

UNIT-3

DIETARY SUPPLEMENTS AND NUTRACEUTICALS

Points to be covered in this topic

Introduction to free radicals

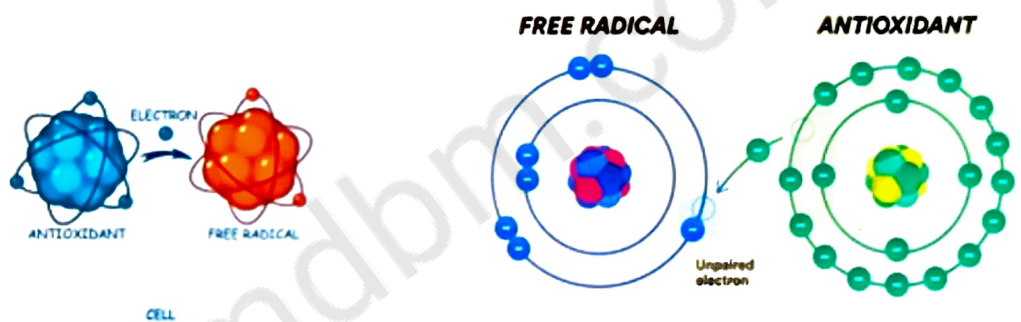
Dietary fibres and complex carbohydrates as functional food ingredients.

INTRODUCTION TO FREE RADICALS

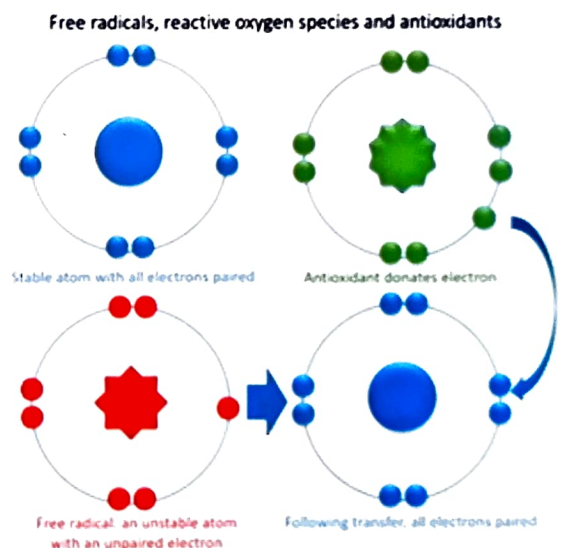
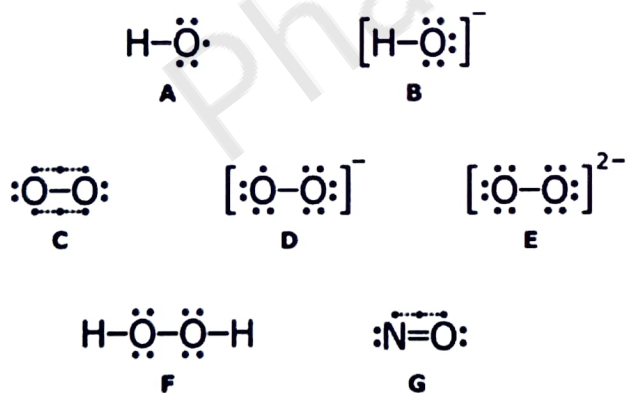
➤ Free radicals

- Free radicals are **highly reactive chemical** species that possess an **unpaired electron in their outermost electron shell**.
- This unpaired electron makes them highly unstable and reactive, as they seek to pair up with another electron to achieve stability.
- Free radicals can be formed through various processes, including normal cellular **metabolism, exposure to environmental** factors such as radiation and pollutants, and as byproducts of chemical reactions in the body.
- The unpaired electron in a free radical gives it the **ability to interact with other molecules in the body**, leading to potentially damaging effects.
- Free radicals can react with important cellular components such as **proteins, lipids, and DNA, causing oxidative stress and disrupting normal cellular function**.
- Oxidative stress occurs when there is an **imbalance between the production of free radicals and the body's antioxidant defenses, leading to an excess** of free radicals.
- While free radicals are generally associated with negative effects on health, they also play essential roles in various biological processes.
- For instance, they are involved in the immune response to **pathogens, cell signaling, and regulation of certain enzymes**.
- However, when free radicals exceed the body's antioxidant capacity, they can cause significant damage to cells and tissues, contributing to the development of various **diseases, including cancer, cardiovascular diseases, neurodegenerative disorders, and aging**.
- To counteract the harmful effects of free radicals, the body has an elaborate **antioxidant defense system**.
- Antioxidants are molecules that can **donate an electron to neutralize free radicals and reduce their reactivity**.

- Antioxidants can be obtained **from the diet, including vitamins (such as vitamins C and E), minerals (such as selenium and zinc), and phytochemicals (found in fruits, vegetables, and other plant-based foods).**
- The body also produces its own **antioxidants, such as glutathione and enzymes like superoxide dismutase and catalase.**
- Maintaining a balance between free radicals and antioxidants is crucial for overall health and well-being.
- Leading a healthy lifestyle that includes a balanced diet rich in antioxidants, regular exercise, minimizing exposure to environmental toxins, and managing stress can help support the body's antioxidant defense system and minimize the potential damage caused by free radicals.



➤ Reactive oxygen species



- Reactive oxygen species (ROS) are a type of **highly reactive molecules derived from oxygen.**
- They include free radicals such as **superoxide anion (O₂⁻), hydroxyl radical (-OH), and non-radical species like hydrogen peroxide (H₂O₂) and singlet oxygen (^1O₂).**

- ROS are natural byproducts of cellular metabolism and are also generated during various biochemical reactions within the body.
- ROS are produced in the **mitochondria, peroxisomes, and certain enzymes such as NADPH oxidases** as a result of the incomplete reduction of oxygen during normal cellular metabolism.
- They can also be generated by external factors like **environmental pollutants, radiation, toxins, and certain drugs**.
- In small amounts, ROS serve important roles in **cell signaling, immune response, and regulation of physiological processes**.
- However, when ROS levels become excessive or the antioxidant defense system is compromised, a condition called **oxidative stress** occurs.
- Oxidative stress arises when there is an **imbalance between the production of ROS and the body's antioxidant capacity**.
- This can lead to cellular damage, as **ROS react with various cellular components including proteins, lipids, and DNA**.
- Oxidative damage to biomolecules can **disrupt cellular function, contribute to the development of diseases**, and accelerate the aging process.
- The harmful effects of ROS have been implicated in a wide range of **health conditions, including cardiovascular diseases, neurodegenerative disorders (such as Alzheimer's and Parkinson's diseases), cancer, diabetes, inflammation, and aging-related conditions**.
- ROS can cause DNA mutations, promote inflammation, impair cellular signaling, and damage cell membranes, leading to tissue dysfunction and organ damage.
- To counteract the damaging effects of ROS, the body has a complex antioxidant defense system. **Antioxidants scavenge and neutralize ROS, minimizing their harmful effects**.
- Antioxidants can be **endogenous (produced by the body) or exogenous (obtained from the diet or supplements)**.
- Endogenous antioxidants include enzymes such as **superoxide dismutase, catalase, and glutathione peroxidase**.

- Exogenous antioxidants are obtained from a variety of **dietary sources**, including **vitamins (such as vitamins C and E)**, **minerals (such as selenium and zinc)**, and **plant-based compounds like flavonoids and carotenoids**.
- Maintaining a healthy **balance between ROS production and the antioxidant defense system** is crucial for overall **health and preventing oxidative stress-related diseases**.

➤ **Production of free radicals in cells**

Free radicals are produced within cells through various processes, both as byproducts of normal cellular metabolism and as a result of external factors.

Here are some key sources of free radical production in cells:

1. Mitochondrial respiration: Mitochondria, the **powerhouses of the cell**, generate **energy through oxidative phosphorylation**. During this process, a small fraction of oxygen molecules can undergo incomplete **reduction, leading to the production of superoxide anion ($O_2^{\cdot-}$) as a free radical**. This occurs primarily at the electron transport chain, where electrons escape and react with oxygen.

2. Inflammation and immune response: Immune cells, such as **neutrophils and macrophages**, produce free radicals as part of their **defense mechanisms against pathogens**. They generate **reactive oxygen species (ROS)** like superoxide anion ($O_2^{\cdot-}$) through an enzyme called **NADPH oxidase**, which helps **destroy invading microorganisms**. However, excessive ROS production during chronic inflammation can lead to tissue damage.

3. Xenobiotic metabolism: Cells have enzymatic systems, particularly in the liver, that help **detoxify and eliminate foreign substances (xenobiotics)** from the body. The metabolism of some xenobiotics, such as **drugs, alcohol, and pollutants**, can generate free radicals as a byproduct.

4. Radiation exposure: Ionizing radiation, such as **X-rays and gamma rays**, can directly ionize molecules in cells, leading to the formation of **free radicals**. These high-energy particles can break chemical bonds, including those in water molecules, resulting in the **production of hydroxyl radicals (OH)**, which are highly reactive free radicals.

5. Environmental factors: Cells can be exposed to environmental factors that induce free radical production. For instance, exposure to **air pollution, cigarette smoke, ultraviolet (UV) radiation from the sun, and certain chemicals** can trigger the formation of free radicals in cells.

It's important to note that while the production of free radicals is a natural and essential process in cells, an imbalance between their production and the body's antioxidant defense system can lead to oxidative stress and potential damage to cellular components. The body relies on antioxidant systems, both endogenous (e.g., enzymes like superoxide dismutase and catalase) and exogenous (e.g., dietary antioxidants), to neutralize and mitigate the harmful effects of free radicals.

➤ **Damaging reactions of free radicals on lipids, proteins, Carbohydrates, nucleic acids**

- Free radicals can cause damage to various biomolecules in cells, including **lipids, proteins, carbohydrates, and nucleic acids**.
- Here's an overview of the damaging reactions of free radicals on each of these biomolecules:

1. Lipids:

- **Lipid peroxidation:** Free radicals, especially reactive oxygen species (ROS), can initiate lipid peroxidation, a chain reaction that damages lipids.
- ROS, such as **hydroxyl radicals (OH) and peroxy radicals (ROO.)**, attack polyunsaturated fatty acids in cell membranes, leading to the formation of lipid radicals.

- These lipid radicals then **react with molecular oxygen to produce lipid peroxy radicals**, which can propagate the chain reaction by attacking other lipids.
- Lipid peroxidation results in the **degradation of cell membrane lipids, compromising their structural integrity and causing membrane damage and dysfunction.**

2. Proteins:

- **Protein Oxidation: Free radicals can oxidize amino acid residues in proteins, leading to protein oxidation.**
- ROS can directly react with proteins, causing modifications in their structure and function.
- This can include oxidation of **sulfur-containing amino acids (such as cysteine and methionine)**, oxidation of aromatic amino acids (such as tyrosine and phenylalanine), and carbonylation of amino acid side chains.
- Protein oxidation can impair enzymatic activity, alter protein-protein interactions, and contribute to **protein misfolding and aggregation.**

3. Carbohydrates:

- **Glycation and Advanced Glycation End Products (AGES):** Free radicals can contribute to the formation of advanced glycation end products (AGES).
- Glycation occurs when free radicals react with sugars (e.g., glucose) to form reactive carbonyl species, which then react with **proteins or lipids.**
- This process leads to the formation of AGES, which are **cross-linked protein or lipid structures that are resistant to degradation.**
- AGES can accumulate in tissues and contribute to the development of various age-related diseases, such as **diabetes, atherosclerosis, and neurodegenerative disorders.**

4. Nucleic Acids:

- **DNA Damage:** Free radicals, particularly **hydroxyl radicals (-OH)**, can **directly attack DNA, causing various types of damage.**
- This includes oxidative modifications to DNA bases, such as **oxidation of guanine to 8-hydroxyguanine (8-OHdG), and strand breaks in the DNA backbone.**
- DNA damage by free radicals can lead to **mutations, genomic instability, and impair DNA replication and transcription processes.**

It's important to note that these damaging reactions can have significant consequences for cellular function and contribute to the development of various diseases, including cancer, cardiovascular diseases, neurodegenerative disorders, and aging-related conditions. The body's antioxidant defense system, including endogenous antioxidants and dietary antioxidants obtained from the diet, helps counteract the damaging effects of free radicals and minimize their impact on biomolecules.

❑ Dietary fibres and complex carbohydrates as functional food ingredients

Dietary fibers and complex carbohydrates are both important functional food ingredients that provide various health benefits.

Let's discuss each of them in detail:

1. Dietary Fibers:

- Dietary fibers are a type of carbohydrate that cannot be digested by human enzymes.
- They are derived from plant sources and are found in foods such as **fruits, vegetables, whole grains, legumes, nuts, and seeds.** Dietary fibers can be categorized into two types:



SOURCES OF DIETARY FIBRE



TYPES OF DIETARY FIBRE



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Soluble Fibre



Insoluble Fibre



a. Soluble Fiber:

- Soluble fibers dissolve in water to form a **gel-like substance in the digestive tract**.
- They are beneficial for heart health as they can help lower cholesterol levels and regulate blood sugar levels.
- **Examples of soluble fibers include pectins, beta-glucans, and gums.**

b. Insoluble Fiber:

- **Insoluble fibers do not dissolve in water and add bulk to the stool, promoting regular bowel movements and preventing constipation.**
- They also help **maintain a healthy digestive system.**
- **Examples of insoluble fibers include cellulose, hemicellulose, and lignin.**

Health benefits of dietary fibers:

- **Promote digestive health:** Dietary fibers add bulk to the stool, preventing constipation and promoting regular bowel movements.
- They can also help alleviate symptoms of irritable bowel syndrome (IBS).
- **Aid in weight management:** High-fiber foods are generally more filling, which can help control appetite and prevent overeating.
- **Support heart health:** Soluble fibers can help lower LDL (bad) cholesterol levels, thus reducing the risk of heart disease.

- **Regulate blood sugar levels:** Soluble fibers can slow down the absorption of sugars, preventing rapid spikes in blood sugar levels and helping manage diabetes.
- **Contribute to a healthy gut microbiota:** Dietary fibers serve as prebiotics, providing nourishment to beneficial gut bacteria, which play a crucial role in digestive and overall health.

2. Complex Carbohydrates:

- Complex carbohydrates are **long chains of sugar molecules**.
- Unlike simple carbohydrates (such as table sugar or sugary beverages), complex carbohydrates are digested more slowly, providing a steady release of energy.
- They are found in **whole grains, legumes, starchy vegetables, and some fruits**.

Health benefits of complex carbohydrates:

- **Sustained energy release:** Complex carbohydrates break down slowly, providing a steady release of glucose into the bloodstream, which helps maintain energy levels throughout the day.
- **Nutrient-rich:** Whole grains and starchy vegetables are good sources of essential nutrients like vitamins, minerals, and dietary fiber.
- **Weight management:** Complex carbohydrates are generally more filling than simple carbohydrates, which can help control appetite and prevent overeating.
- **Heart health:** Diets rich in whole grains have been associated with a reduced risk of heart disease and stroke.
- **Digestive health:** Complex carbohydrates, especially those high in fiber, promote digestive health by adding bulk to the stool and supporting regular bowel movements.