**GLYCOSIDES**

A glycoside is any molecule in which a sugar group is bonded through its anomeric carbon to another group via glycosidic bond. A glycosidic bond is a certain type of chemical bond that joins a sugar molecule to another mol-ecule. Specifically, a glycosidic bond is formed between the hemiacetal group of a saccharide (or a molecule derived from a saccharide) and the hydroxyl group of an alcohol. A substance containing a glycosidic bond is a glycoside. The glycone and aglycone portions can be chemically separated by hydrolysis in the presence of acid. There are also numerous enzymes that can form and break glycosidic bonds.

 The sugar group is known as the glycone and the nonsugar group as the aglycone or genin part of the glycoside. The glycone can consist of a single sugar group (monosaccharide) or several sugar groups (oligosaccharide). The sugars found in glycosides may be glucose and rhamnose (monosaccharides) or, more rarely, deoxysugars such as the cymarose found in cardiac glycosides.

 In plants glycosides are both synthesized and hydrolysed under the influence of more or less specific enzymes. They are crystalline or amorphous substances that are soluble in water or alcohols and insoluble in organic solvents like benzene and ether. The aglycone part is soluble in organic solvents like benzene or ether. They are hydrolysed by water, enzymes and mineral acids. They are optically active. While glycosides do not themselves reduce Fehling’s solution, the simple sugars which they produce on hydrolysis will do so with precipitation of red cuprous oxide. The sugars present in glycoside are of two isomeric forms, that is, α form and β form, but all the natural glycosides contain β-type of sugar.

 The term ‘glycoside’ is a very general one which embraces all the many and varied combinations of sugars and aglycones.

**DISTRIBUTION OF GLYCOSIDES**

Glycosides are widely distributed in nature and are found in plants, animals, and microorganisms. The distribution of glycosides varies depending on the source and type of glycoside. Some of the common sources and types of glycosides are as follows:

Plants: Plants are the richest source of glycosides, and they produce a wide variety of glycosides. Glycosides are present in various parts of the plant, such as leaves, flowers, stems, roots, and fruits.

Some plant families containing important glycosides are listed bellow:

1.     Scrophulareaceae (Digitalis purpurea and Digitalis lanata, Picrorhiza kurroa).

2.     Apocyanaceae (Nerium oliander and Thevetia peruviana).

3.     Liliacea (Urgenea indica and U. maritima, Aloe vera)

4.     Leguminocae (Cassia acutefolia and C. angustefolia, Gly-cyrrhiza glabra, Psoralea corylifolia)

5.     Dioscoreaceae (Dioscorea floribunda)

6.     Rosaceae (Prunus amygdalus, Carategus oxycantha)

7.     Cruciferae (Brassica sp.)

8.     Gentianaceae (Gentian and Chirata)

9.     Acanthaceae (Kalmegh)

10. Simarubaceae (Quassia)

11. Umbelliferae (Ammi majus, Ammi visnaga)

12. Rutaceae: Citrus sp. (Ruta graveolens)

13. Polygonaceae (Fagopyrum sp.)

14. Myrtaceae (Eucalyptus sp.)

Some of the common glycosides found in plants are:

Flavonoid glycosides: These are found in fruits, vegetables, and herbs, and are responsible for their color and flavor. Examples include quercetin glycosides in onions and apples, and hesperidin glycosides in citrus fruits.

Phenol glycosides: These are found in medicinal plants and have antimicrobial, anti-inflammatory, and antioxidant properties. Examples include salicin in willow bark and arbutin in bearberry.

Cardiac glycosides: These are found in digitalis plants and are used to treat heart disease. Examples include digoxin and ouabain.

Cyanogenic glycosides: These are found in cassava, almonds, and other plants, and are toxic if consumed in large quantities. They release cyanide upon hydrolysis.

Iridoid glycosides: These are found in herbs and shrubs and have various pharmacological activities. Examples include aucubin in plantain and harpagoside in devil's claw.

Animals: Glycosides are also found in some animals, particularly invertebrates such as insects and marine organisms. They are involved in various physiological functions, such as defense mechanisms and communication. Some common glycosides found in animals are:

Cardenolide glycosides: These are found in milkweed and other plants, and are used by monarch butterflies as a defense against predators.

Saponin glycosides: These are found in fish, starfish, and sea cucumbers, and are involved in defense mechanisms and cell communication.

Chitin glycosides: These are found in the exoskeletons of insects and crustaceans, and provide structural support.

Microorganisms: Glycosides are also produced by microorganisms, such as bacteria and fungi. They are involved in various biological processes, such as defense mechanisms and signal transduction. Some common glycosides found in microorganisms are:

Antibiotic glycosides: These are produced by bacteria and fungi, and have antimicrobial properties. Examples include gentamicin and erythromycin.

Signal glycosides: These are produced by bacteria and are involved in signal transduction and quorum sensing.

Fungal glycosides: These are produced by fungi and have various pharmacological activities, such as antitumor and immunosuppressive properties.

In summary, glycosides are widely distributed in nature and are found in various sources, including plants, animals, and microorganisms. They have diverse biological functions and applications, making them an important class of compounds in the natural world.

 Glycosides are the class of compounds abundant in nature.

**CLASSIFICATION**

 The glycosides can be classified by the glycone, by the type of glycosidal linkage, and by the aglycone.

On the Basis of Glycone

 If the glycone group of a glycoside is glucose, then the molecule is a glucoside; if it is fructose, then the molecule is a fructoside; if it is glucuronic acid, then the molecule is a glucuronide, etc.

On the Basis of Glycosidic Linkage

1.     O-glycosides: Sugar molecule is combined with phenol or –OH group of aglycon, for example, Amygd-aline, Indesine, Arbutin, Salicin, cardiac glycosides, anthraxquinone glycosides like sennosides etc

2.     N-glycosides: Sugar molecule is combined with N of the –NH (amino group) of aglycon, for example, nucleosides

 3.     S-glycosides: Sugar molecule is combined with the S or SH (thiol group) of aglycon, for example, Sinigrin.

 4.     C-glycosides: Sugar molecule is directly attached with C—atom of aglycon, for example, Anthraquinone glycosides like Aloin, Barbaloin, Cascaroside and Flavan glycosides, etc.

On the Basis of Aglycone

 The various classes according to aglycone moiety are given below:

Glycosides can be classified based on the type of aglycone molecule they contain.

**Some common types of glycosides include:**

Alcoholic glycosides: These are glycosides in which the aglycone is an alcohol or a phenol. Examples include salicin from willow bark, which is converted to salicylic acid in the body and has pain-relieving and anti-inflammatory properties. Another example is arbutin, which is found in the leaves of the bearberry plant and is used as a skin-lightening agent.

Anthraquinone glycosides: These are glycosides in which the aglycone is an anthraquinone, a type of organic compound with a characteristic ring structure. Examples include aloe emodin, found in aloe vera, and rhein, found in rhubarb. Anthraquinone glycosides have laxative properties and are used in some over-the-counter laxatives.

Cardiac glycosides: These are glycosides in which the aglycone is a steroid-like molecule with a specific structure that has a potent effect on the heart. Examples include digoxin, derived from the foxglove plant, and ouabain, derived from the African plant Strophanthus gratus. Cardiac glycosides are used to treat heart failure and certain types of arrhythmia.

Cyanogenic glycosides: These are glycosides in which the aglycone is a cyanide-containing compound. Examples include amygdalin, found in bitter almonds and apricot kernels, and linamarin, found in cassava. Cyanogenic glycosides are toxic and can release cyanide in the body, which can be deadly in high doses.

Flavonoid glycosides: These are glycosides in which the aglycone is a flavonoid, a type of organic compound with a characteristic ring structure. Examples include quercetin, found in onions and apples, and hesperidin, found in citrus fruits. Flavonoid glycosides have antioxidant and anti-inflammatory properties and may have potential health benefits.

Steroidal glycosides: These are glycosides in which the aglycone is a steroid-like molecule. Examples include diosgenin, found in wild yam, and solasodine, found in eggplant. Steroidal glycosides have various biological activities, including anti-inflammatory and anticancer properties.

Terpenoid glycosides: These are glycosides in which the aglycone is a terpenoid, a type of organic compound that is derived from isoprene units. Examples include ginsenosides, found in ginseng, and steviol glycosides, found in the leaves of the stevia plant. Terpenoid glycosides have various biological activities, including antioxidant and anti-inflammatory properties.



**ANTHRACENE GLYCOSIDES**

 Anthracene glycosides are chiefly found in dicot plants but to some extent it is also found in monocot and lower plants. It consists of glycosides formed from aglycone moi-eties like anthraquinones, anthranols, anthrones or dimers of anthrones or their derivatives. Anthrones are insoluble in alkali and do not show strong fluorescence with them, while anthronols which are soluble in alkali show strong fluorescence. The reduced anthraquinones are biologically more active. Anthroquinones that are present in fresh drugs are in reduced form, which on long storage get oxidized and hydrolysed, Glycosides of reduced derivatives are more active than oxidized aglycones. This is due to the fact that sugars take the glycosides to the site of action and thus are more active.

Anthraquinone is an aromatic organic compound and a derivative of anthracene. It has the appearance of yellow or light grey to grey-green solid crystalline powder. Its chemical formula is C14H 8O2. It melts at 286°C, boils at 379.8°C. It is insoluble in water or alcohol, but dissolves in nitrobenzene and aniline. It is chemically fairly stable under normal conditions.

 Anthraquinone naturally occurs in some plants (e.g. aloe, senna, rhubarb and cascara), fungi, lichens and insects, where it serves as a basic skeleton for their pigments. Natural anthraquinone derivates tend to have laxative effects.

 These glycosides are characterized by a chemical test, known as Borntrager test and show the property of micro-sublimation. Most of the glycosides are O-glycosides and



S-glycosides, by their hydrolysis derivatives of 1,8-dihydroxy anthraquinone, anthranol, anthrone, or dianthrone are obtained.

 The common aglycones are aloe-emodin, emodin, rhein, chrysophanol and physcion which may exist as anthraquinones, anthranols or anthrones. The sugars presents are usually arabinose, rhamnose and glucose.

 In the drug originally glycosides of reduced derivatives or their dimers are present. During drying and storage by hydrolysis and oxidation free anthraquinones are produced.

**STEROL OR CARDIAC GLYCOSIDES**

 The cardiac glycosides are an important class of naturally occurring drugs whose actions include both beneficial and toxic effects on the heart. Plants containing cardiac steroids have been used as poisons and heart drugs at least since 1500 B.C. Throughout history these plants or their extracts have been variously used as arrow poisons, emetics, diuretics and heart tonics. Cardiac steroids are widely used in the modern treatment of congestive heart failure and for treatment of atrial fibrillation and flutter. Yet their toxicity remains a serious problem. These drugs all act by affecting the availability of intracellular Ca+2 for myocardial contraction or increasing the sensitivity of myocardial contractile proteins.

 Cardiac glycosides are composed of two structural fea-tures: the sugar (glycone) and the nonsugar (aglycone– steroid) moieties.

 The steroid nucleus has a unique set of fused ring system that makes the aglycone moiety structurally distinct from the other more common steroid ring systems. The steroid nucleus has hydroxyls at 3- and 14-positions of which the sugar attachment uses the 3-OH group. 14-OH is normally unsubstituted. Many genins have OH groups at 12- and 16-positions. These additional hydroxyl groups influence the partitioning of the cardiac glycosides into the aqueous media and greatly affect the duration of action. The lactone moiety at C-17 position is an important structural feature. The size and degree of unsaturation varies with the source of the glycoside. Normally plant sources provide a five-membered unsaturated lactone while animal sources give a six-membered unsaturated lactone.

 One to four sugars are found to be present in most cardiac glycosides attached to the 3β-OH group. The sugars most commonly used include L-rhamnose, D-glucose, D-digitoxose, D-digitalose, D-digginose, D-sarmentose, L-vallarose and D-fructose. These sugars predominantly exist in the cardiac glycosides in the β-conformation. The presence of acetyl group on the sugar affects the lipophilic character and the kinetics of the entire glycoside.

 Two classes have been observed in nature—the cardenolides and the bufadienolides.

 The cardenolides have an unsaturated butyrolactone ring while the bufadienolides have a pyrone ring. The lactone of cardenolides has a single double bond and is attached at the C-17 position of steroidal nucleus. They are five-membered lactone ring and form a C23 steroids (Leguminosae, Cruciferae, Euphorbiaceae, etc.), while the lactone of bufadienolids have two double bond which is attached at the 17 α-position of the steroidal nucleus. They are six-memberd lactone ring and form C24 steroids (Liliaceae, Ranunculaceae).



**SAPONIN GLYCOSIDES**

 Saponins are glycoside compounds often referred to as a ‘natural detergent’ because of their foamy texture. They get their name from the soap wort plant (Saponaria), the root of which was used historically as a soap (Latin sapo— soap). Foremost among this is the strong tendency to froth formation when shaken with water. The other properties are hemolytic activity, sneezing effect, toxicity, complex formation with cholesterol and antibiotic properties.

Saponins have long been known to have strong biologi-cal activity. When studying the effect that saponins have on plants, it has been discovered that saponins are the plants active immune system. They are found in many plants, they consist of a polycyclic aglycone that is either a choline steroid or tritetpenoid attached via C3 and an ether bond to a sugar side chain. The aglycone is referred to as the sapogenin and steroid saponins are called sarsaponins. The ability of a saponin to foam is caused by the combination of the nonpolar sapogenin and the water soluble side chain.

 Saponins are bitter and reduce the palatability of livestock feeds. However if they have a triterpenoid aglycone they may instead have a licorice taste as glucuronic acid replaces sugar in triterpenoids. Some saponins reduce the feed intake and growth rate of nonruminant animals while others are not very harmful. For example, the saponins found in oats and spinach increase and accelerate the body’s ability to absorb calcium and silicon, thus assisting in digestion. As mentioned earlier they are composed of a steroid (C-27) or triterpenoid (C-30) saponin nucleus with one or more carbohydrate branches.

 **Steroid Saponins**

 Steroid saponins are similar to the sapogenins and related to the cardiac glycosides. They have ability to interact medically and beneficially with the cardiac glycosides, sex hormones, Vitamin D and other factors, render these phytochemicals components of great medical significance. Diosgenin is the important steroid sapogenin. Recently from these saponins steroid hormones like progesterone, cortisone etc. are obtained by partial synthesis and thus their importance has increased considerably. Some of the families with steroidal saponins are Solanaceae, Apocynaceae, Liliaceae, Leguminosae, etc.



**Triterpenenoid Saponins**

 Triterpenoid saponins, or sapogenins, are plant glycosides which lather in water and are used in detergents, or as foaming agents or emulsifiers, and have enormous medical implications due to their antifungal, antimicrobial, and adaptogenic properties. Triterpene saponins are usually β-amyrine derivatives and some are also α-amyrine and lupeol derivatives. It has a pentacyclic triterpenoid nucleus which is linked with either sugar or uronic acid. Glycyr-rhizin, from licorice root, is an example of a saponin used for antiinflammatory purposes in place of cortisone.

 They are commonly available in dicot plants belonging to the family Rubiaceae, Compositae, Rutaceae, Umbel-liferae, etc.

 Saponins are rarely crystalline and generally amorphous powder with high molecular weight. They carry many asymmetric centres and are optically active. They are generally soluble in water and form colloidal solutions. These are also soluble in ethyl and methyl alcohol and are usually insoluble in organic solvents like petroleum ether, chloroform and acetone etc. They are bitter in taste and nonalkaline in nature, produce sneezing and have the property of lowering surface tension. They are hydrolysed by acids, alkalies to yield aglycone called sapogenin and one or more molecule of same or different sugars or their oxidation products. They can also be hydrolysed by enzymes, soil bacteria, and by photolysis. In mild conditions using very dilute acids (0.01–0.1 N), organic acids give rise to partially hydrolysed saponins called prosapogenin.

 Saponins are extremely toxic to fishes but do not render them inedible, as saponins are not poisonous to man when taken orally. Very dilute solution of saponins hemolyses red blood corpuscles. The hemolysis take place due to the formation of complex with the cholesterol of erythrocyte membrane causing its destruction, this is a chief property of saponin, very rarely shown by any other plants product. Saponins accelerate the germination and growth of the seeds. Saponins show fungicidal, bactericidal activity, antiviral activity, antibiotic property, inflammation inhibition activity, spermicidal, antifertility, molluscicidal, etc. Saponins have been reported to possess blood purifying and abortion causing properties, anthelmintic effect, sedative property and antispasmodic effects.

 Saponins find wide occurrence in plant kingdom. In a systematic study, 672 triterpenic and 125 steroidal saponins were found in 1730 species belonging to 104 families. In the whole 75% of the families showed the presence of saponins. The wide occurrence and its comparatively higher contents (0.1–30%) in plants, the saponins can be regarded as the most occurring plant materials. Saponins from the different parts of the same plants have found to possess different properties. Saponins may be distributed throughout the plant; their content is affected by variety and stage of growth. Their function in the plant is as storage in form of carbohydrate in the plant and act as immune system of the plant. Saponins have also been identified in the animal kingdom in snake venom, starfish and sea cucumber etc.

**CYANOGENIC GLYCOSIDES**

Cyanogenic glycosides are a group of natural compounds found in many plants, particularly those in the Rosaceae and Fabaceae families, such as apple seeds, peach pits, and cassava. These compounds are formed by the reaction of a sugar molecule (glycoside) with a cyanide group (-CN). Cyanogenic glycosides are generally not harmful when consumed in small amounts, but in large amounts, they can release toxic levels of cyanide, which can lead to poisoning.

Cyanogenic glycosides are found in a wide range of plants, including those that are commonly consumed as food. For example, apple seeds, peach pits, and bitter almonds all contain cyanogenic glycosides. Cassava, a staple food in many parts of the world, also contains high levels of cyanogenic glycosides. In cassava, the cyanogenic glycosides are concentrated in the roots, which must be processed properly to remove the toxins before consumption.

The toxicity of cyanogenic glycosides is due to the release of cyanide when the glycosides are hydrolyzed by enzymes in the body. The hydrolysis can occur in the gut or in damaged plant tissue, such as when apples or peaches are crushed. The cyanide released from the hydrolysis of cyanogenic glycosides can bind to enzymes involved in cellular respiration, preventing the cells from using oxygen, and leading to cell death.

Despite their toxicity, cyanogenic glycosides have been used in traditional medicine for centuries. For example, bitter almonds have been used for their medicinal properties, including as a treatment for coughs, fever, and spasms. In addition, cassava has been used in traditional medicine to treat a variety of ailments, including headaches, fever, and constipation.

In modern times, cyanogenic glycosides have been studied for their potential health benefits. For example, amygdalin, a cyanogenic glycoside found in bitter almonds, has been studied for its potential anticancer activity. Amygdalin has been shown to have cytotoxic effects on cancer cells in vitro, but its effectiveness in vivo is still a subject of debate.

In addition to their potential health benefits, cyanogenic glycosides have also been studied for their role in plant defense against herbivores. When herbivores consume plants containing cyanogenic glycosides, the glycosides are hydrolyzed in the gut, releasing cyanide and potentially deterring the herbivore from consuming more of the plant.

The toxic effects of cyanogenic glycosides can be mitigated by processing the plant material properly. For example, in cassava, the roots must be soaked, grated, and boiled to remove the cyanogenic glycosides before consumption. In addition, the consumption of foods containing cyanogenic glycosides should be limited to avoid toxic levels of cyanide.

In conclusion, cyanogenic glycosides are a group of natural compounds found in many plants, particularly those in the Rosaceae and Fabaceae families. These compounds are formed by the reaction of a sugar molecule (glycoside) with a cyanide group (-CN). Cyanogenic glycosides are generally not harmful when consumed in small amounts, but in large amounts, they can release toxic levels of cyanide, which can lead to poisoning. Despite their toxicity, cyanogenic glycosides have been used in traditional medicine for centuries and have been studied for their potential health benefits. However, the consumption of foods containing cyanogenic glycosides should be limited to avoid toxic levels of cyanide.

These are the glycosides which on hydrolysis yields hydro-cynic acid (HCN), benzaldehyde and sugars. The medicinal activity of cyanogenetic glycosides is due to presence of hydrocyanic acid and these are the characteristics of family rosaceae. For examples Amygdalin obtained from bitter almond (Prunus amygdalus), Prunasin obtained from wild cherry bark.

Identification Tests

1.     A strip of white filter paper is dipped in 10% aqueous solution of picric acid, drain it and dip in a 10% sodium carbonate solution and drain again. Moisten the powdered drug with water and put into a conical flask. Trap the sodium picrate paper on the neck of flask with cork. Because of volatile hydrocyanic acid, the paper will become brick red colour.

2.     When drug treated with 3% aqueous solution of mercurous nitrate reduction to metallic mercury takes place.

ISOTHIOCYNATE GLYCOSIDES

 These are sulphur-containing compounds rich in family cruciferae, also known as glucosinolates and on hydrolysis yields isothiocyanate (-NCS) group. These glycosides are generally irritant and hence used externally as counter irritant, for example, Sinigrin from black mustard, sinalbin from white mustard and gluconapin from rapeseed.

Isothiocyanate glycosides are a group of natural compounds found in many plants, particularly those in the Brassicaceae family, such as broccoli, cauliflower, and mustard greens. These compounds are formed by the reaction of a sugar molecule (glycoside) with an isothiocyanate group (-N=C=S). Isothiocyanate glycosides have been extensively studied for their health benefits, including their anticancer, antimicrobial, and anti-inflammatory properties.

The main isothiocyanate glycosides found in plants are glucosinolates, which are hydrolyzed by plant enzymes (myrosinases) to form isothiocyanates. The hydrolysis of glucosinolates can also be initiated by chewing or crushing the plant tissue, which releases myrosinases and allows the glucosinolates to be converted to isothiocyanates. The isothiocyanates are then rapidly absorbed into the bloodstream and distributed throughout the body.

One of the most extensively studied isothiocyanate glycosides is sulforaphane, which is found in broccoli and other cruciferous vegetables. Sulforaphane has been shown to have potent anticancer activity, particularly against breast, prostate, and colon cancer cells. Sulforaphane works by inhibiting the activity of enzymes involved in cancer cell growth and proliferation, as well as inducing apoptosis (programmed cell death) in cancer cells.

In addition to its anticancer properties, sulforaphane has been shown to have a variety of other health benefits. For example, sulforaphane has been shown to reduce inflammation in the body, improve cardiovascular health by reducing blood pressure and cholesterol levels, and improve cognitive function by protecting against oxidative stress and inflammation in the brain.

Another important isothiocyanate glycoside is allyl isothiocyanate, which is found in mustard seeds and horseradish. Allyl isothiocyanate has potent antimicrobial properties and has been shown to be effective against a wide range of bacteria, fungi, and viruses. Allyl isothiocyanate works by disrupting the cell membrane of microorganisms, leading to their death.

In addition to its antimicrobial properties, allyl isothiocyanate has been shown to have other health benefits. For example, allyl isothiocyanate has been shown to have anti-inflammatory properties, which may help to reduce the risk of chronic diseases such as cardiovascular disease and diabetes. Allyl isothiocyanate has also been shown to have potential as a natural insecticide, as it is toxic to a wide range of insect pests.

Other isothiocyanate glycosides that have been studied for their health benefits include erucin, which is found in broccoli and other cruciferous vegetables, and benzyl isothiocyanate, which is found in garden cress and other plants. Erucin has been shown to have potent anticancer activity, particularly against breast and prostate cancer cells. Benzyl isothiocyanate has been shown to have antimicrobial, anti-inflammatory, and anticancer properties.

Isothiocyanate glycosides are typically found in cruciferous vegetables and other plants that are members of the Brassicaceae family. These plants have been used in traditional medicine for centuries to treat a variety of ailments. For example, mustard has been used for centuries as a natural remedy for respiratory problems, while horseradish has been used as a natural remedy for digestive problems.

In modern times, isothiocyanate glycosides have been isolated from these plants and studied for their health benefits. For example, sulforaphane has been isolated from broccoli and other cruciferous vegetables and has been shown to have

**FLAVONE GLYCOSIDES**

 These are complex organic compounds containing phenyl-benzopyrone ring system. Flavones are present in plants in a free state or in glycosidal state (O-glycoside or C-glycoside) with its different derivatives like flavane, flavonol, flavonone, isoflavone and chalcones, for example, Rutin, quercitrin, hyperoside, diosmin (buchu leaf), hesperidin (lemon and orange peel) and vitexin (Carategus).

Flavone glycosides are a group of natural compounds found in plants that are derived from the flavone backbone. They are composed of a flavone molecule, which consists of two benzene rings connected by a heterocyclic ring, with a sugar molecule (glycoside) attached.

Flavone glycosides are found in a wide range of plants, including fruits, vegetables, and herbs. Some of the most common sources of flavone glycosides include chamomile, celery, parsley, and citrus fruits.

One of the main functions of flavone glycosides in plants is as pigments. They are responsible for the bright colors seen in many fruits and flowers, such as oranges, lemons, and daffodils. Flavone glycosides also play a role in protecting plants from environmental stressors such as UV radiation and pathogen attack.

Flavone glycosides have been found to have a variety of potential health benefits for humans. Some studies have suggested that they may have antioxidant and anti-inflammatory properties, which could make them useful for preventing and treating a range of diseases.

One of the most well-known flavone glycosides is hesperidin, which is found in citrus fruits such as oranges and grapefruits. Hesperidin has been found to have antioxidant properties and may help to reduce inflammation in the body. It has also been shown to have potential benefits for cardiovascular health, such as reducing blood pressure and improving cholesterol levels.

Another flavone glycoside with potential health benefits is apigenin, which is found in parsley, celery, and chamomile. Apigenin has been found to have antioxidant and anti-inflammatory properties, and may also have anticancer properties. Some studies have suggested that apigenin may be useful for preventing and treating breast, prostate, and colon cancer.

Quercetin is another flavone glycoside that has been extensively studied for its potential health benefits. It is found in a variety of fruits, vegetables, and herbs, including onions, apples, and parsley. Quercetin has been found to have antioxidant, anti-inflammatory, and anticancer properties. It may also have benefits for cardiovascular health, such as reducing blood pressure and improving cholesterol levels.

In addition to their potential health benefits, flavone glycosides have also been studied for their potential role in modulating the gut microbiome. Some studies have suggested that flavone glycosides may have prebiotic effects, promoting the growth of beneficial bacteria in the gut. This could have potential benefits for overall health and may help to prevent and treat certain diseases.

Flavone glycosides can be consumed through a variety of sources, including fruits, vegetables, and herbs. They can also be taken as supplements. However, as with any supplement, it is important to talk to a healthcare professional before taking flavone glycosides in supplement form, as they may interact with certain medications and may not be appropriate for everyone.

In conclusion, flavone glycosides are a group of natural compounds found in plants that are composed of a flavone molecule and a sugar molecule. They are responsible for the bright colors seen in many fruits and flowers and play a role in protecting plants from environmental stressors. Flavone glycosides have potential health benefits, including antioxidant, anti-inflammatory, and anticancer properties. They may also have benefits for cardiovascular health and may help to modulate the gut microbiome. Flavone glycosides can be consumed through a variety of sources and may also be taken as supplements, but it is important to talk to a healthcare professional before doing so.

**COUMARIN AND FURANOCOUMARIN GLYCOSIDES**

 In these type of glycosides the aglycone is coumarin. Coumarin is a chemical compound found in many plants, notably in high concentration in the tonka bean, woodruff, and sweet grass. They are benzopyrone derivative have aromatic smell and their alcoholic solutions when made alkaline show blue or green fluorescence. The biosynthesis of coumarin in plants is via hydroxylation, glycolysis and cyclization of cinnamic acid.

 It has clinical value as the precursor for several anticoagulants, notably warfarin. Some naturally occuring coumarin derivatives include umbelliferone (7-hydroxycoumarin), herniarin (7-methoxy-coumarin), psoralen and imperatorin. Coumarins have flavouring property but they cause damage to liver. Coumarin drugs also cause drug interactions with many other drugs. Medicinally, coumarin glycosides have been shown to have hemorrhagic, antifungicidal and antitumor activities.

 Furanocoumarins are toxic compounds that consist of a coumarin nucleus bonded to a furan ring. Several plants contain the psoralens that are generally the precursors of furocoumarins. Furanoccumarins are found especially in Rutaceae, Umbelliferae and Leguminosae. They are also produced by some plants, for example, celery and parsnips, in response to fungal infestation.

**BITTER AND MISCELLANEOUS GLYCOSIDES**

 Bitter glycosides are a class of compounds that plays an important role in the digestive process. Bitter drugs and bitter constituents are used since a very early period as stomachics, febrifuges, and bitter tonics and in digestive disturbances.

 The bitterness of food on the tongue plays a very important role as the taste of bitter foods stimulates the appetite and triggers the secretion of digestive juices in the stomach, which in turn improves the break down of food. Bitters begin by stimulating the taste buds. This triggers off a reflex nerve action which increases the flow of saliva and stomach enzymes. At the same time, the hormone gastrin is secreted by the walls of the stomach. This improves the digestive process, by improving the passage of food from the stomach to the intestines. The sum total of this is an improvement in the digestive function of the stomach and small intestines. Bitters can also be very useful to improve immune disorders resulting from food intolerance or dietary antigen leakage, protect gut tissue (by increasing the tone of the gastro-esophageal sphincter thereby preventing reflux of corrosive stomach contents into the esophagus in ‘heart burn’, hiatus hernia, or esophageal inflammation), promote bile flow (thereby providing for increased ability of the liver to remove a toxic load from incomplete digestion and also provide for better digestion in the duodenum and small intestine), and enhance pancreatic function (normalizing hormone secretions to moderate excessive swings in blood–sugar levels).

 Examples of bitter digestives are Blessed Thistle, Barberry bark, Goldenseal, Dandelion, Hops flowers, Yellow dock, and Gentian root. Bitter drugs preparations should be taken before or during meals otherwise they cause digestive disturbances like diarrhoea, and pain in the stomach.

**ALDEHYDE GLYCOSIDES**

Aldehyde glycosides are a type of organic compound that are composed of a sugar molecule (glycoside) and an aldehyde functional group. The aldehyde functional group contains a carbonyl group (C=O) that is attached to a carbon atom and a hydrogen atom. This combination of functional groups gives aldehyde glycosides unique properties and biological activities.

Aldehyde glycosides are commonly found in plants, where they serve a variety of functions. For example, some aldehyde glycosides act as defensive compounds, protecting the plant from herbivores and pathogens. Others act as pigments, contributing to the coloration of flowers and fruits.

One well-known example of an aldehyde glycoside is salicin, which is found in willow bark. Salicin is metabolized in the body to form salicylic acid, which has analgesic and anti-inflammatory properties and is the active ingredient in aspirin. Salicin is a white crystalline powder that is soluble in water and alcohol. It has a bitter taste and a melting point of 197-200°C.

Another example of an aldehyde glycoside is vanillin, which is found in the seeds of the vanilla orchid. Vanillin is widely used as a flavoring agent in food and beverages. It has a sweet, creamy flavor and a distinctive aroma. Vanillin is a yellow crystalline solid that is soluble in alcohol and oil but insoluble in water.

Aldehyde glycosides have a wide range of biological activities, including antimicrobial, antioxidant, and anti-inflammatory effects. For example, some aldehyde glycosides have been shown to inhibit the growth of bacteria and fungi. Others have been shown to scavenge free radicals and protect cells from oxidative damage.

Aldehyde glycosides also have industrial applications. For example, vanillin is used as a flavoring agent in food and beverages, as well as in perfumes and cosmetics. Salicylic acid, which is produced from salicin, is used as a pain reliever and anti-inflammatory agent in medicines.

The biosynthesis of aldehyde glycosides involves several steps. First, the sugar molecule is activated by attachment to a nucleotide molecule, such as UDP-glucose. Next, the activated sugar is attached to a carrier molecule, such as a lipid or protein. The aldehyde group is then added to the sugar molecule by an enzyme called an aldehyde synthase. Finally, the glycoside is transported to its final destination in the plant, where it may serve a defensive or pigmentary function.

In conclusion, aldehyde glycosides are important compounds with a wide range of biological and industrial applications. They are commonly found in plants and have been used for medicinal and culinary purposes for centuries. Further research into the properties and activities of aldehyde glycosides may lead to new applications in fields such as medicine, food science, and cosmetics.

**PHENOL GLYCOSIDES**

Phenol glycosides are a class of organic compounds that consist of a phenol group and a sugar molecule (glycoside) linked together. Phenols are organic compounds that contain an aromatic ring (a ring of atoms with alternating double bonds) with a hydroxyl (-OH) group attached to it. The sugar molecule in phenol glycosides can be any of a variety of simple or complex sugars.

Phenol glycosides are widely distributed in the plant kingdom and are particularly abundant in medicinal plants. They serve a variety of functions in plants, including defense against herbivores and pathogens, pigmentation of flowers and fruits, and as signaling molecules in plant growth and development.

One well-known example of a phenol glycoside is salicin, which is found in willow bark. Salicin is a natural pain reliever and anti-inflammatory agent. When salicin is metabolized in the body, it is converted to salicylic acid, which is the active ingredient in aspirin.

Another example of a phenol glycoside is arbutin, which is found in the leaves of bearberry and other plants. Arbutin has been used for centuries as a traditional medicine for treating urinary tract infections and other conditions. Arbutin has also been studied for its potential use in cosmetics as a skin whitening agent.

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The biosynthesis of phenol glycosides involves several steps. First, the sugar molecule is activated by attachment to a nucleotide molecule, such as UDP-glucose. Next, the activated sugar is attached to a carrier molecule, such as a lipid or protein. The phenol group is then added to the sugar molecule by an enzyme called a phenol synthase. Finally, the glycoside is transported to its final destination in the plant, where it may serve a defensive or pigmentary function.

Phenol glycosides have been used in traditional medicine for centuries to treat a variety of ailments. For example, willow bark has been used for thousands of years as a natural pain reliever. In modern times, salicin has been isolated from willow bark and used as the basis for the development of aspirin, which is one of the most widely used pain relievers in the world.

Phenol glycosides also have potential applications in the food industry. For example, some phenol glycosides have been shown to have antimicrobial properties that could be used to preserve food. Other phenol glycosides have been shown to have antioxidant properties that could be used to prevent oxidative damage in food products.

In addition, phenol glycosides have potential applications in the cosmetics industry. For example, arbutin has been studied for its potential use as a skin whitening agent. Arbutin is thought to inhibit the production of melanin, which is the pigment that gives skin its color. By inhibiting melanin production, arbutin may help to lighten dark spots and improve overall skin tone.

Despite their potential applications, phenol glycosides can also have negative effects on human health. For example, some phenol glycosides are toxic and can cause gastrointestinal irritation, liver damage, and other health problems. In addition, some phenol glycosides can interact with medications and other substances, leading to potentially harmful side effects.

In conclusion, phenol glycosides are important compounds with a wide range of biological and industrial applications. They are commonly found in medicinal plants and

**STEROIDAL GLYCOSIDES**

Steroidal glycosides are a class of organic compounds that consist of a steroid nucleus and a sugar molecule (glycoside) linked together. Steroids are a family of organic compounds that share a common four-ring structure. Steroidal glycosides are widely distributed in the plant kingdom and are particularly abundant in medicinal plants. They serve a variety of functions in plants, including defense against herbivores and pathogens, pigmentation of flowers and fruits, and as signaling molecules in plant growth and development.

Steroidal glycosides are classified based on the nature of the sugar molecule attached to the steroid nucleus. Some common types of steroidal glycosides include cardiac glycosides, saponins, and steroidal alkaloids.

Cardiac glycosides are a type of steroidal glycoside that have a specific effect on the heart. They are widely used in the treatment of congestive heart failure, arrhythmias, and other cardiovascular conditions. Cardiac glycosides work by inhibiting the activity of the sodium-potassium ATPase pump in heart muscle cells. This leads to an increase in intracellular calcium concentration, which in turn increases the force of cardiac contraction.

One well-known example of a cardiac glycoside is digoxin, which is derived from the foxglove plant. Digoxin has been used for centuries as a traditional medicine for the treatment of heart conditions. In modern times, digoxin has been isolated and used as a medication for the treatment of congestive heart failure, atrial fibrillation, and other cardiovascular conditions.

Saponins are another type of steroidal glycoside that are widely distributed in the plant kingdom. Saponins are named for their ability to form soap-like foams when shaken in water. Saponins have a wide range of biological activities, including antimicrobial, anti-inflammatory, and immunomodulatory effects. Saponins are also used in the food industry as emulsifiers, foaming agents, and stabilizers.

One well-known example of a saponin is soyasaponin, which is found in soybeans. Soyasaponin has been studied for its potential health benefits, including its ability to reduce cholesterol levels, improve blood glucose control, and prevent cancer.

Steroidal alkaloids are a type of steroidal glycoside that contain an additional nitrogen atom in their structure. Steroidal alkaloids are often toxic and have a variety of biological activities, including anti-inflammatory, anti-tumor, and insecticidal effects. Steroidal alkaloids are commonly found in plants of the Solanaceae family, including tomatoes, potatoes, and eggplants.

One well-known example of a steroidal alkaloid is solanine, which is found in green potatoes and other members of the Solanaceae family. Solanine is highly toxic and can cause a variety of symptoms, including nausea, vomiting, diarrhea, and even death in severe cases.

The biosynthesis of steroidal glycosides involves several steps. First, the sugar molecule is activated by attachment to a nucleotide molecule, such as UDP-glucose. Next, the activated sugar is attached to a carrier molecule, such as a lipid or protein. The steroid nucleus is then modified by a series of enzymatic reactions, including oxidation, reduction, and cyclization. Finally, the glycoside is transported to its final destination in the plant, where it may serve a defensive or pigmentary function.

Steroidal glycosides have been used in traditional medicine for centuries to treat a variety of ailments. For example, foxglove has been used for thousands of years as a natural remedy for heart conditions. In modern times, digoxin has been isolated from foxglove and used as a medication for the treatment of congestive heart failure and other cardiovascular conditions.

**ISOLATION**

 Stas-Otto Method

 The general method of extraction of glycosides is outlined here. The drug containing glycoside is finely powdered and the powder is extracted by continuous hot percolation using soxhlet apparatus with alcohol as solvent. During this process, various enzymes present in plant parts are also deactivated due to heating. The thermolabile glycosides, however, should be extracted at temperature preferably below 45°C. The extract is treated with lead acetate to pre-cipitate tannins and thus eliminate nonglycosidal impurities. The excess of lead acetate is precipitated as lead sulphide by passing hydrogen sulphide gas through solution. The extract is filtered, concentrated to get crude glycosides. From the crude extract, the glycosides are obtained in pure form by making use of processes like fractional solubility, fractional crystallization and chromatographic techniques such as preparative thin layer and column chromatography.

 The characterization of isolated purified compounds is done by IR, UV, visible, NMR and mass spectrometry and elemental analysis.

**CHEMICAL TESTS OF GLYCOSIDES**

 Glycosides are the compounds with organic molecules having attached glucose or any mono-oligo saccharide unit. Usually, these are crystalline or amorphous solids; opti-cally active, soluble in water and alcohol but insoluble in organic solvents like ether, chloroform and benzene etc. Generally, aqueous or alcoholic extracts of crude drugs are tested with specific reagents for presence of various types of glycosides.

Chemical Tests for Anthraquinone Glycosides

Borntrager’s test

To 1 gm of drug add 5–10 ml of dilute HCl boil on water bath for 10 min and filter. Filtrate was extracted with CCl4/ benzene and add equal amount of ammonia solution to fil trate and shake. Formation of pink or red colour in ammoni-cal layer due to presence of anthraquinone moiety.

Modified borntrager’s test

 To 1 gm of drug, add 5 ml dilute HCl followed by 5 ml ferric Chloride (5% w/v). Boil for 10 min on water bath, cool and filter, filtrate was extracted with carbon tetra-chloride or benzene and add equal volume of ammonia solution, formation of pink to red colour due to presence of anthraquinone moiety. This is used C-type of anthraqui-none glycosides.

Chemical Tests for Saponin Glycosides

 Haemolysis test

 A drop blood on slide was mixed with few drops of aq. Saponin solution, RBC’s becomes ruptured in presence of saponins.

Foam test

 To 1 gm of drug add 10–20 ml of water, shake for few minutes, formation frothing which persists for 60–120 s in presence of saponins.

Chemical Tests for Steroid and Triterpenoid Glycosides

 Libermann burchard test

 Alcoholic extract of drug was evaporated to dryness and extracted with CHCl3, add few drops of acetic anhydride followed by conc. H2 SO4 from side wall of test tube to the CHCl3 extract. Formation of violet to blue coloured ring at the junction of two liquid, indicate the presence of steroid moiety.

Salkowaski test

 Alcoholic extract of drug was evaporated to dryness and extracted with CHCl3, add conc. H2 SO4 from sidewall of test tube to the CHCl3 extract. Formation of yellow coloured ring at the junction of two liquid, which turns red after 2 min, indicate the presence of steroid moiety.

Antimony trichloride test

Alcoholic extract of drug was evaporated to dryness and extracted with CHCl3, add saturated solution of SbCl3 in CHCl3containing 20% acetic anhydride. Formation of pink colour on heating indicates presence of steroids and triterpenoids.

Trichloro acetic acid test

 Triterpenes on addition of saturated solution of trichloro acetic acid forms coloured precipitate.

Tetranitro methane test

 It forms yellow colour with unsaturated steroids and trit-erpenes.

Zimmermann test

 Meta dinitrobenzene solution was added to the alcoholic solution of drug containing alkali, on heating it forms violet colour in presence of keto steroid.

Chemical Tests for Cardiac Glycosides

 Keller-kiliani test

 To the alcoholic extract of drug equal volume of water and 0.5 ml of strong lead acetate solution was added, shaked and filtered. Filtrate was extracted with equal volume of chloroform. Chloroform extract was evaporated to dryness and residue was dissolved in 3 ml of glacial acetic acid followed by addition of few drops of FeCl3 solution. The resultant solution was transferred to a test tube contain-ing 2 ml of conc. H2SO4. Reddish brown layer is formed, which turns bluish green after standing due to presence of digitoxose.

Legal test

 To the alcoholic extract of drug equal volume of water and 0.5 ml of strong lead acetate solution was added, shaked and filtered. Filtrate was extracted with equal volume of chloroform and the chloroform extract was evaporated to dryness. The residue was dissolved in 2 ml of pyridine and sodium nitropruside 2 ml was added followed by addition of NaOH solution to make alkaline. Formation of pink colour in presence of glycosides or aglycon moiety.

Baljet test

Thick section of leaf of digitalis or the part of drug con-taining cardiac glycoside, when dipped in sodium picrate solution, it forms yellow to orange colour in presence of aglycones or glycosides.

 3,5-dinitro benzoic acid test

 To the alcoholic solution of drug few drops of NaOH followed by 2% solution of 3,5-dinitro benzoic acid was added. Formation of pink colour indicates presence of cardiac glycosides.

Chemical Tests for Coumarin Glycosides

 FeCl3 test

 To the concentrated alcoholic extract of drug few drops of alcoholic FeCl3 solution was added. Formation of deep green colour, which turned yellow on addition of conc. HNO3, indicates presence of coumarins.

Fluorescence test

 The alcoholic extract of drug was mixed with 1N NaOH solution (one ml each). Development of blue-green fluo-rescence indicates presence of coumarins.

Chemical Tests for Cynophoric Glycoside

 Sodium picrate test

 Powdered drug was moistened with water in a conical flask and few drops of conc. Sulphuric acid was added. Filter paper impregnated with sodium picrate solution followed by sodium carbonate solution was trapped on the neck of flask using cork. Formation of brick red colour due to volatile HCN in presence of cynophoric glycosides takes place.

Chemical Tests for Flavonoid Glycosides

 Ammonia test

 Filter paper dipped in alcoholic solution of drug was exposed to ammonia vapor. Formation of yellow spot on filter paper.

Shinoda test

 To the alcoholic extract of drug magnesium turning and dil. HCl was added, formation of red colour indicates the presence of flavonoids. To the alcoholic extract of drug zinc turning and dil. HCl was added, formation of deep red to magenta colour indicates the presence of dihydro flavonoids.

Vanillin HCl test

 Vanillin HCl was added to the alcoholic solution of drug, formation of pink colour due to presence of flavonoids.

**BIOLOGICAL ROLE OF GLYCOSIDES**

Glycosides play important roles in various biological processes in plants, animals, and microorganisms. Some of the key functions of glycosides are as follows:

Pigmentation: Many glycosides are responsible for the colors seen in flowers, fruits, and leaves. For example, anthocyanin glycosides give red, blue, and purple colors to plants, while carotenoid glycosides give orange, yellow, and red colors.

Flavor and aroma: Glycosides contribute to the flavor and aroma of many foods, such as fruits, vegetables, and herbs. For example, glucosinolate glycosides in cruciferous vegetables such as broccoli and cauliflower are responsible for their characteristic bitter taste.

Defense mechanisms: Glycosides are part of the defense mechanisms of plants against herbivores and pathogens. Some glycosides act as toxins or deterrents to herbivores, while others inhibit the growth of pathogens. For example, cyanogenic glycosides can release cyanide upon hydrolysis, which can deter herbivores and kill pathogens.

Medicinal properties: Many glycosides have medicinal properties and are used in traditional medicine. For example, cardiac glycosides are used to treat heart failure and certain types of arrhythmia, while anthraquinone glycosides are used as laxatives.

Anti-inflammatory and antioxidant properties: Some glycosides have anti-inflammatory and antioxidant properties, which may have potential health benefits. For example, flavonoid glycosides such as quercetin and hesperidin have anti-inflammatory and antioxidant properties and may help protect against chronic diseases such as heart disease and cancer.

Enzyme inhibition: Some glycosides can inhibit enzymes in the body, which can have therapeutic effects. For example, glucosinolate glycosides in cruciferous vegetables can inhibit enzymes involved in the metabolism of carcinogens and may help prevent cancer.

Insect behavior modification: Some glycosides can modify the behavior of insects by acting as attractants or repellents. For example, iridoid glycosides in certain plants can attract beneficial insects such as pollinators, while cardenolide glycosides in milkweed can deter herbivorous insects by making them sick or causing them to avoid the plant.

Signal transduction: Some glycosides can act as signaling molecules in plants, animals, and microorganisms. For example, oligosaccharide glycosides in plants can signal the presence of pathogens and trigger defense responses.

Applications of Glycosides Glycosides have numerous applications in medicine, food, and agriculture. Some common applications of glycosides are as follows:

Medicinal uses: Many glycosides have medicinal properties and are used in the treatment of various diseases. For example, cardiac glycosides such as digoxin and ouabain are used to treat heart failure and certain types of arrhythmia, while arbutin is used as a skin-lightening agent.

Flavor and fragrance: Glycosides contribute to the flavor and fragrance of many foods and perfumes. For example, vanillin glycosides in vanilla beans are used to flavor foods and beverages, while monoterpenoid glycosides in lavender and rosemary are used in perfumes and aromatherapy.

Food additives: Some glycosides are used as food additives to improve the texture, stability, and flavor of foods. For example, steviol glycosides are used as a natural sweetener in food and beverages, while naringin and hesperidin glycosides are used as antioxidants and stabilizers in food.

Agricultural uses: Glycosides have various applications in agriculture.