People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research

Chadli Bendjedid University
Faculty of Natural and Life Sciences

Department of Marine Sciences

Biochemistry

Courses and Practical Tutorials – TD

Level: Second Year Undergraduate (L2)
Semester: Semester 1
Prepared and Delivered by: Dr. Nora Mahfouf
Academic Year: 2025–2026

SYLLABUS

Course Information

Course Title: Biochemistry
Program: Marine and Continental Hydrobiology
Level: Second Year Undergraduate (L2)
Semester: Semester 1
Department: Department of Marine Sciences
Faculty: Faculty of Natural and Life Sciences
Institution: Chadli Bendjedid University
Academic Year: 2025–2026
Instructor: Dr. Nora Mahfouf

1. Course Description

This course introduces students to the fundamental principles of biochemistry with emphasis on the structure, properties, and biological roles of major biomolecules. Special attention is given to biochemical processes relevant to aquatic organisms and marine and continental ecosystems.

The course provides essential knowledge required for understanding physiological, metabolic, and ecological processes in hydrobiological systems.

2. Course Objectives

By the end of this course, students will be able to:

Understand the chemical foundations of biological molecules

Describe the structure and function of carbohydrates, proteins, lipids, and nucleic acids

Explain the biological importance of vitamins

Relate biochemical principles to aquatic and marine organisms

Develop analytical skills through tutorial problem-solving sessions

3. Learning Outcomes

Upon successful completion of this module, students will be able to:

Identify and classify different biomolecules

Explain structural differences between mono-, di-, and polysaccharides

Describe protein structure levels and their functional implications

Differentiate between fatty acids and complex lipids

Explain the molecular structure of nucleic acids

Understand the physiological role of vitamins in metabolism

4. Course Content

Chapter 1: Carbohydrates

Monosaccharides

Disaccharides

Polysaccharides

Chapter 2: Proteins

Amino acids: structure and properties

Peptide bond formation

Levels of protein structure

Functional roles of proteins

Chapter 3: Lipids

Fatty acids: structure and classification

Simple and complex lipids

Biological functions of lipids

Chapter 4: Nucleic Acids

Structure of nucleotides

DNA and RNA structure

Biological significance

Chapter 5: Vitamins

Classification (water-soluble and fat-soluble)

Biological functions

Role in enzymatic reactions

5. Teaching Methods

Lectures (theoretical sessions)

Tutorials (TD: exercises, biochemical problem-solving, molecule analysis)

Interactive discussions

6. Assessment Methods

Continuous assessment (TD participation, assignments, quizzes)

Final written examination

7. Prerequisites

Basic knowledge of general chemistry and cell biology.

8. Teaching Volume

Lectures (CM): 3 hours/week

Tutorials (TD): 1.30 hours/week

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Abbreviations

Carbohydrates

Mono – Monosaccharides

Di – Disaccharides

Poly – Polysaccharides

Glc – Glucose

Gal – Galactose

Fruc – Fructose

Suc – Sucrose

Lac – Lactose

Mal – Maltose

Proteins

AA – Amino Acids

Pept – Peptide

Prot – Proteins

BCAA – Branched-Chain Amino Acids

pI – Isoelectric point

Lipids & Fatty Acids

FA – Fatty Acids

TAG – Triacylglycerols

DAG – Diacylglycerol

PL – Phospholipids

Chol – Cholesterol

Nucleic Acids

NA – Nucleic Acids

DNA – Deoxyribonucleic Acid

RNA – Ribonucleic Acid

bp – Base Pair

nt – Nucleotide

Vitamins

Vit A – Vitamin A (Retinol)

Vit D – Vitamin D (Calciferol)

Vit E – Vitamin E (Tocopherol)

Vit K – Vitamin K (Phylloquinone / Menaquinone)

Vit B1 – Thiamine

Vit B2 – Riboflavin

Vit B3 – Niacin

Vit B6 – Pyridoxine

Vit B12 – Cobalamin

Vit C – Ascorbic Acid

Part I : Courses

Introduction to Biochemistry

Biochemistry is the branch of science that explores the chemical processes and molecules that sustain life. It bridges biology and chemistry, focusing on how living organisms function at a molecular level.

What is Biochemistry?

Biochemistry studies the structure, function, and interactions of biological molecules such as proteins, nucleic acids, carbohydrates, and lipids. These molecules are essential for various life processes, including metabolism, cell signaling, and genetic inheritance.

Key Areas of Biochemistry

1. Biomolecules:
   - Proteins: Enzymes, structural proteins, and signaling molecules.
   - Nucleic Acids: DNA and RNA, which store and transmit genetic information.
   - Carbohydrates: Energy sources and structural components (e.g., glucose, starch, cellulose).
   - Lipids: Membrane components and energy storage molecules (e.g., fats, oils, phospholipids).
2. Metabolism:
   - Catabolism: Breaking down molecules for energy.
   - Anabolism: Building complex molecules like proteins and nucleic acids.
   - Enzymes: Biological catalysts that speed up reactions.
3. Genetics and Molecular Biology:
   - How genes are expressed and regulated at the molecular level.
   - The role of DNA replication, transcription, and translation in protein synthesis.
4. Cellular Biochemistry:
   - The biochemical pathways that keep cells alive.
   - Signal transduction and cell communication.
5. Applications of Biochemistry:
   - Medicine: Understanding diseases, drug development, and genetic engineering.
   - Agriculture: Enhancing crop yields, pest resistance, and soil health.
   - Biotechnology: Developing biofuels, pharmaceuticals, and industrial enzymes.

Monosaccharides

Monosaccharides are the simplest form of carbohydrates, serving as fundamental building blocks for more complex carbohydrates like disaccharides and polysaccharides. They play crucial roles in energy production, structural functions, and biological signaling.

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1. Definition

Monosaccharides are single sugar molecules with the general chemical formula (CH2O)n(CH_2O)_n(CH2O)n, where nnn is typically between 3 and 7. Examples include glucose, fructose, and galactose.

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2. Classification

A. Based on Carbon Number

- **Trioses (3 carbons)**: Glyceraldehyde.
- **Tetroses (4 carbons)**: Erythrose.
- **Pentoses (5 carbons)**: Ribose, deoxyribose.
- **Hexoses (6 carbons)**: Glucose, fructose, galactose.

B. Based on Functional Group

- **Aldoses**: Contain an aldehyde group (-CHO). Example: Glucose.
- **Ketoses**: Contain a ketone group (C=O). Example: Fructose.

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3. Structure and Stereochemistry

A. Open-Chain and Cyclic Forms

- Monosaccharides can exist in open-chain or ring (cyclic) forms.
- Cyclic forms result from the reaction between a carbonyl group and a hydroxyl group, forming hemiacetals or hemiketals.

B. Isomerism

1. **Chirality**:
   - Monosaccharides have chiral centers, leading to D- and L-isomers (based on the orientation of the hydroxyl group on the penultimate carbon). ***Fig 01***

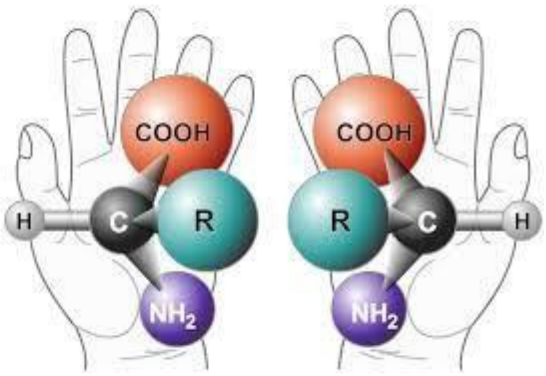

Figure 01 : Chirality

2. **Anomers**:

   - In cyclic forms, the orientation of the hydroxyl group on the anomeric carbon determines α (alpha) or β (beta) forms. ***Fig 02***

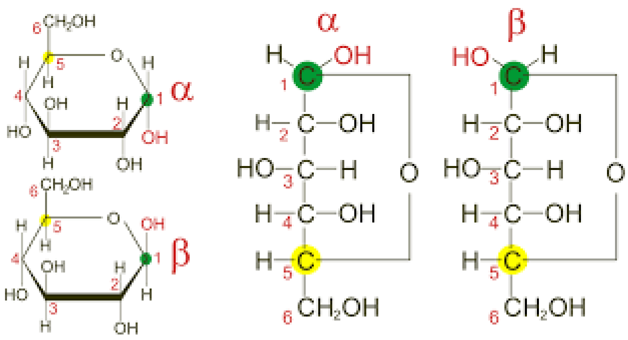

Figure 02 : Anomers

3. **Epimers**:

   - Differ at only one chiral center. Example: Glucose and galactose.

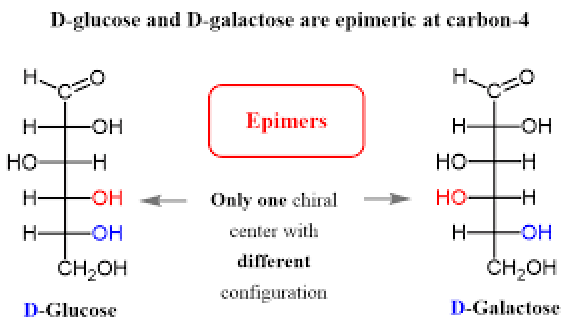

Figure 03 : Epimers

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4. Biological Functions

1. **Energy Production**:

   - Glucose is a primary energy source, undergoing glycolysis to generate ATP.

2. **Structural Role**:
    - Ribose and deoxyribose are essential for nucleic acids (RNA and DNA).
3. **Precursor to Complex Carbohydrates**:
    - Monosaccharides form disaccharides (e.g., sucrose, lactose) and polysaccharides (e.g., starch, cellulose).
4. **Cellular Communication**:
    - Components of glycoproteins and glycolipids involved in cell signaling and recognition.

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5. Examples of Monosaccharides

1. **Glucose**:
    - An aldose sugar and a major energy source in metabolism. ***Fig 4***
2. **Fructose**:
    - A ketose sugar found in fruits and honey. ***Fig4***
3. **Galactose**:
    - An aldose sugar, part of lactose (milk sugar). ***Figure 4***
4. **Ribose and Deoxyribose**:
    - Pentoses involved in RNA and DNA structure, respectively.

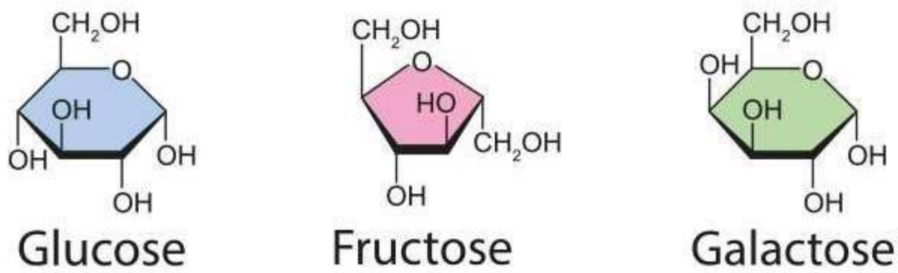

Figure 04 : Monosaccharides

6. Clinical Significance

1. **Diabetes Mellitus**:
    - A condition characterized by abnormal glucose metabolism.

2. **Disorders of Monosaccharide Metabolism**:
   - Fructose intolerance and galactosemia.
3. **Monosaccharides in Therapy**:
   - Glucose monitoring for managing diabetes.

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7. Analytical Methods

1. **Qualitative Tests**:
   - Benedict's test for reducing sugars. ***Fig 05***
   - Barfoed's test to distinguish between monosaccharides and disaccharides. ***Fig 06***

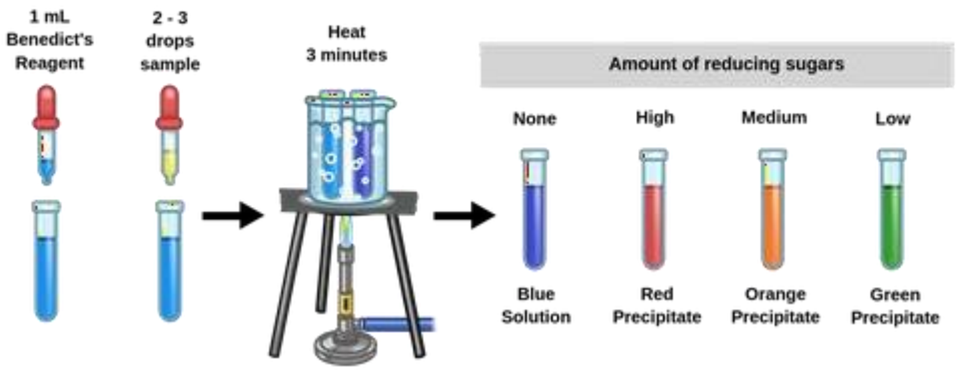

Figure 05 : Benedict's test

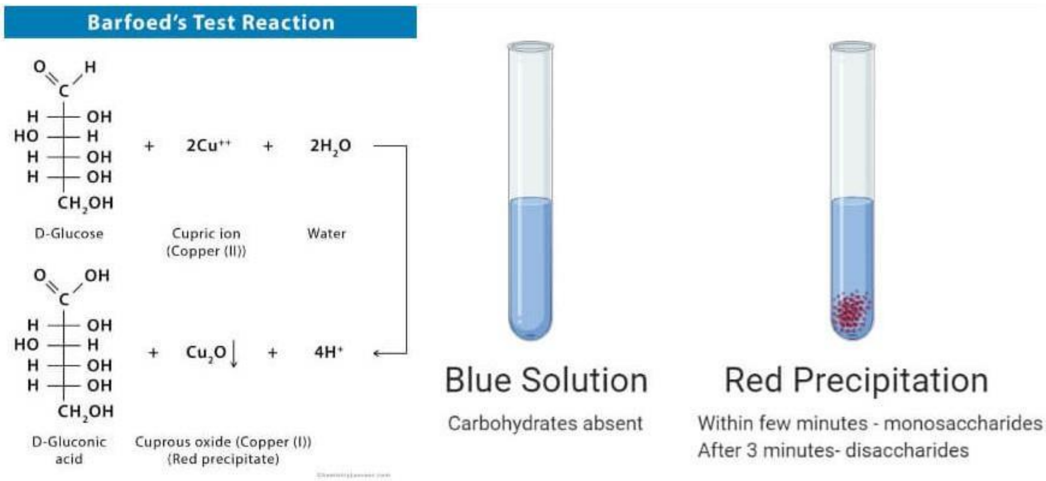

Figure 06 : Barfoed's test

2. **Advanced Techniques**:
   - Chromatography and mass spectrometry for structural analysis.

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8. Applications

1. **Biotechnology**:
   - Monosaccharides are used in producing biofuels and as carbon sources in microbial fermentation.
2. **Medicine**:
   - Research into glucose analogs for diabetes treatment.

Disaccharides

Disaccharides: Overview

Disaccharides are carbohydrates formed by the linkage of two monosaccharides through a **glycosidic bond**. They are a type of **oligosaccharide** and serve important roles in energy storage and transport in various organisms.

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1. Definition

Disaccharides are composed of two monosaccharide units linked by a glycosidic bond. They are **soluble** in water and have a **sweet taste**. The general molecular formula for disaccharides is **$C_{12}H_{22}O_{11}$**. ***fig 07***

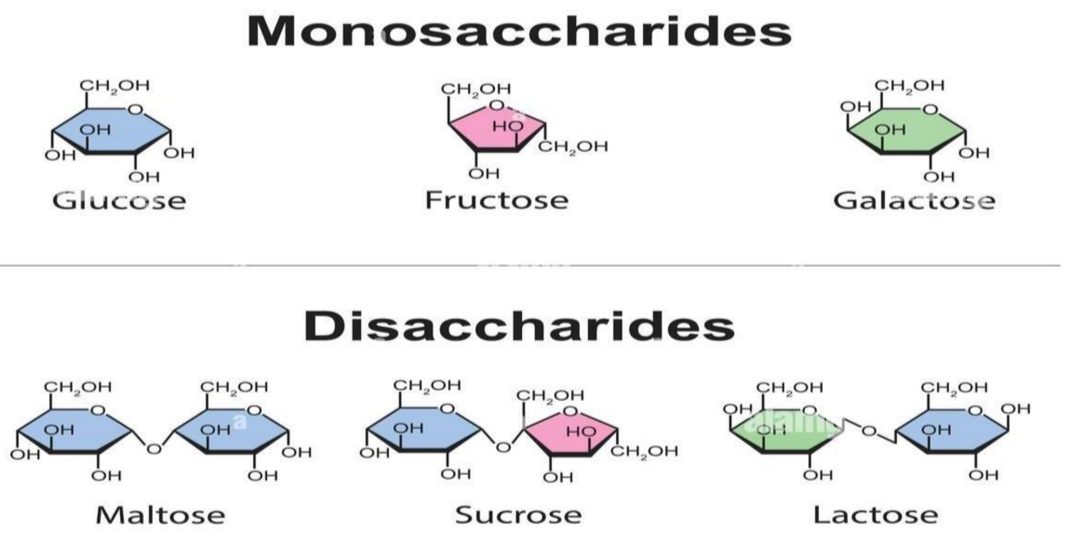

Figure07 : Disacharides

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2. Formation of Glycosidic Bond

- A **glycosidic bond** is formed through a **condensation reaction** (also called dehydration synthesis), where a molecule of water is released when two monosaccharides join.
- The **anomeric hydroxyl group** of one monosaccharide reacts with the **hydroxyl group** of another monosaccharide to form this bond.
- Depending on the **position** of the bond, disaccharides can have different **anomeric configurations** (alpha or beta). ***Fig 08***

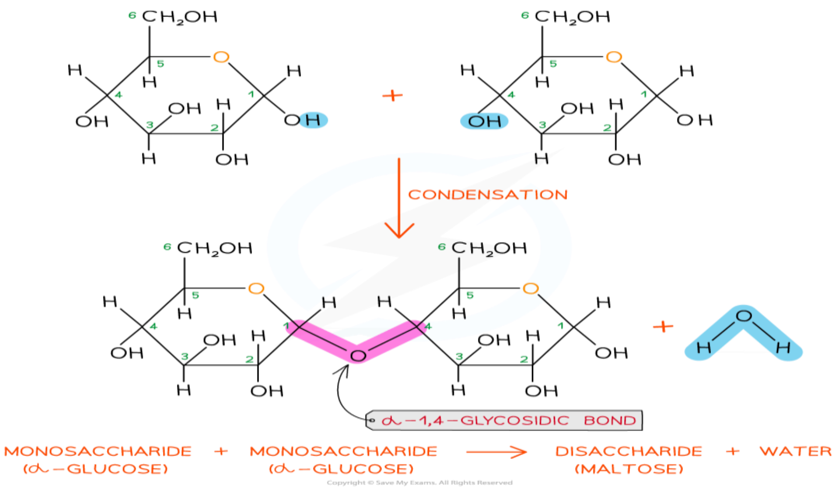

Figure 08 : Formation of Glycosidic Bond

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3. Types of Disaccharides

A. Sucrose (Common Sugar)

- **Monosaccharides**: Glucose and Fructose.
- **Bond**: **α-1,2 glycosidic bond**.
- **Properties**:
    - Non-reducing sugar (because both anomeric carbons are involved in the glycosidic bond, leaving no free aldehyde or ketone group).
    - Found in many plants, especially sugar cane and sugar beets.
    - Used extensively as a sweetener in food and beverages.

B. Lactose (Milk Sugar)

- **Monosaccharides**: Glucose and Galactose.
- **Bond**: **β-1,4 glycosidic bond**.
- **Properties**:
    - Reducing sugar (because the anomeric carbon of glucose is free to react with other molecules).
    - Found in milk and dairy products.
    - Digested by the enzyme **lactase** in humans; individuals who are lactose intolerant lack this enzyme.

C. Maltose (Malt Sugar)

- **Monosaccharides**: Two Glucose molecules.
- **Bond**: **α-1,4 glycosidic bond**.
- **Properties**:

- Reducing sugar (the glucose molecule at the non-reducing end has a free aldehyde group).
- Produced during the breakdown of starch (starch hydrolysis) in the human digestive system or in malt production.
- Common in brewing and distillation industries.

D. Trehalose

- **Monosaccharides**: Two Glucose molecules.
- **Bond**: **α-1,1 glycosidic bond**.
- **Properties**:
    - Non-reducing sugar.
    - Found in mushrooms, insects, and some microorganisms.
    - Plays a role in protecting cells from dehydration and oxidative stress.

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4. Biological Functions of Disaccharides

1. **Energy Source**:
    - Disaccharides, like sucrose and lactose, provide quick sources of energy.
    - They are broken down into monosaccharides (e.g., glucose) in the digestive system to be used in cellular respiration.
2. **Transport of Sugar**:
    - Disaccharides, especially sucrose, are used in plants for the long-distance transport of energy, as they are more stable than monosaccharides.
3. **Structural Role**:
    - Lactose plays a role in mammals by providing energy for newborns, who rely on milk for nourishment.

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5. Hydrolysis of Disaccharides

- Disaccharides can be broken down (hydrolyzed) into their constituent monosaccharides by the addition of water, using the enzyme **sucrase**, **lactase**, or **maltase** (depending on the disaccharide).
- For example: ***Fig 09***
    - **Sucrose + H_2O → Glucose + Fructose** (catalyzed by sucrase).
    - **Lactose + H_2O → Glucose + Galactose** (catalyzed by lactase).

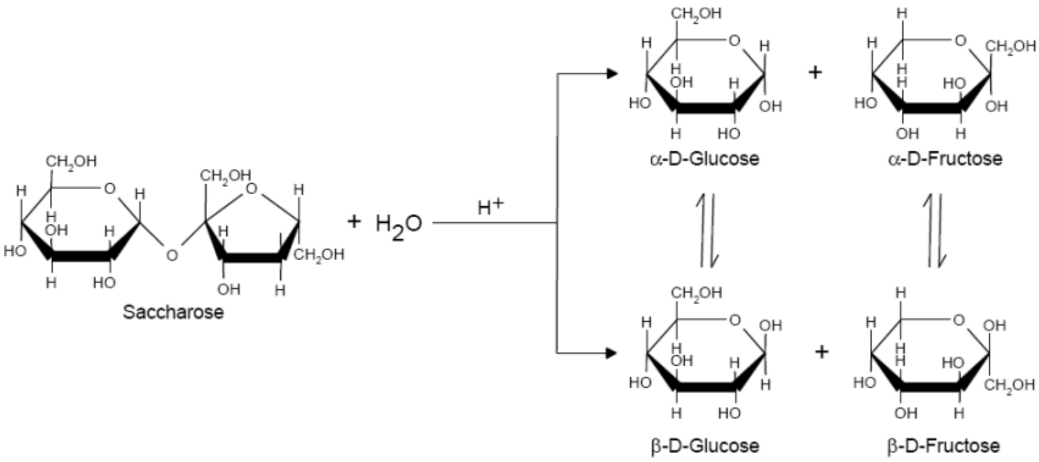

Figure 09 : Hydrolysis of Disaccharides

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6. Disorders Related to Disaccharides

1. **Lactose Intolerance**:
   - Caused by a deficiency in the enzyme **lactase**, leading to difficulty in digesting lactose in dairy products, resulting in gastrointestinal symptoms like bloating and diarrhea.
2. **Sucralose Sensitivity**:
   - Rare, but some individuals have difficulty processing sucrose, leading to health issues due to lack of specific enzymes.

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7. Applications of Disaccharides

1. **Food Industry**:
   - Sucrose is widely used as a sweetener in various food products, from candies to beverages.
   - Maltose is used in brewing and baking.
2. **Pharmaceuticals**:
   - Some disaccharides are used as excipients in the formulation of medicines, especially in tablet binding or as preservatives.
3. **Biotechnology**:
   - Trehalose is explored for its ability to protect proteins and cells during drying or freezing, and is used in cryopreservation.

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8. Analytical Methods for Disaccharides

- **Reducing Sugar Tests**:
  - Benedict’s Test can differentiate reducing sugars (like maltose and lactose) from non-reducing sugars (like sucrose).

- **Fehling's Test** and **Tollens' Test** are also used to identify reducing sugars.

- **Chromatography**:
  - Thin Layer Chromatography (TLC) or High-Performance Liquid Chromatography (HPLC) are used for separating and identifying disaccharides.

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9. Summary of Key Disaccharides : *Tab 01*

Table 01 : Disaccharides

Disaccharide	**Monosaccharide Units**	**Bond**	**Reducing or Non-reducing**	**Common Sources**
Sucrose	Glucose + Fructose	α-1,2 glycosidic bond	Non-reducing	Sugar cane, sugar beets
Lactose	Glucose + Galactose	β-1,4 glycosidic bond	Reducing	Milk and dairy products
Maltose	Glucose + Glucose	α-1,4 glycosidic bond	Reducing	Malt, barley, brewing
Trehalose	Glucose + Glucose	α-1,1 glycosidic bond	Non-reducing	Mushrooms, insects, yeast

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Polysaccharides

Polysaccharides: Overview

Polysaccharides are complex carbohydrates composed of long chains of monosaccharide units linked by **glycosidic bonds**. These molecules serve as energy storage, structural components, and play critical roles in various biological processes.

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1. Definition

Polysaccharides are large, polymeric carbohydrates made up of more than **10 monosaccharide units**. They can be linear or branched, and their size can range from hundreds to thousands of monosaccharides. They are generally **insoluble in water** and do not have a sweet taste, unlike monosaccharides or disaccharides.

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2. Classification of Polysaccharides

A. Based on Function

1. **Storage Polysaccharides**:
    - Serve as energy reserves for organisms.
    - Examples: **Starch** (plants), **Glycogen** (animals), and **Inulin** (plants).
2. **Structural Polysaccharides**:
    - Provide rigidity, support, and protection to cells and organisms.
    - Examples: **Cellulose** (plants), **Chitin** (insects, fungi), and **Peptidoglycan** (bacteria).

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3. Important Polysaccharides

A. Starch (Energy Storage in Plants) ***Fig 10***

- **Monosaccharides**: Glucose.
- **Structure**: Composed of two types of glucose polymers:
    - **Amylose**: Linear, helical structure formed by α-1,4 glycosidic bonds.
    - **Amylopectin**: Branched structure with α-1,4 glycosidic bonds and α-1,6 glycosidic branch points.
- **Function**: Starch is the primary energy storage polysaccharide in plants, stored in the form of granules in the cytoplasm of plant cells (e.g., potatoes, grains).
- **Hydrolysis**: Can be broken down into glucose by amylase during digestion.

B. Glycogen (Energy Storage in Animals)

- **Monosaccharides**: Glucose.
- **Structure**: Similar to amylopectin but more highly branched with α-1,4 and α-1,6 glycosidic bonds. Glycogen is stored primarily in the liver and muscles.
- **Function**: It serves as the main energy reserve in animals. When energy is needed, glycogen is broken down into glucose via **glycogenolysis**.
- **Hydrolysis**: The process of glycogen breakdown is stimulated by hormones like glucagon and adrenaline.

C. Cellulose (Structural Polysaccharide in Plants) *Fig 10*

- **Monosaccharides**: Glucose.
- **Structure**: Composed of linear chains of glucose units connected by **β-1,4 glycosidic bonds**. These chains form strong fibers, and hydrogen bonding between adjacent chains gives cellulose its rigidity and insolubility.
- **Function**: It is the main structural component of the plant cell wall, providing support and shape to the plant. It is not digestible by humans due to the lack of enzymes to break β-1,4 bonds.
- **Hydrolysis**: Only certain organisms like ruminants and some fungi can break down cellulose due to specialized enzymes (cellulase).

D. Chitin (Structural Polysaccharide in Arthropods and Fungi) *Fig 10*

- **Monosaccharides**: **N-acetylglucosamine** (GlcNAc), a derivative of glucose.
- **Structure**: Chitin is similar to cellulose but with **N-acetylglucosamine** units linked by β-1,4 glycosidic bonds.
- **Function**: Chitin provides structural support in the exoskeletons of arthropods (insects, crustaceans) and in the cell walls of fungi.
- **Hydrolysis**: Chitin can be broken down by the enzyme **chitinase**, found in certain organisms.

E. Inulin (Storage Polysaccharide in Plants)

- **Monosaccharides**: **Fructose** units, typically with a glucose molecule at the reducing end.
- **Structure**: Inulin is composed of fructose molecules linked by β-2,1 glycosidic bonds, with a single glucose unit at the end.
- **Function**: It serves as a storage polysaccharide in plants, particularly in roots and tubers (e.g., in chicory, Jerusalem artichokes).
- **Hydrolysis**: Inulin can be broken down by the enzyme **inulinase**, releasing fructose.

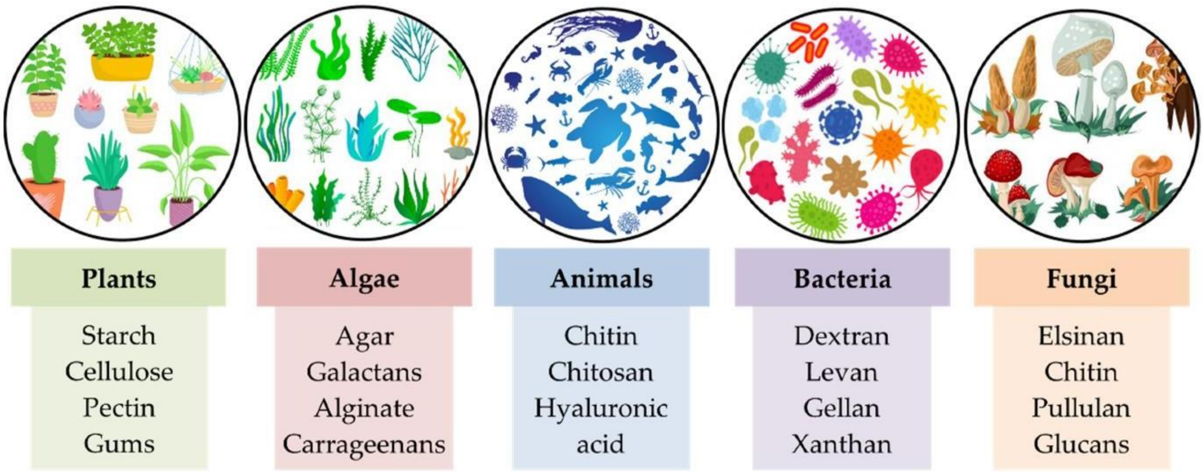

Figure 10 : Sources of polysaccharides

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4. Properties of Polysaccharides

1. **Insolubility**: Most polysaccharides are insoluble in water, making them ideal for storage in cells or tissues (e.g., starch, glycogen).
2. **High Molecular Weight**: Polysaccharides are large macromolecules and can have a high molecular weight, which allows them to form strong structures (e.g., cellulose).
3. **Hydrolysis**: Polysaccharides can be broken down into their monosaccharide units through hydrolysis, typically catalyzed by enzymes.

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5. Biological Roles

1. **Energy Storage**:
    - Polysaccharides like **starch** and **glycogen** store glucose for later energy use in plants and animals, respectively.
2. **Structural Support**:
    - **Cellulose** and **chitin** provide structural integrity and protection to cells and organisms, forming the cell walls of plants and fungi and the exoskeletons of arthropods.
3. **Protection**:
    - **Peptidoglycan** is a polysaccharide found in bacterial cell walls, providing rigidity and protection against osmotic pressure.
4. **Cell Recognition**:
    - Polysaccharides are also important in cell signaling and recognition, particularly in the form of glycoproteins and glycolipids on cell surfaces.

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6. Polysaccharides in the Human Diet

1. **Dietary Fiber**:

- Cellulose is an important component of dietary fiber, which is essential for digestive health. While humans cannot digest cellulose, it aids in bowel regularity and gut health.

2. **Starch**:
   - The primary carbohydrate in the human diet, starch is digested by amylase into glucose, providing a major source of energy.

3. **Chitin**:
   - While not digestible by humans, chitin is present in the exoskeletons of shellfish and insects, and it is sometimes used in the pharmaceutical and cosmetic industries as a source of chitosan (a derivative).

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7. Disorders Related to Polysaccharides

1. **Glycogen Storage Diseases (GSDs)**:
   - These are inherited disorders caused by defects in enzymes involved in glycogen synthesis or breakdown. This leads to abnormal glycogen storage in tissues, resulting in problems like muscle weakness or liver dysfunction.

2. **Cellulose Digestive Disorders**:
   - Certain digestive disorders, such as **celiac disease**, can affect the ability to process certain polysaccharides, particularly those containing gluten (a protein found in some polysaccharides).

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8. Applications of Polysaccharides

1. **Food Industry**:
   - Starch is used in food processing as a thickener, stabilizer, or emulsifier.
   - Inulin is used as a low-calorie sweetener and fiber supplement.

2. **Pharmaceuticals**:
   - Polysaccharides like **chitosan** (from chitin) are used for weight loss products, cholesterol-lowering supplements, and as drug delivery agents.

3. **Biotechnology**:
   - Polysaccharides such as **cellulose** are being explored for use in biofuels, and efforts are being made to develop enzymes that can break down cellulose efficiently for this purpose.

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9. Summary of Key Polysaccharides

Table 02 : Polysaccharides

Polysaccharide	**Monosaccharide Units**	**Bond Type**	**Function**	**Sources**
Starch	Glucose	α-1,4 and α-1,6 glycosidic bonds	Energy storage in plants	Plants (e.g., potatoes, corn)
Glycogen	Glucose	α-1,4 and α-1,6 glycosidic bonds	Energy storage in animals	Liver, muscles (animals)
Cellulose	Glucose	β-1,4 glycosidic bonds	Structural component in plants	Plant cell walls
Chitin	N-acetylglucosamine	β-1,4 glycosidic bonds	Structural component in arthropods, fungi	Insects, fungi
Inulin	Fructose	β-2,1 glycosidic bonds	Energy storage in plants	Chicory, Jerusalem artichoke

Proteins

Proteins: Overview

Proteins are complex, high-molecular-weight molecules that play critical roles in nearly every biological process. They are composed of amino acids linked by peptide bonds and are involved in nearly every cellular function, from structural support to catalyzing biochemical reactions.

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1. Definition of Proteins

Proteins are macromolecules made up of one or more polypeptide chains, which are themselves composed of sequences of amino acids. The sequence of amino acids in a protein determines its three-dimensional structure and function. Proteins are essential for the structure, function, and regulation of the body's cells, tissues, and organs.

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2. Structure of Proteins *Fig 11*

Proteins have four levels of structure, each contributing to their shape and function.

A. Primary Structure

- The primary structure refers to the unique sequence of amino acids in a polypeptide chain, linked by **peptide bonds**.
- The sequence is determined by the gene encoding the protein and dictates the protein's final shape and function.

B. Secondary Structure

- The secondary structure refers to the local folding of the polypeptide chain into specific patterns:
  - **α-helix**: A spiral or helical structure stabilized by hydrogen bonds between the amino acid residues.
  - **β-pleated sheet**: A sheet-like arrangement of polypeptide chains held together by hydrogen bonds.

C. Tertiary Structure

- The tertiary structure is the overall three-dimensional shape of a protein, formed by the folding of the secondary structures.
- This structure is stabilized by various interactions, such as **hydrogen bonds**, **ionic bonds**, **disulfide bridges**, and **hydrophobic interactions**.

D. Quaternary Structure

- The quaternary structure exists in proteins that consist of more than one polypeptide chain (subunit). The arrangement of these subunits into a functional protein is the quaternary structure.
- Example: **Hemoglobin** has four subunits that work together to transport oxygen.

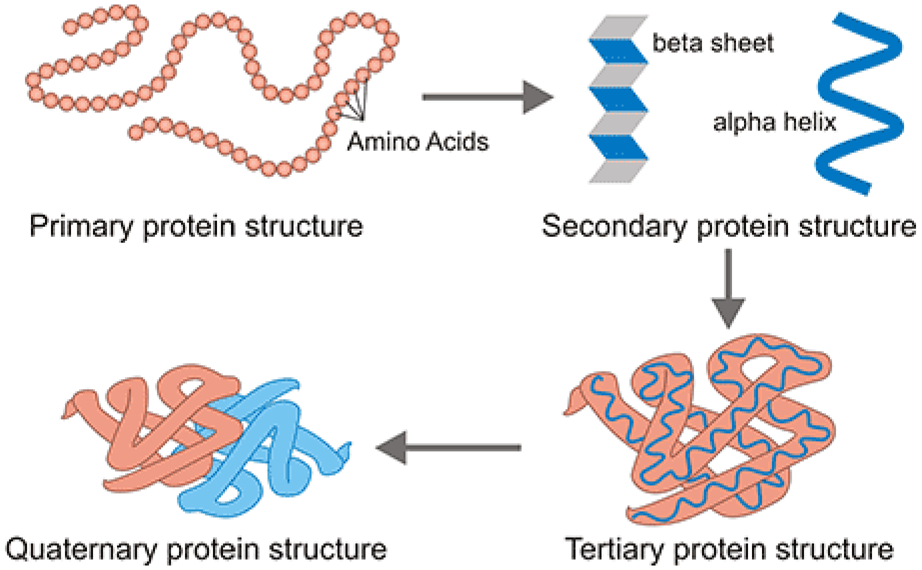

Figure 11 : Structure of Proteins

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3. Classification of Proteins

Proteins can be classified based on their structure, function, and solubility.

A. Based on Structure

1. **Fibrous Proteins**:
   - These proteins are long, linear, and insoluble in water. They are structural proteins that provide support and strength.
   - Examples: **Collagen** (in connective tissue), **Keratin** (in hair and nails), **Elastin** (in elastic tissues).
2. **Globular Proteins**:
   - These proteins are spherical or globular and are generally soluble in water. They function as enzymes, antibodies, hormones, and more.
   - Examples: **Hemoglobin**, **Myoglobin**, **Enzymes** like **amylase**.

B. Based on Function

1. **Enzymes**:
   - Proteins that catalyze biochemical reactions by lowering the activation energy.
   - Examples: **DNA polymerase**, **Lactase**.
2. **Structural Proteins**:
   - Provide support and shape to cells and tissues.
   - Examples: **Collagen**, **Elastin**, **Actin**.
3. **Transport Proteins**:
   - Transport molecules such as gases, ions, and nutrients.

- Examples: **Hemoglobin** (transports oxygen), **Albumin** (transports fatty acids).

4. **Defense Proteins**:
   - Involved in the immune response and protection against pathogens.
   - Examples: **Antibodies**, **Defensins**.
5. **Regulatory Proteins**:
   - Regulate cellular processes and gene expression.
   - Examples: **Insulin**, **Transcription factors**.
6. **Storage Proteins**:
   - Store amino acids or other substances for future use.
   - Examples: **Ferritin** (stores iron), **Casein** (milk protein).

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4. Functions of Proteins

Proteins perform a wide variety of functions in the body:

1. **Catalysis**:
   - **Enzymes** are proteins that accelerate chemical reactions in the body, such as digestion (e.g., **amylase** breaking down starch) and cellular metabolism (e.g., **ATP synthase** generating ATP).
2. **Structure**:
   - Proteins provide structural integrity to cells and tissues. **Collagen** in connective tissue, **actin** in muscle fibers, and **keratin** in skin, hair, and nails are key examples.
3. **Transport**:
   - **Hemoglobin** transports oxygen in the blood, while **albumin** carries fatty acids and hormones.
4. **Movement**:
   - **Actin** and **myosin** are the primary proteins involved in muscle contraction and movement.
5. **Defense**:
   - **Antibodies** are proteins that help protect the body from infections by binding to foreign antigens.
6. **Signaling**:
   - Proteins like **insulin** (a hormone) regulate various physiological processes, including glucose metabolism.
7. **Storage**:
   - **Ferritin** stores iron in the liver, and **casein** stores amino acids in milk.

---

5. Protein Synthesis (Translation)

Protein synthesis occurs in two stages: **transcription** and **translation**.

A. Transcription:

- The process in which the genetic code from **DNA** is copied into **mRNA** (messenger RNA).

B. Translation:

- The mRNA is read by **ribosomes** in the **cytoplasm**, where **tRNA** (transfer RNA) brings amino acids to the ribosome.
- The amino acids are linked together in the correct sequence to form a polypeptide chain, which folds into a functional protein. ***Fig 12***

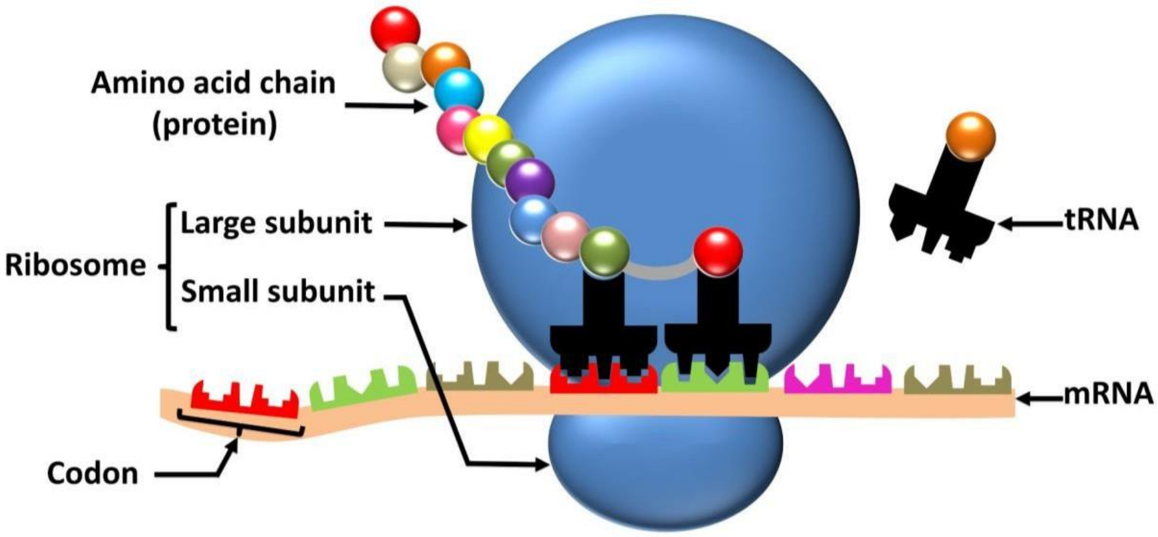

Figure 12 : Protein Synthesis (Translation)

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6. Denaturation of Proteins

Denaturation is the process in which a protein loses its three-dimensional structure and, consequently, its biological function. This can be caused by factors such as:

1. **Heat**: High temperatures can disrupt hydrogen bonds and other forces that maintain a protein's shape.
2. **pH Changes**: Extreme pH levels can alter ionic bonds and hydrogen bonds.
3. **Chemical Agents**: Detergents, salts, or organic solvents can disrupt protein structure.

---

7. Protein-Protein Interactions

Proteins often interact with each other to perform specific functions. These interactions can be **transient** or **stable**:

1. **Enzyme-Substrate Interactions**:

    - Enzymes interact with substrates to catalyze reactions. For example, **hexokinase** interacts with glucose to produce glucose-6-phosphate.

2. **Signal Transduction**:
    - Receptor proteins on the cell surface interact with signaling molecules (e.g., hormones) to transmit signals inside the cell.
3. **Protein Complexes**:
    - Some proteins, such as those in the **photosystem** or **ATP synthase**, form large complexes that work together to carry out biological processes.

---

8. Disorders Related to Proteins

1. **Sickle Cell Anemia**:
    - A genetic disorder caused by a mutation in the hemoglobin protein, leading to abnormal red blood cell shapes that impair oxygen transport.
2. **Cystic Fibrosis**:
    - Caused by mutations in the **CFTR** protein, which impairs chloride ion transport across cell membranes, leading to thick mucus production in various organs.
3. **Alzheimer's Disease**:
    - Associated with the accumulation of misfolded proteins, particularly **amyloid plaques**, which disrupt cell function in the brain.
4. **Prion Diseases**:
    - Caused by abnormal folding of proteins, leading to neurodegenerative diseases like **mad cow disease** and **Creutzfeldt-Jakob disease**.

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9. Protein Structure and Function in Biotechnology

Proteins are essential in various biotechnological applications, including:

1. **Enzyme Engineering**:
    - Altering enzymes for industrial applications, such as in the food industry (e.g., cheese production, brewing) and biotechnology (e.g., gene editing using **CRISPR**).
2. **Protein Therapies**:
    - Recombinant proteins like **insulin** and **growth factors** are used in medicine to treat diseases.
3. **Biomarkers**:
    - Proteins are often used as biomarkers for disease diagnosis, as their expression or levels change in response to disease.

---

10. Summary of Key Protein Types

Table 03 : Protein Types

Type of Protein	Function	Examples
Enzymes	Catalyze biochemical reactions	**Amylase**, **DNA polymerase**
Structural Proteins	Provide mechanical support	**Collagen**, **Keratin**
Transport Proteins	Carry substances across membranes	**Hemoglobin**, **Albumin**
Defense Proteins	Protect against pathogens	**Antibodies**, **Defensins**
Regulatory Proteins	Control metabolic processes	**Insulin**, **Transcription factors**
Storage Proteins	Store molecules for later use	**Ferritin**, **Casein**

Fatty Acids

Fatty Acids: Overview

Fatty acids are long chains of hydrocarbons that end in a carboxyl group (-COOH). They are essential components of lipids and are crucial for various biological functions, such as energy storage, membrane structure, and signaling. Fatty acids can be classified based on their structure, length, and degree of saturation.

---

1. Definition of Fatty Acids

A fatty acid is an organic molecule made up of a **hydrocarbon chain** (a chain of carbon atoms bonded to hydrogen atoms) and a **carboxyl group (-COOH)** at one end. The length and saturation of the hydrocarbon chain determine the fatty acid's properties and function. ***Fig 13***

Fatty acids can be either:

- **Saturated** (no double bonds between carbon atoms).
- **Unsaturated** (one or more double bonds between carbon atoms).

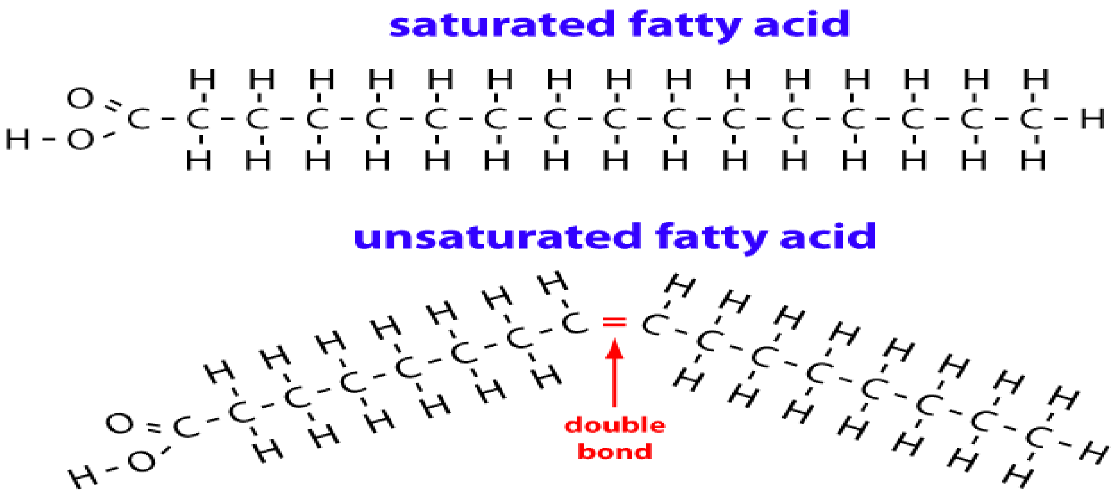

Figure 13 : Fatty acids

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2. Structure of Fatty Acids

A fatty acid consists of:

- **Hydrocarbon Chain**: A chain of carbon atoms bonded to hydrogen atoms. The chain can be short, medium, or long in length.
- **Carboxyl Group (-COOH)**: A functional group consisting of a carbonyl group (C=O) attached to a hydroxyl group (OH).

The general formula for a fatty acid is:

scss

Copier le code

CH3-(CH2)n-COOH

Where:

- **CH3** is the methyl group at one end (the "omega" end).
- **(CH2)n** is a chain of methylene groups (hydrocarbons).
- **COOH** is the carboxyl group at the other end (the "alpha" end).

---

3. Classification of Fatty Acids

Fatty acids can be classified based on their **length**, **saturation**, and **shape**.

A. Based on Saturation

1. **Saturated Fatty Acids**:
   - These fatty acids have **no double bonds** between the carbon atoms, meaning each carbon atom is "saturated" with hydrogen atoms.
   - They tend to be **solid** at room temperature.
   - **Examples**: **Palmitic acid (C16:0)**, **Stearic acid (C18:0)**.
2. **Unsaturated Fatty Acids**:
   - These fatty acids have **one or more double bonds** between carbon atoms, which creates "kinks" in the chain and prevents tight packing.
   - They tend to be **liquid** at room temperature (oils).
   - **Monounsaturated Fatty Acids** (one double bond):
     - **Examples**: **Oleic acid (C18:1)** (found in olive oil).
   - **Polyunsaturated Fatty Acids** (multiple double bonds):
     - **Examples**: **Linoleic acid (C18:2)** (omega-6), **Alpha-linolenic acid (C18:3)** (omega-3).
3. **Trans Fatty Acids**:
   - These are a form of unsaturated fatty acids where the hydrogen atoms are on opposite sides of the double bond (trans configuration), resulting in a straighter chain.
   - Trans fats are **unnatural** and typically created through the process of **hydrogenation** of vegetable oils.
   - **Examples**: Some processed foods and margarine.

B. Based on Chain Length

1. **Short-Chain Fatty Acids**:

- Contain fewer than 6 carbon atoms.
- Often produced by gut bacteria during the fermentation of fiber.
- **Examples**: **Acetic acid (C2:0)**, **Butyric acid (C4:0)**.

2. **Medium-Chain Fatty Acids**:
   - Contain 6 to 12 carbon atoms.
   - Easily absorbed and metabolized for energy.
   - **Examples**: **Caprylic acid (C8:0)**, **Capric acid (C10:0)**.
3. **Long-Chain Fatty Acids**:
   - Contain 13 or more carbon atoms.
   - Most common in dietary fats.
   - **Examples**: **Palmitic acid (C16:0)**, **Stearic acid (C18:0)**.

---

4. Essential Fatty Acids

Some fatty acids are termed **essential** because the body cannot synthesize them, and they must be obtained through the diet. These essential fatty acids are primarily **polyunsaturated fatty acids**.

1. **Omega-3 Fatty Acids**:
   - Important for reducing inflammation, improving heart health, and supporting brain function.
   - **Examples**: **Alpha-linolenic acid (ALA)**, **Eicosapentaenoic acid (EPA)**, **Docosahexaenoic acid (DHA)** (found in fish oils).
2. **Omega-6 Fatty Acids**:
   - Important for cell structure and immune function.
   - **Examples**: **Linoleic acid (LA)**, **Arachidonic acid (AA)** (found in vegetable oils).

---

5. Functions of Fatty Acids

Fatty acids perform a variety of functions in the body:

1. **Energy Storage and Production**:
   - Fatty acids are the primary energy storage molecules in the body. When needed, triglycerides (fat) are broken down into fatty acids and glycerol, which are used for energy production.
2. **Cell Membrane Structure**:
   - Fatty acids are key components of **phospholipids**, which form the basic structure of cell membranes. The **hydrophobic tail** of phospholipids is composed of fatty acids, which help to form the lipid bilayer.
3. **Signal Transduction**:

- Fatty acids, particularly **arachidonic acid**, are involved in signaling pathways and can be converted into **eicosanoids**, such as prostaglandins, which regulate inflammation, blood clotting, and immune responses.

4. **Insulation and Protection**:
   - Fatty acids, stored in adipose tissue, help insulate the body, conserving heat and protecting organs by providing a cushioning effect.

5. **Hormone Regulation**:
   - Some fatty acids are precursors for hormones such as **steroid hormones** (e.g., cortisol, estrogen) and **prostaglandins** that regulate various physiological functions.

---

6. Metabolism of Fatty Acids

Fatty acids are metabolized through a process known as **β-oxidation**, which occurs in the **mitochondria** of cells. During this process:

- Fatty acids are broken down into **acetyl-CoA** units.
- **Acetyl-CoA** then enters the **citric acid cycle** (Krebs cycle) to produce ATP, the cell's energy currency.

In the liver, fatty acids can also be converted into **ketone bodies**, which are used by tissues such as the brain during periods of low glucose availability (e.g., fasting or ketogenic diet).

---

7. Fatty Acids and Health

1. **Saturated Fats**:
   - High consumption of **saturated fats** (found in animal products and some plant oils like coconut and palm oil) has been linked to an increased risk of **heart disease** and **high cholesterol levels**.

2. **Unsaturated Fats**:
   - **Monounsaturated fats** (found in olive oil, avocados) and **polyunsaturated fats** (found in fatty fish, flaxseeds) are generally considered heart-healthy. They can help reduce **bad cholesterol (LDL)** levels and increase **good cholesterol (HDL)**.

3. **Trans Fats**:
   - **Trans fats** are artificially created through hydrogenation and have been shown to increase the risk of heart disease, diabetes, and other chronic conditions. They should be minimized in the diet.

4. **Essential Fatty Acids**:
   - Adequate intake of **omega-3 fatty acids** (e.g., from fish or flaxseed) has been shown to reduce inflammation, support brain health, and improve cardiovascular health.

---

8. Sources of Fatty Acids

1. **Saturated Fatty Acids**:

- Animal fats (beef, pork, lamb)
- Dairy products (cheese, butter, milk)
- Coconut oil and palm oil

2. **Monounsaturated Fatty Acids**:
    - Olive oil
    - Avocados
    - Nuts (almonds, cashews)
    - Peanut oil
3. **Polyunsaturated Fatty Acids**:
    - Fatty fish (salmon, mackerel, sardines)
    - Flaxseeds, chia seeds, walnuts
    - Soybean oil, sunflower oil, corn oil

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8. Summary of Key Fatty Acids

Table 04 : Fatty Acids

Fatty Acid	Type	Sources	Health Benefits
Palmitic Acid	Saturated	Animal fat, palm oil, butter	Provides energy; high intake linked to heart disease
Oleic Acid	Monounsaturated	Olive oil, avocados, nuts	Supports heart health, reduces inflammation
Linoleic Acid	Omega-6 (Polyunsaturated)	Vegetable oils (corn, sunflower)	Supports skin, cell function, and immune system
Alpha-Linolenic Acid (ALA)	Omega-3 (Polyunsaturated)	Flaxseeds, walnuts, chia seeds	Reduces inflammation, improves heart health
Eicosapentaenoic Acid (EPA)	Omega-3 (Polyunsaturated)	Fatty fish (salmon, mackerel)	Reduces inflammation, supports brain and heart health
Docosahexaenoic Acid (DHA)	Omega-3 (Polyunsaturated)	Fatty fish (salmon, sardines)	Supports brain function and cognitive health

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Lipids

Lipids: Overview

Lipids are a diverse group of organic compounds that are insoluble in water but soluble in organic solvents such as chloroform, ether, and alcohol. They play essential roles in the body, including energy storage, structural components of cell membranes, insulation, and serving as signaling molecules. Lipids include fats, oils, waxes, phospholipids, and steroids.

---

1. Definition of Lipids

Lipids are a broad class of hydrophobic or amphipathic (having both hydrophobic and hydrophilic parts) organic molecules. They are not polymers but instead are often simple or complex molecules consisting of carbon, hydrogen, and oxygen atoms. Some lipids also contain nitrogen, phosphorus, and sulfur.

While lipids do not form long chains like carbohydrates or proteins, they are highly important in both energy storage and cellular structure. The main categories of lipids include **fatty acids**, **triglycerides**, **phospholipids**, **steroids**, and **waxes**.

---

2. Types of Lipids

A. Simple Lipids

1. **Fatty Acids**
   - Fatty acids are long hydrocarbon chains with a carboxyl group (-COOH) at one end. They are the building blocks of many other lipids.
   - Fatty acids can be **saturated** (no double bonds) or **unsaturated** (with one or more double bonds).
     - **Saturated fatty acids** (e.g., stearic acid) tend to be solid at room temperature.
     - **Unsaturated fatty acids** (e.g., oleic acid) are typically liquid at room temperature and are commonly found in plant oils and fish.
2. **Triglycerides (Triacylglycerols)**
   - Triglycerides are the most common type of fat in the body and diet. They consist of a **glycerol backbone** attached to three fatty acid molecules.
   - Triglycerides serve as **energy storage** molecules, with fats providing more energy per gram than carbohydrates or proteins.
   - They are found in adipose tissue and also in food sources like oils, butter, and animal fats.
   - **Structure**:
     - Glycerol + 3 fatty acids → Triglyceride.
3. **Waxes**
   - Waxes are long-chain fatty acids esterified to long-chain alcohols.

- They are used by plants and animals for **protection**, such as coating the surfaces of leaves to prevent water loss, or in the production of **earwax** in humans.
- **Example**: Beeswax, which is used by bees to build honeycombs.

B. Complex Lipids

1. **Phosphlipids**

   - Phospholipids are the primary component of **cell membranes**. They have a glycerol backbone attached to two fatty acids and a phosphate group.
   - The **hydrophobic tails** (fatty acids) are repelled by water, while the **hydrophilic head** (phosphate group) is attracted to water. This property allows phospholipids to form bilayers in cell membranes. ***Fig 14***
   - **Example**: **Phosphatidylcholine**, a common phospholipid found in cell membranes.
   - **Structure**:
     - Glycerol + 2 fatty acids + phosphate group → Phospholipid.

2. **Glycolipids**

   - Glycolipids are lipids with a carbohydrate group attached to the lipid moiety. They are important components of the cell membrane and are involved in cell recognition and signaling.
   - **Example**: **Gangliosides**, which are found in nerve cells and play a role in cell-to-cell communication.

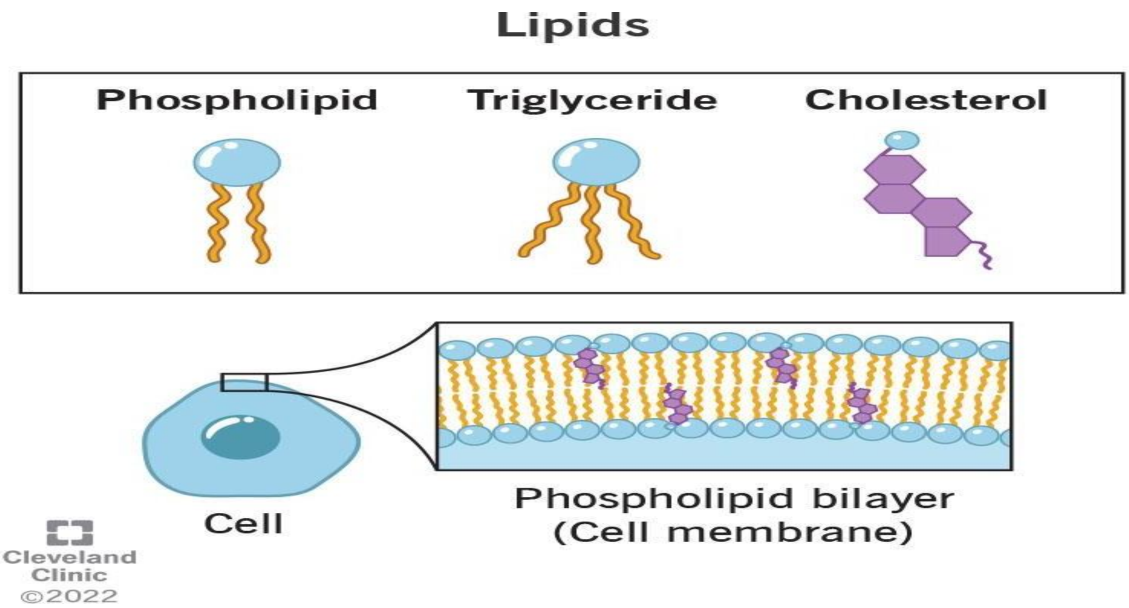

Figure 14 : Phospholipid bilayer

C. Steroids

1. **Steroids**
    - Steroids are a class of lipids characterized by a structure of **four fused carbon rings**. They include hormones like **estrogen**, **testosterone**, and **cortisol**, as well as compounds like **cholesterol**.
    - **Cholesterol** is an essential component of cell membranes and serves as a precursor for the synthesis of steroid hormones, bile acids, and vitamin D.
    - **Structure**: Steroid molecules have a unique four-ring structure (three six-membered rings and one five-membered ring).
2. **Cholesterol**
    - Cholesterol is the most well-known steroid and is produced by the liver or obtained from dietary sources.
    - It is vital for the fluidity and structure of cell membranes and is the precursor for many important molecules such as bile salts and steroid hormones.

---

3. Functions of Lipids

Lipids perform a wide variety of biological functions in the body:

1. **Energy Storage**
    - Triglycerides stored in adipose tissue serve as the body's primary energy reserve. When the body requires energy, triglycerides are broken down into fatty acids and glycerol, which are used in **oxidative metabolism** to generate ATP.
2. **Cell Membrane Structure**
    - Phospholipids, cholesterol, and glycolipids are essential components of **biological membranes**. They provide structural integrity, flexibility, and selective permeability to the cell membrane.
3. **Insulation and Protection**
    - Lipids, particularly triglycerides, serve as insulation to help maintain body temperature and protect vital organs. Fat pads around organs like the kidneys act as cushions, reducing physical damage.
4. **Signaling**
    - Lipids are involved in cellular signaling. For example, **eicosanoids**, derived from fatty acids like arachidonic acid, regulate inflammation, blood clotting, and immune response.
    - Steroid hormones (e.g., cortisol, estrogen) and phospholipids (e.g., in lipid rafts) also play important roles in signal transduction.
5. **Protection Against Water Loss**
    - Waxes on plant leaves and the skin of animals help reduce water loss by forming a **hydrophobic barrier**.

---

4. Metabolism of Lipids

1. **Fatty Acid Metabolism**
   - Fatty acids are broken down through **β-oxidation**, which occurs in the **mitochondria**. This process involves the removal of two-carbon units from the fatty acid chain, converting them into **acetyl-CoA**, which then enters the **Krebs cycle** to generate ATP.
2. **Cholesterol Metabolism**
   - Cholesterol is synthesized in the **liver** and can be converted into **bile acids** for digestion or used to produce **steroid hormones**.
   - Cholesterol is transported in the bloodstream by lipoproteins: **HDL (high-density lipoprotein)** and **LDL (low-density lipoprotein)**. HDL is considered "good" cholesterol, while LDL is considered "bad" cholesterol, as high levels of LDL are associated with cardiovascular disease. ***Fig 15***

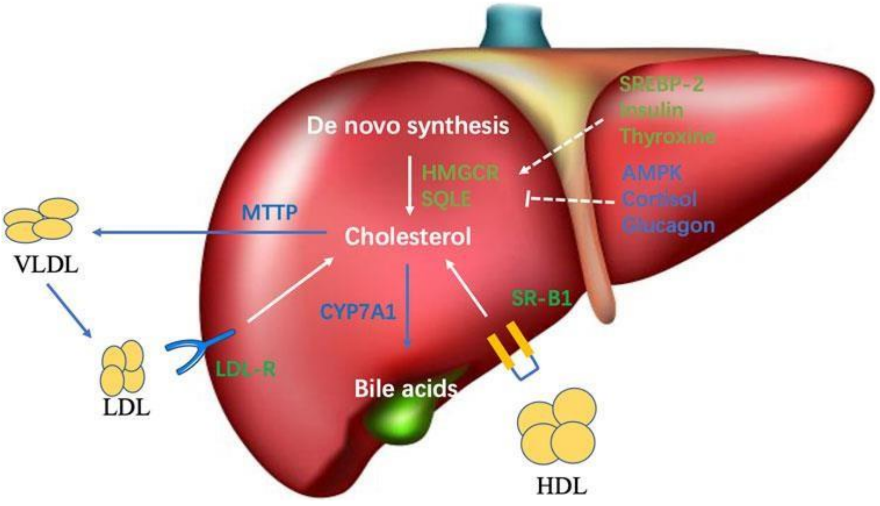

Figure 15 : Cholesterol Metabolism

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5. Lipids and Health

1. **Saturated Fats**
   - Found in animal products and some tropical oils (e.g., coconut oil), **saturated fats** can raise levels of LDL cholesterol and increase the risk of heart disease when consumed in excess.
2. **Unsaturated Fats**
   - **Monounsaturated fats** (e.g., olive oil, avocados) and **polyunsaturated fats** (e.g., omega-3 and omega-6 fatty acids found in fatty fish and flaxseed) are considered heart-healthy and can lower LDL cholesterol levels.
3. **Trans Fats**
   - **Trans fats**, often found in processed foods (such as margarine and baked goods), are harmful fats that increase LDL cholesterol and lower HDL cholesterol, leading to an increased risk of cardiovascular disease.

4. **Essential Fatty Acids**

   - **Omega-3 fatty acids** (found in fatty fish, flaxseeds) are essential for health, helping to reduce inflammation and promoting heart and brain health. **Omega-6 fatty acids** are also essential but should be consumed in balanced amounts to avoid promoting inflammation.

---

6. Sources of Lipids

- **Saturated Fats**: Animal fats (butter, lard), dairy products, tropical oils (coconut oil, palm oil).
- **Unsaturated Fats**: Olive oil, avocados, nuts, seeds, and fatty fish (salmon, mackerel).
- **Trans Fats**: Processed foods, hydrogenated oils, fast food, margarine.
- **Essential Fatty Acids**: Omega-3 (fish oil, flaxseeds, walnuts) and Omega-6 (vegetable oils, nuts, seeds).

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6. Summary of Lipid Types

Table 05 : Lipid types

Lipid Type	**Function**	**Sources**
Fatty Acids	Energy storage, component of cell membranes	Animal fat, plant oils, nuts, seeds
Triglycerides	Primary energy storage, insulation	Oils, butter, lard, animal fats
Phospholipids	Cell membrane structure, signaling	Eggs, soybeans, lecithin, organ meats
Steroids	Hormone production, cell membrane structure	Animal products, cholesterol (liver)
Waxes	Protection against water loss	Beeswax, plant coatings, earwax

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8. Conclusion

Lipids are essential biomolecules that serve a wide range of functions, from energy storage to cell membrane integrity and hormone regulation. Understanding the different types of lipids, their functions, and their impact on health is crucial for maintaining proper nutrition and overall health. Proper balance of different types of fats in the diet is essential for heart health, brain function, and optimal body function.

Nucleic acids

Nucleic acids are essential biomolecules that play a central role in storing and transmitting genetic information in living organisms. There are two primary types of nucleic acids: **DNA (Deoxyribonucleic Acid)** and **RNA (Ribonucleic Acid)**. These molecules are polymers made up of smaller subunits called **nucleotides**. ***Fig 16***

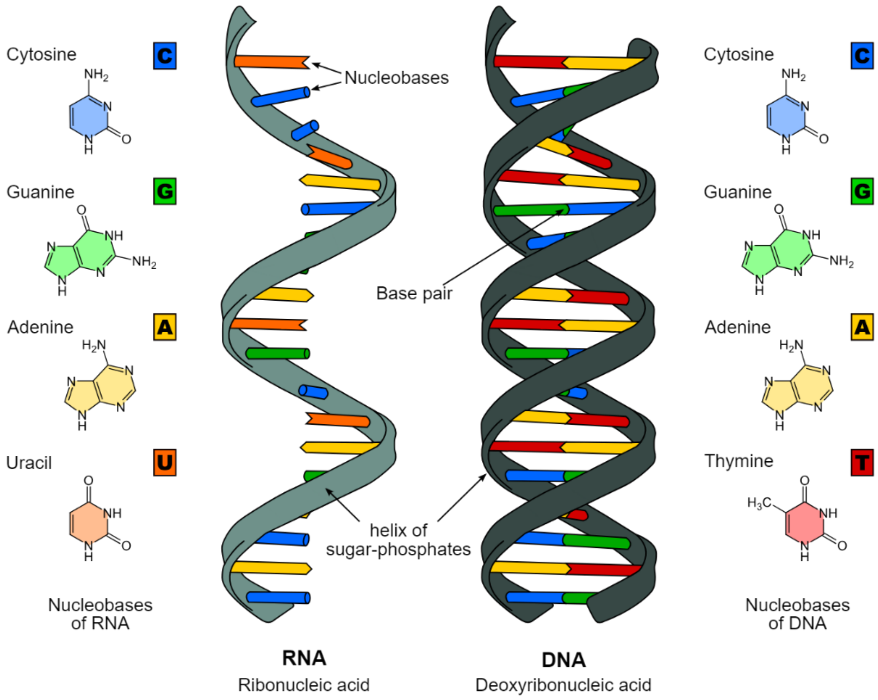

Figure 16 : Nucleic acids

1. Structure of Nucleic Acids

A. Nucleotides

Nucleotides are the basic building blocks of nucleic acids. Each nucleotide consists of three components:

- **Phosphate Group**: A molecule containing phosphorus that connects the nucleotides together in a chain.
- **Sugar**: A 5-carbon sugar molecule. In DNA, it's **deoxyribose**, while in RNA, it's **ribose**.
- **Nitrogenous Base**: One of four possible bases, which can be divided into two categories:
    - **Purines**: Adenine (A) and Guanine (G).
    - **Pyrimidines**: Cytosine (C), Thymine (T) (only in DNA), and Uracil (U) (only in RNA).

B. DNA Structure

DNA is a double-stranded molecule, where the two strands are held together by **hydrogen bonds** between complementary nitrogenous bases. The structure of DNA is a **double helix**, resembling a twisted ladder, where:

- **Adenine (A)** pairs with **Thymine (T)**.
- **Cytosine (C)** pairs with **Guanine (G)**.

The strands run in opposite directions, referred to as **anti-parallel** orientation. This means one strand runs in the 5' to 3' direction, while the other runs in the 3' to 5' direction.

C. RNA Structure

RNA is typically single-stranded and differs from DNA in several ways:

- **Sugar**: RNA contains **ribose** instead of deoxyribose.
- **Bases**: RNA uses **Uracil (U)** instead of **Thymine (T)**. Therefore, in RNA:
    - **Adenine (A)** pairs with **Uracil (U)**.
    - **Cytosine (C)** pairs with **Guanine (G)**.

2. Functions of Nucleic Acids

A. DNA (Deoxyribonucleic Acid)

DNA serves as the primary **genetic material** in living organisms. It stores the instructions necessary for the development, functioning, and reproduction of organisms. DNA is found in the **nucleus** (in eukaryotes) and the **cytoplasm** (in prokaryotes). Its functions include:

- **Genetic Information Storage**: DNA contains the genetic code used for the synthesis of proteins.
- **Replication**: DNA can replicate itself during cell division, ensuring that each new cell has an identical copy of the genetic material.
- **Gene Expression**: DNA provides the instructions for making proteins through the processes of **transcription** and **translation**.

B. RNA (Ribonucleic Acid)

RNA is involved in **protein synthesis** and other cellular functions. There are several types of RNA, each with distinct roles:

- **mRNA (messenger RNA)**: Carries the genetic information from DNA in the form of codons to the ribosomes for protein synthesis.
- **tRNA (transfer RNA)**: Brings amino acids to the ribosome to be added to the growing protein chain.
- **rRNA (ribosomal RNA)**: Makes up the structure of the ribosomes, the machinery where proteins are synthesized.

3. Key Processes Involving Nucleic Acids

A. DNA Replication

DNA replication is the process by which DNA makes an identical copy of itself before a cell divides. This is crucial for ensuring that each new cell receives a complete set of genetic instructions. The process involves several key enzymes:

- **DNA Helicase**: Unwinds the DNA double helix.
- **DNA Polymerase**: Adds complementary nucleotides to each original strand.
- **DNA Ligase**: Seals the gaps between newly formed DNA strands.

B. Transcription (DNA → RNA)

Transcription is the process in which a segment of DNA is used to synthesize mRNA. During this process:

- RNA polymerase binds to the promoter region of the gene and unwinds the DNA.
- It then builds the mRNA strand by adding complementary RNA nucleotides.
- The mRNA is then processed and transported to the ribosome for translation.

C. Translation (RNA → Protein)

Translation is the process by which the mRNA is read by ribosomes to build a protein. This involves:

- The mRNA binds to a ribosome.
- tRNA molecules bring amino acids to the ribosome, matching their anticodons with the codons on the mRNA.
- The ribosome links the amino acids together, forming a polypeptide chain, which folds into a functional protein.

4. Applications of Nucleic Acids

- **Genetic Engineering**: Nucleic acids are used in gene editing technologies like **CRISPR-Cas9**, allowing scientists to modify genes in organisms to study diseases or improve agricultural traits.
- **DNA Profiling**: DNA is used in forensic science to identify individuals based on their unique genetic makeup.
- **Gene Therapy**: Altering an individual's DNA to treat or cure diseases caused by genetic defects.
- **mRNA Vaccines**: mRNA technology is used in vaccines, such as the COVID-19 vaccine, to instruct cells to produce a protein that triggers an immune response.

Vitamins

Vitamins: Overview

Vitamins are essential organic compounds that the body requires in small amounts for a variety of physiological functions. They cannot be synthesized by the body in sufficient quantities, so they must be obtained through diet. Vitamins play key roles in metabolism, immunity, growth, and overall health.

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1. Definition of Vitamins

Vitamins are organic molecules that are crucial for the normal functioning of the body. They are required in **minute amounts** and are involved in a wide range of biochemical processes. While they do not provide energy (calories), they support the body in utilizing energy from carbohydrates, fats, and proteins.

There are **13 essential vitamins**, divided into two groups based on their solubility:

- **Fat-soluble vitamins**: A, D, E, K.
- **Water-soluble vitamins**: B-vitamins (B1, B2, B3, B5, B6, B7, B9, B12) and vitamin C.

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2. Classification of Vitamins

A. Fat-Soluble Vitamins

1. **Vitamin A (Retinol)**
    - **Function**: Essential for vision (especially night vision), immune function, skin health, and cell growth.
    - **Sources**: Liver, dairy products, carrots, spinach, sweet potatoes, and leafy greens (as provitamin A carotenoids).
    - **Deficiency**: Night blindness, dry skin, immune dysfunction.
2. **Vitamin D**
    - **Function**: Helps with calcium and phosphorus absorption in the intestines, promoting bone health, and supporting immune function.
    - **Sources**: Sunlight (skin synthesis), fatty fish, fortified dairy products, egg yolks.
    - **Deficiency**: Rickets (in children), osteomalacia (in adults), weakened immune response.
3. **Vitamin E (Tocopherol)**
    - **Function**: Acts as an antioxidant, protecting cells from oxidative damage. Supports immune function and skin health.
    - **Sources**: Vegetable oils (sunflower, wheat germ oil), nuts, seeds, spinach, and broccoli.

- **Deficiency**: Nerve and muscle damage, weakened immune response.

4. **Vitamin K**
   - **Function**: Vital for blood clotting and bone health. It helps in the synthesis of clotting factors in the liver.
   - **Sources**: Leafy green vegetables (spinach, kale), broccoli, and fermented foods.
   - **Deficiency**: Increased bleeding tendency, poor bone health.

B. Water-Soluble Vitamins

1. **Vitamin B1 (Thiamine)**
   - **Function**: Involved in energy metabolism, especially in the conversion of carbohydrates into energy. Supports nerve function.
   - **Sources**: Whole grains, pork, legumes, nuts, seeds.
   - **Deficiency**: Beriberi (affects the nervous and cardiovascular systems), Wernicke-Korsakoff syndrome (neurological disorder).
2. **Vitamin B2 (Riboflavin)**
   - **Function**: Crucial for energy production, and the metabolism of fats, drugs, and steroids. Supports skin and eye health.
   - **Sources**: Dairy products, meat, eggs, leafy green vegetables, nuts.
   - **Deficiency**: Skin disorders, cracks or sores on the lips (cheilosis), and tongue inflammation (glossitis).
3. **Vitamin B3 (Niacin)**
   - **Function**: Involved in energy production, maintaining healthy skin, and nervous system function. It also helps in DNA repair.
   - **Sources**: Meat, fish, whole grains, legumes, seeds.
   - **Deficiency**: Pellagra (characterized by diarrhea, dermatitis, and dementia).
4. **Vitamin B5 (Pantothenic Acid)**
   - **Function**: Essential for the synthesis of coenzyme A, which is involved in fatty acid metabolism, and in the synthesis of steroid hormones.
   - **Sources**: Chicken, beef, potatoes, oats, tomatoes, whole grains, eggs.
   - **Deficiency**: Rare, but can cause fatigue, irritability, digestive issues, and skin problems (called "burning feet syndrome").
5. **Vitamin B6 (Pyridoxine)**
   - **Function**: Involved in amino acid metabolism, neurotransmitter synthesis, and red blood cell production.
   - **Sources**: Poultry, fish, potatoes, chickpeas, bananas, fortified cereals.

- **Deficiency**: Anemia, depression, confusion, weakened immune function.

6. **Vitamin B7 (Biotin)**
    - **Function**: Plays a role in carbohydrate, fat, and protein metabolism. Important for healthy skin, hair, and nails.
    - **Sources**: Eggs, nuts, seeds, fish, sweet potatoes, broccoli.
    - **Deficiency**: Hair loss, skin rashes, brittle nails, neurological symptoms.
7. **Vitamin B9 (Folate)**
    - **Function**: Essential for DNA synthesis and cell division, particularly important during pregnancy for fetal development.
    - **Sources**: Leafy green vegetables, legumes, citrus fruits, fortified grains.
    - **Deficiency**: Megaloblastic anemia, birth defects (neural tube defects in infants).
8. **Vitamin B12 (Cobalamin)**
    - **Function**: Required for red blood cell formation, neurological function, and DNA synthesis.
    - **Sources**: Animal products (meat, fish, dairy, eggs), fortified cereals.
    - **Deficiency**: Pernicious anemia, neurological damage (numbness, memory loss), fatigue.
9. **Vitamin C (Ascorbic Acid)**
    - **Function**: Acts as an antioxidant, supports immune function, and is essential for the synthesis of collagen (important for skin, blood vessels, and bones).
    - **Sources**: Citrus fruits (oranges, lemons), strawberries, bell peppers, broccoli, spinach.
    - **Deficiency**: Scurvy (gum disease, fatigue, skin issues, poor wound healing).

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3. Functions of Vitamins

Vitamins are involved in a wide range of physiological processes:

- **Energy Production**: Many B vitamins are essential for metabolizing carbohydrates, fats, and proteins into energy.
- **Immune Support**: Vitamins such as A, C, D, and E are crucial for maintaining immune function and protecting the body against infections.
- **Antioxidant Protection**: Vitamins E and C act as antioxidants, neutralizing free radicals and reducing oxidative stress, which can damage cells and tissues.
- **Bone Health**: Vitamin D regulates calcium absorption and bone mineralization, while vitamin K is essential for bone formation and blood clotting.
- **Growth and Development**: Vitamin A supports cell differentiation, vision, and reproduction. Vitamin D promotes healthy bone development.

4. Vitamin Deficiency and Toxicity

Deficiency Symptoms:

- **Vitamin A**: Night blindness, skin disorders, weakened immune system.
- **Vitamin D**: Rickets (in children), osteomalacia (in adults), osteoporosis, weakened immunity.
- **Vitamin E**: Nerve damage, muscle weakness, immune dysfunction.
- **Vitamin K**: Easy bruising, excessive bleeding.
- **B Vitamins**: Vary depending on the type, but generally include fatigue, anemia, neurological issues, and skin conditions.
- **Vitamin C**: Scurvy (gum disease, bleeding, joint pain, fatigue).

Toxicity (mostly related to fat-soluble vitamins):

- **Vitamin A**: Can cause liver damage, headaches, nausea, and even coma if taken in excessive amounts.
- **Vitamin D**: Hypercalcemia (high calcium levels in the blood), kidney stones, and damage to kidneys.
- **Vitamin E**: Interferes with blood clotting, leading to an increased risk of bleeding.
- **Vitamin K**: Rare toxicity, but high doses may interfere with anticoagulant medications.

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5. Vitamin Supplementation

While a well-balanced diet typically provides all the vitamins needed, some individuals may require supplements due to dietary restrictions, medical conditions, or specific life stages (e.g., pregnancy, old age). However, excessive supplementation of vitamins, particularly fat-soluble ones, can lead to toxicity.

Key Considerations:

- **Pregnancy**: Folate (vitamin B9) supplementation is recommended to prevent neural tube defects.
- **Vegetarians/Vegans**: Vitamin B12 (cobalamin) supplementation may be needed as it is found primarily in animal products.
- **Older Adults**: May require additional vitamin D, vitamin B12, and sometimes vitamin A due to decreased absorption.

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6. Summary of Key Vitamins

Table 06 : Vitamins

Vitamin	**Function**	**Sources**	**Deficiency Symptoms**
Vitamin A	Vision, immune function, skin health	Liver, carrots, spinach, sweet potatoes	Night blindness, dry skin, weakened immune system
Vitamin D	Calcium absorption, bone health, immune function	Sunlight, fatty fish, egg yolks	Rickets, osteomalacia, weakened immunity
Vitamin E	Antioxidant, protects cells, immune health	Vegetable oils, nuts, seeds, spinach	Nerve damage, weakened immune response
Vitamin K	Blood clotting, bone health	Leafy greens, broccoli, fermented foods	Increased bleeding tendency, poor bone health
Vitamin B1 (Thiamine)	Energy metabolism, nerve function	Whole grains, pork, legumes	Beriberi, Wernicke-Korsakoff syndrome
Vitamin B2 (Riboflavin)	Energy metabolism, skin and eye health	Dairy, eggs, meat, leafy vegetables	Cracked lips, skin disorders
Vitamin B3 (Niacin)	Energy metabolism, skin health, nervous system	Meat, fish, whole grains, legumes	Pellagra (diarrhea, dermatitis, dementia)
Vitamin B5 (Pantothenic Acid)	Fatty acid metabolism, hormone synthesis	Chicken, beef, eggs, whole grains	Fatigue, irritability, digestive issues
Vitamin B6 (Pyridoxine)	Amino acid metabolism, neurotransmitter synthesis	Poultry, fish, bananas, chickpeas	Anemia, depression, confusion
Vitamin B7 (Biotin)	Fat, carbohydrate, protein metabolism	Eggs, nuts, fish, sweet potatoes	Hair loss, skin rashes
Vitamin B9 (Folate)	DNA synthesis, cell division, pregnancy health	Leafy greens, citrus, legumes	Megaloblastic anemia, birth defects
Vitamin B12 (Cobalamin)	Red blood cell formation, neurological function	Animal products, fortified cereals	Pernicious anemia, neurological damage
Vitamin C	Antioxidant, collagen synthesis, immune function	Citrus fruits, bell peppers, broccoli	Scurvy (gum disease, fatigue, poor healing)

Part II : Tutorial

Tutorial 01: Carbohydrates

Exercise 1
Classify the following as monosaccharide, disaccharide, or polysaccharide:
a) Lactose
b) Starch
c) Fructose

Solution:
a) Lactose → Disaccharide
b) Starch → Polysaccharide
c) Fructose → Monosaccharide

Exercise 2
Write the general chemical formula for a carbohydrate and explain why water is part of its name "hydrate of carbon".

Solution:
General formula: $C_n(H_2O)_m$
Carbohydrates are called "hydrates of carbon" because the hydrogen and oxygen atoms are present in the same ratio as in water (H_2O).

Exercise 3
A solution of sucrose ($C_{12}H_{22}O_{11}$) is hydrolyzed to glucose ($C_6H_{12}O_6$) and fructose ($C_6H_{12}O_6$).
a) What type of carbohydrate is sucrose?
b) What type of reaction is this?

Solution:
a) Sucrose is a disaccharide
b) The reaction is hydrolysis

Exercise 4
Identify whether glucose and cellulose are reducing sugars. Give a brief explanation.

Solution:
Glucose is a reducing sugar because it has a free aldehyde group
Cellulose is not a reducing sugar because its glucose units are linked in a way that does not expose a free reducing end

Exercise 5
List two examples of monosaccharides and two examples of polysaccharides.

Solution:
Examples of monosaccharides: Glucose, Fructose
Examples of polysaccharides: Starch, Glycogen

Exercise 6
Explain the difference between an aldose and a ketose carbohydrate. Give one example of each.

Solution:
Aldose: carbohydrate with an aldehyde group (example: Glucose)
Ketose: carbohydrate with a ketone group (example: Fructose)

Tutorial 02: Amino Acids

Exercise 1
Classify the following amino acids as polar, nonpolar, acidic, or basic:
a) Lysine
b) Leucine
c) Aspartic acid
d) Serine

Solution:
a) Lysine → Basic
b) Leucine → Nonpolar
c) Aspartic acid → Acidic
d) Serine → Polar

Exercise 2
Determine the isoelectric point (pI) of glycine given its pKa values: pKa1 (COOH) = 2.34, pKa2 (NH_3^+) = 9.60

Solution:
pI = (pKa1 + pKa2) / 2 = (2.34 + 9.60) / 2 = 5.97

Exercise 3
Explain the difference between essential and non-essential amino acids. Give two examples of each.

Solution:
Essential amino acids cannot be synthesized by the human body and must be obtained from the diet (e.g., Lysine, Leucine)
Non-essential amino acids can be synthesized by the human body (e.g., Glycine, Alanine)

Exercise 4
A peptide has the sequence: Ala–Gly–Ser. Draw the peptide bond formation and identify which end is N-terminal and which is C-terminal.

Solution:
The N-terminal is Ala (free amino group)
The C-terminal is Ser (free carboxyl group)
Peptide bonds are formed between the carboxyl group of one amino acid and the amino group of the next

Exercise 5
List the four levels of protein structure and give a brief explanation of each.

Solution:

- Primary: sequence of amino acids
- Secondary: alpha-helix and beta-sheet formed by hydrogen bonds
- Tertiary: 3D folding of a single polypeptide chain
- Quaternary: assembly of multiple polypeptide chains

Exercise 6
Explain what denaturation is and give two examples of factors that can denature a protein.

Solution:
Denaturation is the loss of a protein’s native structure without breaking peptide bonds
Examples: high temperature, extreme pH, organic solvents

Tutorial 03: Proteins

Exercise 1
Name the bond that links amino acids together in a protein.

Solution:
A peptide bond links amino acids in a protein.

Exercise 2
List the three types of interactions that stabilize the tertiary structure of proteins.

Solution:

1. Hydrogen bonds
2. Ionic bonds
3. Hydrophobic interactions
4. Disulfide bridges (covalent bonds)

Exercise 3
Explain the difference between fibrous and globular proteins and give one example of each.

Solution:
Fibrous proteins: elongated, structural (e.g., Collagen)
Globular proteins: compact, functional (e.g., Hemoglobin)

Exercise 4
A protein consists of four polypeptide chains. What level of structure is this?

Solution:
This is **quaternary structure**.

Exercise 5
Define denaturation of a protein and give two examples of factors that cause it.

Solution:
Denaturation is the loss of a protein's native structure without breaking peptide bonds.
Factors: high temperature, extreme pH, organic solvents.

Exercise 6
Explain what is meant by the "primary structure" of a protein and why it is important.

Solution:
Primary structure is the linear sequence of amino acids in a polypeptide chain.
It determines all higher levels of protein structure and ultimately its function.

Tutorial 04: Fatty Acids

Exercise 1
Define a fatty acid and distinguish between saturated and unsaturated fatty acids.

Solution:
A fatty acid is a carboxylic acid with a long hydrocarbon chain.
Saturated fatty acids have no double bonds; unsaturated fatty acids have one or more double bonds.

Exercise 2
Name two examples of essential fatty acids.

Solution:
Linoleic acid (omega-6) and alpha-linolenic acid (omega-3) are essential fatty acids.

Exercise 3
What type of bond links fatty acids to glycerol in triglycerides?

Solution:
Ester bonds link fatty acids to glycerol in triglycerides.

Exercise 4
Explain the difference between a phospholipid and a triglyceride.

Solution:
Triglycerides are composed of glycerol + three fatty acids.
Phospholipids are composed of glycerol + two fatty acids + a phosphate group; they are amphipathic and form cell membranes.

Exercise 5
A fatty acid has the formula C18:1. Explain what this notation means.

Solution:
C18:1 indicates a fatty acid with 18 carbon atoms and 1 double bond (monounsaturated fatty acid).

Exercise 6
Identify the essential fatty acids and explain why they are called essential.

Solution:
Essential fatty acids: Linoleic acid (omega-6), Alpha-linolenic acid (omega-3)
They are called essential because the human body **cannot synthesize them** and they must be obtained from the diet.

Tutorial 05: Lipids

Exercise 1
Define a lipid and describe its main characteristics.

Solution:
Lipids are hydrophobic or amphipathic molecules, insoluble in water but soluble in organic solvents. They serve as energy storage, structural components, and signaling molecules.

Exercise 2
Name three major classes of lipids found in biological membranes.

Solution:

1. Phospholipids
2. Sterols (e.g., cholesterol)
3. Glycolipids

Exercise 3
Explain the role of cholesterol in cell membranes.

Solution:
Cholesterol modulates membrane fluidity and stability, preventing membranes from becoming too rigid or too fluid.

Exercise 4
Compare triglycerides and phospholipids in terms of structure and function.

Solution:

- Triglycerides: glycerol + three fatty acids; mainly energy storage
- Phospholipids: glycerol + two fatty acids + phosphate group; major component of cell membranes

Exercise 5
What is a sphingolipid and where is it commonly found?

Solution:
Sphingolipids are lipids with a sphingosine backbone instead of glycerol. They are commonly found in the plasma membrane, especially in nerve cells.

Exercise 6
Describe two functions of lipids other than energy storage.

Solution:

Structural component of membranes (phospholipids, sterols)

Signaling molecules (steroids, eicosanoids, hormones)

Tutorial 06: Nucleic Acids

Exercise 1
Name the two main types of nucleic acids and state their primary function.

Solution:

DNA (Deoxyribonucleic Acid): stores genetic information

RNA (Ribonucleic Acid): transfers genetic information and assists in protein synthesis

Exercise 2
List the four nitrogenous bases found in DNA and classify them as purines or pyrimidines.

Solution:
Purines: Adenine (A), Guanine (G)
Pyrimidines: Cytosine (C), Thymine (T)

Exercise 3
Explain the difference between DNA and RNA in terms of sugar, strands, and base composition.

Solution:

Sugar: DNA → deoxyribose, RNA → ribose

Strands: DNA → double-stranded, RNA → single-stranded

Bases: DNA → T (thymine), RNA → U (uracil)

Exercise 4
What type of bond connects nucleotides in a nucleic acid chain?

Solution:
Phosphodiester bonds connect nucleotides via the phosphate group and sugar.

Exercise 5
Explain complementary base pairing in DNA.

Solution:
Adenine pairs with Thymine via 2 hydrogen bonds
Guanine pairs with Cytosine via 3 hydrogen bonds

Exercise 6
Define a nucleotide and name its three components.

Solution:
A nucleotide is the building block of nucleic acids, composed of:

1. Nitrogenous base (A, T, G, C, or U)
2. Pentose sugar (ribose or deoxyribose)
3. Phosphate group

Biochemistry Test (20 Points)

1. Multiple Choice (10 × 1 point)

1. Which macromolecule is NOT a carbohydrate?

A) Glucose B) Starch C) Cellulose D) Phospholipid

Answer: D

2. What is the primary storage form of glucose in animals?

A) Cellulose B) Starch C) Glycogen D) Chitin

Answer: C

3. Which type of bond links amino acids in a protein?

A) Glycosidic B) Peptide C) Phosphodiester D) Hydrogen

Answer: B

4. The double helix structure of DNA is stabilized by:

A) Ionic bonds B) Peptide bonds C) Hydrogen bonds D) Van der Waals

Answer: C

5. Which of the following is a saturated fatty acid?

A) Oleic acid B) Linoleic acid C) Palmitic acid D) α-linolenic acid

Answer: C

6. Which vitamin is water-soluble?

A) Vitamin A B) Vitamin D C) Vitamin C D) Vitamin E

Answer: C

7. What is the function of ATP in cells?

A) Genetic information B) Energy currency C) Membrane structure D) Hormone

Answer: B

8. The pI (isoelectric point) of an amino acid is the pH at which it carries:

A) Net positive charge B) Net negative charge C) Zero net charge D) Maximum charge

Answer: C

9. Which base is found in RNA but not DNA?

A) Adenine B) Guanine C) Uracil D) Thymine

Answer: C

10. The enzyme that catalyzes the first step of glycolysis is:

A) Hexokinase B) Lactase C) DNA polymerase D) Lipase

Answer: A

2. Short Answer (5 × 1 point)

11. Define a monosaccharide.

Expected Answer: A simple sugar that cannot be hydrolyzed into smaller carbohydrates; basic unit of carbohydrates (e.g., glucose).

12. What is the main structural difference between RNA and DNA?

Expected Answer: RNA has ribose sugar and uracil; DNA has deoxyribose sugar and thymine.

13. Name one essential fatty acid.

Expected Answer: Linoleic acid or α-linolenic acid.

14. Give one role of proteins in the body (other than as enzymes).

Expected Answer: Structural (e.g., collagen), transport (e.g., hemoglobin), or regulatory (e.g., hormones).

15. Why are enzymes important in metabolism?

Expected Answer: They lower activation energy and speed up biochemical reactions.

3. Short Explanation (5 × 1 point)

16. Explain why double bonds in fatty acids affect melting point.

Expected Answer: Double bonds introduce kinks, preventing tight packing → lower melting point.

17. What does "reducing sugar" mean?

Expected Answer: A sugar capable of donating electrons/being oxidized; has a free aldehyde or ketone group.

18. Why is the peptide bond planar?

Expected Answer: Partial double-bond character due to resonance limits rotation.

19. Describe complementary base pairing in DNA.

Expected Answer: A pairs with T via two hydrogen bonds; G pairs with C via three hydrogen bonds.

20. Define an enzyme cofactor.

Expected Answer: A non-protein molecule that assists enzyme activity (e.g., metal ion or coenzyme).

Biochemistry Revision

1. Define a monosaccharide and give two examples.
2. What distinguishes an aldose from a ketose sugar?
3. Explain the difference between amylose and amylopectin.
4. What type of carbohydrate linkage is found in cellulose?
5. Why is glycogen more branched than starch?
6. What is the general formula of a carbohydrate?
7. Describe how disaccharides are formed from monosaccharides.
8. What is a peptide bond?
9. List the four levels of protein structure.
10. Explain what is meant by denaturation of a protein.
11. Give two examples of fibrous proteins and two of globular proteins.
12. What is the isoelectric point (pI) of an amino acid?
13. How does the side chain (R group) affect amino acid properties?
14. What role do enzymes play in metabolism?
15. Define activation energy in an enzyme-catalyzed reaction.
16. What is a coenzyme and give one example.
17. Describe the amphipathic nature of phospholipids.

18. What structural feature distinguishes triglycerides from phospholipids?

19. Explain why saturated fatty acids have higher melting points than unsaturated fatty acids.

20. Define essential fatty acid and give an example.

21. What is the main function of cholesterol in cell membranes?

22. Name the subunits of nucleic acids.

23. Describe complementary base pairing in DNA.

24. What is the difference between DNA and RNA in terms of sugar and bases?

25. Define a nucleotide.

26. Explain the role of ATP in the cell.

27. Name two water-soluble vitamins and state one of their functions.

28. Name two fat-soluble vitamins and state one of their functions.

29. What is a reducing sugar?

30. Explain the role of hydrogen bonds in the secondary structure of proteins.

Biochemistry Revision (Answers)

1. Define a monosaccharide and give two examples.
   A monosaccharide is a simple sugar that cannot be hydrolyzed into smaller carbohydrates. Examples: glucose, fructose
2. What distinguishes an aldose from a ketose sugar?
   An aldose has an aldehyde group; a ketose has a ketone group
3. Explain the difference between amylose and amylopectin.
   Amylose is linear; amylopectin is branched
4. What type of carbohydrate linkage is found in cellulose?
   Cellulose has $\beta(1\rightarrow4)$ glycosidic bonds
5. Why is glycogen more branched than starch?
   More branching allows faster mobilization of glucose
6. What is the general formula of a carbohydrate?
   $C_n(H_2O)_n$
7. Describe how disaccharides are formed from monosaccharides.
   Disaccharides form by a dehydration reaction creating a glycosidic bond between two monosaccharides
8. What is a peptide bond?
   A covalent bond between the amino group of one amino acid and the carboxyl group of another
9. List the four levels of protein structure.
   Primary, Secondary, Tertiary, Quaternary
10. Explain what is meant by denaturation of a protein.
    Loss of native structure due to heat, pH, or chemicals without breaking peptide bonds
11. Give two examples of fibrous proteins and two of globular proteins.
    Fibrous: collagen, keratin. Globular: hemoglobin, myoglobin
12. What is the isoelectric point (pI) of an amino acid?
    The pH at which an amino acid has zero net charge
13. How does the side chain (R group) affect amino acid properties?
    It determines polarity, charge, and chemical reactivity
14. What role do enzymes play in metabolism?
    They lower activation energy and speed up biochemical reactions
15. Define activation energy in an enzyme-catalyzed reaction.
    Energy barrier that must be overcome for the reaction to occur
16. What is a coenzyme and give one example.
    A non-protein molecule that assists enzyme function. Example: NAD^+
17. Describe the amphipathic nature of phospholipids.
    Phospholipids have hydrophilic heads and hydrophobic tails
18. What structural feature distinguishes triglycerides from phospholipids?
    Triglycerides have three fatty acids; phospholipids have two fatty acids plus a phosphate group
19. Explain why saturated fatty acids have higher melting points than unsaturated fatty acids.
    Saturated chains pack tightly; unsaturated chains have kinks which lower the melting point
20. Define an essential fatty acid and give an example.
    Cannot be synthesized by the body. Example: linoleic acid (omega-6)
21. What is the main function of cholesterol in cell membranes?
    Modulates membrane fluidity and stability
22. Name the subunits of nucleic acids.
    Nucleotides (base + sugar + phosphate group)
23. Describe complementary base pairing in DNA.
    A pairs with T via 2 hydrogen bonds; G pairs with C via 3 hydrogen bonds
24. What is the difference between DNA and RNA in terms of sugar and bases?
    DNA has deoxyribose and thymine; RNA has ribose and uracil

25. Define a nucleotide.
A nucleotide consists of a nitrogenous base, a pentose sugar, and a phosphate group
26. Explain the role of ATP in the cell.
ATP is the main energy currency of the cell
27. Name two water-soluble vitamins and state one of their functions.
Vitamin C (antioxidant) and Vitamin B1 (coenzyme in metabolism)
28. Name two fat-soluble vitamins and state one of their functions.
Vitamin A (vision) and Vitamin D (bone metabolism)
29. What is a reducing sugar?
A sugar capable of donating electrons, having a free aldehyde or ketone group
30. Explain the role of hydrogen bonds in the secondary structure of proteins.
Hydrogen bonds stabilize α-helices and β-sheets in proteins

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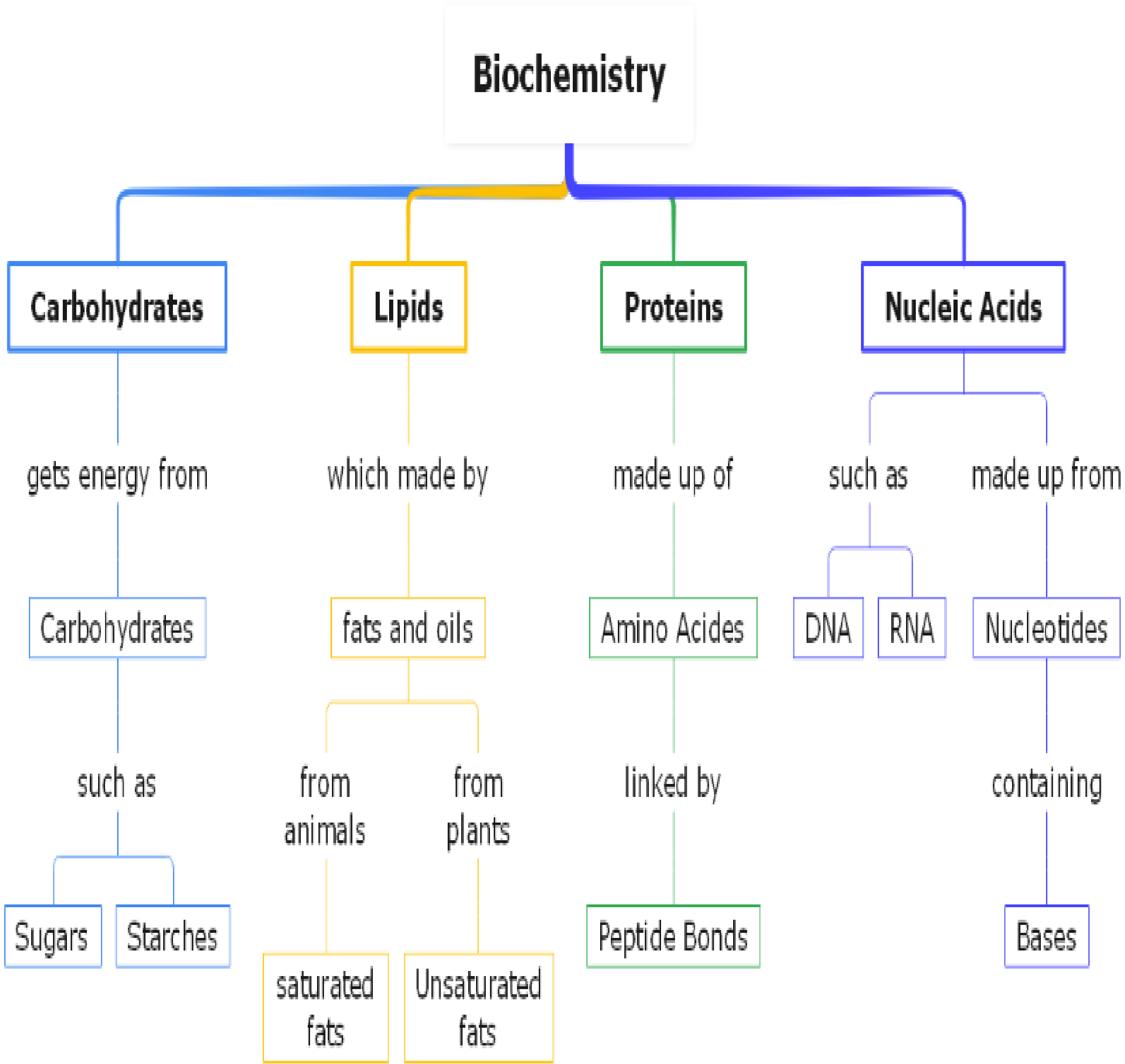
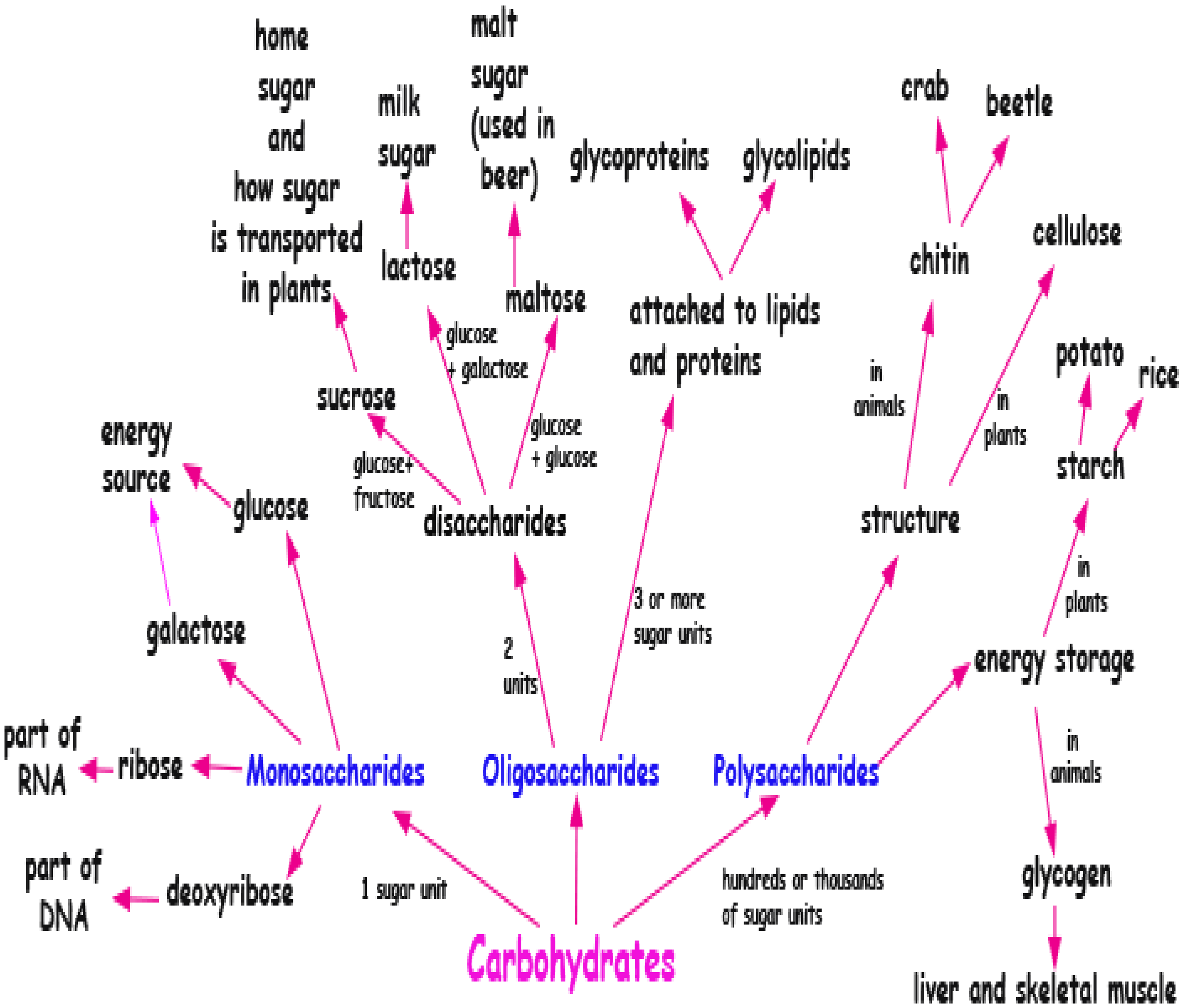
Appendices

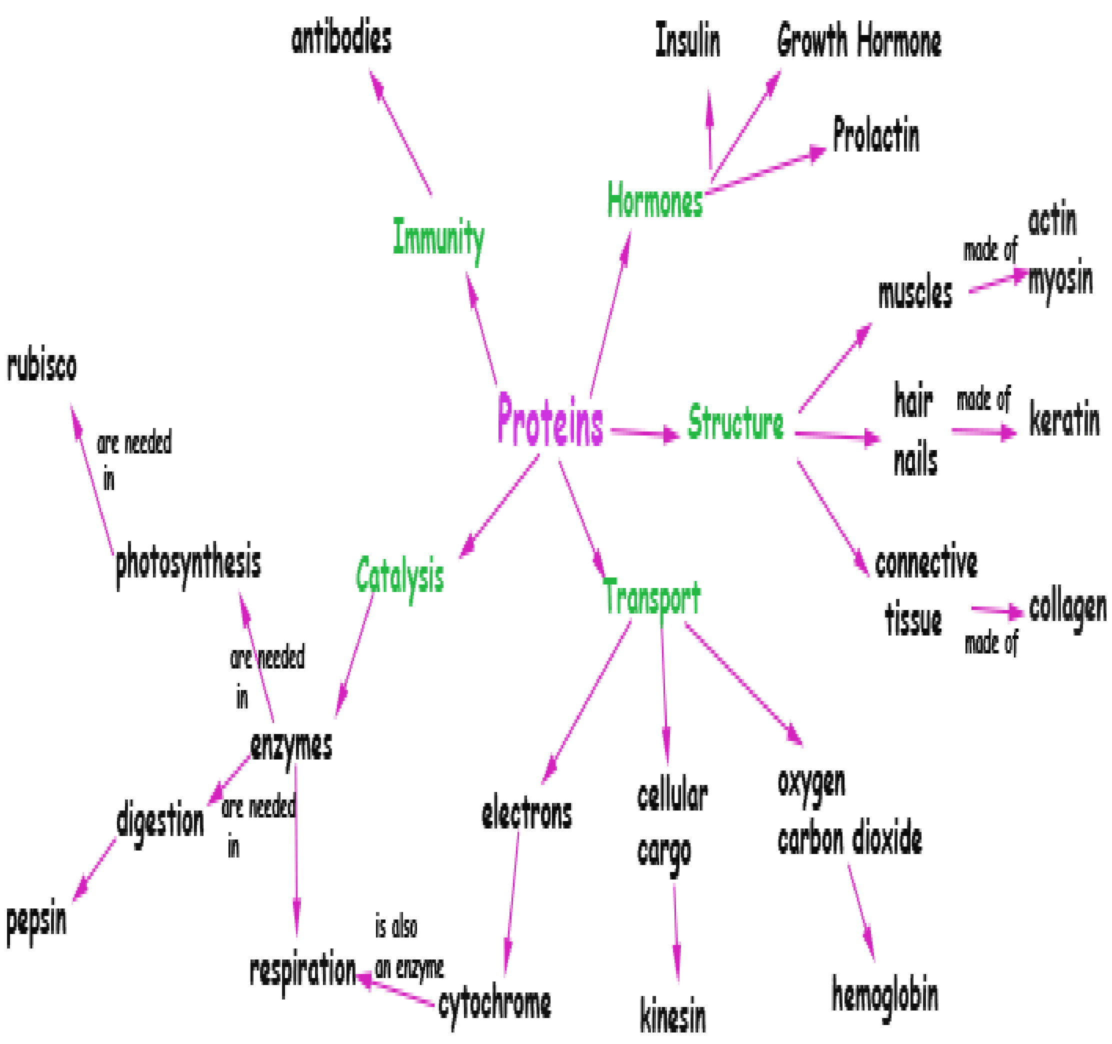
Appendix A: Mind Map – Biochemistry



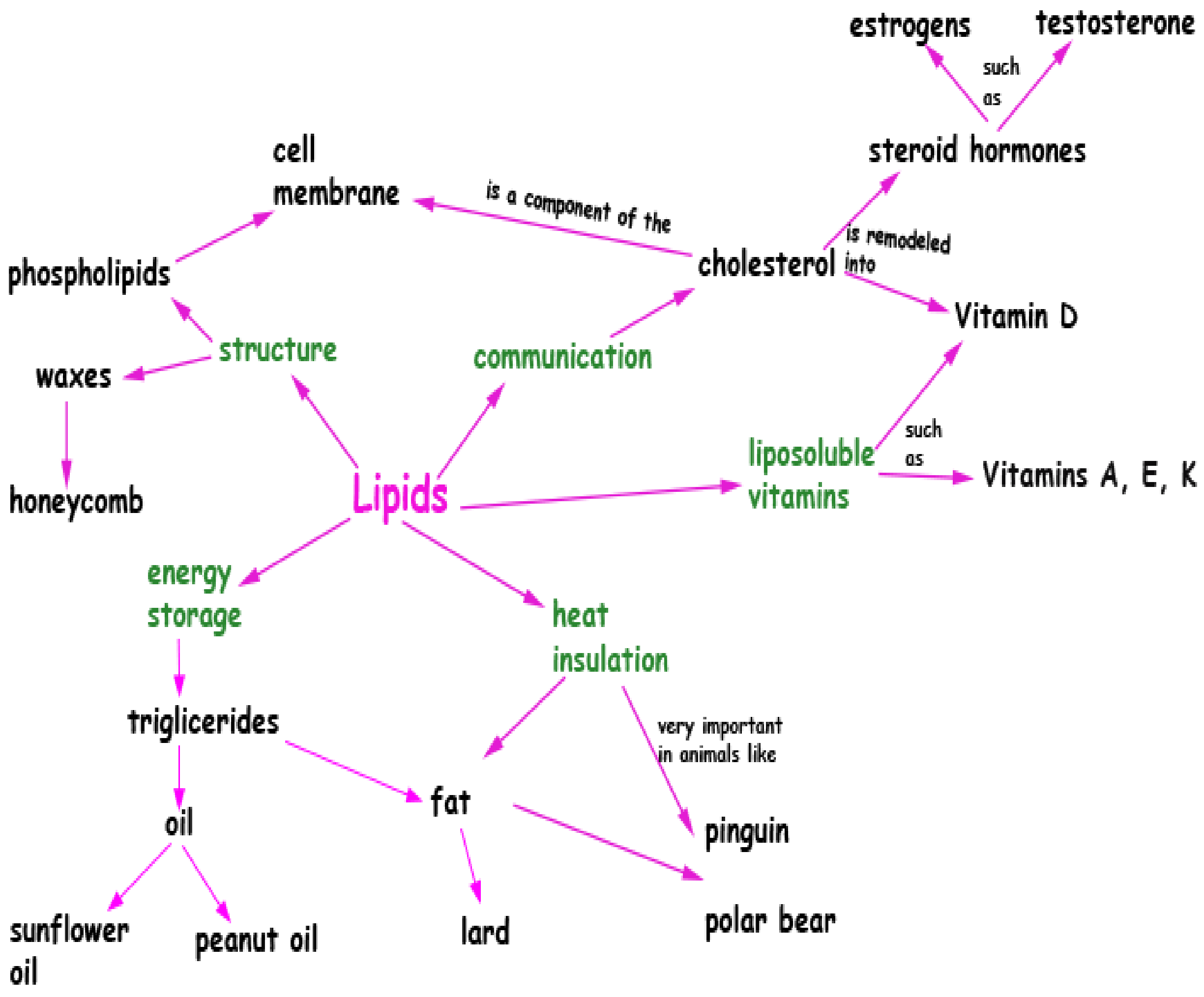
Appendix B: Mind Map – Carbohydrates



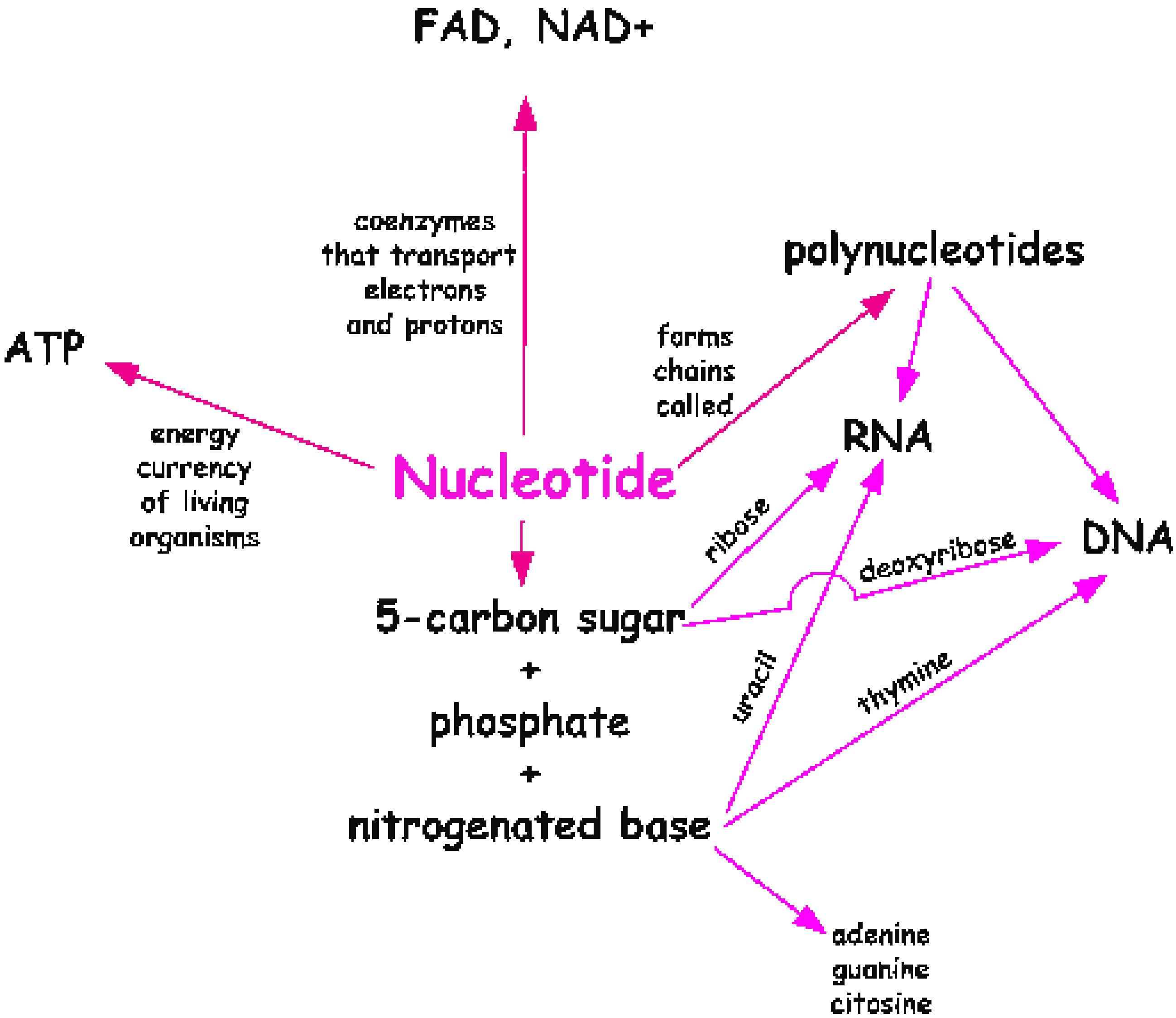
Appendix C: Mind Map – Proteins



Appendix D: Mind Map – Lipids



Appendix E: Mind Map – Nucleic Acids



Appendix F: Mind Map – Vitamins