AU-6924
B.Sc. (Hon's) (First Semester) Examination, 2014
Biotechnology
Paper: LBTC-101
(Biomoleculesa-I)
Model answer

Ans. A.

1. (b)
2. (b)
3. (a)
4. (b)
5. (c)
6. (c)
7. (d)
8. (c)
9. (d)
10. (e)

Ans. B.2

A carbohydrate is a large biological molecule, or macromolecule, consisting of carbon (C), hydrogen (H), and oxygen (O) atoms, usually with a hydrogen:oxygen atom ratio of 2:1 (as in water); in other words, with the empirical formula Cm(H2O)n (where m could be different from n). Some exceptions exist; for example, deoxyribose, a sugar component of DNA,[2] has the empirical formula C5H10O4. Carbohydrates are technically hydrates of carbon; structurally it is more accurate to view them as polyhydroxy aldehydes and ketones.

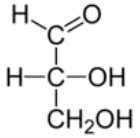
Common Carbohydrates	
Name	Derivation of name and Source
Monosaccharides	
Glucose	From Greek word for sweet wine; grape sugar, blood sugar, dextrose.
Galactose	Greek word for milk--"galact", found as a component of lactose in milk.
Fructose	Latin word for fruit--"fructus", also known as levulose, found in fruits and honey; sweetest sugar.
Ribose	Ribose and Deoxyribose are found in the backbone structure of RNA and DNA, respectively.
Disaccharides - contain two monosaccharides	
Sucrose	French word for sugar--"sucre", a disaccharide containing **glucose and fructose**; table sugar, cane sugar, beet sugar.
Lactose	Latin word for milk--"lact"; a disaccharide found in milk containing **glucose and galactose**.
Maltose	French word for "malt"; a disaccharide containing **two units of glucose**; found in germinating grains, used to make beer.

Common Polysaccharides	
Name	Source
Starch	Plants store glucose as the polysaccharide starch. The cereal grains (wheat, rice, corn, oats, barley) as well as tubers such as potatoes are rich in starch.
Cellulose	The major component in the rigid cell walls in plants is cellulose and is a linear polysaccharide polymer with many glucose monosaccharide units.

Glycogen	This is the storage form of glucose in animals and humans which is analogous to the starch in plants. Glycogen is synthesized and stored mainly in the liver and the muscles.

Ans. B.3

Glyceraldehyde serves as the basis in naming monosaccharides since it is the simplest monosaccharide, having only one asymmetric carbon. (+)-Glyceraldehyde was arbitrarily named the D-enantiomer (the hydroxy group is on the right when drawn as a Fischer Projection). Proof that the structure matched the optical rotation was not obtained until many years later.



D-Glyceraldehyde

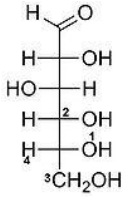
(+) and (-) enantiomers

(+) enantiomers rotate plane-polarized light clockwise (also called dextrorotary, abbreviated *d*), while (-) enantiomers rotate it counter-clockwise (levorotary, or *l*). This must be determined empirically.

D and L enantiomers

D and L enantiomers refer to the configurational stereochemistry of the molecule. L isomers have the hydroxy group attached to the left side of the asymmetric carbon furthest from the carbonyl, while D isomers have the hydroxy group on the right side. Naturally occurring sugars are D isomers. This system of nomenclature is NOT necessarily the same as optical rotation (D and L are not the same as *d* and *l*). In other words, D and L configurations do not fully designate absolute stereochemistry, rather they are determined on the basis of the anomeric carbon center and how its orientation compares to glyceraldehyde, the most basic and simple chiral sugar molecule.

R and S enantiomers



D-Glucose

Like naming sugars based on D and L, the asymmetric carbon furthest the carbonyl is the one that determines the name.

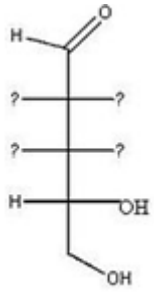
All D sugars are R isomers because they all have the hydroxy group attached to the right of the last asymmetric carbon. By the Cahn-Ingold-Prelog rules for naming stereochemistry, the hydroxy group will always be priority 1, the carbon of the primary alcohol (the terminal carbon) will always be priority 3, the rest of the carbon chain will be priority 2, leaving hydrogen as priority 4 (as shown below). With the hydroxy on the right, the carbon of interest will always be an R isomer.

The example on the right shows D-Glucose with priorities of each substituent numbered. When rotated to view down the C-H bond, the priorities decrease in a clockwise fashion, hence that stereocenter is designated R. However, the enantiomer of D-glucose, the priorities decrease in a counterclockwise fashtion indicating that the stereocenter is designated S.

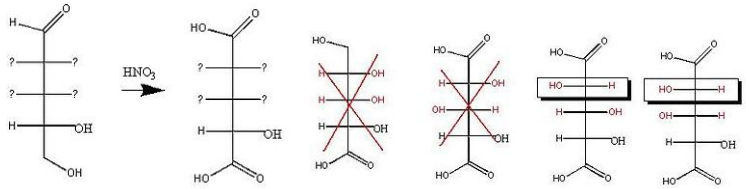
Fischer Stereochemistry Proof

Herman Emil Fischer presented the stereochemical configuration relationship in sugar through a series of experiments with ribose. At the time when this experiment was conducted, all they had was optical rotation to determine stereochemistry. Optical rotation assigns (+) for one enantiomer and (-) for the opposite one. However there were no direct correlations with (+/-) and (R/S) for all chiral sugars. For example, for a particular sugar, the R form may be (+) and the S form (-), but in another sugar, the R may be (-) and the S form (+). Fischer was able to manipulate a series of reactions to assign stereochemistry among sugars. At first he just assumed the penultimate position of the experimental arabinose was in R-configuration. He had a 50/50 chance of picking the correct conformation and if, in the future, the

experimental arabinose turn out to be in L form, all his data is still relatively correct, just inverted. Luckily, the arabinose was later proved to be in D-conformation.

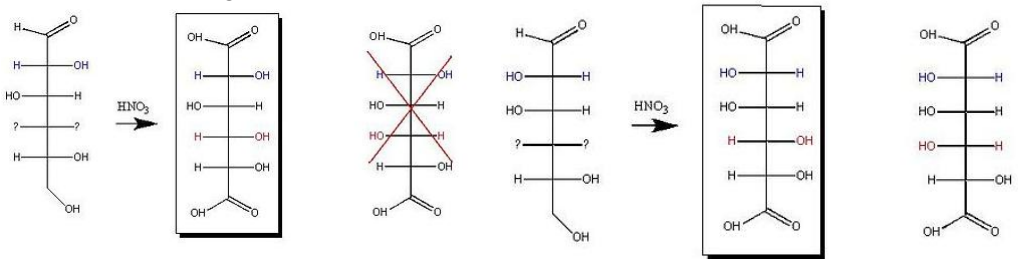


Under the Kiliani-Fischer synthesis condition, arabinose will produce two epimeric sugars, mannose and glucose. Although it remained unknown which one was glucose and which one was mannose.
By adding the HNO¬¬3 to arabinose, arabinose will be oxidized into an optically active aldaric acid. Out of the four possible aldaric acid derivatives from a set R penultimate configuration, two were eliminated because they were not optically active. The two remaining candidates' C2 have the same S stereocenter configuration.

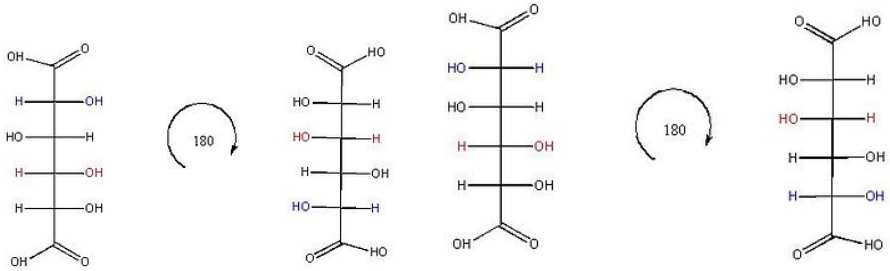


Possible aldaric acid

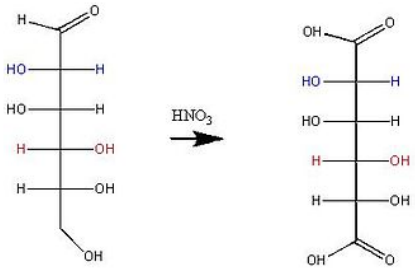
Next, mannose and glucose were oxidized by HCO3. Mannaric acid and glucaric acid were also optically active. With only one unknown stereocenter, there are two possible forms of aldaric acid for each sugar. Out of the four total predictions of glucose and mannose, one of the aldaric acids is meson and therefore cannot be either Mannaric or glucaric acid. Mannaric acid and glucaric acid should have the same stereocenters except for the inverted C2 stereocenter. When one of the models below was rejected, the other model whose C4 is in an S configuration was also rejected. Below, the two circled aldaric acids are mannaric acid and glucaric acid.



The last part of the Fischer proof was to figure out which one is actually glucose. The last clue to Fischer's proof was that, while glucaric acid can be derived from two sugars, mannaric acid can only be derived from the oxidation of mannose, because mannaric acid is rotationally symmetrical.
Glucaric acid:



Mannaric Acid:



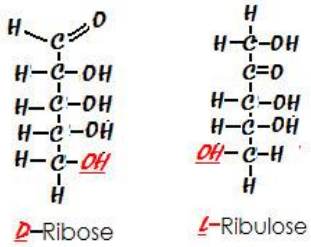
Haworth projection

Haworth projection is used to present cyclic hemiacetals. These followings are steps to convert monosaccharides to cyclic hemiacetals:

1. Choose the position for the oxygen
    1. The oxygen is in the back right-hand corner of the ring (for six-membered ring.)
    2. The oxygen is away from the viewer (for five-membered ring.)
2. The left of the oxygen is C5 with the hydroxymethyl group drawn up.
3. The right of the oxygen is C1 with hydroxyl group drawn up or down depending on the α or β structure.
4. –OH groups on the right side of the Fischer projection is drawn down.
5. –OH groups on the left side of the Fischer projection is drawn up.

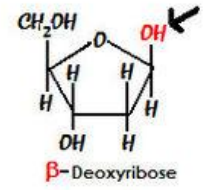
D&L enantiomers

If these positions are switched, you will instead have the L (-) enantiomer of glyceraldehdye. For monosaccharides, D and L will be used as prefixes instead of R and S, respectively, in regards to stereochemistry. The stereochemistry of all other monosaccharides can be determined by comparing their Fischer projections to that of D-(+)-Glyceraldehyde. This can be done by examining the stereocenter in the monosaccharide closest to the terminal carbon (the highest-numbered stereocenter)and comparing its configuration to that of glygeraldehyde. That is, if the hydroxy group is on the right, it will be named D- and if the hydroxy group is on the left it will be named L-. It is important to note that for all monosaccharides other than glyceraldehyde, the labels D and L do not necessarily say anything about its optical rotation. For instance, D-Glucose and D-Gulose have both been assigned the stereochemical label D due to their highest-numbered stereocenter (the chiral center furthest from the carbonyl group) having a hydroxy group on the right in their Fischer projections despite Glucose having a positive (dextro-) optical rotation and Gulose having a negative (levo-) optical rotation.



Alpha vs Beta Anomers

Hexoses and pentoses can convert to cyclic pyranoses or furanoses. As these monosaccharides convert between their linear and cyclic formations, the hydroxyl group on the C5 or C6 carbon can attack on either side of the carbonyl of C1(as shown in image above). If the hydroxyl group is pointed in the opposite direction of the CH2OH group, the ring is in its alpha form. However if it is pointed in the same direction, the ring is in its beta form.



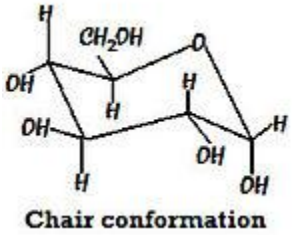
Beta

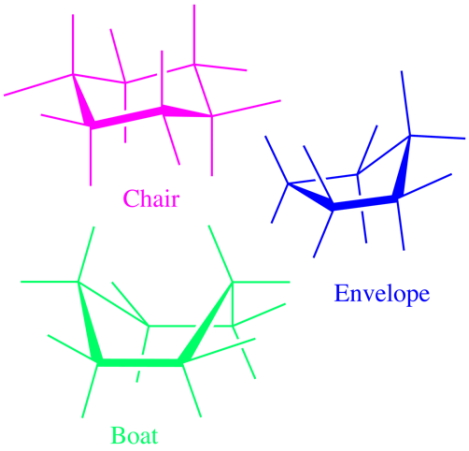
Diastereomers and Epimers

Two non-identical monosaccharides are said to be **diastereomers** if they are of the same type (either both aldoses or both ketoses), have the same stereochemistry at their highest-numbered stereocenter, and have the same number of carbons (i.e. are both tetroses). This is because having the same stereochemistry at their highest-numbered asymmetric carbon ensures that the two non-identical monosachharides will not be mirror images of each other and are therefore not enantiomers. Two monosaccharides that are diastereomers that have differing stereochemistry at only 1 asymmetric carbon (this carbon cannot be the highest-numbered asymmetric carbon) are called **epimers**. For instance, D-Glucose and D-Mannose are both epimers and diastereomers, while D-Glucose and D-Galactose are only diastereomers.

Conformational Isomers

Hexoses and pentoses that have converted into pyranoses or furanoses take on either chair, boat, or envelope conformations due to the tetrahedral geometry of their carbons. Pyranose rings can form either **chair** or **boat** conformational isomers (conformers) while furanose rings take on the **envelope** (also called half-boat) conformation. Substituents on the carbons in the monosaccharides are now either in axial or equatorial positions. The favored conformational isomer will be that which is the least sterically hindered, often containing the majority of its bulkier substituents in equatorial positions, since substituents in axial positions on the same side of the ring create steric hindrance. The chair conformation of pyranose rings can also undergo a **ring flip**, which switches the orientation of substituents from axial to equatorial and vice-versa, to produce an additional conformational isomer. Chair conformation of six-membered rings is most favorable as it reduces steric interference between two carbon substituents. Boat and Envelope conformations do not exist, but are theorized to act as an intermediate structure existing briefly between a ring flip transition in which axial substituents become equatorial and vice versa.





Ans. B.4

The term *secondary structure* refers to the interaction of the hydrogen bond donor and acceptor residues of the repeating peptide unit. The two most important secondary structures of proteins, the alpha helix and the beta sheet, were predicted by the American chemist Linus Pauling in the early 1950s. Pauling and his associates recognized that folding of peptide chains, among other criteria, should preserve the bond angles and planar configuration of the peptide bond, as well as keep atoms from coming together so

closely that they repelled each other through van der Waal's interactions. Finally, Pauling predicted that **hydrogen bonds** must be able to stabilize the folding of the peptide backbone. Two secondary structures, the **alpha helix** and the **beta pleated sheet,** fulfill these criteria well (see Figure). Pauling was correct in his prediction. Most defined secondary structures found in proteins are one or the other type.

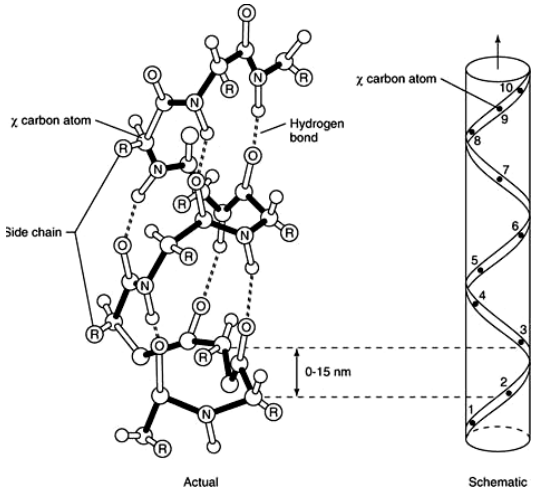
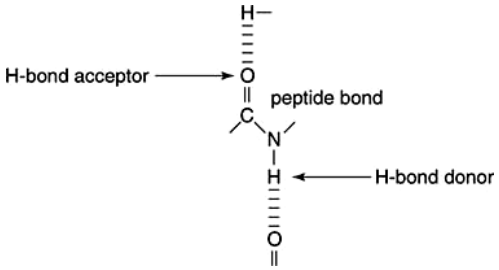


Figure 1

Alpha helix. The alpha helix involves regularly spaced H-bonds between residues along a chain. The amide hydrogen and the carbonyl oxygen of a peptide bond are H-bond donors and acceptors respectively:



The alpha helix is **right-handed** when the chain is followed from the amino to the carboxyl direction. (The helical nomenclature is easily visualized by pointing the thumb of the right hand upwards—this is the amino to carboxyl direction of the helix. The helix then turns in the same direction as the fingers of the right hand curve.) As the helix turns, the carbonyl oxygens of the peptide bond point upwards toward the downward-facing amide protons, making the hydrogen bond. The R groups of the amino acids point outwards from the helix.

Helices are characterized by the number of residues per turn. In the alpha helix, there is not an integral number of amino acid residues per turn of the helix. There are 3.6 residues per turn in the alpha helix; in other words, the helix will repeat itself every 36 residues, with ten turns of the helix in that interval.

Beta sheet. The beta sheet involves H-bonding between backbone residues in adjacent chains. In the beta sheet, a single chain forms H-bonds with its neighboring chains, with the donor (amide) and acceptor (carbonyl) atoms pointing sideways rather than along the chain, as in the alpha helix. Beta sheets can be either parallel, where the chains point in the same direction when represented in the amino- to carboxyl-terminus, or antiparallel, where the amino- to carboxyl- directions of the adjacent chains point in the same direction. (See Figure 2 .)

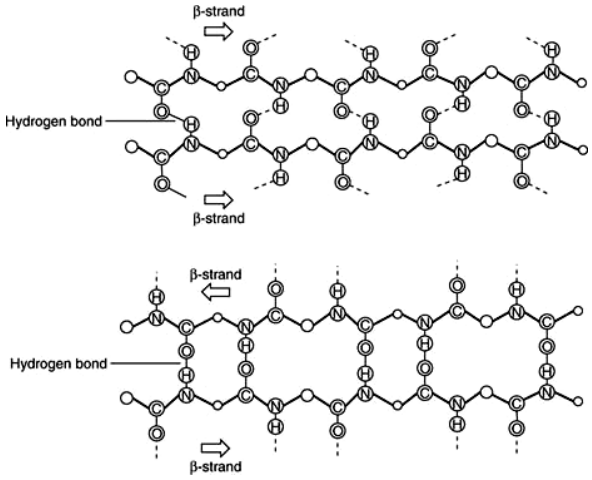


Figure 2

Different amino acids favor the formation of alpha helices, beta pleated sheets, or loops. The primary sequences and secondary structures are known for over 1,000 different proteins. Correlation of these sequences and structures revealed that some amino acids are found more often in alpha helices, beta sheets, or neither. Helix formers include alanine, cysteine, leucine, methionine, glutamic acid, glutamine, histidine, and lysine. Beta formers include valine, isoleucine, phenylalanine, tyrosine, tryptophan, and threonine. Serine, glycine, aspartic acid, asparagine, and proline are found most often in turns.

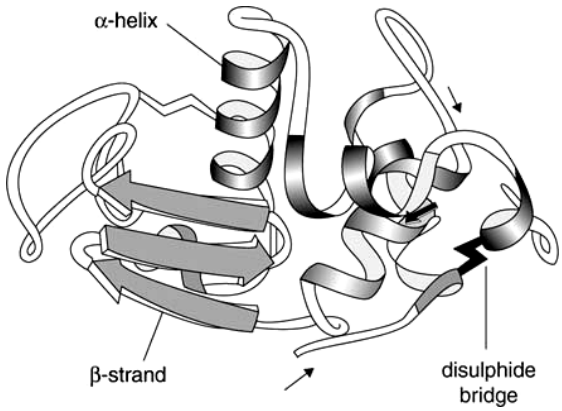
No relationship is apparent between the chemical nature of the amino acid side chain and the existence of amino acid in one structure or another. For example, Glu and Asp are closely related chemically (and can often be interchanged without affecting a protein's activity), yet the former is likely to be found in helices and the latter in turns. Rationalizing the fact that Gly and Pro are found in turns is somewhat easier. Glycine has only a single hydrogen atom for its side chain. Because of this, a glycine peptide bond is more flexible than those of the other amino acids. This flexibility allows glycine to form turns between secondary structural elements. Conversely, proline, because it contains a secondary amino group, forms rigid peptide bonds that cannot be accommodated in either alpha or beta helices.

Fibrous and globular proteins

The large-scale characteristics of proteins are consistent with their secondary structures. Proteins can be either fibrous (derived from fibers) or globular (meaning, like a globe). Fibrous proteins are usually important in forming biological structures. For example, collagen forms part of the matrix upon which cells are arranged in animal tissues. The fibrous protein keratin forms structures such as hair and fingernails. The structures of keratin illustrate the importance of secondary structure in giving proteins their overall properties.

Alpha keratin is found in sheep wool. The springy nature of wool is based on its composition of alpha helices that are coiled around and cross-linked to each other through cystine residues. Chemical reduction of the cystine in keratin to form cysteines breaks the cross-links. Subsequent oxidation of the cysteines allows new cross-links to form. This simple chemical reaction sequence is used in beauty shops and home permanent products to restructure the curl of human hair—the reducing agent accounts for the characteristic odor of these products. Beta keratin is found in bird feathers and human fingernails. The more brittle, flat structure of these body parts is determined by beta keratin being composed of beta sheets almost exclusively.

Globular proteins, such as most enzymes, usually consist of a combination of the two secondary structures—with important exceptions. For example, hemoglobin is almost entirely alpha-helical, and antibodies are composed almost entirely of beta structures. The secondary structures of proteins are often depicted in ribbon diagrams, where the helices and beta sheets of a protein are shown by corkscrews and arrows respectively, as shown in Figure 3 .



Ans. B. 5

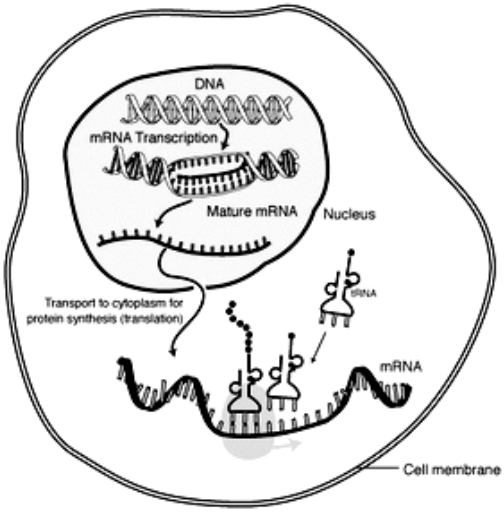
RNA (ribo nucleic acid) is a complex organic compound in living cells that is concerned with protein synthesis. RNA is the genetic material in some viruses that differs from DNA in having ribose in place of deoxyribose.

Most RNA is synthesized in the nucleus and then distributed to various parts of the cytoplasm. An RNA molecule consists of a long chain of nucleotides in which the sugar is ribose and the bases are adenine, cytosine, guanine and uracil.

Three types of RNA are-mRNA (**Messenger RNA**), rRNA (**Ribosomal RNA)** , and tRNA **(Transfer RNA). Messenger RNA** (mRNA) is the class of RNA molecule that serves as messenger between genes (DNA) and protein synthesis.

Messenger RNA (mRNA) carries the coding instructions for polypeptide chains from DNA to the ribosome. After attaching to a ribosome, an m RNA molecules specific the sequence of the amino acids in a polypeptide chain and provides a template for joining amino acids.

- The process of formation of mRNA from DNA template is called transcription
- The process of formation of protein from DNA mRNA is called translation



Transfer RNA (tRNA) is the class of RNA molecules that carry amino acids to the ribosome for protein synthesis.

It serves as the link between the coding sequence of nucleotides in the mRNA and the amino acid sequence of a polypeptide chain. Each tRNA attaches to one particular type of amino acid and helps to incorporate that amino acid into a polypeptide chain.

Messenger RNA (mRNA) and Transfer RNA (tRNA)
Messenger RNA
1. Location of function in eukaryotic cell- Nucleus and cytoplasm
2. Functions- carries genetic code for proteins.

Transfer RNA
1. Location of function in eukaryotic cell- Cytoplasm.
2. Functions- Helps incorporate amino acids into polypeptide chain.

Ans. B.6
We can classify vitamins into two main categories, 1)fat-soluble, and 2)water-soluble. Being soluble simply means having the ability to dissolve in. Therefore, fat-soluble vitamins can dissolve in fat, and water-soluble vitamins have the ability to dissolve in water. By dissolving in water or fat, vitamins can then be absorbed by, transported into, and utilised by the body.
The fat-soluble vitamins include vitamins A, D, E, and K. The fat-soluble vitamins tend to be stored in the body in moderate amounts compared to water-soluble vitamins, and they are not normally excreted in the urine.

Water-soluble vitamins are all the vitamins that are soluble in water (ie., all but A, D, E, and K, which are fat-soluble). Basically, the water-soluble vitamin group contains all the vitamins other than A, D, E, and K. The water-soluble vitamins are excreted in the urine, compared with the fat-soluble vitamins, which are not. The other main difference between the two groups is the water-soluble vitamins are not stored in the body in any appreciable amount. Already, you have some useful information. By knowing that water-soluble vitamins are not stored in the body, we then realize that we must replenish these vitamins often.

Each vitamin is designated by its own letter. Denoting a particular vitamin by a letter makes it both easy to identify and of course, quicker to write. For example, ascorbic acid is given the letter "C". These designations are less cumbersome, yet still convey the vitamin. Let's construct a simple list some of the common vitamins that we may have heard of, and their letter designations.

vitamin A - this is a collective term for retinol and related compounds.
vitamin B complex - A group of more than a dozen water-soluble substances.

vitamin C - ascorbic acid
vitamin D - ergocalciferol
vitamin E - tocopherol and other related compounds with antioxidant activity.
vitamin K - phytonadione and others in this group of structurally related compounds which promote blood clotting

Vitamin A: Retinol

Vitamin A, also called retinol, has many functions in the body. In addition to helping the eyes adjust to light changes, vitamin A plays an important role in bone growth, tooth development, reproduction, cell division, gene expression, and regulation of the immune system. The skin, eyes, and mucous membranes of the mouth, nose, throat and lungs depend on vitamin A to remain moist. Vitamin A is also an important antioxidant that may play a role in the prevention of certain cancers.

Food Sources for Vitamin A

Eating a wide variety of foods is the best way to ensure that the body gets enough vitamin A. The retinol, retinal, and retinoic acid forms of vitamin A are supplied primarily by foods of animal origin such as dairy products, fish and liver. Some foods of plant origin contain the antioxidant, betacarotene, which the body converts to vitamin A. Beta-carotene, comes from fruits and vegetables, especially those that are orange or dark green in color. Vitamin A sources also include carrots, pumpkin, winter squash, dark green leafy vegetables and apricots, all of which are rich in beta-carotene.

Vitamin D

Vitamin D plays a critical role in the body's use of calcium and phosphorous. It works by increasing the amount of calcium absorbed from the small intestine, helping to form and maintain bones. Vitamin D benefits the body by playing a role in immunity and controlling cell growth. Children especially need adequate amounts of vitamin D to develop strong bones and healthy teeth.

Food Sources for Vitamin D

The primary food sources of vitamin D are milk and other dairy products fortified with vitamin D. Vitamin D is also found in oily fish (e.g., herring, salmon and sardines) as well as in cod liver oil. In addition to the vitamin D provided by food, we obtain vitamin D through our skin which produces vitamin D in response to sunlight.

Vitamin E: Tocopherol

Vitamin E benefits the body by acting as an antioxidant, and protecting vitamins A and C, red blood cells, and essential fatty acids from destruction. Research from decades ago suggested that taking antioxidant supplements, vitamin E in particular, might help prevent heart disease and cancer. However, newer findings indicate that people who take antioxidant and vitamin E supplements are not better protected against heart disease and cancer than non-supplement users. Many studies show a link between regularly eating an antioxidant rich diet full of fruits and vegetables, and a lower risk for heart disease, cancer, and several other diseases. Essentially, recent research indicates that to receive the full benefits of antioxidants and phytonutrients in the diet, one should consume these compounds in the form of fruits and vegetables, not as supplements.

Food Sources for Vitamin E

About 60 percent of vitamin E in the diet comes from vegetable oil (soybean, corn, cottonseed, and safflower). This also includes products made with vegetable oil (margarine and salad dressing). Vitamin E sources also include fruits and vegetables, grains, nuts (almonds and hazelnuts), seeds (sunflower) and fortified cereals.

Vitamin K

Vitamin K is naturally produced by the bacteria in the intestines, and plays an essential role in normal blood clotting, promoting bone health, and helping to produce proteins for blood, bones, and kidneys.

Food Sources for Vitamin K

Good food sources of vitamin K are green, leafy-vegetables such as turnip greens, spinach, cauliflower, cabbage and broccoli, and certain vegetables oils including soybean oil, cottonseed oil, canola oil and olive oil. Animal foods, in general, contain limited amounts of vitamin K.

Ans. B. 7

Pure fatty acids form crystals that consist of stacked layers of molecules, with each layer the thickness of two extended molecules. The molecules in a layer are arranged so that the hydrophobic (water-fearing) hydrocarbon chains form the interior of the layer and the hydrophilic (water-loving) carboxylic acid groups

form the two faces. For a specific fatty acid the details of the molecular packing may vary, giving rise to different crystal forms termed polymorphs.

The melting temperatures of saturated fatty acids of biological interest are above 27 °C (81 °F) and rise with increasing length of the hydrocarbon chain. Monounsaturated and polyunsaturated molecules melt at substantially lower temperatures than do their saturated analogs, with the lowest melting temperatures occurring when the carbon-carbon double bonds are located near the centre of the hydrocarbon chain, as they are in most biological molecules. As a result, these molecules form viscous liquids at room temperature.

The hydrophobic character of the hydrocarbon chain of most biological fatty acids exceeds the hydrophilic nature of the carboxylic acid group, making the water solubility of these molecules very low. For example, at 25 °C (77 °F) the solubility in grams of fatty acid per gram of solution is 3×10^{-6}. Water solubility decreases exponentially with the addition of each carbon atom to the hydrocarbon chain. This relationship reflects the energy required to transfer the molecule from a pure hydrocarbon solvent to water. With each CH_2 group, for instance, more energy is required to order water molecules around the hydrocarbon chain of the fatty acid, which results in the hydrophobic effect.

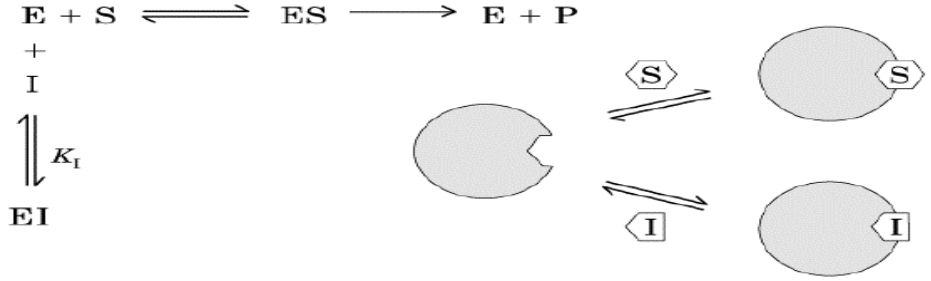
In pure water the carboxylate group can dissociate a positively charged hydrogen ion to only a very small degree thus: $R{-}COOH \rightarrow RCOO^- + H^+$.

Here R represents the hydrocarbon chain. The carboxylate ion, bearing a negative charge, is more polar than the undissociated acid. RCOOH can be converted completely to the ion $RCOO^-$ by adding an equal number of molecules of a base such as sodium hydroxide (NaOH). This effectively replaces the H^+ with Na^+ to give the salt of the fatty acid, which is a soap. The very useful detergent property of soaps stems from the fact that the $RCOO^-$ anions in water spontaneously form stable, spherical aggregates called micelles, the general structure of which is shown in cross section in the figure. The interior of these structures, formed by the hydrocarbon chains, is an excellent solvent in which grease and hydrophobic dirt of all sorts can be sequestered. The diameter of each micelle is roughly twice the length of the extended fatty acid. Dispersions of micelles in water can be made quite concentrated and exhibit great cleansing power. These dispersions are stable and generally look very much like pure water. Bubbles and foams on the surface of soap dispersions are the result of the spontaneous adsorption of $RCOO^-$ ions at the interface between the aqueous dispersion and air, with the result that the air-water interfaces are energetically stabilized and can therefore be mechanically expanded.

Ans. B. 8

An enzyme inhibitor is a molecule that binds to an enzyme and decreases its activity. Since blocking an enzyme's activity can kill a pathogen or correct a metabolic imbalance, many drugs are enzyme inhibitors. They are also used as herbicides and pesticides. Not all molecules that bind to enzymes are inhibitors; *enzyme activators* bind to enzymes and increase their enzymatic activity, while enzyme substrates bind and are converted to products in the normal catalytic cycle of the enzyme

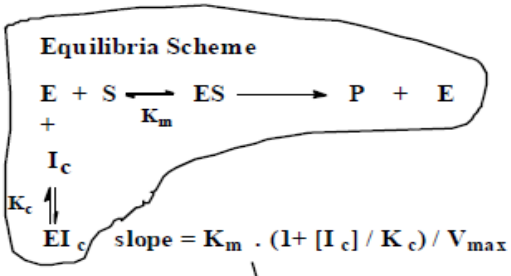
Competitive Inhibition

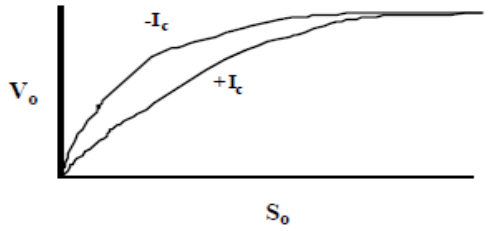


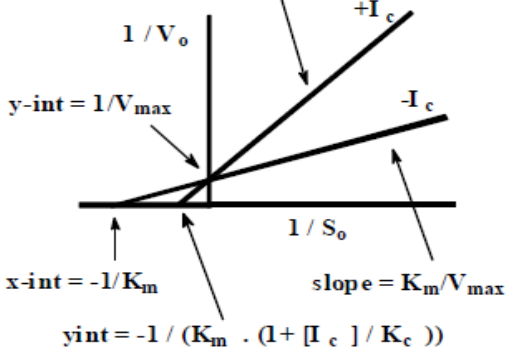
(a) Competitive inhibition

COMPETITIVE

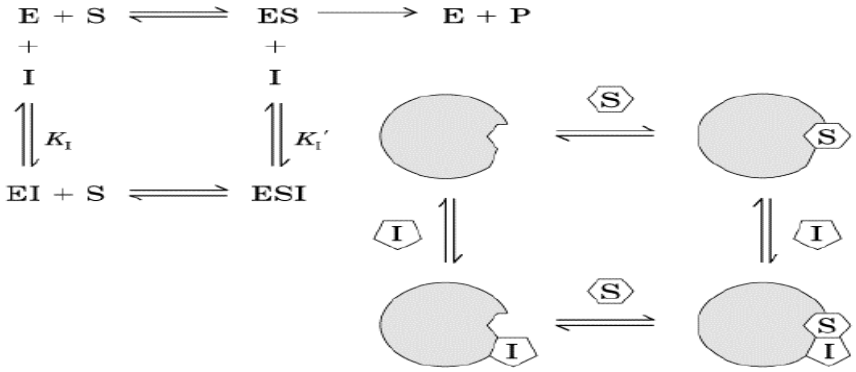
- $-I_c$ structrually resembles S, but is not an S
- $-I_c$ binds to free E at active site where S binds
- $-I_c$ competes with S for free E
- High S overcomes inhibition because all E is bound in ES complex; since rate [ES] and [ES] is max, rate is max; no EI_c is present







Noncompetitive Inhibition

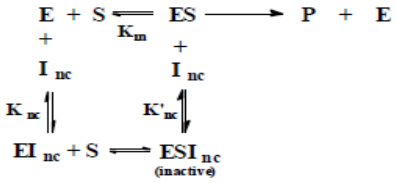


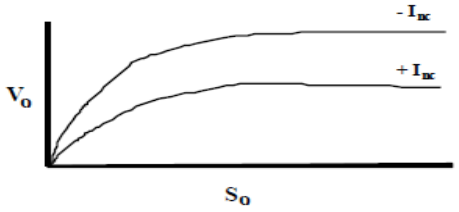
(c) Mixed inhibition

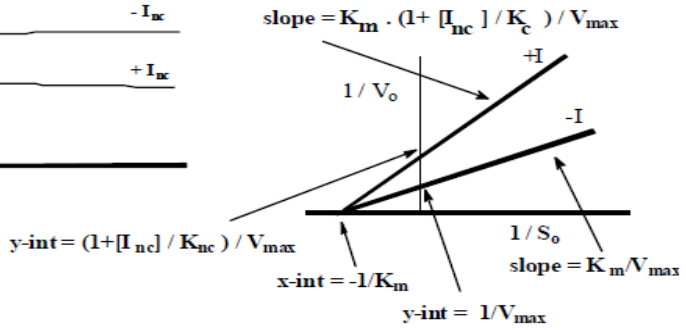
NONCOMPETITIVE

- $-I_{nc}$ is not structurally similar to S; is not an S
- $-I_{nc}$ binds to free E or ES at a site where S does not bind
- $-I_{nc}$ does NOT compete with S for free E
- High S cannot overcome inhibition because I_{nc} binds to ES complex, inactivating it

Equilibria Scheme

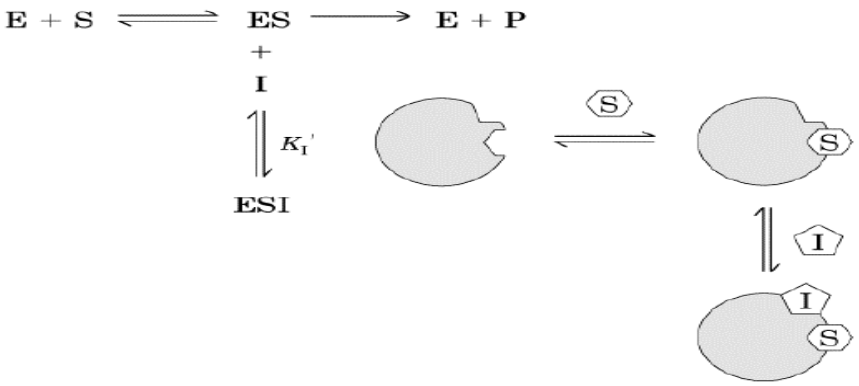






Uncompetitive Inhibition

This type of inhibition requires that one or more substrates bind to E before the inhibitor can bind



(b) Uncompetitive inhibition

This type of inhibition requires that one or more substrates bind to E before the inhibitor can bind

UNCOMPETITIVE

- $-I_u$ is not structurally similar to S; is not an S
- $-I_u$ binds to ES only; S opens up a site for I^u
- $-I_u$ binding site may be in active site but binding of I^u requires prior binding of S
- High S cannot overcome inhibition because presence of S is required to provide a site for binding of I^u

Equilibria Scheme