

Dr. (Mrs) J. M. Babajide and Dr (Mrs) Nike Adegunwa

## A. Carbohydrate

### Definition:

The term carbohydrate often means any food that is particularly rich in the complex carbohydrate starch (such as cereals, bread, and pasta) or simple carbohydrates, such as sugar (found in candy, jams, and desserts).

### Composition:

A carbohydrate is an organic compound with the empirical formula  $C_m(H_2O)_n$ ; that is, consists only of carbon, hydrogen, and oxygen, with a hydrogen:oxygen atom ratio of 2:1 (as in water). Carbohydrates can be viewed as hydrates of carbon, hence their name. Structurally however, it is more accurate to view them as polyhydroxy, aldehydes and ketones.

### Function:

Carbohydrates serve several biochemical functions:

- Monosaccharides are a fuel for cellular metabolism.
  - Monosaccharides are used in several biosynthesis reactions.
  - Monosaccharides may be converted into space-saving polysaccharides, such as glycogen and starch. These molecules provide stored energy for plant and animal cells.
- Carbohydrates are used to form structural elements, such as chitin in animals and cellulose in plants.
- The 5-carbon monosaccharide ribose is an important component of coenzymes (e.g., ATP, FAD, and NAD) and the backbone of the genetic molecule known as RNA. The related deoxyribose is a component of DNA.
  - Saccharides and their derivatives include many other important biomolecules that play key roles in the immune system, fertilization, preventing pathogenesis, blood clotting, and development.

### Classification and names:

- The carbohydrates (saccharides) are divided into four chemical groupings: monosaccharides (e.g glucose, fructose, galactose), disaccharides (sucrose, lactose) , oligosaccharides, and polysaccharides (chitin, cellulose).
- In general, the monosaccharides and disaccharides, which are smaller (lower molecular weight) carbohydrates, are commonly referred to as sugars.
- The word *saccharide* comes from the Greek word *σάκχαρον* (*sákkharon*), meaning "sugar". While the scientific nomenclature of carbohydrates is complex, the names of the monosaccharides and disaccharides very often end in the suffix -ose.
- For example, blood sugar is the monosaccharide glucose, table sugar is the disaccharide sucrose, and milk sugar is the disaccharide lactose.

### Characteristics used to classify monosaccharides:

- number of carbon atoms in the molecule
- location of the carbonyl group

- the chirality of the carbohydrate

**aldose** - monosaccharide in which the carbonyl group is an aldehyde

**ketone** - monosaccharide in which the carbonyl group is a ketone

**triose** - monosaccharide with 3 carbon atoms

**tetrose** - monosaccharide with 4 carbon atoms

**pentose** - monosaccharide with 5 carbon atoms

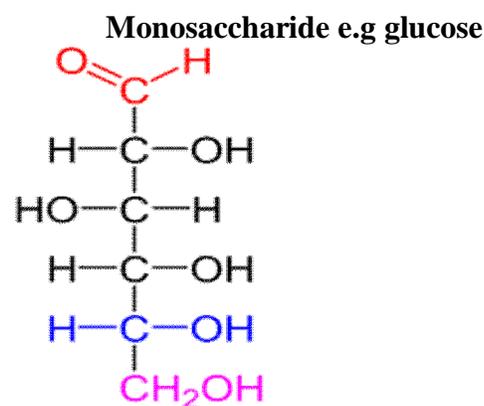
**hexose** - monosaccharide with 6 carbon atoms

**aldohexose** - 6-carbon aldehyde (e.g., glucose)

**aldopentose** - 5-carbon aldehyde (e.g., ribose)

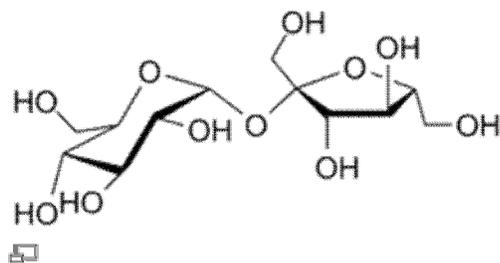
**ketohexose** - 6-carbon hexose (e.g., fructose)

### Structure, Forms and Isomers:



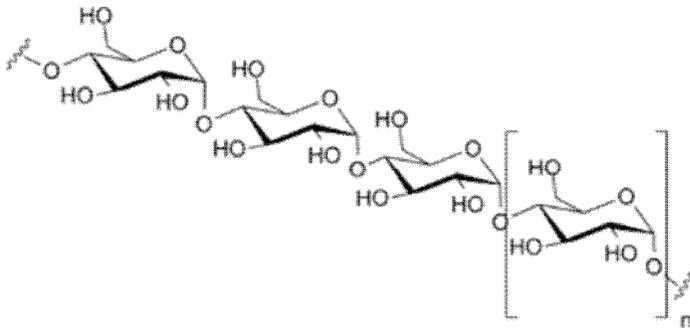
D-glucose is an aldohexose with the formula  $(\text{C}\cdot\text{H}_2\text{O})_6$ . The red atoms highlight the aldehyde group, and the blue atoms highlight the asymmetric center furthest from the aldehyde; because this -OH is on the right of the Fischer projection, this is a D sugar. Glucose can exist in both a straight-chain and ring form. The aldehyde or ketone group of a straight-chain monosaccharide will react reversibly with a hydroxyl group on a different carbon atom to form a hemiacetal or hemiketal, forming a heterocyclic ring with an oxygen bridge between two carbon atoms. Rings with five and six atoms are called furanose and pyranose forms, respectively, and exist in equilibrium with the straight-chain form.

### Disaccharides e.g sucrose

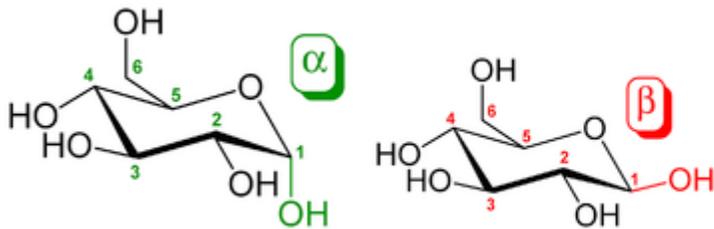


Sucrose, also known as table sugar, is a common disaccharide. It is composed of two monosaccharides: D-glucose (left) and D-fructose (right).

### Oligosaccharides and polysaccharides



Amylose is a linear polymer of glucose mainly linked with  $\alpha(1\rightarrow4)$  bonds. It can be made of several thousands of glucose units. It is one of the two components of starch, the other being amylopectin.



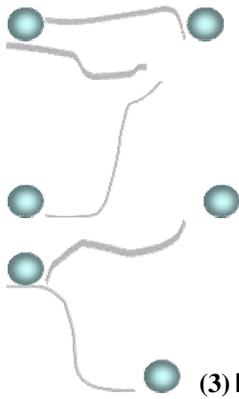
The  $\alpha$  and  $\beta$  anomers of glucose. Note the position of the hydroxyl group (red or green) on the anomeric carbon relative to the  $\text{CH}_2\text{OH}$  group bound to carbon 5: they are either on the opposite sides ( $\alpha$ ), or the same side ( $\beta$ ).

### Starch Gelatinization and Pasting, Gelation, and Uglification

Starch granules contain both linear amylose and branched amylopectin. The following illustrations take place when heat is applied to starch.

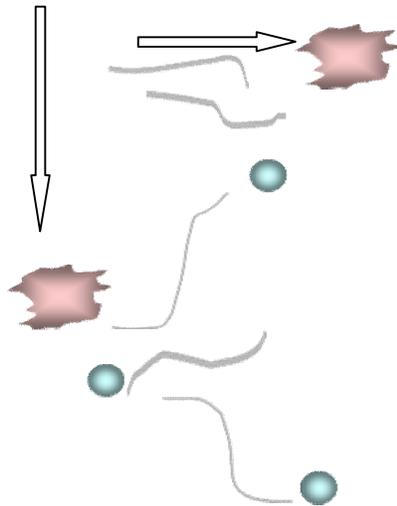
- ●
- 
- ● (1) Raw, uncooked starch granules heated in water

(2) Swelling is evident



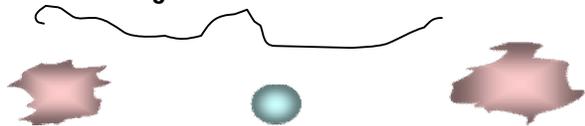
(3) Notice loss of amylose from the granules

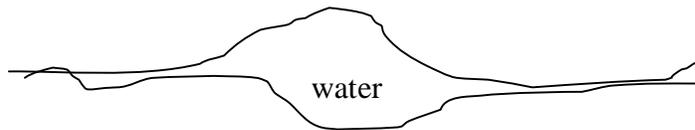
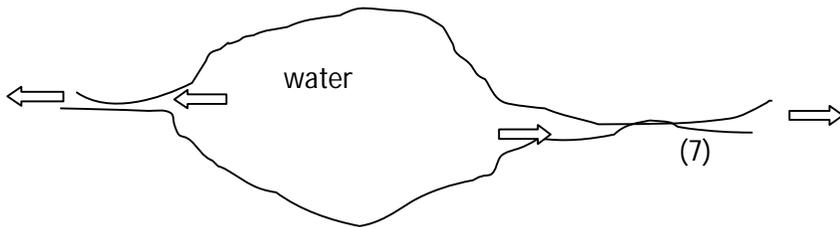
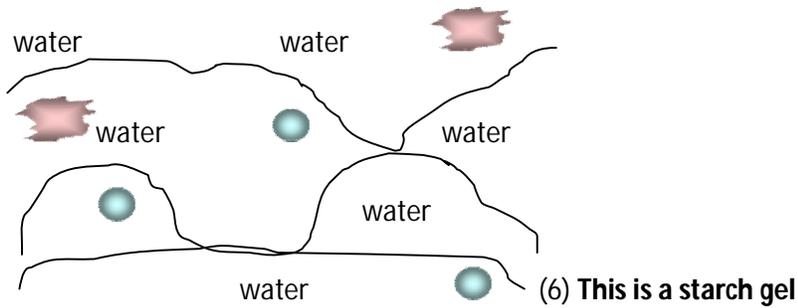
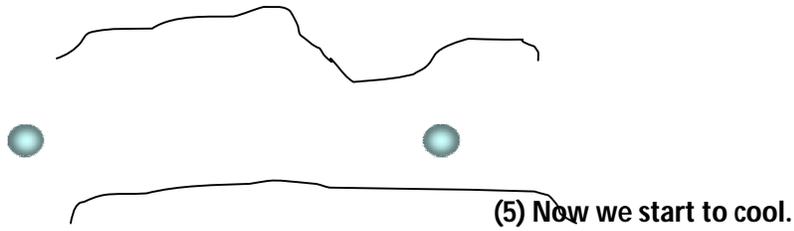
(4) Some granules have collapsed



Gelatinization and pasting are complete

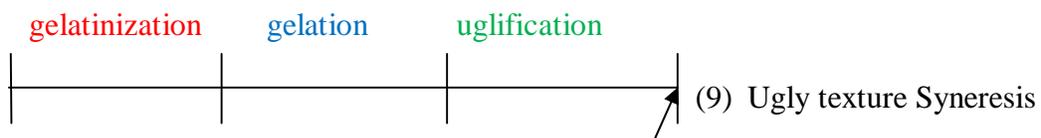
After heating:





(8) WATER of SYNERESIS that has been squeezed out of the gel structure  
The texture gets very ugly when this happens.

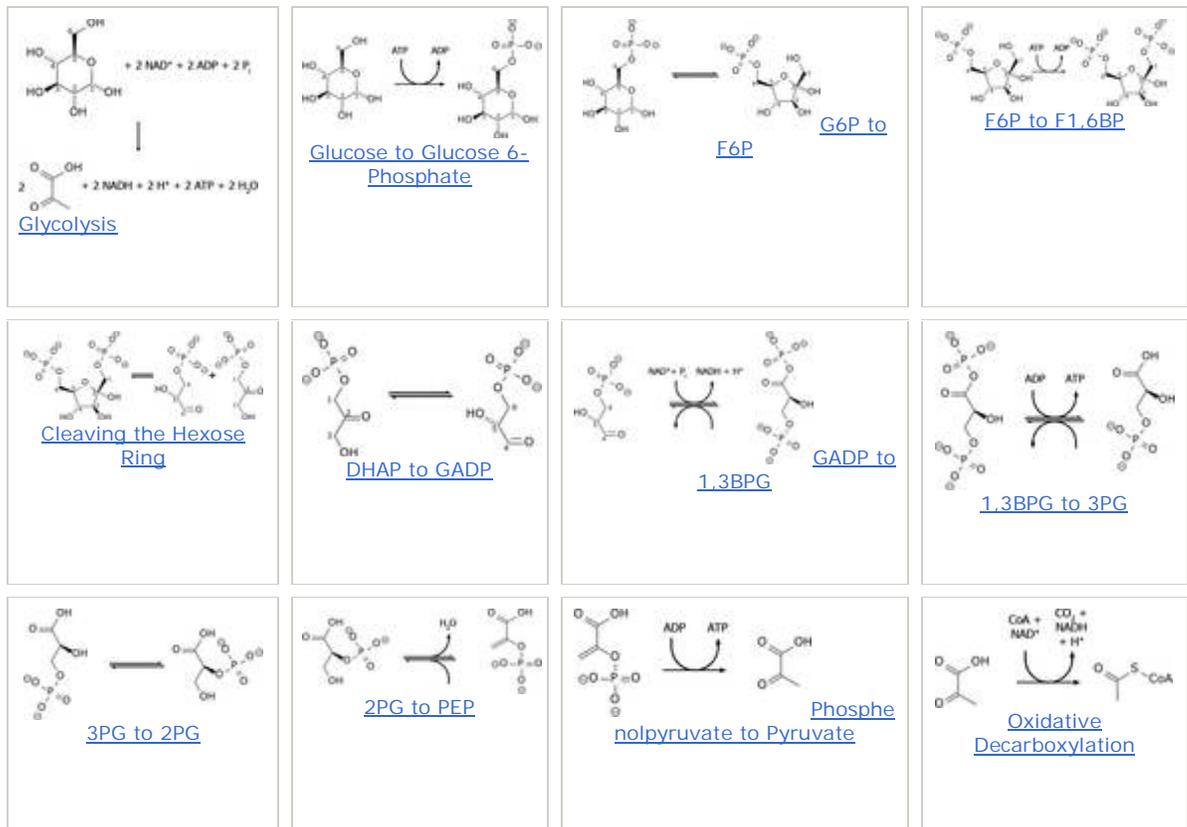
### Timeline



## Carbohydrate metabolism

**Catabolism** is the metabolic reaction cells undergo to extract energy. There are two major metabolic pathways of monosaccharide catabolism: glycolysis and the citric acid cycle.

**Glycolysis** is the name given to the series of biochemical reactions in which glucose is converted into pyruvate. This carbohydrate catabolism takes place in the cytoplasm of cells. Several reactions take place, with products that are vital to the functioning of cell as shown below.



## B. LIPIDS

### What Is a Lipid?

A lipid is a fat-soluble molecule. To put it another way, lipids are insoluble in water but soluble in at least one organic solvent. The other major classes of organic compounds (nucleic acids, proteins, and carbohydrates) are much more soluble in water than in an organic solvent. Lipids do not share a common molecule structure.

## Examples of Common Lipids

There are many different types of lipids. Examples of common lipids include butter, vegetable oil, cholesterol and other steroids, waxes, phospholipids, and fat-soluble vitamins. The common characteristic of all of these compounds is that they are essentially insoluble in water yet soluble in one or more organic solvents.

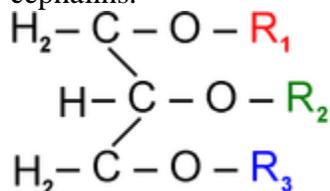
## What Are the Functions of Lipids?

Lipids are used by organisms for energy storage, as a signaling molecule (e.g., steroid hormones), and as a structural component of cell membranes.

## Lipid Structure

Although there is no single common structure for lipids, the most commonly occurring class of lipids are triglycerides, which are fats and oils. Triglycerides have a glycerol backbone bonded to three fatty acids. If the three fatty acids are identical then the triglyceride is termed a *simple triglyceride*. Otherwise, the triglyceride is called a *mixed triglyceride*.

The second most abundant class of lipids are the phospholipids, which are found in animal and plant cell membranes. Phospholipids also contain glycerol and fatty acids, plus they contain phosphoric acid and a low-molecular-weight alcohol. Common phospholipids include lecithins and cephalins.



This is the general chemical structure of triacylglycerol, a triglyceride and the most abundant form of lipid. Triglycerides result from the reaction between glycerol and fatty acids.

## Types of fatty acids

Fatty acids can be saturated and unsaturated, depending on double bonds. They differ in length as well.

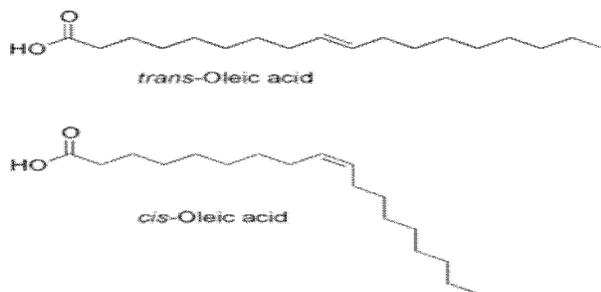
## Long and short fatty acids

In addition to saturation, fatty acids have different lengths, often categorized as short, medium, or long.

- Short-chain fatty acids (SCFA) are fatty acids with aliphatic tails of fewer than six carbons.
- Medium-chain fatty acids (MCFA) are fatty acids with aliphatic tails of 6–12 carbons, which can form medium-chain triglycerides.
- Long-chain fatty acids (LCFA) are fatty acids with aliphatic tails longer than 12 carbons.

- Very-Long-chain fatty acids (VLCFA) are fatty acids with aliphatic tails longer than 22 carbons

## Unsaturated fatty acids



Comparison of the *trans* isomer (top) Elaidic acid and the *cis*-isomer oleic acid.

Unsaturated fatty acids resemble saturated fatty acids, except that the chain has one or more double-bonds between carbon atoms. The two carbon atoms in the chain that are bound next to either side of the double bond can occur in a *cis* or *trans* configuration.

A *cis* configuration means that adjacent hydrogen atoms are on the same side of the double bond. The rigidity of the double bond freezes its conformation and, in the case of the *cis* isomer, causes the chain to bend and restricts the conformational freedom of the fatty acid. The more double bonds the chain has in the *cis* configuration, the less flexibility it has. When a chain has many *cis* bonds, it becomes quite curved in its most accessible conformations. For example, oleic acid, with one double bond, has a "kink" in it, whereas linoleic acid, with two double bonds, has a more pronounced bend. Alpha-linolenic acid, with three double bonds, favors a hooked shape. The effect of this is that, in restricted environments, such as when fatty acids are part of a phospholipid in a lipid bilayer, or triglycerides in lipid droplets, *cis* bonds limit the ability of fatty acids to be closely packed, and therefore could affect the melting temperature of the membrane or of the fat.

A *trans* configuration, by contrast, means that the next two hydrogen atoms are bound to *opposite* sides of the double bond. As a result, they do not cause the chain to bend much, and their shape is similar to straight saturated fatty acids.

In most naturally occurring unsaturated fatty acids, each double bond has three *n* carbon atoms after it, for some *n*, and all are *cis* bonds. Most fatty acids in the *trans* configuration (*trans* fats) are not found in nature and are the result of human processing (e.g., hydrogenation).

The differences in geometry between the various types of unsaturated fatty acids, as well as between saturated and unsaturated fatty acids, play an important role in biological processes, and in the construction of biological structures (such as cell membranes).

## Examples of Unsaturated Fatty Acids

Common name	Chemical structure	C:D <i>n</i> -x
Myristoleic acid	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>3</sub> CH=CH(CH <sub>2</sub> ) <sub>7</sub> COOH	14:1 <i>n</i> -5
Palmitoleic acid	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>5</sub> CH=CH(CH <sub>2</sub> ) <sub>7</sub> COOH	16:1 <i>n</i> -7
Sapienic acid	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>8</sub> CH=CH(CH <sub>2</sub> ) <sub>4</sub> COOH	16:1 $\frac{n-1}{0}$
Oleic acid	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>7</sub> CH=CH(CH <sub>2</sub> ) <sub>7</sub> COOH	18:1 <i>n</i> -9
Elaidic acid	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>7</sub> CH=CH(CH <sub>2</sub> ) <sub>7</sub> COOH	18:1 <i>n</i> -9
Vaccenic acid	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>5</sub> CH=CH(CH <sub>2</sub> ) <sub>9</sub> COOH	18:1 <i>n</i> -7
Linoleic acid	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>4</sub> CH=CHCH <sub>2</sub> CH=CH(CH <sub>2</sub> ) <sub>7</sub> COOH	18:2 <i>n</i> -6
Linoelaidic acid	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>4</sub> CH=CHCH <sub>2</sub> CH=CH(CH <sub>2</sub> ) <sub>7</sub> COOH	18:2 <i>n</i> -6
α-Linolenic acid	CH <sub>3</sub> CH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CH(CH <sub>2</sub> ) <sub>7</sub> COOH	18:3 <i>n</i> -3
Arachidonic acid	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>4</sub> CH=CHCH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CH(CH <sub>2</sub> ) <sub>3</sub> COOH <sup>NIST</sup>	20:4 <i>n</i> -6
Eicosapentaenoic acid	CH <sub>3</sub> CH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CH(CH <sub>2</sub> ) <sub>3</sub> COOH	20:5 <i>n</i> -3
Erucic acid	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>7</sub> CH=CH(CH <sub>2</sub> ) <sub>11</sub> COOH	22:1 <i>n</i> -9
Docosahexaenoic acid	CH <sub>3</sub> CH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CHCH <sub>2</sub> CH=CH(CH <sub>2</sub> ) <sub>2</sub> COOH	22:6 <i>n</i> -3

### Essential fatty acids

Fatty acids that are required by the human body but cannot be made in sufficient quantity from other substrates and therefore must be obtained from food and are called essential fatty acids. There are two series of essential fatty acids: one has a double bond three carbon atoms removed from the methyl end; the other has a double bond six carbon atoms removed from the methyl end. Humans lack the ability to introduce double bonds in fatty acids beyond carbons 9 and 10, as counted from the carboxylic acid side., Two essential fatty acids are linoleic acid (LA) and alpha-linolenic acid (ALA). They are widely distributed in plant oils. The human body has a limited ability to convert ALA into the longer-chain *n*-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which can also be obtained from fish.

### Saturated fatty acids

Saturated fatty acids are long-chain carboxylic acids that usually have between 12 and 24 carbon atoms and have no double bonds. Thus, saturated fatty acids are saturated with hydrogen (since

double bonds reduce the number of hydrogens on each carbon). Because saturated fatty acids have only single bonds, each carbon atom within the chain has 2 hydrogen atoms (except for the omega carbon at the end that has 3 hydrogens).

### Examples of Saturated Fatty Acids

Common name	Chemical structure	C:D
Lauric acid	$\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$	12:0
Myristic acid	$\text{CH}_3(\text{CH}_2)_{12}\text{COOH}$	14:0
Palmitic acid	$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$	16:0
Stearic acid	$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$	18:0
Arachidic acid	$\text{CH}_3(\text{CH}_2)_{18}\text{COOH}$	20:0
Behenic acid	$\text{CH}_3(\text{CH}_2)_{20}\text{COOH}$	22:0
Lignoceric acid	$\text{CH}_3(\text{CH}_2)_{22}\text{COOH}$	24:0
Cerotic acid	$\text{CH}_3(\text{CH}_2)_{24}\text{COOH}$	26:0

## C. Protein

**Proteins** are biochemical compounds consisting of one or more polypeptides typically folded into a globular or fibrous form in a biologically functional way. A polypeptide is a single linear polymer chain of amino acids bonded together by peptide bonds between the carboxyl and amino groups of adjacent amino acid residues. The sequence of amino acids in a protein is defined by the sequence of a gene, which is encoded in the genetic code. In general, the genetic code specifies 20 standard amino acids; however, in certain organisms the genetic code can include selenocysteine—and in certain archaea—pyrrolysine. Shortly after or even during synthesis, the residues in a protein are often chemically modified by post-translational modification, which alters the physical and chemical properties, folding, stability, activity, and ultimately, the function of the proteins. Sometimes proteins have non-peptide groups attached, which can be called prosthetic groups or cofactors. Proteins can also work together to achieve a particular function, and they often associate to form stable complexes.

### Protein Structure

Most proteins fold into unique 3-dimensional structures. The shape into which a protein naturally folds is known as its native conformation. Although many proteins can fold unassisted, simply through the chemical properties of their amino acids, others require the aid of molecular chaperones to fold into their native states. Biochemists often refer to four distinct aspects of a protein's structure:

- *Primary structure*: the amino acid sequence.

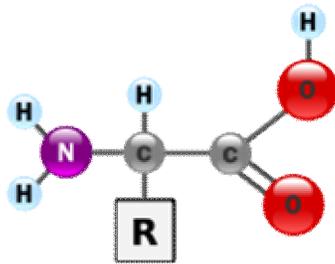
- *Secondary structure*: regularly repeating local structures stabilized by hydrogen bonds. The most common examples are the alpha helix, beta sheet and turns. Because secondary structures are local, many regions of different secondary structure can be present in the same protein molecule.
- *Tertiary structure*: the overall shape of a single protein molecule; the spatial relationship of the secondary structures to one another. Tertiary structure is generally stabilized by nonlocal interactions, most commonly the formation of a hydrophobic core, but also through salt bridges, hydrogen bonds, disulfide bonds, and even post-translational modifications. The term "tertiary structure" is often used as synonymous with the term *fold*. The tertiary structure is what controls the basic function of the protein.
- *Quaternary structure*: the structure formed by several protein molecules (polypeptide chains), usually called *protein subunits* in this context, which function as a single protein complex.



- 
- 

## • **Amino Acids**

- **Amino acids** are molecules containing an amine group, a carboxylic acid group and a side-chain that varies between different amino acids. The key elements of an amino acid are carbon, hydrogen, oxygen, and nitrogen. They are particularly important in biochemistry, where the term usually refers to *alpha-amino acids*.



Positive Negative

+ Table shows charges at physiological pH 7.4

### Twenty-One Amino Acids

**A. Amino Acids with Electrically Charged Side Chains**

Positive Negative

**Arginine (Arg) (R)**

**Histidine (His) (H)**

**Lysine (Lys) (K)**

**Aspartic Acid (Asp) (D)**

**Glutamic Acid (Glu) (E)**

**B. Amino Acids with Polar Uncharged Side Chains**

**Serine (Ser) (S)**

**Threonine (Thr) (T)**

**Asparagine (Asn) (N)**

**Glutamine (Gln) (Q)**

**C. Special Cases**

**Cysteine (Cys) (C)**

**Selenocysteine (Sec) (U)**

**Glycine (Gly) (G)**

**Proline (Pro) (P)**

**D. Amino Acids with Hydrophobic Side Chain**

**Alanine (Ala) (A)**

**Isoleucine (Ile) (I)**

**Leucine (Leu) (L)**

**Methionine (Met) (M)**

**Phenylalanine (Phe) (F)**

**Tryptophan (Trp) (W)**

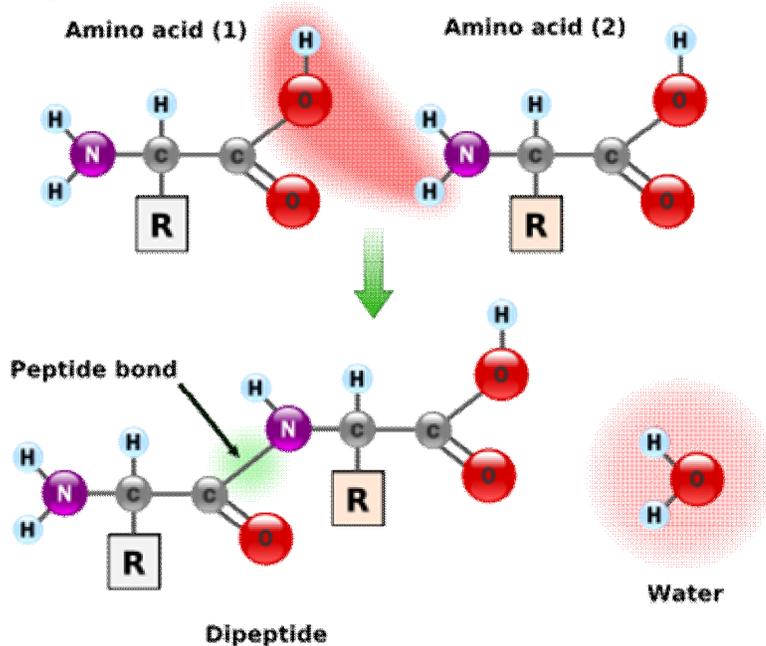
**Tyrosine (Tyr) (Y)**

**Valine (Val) (V)**

pKa Data: CRC Handbook of Chemistry, ©2014

©2014 Copyright, 2014e Student of Molecular Biophysics, University of Toronto, 2017

- **Peptide bond formation**



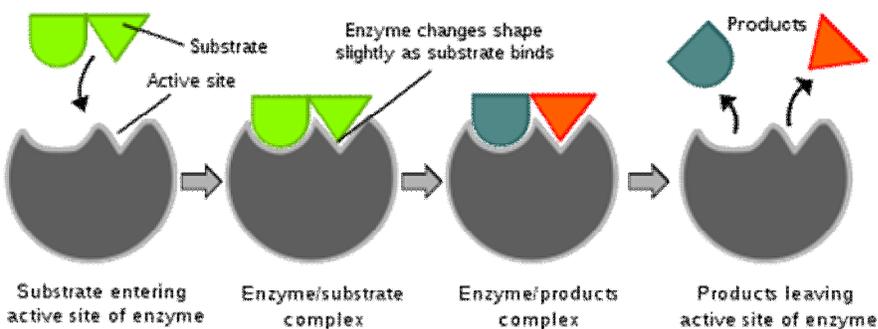
- 
- The condensation of two amino acids to form a peptide bond. As both the amine and carboxylic acid groups of amino acids can react to form amide bonds, one amino acid molecule can react with another and become joined through an amide linkage. This polymerization of amino acids is what creates proteins.

## D. Enzymes

**Enzymes** are proteins that catalyze (*i.e.*, increase or decrease the rates of) chemical reactions. In enzymatic reactions, the molecules at the beginning of the process are called substrates, and they are converted into different molecules, called the products. Almost all processes in a biological cell need enzymes to occur at significant rates.

### "Lock and key" model of enzymes

Enzymes are very specific because both the enzyme and the substrate possess specific complementary geometric shapes that fit exactly into one another. This is often referred to as "the lock and key" model.



## Mechanism of Enzyme actions

Enzymes can act in several ways, all of which lower  $\Delta G^\ddagger$ :

- Lowering the activation energy  $\Delta G^\ddagger$  by creating an environment in which the transition state is stabilized (e.g. straining the shape of a substrate—by binding the transition-state conformation of the substrate/product molecules, the enzyme distorts the bound substrate(s) into their transition state form, thereby reducing the amount of energy required to complete the transition).
- Lowering the energy of the transition state, but without distorting the substrate, by creating an environment with the opposite charge distribution to that of the transition state.
- Providing an alternative pathway. For example, temporarily reacting with the substrate to form an intermediate ES complex, which would be impossible in the absence of the enzyme.
- Reducing the reaction entropy change by bringing substrates together in the correct orientation to react. Considering  $\Delta H^\ddagger$  alone overlooks this effect.
- Increases in temperatures speed up reactions. Thus, temperature increases help the enzyme function and develop the end product even faster. However, if heated too much, the enzyme's shape deteriorates and the enzyme becomes denatured. Some enzymes like thermolabile enzymes work best at low temperatures.

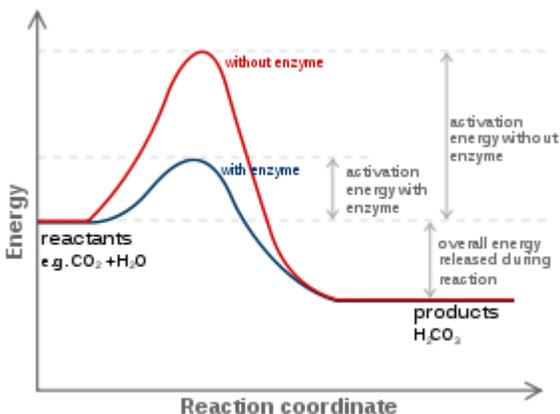
Interestingly, this entropic effect involves destabilization of the ground state, and its contribution to catalysis is relatively small.

## Cofactors

Some enzymes do not need any additional components to show full activity. However, others require non-protein molecules called cofactors to be bound for activity. Cofactors can be either inorganic (e.g., metal ions and iron-sulfur clusters) or organic compounds (e.g., flavin and heme). Organic cofactors can be either prosthetic groups, which are tightly bound to an enzyme, or coenzymes, which are released from the enzyme's active site during the reaction. Coenzymes include NADH, NADPH and adenosine triphosphate. These molecules transfer chemical groups between enzymes.

An example of an enzyme that contains a cofactor is carbonic anhydrase, and is shown in the ribbon diagram above with a zinc cofactor bound as part of its active site.

## Enzyme Thermodynamics

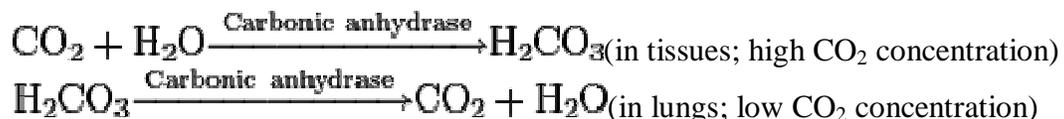


The energies of the stages of a chemical reaction. Substrates need a lot of energy to reach a transition state, which then decays into products. The enzyme stabilizes the transition state, reducing the energy needed to form products.

As all catalysts, enzymes do not alter the position of the chemical equilibrium of the reaction. Usually, in the presence of an enzyme, the reaction runs in the same direction as it would without the enzyme, just more quickly. However, in the absence of the enzyme, other possible uncatalyzed, "spontaneous" reactions might lead to different products, because in those conditions this different product is formed faster.

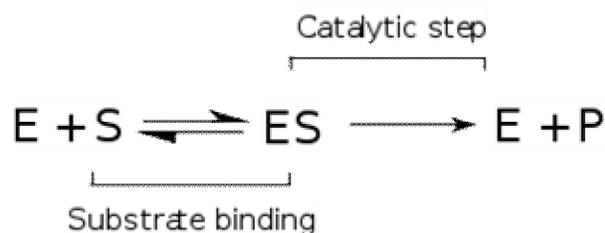
Furthermore, enzymes can couple two or more reactions, so that a thermodynamically favorable reaction can be used to "drive" a thermodynamically unfavorable one. For example, the hydrolysis of ATP is often used to drive other chemical reactions.

Enzymes catalyze the forward and backward reactions equally. They do not alter the equilibrium itself, but only the speed at which it is reached. For example, carbonic anhydrase catalyzes its reaction in either direction depending on the concentration of its reactants.



Nevertheless, if the equilibrium is greatly displaced in one direction, that is, in a very exergonic reaction, the reaction is *effectively* irreversible. Under these conditions the enzyme will, in fact, only catalyze the reaction in the thermodynamically allowed direction.

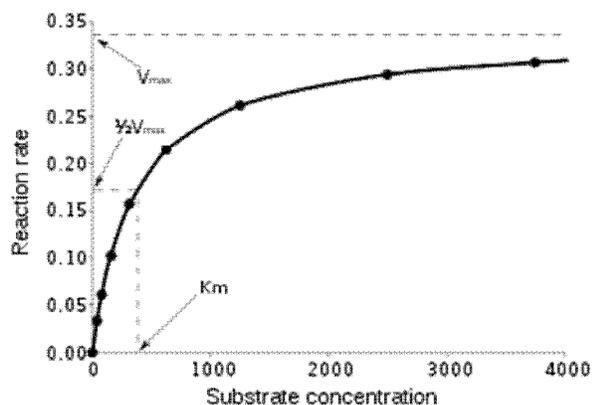
## Enzyme Kinetics



Mechanism for a single substrate enzyme catalyzed reaction. The enzyme (E) binds a substrate (S) and produces a product (P).

Enzyme kinetics is the investigation of how enzymes bind substrates and turn them into products. The rate data used in kinetic analyses are obtained from enzyme assays.

The enzyme reactions are in two stages. In the first, the substrate binds reversibly to the enzyme, forming the enzyme-substrate complex. This is sometimes called the Michaelis complex. The enzyme then catalyzes the chemical step in the reaction and releases the product.



Saturation curve for an enzyme reaction showing the relation between the substrate concentration (S) and rate ( $v$ )

Enzymes can catalyze up to several million reactions per second. Enzyme rates depend on solution conditions and substrate concentration. Conditions that denature the protein abolish enzyme activity, such as high temperatures, extremes of pH or high salt concentrations, while raising substrate concentration tends to increase activity. To find the maximum speed of an enzymatic reaction, the substrate concentration is increased until a constant rate of product formation is seen. This is shown in the saturation curve on the right. Saturation happens because, as substrate concentration increases, more and more of the free enzyme is converted into the substrate-bound ES form. At the maximum reaction rate ( $V_{\max}$ ) of the enzyme, all the enzyme active sites are bound to substrate, and the amount of ES complex is the same as the total amount of enzyme. However,  $V_{\max}$  is only one kinetic constant of enzymes. The amount of substrate needed to achieve a given rate of reaction is also important. This is given by the Michaelis-Menten constant ( $K_m$ ), which is the

substrate concentration required for an enzyme to reach one-half its maximum reaction rate. Each enzyme has a characteristic  $K_m$  for a given substrate, and this can show how tight the binding of the substrate is to the enzyme. Another useful constant is  $k_{cat}$ , which is the number of substrate molecules handled by one active site per second.

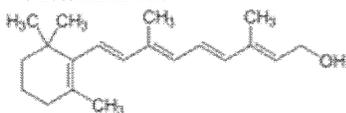
## E. Vitamins

A **vitamin** is an organic compound required as a nutrient in tiny amounts by an organism.<sup>[1]</sup> In other words, an organic chemical compound (or related set of compounds) is called a vitamin when it cannot be synthesized in sufficient quantities by an organism, and must be obtained from the diet.

### Types of vitamin and their structures

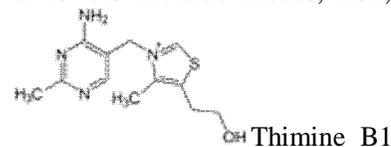
The types of vitamins are Vitamin C, Vitamin B1 (Thiamin), Niacin, Riboflavin, Vitamin B6, Folic Acid (Folacin), Vitamin B12 (Cobalamin), Vitamin A, Vitamin D, Vitamin E, Vitamin K, Biotin, Pantothenic Acid.

#### Vitamin A:

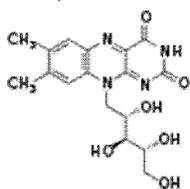


#### Vitamin B

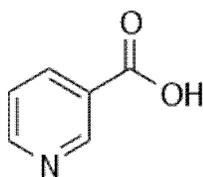
A vitamin that can be dissolved in water. It is one of the B complex vitamins. Vitamin B6 helps the body by building protein, making antibodies and making the red blood cells. There are actually eight separate vitamins in the B family: thiamin (vitamin B1), riboflavin (vitamin B2), niacin, vitamin B6, folate, vitamin B12, biotin, and pantothenic. B vitamins increase energy levels, regulate metabolism, and help create new red blood cells. Foods with high B levels include meats, fish,



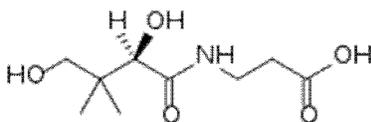
liver, dark/leafy vegetables, whole-grains, and fortified products.



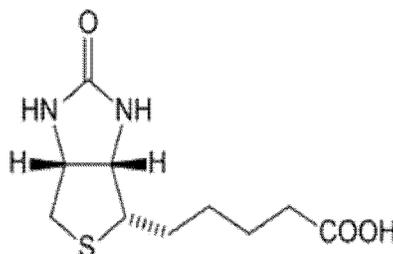
Riboflavin B2



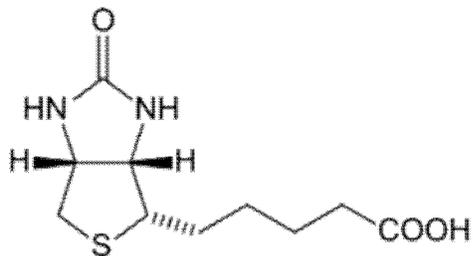
Niacin B3



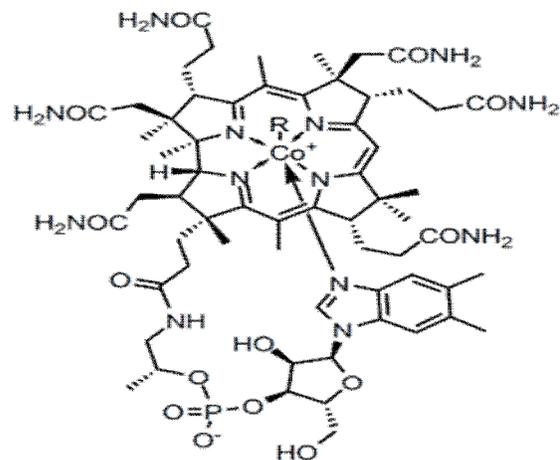
Pantothenic acid B5



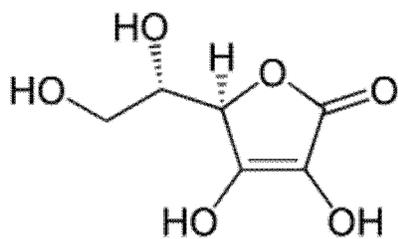
Biotin B7



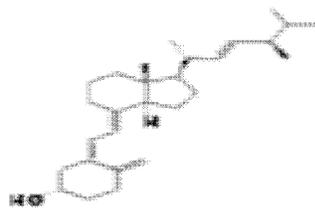
Folic acid B9



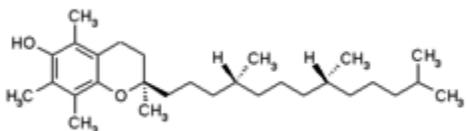
R = 5'-deoxyadenosyl, Me, OH, CN  
Cobalamin B12



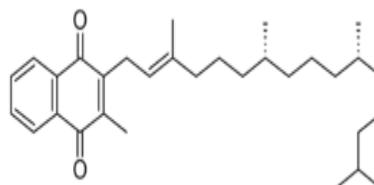
L-Ascorbic acid C



ergocalciferol D2



Tocopherol E



Phylloquinone K

### Biotin:

The B vitamin complex includes vitamins B1, niacin, B6, B12, folate, biotin, and pantothenic acid. Biotin helps the body use protein, fat and carbohydrate from foods for energy. It helps the body produce energy in the cells. Pantothenic acid is needed to make cholesterol, bile, some fats, red blood cells, hormones and nerve regulators.

### Folic Acid:

Folacin is also known as folic acid and folate. It is a water-soluble vitamin and is one of 8 members of the B complex including vitamins B1, B2, B3, B6, B12, biotin and pantothenic acid. Fortified grain products such as commercial breads, cereals and pastas are good sources of folacin.

Folate assists prevention of neural tube defects (spina bifida) in fetuses before birth and involvement in production of neurotransmitters, such as serotonin, that regulate mood, sleep, and appetite.

### **Niacin**

Niacin is one of the eight B complex vitamins including vitamins B1, B2, B6, B12, folate, biotin, and pantothenic acid. Niacin works closely with vitamin B1, B2, B6, pantothenic acid, and biotin to break the carbohydrates, fats, and proteins in food down into energy. Without niacin, the body would not be able to convert the food we eat into energy. Niacin has been used with some success to treat people with high cholesterol levels.

### **Pantothenic Acid:**

Pantothenic Acid and biotin are water-soluble vitamins.

### **Riboflavin:**

Riboflavin is also called Vitamin B2. Milk products supply about half of the riboflavin that people get and unlike other vitamins, riboflavin is not destroyed by cooking. Vegetarians may have riboflavin deficiencies. Children who do not get enough riboflavin may have poor growth. Vitamin supplements usually reverse symptoms within days to a few weeks.

### **Thiamine:**

Thiamine, also known as Vitamin B1 and because thiamine is water-soluble, any extra is passed out of the body in the urine. Thiamine is needed each day to maintain health. Thiamine can be lost in cooking due to heat. A well balanced diet based on the New Food Pyramid should provide enough thiamine daily.

**Vitamin E** is involved with immune system, DNA, and metabolism maintenance. As an antioxidant, research indicates that it may have a positive effect against cardiovascular disease and cancer. Vitamin E can be found in nuts, particularly almonds, wheat germ oil, vegetable oil, green/leafy vegetables, and enriched cereals.

### **Vitamin K:**

While involved in protection against osteoporosis, skin wounds, and possibly cancer, Vitamin K significantly helps blood to clot after an injury. Also found in a variety of foods, especially vegetables, K most often forms from intestine bacteria in the body.

**Vitamin K is in foods:** collards, kale, and other green leafy vegetables cabbage family including broccoli, cauliflower and Brussels, sprouts, egg yolk, some fruits, liver, cheese, milk.

### **Course requirements:**

- **CAT: 30% (Test 20% & assignment 10%)**
- **Exam: 70%**
- **70% Class attendance compulsory**