FOOD SCIENCE AND TECHNOLOGY

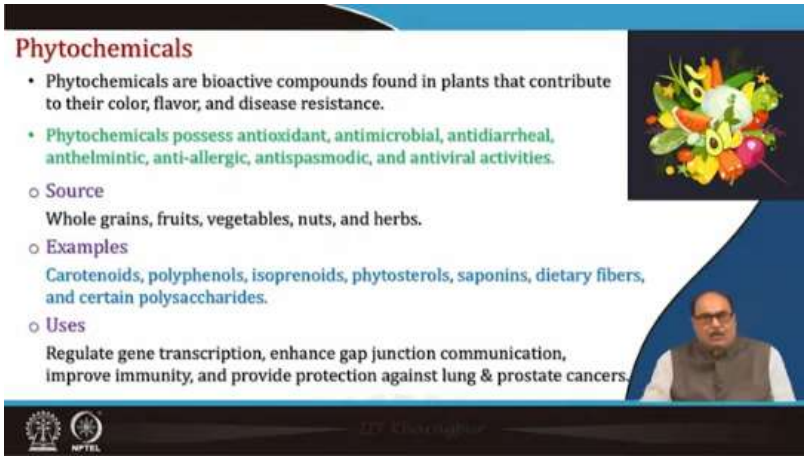
Lecture28

Lecture 28: Phytochemicals and Bioactives

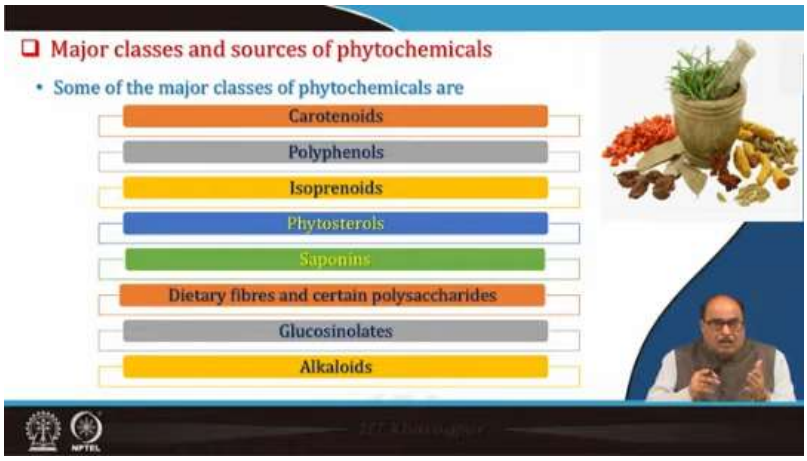
Hello everyone, Namaste.

So, in this lecture today, we shall be talking about phytochemicals. We are now in the sixth module, where we are discussing micronutrients and bioactive compounds present in food.

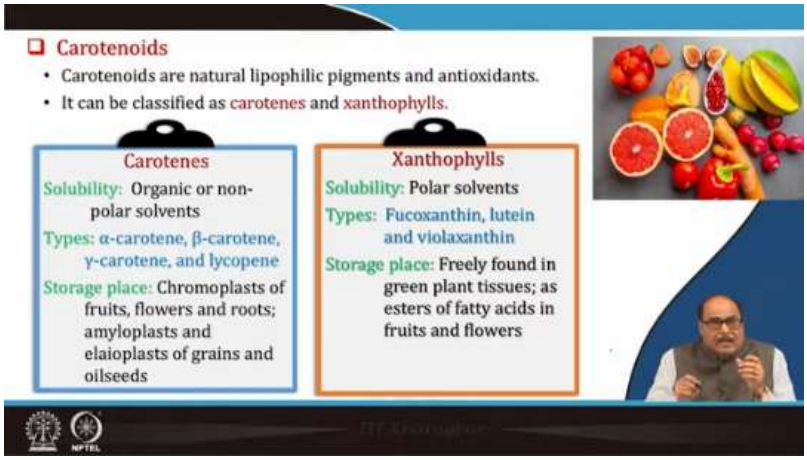
So, in today's lecture on phytochemicals, the concepts that we will cover include the major classes and sources of phytochemicals. We will discuss the health benefits of phytochemicals, the mechanism of action of phytochemicals, and finally, we will also talk about the bioavailability and absorption of phytochemicals.



So, let us talk about what phytochemicals are. Phytochemicals are bioactive compounds found in plants that contribute to the color, flavor, and various disease resistance-related properties in the plant. Phytochemicals possess antioxidant, antimicrobial, antidiarrheal, antihelminthic, antiallergic, antispasmodic, and antiviral activities, among many other health-promoting activities. Phytochemicals are mainly found in whole grains, fruits, vegetables, nuts, and herbs. Some common examples of phytochemicals include carotenoids, polyphenols, isoprenoids, phytosterols, saponins, dietary fibers, and certain polysaccharides. As far as the usage of phytochemicals is concerned, they regulate gene transcription, enhance gap junction communication, improve immunity, and provide protection against lung and prostate cancers.

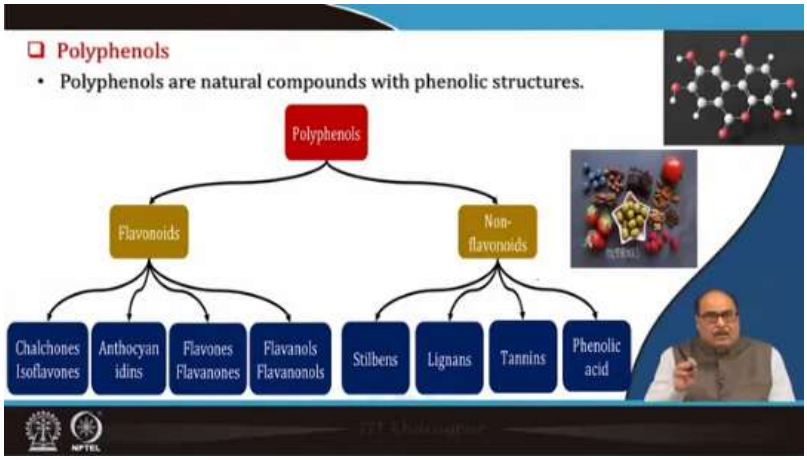


The major classes of phytochemicals include carotenoids, polyphenols, isoprenoids, saponins, some dietary fibers, certain polysaccharides, glucosinolates, and alkaloids. So, we will discuss almost all major aspects of these phytochemicals briefly in the coming slides.

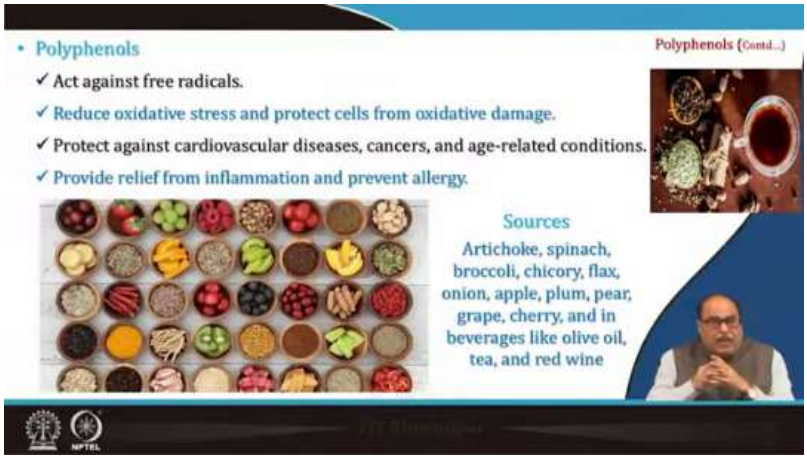


So, let us first talk about carotenoids. Carotenoids are natural lipophilic pigments and antioxidants. They can be classified as carotenes and xanthophylls. The carotenes are soluble in organic and non-polar solvents. They are mainly alpha carotene, beta carotene, gamma carotene, and lycopene. They are generally found in chromoplasts of fruits, flowers, and roots, as well as in amyloplasts and elaioplasts of grains and oilseeds. Whereas, on the other hand, their types include fucoxanthin, lutein, and biloxanthin. They are normally found in green plant tissues. They are also found as esters of fatty acids in fruits and flowers.

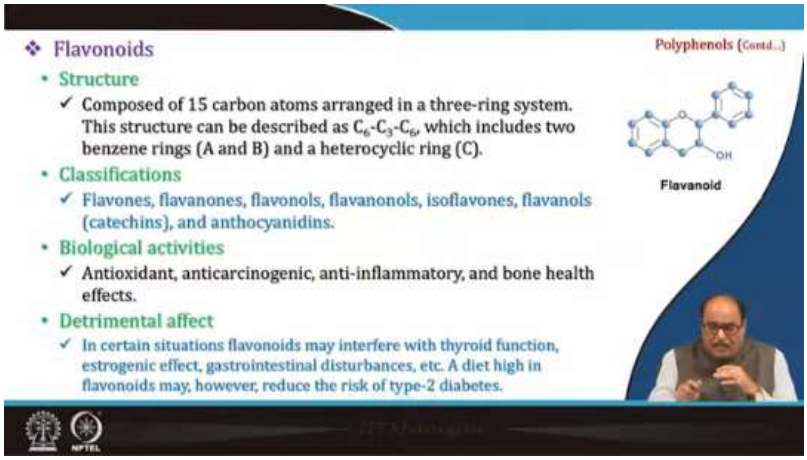
The different major food sources of carotenoids, if you talk about zeaxanthin, it is majorly found in corn, eggs, orange peppers, and goji berries. Lycopene, a very popular source of lycopene, is tomatoes. It is also found in papaya, watermelons, and red carrots. Astaxanthins are found in algae, salmon, shrimp, and trout. Whereas beta-carotene, carrot is the major source of beta-carotene. It is also found in mangoes, pumpkins, and sweet potatoes. Lutein is mainly found in avocados, egg yolk, spinach, and basil.



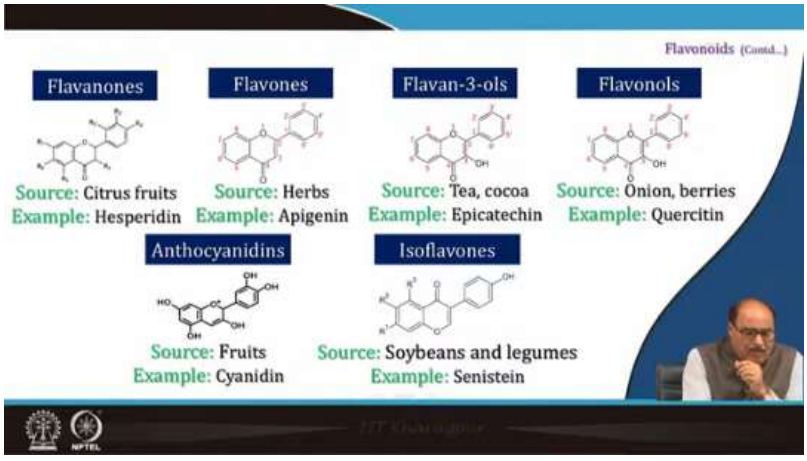
Now, the polyphenols: what are polyphenols? They are basically natural compounds with a phenolic structure. They can be broadly classified into two major groups: one is the flavonoids, and the other is non-flavonoids. The flavonoids include chalcones, isoflavones, anthocyanidins, flavones, flavanones, and flavonols. Similarly, non-flavonoid polyphenols include stilbenes, lignins, tannins, and phenolic acids.



Polyphenols act against free radicals. They reduce oxidative stress and protect cells from oxidative damage. They protect against cardiovascular diseases, cancers, and age-related conditions. Polyphenols provide relief from inflammation and prevent allergies. Major sources of polyphenols include artichoke, spinach, broccoli, chicory, flax, onion, apple, plum, and pear. Grape, cherry, and also, they are found in some beverages like olive oil, tea, as well as red wine. Red wines are considered the major and very good sources of polyphenols.

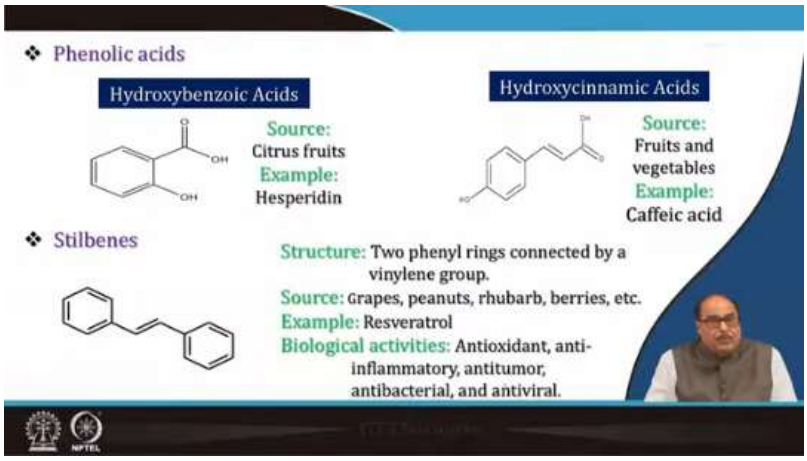


You can see here in this structure; they are composed of 15 carbon atoms arranged in a three-ring system. This structure can be described as C_6, C_3, and C_6, which includes two benzene rings, that is A and B, and one heterocyclic ring, which is called C. As far as the classification of flavonoids is concerned, there are different types. Flavones, flavonones, flavonols, flavanonols, isoflavones, again flavanols, and there are catechins and anthocyanidins. Their biological activities include acting as antioxidants, anti-carcinogenic agents, anti-inflammatory, and also bone health effects. They have bone health effects. However, in certain situations, flavonoids may interfere with thyroid function., estrogenic effects they may have, or they may also have gastrointestinal disturbances, etcetera, and this may be considered that, particularly if they are taken in larger amounts, they may be detrimental. A diet high in flavonoids may, however, reduce the risk of type 2 diabetes, and there is sufficient literature which proves this.

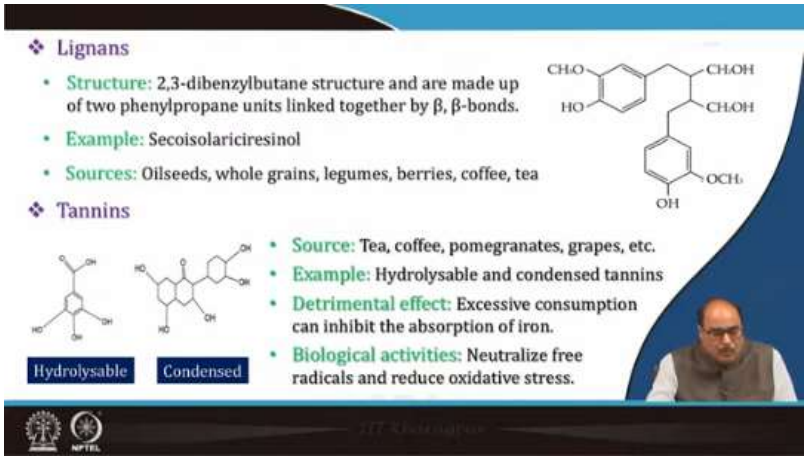


Now, the different major types of flavonoids, like flavanones, are found mainly in citrus foods, and a very good example of the flavonoids found in citrus foods is hesperidin; its structure is provided here. Similarly, flavones are found in herbs, and apigenin is the major

one. Flavan-3-ols, for example, epicatechin, are mainly found in tea and cocoa; their structure is given here. Flavonols, a very good example of which is quercetin, are found in onions as well as in berries. Anthocyanidins, for example, cyanidin, are found mainly in fruits. Isoflavones, such as genistein, are found in soybeans and other legumes.

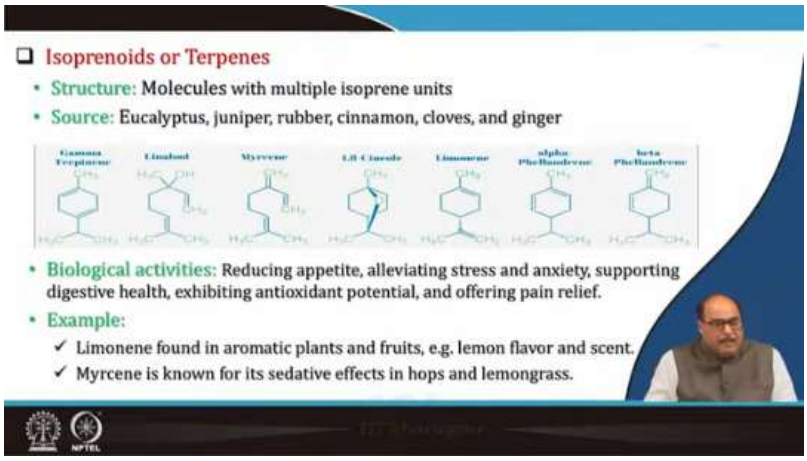


Phenolic acids, like hydroxybenzoic acids, have a common example in hesperidin, which is found in citrus fruits. Stilbenes, whose structure you can see here, have two phenyl rings connected by a vinylene group. Their sources include grapes, peanuts, rhubarb, berries, etc. An example of stilbenes is resveratrol. Their biological activities include strong antioxidant potential, anti-inflammatory properties, anti-tumor, antibacterial, and antiviral effects. Hydroxycinnamic acid has a major example in caffeic acid. It is found in fruits and vegetables. It also has very health-promoting activities.

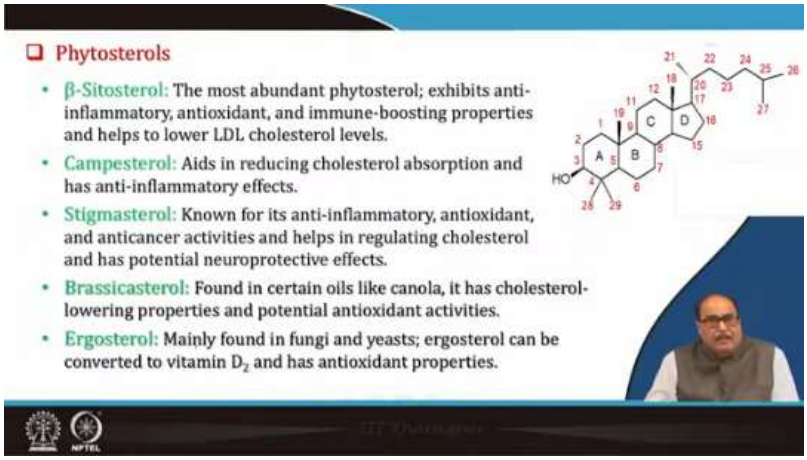


Lignans, whose structure you can see here, have a lignan structure provided. They have a 2,3-dibenzyl butane structure and are made up of two phenyl propane units linked together by beta-beta bonds and their sources include oilseeds, whole grains, legumes, berries,

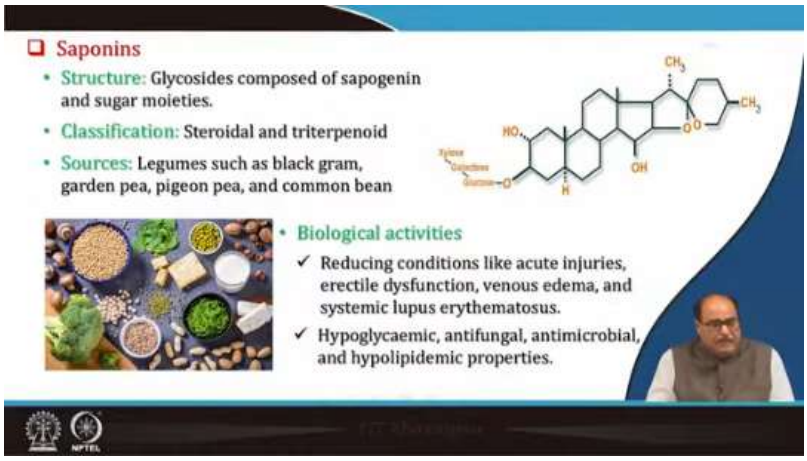
coffee, and tea. Another major group of compounds found in this polyphenol group is the tannin. This is mainly found in tea, coffee, pomegranate, grapes, etcetera, and the common examples of these tannins. includes hydrolyzable and condensed tannins. You can see the structure here: hydrolyzable and condensed tannins, and they have detrimental effects as well. Sometimes, for example, if one takes excessive consumption of these tannins, it can inhibit the absorption of iron in the body. The biological activities of tannin include neutralizing free radicals and reducing oxidative stress.



Then, another class is the isoprenoids or terpenes. They are molecules with multiple isoprene units. Their sources may be eucalyptus, juniper, rubber, cinnamon, cloves, and ginger. The major classes of compounds which are categorized in these isoprenoids or terpenes include gamma terpinene, linalool, myrcene, 1,3 cineole, limonene, alpha phellandrene, and beta phellandrene. These are their names and structures, which you can easily see provided here. Their biological activities include reducing appetite, elevating stress and anxiety, supporting digestive health, exhibiting antioxidant potential, and offering pain relief. We have already given the names here and the structure here, but some of the major isoprenoids or terpenes like limonene are found in aromatic plants and fruits. It is also a major compound that contributes to the flavor of lemon and the lemon scent, which is limonene. Similarly, myrcene is known for its sedative effects in hops and lemongrass.

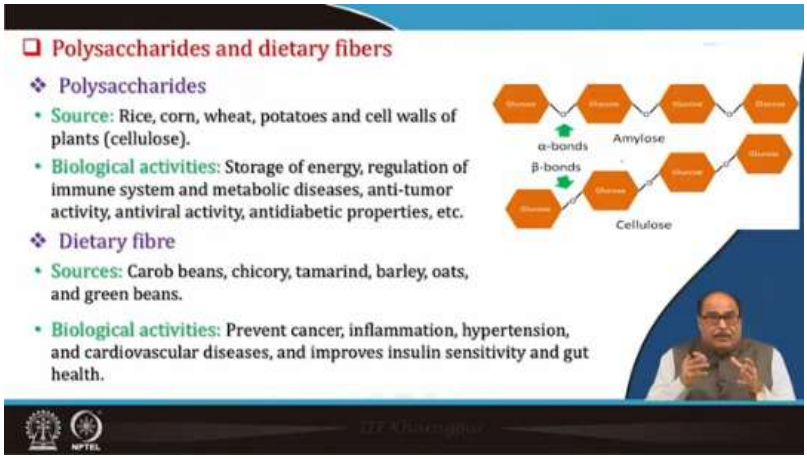


Then, let us talk about phytosterols. There are different types of phytosterols like beta-sitosterol, campesterol, stigmasterol, brassicasterol, ergosterol, etc. Beta-sitosterol is the most abundant phytosterol. It exhibits anti-inflammatory, antioxidant, and immune-boosting properties and also helps to lower LDL cholesterol levels. Campesterol aids in reducing cholesterol absorption and has anti-inflammatory effects. Stigmasterol is known for its anti-inflammatory, antioxidant, and anti-cancer activities. It helps in regulating cholesterol and has potential neuroprotective effects. Brassicasterol is found in certain oils like canola oil. It has cholesterol-lowering properties and potential antioxidant activities. Ergosterol is mainly found in fungi and yeast. Ergosterol can be converted to vitamin D_2, and it has potential antioxidant activity.

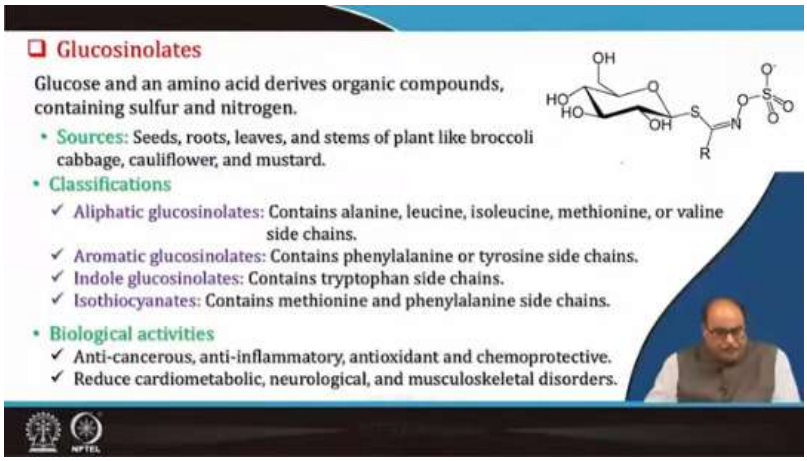


Then, saponins: Saponins are glycosides which are composed of sapogenin and sugar moieties like xylose, galactose, glucose, etcetera. You can see the structure is provided here. They can be classified into steroidal as well as triterpenoids. Sources of these saponins include legumes such as black gram, garden pea, pigeon pea, and even common beans, which contain a sufficient or good amount of saponins. The biological activities of

saponins include reducing conditions like acute injuries and erectile dysfunction. Venous edema and systemic lupus erythematosus. They have hypoglycemic, antifungal, antimicrobial, and hypolipidemic properties.

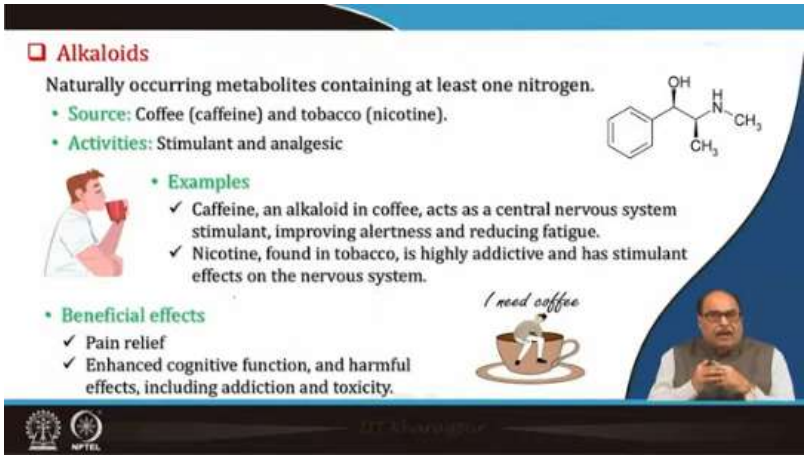


In another group of bioactive or active compounds which are found in food may include certain polysaccharides and dietary fibers. They are also sometimes considered, some of them, as phytochemicals. So, polysaccharides like those found in corn, wheat, potatoes, and the cell walls of plants like cellulose, etcetera. They have biological activities like the storage of energy, regulation of the immune system, and metabolic diseases. They have anti-tumor activity, anti-viral activity, and anti-diabetic properties, etcetera. Similarly, dietary fibers are found mainly in carob beans, chicory, tamarind, barley, oats, and green beans. Their biological activities include preventing cancer, inflammation, hypertension, and cardiovascular diseases. They also improve insulin sensitivity and gut health.

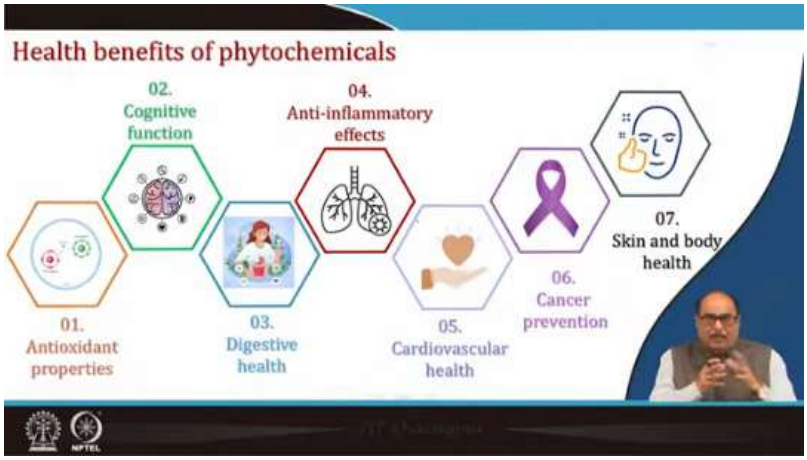


Glucosinolates, a compound of glucose and an amino acid, are derived from glucose and an amino acid, forming organic compounds containing sulfur and nitrogen. These are the

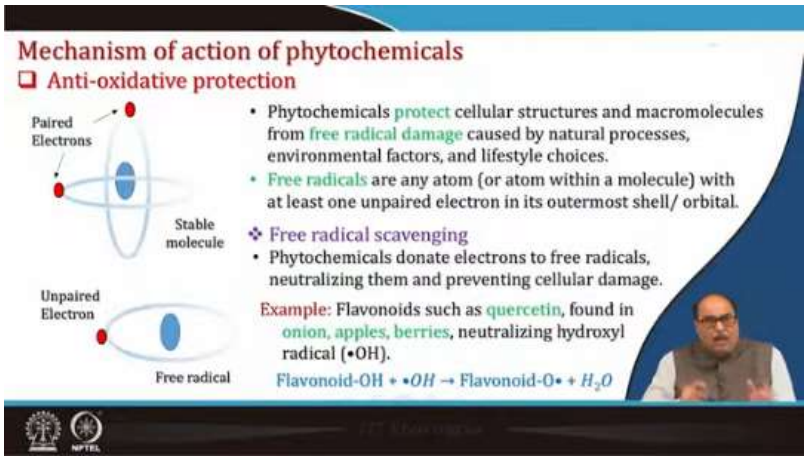
glucosinolates. They are found mainly in seeds, roots, leaves, and stems of plants like broccoli, cabbage, cauliflower, and mustard. Mustard seeds are a major source of glucosinolates. They can be classified into various groups, such as aliphatic glucosinolates. These contain alanine, leucine, isoleucine, methionine, or valine as side chains. Aromatic glucosinolates contain phenylalanine or tyrosine side chains. Indole glucosinolates contain tryptophan side chains and isothiocyanates contain methionine and phenylalanine side chains. So, depending on the type of amino acid present, they can be grouped into various categories. The biological activities of glucosinolates include being anti-cancerous, anti-inflammatory, antioxidant, and chemoprotective. They reduce cardiometabolic risks, neurological and musculoskeletal disorders.



Now, let us talk about alkaloids, another important group of phytochemicals. They are naturally occurring metabolites containing at least one nitrogen in their structure. Their sources mainly include caffeine, which is found in coffee, and nicotine, found in tobacco,. Their activities mainly include acting as stimulants and analgesics; they act as stimulants. For example, caffeine, which is an alkaloid in coffee, acts as a central nervous system stimulant, improving alertness and reducing fatigue. Similarly, nicotine, which is found in tobacco, is highly addictive and has a stimulant effect on the nervous system. The biological effects of alkaloids include pain relief, enhanced cognitive function, and harmful effects, including addiction and toxicity.

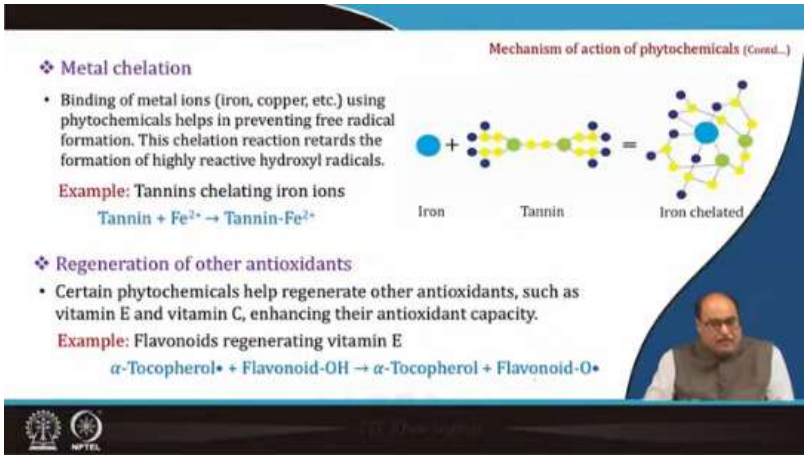


Now, let us talk about health benefits of the majority of phytochemical classes and major compounds we discussed. Now, as a whole, the health benefits of phytochemicals may be summarized as follows: Number one, they have antioxidant properties, they support cognitive functions, they promote digestive health, okay, they have anti-inflammatory effects, they improve cardiovascular health, they have cancer prevention properties, and finally, they have beneficial effects on the skin as well as the body. So, they improve skin and body health. So, these are the major health benefits of consuming phytochemicals.

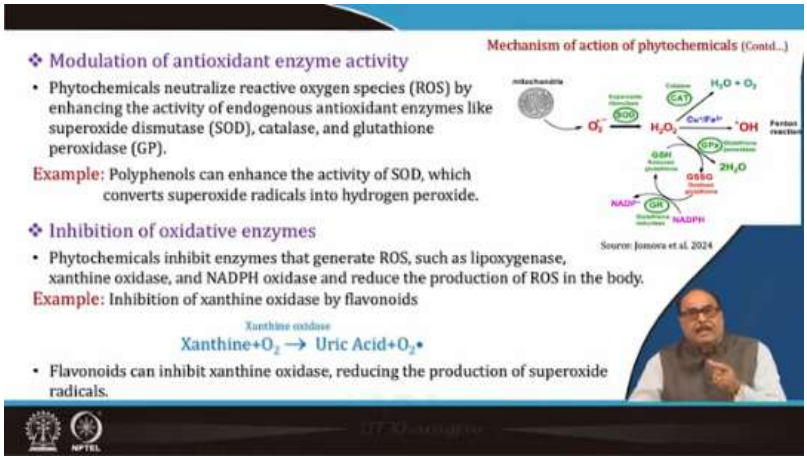


Now let us talk about the mechanism by which these phytochemicals act in the body. When we consume any phytochemicals, what is the way by which they act? So, number one is the major activity, which is the antioxidative protection. They act as antioxidants, meaning they prevent the oxidation process. That is, phytochemicals protect the cellular structure and macromolecules from oxidation. Free radical damage caused by natural processes, environmental factors, and lifestyle choices. The free radicals, as you can see here, are any atom or atom within a molecule with at least one unpaired electron in the outermost orbital, okay. So, the These phytochemicals have free radical scavenging activity, meaning the

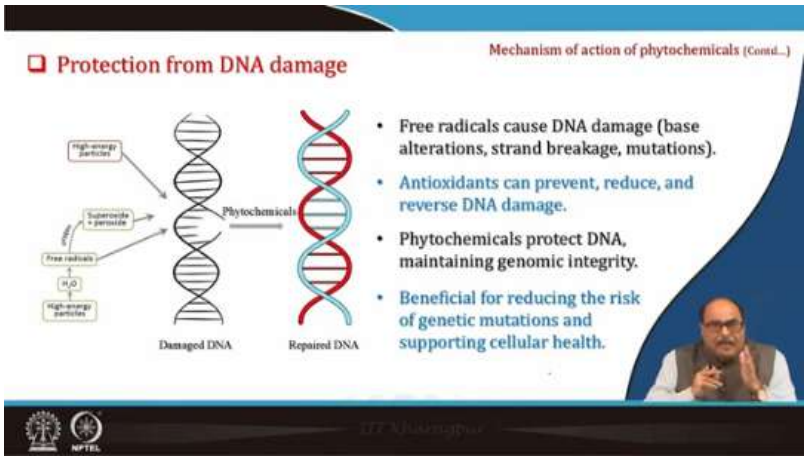
phytochemicals donate electrons to these free radicals, neutralizing them and preventing cellular damage. For example, flavonoids such as quercetin, which is found in onions, apples, and berries, neutralize the hydroxyl free radical. The equation is given here: the hydroxyl free radical is finally converted into water, and the flavonoid becomes the flavonoid free radical.



Similarly, they have metal chelation activity. Metal chelation means, as we discussed in earlier classes, what are the chelates? So, these phytochemicals bind metal ions like iron, copper, etcetera, and the chelation of the metal with the phytochemicals helps in preventing free radical formation, that is, these metals which promote the oxidation process. So, that is stopped. So, the free radical formation process is stopped, and this chelation reaction can retard the highly reactive hydroxy radicals, as you see that iron for tannins. Iron is chelated by these tannins, and therefore, the oxidation process is stopped. Also, they act as a regeneration of other antioxidants like certain phytochemicals, which help regenerate other antioxidants such as vitamin E and vitamin C, and therefore, enhance their antioxidant capacity. For example, flavonoids regenerate vitamin E. There is alpha-tocopherol and flavonoid free radicals.

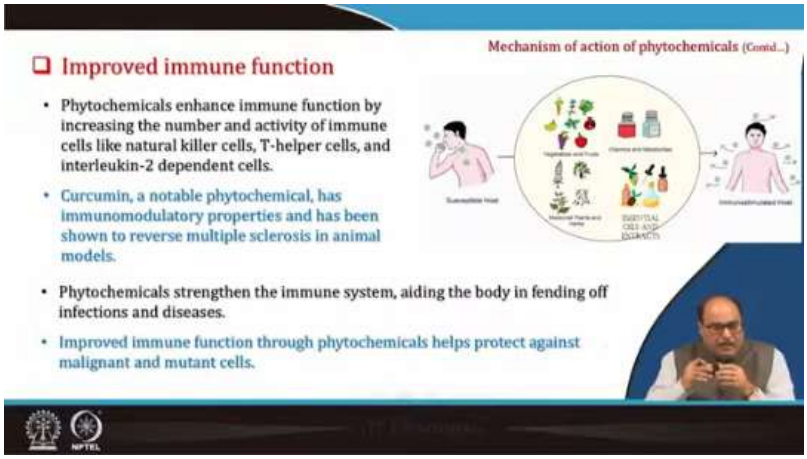


Then, they also modulate antioxidant enzyme activity that is, these phytochemicals neutralize reactive oxygen species by enhancing the activity of indigenous antioxidant enzymes like superoxide dismutase. catalase and glutathione peroxidase, commonly known as GP. For example, polyphenols can enhance the activity of superoxide dismutase which converts superoxide radicals into hydrogen peroxide, as you can see here in this reaction, it is shown in the cell. These phytochemicals act by inhibiting the oxidative enzymes. That is, the inhibition of the oxidative enzymes, which generate ROS, that is, reactive oxygen species. So, the phytochemicals inhibit these enzymes, such as lipoxygenase, xanthine oxidase, and NADPH oxidase, etc., and reduce the production of ROS in the body. As an example, you can see that these phytochemicals inhibit xanthine oxidase by flavonoids, which is the inhibition of xanthine oxidase by flavonoids. Flavonoids can inhibit xanthine oxidase and reduce the production of superoxide radicals or ROS.

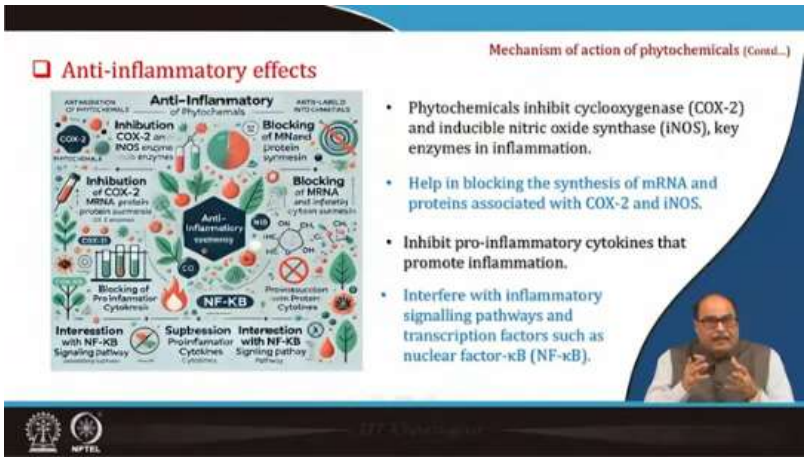


Then, the other way they act is by preventing the DNA damage protection, that is, these phytochemicals protect the DNA and protect the cell from DNA damage. As you know,

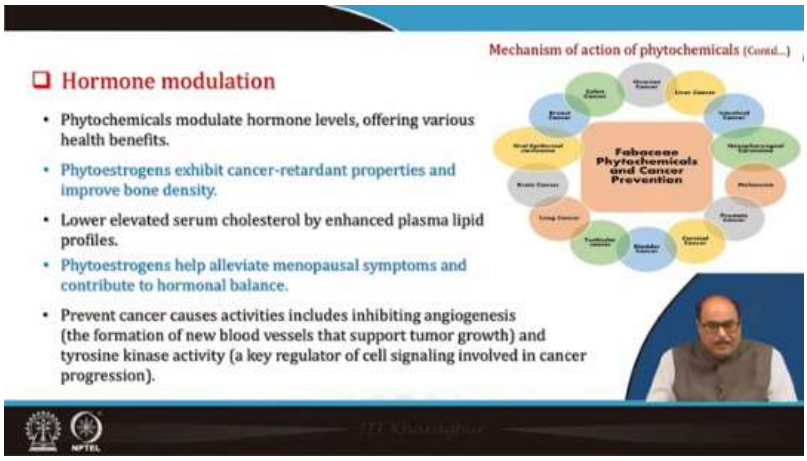
free radicals cause DNA damage like base alteration, strand breakdown, mutations, etc., which has been shown in this slide. See this figure, alright, how these free radicals, etc., vary the structure of the DNA is damaged. So, these antioxidants, or these phytochemicals, can prevent, reduce, and reverse this DNA damage. Phytochemicals protect the DNA, maintaining genomic integrity, they are beneficial for reducing the risk of genetic mutation and supporting cellular health.



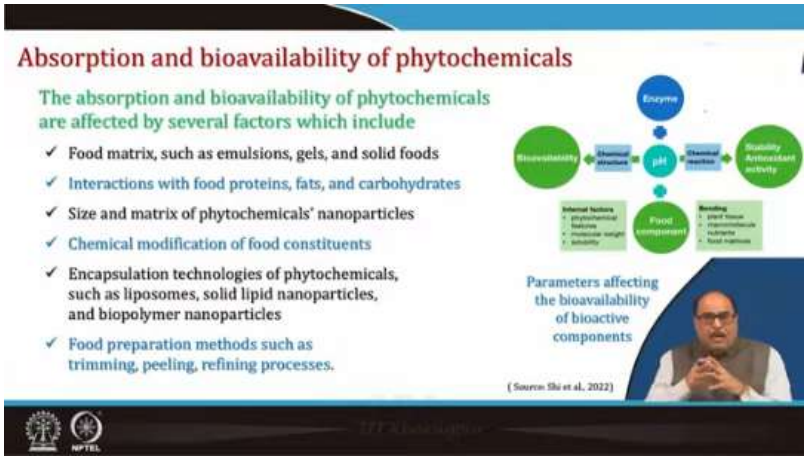
Then, another way these phytochemicals act, what is the mechanism, is that they improve immune function. Phytochemicals enhance immune function by increasing the number and activity of immune cells like natural killer cells, T helper cells, and interleukin-dependent cells. For example, curcumin, which is a notable phytochemical, has immunomodulatory properties and has been shown to reverse multiple sclerosis in animal models. Phytochemicals strengthen the immune system, aiding the body in fending off infections and diseases. They also improve immune function through phytochemicals and this improved immune function through phytochemicals helps protect against malignant and mutant cells.



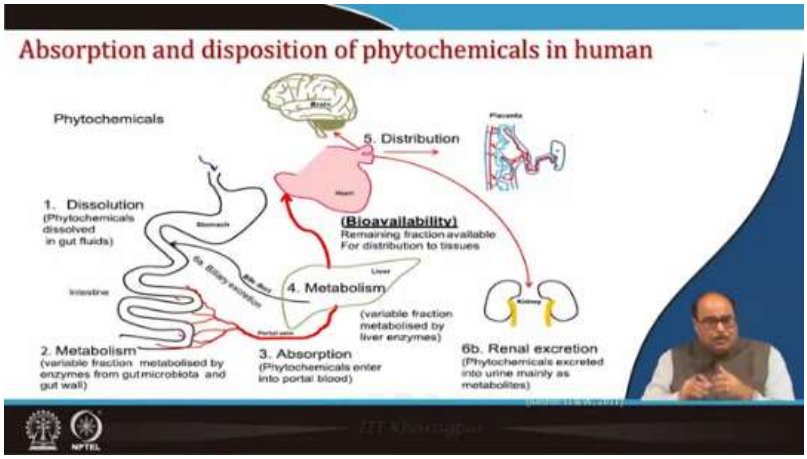
Another with the anti-inflammatory effect of the phytochemicals means the phytochemicals inhibit cyclooxygenase COX-2 and reduce inducible nitric oxide synthase like iNOS, which are the key enzymes for inflammation. So, these phytochemicals help in blocking the synthesis of mRNA and protein associated with COX-2 and iNOS. They also inhibit pro-inflammatory cytokines that promote inflammation. The phytochemicals interfere with the inflammatory signaling pathway and transcription factors such as nuclear factor KB, nuclear factor KB, INF KB.



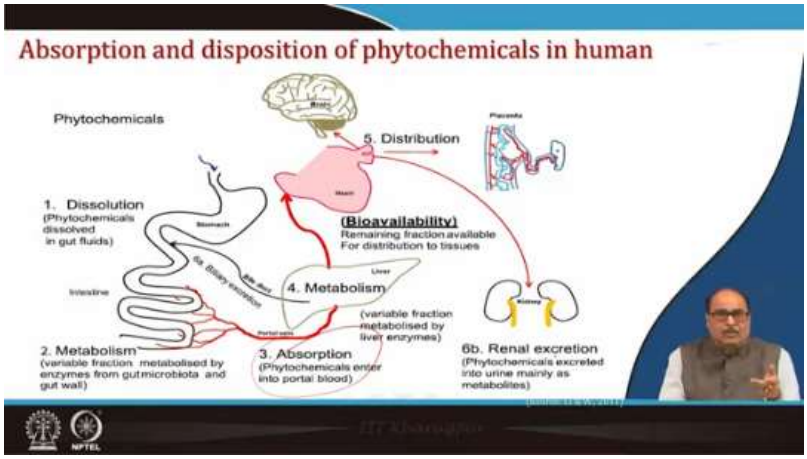
Then also the hormone modulations. Phytochemicals modulate hormone levels, offering nervous health benefits, offering various health benefits that phytoestrogens exhibit cancer-retardant properties and improve bone density, lower elevated serum cholesterol by enhancing plasma lipid profiles. Phytoestrogens help alleviate menopausal symptoms and contribute to hormonal balance. They prevent cancer and cause activity that is the cancer-causing activities prevention includes inhibiting angiogenesis that is the formation of new blood vessels that support tumor growth and also the tyrosine kinase activity which is a key regulator of cell signaling involved in cancer progression. So, these processes which aid in the formation of cancer bodies or cancer cells, these are prevented by the phytochemicals. They modulate the hormonal function process preventing the cancers.



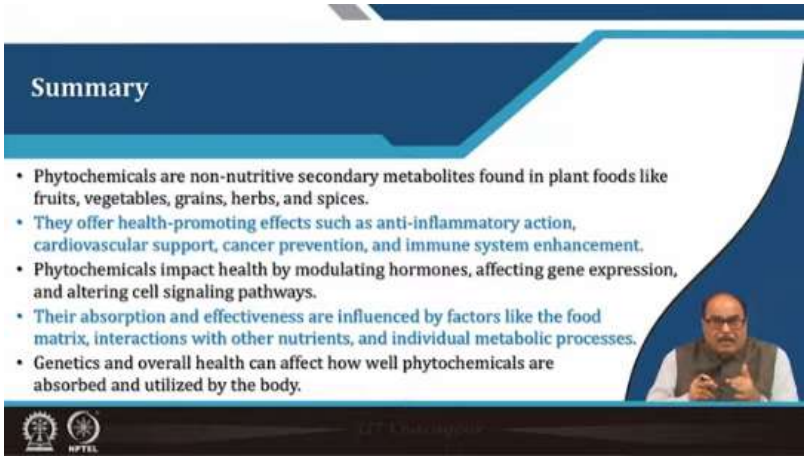
Now, let us talk about the absorption and bioavailability of phytochemicals in the body. Obviously, the absorption and bioavailability of phytochemicals are affected by several factors. These factors include the food matrix itself, such as the form in which the food is taken, whether it is in emulsion form, gel form, or solid foods. Then, interactions within the food constituents, such as food proteins, fats, carbohydrates, etcetera. So, their interactions, because they are generally found in association with these compounds. So, that also will influence how they interact with these components and nutrients or other constituents of the food, which also influences absorption and bioavailability. Then, the size and matrix of phytochemical nanoparticles, chemical modification of food constituents, encapsulation technologies of phytochemicals, such as liposomes, solid lipid nanoparticles, and biopolymer nanoparticles. Finally, the food preparation methods, such as trimming, peeling, refining processes, etcetera, because these preparation methods may influence the structure, properties, and characteristics of the food constituents including phytochemicals, etcetera, which are present inside the food, and that ultimately affects its absorption, its bioavailability, and so on.



So, then let us talk about the absorption and disposition of phytochemicals in human beings. When you take any food or any phytochemical in the form of food, what happens, how it goes inside our system, and at various functions, how it is converted, reformed, broken down, or metabolized. Then it gives its various effects, that is, the health-promoting effects. So, the first thing is that when you take it from the mouth, it comes into the stomach. Where the first action it takes is the dissolution of these phytochemicals. That is, they are dissolved in the gut fluid in the stomach and then from the stomach, it goes through the intestine. Where the metabolism starts, and as a result of metabolism, these phytochemicals are broken into various fractions and these are metabolized by enzymes from gut microbiota and the gut wall.



Then after that metabolism, the next step is absorption where these phytochemicals enter into portal blood, that is, they are absorbed and then come again into the liver. In the liver, metabolism takes place again, where the various functions are metabolized by liver enzymes. From the liver, it goes to the heart, where it is distributed mainly in the metabolized form. It comes to the heart, and from the heart, it is distributed to the brain, placenta, or kidney, where it performs all activity, like after the metabolism in the liver. It also goes to the bile duct, where it stimulates biliary excretion and improves bile production. Also, in the kidney, it has renal excretion, like phytochemicals excreted into urine mainly as metabolites or that is, in the bile, it is excreted in the bile. So, this is the way how these, in the different forces, particularly from the blood through the heart that is where its bioavailability remains the fraction available for distribution to tissue, it is bioabsorbed. Then it is distributed to different tissues like the brain, placenta, kidney, etcetera, where they perform their actual activities.



Now, here is a summary of this lecture. I can tell you that these phytochemicals are non-nutritive secondary metabolites found in plant foods like fruits, vegetables, grains, herbs, and spices. So, although they are non-nutritive and do not have any nutritional value. They offer health-promoting effects such as anti-inflammatory action, cardiovascular support, cancer prevention, and immune system enhancement. So, they have very good health-promoting activities. Phytochemicals impact health by modulating hormones, affecting gene expression, and altering cell signaling pathways. Their absorption and effectiveness are influenced by factors like the food matrix, interaction with other nutrients, and also the individual metabolic process. Genetics and overall health can affect how well phytochemicals are absorbed and utilized by the body. So, it is a good thing that one should consider taking more natural phytochemicals like fruits, vegetables, or even grains, millet, etcetera which are good sources of phytochemicals. Also, these natural bio-phytochemicals obviously have more absorption and bioavailability than the synthetic ones.

So, with this, these are the references which were used in this lecture.

Thank you very much for your patient hearing.