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A Review on Role of Iron in Human Its Mechanisms Deficiencies Treatment

*A. Ravi Kumar, ** G. Uma Sowndarya, **Shaik Jameer, **Shaik Rasool Basha, ** Manda Ajay Kumar, **Battula Vamsi, **Indupalli Akarsh

*Post Graduate Head, Nimra College of Pharmacy Vijayawada 521456 AP INDIA

** Department of Pharmaceutical Chemistry, Nimra College of Pharmacy Vijaywada 521456 AP INDIA

Corresponding Author: karavi315@gmail.com

ABSTRACT

Iron is essential for several important functions in the body, including the transport of oxygen, energy production, immune function, and maintaining brain health. A lack of iron can lead to anemia, which presents with symptoms such as fatigue, weakness, and difficulty concentrating. This condition is particularly common in women, especially during pregnancy or menstruation, as well as in people with poor dietary intake or absorption problems. Functions of Iron Oxygen Transport Iron is an integral part of hemoglobin in red blood cells, enabling them to carry oxygen from the lungs to tissues and organs throughout the body.Energy Production Iron helps produce ATP by supporting the electron transport chain within cells, which is crucial for energy production.Immune Support Iron plays a vital role in immune health by aiding in the production of white blood cells and helping the body defend against infections.Cognitive Health Sufficient iron levels are necessary for optimal brain function, as iron is needed for the production of neurotransmitters, which influence mood, memory, and cognitive performance.Enzyme Function Iron acts as a cofactor for several enzymes involved in important metabolic processes, such as the synthesis of DNA and collagen.Iron deficiency can cause significant health issues, but proper intake through foods like meat, legumes, and leafy greens can help maintain these critical bodily functions.

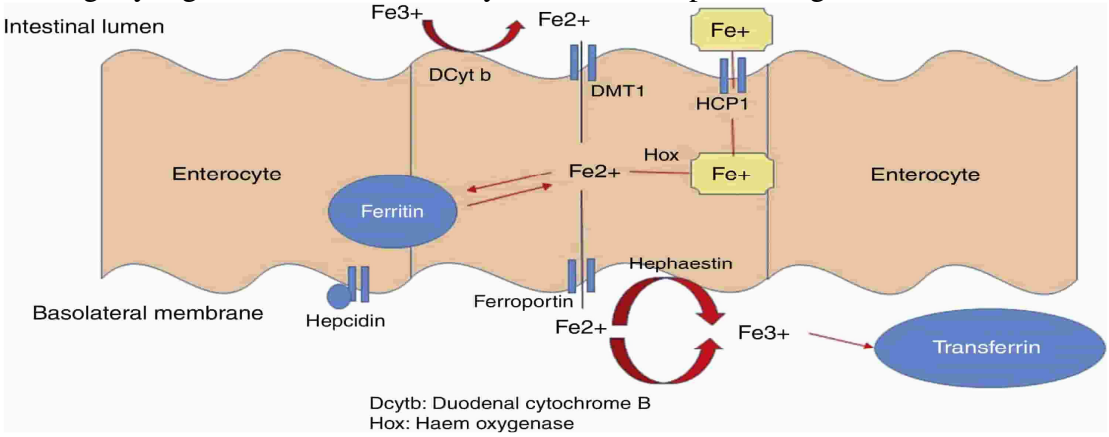
Keywords: Iron Deficiency, Iron Metabolism, Iron Functions, Iron Precautions Taken,

INTRODUCTION

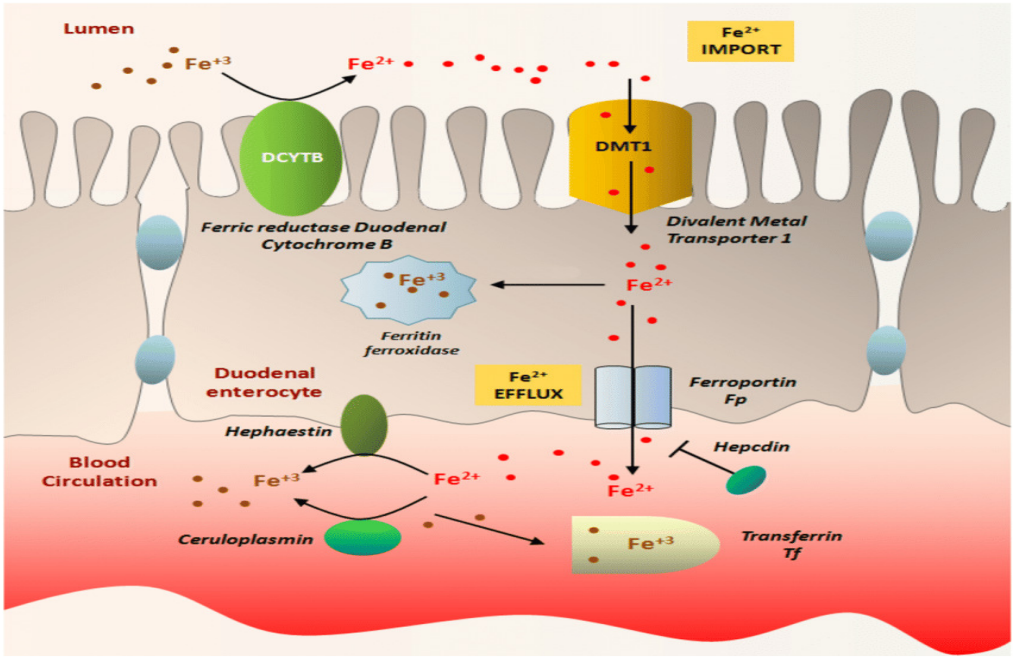
Iron plays a crucial role in the human body, particularly in oxygen transport, metabolism, and various cellular functions. It is a trace element, meaning the body requires it in small amounts, but it is indispensable for several vital processes.

1. Iron Absorption:

Iron is primarily absorbed in the **small intestine**, especially in the **duodenum** and the **upper jejunum**. The process is tightly regulated to meet the body's needs while preventing excess, which could be toxic.



- **Forms of Iron:**
  - **Heme iron** (from animal products like meat, poultry, and fish) is absorbed more efficiently than **non-heme iron** (found in plant-based foods like vegetables, legumes, and grains).
  - The absorption of non-heme iron can be enhanced by factors like **vitamin C**, which helps convert iron into a more absorbable form.
- **Absorption Process:**
  - Iron enters the duodenum in either the **ferrous (Fe^{2+})** or **ferric (Fe^{3+})** state. The enzyme **duodenal cytochrome b (Dcytb)** reduces ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}), which can be absorbed by intestinal cells.
  - The **Divalent Metal Transporter 1 (DMT1)** transports ferrous iron into the enterocytes (intestinal cells).
  - Inside the enterocyte, iron may either be stored as **ferritin** or transported across the cell to the bloodstream.



2. Iron Transport in the Blood:

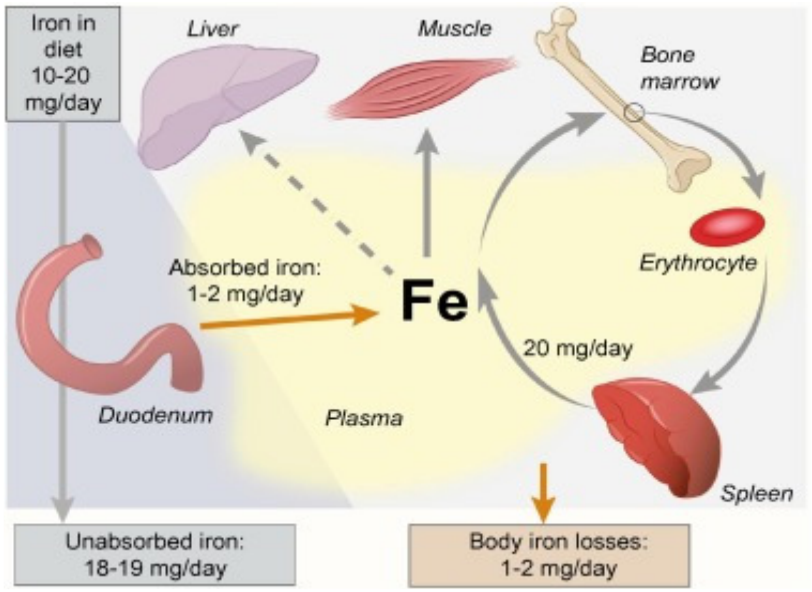
Once absorbed, iron binds to **transferrin**, a glycoprotein that facilitates iron transport throughout the body.

- **Transferrin and its Receptor:**
  - Transferrin binds to **transferrin receptors (TfR1)** on cells, including those in the liver, bone marrow, and muscles.
  - The transferrin-bound iron is internalized via endocytosis.
  - Once inside the cell, the iron is released in an acidic environment and can be used or stored.

3. Iron Storage:

Excess iron is stored in the **liver**, **muscles**, and **spleen** in the form of **ferritin** or **hemosiderin**.

- **Ferritin** is the main protein that stores iron in a non-toxic and soluble form. Each ferritin molecule can hold up to 4,500 iron atoms.
- **Hemosiderin** forms when ferritin becomes saturated with iron and is less readily available for future use.



4. Iron Utilization in Hemoglobin Synthesis:

One of iron's key roles is in the formation of **hemoglobin**, a protein in red blood cells that carries oxygen.

- **Heme Synthesis:**
  - In the mitochondria of erythroblasts (immature red blood cells), iron (Fe^{2+}) is incorporated into **protoporphyrin IX**, forming **heme**.
  - The heme then integrates into **hemoglobin**, which carries oxygen through the bloodstream.

Once hemoglobin is produced, it helps transport oxygen from the lungs to tissues throughout the body.

5. Iron in Myoglobin:

Iron is also a crucial component of **myoglobin**, a protein found in muscle tissue. Myoglobin helps store and release oxygen in muscles during physical activity. It functions similarly to hemoglobin but specifically within muscle cells, helping muscles maintain oxygen reserves.

6. Iron in Enzyme Systems:

Iron is a cofactor for various enzymes involved in essential biochemical reactions:

- It plays a role in the **electron transport chain (ETC)** in mitochondria, which is important for **ATP production**.
- **Cytochrome P450 enzymes** are involved in **drug metabolism** and the synthesis of hormones.
- **Ribonucleotide reductase** is needed for **DNA synthesis**, particularly for dividing cells.
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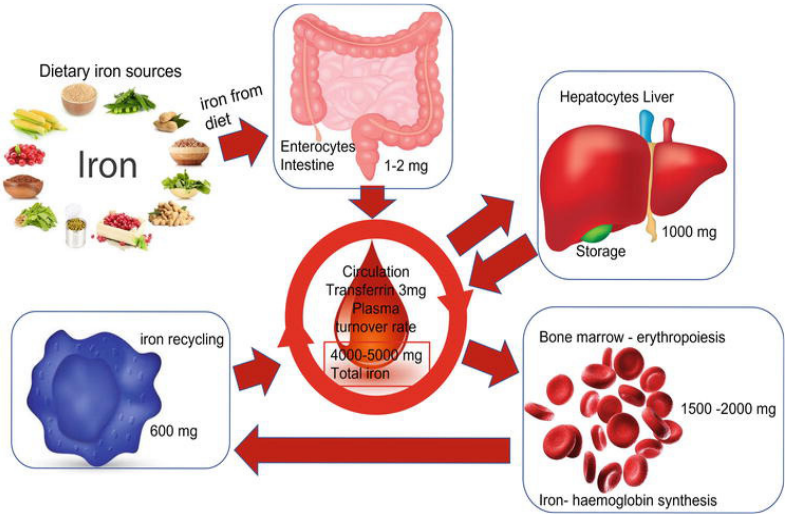


7. Iron Homeostasis and Regulation:

Iron levels are closely regulated to prevent both deficiency and overload.

- **Hepcidin Regulation:**
  - The liver produces **hepcidin**, a hormone that plays a central role in iron homeostasis.
  - When iron levels are high, hepcidin is produced, inhibiting iron absorption by binding to **ferroportin**, the protein that exports iron from enterocytes into the bloodstream.
  - When iron levels are low, hepcidin production decreases, allowing more iron to be absorbed and released.
- **Iron Recycling:**
  - The body also recycles iron from **old red blood cells**, which are broken down by **macrophages** in the spleen and liver. This recycled iron is reused for the production of new red blood cells.

8. Iron Deficiency and Excess:

- **Iron Deficiency:**
  - **Iron deficiency** can lead to **anemia**, where there are insufficient healthy red blood cells to transport oxygen, causing symptoms like fatigue, weakness, and pallor.
- **Iron Overload:**
  - **Iron overload**, as seen in **hemochromatosis**, can lead to the accumulation of excess iron in tissues, potentially causing **oxidative damage** and **organ failure**.
  -

IRON DEFICIENCY SYMPTOMS

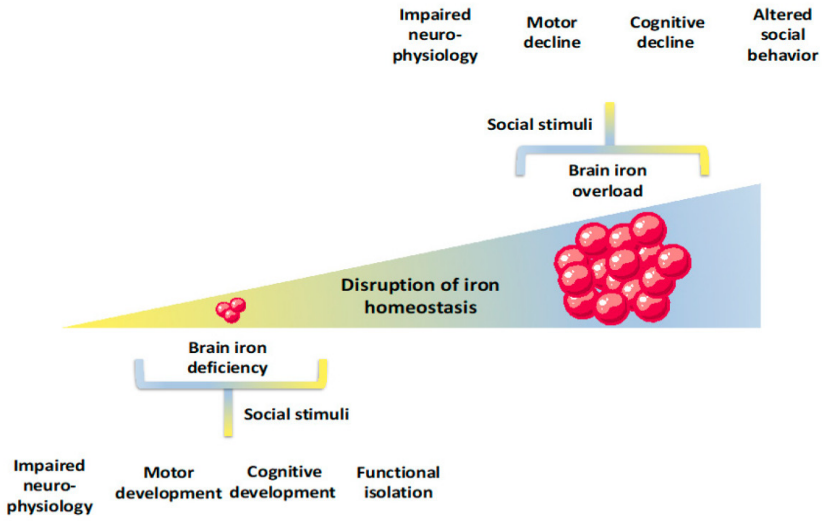
9. Iron in Immune Function:

Iron is essential for the proper functioning of the **immune system**. It supports **T lymphocytes (T cells)** and **macrophages**, which rely on iron for energy and metabolism. Additionally, iron plays a role in the **oxidative burst** used by macrophages to kill pathogens.

10. Iron and the Brain:

Iron is critical for **brain function** and development. It is involved in:

- The synthesis of important **neurotransmitters** like **dopamine** and **serotonin**.
- The **myelination** of neurons, which is necessary for efficient nerve signal transmission.
- Iron deficiencies during crucial developmental stages can lead to **cognitive impairments**.



Summary of Iron's Role in the Body:

- **Absorption** in the intestines.
- **Transport** by transferrin through the bloodstream to various tissues.
- **Storage** in ferritin or hemosiderin in the liver and other tissues.
- **Utilization** in hemoglobin and myoglobin for oxygen transport.
- **Enzyme function** as a cofactor in numerous metabolic processes.
- **Regulation** via hepcidin and recycling of iron from old red blood cells.

Iron deficiency happens when the body lacks sufficient iron, a key element required for oxygen transport and energy production. It's the most common nutritional deficiency globally and can lead to serious health issues if untreated.

1. Causes of Iron Deficiency

a) Inadequate Iron Intake

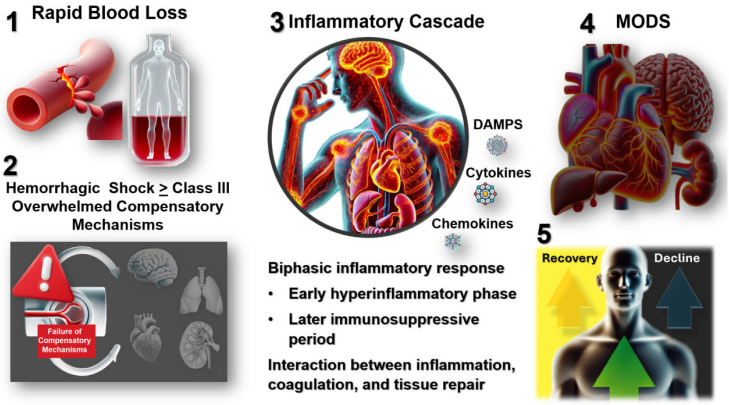
- **Diet**: A poor diet lacking in iron-rich foods like meat, leafy greens, and fortified cereals can lead to low iron levels. Vegetarians and vegans may be at higher risk since plant-based iron is less absorbable.

b) Increased Iron Demand

- **Pregnancy**: Pregnant women need more iron for the growing fetus and placenta.
- **Growth Phases**: Children, teenagers (especially girls), and women in their reproductive years often require more iron due to growth or menstruation.

c) Blood Loss

- **Menstruation**: Heavy or prolonged menstrual bleeding is a common cause of iron loss.
- **Gastrointestinal Bleeding**: Internal bleeding from ulcers, hemorrhoids, or other digestive issues can gradually deplete iron stores.



d) Impaired Absorption

- **Gastrointestinal Issues**: Disorders like celiac disease or Crohn's disease can interfere with iron absorption.
- **Medications**: Drugs like proton pump inhibitors (used for acid reflux) can reduce iron absorption.

e) Chronic Diseases

- **Chronic Inflammation**: Conditions like rheumatoid arthritis can disrupt iron metabolism, leading to its sequestration in storage proteins.
- **Infections**: Certain infections increase iron demand or reduce absorption.

2. Symptoms of Iron Deficiency

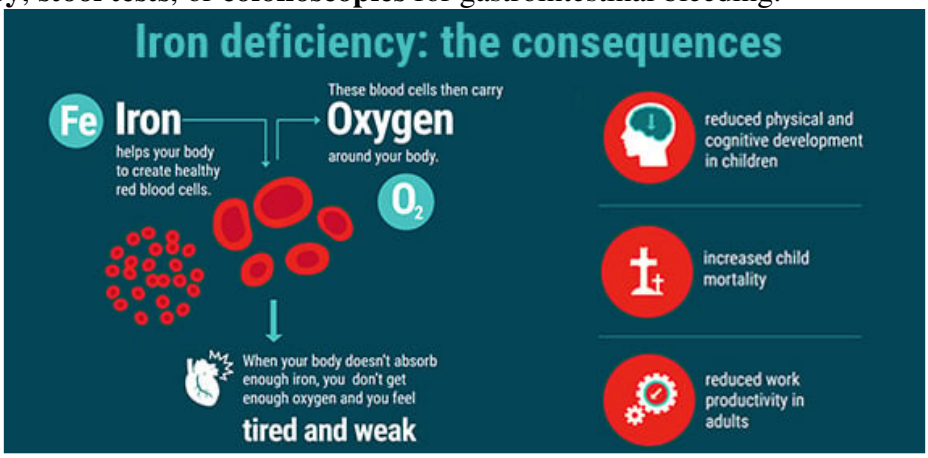
Symptoms occur mainly because the body cannot transport enough oxygen to tissues and produce energy efficiently:

- **Fatigue & Weakness**: Low hemoglobin levels lead to constant tiredness and reduced stamina.
- **Paleness**: Reduced red blood cells cause a pale complexion, particularly noticeable in the face and nail beds.
- **Shortness of Breath**: Reduced oxygen in the blood can make physical activity more exhausting and lead to dizziness.
- **Cold Extremities**: Iron deficiency can impair circulation, causing cold hands and feet.
- **Headaches**: Low oxygen levels can lead to frequent headaches.
- **Brittle Nails & Hair**: Nails may become thin, brittle, and develop spoon-like indentations (koilonychia), and hair may fall out more easily.
- **Restless Legs Syndrome (RLS)**: Iron deficiency is linked to leg discomfort and the urge to move the legs, particularly at night.
- **Cravings for Non-Food Items (Pica)**: A rare symptom where individuals crave substances like dirt, clay, or ice.
- **Glossitis**: The tongue may become swollen, smooth, or sore, often accompanied by mouth ulcers.

3. Diagnosis of Iron Deficiency

A combination of clinical assessment and blood tests is used to diagnose iron deficiency:

- **Blood Tests**: A **Complete Blood Count (CBC)** can show low red blood cell count. **Serum ferritin** measures stored iron; low levels indicate deficiency. Tests like **serum iron**, **TIBC** (total iron-binding capacity), and **transferrin saturation** help assess iron availability in the blood.
- **Other Tests**: Additional tests might be needed to identify the underlying cause, such as **endoscopy**, **stool tests**, or **colonoscopies** for gastrointestinal bleeding.



4. Treatment of Iron Deficiency

Treatment depends on the severity and cause of the deficiency:

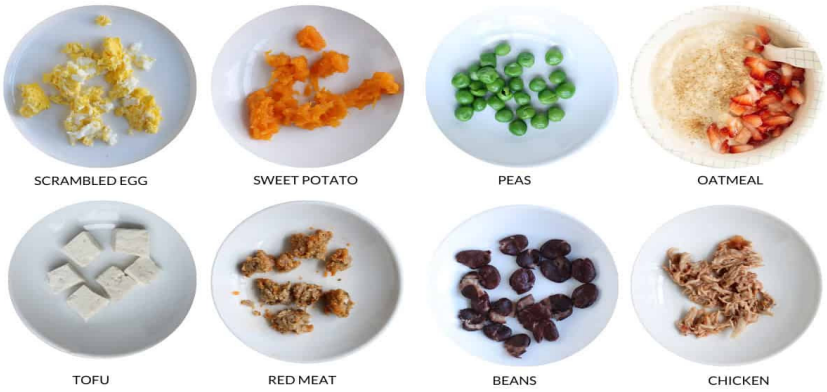
a) Dietary Changes

- **Iron-Rich Foods**: Increasing the intake of iron-rich foods is the first step. **Heme iron** from animal sources (red meat, poultry, fish) is more easily absorbed than **non-heme iron** from plant sources (lentils, beans, tofu, spinach).

- **Vitamin C**: This vitamin enhances the absorption of non-heme iron, so pairing iron-rich foods with citrus fruits, bell peppers, or strawberries can help.

b) Iron Supplements

- **Iron Tablets**: Supplements like **ferrous sulfate** or **ferrous gluconate** may be prescribed to restore iron levels. These should be taken on an empty stomach for better absorption, though they can cause side effects like constipation or stomach upset.



IRON SUPPLEMENTS NATURAL

c) Intravenous (IV) Iron or Blood Transfusions

- In severe cases, IV iron may be necessary for rapid replenishment, or a **blood transfusion** may be required to restore red blood cell levels.

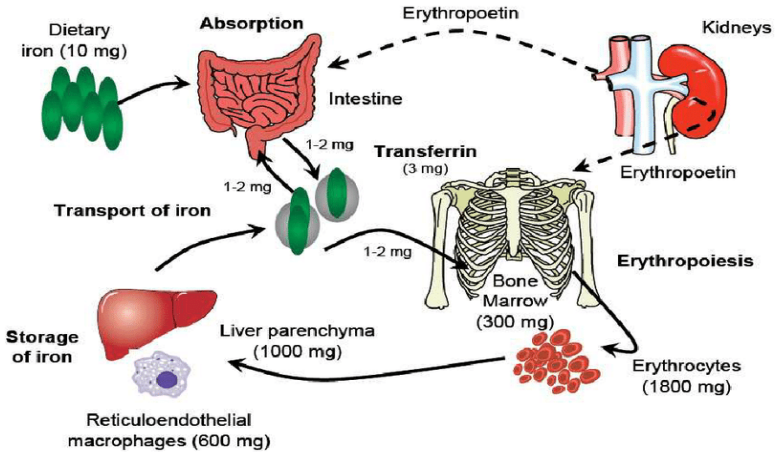
d) Treating Underlying Conditions

- If iron deficiency is due to an underlying cause (like gastrointestinal bleeding or heavy menstruation), addressing that issue is crucial for preventing recurrence.

5. Prevention of Iron Deficiency

To prevent iron deficiency:

- **Balanced Diet**: Eating a varied, iron-rich diet can maintain healthy iron levels.
- **Fortified Foods**: Many foods, such as cereals and grains, are fortified with iron, helping to prevent deficiency.
- **Iron Supplements**: For at-risk groups (like pregnant women or those with heavy periods), supplements may be recommended.
- **Monitor for Risk Factors**: People with a history of gastrointestinal issues or excessive bleeding should regularly monitor iron levels.



Iron-Containing Inorganic Compounds and Their Uses

Iron-containing inorganic compounds are essential in various industries due to their ability to exist in different oxidation states (Fe^{2+} and Fe^{3+}). These compounds are widely used in sectors such as water treatment, agriculture, manufacturing, and electronics.

1. Iron(II) Sulfate ($FeSO_4$)

- **Also Known As**: Copperas, Green Vitriol
- **Uses**:
  - **Water Treatment**: Removes contaminants like phosphorus and serves as a coagulating agent.
  - **Agriculture**: Treats iron chlorosis in plants, especially in acidic soils.
  - **Pigment Production**: Used to create iron-based greens and browns.

2. Iron(III) Oxide (Fe_2O_3)

- **Also Known As**: Ferric Oxide, Rust
- **Uses**:
  - **Pigment**: The red form is used in paints, cosmetics, and ceramics.
  - **Polishing Agent**: Finely ground iron oxide (rouge) is used for polishing metal and jewelry.
  - **Steel Production**: Involved in oxidation-reduction reactions in steel manufacturing.

3. Iron(III) Chloride ($FeCl_3$)

- **Uses**:
  - **Water Treatment**: Coagulates and flocculates suspended particles in wastewater.
  - **Electroplating**: Used in certain electroplating processes.
  - **Etching**: Common in the etching of copper in printed circuit board production.

4. Iron(II) Chloride ($FeCl_2$)

- **Uses**:
  - **Reducing Agent**: Used in chemical processes to reduce other metal ions.
  - **Water Treatment**: Removes impurities in water.
  - **Pigment Production**: Involved in creating iron-based pigments and dyes.

5. Iron(III) Acetate ($Fe(C_2H_3O_2)_3$)

- **Uses**:
  - **Catalysis**: Used as a catalyst in organic chemical reactions.
  - **Textile Industry**: Employed in dyeing and producing textile inks, especially for dark shades.

6. Iron(III) Hydroxide ($Fe(OH)_3$)

- **Uses**:
  - **Water Purification**: Removes contaminants such as arsenic by precipitating them.
  - **Pigment**: Sometimes used in paints, though less common than other iron oxides.

7. Ferrous Sulfide (FeS)

- **Uses**:
  - **Industrial Production**: Used in producing sulfur and hydrogen sulfide.
  - **Catalysis**: Employed as a catalyst in the petroleum and chemical industries.

8. Iron(II) Carbonate ($FeCO_3$)

- **Uses**:
  - **Precursor in Production**: Used as a starting material for producing iron salts.
  - **Soil Amendment**: Adjusts the pH of acidic soils, though less frequently used than other compounds.

9. Iron(III) Nitrate ($Fe(NO_3)_3$)

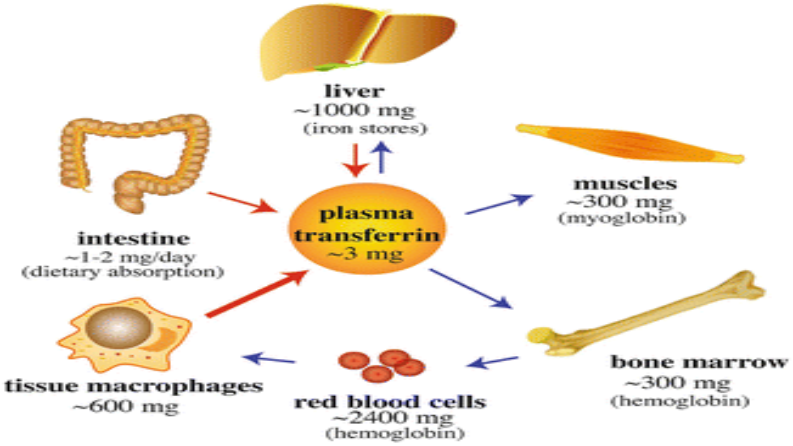
- **Uses**:
  - **Oxidizing Agent**: Used in industrial and laboratory processes as a powerful oxidizing agent.
  - **Catalyst Production**: Used in the manufacture of iron-based catalysts.

10. Iron(III) Phosphate ($FePO_4$)

- **Uses**:
  - **Fertilizer**: Corrects iron deficiency in plants.
  - **Pest Control**: Used as a molluscicide in organic gardening to control snails and slugs.

Other Notable Iron Compounds:

- **Ferrites (Fe_3O_4)**: Used in magnetic materials, ceramics, and electronics, particularly in telecommunications.
- **Iron(II) Cyanide ($Fe(CN)_6^{2-}$)**: Used in gold mining for extracting gold from ores.
- **Iron Carbonyls ($Fe(CO)_5$)**: Serve as catalysts in organic chemistry processes such as hydroformylation and polymerization.



Summary of Key Uses:

- **Pigments**: Iron compounds are crucial in paints, cosmetics, and textiles.
- **Water Treatment**: Iron salts help remove impurities from water in various industrial processes.
- **Catalysis**: Iron compounds are integral in catalyzing industrial chemical reactions.
- **Agriculture**: Used to correct iron deficiencies in plants through fertilizers and soil amendments.
- **Manufacturing**: Involved in the production of steel, electroplating, and pigment manufacturing.

1. Iron Pentacarbonyl ($Fe(CO)_5$)

- **Uses**:
  - **Catalysis**: Key in organic synthesis, especially **hydroformylation**, the addition of CO and H_2 to olefins to form aldehydes.
  - **Polymerization**: Catalyzes the polymerization of olefins.
  - **Hydrocarbon Production**: Used in petrochemical processes for producing hydrocarbons.

2. Ferrocene ($Fe(C_5H_5)_2$)

- **Uses**:
  - **Fuel Additive**: Enhances gasoline combustion efficiency, preventing engine knocking.
  - **Catalysis**: Acts as a catalyst or catalyst precursor in organic molecule synthesis.
  - **Anticorrosive Agent**: Prevents rust and corrosion in coatings and paints.

3. Iron Porphyrins

- **Uses**:
  - **Biological Catalysis**: Iron porphyrins form the core of heme, crucial for **oxygen transport** and **storage** in hemoglobin and myoglobin.
  - **Synthetic Catalysis**: Catalyze oxidation reactions, such as converting alkenes to epoxides or hydrocarbons to alcohols.
  - **Research**: Studied for enzyme mechanisms and iron's biological functions.

4. Iron(III) Acetylacetonate ($Fe(C_5H_7O_2)_3$)

- **Uses**:
  - **Catalysis**: Involved in organic reactions like **polymerization** and **oxidation** processes.
  - **Dye Production**: Used to make **iron-based dyes** for textiles.
  - **Materials Science**: Applied in **electronics** for producing thin films and coatings.

5. Iron-Organic Complexes in Medicine

- **Uses**:
  - **Iron Supplements**: Organic iron compounds (e.g., **iron gluconate**, **iron sulfate**) treat **iron deficiency anemia**.
  - **Drug Delivery**: Explored for **targeted delivery**, particularly to cancer cells.
  - **MRI Contrast Agents**: Iron oxide nanoparticles enhance **MRI imaging**.

6. Iron Organic Nanoparticles (Iron Oxide Nanoparticles)

- **Uses**:
  - **Medical Imaging & Therapy**: Used in **MRI** and **hyperthermia therapy** for cancer treatment.
  - **Environmental Cleanup**: Aid in remediating **contaminated groundwater** by removing pollutants such as heavy metals.
  - **Drug Delivery**: Navigate drugs to specific areas in the body, utilizing magnetic properties.

7. Iron(III) Chloride/Organic Compounds ($FeCl_3$)

- **Uses**:
  - **Etching Agent**: Used for etching metal surfaces in **PCB production** (especially copper).
  - **Catalysis**: Acts as a catalyst in reactions like **Friedel-Crafts acylation** or alkylation.

8. Iron(II) Organometallic Compounds

- **Uses**:
  - **Fine Chemical Synthesis**: Employed in the production of **polymers** and **fine chemicals**.
  - **Agriculture**: Used as **plant growth regulators** or for providing iron in fertilizers.

9. Iron(III) Phthalocyanine

- **Uses**:
  - **Catalysis**: Involved in **oxidative desulfurization** and the oxidation of organic compounds.
  - **Dyeing**: Used as a dye in **textile** and **printing** industries.
  - **Solar Cells**: Promising for use in **dye-sensitized solar cells** due to its electronic properties.

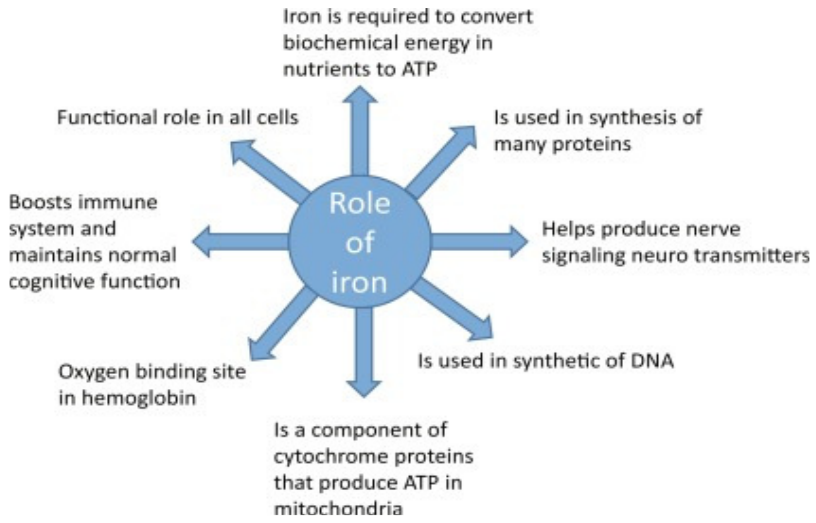
10. Iron Complexes in Organic Synthesis (e.g., Cross-Coupling Reactions)

- **Uses**:
  - **Organic Synthesis**: Essential in reactions like **Suzuki-Miyaura coupling** and **Heck reaction** for creating **carbon-carbon bonds** in pharmaceuticals, agrochemicals, and fine chemicals.

Summary of Key Uses of Iron-Containing Organic Compounds:

- **Catalysis**: Iron compounds such as ferrocene, iron pentacarbonyl, and iron porphyrins are essential for catalyzing a wide range of industrial and synthetic chemical processes.
- **Biological Functions**: Iron-organic compounds (e.g., heme) are vital for **oxygen transport** in the human body and other organisms.
- **Medical Applications**: Used in **iron supplements**, **drug delivery systems**, and as **MRI contrast agents**.
- **Environmental Remediation**: **Iron nanoparticles** are useful in **pollution control** and **environmental cleanup**.
- **Materials Science**: Important in producing **electronics**, **coatings**, and **dyes** for industrial uses.

Iron-containing organic compounds play a significant role in **chemical processes**, **biological systems**, and **technological advancements** due to their versatile nature and reactive properties.



CONCLUSION

Iron is an essential element in the human body, involved in numerous vital processes that support overall health. It is central to life-sustaining functions such as oxygen transport, energy production, immune defense, and brain function.

1. Oxygen Transport

Iron is a crucial component of **hemoglobin**, the protein in red blood cells that carries oxygen from the lungs to tissues throughout the body. Each hemoglobin molecule contains iron atoms that bind to oxygen, allowing efficient oxygen transport.

- **Hemoglobin in Red Blood Cells**: Hemoglobin binds to oxygen in the lungs, then releases it to tissues and organs that require oxygen.
- **Myoglobin in Muscles**: Iron is also a part of **myoglobin**, a protein found in muscles that stores oxygen for immediate use during physical activity.

2. Energy Production

Iron is essential for **cellular respiration**, the process that takes place in the mitochondria to produce energy (ATP). Iron supports several enzymes involved in **oxidative phosphorylation**, the final step in energy production within cells.

- **Electron Transport Chain**: Iron acts as a cofactor for enzymes in the **electron transport chain** (ETC), a crucial part of ATP generation.

3. Immune Function

Iron plays a key role in supporting the immune system. It helps in the production and activity of **white blood cells**, which are responsible for defending the body against infections.

- **White Blood Cells**: Iron is involved in the growth and differentiation of immune cells like T-cells and macrophages that fight off pathogens.
- **Antioxidant Enzymes**: Iron is also essential for some enzymes that protect cells from damage caused by free radicals, supporting overall immune health.

4. Cognitive Function and Brain Health

Iron is important for maintaining proper **brain function**. It is involved in the synthesis of neurotransmitters (chemical messengers in the brain), such as dopamine, serotonin, and norepinephrine, which are vital for mood, memory, and cognitive performance.

- **Neurotransmitter Synthesis**: Iron is necessary for the production of **dopamine**, which regulates mood, attention, and motor skills. A deficiency in iron can impair brain function, leading to symptoms like poor concentration, memory issues, and even depression.

- **Myelin Formation**: Iron is involved in **myelination**, the process of forming the protective sheath around nerve fibers, essential for fast signal transmission in the nervous system.

5. Enzyme Function and Metabolism

Iron acts as a cofactor for a variety of enzymes involved in essential metabolic processes, such as **DNA synthesis** and the production of **collagen**.

- **DNA Synthesis**: Iron is required for enzymes like **ribonucleotide reductase**, which helps in DNA synthesis and cell division. Iron deficiency can hinder cell growth and function.
- **Collagen Production**: Iron is essential for enzymes that aid in the formation of **collagen**, a protein critical for the health of connective tissues, skin, and bones.

6. Iron Storage and Regulation

The body tightly regulates its iron levels to maintain balance, storing excess iron in the liver, spleen, and bone marrow.

- **Ferritin and Hemosiderin**: Iron is stored in the form of **ferritin** and **hemosiderin**, which the body can mobilize when iron is needed, such as during growth, blood loss, or pregnancy.
- **Hepcidin**: This hormone regulates iron absorption and release, ensuring that iron levels remain balanced. It reduces absorption when iron levels are sufficient and increases it when more iron is needed.

7. Iron Deficiency and Overload

- **Iron Deficiency**: A lack of iron can lead to **anemia**, which is characterized by low red blood cell count and insufficient oxygen delivery to tissues. Symptoms include fatigue, weakness, and pale skin.
- **Iron Overload**: Excess iron, also known as **hemochromatosis**, can damage organs like the liver, heart, and pancreas.

8. Sources of Iron

Iron comes in two forms from food sources:

- **Heme Iron**: Found in animal-based foods such as meat, poultry, and seafood. This form of iron is more efficiently absorbed by the body.
- **Non-Heme Iron**: Found in plant-based foods like beans, lentils, spinach, and fortified cereals. While non-heme iron is not absorbed as efficiently, its absorption can be enhanced by consuming vitamin C-rich foods.

Iron is vital for numerous physiological processes, including oxygen transport, energy production, immune function, and brain health. Adequate iron intake is crucial for these functions, and a deficiency can result in various health problems. Proper regulation of iron levels in the body is necessary for maintaining overall health and well-being.

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