Carbohydrates play several roles in living organisms, including providing energy. Byproducts of carbohydrates are involved in the immune system, the development of disease, blood clotting, and reproduction. This unit looks at types of carbohydrates, nutrition, and their effects on health. We also look at the relationship between carbohydrates and diabetes.

Carbohydrates, also known as saccharides or carbs, provide energy for the body. Each gram of carbohydrates provides 4 calories. The body breaks carbohydrates down into glucose, which is the primary energy source for the brain and muscles. Carbohydrates are one of three macronutrients, which are nutrients that the body needs in larger amounts. The other macronutrients are protein and fats. Proteins provide 4 calories per gram, and fats provide 9 calories per gram.

Objectives

This is the second unit (Carbohydrates) under first block (Introduction to Biochemistry; Carbohydrates and Lipids). Under this unit, we have following objectives. These are as under:

- Introduction to carbohydrates
- To know different types of carbohydrates & their structure
- To discuss digestion and absorption of carbohydrates
- To know about properties and functions of carbohydrates

2.2 Carbohydrates

Carbohydrates are an important source of energy for the body. Some types are more healthful than others. For instance, dietary fiber is a carbohydrate that protects heart and gut health, whereas added sugars can lead to an increased risk of type 2 diabetes, heart disease, and overweight. Following a well-balanced diet that includes unprocessed carbohydrates, and getting enough sleep and physical activity, are more likely to lead to good health and a healthful body weight than focusing on or eliminating a particular nutrient.

Carbohydrates are found in a wide array of both healthy and unhealthy foods—bread, beans, milk, popcorn, potatoes, cookies, spaghetti, soft drinks, corn, and cherry pie. They also come in a variety of forms. The most common and abundant forms are sugars, fibers, and starches. Foods high in carbohydrates are an important part of a healthy diet. Carbohydrates provide the body with glucose, which is converted to energy used to support bodily functions and physical activity. But carbohydrate quality is important; some types of carbohydrate-rich foods are better than others:

- The healthiest sources of carbohydrates—unprocessed or minimally processed whole grains, vegetables, fruits and beans—promote good health by delivering vitamins, minerals, fiber, and a host of important phytonutrients.

- Unhealthier sources of carbohydrates include white bread, pastries, sodas, and other highly processed or refined foods. These items contain easily digested carbohydrates that may contribute to weight gain, interfere with weight loss, and promote diabetes and heart disease.

The Healthy Eating Plate recommends filling most of your plate with healthy carbohydrates – with vegetables (except potatoes) and fruits taking up about half of your plate, and whole grains filling up about one fourth of your plate.

2.3 Nutrition

It’s generally recommended that people consume between 45-65% of their total calories in the form of carbohydrates per day. However, carbohydrate needs depend on many factors, including body size, activity levels, and blood sugar control. The Food and Drug Administration (FDA) recommend that people get 275 g of carbohydrate each day in a 2,000-calorie diet. This includes dietary fiber, total sugars, and added sugars, which are listed on food labels. Carbohydrates in foods occur in various forms, including the following:

- **Dietary fiber**, a type of carbohydrate that the body cannot easily digest. It occurs naturally in fruits, vegetables, nuts, seeds, beans, and whole grains.
- **Total sugars**, which include sugars that occur naturally in foods, such as dairy products, as well as added sugars, which are common in baked goods, sweets, and desserts. The body very easily digests and absorbs sugars.
- **Sugar alcohols**, a type of carbohydrate that the body does not fully absorb. They have a sweet taste and fewer calories than sugar. Sugar alcohols are added to foods as reduced-calorie sweeteners, such as in chewing gum, baked goods, and sweets.

Dietary fiber helps promote regular bowel movements, lowers blood sugar and cholesterol, and may help reduce a person’s calorie intake. The FDA recommend that people get 28 grams (g) of dietary fiber per day in a 2,000-calorie diet. Most people in the United States exceed the recommended daily limits for added sugar. This can increase a person’s risk of developing cardiovascular disease and dental cavities. The Dietary Guidelines for Americans 2015–2020Trusted Source recommend that people get less than 10% of their total daily calories from added sugars, which means less than 50 g of added sugars each day. However, limiting added sugar as much as possible is best for overall health. The American Heart AssociationTrusted Source recommends that women limit added sugar to less than 6 teaspoons (25 g) per day and men limit their intake to less than 9 teaspoons (36 g) per day.

2.4 Chemistry

The chemical structures of carbohydrates contain carbon, hydrogen, and oxygen atoms. Two basic compounds make up carbohydrates: Aldehydes, which are double-bonded carbon and oxygen atoms, plus a hydrogen atom, and ketones, which are double-bonded carbon and oxygen atoms, plus two additional carbon atoms. Carbohydrates can combine to form polymers, or chains, to create different types of carbohydrates. Carbohydrate can be monosaccharides, disaccharides, or polysaccharides.

2.4.1 Monosaccharides

Monosaccharides are single units of sugar. Examples include:

- glucose, the body's main source of energy
- galactose, which is most readily available in milk and dairy products
- fructose, which mostly occurs in fruits and vegetables

2.4.2 Disaccharides

Disaccharides are two sugar molecules joined together. Examples include:

- lactose, found in milk, which is made up of glucose and galactose
- Sucrose, or table sugar, which is made up of glucose and fructose

2.4.3 Polysaccharides

Polysaccharides are chains of many sugars. They can consist of hundreds or thousands of monosaccharides. Polysaccharides act as food stores for plants and animals. Examples include:

- Glycogen, which stores energy in the liver and muscles
- Starches, which are abundant in potatoes, rice, and wheat
- Cellulose, one of the main structural components of plants

Simple and complex carbohydrates

Monosaccharides and disaccharides are simple carbohydrates, and polysaccharides are complex carbohydrates. Simple carbohydrates are sugars. They consist of just one or two molecules. They provide a rapid source of energy, but the person soon feels hungry again.

Examples include white bread, sugars, and candies. Complex carbohydrates consist of long chains of sugar molecules. This includes whole grains and foods that contain fiber. Examples include fruits, vegetables, beans, and whole grain pasta. Complex carbohydrates make a person feel full for longer and have more health benefits than simple carbohydrates, as they contain more vitamins, minerals, and fiber.

In a typical diet, carbohydrates are the main energy source for the body. The body uses them as fuel for the cells. Many people have turned to low carb diets, such as the keto diet, for their potential health benefits and weight loss. However, some types of carbohydrates – including whole grains and dietary fiber – have substantial health benefits. In fact, according to the Physicians Committee for Responsible Medicine, those who eat the most carbohydrates – especially from natural sources such as beans, whole grains, and vegetables — have a lower risk for obesity, type 2 diabetes, and heart disease.

Other types of carbohydrates, including simple carbohydrates such as white bread, have much lower nutritional value. Added sugars are a type of carbohydrate that can have adverse health effects. Eating large amounts of foods that contain added sugars can contribute to obesity, type 2 diabetes, and cardiovascular disease. When making dietary changes, it is important to aim for a healthful diet that contains the range of nutrients that the body needs.

Carbohydrates and Obesity

Some argue that the global rise in obesity is linked to a high intake of carbs. However, a number of factors contribute to rising obesity rates, inclding

- Lower physical activity levels
- Greater availability of ultraprocessed food or “junk food”
- A lack of access to affordable fresh produce
- Oversized portions, which increase a person’s calorie intake
- Fewer hours of sleep
- Genetic factors
- Stress and emotional factors

What about diet foods?

Many manufacturers promote low carb diets to sell weight loss products, including nutritional bars and powders. These products are not often healthful as many contain colorings, artificial sweeteners, emulsifiers, and other additives and are typically low in vitamins, minerals, and antioxidants, making them similar to junk food. Carbohydrates often get a bad rap, especially when it comes to weight gain. But carbohydrates, often called carbs, aren't all bad. Because of their many health benefits, carbs have a rightful place in the diet. In fact, the body needs carbs to work well. But some carbs can be better for you than others. Understand more about carbohydrates and how to make healthy diet choices.

Understanding carbohydrates

Carbohydrates are a type of macronutrient found in many foods and beverages. Most carbs occur naturally in plant-based foods, such as grains. Food manufacturers also add carbs to processed foods in the form of starch or added sugar. Common sources of naturally occurring carbohydrates include:

- Fruits
- Vegetables
- Milk
- Nuts
- Grains
- Seeds
- Beans, peas and lentils

2.5 Types of carbohydrates

There are three main types of carbohydrates:

- **Sugar.** Sugar is the simplest form of carbohydrate. It occurs naturally in some foods, including fruits, vegetables, milk and milk products. Types of sugar include fruit sugar (fructose), table sugar (sucrose) and milk sugar (lactose). Added sugars can be found in many foods, such as cookies, sugary drinks and candy.
- **Starch.** Starch is a complex carbohydrate. This means it is made of many sugar units bonded together. Starch occurs naturally in vegetables, grains, and cooked dry beans and peas.

- **Fiber.** Fiber also is a complex carbohydrate. It occurs naturally in fruits, vegetables, whole grains, and cooked dry beans and peas.

More carbohydrate terms: Net carbs and glycemic index

The terms "low carb" or "net carbs" often appear on product labels. But the Food and Drug Administration doesn't use these terms, so there's no standard meaning. Typically, the term "net carbs" is used to mean the amount of carbs in a product excluding fiber or excluding both fiber and sugar alcohols. The glycemic responses of various foods have been measured and then ranked in comparison to a reference food, usually a slice of white bread or just straight glucose, to create a numeric value called the glycemic index (GI). Foods that have a low GI do not raise blood-glucose levels neither as much nor as fast as foods that have a higher GI. A diet of low-GI foods has been shown in epidemiological and clinical trial studies to increase weight loss and reduce the risk of obesity.

Foods	**GI**	**Foods**	**GI**
Apple, raw	36	Carrots, boiled	39
Orange, raw	43	Taro, boiled	53
Banana, raw	51	Corn tortilla	46
Mango, raw	51	Spaghetti (whole wheat)	37
Ice-cream	51	Whole wheat bread	69
Pineapple, raw	59	Taro, boiled	53
Mashed potatoes	70	Medium GI foods	(56-69)

Fig. The Glycemic index: foods in comparison to glucose

Weight-loss diets based on the glycemic index typically suggest limiting foods that are higher on the glycemic index. Foods with a relatively high glycemic index ranking include potatoes, white bread, and snack foods and desserts that have refined flours. Many healthy foods are naturally lower on the glycemic index. Examples include whole grains, legumes, vegetables, fruits and low-fat dairy products.

Low GI diet

One factor that increases the GI score of a food is the milling and grinding process, which often leaves no more than the starchy endosperm, or the inner part, of the seed or grain. This is mainly starch.This process also eliminates other nutrients, such as minerals, vitamins, and dietary fibers. To follow a low GI diet, a person can eat more unrefined foods, such as:

- oats, barley, or bran
- whole-grain bread
- brown rice
- plenty of fresh fruit and vegetables
- fresh, whole fruit instead of juice
- whole-grain pasta
- salads and raw vegetables

How many carbohydrates do you need?

The Dietary Guidelines for Americans recommend that carbohydrates make up 45% to 65% of total daily calories. So if you get 2,000 calories a day, between 900 and 1,300 calories should be from carbohydrates. That translates to between 225 and 325 grams of carbs a day. You can find the carbohydrate content of packaged foods on the Nutrition Facts label. The label shows total carbohydrates - which can include fiber, total sugars and added sugars.

Carbohydrates and your health

Despite their bad reputation, carbohydrates are vital to your health for many reasons.

Providing energy

Carbohydrates are the body's main fuel source. During digestion, sugars and starches are broken down into simple sugars. They're then absorbed into the bloodstream, where they're known as blood sugar (blood glucose). From there, glucose enters the body's cells with the help of insulin. Glucose is used by the body for energy. Glucose fuels your activities — whether it's going for a jog or simply breathing and thinking. Extra glucose is stored in the liver, muscles and other cells for later use. Or extra glucose is converted to fat.

Protecting against disease

Some evidence suggests that whole grains and dietary fiber from whole foods help lower your risk of heart disease and stroke. Fiber may also protect against obesity, colon and rectal cancers, and type 2 diabetes. Fiber is also essential for optimal digestive health.

Controlling weight

Evidence shows that eating plenty of fruit, vegetables and whole grains can help you control your weight. Their bulk and fiber content aids weight control by helping you feel full on fewer calories. Despite what proponents of low-carb diets claim, few studies show that a diet rich in healthy carbs leads to weight gain or obesity.

Choose your carbohydrates wisely

Carbohydrates are an essential part of a healthy diet, and they provide many important nutrients. Still, not all carbs are equally good for you. Here's how to make healthy carbohydrates work in a balanced diet:

- **Focus on eating fiber-rich fruits and vegetables.** Aim for whole fresh, frozen and canned fruits and vegetables without added sugar. Or have measured portions of fruit juices and dried fruits, which are concentrated sources of natural sugar, but have more calories. Whole fruits and vegetables have many health benefits. They add fiber, water and bulk, which help you feel fuller on fewer calories.
- **Choose whole grains.** Whole grains are better sources than refined grains of fiber and other important nutrients, such as B vitamins. Refined grains go through a process that strips out parts of the grain — along with some of the nutrients and fiber.
- **Stick to low-fat dairy products.** Milk, cheese, yogurt and other dairy products are good sources of calcium, protein, vitamin D, potassium, and other vitamins and minerals. Consider the low-fat versions to help limit calories and saturated fat. And watch out for dairy products that have added sugar.
- **Eat more beans, peas and lentils.** Beans, peas and lentils are among the most versatile and nutritious foods. They are typically low in fat and high in folate, potassium, iron and magnesium. And they have useful fats and fiber. They are a good source of protein and can be a healthy substitute for meat, which has more saturated fat and cholesterol.
- **Limit added sugars.** Added sugar probably isn't harmful in small amounts. But there's no health benefit to having any amount of added sugar, such as in cookies and pastries. The Dietary Guidelines for Americans recommend that less than 10% of calories you eat or drink every day come from added sugar. Eating or drinking too many foods with sugar can also causes you to take in more than the calories you need each day.

So choose your carbohydrates wisely. Limit foods with added sugars and refined grains, such as sugary drinks, desserts and candy. These are high in calories but low in nutrition. Instead, select fruits, vegetables and whole grains.

2.6 Digestion and Absorption of Carbohydrates

Digestion

Digestion is the process of breaking large, insoluble food molecules into smaller molecules for absorption into the bloodstream. This process involves the use of many digestive fluids and enzymes such as saliva, mucus, bile and hydrochloric acid, among others.There are four primary stages of food digestion in the human bodies that include:

- After the intake of food through the mouth, it makes its way through the stomach into the small intestine, where it is digested.
- The nutrients from the digested food get absorbed into the bloodstream through small pores in the small intestine.
- The remaining undigested food is sent to the large intestine, where any unprocessed water or nutrients are reabsorbed into the body.
- The remaining waste food product is passed out of the body in the form of stools.

Absorption

Absorption is the process of the absorbing or assimilating substances into the cells or across the tissues and organs through the process of diffusion or osmosis.

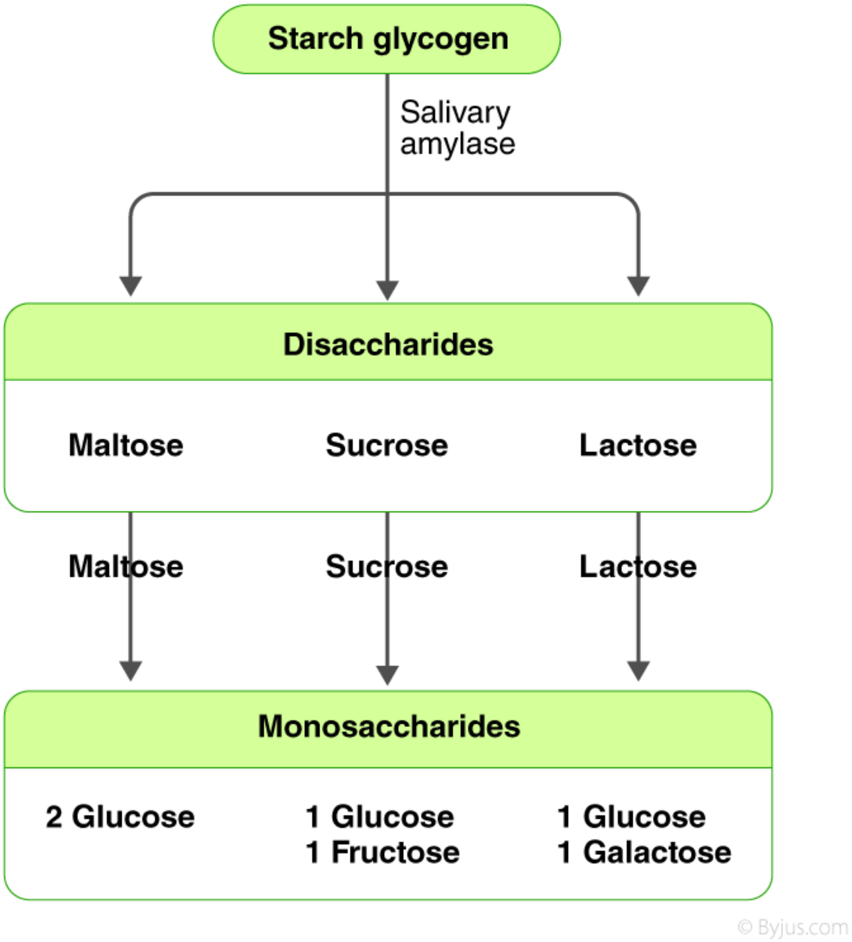

Fig. Digestion and Absorption of Carbohydrates

Carbohydrates are one of the essential nutrients in the human diet. There are two types of carbohydrates that can be digested by the human digestive system– sugar and starch. Sugar is broken down in the gastrointestinal tract by the small intestine and three enzymes present in the mouth, namely, Lactase, Sucrase, and Maltase. In the same way, starch is broken down with the help of the Amylase enzymes which are present in the mouth and the stomach. After digestion, carbohydrates are absorbed in the small intestine with the help of minute finger-shaped projections known as Villi. The chemical digestion of carbohydrates begins in the mouth. The below flowchart explains in detail about the series of steps involved in breaking down the carbohydrates into their monomers.

2.7 Absorption of Carbohydrates

2.7.1 Absorption of Fructose

The end products of sugars and starches digestion are the monosaccharides glucose, fructose, and galactose. Glucose, fructose, and galactose are absorbed across the membrane of the small intestine and transported to the liver where they are either used by the liver, or further distributed to the rest of the body (3, 4).

There are two major pathways for the metabolism of fructose (5, 6): the more prominent pathway is in the liver and the other occurs in skeletal muscle. The breakdown of fructose in skeletal muscle is similar to glucose. In the liver and depending on exercise condition, gender, health status and the availability of other energy sources (e.g. glucose), the majority of fructose is used for energy production, or can be enzymatically converted to glucose and then potentially glycogen, or is converted to lactic acid. The notion that fructose is an unregulated energy substrate and directly fuels fat synthesis in the liver is not supported by the scientific literature; within the normal consumption range very minimal amounts (<1%) of fructose are converted to fat (5, 6). It is important to note that the metabolism of fructose involves many regulated reactions and its fate may vary depending on nutrients consumed simultaneously with fructose (e.g. glucose) as well as the energy status of the body.

Important Questions

Q. 1 What are carbohydrates?

Carbohydrates are the sugars, starches and fibres present in the products of fruits, grains, vegetables and milk. The American Diabetes Association states that carbohydrates are the primary source of energy for the body. They are called carbohydrates, as they contain carbon, hydrogen and oxygen at the chemical level.

Q. 2 What types of foods are carbohydrates?

Carbohydrates are present in a wide range of safe as well as unhealthy foods — bread, beans, milk, popcorn, potatoes, cookies, pasta, soft drinks, corn, and cherry pie. They come in a range of shapes too. The most natural and abundant types are sugars, starches and fibres.

Q. 3 What are the major functions of carbohydrates?

The four primary carbohydrate functions in the body are to provide energy, store energy, create macromolecules and spare protein and fat for other uses. Glucose energy is processed in the form of glycogen, with most in the muscle and liver.

Q. 4 What are the main carbohydrates?

Foods rich in carbohydrates include bread, vegetables and fruits, as well as dairy. Carbohydrates are the sugars, starches and fibres present in the products of fruits, grains, vegetables and milk. Even though often maligned in trendy diets, carbohydrates are essential to a healthy diet as one of the basic food groups.

Q. 5 What are the two sources of carbohydrates?

Healthy carbohydrate sources include both animal and plant food sources, such as fresh fruits, tomatoes, corn, potatoes, meat, and milk products. Examples that are not safe include soda, white bread, added sugar, pastries and other highly processed food.

Q. 6 What is a simple carbohydrate?

The body rapidly breaks down simple carbohydrates to be used as energy. Simple carbohydrates are naturally found in foods such as fruit, milk, and dairy products. In processed and refined sugars such as candy, table sugar, syrups and soft drinks, are also found.

Q. 7 What is a complex carbohydrate?

Simple carbohydrates consist of sugar molecules, which are bound together in long, complex chains. Foods such as peas, beans, whole grains, and vegetables contain complex carbohydrates. Within the body, both simple and complex carbohydrates are converted into glucose (blood sugar) and used as energy.

Q. 8 What is the difference between complex and simple carbohydrates?

Simple carbohydrates are present in such foods as table sugar and syrups. Complex carbohydrates contain longer sugar molecular chains than mere carbohydrates. Since complex carbohydrates have longer chains, they take longer than simple carbohydrates to break down and provide more lasting energy in the body.

Factors that Affect Absorption of Carbohydrates

A number of factors affect carbohydrate digestion and absorption, such as the food matrix and other foods eaten at the same time. Glycemic Index (GI) is a scale that uses a numbering system to rank carbohydrate rich foods as “high GI”, “medium GI”, and “low GI” based on the rate that glucose-containing carbohydrates are digested and absorbed, and the rate they increase blood glucose levels. Foods with a high GI are more quickly digested, and cause a larger increase in blood glucose level compared to foods with a low GI. Foods with a low GI are digested more slowly and do not raise blood glucose as high, or as quickly, as high GI foods. Examples of factors that affect carbohydrate absorption are described in the table below:

S. No.	Factors that Affect Carbohydrate Absorption	Examples
1.	**Fibre:** Fibre helps to slow digestion of carbohydrate foods. High-fibre foods tend to have a lower GI than low fibre foods.	Less processed foods, such as slow cooking oats or brown rice, have a lower GI than more processed foods such as instant oats or instant rice. Pasta cooked 'al dente' (tender yet firm) has a lower GI than pasta cooked until very tender.
2.	**Fat and Protein:** Fat or protein eaten along with carbohydrate helps to slow down digestion and reduces the GI of carbohydrate.	High fibre foods such as whole grain breads, oats, beans, and lentils, have a lower GI than low fibre foods such as white bread and rice cereal.
3.	**Acids in Foods:** Acids in foods slow the time it takes for the stomach to empty after eating. Acids lower the GI of carbohydrate foods.	A snack that includes carbohydrate with protein or fat has a lower GI than a snack with carbohydrate only. For example, crackers with peanut butter have a lower GI than crackers alone.
4.	**Fibre:** Fibre helps to slow digestion of carbohydrate foods. High-fibre foods tend to have a lower GI than low fibre foods.	Vinegar, lemon juice, or citrus fruits added to foods will lower the GI of those foods.

2.8 Structure of Carbohydrates

Carbohydrates are organic compounds that contain only carbon (C), hydrogen (H), and oxygen (O). They contain a chain of carbons, an aldehyde or a ketone, and hydroxyl groups. Every carbon atom is attached to one oxygen atom. There are thousands of different carbohydrates, but they all consist of one or more smaller units called monosaccharides.

2.8.1 Monosaccharides

The general formula for a monosaccharide is $(CH_2O)_n$, where n can be any number greater than two. For example, if n is 6, then the formula can be written $C_6H_{12}O_6$. This is the formula for the monosaccharide glucose. Another monosaccharide, fructose, has the same chemical formula as glucose, but the atoms are arranged differently. Carbohydrates have many isomers because of the arrangement of the −OH−OH groups in their structures. Compare the glucose and fructose molecules in the figure below. The only differences are the positions of some of the atoms. These differences affect the properties of the two monosaccharides.

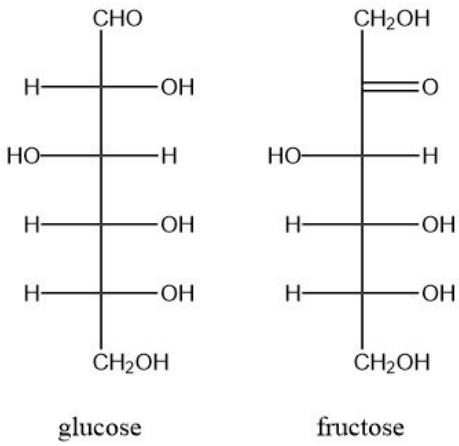

Fig. Structures of glucose and fructose.

Monosaccharides can be classified by the number of carbon atoms they contain: diose (2), triose (3), tetrose (4), pentose (5), hexose (6), heptose (7), and so on. They can also be classified based on whether or not they contain an aldehyde (aldose) or ketone (ketose). We can also combine these two designations to refer to classes of carbohydrates. For example, an aldohexose is a carbohydrate (indicated by the *-ose* ending) with six carbons (*hex*) and an aldehyde group (*aldo*). A ketopentose is a carbohydrate with a ketone and 5 carbons. Both glucose and fructose are hexoses because they contain six carbons but glucose is an aldohexose while fructose (also known as "fruit sugar") is a ketohexose. Other common monosaccharides include galactose (part of lactose), xylose ("wood sugar"), ribose (in RNA), and deoxyribose (in DNA).

2.8.2 Disaccharides

If two monosaccharides bond together, they form a carbohydrate called a disaccharide**.** Two monosaccharides will bond together through a dehydration reaction, in which a water molecule is lost. A dehydration reaction is a condensation reaction**,** a chemical reaction in which two molecules combine to form one single molecule, losing a small molecule in the process. In the dehydration reaction, this small molecule is water. The bond between two monosaccharides is known as a glycosidic bond**.** An example of a disaccharide is sucrose (table sugar), which consists of the monosaccharides glucose and fructose (see figure below). Other common disaccharides include lactose ("milk sugar") and maltose.

Monosaccharides and disaccharides are also called *simple sugars*. They provide the major source of energy to living cells.

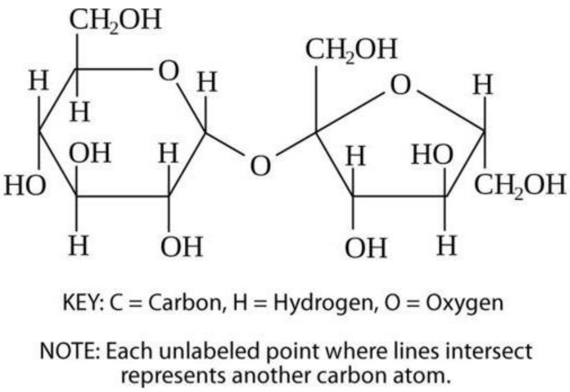

Fig. Sucrose molecule. This sucrose molecule is a disaccharide. It is made up of two monosaccharides: glucose on the left and fructose on the right.

2.8.3 Oligosaccharides

An oligosaccharide is a saccharide polymer containing a small number (typically two to ten) of monosaccharides. Oligosaccharides can have many functions; for example, they are commonly found on the plasma membrane of animal cells where they can play a role in cell-cell recognition. In general, they are found attached to compatible amino acid side-chains in proteins or to lipids. Oligosaccharides are often found as a component of glycoproteins or glycolipids**.** They are often used as chemical markers on the outside of cells, often for cell recognition. Oligosaccharides are also responsible for determining blood type.

2.8.4 Polysaccharides

Polysaccharides are long carbohydrate molecules of repeated monomer units joined together by glycosidic bonds. A polysaccharide may contain anywhere from a few monosaccharides to several thousand monosaccharides. Polysaccharides are also called complex carbohydrates**.** Polysaccharides have a general formula of Cx(H2O)y, where x is usually a large number between 200 and 2500. Starches are one of the more common polysaccharides. Starch is made up of a mixture of amylose (15-20%) and amylopectin (80-85%). Amylose consists of a linear chain of several hundred glucose molecules and amylopectin is a branched molecules made of several thousand glucose units.

Starches can be digested by hydrolysis reactions**,** catalyzed by enzymes called amylases**,** which can break the glycosidic bonds. Humans and other animals have amylases, so they can digest starches. Potato, rice, wheat, and maize are major sources of starch in the human diet. The formations of starches are the ways that plants store glucose. Glycogen is sometimes referred to as *animal starch*. Glycogen is used for long-term energy storage in animal cells. Glycogen is made primarily by the liver and the muscles.

Blood Type

Carbohydrates attached to red blood cells also determine blood type (see figure below). Of the four blood types, type O has the fewest types of saccharides attached to it while type AB has the most. As a result, type O blood is considered the universal donor because it doesn't have any saccharides present that will appear as foreign when transfused into blood of another type. The reverse is not true. For example, if type A blood is given to a patient with type O blood, it will be rejected by the body because there is an unknown species being introduced to the body. Type A blood cells contain N-acetyl-galactosamine which is not present in type O blood. A person with type O blood would undergo rejection upon receiving type A blood. The Rhesus factor (Rh) in blood also affects donor and acceptor properties but it does not depend on carbohydrates. The Rh factor is determined by the presence (Rh+) or absence (Rh-) of a specific protein on the surface of red blood cells.

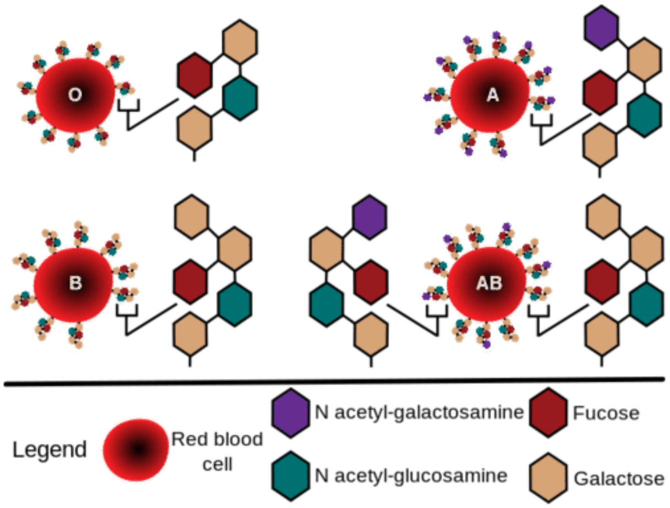

Fig.ABO blood types

2.9 Properties of Carbohydrates

Physical Properties of Carbohydrates

- **Stereoisomerism** – Compound shaving the same structural formula but they differ in spatial configuration. Example: Glucose has two isomers with respect to the penultimate carbon atom. They are D-glucose and L-glucose.
- **Optical Activity** – It is the rotation of plane-polarized light forming (+) glucose and (-) glucose.
- **Diastereo isomers** – It the configurational changes with regard to C2, C3, or C4 in glucose. Example: Mannose, galactose.
- **Annomerism** – It is the spatial configuration with respect to the first carbon atom in aldoses and the second carbon atom in ketoses.

Chemical Properties of Carbohydrates

- **Osazone formation**: Osazone are carbohydrate derivatives when sugars are reacted with an excess of phenylhydrazine. eg. Glucosazone
- **Benedict's test:** Reducing sugars when heated in the presence of an alkali gets converted to powerful reducing species known as enediols. When Benedict's reagent solution and reducing sugars are heated together, the solution changes its color to orange-red/ brick red.
- **Oxidation:** Monosaccharides are reducing sugars if their carbonyl groups oxidize to give carboxylic acids. In Benedict's test, D-glucose is oxidized to D-gluconic acid thus, glucose is considered a reducing sugar.
- **Reduction to alcohols:** The C=O groups in open-chain forms of carbohydrates can be reduced to alcohols by sodium borohydride, $NaBH_4$, or catalytic hydrogenation (H_2, Ni, EtOH/H2O). The products are known as "alditols".

Properties of Monosaccharides

- Most monosaccharides have a sweet taste (fructose is sweetest; 73% sweeter than sucrose).
- They are solids at room temperature.
- They are extremely soluble in water: – Despite their high molecular weights, the presence of large numbers of OH groups makes the monosaccharides much more water-soluble than most molecules of similar MW.
- Glucose can dissolve in minute amounts of water to make a syrup (1 g / 1 ml H2O).

Oligosaccharides

- Oligosaccharides are compound sugars that yield 2 to 10 molecules of the same or different monosaccharides on hydrolysis.
- The monosaccharide units are joined by glycosidic linkage.
- Based on the number of monosaccharide units, it is further classified as a disaccharide, trisaccharide, tetrasaccharide, etc.
- The general formula of disaccharides is $C_n(H2O)_{n-1}$and that of trisaccharides is $C_n(H2O)_{n-2}$ and so on.
- Examples: Disaccharides include sucrose, lactose, maltose, etc.
- Trisaccharides are Raffinose, Rabinose.

Polysaccharides

- They are also called "glycans".
- Polysaccharides contain more than 10 monosaccharide units and can be hundreds of sugar units in length.
- They yield more than 10 molecules of monosaccharides on hydrolysis.
- Polysaccharides differ from each other in the identity of their recurring monosaccharide units, in the length of their chains, in the types of bond linking units and in the degree of branching.
- They are primarily concerned with two important functions ie. Structural functions and the storage of energy.

2.10 Functions of Carbohydrates

Carbohydrates are widely distributed molecules in plant and animal tissues. In plants and arthropods, carbohydrates from the skeletal structures, they also serve as food reserves in plants and animals. They are important energy sources required for various metabolic activities, the energy is derived by oxidation.

Some of their major functions include

- Living organisms use carbohydrates as accessible energy to fuel cellular reactions. They are the most abundant dietary source of energy (4kcal/gram) for all living beings.
- Carbohydrates along with being the chief energy source, in many animals, are instant sources of energy. Glucose is broken down by glycolysis/ Kreb's cycle to yield ATP.
- Serve as energy stores, fuels, and metabolic intermediates. It is stored as glycogen in animals and starch in plants.
- Stored carbohydrates act as an energy source instead of proteins.

- They form structural and protective components, like in the cell wall of plants and microorganisms. Structural elements in the cell walls of bacteria (peptidoglycan or murein), plants (cellulose), and animals (chitin).
- Carbohydrates are intermediates in the biosynthesis of fats and proteins.
- Carbohydrates aid in the regulation of nerve tissue and is the energy source for the brain.

2.11 Summary

Under this unit we have discussed the general properties, digestion and absorption of carbohydrates. They constitute a group of chemically defined substances with a range of physical and physiological properties and health benefits for consumers. Their main function is to provide energy, but they also play an important role in the structure and function of cells, tissues, and organs. Some carbohydrates have specific nutritional actions. For example, inulin acts as a prebiotic, which means it resists gastric acidity, hydrolysis by mammalian enzymes and gastrointestinal absorption, it is fermented by the intestinal microflora and stimulates selectively the growth and activity of intestinal bacteria associated with health and well-being. In relation to food products, carbohydrates are components, ingredients, and additives that contribute not only to their nutritional value but also to their organoleptical properties.

2.12 Terminal questions

Q.1 Describe carbohydrates with its digestion and absorption.

Answer:---

Q.2 What are the general properties of carbohydrates? Explain with examples.

Answer:---

Q.3 Explain the digestion process of carbohydrates.

Answer:--

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Q. 4 Describe different types of carbohydrates with examples.

Answer:--

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Q. 5 Write short notes on the followings.

(i) Absorption of carbohydrates

(ii) Glucose

Answer:--

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Further readings

1. Biochemistry- Lehninger A.L.
2. Textbook of Nutrition and Dietetics Ranjana Mahna
3. Biochemistry fourth edition-David Hames and Nigel Hooper.
4. Textbook of Biochemistry for Undergraduates - Rafi, M.D.
5. Textbook of Nutrition and Dietetics- Monika Sharma

Unit 3: Types of Carbohydrates:

Structure

Objectives

3.1 Introduction

3.2 Types of Carbohydrates

3.1 Introduction

Carbohydrates are macronutrients and are one of the three main ways by which our body obtains its energy. They are called carbohydrates as they comprise ***carbon***, ***hydrogen*** and ***oxygen*** at their chemical level. Carbohydrates are essential nutrients which include sugars, fibers and starches. They are found in grains, vegetables, fruits and in milk and other dairy products. They are the basic food groups which play an important role in a healthy life. The food containing carbohydrates are converted into glucose or blood sugar during the process of digestion by the digestive system. Our body utilizes this sugar as a source of energy for the cells, organs and tissues. The extra amount of energy or sugar is stored in our muscles and liver for further requirement. The term 'carbohydrate' is derived from a French term *'hydrate de carbone' meaning 'hydrate of carbon'*. The general formula of this class of organic compounds is $C_n(H_2O)_n$**.**

Objectives

This is the third unit (Types of Carbohydrates) of block 1st (Introduction to Biochemistry: Carbohydrates and Lipids). Under this unit, we have following objectives. These are as under:

- To introduce the carbohydrates
- To know the structure and types of carbohydrates

- To discuss about maltose, lactose and sucrose
- To discuss dextrin, glycogen and fructose with their functions

To know the concept of vegetative structures, reproduction and thallus organization

3.2 Types of Carbohydrates

Did you know there are three main types of carbohydrate in food? There are

- Starches (also known as complex carbohydrates)
- Sugars
- Fiber

You'll also hear terms like naturally occurring sugar, added sugar, low-calorie sweeteners, sugar alcohols, reduced-calorie sweeteners, processed grains, enriched grains, complex carbohydrate, sweets, refined grains and whole grains. No wonder knowing what kind and how much carbohydrate to eat can be confusing! On the nutrition label, the term "total carbohydrate" includes all three types of carbohydrates. This is the number you should pay attention to if you are carbohydrate counting.

Starch

Foods high in starch include:

- Starchy vegetables like peas, corn, lima beans and potatoes
- Dried beans, lentils and peas such as pinto beans, kidney beans, black eyed peas and split peas
- Grains like oats, barley and rice. (The majority of grain products in the US are made from wheat flour. These include pasta, bread and crackers but the variety is expanding to include other grains as well.)

The grain group can be broken down even further into whole grain or refined grain. A grain contains three parts:

- bran
- germ
- endosperm

The bran is the outer hard shell of the grain. It is the part of the grain that provides the most fiber and most of the B vitamins and minerals. The germ is the next layer and is packed with nutrients including essential fatty acids and vitamin E. The endosperm is the soft part in the center of the grain. It contains the starch. Whole grain means that the entire grain kernel is in the food. If you eat a whole grain food, it contains the bran, germ, and endosperm so you get all of the nutrients that whole grains have to offer. If you eat a refined grain food, it contains only the endosperm or the starchy part so you miss out on a lot of vitamins and minerals. Because whole grains contain the entire grain, they are much more nutritious than refined grains.

Sugar

Sugar is another type of carbohydrate. You may also hear sugar referred to as simple or fast-acting carbohydrate. There are two main types of sugar:

- naturally occurring sugars such as those in milk or fruit
- added sugars such as those added during processing such as fruit canned in heavy syrup or sugar added to make a cookie

On the nutrition facts label, the number of sugar grams includes both added and natural sugars. There are many different names for sugar. Examples of common names are table sugar, brown sugar, molasses, honey, beet sugar, cane sugar, confectioner's sugar, powdered sugar, raw sugar, turbinado, maple syrup, high-fructose corn syrup, agave nectar and sugar cane syrup. You may also see table sugar listed by its chemical name, sucrose. Fruit sugar is also known as fructose and the sugar in milk is called lactose. You can recognize other sugars on labels because their chemical names also end in "-ose." For example glucose (also called dextrose), fructose (also called levulose), lactose and maltose.

Fiber

Fiber comes from plant foods so there is no fiber in animal products such as milk, eggs, meat, poultry, and fish. Fiber is the indigestible part of plant foods, including fruits, vegetables, whole grains, nuts and legumes. When you consume dietary fiber, most of it passes through the intestines and is not digested. For good health, adults need to try to eat 25 to 30 grams of fiber each day. Most Americans do not consume nearly enough fiber in their diet, so while it is wise to aim for this goal, any increase in fiber in your diet can be beneficial. Most of us only get about half of what is recommended. Fiber contributes to digestive health, helps to keep you regular, and helps to make you feel full and satisfied after eating. Additional health benefits, of a diet high in fiber—such as a reduction in cholesterol levels—have been suggested by some so may be an additional benefit.

Good sources of dietary fiber include:

- Beans and legumes. Think black beans, kidney beans, pintos, chickpeas (garbanzos), white beans, and lentils.
- Fruits and vegetables, especially those with edible skin (for example, apples, corn and beans) and those with edible seeds (for example, berries).

- Whole grains such as:
- Whole wheat pasta
- Whole grain cereals (Look for those with three grams of dietary fiber or more per serving, including those made from whole wheat, wheat bran, and oats.)
- Whole grain breads (To be a good source of fiber, one slice of bread should have at least three grams of fiber. Another good indication: look for breads where the first ingredient is a whole grain. For example, whole wheat or oats.) Many grain products now have "double fiber" with extra fiber added.
- Nuts — try different kinds. Peanuts, walnuts and almonds are a good source of fiber and healthy fat, but watch portion sizes, because they also contain a lot of calories in a small amount.

In general, an excellent source of fiber contains five grams or more per serving, while a good source of fiber contains 2.5–4.9 grams per serving.

3.3 Classification of Carbohydrates

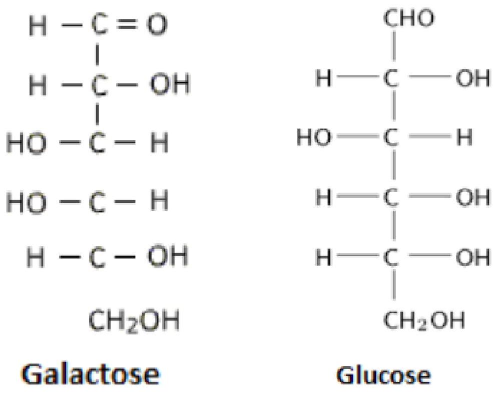
The carbohydrates are further classified into simple and complex which is mainly based on their chemical structure and degree of polymerization.

Simple Carbohydrates (Monosaccharides, Disaccharides and Oligosaccharides)

Simple carbohydrates have one or two sugar molecules. In simple carbohydrates, molecules are digested and converted quickly resulting in a rise in the blood sugar levels. They are abundantly found in milk products, beer, fruits, refined sugars, candies, etc. These carbohydrates are called empty calories, as they do not possess fiber, vitamins and minerals. Plants, being producers, synthesize glucose ($C_6H_{12}O_6$) using raw materials like carbon dioxide and water in the presence of sunlight. This process of photosynthesis converts solar energy to chemical energy. Consumers feed on plants and harvest energy stored in the bonds of the compounds synthesized by plants.

Monosaccharides

Glucose is an example of a carbohydrate monomer or monosaccharide. Other examples of monosaccharides include mannose, galactose, fructose, etc. The structural organization of monosaccharides is as follows:



Galactose Glucose

Fig. Structure of galactose and glucose

Monosaccharides may be further classified depending on the number of carbon atoms:

(i) Trioses ($C_3H_6O_3$): These have three carbon atoms per molecule. Example: Glyceraldehyde

(ii) Tetroses ($C_4H_6O_4$): These monosaccharides have four carbon atoms per molecule. Example: Erythrose.

Similarly, we have-

(iii) Pentoses,

(iv) Hexoses, and

(v) Heptoses

Glucose

Glucose comes from the Greek word for "sweet." It's a type of sugar you get from foods you eat, and your body uses it for energy. As it travels through your bloodstream to your cells, it's called blood glucose or blood sugar. Insulin is a hormone that moves glucose from your blood into the cells for energy and storage. People with diabetes have higher-than-normal levels of glucose in their blood. Either they don't have enough insulin to move it through or their cells don't respond to insulin as well as they should. High blood glucose for a long period of time can damage your kidneys, eyes, and other organs.

How Your Body Makes Glucose

It mainly comes from foods rich in carbohydrates, like bread, potatoes, and fruit. As you eat, food travels down your esophagus to your stomach. There, acids and enzymes break it down into tiny pieces. During that process, glucose is released. It goes into your intestines where it's absorbed. From there, it passes into your bloodstream. Once in the blood, insulin helps glucose get to your cells.

Energy and Storage

Your body is designed to keep the level of glucose in your blood constant. Beta cells in your pancreas monitor your blood sugar level every few seconds. When your blood glucose rises after you eat, the beta cells release insulin into your bloodstream. Insulin acts like a key, unlocking muscle, fat, and liver cells so glucose can get inside them. Most of the cells in your body use glucose along with amino acids (the building blocks of protein) and fats for energy. But it's the main source of fuel for your brain. Nerve cells and chemical messengers there need it to help them process information. Without it, your brain wouldn't be able to work well.

After your body has used the energy it needs, the leftover glucose is stored in little bundles called glycogen in the liver and muscles. Your body can store enough to fuel you for about a day.

After you haven't eaten for a few hours, your blood glucose level drops. Your pancreas stops churning out insulin. Alpha cells in the pancreas begin to produce a different hormone called glucagon. It signals the liver to break down stored glycogen and turn it back into glucose. That travels to your bloodstream to replenish your supply until you're able to eat again. Your liver can also make its own glucose using a combination of waste products, amino acids, and fats.

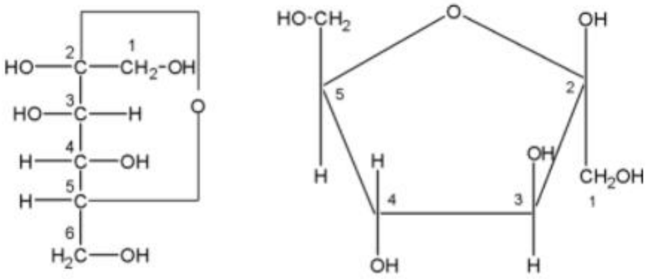
3.4 Fructose

Fructose, a member of a group of carbohydrates known as simple sugars, or monosaccharides. Fructose, along with glucose, occurs in fruits, honey, and syrups; it also occurs in certain vegetables. It is a component, along with glucose, of the disaccharide sucrose, or common table sugar. Phosphate derivatives of fructose (e.g., fructose-1-phosphate, fructose-1,6-diphosphate) are important in the metabolism of carbohydrates.

Structure of Fructose

- Fructose has a cyclic structure.
- Due to the presence of the keto group, it results in the formation of the intramolecular hemiacetal.

- In this arrangement, C_5-OH combines with the ketonic group present in the second position.
- This results in the formation of chiral carbon and two arrangements of CH_2OH and OH group.
- Hence, D-fructose exhibits stereoisomerism in which α-D-fructopyranose and β-D-fructopyranose are the isomers.



β-D-Fructose

Uses of Fructose

- Crystalline fructose is used in enhancing the taste in food industries.
- It is used in flavoured water, energy drinks, low-calorie products, etc.
- Fruit sugar is used in the manufacturing of soft moist cookies, nutrition bars, reduced-calorie products etc.

3.5 Galactose

Galactose is a monosaccharide and has the same chemical formula as glucose, i.e., $C_6H_{12}O_6$. It is similar to glucose in its structure, differing only in the position of one hydroxyl group. This difference, however, gives galactose different chemical and biochemical properties to glucose. The major dietary source of galactose is lactose, a disaccharide formed from one molecule of glucose plus one of galactose. Lactose is found only in milk; after weaning, significant quantities of dietary lactose are found only in dairy products (Table 1). Lactose levels are lower than expected in some dairy products, where it has been used by the microbes involved in processing the food.

Food	***Lactose content (g per***

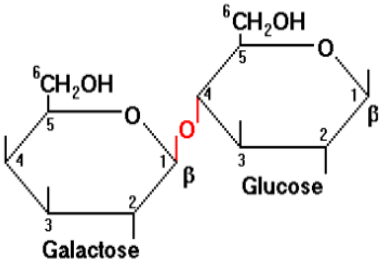
	100 g)
Cows' milk	4.7
Goats' milk	4.6
Human milk	7.2
Butter	Trace
Cream	2.0–3.2
Cottage cheese	1.4
Yogurt	3.2–4.8

Table 1. Lactose content of milk and dairy products

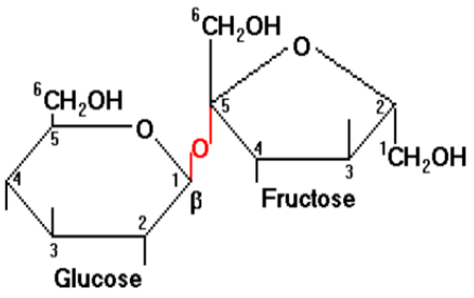
Lactose, a byproduct of the dairy industry, can be hydrolyzed to produce lactose hydrolysate syrup, which contains lactose, galactose, and glucose. This syrup is used as a sweetener in biscuits, confectionery, and some dairy desserts. Thus, small amounts of lactose and galactose can appear in nondairy foods. Apart from its presence in lactose hydrolysate syrup, the monosaccharide galactose is seldom found in the diet, although it has been identified as a trace component of some seeds and pulses.

Disaccharides

Two monosaccharides combine to form a disaccharide. Examples of carbohydrates having two monomers include- Sucrose, Lactose, Maltose, etc.



LACTOSE= GLUCOSE +GALACTOSE



SUCROSE= GLUCOSE + FRUCTOSE

3.6 Maltose

Maltose, also known as malt, is a disaccharide made up of two alpha D-glucose units. The two units of glucose are linked with an alpha 1,4 glycosidic bond. In the small intestinal lining in humans, the enzyme maltase and isomaltase break down the molecules of maltose into two glucose molecules, which is then absorbed by the body. Starch is the most abundant polysaccharide in plant cells after cellulose. On the contrary, a carbohydrate formed by the joining of two units of glucose is called a disaccharide. The three common types of disaccharides are sucrose, maltose and lactose. The other disaccharides which are less commonly known are lactulose, trehalose, and cellobiose. When one water molecule is removed by the joining of two monosaccharides, then a molecule of a disaccharide is formed, and the reaction which takes place during this process is known as the dehydration reaction.

Properties of Maltose

- Maltose is a reducing sugar. It tastes sweet but is only 30-60% as sweet as sugar.
- The hydrolysis reaction of maltose in the presence of an acid catalyst gives two molecules of alpha D-glucose.
- There is a free anomeric carbon present in the structure of maltose which can undergo mutarotation in solution. The resultant solution will be a mixture of alpha and beta maltose.
- Since the aldehydic group is formed in the solution, maltose gives a positive test with Benedicts and Tollens reagents.

Uses of Maltose

- Disaccharide such as sucrose is very sweet and is used as a sweetener in food products, but maltose lacks sweetness and is not used as a sweetener. Instead, it is used in the malting of barley for the manufacturing of beer.
- It is used extensively in alcohol production.
- Free maltose, as well as maltose formed by the digestion of starch in the mouth, can cause dental caries.
- Enzyme maltase and isomaltase present in the small intestine break down maltose into two glucose units which are then absorbed. Our body has the capacity to absorb maltose directly, which later on can be broken down into glucose units for producing energy.
- Due to a high glycemic index, maltose increases blood sugar levels.

3.7 Sucrose

Sucrose, or table sugar, organic compound, colourless sweet-tasting crystals that dissolve in water. Sucrose ($C_{12}H_{22}O_{11}$) is a disaccharide; hydrolysis, by the enzyme invertase, yields "invert sugar" (so called because the hydrolysis results in an inversion of the rotation of plane polarized light), a 50:50 mixture of fructose and glucose, its two constituent monosaccharides. Sucrose occurs naturally in sugarcane, sugar beets, sugar maple sap, dates, and honey. It is produced commercially in large amounts (especially from sugarcane and sugar beets) and is used almost entirely as food. *See also* sugar.

Sucrose Uses

Sucrose is the most common form of carbohydrate used to transport carbon within a plant. Sucrose is able to be dissolved into water, while maintaining a stable structure. Sucrose can then be exported by plant cells into the *phloem*, the special vascular tissue designed to transport sugars. From the cells in which it was produces, the sucrose travels through the intercellular spaces within the leaf. It arrives at the *vascular bundle*, where specialized cells pump it into the phloem. The *xylem*, or vascular tube which carries water, adds small amounts of water to the phloem to keep the sugar mixture from solidifying. The sucrose mixture then makes its way down the phloem, arriving at cells in the stem and roots which have no chloroplasts and rely on the leaves for energy.

The sucrose is absorbed into these cells, and enzymes begin breaking the sucrose back into its constituent parts. The six-carbon glucose and fructose can be broken down into 3-carbon molecules, which are imported into the mitochondria, where they go through the *citric acid cycle* (AKA the Krebs Cycle). This process reduces coenzymes, which are then used in *oxidative phosphorylation* to create ATP. The energy within the bonds of ATP can power many of the reactions these cells need to complete in order to maintain the stem and roots.

Likewise, all other life on Earth is dependent upon sucrose and other carbs produced by plants. Sucrose was one of the first substances to be extracted from plants on a mass-scale, creating the white table sugar we know today. These sugars are extracted and purified from large crops, including sugar cane and sugar beets. To extract the sugar, the plants are usually boiled or heated, releasing the sugar. "Sugar in the Raw" is sugar which has not been treated further, while white table sugar undergoes more purification.

Lactose is a disaccharide derived from the condensation of galactose and glucose, which form a β-1→4 glycosidic linkage. Its systematic name is β-D-galactopyranosyl-(1→4)-D-glucose. The glucose can be in either the α-pyranose form or the β-pyranose form, whereas the galactose can only have the β-pyranose form: hence α-lactose and β-lactose refer to the anomeric form of the glucopyranose ring alone. Detection reactions for lactose are the Woehlk- and Fearon's test. Both can be easily used in school experiments to visualise the different lactose content of different dairy products such as whole milk, lactose free milk, yogurt, buttermilk, coffee creamer, sour cream, kefir, etc.

Lactose is hydrolysed to glucose and galactose, isomerised in alkaline solution to lactulose, and catalytically hydrogenated to the corresponding polyhydric alcohol, lactitol.[9] Lactulose is a commercial product, used for treatment of constipation.

Lactose composes about 2–8% of milk by weight. Several million tons are produced annually as a by-product of the dairy industry. Whey or milk plasma is the liquid remaining after milk is curdled and strained, for example in the production of cheese. Whey is made up of 6.5% solids, of which 4.8% is lactose, which is purified by crystallisation.Industrially, lactose is produced from whey permeate – that is whey filtrated for all major proteins. The protein fraction is used in infant nutrition and sports nutrition while the permeate can be evaporated to 60–65% solids and crystallized while cooling.Lactose can also be isolated by dilution of whey with ethanol. Dairy products such as yogurt and cheese contain very little lactose. This is because the bacteria used to make these products breaks down lactose through the use of lactase.

Applications

Its mild flavor and easy handling properties have led to its use as a carrier and stabiliser of aromas and pharmaceutical products. Lactose is not added directly to many foods, because its solubility is less than that of other sugars commonly used in food. Infant formula is a notable exception, where the addition of lactose is necessary to match the composition of human milk. Lactose is not fermented by most yeast during brewing, which may be used to advantage. For example, lactose may be used to sweeten stout beer; the resulting beer is usually called a milk stout or a cream stout.

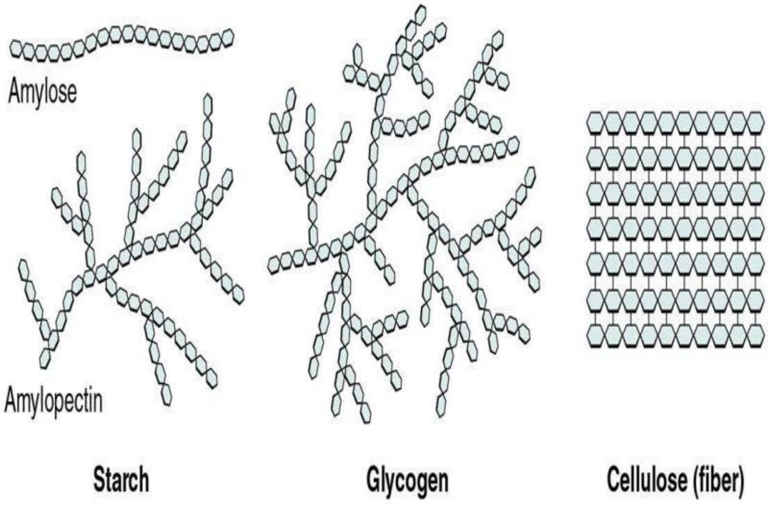
Yeast belonging to the genus *Kluyveromyces* have a unique industrial application, as they are capable of fermenting lactose for ethanol production. Surplus lactose from the whey by-product of dairy operations is a potential source of alternative energy. Another significant lactose use is in the pharmaceutical industry. Lactose is added to tablet and capsule drug products as an ingredient because of its physical and functional properties.[For similar reasons, it can be used to dilute illicit drugs such as cocaine or heroin.

Oligosaccharides

Carbohydrates formed by the condensation of 2-9 monomers are called oligosaccharides. By this convention, trioses, pentoses, hexoses are all oligosaccharides.

3.8 Complex Carbohydrates (Polysaccharides)

Complex carbohydrates have two or more sugar molecules, hence they are referred to as starchy foods. In complex carbohydrates, molecules are digested and converted slowly compared to simple carbohydrates. They are abundantly found in lentils, beans, peanuts, potatoes, peas, corn, whole-grain bread, cereals, etc. Polysaccharides are complex carbohydrates formed by the polymerization of a large number of monomers. Examples of polysaccharides include starch, glycogen, cellulose, etc. which exhibit extensive branching and are homopolymers – made up of only glucose units.



1. Starch is composed of two components- amylose and amylopectin. Amylose forms the linear chain and amylopectin is a much-branched chain.
2. Glycogen is called animal starch. It has a structure similar to starch, but has more extensive branching.
3. Cellulose is a structural carbohydrate and is the main structural component of the plant cell wall. It is a fibrous polysaccharide with high tensile strength. In contrast to starch and glycogen, cellulose forms a linear polymer.

3.9Dextrin

Dextrin is a generic term applied to a variety of products obtained by heating a starch in the presence of small amounts of moisture and an acid. Dextrins can be made from any starch and are generally classified as white dextrins, yellow (or canary) dextrins, and British gums. Each is more water-soluble and produces less viscous solutions or dispersions than its parent starch. Each is produced by combinations of slight depolymerization (hydrolysis) and transglycosylation (molecular rearrangement). Transglycosylation produces more highly branched structures and forms glycosidic linkages not found in native starches. Most dextrins are used as adhesives for paper products. Only white dextrins and only small amounts of them are used in prepared foods. White dextrins are prepared by heating a dried, acidified starch.

3.10 Starch

Starch or amylum is a polymeric carbohydrate consisting of numerous glucose units joined by glycosidic bonds. This polysaccharide is produced by most green plants for energy storage. Worldwide, it is the most common carbohydrate in human diets, and is contained in large amounts in staple foods such as wheat, potatoes, maize (corn), rice, and cassava (manioc). Pure starch is a white, tasteless and odorless powder that is insoluble in cold water or alcohol. It consists of two types of molecules: the linear and helical amylose and the branched amylopectin.

Depending on the plant, starch generally contains 20 to 25% amylose and 75 to 80% amylopectin by weight. Glycogen, the energy reserve of animals, is a more highly branched version of amylopectin. In industry, starch is often converted into sugars, for example by malting. These sugars may be fermented to produce ethanol in the manufacture of beer, whisky and biofuel. In addition, sugars produced from processed starch are used in many processed foods. Mixing most starches in warm water produces a paste, such as wheatpaste, which can be used as a thickening, stiffening or gluing agent. The principal non-food, industrial use of starch is as an adhesive in the papermaking process. A similar paste, clothing starch, can be applied to certain textile goods before ironing to stiffen them.

Most green plants store energy as starch, which is packed into semicrystalline granules.The extra glucose is changed into starch which is more complex than the glucose produced by plants. Young plants live on this stored energy in their roots, seeds, and fruits until it can find suitable soil in which to grow. An exception is the family Asteraceae (asters, daisies and sunflowers), where starch is replaced by the fructan inulin. Inulin-like fructans are also present in grasses such as wheat, in onions and garlic, bananas, and asparagus. In photosynthesis, plants use light energy to produce glucose from carbon dioxide.

The glucose is used to generate the chemical energy required for general metabolism, to make organic compounds such as nucleic acids, lipids, proteins and structural polysaccharides such as cellulose, or is stored in the form of starch granules, in amyloplasts. Toward the end of the growing season, starch accumulates in twigs of trees near the buds. Fruit, seeds, rhizomes, and tubers store starch to prepare for the next growing season.

Green algae and land-plants store their starch in the plastids, while red algae, glaucophytes, cryptomonads, dinoflagellates and the parasitic apicomplexa store a similar type of polysaccharide called floridean starch in their cytosol or periplast. Glucose is soluble in water, hydrophilic, binds with water and then takes up much space and is osmotically active; glucose in the form of starch, on the other hand, is not soluble, therefore osmotically inactive and can be stored much more compactly. The semicrystalline granules generally consist of concentric layers of amylose and amylopectin which can be made bioavailable upon cellular demand in the plant. Glucose molecules are bound in starch by the easily hydrolyzed alpha bonds. The same type of bond is found in the animal reserve polysaccharide glycogen. This is in contrast to many structural polysaccharides such as chitin, cellulose and peptidoglycan, which are bound by beta bonds and are much more resistant to hydrolysis.

3.11 Glycogen

Glycogen is a form of glucose, a main source of energy that your body stores primarily in your liver and muscles. Your body needs carbohydrates from the food you eat to form glucose and glycogen. Glycogen is the stored form of glucose that’s made up of many connected glucose molecules. Glucose (sugar) is your body’s main source of energy. It comes from carbohydrates (a macronutrient) in certain foods and fluids you consume. When your body doesn’t immediately need glucose from the food you eat for energy, it stores glucose primarily in your muscles and liver as glycogen for later use.

Your body creates glycogen from glucose through a process called glycogenesis. Your body breaks down glycogen for use through a process called glycogenolysis. Several different enzymes are responsible for these two processes. An enzyme is a type of protein in a cell that acts as a catalyst and allows certain bodily processes to happen. There are thousands of enzymes throughout your body that have important functions.

Dextrins are a group of low-molecular-weight carbohydrates produced by the hydrolysis of starchand glycogen. Dextrins are mixtures of polymers of D-glucose units linked by α-(1→4) or α-(1→6) glycosidic bonds. Dextrins can be produced from starch using enzymes like amylases, as during digestion in the human body and during malting and mashing, or by applying dry heat under acidic conditions (pyrolysis or roasting). This procedure was first discovered in 1811 by Edme-Jean Baptiste Bouillon-Lagrange.

The latter process is used industrially, and also occurs on the surface of bread during the baking process, contributing to flavor, color and crispness. Dextrins produced by heat are also known as pyrodextrins. Starch hydrolyses during roasting under acidic conditions, and short-chained starch parts partially rebranch with α-(1, 6) bonds to the degraded starch molecule. See also Maillard reaction. Dextrins are white, yellow, or brown powder that are partially or fully water-soluble, yielding optically active solutions of low viscosity. Most of them can be detected with iodine solution, giving a red coloration; one distinguishes erythrodextrin (dextrin that colours red) and achrodextrin (giving no colour).

Uses

Yellow dextrins are used as water-soluble glues in remoistenable envelope adhesives and paper tubes, in the mining industry as additives in froth flotation, in the foundry industry as green strength additives in sand casting, as printing thickener for batik resist dyeing, and as binders in gouache paint and also in the leather industry.White dextrins are used as:

- a crispness enhancer for food processing, in food batters, coatings, and glazes, (INS number 1400)
- a textile finishing and coating agent to increase weight and stiffness of textile fabrics
- a thickening and binding agent in pharmaceuticals and paper coatings
- a pyrotechnic binder and fuel; this is added to fireworks and sparklers, allowing them to solidify as pellets or "stars"

- a stabilizing agent for certain explosive metal azides, particularly Lead (II) azide

Owing to their rebranching, dextrins are less digestible. Indigestible dextrins have been developed as soluble stand-alone fiber supplements and for adding to processed food products.

Q. 1 How are the carbohydrates classified?

Carbohydrates are classified into the following:

- Simple carbohydrates
- Complex carbohydrates

Q. 2 How are the carbohydrates important to our body?

Carbohydrates provide energy to the body. It breaks down into glucose and enters our bloodstream. The body cells utilize glucose to produce ATP.

Q. 3 Name a few sources of carbohydrates.

Carbohydrates are obtained from a variety of sources such as bread, milk, potatoes, cookies, corn, etc.

Q. 4 How are the carbohydrates digested?

Carbohydrates start being digested in the mouth by the action of salivary amylase. They are not completely broken down in the stomach, but in the intestine.

Q. 5 What are simple carbohydrates? Give examples.

Simple carbohydrates are the ones that are quickly broken down by the body to be converted into energy. Fruits, milk and milk products are the main sources of simple carbohydrates.

Q. 6 How are complex carbohydrates different from simple carbohydrates?

Complex carbohydrates are the ones in which the sugar molecules are strung in long, complex chains. Peas, beans, vegetables and grains are the important sources of carbohydrates.

Q. 7 What are the three types of simple carbohydrates?

Three types of simple carbohydrates include:

- Monosaccharides
- Disaccharides
- Polysaccharides

Q. 8 Name some bad carbohydrates that are harmful to the body.

The bad carbs include:

- White bread
- Sugary drinks
- Pastries
- Candies and chocolates

3.12 Functions of Carbohydrates

The main function of carbohydrates is to provide energy and food to the body and to the nervous system. Carbohydrates are known as one of the basic components of food, including sugars, starch, and fibre which are abundantly found in grains, fruits and milk products. Carbohydrates are also known as starch, simple sugars, complex carbohydrates and so on. It is also involved in fat metabolism and prevents ketosis. Inhibits the breakdown of proteins for energy as they are the primary source of energy. An enzyme by name amylase assists in the breakdown of starch into glucose, finally to produce energy for metabolism.

Sources of Carbohydrates

1. Simple sugars are found in the form of fructose in many fruits.
2. Galactose is present in all dairy products.
3. Lactose is abundantly found in milk and other dairy products.
4. Maltose is present in cereal, beer, potatoes, processed cheese, pasta, etc.
5. Sucrose is naturally obtained from sugar and honey containing small amounts of vitamins and minerals.

These simple sugars that consist of minerals and vitamins exist commonly in milk, fruits, and vegetables. Many refined and other processed foods like white flour, white rice, and sugar, lack important nutrients and hence, they are labelled "*enriched*." It is quite healthy to use vitamins, carbohydrates and all other organic nutrients in their normal forms.

Carbohydrate Foods

Eating too much sugar results in an abnormal increase in calories, which finally leads to obesity and in turn low calories leads to malnutrition. Therefore, a well-balanced diet needs to be maintained to have a healthy life. That is the reason a balanced diet is stressed so much by dietitians. Let us look into the differences between the good and bad carbohydrates.

Good Carbohydrates	Bad Carbohydrates

High in Nutrients	Low in nutrients
Moderate in calories	High in calories
Low in sodium and saturated fats	High in sodium and saturated fats
Low in trans-fat and cholesterol	High in trans-fat and cholesterol
They are complex carbs. For instance: Legumes, vegetables, whole grains, fruits, and beans.	Foods considered bad carbs rarely have any nutritional value. Some of the foods include white flour, rice, pastries, sodas and processed foods.

Examples of Carbohydrates

Following are the important examples of carbohydrates:

- Glucose
- Galactose
- Maltose
- Fructose
- Sucrose
- Lactose
- Starch
- Cellulose
- Chitin

How many carbohydrates do you need?

The Dietary Guidelines for Americans recommend that carbohydrates make up 45% to 65% of total daily calories. So if you get 2,000 calories a day, between 900 and 1,300 calories should be from carbohydrates. That translates to between 225 and 325 grams of carbs a day.

Carbohydrates and your health

Despite their bad reputation, carbohydrates are vital to your health for many reasons.

Providing energy

Carbohydrates are the body's main fuel source. During digestion, sugars and starches are broken down into simple sugars. They're then absorbed into the bloodstream, where they're known as blood sugar (blood glucose). From there, glucose enters the body's cells with the help of insulin. Glucose is used by the body for energy. Glucose fuels your activities - whether it's going for a jog or simply breathing and thinking. Extra glucose is stored in the liver, muscles and other cells for later use. Or extra glucose is converted to fat.

Protecting against disease

Some evidence suggests that whole grains and dietary fiber from whole foods help lower your risk of heart disease and stroke. Fiber may also protect against obesity, colon and rectal cancers, and type 2 diabetes. Fiber is also essential for optimal digestive health.

Controlling weight

Evidence shows that eating plenty of fruit, vegetables and whole grains can help you control your weight. Their bulk and fiber content aids weight control by helping you feel full on fewer calories. Despite what proponents of low-carb diets claim, few studies show that a diet rich in healthy carbs leads to weight gain or obesity.

3.13 Summary

Under this unit we have discussed the different types of carbohydrates such as glucose, fructose and galactose. They are the primary macronutrients that humans consume in large quantities in their daily diet to provide the energy needed in order to support various metabolic processes in the human body. Carbohydrates are found in a wide variety of foods, mostly originating from plant tissues. Depending on the type of dietary carbohydrate and its structure, each one can exhibit varying digestibility properties in the normal digestion system of humans, from rapid digestion to indigestibility. Carbohydrates that demonstrate rapid digestibility, such as glucose and starch, are readily utilized for metabolism; indigestible carbohydrates, such as plant cell wall non-starch polysaccharides, resistant starch, and some oligosaccharides, are fermented in the large intestine after undergoing digestion and absorption in the small intestine.

3.14 Terminal questions

Q.1 Describe different type of carbohydrates with examples.

Answer:---

Q.2 What are the general properties of fatty acids? Explain with examples.

Answer:---

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Q.3 Explain the difference between structure of glucose and fructose.

Answer:---

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Q. 4 Describe polysaccharides with examples.

Answer:---

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Q. 5 Write short notes on the followings.

(i) Sucrose

(ii) Glucose

Answer:---

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Q. 6 Write short notes on the followings.

(i) Starch

(ii) Glycogen

Answer:---

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Further readings

1. Biochemistry- Lehninger A.L.
2. Textbook of Nutrition and Dietetics Ranjana Mahna

3. Biochemistry fourth edition-David Hames and Nigel Hooper.
4. Textbook of Biochemistry for Undergraduates - Rafi, M.D.
5. Textbook of Nutrition and Dietetics- Monika Sharma

Unit 4: Lipids

Structure

4.1. Introduction
Objectives
4.2 Lipids
4.3 Key concepts of Lipids
4.4 Lipid digestion and absorption
4.5 Lipid absorption from the small intestine
4.6 Special adaptations for lipid digestion in infants
4.7 Properties of Lipids
4.8 Fatty Acids/Lipids & Triacylglycerides
4.9 Classification of Lipids
4.10 Phospholipids
4.12 Iodine value
4.13 Saponification
4.14 Summary
4.15 Terminal Questions
Further readings

4.1. Introduction

Lipids are fatty compounds that perform a variety of functions in your body. They’re part of your cell membranes and help control what goes in and out of your cells. They help with moving and storing energy, absorbing vitamins and making hormones. Having too much of some lipids is harmful. A lipid panel can tell you if you have normal levels.Lipids are chemical compounds (elements that make a chemical bond) in your body that help with some of its functions. These are fatty or waxy substances your body makes that don’t dissolve in water. Cholesterol is a lipid in your blood. Your body needs it to help you take in fats and vitamins and make hormones. Cholesterol and triglycerides avoid water, so they can’t travel through blood themselves. This is why they combine with proteins to make lipoproteins that can move throughout your body.Oxygen, carbon and hydrogen bond to each other to form lipids. Lipids like cholesterol are part of your cell membranes. They give your cells structure and allow substances to go in and out of your cells.

Objectives

This is the fourth unit (Lipids) under first block (Introduction to Biochemistry; Carbohydrates and Lipids). Under this unit, we have following objectives. These are as under:

- Introduction to lipids
- To know about fatty acids and properties of lipids
- To know about lipid structure and its classification
- To discuss about digestion and absorption of lipids
- To discuss iodine value, acid value and saponification

4.2 Lipids

Lipids comprise a diverse range of molecules and to some extent is a catchall for relatively water-insoluble or nonpolar compounds of biological origin, including waxes, fatty acids, fattyacidderived phospholipids, sphingolipids, glycolipids,and terpenoids (e.g., retinoids and steroids). Some lipids are linear, open-chain aliphatic molecules, while others have ring structures. Some are aromatic (with a cyclic [ring] and planar [flat] structure) while others are not. Some are flexible, while others are rigid. Lipids are usually made from one molecule of glycerol combined with other molecules. In triglycerides, the main group of bulk lipids, there is one molecule of glycerol and three fatty acids. Fatty acids are considered the monomer in that case, and may be saturated (no double bonds in the carbon chain) or unsaturated (one or more double bonds in the carbon chain).

Most lipids have some polar character in addition to being largely nonpolar. In general, the bulk of their structure is nonpolar or hydrophobic ("water-fearing"), meaning that it does not interact well with polar solvents like water. Another part of their structure is polar or hydrophilic ("water-loving") and will tend to associate with polar solvents like water. This makes them amphiphilic molecules (having both hydrophobic and hydrophilic portions). In the case of cholesterol, the polar group is a mere –OH (hydroxyl or alcohol). In the case of phospholipids, the polar groups are considerably larger and more polar..

Lipids are an integral part of our daily diet. Most oils and milk products that we use for cooking and eating like butter, cheese, ghee etc., are composed of fats. Vegetable oils are rich in various polyunsaturated fatty acids (PUFA). Lipid-containing foods undergo digestion within the body and are broken into fatty acids and glycerol, which are the final degradation products of fats and lipids. Lipids, especially phospholipids, are also used in various pharmaceutical products, either as co-solubilisers (e.g., in parenteral infusions) or else as drug carrier components (e.g., in a liposome or transfersome).

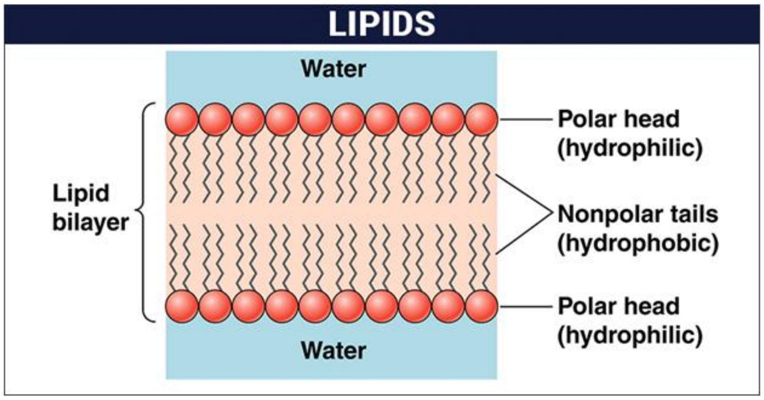


Fig. Structure of lipids

4.3 Key concepts of Lipids

- Lipids are composed mainly of carbon and hydrogen, but they can also contain oxygen, nitrogen, sulfur, and phosphorous. They provide nutrients for organisms, store carbon and energy, play structural roles in membranes, and function as hormones, pharmaceuticals, fragrances, and pigments.
- Fatty acids are long-chain hydrocarbons with a carboxylic acid functional group. Their relatively long nonpolar hydrocarbon chains make them hydrophobic.Fatty acids with no double bonds are saturated; those with double bonds are unsaturated.

- Fatty acids chemically bond to glycerol to form structurally essential lipids such as triglycerides and phospholipids. Triglycerides comprise three fatty acids bonded to glycerol, yielding a hydrophobic molecule. Phospholipids contain both hydrophobic hydrocarbon chains and polar head groups, making them amphipathic and capable of forming uniquely functional large scale structures.

- Biological membranes are large-scale structures based on phospholipid bilayers that provide hydrophilic exterior and interior surfaces suitable for aqueous environments, separated by an intervening hydrophobic layer. These bilayers are the structural basis for cell membranes in most organisms, as well as subcellular components such as vesicles.
- Isoprenoids are lipids derived from isoprene molecules that have many physiological roles and a variety of commercial applications.
- A wax is a long-chain isoprenoid that is typically water resistant; an example of a wax-containing substance is sebum, produced by sebaceous glands in the skin. Steroids are lipids with complex, ringed structures that function as structural components of cell membranes and as hormones. Sterols are a subclass of steroids containing a hydroxyl group at a specific location on one of the molecule's rings; one example is cholesterol.
- Bacteria produce hopanoids, structurally similar to cholesterol, to strengthen bacterial membranes. Fungi and protozoa produce a strengthening agent called ergosterol.

4.4 Lipid digestion and absorption

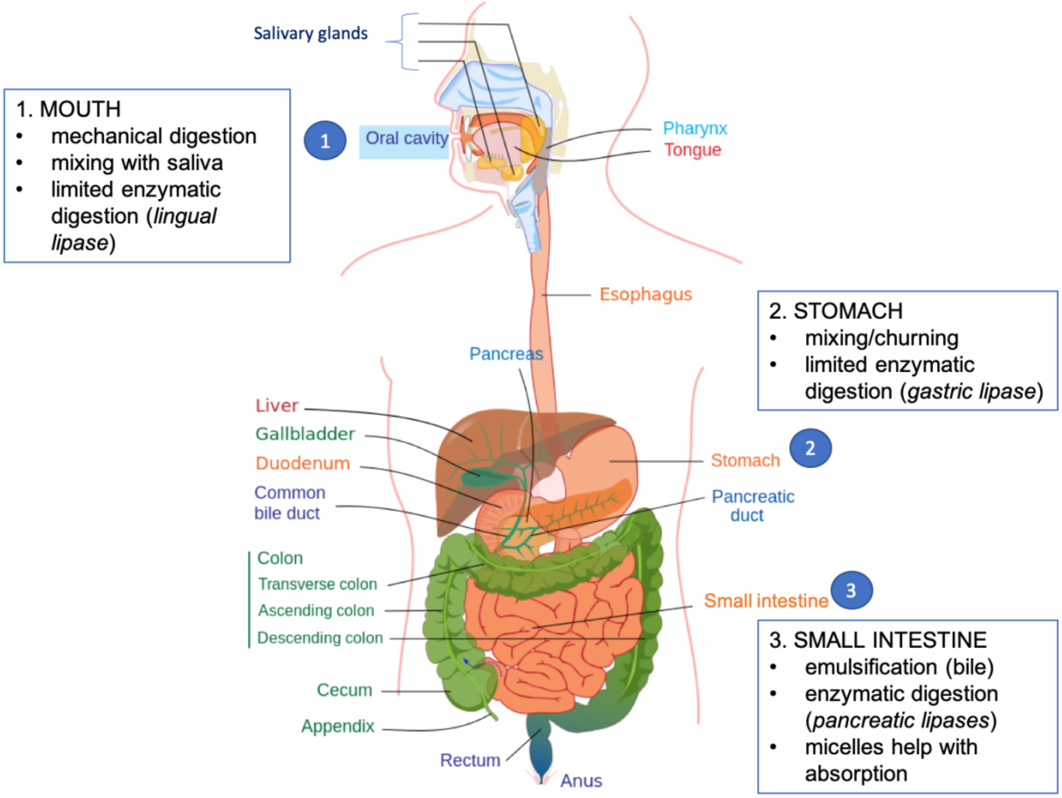
Lipid digestion and absorption pose some special challenges. Triglycerides are large molecules, and unlike carbohydrates and proteins, they're not water-soluble. Because of this, they like to cluster together in large droplets when they're in a watery environment like the digestive tract. The digestive process has to break those large droplets of fat into smaller droplets and then enzymatically digest lipid molecules using enzymes called ***lipases***. The mouth and stomach play a small role in this process, but most enzymatic digestion of lipids happens in the small intestine. From there, the products of lipid digestion are absorbed into circulation and transported around the body, which again requires some special handling since lipids are not water-soluble and do not mix with the watery blood. Let's start at the beginning to learn more about the path of lipids through the digestive tract.

Lipid digestion in the mouth

A few things happen in the mouth that starts the process of lipid digestion. Chewing mechanically breaks food into smaller particles and mixes them with saliva. An enzyme called ***lingual lipase*** is produced by cells on the tongue ("lingual" means relating to the tongue) and begins some enzymatic digestion of triglycerides, cleaving individual fatty acids from the glycerol backbone.

Lipid digestion in the stomach

In the stomach, mixing and churning helps to disperse food particles and fat molecules. Cells in the stomach produce another lipase, called ***gastric lipase*** ("gastric" means relating to the stomach) that also contributes to enzymatic digestion of triglycerides. Lingual lipase swallowed with food and saliva also remains active in the stomach. But together, these two lipases play only a minor role in fat digestion (except in the case of infants, as explained below), and most enzymatic digestion happens in the small intestine.



1. MOUTH
- mechanical digestion
- mixing with saliva
- limited enzymatic digestion (*lingual lipase*)

2. STOMACH
- mixing/churning
- limited enzymatic digestion (*gastric lipase*)

3. SMALL INTESTINE
- emulsification (bile)
- enzymatic digestion (*pancreatic lipases*)
- micelles help with absorption

Fig. Overview of lipid digestion in the human gastrointestinal tract

Lipid digestion in the small intestine

As the stomach contents enter the small intestine, most of the dietary lipids are undigested and clustered in large droplets. Bile**,** which is made in the liver and stored in the gallbladder, is released into the duodenum, the first section of the small intestine. Bile salts have both a hydrophobic and a hydrophilic side, so they are attracted to both fats and water. This makes them effective emulsifiers, meaning that they break large fat globules into smaller droplets. Emulsification makes lipids more accessible to digestive enzymes by increasing the surface area for them to act. The pancreas secretes ***pancreatic lipases*** into the small intestine to enzymatically digest triglycerides. Triglycerides are broken down to fatty acids, monoglycerides (glycerol backbone with one fatty acid still attached), and some free glycerol. Cholesterol and fat-soluble vitamins do not need to be enzymatically digested .

4.5 Lipid absorption from the small intestine

Next, those products of fat digestion (fatty acids, monoglycerides, glycerol, cholesterol, and fat-soluble vitamins) need to enter into the circulation so that they can be used by cells around the body. Again, bile helps with this process. Bile salts cluster around the products of fat digestion to form structures called *micelles*, which help the fats get close enough to the microvilli of intestinal cells so that they can be absorbed. The products of fat digestion diffuse across the membrane of the intestinal cells, and bile salts are recycled back to do more work emulsifying fat and forming micelles.

Once inside the intestinal cell, short- and medium-chain fatty acids and glycerol can be directly absorbed into the bloodstream, but larger lipids such as long-chain fatty acids, monoglycerides, fat-soluble vitamins, and cholesterol need help with absorption and transport to the bloodstream. Long-chain fatty acids and monoglycerides reassemble into triglycerides within the intestinal cell, and along with cholesterol and fat-soluble vitamins, are then incorporated into transport vehicles called chylomicrons. Chylomicrons are large structures with a core of triglycerides and cholesterol and an outer membrane made up of phospholipids, interspersed with proteins (called apolipoproteins) and cholesterol. This outer membrane makes them water-soluble so that they can travel in the aqueous environment of the body. Chylomicrons from the small intestine travel first into lymph vessels, which then deliver them to the bloodstream.

4.6 Special adaptations for lipid digestion in infants

Lipids are an important part of an infant’s diet. Breast milk contains about 4 percent fat, similar to whole cow’s milk. Whether breastfed or formula-fed, fat provides about half of an infant’s calories, and it serves an important role in brain development. Yet, infants are born with low levels of bile and pancreatic enzyme secretion, which are essential contributors to lipid digestion in older children and adults. So, how do babies digest all of the fat in their diet? Infants have a few special adaptations that allow them to digest fat effectively.

First, they have plenty of lingual and gastric lipases right from birth. These enzymes play a much more important role in infants than they do in adults. Second, breast milk actually contains lipase enzymes that are activated in the baby’s small intestine. In other words, the mother makes lipases and sends them in breast milk to help her baby digest the milk fats. Amazing, right? Between increased activity of lingual and gastric lipases and the lipases contained in breast milk, young infants can efficiently digest fat and reap its nutritional value for growth and brain development. Studies show that fat digestion is more efficient in premature infants fed breast milk compared with those fed formula. Even pasteurized breast milk, as is used when breast milk is donated for feeding babies in the hospital, is a little harder to digest, because heat denatures the lipases. (Infants can still digest pasteurized breast milk and formula; they’re just less efficient at doing so and absorb less of the products of triglyceride digestion).

These organic compounds are nonpolar molecules, which are soluble only in nonpolar solvents and insoluble in water because water is a polar molecule. In the human body, these molecules can be synthesized in the liver and are found in oil, butter, whole milk, cheese, fried foods and also in some red meats. Let us have a detailed look at the lipid structure, properties, types and classification of lipids.

4.7 Properties of Lipids

Lipids are a family of organic compounds, composed of fats and oils. These molecules yield high energy and are responsible for different functions within the human body. Listed below are some important characteristics of Lipids.

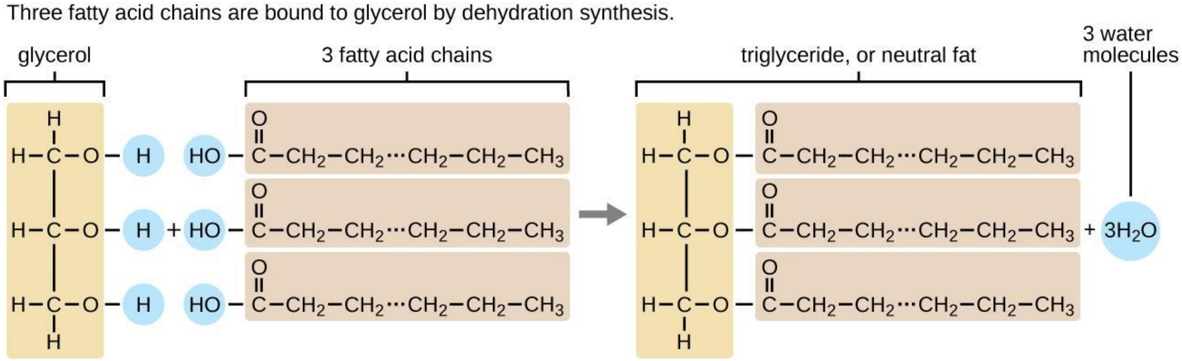
1. Lipids are oily or greasy nonpolar molecules, stored in the adipose tissue of the body.

2. Lipids are a heterogeneous group of compounds, mainly composed of hydrocarbon chains.
3. Lipids are energy-rich organic molecules, which provide energy for different life processes.
4. Lipids are a class of compounds characterised by their solubility in nonpolar solvents and insolubility in water.
5. Lipids are significant in biological systems as they form a mechanical barrier dividing a cell from the external environment known as the cell membrane.

4.8 Fatty Acids/Lipids & Triacylglycerides

The fatty acids are lipids that contain long-chain hydrocarbons terminated with a carboxylic acid functional group. Because of the long hydrocarbon chain, fatty acids are hydrophobic (“water fearing”) or nonpolar. Fatty acids with hydrocarbon chains that contain only single bonds are called saturated fatty acids because they have the greatest number of hydrogen atoms possible and are, therefore, “saturated” with hydrogen. Fatty acids with hydrocarbon chains containing at least one double bond are called unsaturated fatty acids because they have fewer hydrogen atoms. Saturated fatty acids have a straight, flexible carbon backbone, whereas unsaturated fatty acids have “kinks” in theircarbon skeletonbecause each double bond causes a rigid bend of the carbon skeleton. These differences in saturated versus unsaturated fatty acid structure result in different properties for the corresponding lipids in which the fatty acids are incorporated. For example, lipids containing saturated fatty acids are solids at room temperature, whereas lipids containing unsaturated fatty acids are liquids.

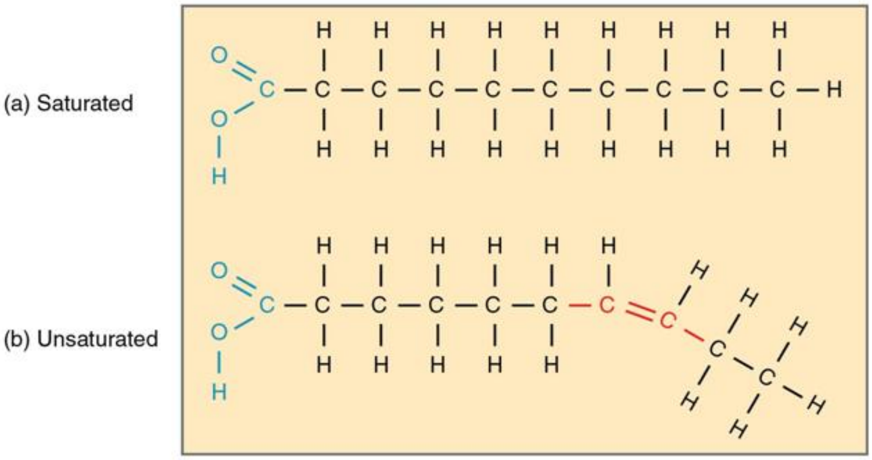
A triacylglycerol, or triglyceride, is formed when three fatty acids are chemically linked to a glycerol molecule (as in given figure). Triglycerides are the primary components of adipose tissue (body fat), and are major constituents of sebum (skin oils). They play an important metabolic role, serving as efficient energy-storage molecules that can provide more than double the caloric content of both carbohydrates and proteins.



FigTriglycerides are composed of a glycerol molecule attached to three fatty acids by a dehydration synthesis reaction.

Lipid Structure

Lipids are the polymers of fatty acids that contain a long, non-polar hydrocarbon chain with a small polar region containing oxygen. The lipid structure is explained in the diagram below:



Lipid Structure – Saturated and Unsaturated Fatty Acids

4.9 Classification of Lipids

Lipids can be classified into two main classes:

1. Nonsaponifiable lipids
2. Saponifiable lipids

Nonsaponifiable Lipids

A nonsaponifiable lipid cannot be disintegrated into smaller molecules through hydrolysis. Nonsaponifiable lipids include cholesterol, prostaglandins, etc

Saponifiable Lipids

A saponifiable lipid comprises one or more ester groups, enabling it to undergo hydrolysis in the presence of a base, acid, or enzymes**,** including waxes, triglycerides, sphingolipids and phospholipids. Further, these categories can be divided into non-polar and polar lipids. Nonpolar lipids, namely triglycerides, are utilized as fuel and to store energy. Polar lipids, that could form a barrier with an external water environment, are utilized in membranes. Polar lipids comprise sphingolipids and glycerophospholipids. Fatty acids are pivotal components of all these lipids.

Types of Lipids

Within these two major classes of lipids, there are numerous specific types of lipids, which are important to life, including fatty acids, triglycerides, glycerophospholipids, sphingolipids and steroids. These are broadly classified as simple lipids and complex lipids.

Simple Lipids

Esters of fatty acids with various alcohols.

1. **Fats:** Esters of fatty acids with glycerol. Oils are fats in the liquid state

2. **Waxes**: Esters of fatty acids with higher molecular weight monohydric alcohols

Complex Lipids

Esters of fatty acids containing groups in addition to alcohol and fatty acid.

1. **Phospholipids**: These are lipids containing, in addition to fatty acids and alcohol, phosphate group. They frequently have nitrogen-containing bases and other substituents, eg, in glycerophospholipids the alcohol is glycerol and in sphingophospholipids the alcohol is sphingosine.

2. **Glycolipids (glycosphingolipids)**: Lipids containing a fatty acid, sphingosine and carbohydrate.

3. **Other complex lipids**: Lipids such as sulfolipids and amino lipids. Lipoproteins may also be placed in this category.

Precursor and Derived Lipids

These include fatty acids, glycerol, steroids, other alcohols, fatty aldehydes, and ketone bodies, hydrocarbons, lipid-soluble vitamins, and hormones. Because they are uncharged, acylglycerols (glycerides), cholesterol, and cholesteryl esters are termed neutral lipids. These compounds are produced by the hydrolysis of simple and complex lipids. Some of the different types of lipids are described below in detail.

Fatty Acids

Fatty acids are carboxylic acids (or organic acid), usually with long aliphatic tails (long chains), either unsaturated or saturated.

Saturated fatty acids

Lack of carbon-carbon double bonds indicate that the fatty acid is saturated. The saturated fatty acids have higher melting points compared to unsaturated acids of the corresponding size due to their ability to pack their molecules together thus leading to a straight rod-like shape.

Unsaturated fatty acids

Unsaturated fatty acid is indicated when a fatty acid has more than one double bond. “Often, naturally occurring fatty acids possesses an even number of carbon atoms and are unbranched.” On the other hand, unsaturated fatty acids contain a cis-double bond(s) which create a structural kink that disables them to group their molecules in straight rod-like shape.

Role of Fats

Fats play several major roles in our body. Some of the important roles of fats are mentioned below:

- Fats in the correct amounts are necessary for the proper functioning of our body.
- Many fat-soluble vitamins need to be associated with fats in order to be effectively absorbed by the body.
- They also provide insulation to the body.
- They are an efficient way to store energy for longer periods.

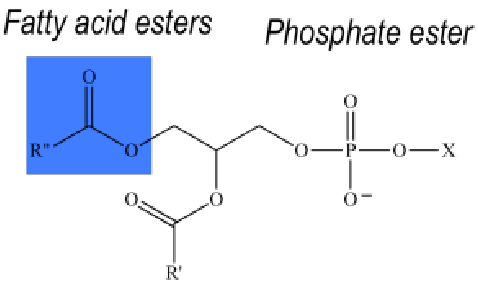
Examples of Lipids

There are different types of lipids. Some examples of lipids include butter, ghee, vegetable oil, cheese, cholesterol and other steroids, waxes, phospholipids, and fat-soluble vitamins. All these compounds have similar features, i.e. insoluble in water and soluble in organic solvents, etc.

Waxes

Waxes are “esters” (an organic compound made by replacing the hydrogen with acid by an alkyl or another organic group) formed from long-alcohols and long-chain carboxylic acids. Waxes are found almost everywhere. The fruits and leaves of many plants possess waxy coatings, that can safeguard them from small predators and dehydration. Fur of a few animals and the feathers of birds possess the same coatings serving as water repellants. Carnauba wax is known for its water resistance and toughness (significant for car wax).

4.10 Phospholipids



Membranes are primarily composed of phospholipids that are Phosphoacylglycerols. Triacylglycerols and phosphoacylglycerols are the same, but, the terminal OH group of the phosphoacylglycerol is esterified with phosphoric acid in place of fatty acid which results in the formation of phosphatidic acid. The name phospholipid is derived from the fact that phosphoacylglycerols are lipids containing a phosphate group.

Steroids

Our bodies possess chemical messengers known as hormones**,** which are basically organic compounds synthesized in glands and transported by the bloodstream to various tissues in order to trigger or hinder the desired process. Steroids are a kind of hormone that is typically recognized by their tetracyclic skeleton, composed of three fused six-membered and one five-membered ring, as seen above. The four rings are assigned as A, B, C & D as observed in the shade blue, while the numbers in red indicate the carbons.

Cholesterol

- Cholesterol is a wax-like substance, found only in animal source foods. Triglycerides, LDL, HDL, VLDL are different types of cholesterol found in the blood cells.

- Cholesterol is an important lipid found in the cell membrane. It is a sterol, which means that cholesterol is a combination of steroid and alcohol. In the human body, cholesterol is synthesized in the liver.
- These compounds are biosynthesized by all living cells and are essential for the structural component of the cell membrane.
- In the cell membrane, the steroid ring structure of cholesterol provides a rigid hydrophobic structure that helps boost the rigidity of the cell membrane. Without cholesterol, the cell membrane would be too fluid.
- It is an important component of cell membranes and is also the basis for the synthesis of other steroids, including the sex hormones estradiol and testosterone, as well as other steroids such as cortisone and vitamin D.

Frequently Asked Questions

Q. 1 What are lipids?

Lipids are organic compounds that are fatty acids or derivatives of fatty acids, which are insoluble in water but soluble in organic solvents. For eg., natural oil, steroid, waxes.

Q. 2 How are lipids important to our body?

Lipids play a very important role in our body. They are the structural component of the cell membrane. They help in providing energy and produce hormones in our body. They help in the proper digestion and absorption of food. They are a healthy part of our diet if taken in proper amounts. They also play an important role in signalling.

Q. 3 How are lipids digested?

The enzyme lipase breaks down fats into fatty acids and glycerol, which is facilitated by bile in the liver.

Q. 4 What is lipid emulsion?

It refers to an emulsion of lipid for human intravenous use. These are also referred to as intralipids which is the emulsion of soybean oil, glycerin and egg phospholipids. It is available in 10%, 20% and 30% concentrations.

Q. 5 How are lipids metabolized?

Lipid metabolism involves the oxidation of fatty acids to generate energy to synthesize new lipids from smaller molecules. The metabolism of lipids is associated with carbohydrate metabolism as the products of glucose are converted into lipids.

Q. 6 How are lipids released in the blood?

The medium-chain triglycerides with 8-12 carbons are digested and absorbed in the small intestine. Since lipids are insoluble in water, they are carried to the bloodstream by lipoproteins which are water-soluble and can carry the lipids internally.

Q. 7 What are the main types of lipids?

There are two major types of lipids- simple lipids and complex lipids. Simple lipids are esters of fatty acids with various alcohols. For eg., fats and waxes. On the contrary, complex lipids are esters of fatty acids with groups other than alcohol and fatty acids. For eg., phospholipids and sphingolipids.

Q. 8 What are lipids made up of?

Lipids are made up of a glycerol molecule attached to three fatty acid molecules. Such a lipid is called triglyceride.

4.11 Acid value

In chemistry, acid value (AV, acid number, neutralization number or acidity) is a number used to quantify the acidity of a given chemical substance. It is the quantity of base (usually potassium hydroxide (KOH)), expressed as milligrams of KOH required to neutralize the acidic constituents in 1 gram of a sample. The acid number is a measure of the number of carboxylic acid groups (−C(=O)OH) in a chemical compound, such as a fatty acid, or in a mixture of compounds. In other words, it is a measure of free fatty acids (FFAs) present in a substance. In a typical procedure, a known amount of sample dissolved in an organic solvent (often isopropanol) and titrated with a solution of alcoholic potassium hydroxide (KOH) of known concentration using phenolphthalein as a colour indicator. The acid number for an oil sample is indicative of the age of the oil and can be used to determine when the oil must be changed.

A liquid fat sample combined with neutralized 95% ethanol is titrated with standardized sodium hydroxide of 0.1 eq/L normality to a phenolphthalein endpoint. The volume and normality of the sodium hydroxide are used, along with the weight of the sample, to calculate the free fatty acid value. Acid value is usually measured as milligrams of KOH per gram of sample (mg KOH/g fat/oil), or grams of KOH per gram of sample (g KOH/g fat/oil).

Definition of Acid Value

The amount of free fatty acids that are present in a substance typically a fat or oil is measured by its acid value and called as acid value in fats and oils. It is expressed as the amount of potassium hydroxide (KOH) required to neutralize the free fatty acids present in one gram of the substance.

- Oils and fats used in a variety of industries, including food, cosmetics, and pharmaceuticals, are evaluated for their quality and purity using a measure known as the acid value.
- Considering that the presence of free fatty acids is an indication of oxidation, it can also be used to determine the level of rancidity in oils and fats.
- Since free fatty acids are often produced during the breakdown of triglycerides, it is a relative indicator of rancidity. Additionally, the value is given as a percentage of the free fatty acids oleic, lauric, ricinoleic, and palmitic acids.

Principle

- The amount of carboxylic acid groups in an organic compound, like a fatty acid, can be measured by the acid number. A common method involves titrating a known quantity of sample that has been dissolved in an organic solvent with a potassium hydroxide solution that has a known concentration and uses phenolphthalein as a color indicator.
- By dissolving a known amount of fat or oil in pure alcohol and titrating the result against a standard KOH solution while using phenolphthalein as an indicator, it can be calculated.
- The number of free acids contained in a specific fat or oil can be determined by the acid value.
- A high acid value implies that the given sample of oil is an old one which has gone rancid.

Procedure for determining Acid value in Fats and Oils

Apparatus required

- Balance machine
- Burette with stand
- Measuring cylinder

- Conical flask
- Hot plate

Procedure

1. Chemical preparation

- **Phenolphthalein indicator solution:** Dissolve 2 gram of phenolphthalein in 100mL of ethyl alcohol and mix well by shaking.
- **0.1N Sodium hydroxide solution preparation:** Dissolve 4g sodium hydroxide pellets into 900ml of distilled water, cool and makes a final volume of 1000ml. standardize the solution before use.

2. Sample preparation

- Take 10g of oil sample in a conical flask and note the sample weight.
- Measure 50ml ethanol (99%) and pour into another conical flask(150ml).
- Add 2-3 drops of phenolphthalein indicator solution and shake and neutralize by adding 0.1N NaOH until the light pink colour solution is formed.
- Now, the neutralized ethanol is added to the flask containing sample and shake the flask to mix the solution.
- Boil the mixture by placing the flask on hot plate until the sample dissolve in ethanol completely.
- Continue the boiling until the sample is dissolved completely.
- Shaking with hands should be continued periodically.

3. Titration

- Take0.1N NaOH (standardized) in a burette.
- Note the initial burette reading.
- Start titration by adding few drops of phenolphthalein indicator.
- Titration should be carried out with vigorous agitation of the flask to get accurate result.
- Stop the titration when the solution colour is changed into a white pink.
- Note the final burette reading.

4.12 Iodine value

Iodine value, also called iodine number, in analytical chemistry, measure of the degree of unsaturation of an oil, fat, or wax; the amount of iodine, in grams, that is taken up by 100 grams of the oil, fat, or wax. Saturated oils, fats, and waxes take up no iodine, and therefore their iodine value is zero, but unsaturated oils, fats, and waxes take up iodine. (Unsaturated compounds contain molecules with double or triple bonds, which are very reactive toward iodine.) The more iodine is attached, the higher is the iodine value, and the more reactive, less stable, softer, and more susceptible to oxidation and rancidification is the oil, fat, or wax. In performing the test, a known excess of iodine, often in the form of iodine monochloride, is allowed to react with a known weight of the oil, fat, or wax, and then the amount of iodine remaining unreacted is determined by titration.

Drying oils, such as linseed oil, used in the paint and varnish industry have relatively high iodine values (about 190). Semidrying oils, such as soybean oil, have intermediate iodine values (about 130). Nondrying oils, such as olive oil, used for soap making and in food products, have relatively low iodine values (about 80).

4.13 Saponification

Saponification is a chemical reaction in which aqueous alkali converts fat, oil, or lipid into soap and alcohol (e.g. NaOH). Soaps are carboxylic acids with long carbon chains, which are salts of fatty acids. Sodium oleate is a standard soap. Saponified materials include vegetable oils and animal fats. These oily compounds, known as triglycerides, are made up of a variety of fatty acids. Triglycerides can be made into soap in one or two steps. The triglyceride is processed with a strong base (e.g. lye) in the classic one-step procedure, which cleaves the ester link, producing fatty acid salts (soaps) and glycerol.

Saponification Value or Saponification Number

The number of milligrams of potassium hydroxide (KOH) or sodium hydroxide (NaOH) necessary to saponify one gramme of fat under the stated conditions is referred to as the saponification value or saponification number (**SV** or **SN**). It is a measurement of the average molecular weight (or chain length) of all fatty acids present as triglycerides in the sample. The smaller the average length of fatty acids, the lower the mean molecular weight of triglycerides, and vice versa, the higher the saponification value. In practise, fats or oils having a high saponification value (such as coconut and palm oil) are better for manufacturing soap.

Determining Saponification Value (Formula)

To quantify SV, the sample is saponified entirely with an excess of alkali, and the excess is measured by titration (in mg KOH/g). The molecular weight and percentage concentration of fatty acid components present in FAMEs of oil determine the saponification number. The SV is a useful tool for calculating the average relative molecular mass of oils and fats. Glycerides, such as triglycerides, diglycerides, and monoglycerides, but also free fatty acids and other ester-like components such as lactones, consume alkali. The remaining alkali is titrated against a standard solution of hydrochloric acid at the end of the reaction (HCl). As a result, the SV (milligrams of potassium hydroxide per gram of sample) is calculated as follows:

$$\mathrm{SV} = \frac{(\mathrm{B} - \mathrm{S}) \times \mathrm{M} \times 56.1}{\mathrm{W}}$$

where,

(B – S) is indicated as the difference between the volume (in mL) of HCl solution used for the blank run and for the tested sample;

M is defined as the molarity of HCl solution, in $\mathrm{mol \cdot L^{-1}}$;

56.1 is indicated as the molecular weight of KOH, in $\mathrm{g \cdot mol^{-1}}$; and

W is indicated as the weight of sample, in g.

The SV can also be estimated using gas chromatography data on fatty acid composition.

Relationship with Fats and Oils' Average Molecular Weight

A pure triglyceride molecule's theoretical SV can be computed using the following equation (where MW is its molecular weight):

Molecular Weight (oil/fat) = (3 * 1000 * {56.1}/SV) + 38.049

Where, 3 is the fatty acids residues per triglyceride, 1000 is a conversion factor (mg/g) and 56.1 is the molecular weight of KOH.

Three oleic acid residues are esterified to a molecule of glycerol with a total MW of 885.4 ($\mathrm{g \cdot mol^{-1}}$) in triolein, a triglyceride found in many fats and oils. As a result, its SV is 190 ($\mathrm{mg\ KOH \cdot g^{-1}}$). Trilaurin has a MW of 639 and an SV of 263, while lauric acid contains three shorter fatty acid residues. The SV of a fat is inversely proportional to its molecular weight, as shown by the formula above. Because fats and oils contain a variety of triglyceride species, the average MW can be computed using the following formula:

$$\mathrm{MW_{oil/fat}} = 3 \times 56,106 \div \mathrm{SV}$$

This means that coconut oil, which is high in medium-chain fatty acids (mostly lauric), contains more fatty acids per unit of weight than olive oil, for example (mainly oleic). As a result, there were more ester saponifiable functions per gramme of coconut oil, implying that more KOH is needed to saponify the same amount of matter, resulting in a higher SV. Fats and oils with substantial levels of unsaponifiable material, free fatty acids (> 0.1%), or mono- and diacylglycerols (> 0.1%) are not eligible for the computed molecular weight.

Important Questions on Saponification Value Formula Derivation

Q. 1 What do you mean by unsaponifiables?

Unsaponifiables are fatty substance components (oil, fat, wax) that do not produce soap when exposed to alkali and remain insoluble in water but soluble in organic solvents. Nonvolatile components such as alkanes, sterols, triterpenes, fatty alcohols, tocopherols, and carotenoids, as well as those that primarily emerge from the saponification of fatty esters, are classified as unsaponifiables (sterols esters, wax esters, etc.).

Q. 2 What is the saponification equation?

General saponification equation is fat + chemical salt + water → glycerol + fatty acid salt (soap). Fat and chemical salts are the reactants, while glycerol and soap are the products.

Q. 3 Why do we determine saponification value?

The saponification number is the amount of potassium hydroxide required to saponify one gram of fat. This data can be used to compute the number of acids (esters and free acids) in a fat or oil. The more saponification, the more short- and medium-chain fatty acids are present in the fat.

Q. 4 What are the factors that affect saponification?

The effect of three parameters, such as ethanolic KOH content, reaction temperature, and reaction time, which were explored for the optimum saponification, were evaluated using a D-optimal design.

Q. 5 Does the saponification value of soap impact its quality?

The saponification value is sometimes used to check for adulteration. The higher the saponification number, the more capable the oil is in making soap. Higher triglyceride saponification values suggest more medium chain fatty acids.

4.14 Summary

Under this unit we have discussed the types of lipids, properties, digestion and absorption. They are a large and wide group of molecules that are present in all living organism and also in foods and characterized by particular physicochemical properties, such as their non polarity and their solubility in organic solvents. Some lipids, in particular fatty acids and sterols, are essential for animal and plant life. Another important aspect related to lipids is their important involvement, either in the treatment and/or the origin of many diseases which can affect humans. Structural and functional characteristics of lipids, discussed in this chapter, will allow you to integrate those metabolic aspects of these important and essential molecules in close relationship of how foods containing these molecules can have a relevant influence in the health or illness of an individual.

4.15 Terminal questions

Q.1 Describe different type of lipids with examples.

Answer:---

Q.2 What are the general properties of lipids? Explain with examples.

Answer:---

Q.3 Explain the composition of lipids.

Answer:---

Q. 4 Describe the digestion and absorption of lipids.

Answer:---

Q. 5 Write short notes on the followings.

(i) Fatty acids

(ii) Iodine value

Answer:---

Q. 6 Write short notes on the followings.

(i) Saponification value

(ii) Acid value

Answer:---

Further readings

6. Biochemistry- Lehninger A.L.
7. Textbook of Nutrition and Dietetics Ranjana Mahna
8. Biochemistry fourth edition-David Hames and Nigel Hooper.
9. Textbook of Biochemistry for Undergraduates - Rafi, M.D.
10. Textbook of Nutrition and Dietetics- Monika Sharma

Unit 5: Proteins

Structure

Objectives

5.1. Introduction

5.2 General structure and properties of proteins

5.3 Protein synthesis

5.4 Structures of common amino acids

5.5 Levels of structural organization in proteins

5.5.1 Primary structure

5.5.2 Secondary structure

5.5.3 Tertiary structure

5.5.4 Quaternary structure

5.1. Introduction

Proteins are large, complex molecules that play many critical roles in the body. They do most of the work in cells and are required for the structure, function, and regulation of the body’s tissues and organs. Proteins are made up of hundreds or thousands of smaller units called amino acids, which are attached to one another in long chains. There are 20 different types of amino acids that can be combined to make a protein. The sequence of amino acids determines each protein’s unique 3-dimensional structure and its specific function. Amino acids are coded by combinations of three DNA building blocks (nucleotides), determined by the sequence of genes.

Protein**,** highly complex substance that is present in all living organisms. Proteins are of great nutritional value and are directly involved in the chemical processes essential for life. The importance of proteins was recognized by chemists in the early 19th century, including Swedish chemist Jöns Jacob Berzelius, who in 1838 coined the term *protein,* a word derived from the Greek *prōteios*, meaning “holding first place.” Proteins are species-specific; that is, the proteins of one species differ from those of another species.

Objectives

This is the fifth unit (proteins) under second block (Introduction to proteins and enzymes). Under this unit, we have following objectives. These are as under:

- To know about proteins and its structure
- To discuss different types of proteins.
- To know about protein synthesis and protein denaturation

- To discuss immunoglobulin and antibodies

They are also organ-specific; for instance, within a single organism, muscle proteins differ from those of the brain and liver. A protein molecule is very large compared with molecules of sugar or salt and consists of many amino acids joined together to form long chains, much as beads are arranged on a string. There are about 20 different amino acids that occur naturally in proteins. Proteins of similar function have similar amino acid composition and sequence. Although it is not yet possible to explain all of the functions of a protein from its amino acid sequence, established correlations between structure and function can be attributed to the properties of the amino acids that compose proteins.

Plants can synthesize all of the amino acids; animals cannot, even though all of them are essential for life. Plants can grow in a medium containing inorganic nutrients that provide nitrogen, potassium, and other substances essential for growth. They utilize the carbon dioxide in the air during the process of photosynthesis to form organic compounds such as carbohydrates. Animals, however, must obtain organic nutrients from outside sources. Because the protein content of most plants is low, very large amounts of plant material are required by animals, such as ruminants (e.g., cows), that eat only plant material to meet their amino acid requirements. Nonruminant animals, including humans, obtain proteins principally from animals and their products—e.g., meat, milk, and eggs. The seeds of legumes are increasingly being used to prepare inexpensive protein-rich food.

The protein content of animal organs is usually much higher than that of the blood plasma. Muscles, for example, contain about 30 percent protein, the liver 20 to 30 percent, and red blood cells 30 percent. Higher percentages of protein are found in hair, bones, and other organs and tissues with a low water content. The quantity of free amino acids and peptides in animals is much smaller than the amount of protein; protein molecules are produced in cells by the stepwise alignment of amino acids and are released into the body fluids only after synthesis is complete.

The high protein content of some organs does not mean that the importance of proteins is related to their amount in an organism or tissue; on the contrary, some of the most important proteins, such as enzymes and hormones, occur in extremely small amounts. The importance of proteins is related principally to their function. All enzymes identified thus far are proteins. Enzymes, which are the catalysts of all metabolic reactions, enable an organism to build up the chemical substances necessary for life-proteins, nucleic acids, carbohydrates, and lipids—to convert them into other substances, and to degrade them. Life without enzymes is not possible. There are several protein hormones with important regulatory functions. In all vertebrates, the respiratory protein hemoglobin acts as oxygen carrier in the blood, transporting oxygen from the lung to body organs and tissues. A large group of structural proteins maintains and protects the structure of the animal body.

5.2 General structure and properties of proteins

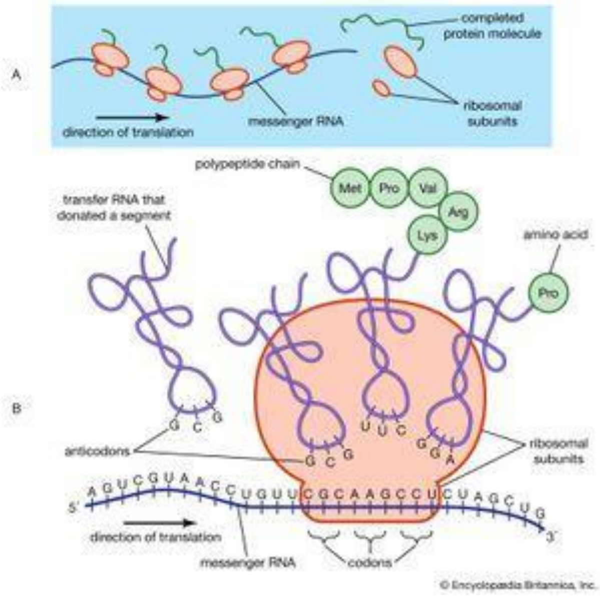


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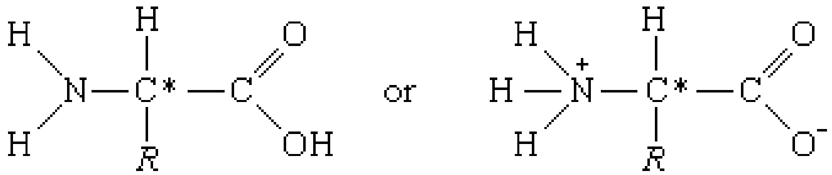
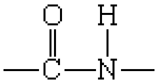
Fig. The amino acid composition of proteins

5.3 Protein synthesis

The common property of all proteins is that they consist of long chains of α-amino (alpha amino) acids. The general structure of α-amino acids is shown in. The α-amino acids are so called because the α-carbon atom in the molecule carries an amino group (—NH_2); the α-carbon atom also carries a carboxyl group (—COOH).

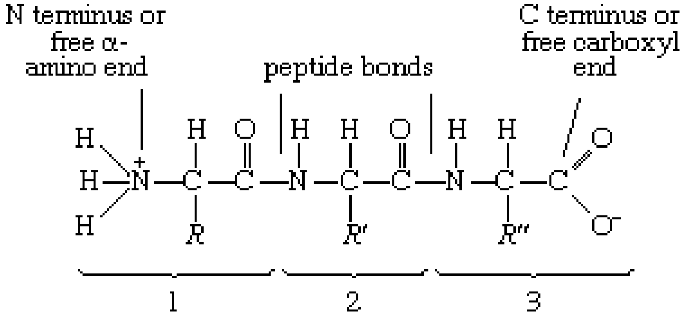


In acidic solutions, when the pH is less than 4, the -COO groups combine with hydrogen ions (H^+) and are thus converted into the uncharged form (-COOH). In alkaline solutions, at pH above 9, the ammonium groups (—$NH^{+}{}_{3}$) lose a hydrogen ion and are converted into amino groups (—NH_2). In the pH range between 4 and 8, amino acids carry both a positive and a negative charge and therefore do not migrate in an electrical field. Such structures have been designated as dipolar ions, or zwitterions (i.e., hybrid ions). Although more than 100 amino acids occur in nature, particularly in plants, only 20 types are commonly found in most proteins. In protein molecules the α-amino acids are linked to each other by peptide bonds between the amino group of one amino acid and the carboxyl group of its neighbour.



$$-\overset{\overset{O}{\|}}{C}-\overset{\overset{H}{|}}{N}-$$

The condensation (joining) of three amino acids yields the tripeptide.



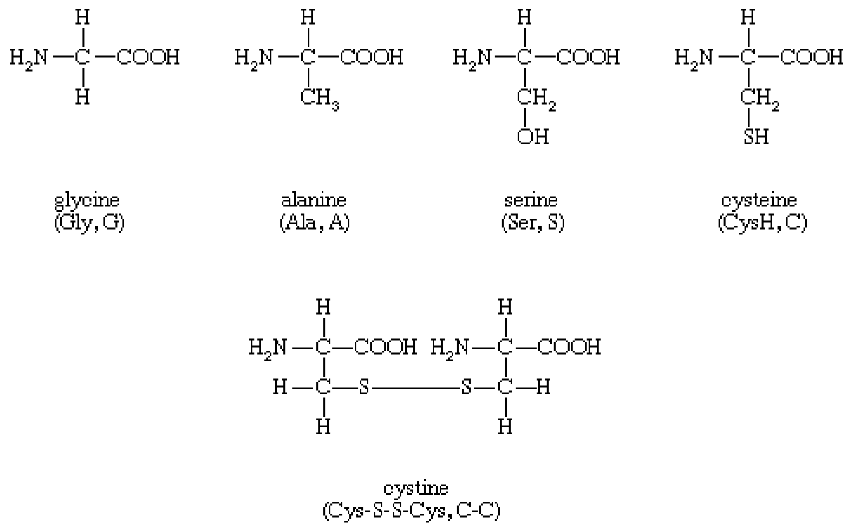
three amino acids joined by peptide bonds

It is customary to write the structure of peptides in such a way that the free α-amino group (also called the N terminus of the peptide) is at the left side and the free carboxyl group (the C terminus) at the right side. Proteins are macromolecular polypeptides—i.e., very large molecules (macromolecules) composed of many peptide-bonded amino acids. Most of the common ones contain more than 100 amino acids linked to each other in a long peptide chain. The average molecular weight (based on the weight of a hydrogen atom as 1) of each amino acid is approximately 100 to 125; thus, the molecular weights of proteins are usually in the range of 10,000 to 100,000 daltons (one dalton is the weight of one hydrogen atom). The species-specificity and organ-specificity of proteins result from differences in the number and sequences of amino acids. Twenty different amino acids in a chain 100 amino acids long can be arranged in far more than 10^{100} ways (10^{100} is the number one followed by 100 zeroes).

5.4 Structures of common amino acids

The amino acids present in proteins differ from each other in the structure of their side (*R*) chains. The simplest amino acid is glycine, in which *R* is a hydrogen atom. In a number of amino acids, *R* represents straight or branched carbon chains. One of these amino acids is alanine, in which *R* is the methyl group ($-CH_3$). Valine, leucine, and isoleucine, with longer *R* groups, complete the alkyl side-chain series. The alkyl side chains (*R* groups) of these amino acids are nonpolar; this means that they have no affinity for water but some affinity for each other. Although plants can form all of the alkyl amino acids, animals can synthesize only alanine and glycine; thus valine, leucine, and isoleucine must be supplied in the diet.

Two amino acids, each containing three carbon atoms, are derived from alanine; they are serine and cysteine. Serine contains an alcohol group ($—CH_2OH$) instead of the methyl group of alanine, and cysteine contains a mercapto group ($—CH_2SH$). Animals can synthesize serine but not cysteine or cystine. Cysteine occurs in proteins predominantly in its oxidized form (oxidation in this sense meaning the removal of hydrogen atoms), called cystine. Cystine consists of two cysteine molecules linked by the disulfide bond (—S—S—) that results when a hydrogen atom is removed from the mercapto group of each of the cysteines. Disulfide bonds are important in protein structure because they allow the linkage of two different parts of a protein molecule to—and thus the formation of loops in-the otherwise straight chains.



glycine
(Gly, G)

alanine
(Ala, A)

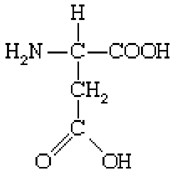
serine
(Ser, S)

cysteine
(CysH, C)

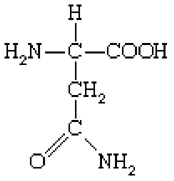
cystine
(Cys-S-S-Cys, C-C)

Fig. Some proteins contain small amounts of cysteine with free sulfhydryl (−SH) groups.

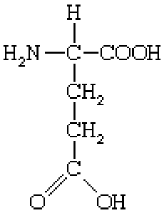
Four amino acids, each consisting of four carbon atoms, occur in proteins; they are aspartic acid, asparagine, threonine, and methionine. Aspartic acid and asparagine, which occur in large amounts, can be synthesized by animals. Threonine and methionine cannot be synthesized and thus are essential amino acids; i.e., they must be supplied in the diet. Most proteins contain only small amounts of methionine. Proteins also contain an amino acid with five carbon atoms (glutamic acid) and a secondary amine (in proline), which is a structure with the amino group (—NH_2) bonded to the alkyl side chain, forming a ring. Glutamic acid and aspartic acid are dicarboxylic acids; that is, they have two carboxyl groups (—COOH).



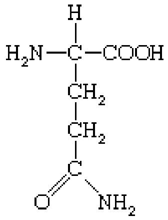
aspartic acid
(Asp, D; Asx or B)



asparagine
($AspNH_2$ or Asn, N; Asx or B)



glutamic acid
(Glu, E; Glx or Z)



glutamine
($GluNH_2$, GluN,
or Gln, Q; Glx or Z)

Glutamine is similar to asparagine in that both are the amides of their corresponding dicarboxylic acid forms; i.e., they have an amide group (—$CONH_2$) in place of the carboxyl (—COOH) of the side chain. Glutamic acid and glutamine are abundant in most proteins; e.g., in plant proteins they sometimes comprise more than one-third of the amino acids present. Both glutamic acid and glutamine can be synthesized by animals.

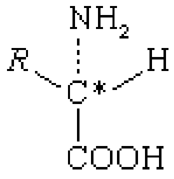
The amino acids proline and hydroxyproline occur in large amounts in collagen, the protein of the connective tissue of animals. Proline and hydroxyproline lack free amino (—NH_2) groups because the amino group is enclosed in a ring structure with the side chain; they thus cannot exist in a zwitterion form. Although the nitrogen-containing group (>NH) of these amino acids can form a peptide bond with the carboxyl group of another amino acid, the bond so formed gives rise to a kink in the peptide chain; i.e., the ring structure alters the regular bond angle of normal peptide bonds.

Proteins usually are almost neutral molecules; that is, they have neither acidic nor basic properties. This means that the acidic carboxyl (—COO^-) groups of aspartic and glutamic acid are about equal in number to the amino acids with basic side chains. Three such basic amino acids, each containing six carbon atoms, occur in proteins. The one with the simplest structure, lysine, is synthesized by plants but not by animals.

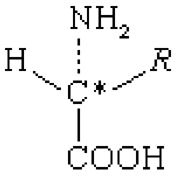
Physicochemical properties of the amino acids

The physicochemical properties of a protein are determined by the analogous properties of the amino acids in it. The α-carbon atom of all amino acids, with the exception of glycine, is asymmetric; this means that four different chemical entities (atoms or groups of atoms) are attached to it. As a result, each of the amino acids, except glycine, can exist in two different spatial, or geometric, arrangements (i.e., isomers), which are mirror images akin to right and left hands.

These isomers exhibit the property of optical rotation. Optical rotation is the rotation of the plane of polarized light, which is composed of light waves that vibrate in one plane, or direction, only. Solutions of substances that rotate the plane of polarization are said to be optically active, and the degree of rotation is called the optical rotation of the solution. The direction in which the light is rotated is generally designed as plus, or *d*, for dextrorotatory (to the right), or as minus, or *l*, for levorotatory (to the left). Some amino acids are dextrorotatory, others are levorotatory. With the exception of a few small proteins (peptides) that occur in bacteria, the amino acids that occur in proteins are L-amino acids.



L-amino acid



D-amino acid

In bacteria, D-alanine and some other D-amino acids have been found as components of gramicidin and bacitracin. These peptides are toxic to other bacteria and are used in medicine as antibiotics. The D-alanine has also been found in some peptides of bacterial membranes. In contrast to most organic acids and amines, the amino acids are insoluble in organic solvents. In aqueous solutions they are dipolar ions (zwitterions, or hybrid ions) that react with strong acids or bases in a way that leads to the neutralization of the negatively or positively charged ends, respectively. Because of their reactions with strong acids and strong bases, the amino acids act as buffers—stabilizers of hydrogen ion (H^+) or hydroxide ion (OH^-) concentrations.

Amino acid sequence in protein molecules

Since each protein molecule consists of a long chain of amino acid residues, linked to each other by peptide bonds, the hydrolytic cleavage of all peptide bonds is a prerequisite for the quantitative determination of the amino acid residues. Hydrolysis is most frequently accomplished by boiling the protein with concentrated hydrochloric acid. The quantitative determination of the amino acids is based on the discovery that amino acids can be separated from each other by chromatography on filter paper and made visible by spraying the paper with ninhydrin. The amino acids of the protein hydrolysate are separated from each other by passing the hydrolysate through a column of adsorbents, which adsorb the amino acids with different affinities and, on washing the column with buffer solutions, release them in a definite order. The amount of each of the amino acids can be determined by the intensity of the colour reaction with ninhydrin.

To obtain information about the sequence of the amino acid residues in the protein, the protein is degraded stepwise, one amino acid being split off in each step. This is accomplished by coupling the free α-amino group ($—NH_2$) of the N-terminal amino acid with phenyl isothiocyanate; subsequent mild hydrolysis does not affect the peptide bonds.

The procedure, called the Edman degradation, can be applied repeatedly; it thus reveals the sequence of the amino acids in the peptide chain.

5.5 Levels of structural organization in proteins

5.5.1 Primary structure

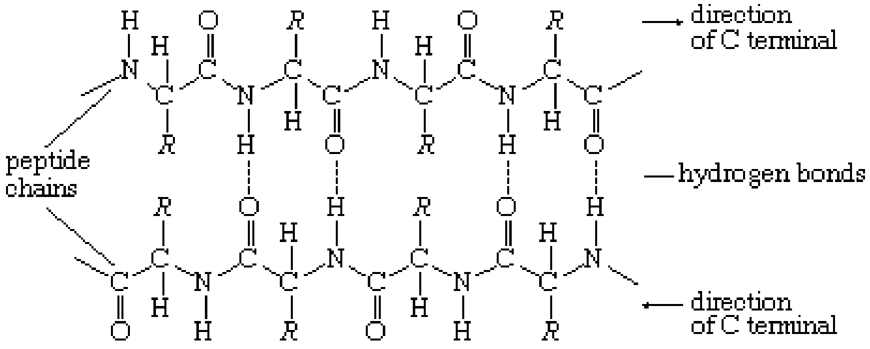
The terms *secondary*, *tertiary*, and *quaternary structure* are frequently applied to the configuration of the peptide chain of a protein. A nomenclature committee of the International Union of Biochemistry (IUB) has defined these terms as follows: The primary structure of a protein is determined by its amino acid sequence without any regard for the arrangement of the peptide chain in space. The secondary structure is determined by the spatial arrangement of the main peptide chain without any regard for the conformation of side chains or other segments of the main chain. The tertiary structure is determined by both the side chains and other adjacent segments of the main chain, without regard for neighboring peptide chains. Finally, the term *quaternary structure* is used for the arrangement of identical or different subunits of a large protein in which each subunit is a separate peptide chain.

5.5.2 Secondary structure

The nitrogen and carbon atoms of a peptide chain cannot lie on a straight line, because of the magnitude of the bond angles between adjacent atoms of the chain; the bond angle is about 110°. Each of the nitrogen and carbon atoms can rotate to a certain extent, however, so that the chain has a limited flexibility. Because all of the amino acids, except glycine, are asymmetric L-amino acids, the peptide chain tends to assume an asymmetric helical shape; some of the fibrous proteins consist of elongated helices around a straight screw axis. Such structural features result from properties common to all peptide chains. The product of their effects is the secondary structure of the protein.

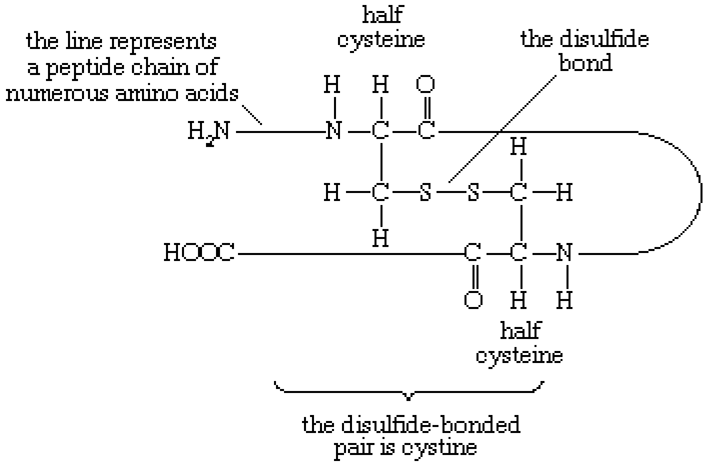
5.5.3 Tertiary structure

The tertiary structure is the product of the interaction between the side chains (*R*) of the amino acids composing the protein. Some of them contain positively or negatively charged groups, others are polar, and still others are nonpolar. The number of carbon atoms in the side chain varies from zero in glycine to nine in tryptophan. Positively and negatively charged side chains have the tendency to attract each other; side chains with identical charges repel each other. The bonds formed by the forces between the negatively charged side chains of aspartic or glutamic acid on the one hand, and the positively charged side chains of lysine or arginine on the other hand, are called salt bridges. Mutual attraction of adjacent peptide chains also results from the formation of numerous hydrogen bonds.



Hydrogen bonds form as a result of the attraction between the nitrogen-bound hydrogen atom (the imide hydrogen) and the unshared pair of electrons of the oxygen atom in the double bonded carbon–oxygen group (the carbonyl group). The result is a slight displacement of the imide hydrogen toward the oxygen atom of the carbonyl group. Although the hydrogen bond is much weaker than a covalent bond (i.e., the type of bond between two carbon atoms, which equally share the pair of bonding electrons between them), the large number of imide and carbonyl groups in peptide chains results in the formation of numerous hydrogen bonds. Another type of attraction is that between nonpolar side chains of valine, leucine, isoleucine, and phenylalanine; the attraction results in the displacement of water molecules and is called hydrophobic interaction.

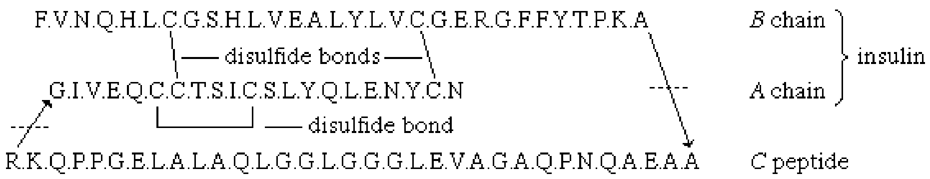
In proteins rich in cystine, the conformation of the peptide chain is determined to a considerable extent by the disulfide bonds (—S—S—) of cystine. The halves of cystine may be located in different parts of the peptide chain and thus may form a loop closed by the disulfide bond.



If the disulfide bond is reduced (i.e., hydrogen is added) to two sulfhydryl (—SH) groups, the tertiary structure of the protein undergoes a drastic change-closed loops are broken and adjacent disulfide-bonded peptide chains separate.

5.5.4 Quaternary structure

The nature of the quaternary structure is demonstrated by the structure of hemoglobin. Each molecule of human hemoglobin consists of four peptide chains, two α-chains and two β-chains; i.e., it is a tetramer. The four subunits are linked to each other by hydrogen bonds and hydrophobic interaction. Because the four subunits are so closely linked, the hemoglobin tetramer is called a molecule, even though no covalent bonds occur between the peptide chains of the four subunits. In other proteins, the subunits are bound to each other by covalent bonds (disulfide bridges). The amino acid sequence of porcine proinsulin is shown below. The arrows indicate the direction from the N terminus of the β-chain (B) to the C terminus of the α-chain (A).



5.6 Electrochemistry of proteins

Because the α-amino group and α-carboxyl group of amino acids are converted into peptide bonds in the protein molecule, there is only one α-amino group (at the N terminus) and one α-carboxyl group (at the C terminus) in a given protein molecule. The electrochemical character of a protein is affected very little by these two groups. Of importance, however, are the numerous positively charged ammonium groups (—NH_3^+) of lysine and arginine and the negatively charged carboxyl groups (—COO^-) of aspartic acid and glutamic acid. In most proteins, the number of positively and negatively charged groups varies from 10 to 20 per 100 amino acids.

Electrophoresis

The positively and negatively charged side chains of proteins cause them to behave like amino acids in an electrical field; that is, they migrate during electrophoresis at low pH values to the cathode (negative terminal) and at high pH values to the anode (positive terminal). The isoelectric point, the pH value at which the protein molecule does not migrate, is in the range of pH 5 to 7 for many proteins. Proteins such as lysozyme, cytochrome *c*, histone, and others rich in lysine and arginine, however, have isoelectric points in the pH range between 8 and 10. The isoelectric point of pepsin, which contains very few basic amino acids, is close to 1.

Conformation of globular proteins

Optical activity

It will be recalled that the amino acids, with the exception of glycine, exhibit optical activity (rotation of the plane of polarized light; *see above* Physicochemical properties of the amino acids). It is not surprising, therefore, that proteins also are optically active. They are usually levorotatory (i.e., they rotate the plane of polarization to the left) when polarized light of wavelengths in the visible range is used. Although the specific rotation (a function of the concentration of a protein solution and the distance the light travels in it) of most L-amino acids varies from −30° to +30°, the amino acid cystine has a specific rotation of approximately −300°. Although the optical rotation of a protein depends on all of the amino acids of which it is composed, the most important ones are cystine and the aromatic amino acids phenylalanine, tyrosine, and tryptophan. The contribution of the other amino acids to the optical activity of a protein is negligibly small.

5.7 Protein denaturation

When a solution of a protein is boiled, the protein frequently becomes insoluble—i.e., it is denatured—and remains insoluble even when the solution is cooled. The denaturation of the proteins of egg white by heat—as when boiling an egg—is an example of irreversible denaturation. The denatured protein has the same primary structure as the original, or native, protein. The weak forces between charged groups and the weaker forces of mutual attraction of nonpolar groups are disrupted at elevated temperatures, however; as a result, the tertiary structure of the protein is lost. In some instances the original structure of the protein can be regenerated; the process is called renaturation.

Denaturation can be brought about in various ways. Proteins are denatured by treatment with alkaline or acid, oxidizing or reducing agents, and certain organic solvents. Interesting among denaturing agents are those that affect the secondary and tertiary structure without affecting the primary structure. The agents most frequently used for this purpose are urea and guanidinium chloride. These molecules, because of their high affinity for peptide bonds, break the hydrogen bonds and the salt bridges between positive and negative side chains, thereby abolishing the tertiary structure of the peptide chain.

When denaturing agents are removed from a protein solution, the native protein re-forms in many cases. Denaturation can also be accomplished by reduction of the disulfide bonds of cystine—i.e., conversion of the disulfide bond (—S—S—) to two sulfhydryl groups (—SH). This, of course, results in the formation of two cysteines. Reoxidation of the cysteines by exposure to air sometimes regenerates the native protein. In other cases, however, the wrong cysteines become bound to each other, resulting in a different protein. Finally, denaturation can also be accomplished by exposing proteins to organic solvents such as ethanol or acetone. It is believed that the organic solvents interfere with the mutual attraction of nonpolar groups.

Structural proteins

Collagen

Collagen is the structural protein of bones, tendons, ligaments, and skin. For many years collagen was considered to be insoluble in water. Part of the collagen of calf skin, however, can be extracted with citrate buffer at pH 3.7. A precursor of collagen called procollagen is converted in the body into collagen. Procollagen has a molecular weight of 120,000. Cleavage of one or a few peptide bonds of procollagen yields collagen, which has three subunits, each with a molecular weight of 95,000; therefore, the molecular weight of collagen is 285,000 (3 × 95,000). The three subunits are wound as spirals around an elongated straight axis. The length of each subunit is 2,900 angstroms, and its diameter is approximately 15 angstroms. The three chains are staggered, so that the trimer has no definite terminal limits.

Collagen seems to undergo an aging process in living organisms that may be caused by the formation of cross links between collagen fibres. They are formed by the conversion of some lysine side chains to aldehydes (compounds with the general structure *R*CHO), and the combination of the aldehydes with the ε-amino groups of intact lysine side chains. The protein elastin, which occurs in the elastic fibres of connective tissue, contains similar cross links and may result from the combination of collagen fibres with other proteins. When cross-linked collagen or elastin is degraded, products of the cross-linked lysine fragments, called desmosins and isodesmosins, are formed.

Keratin

Keratin, the structural protein of epithelial cells in the outermost layers of the skin, has been isolated from hair, nails, hoofs, and feathers. Keratin is completely insoluble in cold or hot water; it is not attacked by proteolytic enzymes (i.e., enzymes that break apart, or lyse, protein molecules), and therefore cannot replace proteins in the diet. The great stability of keratin results from the numerous disulfide bonds of cystine. The amino acid composition of keratin differs from that of collagen. Cystine may account for 24 percent of the total amino acids. The peptide chains of keratin are arranged in approximately equal amounts of antiparallel and parallel pleated sheets, in which the peptide chains are linked to each other by hydrogen bonds between the carbonyl and imino groups.

The most thoroughly investigated keratin is hair keratin, particularly that of wool. It consists of a mixture of peptides with high and low cystine content. When wool is heated in water to about 90° C (190° F), it shrinks irreversibly. This is attributed to the breakage of hydrogen bonds and other noncovalent bonds; disulfide bonds do not seem to be affected.

Others

The most thoroughly investigated scleroprotein has been fibroin, the insoluble material of silk. The raw silk comprising the cocoon of the silkworm consists of two proteins. One, sericin, is soluble in hot water; the other, fibroin, is not. The amino acid composition of the latter differs from that of all other proteins. It contains large amounts of glycine, alanine, tyrosine, and serine; small amounts of the other amino acids; and no sulfur-containing ones. The peptide chains are arranged in antiparallel β-structures. Fibroin is partly soluble in concentrated solutions of lithium thiocyanate or in mixtures of cupric salts and ethylene diamine. Such solutions contain a protein of molecular weight 170,000, which is a dimer of two subunits. Little is known about either the scleroproteins of the marine sponges or the insoluble proteins of the cellular membranes of animal cells. Some of the membranes are soluble in detergents; others, however, are detergent-insoluble.

The muscle proteins

The total amount of muscle proteins in mammals, including humans, exceeds that of any other protein. About 40 percent of the body weight of a healthy human adult weighing about 70 kilograms (150 pounds) is muscle, which is composed of about 20 percent muscle protein. Thus, the human body contains about 5 to 6 kilograms (11 to 13 pounds) of muscle protein. An albumin-like fraction of these proteins, originally called myogen, contains various enzymes—phosphorylase, aldolase, glyceraldehyde phosphate dehydrogenase, and others; it does not seem to be involved in contraction. The globulin fraction contains myosin, the contractile protein, which also occurs in blood platelets, small bodies found in blood. Similar contractile substances occur in other contractile structures; for example, in the cilia or flagella (whiplike organs of locomotion) of bacteria and protozoans. In contrast to the scleroproteins, the contractile proteins are soluble in salt solutions and susceptible to enzymatic digestion.

The energy required for muscle contraction is provided by the oxidation of carbohydrates or lipids. The term *mechanochemical reaction* has been used for this conversion of chemical into mechanical energy. The molecular process underlying the reaction is known to involve the fibrous muscle proteins, the peptide chains of which undergo a change in conformation during contraction.

Fibrinogen and fibrin

Fibrinogen, the protein of the blood plasma, is converted into the insoluble protein fibrin during the clotting process. The fibrinogen-free fluid obtained after removal of the clot, called blood serum, is blood plasma minus fibrinogen. The fibrinogen content of the blood plasma is 0.2 to 0.4 percent. Fibrinogen can be precipitated from the blood plasma by half-saturation with sodium chloride.

The clotting process is initiated by the enzyme thrombin, which catalyzes the breakage of a few peptide bonds of fibrinogen; as a result, two small fibrinopeptides with molecular weights of 1,900 and 2,400 are released. The remainder of the fibrinogen molecule, a monomer, is soluble and stable at pH values less than 6 (i.e., in acid solutions). In neutral solution (pH 7) the monomer is converted into a larger molecule, insoluble fibrin; this results from the formation of new peptide bonds. The newly formed peptide bonds form intermolecular and intramolecular cross links, thus giving rise to a large clot, in which all molecules are linked to each other. Clotting, which takes place only in the presence of calcium ions, can be prevented by compounds such as oxalate or citrate, which have a high affinity for calcium ions.

Albumins, globulins, and other soluble proteins

The blood plasma, the lymph, and other animal fluids usually contain one to seven grams of protein per 100 millilitres of fluid, which includes small amounts of hundreds of enzymes and a large number of protein hormones. The discussion below is limited largely to the proteins that occur in large amounts and can be easily isolated from the body fluids.

Milk proteins

Milk contains the following: an albumin, α-lactalbumin; a globulin, beta-lactoglobulin; and a phosphoprotein, casein. If acid is added to milk, casein precipitates. The remaining watery liquid (the supernatant solution), or whey, contains α-lactalbumin and βlactoglobulin. Both have been obtained in crystalline form; in bovine milk, their molecular weights are approximately 14,000 and 18,400, respectively. Lactoglobulin also occurs as a dimer of molecular weight 37,000. Genetic variations can produce small variations in the amino acid composition of lactoglobulin. The amino acid composition and the tertiary structure of lactalbumin resemble that of lysozyme, an egg protein.

Casein is precipitated not only by the addition of acid but also by the action of the enzyme rennin, which is found in gastric juice. Rennin from calf stomachs is used to precipitate casein, from which cheese is made. Milk fat precipitates with casein; milk sugar, however, remains in the supernatant (whey). Casein is a mixture of several similar phosphoproteins, called α-, β-, γ–, and κ-casein, all of which contain some serine side chains combined with phosphoric acid. Approximately 75 percent of casein is α-casein. Cystine has been found only in κ-casein. In milk, casein seems to form polymeric globules (micelles) with radially arranged monomers, each with a molecular weight of 24,000; the acidic side chains occur predominantly on the surface of the micelle, rather than inside.

Egg proteins

About 50 percent of the proteins of egg white are composed of ovalbumin, which is easily obtained in crystals. Its molecular weight is 46,000 and its amino acid composition differs from that of serum albumin. Other proteins of egg white are conalbumin, lysozyme, ovoglobulin, ovomucoid, and avidin. Lysozyme is an enzyme that hydrolyzes the carbohydrates found in the capsules certain bacteria secrete around themselves; it causes lysis (disintegration) of the bacteria. The molecular weight of lysozyme is 14,100. Its three-dimensional structure is similar to that of α-lactalbumin, which stimulates the formation of lactose by the enzyme lactose synthetase. Lysozyme has also been found in the urine of patients suffering from leukemia, meningitis, and renal disease. Avidin is a glycoprotein that combines specifically with biotin, a vitamin. In animals fed large amounts of raw egg white, the action of avidin results in “egg-white injury.” The molecular weight of avidin, which forms a tetramer, is 16,200. Its

Egg-yolk proteins contain a mixture of lipoproteins and livetins. The latter are similar to serum albumin, α-globulin, and β-globulin. The yolk also contains a phosphoprotein, phosvitin. Phosvitin, which has also been found in fish sperm, has a molecular weight of

40,000 and an unusual amino acid composition; one third of its amino acids are phosphoserine.

Protamines and histones

Protamines are found in the sperm cells of fish. The most thoroughly investigated protamines are salmine from salmon sperm and clupeine from herring sperm. The protamines are bound to deoxyribonucleic acid (DNA), forming nucleoprotamines. The amino acid composition of the protamines is simple; they contain, in addition to large amounts of arginine, small amounts of five or six other amino acids. The composition of the salmine molecule, for example, is: Arg_{51}, Ala_4, Val_4, Ile_1, Pro_7, and Ser_6, in which the subscript numbers indicate the number of each amino acid in the molecule. Because of the high arginine content, the isoelectric points of the protamines are at pH values of 11 to 12; i.e., the protamines are alkaline. The molecular weights of salmine and clupeine are close to 6,000. All of the protamines investigated thus far are mixtures of several similar proteins.

Plant proteins

Plant proteins, mostly globulins, have been obtained chiefly from the protein-rich seeds of cereals and legumes. Small amounts of albumins are found in seeds. The best known globulins, insoluble in water, can be extracted from seeds by treatment with 2 to 10 percent solutions of sodium chloride. Many plant globulins have been obtained in crystalline form; they include edestin from hemp, molecular weight 310,000; amandin from almonds, 330,000; concanavalin A (42,000) and B (96,000); and canavalin (113,000) from jack beans. They are polymers of smaller subunits; edestin, for example, is a hexamer of a subunit with a molecular weight of 50,000, and concanavalin B a trimer of a subunit with a molecular weight of 30,000.

After extraction of lipids from cereal seeds by ether and alcohol, further extraction with water containing 50 to 80 percent of alcohol yields proteins that are insoluble in water but soluble in water–ethanol mixtures and have been called prolamins. Their solubility in aqueous ethanol may result from their high proline and glutamine content. Gliadin, the prolamin from wheat, contains 14 grams of proline and 46 grams of glutamic acid in 100 grams of protein; most of the glutamic acid is in the form of glutamine. The total amounts of the basic amino acids (arginine, lysine, and histidine) in gliadin are only 5 percent of the weight of gliadin. Because the glysine content is either low or nonexistent, human populations dependent on grain as a sole protein source suffer from lysine deficiency.

5.8 Mucoproteins and glycoproteins

The prosthetic groups in mucoproteins and glycoproteins are oligosaccharides (carbohydrates consisting of a small number of simple sugar molecules) usually containing from four to 12 sugar molecules; the most common sugars are galactose, mannose, glucosamine, and galactosamine. Xylose, fucose, glucuronic acid, sialic acid, and other simple sugars sometimes also occur. Some mucoproteins contain 20 percent or more of carbohydrate, usually in several oligosaccharides attached to different parts of the peptide chain. The designation mucoprotein is used for proteins with more than 3 to 4 percent carbohydrate; if the carbohydrate content is less than 3 percent, the protein is sometimes called a glycoprotein or simply a protein.

Mucoproteins, highly viscous proteins originally called mucins, are found in saliva, in gastric juice, and in other animal secretions. Mucoproteins occur in large amounts in cartilage, synovial fluid (the lubricating fluid of joints and tendons), and egg white. The mucoprotein of cartilage is formed by the combination of collagen with chondroitinsulfuric acid, which is a polymer of either glucuronic or iduronic acid and acetylhexosamine or acetylgalactosamine. It is not yet clear whether or not chondroitinsulfate is bound to collagen by covalent bonds.

Lipoproteins and proteolipids

The bond between the protein and the lipid portion of lipoproteins and proteolipids is a noncovalent one. It is thought that some of the lipid is enclosed in a meshlike arrangement of peptide chains and becomes accessible for reaction only after the unfolding of the chains by denaturing agents. Although lipoproteins in the α- and β-globulin fraction of blood serum are soluble in water (but insoluble in organic solvents), some of the brain lipoproteins, because they have a high lipid content, are soluble in organic solvents; they are called proteolipids. The β-lipoprotein of human blood serum is a macroglobulin with a molecular weight of about 1,300,000, 70 percent of which is lipid; of the lipid, about 30 percent is phospholipid and 40 percent cholesterol and compounds derived from it. Because of their lipid content, the lipoproteins have the lowest density (mass per unit volume) of all proteins and are usually classified as low- and high-density lipoproteins (LDL and HDL).

Metalloproteins

Proteins in which heavy metal ions are bound directly to some of the side chains of histidine, cysteine, or some other amino acid are called metalloproteins. Two metalloproteins, transferrin and ceruloplasmin, occur in the globulin fractions of blood serum; they act as carriers of iron and copper, respectively. Transferrin has a molecular weight of about 80,000 and consists of two identical subunits, each of which contains one ferric ion (Fe^{3+}) that seems to be bound to tyrosine. Several genetic variants of transferrin are known to occur in humans. Another iron protein, ferritin, which contains 20 to 22 percent iron, is the form in which iron is stored in animals; it has been obtained in crystalline form from liver and spleen. A molecule consisting of 20 subunits, its molecular weight is approximately 480,000. The iron can be removed by reduction from the ferric (Fe^{3+}) to the ferrous (Fe^{2+}) state. The iron-free protein, apoferritin, is synthesized in the body before the iron is incorporated.

Green plants and some photosynthetic and nitrogen-fixing bacteria (i.e., bacteria that convert atmospheric nitrogen, N_2, into amino acids and proteins) contain various ferredoxins. They are small proteins containing 50 to 100 amino acids and a chain of iron and disulfide units (FeS_2), in which some of the sulfur atoms are contributed by cysteine; others are sulfide ions (S^{2-}). The number of FeS_2 units per ferredoxin molecule varies from five in the ferredoxin of spinach to 10 in the ferredoxin of certain bacteria. Ferredoxins act as electron carriers in photosynthesis and in nitrogen fixation.

Nucleoproteins

When a protein solution is mixed with a solution of a nucleic acid, the phosphoric acid component of the nucleic acid combines with the positively charged ammonium groups ($—NH_3^+$) of the protein to form a protein–nucleic acid complex. The nucleus of a cell contains predominantly deoxyribonucleic acid (DNA) and the cytoplasm predominantly ribonucleic acid (RNA); both parts of the cell also contain protein. Protein–nucleic acid complexes, therefore, form in living cells. The only nucleoproteins for which some evidence for specificity exists are nucleoprotamines, nucleohistones, and some RNA and DNA viruses. The nucleoprotamines are the form in which protamines occur in the sperm cells of fish; the histones of the thymus and of pea seedlings and other plant material apparently occur predominantly as nucleohistones. Both nucleoprotamines and nucleohistones contain only DNA.

5.9 Respiratory proteins

Hemoglobin

Hemoglobin is the oxygen carrier in all vertebrates and some invertebrates. In oxyhemoglobin (HbO_2), which is bright red, the ferrous ion (Fe^{2+}) is bound to the four nitrogen atoms of porphyrin; the other two substituents are an oxygen molecule and the histidine of globin, the protein component of hemoglobin. Deoxyhemoglobin (deoxy-Hb), as its name implies, is oxyhemoglobin minus oxygen (i.e., reduced hemoglobin); it is purple in colour. Oxidation of the ferrous ion of hemoglobin yields a ferric compound, methemoglobin, sometimes called hemiglobin or ferrihemoglobin. The oxygen of oxyhemoglobin can be displaced by carbon monoxide, for which hemoglobin has a much greater affinity, preventing oxygen from reaching the body tissues.

The hemoglobins of all mammals, birds, and many other vertebrates are tetramers of two α- and two β-chains. The molecular weight of the tetramer is 64,500; the molecular weight of the α- and β-chains is approximately 16,100 each, and the four subunits are linked to each other by noncovalent interactions. If hemin (the ferric porphyrin component) is removed from globin (the protein component), two molecules of globin, each consisting of one α- and one β-chain, are obtained; the molecular weight of globin is 32,200. In contrast to hemoglobin, globin is an unstable protein that is easily denatured. If native globin is incubated with a solution of hemin at pH values of 8 to 9, native hemoglobin is reconstituted. Myoglobin, the red pigment of mammalian muscles, is a monomer with a molecular weight of 16,000.

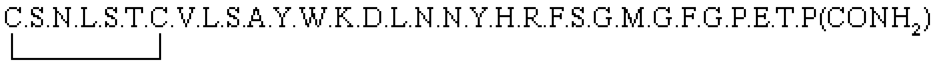
Protein hormones

Some hormones that are products of endocrine glands are proteins or peptides, others are steroids. (The origin of hormones, their physiological role, and their mode of action are dealt with in the article hormone.) None of the hormones has any enzymatic activity. Each has a target organ in which it elicits some biological action—e.g., secretion of gastric or pancreatic juice, production of milk, production of steroid hormones. The mechanism by which the hormones exert their effects is not fully understood. Cyclic adenosine monophosphate is involved in the transmittance of the hormonal stimulus to the cells whose activity is specifically increased by the hormone.

Hormones of the thyroid gland

Thyroglobulin, the active groups of which are two molecules of the iodine-containing compound thyroxine, has a molecular weight of 670,000. Thyroglobulin also contains thyroxine with two and three iodine atoms instead of four and tyrosine with one and two iodine atoms. Injection of the hormone causes an increase in metabolism; lack of it results in a slowdown.

Another hormone, calcitonin, which lowers the calcium level of the blood, occurs in the thyroid gland. The amino acid sequences of calcitonin from pig, beef, and salmon differ from human calcitonin in some amino acids. All of them, however, have the half-cystines (C) and the prolinamide (P) in the same position.

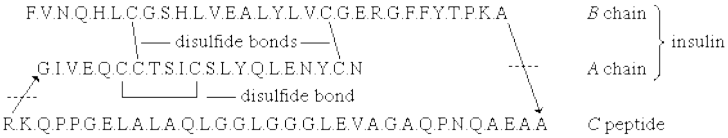


$\mathrm{C.S.N.L.S.T.C.V.L.S.A.Y.W.K.D.L.N.N.Y.H.R.F.S.G.M.G.F.G.P.E.T.P(CONH_2)}$

Parathyroid hormone (parathormone), produced in small glands that are embedded in or lie behind the thyroid gland, is essential for maintaining the calcium level of the blood. A decrease in its production results in hypocalcemia (a reduction of calcium levels in the bloodstream below the normal range). Bovine parathormone has a molecular weight of 8,500; it contains no cystine or cysteine and is rich in aspartic acid, glutamic acid, or their amides.

Hormones of the pancreas

Although the amino acid structure of insulin has been known since 1949, repeated attempts to synthesize it gave very poor yields because of the failure of the two peptide chains to combine forming the correct disulfide bridge. The ease of the biosynthesis of insulin is explained by the discovery in the pancreas of proinsulin, from which insulin is formed. The single peptide chain of proinsulin loses a peptide consisting of 33 amino acids and called the connecting peptide, or C peptide, during its conversion to insulin. The disulfide bridges of proinsulin connect the A and B chains.



In aqueous solutions, insulin exists predominantly as a complex of six subunits, each of which contains an A and a B chain. The insulins of several species have been isolated and analyzed; their amino acid sequences have been found to differ somewhat, but all apparently contain the same disulfide bridges between the two chains. Although the injection of insulin lowers the blood sugar, administration of glucagon, another pancreas hormone, raises the blood sugar level. Glucagon consists of a straight peptide chain of 29 amino acids. It has been synthesized; the synthetic product has the full biological activity of natural glucagon. The structure of glucagon is free of cystine and isoleucine.

The pituitary gland has an anterior lobe, a posterior lobe, and an intermediate portion; they differ in cellular structure and in the structure and action of the hormones they form. The posterior lobe produces two similar hormones, oxytocin and vasopressin. The former causes contraction of the pregnant uterus; the latter raises the blood pressure. Both are octapeptides formed by a ring of five amino acids (the two cystine halves count as one amino acid) and a side chain of three amino acids. The two cystine halves are linked to each other by a disulfide bond, and the C terminal amino acid is glycinamide. The structure has been established and confirmed. Human vasopressin differs from oxytocin in that isoleucine is replaced by phenylalanine and leucine by arginine.

Peptides with hormone like activity

Small peptides have been discovered that, like hormones, act on certain target organs. One peptide, angiotensin (angiotonin or hypertensin), is formed in the blood from angiotensinogen by the action of renin, an enzyme of the kidney. It is an octapeptide and increases blood pressure. Similar peptides include bradykinin, which stimulates smooth muscles; gastrin, which stimulates secretion of hydrochloric acid and pepsin in the stomach; secretin, which stimulates the flow of pancreatic juice; and kallikrein, the activity of which is similar to bradykinin.

5.10Immunoglobulins and antibodies

Antibodies, proteins that combat foreign substances in the body, are associated with the globulin fraction of the immune serum. As stated previously, when the serum globulins are separated into α-, β-, and γ- fractions, antibodies are associated with the γ-globulins. Antibodies can be purified by precipitation with the antigen (i.e., the foreign substance) that caused their formation, followed by separation of the antigen-antibody complex. Antibodies prepared in this way consist of a mixture of many similar antibody molecules, which differ in molecular weight, amino acid composition, and other properties.

The same differences are found in the γ-globulins of normal blood serums. The γ-globulin of normal blood serum is thought to consist of a mixture of hundreds of different γ-globulins, each of which occurs in amounts too small for isolation. Because the physical and chemical properties of normal γ-globulins are the same as those of antibodies, the γ-globulins are frequently called immunoglobulins. They may be considered to be antibodies against unknown antigens. If solutions of γ-globulin are resolved by gel filtration through dextran, the first fraction has a molecular weight of 900,000. This fraction is called IgM or γM; Ig is an abbreviation for immunoglobulin and M for macroglobulin. The next two fractions are IgA (γA) and IgG (γG), with molecular weights of about 320,000 and 150,000 respectively. Two other immunoglobulins, known as IgD and IgE, have also been detected in much smaller amounts in some immune sera.

Enzymes

Practically all of the numerous and complex biochemical reactions that take place in animals, plants, and microorganisms are regulated by enzymes. These catalytic proteins are efficient and specific—that is, they accelerate the rate of one kind of chemical reaction of one type of compound, and they do so in a far more efficient manner than human-made catalysts. They are controlled by activators and inhibitors that initiate or block reactions. All cells contain enzymes, which usually vary in number and composition, depending on the cell type; an average mammalian cell, for example, is approximately one one-billionth (10^{-9}) the size of a drop of water and generally contains about 3,000 enzymes.

5.11 Summary

Under this unit we have discussed the properties, digestion and absorption of proteins. Proteins are built as chains of amino acids, which then fold into unique three-dimensional shapes. Bonding within protein molecules helps stabilize their structure, and the final folded forms of proteins are well-adapted for their functions. Protein is very important for almost all of the processes that occur in your body. It is necessary for your body to make antibodies, which fight against infection and illness, and protein is what keeps our hair, skin and bones healthy. Protein is an important part of our daily diet and it should be consumed every day. Nutritionists recommend that you eat 2-3 servings of dairy products every day and 2-3 servings of meat, poultry, fish, or shellfish a day. They also suggested that 10-35% of your calorie intake should be protein. Many nutritionists also recommend an intake of 1 gram of protein per 1 kilogram of body weight. Protein is needed for the growth of your body. Protein can help you lose weight, increase your metabolism and suppress your appetite. Also women who are pregnant need protein for their fetus and to supply breast milk.Without proteins, your body would lack the enzymes and hormones you need for metabolism, digestion and other important processes.

5.12 Terminal questions

Q.1 Describe proteins with examples.

Answer:---

Q.2 What are the building blocks of proteins? Explain with examples.

Answer:---

Q.3 Explain the structure of any 4 amino acids.

Answer:---

Q. 4 Describe the digestion and absorption of proteins.

Answer:--

Q. 5 Write short notes on the followings.

(i) Amino acids

(ii) Enzymes

Answer:--

Q. 6 Describe different structures of proteins with examples.

Answer:--

Further readings

1. Biochemistry- Lehninger A.L.
2. Textbook of Nutrition and Dietetics Ranjana Mahna
3. Biochemistry fourth edition-David Hames and Nigel Hooper.
4. Textbook of Biochemistry for Undergraduates - Rafi, M.D.
5. Textbook of Nutrition and Dietetics- Monika Sharma

Unit 6: Essential & non-essential amino acids

Structure

6.1 Introduction

Amino acidsthe organic compounds that combine to form proteins, hence they are referred to as the building components of proteins. These biomolecules are involved in several biological and chemical functions in the human body and are the necessary ingredients for the growth and development of human beings. Theyare the building blocks of protein. Proteins are long chains of amino acids. Your body has thousands of different proteins that each has important jobs. Each protein has its own sequence of amino acids. The sequence makes the protein take different shapes and have different functions in your body.You can think of amino acids like the letters of the alphabet. When you combine letters in various ways, you make different words. The same goes for amino acids — when you combine them in various ways, you make different proteins.

There are about 300 amino acids that occur in nature. Amino acids are organic compounds containing the basic amino groups (-NH2) and carboxyl groups (-COOH). The ingredients present in proteins are amino acids. Both peptides and proteins are long chains of amino acids. Altogether, there are twenty amino acids, which are involved in the construction of proteins.

Objectives

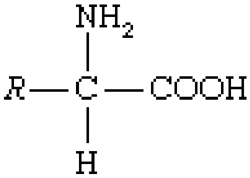
This is the sixth unit (Essential & Non-essential amino acids) under second block (Introduction to proteins and enzymes). Under this unit, we have following objectives. These are as under:

- To know about amino acids and its structure

- To discuss essential and non-essential amino acids
- To know about sources and uses of amino acids
- To discuss its synthesis and its clinical significance

6.2 Amino acids

Amino acid, any of a group of organic molecules that consist of a basic amino group (—NH_2), an acidic carboxyl group (—COOH), and an organic *R* group (or side chain) that is unique to each amino acid. The term *amino acid* is short for *α-amino [alpha-amino] carboxylic acid*. Each molecule contains a central carbon (C) atom, called the α-carbon, to which both an amino and a carboxyl group are attached. The remaining two bonds of the α-carbon atom are generally satisfied by a hydrogen (H) atom and the *R* group. The formula of a general amino acid is:



$$R-\overset{\displaystyle NH_2}{\underset{\displaystyle H}{\overset{|}{\underset{|}{C}}}}-COOH$$

The amino acids differ from each other in the particular chemical structure of the *R* group.

General properties of Amino acids

- They have a very high melting and boiling point.
- Amino acids are white crystalline solid substances.
- In taste, few Amino acids are sweet, tasteless, and bitter.
- Most of the amino acids are soluble in water and are insoluble in organic solvents.

6.3 Essential and Non-essential Amino acids

Out of 20 amino acids, our body can easily synthesize a few on its own, which are called non-essential amino acids. These include alanine, asparagine, arginine, aspartic acid, glutamic acid, cysteine, glutamine, proline, glycine, serine, and tyrosine. Apart from these, there are other nine amino acids, which are very much essential as they cannot be synthesized by our body. They are called essential amino acids, and they include isoleucine, histidine, lysine, leucine, phenylalanine, tryptophan, methionine, threonine, and valine.

6.4 Structure of Amino acids

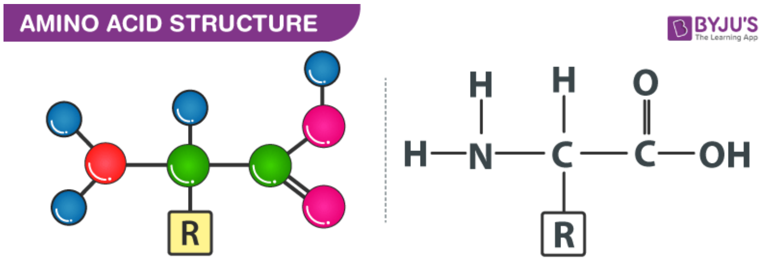
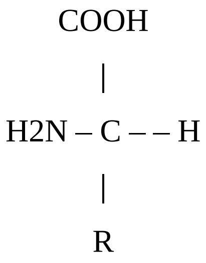


Fig. Structure of amino acid

The general structure of Amino acids is $H_2NCH\ RCOOH$, and it can be written as:



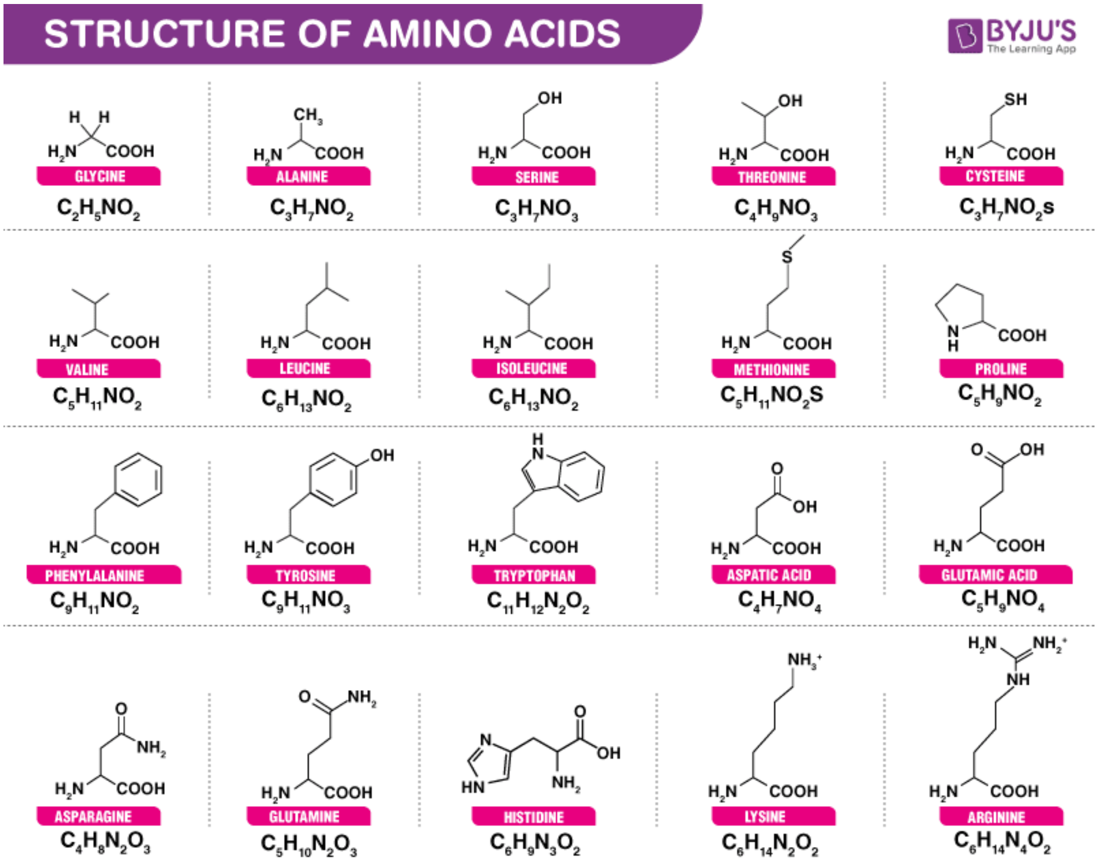
$$\begin{array}{c} COOH \\ | \\ H2N - C - - H \\ | \\ R \end{array}$$

There are 20 naturally occurring amino acids and all have common structural features – an amino group (-NH3+), a carboxylate (-COO-) group and a hydrogen-bonded to the same carbon atom. They differ from each other in their side-chain called the R group. Each amino acid has 4 different groups attached to α- carbon.

These 4 groups are:

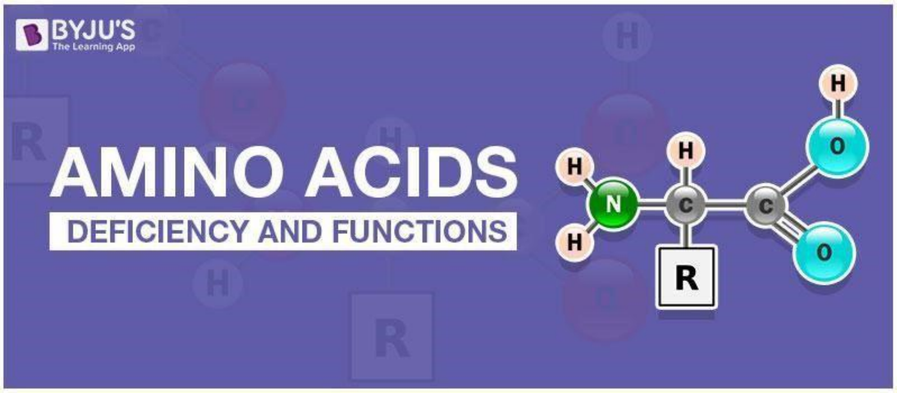
- Amino group,
- COOH,
- Hydrogen atom,
- Sidechain (R).

Structure of 20 Amino acids with their chemical formula Here is the structure of twenty amino acids with their chemical formula.



6.5 Sources of Amino acids

Amino acids play an important role in performing several biological and chemical functions in different parts of our body, including building and repairing the tissues, the formation and function of enzymes, food digestion, the transportation of molecules, etc. Our body can synthesize only certain amino acids and the rest of the amino acids which are called essential amino acids should be supplied through protein-rich foods in our daily diet. Foods rich in amino acids include plant-based products like broccoli, beans, beetroots, pumpkin, cabbage, nuts, dry fruits, chia seeds, oats, peas, carrots, cucumber, green leafy vegetables, onions, soybeans, whole grain, peanuts legumes, lentils, etc. Fruits rich in amino acids are apples, bananas, berries, figs, grapes, melons, oranges, papaya, pineapple, and pomegranates. Other animal products include dairy products, eggs, seafood, chicken, meat, pork etc.



6.6 Functions of Amino acids

- Functions of Essential Amino acids
- Phenylalanine helps in maintaining a healthy nervous system and in boosting memory power.
- Valine acts as an important component in promoting muscle growth.
- Threonine helps in promoting the functions of the immune system.
- Tryptophan is involved in the production of vitamin B3 and serotonin hormones. This serotonin hormone plays a vital role in maintaining our appetite, regulating sleep and boosting our moods.
- Isoleucine plays a vital role in the formation of haemoglobin, stimulating the pancreas to synthesize insulin, and transporting oxygen from the lungs to the various parts.
- Methionine is used in the treatment of kidney stones, maintaining healthy skin and also used in controlling invade of pathogenic bacteria.
- Leucine is involved in promoting protein synthesis and growth hormones.
- Lysine is necessary for promoting the formation of antibodies, hormones, and enzymes and in the development and fixation of calcium in bones.

- Histidine is involved in many enzymatic processes and in the synthesizing of both red blood cells (erythrocytes) and white blood cells (leukocytes).
- Functions of Non-Essential Amino acids
- Alanine functions by removing toxins from our body and in the production of glucose and other amino acids.
- Cysteine acts as an antioxidant and provides resistance to our body; it is important for making collagen. It affects the texture and elasticity of the skin
- Glutamine promotes a healthy brain function and is necessary for the synthesis of nucleic acids – DNA and RNA.
- Glycine is helpful in maintaining the proper cell growth, and its function, and it also plays a vital role in healing wounds. It acts as a neurotransmitter.
- Glutamic acid acts as a neurotransmitter and is mainly involved in the development and functioning of the human brain.
- Arginine helps in promoting the synthesis of proteins and hormones, detoxification in the kidneys, healing wounds, and maintaining a healthy immune system.
- Tyrosine plays a vital role in the production of the thyroid hormones -T3 and T4, in synthesizing a class of neurotransmitters and melanin, which are natural pigments found in our eyes, hair, and skin.

Deficiency of Amino acids

As mentioned above, amino acids are the building blocks of proteins and proteins play a fundamental role in almost all life processes. Therefore, it is necessary to include all nine essential amino acids in our daily diet to maintain a healthy and proper function of our body. The deficiency of amino acids may include different pathological disorders, including:

- Edema.
- Anemia.
- Insomnia.
- Diarrhea.
- Depression.
- Hypoglycemia.
- Loss of Appetite.
- Fat deposit in the liver.
- Skin and hair related problems.

- Headache, weakness, irritability, and fatigue.

Important Questions

Q. 1 Define amino acids.

In simpler terms, Amino acids are organic compounds containing the basic amino groups (-NH_2) and carboxyl groups (-COOH).

Q. 2 Give examples of essential amino acids.

Essential amino acids cannot be synthesized and hence must come from our diet. The 9 essential amino acids are – Isoleucine, histidine, lysine, leucine, phenylalanine, tryptophan, methionine, threonine, and valine.

Q. 3 Why are amino acids called amphoteric?

Amino acids have both acidic and basic properties. This is why they are amphoteric. The predominant form of the amino acid is based on the pH of the solution.

Q. 4 What is zwitterion?

The actual structure of amino acids is ionic and depends on pH even though we usually write amino acids with a carboxyl group and amino group. The carboxyl group gives up a proton, donating a carboxylate ion. The amino group is protonated to an ammonium ion. This structure is referred to as a zwitterion or dipolar ion.

Q. 5 Give an example of a transport protein and mention its function.

Haemoglobin is a transport protein. It is involved in the transportation of oxygen to the cells.

Q. 6 Name a sulphur-containing amino acid.

Methionine and cysteine are sulphur-containing amino acids.

Q. 7 Are amino acids and proteins same?

Proteins are composed of monomers called amino acids. A protein comprises one or more polypeptides, which are individual linear chains of amino acids.

Q. 8 How many amino acids are found in proteins?

20 basic amino acids are used to make both plant and animal proteins.

Q. 9 What are protein amino acids?

Protein amino acids are called alpha amino acids.

Q. 10 Name the amino acid found in protein structure.

Protein structures contain the four amino acids asparagine, aspartic acid, threonine, and methionine, each of which has four carbon atoms.

6.7 Uses in industry

Fertilizer

The chelating ability of amino acids is sometimes used in fertilizers to facilitate the delivery of minerals to plants in order to correct mineral deficiencies, such as iron chlorosis. These fertilizers are also used to prevent deficiencies from occurring and to improve the overall health of the plants.

Animal feed

Amino acids are sometimes added to animal feed because some of the components of these feeds, such as soybeans, have low levels of some of the essential amino acids, especially of lysine, methionine, threonine, and tryptophan. Likewise amino acids are used to chelate metal cations in order to improve the absorption of minerals from feed supplements.

Food

The food industry is a major consumer of amino acids, especially glutamic acid, which is used as a flavor enhancer, and aspartame (aspartylphenylalanine 1-methyl ester), which is used as an artificial sweetener. Amino acids are sometimes added to food by manufacturers to alleviate symptoms of mineral deficiencies, such as anemia, by improving mineral absorption and reducing negative side effects from inorganic mineral supplementation.

Pharmaceuticals and cosmetics

Similarly, some amino acids derivatives are used in pharmaceutical industry. They include 5-HTP (5-hydroxytryptophan) used for experimental treatment of depression, L-DOPA (L-dihydroxyphenylalanine) for Parkinson's treatment, and eflornithine drug that inhibits ornithine decarboxylase and used in the treatment of sleeping sickness.[116] Amino acids are used in the synthesis of some cosmetics.

Expanded genetic code

Since 2001, 40 non-natural amino acids have been added into protein by creating a unique codon (recoding) and a corresponding transfer-RNA:aminoacyl – tRNA-synthetase pair to encode it with diverse physicochemical and biological properties in order to be used as a tool to exploring protein structure and function or to create novel or enhanced proteins.

Nullomers

Nullomers are codons that in theory code for an amino acid, however, in nature there is a selective bias against using this codon in favor of another, for example bacteria prefer to use CGA instead of AGA to code for arginine. This creates some sequences that do not appear in the genome. This characteristic can be taken advantage of and used to create new selective cancer-fighting drugs and to prevent cross-contamination of DNA samples from crime-scene investigations.

Chemical building blocks

Amino acids are important as low-cost feedstocks. These compounds are used in chiral pool synthesis as enantiomerically pure building blocks. Amino acids have been investigated as precursors chiral catalysts, such as for asymmetric hydrogenation reactions, although no commercial applications exist.

Biodegradable plastics

Amino acids have been considered as components of biodegradable polymers, which have applications as environmentally friendly packaging and in medicine in drug delivery and the construction of prosthetic implants. An interesting example of such materials is polyaspartate, a water-soluble biodegradable polymer that may have applications in disposable diapers and agriculture. Due to its solubility and ability to chelate metal ions, polyaspartate is also being used as a biodegradable antiscaling agent and a corrosion inhibitor. In addition, the aromatic amino acid tyrosine has been considered as a possible replacement for phenols such as bisphenol A in the manufacture of polycarbonates.

6.8 Synthesis

Chemical synthesis

The commercial production of amino acids usually relies on mutant bacteria that overproduce individual amino acids using glucose as a carbon source. Some amino acids are produced by enzymatic conversions of synthetic intermediates. 2-Aminothiazoline-4-carboxylic acid is an intermediate in one industrial synthesis of L-cysteine for example. Aspartic acid is produced by the addition of ammonia to fumarate using a lyase.

Biosynthesis

In plants, nitrogen is first assimilated into organic compounds in the form of glutamate, formed from alpha-ketoglutarate and ammonia in the mitochondrion. For other amino acids, plants use transaminases to move the amino group from glutamate to another alpha-keto acid. For example, aspartate aminotransferase converts glutamate and oxaloacetate to alpha-ketoglutarate and aspartate. Other organisms use transaminases for amino acid synthesis, too.

Nonstandard amino acids are usually formed through modifications to standard amino acids. For example, homocysteine is formed through the transsulfuration pathway or by the demethylation of methionine via the intermediate metabolite *S*-adenosylmethionine, while hydroxyproline is made by a post translational modification of proline. Microorganisms and plants synthesize many uncommon amino acids. For example, some microbes make 2-aminoisobutyric acid and lanthionine, which is a sulfide-bridged derivative of alanine. Both of these amino acids are found in peptidic lantibiotics such as alamethicin. However, in plants, 1-aminocyclopropane-1-carboxylic acid is a small disubstituted cyclic amino acid that is an intermediate in the production of the plant hormone ethylene.

Primordial synthesis

The formation of amino acids and peptides are assumed to precede and perhaps induce the emergence of life on earth. Amino acids can form from simple precursors under various conditions Surface-based chemical metabolism of amino acids and very small compounds may have led to the build-up of amino acids, coenzymes and phosphate-based small carbon molecules. Amino acids and similar building blocks could have been elaborated into proto-peptides, with peptides being considered key players in the origin of life.

In the famous Urey-Miller experiment, the passage of an electric arc through a mixture of methane, hydrogen, and ammonia produces a large number of amino acids. Since then, scientists have discovered a range of ways and components by which the potentially prebiotic formation and chemical evolution of peptides may have occurred, such as condensing agents, the design of self-replicating peptides and a number of non-enzymatic mechanisms by which amino acids could have emerged and elaborated into peptides. Several hypotheses invoke the Strecker synthesis whereby hydrogen cyanide, simple aldehydes, ammonia, and water produce amino acids.

According to a review, amino acids, and even peptides, "turn up fairly regularly in the various experimental broths that have been allowed to be cooked from simple chemicals. This is because nucleotides are far more difficult to synthesize chemically than amino acids." For a chronological order, it suggests that there must have been a 'protein world' or at least a 'polypeptide world', possibly later followed by the 'RNA world' and the 'DNA world'. Codon–amino acids mappings may be the biological information system at the primordial origin of life on Earth. While amino acids and consequently simple peptides must have formed under different experimentally probed geochemical scenarios, the transition from an abiotic world to the first life forms is to a large extent still unresolved.

6.9 Clinical Significance

The classification of essential and nonessential amino acids was first reported in nutritional studies done in the early 1900s. One study (Rose 1957), found that the human body was capable of staying in nitrogen balance with a diet of only eight amino acids. These eight amino acids were the first classification of essential amino acids or indispensable amino acids. At this time, scientists were able to identify essential amino acids by conducting feeding studies with purified amino acids. The researchers found that when they removed individual essential amino acids from a diet, the subjects would be unable to grow or stay in nitrogen balance. Later studies found that certain amino acids are "conditionally essential," depending on the subject's metabolic state. For example, although a healthy adult may be able to synthesize tyrosine from phenylalanine, a young child may not have developed the required enzyme (phenylalanine hydroxylase) to perform this synthesis, and so they would be unable to synthesize tyrosine from phenylalanine, making tyrosine an essential amino acid under those circumstances. \

This concept also appears in different disease states. Basically, deviations from a standard healthy adult's metabolic state may place the body in a metabolic state that requires more than the standard-essential amino acids to be nitrogen balance. In general, the optimal ratio of essential amino acids and nonessential amino acids requires a balance dependent on physiological needs that differs between individuals. Finding the optimal ratio of amino acids in total parenteral nutrition for liver or kidney disease is a good example of different physiological states requiring different nutrient intakes. Therefore, the terms "essential amino acid" and "nonessential amino acids" may be misleading since all amino acids may be necessary to ensure optimal health.

During states of inadequate intake of essential amino acids such as vomiting or low appetite, clinical symptoms may appear. These symptoms may include depression, anxiety, insomnia, fatigue, weakness, growth stunting in the young, etc. These symptoms are mostly caused by a lack of protein synthesis in the body because of the lack of essential amino acids. Required amounts of amino acids are necessary to produce neurotransmitters, hormones, the growth of muscle, and other cellular processes. These deficiencies are usually present in poorer parts of the world or elderly adults with inadequate care.

Kwashiorkor and marasmus are examples of more severe clinical disorders caused by malnutrition and inadequate intake of essential amino acids. Kwashiorkor is a form of malnutrition characterized by peripheral edema, dry peeling skin with hyperkeratosis and hyperpigmentation, ascites, liver malfunction, immune deficits, anemia, and relatively unchanged muscle protein composition. It results from a diet with insufficient protein but adequate carbohydrates. Marasmus is a form of malnutrition characterized by wasting caused by inadequate protein and overall inadequate caloric intake.

6.10 Summary

Under this unit we have discussed as proteins are built as chains of amino acids, which then fold into unique three-dimensional**.** They are building blocks of proteins that are involved in every metabolic function of organisms. The side chain of the amino acids determines their physical and chemical properties. The chemical nature of these amino acids is determined by their functional groups. These functional groups are involved in carrying out several chemical processes in the organisms.Today, several tools are present to isolate and study amino acids in labs. The advanced technology has facilitated the sequencing of every protein to study from their basic unit, that is, the amino acid. Scientists are meticulously developing several other tools to tackle the challenges faced during the study of these molecules. The area of amino acid and protein research creates an intriguing possibility to discover and uncover several other mysterious properties of these amino acids and their functions in organisms.

6.11 Terminal questions

Q.1 Describe essential amino acids with examples.

Answer:---

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Q.2 What are the building blocks of proteins? Explain with examples.

Answer:--

Q.3 Explain the structure of any 4 amino acids.

Answer:--

Q. 4 Classify the amino acids with examples.

Answer:--

Q. 5 Write short notes on the followings.

(i) Essential amino acids

(ii) Non-essential amino acids

Answer:--

Q. 6 Describe different structures of amino acids with examples.

Answer:--

Further readings

1. Biochemistry- Lehninger A.L.
2. Textbook of Nutrition and Dietetics Ranjana Mahna
3. Biochemistry fourth edition-David Hames and Nigel Hooper.
4. Textbook of Biochemistry for Undergraduates - Rafi, M.D.
5. Textbook of Nutrition and Dietetics- Monika Sharma

Unit 7: Elementary knowledge & Structure

Structure

7.1 Introduction

Protein is a highly complicated molecule found in all living things and is very important for staying alive. Proteins also have a lot of nutrients in them, and they play a significant role in a lot of the chemical reactions that make life possible. Proteins were essential to scientists in the early 1800s, including Swedish chemist Jöns Jacob Berzelius, who came up with the term protein in 1838. It comes from the Greek word precious, which means "first in line". Proteins were discovered by accident in the early 1800s. Proteins are unique to each species, which means that the proteins of one species are not the same as the proteins of another. They are also specific to each organ in the body. For example, muscle proteins are different from those found in the liver and brain.

Proteins are immense biomolecules and macromolecules that are comprised of at least one long chain of amino acids. Proteins play an assortment of jobs in creatures, including starting metabolic occasions, DNA replication, answering boosts, giving cells and organic entities structure, and moving materials starting with one spot then onto the next. Proteins vary essentially in their amino corrosive succession, which is represented by their qualities' nucleotide arrangement and typically finishes in protein collapsing into such a particular 3D design that directs its action. A polypeptide is a straight chain of amino corrosive deposits. No less than one extensive polypeptide can be found in a protein. Short polypeptides (under 20-30 build-ups) are by and large alluded to as peptides and are seldom viewed as proteins.

Objectives

This is the seventh unit (Elementary knowledge & Structure) under second block (Introduction to proteins and enzymes). Under this unit, we have following objectives. These are as under:

- To know elementary knowledge of amino acids
- To discuss different structures of proteins
- To know nutritional value of protein and protein foods
- To discuss protein deficiency and protein supplements

7.2 Elementary knowledge

Each amino acid has a peptide bond that connects it to the next one. A polypeptide chain is made up of a lot of these bonds. This is when one or more of these peptide chains start to twist or fold on their own, making a protein. Primary Protein Structure is the unique configuration and order in which the amino acids (the building blocks) mix and join together to create a protein molecule that we are interested in. In the secondary structure, two forms are created: α-helix

Protein molecules are much bigger than salt and sugar molecules and are made up of many amino acids linked together to make long chains, just like beads are strung together on a string. About 20 different amino acids are found in naturally occurring amounts in proteins.

Proteins that do the same thing have similar amino acid compositions and sequences. Despite the knowledge that it isn't yet possible to figure out all of a protein's functions from its amino acid sequence, there are known relationships between structure and function attributed to the amino acids that make up proteins.

7.3 Brief outline on elementary idea of proteins

Protein structure:

The majority of proteins fold into distinct three-dimensional structures. The native conformation of a protein is the shape into which it folds spontaneously. Many proteins can fold by themselves due to the chemical characteristics of their amino acids, but others require the assistance of molecular chaperones to fold in their native states.

- The amino acid sequence is the primary structure**.** A polyamide is a type of protein.
- **Secondary structure**: local structures that repeat in a regular pattern and are held together by hydrogen bonds. The -helix, -sheet, and twists are the most typical examples. Since secondary structures are local, a protein molecule can have several different secondary structure regions.
- The overall form of a single protein molecule, as well as the spatial relationship between the secondary structures. Nonlocal interactions, such as the development of a hydrophobic core, but also salt bridges, hydrogen bonds, disulphide bonds, and even posttranslational changes, are used to stabilize the tertiary structure. The terms "tertiary structure" and "fold" are frequently interchanged. The protein's basic function is controlled by the tertiary structure.
- In this application, quaternary structure refers to the structure generated by multiple protein molecules (polypeptide chains) that operate as a single protein complex.

Important Questions

Q. 1 What is protein and why is it necessary?

Proteins are the building blocks of living beings. Protein is present in every human cell. An amino acid chain forms the basic building block of proteins. For our body to repair damaged cells and create new ones, we need protein in our daily diet. Children, teenagers, and pregnant women all need protein for healthy growth and development.

Q. 2 What is protein deficiency?

When protein consumption is insufficient to meet our body's needs, we have a protein deficiency. Worldwide, an estimated 1 billion people experience inadequate protein intake. Up to 30% of South Asia and Central Africa children have insufficient protein intake, making these regions among the worst affected.

Q. 3 What are the four types of proteins?

Primary, secondary, tertiary, and quaternary structures are the four levels of complexity that can be used to characterize the entire structure of a protein.

7.4 Proteins and Their Functions

Catalysts

Enzymes are the proteins that do every one of the substance occasions that happen inside a cell. They likewise aid the recovery and production of DNA particles, as well as the execution of mind-boggling methodology.

7.4.1 Chemicals

Proteins are associated with the creation of an assortment of chemicals that guide the adjusting of the body's parts. For example, chemicals, for example, insulin, which helps with glucose guidelines, and secretin. It likewise assumes a part in the processing and the creation of stomach-related juices.

7.4.2 Primary structure of the protein

Proteins' primary structure is the specific arrangement of amino acids that form their chains. The precise sequence of proteins is critical since it defines the protein's ultimate fold and, as a result, its function. Proteins are composed of a large number of peptide chains linked collectively. The amino acids in these chains are organized in a specific sequence that is unique to each protein. Any alteration in the protein's sequence has an impact on the complete protein. The amino acid sequence in the polypeptide chain is the protein's fundamental structure. If proteins were popcorn stringers, their basic structure would be the sequence in which shapes and variations of popped maize are strung together to construct a Christmas tree.

The core structure of a protein is maintained by covalent peptide bonds that connect the amino acids. The primary insulin structure, which was the first protein sequenced, is depicted in the diagram below. All known genetic illnesses, including cystic fibrosis, sickle cell anaemia, albinism, and others, are produced by mutations that create changes in primary protein structures, which then lead to changes in secondary, tertiary, and most likely quarterly structures.

7.4.3 Secondary structure of the protein

The connection among the amine and carboxyl gatherings of the peptide interface causes these polypeptide chains to crease. The construction alludes to the conceivable state of an extensive polypeptide chain. They can be found in two primary sorts of constructions: helix and creased sheet structures.

The Helix is one of the most well-known ways for a polypeptide chain to create all potential hydrogen bonds by curving into a right-given screw and hydrogen-holding the – NH gathering of every amino corrosive build-up to the – CO of the adjoining helix turn. The polypeptide chains shaped a right-given screw as they wound. All peptide chains are stretched to nearly maximum extension and then arranged side by side in this structure, which is kept together by a hydrogen bond. A pleated sheet is the name given to the structure because it mimics the pleated folds of drapery.

7.4.4 Nutritional value of protein

The nutritional value of a protein is measured by the quantity of essential amino acids it contains. Different foods contain different amounts of essential amino acids. Generally:

- Animal products (such as chicken, beef or fish and dairy products) have all of the essential amino acids and are known as 'complete' protein (or ideal or high-quality protein).
- **Soy products**, quinoa and the seed of a leafy green called amaranth (consumed in Asia and the Mediterranean) also have all of the essential amino acids.
- Plant proteins (beans, lentils, nuts and **whole grains**) usually lack at least one of the essential amino acids and are considered 'incomplete' proteins.

People following a strict vegetarian or vegan diet need to choose a variety of protein sources from a combination of plant foods every day to make sure they get an adequate mix of essential amino acids. If you follow a vegetarian or vegan diet, as long as you eat a wide variety of foods, you can usually get the protein you need. For example, a meal containing cereals and legumes, such as baked beans on toast, provides all the essential amino acids found in a typical meat dish.

7.5 Protein foods

Some food sources of dietary protein include:

- lean meats – beef, lamb, veal, pork, kangaroo
- poultry – chicken, turkey, duck, emu, goose, bush birds
- fish and seafood – fish, prawns, crab, lobster, mussels, oysters, scallops, clams
- eggs
- dairy products – milk, yoghurt (especially Greek yoghurt), cheese (especially cottage cheese)
- nuts (including nut pastes) and seeds – almonds, pine nuts, walnuts, macadamias, hazelnuts, cashews, pumpkin seeds, sesame seeds, sunflower seeds
- legumes and beans – all beans, lentils, chickpeas, split peas, tofu.

Some grain and cereal-based products are also sources of protein, but are generally not as high in protein as meat and meat-alternative products.

7.6 Food groups

We often see bodybuilders and physical trainer drinking whey protein along with milk to build-up metabolism and strength. When it comes to our body, our hair and nails are mostly made of proteins. Basically, proteins are the fundamental building blocks of our body. They are large and complex macromolecules or bio-molecules which perform a major role in the functioning and regulating of our body cells, tissues and other organs in the human body. They are also used in providing strength to our body in producing hormones, enzymes, and other metabolic chemicals. They are also involved in functioning and regulating of our body cells, tissues and organs.

Proteins are composed of amino acids, arranged into different groups. These fundamental amino acids sequences are specific and its arrangements are controlled by the DNA. Since our body cannot synthesize these essential amino acids by its own, we should have plenty of protein foods in our everyday diet to keep our body metabolisms stable.

The different food groups are:

- Fruit and Vegetables - These are good sources of vitamins and minerals and fibre. You should aim to eat 5 portions a day.
- Proteins - Proteins such as beans, fish, eggs and meat are important to help us grow and build muscles.

- Carbohydrates - Starchy foods like potatoes, bread, rice and pasta should make up just a third of the food you eat. They give us energy.
- Oil and spreads - Choose unsaturated oils and spreads and use in small amounts.
- Dairy and Alternative - These are a source of calcium which is important for strong teeth and bones.

7.7 Protein deficiency

Protein deficiency means not getting enough protein in your diet. Protein deficiency is rare in Australia, as the Australian diet generally includes far more protein than we actually need. However, protein deficiency may occur in people with special requirements, such as older people and people following strict vegetarian or vegan diets. Symptoms of protein deficiency include:

- Wasting and shrinkage of muscle tissue
- Oedema (build-up of fluids, particularly in the feet and ankles)
- Anaemia (the blood’s inability to deliver sufficient oxygen to the cells, usually caused by dietary deficiencies such as lack of iron)
- Slow growth (in children).

Protein (maintaining muscle)

From around 50 years of age, humans begin to gradually lose skeletal muscle. This is known as sarcopenia and is common in older people. Loss of muscle mass is worsened by chronic illness, poor diet and inactivity. Meeting the daily recommended protein intake may help you maintain muscle mass and strength. This is important for maintaining your ability to walk and reducing your risk of injury from falls. To maintain muscle mass, it’s important for older people to eat protein ‘effectively’. This means consuming high-quality protein foods, such as lean meats.

7.8 Protein shakes, powders and supplements

Protein shakes, powders and supplements are unnecessary for most Australians’ health needs. According to the most recent national nutrition survey, 99% of Australians get enough protein through the food they eat. Any protein you eat on top of what your body needs will either be excreted from your body as waste, or stored as weight gain. The best way for you to get the protein you need is to eat a wide variety of protein-rich foods as outlined in the Australian Dietary Guidelines, as part of a balanced diet. But if you are still interested in using protein shakes, powders and supplements, talk to your doctor.

7.9 Protein and exercise

Soon after exercising, it’s recommended that you have a serve of high-quality protein (such as a glass of milk or tub of yoghurt) with a carbohydrate meal to help maintain your body’s protein balance. Studies have shown this is good for you, even after low to moderate aerobic exercise (such as walking), particularly for older adults. People who exercise vigorously or are trying to put on muscle mass do not need to consume extra protein. High-protein diets do not lead to increased muscle mass. It’s the stimulation of muscle tissue through exercise, not extra dietary protein, which leads to muscle growth.

Studies show that weight-trainers who do not eat extra protein (either in food or protein powders) still gain muscle at the same rate as weight-trainers who supplement their diets with protein. The protein recommendations in the Guidelines provide enough protein to build and repair muscles, even for body builders and athletes. A very high-protein diet can strain the kidneys and liver. It can also prompt excessive loss of the mineral calcium, which can increase your risk of osteoporosis.

7.10 Summary

Under this unit we have discussed as proteins are built as chains of amino acids, which then fold into unique three-dimensional**.** They are building blocks of proteins that are involved in every metabolic function of organisms. The side chain of the amino acids determines their physical and chemical**.** The total amino acid profile of a food protein expressed in relation to some standard is a good indicator of the potential nutritive value, but it may at times be misleading if one or more of the essential amino acids are only partially available. If this is true, the "actual" nutritive value of the protein will be less than its "predicted" value, obtained from its amino acid profile. It is therefore critical that the availability of the reactive, but most frequently limiting essential amino acids, Iysine, methionine, and cystine, be known. This is especially true for proteins present in processed foods and food ingredients.

7.11 Terminal questions

Q.1 Explain proteins with examples.

Answer:---

Q.2 What are the building blocks of proteins? Explain with examples.

Answer:---

Q.3 Explain digestion of proteins.

Answer:---

Q. 4 Describe different structures of proteins.

Answer:---

Q. 5 Write short notes on the followings.

(i) Amino acids

(ii) Primary structure of proteins

Answer:---

Q. 6 Describe digestion and absorption of proteins.

Answer:---

Further readings

1. Biochemistry- Lehninger A.L.

2. Textbook of Nutrition and Dietetics Ranjana Mahna

3. Biochemistry fourth edition-David Hames and Nigel Hooper.

4. Textbook of Biochemistry for Undergraduates - Rafi, M.D.

5. Textbook of Nutrition and Dietetics- Monika Sharma

Unit 7: Elementary knowledge & Structure

Structure

7.1 Introduction

Protein is a highly complicated molecule found in all living things and is very important for staying alive. Proteins also have a lot of nutrients in them, and they play a significant role in a lot of the chemical reactions that make life possible. Proteins were essential to scientists in the early 1800s, including Swedish chemist Jöns Jacob Berzelius, who came up with the term protein in 1838. It comes from the Greek word precious, which means “first in line”. Proteins were discovered by accident in the early 1800s. Proteins are unique to each species, which means that the proteins of one species are not the same as the proteins of another. They are also specific to each organ in the body. For example, muscle proteins are different from those found in the liver and brain.

Proteins are immense biomolecules and macromolecules that are comprised of at least one long chain of amino acids. Proteins play an assortment of jobs in creatures, including starting metabolic occasions, DNA replication, answering boosts, giving cells and organic entities structure, and moving materials starting with one spot then onto the next. Proteins vary essentially in their amino corrosive succession, which is represented by their qualities' nucleotide arrangement and typically finishes in protein collapsing into such a particular 3D design that directs its action. A polypeptide is a straight chain of amino corrosive deposits. No less than one extensive polypeptide can be found in a protein. Short polypeptides (under 20-30 build-ups) are by and large alluded to as peptides and are seldom viewed as proteins.

Objectives

This is the seventh unit (Elementary knowledge & Structure) under second block (Introduction to proteins and enzymes). Under this unit, we have following objectives. These are as under:

- To know elementary knowledge of amino acids
- To discuss different structures of proteins
- To know nutritional value of protein and protein foods
- To discuss protein deficiency and protein supplements

7.2 Elementary knowledge

Each amino acid has a peptide bond that connects it to the next one. A polypeptide chain is made up of a lot of these bonds. This is when one or more of these peptide chains start to twist or fold on their own, making a protein. Primary Protein Structure is the unique configuration and order in which the amino acids (the building blocks) mix and join together to create a protein molecule that we are interested in. In the secondary structure, two forms are created: α-helix

Protein molecules are much bigger than salt and sugar molecules and are made up of many amino acids linked together to make long chains, just like beads are strung together on a string. About 20 different amino acids are found in naturally occurring amounts in proteins. Proteins that do the same thing have similar amino acid compositions and sequences. Despite the knowledge that it isn't yet possible to figure out all of a protein's functions from its amino acid sequence, there are known relationships between structure and function attributed to the amino acids that make up proteins.

7.3 Brief outline on elementary idea of proteins

Protein structure:

The majority of proteins fold into distinct three-dimensional structures. The native conformation of a protein is the shape into which it folds spontaneously. Many proteins can fold by themselves due to the chemical characteristics of their amino acids, but others require the assistance of molecular chaperones to fold in their native states.

- The amino acid sequence is the **primary structure.** A polyamide is a type of protein.
- **Secondary structure**: local structures that repeat in a regular pattern and are held together by hydrogen bonds. The -helix, -sheet, and twists are the most typical examples. Since secondary structures are local, a protein molecule can have several different secondary structure regions.
- The overall form of a single protein molecule, as well as the spatial relationship between the secondary structures. Nonlocal interactions, such as the development of a hydrophobic core, but also salt bridges, hydrogen bonds, disulphide bonds, and even posttranslational changes, are used to stabilize the tertiary structure. The terms "tertiary structure" and "fold" are frequently interchanged. The protein's basic function is controlled by the tertiary structure.
- In this application, quaternary structure refers to the structure generated by multiple protein molecules (polypeptide chains) that operate as a single protein complex.

Important Questions

Q. 1 What is protein and why is it necessary?

Proteins are the building blocks of living beings. Protein is present in every human cell. An amino acid chain forms the basic building block of proteins. For our body to repair damaged cells and create new ones, we need protein in our daily diet. Children, teenagers, and pregnant women all need protein for healthy growth and development.

Q. 2 What is protein deficiency?

When protein consumption is insufficient to meet our body's needs, we have a protein deficiency. Worldwide, an estimated 1 billion people experience inadequate protein intake.

Up to 30% of South Asia and Central Africa children have insufficient protein intake, making these regions among the worst affected.

Q. 3 What are the four types of proteins?

Primary, secondary, tertiary, and quaternary structures are the four levels of complexity that can be used to characterize the entire structure of a protein.

7.4 Proteins and Their Functions

Catalysts

Enzymes are the proteins that do every one of the substance occasions that happen inside a cell. They likewise aid the recovery and production of DNA particles, as well as the execution of mind-boggling methodology.

7.4.1 Chemicals

Proteins are associated with the creation of an assortment of chemicals that guide the adjusting of the body's parts. For example, chemicals, for example, insulin, which helps with glucose guidelines, and secretin. It likewise assumes a part in the processing and the creation of stomach-related juices.

7.4.2 Primary structure of the protein

Proteins' primary structure is the specific arrangement of amino acids that form their chains. The precise sequence of proteins is critical since it defines the protein's ultimate fold and, as a result, its function. Proteins are composed of a large number of peptide chains linked collectively. The amino acids in these chains are organized in a specific sequence that is unique to each protein. Any alteration in the protein's sequence has an impact on the complete protein. The amino acid sequence in the polypeptide chain is the protein's fundamental structure. If proteins were popcorn stringers, their basic structure would be the sequence in which shapes and variations of popped maize are strung together to construct a Christmas tree.

The core structure of a protein is maintained by covalent peptide bonds that connect the amino acids. The primary insulin structure, which was the first protein sequenced, is depicted in the diagram below. All known genetic illnesses, including cystic fibrosis, sickle cell anaemia, albinism, and others, are produced by mutations that create changes in primary protein structures, which then lead to changes in secondary, tertiary, and most likely quarterly structures.

7.4.3 Secondary structure of the protein

The connection among the amine and carboxyl gatherings of the peptide interface causes these polypeptide chains to crease. The construction alludes to the conceivable state of an extensive polypeptide chain. They can be found in two primary sorts of constructions: helix and creased sheet structures.

The Helix is one of the most well-known ways for a polypeptide chain to create all potential hydrogen bonds by curving into a right-given screw and hydrogen-holding the – NH gathering of every amino corrosive build-up to the – CO of the adjoining helix turn. The polypeptide chains shaped a right-given screw as they wound. All peptide chains are stretched to nearly maximum extension and then arranged side by side in this structure, which is kept together by a hydrogen bond. A pleated sheet is the name given to the structure because it mimics the pleated folds of drapery.

7.4.4 Nutritional value of protein

The nutritional value of a protein is measured by the quantity of essential amino acids it contains. Different foods contain different amounts of essential amino acids. Generally:

- Animal products (such as chicken, beef or fish and dairy products) have all of the essential amino acids and are known as 'complete' protein (or ideal or high-quality protein).
- **Soy products**, quinoa and the seed of a leafy green called amaranth (consumed in Asia and the Mediterranean) also have all of the essential amino acids.
- Plant proteins (beans, lentils, nuts and whole grains) usually lack at least one of the essential amino acids and are considered 'incomplete' proteins.

People following a strict vegetarian or vegan diet need to choose a variety of protein sources from a combination of plant foods every day to make sure they get an adequate mix of essential amino acids. If you follow a vegetarian or vegan diet, as long as you eat a wide variety of foods, you can usually get the protein you need. For example, a meal containing cereals and legumes, such as baked beans on toast, provides all the essential amino acids found in a typical meat dish.

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Some food sources of dietary protein include:

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- poultry – chicken, turkey, duck, emu, goose, bush birds
- fish and seafood – fish, prawns, crab, lobster, mussels, oysters, scallops, clams
- eggs
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- legumes and beans – all beans, lentils, chickpeas, split peas, tofu.

Some grain and cereal-based products are also sources of protein, but are generally not as high in protein as meat and meat-alternative products.

7.6 Food groups

We often see bodybuilders and physical trainer drinking whey protein along with milk to build-up metabolism and strength. When it comes to our body, our hair and nails are mostly made of proteins. Basically, proteins are the fundamental building blocks of our body. They are large and complex macromolecules or bio-molecules which perform a major role in the functioning and regulating of our body cells, tissues and other organs in the human body. They are also used in providing strength to our body in producing hormones, enzymes, and other metabolic chemicals. They are also involved in functioning and regulating of our body cells, tissues and organs.

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7.7 Protein deficiency

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- Wasting and shrinkage of muscle tissue
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Protein (maintaining muscle)

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7.8 Protein shakes, powders and supplements

Protein shakes, powders and supplements are unnecessary for most Australians’ health needs. According to the most recent national nutrition survey, 99% of Australians get enough protein through the food they eat. Any protein you eat on top of what your body needs will either be excreted from your body as waste, or stored as weight gain. The best way for you to get the protein you need is to eat a wide variety of protein-rich foods as outlined in the Australian Dietary Guidelines, as part of a balanced diet. But if you are still interested in using protein shakes, powders and supplements, talk to your doctor.

7.9 Protein and exercise

Soon after exercising, it’s recommended that you have a serve of high-quality protein (such as a glass of milk or tub of yoghurt) with a carbohydrate meal to help maintain your body’s protein balance. Studies have shown this is good for you, even after low to moderate aerobic exercise (such as walking), particularly for older adults. People who exercise vigorously or are trying to put on muscle mass do not need to consume extra protein. High-protein diets do not lead to increased muscle mass. It’s the stimulation of muscle tissue through exercise, not extra dietary protein, which leads to muscle growth.

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7.10 Summary

Under this unit we have discussed as proteins are built as chains of amino acids, which then fold into unique three-dimensional**.** They are building blocks of proteins that are involved in every metabolic function of organisms. The side chain of the amino acids determines their physical and chemical**.** The total amino acid profile of a food protein expressed in relation to some standard is a good indicator of the potential nutritive value, but it may at times be misleading if one or more of the essential amino acids are only partially available. If this is true, the "actual" nutritive value of the protein will be less than its "predicted" value, obtained from its amino acid profile. It is therefore critical that the availability of the reactive, but most frequently limiting essential amino acids, Iysine, methionine, and cystine, be known. This is especially true for proteins present in processed foods and food ingredients.

7.11 Terminal questions

Q.1 Explain proteins with examples.

Answer:---

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Q.2 What are the building blocks of proteins? Explain with examples.

Answer:--

Q.3 Explain digestion of proteins.

Answer:--

Q. 4 Describe different structures of proteins.

Answer:--

Q. 5 Write short notes on the followings.

(i) Amino acids

(ii) Primary structure of proteins

Answer:--

Q. 6 Describe digestion and absorption of proteins.

Answer:--

Further readings

1. Biochemistry- Lehninger A.L.
2. Textbook of Nutrition and Dietetics Ranjana Mahna
3. Biochemistry fourth edition-David Hames and Nigel Hooper.
4. Textbook of Biochemistry for Undergraduates - Rafi, M.D.
5. Textbook of Nutrition and Dietetics- Monika Sharma

Unit 8: Enzymes

Structure

8.1 Introduction

The cell is the structural and functional unit of life—the basic building block of living systems. Cells have the capability to effectively utilize biocatalysts, known as enzymes, which have outstanding catalytic efficiency and both substrate and reaction specificity. Enzymes have amazing catalytic power and their high level of specificity for their substrate makes them suitable for biological reactions. They are crucial for cellular metabolism.

Each and every chemical reaction that takes place in plants, micro-organisms and animals proceeds at a quantifiable rate as a direct result of enzymatic catalysis. Most of the history of biochemistry is directly or indirectly related to the history of enzyme research. Catalysis in biological systems was initially reported in the early 1800s based on research into the digestion of meat. In this report the catalytic activity of secretions from the stomach, the conversion of starch into sugar by saliva, and various plant extracts were reported.

Objectives

This is the eight unit (Enzymes) under second block (Introduction to proteins and enzymes) of Fundamentals of nutritional Biochemistry. Under eighth unit, we have following objectives. These are as under:

- To know the introduction and definition of enzymes
- To know the general properties of enzymes
- To discuss cofactor, coenzyme and active sites
- To discuss nomenclature and classification of enzymes

8.1 Introduction

Enzymes are the biological macromolecules which speed up the rate of biochemical reactions in living organisms without undergoing any change. They are also called as biological catalysts. Enzymes are also called as biocatalyst becausethey act as a catalyst in living organisms and regulate the rate of chemical reactions without itself being altered in the process. Enzymes are not only used to catalyse biochemical reactions in living cells but also used to catalyse a wide range of commercially important processes such as in the production of sweetening agents and the modification of antibiotics, in washing powders in analytical assays for clinical, forensic and environmental applications.

Enzymes are the complex protein molecules, often called biocatalysts, which are produced by living cells. They are highly specific both in the reactions that they catalyze and in their choice of reactants, which are known as substrates. An enzyme typically catalyzes a single chemical reaction or a set of closely related reactions. Side reactions resulting in the wasteful formation of by-products are rare in enzyme-catalyzed reactions, in comparison to uncatalyzed ones. Enzymes can also be defined as soluble, colloidal and organic catalysts that are produced by living cells, but are capable of acting independently of the cells.

8.2 Brief History of Enzymes

The existence of biological catalysis was first recognized and described during the late 18th century while studying the digestion of meat by secretion of the stomach. Subsequently, Louis Pasteur concluded in 1850s that fermentation of sugar into alcohol by yeast is catalyzed by “ferments”. He postulated that these ferments were inseparable from the structure of living yeast cells, a view called ‘vitalism’ that prevailed for many years. He wrote that "alcoholic fermentation is an act correlated with the life and the organization of the yeast cells, not with the death or putrefaction. The first enzyme discovered was Diastase from malt by Anselme Payen in 1833.

The German physiologist F.W. Kuhne coined the term enzyme (Greek meaning "in heaven") in 1878 to represent the “ferments”when he was studying the ability of yeast to produce alcohol from sugars. In 1898, Duclaux proposed that all enzymes should have suffix ―ase. The word enzyme is derived from the Greek words *en* (meaning ‘within’) and *zume* (meaning ‘yeast’). In 1897, Eduard Buchner studied the ability of dead yeast extracts to ferment sugar and he found that the sugar was fermented even when there was no living yeast cells in the mixture.

Eduard Buchner isolated the enzyme for the first time in 1903 for which he was awarded Nobel Prize in Chemistry for the discovery of "cell free fermentation". First enzyme recognized as protein was jack bean urease, crystallized in 1926 by James B. Sumner of Cornell University. He later, in 1946, received the Nobel Prize for his work with the enzyme urease. Urease is an enzyme that catalyzes the conversion of urea to ammonia and carbon dioxide. Certain bacteria that convert urea to ammonia as part of the nitrogen cycle contain this enzyme.

8.3 General Properties of Enzymes

The general properties of enzymes can be summarized as follows.

8.3.1 Proteinaceous in nature

All enzymes are proteins, except ribozymes (RNA molecules having catalytic activity).

8.3.2 Colloidal nature

Enzymes exist as hydrophilic colloids in protoplasm.

8.3.3 Substrate specificity

Enzymes possess remarkable specificity in that they generally catalyse the conversion of only one type of substrate molecule into product molecules. For example, maltase acts only on maltose while pancreatic lipase acts in a variety of fats. The substrate specificity of enzyme is based on amino acids sequence in the catalytic site as well as the optical isomeric form of the substrate.

Fig. 1 Different properties of enzymes

8.3.4 Catalytic properties

- Enzymes are only required in very low concentrations.
- They don't initiate the catalysis but accelerate the rate of catalysis by lowering the activation energy.
- They remain unchanged at the end of reaction.
- They do not alter the properties of end products.
- Enzymes accelerate the forward or reverse reactions to attain the equilibrium but don't shift the equilibrium.
- Most of the enzymes catalyzed reactions are reversible.

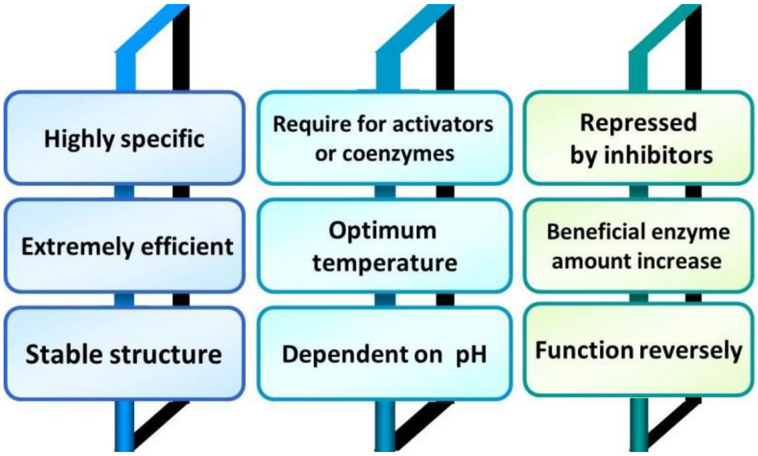
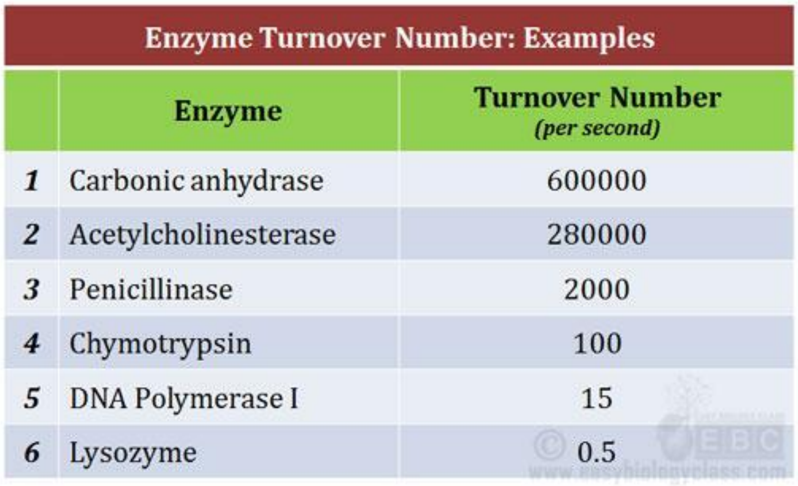


Fig. 2 Catalytic properties of enzymes

8.3.5 Turn over Number

It is the number of substrate molecules converted per unit of time when its active site is saturated with substrate. Turn over number varies from 10^2 to 10^3 $sec^{-1.}$ For example the turn over number for sucrose is 10^4, that means, one sucrase molecule converts 10,000 sucrose molecules into products. Similarly, it is 36 million for carbonic anhydrase (fastest enzyme) and 5 million for catalase (2nd fastest enzymes).



Enzyme Turnover Number: Examples

	Enzyme	Turnover Number (per second)
1	Carbonic anhydrase	600000
2	Acetylcholinesterase	280000
3	Penicillinase	2000
4	Chymotrypsin	100
5	DNA Polymerase I	15
6	Lysozyme	0.5

Fig. 3

8.3.6 Sensitivity

Enzymes are highly sensitive to change in pH, temperature and inhibitors. Enzymes work best at a narrow range of condition called optimum.

8.3.7 Temperature

Enzymes are very sensitive to heat and temperature i.e. they are heat labile. The optimum temp of enzymes is 20-35°C. They become inactivated at very low temperature and denatured (destroyed) at very high temp i.e. greater than 45°C. In archebacterium, Pyrococcus furious, the optimum temperature of hydrogenise is greater than 95°C. This heat-stable enzyme enables *Pyrococcus* to grow at 100°C.

8.3.8 pH Value

The optimum pH of most endoenzyme is pH 7.0 (neutral pH). However, digestive enzymes can function at different pH. For example, salivary amylase act best at pH 6.8, pepsin act best at pH 2.0 etc. Sometime a change in pH causes the reverse reaction, e.g. at pH 7.0

phosphorylase break down starch into glucose 1- phosphate while at pH5 the reverse reaction occurs.

8.3.9 Inhibitors

Enzymes are also sensitive to certain inhibitors. Inhibitors are any molecules like cellular metabolites, drugs or toxins which reduce or check enzyme activity.

8.4 Chemical Nature

Almost all enzymes are proteins except ribozymes (catalytic RNAs).Ribozymes are RNA molecule having catalytic activity and are discovered during 1980s. Protein enzyme molecule is composed of one or more amino acid chains called polypeptide chains. The amino acid sequence determines the characteristic folding patterns of the protein's structure, which is essential to enzyme specificity. Amino acid-based enzymes are globular proteins that range in size from less than 100 to more than 2 000 amino acid residues. These amino acids can be arranged as one or more polypeptide chains that are folded and bent to form a specific three-dimensional structure, incorporating a small area known as the active site, where the substrate actually binds.

8.5 Cofactors and Coenzyme

A **coenzyme** is a substance that works with an enzyme to initiate or aid the function of the enzyme. It can be considered a helper molecule for a biochemical reaction. Coenzymes are small, nonproteinaceous molecules that provide a transfer site for a functioning enzyme. They are intermediate carriers of an atom or group of atoms, allowing a reaction to occur. Coenzymes are not considered part of an enzyme's structure. They are sometimes referred to as **cosubstrates**. Coenzymes cannot function on their own and require the presence of an enzyme. Some enzymes require several coenzymes and cofactors. Some examples of coenzymes are as given below.

Examples: The B vitamins serve as coenzymes essential for enzymes to form fats, carbohydrates, and proteins. An example of a non-vitamin coenzyme is S-adenosyl methionine, which transfers a methyl group in bacteria as well as in eukaryotes and archaea.

Coenzymes, Cofactors, and Prosthetic groups

Some texts consider all helper molecules that bind to an enzyme to be types of cofactors, while others divide the classes of chemicals into three groups:

- **Coenzymes** are nonprotein organic molecules that bind loosely to an enzyme. Many (not all) are vitamins or are derived from vitamins. Many coenzymes contain adenosine monophosphate (AMP). Coenzymes may be described as either cosubstrates or prosthetic groups.
- **Cofactors** are inorganic species or at least non-protein compounds that aid enzyme function by increasing the rate of catalysis. Typically, cofactors are metal ions. Some metallic elements have no nutritional value, but several trace elements function as cofactors in biochemical reactions, including iron, copper, zinc, magnesium, cobalt, and molybdenum. Some trace elements that appear to be important for nutrition do not appear to act as cofactors, including chromium, iodine, and calcium.
- **Cosubstrates** are coenzymes that bind tightly to a protein, yet will be released and bind again at some point.
- **Prosthetic groups** are enzyme partner molecules that bind tightly or covalently to the enzyme (remember, coenzymes bind loosely). While cosubstrates bind temporarily, prosthetic groups permanently bond with a protein. Prosthetic groups help proteins bind other molecules, act as structural elements, and act as charge carriers. An example of a prosthetic group is heme in hemoglobin, myoglobin, and cytochrome. The iron (Fe) found at the center of the heme prosthetic group allows it to bind and release oxygen in the lung and tissues, respectively. Vitamins are also examples of prosthetic groups.

An argument for using the term cofactors to encompass all types of helper molecules is that many times both organic and inorganic components are necessary for an enzyme to function. There are a few related terms also related to coenzymes:

- **Apoenzyme** is the name given to an inactive enzyme that lacks its coenzymes or cofactors.
- The protein part of the enzyme on its own without its cofactor is termed as apoenzyme.
- **Holoenzyme** is the term used to describe an enzyme that is complete with its coenzymes and cofactors.
- **Holoprotein** is the word used for a protein with a prosthetic group or cofactor.

A coenzyme binds to a protein molecule (the apoenzyme) to form an active enzyme (the holoenzyme).

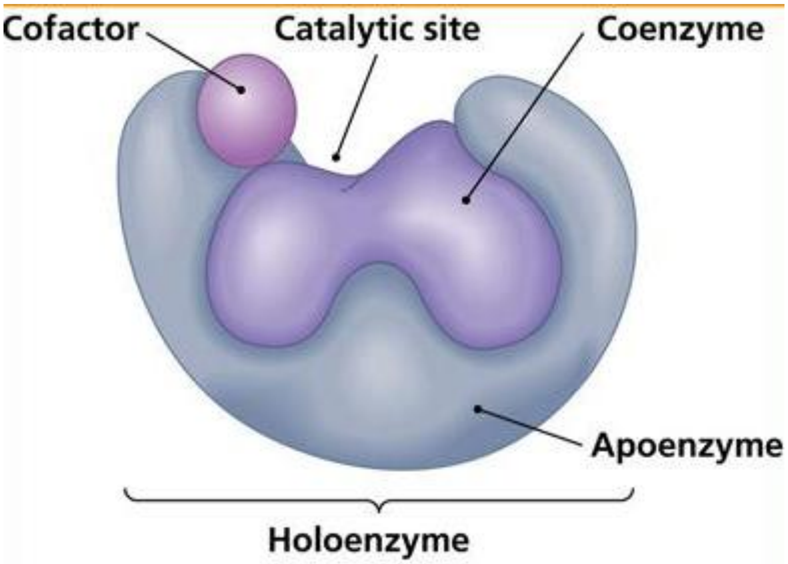
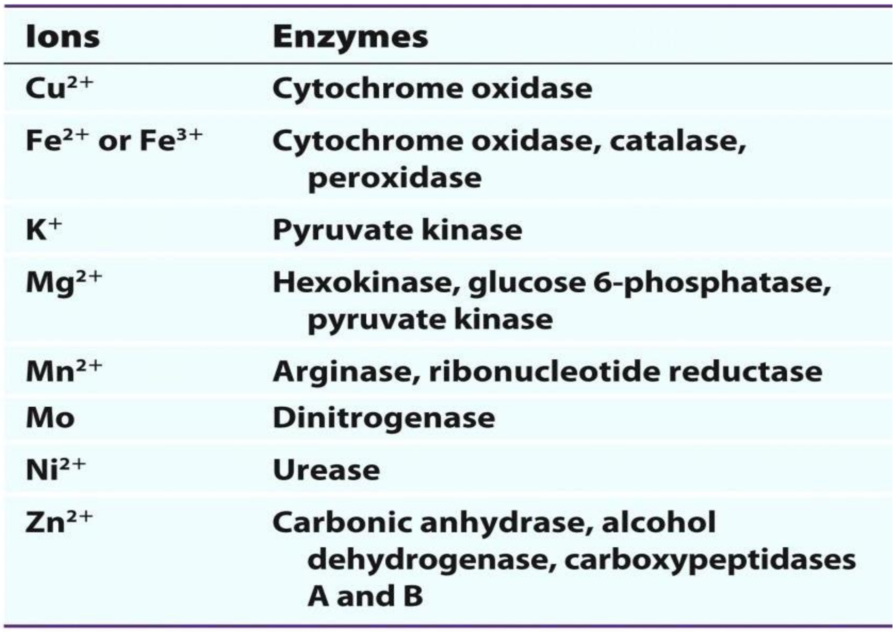


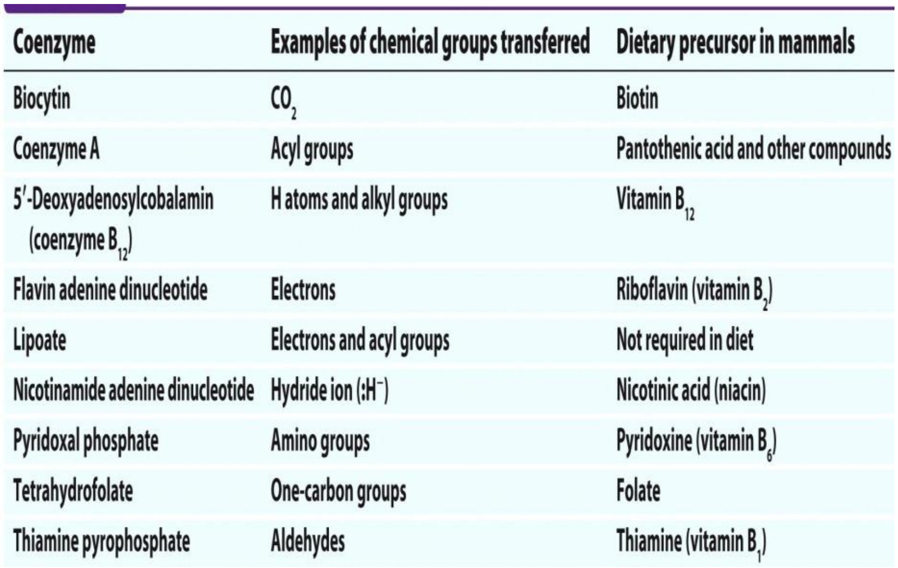
Fig. 4 Holoenzyme

Some inorganic ions that serve as cofactors for enzymes are given in the following table.



Ions	Enzymes
Cu^{2+}	Cytochrome oxidase
Fe^{2+} or Fe^{3+}	Cytochrome oxidase, catalase, peroxidase
K^{+}	Pyruvate kinase
Mg^{2+}	Hexokinase, glucose 6-phosphatase, pyruvate kinase
Mn^{2+}	Arginase, ribonucleotide reductase
Mo	Dinitrogenase
Ni^{2+}	Urease
Zn^{2+}	Carbonic anhydrase, alcohol dehydrogenase, carboxypeptidases A and B

Some coenzymes that serve as transient carrier of specific atoms or functional groups are given in the following table.



Coenzyme	Examples of chemical groups transferred	Dietary precursor in mammals
Biocytin	CO_2	Biotin
Coenzyme A	Acyl groups	Pantothenic acid and other compounds
5′-Deoxyadenosylcobalamin (coenzyme B_{12})	H atoms and alkyl groups	Vitamin B_{12}
Flavin adenine dinucleotide	Electrons	Riboflavin (vitamin B_2)
Lipoate	Electrons and acyl groups	Not required in diet
Nicotinamide adenine dinucleotide	Hydride ion (:H^-)	Nicotinic acid (niacin)
Pyridoxal phosphate	Amino groups	Pyridoxine (vitamin B_6)
Tetrahydrofolate	One-carbon groups	Folate
Thiamine pyrophosphate	Aldehydes	Thiamine (vitamin B_1)

8.6 Enzyme Active Sites

Enzyme-catalyzed reactions take place within the confines of a pocket on the enzyme called the active site. Uncatalyzed reactions tend to be slow because most biological molecules are quite stable in the neutral-pH, mild-temperature, aqueous environment inside cells. Enzymes greatly increase the rates of biological reactions by providing a specific environment within which a reaction can occur more rapidly. The active site may well involve only a small number (less than 10) of the constituent amino acids.

The reactant molecule is referred to as the substrate. The surface of the active site is lined with amino acid residues with substituent groups that bind to the substrate and catalyze its chemical transformation. Often, the active site encloses the substrate, sequestering it from solution. The active site of the enzyme chymotypsin is shown in given fig.

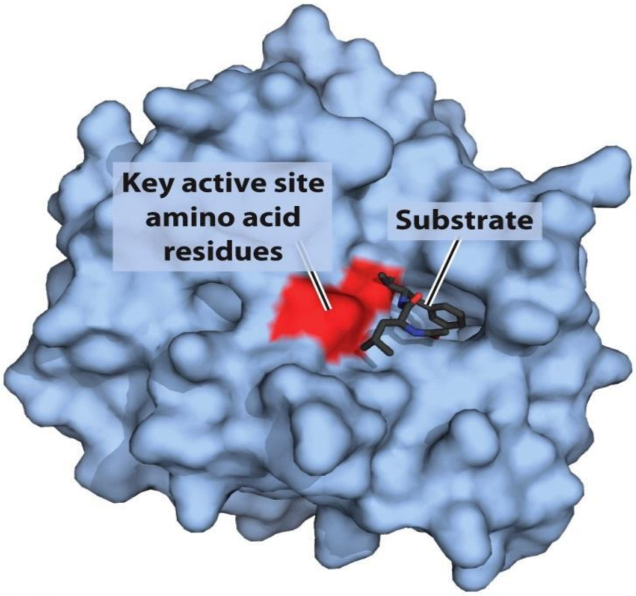


Fig. 5 Active Site of the Enzyme Chymotrypsin

8.7 Nomenclature

Many enzymes have been named by adding the suffix -ase to the name of their substrate which refer to the reaction that they catalyse (e.g. oxidase, dehydrogenase, carboxylase) while some individual proteolytic enzymes generally have the suffix *-in* (e.g. trypsin, chymotrypsin, papain) on their names. Biochemists by international agreement have adopted a system for naming and classifying enzymes based on the type of reaction catalyzed. International Union of Biochemistry set up the Enzyme Commission to address this issue. The first Enzyme Commission Report was published in 1961 in which a systematic approach to the naming of enzymes was explained. The sixth edition, published in 1992, contained details of nearly 3 200 different enzymes, and supplements published annually have now extended this number to over 5 000. Each enzyme is assigned a four-part classification number and a systematic name, which identifies the reaction it catalyzes. Some examples are explained as given below.

Trypsin

Trypsin has the Enzyme Commission (EC) number 3.4.21.4, where

1. The first number (3) denotes that it is a hydrolase
2. The second number (4) that it is a protease that hydrolyzes peptide bonds
3. The third number (21) that it is a serine protease with a critical serine residue at the active site, and
4. The fourth number (4) indicates that it was the fourth enzyme to be assigned to this class.

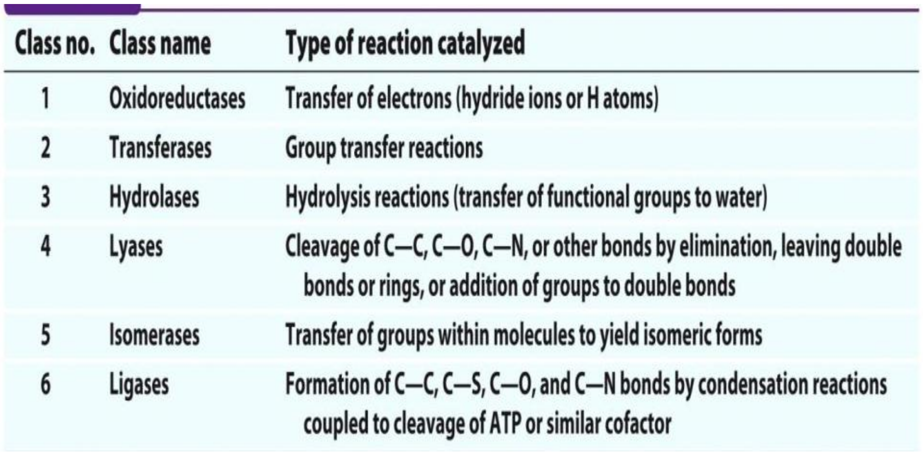
Glucose phosphotransferase

Enzyme hexokinase is formally known as ATP: glucose phosphotransferase has Enzyme Commission number 2.7.1.1, in which the first number (2) denotes the class name (transferase); the second number (7), denotes the subclass (phosphotransferase); the third number (1), a phosphotransferase with a hydroxyl group as acceptor; and the fourth number (1), D-glucose as the phosphoryl group acceptor. In this way the enzyme chymotrypsin has the EC number 3.4.21.1, and elastase 3.4.21.36.

8.8 Classification of enzymes

- Classification Based upon the type of reaction catalyzed.
- All enzymes have been placed into six major classes.

International Classification of Enzymes



Class no.	Class name	Type of reaction catalyzed
1	Oxidoreductases	Transfer of electrons (hydride ions or H atoms)
2	Transferases	Group transfer reactions
3	Hydrolases	Hydrolysis reactions (transfer of functional groups to water)
4	Lyases	Cleavage of C—C, C—O, C—N, or other bonds by elimination, leaving double bonds or rings, or addition of groups to double bonds
5	Isomerases	Transfer of groups within molecules to yield isomeric forms
6	Ligases	Formation of C—C, C—S, C—O, and C—N bonds by condensation reactions coupled to cleavage of ATP or similar cofactor

Oxidoreductases

These catalyze oxidation-reduction reactions where electrons are transferred. These electrons are usually in the form of hydride ions or hydrogen atoms. Oxidoreductases are of three types—oxidases, dehydrogenases and reductases, e.g., cytochrome oxidase (oxidises cytochrome), succinate dehydrogenase, nitrate reductase.

$$2AH_2 + O_2 \xrightarrow{\text{oxidase}} 2A + 2H_2O$$

$$AH_2 \xrightarrow{\text{dehydrogenase}} A + 2(H)$$

$$A + 2(H) \xrightarrow{\text{reductase}} AH_2$$

Transferases

These catalyze group transfer reactions. The transfer occurs from one molecule that will be the donor to another molecule that will be the acceptor. Most of the time, the donor is a cofactor that is charged with the group about to be transferred. Hexokinase used in glycolysis And Transaminase which catalyses the transfer of amino group from amino acid to a keto acid to form a new keto acid and a new amino acid.

(α-Ketoglutarate + Alanine—alanine aminotransferase → Glutamate + Pyruvate

Aspartate + α-Ketoglutarate —aspartate aminotransferase Oxaloacetate + Glutamate

Hydrolases

These catalyze reactions that involve hydrolysis. It usually involves the transfer of functional groups to water. When the hydrolase acts on amide, glycosyl, peptide, ester, or other bonds, they not only catalyze the hydrolytic removal of a group from the substrate but also a transfer of the group to an acceptor compound. Digestive enzymes belong to this group, e.g., amylase (hydrolysis of starch), sucrase, and lactase.

$$\underset{\text{maltose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{maltase}} \underset{\text{glucose}}{2C_6H_{12}O_6}$$

Lyases

Catalyze reactions where functional groups are added to break double bonds in molecules or the reverse where double bonds are formed by the removal of functional groups. For example: histidine decarboxylase (breaks histidine to histamine and CO_2), Fructose bisphosphate aldolase used in converting fructose 1,6-bisphospate to Glyceraldehyde 3 Phosphate and Dihydroxyacetone Phosphate by cutting C-C bond.

$$\text{Fructose 1, 6-diphosphate} \xrightarrow{\text{aldolase}} \text{Dihydroxy acetone phosphate} + \text{Glyceraldehyde phosphate.}$$

Isomerases

Catalyze reactions that transfer functional groups within a molecule so that isomeric forms are produced. These enzymes allow for structural or geometric changes within a compound. They are of three types, isomerases (aldose to ketose group of vice-versa like glucose 6-phosphate to fructose 6-phosphate), epimerases (change in position of one constituent or carbon group like xylulose phosphate to ribulose phosphate) and mutases (shifting the position of side group like glucoses- phosphate to glucose-l-phosphate). Phosphoglucose isomerase for converting glucose 6-phosphate to fructose 6-phosphate. Moving chemical group inside same substrate.

$$\text{Glucose 6-phosphate} \xrightarrow{\text{isomerase}} \text{Fructose 6-phosphate}$$
$$\text{Glucose 6-phosphate} \xrightarrow{\text{mutase}} \text{Glucose 1-phosphate}$$
$$\text{Xylulose 5-phosphate} \xrightarrow{\text{epimerase}} \text{Ribulose 5-phosphate}$$

Ligases

They are involved in catalysis where two substrates are ligated and the formation of carbon-carbon, carbon-sulfide, carbon-nitrogen, and carbon-oxygen bonds due to condensation reactions.These reactions are coupled to the cleavage of ATP. Phosphenol pyruvate PEP carboxylase (combines phosphenol pyruvate with carbon dioxide forming oxaloacetate accompanied by hydrolysis of ATP.)

$$PEP + CO_2 + ATP \xrightarrow{\text{PEP Carboxylase}} \text{Oxaloacetic Acid} + ADP + P$$

8.9 Classification based upon the presence or absence at a given time

Two types are identified:

Inducible enzymes:

Those enzymes that are synthesized by the cell whenever they are required. Synthesis of these enzymes usually requires an inducer. Invertase, HMG-CoA reductase, p-galactosidase and enzymes involved in urea cycle.

Constitutive enzymes:

Enzymes which are constantly present in normal amounts in the body, irrespective of inducers. e.g Enzymes of glycolysis.

Classification based upon the regulation of enzyme action

They are of two types:

Regulatory enzymes:

The action of these enzymes is regulated depending upon the status of the cell. The action of regulatory enzymes is either increased or decreased by a modulator at a site other than the active site called the “allosteric site”. Ex. Phosphofructokinase (PFK) and glutamate dehydrogenase.

Non-regulatory enzymes:

The action of these enzymes is not regulated. eg. Succinate dehydrogenase.

Classification based upon the place of action:

Depending upon the two sites of action, they are divided into—

Intracellular enzymes:

Enzymes that are produced by the cell and act inside the same cell are known as intracellular enzymes. Ex. All the enzymes of glycolysis and TCA cycle.

Extracellular enzymes:

Enzymes produced by a cell but act outside that cell independent of it. Ex, All the digestive enzymes viz. trypsin, pancreatic lipase etc.

8.10 Summary

Under this unit we have discussed as enzymes have both biological and chemical attributes. Their sequences and structures delineate their role in the genome and proteome of all living organisms and their ability to catalyze chemical reactions extends their biological function to metabolic pathways and networks. **They**acts as a catalyst in living organisms, regulating the rate at which life’s chemical reactions proceed without being altered in the process. Enzymes reduce the activation energy needed to start these reactions; without them, most such reactions would not take place at a useful rate. Because enzymes are not consumed, only tiny amounts of them are needed. Enzymes catalyze all aspects of cell metabolism, including the digestion of food, in which large nutrient molecules (including proteins, carbohydrates, and fats) are broken down into smaller molecules; the conservation and transformation of chemical energy; and the construction of cellular materials and components.

8.11 Terminal questions

Q. 1 Explain enzymes with examples.

Answer:---

Q. 2 What do you mean by enzyme? Explain with examples.

Answer:---

Q.3 Explain enzymatic reaction in digestion of proteins.

Answer:---

Q. 4 Describe different digestive enzymes of carbohydrates, proteins and fats.

Answer:---

Q. 5 Write short notes on the followings.

(i) Co-enzymes

(ii) Enzyme inhibition

Answer:---
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Q. 6 Describe the role of enzymes in digestion of different food materials.

Answer:---
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Further readings

1. Biochemistry- Lehninger A.L.
2. Textbook of Nutrition and Dietetics Ranjana Mahna
3. Biochemistry fourth edition-David Hames and Nigel Hooper.
4. Textbook of Biochemistry for Undergraduates - Rafi, M.D.
5. Textbook of Nutrition and Dietetics- Monika Sharma

Unit 9: Vitamins

Structure

9.1 Introduction

Vitamins and minerals are micronutrients, and by definition, they make up a relatively small part of our diet. However, when it comes to vitamins and minerals, a little bit goes a long way. They have many essential jobs in our bodies. For example, if you’ve taken a drink of water today, you can thank the minerals that serve as electrolytes, helping to balance fluids in the body. If you’ve taken a breath of air, you can thank the vitamins and minerals that act as antioxidants, protecting vital molecules from free radical damage. If you’ve taken a step, you can thank the vitamin D, calcium, and other minerals that make your bones strong. If you’ve moved a muscle, you can thank the many vitamins and minerals that serve as cofactors in metabolic reactions, which unlock the energy contained in nutrients so that your body can use it.

There are some 13 vitamins and 16 minerals important to human nutrition, and each serves multiple functions in the body. Entire books have been written about each one, and we could easily spend whole term learning about all of these amazing nutrients. But as this is an introductory course, we’ll use the next two units to introduce you to some of the most interesting vitamins and minerals, with a focus on those that are commonly limiting in the human diet. We’ll begin this unit with a general introduction to vitamins and minerals, and we’ll consider the role of dietary supplements in meeting our vitamin and mineral requirements. Then, we’ll spend the remainder of this unit and the next exploring major functions of vitamins and minerals, where we find them in food, and what happens if we consume too little or too much of each.

Objectives

This is the ninth unit (Vitamins) under third block (Introduction to vitamins and minerals) of Fundamentals of nutritional Biochemistry. Under ninth unit, we have following objectives. These are as under:

- To know the introduction and definition of vitamins
- To discuss stress, tiredness and vitamin pills
- To discuss water soluble and fat soluble vitamins
- To discuss vitamin deficiency and anti-ageing vitamins

9.2 Vitamins

Vitamins are organic substances, which mean they’re made by plants or animals. Minerals are inorganic elements that come from soil and water, and are absorbed by plants or eaten by animals. Your body needs larger amounts of some minerals, such as calcium, to grow and stay healthy. Other minerals like chromium, copper, iodine, iron, selenium, and zinc are called trace minerals because you need only very small amounts of them.

Vitamins and minerals boost the immune system, support normal growth and development, and help cells and organs do their jobs. For example, you've probably heard that carrots are good for your eyes. It's true! Carrots are full of substances called carotenoids that your body converts into vitamin A, which helps prevent eye problems. Vitamin K helps blood to clot, so cuts and scrapes stop bleeding quickly. You'll find vitamin K in green leafy vegetables, broccoli, and soybeans. And to have strong bones, you need to eat foods such as milk, yogurt, and green leafy vegetables, which are rich in the mineral calcium.

9.3 About vitamin supplements

Vitamins are organic compounds that our bodies use, in very small amounts, for a variety of metabolic processes. It is best to get vitamins and minerals from eating a variety of healthy unprocessed foods.While taking a general ‘broad-spectrum’ vitamin and mineral supplement ‘just in case’ poses little health risk, and may benefit a person whose diet is restricted and lacks variety, taking vitamin and mineral supplements instead of eating a nutritious diet is not recommended.Vitamin and mineral supplements are frequently misused and taken without professional advice. They are often used as a form of medicine to treat ailments such as colds, or to counteract lifestyle issues such as stress. Contrary to popular belief, vitamins aren’t drugs or miracle cures. They are organic compounds that participate in various metabolic functions. High-dose supplements should not be taken unless recommended under medical advice.

9.4 Vitamins and minerals are obtained from food

Research indicates that most of the vitamins you get from the food you eat are better than those contained in pills. Even though vitamins in supplements are synthesised to the exact chemical composition of naturally-occurring vitamins, they still don’t seem to work as well. The main exception to this is folate. The synthetic form (in a supplement or fortified food) is better absorbed by the body than folate from food sources.

Food is a complex source of vitamins, minerals and phytochemicals (plant chemicals), which all work together. Supplements tend to work in isolation. Research shows a food component that has an effect on the body may not have the same effect when it is isolated and taken as a supplement. This could be because the vitamins and minerals in foods are also influenced by other components of the food, not just the ‘active ingredient’. Phytochemicals are an important component of food and are thought to reduce the incidence of heart disease and some cancers. Supplements do not provide the benefits of phytochemicals and other components found in food. Taking vitamin and mineral supplements is no substitute for a healthy diet.

9.4.1 Vitamin and mineral deficiencies

Our body only needs a small amount of vitamins and minerals every day. A varied diet generally provides enough of each vitamin and mineral. However, some people may need supplements to correct vitamin or mineral deficiencies and this includes:

- pregnant women and women who are breastfeeding
- people who smoke, drink alcohol in excess or use illegal drugs
- crash dieters or those on very strict diets

- the elderly (especially those who are disabled or chronically ill)
- some vegetarians or vegans
- women with heavy periods
- people with food allergies
- those with malabsorption problems (such as diarrhoea, coeliac disease, cystic fibrosis or pancreatitis).

9.42 Folate and pregnancy

Women who are pregnant or planning a pregnancy are recommended folic acid (also known as folate) supplements to reduce their risk of having a child with a neural tube defect, such as spina bifida. Folic acid is a B-group vitamin which can also be found in some fortified foods such as breads and breakfast cereals. Foods fortified with folic acid have the nutrient added to them during production to boost their nutritional value.

9.4.3 Vegan diets and vitamin supplements

People who follow vegan diets, especially if pregnant, may benefit from vitamin B12 supplements.

9.4.4 Vitamin pills are not miracle cures

It is commonly believed that taking mega-doses of certain vitamins will act like medicine to cure or prevent certain ailments. For instance, vitamin C is suggested as a cure for the common cold, and vitamin E is widely promoted as a beneficial antioxidant to help prevent heart disease. After extensive research, however, neither of these claims has been shown to be true. Large-scale studies have consistently shown little benefit in taking mega-doses of supplements. In fact, there is some evidence that taking high-dose supplements to prevent or cure major chronic diseases (such as heart disease and cancer), may be harmful to your health.

9.4.5 Stress, tiredness and vitamin pills

Vitamin supplements are commonly considered to be an antidote to **stress**. Feeling under pressure doesn’t automatically lead to a vitamin deficiency, so taking a vitamin supplement won’t necessarily make stressful feelings go away. Popping a pill will not likely cure persistent tiredness either. If you are feeling run down, it is more likely to be due to stress, depression, insufficient sleep or other factors, rather than a vitamin deficiency. If you feel like this regularly, seek medical advice.

9.4.6 Anti-ageing vitamins

Vitamin E is often singled out as the potential fountain of youth. However, there is no evidence that taking large doses of any vitamin can stall or reverse the effects of ageing. Neither can one vitamin restore a flagging sex drive or cure infertility.

9.5 Vitamin use and cancer claims

Some claims have been made that certain vitamins can treat different **cancers**. However, research shows this is not the case. For example:

- Vitamin A (beta-carotene) in large doses does not cure cancer and can be toxic, particularly if taken as pills rather than food. Studies have linked vitamin A to an increase in other cancers – such as lung cancer in smokers, if taken in supplement form.
- Although there is some evidence vitamin E could play a small role in preventing some cancers, equally there is evidence that it could speed up the onset of other types of cancer. However, this has not been proved or disproved.
- High doses of antioxidants are unlikely to help with the effectiveness of conventional cancer treatments (such as chemotherapy and radiotherapy). In fact, megadoses of antioxidants can interfere with some medical treatments for cancer by helping to protect the cancer cells that the therapies aim to destroy.
- Some studies have shown prostate, breast and lung cancer risk are not decreased by taking high-dose supplements containing vitamins E or C or selenium.

9.6 Vitamin and mineral supplements can be dangerous

Proper balance and adequate levels of essential nutrients is important for a range of complex processes in our body. When vitamins are taken as supplements, they are introduced into the body at levels that could never be achieved by eating even the healthiest of diets. Supplementation can also result in large doses of a single vitamin being eaten ‘alone.’ When vitamins are consumed from foods, they have many companions to help them along the way. For instance, provitamin A (beta-carotene) in food is accompanied by hundreds of its carotenoid relatives.

Simply taking a vitamin pill is not an instant fix for feeling run down or lacking in energy. It is the combination of a whole range of compounds in foods that gives us the protection (most of which we probably don't even know about). When you artificially remove one of them and provide it completely out of context, it may not be as effective and, in the case of some vitamins, can have negative effects. Vitamin and mineral supplements can also interfere with prescription medicines and medical treatments. In extreme cases, for example, where people take 100 times the recommended dietary intake (RDI), this can stop the work of anticonvulsant drugs, such as those used in epilepsy.

9.7 High doses of vitamin supplements are unsafe

Many people mistakenly believe that since small amounts of vitamins are good for you, then large amounts must be better. However, it is better to follow the rule of 'less is more'. Taking higher than recommended doses of some vitamins may cause health problems. Such as:

- Vitamins A, D, E and K are fat soluble, which means they are stored in the body and if taken in high doses can be toxic.
- High doses of some water-soluble vitamins, such as vitamin B6, can also become toxic.
- Large folate intakes can hide vitamin B12 deficiencies.
- High levels of vitamin B6 have also been linked to some types of nerve damage.
- Doses of vitamin C above one gram can cause diarrhoea.
- Large doses of vitamin C may also cause nausea, abdominal cramps, headaches, fatigue, kidney stones interfere with your body's ability to process (metabolise) other nutrients – such as dangerously raising your iron levels.
- Excessive amounts of vitamin C in the body can also interfere with medical tests – such as diabetes tests, by giving a false result.
- High doses of vitamin A may cause birth defects, as well as central nervous system, liver, bone and skin disorders.
- High-dose vitamin E supplements have been linked to higher rates of early death (mortality).

Large doses of minerals can also lead to health problems

Excessive doses of some minerals may also cause problems for example:

- At just 5 times the RDI, zinc, iron, chromium and selenium can be raised to toxic levels in the body.

- Large intakes of fluoride (especially in childhood) may stain, and even weaken, the teeth.
- Very large doses of fish oil can lead to decreased blood clotting.
- Iron toxicity is also common. Even a small amount over the RDI can cause gastrointestinal upset, nausea and black bowel actions (poo). Severe toxicity can lead to coma and even death.

Stay safe and keep to the recommended dose

For a healthy adult, if supplements are used, they should generally be taken at levels close to the RDI. High-dose supplements should not be taken unless recommended under medical advice.

Vitamin and mineral supplements are a short-term measure

Taking vitamin and mineral supplements is a short-term measure. The long-term use of some high-dose supplements can lead to symptoms of toxicity. If you feel that you could be lacking in certain vitamins and minerals, it may be better to look at changing your diet and lifestyle rather than reaching for supplements. If you need help, see your doctor or a dietitian.

Seek professional advice when taking vitamin and mineral supplements

Some complementary medicines, such as vitamin and mineral supplements can interact with prescription medicines and medical treatments. That’s why it’s important to seek advice from your doctor. If you are advised to take vitamin supplements, it is a good idea to see a dietitian, who can work with your doctor or other health professionals to provide dietary advice related to your situation. And if you do need to take a supplement, it is best to take multivitamins at the recommended dietary level, rather than single nutrient supplements or high-dose multivitamins. Remember, to report any complementary medicines (including vitamin and mineral supplements) you are taking when you visit any healthcare professional.

9.8 Essential nutrients for your body

Every day, your body produces skin, muscle, and bone. It churns out rich red blood that carries nutrients and oxygen to remote outposts, and it sends nerve signals skipping along thousands of miles of brain and body pathways. It also formulates chemical messengers that shuttle from one organ to another, issuing the instructions that help sustain your life. But to do all this, your body requires some raw materials. These include at least 30 vitamins, minerals, and dietary components that your body needs but cannot manufacture on its own in sufficient amounts.

Vitamins and minerals are considered essential nutrients—because acting in concert, they perform hundreds of roles in the body. They help shore up bones, heal wounds, and bolster your immune system. They also convert food into energy, and repair cellular damage. But trying to keep track of what all these vitamins and minerals do can be confusing. Read enough articles on the topic, and your eyes may swim with the alphabet-soup references to these nutrients, which are known mainly be their initials (such as vitamins A, B, C, D, E, and K—to name just a few). In this unit, you'll gain a better understanding of what these vitamins and minerals actually do in the body and why you want to make sure you're getting enough of them.

9.9 Micronutrients with a big role in the body

Vitamins and minerals are often called micronutrients because your body needs only tiny amounts of them. Yet failing to get even those small quantities virtually guarantees disease. Here are a few examples of diseases that can result from vitamin deficiencies:

- **Scurvy.** Old-time sailors learned that living for months without fresh fruits or vegetables—the main sources of vitamin C—causes the bleeding gums and listlessness of scurvy.
- **Blindness.** In some developing countries, people still become blind from vitamin A deficiency.
- **Rickets.** A deficiency in vitamin D can cause rickets, a condition marked by soft, weak bones that can lead to skeletal deformities such as bowed legs. Partly to combat rickets, the U.S. has fortified milk with vitamin D since the 1930s.

Just as a lack of key micronutrients can cause substantial harm to your body, getting sufficient quantities can provide a substantial benefit. Some examples of these benefits:

- **Strong bones.** A combination of calcium, vitamin D, vitamin K, magnesium, and phosphorus protects your bones against fractures.

- **Prevents birth defects.** Taking folic acid supplements early in pregnancy helps prevent brain and spinal birth defects in offspring.
- **Healthy teeth.** The mineral fluoride not only helps bone formation but also keeps dental cavities from starting or worsening.

The difference between vitamins and minerals

Although they are all considered micronutrients, vitamins and minerals differ in basic ways. Vitamins are organic and can be broken down by heat, air, or acid. Minerals are inorganic and hold on to their chemical structure. So why does this matter? It means the minerals in soil and water easily find their way into your body through the plants, fish, animals, and fluids you consume. But it's tougher to shuttle vitamins from food and other sources into your body because cooking, storage, and simple exposure to air can inactivate these more fragile compounds.

Interacting—in good ways and bad

Many micronutrients interact. Vitamin D enables your body to pluck calcium from food sources passing through your digestive tract rather than harvesting it from your bones. Vitamin C helps you absorb iron. The interplay of micronutrients isn't always cooperative, however. For example, vitamin C blocks your body's ability to assimilate the essential mineral copper. And even a minor overload of the mineral manganese can worsen iron deficiency.

9.10 Water-soluble vitamins

B vitamins:

- Biotin (vitamin B7)
- Folic acid (folate, vitamin B9)
- Niacin (vitamin B3)
- Pantothenic acid (vitamin B5
- Riboflavin (vitamin B2)
- Thiamin (vitamin B1)
- Vitamin B6
- Vitamin B12

Vitamin C

What they do

Although water-soluble vitamins have many tasks in the body, one of the most important is helping to free the energy found in the food you eat. Others help keep tissues healthy. Here are some examples of how different vitamins help you maintain health:

- **Release energy.** Several B vitamins are key components of certain coenzymes (molecules that aid enzymes) that help release energy from food.
- **Produce energy.** Thiamin, riboflavin, niacin, pantothenic acid, and biotin engage in energy production.
- **Build proteins and cells.** Vitamins B6, B12, and folic acid metabolize amino acids (the building blocks of proteins) and help cells multiply.
- **Make collagen.** One of many roles played by vitamin C is to help make collagen, which knits together wounds, supports blood vessel walls, and forms a base for teeth and bones.

Contrary to popular belief, some water-soluble vitamins can stay in the body for long periods of time. You probably have several years' supply of vitamin B12 in your liver. And even folic acid and vitamin C stores can last more than a couple of days. Generally, though, water-soluble vitamins should be replenished every few days. Just be aware that there is a small risk that consuming large amounts of some of these micronutrients through supplements may be quite harmful. For example, very high doses of B6—many times the recommended amount of 1.3 milligrams (mg) per day for adults—can damage nerves, causing numbness and muscle weakness.

Fat-soluble vitamins

- Vitamin A
- Vitamin D
- Vitamin E
- Vitamin K

What they do

Together this vitamin quartet helps keep your eyes, skin, lungs, gastrointestinal tract, and nervous system in good repair. Here are some of the other essential roles these vitamins play:

- **Build bones.** Bone formation would be impossible without vitamins A, D, and K.
- **Protect vision.** Vitamin A also helps keep cells healthy and protects your vision.
- **Interact favorably.** Without vitamin E, your body would have difficulty absorbing and storing vitamin A.
- **Protect the body.** Vitamin E also acts as an antioxidant (a compound that helps protect the body against damage from unstable molecules).

9.12 Major minerals

- Calcium
- Chloride
- Magnesium
- Phosphorus
- Potassium
- Sodium
- Sulfur

What they do

One of the key tasks of major minerals is to maintain the proper balance of water in the body. Sodium, chloride, and potassium take the lead in doing this. Three other major minerals—calcium, phosphorus, and magnesium—are important for healthy bones. Sulfur helps stabilize protein structures, including some of those that make up hair, skin, and nails.

9.13 Summary

Under this unit we have discussed as **vitamins,** are Organic compound required in small amounts in the diet to maintain normal metabolic functions. The term *vitamine* (1911) was changed to *vitamin* when it was realized that not all vitamins are amines. Many vitamins act as or are converted to coenzymes. They neither provide energy nor are incorporated into tissues. Water-soluble vitamins (vitamin B complex, vitamin C) are excreted quickly. Fat-soluble vitamins (vitamin A, vitamin D, vitamin E, and vitamin K) require bile salts for absorption and are stored in the body. The normal functions of many vitamins are known. Deficiency of specific vitamins can lead to diseases (including beriberi, neural tube defect, pernicious anemia, rickets, and scurvy). Excess amounts, especially of fat-soluble vitamins, can also be dangerous: e.g., too much vitamin A causes liver damage, an effect not seen with beta-carotene, which the body converts into vitamin A. Several vitamins are now known to support the immune system. Most vitamins are adequately supplied by a balanced diet, but people with higher requirements may need supplements.

9.14 Terminal questions

Q.1 Explain vitamins with examples.

Answer:---

Q.2 What are the water soluble vitamins? Explain with examples.

Answer:---

Q.3 Explain biochemical role of vitamins.

Answer:---

Q. 4 Describe different type of vitamins in food materials.

Answer:---

Q. 5 Write short notes on the followings.

(i) Vitamin A

(ii) Vitamin C

Answer:---

Q. 6 Describe different sources of Vitamin A, B, C, D and E..

Answer:---

Further readings

- Biochemistry- Lehninger A.L.
- Textbook of Nutrition and Dietetics Ranjana Mahna
- Biochemistry fourth edition-David Hames and Nigel Hooper.
- Textbook of Biochemistry for Undergraduates - Rafi, M.D.
- Textbook of Nutrition and Dietetics- Monika Sharma

Unit 10: Water soluble vitamins

Structure

Objectives

10.1 Introduction

10.2 Vitamin B1/Thiamine

10.2.1 Benefits
10.2.2 Uses in medicine
10.2.3 Deficiency symptoms

10.3 Vitamin B2 (Riboflavin)

10.3.1 Vitamin B2 Benefits
10.3.2 Migraines
10.3.3 Cancer
10.3.4 Corneal Disorders
10.4 Homocysteinemia
10.5 Niacin (Vitamin B3)
10.6 Cataracts
10.7 Pyridoxine
10.8 Folate (Folic Acid) – Vitamin B9

10.1 Introduction

Vitamins have diverse biochemical functions. Vitamin A acts as a regulator of cell and tissue growth and differentiation. Vitamin D provides a hormone-like function, regulating mineral metabolism for bones and other organs. The B complex vitamins function as enzyme cofactors (coenzymes) or the precursors for them. Vitamins C and E function as antioxidants. Both deficient and excess intake of a vitamin can potentially cause clinically significant illness, although excess intake of water-soluble vitamins is less likely to do so.

All the vitamins were discovered between 1913 and 1948. Historically, when intake of vitamins from diet was lacking, the results were vitamin deficiency diseases. Then, starting in 1935, commercially produced tablets of yeast-extract vitamin B complex and semi-synthetic vitamin C became available. This was followed in the 1950s by the mass production and marketing of vitamin supplements, including multivitamins, to prevent vitamin deficiencies in the general population. Governments have mandated the addition of some vitamins to staple foods such as flour or milk, referred to as food fortification, to prevent deficiencies. Recommendations for folic acid supplementation during pregnancy reduced risk of infant neural tube defects.

Objectives

This is the tenth unit (Fat soluble vitamins) under third block (Introduction to vitamins and minerals) of Fundamentals of nutritional Biochemistry. Under tenth unit, we have following objectives. These are as under:

- To know the introduction and definition of different vitamins
- To discuss migraines and cancer
- To discuss homocysteinemia and cataracts

- To discuss foods and cancer prevention

This is the ninth unit (vitamins) under second block (Introduction to vitamins and minerals) of Fundamentals of Nutritional Biochemistry. Under ninth unit, we have following objectives. These are as under:

- To know definition of enzymes.
- To know about nomenclature and classification of enzymes
- To know about cofactors and its specificity.

10.2 Vitamin B1/Thiamine

Vitamin B1 or thiamin is essential for glucose metabolism and nerve, muscle, and heart function. People may need supplements if their diet does not provide enough B vitamins, during hemodialysis, and for other reasons. Also known as thiamine or thiamin, vitamin B1 is a water-soluble vitamin, as are all vitamins of the B complex. It enables the body to use carbohydrates as energy. Vitamins are classified according to the materials they dissolve in. Some dissolve in water, and others dissolve in fat. Water-soluble vitamins are carried through the bloodstream. Whatever the body does not use is eliminated in urine. There are high concentrations of Vitamin B1 in the outer layers and germ of cereals, as well as in yeast, beef, pork, nuts, whole grains, and pulses. Fruit and vegetables that contain it include cauliflower, oranges, potatoes, asparagus, and kale. Other sources include liver, eggs, brewer’s yeast, and blackstrap molasses.

Breakfast cereals and products made with white flour or white rice may be enriched with vitamin B. In the United States, people consume around half of their vitamin B1 intake in foods that naturally contain thiamin, while the rest comes from foods that are fortified with the vitamin. Heating, cooking, and processing foods, and boiling them in water, destroy thiamin. As vitamin B1 is water-soluble, it dissolves into cooking water. White rice that is not enriched will contain only one tenth of the thiamin available in brown rice.

The National Institutes of Health (NIH) Office of Dietary Supplements (ODS) note that one serving of fortified breakfast cereal provides 1.5 milligrams (mg) of thiamin, which is more than 100 percent of the daily recommended amount. One slice of whole wheat bread contains 0.1 mg, or 7 percent of the daily requirement. Cheese, chicken, and apples contain no thiamin. Humans need a continuous supply of vitamin B1, because it is not stored in the body. It should be part of the daily diet.

10.2.1 Benefits

Vitamin B1, or thiamin, helps prevent complications in the nervous system, brain, muscles, heart, stomach, and intestines. It is also involved in the flow of electrolytes into and out of muscle and nerve cells. It helps prevent diseases such as beriberi, which involves disorders of the heart, nerves, and digestive system.

10.2.2 Uses in medicine

Patients who may receive thiamin to treat low levels of vitamin B1 include those with peripheral neuritis, which is an inflammation of the nerves outside the brain, or pellagra. People with ulcerative colitis, persistent diarrhea, and poor appetite may also receive thiamin. Those who are in a coma may be given thiamin injections. Some athletes use thiamin to help improve their performance. It is not a prohibited substances for athletes in the U.S. Other conditions in which thiamin supplements may help include:

- AIDS
- canker sores
- cataracts
- glaucoma and other vision problems
- cerebellar syndrome, a type of brain damage
- cervical cancer
- diabetic pain
- stress
- heart disease
- kidney disease in patients with diabetes type 2
- motion sickness
- a weakened immune system.

10.2.3 Deficiency symptoms

A deficiency of vitamin B1 commonly leads to beriberi, a condition that features problems with the peripheral nerves and wasting. Weight loss and anorexia can develop. There may be mental problems, including confusion and short-term memory loss. Muscles may become weak, and cardiovascular symptoms can occur, for example, an enlarged heart.

How much vitamin B1 do we need?

In the U.S., the recommended daily allowance (RDA) of thiamin taken by mouth is 1.2 mg for males and 1.1 mg for females over the age of 18 years. Pregnant or breastfeeding women of any age should consume 1.4 mg each day.

Who is at risk of B1 deficiency?

People with poor diet, cancer, "morning sickness" during pregnancy, bariatric surgery, and hemodialysis are at risk of thiamin deficiency. People who regularly drink alcohol to excess may have a deficiency, as they may not absorb thiamin from their food. Wernicke-Korsakoff syndrome is a disorder that affects people with chronic alcoholism. It is linked to a lack of thiamin, and it can be fatal if not treated. People with Wernicke-Korsakoff syndrome and those who are withdrawing from alcohol may receive thiamin injections to help them recover. Other diseases, such as HIV, can reduce the absorption of nutrients, and this can lead to a deficiency of vitamin B1.

10.3 Vitamin B2 (Riboflavin)

Vitamin B2, also called riboflavin, is one of 8 B vitamins. All B vitamins help the body to convert food (carbohydrates) into fuel (glucose), which is used to produce energy. These B vitamins, often referred to as B-complex vitamins, also help the body metabolize fats and protein. B complex vitamins are necessary for a healthy liver, skin, hair, and eyes. They also help the nervous system function properly. All B vitamins are water soluble, meaning the body does not store them.

Riboflavin (vitamin B2) is a water-soluble vitamin that plays a key role in several important functions of the body. Among other things, it helps metabolize glucose—the form of sugar that the body uses for energy—and supports the production of healthy red blood cells. Riboflavin also serves as an antioxidant, preventing free radicals from damaging cells and increasing the risk of many aging-related diseases. Vitamin B2 is found naturally in many different foods, most of which are common in the American diet. Because of this, riboflavin deficiency is infrequently seen in the United States. If it does occur, it is usually a result of severe malnutrition or conditions that impair vitamin absorption.

10.3.1 Vitamin B_2 Benefits

Riboflavin, along with all other B vitamins, plays an important role in breaking down nutrients in food—including carbohydrates, proteins, and fats—to produce energy. Without it, we simply could not function. It can also help prevent or treat migraines, certain cancers, cataracts, preeclampsia, seizures, and dementia. Vitamin B2 is also beneficial for heart health. It appears to do so by maintaining the metabolic integrity of the body, while minimizing certain byproducts of metabolism, such as homocysteine, that are harmful to cells. In addition to its role in metabolism and blood cell synthesis, vitamin B2 enables the conversion of vitamin B6 (pyridoxine) to its active coenzyme form and the conversion of tryptophan to niacin. Here is what some of the current research says:

10.3.2 Migraines

According to the National Institutes of Health, vitamin B2 is showing a lot of promise as a potential treatment for migraine headaches. Migraines are believed to be caused by changes in the brainstem or Imbalances in brain chemicals. Riboflavin appears to help overcome these imbalances by improving respiration and energy production within the mitochondria of brain cells. A 1998 study published in the journal *Neurology* found that migraine-prone adults who took 400 milligrams (mg) of riboflavin per day had two fewer migraine attacks per month than people who took a placebo.

10.3.3 Cancer

There is also evidence that vitamin B2 be helpful in preventing cancer.[5] The underlying theory is that riboflavin can protect cellular DNA from being damaged by cancer-causing agents like cigarette smoke. At its heart, cancer is the breakdown of normal cellular function in which cells no longer undergo apoptosis (programmed cell death). If this happens, cells can suddenly reproduce out of control and form tumors. By stabilizing the structure of cellular DNA, scientists believe that certain cancers, like esophageal cancer and cervical cancer, may be avoided. Although riboflavin deficiency is known to be an independent risk factor for both of the conditions, it is unclear what, if any, amount of riboflavin would be needed to achieve a tangible reduction in risk.

10.3.4 Corneal Disorders

Cataracts are a common aging-related condition in which the lens of the eye begins to cloud over. People who have riboflavin in their diet appear to have a lower risk of developing cataracts. A 2014 study from Tufts University suggested that as little as 2 micrograms (μg) of riboflavin can reduce the risk of cataracts in malnourished people. Riboflavin is also important in the synthesis of niacin, with higher niacin levels corresponding to a reduction in cataract risk. Riboflavin eye drops are sometimes used with ultraviolet (UV) light therapy to treat a degenerative eye disorder known as keratoconus. When used together, the eye drops and UV radiation reinforces the corneal collagen and stabilizes the lens.

10.4 Homocysteinemia

Homocysteine is a common amino acid found in the blood. High levels of homocysteine (referred to as homocysteinemia) are associated with an array of adverse medical conditions, including stroke, dementia, heart attacks. Riboflavin supplements taken daily can reduce homocysteine levels by up to 40% in some people. According to a study published in *Circulation,* a 25% reduction of homocysteine reduces the risk of coronary artery disease (CAD) by 11% to 16% and the risk of stroke by 19% to 24%.

Similarly, a reduction in homocysteine may reduce the risk of neurocognitive disorders, including Alzheimer's disease, Parkinson's disease, vascular dementia, and epilepsy, according to research from Northumbria University in England. When prescribed with anticonvulsant drugs, riboflavin lowers homocysteine levels by 26%, ensuring better seizure control. High homocysteine level can also increase the risk of preeclampsia, a potentially dangerous complication of pregnancy characterized by a sharp rise in blood pressure. Supplementation with riboflavin, folic acid, and vitamin B12 is commonly used to reduce the risk.

Possible Side Effects

If you are not getting enough vitamin B2 in your diet, your doctor may recommend either a daily multivitamin or a B-complex supplement. Always use supplements as prescribed. Most offer between 25 mg and 100 mg of riboflavin, only a small amount of which is absorbed in the intestines. The rest is quickly excreted in stool. Even small doses of riboflavin can cause your urine to turn a bright yellow color (a side effect known as flavinuria). Doses greater than 100 mg may cause itchiness, diarrhea, stomach cramps, numbness, light sensitivity, blurriness, and a burning sensation on the skin.

While it is impossible to overdose on vitamin B2 (given the high rate of excretion and the low level of absorption) that shouldn't suggest that there will no adverse effects. While rare, induced light sensitivity can increase the risk of eye damage from direct sun exposure. With that being said, there are no known toxic effects associated with high riboflavin intake, either by oral or injected use.

10.5 Niacin (Vitamin B3)

Having enough niacin, or vitamin B3, in the body is important for general good health. As a treatment, higher amounts of niacin can improve cholesterol levels.

Why do people take niacin?

As a cholesterol treatment, there are good studies showing that niacin can boost levels of good HDL cholesterol and lower triglycerides. Niacin also modestly lowers bad LDL cholesterol. It's sometimes prescribed in combination with statins for cholesterol control, such as rosuvastatin (Crestor, Ezallor), simvastatin (Flolipid, Zocor), fluvastatin (Lescol), atorvastatin (Lipitor) and pravastatin (Pravachol).

However, niacin is only effective as a cholesterol treatment at fairly high doses. These doses could pose risks, such as liver damage, gastrointestinal problems, or glucose intolerance. So don't treat yourself with over-the-counter niacin supplements. Instead, get advice from your health care provider, who can prescribe FDA-approved doses of niacin instead if recommended. In addition, niacin is an FDA-approved treatment for pellagra, a rare condition that develops from niacin deficiency.

What are the risks of taking niacin?

- **Side effects.** Niacin can cause flushing, especially when you first begin taking it. Your health care provider will probably suggest increasing the dose slowly to reduce this problem. They might also offer a time-release prescription formulation to control flushing. Niacin can cause upset stomach and diarrhea. However, all of these side effects tend to fade over time.
- **Risks.** Niacin does have risks. It can cause liver problems, stomach ulcers, changes to glucose levels, muscle damage, low blood pressure, heart rhythm changes, and other issues. People with any health condition including liver or kidney disease, diabetes, high blood pressure, or cardiovascular problems need to talk to a doctor

before using niacin supplements. Do not treat high cholesterol on your own with over-the-counter niacin supplements.

- **Interactions.** If you take any medicines or supplements regularly, talk to your doctor before you start using niacin supplements. They could interact with medicines like diabetes drugs, blood thinners, anticonvulsants, blood pressure medicines, thyroid hormones, and antibiotics as well as supplements like ginkgo biloba and some antioxidants. Alcohol might increase the risk of liver problems. Though niacin is often used along with statins for high cholesterol, this combination may increase the risk for side effects. Get advice from your healthcare provider.

In addition to producing energy for the body, riboflavin works as an antioxidant, fighting damaging particles in the body known as free radicals. Free radicals can damage cells and DNA, and may contribute to the aging process, as well as the development of a number of health conditions, such as heart disease and cancer. Antioxidants, such as riboflavin, can fight free radicals and may reduce or help prevent some of the damage they cause. Riboflavin is also needed to help the body change vitamin B6 and folate into forms it can use. It is also important for growth and red blood cell production.

Most healthy people who eat a well-balanced diet get enough riboflavin. However, elderly people and alcoholics may be at risk for riboflavin deficiency because of poor diet. Symptoms of riboflavin deficiency include:

- Fatigue
- Slowed growth
- Digestive problems
- Cracks and sores around the corners of the mouth
- Swollen magenta-colored tongue
- Eye fatigue
- Swelling and soreness of the throat
- Sensitivity to light

10.6 Cataracts

Vitamin B2, along with other nutrients, is important for normal vision. Early studies suggest that riboflavin might help prevent cataracts, damage to the lens of the eye, which can lead to cloudy vision. In one double-blind, placebo-controlled study, people who took a niacin and riboflavin supplement had fewer cataracts than people who took other vitamins and nutrients. However, researchers do not know whether that was due to riboflavin, niacin, or the combination of the two. More research is needed to see if riboflavin can really help prevent cataracts.

Migraine headache

Several studies suggest that people who get migraines may reduce how often they get migraines and how long the migraines last by taking riboflavin. One double-blind, placebo-controlled study showed that taking 400 mg of riboflavin a day cut the number of migraine attacks in half. However, the study did not compare riboflavin to conventional medications used to prevent migraines. More research is needed.

Autism

Preliminary research suggests that supplementation with vitamin B2, along with vitamin B6, and magnesium reduces the level of dicarboxylic acids (abnormal organic acids) in the urine of autistic children.

Dietary Sources

The best sources of riboflavin include:

- Brewer's yeast
- Almonds
- Organ meats
- Whole grains
- Wheat germ
- Wild rice
- Mushrooms
- Soybeans
- Milk
- Yogurt
- Eggs
- Broccoli
- Brussels sprouts
- Spinach

Flours and cereals are often fortified with riboflavin. Riboflavin is destroyed by light. So food should be stored away from light to protect its riboflavin content. While riboflavin is not destroyed by heat, it can be lost in water when foods are boiled or soaked. Roasting and steaming foods preserves more riboflavin than frying or scalding your foods.

10.7 Pyridoxine

Vitamin B6 is a type of B vitamin. Pyridoxine, pyridoxal, and pyridoxamine are all forms of vitamin B6. It's found in certain foods and also made in a lab. Vitamin B6 is needed for the proper function of sugars, fats, and proteins in the body. It's also necessary for the development of the brain, nerves, skin, and many other parts of the body. It's found in cereals, legumes, and eggs, and often used with other B vitamins in vitamin B complex products. People commonly use vitamin B6 for preventing and treating vitamin B6 deficiency. It is also used for heart disease, premenstrual syndrome (PMS), depression, morning sickness, Alzheimer disease, menstrual cramps, diabetes, and many other conditions, but there is no good scientific evidence to support many of these other uses.

10.8 Folate (Folic Acid) – Vitamin B9

Folate is the natural form of vitamin B9, water-soluble and naturally found in many foods. It is also added to foods and sold as a supplement in the form of folic acid; this form is actually better absorbed than that from food sources—85% vs. 50%, respectively. Folate helps to form DNA and RNA and is involved in protein metabolism. It plays a key role in breaking down homocysteine, an amino acid that can exert harmful effects in the body if it is present in high amounts. Folate is also needed to produce healthy red blood cells and is critical during periods of rapid growth, such as during pregnancy and fetal development.

Folate and folic acid are forms of vitamin B9 used for deficiency and to prevent pregnancy complications. Many foods contain folate or have folic acid added. Since 1998, folic acid has been added to cold cereals, flour, breads, pasta, bakery items, cookies, and crackers, as required by federal law. Foods that are naturally high in folate include leafy vegetables, okra, asparagus, certain fruits, beans, yeast, mushrooms, animal liver and kidney, orange juice, and tomato juice. Folic acid is also available as a supplement, and is often used in combination with other B vitamins.

Folic acid is used for preventing and treating low blood levels of folate (folate deficiency) and high blood levels of homocysteine (hyperhomocysteinemia). People who are pregnant or might become pregnant take folic acid to prevent serious birth defects such as spina bifida. Folic acid is also used for many other conditions including depression, stroke, decline in memory and thinking skills, and many others.

10.9Vitamin B12

Vitamin B12 is an essential vitamin found in foods such as meat, fish, and dairy. It can also be made in a lab and is often taken with other B vitamins. Vitamin B12 is required for the function and development of many parts of the body, including the brain, nerves, and blood cells. Methylcobalamin is the active form of vitamin B12. Cyanocobalamin, which must be processed by the body into the active form, is the most common type used in supplements.

People commonly use vitamin B12 for vitamin B12 deficiency, cyanide poisoning, and high levels of homocysteine in the blood. It is also used for canker sores, cataracts, Alzheimer disease, osteoporosis, fatigue, and many other conditions, but there is no good scientific evidence to support most of these other uses. Vitamin B12 (cobalamin) is crucial for nerve tissue, brain function, and red blood cells. Sources include meat, eggs, and some yeast products. People whose diet is low on B12 may need supplements. Signs of a deficiency include headaches and fatigue.

A deficiency or insufficiency can occur when levels of vitamin B12 become too low to meet the demands of the body. This can lead to a number of symptoms and can even progress to irreversible neurological issues if left untreated. In the United States and United Kingdom, approximately 6% of adults aged 60 or younger have vitamin B12 deficiency. The rate jumps to 20% in people older than 60.

Vitamin B12 is a water-soluble vitamin, like all other B vitamins. This means it can dissolve in water and travel through the bloodstream. The body can store vitamin B12 for up to 4 years, and it can get rid of any excess or unwanted vitamin B12 in the urine. Vitamin B12 is the largest and most structurally complicated vitamin. It occurs naturally in animal products like meat and eggs, and manufacturers can produce it through bacterial fermentation synthesis. This unit explores the functions of vitamin B12, how a person would know they are not consuming enough vitamin B12, and how to increase intake. Vitamin B12 is crucial to various bodily processes, including:

- normal functioning of the brain and nervous system
- cognitive functioning (ability to think)
- formation of red blood cells and anemia prevention
- helping create and regulate DNA
- possibly preventing congenital abnormalities
- helping protect the eyes from macular degeneration
- necessary for energy production

Vitamin B12 is essential for healthy blood. When the body does not have enough B12, it leads to decreased normal red blood cell production (anemia), which impairs oxygen delivery. Megaloblastic anemia, also called nutritional-deficiency anemia, is a type of anemia caused by B12 or folate deficiency. Megaloblastic anemia is characterized by impaired DNA synthesis and the formation of large, abnormal, immature red blood cells.

Intake requirements

The National Institutes of Health (NIH) recommend that teens and adults over the age of 14 should consume 2.4 micrograms (mcg) of vitamin B12 daily. Pregnant people should consume 2.6 mcg, and lactating people 2.8 mcg. Excessive intake of vitamin B12 has not shown toxic or harmful qualities. However, people should speak with their physician before starting any new supplements. Some medications may decrease the absorption of vitamin B12 from foods. These medications include:

- metformin
- proton pump inhibitors
- H2 receptor agonists, often used for peptic ulcer disease

10.10 Foods

Vitamin B12 occurs naturally in many animal products. It does not typically occur in plant foods, unless it is supplemented. Good dietary sources of vitamin B12 include:

- beef
- pork

- ham
- poultry
- lamb
- fish, especially haddock and tuna
- dairy products, such as milk, cheese, and yogurt
- some nutritional yeast products
- eggs

Additionally, manufacturers fortify some types of plant milk and breakfast cereals with vitamin B12. Even though vitamin B12 is found in a variety of foods, some people are at an increased risk of developing B12 deficiency or insufficiency. Groups at an increased risk include:

- older adults
- those on restrictive diets like vegan diets
- people with certain health conditions such as celiac disease

Learn more about vitamin B12 foods for vegetarians and vegans.

Deficiency symptoms

Having low or deficient B12 levels can lead to a number of symptoms, some of which can be serious. It can result in irreversible and potentially severe damage, especially to the nervous system and brain. It is slightly lower-than-normal levels of vitamin B12 can trigger symptoms. However, these symptoms are nonspecific and are not enough to diagnose vitamin B12 deficiency. Symptoms may include:

- depression
- confusion
- memory problems
- fatigue
- headaches
- mood changes
- difficulty concentrating

Once symptoms worsen, they can include neurological changes, such as numbness and tingling in the hands and feet. Some people may have difficulty maintaining balance.

Infants who lack vitamin B12 may show:

- unusual movements, such as face tremors
- reflex problems
- feeding difficulties
- irritation
- eventual growth problems if left untreated

B12 deficiency has been linked to an increased risk of cognitive impairment and depression. Insufficient vitamin B12 can also lead to anemia. The most common symptoms of anemia are fatigue, shortness of breath, and an irregular heartbeat. People with anemia might also experience:

- a sore mouth or tongue
- weight loss
- pale or yellowing skin
- diarrhea
- menstrual problems

10.11 Vitamin C (L-ascorbic acid)

Vitamin C, also known as L-ascorbic acid, is a water-soluble vitamin that is naturally present in some foods, added to others, and available as a dietary supplement. Humans, unlike most animals, are unable to synthesize vitamin C endogenously, so it is an essential dietary component. Vitamin C is required for the biosynthesis of collagen, L-carnitine, and certain neurotransmitters; vitamin C is also involved in protein metabolism. Collagen is an essential component of connective tissue, which plays a vital role in wound healing. Vitamin C is also an important physiological antioxidant and has been shown to regenerate other antioxidants within the body, including alpha-tocopherol (vitamin E). Ongoing research is examining whether vitamin C, by limiting the damaging effects of free radicals through its antioxidant activity, might help prevent or delay the development of certain cancers, cardiovascular disease, and other diseases in which oxidative stress plays a causal role. In addition to its biosynthetic and antioxidant functions, vitamin C plays an important role in immune function and improves the absorption of nonheme iron, the form of iron present in plant-based foods. Insufficient vitamin C intake causes scurvy, which is characterized by fatigue or lassitude, widespread connective tissue weakness, and capillary fragility.

Today, vitamin C deficiency and scurvy are rare in developed countries. Overt deficiency symptoms occur only if vitamin C intake falls below approximately 10 mg/day for many weeks. Vitamin C deficiency is uncommon in developed countries but can still occur in people with limited food variety.

Groups at Risk of Vitamin C Inadequacy

Vitamin C *inadequacy* can occur with intakes that fall below the RDA but are above the amount required to prevent overt deficiency (approximately 10 mg/day). The following groups are more likely than others to be at risk of obtaining insufficient amounts of vitamin C.

Smokers and passive “smokers”

Studies consistently show that smokers have lower plasma and leukocyte vitamin C levels than nonsmokers, due in part to increased oxidative stress. For this reason, the IOM concluded that smokers need 35 mg more vitamin C per day than nonsmokers. Exposure to secondhand smoke also decreases vitamin C levels. Although the IOM was unable to establish a specific vitamin C requirement for nonsmokers who are regularly exposed to secondhand smoke, these individuals should ensure that they meet the RDA for vitamin C .

Infants fed evaporated or boiled milk

Most infants in developed countries are fed breastmilk and/or infant formula, both of which supply adequate amounts of vitamin C. For many reasons, feeding infants evaporated or boiled cow’s milk is not recommended. This practice can cause vitamin C deficiency because cow’s milk naturally has very little vitamin C and heat can destroy vitamin C.

Individuals with limited food variety

Although fruits and vegetables are the best sources of vitamin C, many other foods have small amounts of this nutrient. Thus, through a varied diet, most people should be able to meet the vitamin C RDA or at least obtain enough to prevent scurvy. People who have limited food variety—including some elderly, indigent individuals who prepare their own food; people who abuse alcohol or drugs; food faddists; people with mental illness; and, occasionally, children—might not obtain sufficient vitamin C.

People with malabsorption and certain chronic diseases

Some medical conditions can reduce the absorption of vitamin C and/or increase the amount needed by the body. People with severe intestinal malabsorption or cachexia and some cancer patients might be at increased risk of vitamin C inadequacy. Low vitamin C concentrations can also occur in patients with end-stage renal disease on chronic hemodialysis.

Vitamin C and Health

Due to its function as an antioxidant and its role in immune function, vitamin C has been promoted as a means to help prevent and/or treat numerous health conditions. This section focuses on four diseases and disorders in which vitamin C might play a role: cancer (including prevention and treatment), cardiovascular disease, age-related macular degeneration (AMD) and cataracts, and the common cold.

10.12 Cancer prevention

Epidemiologic evidence suggests that higher consumption of fruits and vegetables is associated with lower risk of most types of cancer, perhaps, in part, due to their high vitamin C content. Vitamin C can limit the formation of carcinogens, such as nitrosamines, in vivo; modulate immune response; and, through its antioxidant function, possibly attenuate oxidative damage that can lead to cancer. Most case-control studies have found an inverse association between dietary vitamin C intake and cancers of the lung, breast, colon or rectum, stomach, oral cavity, larynx or pharynx, and esophagus. Plasma concentrations of vitamin C are also lower in people with cancer than controls.

10.13 Summary

Under this unit we have discussed as the human body is a magnificent machine, and to function well, the body needs certain supplements. Vitamins are one of the most essential elements for the body. There are nutrients that the body can make on its own, and there are others that the body is not able to make. Vitamins are one of the nutrients that the body is unable to make, so they must be consumed from aliments. Vitamins are an organic molecule, which is an essential micronutrient that an organism needs for its metabolism to function. They are divided into two groups, fat-soluble vitamins and water-soluble vitamins. The first group contains vitamins A, D, E, and K, while the second consists of thiamin (B_1), riboflavin (B_2), niacin (B_3), pantothenic acid (B_5), pyridoxal, pyridoxamine, pyridoxine (B_6), biotin-cobalamin (B_{12}), folic acid, and ascorbic acid.

10.14 Terminal questions

Q.1 What are vitamins? Explain it with examples.

Answer:---

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Q.2 What do you mean by vitamin B-complex? Explain with examples.

Answer:---

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Q.3 Explain water soluble vitamins.

Answer:---

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Q. 4 Describe folic acid and vitamin C.

Answer:---

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Q. 5 Write short notes on the followings.

(i) Fat soluble vitamins

(ii) Water soluble vitamins

Answer:---

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Q. 6 Describe different vitamins with their sources..

Answer:--

Further readings

- Biochemistry- Lehninger A.L.
- Textbook of Nutrition and Dietetics Ranjana Mahna
- Biochemistry fourth edition-David Hames and Nigel Hooper.
- Textbook of Biochemistry for Undergraduates - Rafi, M.D.
- Textbook of Nutrition and Dietetics- Monika Sharma

Unit 11: Minerals (Group I)

Structure

Objectives

11.1 Introduction

11.2 Nomenclature

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11.1 Introduction

Minerals are inorganic elements present in soil and water, which are absorbed by plants or consumed by animals. While you're likely familiar with calcium, sodium, and potassium, there is a range of other minerals, including trace minerals (e.g. copper, iodine, and zinc) needed in very small amounts. **Mineral,** naturally occurring homogeneous solid with a definite chemical composition and a highly ordered atomic arrangement; it is usually formed by inorganic processes. There are several thousand known mineral species, about 100 of which constitute the major mineral components of rocks; these are the so-called rock-forming minerals.

Definition

A mineral, which by definition must be formed through natural processes, is distinct from the synthetic equivalents produced in the laboratory. Artificial versions of minerals, including emeralds, sapphires, diamonds, and other valuable gemstones, are regularly produced in industrial and research facilities and are often nearly identical to their natural counterparts.

Objectives

This is the eleventh unit (minerals, group-I) under third block (Introduction to vitamins and minerals) of Fundamentals of Nutritional Biochemistry. Under eleventh unit, we have following objectives. These are as under:

- To know introduction of minerals.
- To know about nomenclature and importance of minerals
- To know about microelements and macroelements
- To discuss the biological importance of Ca, Fe, Cu, I and P

By its definition as a homogeneous solid, a mineral is composed of a single solid substance of uniform composition that cannot be physically separated into simpler chemical compounds. Homogeneity is determined relative to the scale on which it is defined. A specimen that appears homogeneous to the unaided eye, for example, may reveal several mineral components under a microscope or upon exposure to X-ray diffraction techniques.

Most rocks are composed of several different minerals; e.g., granite consists of feldspar, quartz, mica, and amphibole. In addition, gases and liquids are excluded by a strict interpretation of the above definition of a mineral. Ice, the solid state of water (H_2O), is considered a mineral, but liquid water is not; liquid mercury, though sometimes found in mercury ore deposits, is not classified as a mineral either. Such substances that resemble minerals in chemistry and occurrence are dubbed mineraloids and are included in the general domain of mineralogy.

Since a mineral has a definite composition, it can be expressed by a specific chemical formula. Quartz (silicon dioxide), for instance, is rendered as SiO_2, because the elements silicon (Si) and oxygen (O) are its only constituents and they invariably appear in a 1:2 ratio. The chemical makeup of most minerals is not as well defined as that of quartz, which is a pure substance. Siderite, for example, does not always occur as pure iron carbonate ($FeCO_3$); magnesium (Mg), manganese (Mn), and, to a limited extent, calcium (Ca) may sometimes substitute for the iron. Since the amount of the replacement may vary, the composition of siderite is not fixed and ranges between certain limits, although the ratio of the metal cation to the anionic group remains fixed at 1:1. Its chemical makeup may be expressed by the general formula $(Fe, Mn, Mg, Ca)CO_3$, which reflects the variability of the metal content.

Minerals display a highly ordered internal atomic structure that has a regular geometric form. Because of this feature, minerals are classified as crystalline solids. Under favourable conditions, crystalline materials may express their ordered internal framework by a well-developed external form, often referred to as crystal form or morphology. Solids that exhibit no such ordered internal arrangement are termed amorphous. Many amorphous natural solids, such as glass, are categorized as mineraloids.

Traditionally, minerals have been described as resulting exclusively from inorganic processes; however, current mineralogic practice often includes as minerals those compounds that are organically produced but satisfy all other mineral requirements. Aragonite ($CaCO_3$) is an example of an inorganically formed mineral that also has an organically produced, yet otherwise identical, counterpart; the shell (and the pearl, if it is present) of an oyster is composed to a large extent of organically formed aragonite. Minerals also are produced by the human body: hydroxylapatite [$Ca_5(PO_4)_3(OH)$] is the chief component of bones and teeth, and calculi are concretions of mineral substances found in the urinary system.

11.2 Nomenclature

While minerals are classified in a logical manner according to their major anionic (negatively charged) chemical constituents into groups such as oxides, silicates, and nitrates, they are named in a far less scientific or consistent way. Names may be assigned to reflect a physical or chemical property, such as colour, or they may be derived from various subjects deemed appropriate, such as, for example, a locality, public figure, or mineralogist.

Some examples of mineral names and their derivations follow: albite ($NaAlSi_3O_8$) is from the Latin word (*albus*) for “white” in reference to its colour; goethite ($FeO \cdot OH$) is in honour of Johann Wolfgang von Goethe, the German poet; manganite ($MnO \cdot OH$) reflects the mineral’s composition; franklinite ($ZnFe_2O_4$) is named after Franklin, New Jersey, U.S., the site of its occurrence as the dominant ore mineral for zinc (Zn); and sillimanite (Al_2SiO_4) is in honour of the American chemist Benjamin Silliman.

Since 1960 the Commission on New Minerals and Mineral Names of the International Mineralogical Association has reviewed descriptions of new minerals and proposals for new mineral names and has attempted to remove inconsistencies. Any new mineral name must be approved by this committee, and the type material is usually stored in a museum or university collection.

11.3 Occurrence and formation

Minerals form in all geologic environments and thus under a wide range of chemical and physical conditions, such as varying temperature and pressure. The four main categories of mineral formation are:

- Igneous, or magmatic, in which minerals crystallize from a melt,
- Sedimentary, in which minerals are the result of sedimentation, a process whose raw materials are particles from other rocks that have undergone weathering or erosion,

- Metamorphic, in which new minerals form at the expense of earlier ones owing to the effects of changing—usually increasing—temperature or pressure or both on some existing rock type, and
- Hydrothermal, in which minerals are chemically precipitated from hot solutions within Earth.

The first three processes generally lead to varieties of rocks in which different mineral grains are closely intergrown in an interlocking fabric. Hydrothermal solutions, and even solutions at very low temperatures (e.g., groundwater), tend to follow fracture zones in rocks that may provide open spaces for the chemical precipitation of minerals from solution. It is from such open spaces, partially filled by minerals deposited from solutions, that most of the spectacular mineral specimens have been collected. If a mineral that is in the process of growth (as a result of precipitation) is allowed to develop in a free space, it will generally exhibit a well-developed crystal form, which adds to a specimen's aesthetic beauty. Similarly, geodes, which are rounded, hollow, or partially hollow bodies commonly found in limestones, may contain well-formed crystals lining the central cavity. Geodes form as a result of mineral deposition from solutions such as groundwater.

Minerals are important for your body to stay healthy. Your body uses minerals for many different jobs, including keeping your bones, muscles, heart, and brain working properly. Minerals are also important for making enzymes and hormones. There are two kinds of minerals: macrominerals and trace minerals. You need larger amounts of macrominerals. They include calcium, phosphorus, magnesium, sodium, potassium, chloride and sulfur. You only need small amounts of trace minerals. They include iron, manganese, copper, iodine, zinc, cobalt, fluoride and selenium.

Most people get the amount of minerals they need by eating a wide variety of foods. In some cases, your doctor may recommend a mineral supplement. People who have certain health problems or take some medicines may need to get less of one of the minerals. For example, people with chronic kidney disease need to limit foods that are high in potassium.

11.4 Biological important minerals

In the context of nutrition, a mineral is a chemical element required as an essential nutrient by organisms to perform functions necessary for life. Minerals originate in the earth and cannot be made by living organisms. Plants get minerals from soil. Most of the minerals in a human diet come from eating plants and animals or from drinking water. As a group, minerals are one of the four groups of essential nutrients, the others of which are vitamins, essential fatty acids, and essential amino acids. The five major minerals in the human body are calcium, phosphorus, potassium, sodium, and magnesium. All of the remaining elements in a human body are called “trace elements”. The trace elements that have a specific biochemical function in the human body are sulfur, iron, chlorine, cobalt, copper, zinc, manganese, molybdenum, iodine and selenium.

11.5 General functions

The general function of minerals and trace elements can be summarized as follows:

- Minerals are essential constituents of skeletal structures such as bones and teeth.
- Minerals play a key role in the maintenance of osmotic pressure, and thus regulate the exchange of water and solutes within the animal body.
- Minerals serve as structural constituents of soft tissues.
- Minerals are essential for the transmission of nerve impulses and muscle contraction.
- Minerals play a vital role in the acid-base equilibrium of the body, and thus regulate the pH of the blood and other body fluids.
- Minerals serve as essential components of many enzymes, vitamins, hormones, and respiratory pigments, or as cofactors in metabolism, catalysts and enzyme activators.

11.6 Macroelements

11.6.1 Calcium:

Biological function:

- Calcium is an essential component of bone, cartilage and the crustacean exoskeleton.
- Calcium is essential for the normal clotting of blood, by stimulating the release of thromboplastin from the blood platelets.
- Calcium is an activator for several key enzymes, including pancreatic lipase, acid phosphatase, cholinesterase, ATPases, and succinic dehydrogenase.

- Through its role in enzyme activation, calcium stimulates muscle contraction (ie. promotes muscle tone and normal heart beat) and regulates the transmission of nerve impulses from one cell to another through its control over acetylcholine production.
- Calcium, in conjunction with phospholipids, plays a key role in the regulation of the permeability of cell membranes and consequently over the uptake of nutrients by the cell.
- Calcium is believed to be essential for the absorption of vitamin B12 from the gastro-intestinal tract.

Dietary sources and absorption

Rich dietary sources of calcium include limestone, oyster shell grit, bone meal, rock phosphate (40–30%); white fish meal, poultry manure, meat meal (10–5%); and brown fish meal, D-lactose powder, dried skim milk, poultry by-product meal, beans, leafy vegitables, cabbage, egg yolk. Calcium is readily absorbed through the gastro-intestinal tract (through vitamin D3 action).

11.62 Phosphorus

Biological function:

- Phosphorus is an essential component of bone, cartilage and the crustacean exoskeleton.
- Phosphorus is an essential component of phospholipids, nucleic acids, phosphoproteins (casein), high energy phosphate esters (ATP), hexose phosphates, creatine phosphate, and several key enzymes.
- As a component of these important biological substances, phosphorus plays a central role in energy and cell metabolism.
- Inorganic phosphates serve as important buffers to regulate the normal acidbase balance (i.e. pH) of animal body fluids.

Dietary sources and absorption:

Rich dietary sources of phosphorus include rock phosphate, dicalcium phosphate, bone meal (20–10% P); meat and bone meal, meat meal, white fish meal, poultry by-product meal, milk, cereals, leafy vegetables, meat, eggs. Phosphate absorption occurs from jejenum. Calcitriol promotes phosphate uptake along with calcium. Acidity favours while phytate decreases phosphate uptake by intestinal cells.

11.7 Microelements

11.7.1 Iron

Biological function:

- Iron is an essential component of the respiratory pigments haemoglobin and myoglobin.
- Iron is an essential component of various enzyme systems including the cytochromes, catalases, peroxidases, and the enzymes xanthine and aldehyde oxidase, and succinic dehydrogenase.
- As a component of the respiratory pigments and enzymes concerned in tissue oxidation, iron is essential for oxygen and electron transport within the body.

Dietary sources and absorption:

Rich sources are organ meats (liver, heart, spleen), Good sources are leafy vegetables, pulses, cereals, fish, apples, dried fruits, molasses and poor sources are milk, wheat and polished rice. Iron is readily absorbed in the stomach and duodenum. Dietary iron availability and absorption is usually depressed by high dietary intakes of phosphate, calcium, phytates, copper and zinc. In general, inorganic sources of iron are more readily absorbed than organic sources; the ferrous iron (Fe++) being more available for absorption than ferric iron (Fe^{+++}). Reducing substances such as vitamin C enhance the absorption of non-haem iron.

11.72 Manganese

Biological function:

- Manganese functions in the body as an enzyme activator for those enzymes that mediate phosphate group transfer (ie. phosphate transferases and phosphate dehydrogenases), particularly those concerned with the citric acid cycle including arginase, alkaline phosphatase and hexokinase.
- Manganese is an essential component of the enzyme pyruvate carboxylase
- As a cofactor or component of several key enzyme systems, manganese is essential for bone formation (re. mucopolysaccharide synthesis), the regeneration of red blood cells, carbohydrate metabolism, and the reproductive cycle.

Dietary sources and absorption:

Rich sources of cereals, nuts, leafy vegetables, and fruits. Tea is rich sources of Mn. Manganese is readily absorbed from the gastro-intestinal tract. Iron inhibits Mn absorption.

11.73 Manganese

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Dietary sources and absorption

Rich sources of cereals, nuts, leafy vegetables, and fruits. Tea is rich sources of Mn. Manganese is readily absorbed from the gastro-intestinal tract. Iron inhibits Mn absorption.

11.74 Copper

Biological function:

- Copper is an essential component of numerous oxidation-reduction enzyme systems. For example, copper is a component of the enzymes cytochrome oxidase, uricase, tyrosinase, superoxide dismutase, amine oxidase, lysyl oxidase, and caeruloplasmin.
- As a component of the enzyme caeruloplasmin (ferroxidase), copper is intimately involved with iron metabolism, and therefore haemoglobin synthesis and red blood cell production and maintenance.
- Copper is also believed to be necessary for the formation of the pigment melanin and consequently skin pigmentation, for the formation of bone and connective tissue, and for maintaining the integrity of the myelin sheath of nerve fibres.

Dietary sources and absorption

Rich dietary sources of copper include liver, kidney, meat, egg yolk, cereals, nuts and green leafy vegetables. Milk is poor source. Copper is readily absorbed from the gastro-intestinal tract.

11.75Iodine

Biological function:

- Iodine is an integral component of the thyroid hormones, thyroxine and tri-iodo-thyronine, and as such is essential for regulating the metabolic rate of all body processes.
- Dietary sources and absorption: Rich dietary sources of iodine include sea foods, drinking water, vegetables, and fruits. Iodine is readily absorbed from the gastro-intestinal tract.

11.8 Summary

Under this unit we have discussed as minerals are important for our body to stay healthy. Our body uses minerals for many different jobs, including keeping your bones, muscles, heart, and brain working properly. Minerals are also important for making enzymes and hormones. There are two kinds of minerals: macrominerals and trace minerals. **They** are naturally occurring homogeneous solid that has a definite (but not fixed) chemical composition and a distinctive internal crystal structure. Minerals are usually formed by inorganic processes. Synthetic equivalents of various minerals, such as emeralds and diamonds, are manufactured for commercial purposes. Although most minerals are chemical compounds, a small number (e.g., sulfur, copper, gold) are elements. Minerals combine with each other to form rocks. For example, granite consists of the minerals feldspar, quartz, mica, and amphibole in varying amounts. Rocks are generally, therefore, an intergrowth of various minerals.

11.9 Terminal questions

Q.1 What are minerals? Explain it with examples.

Answer:---

Q.2 What do you mean by biological role of minerals? Explain it with examples.

Answer:---

Q.3 Explain different micronutrients.

Answer:---

Q. 4 Describe different minerals with examples.

Answer:---

Q. 5 Write short notes on the followings.

(i) Biological role of minerals

(ii) Occurrence of minerals

Answer:---

Q. 6 Describe different macronutrients with their examples.

Answer:---

Further readings

- Biochemistry- Lehninger A.L.
- Textbook of Nutrition and Dietetics Ranjana Mahna
- Biochemistry fourth edition-David Hames and Nigel Hooper.
- Textbook of Biochemistry for Undergraduates - Rafi, M.D.
- Textbook of Nutrition and Dietetics- Monika Sharma

Unit 12: Minerals (Group II)

Structure

12.1 Introduction

Iodine is an essential trace mineral not made by the body so must be obtained by food or supplements. It is found naturally in some foods and is added to supplements and some salt seasonings. Iodine is needed to make the thyroid hormones thyroxine and triiodothyronine, which assist with the creation of proteins and enzyme activity, as well as regulating normal metabolism. Without enough iodine, these thyroid hormones do not work properly and can lead to an under-active or overactive thyroid gland, causing the medical conditions of hypothyroidism and hyperthyroidism with various negative side effects in the body.

Iodine (I), chemical element, a member of the halogen elements, or Group 17 (Group VIIa) of the periodic table.Iodine is an element that is used by the thyroid. Humans cannot produce iodine, so it must be consumed. It is added to some foods and also to salt. Iodine reduces thyroid hormone and can kill fungus, bacteria, and other microorganisms such as amoebas. Iodine deficiency is one of the most common and preventable world health problems. Most iodine is found in the ocean, where it is concentrated by sea life, particularly in seaweed. Iodine is taken by mouth to prevent and treat iodine deficiency and its consequences, including goiter and some thyroid disorders. A specific kind of iodine called potassium iodide is also US FDA approved to prevent thyroid damage after a radioactive accident. Iodine is also used for pink eye, gum infections, wound healing, and many other conditions, but there is limited scientific evidence to support many of these uses.

Objectives

This is the twelfth unit (minerals-group II) under third block (Introduction to vitamins and minerals) of Fundamentals of Nutritional Biochemistry. Under eleventh unit, we have following objectives. These are as under:

- To know the history of minerals
- To know about occurrence and distribution of minerals.
- To discuss the need of iodine in food sources
- To discuss different food sources

12.2 History

In 1811 the French chemist Bernard Courtois obtained a violet vapour by heating seaweed ashes with sulfuric acid as a by-product of the manufacture of saltpetre. This vapour condensed to a black crystalline substance, which he called “substance X.” In 1813 British chemist Sir Humphry Davy, who was passing through Paris on his way to Italy, recognized substance X as an element analogous to chlorine; he suggested the name *iodine* from the Greek word *ioeides*, “violet coloured.”

12.3 Occurrence and distribution

Iodine is never found in nature uncombined, and it is not concentrated sufficiently to form independent minerals. It is present in seawater, but sparingly, as the iodide ion, I^-, to the extent of approximately 50 mg per metric ton (0.0016 ounce per ton) of seawater. It is also formed in seaweeds, oysters, and cod livers. Sodium iodate ($NaIO_3$) is contained in crude Chile saltpetre (sodium nitrate, $NaNO_3$). The human body contains iodine in the compound thyroxine, which is produced in the thyroid gland.

The only naturally occurring isotope of iodine is stable iodine-127. An exceptionally useful radioactive isotope is iodine-131, which has a half-life of eight days. It is employed in medicine to monitor thyroid gland functioning, to treat goitre and thyroid cancer, and to locate tumours of the brain and of the liver. It is also used in investigations to trace the course of compounds in metabolism. Several iodine compounds are used as contrast mediums in diagnostic radiology. In aqueous solution even minute amounts of iodine in the presence of starch produce a blue-black colour. Iodine helps make thyroid hormones, which help keep cells and the metabolic rate (the speed at which chemical reactions take place in the body) healthy.

12.4 Good sources of iodine

Good food sources of iodine include:

- cows' milk and dairy products
- eggs
- sea fish
- shellfish

Iodine can also be found in plant foods, such as cereals and grains, but the levels vary depending on the amount of iodine in the soil where the plants are grown.

12.5 How much iodine do I need?

Adults need 140 micrograms (µg) of iodine a day. Most people should be able to get all the iodine they need by eating a varied and balanced diet. If you are following a strict vegan diet and do not eat any fish, eggs, cows' milk or other dairy products, then you may want to consider foods fortified with iodine or consider taking an iodine supplement. Some types of plant-based drinks (such as soya or oat) are also fortified with iodine.

Check the label to see if it includes iodine. If you are considering taking a supplement seek advice from a healthcare professional. Taking high doses of iodine for long periods of time could change the way your thyroid gland works. This can lead to a wide range of different symptoms, such as weight gain. If you take iodine supplements, do not take too much as this could be harmful. Taking 0.5mg or less a day of iodine supplements is unlikely to cause any harm.

Social care advise from department of health

One should be able to get all the iodine you need by eating a varied and balanced diet. If you take iodine supplements, do not take too much as this could be harmful. Taking 0.5mg or less a day of iodine supplements is unlikely to cause any harm.

12.6 Iodine and Health

12.7 Food Sources

Iodine is found in soil and the ocean, which varies in amount and will affect how much of the mineral is contained in a food. Iodine is found mainly in animal protein foods and sea vegetables, and to a lesser extent in fortified foods like breads, cereals, and milk.

- Seaweed (nori, kelp, kombu, wakame)
- Fish, shellfish (cod, canned tuna, oysters, shrimp)
- Table salts labeled “iodized”
- Dairy (milk, cheese, yogurt)
- Eggs
- Beef liver
- Chicken
- Fortified infant formula

Selenium is a mineral found in the soil. Selenium naturally appears in water and some foods. While people only need a very small amount, selenium plays a key role in their metabolism.

Why do people take selenium?

Selenium has attracted attention because of its antioxidant properties. Antioxidants protect cells from damage. Evidence that selenium supplements may reduce the odds of prostate cancer has been mixed, but most studies suggest there is no real benefit. Selenium does not seem to affect the risk of colorectal or lung cancer. But beware: some studies suggest that selenium may increase the risk of non-melanoma skin cancer. Among healthy people in the U.S., selenium deficiencies are uncommon.

But some health conditions -- such as HIV, Crohn's disease, and others -- are associated with low selenium levels. People who are fed intravenously are also at risk for low selenium. Doctors sometimes suggest that people with these conditions use selenium supplements. Selenium has also been studied for the treatment of dozens of conditions. They range from asthma to arthritis to dandruff to infertility. However, the results have been inconclusive.

How much selenium should you take?

The recommended dietary allowance (RDA) includes the total amount of selenium you should get from foods and from any supplements you take. Most people can get their RDA of selenium from food. In some studies to determine if selenium could aid in prostate cancer prevention, men took 100 micrograms daily. The safe upper limit for selenium is 400 micrograms a day in adults. Anything above that is considered an overdose.

12.8 What are the risks of taking selenium?

Side effects

Taken at normal doses, selenium does not usually have side effects. An overdose of selenium may cause bad breath, fever, and nausea, as well as liver, kidney and heart problems and other symptoms. At high enough levels, selenium could cause death.

Interactions

Selenium may also interact with other medicines and supplements, such as some antacids, chemotherapy drugs, corticosteroids, niacin, cholesterol-lowering statin drugs, and birth control pills.

Skin cancer

Selenium supplements may be associated with a risk of skin cancer (squamous cell carcinoma), so people at high risk of skin cancer should not take these supplements.

12.9 Zinc

Biological functions:

- Zinc is an essential component of more than 80 metalloenzymes, including carbonic anhydrase (required for the transport of carbon dioxide by the blood and for the secretion of HCI in the stomach), glutamic dehydrogenase, alkaline phosphatase, pyridine nucleotide dehydrogenase, alcohol dehydrogenase, superoxide dismutase, pancreatic carboxy peptidase.
- Zinc serves as a cofactor in many enzyme systems, including arginase, enolase, several peptidases, and oxalacetic decarboxylase.
- As an active component or cofactor for many important enzyme systems zinc plays a vital role in lipid, protein, and carbohydrate metabolism; being particularly active in the synthesis and metabolism of nucleic acids (RNA) and proteins.
- Although not proven, it has been suggested that zinc plays a role in the action of hormones such as insulin, glucagon, corticotrophin, FSH and LH.
- Zinc is believed to play a positive role in wound healing.

12.10 Dietary sources and absorption:

Rich sources of meat, fish, eggs, milk, beans, and nuts. Zinc is readily absorbed from the gastro-intestinal tract. Dietary zinc availability and absorption is reduced in the presence of phytates, and high dietary intakes of calcium, phopshorus and copper.

12.11 Summary

Under this unit we have discussed as minerals are important for our body to stay healthy. We need larger amounts of macrominerals. They include calcium, phosphorus, magnesium, sodium, potassium, chloride and sulfur. You only need small amounts of trace minerals. They include iron, manganese, copper, iodine, zinc, cobalt, fluoride and selenium.Some minerals are more essential than others, in the sense that they have few if any substitutes capable of providing similar functionality at similar costs. Rocks and minerals are important for learning about earth materials, structure, and systems. Studying these natural objects incorporates an understanding of earth science, chemistry, physics, and math. The availability of these minerals is a function of geologic, technical, environmental and social, political, and economic factors.

12.12 Terminal questions

Q.1 What are micronutrients? Explain it with examples.

Answer:---

Q.2 What do you mean by inorganic elements? Explain it with examples.

Answer:---

Q.3 Explain iodine with its role in our body.

Answer:---

Q. 4 Describe role of calcium, phosphorus and iron in our body.

Answer:---

Q. 5 Write short notes on the followings.

(i) Iron

(ii) Calcium

Answer:---

Q. 6 Describe role of iodine, selenium and zinc in our body.

Answer:---

Further readings

- Biochemistry- Lehninger A.L.
- Textbook of Nutrition and Dietetics Ranjana Mahna
- Biochemistry fourth edition-David Hames and Nigel Hooper.
- Textbook of Biochemistry for Undergraduates - Rafi, M.D.
- Textbook of Nutrition and Dietetics- Monika Sharma