General Biochemistry

Al-Karkh University for Science

College of Energy & Environment Science

Department of Environment

2rd class/ Environment

By

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Biochemistry

definition:

study of the chemical substances and processes that occur in plants, animals, and microorganisms and of the changes they undergo during development and life

B.1 Introduction to biochemistry

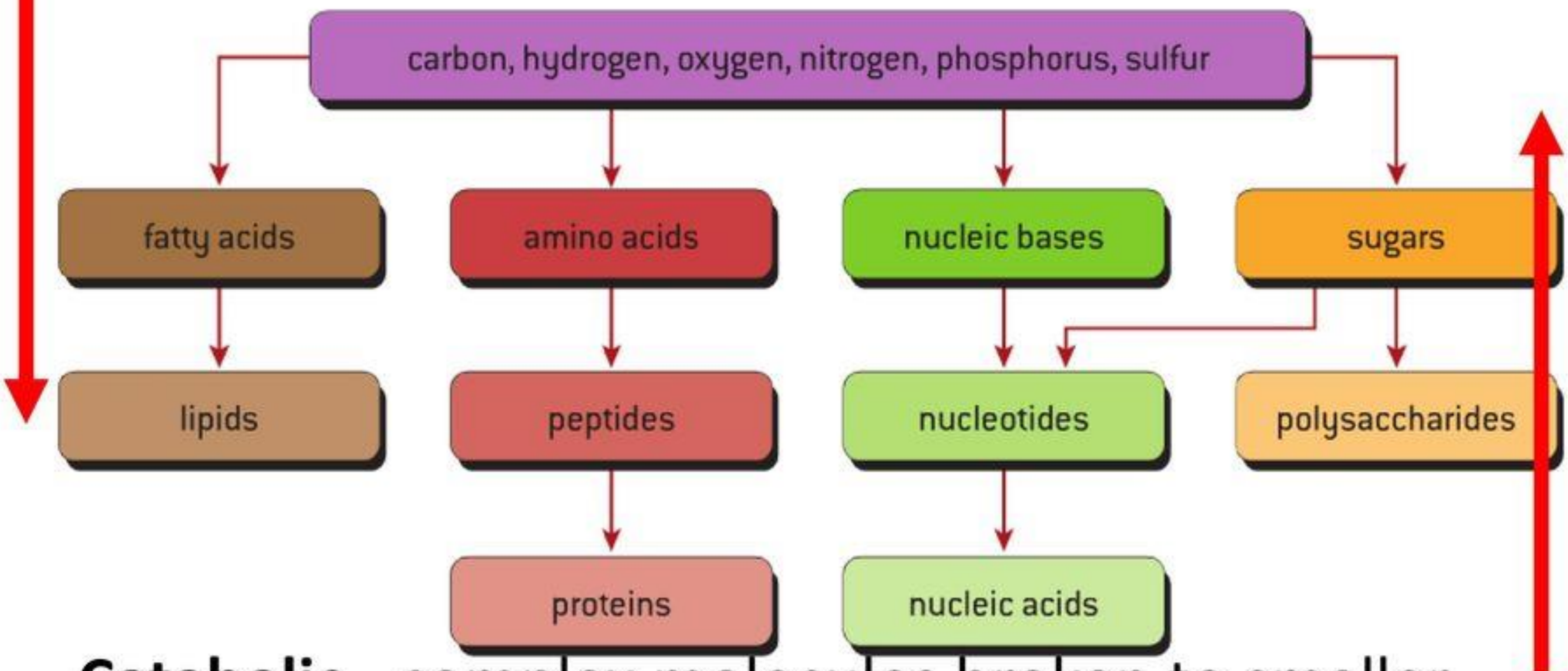
OBJECTIVES

- The diverse functions of biological molecules depend on their structures and shapes.
- Metabolic reactions take place in highly controlled aqueous environments.
- Reactions of breakdown are called catabolism and reactions of synthesis are called anabolism.
- Biopolymers form by condensation reactions and are broken down by hydrolysis reactions.
- Photosynthesis is the synthesis of energy-rich molecules from carbon dioxide and water using light energy.
- Respiration is a complex set of metabolic processes providing energy for cells.
- Explanation of the difference between condensation and hydrolysis reactions.
- The use of summary equations of photosynthesis and respiration to explain the potential balancing of oxygen and carbon dioxide in the atmosphere.

(Intermediates of aerobic respiration and photosynthesis are not required.)

Classification of biomolecules

Anabolic - complex molecules from smaller inorganic or organic substances



Catabolic - complex molecules broken to smaller fragments

carbohydrates

- Definition

Carbohydrates are polyhy droxylated aldehydes or ketones and their derivatives. The word "carbohydrate" includes polymers and other compounds synthesized from polyhy droxylated aldehydes and ketones. They can be synthesized in the laboratory or in living cells. Simple carbohydrates or the entire carbohydrate family may also be called saccharides. In general carbohydrates have the empirical formula (CH2O)n .The term generated from carbon and hydrate; though some also contain nitrogen, phosphorus, or sulfur. Chemically, carbohydrates are molecules that are composed of carbon, along with hydrogen and oxygen - usually in the same ratio as that found in water (H2O).

They originate as products of photosynthesis, an endothermic reductive condensation of carbon dioxide requiring light energy and the pigment chlorophyll.

$$nCO2 + nH2O + energy \longrightarrow CnH2nOn + nO2$$

Importance of carbohydrates

1. Carbohydrates are of great importance in biology. The unique reaction, which makes life possible on the Earth, namely the assimilation of the green plants, produces sugar, from which originate

2.They are the major source of energy to human beings

3.They act as storehouses of chemical energy (starch , glycogen)

4. Carbohydrates play a major role in promoting health fitness, form a major part of food and help a great deal in building body strength, by generating energy5. Derivatives of CHO involved in :drugs , as vitamins , Anit freeze glycoprotein.

5. Derivatives of CHO involved in :drugs and vitamins

6. Carbohydrates are source of carbon for biosynthesis of other compounds. Most people know that the body uses carbohydrates for energy. For example, the simple carbohydrate glucose (dextrose) gets oxidized by liver cells. In exchange, the cells produce adenosine triphosphate (ATP), the main energy-providing compound in the cell. However, carbohydrates are used in a number of ways by plants, animals and bacteria, not just for energy.

Classification of Carbohydrates

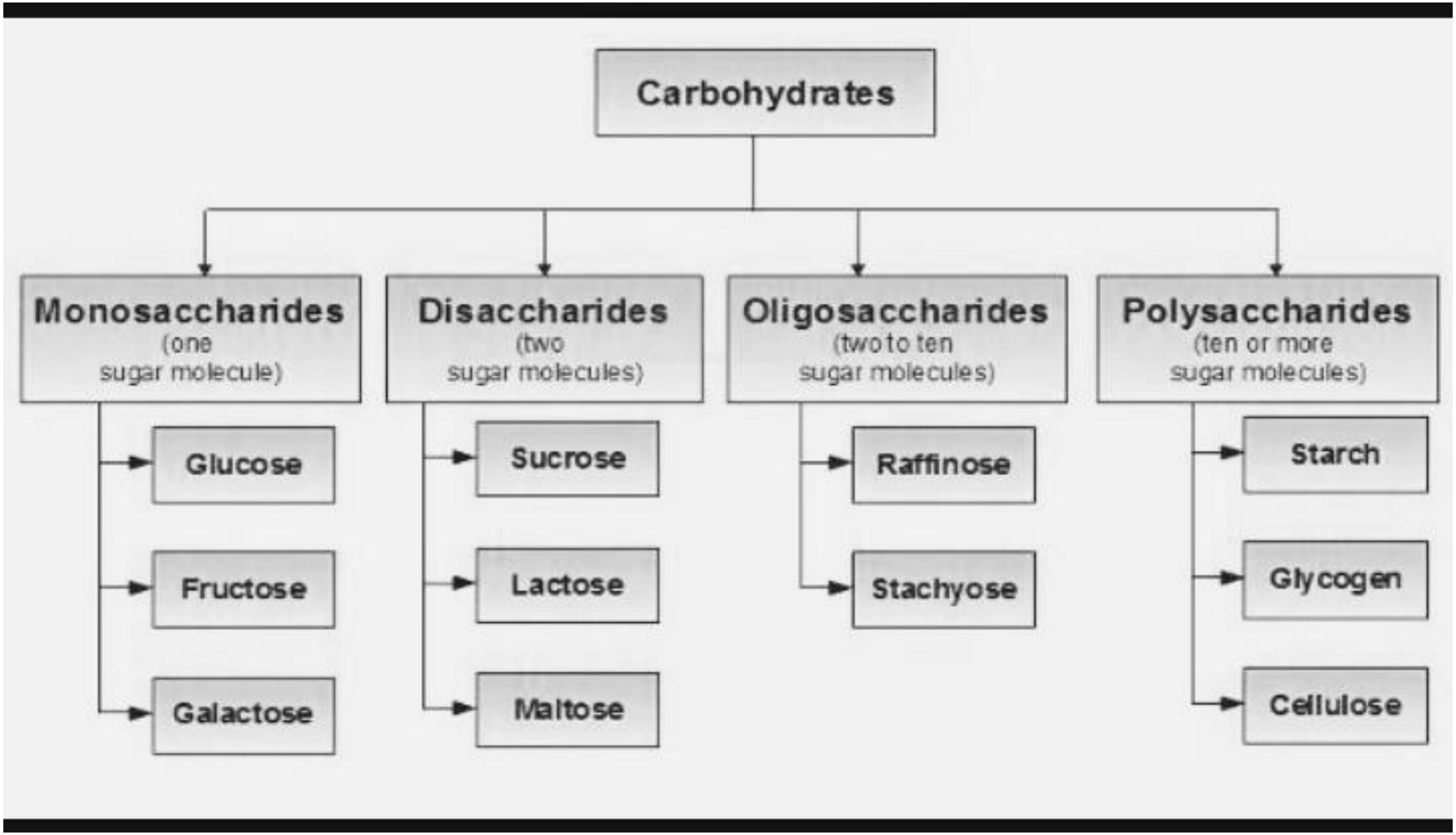
- Simple sugars (monosaccharides): can't be converted into smaller sugars by hydrolysis.

- Two Monosaccharides can be joined to form disaccharides,, disaccharides include lactose (galactose + glucose), sucrose (glucose + fructose) and maltose (glucose + glucose).

- **Oligosaccharides** :yield 2-10 molecules of the same or different monosaccharide units when hydrolyzed

- **Polysaccharides** :Are macromolecular substances that can be hydrolyzed to yield more than 10 molecules of the same or different monosaccharides

Classification of carbohydrates



Aldoses and Ketoses

- *aldo*- and *keto*- prefixes identify the nature of the carbonyl group
- -*ose* suffix designates a carbohydrate
- Number of C's in the monosaccharide indicated by root (-tri-, tetr-, pent-, hex-)
- **Tri- = 3**
- **Tetr- = 4**
- **Pent- = 5**
- **Hex- =6**
- **Hept- = 7**
- **Oct- = 8**

Aldehydes = Aldoses

Ketones = Ketoses

Some important monosaccharides

1-**Glucose**

* Glucose is known as dextrose, blood sugar or grape sugar.

* It is a component of the disaccharides:

* is the monomer of the polysaccharides:

* Glucose is carried by the bloodstream to all body parts.

* Glucose is found in the urine of those who have diabetes mellitus (sugar diabetes).

glycosuria.

Glycemic Index

* It is a scale that compares the blood sugar response from eating CHO with response evoked by glucose.

- 2-**Galactose**
- Galactose is also an aldohexose occurs, along with glucose, in lactose and in many oligo-and polysaccharides
- Galactose is synthesized in the mammary glands to make the lactose of milk.

Galactosemia

* infants is born with a genetic defect, that the child unable to utilize the galactose, When the enzyme galactose-1-phosphate uridinyltransferaseis defective, however, the disorder is called galactosemia

3-Fructose

* Fructose, also known as levulose, is a ketohexose that occurs in fruit juices, honey, and, along with glucose, as a constituent of sucrose.

* Fructose is the major constituent of the polysaccharide

4 - Ribose

* D-ribose & D 2 deoxyribose are most interesting pentoses , because their relationship to nucleic acids (genetic material) &

genetic codes

* Ribose in RNA (Ribonucleic Acid)

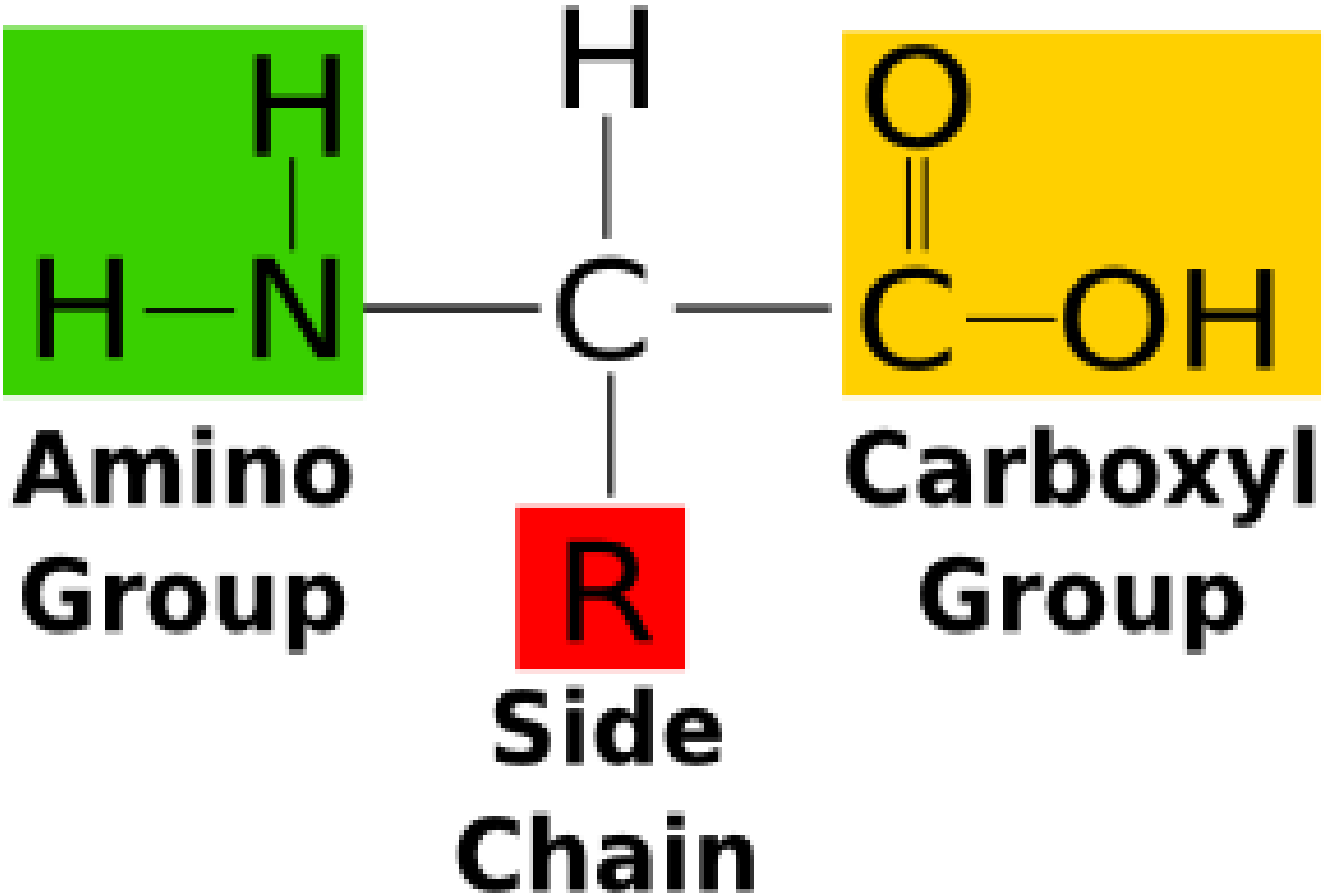
* D-2 deoxyribose in DNA (Deoxy Ribonucleic Acid)

* It is a constituent of coenzyme A (CoA) and second messenger (cAMP /cyclic adenosine

Lec.3

Amino Acids

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


H
H—N
H
C
O
C—OH
R
Amino Group
Side Chain
Carboxyl Group

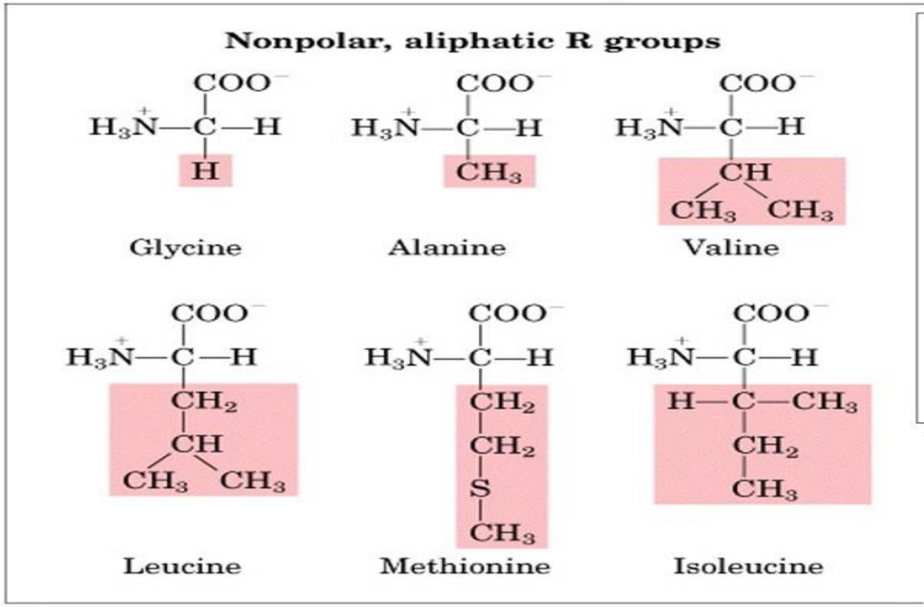
Classification of amino acids on the basis of R-group

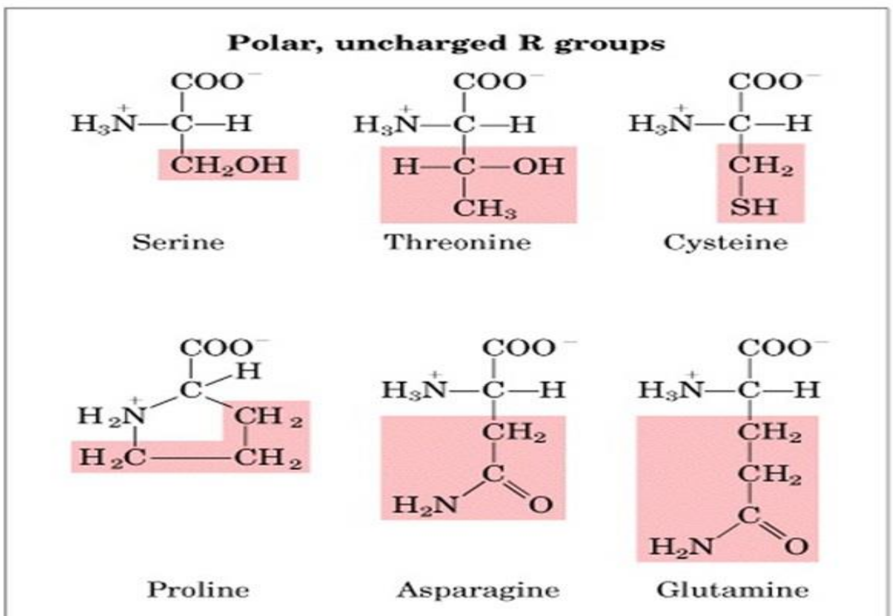
- **Nonpolar, Aliphatic amino acids**: The R groups in this class of amino acids are nonpolar and hydrophobic. Glycine, Alanine, Valine, leucine, Isoleucine, Methionine, Proline.
- **Aromatic amino acids:** Phenylalanine, tyrosine, and tryptophan, with their aromatic side chains, are relatively nonpolar (hydrophobic). All can participate in hydrophobic interactions.

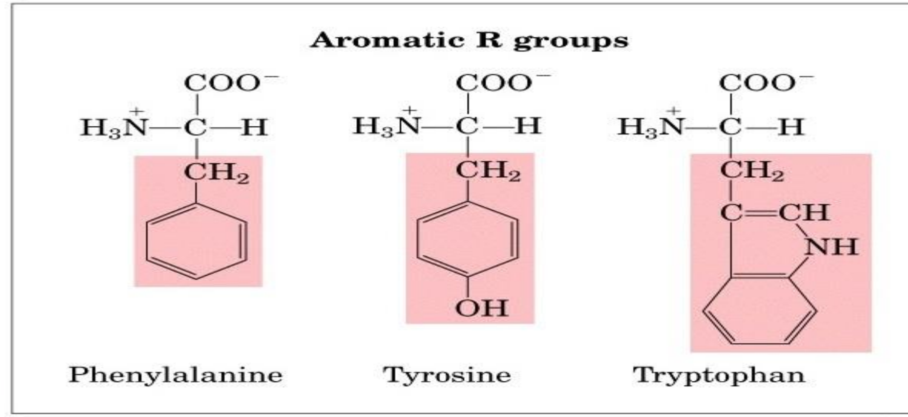
- **Polar, Uncharged amino acids:** The R groups of these amino acids are more soluble in water, or more hydrophilic, than those of the nonpolar amino acids, because they contain functional groups that form hydrogen bonds with water. This class of amino acids includes serine, threonine, cysteine, asparagine, and glutamine.

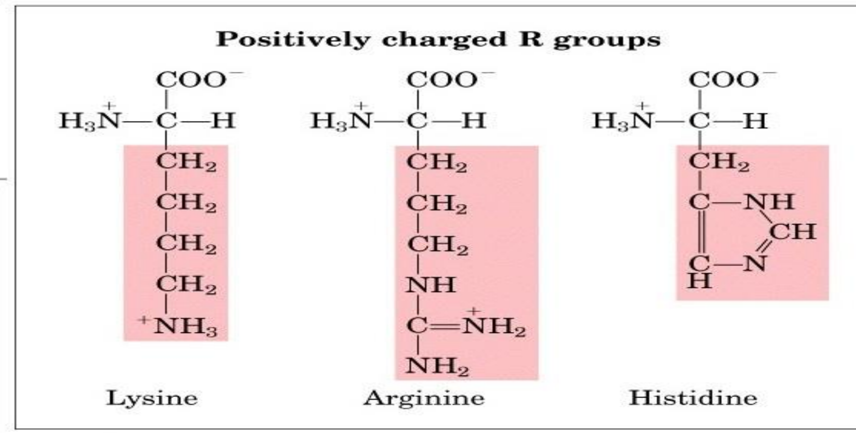
- **Acidic amino acids:** Amino acids in which R-group is acidic or negatively charged. Glutamic acid and Aspartic acid

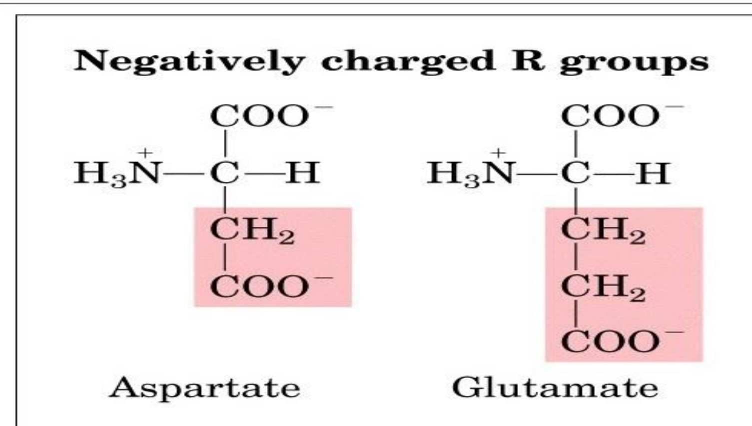
- **Basic amino acids:** Amino acids in which R-group is basic or positively charged. Lysine, Arginine, Histidine


Nonpolar, aliphatic R groups
Glycine
Alanine
Valine
Leucine
Methionine
Isoleucine


Polar, uncharged R groups
Serine
Threonine
Cysteine
Proline
Asparagine
Glutamine


Aromatic R groups
Phenylalanine
Tyrosine
Tryptophan


Positively charged R groups
Lysine
Arginine
Histidine


Negatively charged R groups
Aspartate
Glutamate

Classification of amino acids on the basis of nutrition

1- Essential amino acids

- Ten amino acids cannot be synthesized in the body and, therefore, must be present in the diet in order for protein synthesis to occur.
- These essential amino acids are arginine , histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine

2- Non-essential amino acids

- These amino acids can be synthesized in the body itself and hence not necessarily need to be acquired through diet.
- These non - essential amino acids are alanine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine and Tyrosine

Importance of Amino Acids

1. Formation of proteins: amino acids are joined to each other by peptide bonds to form proteins and peptides.

2. Formation of glucose: glucogenic amino acids are converted to glucose in the body.

3. Enzyme activity: the thiol group (-SH) of cysteine has an important role in certain enzyme activity.

4.Transport and storage form of ammonia: amino acid glutamine play an important role in transport and storage of amino nitrogen in the form of ammonia

5. As a buffer: both free amino acids and some amino acids present in protein can potentially act as buffer , e.g. histidine can serve as the best buffer at physiological buffer (pH= 7).

6. Detoxification reactions: Glycine , cysteine and methionine are involved in the detoxification of toxic substances.

7. Formation of biologically important compounds: specific amino acids can give rise to specific biologically important compounds in the body

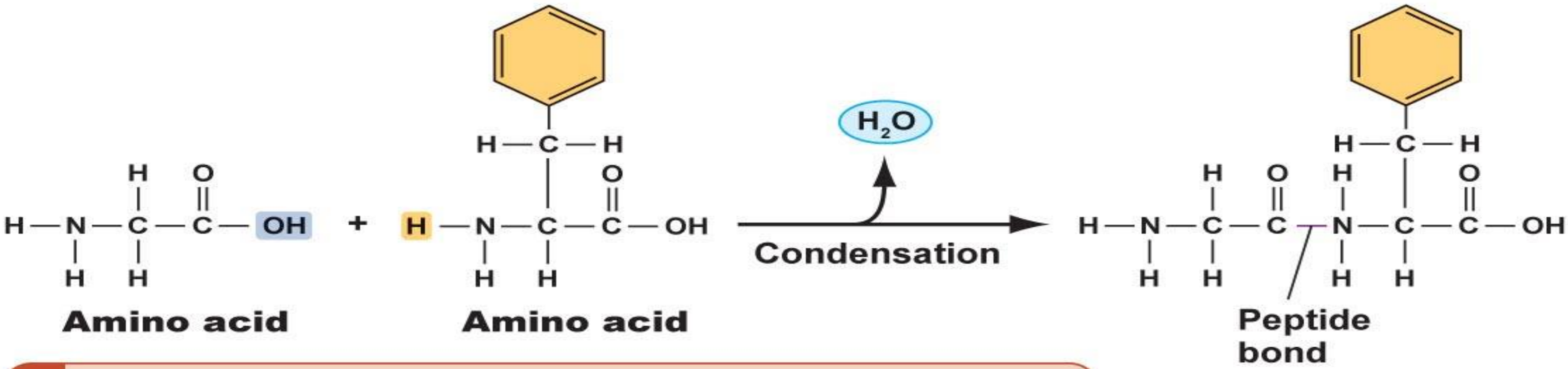
PEPTIDE & PROTEIN

Peptides

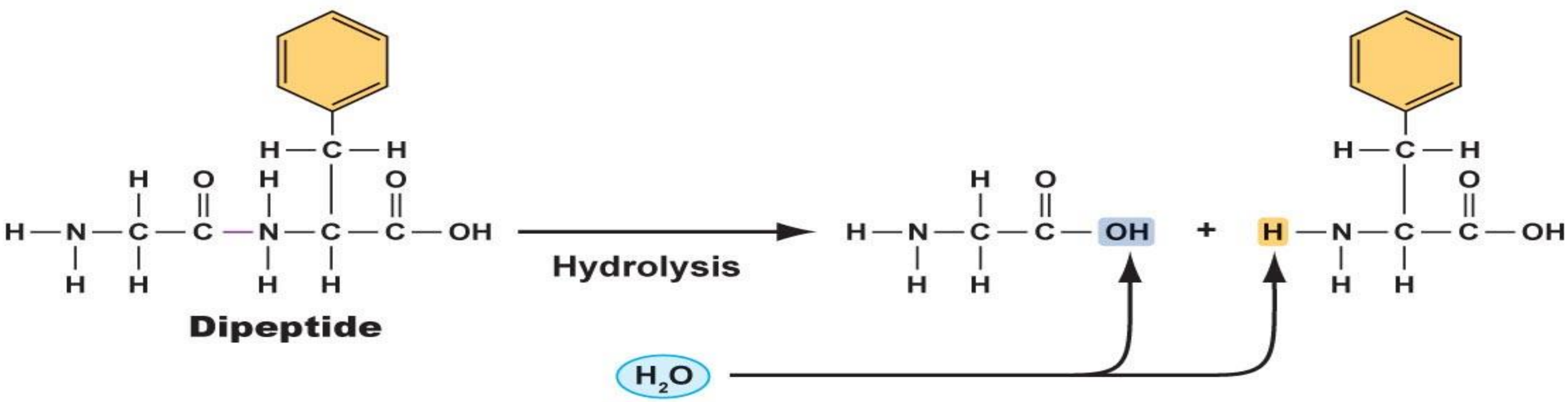
The amino acid units can be covalently joined through a substituted amide linkage, termed a peptide bond, acid amide bond

The part left over after losing a hydrogen atom from its amino group and the hydroxyl moiety from its carboxyl group

Condensation and Hydrolytic Reactions



a A peptide bond forms by condensation when the acid group (COOH) and amine group of two different amino acids join and release a molecule of water.



b When peptide bonds are broken by hydrolysis, the hydroxyl group (OH) and hydrogen (H) from water are added.

Classified by number of amino acids in a chain

Peptides: fewer than 50 amino acids

- Dipeptides: 2 amino acids
- Tripeptides: 3 amino acids
- Polypeptides: more than 10 amino acids

Proteins: more than 50 amino acids

- Typically 100 to 10,000 amino acids linked together

Chains are synthesizes based on specific bodily DNA

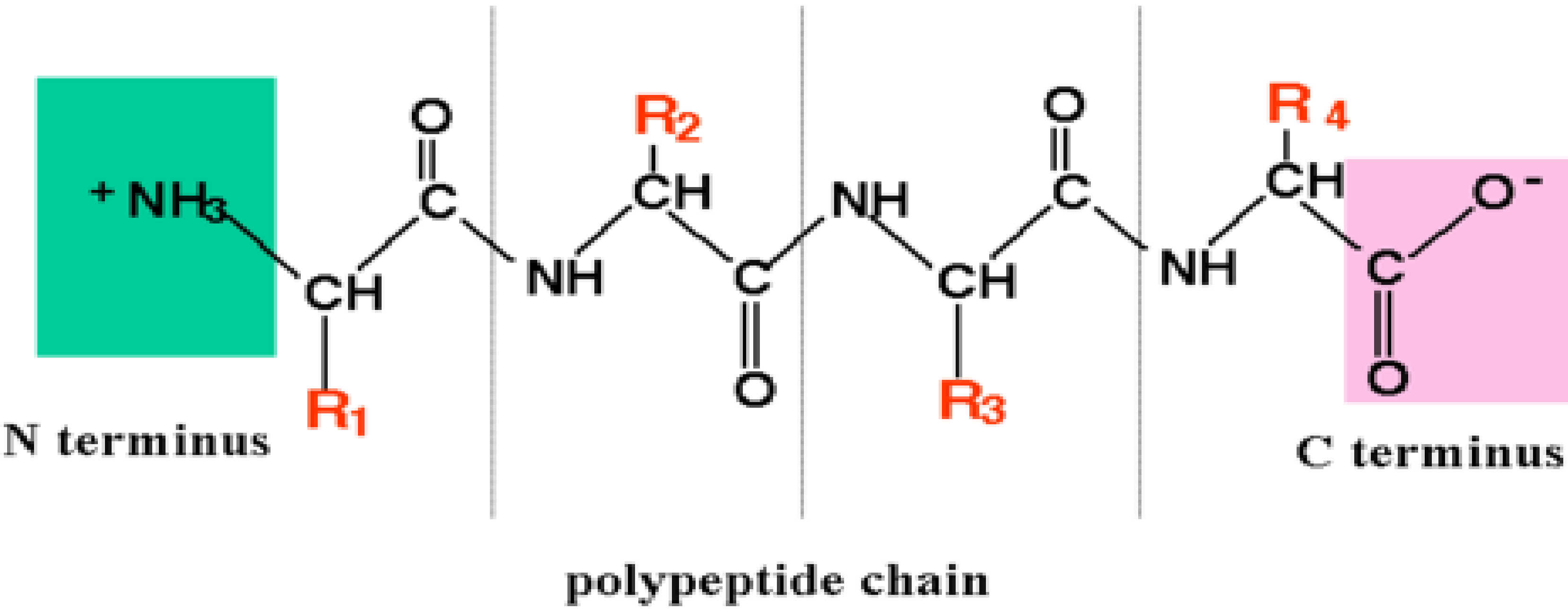
Amino acids are composed of carbon, hydrogen, oxygen, and nitrogen

In a peptide

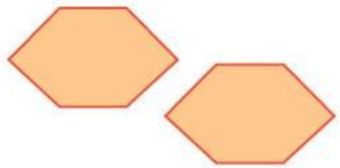
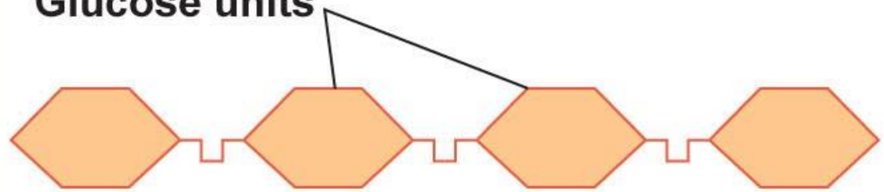
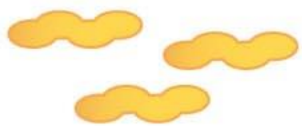
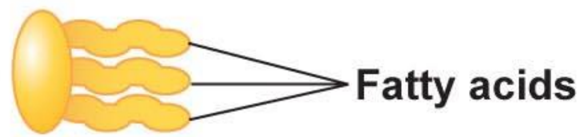
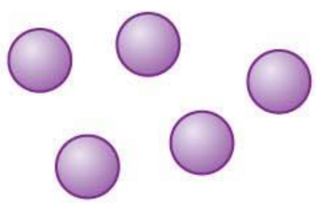
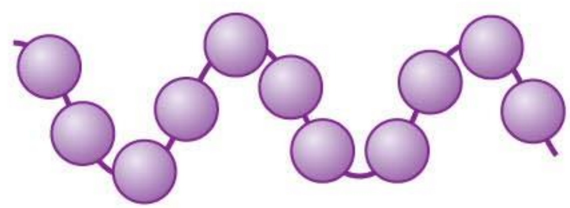
the amino acid residue at the end with a free αamino group is the amino-terminal (or N terminal) residue

The residue at the other end, which has a free carboxyl group, is the carboxyl-terminal (or C terminal) residue

Peptide = chain of amino acids



Structural Differences Between Carbohydrates, Lipids, and Proteins

Macronutrients	Chains of	Example
Carbohydrates	Glucose 	Glucose units 
Lipids	Fatty acids 	Triglyceride 
Proteins	Amino acids 	Amino acids 

Levels of Protein Structure

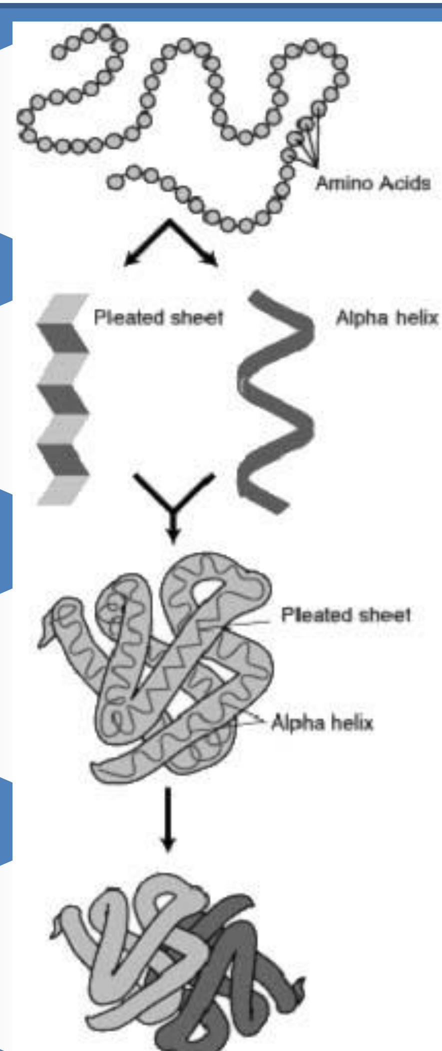
STRUCTURE

Primary — Assembly

Secondary — Folding

Tertiary — Packing

Quaternary — Interaction

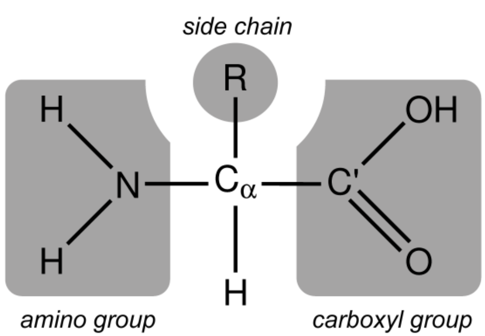


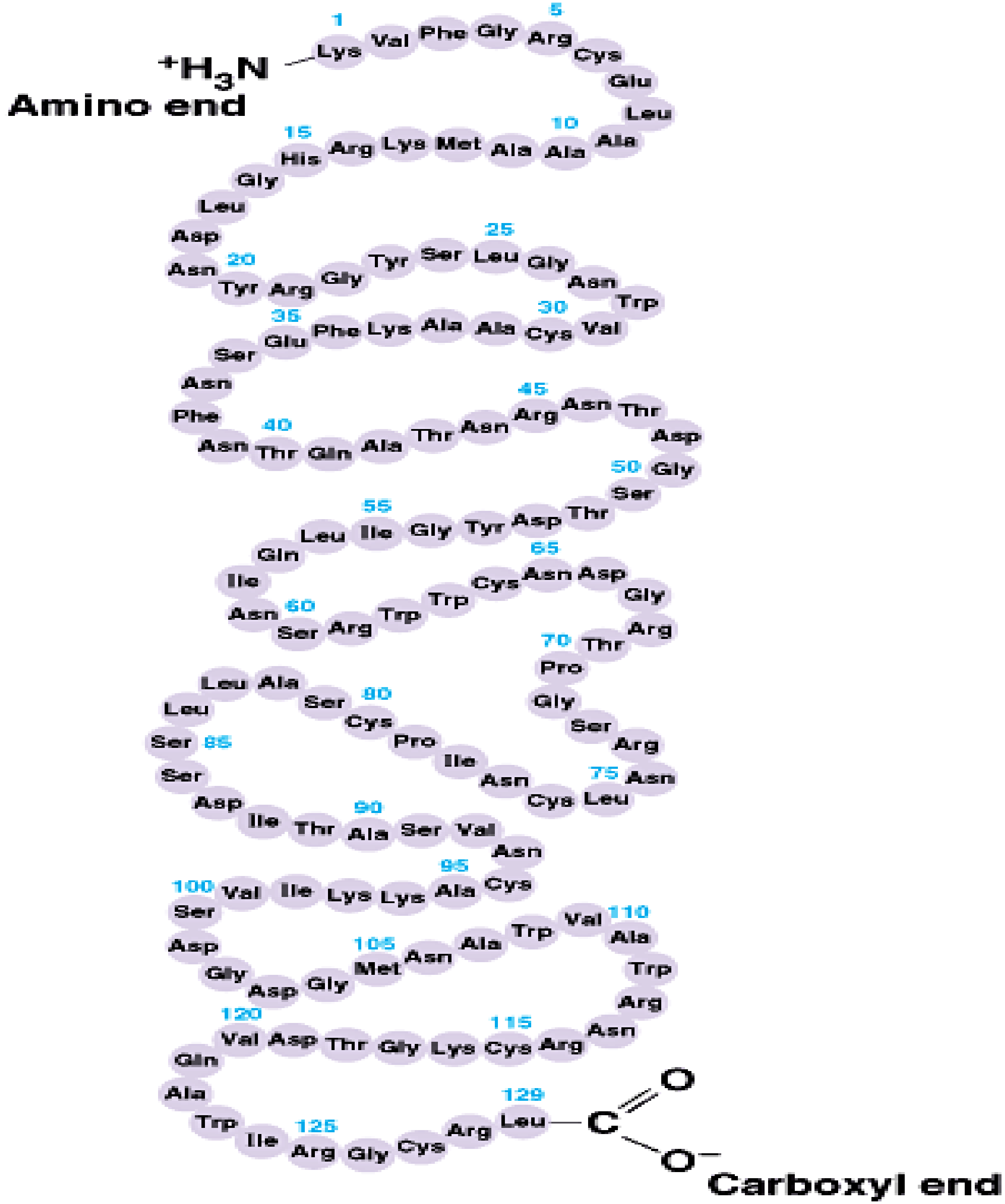
PROCESS

Primary Structure

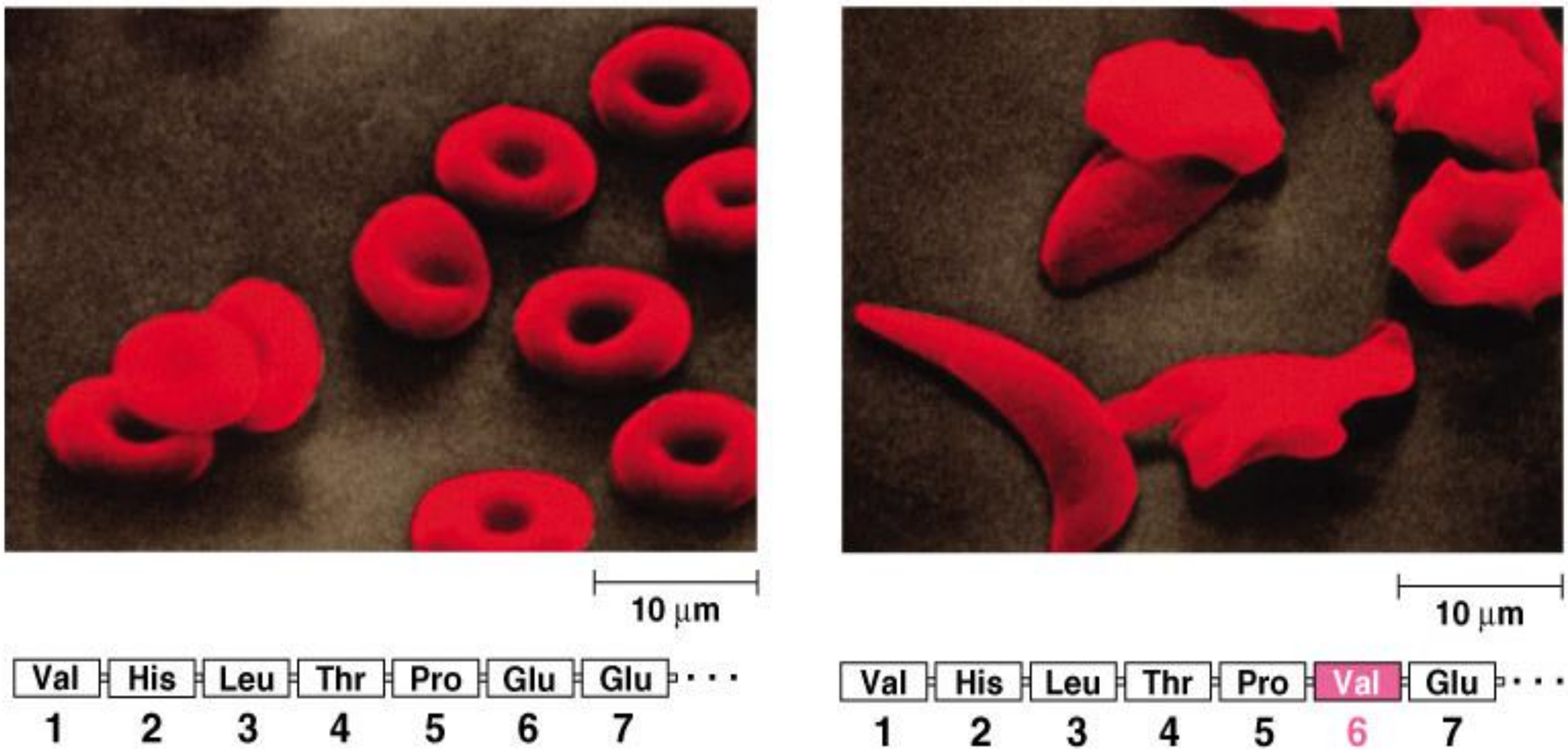
Sequence of a.a bonded to form polypeptide

*occurs at the ribosome





A slight change in primary structure can affect a protein's conformation and ability to function.

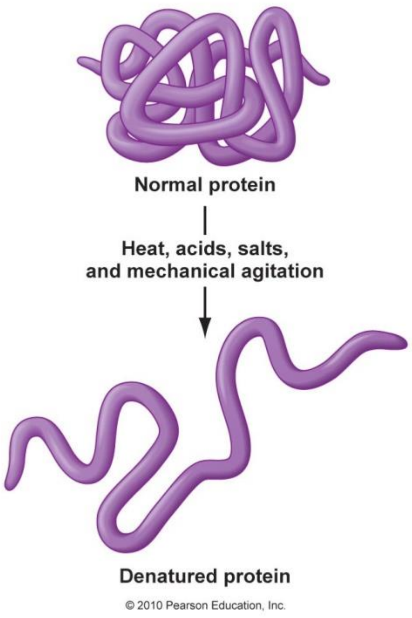


(a) Normal red blood cells and the primary structure of normal hemoglobin

(b) Sickled red blood cells and the primary structure of sickle-cell hemoglobin

Denaturing

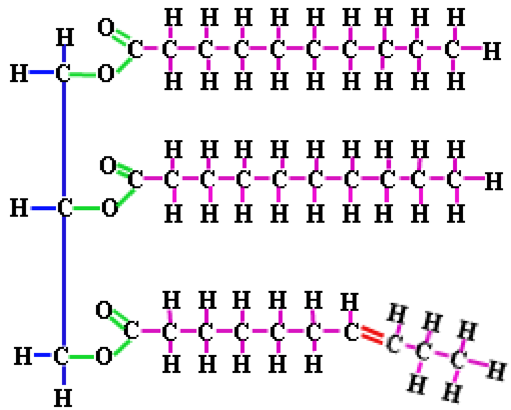
- Alteration of the protein' shape and thus functions through the use of
  - Heat
  - Acids
  - Bases
  - Salts
  - Mechanical agitation
- Primary structure is unchanged by d



PROTEINS CLASSIFIED BY FUNCTION

CATALYTIC: enzymes
STORAGE: ovalbumen (in eggs), casein (in milk), zein (in maize)
TRANSPORT: haemoglobin
COMMUNICATION: hormones (eg insulin) and neurotransmitters
CONTRACTILE: actin, myosin, dynein (in microtubules)
PROTECTIVE: Immunoglobulin, fibrinogen, blood clotting factors
TOXINS: snake venom
STRUCTURAL: cell membrane proteins, keratin (hair), collagen

FATTY ACIDS & LIPIDS



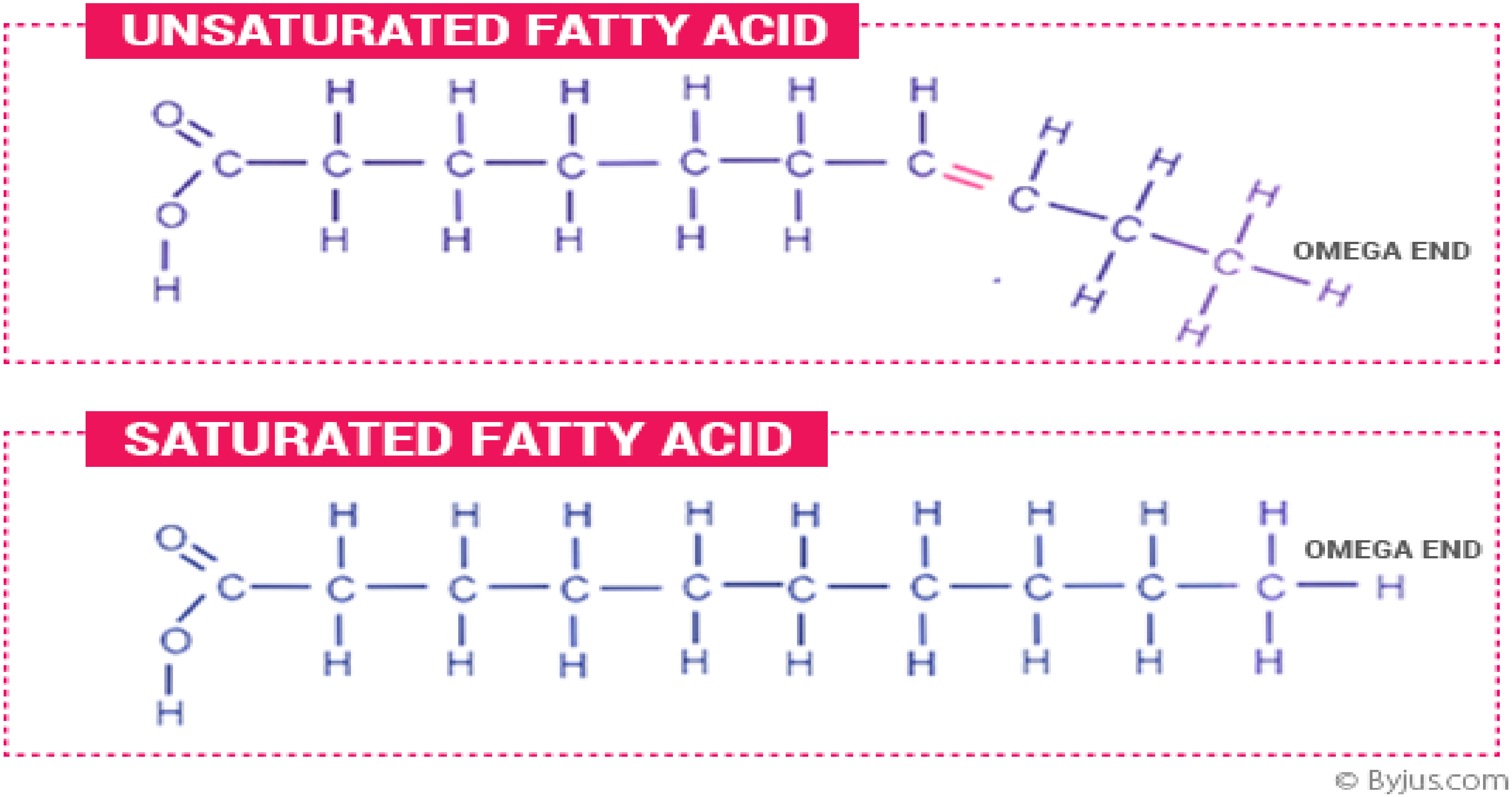
Fatty acids

Fatty acids are the building blocks of the fat in our bodies and in the food we eat. During digestion, the body breaks down fats into fatty acids, which can then be absorbed into the blood. Fatty acid molecules are usually joined together in groups of three, forming a molecule called a triglyceride. Triglycerides are also made in our bodies from the carbohydrates that we eat.

Fatty acids are composed of carbon chains containing a methyl group at one end and a carboxyl group at the other. The methyl group is termed the omega (ω) and the carbon atom situated next to the carboxyl group is termed the "α" carbon, followed by the "β etc. **Fatty acid molecules also have two chemically distinct regions:**

1) **a long hydrophobic hydrocarbon chain, which is not highly reactive**
2) **2) a carboxyl (-COOH) group, which is hydrophilic and highly reactive.**

Structure of fatty acids



Function of Fatty Acids

Fatty acids have important roles in:

1) signal-transduction pathways;

2) cellular fuel sources;

3) the composition of hormones and lipids;

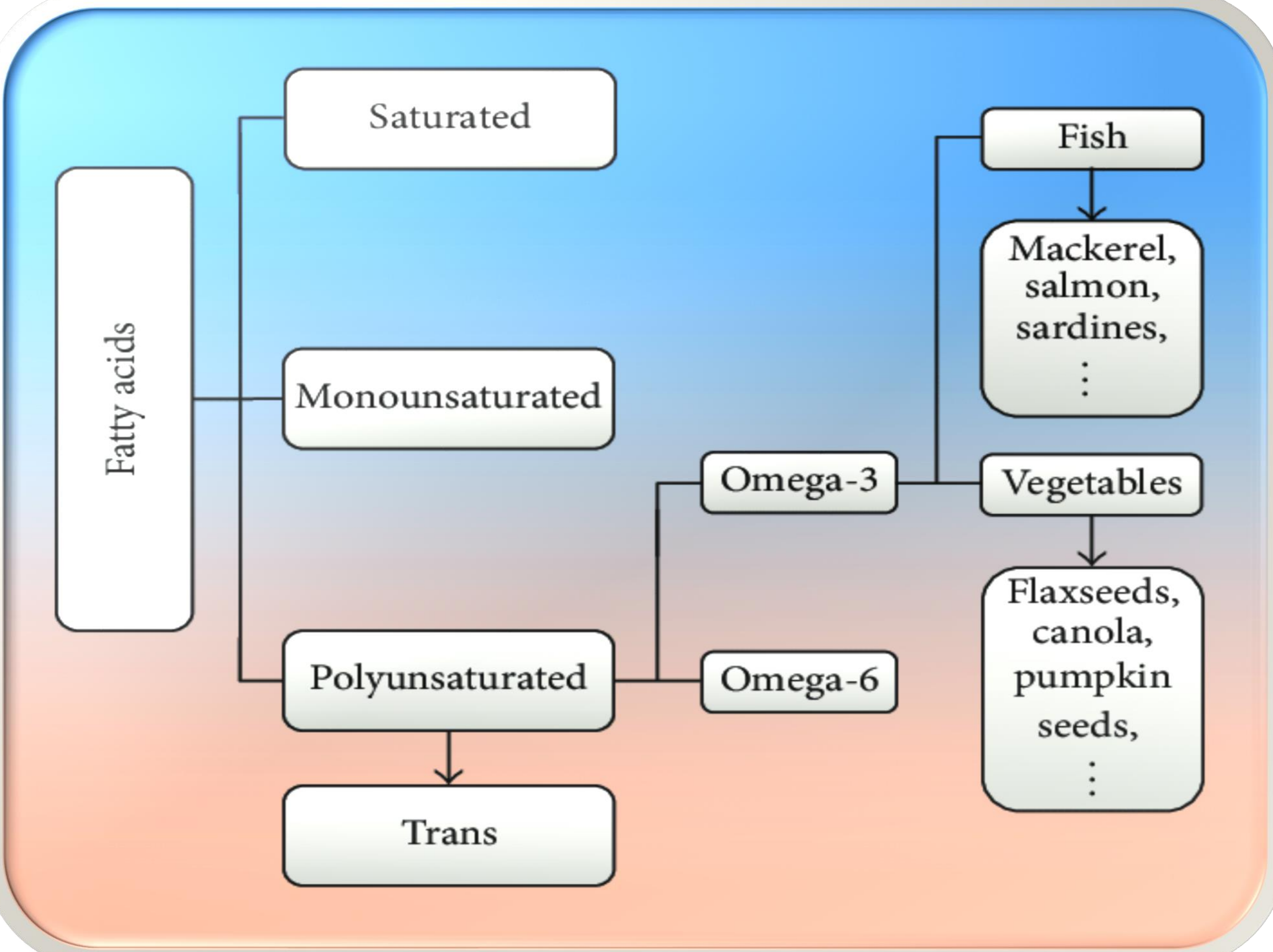
4) the modification of proteins

5)

Classified of fatty acids

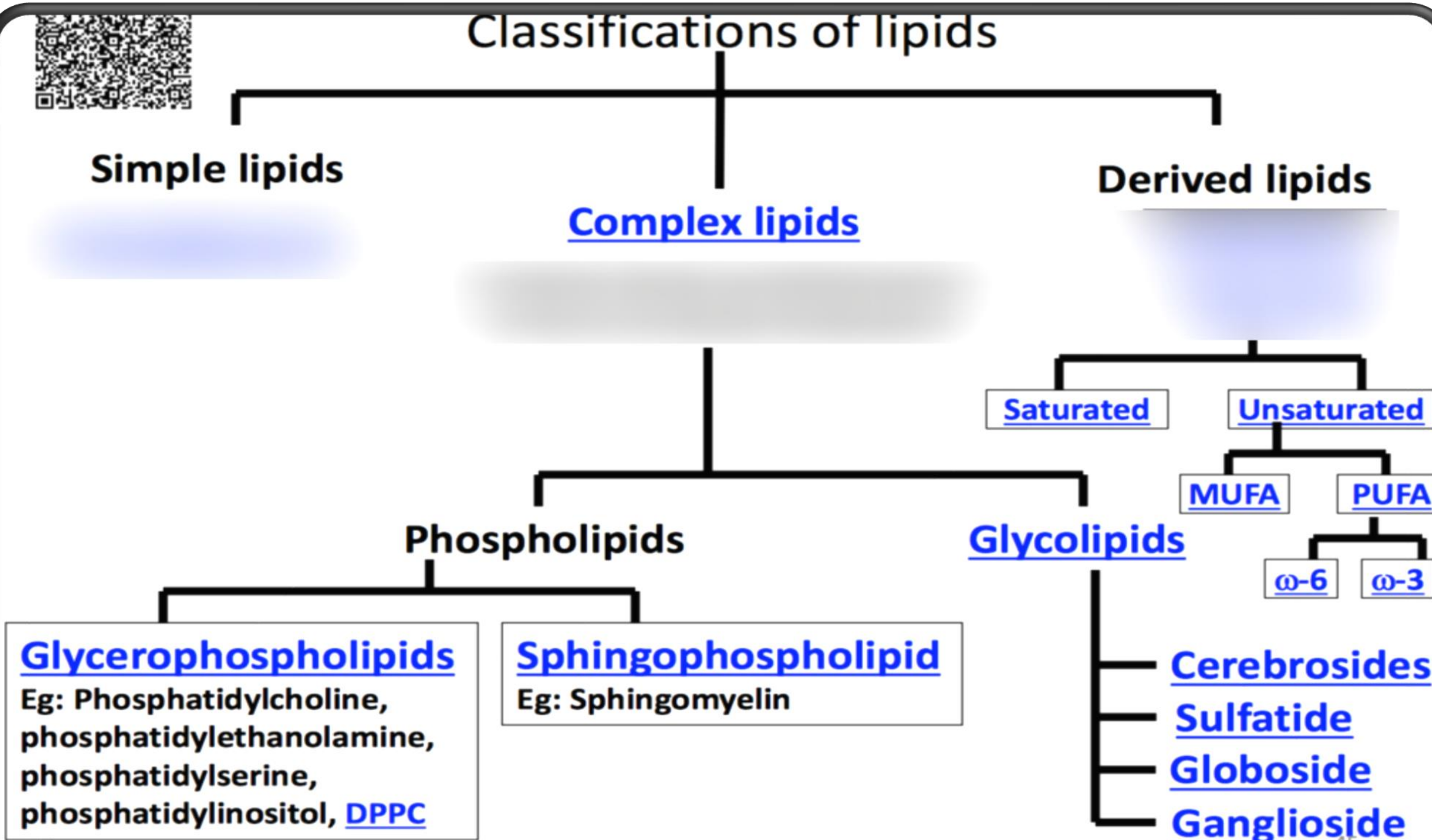
Short-chain fatty acids (SCFA) are fatty acids with up to 5 carbon atoms, medium-chain fatty acids (MCFA) have 6 to 12, long-chain fatty acids (LCFA) 13 to 21, and very long chain fatty acids (VLCFA) are fatty acids with more than 22 carbon atoms

Fatty acids are classified according to the presence and number of double bonds in their carbon chain. Saturated fatty acids (SFA) contain no double bonds, monounsaturated fatty acids (MUFA) contain one double bond, and polyunsaturated fatty acids (PUFA) contain more than one double bond


Fatty acids
Saturated
Monounsaturated
Polyunsaturated
Trans
Omega-3
Omega-6
Fish
Mackerel,
salmon,
sardines,
⋮
Vegetables
Flaxseeds,
canola,
pumpkin
seeds,
⋮

lipids

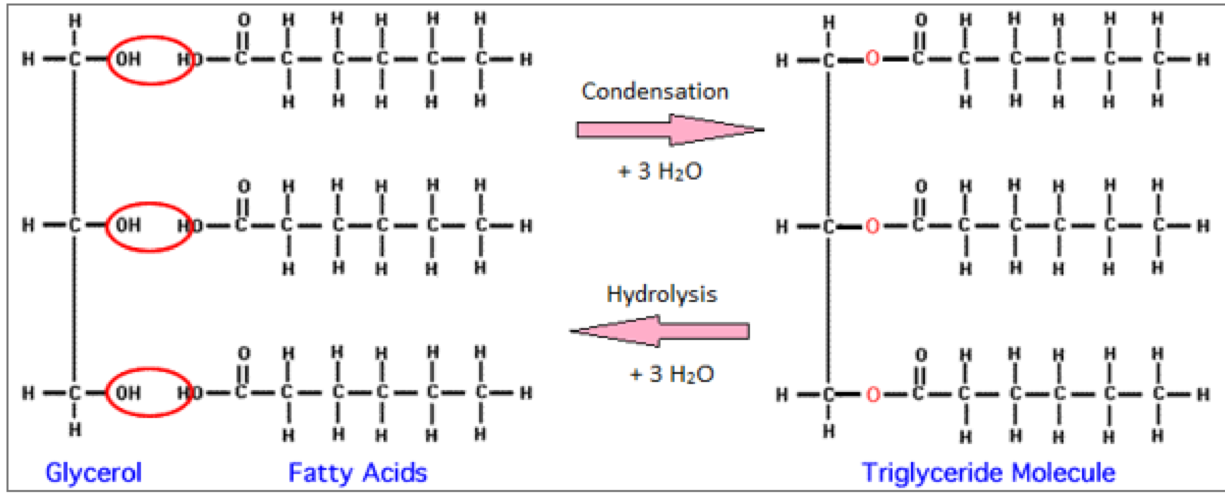
Classified of lipids



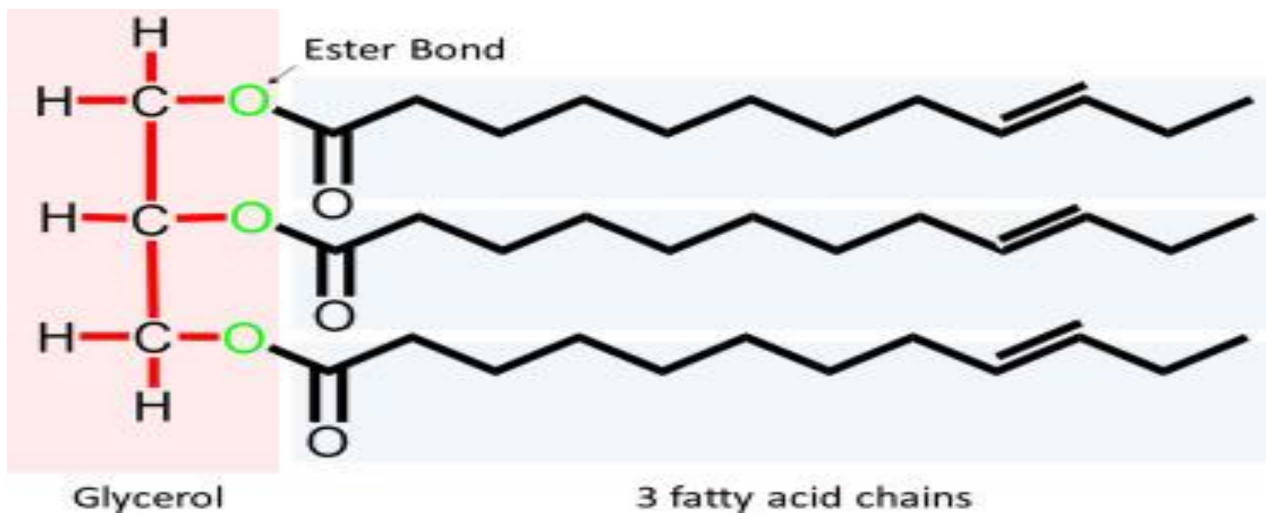
Important of lipids

Structure of lipids

Saturated lipid



Unsaturated lipid



Properties of lipids

Lipids may be either liquids or non-crystalline solids at room temperature.

- Pure fats and oils are colorless, odorless, and tasteless.
- They are energy-rich organic molecules
- Insoluble in water
- Soluble in organic solvents like alcohol, chloroform, acetone, benzene, etc.
- No ionic charges
- Solid triglycerols (Fats) have high proportions of saturated fatty acids.
- Liquid triglycerols (Oils) have high proportions of unsaturated fatty acids.

What are Enzymes?

- Enzymes are biological molecules (typically proteins) that significantly speed up the rate of virtually all of the chemical reactions that take place within cells.
- Their subunits are amino acids.
- Enzymes are used by cells to trigger and control **chemical reactions**.
- Without enzymes, several reactions in cells would never occur or happen to slowly to be useful.

What is a chemical reaction?

- They are vital for life and serve a wide range of important functions in the body, such as aiding in digestion and metabolism.

- Some enzymes help break large molecules into smaller pieces that are more easily absorbed by the body. Other enzymes help bind two molecules together to produce a new molecule. Enzymes are highly selective catalysts, meaning that each enzyme only speeds up a specific reaction.

FUNCTION OF Enzymes?

- Macromolecules Degradation
- Signal Transduction
- Energy Generation
- Ion Pumps
- Defense and Clearance
- Cell Regulation
- immune responses and aging processes

Types of Enzymes:

- The biochemical reactions occurring in the body are basically of 6 types and the enzymes that bring about these reactions are named accordingly

1. **Oxidoreductases** - catalyzing oxidation reduction reactions.
2. **Transferases** - catalyzing transfer of functional groups.
3. **Hydrolases** - catalyzing hydrolysis reactions.
4. **Lyases** - catalyzing group elimination reactions to form double bonds.
5. **Isomerases** - catalyzing isomerizations (bond rearrangements).
6. **Ligases** - catalyzing bond formation reactions couples with ATP hydrolysis.

Factors effecting enzyme activity

- enzyme concentration
- Substrate concentration
- Inhibitors
- Temperature
- pH

Coenzymes

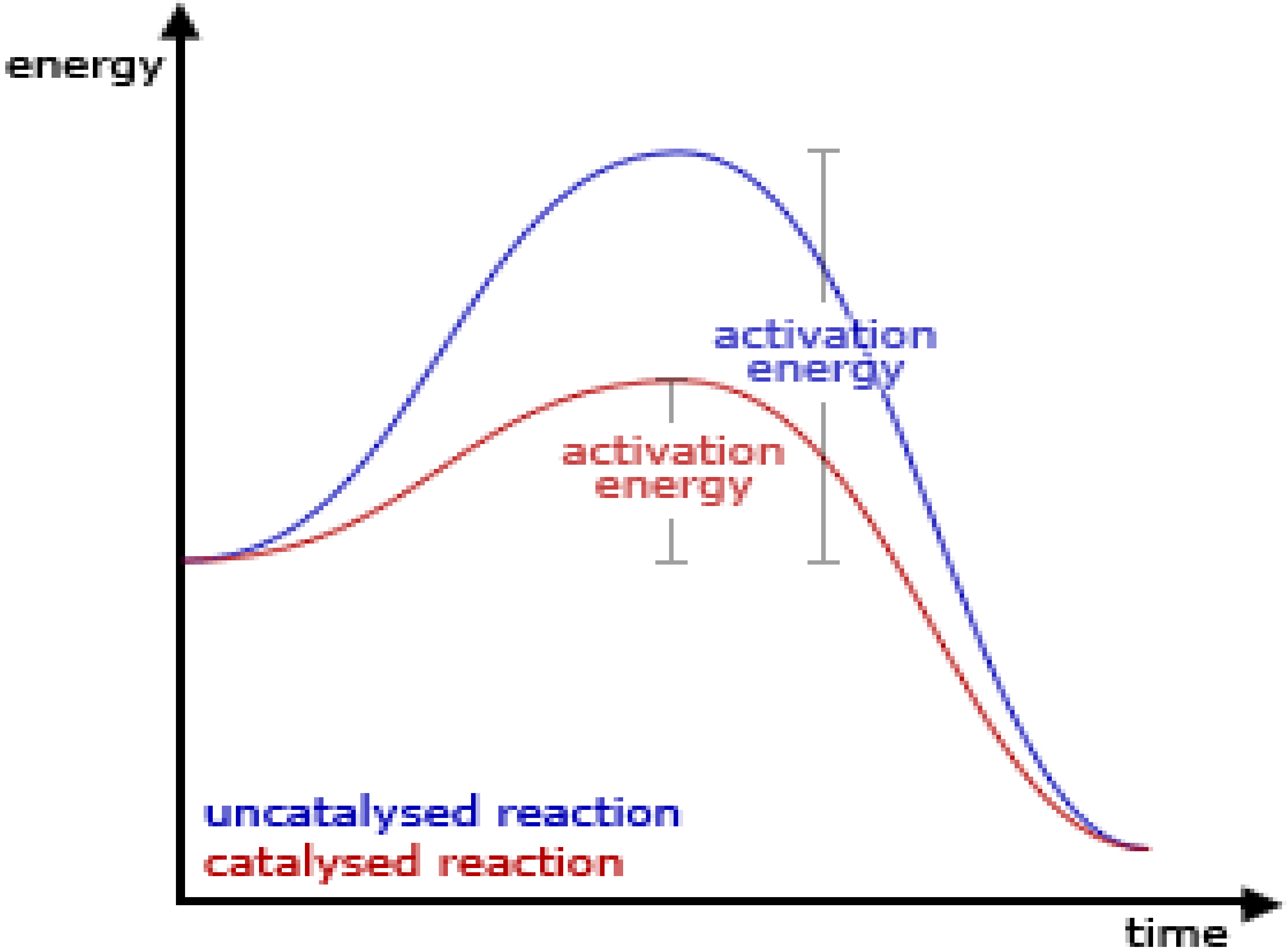
- These are reusable non-protein molecules that contain carbon (organic). They bind loosely to an enzyme at the active site to help catalyze reactions. Most are vitamins, vitamin derivatives, or form from nucleotides.

Cofactors

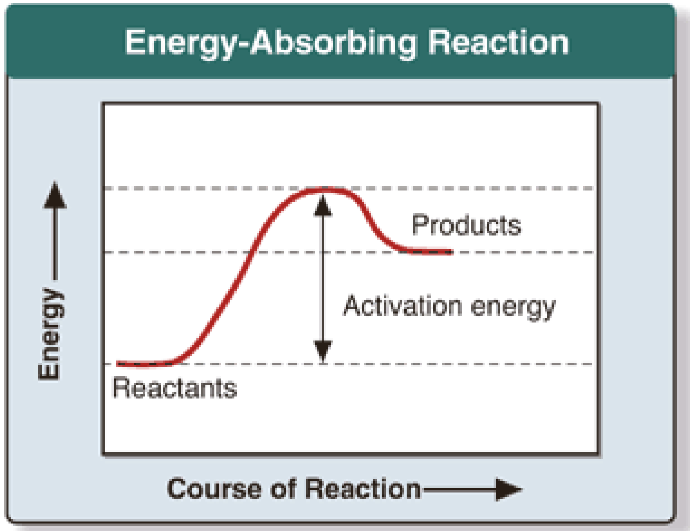
- Unlike coenzymes, true cofactors are reusable non-protein molecules that do not contain carbon (inorganic). Usually, cofactors are metal ions such as iron, zinc, cobalt, and copper that loosely bind to an enzyme’s active site. They must also be supplemented in the diet as most organisms do not naturally synthesize metal ions.

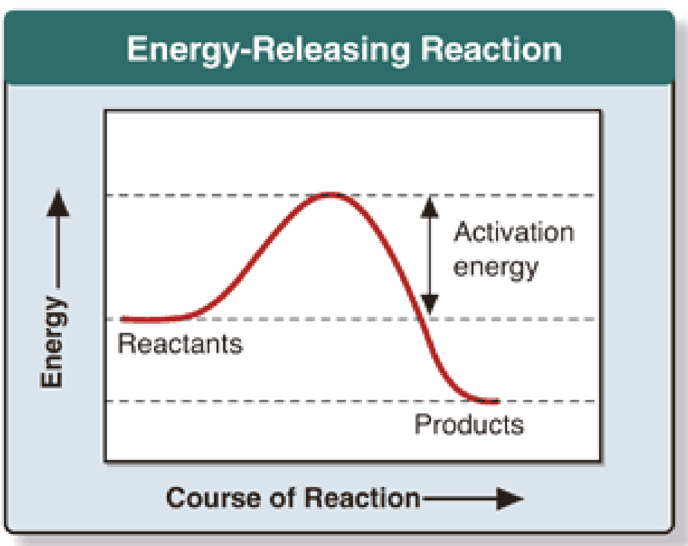
What is a catalyst?

- It is a substance that speeds up the rate of a chemical reaction.
- It lowers the **activation energy**.

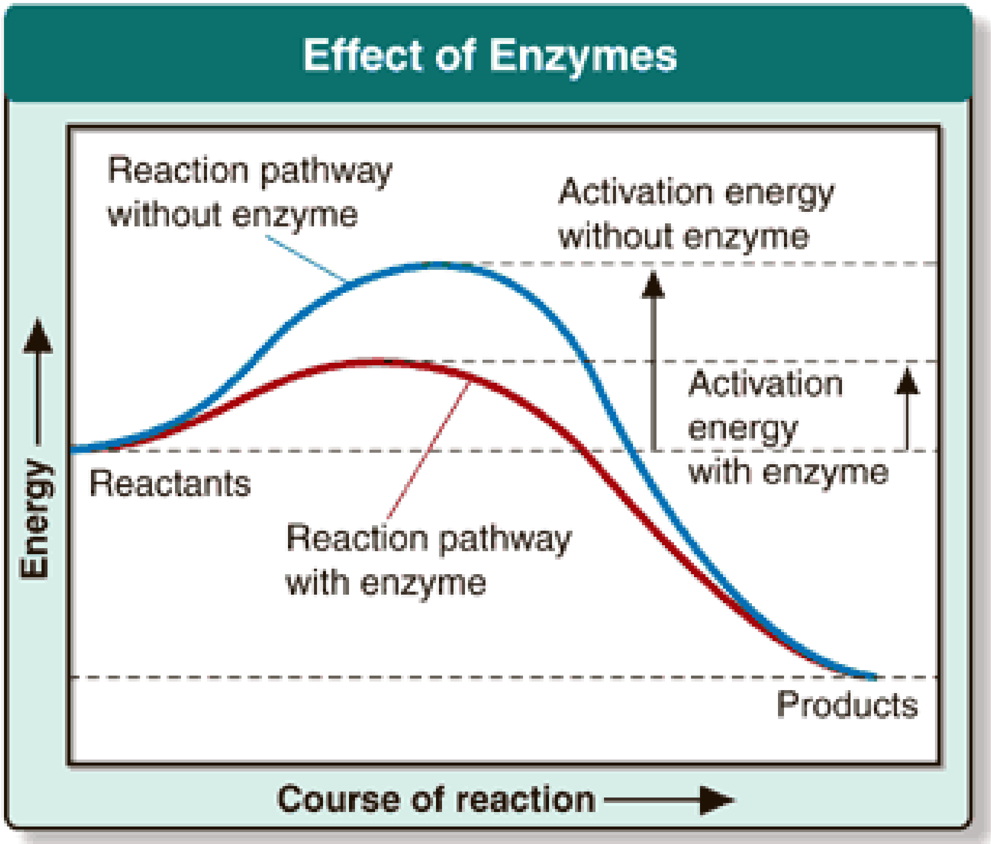

energy
activation
energy
activation
energy
uncatalysed reaction
catalysed reaction
time

What is activation energy?





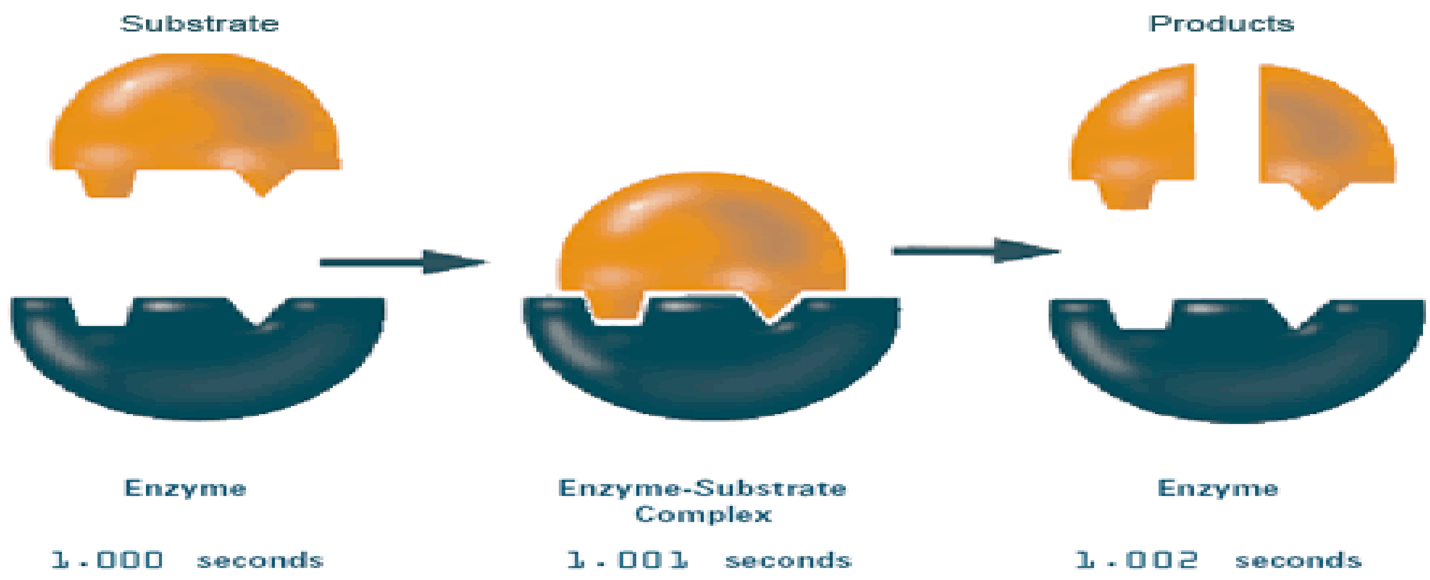
- Activation energy is the amount of energy needed to start a chemical reaction.



- Enzymes speed up chemical reactions by lowering their activation energy.

What is a substrate?

- Enzymes bind to molecules called **substrates**.
- These substrates are the reactants that are catalyzed by the enzyme.



What is a catalyst?

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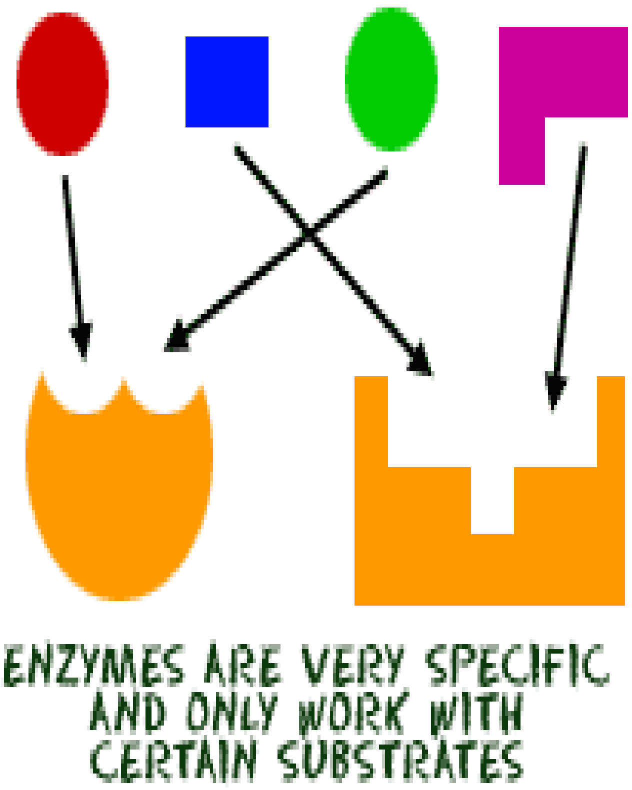
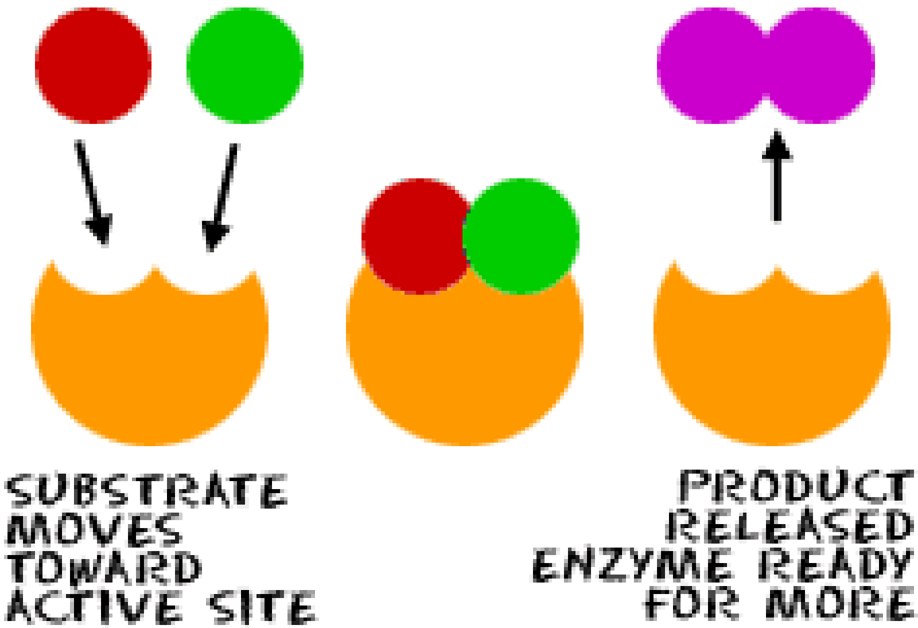
- It lowers the **activation energy**.

Lock and Key Hypothesis

- Each protein has a specific shape, therefore enzymes bind to substrates based on shape.
- The site on the enzyme where the substrates bind is called the **active site**.
- Enzymes bind to the substrates based on their complementary shape..
- The fit is so exact that the active site and substrates are compared to a "lock and key".



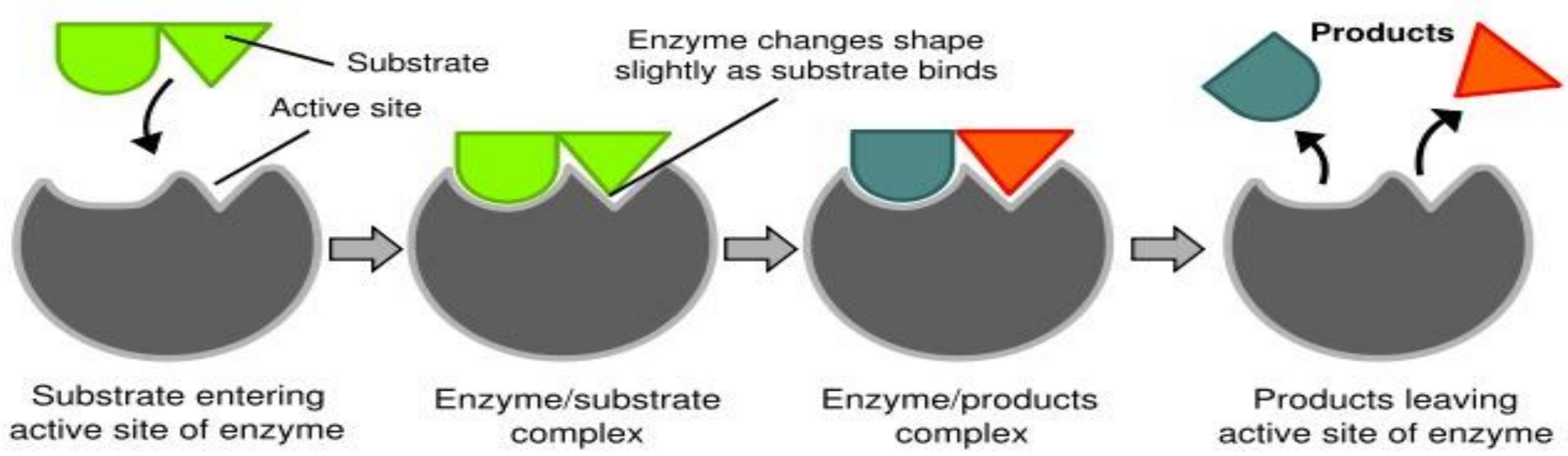
How are enzymes affected by the reactions?



- Enzymes are **NOT** changed by the reactions they catalyze, therefore they are reusable!

Induce Fit Hypothesis

- Enzymes can change shape slightly to fit the substrate a little better (like a hand in glove).

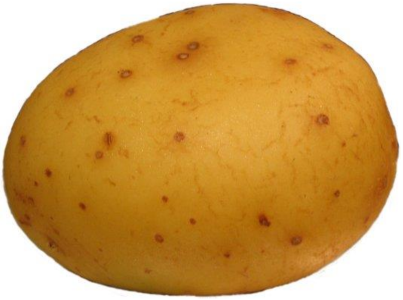


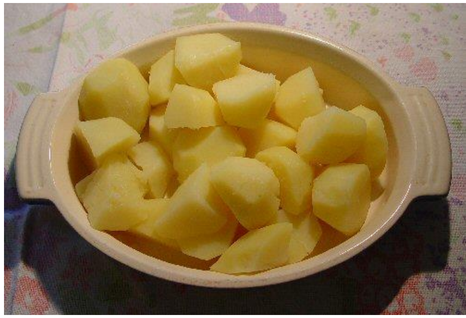
How can enzymes be affected?

- Enzymes can be affected by **temperature** and **pH**.
- Temperatures outside the correct range can cause enzymes to break down or change shape.
- This break down is called **denaturation**.
- Therefore, enzymes in our body work best at 37°C (98.6°F) and at a pH between 6.5 to 7.5.

Ex: Catalase is an enzyme that breaks down hydrogen peroxide.

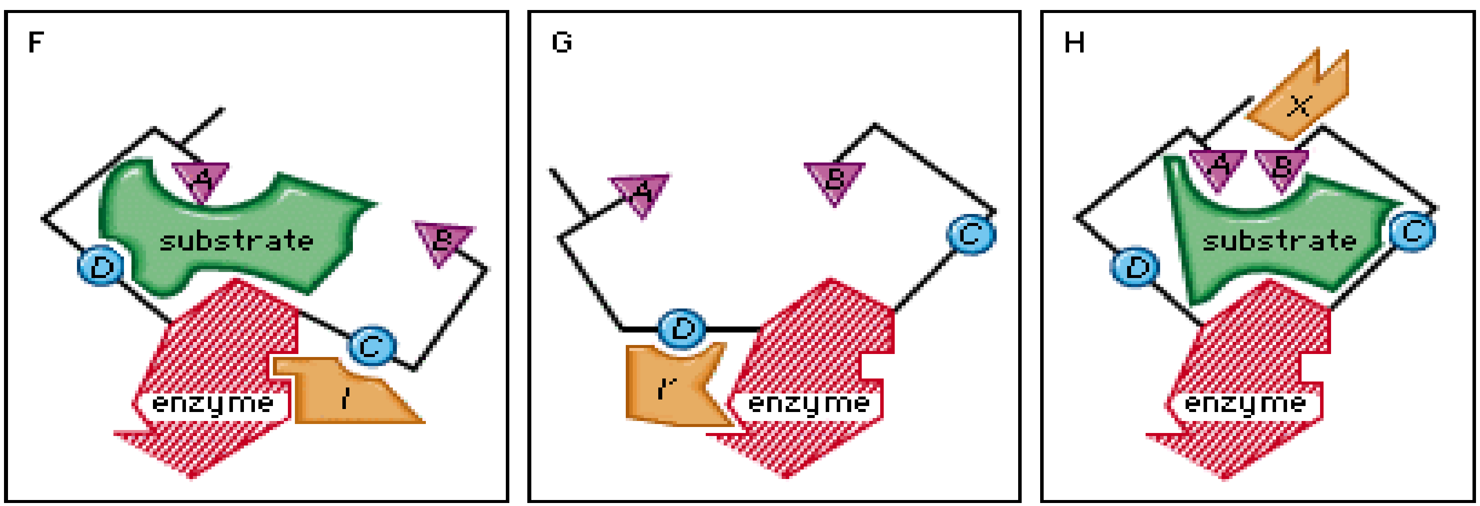
- $H_2O_2 \rightarrow H_2O + O_2$ (gas)
- A raw potato in H2O2 gives off O2. The boiled potato give no bubbles because the enzyme has changed due to heat.





Enzymes can turn On & Off

- Most cells contain proteins that turn enzymes on or off during critical stages of development.



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Hormones

Hormones are chemicals released by the body to control and regulate the activity of certain cells and organs. Special glands known as endocrine glands secrete these hormones

hormones are chemicals that essentially function as messengers of the body. These chemicals are secreted by special glands known as the endocrine glands. These endocrine glands are distributed throughout the body. These messengers control many physiological functions as well as psychological health. They are also quite important in maintaining homeostasis in the body

Types of Hormones

- To regulate various functions, different types of hormones are produced in the body. They are classified as follows:
- Peptide Hormones
- Steroid Hormones

Peptide Hormones

Peptide hormones are composed of **amino acids** and are soluble in water. Peptide hormones are unable to pass through the cell membrane as it contains a phospholipid bilayer that stops any fat-insoluble molecules from diffusing into the cell. Insulin is an important peptide hormone produced by the pancreas.

Steroid Hormones

Unlike peptide hormones, steroid hormones are **fat-soluble** and are able to pass through a cell membrane. Sex hormones such as testosterone, estrogen and progesterone are examples of steroid hormones.

Endocrine system

- **Hypothalamus:** It regulates the body temperature, controls thirst, sleep, hunger, emotions, moods and allow the release of hormones.
- **Pineal**: Pineal is also known as the thalamus, it develops serotonin derivatives of melatonin, which can affect sleep.
- **Parathyroid**: This gland helps in controlling the amount of calcium present in the body.
- **Thymus**: It helps in the functioning of the adaptive immune system, produces T-cells and maturity of the thymus.
- **Thyroid:** It produces hormones that affect the heart rate and how calories are burnt.
- **Adrenal**: This gland produces the hormones that control the sex drive, cortisol and stress hormone.
- **Pituitary**: It is also termed as the "master control gland,". This is because the pituitary gland helps in controlling other glands. Moreover, it develops the hormones that trigger growth and development.
- **Pancreas**: This gland produces insulin crucial to maintain blood sugar levels.
- **Testes:** In men, the testes secrete the male sex hormone, testosterone. It also produces sperm.
- **Ovaries**: In women, the ovaries secrete estrogen, progesterone, testosterone, and other female sex hormones.

List of Important Hormones

1. **Progesterone** – It is a female sex hormone also responsible for menstrual cycle, pregnancy and embryo genesis.
2. **Estrogen-**This is the main sex hormone present in women which bring about puberty, prepares the uterus and body for pregnancy and even regulates the menstrual cycle. Estrogen level changes during menopause because of which women experience many uncomfortable symptoms.
3. **Cortisol** – It has been named as the "stress hormone" as it helps the body in responding to stress. This is done by increasing the heart rate, elevating blood sugar levels etc.
4. **Melatonin** – It primarily controls the circadian rhythm or sleep cycles.
5. **Testosterone** – This is the main sex hormone present in men which cause puberty, muscle mass growth, and strength, increases bone density and handles facial hair growth.

Hormonal Diseases

Several hormonal diseases arise when the endocrine glands malfunctions. Common hormonal issues are associated with hypothalamus, adrenal and pituitary glands**.** An increase or decrease in the secretion of these hormones can severely affect growth, metabolism and development.

Diseases such as hyperthyroidism, osteoporosis, and diabetes are caused due to hormonal imbalance. The factors responsible for hormonal diseases can be genetic, environmental, or related to diet.

NUCLEOTIDES & NUCLEIC ACIDS

Assisst.Prof.Dr. Zahraa Jaafar Jameel

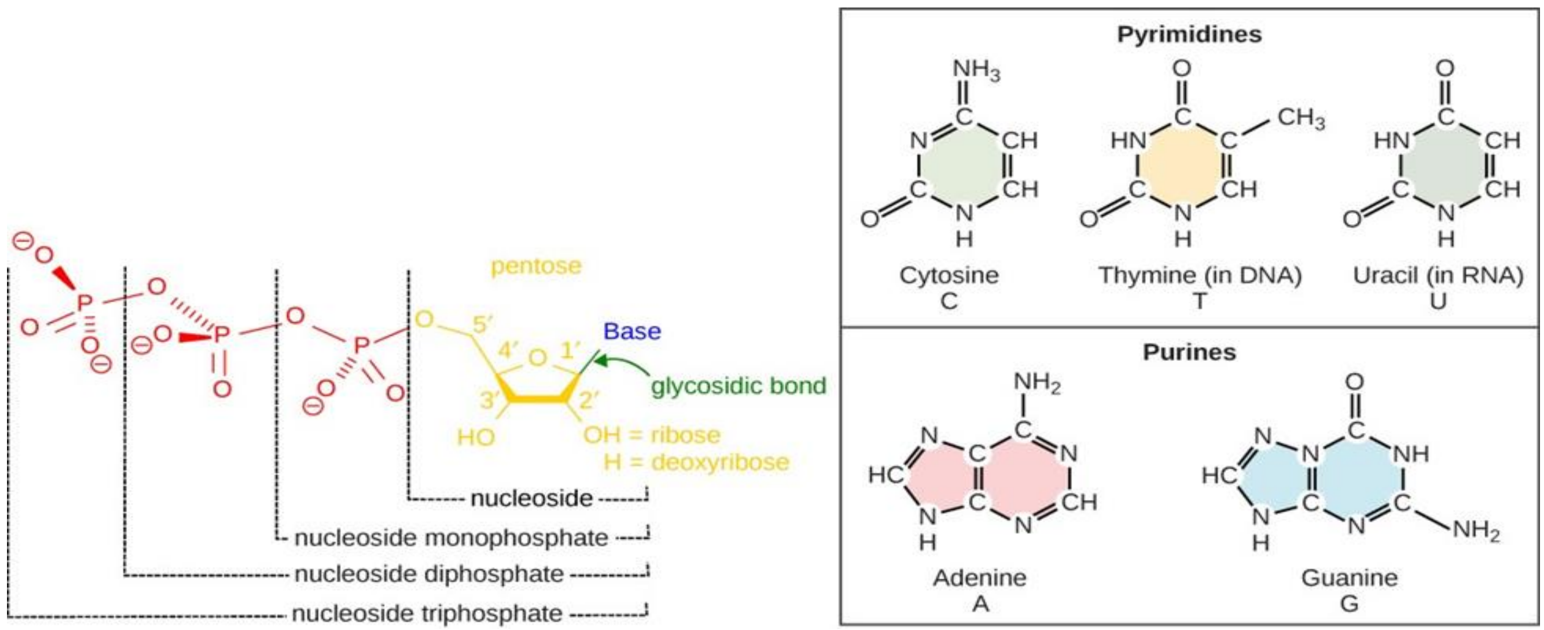
Nucleic acids are macromolecules made up of monomers called **nucleotides**. They are the most important macromolecules for the continuity of life. They **carry the genetic information of a cell and instructions for the functioning of the cell**. Nucleic acids are information molecules that serve as blueprints for the proteins that are made by cells. They are also the hereditary material in cells, as reproducing cells pass the blueprints on to their offspring.

The two main types of nucleic acids are deoxyribonucleic acid (**DNA**) and ribonucleic acid (**RNA**). DNA is the genetic material found in all living organisms. It is found in the nucleus of eukaryotes and in the chloroplasts and mitochondria. In prokaryotes, the DNA is not enclosed in a nucleus

The entire genetic content of a cell is known as its **genome.** In eukaryotic cells, DNA forms a complex with histone proteins to form **chromatin**, the substance of eukaryotic chromosomes. A chromosome may contain tens of thousands of genes. Many genes contain the information to make protein products; other genes code for RNA products. DNA controls all of the cellular activities by turning the genes “on” or “off.”

The other type of nucleic acid, RNA, is mostly involved in protein synthesis. DNA molecules use an intermediary, called messenger RNA (mRNA), to communicate with the rest of the cell. Other types of RNA, such as rRNA, tRNA, and microRNA, are involved in protein synthesis and its regulation.

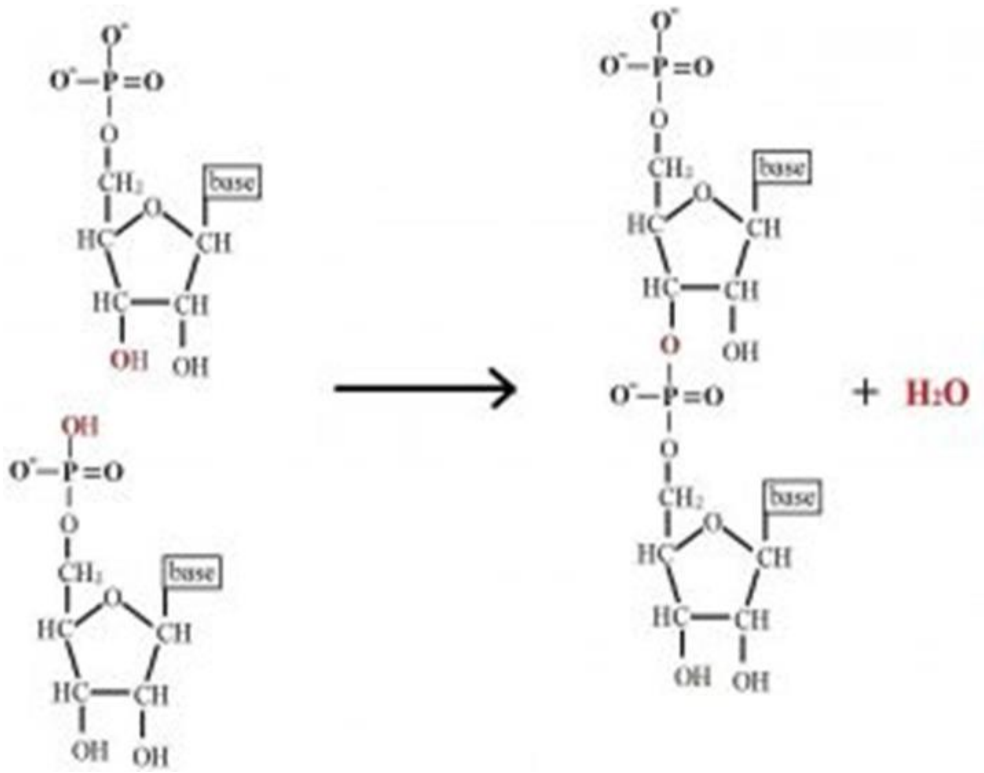
DNA and RNA are made up of monomers known as **nucleotides**. The nucleotides combine with each other to form a nucleic acid, DNA or RNA. Each nucleotide is made up of <u>three</u> components: a nitrogenous base, a pentose (five-carbon) sugar, and a phosphate group (Figure 5.2). Each nitrogenous base in a nucleotide is attached to a sugar molecule, which is attached to one or more phosphate groups.



Each nucleotide in DNA contains one of four possible nitrogenous bases: adenine (A), guanine (G) cytosine (C), and thymine (T). Each nucleotide in RNA contains one of four possible nitrogenous bases: adenine (A), guanine (G) cytosine (C), and uracil (U). Adenine and guanine are classified as purines and have two carbon-nitrogen rings. Cytosine, thymine, and uracil are classified as pyrimidines, which have a single carbon-nitrogen ring

The carbon atoms of the pentose sugar molecule in each nucleotide are numbered as 1′, 2′, 3′, 4′, and 5′ (1′ is read as "one prime"). The nitrogenous base is attached to the 1′ carbon and the phosphate group is attached to the hydroxyl group of the 5′ carbon. In RNA, the pentose sugar is ribose, which has a hydroxyl group attached to the 2′ carbon. In DNA, the pentose sugar is deoxyribose, which has a hydrogen atoms attached to the 2′ carbon. The "deoxy" in the name of DNA refers to the missing oxygen atom at the 2′ carbon

Nucleic acids are long, linear chains of nucleotides. Phosphodiester linkages are covalent bonds between the 3′ carbon of one nucleotide and the 5′ phosphate group of another. They form by dehydration synthesis reactions (Figure). Nucleic acids have directionality: the first nucleotide in the chain has a free phosphate group at the 5′ end of the molecule. The last nucleotide added has a free 3′ hydroxy group at the 3′ end of the molecule. Nucleotides are always added on to the 3′ end.



Two strands of nucleotides are held together by hydrogen bonds that form between pairs of nitrogenous bases. The sugar and phosphate “backbone” forms the outside of the helix. The nitrogenous bases are stacked in the interior, like the steps of a ladder. The two strands are anti-parallel in nature; that is, the 3′ end of one strand faces the 5′ end of the other strand.

Only certain types of base pairing occur. A can only pair with T, and G can only pair with C, as shown in Figure 5.5. This is known as the base complementary rule. In other words, the DNA strands are complementary to each other. If the sequence of one strand is 5′-AATTGGCC-3′, the complementary strand would have the sequence 3′-TTAACCGG-5′. The fact that the two strands of a DNA molecule are complementary allows DNA to replicate. During DNA replication, each strand is copied, resulting in a daughter DNA double helix containing one parental DNA strand and a newly synthesized strand. The base pairs are stabilized by hydrogen bonds; adenine and thymine form two hydrogen bonds and cytosine and guanine form three hydrogen bonds.

Ribonucleic acid, or RNA, is mainly involved in protein synthesis. Like DNA, RNA is made of nucleotides linked by phosphodiester bonds. However, the nucleotides in RNA contain ribose sugar instead of deoxyribose and the nitrogenous base uracil (U) instead of thymine (T). Unlike DNA, RNA is usually single-stranded. However, most RNAs show internal base pairing between complementary sequences, creating a three-dimensional structure essential for their function.

There are four major types of RNA: messenger RNA (mRNA), ribosomal RNA (rRNA), transfer RNA (tRNA), and microRNA (miRNA). mRNA carries a copy of the genetic code from DNA. If a cell requires a certain protein to be synthesized, the gene is turned "on" and the corresponding messenger RNA is synthesized. The RNA sequence is complementary to the sequence of the DNA (except U replaces T). If the DNA strand has a sequence 5′-AATTGCGC-3′, the sequence of the complementary RNA is 3′-UUAACGCG-5′. The mRNA then interacts with ribosomes and other cellular machinery so that a protein can be made from the coded message. The mRNA is read in sets of three bases known as codons. Each codon codes for a single amino acid.

Thus, information flow in an organism goes from DNA to mRNA to protein. DNA dictates the sequence of mRNA in a process known as transcription, and RNA dictates the structure of protein in a process known as translation. This is known as the **Central Dogma of Molecular Biology**.

rRNA is a major constituent of ribosomes, to which the mRNA binds to make a protein product. tRNA carries the correct amino acid to the site of protein synthesis. miRNAs play a role in the regulation of gene expression. Table 1 summarizes features of DNA and RNA.

Table 1 Features of DNA and RNA

	DNA	RNA
Function	Carries genetic information	Involved in protein synthesis and regulation of gene expression
Location	Remains in the nucleus	Leaves the nucleus
Structure	Double helix	Usually single-stranded
Sugar	Deoxyribose	Ribose
Pyrimidines	Cytosine, thymine	Cytosine, uracil
Purines	Adenine, guanine	Adenine, guanine

Referance

Introduction to Molecular and Cell Biology by Katherine R. Mattaini

Robert K. Murray, David A Bender, Kathleen M. Botham , Peter J. Kennelly, Victor W. Rodwell , P. Anthony Weil ,Harper's Illustrated Biochemistry, 29edition(2012)

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