BIOLOGY

IMAT REVIEW COURSE 2024

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Biological Molecules

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DEHYDRATION & HYDROLYSIS

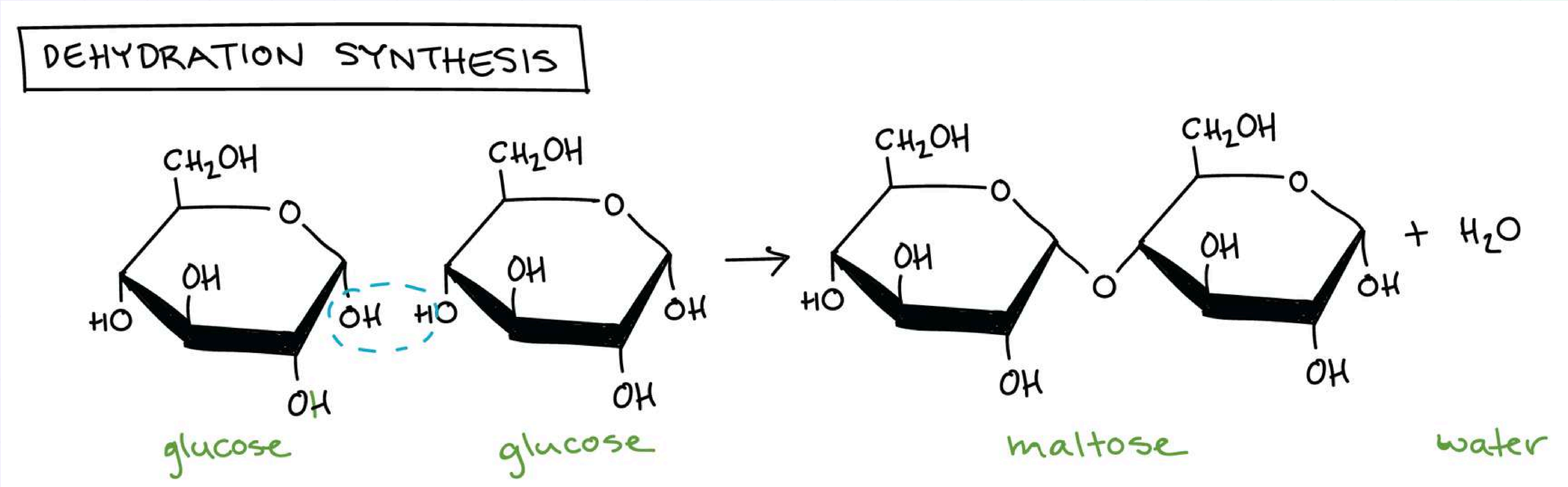
- Dehydration reactions (condensation reactions) involve the removal of a water molecule.

- These reactions connect smaller molecules to form larger ones.

- They result in the creation of new macromolecules, such as proteins, nucleic acids, and carbohydrates.

DEHYDRATION

- Dehydration synthesis example: Glucose molecules combine to form maltose and release water in the process.
- Peptide bonds in proteins are created through dehydration reactions.



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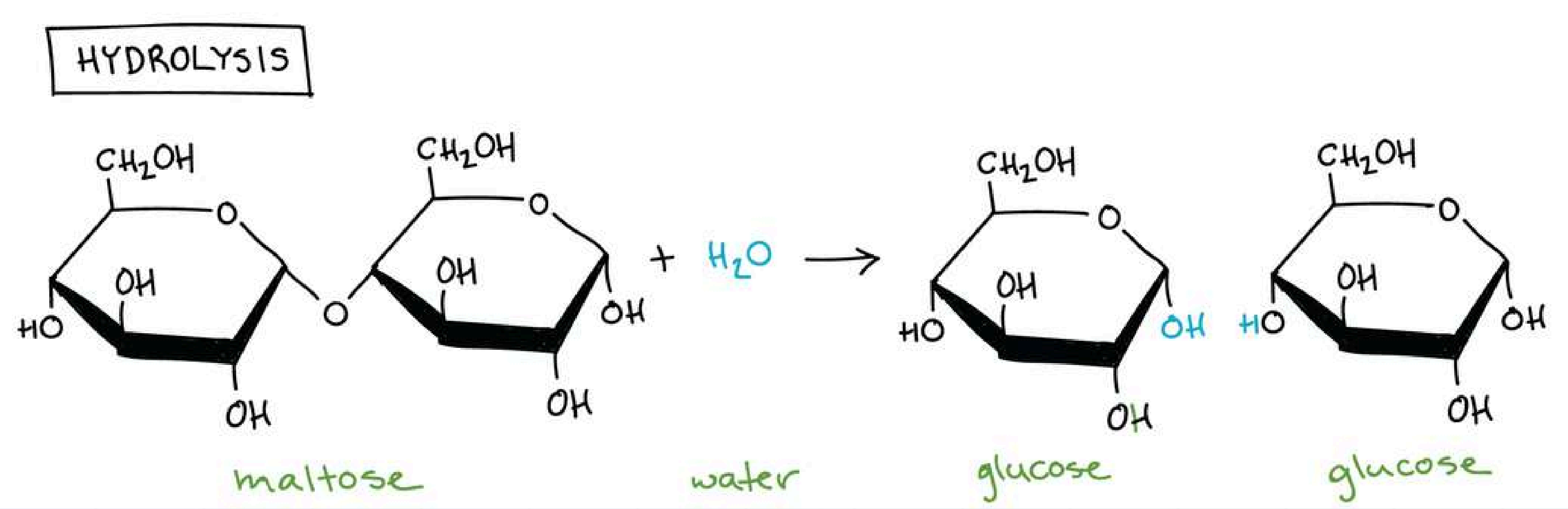
HYDROLYSIS

- Hydrolysis reactions (catabolic reactions) involve the addition of water molecules to break down larger molecules.
- These reactions are important for releasing energy and breaking down complex molecules.
- Hydrolysis breaks down nucleic acids into nucleotides.
- Proteins are broken down into amino acids through hydrolysis.



HYDROLYSIS

	DEHYDRATION	HYDROLYSIS
DEFINITION	Removal of water molecule	Addition of water molecule
TYPE OF REACTION	Anabolic (building) reaction	Catabolic (breaking down) reaction
PURPOSE	Formation of larger molecules	Breakdown of larger molecules
RESULT	Creates new macromolecules	Yields smaller molecules
EXAMPLES	Formation of proteins, nucleic acids, and carbohydrates	Digestion of carbohydrates, proteins, and fats
KEY ROLE	Synthesis of macromolecules	Energy release and molecule breakdown

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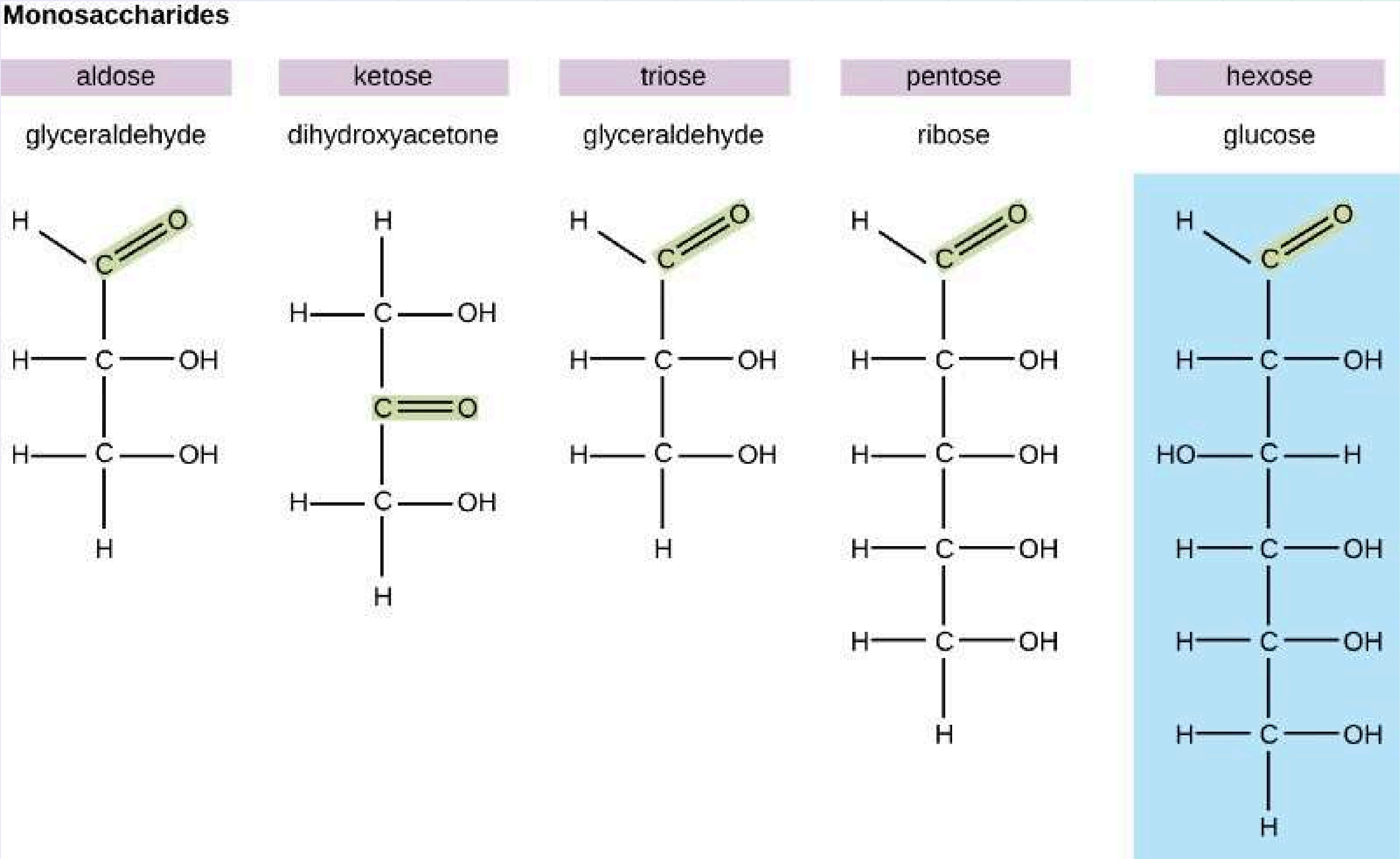
CARBOHYDRATES

- Provide primary sources of energy and structural support.
- Composed of carbon, hydrogen, and oxygen atoms.
- Classified into monosaccharides, disaccharides, and polysaccharides.

CARBOHYDRATES

- Monosaccharides are simple sugars, such as glucose, fructose, and galactose.
- They cannot be broken down into smaller sugars.
- Monosaccharides can be joined through dehydration synthesis to form complex carbohydrates.

MONOSACCHARIDES



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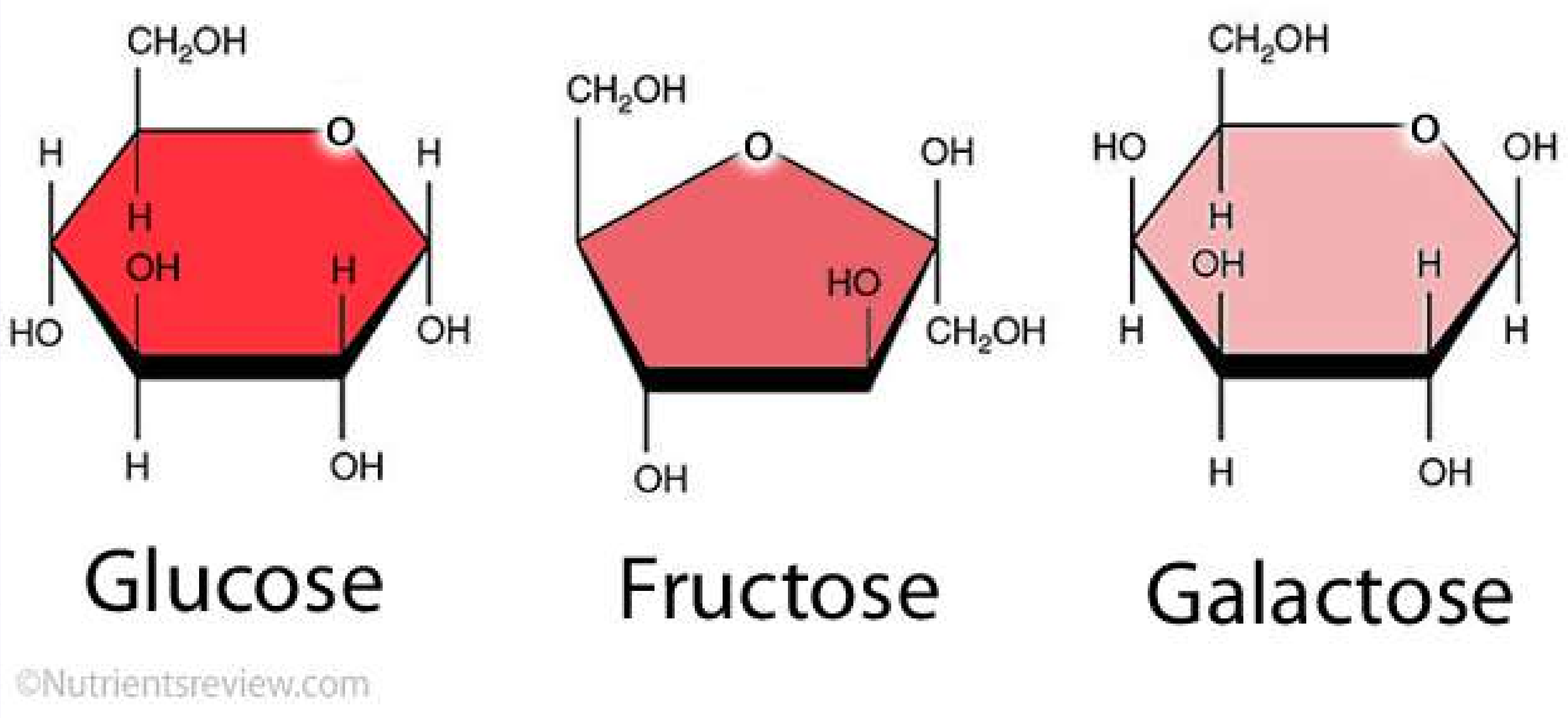
MONOSACCHARIDES



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DISACCHARIDES

- Disaccharides are formed by linking two monosaccharides.
- These sugars are connected by a glycosidic bond through a dehydration reaction.
- Examples of disaccharides include sucrose, lactose, and maltose.

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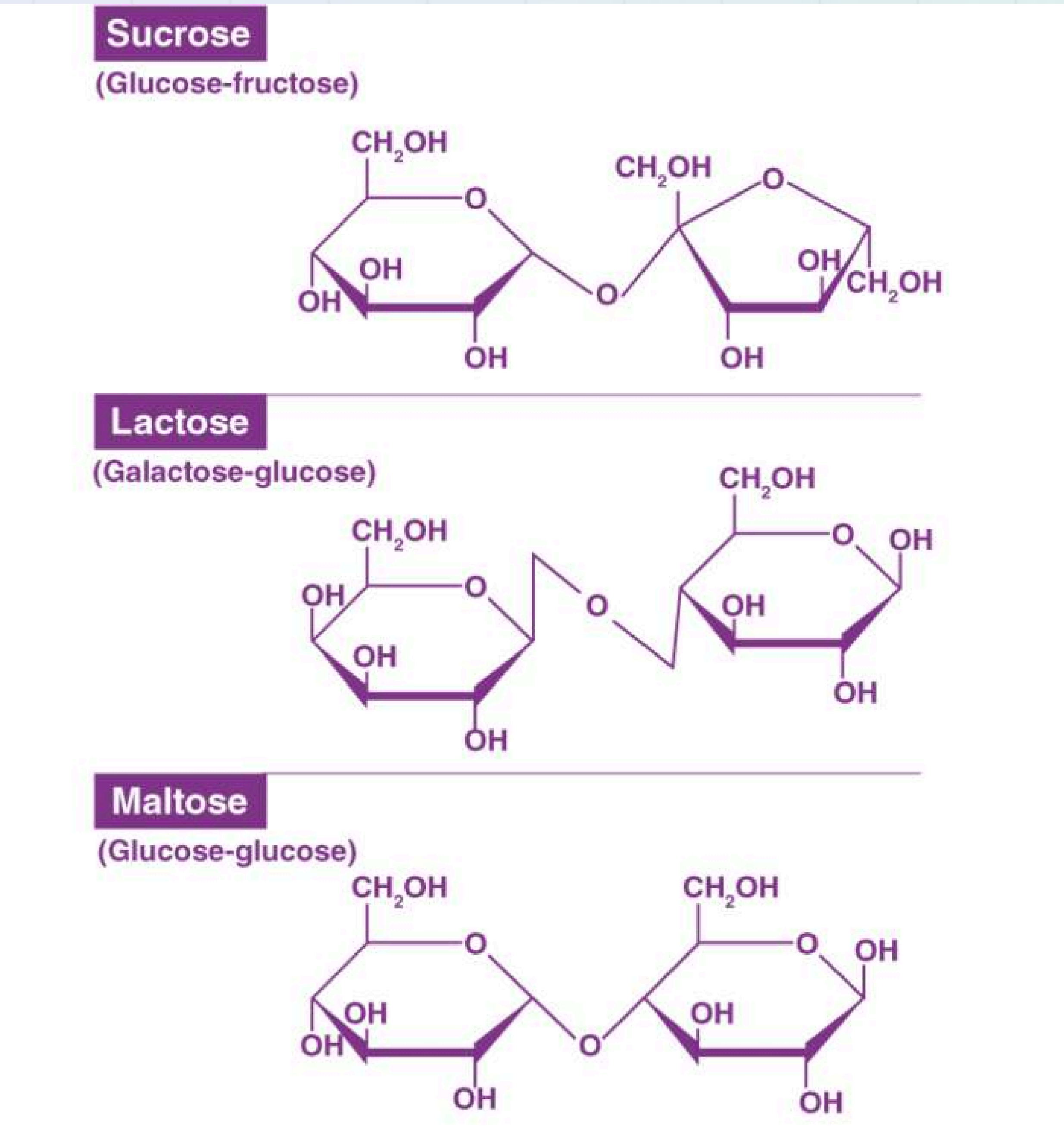
DISACCHARIDES



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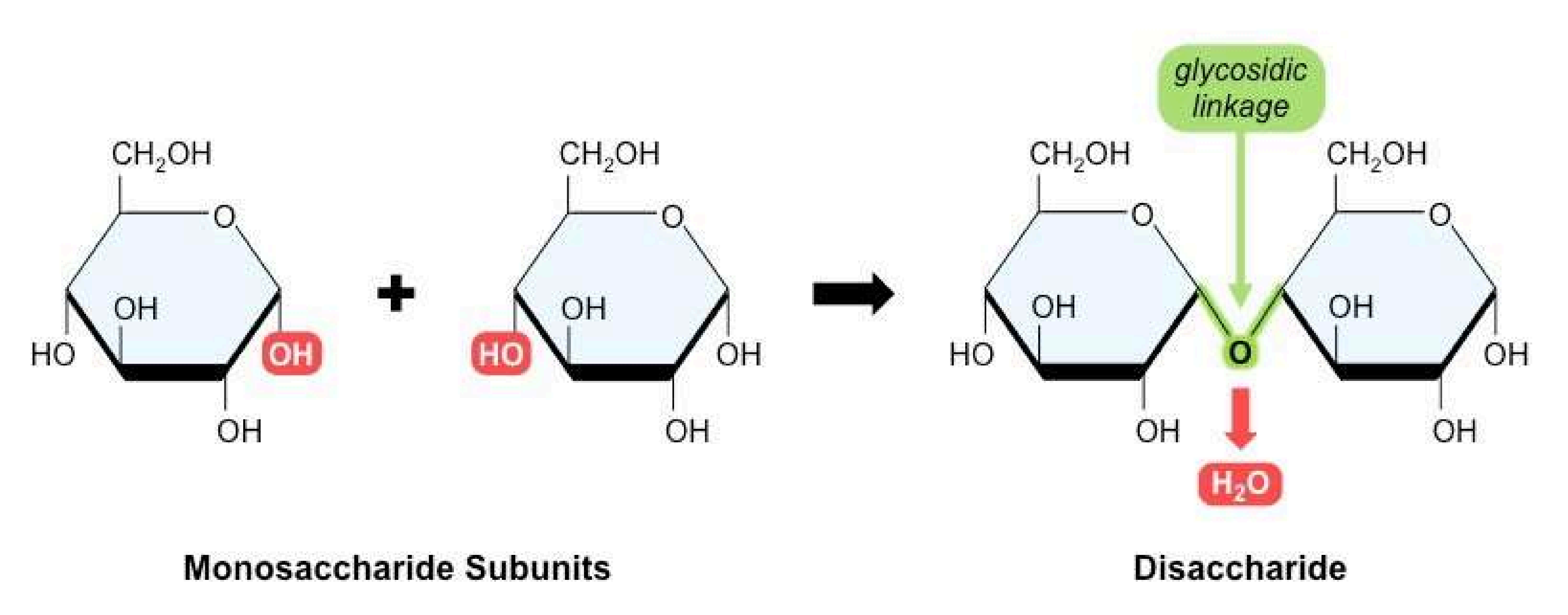
DISACCHARIDES FORMATION



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POLYSACCHARIDES

- Polysaccharides are composed of long chains of monosaccharides.
- These monosaccharides are joined by glycosidic bonds.
- Polysaccharides are classified into two categories: homopolysaccharides and heteropolysaccharides.

POLYSACCHARIDES

- Common polysaccharides include glycogen, cellulose, amylose, and amylopectin.
- Glycogen: A storage form of glucose in animals with a branching structure.
- Cellulose: Provides structural support in plant cell walls.
- Amylose and Amylopectin: Forms of starch in plants, differing in their linkages.

Summary

Carbohydrates	Organic compounds made of carbon, hydrogen, and oxygen in a 1:2:1 ratio.
Monosaccharides	The simplest form of carbohydrates, consisting of a single sugar molecule, is a monosaccharide.
Disaccharides	Carbohydrates composed of two monosaccharides joined by a glycosidic bond are called disaccharides.
Polysaccharides	Complex carbohydrates are made up of multiple monosaccharide units.

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Summary

Energy source	Carbohydrates are the primary source of energy for the body
Structural support	Carbohydrates contribute to the structural integrity of cells and tissues
Storage	Carbohydrates are stored as glycogen in animals and as starch in plants
Dietary fiber	Certain carbohydrates, such as cellulose and chitin, provide dietary fiber
Blood sugar regulation	Carbohydrates impact blood sugar levels and play a role in glucose homeostasis

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Summary

Glucose	Most common monosaccharide and primary source of energy in the body
Fructose	Naturally occurring monosaccharide found in fruits and honey
Galactose	Component of lactose, a monosaccharide present in milk
Sucrose	Disaccharide composed of glucose and fructose, commonly known as table sugar
Lactose	Disaccharide consisting of glucose and galactose, found in milk and dairy products
Maltose	Disaccharide formed by the breakdown of starch, composed of two glucose units

Summary

Starch	Storage form of glucose in plants, found in grains, potatoes, and legumes	α-1,4-glycosidic bonds
Glycogen	Storage form of glucose in animals, primarily stored in the liver and muscles	α-1,4-glycosidic bonds
Cellulose	Structural polysaccharide found in the cell walls of plants, providing rigidity	β-1,4-glycosidic bonds
Chitin	Polysaccharide present in the exoskeleton of arthropods and cell walls of fungi	β-1,4-glycosidic bonds

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Amino Acid

- Amino acids are the building blocks of proteins.
- Some amino acids are essential for life, while others are not.
- The structure and function of proteins are determined by the specific amino acids they contain.
- A balanced and varied diet is necessary to provide all the different amino acids.

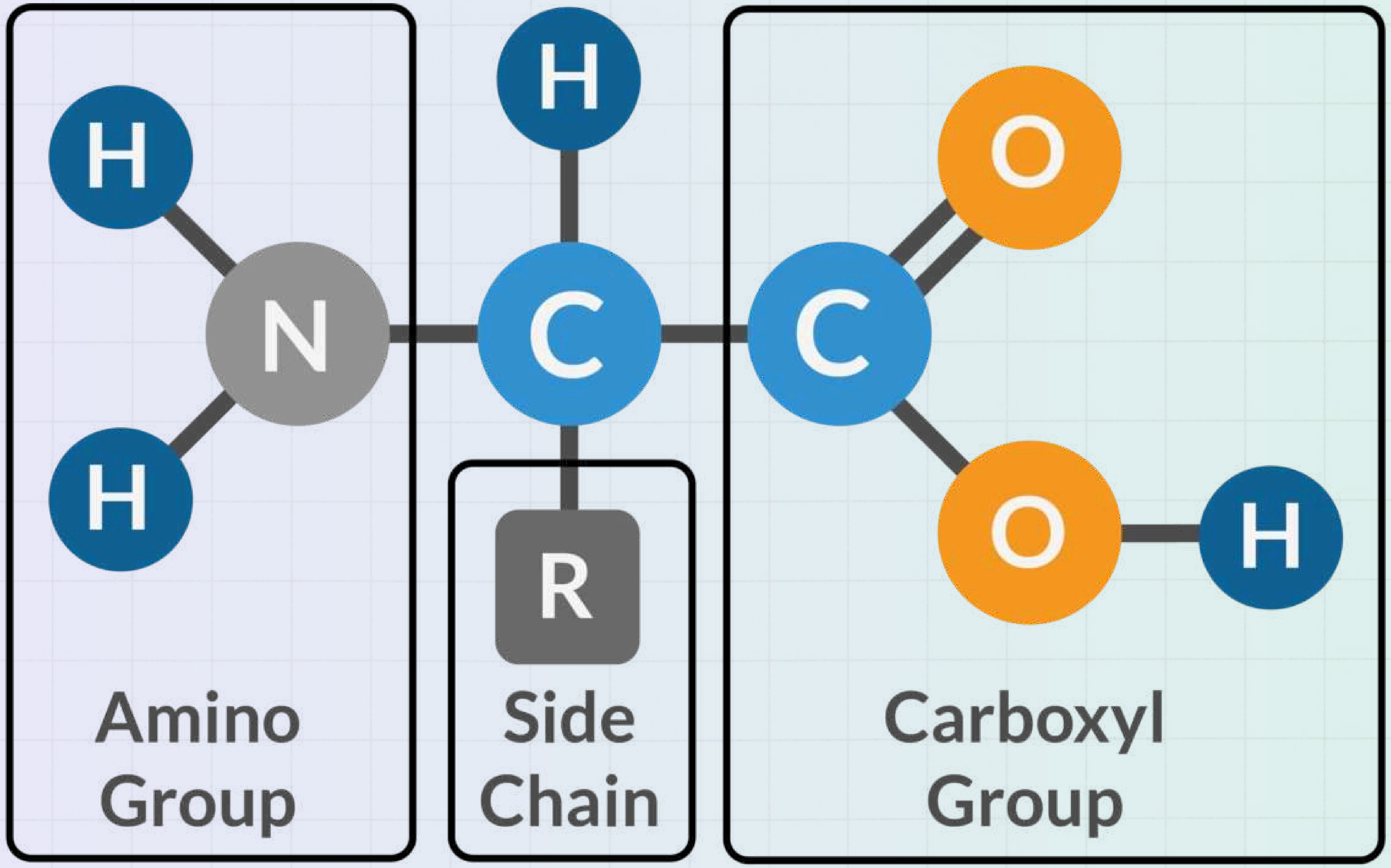
Amino Acid

Amino acids have specific structures, including:

- A central chiral carbon (alpha carbon).
- An amino group (-NH_2) and a carboxyl group (-COOH).
- A variable side chain (-R) that determines their unique properties.

Glycine is an exception, with a hydrogen atom as its side chain.

Amino Acid



STRUCTURAL LEVELS

- Primary structure: The linear sequence of amino acids in a protein.
- Secondary structure: Regular folding patterns, such as alpha helices and beta sheets.
- Tertiary structure: The three-dimensional folding of the protein, crucial for its function.

Connected through hydrogen bonds, disulfide bridges, and other interactions.

STRUCTURAL LEVELS

- Quaternary structure: Multiple protein subunits come together to form a complex.
- Found in proteins with more than one polypeptide chain.
- Important for functions such as enzyme activity.
- Stabilized by various interactions between subunits.

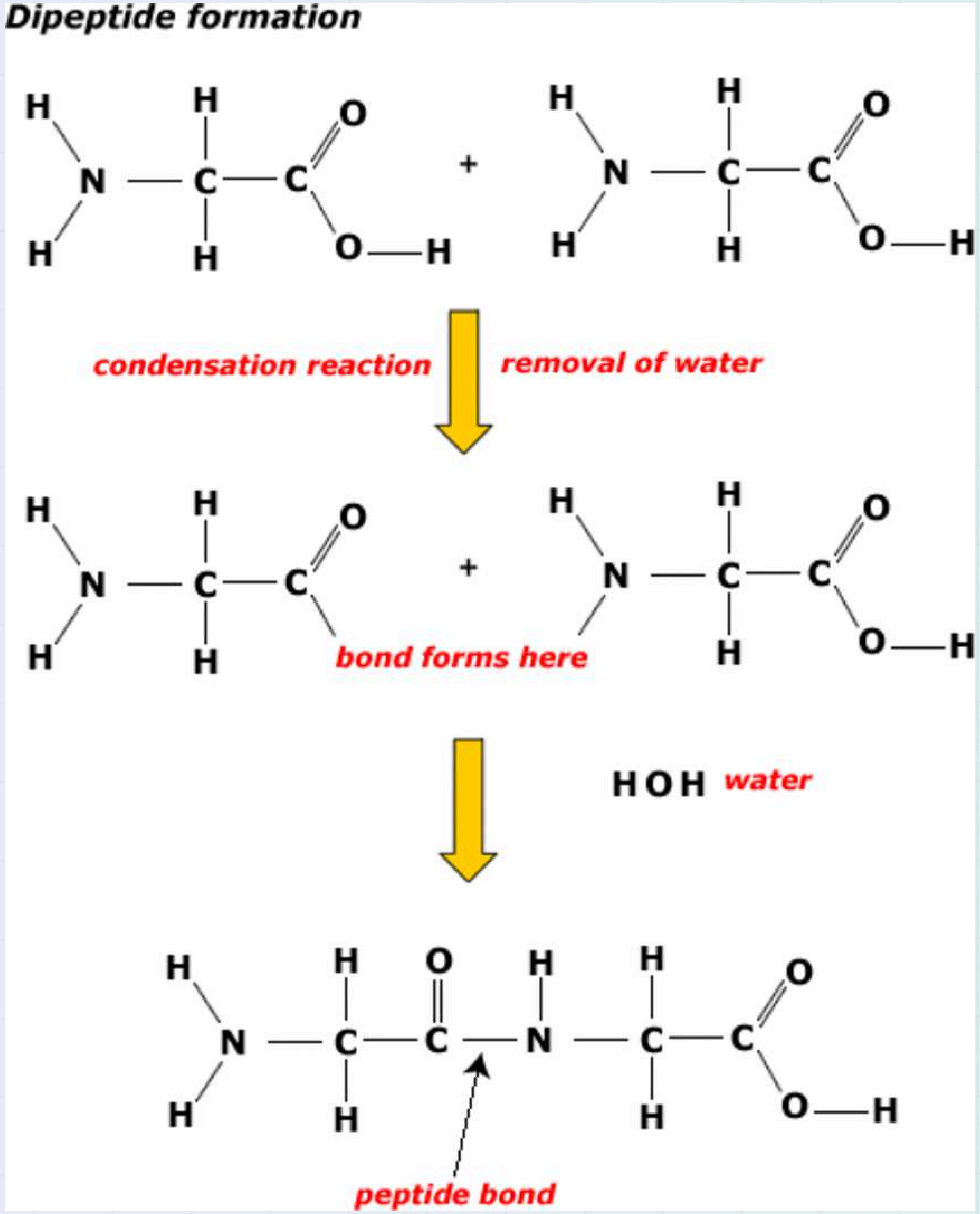
STRUCTURAL LEVELS

- Protein structure determines how proteins interact with other molecules.
- Key interactions include hydrogen bonds, disulfide bridges, van der Waals interactions, and hydrophobic interactions.
- The quaternary structure enhances protein functionality.
- Understanding amino acids and protein structure is crucial for comprehending protein function.

Primary Structure

- The primary structure of a protein is the linear sequence of amino acids.
- It determines the protein's three-dimensional shape and function.
- Amino acids are joined by peptide bonds through a dehydration reaction.
- The primary structure is the first level of protein organization.

Primary Structure



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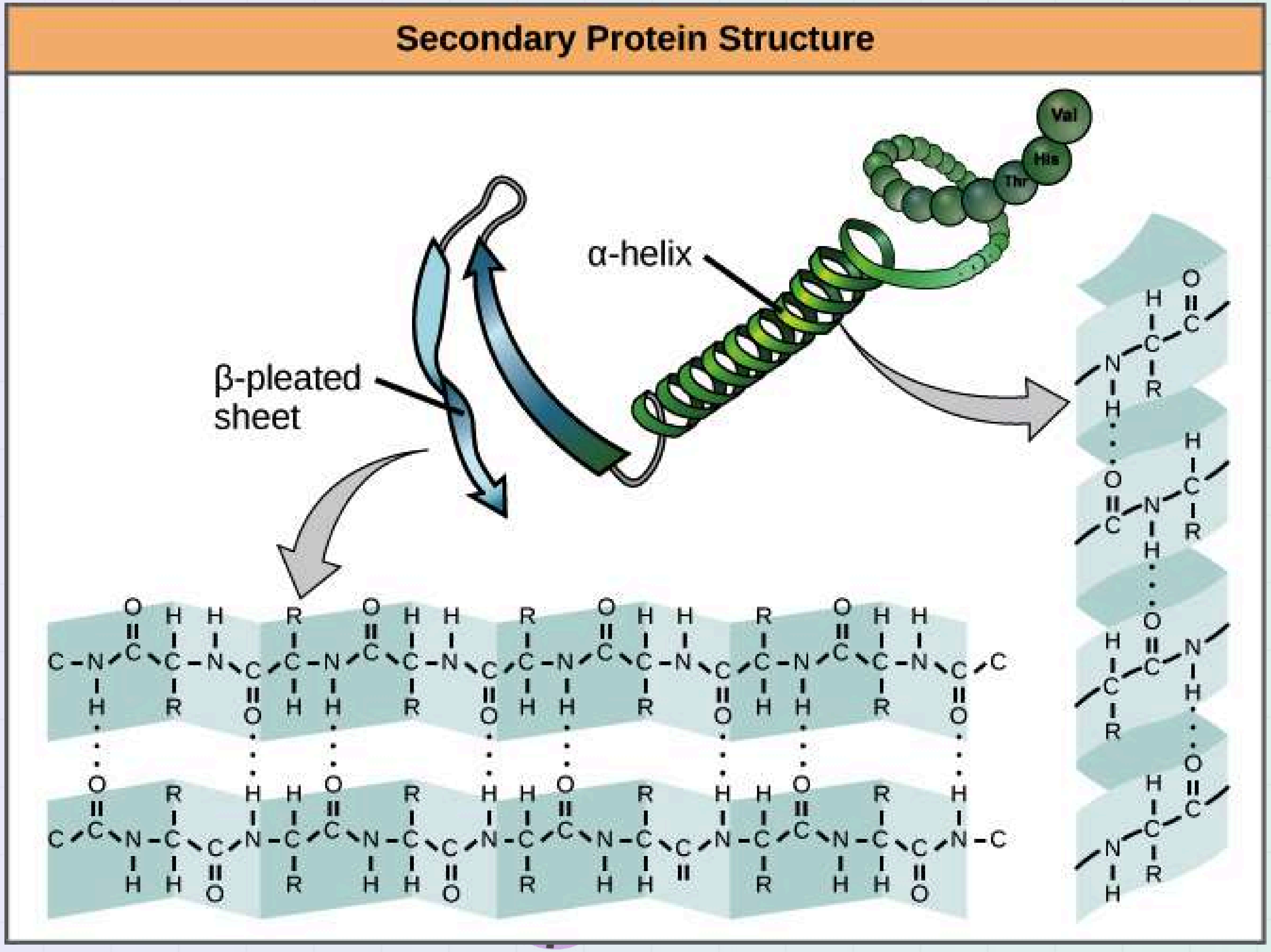
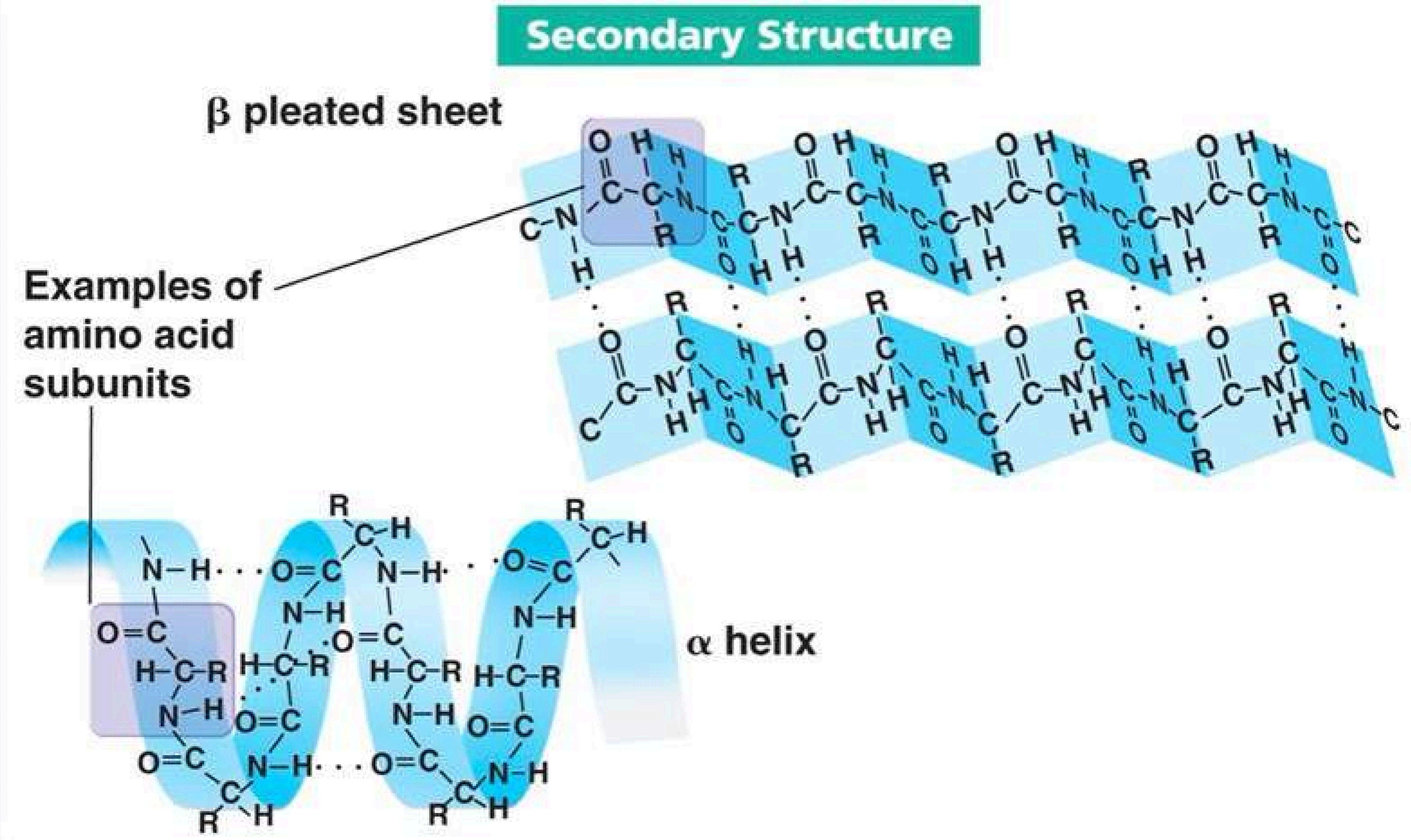
Secondary Structure

- Interactions between amino acid backbones create two types of secondary structures: alpha helices and beta sheets.
- Alpha helices are held together by hydrogen bonds within the helix.
- Beta sheets are formed by parallel or antiparallel strands held together by hydrogen bonds.
- This folding constitutes the secondary structure of the protein.

Secondary Structure



Secondary Structure



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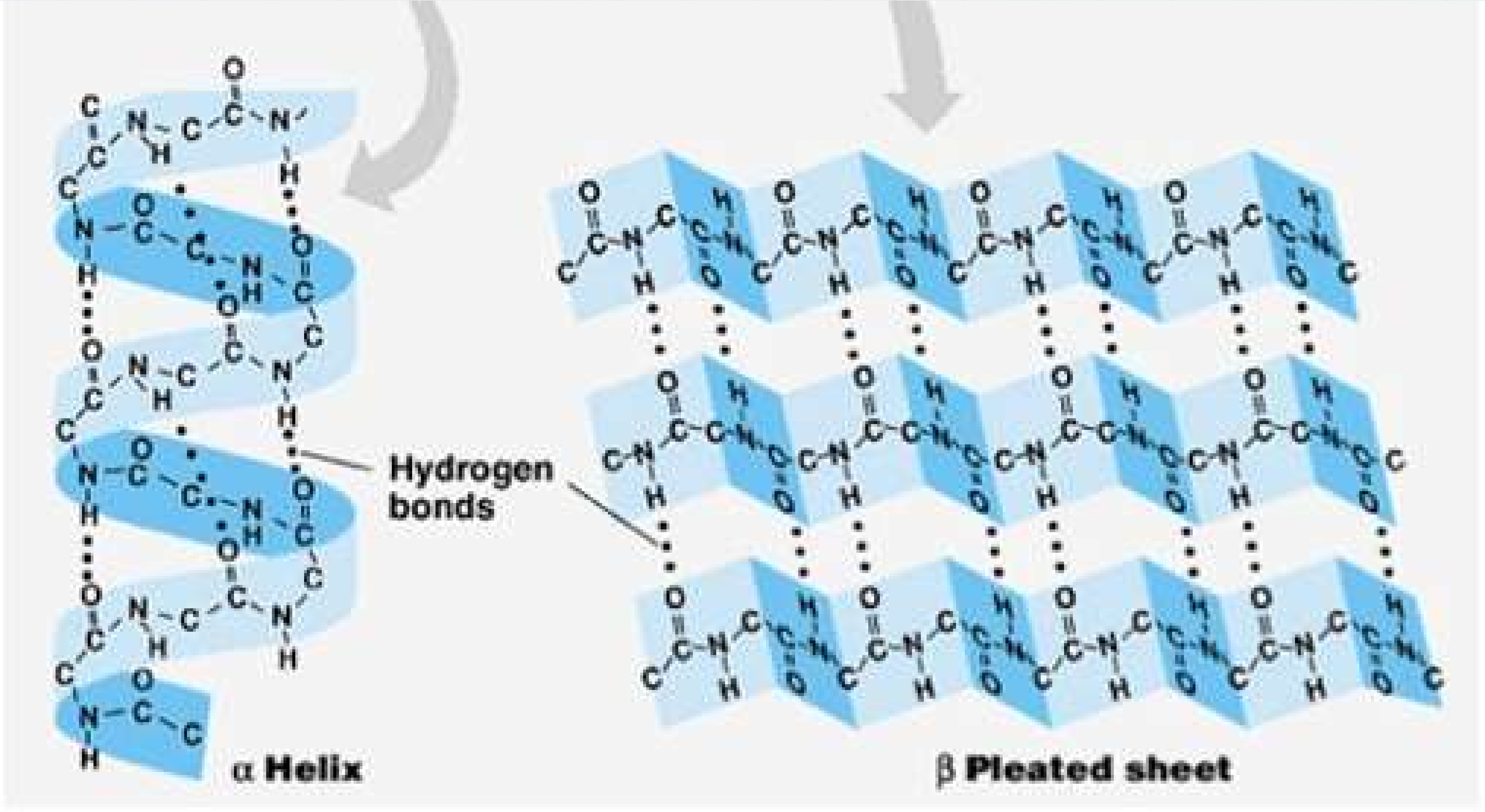
Secondary Structure bond



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Tertiary Structure

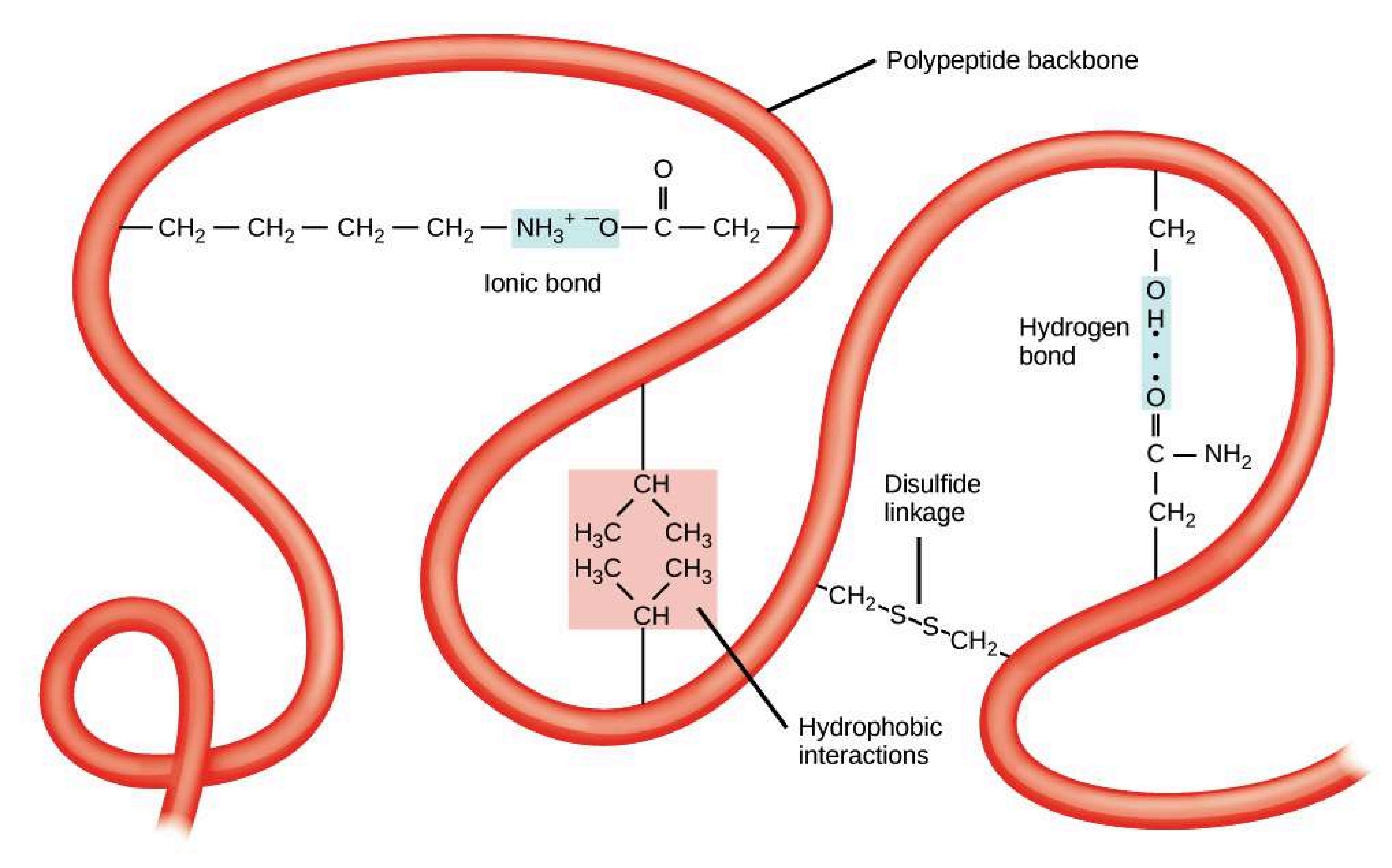
- Interactions between side chains (R groups) help stabilize the tertiary structure of a protein.
- Hydrophilic side chains are typically on the outside, interacting with the aqueous environment, while hydrophobic side chains are on the inside, away from water.
- These interactions give the protein its three-dimensional shape.

Tertiary Structure

Types of interactions that stabilize the tertiary structure include:

- Disulfide bridges: Covalent bonds formed between cysteine residues.
- Hydrogen bonding: Bonds between polar side chains.
- Hydrophobic interactions: Nonpolar side chains cluster together away from water.
- The tertiary structure determines the overall shape and function of the protein.

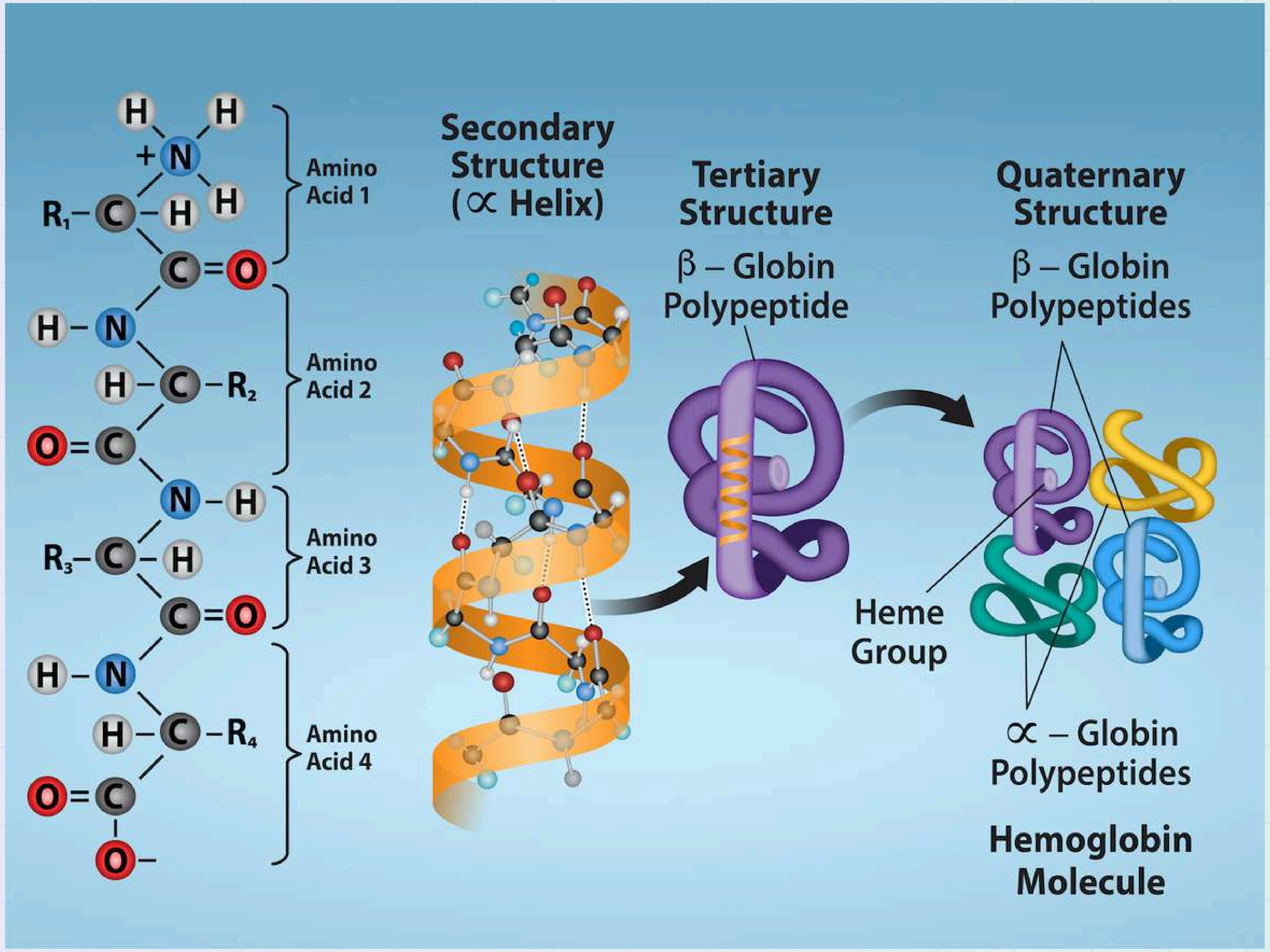
Tertiary Structure



Quaternary Structure

- Multiple proteins coming together to form a complex can involve either identical or different proteins.
- These complexes can have various arrangements and shapes.
- The overall function of the protein complex is determined by its structure.
- Stabilization is achieved through various interactions, including hydrophobic interactions, hydrogen bonds, and salt bridges.

Quaternary Structure



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HEMOGLOBIN COOPERATIVE BINDING

- Hemoglobin is an example of a protein complex with four subunits arranged in a specific structure.
- It carries oxygen in red blood cells.
- Fetal hemoglobin has a higher affinity for oxygen, while adult hemoglobin is more efficient at releasing oxygen.

HEMOGLOBIN COOPERATIVE BINDING

- Hemoglobin cooperative binding refers to how hemoglobin binds to oxygen.
- When oxygen binds to one subunit, it changes the shape of the protein, making it easier for the other subunits to bind to oxygen.
- This cooperative binding allows hemoglobin to bind more oxygen efficiently, even at lower oxygen partial pressures.

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HEMOGLOBIN COOPERATIVE BINDING

- Cooperative binding ensures a constant supply of oxygen to meet the changing needs of the body's tissues.
- This process is a result of hemoglobin's quaternary structure.
- The subunits of hemoglobin work together, much like ingredients in a recipe, to transport oxygen throughout the body.

Globular and Fibrous proteins

Two main categories of protein structure:

- Globular proteins:
    - Spherical shape and soluble in water.
    - Perform various functions.
    - Examples: Hemoglobin, lactoglobulin.
- Fibrous proteins:
    - Long and slender shape, insoluble in water.
    - Provide structural support.
    - Examples: Collagen, keratin.

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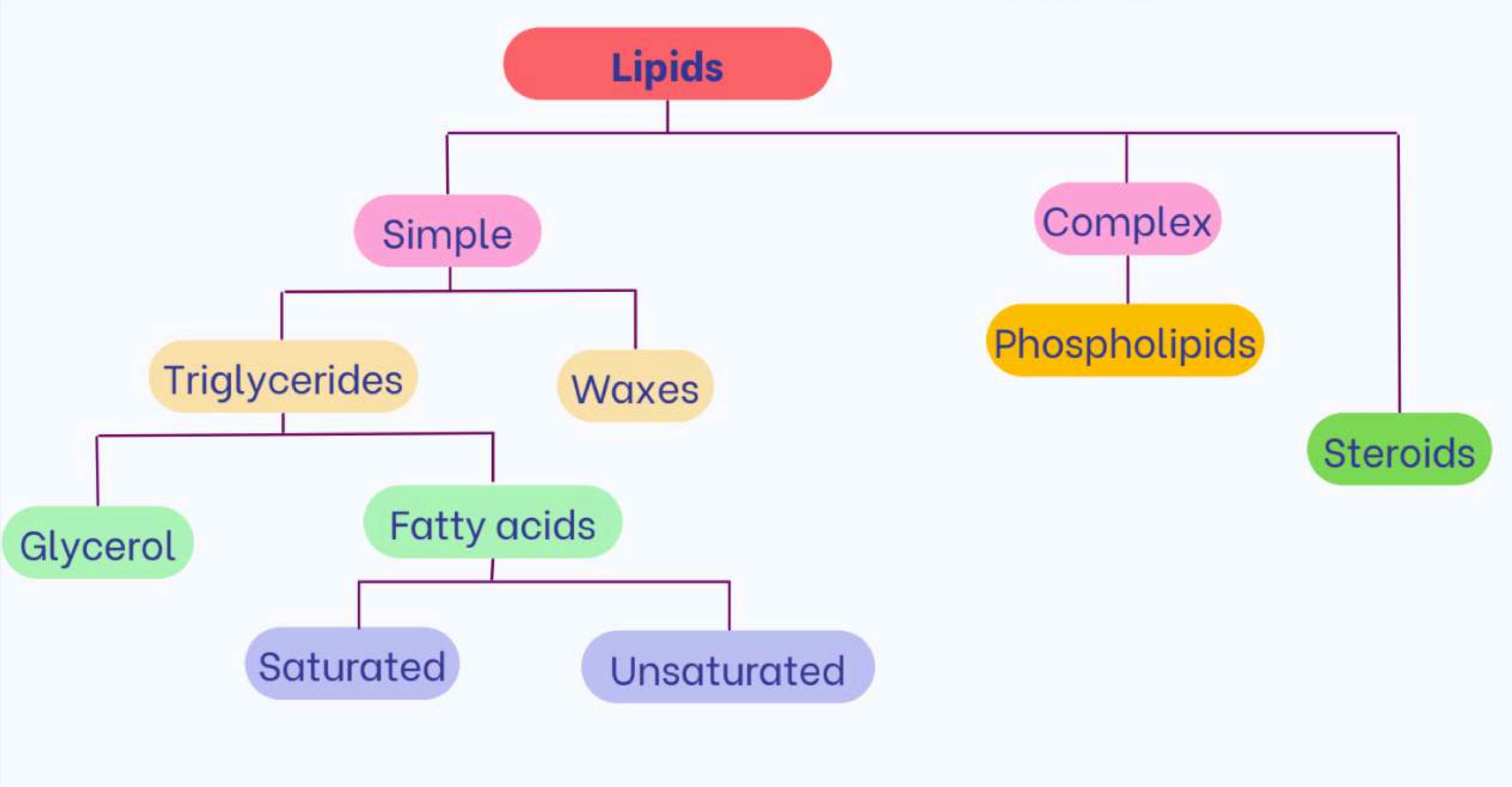
Lipids



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Lipids

- Lipids include fats, waxes, sterols, and certain types of oils.
- They are characterized by their ability to dissolve in nonpolar solvents.
- Lipids do not dissolve in water.
- The saying "like dissolves like" means that substances dissolve more readily in solvents with similar polarity.

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Lipids

- Polar substances have an uneven distribution of charge and dissolve in polar solvents.
- Nonpolar substances have an even distribution of charge and dissolve in nonpolar solvents.
- Water (H_2O) is a polar substance with partially positive charges on the hydrogen atoms and a partially negative charge on the oxygen atom.
- Hexane (C_6H_{14}) is a nonpolar substance with an even distribution of charge.

Lipids

- Lipids serve as an important energy store.
- Fats and oils are composed of glycerol and fatty acids.
- The body can break down fats and oils to release large amounts of energy.
- Lipids are also structural components of cell membranes, helping to maintain membrane integrity and fluidity.

Lipids

- Sterols, such as cholesterol, are important components of cell membranes.
- Sterols act as precursors to hormones and other signaling molecules.
- Waxes are used for waterproofing and protection in plants and animals.

Lipids

Common types of lipids include:

- Triglycerides (fats and oils).
- Phospholipids, which are components of cell membranes.
- Carotenoids, which serve as pigments in plants and animals and provide protection from UV radiation.

Saturated Fats

- Saturated fatty acids have only single bonds between carbon atoms.
- They have the maximum number of hydrogen atoms and are solid at room temperature.
- Examples of saturated fatty acids include palmitic acid and stearic acid.
- They are commonly found in animal fats.

Unsaturated Fats

- Unsaturated fatty acids have one or more carbon-carbon double bonds.
- They have fewer hydrogen atoms and are liquid at room temperature.
- Examples of unsaturated fatty acids include oleic acid and linoleic acid.
- They are commonly found in vegetable oils.

Saturated and unaturated Fats

- The degree of saturation affects the melting point of lipids.
- Saturated lipids have higher melting points than unsaturated lipids.
- Strong interactions between saturated fatty acid chains make it difficult for the molecules to move, resulting in a solid state at higher temperatures.
- Double bonds in unsaturated fatty acids create kinks in the chains, preventing close packing and lowering the melting point.

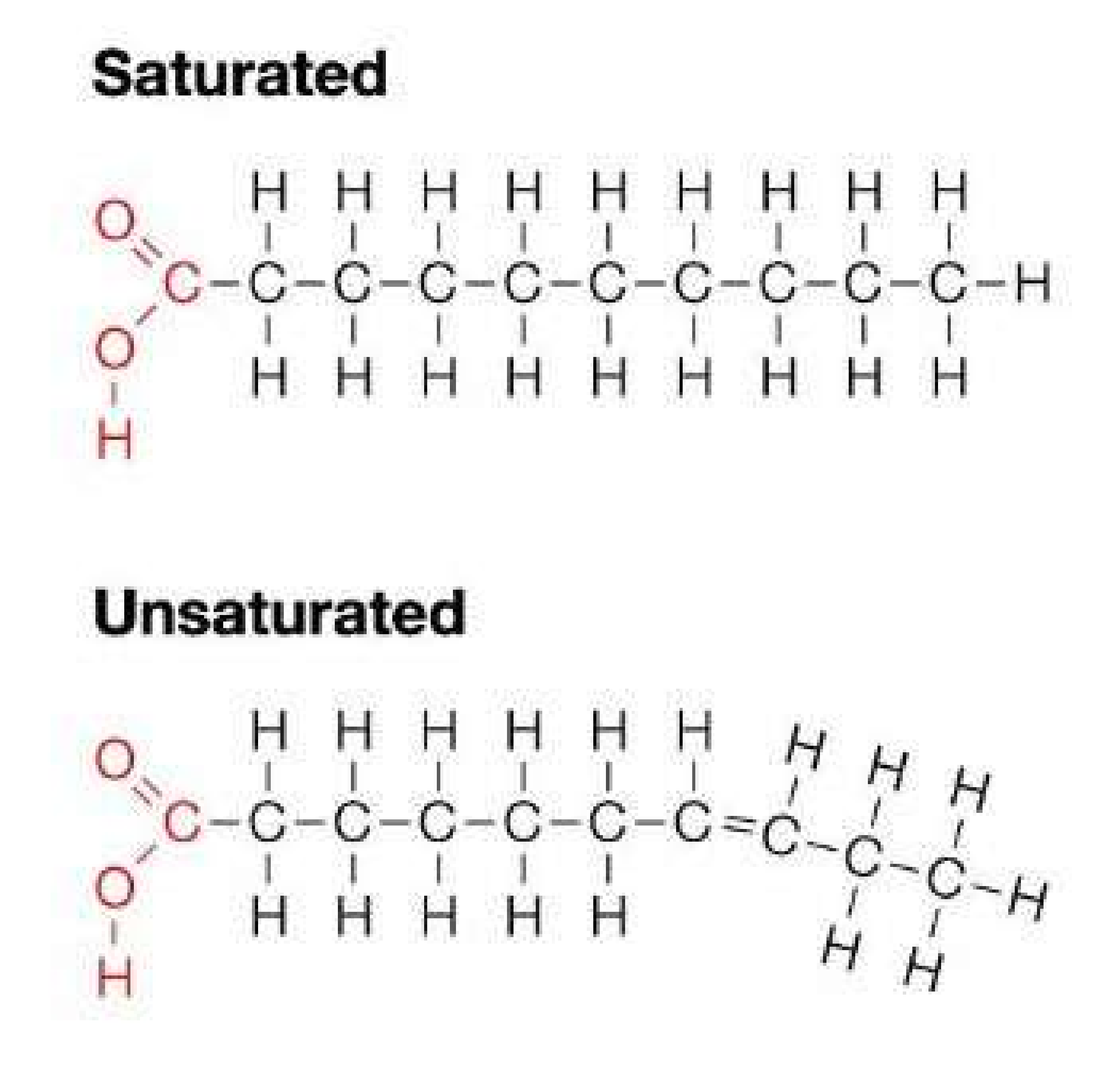
Saturated and unaturated Fats

- Lipids can be classified as saturated, monounsaturated, or polyunsaturated.
- Saturated lipids contain only saturated fatty acids.
- Unsaturated lipids contain one or more unsaturated fatty acids.
- Monounsaturated lipids have one double bond.
- Polyunsaturated lipids have two or more double bonds.

Saturated and unaturated Fats

- The degree of saturation in lipids affects their function and their association with heart disease risk.
- More double bonds in lipids lead to increased fluidity of cell membranes.

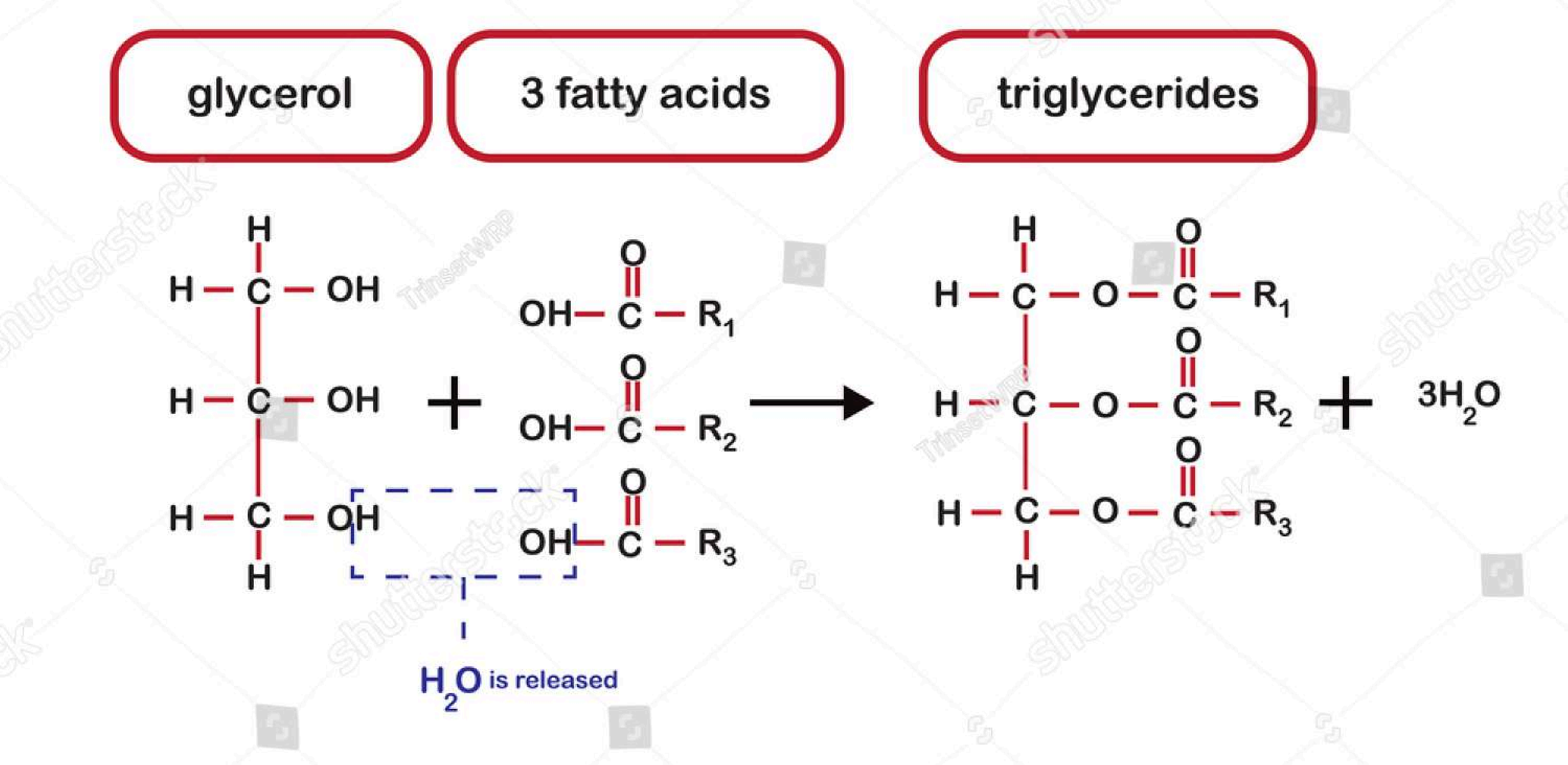
Saturated and unaturated Fats



TRIGLYCERIDES

- Triglycerides are a type of lipid in the body.
- They consist of three fatty acid molecules bonded to a glycerol molecule.
- Triglycerides can be either saturated or unsaturated.
- The degree of saturation affects their physical properties.
- Excessive consumption of triglycerides can lead to obesity and various health problems.

TRIGLYCERIDES



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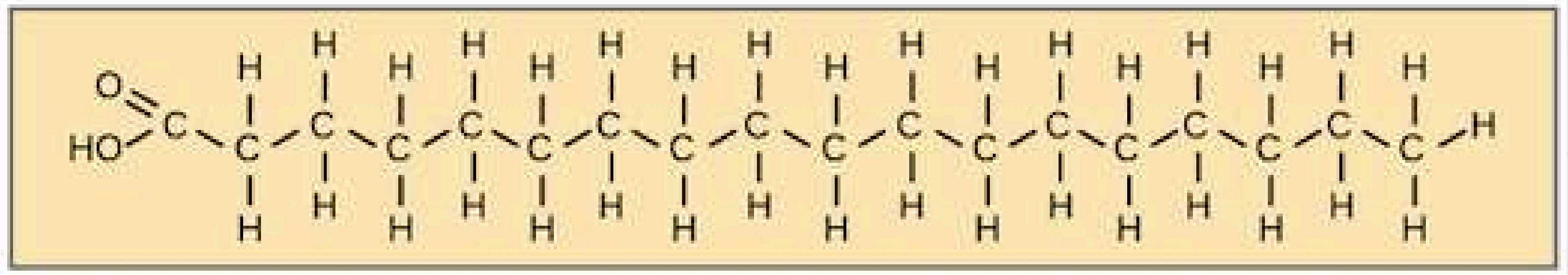
TRIGLYCERIDES

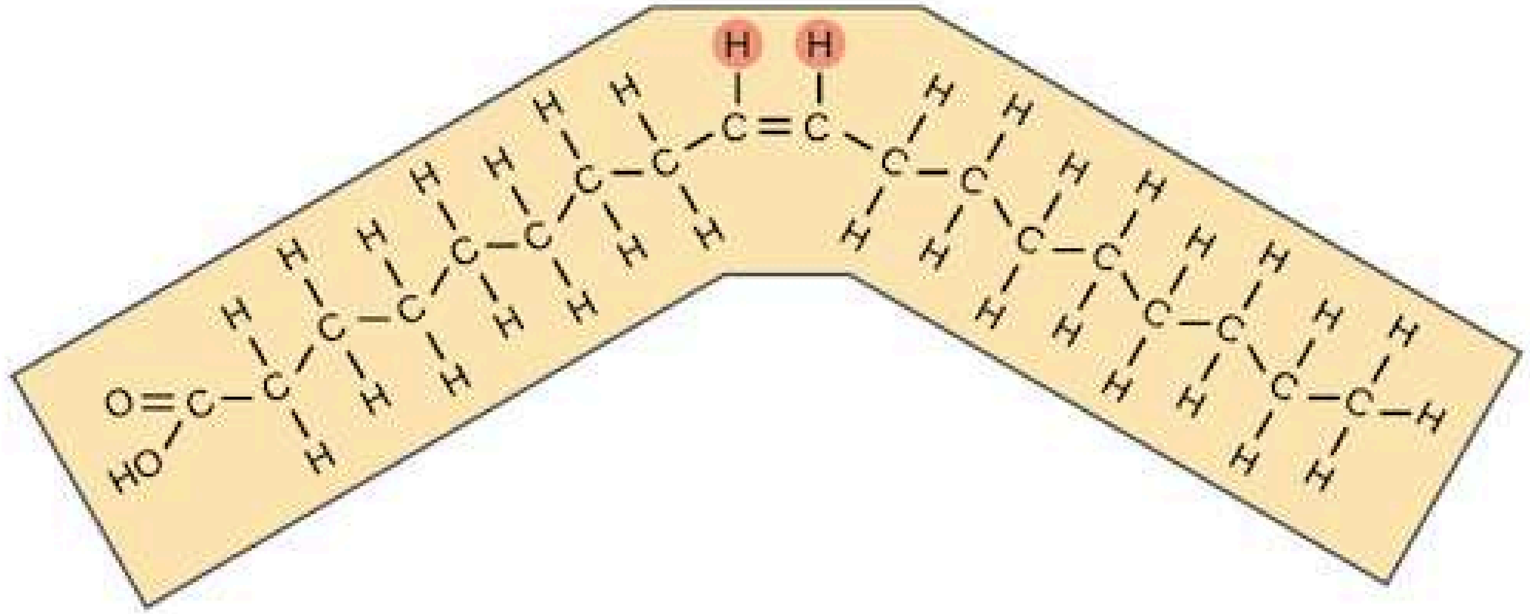
Saturated fatty acid

Stearic acid

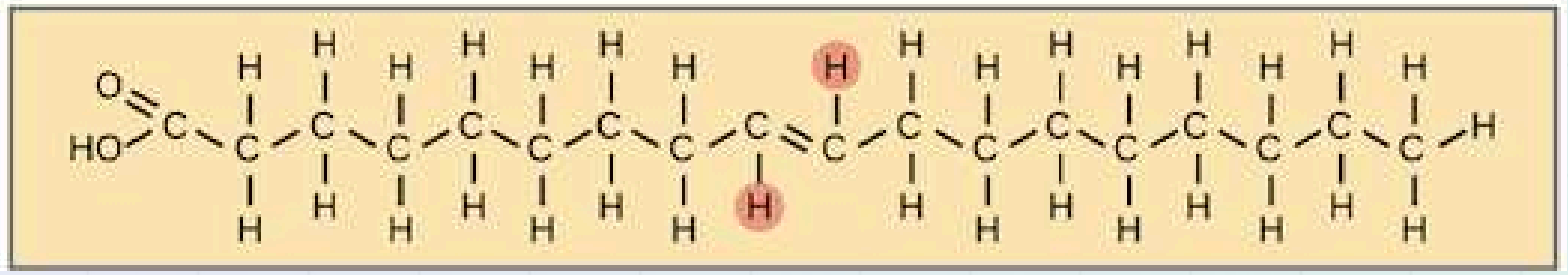


Unsaturated fatty acids

Cis oleic acid



Trans oleic acid



TRIGLYCERIDES

- Triglycerides are stored as the main form of fat in the body.
- They are also found in foods such as vegetable oils, butter, and lard.
- Triglycerides serve as a crucial source of energy for cells.
- Glycerol can be converted to glucose for energy.
- Fatty acid molecules are broken down into ketone bodies for energy.

TRIGLYCERIDES

- Triglycerides play a role in the structure and function of cell membranes.
- They are a major component of the phospholipid bilayer.
- Fatty acid chains in triglycerides contribute to the membrane's fluidity and flexibility.
- This fluidity allows cells to perform their functions effectively.
- Triglycerides help form the basic structure of cell membranes.

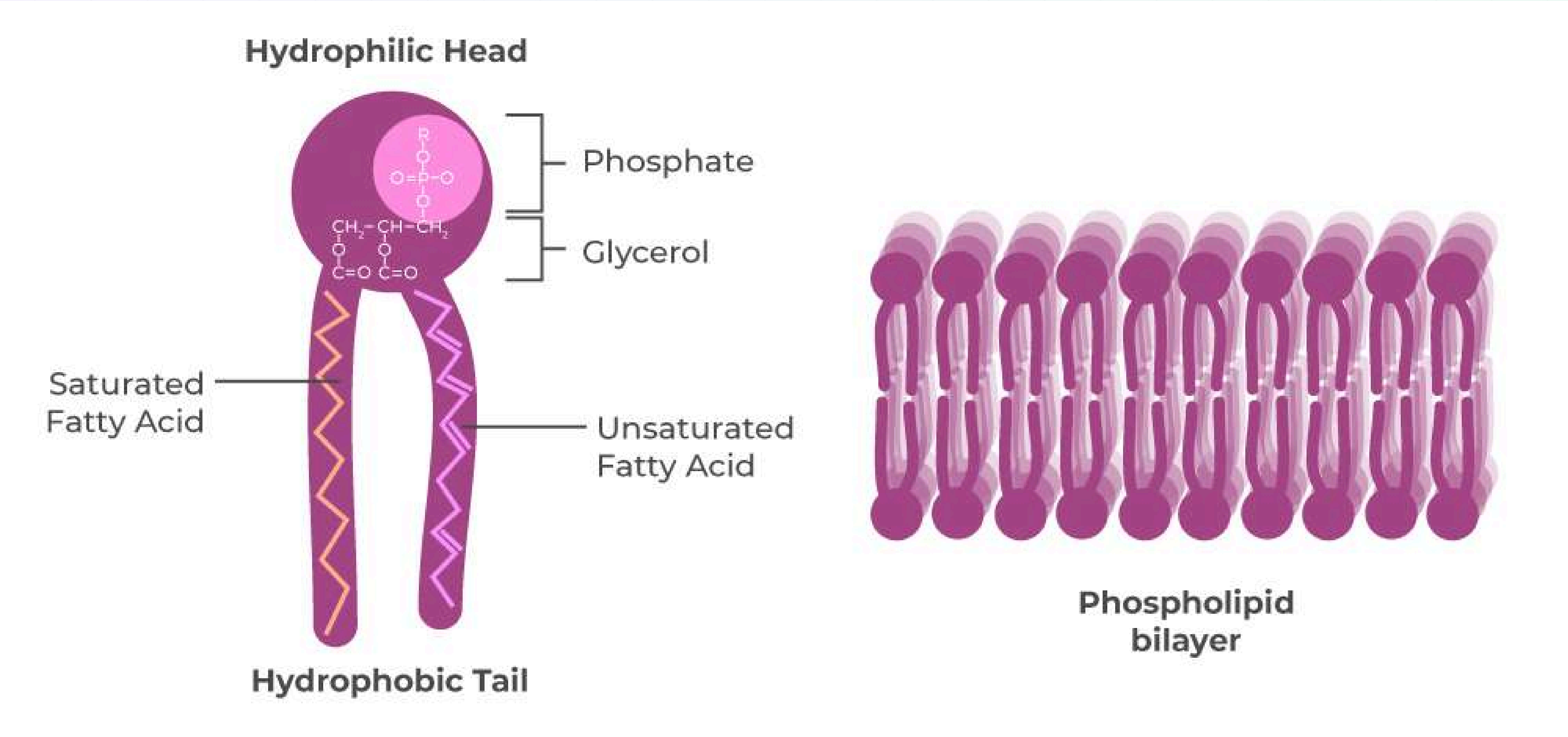
TRIGLYCERIDES

- Triglycerides are found in adipose tissue, which stores fat.
- Adipose tissue is concentrated in areas such as the abdomen, hips, and thighs.
- Triglycerides are also present in the bloodstream.
- Blood tests can measure triglyceride levels.
- High triglyceride levels may indicate health issues like metabolic disorders or cardiovascular disease.

Phospholipids

- Phospholipids are essential for cell membrane structure and function.
- They consist of a glycerol backbone, two fatty acid chains, and a phosphate group.
- The negatively charged phosphate group imparts unique properties to phospholipids.
- Phospholipids are key building blocks of cell membranes and help regulate cell transport.

Phospholipids



Phospholipids

- Phospholipids are involved in cell signaling, blood clotting, and inflammation.
- They are found in cell membranes, nerve tissue, and the brain.
- Dietary sources of phospholipids include egg yolks and soybeans.
- Deficiencies in phospholipids are linked to neurological disorders and liver disease.
- Adequate phospholipid intake is crucial for overall health.

Phospholipids

- Fatty acid chains in phospholipids are hydrophobic.
- These chains vary in length and degree of saturation.
- The hydrophilic phosphate group and glycerol molecule are polar and attract water.
- Phosphate groups are often attached to polar or charged molecules.
- Phospholipids are amphipathic, meaning they have hydrophilic heads and hydrophobic tails.

Phospholipids

- Phospholipids spontaneously form bilayers.
- In these bilayers, hydrophobic tails face inward, away from water, while hydrophilic heads face outward, towards the water.
- Phospholipid bilayers form the basis of cell membranes and organelles.
- These bilayers act as barriers, regulate transport, and facilitate cell signaling.
- Selective permeability allows certain ions and molecules to pass through while blocking others.

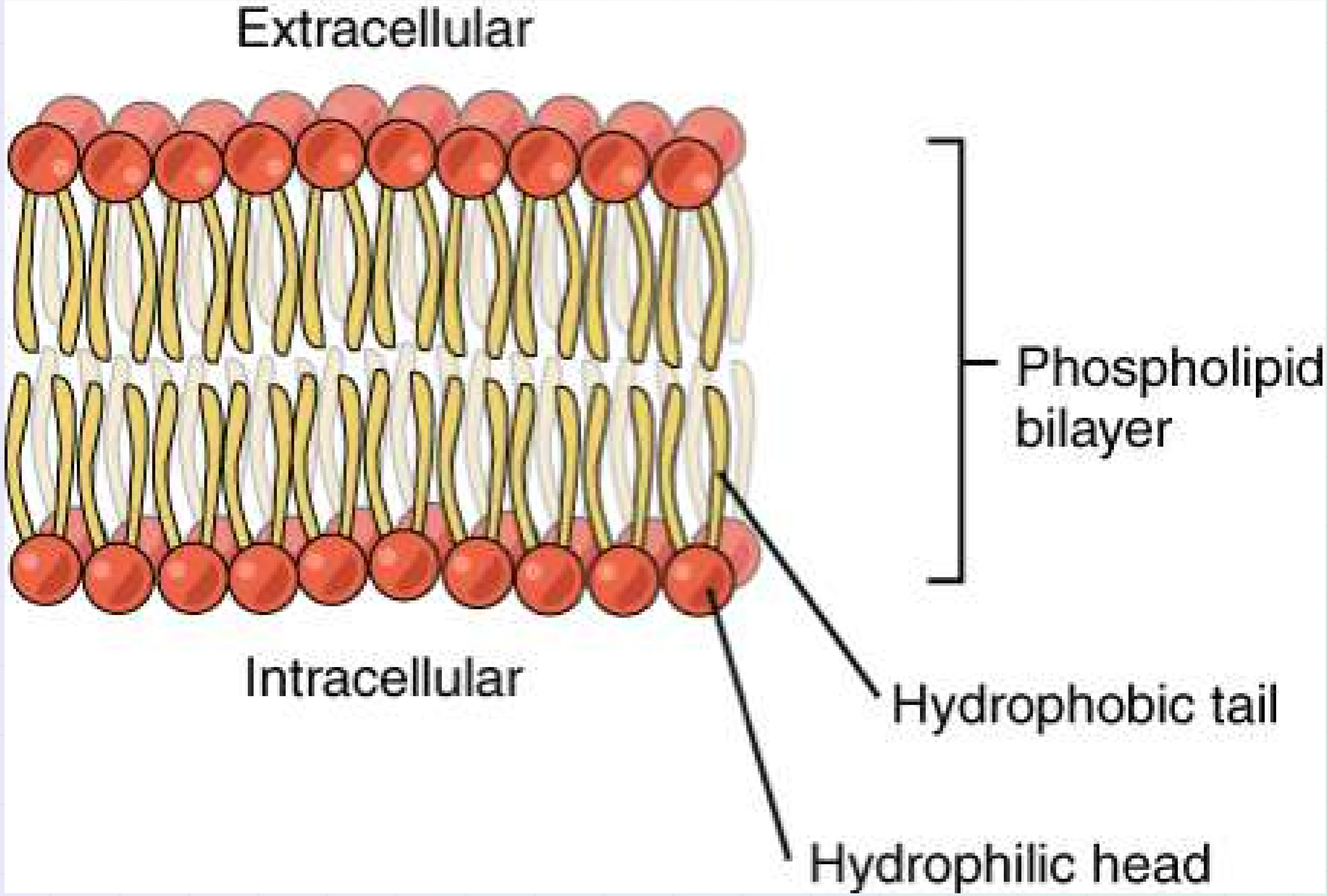
Phospholipids

- Phospholipid bilayers contain other lipids, such as cholesterol, and various proteins.
- Proteins in the bilayer can function as transport channels, enzymes, or receptors.
- The lipid composition of the bilayer affects membrane fluidity and stability.
- Phospholipid bilayers are critical for cell survival and overall organism function.

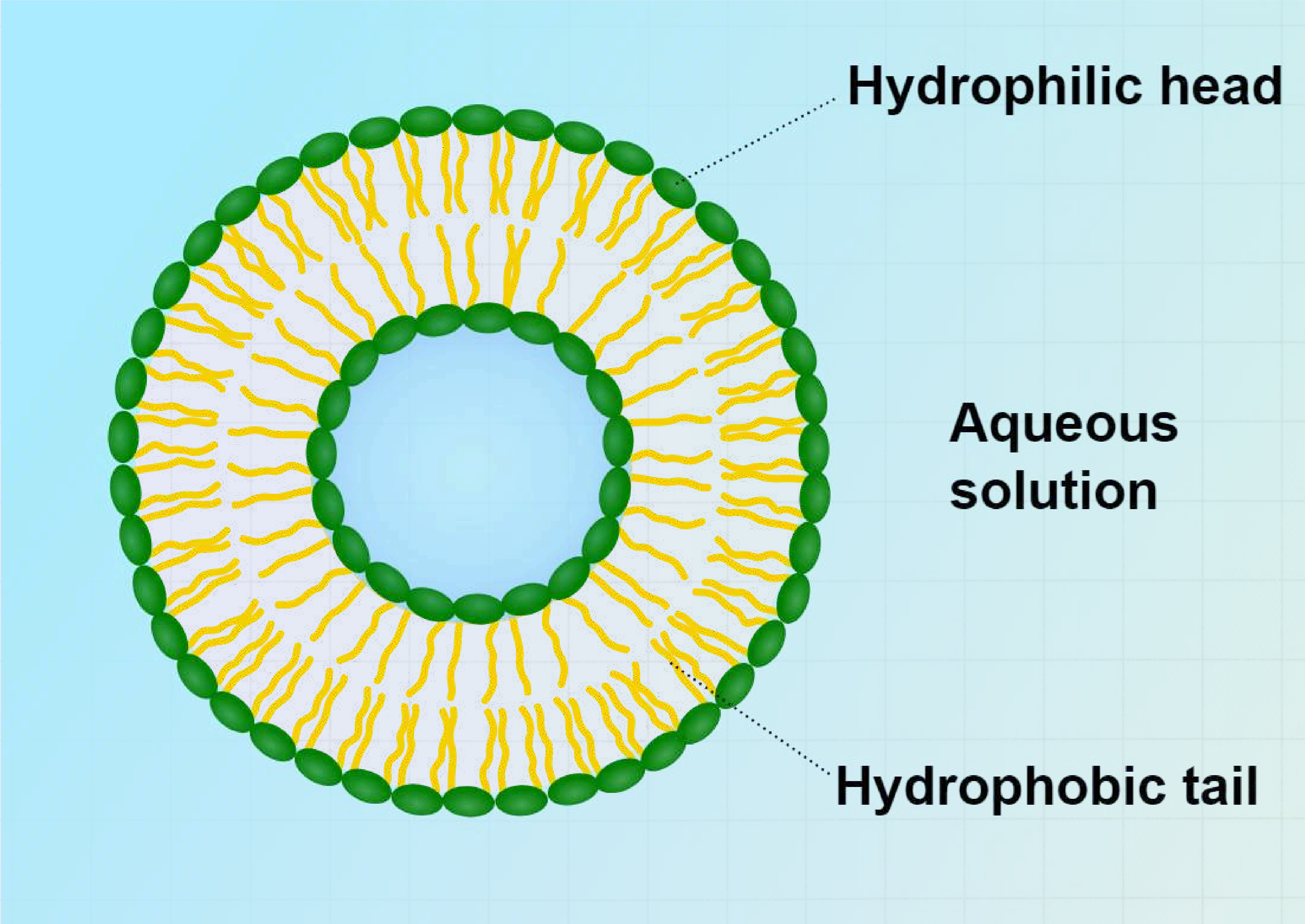
Phospholipids

- Lipid bilayers can form vesicles through self-assembly.
- Vesicles are created when lipids arrange themselves spontaneously in an aqueous solution.
- Phospholipid bilayers separate the inside of the cell from the outside environment.
- Proteins and structures on the bilayer's surface perform various functions, such as transport and signaling.

Phospholipids



Phospholipids



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STEROLS

- Sterols are a unique class of lipids with a fused ring structure.
- They play crucial structural and biological roles in cells.
- Sterols have a structure consisting of four rings: three six-membered rings and one five-membered ring.
- This fused ring structure is important for regulating membrane fluidity and permeability.
- Cholesterol is the most well-known sterol found in animal cells.

Cholesterol

- Cholesterol is an essential component of the human body.
- Its structure includes a fused ring system and a hydrocarbon tail.
- Cholesterol is amphipathic, having both hydrophilic and hydrophobic regions.
- It interacts with the hydrophobic tails of phospholipids in cell membranes.
- Cholesterol helps maintain membrane fluidity and rigidity.

Cholesterol

- Cholesterol serves as a precursor for the synthesis of steroid hormones.
- It is involved in the production of hormones such as testosterone and estrogen.
- Cholesterol is also a precursor for bile acids, which are essential for fat digestion.
- The liver synthesizes cholesterol, and it can also be obtained from the diet.

STEROLS

- Ergosterol is a sterol found in fungi and plant cells.
- Stigmasterol is another sterol found in plants.
- These sterols have different biological functions.
- Ergosterol and stigmasterol share a similar chemical structure to cholesterol.

STEROLS

- Sterols are involved in the synthesis of hormones and other biomolecules.
- They help regulate cell membrane fluidity and structure.
- Sterols play a role in the absorption and metabolism of fats.
- They contribute to the overall health of cells and tissues.

Waxes

- Waxes are complex lipids with unique physical and chemical properties.
- Their intricate structure contributes to their distinct characteristics.
- Waxes are hydrophobic and water-resistant due to their high molecular weight.
- Their water-repelling properties make them crucial for waterproofing and protection.

Waxes

- Waxes are complex lipids with unique physical and chemical properties.
- Their intricate structure gives them distinct characteristics.
- Waxes are hydrophobic and water-resistant because of their high molecular weight.
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Nucleic Acids

- Nucleic acids are crucial biomolecules involved in the transmission and expression of genetic information.
- They determine an organism's physical traits, cellular functions, and behaviors.
- Nucleic acids are essential for DNA repair, RNA synthesis, and protein synthesis.

Nucleic Acids

- Deoxyribonucleic acid (DNA) contains genetic information and is primarily located in the cell nucleus.
- Ribonucleic acid (RNA) is synthesized from DNA and is essential for protein production.

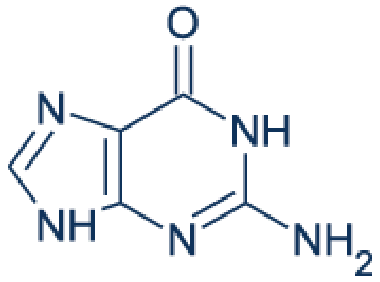
PURINES AND PYRIMIDINES

- Purines and pyrimidines are nitrogenous bases found in nucleotides.
- Purines, which include adenine (A) and guanine (G), have a larger structure with fused rings.
- Pyrimidines, which include cytosine (C), thymine (T), and uracil (U), have a single-ring structure.
- Thymine is present in DNA, while uracil is found in RNA.
- Nucleotides are the building blocks of nucleic acids such as DNA and RNA.

PURINES AND PYRIMIDINES

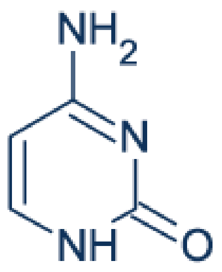
Purines

Adenine

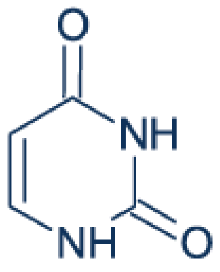


Guanine

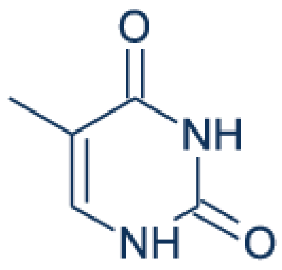
Pyrimidines



Cytosine



Uracil



Thymine

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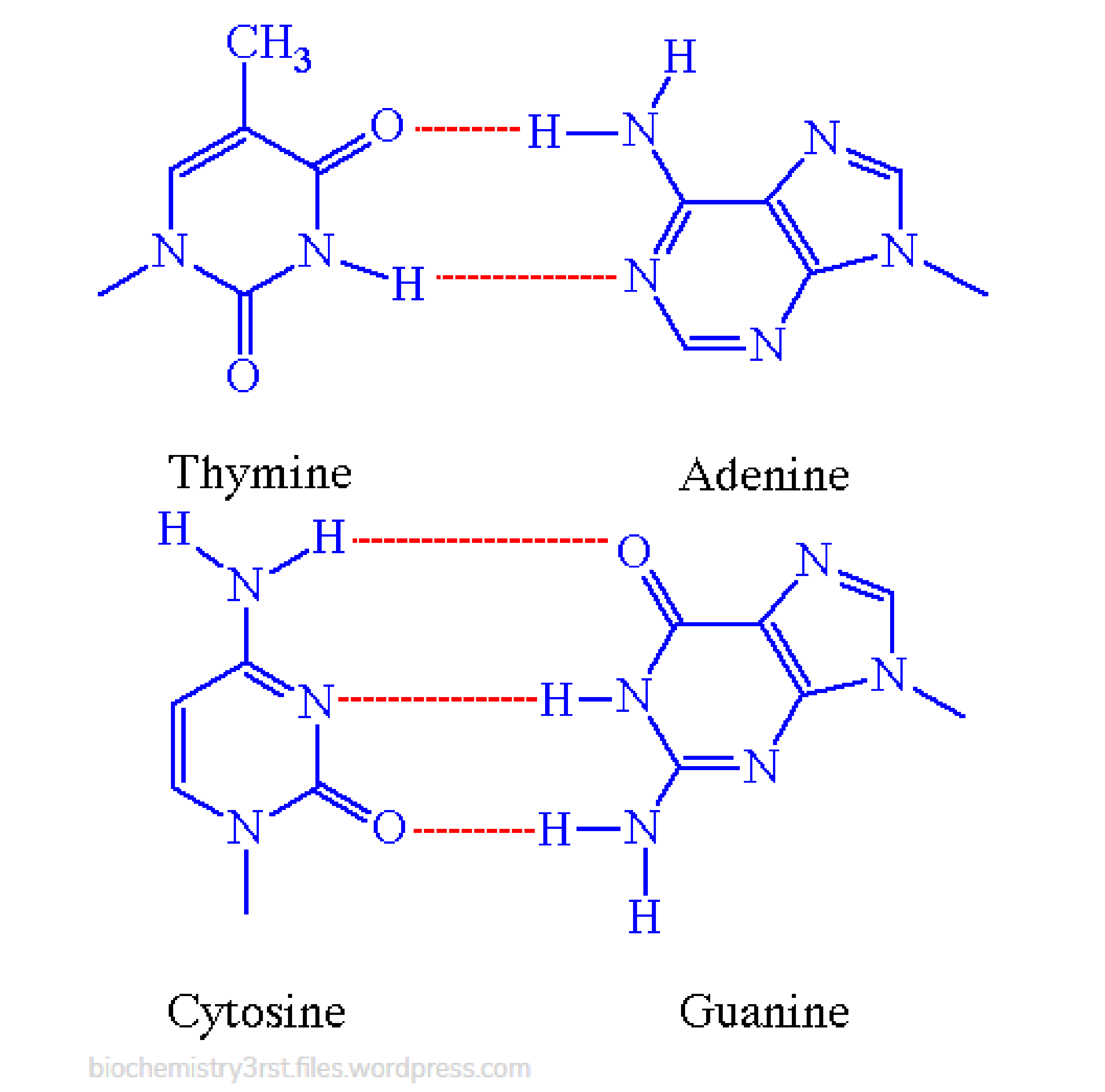
PURINES AND PYRIMIDINES



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PURINES AND PYRIMIDINES

- The size difference between purines and pyrimidines is significant.
- Purines pair more easily with pyrimidines due to their larger size.
- Base pairing is crucial for the structural stability and proper functioning of DNA and RNA.

PURINES AND PYRIMIDINES

- Understanding the differences between purines and pyrimidines is crucial for comprehending the molecular basis of genetics.
- Purines and pyrimidines are fundamental to the transmission of genetic information.
- They play a vital role in the processes underlying genetic inheritance.
- Purines and pyrimidines are essential components of DNA and RNA.

DNA

- DNA (deoxyribonucleic acid) is the genetic material in living organisms.
- It is a double-stranded molecule with a sugar-phosphate backbone.
- The four nitrogenous bases in DNA are adenine (A), cytosine (C), guanine (G), and thymine (T).
- Base pairing occurs through hydrogen bonds: A pairs with T, and C pairs with G.

DNA

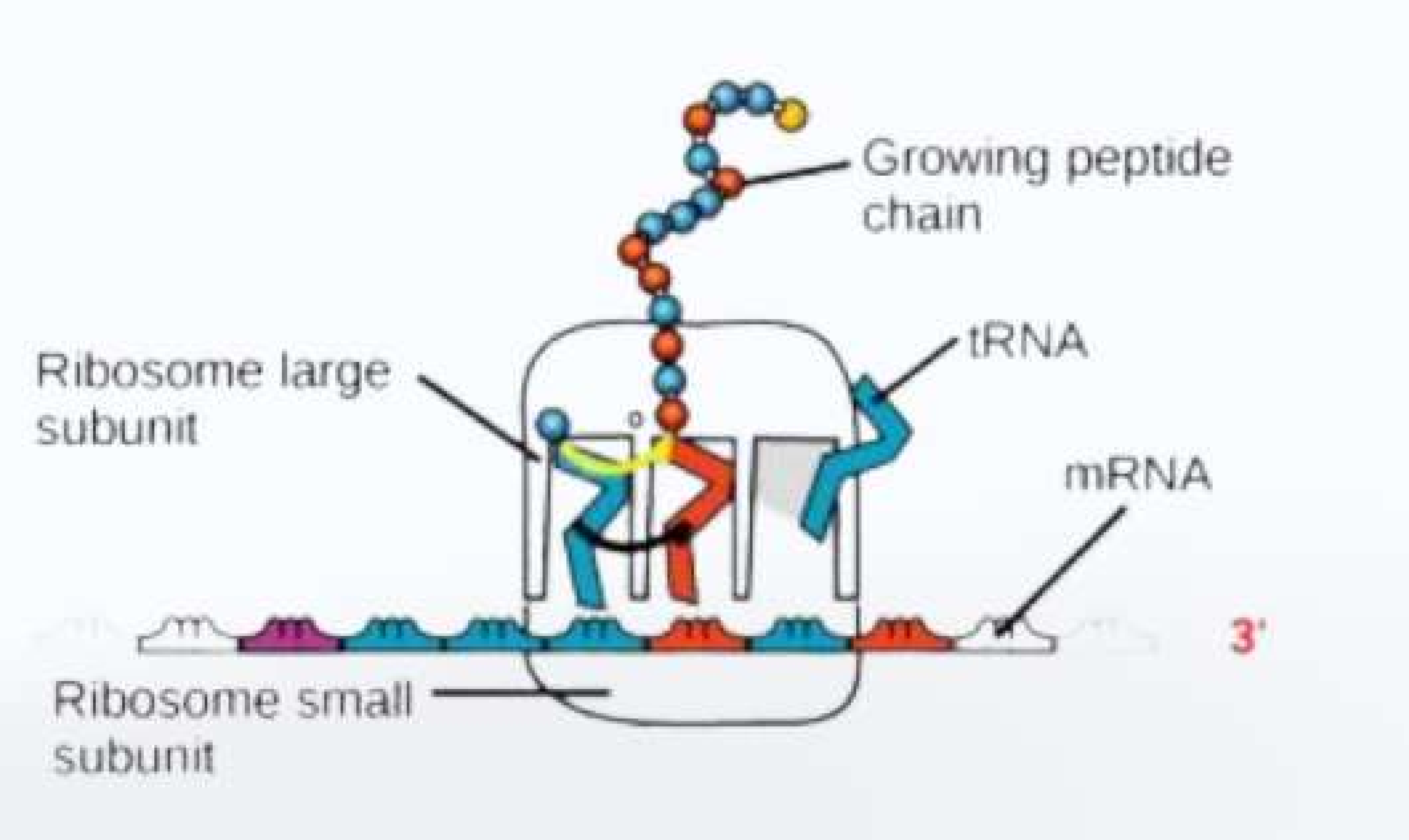
- DNA is wrapped around proteins called histones, forming chromatin.
- Chromatin can further compact into chromosomes during cell division.
- DNA regulation involves the compacting and accessibility of chromatin.

DNA

- Heterochromatin is tightly packed DNA, while euchromatin is more open and accessible.
- Euchromatin is actively transcribed, whereas heterochromatin is usually not.
- DNA encodes information for protein synthesis and other essential molecules.
- Transcription converts DNA into RNA using RNA polymerase.
- RNA carries genetic information from the nucleus to ribosomes.

DNA

- Translation synthesizes proteins using the RNA template.
- Proper gene expression and molecule production are essential for cell function.



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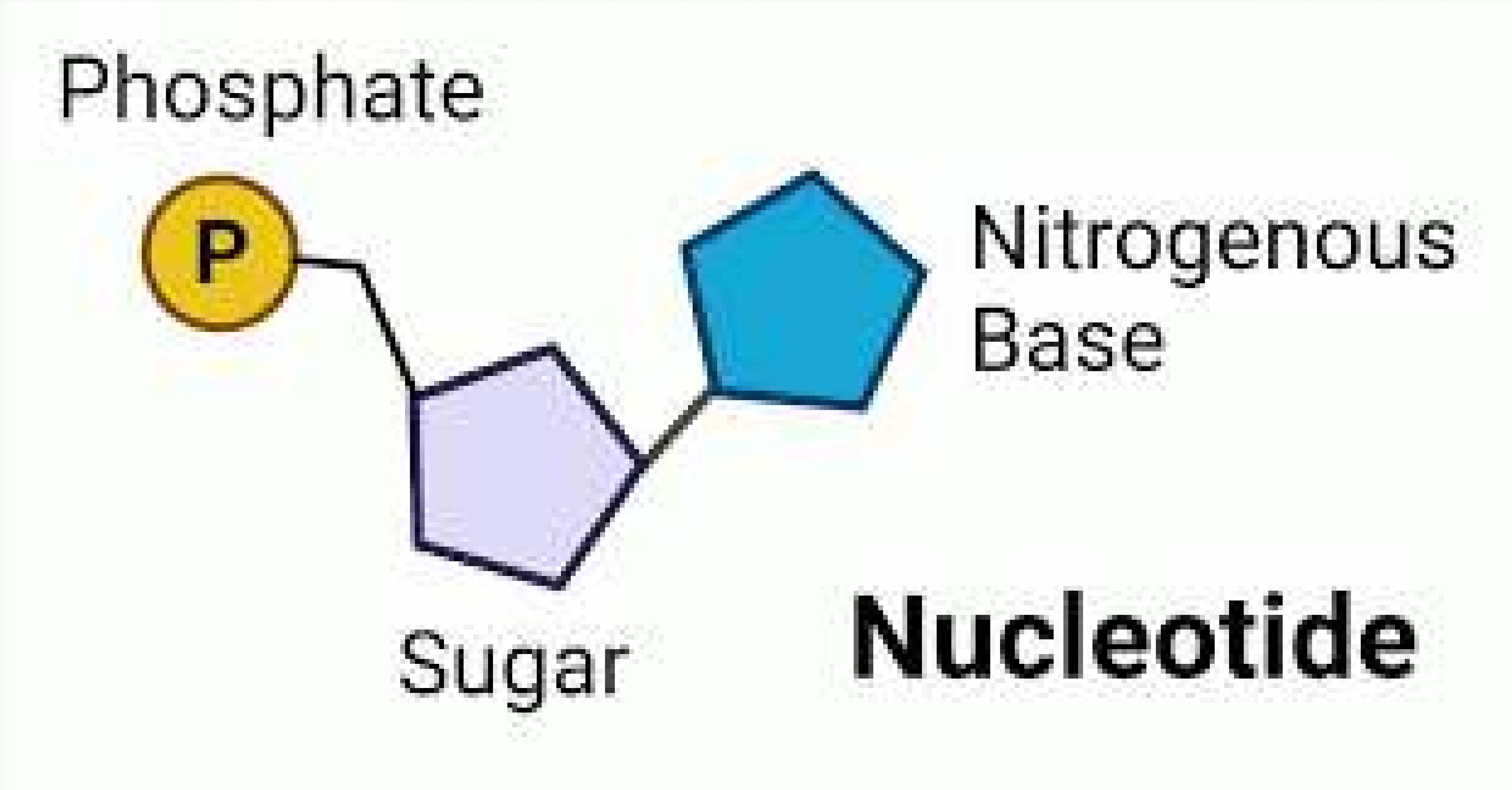
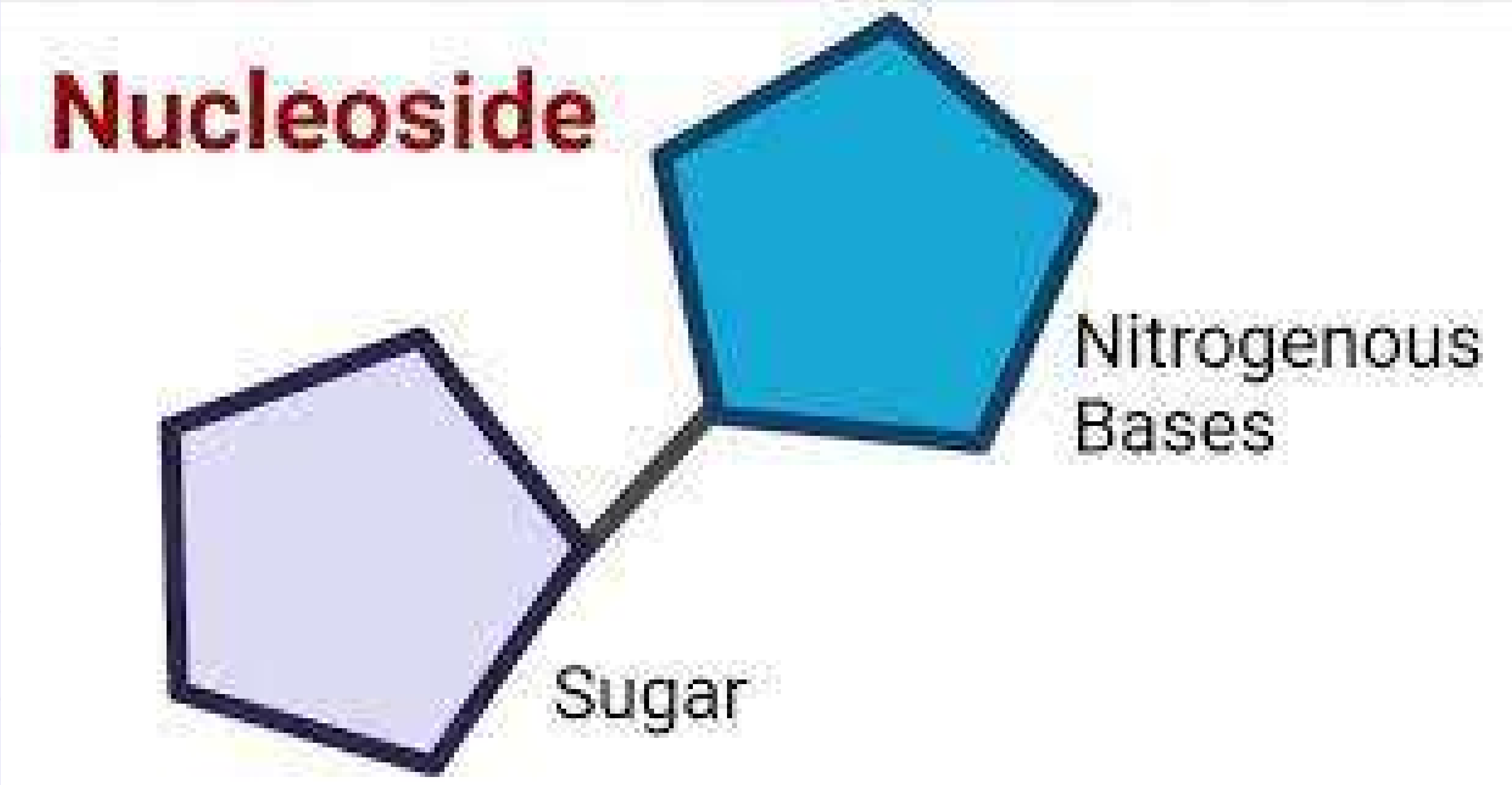
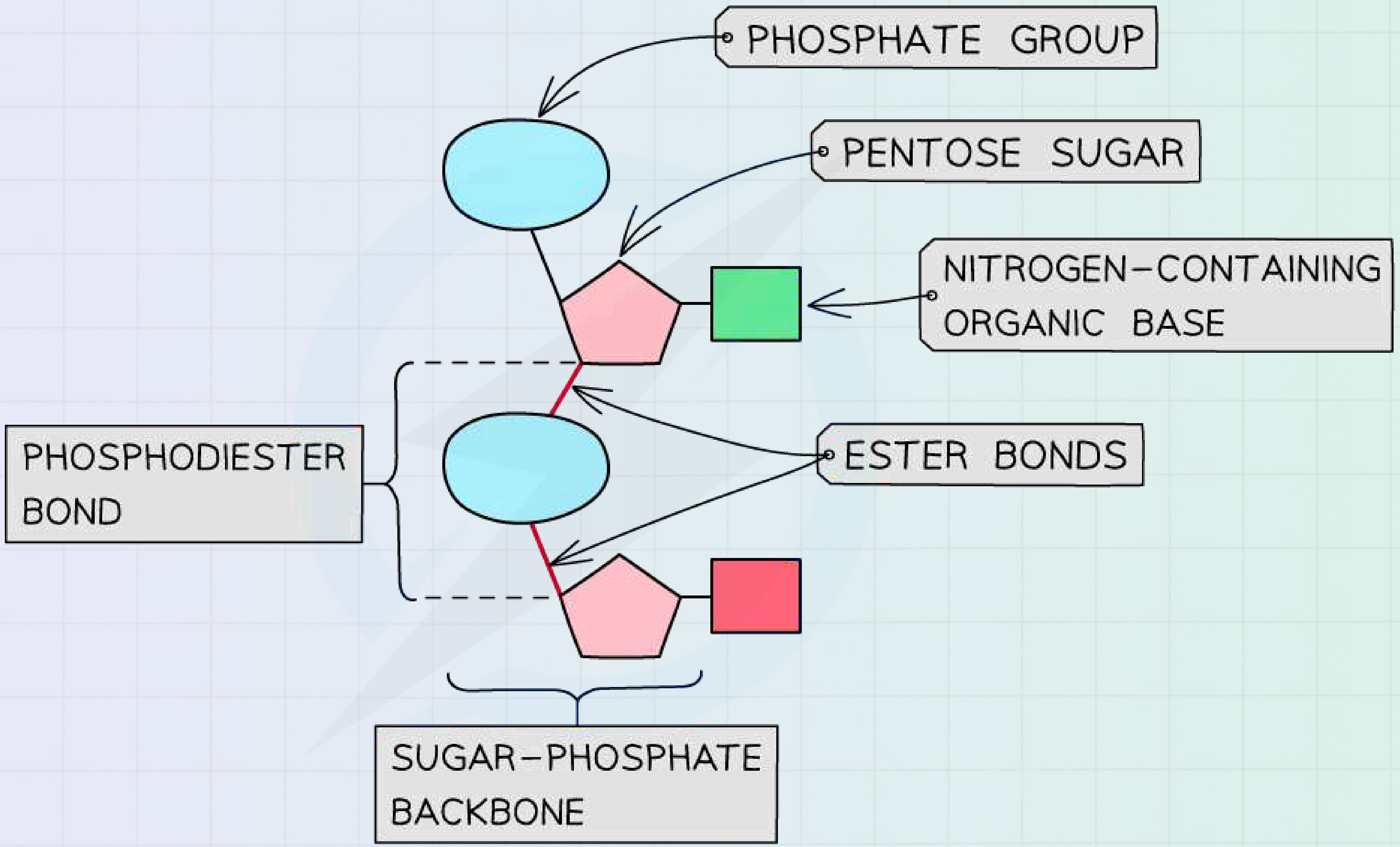
Nucleotide



Nucleoside

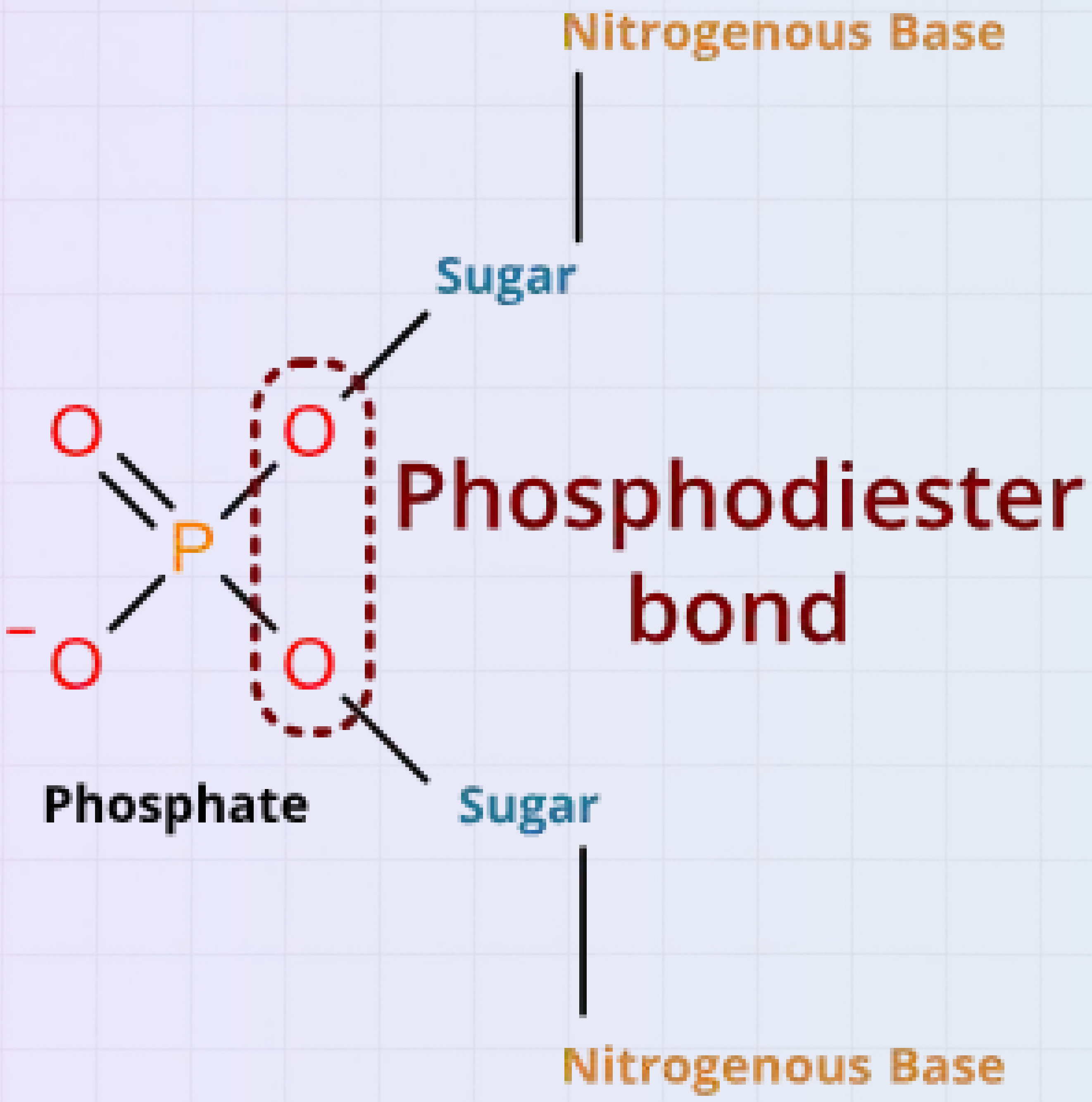


Bonds

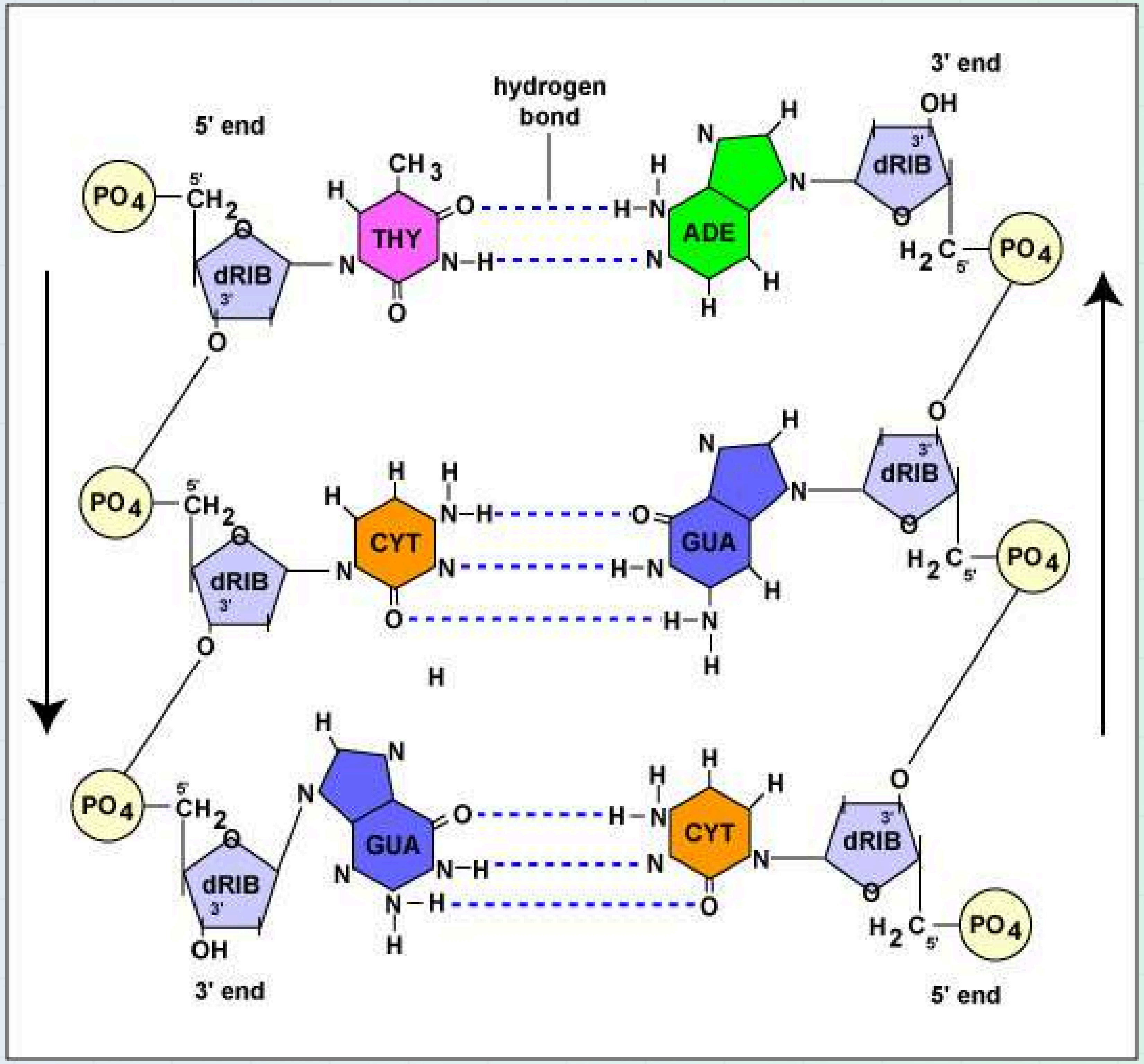


PHOSPHATE GROUP
PENTOSE SUGAR
NITROGEN–CONTAINING ORGANIC BASE
PHOSPHODIESTER BOND
ESTER BONDS
SUGAR–PHOSPHATE BACKBONE

Bonds



Nitrogenous Base
Sugar
O
P
O
O
O
Phosphodiester bond
Phosphate
Sugar
Nitrogenous Base



5' end
hydrogen bond
3' end
OH
PO4
CH2
dRIB
THY
ADE
CYT
GUA
dRIB
CYT
GUA
OH
3' end
5' end

RNA

- RNA (ribonucleic acid) is a single-stranded molecule.
- It consists of a ribose sugar-phosphate backbone and four nitrogenous bases: adenine (A), cytosine (C), guanine (G), and uracil (U).
- Uracil replaces thymine in RNA, which is present in DNA.

RNA

- RNA plays a central role in transferring genetic information from DNA to ribosomes for protein synthesis.
- There are different types of RNA:
- mRNA (messenger RNA) carries the genetic code from DNA to ribosomes.
- rRNA (ribosomal RNA) forms part of the ribosome and helps in protein synthesis.
- tRNA (transfer RNA) brings amino acids to the ribosome during protein synthesis.
- miRNA (microRNA) regulates gene expression by binding to mRNA.

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Summary

mRNA (messenger RNA)	**Carries genetic information from DNA to ribosomes for protein synthesis**
rRNA (ribosomal RNA)	Component of ribosomes involved in protein synthesis
tRNA (transfer RNA)	Brings amino acids to the ribosome for protein assembly
miRNA (microRNA)	Regulates gene expression by binding to mRNA
Ribozymes	RNA molecules with catalytic functions
mRNA (messenger RNA)	Carries genetic information from DNA to ribosomes for protein synthesis
rRNA (ribosomal RNA)	Component of ribosomes involved in protein synthesis
tRNA (transfer RNA)	Brings amino acids to the ribosome for protein assembly

Summary

Characteristic	DNA	RNA
Structure	Double-stranded molecule	Single-stranded molecule
Sugar Component	Deoxyribose	Ribose
Nitrogenous Bases	Adenine (A), Cytosine (C), Guanine (G), Thymine (T)	Adenine (A), Cytosine (C), Guanine (G), Uracil (U)
Base Pairing	A pairs with T, C pairs with G	A pairs with U, C pairs with G
Genetic Information Carrier	Carries the hereditary information in all living organisms	Transfers genetic information from DNA to ribosomes for protein synthesis
Chromosome Organization	Forms chromatin that can compact into chromosomes during cell division	Does not form chromosomes; present as a single strand
Function	Determines an organism's physical traits and cellular functions	Plays a role in protein synthesis, gene regulation, and catalytic functions

ANY QUESTIONS?

MESSAGE ON WHATSAP

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