

COURSE CODE:	ANN 202
COURSE TITLE:	Introductory Animal Biochemistry
NUMBER OF UNITS:	3 Units
COURSE DURATION:	3 Hours

COURSE DETAILS:

Course Coordinator:	Dr. Adebayo Olusoji Oni
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Other Lecturers:	Prof. daisy Eruvbetine, Dr Olubukola Ajike Isah, Dr. Adebayo Vincent Jegede, Dr. Funmilayo Lala

COURSE CONTENT:

Chemical composition of plant and animal bodies. Classification, properties and functions of carbohydrates, proteins, fats, mineral and vitamins. The simple chemistry and metabolism of carbohydrates. The simple chemistry and metabolism of proteins. The simple chemistry and metabolism of fats. The simple chemistry and metabolism of minerals and vitamins

Practicals:

Testing of carbohydrates, Acidic hydrolysis of starch (Polysaccharides), Tests for lipids – Saturated and unsaturated, Tests for Proteins, Proximate analysis of plant and animal Products.

COURSE REQUIREMENTS:

This is a compulsory course for all Agricultural and some non-agricultural students in their second year in the University. This course is being offered in lecture format on-campus for 14 weeks, students are expected to attend lectures and practical classes, 3 hours of lecture per week. Students are expected have minimum of 75% attendance to be able to write the final examination.

The course grade will be based on 1 exams, CAT and practical work.

LECTURE NOTES

CHEMICAL COMPOSITION OF PLANT AND ANIMAL BODIES

Plant and Animal bodies consists of:

Water

Organic acids (carbohydrates, lipids, proteins, complexes of lipids, proteins and carbohydrates, Nucleic acids and vitamins)

Inorganic salts (minerals)

Water

Constitutes 50% -60% of body mass of adult animals, higher amount is found in newborns.

Functions of water are 2 fold:

(a) It performs a key role in body metabolism since all biochemical reactions in the body require water.

Water acts as a solvent, a transport medium for dissolved substances in blood, tissue fluids etc.

It is a component in many chemical reactions such as hydrolysis and oxidation

(b) It also helps in maintaining body temperature through evaporative cooling, blood flow etc.

In animals, water is supplied as:

Drinking water

Water in feeds

Water from metabolic reactions e.g. water associated with fat or protein breakdown (negative energy balance).

In plants, water is absorbed from:

The soil or

The atmosphere.

Carbohydrates

Carbohydrates composed of carbon, hydrogen and oxygen and are often known as sugars.

They are classified into various groups based upon number of sugar molecules that are linked together.

Monosaccharides (one molecule)

Pentoses (5 carbons): e.g.

$C_5H_{10}O_5$ - arabinose, xylose, ribose.

Hexoses (6 carbons): e.g.

$C_6H_{12}O_6$ - glucose, fructose, galactose

While we represent ribose as $C_5H_{10}O_5$ or glucose $C_6H_{12}O_6$. In actuality they are ring structures.

Disaccharides: (2 monosaccharides linked together)

$C_{12}H_{22}O_{11}$ (note loss of one H_2O)

Sucrose (glucose+ fructose)

Lactose (glucose + galactose)

Cellobiose (glucose+ glucose)

Trisaccharides: (3 monosaccharides linked together)

$C_{18}H_{32}O_{16}$ (note loss of one more H_2O)

Raffinose (glucose+ fructose+ galactose)

Polysaccharides

Many pentoses or hexoses linked together

Xylan: (xylose-----xylose)

Starch: (glucose-----glucose) alpha linked

Cellulose: (glucose -----glucose) beta linked

Functions of carbohydrates:

It provides cells with energy.

It gives structural support for living plants.

They are major constituents of plant and animal tissues.

Supply carbon for biosynthesis

Storage of chemical energy

Cellulose has no nutritive value because it cannot be digested by humans, but it is essential for bulk fiber movement to eliminate waste from the gut..

Lipids

The term lipid comprises of a diverse range of molecules.

They are relatively water-insoluble or nonpolar compounds of biological origin.

They including waxes, fatty acids, fatty acid- derived phospholipids, sphingolipids, glycolipids and terpenoids (eg. retinoids and steroids).

Some lipids are linear aliphatic molecules, while others have ring structures.

Some are aromatic, while others are not.

Some are flexible, while others are rigid.

Lipids are an integral part of our daily diet.

Most oils and milk products that we use for cooking and eating like butter, cheese, ghee etc, are comprised of fats.

Vegetable oils are rich in various polyunsaturated fatty acids (PUFA).

Lipid-containing foods undergo digestion within the body and are broken into fatty acids and glycerol.

These are the final degradation products of fats and lipids.

Most lipids have some polar character in addition to being largely non polar.

Generally, the bulk of their structure is non polar or hydrophobic ("water-fearing"), meaning that it does not interact well with polar solvents like water.

Another part of their structure is polar or hydrophilic ("water-loving") and will tend to associate with polar solvents like water.

This makes them amphiphilic molecules (having both hydrophobic and hydrophilic properties).

In the case of cholesterol, the polar group is a mere -OH (hydroxyl or alcohol).

In the case of phospholipids, the polar groups are considerably larger and more polar.

Simplest fatty acid is a 2 carbon structure: e.g. (acetic acid - CH_3COOH .)

Longest is 24 carbons in length. e. g. $\text{CH}_3\text{CH}_2\text{CH}_2\text{-----COOH}$.

(1) **Fatty acids** may be:

Saturated (no double bonds) -C-C-C-C

Monounsaturated (one double bond) -C-C=C- or

Polyunsaturated (more than one double bond) -C=C=C-C

(2) **Glycerol** structure is:

HOCH₂

1

HOCH

1

HOCH₂

Mono, di and tri glycerides are esters of fatty acids and glycerol e g

Monoglyceride:

HOCH₂

1

HOCH

1

Fatty acid-----OCH₂

Diglyceride:

HOCH₂

1

Fatty acid-----OCH

1

Fatty acid-----OCH₂

Phospholipids

The only difference between triglycerol and phospholipids is that one of the hydroxyl groups of the glycerol is linked to a phosphate.

Steroids:

Steroids are composed of four interconnected carbon rings.

They are soluble in water due to their polarity, e.g. sex hormones such as testosterone and oestrogen.

Lipids have 5 major functions:

Supply of energy

Source of essential fatty acids (linoleic and linolenic)

They carry fat soluble vitamins

They are component of membranes.

They are components and precursors of hormones and vitamin D.

Proteins

Proteins consist of amino-acids linked together in chains through peptide bonds.

An amino acid consists of a carbon atom bound to four groups:

- 1) One is an amino group, —NH_2
- 2) One is a carboxylic acid group, —COOH (although these exist as —NH_3^+ and —COO^- under physiologic conditions).
- 3) The third is a simple hydrogen atom.
- 4) The fourth is commonly denoted " —R " and is different for each amino acid.

The Simplest structure is:

Glycine: $\text{NH}_2.\text{CH}_2.\text{COOH}$

Next would be:

Alanine: $\text{CH}^3.\text{NH}_2.\text{CH}.\text{COOH}$

There are twenty standard amino acids.

Some of these have functions by themselves or in a modified form; for instance, glutamate functions as an important neurotransmitter.

The structure of proteins is traditionally described in a hierarchy of four levels.

The **primary structure** of a protein simply consists of its linear sequence of amino acids; for instance, "alanine-glycine-tryptophan-serine-glutamate-asparagine-glycine-lysine-...".

The **Secondary structure** is concerned with local morphology.

Some combinations of amino acids will tend to curl up in a coil called an α -helix or into a sheet called a β -sheet;

Some α -helices can be seen in the hemoglobin schematic.

The **Tertiary structure** is the entire three-dimensional shape of the protein.

This shape is determined by the sequence of amino acids.

In fact, a single change can change the entire structure.

The alpha chain of haemoglobin contains 146 amino acid residues; Substitution of the glutamate residue at position 6 with a Valine residue changes the behavior of hemoglobin so much that it results in sickle-cell disease.

Finally **quaternary structure** is concerned with the structure of a protein with multiple peptide subunits, like hemoglobin with its four subunits.

Ingested proteins are usually broken up into single amino acids or dipeptides in the small intestine, and then absorbed.

They can then be joined together to make new proteins.

Intermediate products of glycolysis, in the citric acid cycle, and the pentose phosphate pathway can be used to make all twenty amino acids,

Most bacteria and plants possess all the necessary enzymes to synthesize them.

Humans and other mammals, however, can only synthesize half of them.

They cannot synthesize isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.

These are the **essential amino acids**, since it is essential to ingest them.

Mammals do possess the enzymes to synthesize alanine, asparagine, aspartate, cysteine, glutamine, glycine, proline, serine, and tyrosine.

These are **nonessential amino acids**.

While they can synthesize arginine and histidine, they cannot produce it in sufficient amounts for young, growing animals, and so these are often considered **essential amino acids**.

Proteins play key role as:

Body components (blood, muscle etc.)

Catalysts of chemical reactions (enzymes)

Direct biochemical effects on metabolism, synthesis and immunity (constituent of peptides, hormones, antibodies)

Can be an energy source

Other organic compounds

Other organic compounds in plant and animal bodies include:

Protein- lipid complexes (Lipoproteins)

Protein- carbohydrate complexes (Glycoproteins)

Nucleic acids

Protein- lipid complexes (Lipoproteins)

Found in egg yolk and membrane proteins of animal cells. These membranes are composed of proteins, lipids and carbohydrates in various proportions.

Myelin is a lipoprotein abundant in the nervous system as a sheath around the nerve fibre.

Protein- carbohydrate complexes (Glycoproteins)

Proteins can complex with carbohydrates to form glycoproteins.

These complexes arise from the acceptance of sugars by amino acid residues in the poly-peptide chain.

Mucoproteins are complexes of proteins with amino sugars, glycosamine and galactosamine.

Nucleic acids

Nucleic acids store, transmit and expresses genetic information.

Nucleic acids are composed of subunits called nucleotides.

Nucleotides contain a phosphate group, a sugar and a ring of carbon and nitrogen atoms.

Two types:

DNA (Deoxyribonucleic acid)

These store genetic information in the sequence of the nucleotide subunits.

DNA nucleotides contain a five carbon sugar called deoxyribose. A DNA molecule looks like a double helix.

RNA (Ribonucleic acid)

RNA uses the information in DNA to write the instructions for linking together specific sequence of amino acids in order to form polypeptides per original DNA instruction.

RNA is a single chain of nucleotides. It contains the sugar ribose.

Vitamins :

They are required in small amounts for metabolism and health and can be classified as fat soluble and water soluble.

Fat soluble - vitamins A,D,E and K

Water soluble - B1, B2, B6, B12, niacin, C. etc.

The following are lipid soluble vitamins with their major functions:

A Carotene or Retinol - skin and vision

D Calciferol - works with parathormone; bone calcium

E Tocopherol - RBC membranes

K Naphthoquinone -liver coenzyme; some plasma protein synthesis

The following are water soluble vitamins with their related functions:

B1 - Thiamine - coenzyme in decarboxylation; handling one C units

B2 Riboflavine - coenzyme FAD; H₂ transport in Kreb's cycle

Niacin- coenzymes NAD, NADP; H₂ transport in Kreb's cycle

B₆ Pyridoxine - coenzyme in fat and amino acid metabolism. Deficiency causes nervous disorders and dermatitis

B₁₂ - Cyanocobalamin - coenzyme in nucleoprotein synthesis; Anemia nerve regeneration

Folic acid - coenzyme in nucleoprotein synthesis; anemia

Pantothenic acid - coenzyme A; 2C units as in acetate

Biotin - protein synthesis

C - Ascorbic acid - coenzyme in protein synthesis; collagen synthesis

Minerals

Minerals are inorganic elements that originate in the earth and cannot be made in the body. They play important roles in various body functions

They are necessary to sustain life and maintain optimal health, and thus are essential **nutrients**.

Most of the minerals in the human **diet** come directly from plants and water, or indirectly from animals.

However, the mineral content of water and plant foods varies geographically because of variations in the mineral content of soil from region to region.

The amount of minerals present in the body, and their **metabolic** roles, varies considerably.

Minerals provide structure to bones and teeth and participate in **energy** production, the building of **protein**, blood formation, and several other metabolic processes.

Minerals are categorized into **major** and **trace** minerals, depending on the amount needed per day.

Major minerals are those that are required in the amounts of 100 mg (milligrams) or more per day while trace minerals are required in amounts less than 100 mg per day.

The terms *major* and *trace*, however, do not reflect the importance of a mineral in maintaining health, as a deficiency of either can be harmful.

Some body processes require several minerals to work together. For example, **calcium**, magnesium, and **phosphorus** are all important for the formation and maintenance of healthy bones.

Some minerals compete with each other for **absorption**, and they interact with other nutrients as well, which can affect their **bioavailability**.

Mineral Bioavailability

The degree to which the amount of an ingested nutrient is absorbed and available to the body is called bioavailability.

Mineral bioavailability depends on several factors:

Higher absorption occurs among individuals who are deficient in a mineral, while some elements in the diet (e.g., oxalic acid or oxalate in spinach) can decrease mineral availability by chemically binding to the mineral.

In addition, excess intake of one mineral can influence the absorption and metabolism of other minerals. For example, the presence of a large amount of **zinc** in the diet decreases the absorption of **iron** and **copper**.

On the other hand, the presence of **vitamins** in a meal enhances the absorption of some minerals in the meal. For example, **vitamin C** improves iron absorption, and **vitamin D** aids in the absorption of calcium, phosphorous, and magnesium.

In general, minerals from animal sources are absorbed better than those from plant sources. This is because minerals are present in forms that are readily absorbed and binders that inhibit absorption, such as **phytates**, are absent.

Major Minerals

The major minerals present in the body include:

Sodium,

Potassium,

Chloride,

Calcium,

Magnesium,

Phosphorus,

and Sulphur.

Functions

The fluid balance in the body that is vital for all life processes, is maintained largely by sodium, potassium, and chloride.

Fluid balance is regulated by charged sodium and chloride ions in the extracellular fluid (outside the cell) and potassium in the intracellular fluid (inside the cell), and by some other **electrolytes** across cell membranes.

Sodium plays an important role in the absorption of other nutrients, such as **glucose**, **amino acids**, and water.

Chloride is a component of hydrochloric acid, an important part of **gastric** juice (an acidic liquid secreted by glands in the stomach lining) and aids in food digestion.

Potassium and sodium act as cofactors for certain **enzymes**.

Calcium, magnesium, and phosphorus are known for their structural roles, as they are essential for the development and maintenance of bones and teeth.

They are also needed for maintaining cell membranes and connective tissue.

Several enzymes, **hormones**, and proteins that regulate energy and **fat** metabolism require calcium, magnesium and/or phosphorus to become active.

Calcium also aids in **blood clotting**. Sulphur is a key component of various proteins and vitamins and participates in drug-detoxifying pathways in the body.

Toxicity

Toxicity from excessive dietary intake of major minerals rarely occurs in healthy individuals.

Kidneys that are functioning normally can regulate mineral concentrations in the body by excreting the excess amounts in urine.

Toxicity symptoms from excess intakes are more likely to appear with **acute** or chronic kidney failure.

Sodium and chloride toxicity can develop due to low intake or excess loss of water.

Accumulation of excess potassium in **plasma** may result from the use of potassium-sparing diuretics (medications used to treat high blood pressure, which increase urine production, excreting sodium but not potassium)

Magnesium intake from foods has no adverse effects, but a high intake from supplements when kidney function is limited increases the risk of toxicity.

The most serious complication of potassium or magnesium toxicity is cardiac arrest. Adverse effects from excess calcium have been reported only with consumption of large quantities of supplements.

Phosphate toxicity can occur due to absorption from phosphate salts taken by mouth or in **enemas**.

Trace Minerals

Trace minerals are present (and required) in very small amounts in the body.

The most important trace minerals are iron, zinc, copper, chromium, fluoride, iodine, selenium, manganese, and molybdenum.

Some others, such as arsenic, boron, cobalt, nickel, silicon, and vanadium, are recognized as essential for some animals.

While others, such as barium, bromine, cadmium, gold, silver, and aluminum, are found in the body, though little is known about their role in health.

Functions of Trace Minerals

Trace minerals have specific **biological** functions.

They are essential in the absorption and utilization of many nutrients and aid enzymes and hormones in activities that are vital to life.

Iron plays a major role in **oxygen** transport and storage and is a component of **hemoglobin** in red blood cells and **myoglobin** in muscle cells.

Cellular energy production requires many trace minerals, including iron, copper, and zinc, which act as enzyme cofactors in the synthesis of many proteins, hormones, neurotransmitters, and genetic material.

Iron and zinc support immune function, while chromium and zinc aid insulin action. Zinc is also essential for many other bodily functions, such as growth, development of sexual organs, and reproduction.

Zinc, copper and selenium prevent **oxidative** damage to cells.

Fluoride stabilizes bone mineral and hardens tooth enamel, thus increasing resistance to tooth decay.

Iodine is essential for normal thyroid function, which is critical for many aspects of growth and development, particularly brain development.

Thus, trace minerals contribute to physical growth and mental development.

Role in disease prevention and treatment

In addition to clinical deficiency diseases such as anemia and goiter, research indicates that trace minerals play a role in the development, prevention, and treatment of chronic diseases.

Iron, zinc, copper, and selenium have been associated with immune response conditions.

Copper, chromium and selenium have been linked to the prevention of cardiovascular disease.

Excess iron in the body, on the other hand, can increase the risk of cardiovascular disease, liver and colorectal cancer, and neurodegenerative diseases such as Alzheimer's disease.

Chromium supplementation has been found to be beneficial in many studies of impaired glucose tolerance, a metabolic state between normal glucose regulation and diabetes.

Fluoride has been known to prevent dental **caries** and osteoporosis

While potassium iodide supplements taken immediately before or after exposure to radiation can decrease the risk of radiation-induced thyroid cancer.

Carbohydrate

DEFINITION: carbohydrates are derivative of aldehydes and ketones. They are polyhydroxyl in nature. On hydrolysis they yield these compounds

Carbohydrates are grouped into 4 main classes: Monosaccharides, Disaccharides, Oligosaccharides and Polysaccharides.

Monosaccharides

Monosaccharides are the most basic units of biologically important carbohydrates. They are the simplest form of sugar and are usually colorless, water-soluble, crystalline solids. Some monosaccharides have a sweet taste. Examples of monosaccharides include glucose (dextrose), fructose (levulose), galactose, xylose and ribose. Monosaccharides are the building blocks of disaccharides such as sucrose and polysaccharides (such as cellulose and starch). Further, each carbon atom that supports a hydroxyl group (except for the first and last) is chiral, giving rise to a number of isomeric forms all with the same chemical formula. For instance, galactose and glucose are both aldohexoses, but have different chemical and physical properties.

Monosaccharides can be categorized according to their value of 'n,' (number of carbon atom) as shown below:

n	Category
3	Triose
4	Tetrose
5	Pentose
6	Hexose
7	Heptose
8	Octose

Monosaccharides can exist as aldehydes (CHO or H C=O) or ketones (CO or C=O) and are called **aldoses** or **ketoses**, respectively. For example, below are the structures of **glyceraldehyde**, an aldo-triose, and **dihydroxyacetone**, a **keto-triose**. Glyceraldehyde and dihydroxyacetone have the same atomic composition, but differ only in the position of the hydrogens and double bonds.

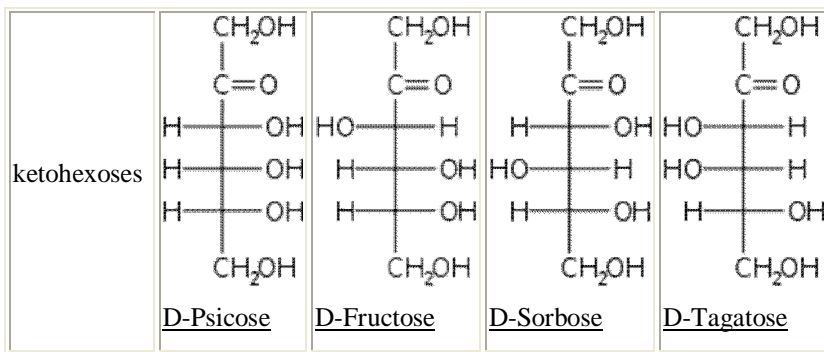
Carbons in a monosaccharide are numbered such that the aldehyde group is carbon number one or the ketone group is carbon number two.

Aldoses	
Aldotriose	$ \begin{array}{c} \text{H} \\ \diagdown \\ \text{C}=\text{O} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Glyceraldehyde</u></p>
Aldotetroses	$ \begin{array}{c} \text{H} \\ \diagdown \\ \text{C}=\text{O} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Erythrose</u></p>
	$ \begin{array}{c} \text{H} \\ \diagdown \\ \text{C}=\text{O} \\ \\ \text{OH}-\text{C}-\text{H} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Threose</u></p>

Aldopentoses	$ \begin{array}{c} \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{O} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Ribose</u></p>	$ \begin{array}{c} \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{O} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Arabinose</u></p>	$ \begin{array}{c} \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{O} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Xylose</u></p>	$ \begin{array}{c} \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{O} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Lyxose</u></p>		
	Aldohexoses	$ \begin{array}{c} \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{O} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Glucose</u></p>	$ \begin{array}{c} \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{O} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Mannose</u></p>	$ \begin{array}{c} \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{O} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Gulose</u></p>	$ \begin{array}{c} \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{O} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Idose</u></p>	$ \begin{array}{c} \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{O} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Galactose</u></p>

Ketoses

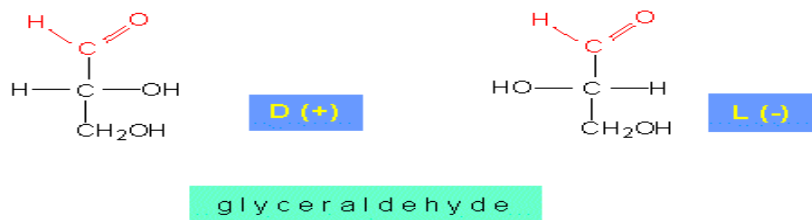
Ketotriose	$ \begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{C}=\text{O} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>Dihydroxyacetone</u></p>
ketotetrose	$ \begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{C}=\text{O} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Erythrulose</u></p>
ketopentoses	$ \begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{C}=\text{O} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Ribulose</u></p>
	$ \begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{C}=\text{O} \\ \\ \text{HO} - \text{C} - \text{H} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $ <p><u>D-Xylulose</u></p>



Isomerism

The total number of **possible stereoisomers of one compound (n)** is dependent on the **number of stereogenic centers (c) in the molecule**. The upper limit for the number of possible stereoisomers is $n = 2^c$. The only monosaccharide without an isomer is dihydroxyacetone or DHA.

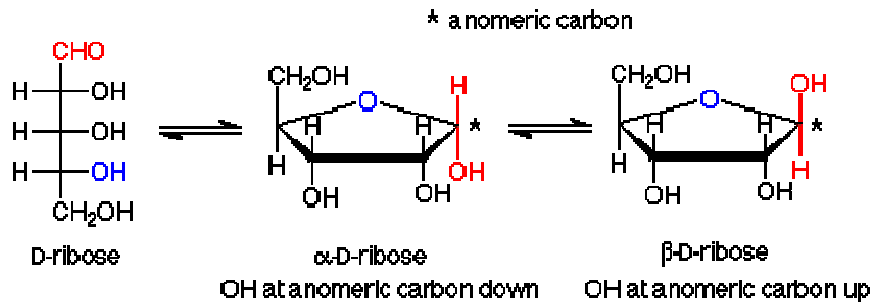
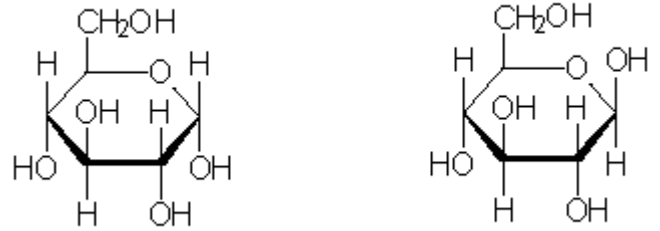
Monosaccharides are classified according to their molecular configuration at the chiral carbon furthest removed from the aldehyde or ketone group. The chirality at this carbon is compared to the chirality of carbon 2 on glyceraldehyde or the penultimate chiral carbon of any monosaccharide. If it is the OH of the penultimate carbon rotate to the right equivalent to D-glyceraldehyde's C2, the sugar is D; if it is equivalent to L-glyceraldehyde's C2, the sugar is L. Due to the chirality of the sugar molecules, an aqueous solution of a D or L saccharides will rotate light. D-glyceraldehyde causes polarized light to rotate clockwise (dextrorotary); L-glyceraldehyde causes polarized light to rotate counterclockwise (levorotary). Unlike glyceraldehyde, D/L designation on more complex sugars is not associated with their direction of light rotation. Since more complex sugars contain multiple chiral carbons, the direction of light rotation cannot be predicted by the chirality of the carbon that defines D/L nomenclature.



Sugar Ring Structures

When sugars cyclize, they typically form **furanose** or **pyranose** structures. These are molecules with five-membered or six-membered rings, respectively. Cyclization creates a carbon with two possible orientations of the hydroxyl around it. Cyclization of an aldose occurs by intramolecular reaction with the aldehyde and alcohol groups to form a **hemiacetal**. Cyclization of a ketose occurs by intramolecular reaction with the ketone and alcohol groups to form a **hemiketal**. In either case, a new asymmetric carbon is created by the reaction and we refer to the carbon as the **anomeric carbon** and the two possible configurations as **anomers**. The two possible configurations of the hydroxyl group are called **alpha** and **beta**, which correspond to the hydroxyl being in the "down" and "up" positions, respectively, in standard projections. Anomers are capable of interconverting between alpha and beta positions in a process called mutarotation IF the hydroxyl group of the hemiacetal or hemiketal is unaltered.

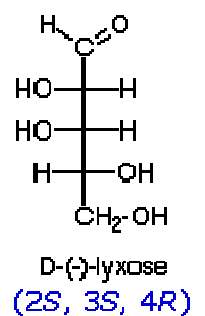
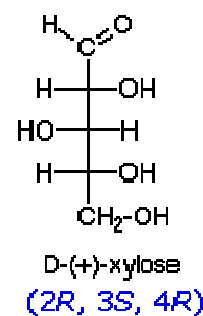
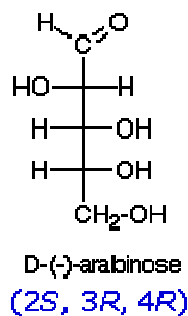
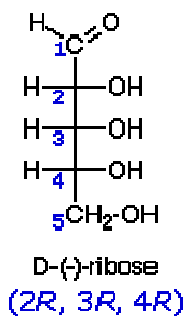
D - glucose, α - und β - configuration



Epimers: They are a special case of diastereoisomerism where there is a difference for one and only one asymmetric center. e.g. D-glucose and D-mannose; D-glucose and D-galactose are epimers.

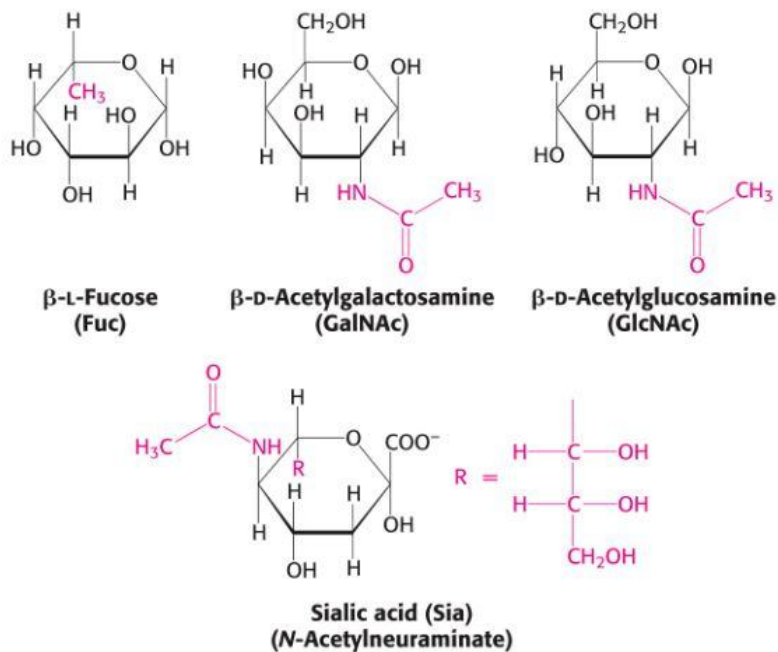
epimer, is used to designate diastereomers that differ in configuration at only one chiral center. Thus, ribose and arabinose are epimers at C-2, and arabinose and lyxose are epimers at C-3. However, arabinose and xylose are not epimers, since their configurations differ at both C-2 and C-3.

Four Diastereomeric $C_5H_{10}O_5$ Aldopentoses



Amino Sugars - made by replacing a hydroxyl of a sugar with an amine group. Two common examples are **beta-D-glucosamine** and **beta-D-galactosamine**. Common molecules derived from these include beta-D-N-acetylglucosamine, muramic acid, N-

acetylmuramic acid, -D-N-acetylgalactosamine, and **N-acetyl-neuraminic acid** (also called sialic acid). Amino sugars are often found in oligosaccharides and polysaccharides. It is significant in several biological systems. It is part of a biopolymer in the bacterial cell wall, GlcNAc is the monomeric unit of the polymer chitin, which forms the outer coverings of insects and crustaceans. GlcNAc is also of note in neurotransmission, where it is thought to be an atypical neurotransmitter functioning in nociceptive (pain) pathways. It has been proposed as a treatment for autoimmune diseases.



Disaccharide

is the carbohydrate formed when two monosaccharides undergo a condensation reaction which involves the elimination of a small molecule, such as water, from the functional groups only. Like monosaccharides, disaccharides also dissolve in water, taste sweet and are called sugars. There are two basic types of disaccharides: reducing disaccharides, in which the monosaccharide components are bonded by hydroxyl groups; and non-reducing disaccharides, in which the components bond through their anomeric centers.

It is formed when two monosaccharides are joined together and a molecule of water is removed. For example; milk sugar (lactose) is made from glucose and galactose whereas cane sugar (sucrose) is made from glucose and fructose.

The two monosaccharides are bonded via a dehydration reaction (also called a condensation reaction or dehydration synthesis) that leads to the loss of a molecule of water and formation of a glycosidic bond.

Common disaccharides

Disaccharide

Unit 1 Unit 2 Bond

Sucrose (*table sugar, cane sugar, saccharose, or beet sugar*) glucose fructose $\alpha(1\rightarrow2)$

Lactulose galactose fructose $\beta(1\rightarrow4)$

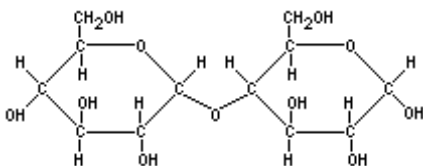
Lactose (*milk sugar*) galactose glucose $\beta(1\rightarrow4)$

Maltose glucose glucose $\alpha(1\rightarrow4)$

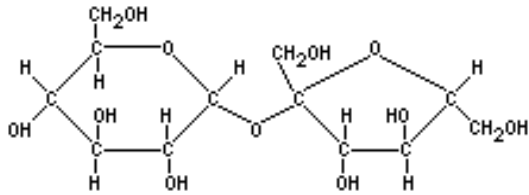
Trehalose glucose glucose $\alpha(1\rightarrow1)\alpha$

Cellobiose glucose glucose $\beta(1\rightarrow4)$

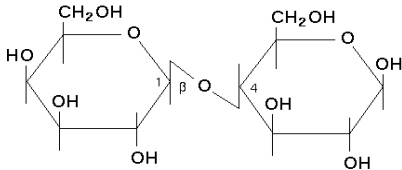
Maltose



Sucrose

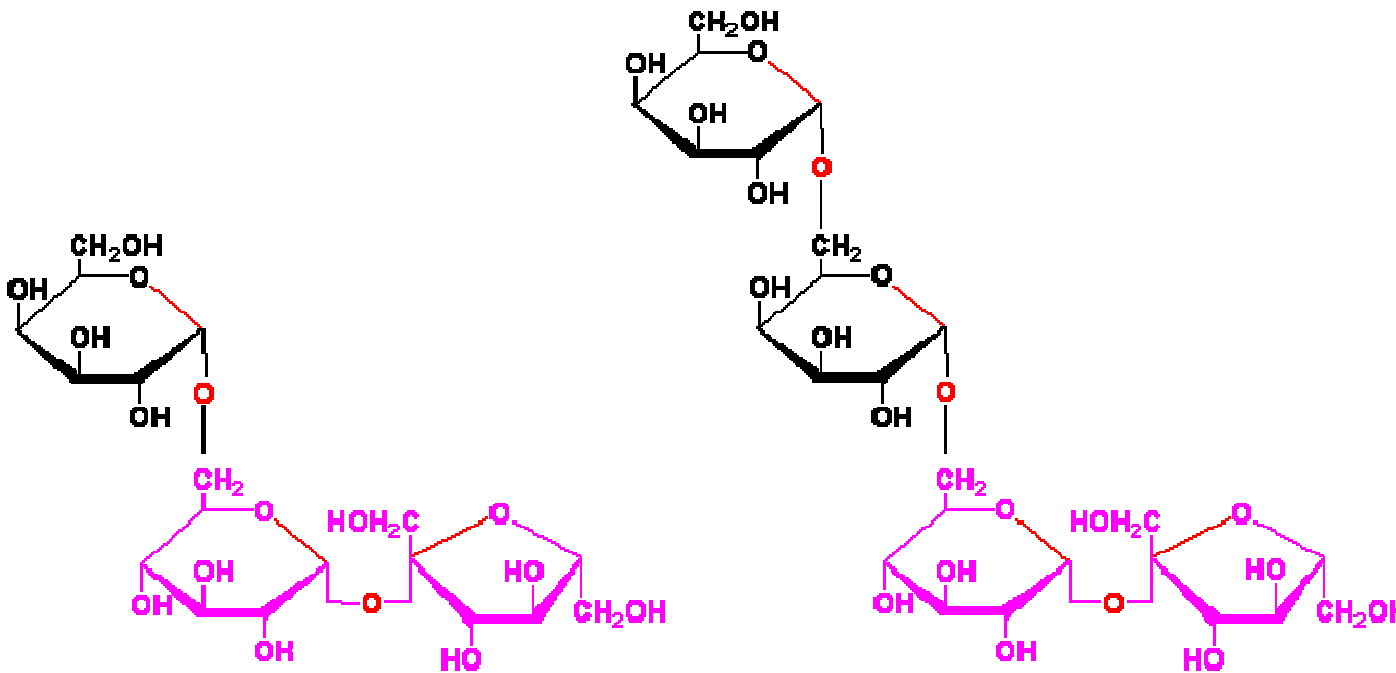


Lactose



Oligosaccharides are also found as part of **glycoproteins** and play a role in cell recognition/identity. **Oligosaccharides** form the blood group antigens. In some cells, these antigens are attached as O-linked glycans to membrane proteins. Alternatively, the **oligosaccharide** may be linked to a lipid molecule to form a glycolipid. These **oligosaccharides** determine the blood group types in humans.

Sucrose is a precursor to a group of carbohydrates in plants known as the **raffinose family of oligosaccharides** found in many plant seeds especially legumes. This family contains the trisaccharide raffinose, the tetrasaccharide **stachyose** and the pentasaccharide **verbascose**:



Oligosaccharides play a role in cell recognition/identity. **Oligosaccharides** form the blood group antigens) by linkage to proteins in blood cell membranes forming glycoproteins or, in some cases, to lipids, forming glycolipids. Three different oligosaccharide structures give rise to the blood groups - A, B, and O. The base structure of each contains the structure of the O antigen. Specific glycosyltransferases add the extra monosaccharide to the O antigen to give rise to either the A or B antigen.

Polysaccharides

Polysaccharides are polymers of **monosaccharide** units. The monomeric units of a **polysaccharide** are usually all the same (called homopolysaccharides (polymer of one sugar)), though there are exceptions (called heteropolysaccharides (more than one sugar in polymer chain)

In some cases, the monomeric units are modified monosaccharides. **Polysaccharides** differ in the composition of the monomeric unit, the linkages between them, and the ways

in which branches from the chains occur. Common polymers, their monomeric units, and linkages/branches are shown below:

Polysaccharide Name	Monomeric Unit	Linkages
Glycogen	D-Glucose	alpha 1->4 links with extensive alpha1->6 branches
Cellulose	D-Glucose	beta 1->4
Chitin	N-Acetyl-D-glucosamine	beta 1->4
Amylopectin	D-Glucose	alpha 1->4 links with some alpha 1->6 branches
Amylose	D-Glucose	alpha 1->4

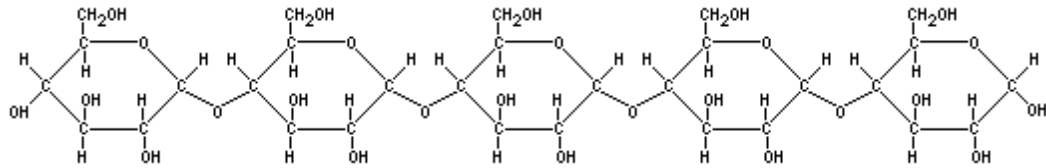
Linkages between the individual units require special enzymes to break them down. For example, the alpha 1-> 4 linkages between glucose units in glycogen, amylose, and amylopectin, are readily broken down by all animals, but only ruminants (cows) and related animals contain symbiotic bacteria with an enzyme (cellulase) that can break down the beta 1-> 4 linkages between individual glucose units in cellulose. As a result, the huge amount of cellulose in the biosphere is unavailable as an energy source to most animals.

Storage Polysaccharides

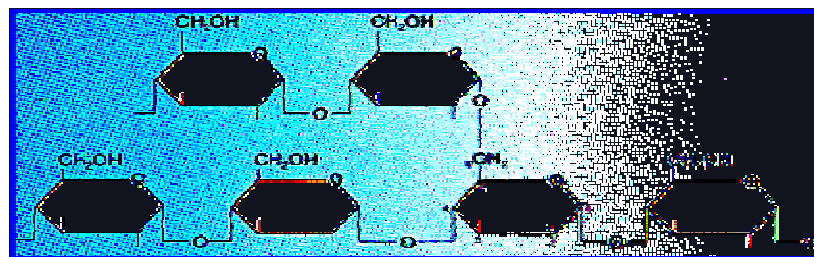
Polysaccharides are used to some extent for energy storage in almost all higher organisms. Plants use starch, Starches are insoluble in water and thus can serve as storage depots of glucose. Plants convert excess glucose into starch for storage. Rice, wheat, and corn are also major sources of starch in the human diet.

Starch composed of amylose and amylopectin

- **amylose** consists of linear, unbranched chains of several hundred glucose residues (units). The glucose residues are linked by a glycosidic bond between their #1 and #4 carbon atoms.



- **amylopectin** differs from amylose in being highly branched. At approximately every thirtieth residue along the chain, a short side chain is attached by a glycosidic bond to the #6 carbon atom (the carbon above the ring). The total number of glucose residues in a molecule of amylopectin is several thousand.



Glycogen

Animals store excess glucose by polymerizing it to form **glycogen**. The structure of glycogen is similar to that of amylopectin, although the branches in glycogen tend to be shorter and more frequent. Glycogen is broken back down into glucose when energy is needed (a process called glycogenolysis). The liver and skeletal muscle are major depots of glycogen.

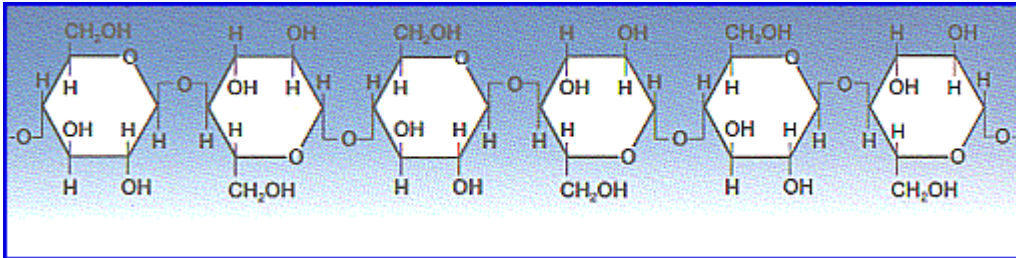
Structural Polysaccharides

plants use different **polysaccharides**, such as cellulose, for structural purposes in their cell walls. The exoskeleton of many arthropods and mollusks is composed of chitin, a **polysaccharide** of N-acetyl-D-glucosamine.

Cellulose

Cellulose is probably the single most abundant organic molecule in the biosphere. It is the major structural material of which plants are made. Wood is largely cellulose and lignin while cotton and paper are almost pure cellulose. Cellulose is derived from D-glucose units, which condense through $\beta(1\rightarrow4)$ -glycosidic bonds. Cellulose is a straight

chain polymer: unlike starch, no coiling or branching occur Cellulose is a polymer made with repeated glucose units bonded together by *beta*-linkages. Humans and many other animals lack an enzyme to break the beta-linkages, so they do not digest cellulose. Certain animals can digest cellulose, because bacteria possessing the enzyme cellulase are present in the gut. Classical examples are ruminant and termites.



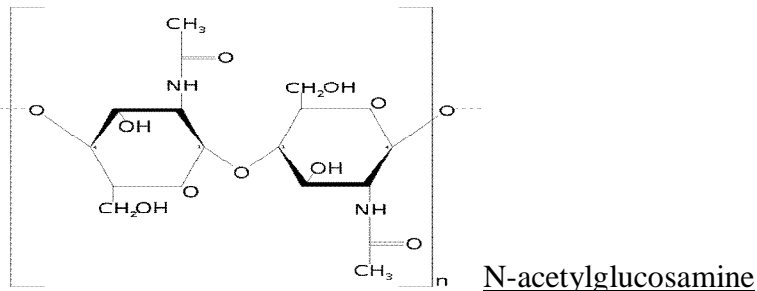
Hemicellulose

Hemicellulose is a polysaccharide related to cellulose that comprises ca. 20% of the biomass of most plants. In contrast to cellulose, hemicellulose is derived from several sugars in addition to glucose, including especially xylose but also mannose, galactose, rhamnose, and arabinose. Hemicellulose consists of shorter chains - around 200 sugar units. Furthermore, hemicellulose is branched, whereas cellulose is unbranched.

Chitin

is a homopolymer of N-acetyl-D-glucosamine, with units joined by beta 1-> 4 bonds. Chitin is found in organisms as diverse as algae, fungi, insects, arthropods, mollusks, and insects. Chitin is a long-chain polymer of a N-acetylglucosamine, a derivative of glucose, and is found in many places throughout the natural world. It is the main component of the cell walls of fungi, the exoskeletons of arthropods such as crustaceans (e.g. crabs, lobsters and shrimps) and insects, the radulas of mollusks and the beaks of cephalopods, including squid and octopuses. Chitin has also proven useful for several medical and industrial purposes. Chitin may be compared to the polysaccharide

cellulose and to the protein keratin. Although keratin is a protein, and not a carbohydrate like chitin, keratin and chitin have similar structural functions.



Uses

Agriculture

Most recent studies point out that chitin is a good inducer for defense mechanisms in plants.^[4] It was recently tested as a fertilizer that can help plants develop healthy immune responses, and have a much better yield and life expectancy.^[5] The Chitosan is derived from chitin, which is used as a biocontrol elicitor in agriculture and horticulture.

Industrial

Chitin is used industrially in many processes. It is used in water purification, and as an additive to thicken and stabilize foods and pharmaceuticals. It also acts as a binder in dyes, fabrics, and adhesives. Industrial separation membranes and ion-exchange resins can be made from chitin. Processes to size and strengthen paper employ chitin.

Medicine

Chitin's properties as a flexible and strong material make it favorable as surgical thread. Its bio-degradability means it wears away with time as the wound heals. Moreover, chitin has some unusual properties that accelerate healing of wounds in humans.^[7]