Nutrition and Digestive System

Nutrition is the process by which living organisms obtain and utilize food for growth, energy, and maintenance of body functions. Food provides essential nutrients, which are classified into six main groups:

1. **Carbohydrates**: Provides energy (e.g., rice, bread).
2. **Proteins**: Helps in growth and repair of tissues (e.g., eggs, fish).
3. **Fats**: Serves as energy reserves and are essential for cell membranes (e.g., oils, butter).
4. **Vitamins**: Regulates metabolic processes (e.g., Vitamin C for immunity).
5. **Minerals**: Supports bone health, nerve function, and more (e.g., calcium, iron).
6. **Water**: Essential for hydration and metabolic processes.

Balanced nutrition is vital for maintaining health and preventing diseases like obesity, diabetes, and malnutrition.

The digestive system is a complex network of organs that work together to break down food into simpler forms so that the body can absorb and utilize nutrients for energy, growth, and repair. This process is called **digestion**, and it involves both mechanical and chemical breakdown of food.

Main Components of the Digestive System

- Mouth

-Digestion begins in the mouth where food is chewed into smaller pieces (mechanical digestion).

-Saliva, produced by salivary glands, contains an enzyme called amylase, which begins the breakdown of carbohydrates into simpler sugars.

- Esophagus

-A muscular tube that transports food from the mouth to the stomach through a wave-like movement called peristalsis.

-A muscular valve called the lower esophageal sphincter prevents stomach acid from entering the esophagus.

- Stomach

-The stomach is a muscular sac that churns food and mixes it with gastric juices containing hydrochloric acid (HCl) and enzymes like pepsin, which breaks down proteins.

-Food is converted into a semi-liquid substance called chyme.

- Small Intestine

-The small intestine is the primary site for digestion and absorption of nutrients. It has three parts:

Duodenum: Digestive juices from the pancreas and bile from the liver mix with chyme here.

Jejunum and Ileum: Nutrients are absorbed through the walls of these sections into the bloodstream.

-The lining of the small intestine has finger-like projections called villi and smaller structures called microvilli, which increase surface area for absorption.

- Large Intestine (Colon)

-The large intestine absorbs water, electrolytes, and vitamins produced by gut bacteria (e.g., Vitamin K).

-It compacts undigested food into feces for elimination.

- Rectum and Anus

The rectum stores faeces until it is expelled through the anus during defecation.

Accessory Organs of Digestion

- Liver

-Produces bile, which helps emulsify fats, making them easier to digest.

-Processes nutrients absorbed from the small intestine and detoxifies harmful substances.

- Gallbladder

-Stores and releases bile into the small intestine when fats are present.

- Pancreas

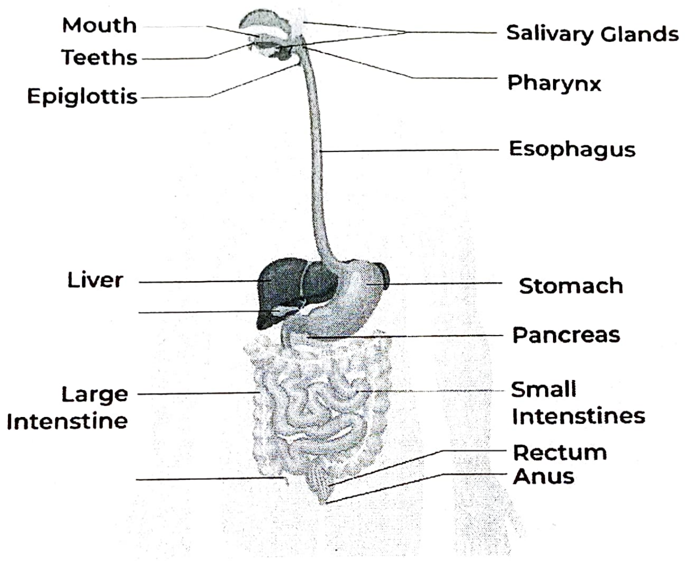
-Produces digestive enzymes like lipase (for fats), amylase (for carbohydrates), and proteases (for proteins).

-Releases bicarbonate to neutralize stomach acid in the small intestine.

Processes involved in digestion:

1. Ingestion: Food is taken into the mouth.
2. Propulsion: Food is moved through the digestive tract via swallowing and peristalsis.
3. Digestion: Mechanical and chemical breakdown of food into absorbable units.
4. Absorption: Nutrients are absorbed into the blood or lymph through the intestinal walls.
5. Elimination: Undigested waste is excreted as fΛeces.

Human Digestive System



Bioenergetics and Thermodynamics

Bioenergetics is the study of energy flow and transformation in living organisms. It is a fundamental concept that explains how cells and organisms obtain, store, and utilize energy to carry out essential functions like growth, reproduction, and homeostasis. Thermodynamics on the other hand is the branch of physics that deals with energy transformations, is directly applied to bioenergetics to understand how energy flows through biological systems.

Key Concepts in Thermodynamics

Energy and Systems:

Energy: The capacity to do work or produce change.

Systems: A defined portion of the universe under study, e.g., a cell. Systems can be:

1. Open systems: Exchange energy and matter with surroundings (e.g., living organisms).
2. Closed systems: Only exchange energy, not matter.
3. Isolated systems: Exchange neither energy nor matter.

First Law of Thermodynamics (Law of Energy Conservation):

-Energy can neither be created nor destroyed, only transformed from one form to another.

-In biological systems, energy transformations occur during processes like cellular respiration, where chemical energy from glucose is converted into ATP (adenosine triphosphate), the usable form of energy.

Second Law of Thermodynamics (Entropy):

-Every energy transfer increases the entropy (disorder) of the universe.

-Biological systems maintain order and low entropy internally by expending energy. For instance, organisms use ATP to drive reactions that maintain cellular organization.

Gibbs Free Energy (G):

Determines whether a reaction is spontaneous or requires energy.

1. $\Delta G = \Delta H - T\Delta S$, where:
   1. ΔG: Change in free energy.
   2. ΔH: Change in enthalpy (heat content).
   3. T: Temperature in Kelvin.
   4. ΔS: Change in entropy.

2. If $\Delta G<0$: Reaction is exergonic (releases energy, spontaneous).
3. If $\Delta G>0$: Reaction is endergonic (requires energy input).

Significance: Understanding bioenergetics and thermodynamics is essential for exploring:

- How cells harness energy (e.g., photosynthesis, respiration).
- Disease mechanisms involving metabolic dysregulation.
- Development of drugs targeting energy-dependent processes.

Bioenergetics in Biological Systems

- ATP: The Energy Currency: ATP stores energy in high-energy phosphate bonds. When ATP is hydrolyzed (ATP → ADP + Pi), energy is released to fuel cellular processes.
- Metabolism: Catabolism: Breakdown of molecules to release energy (e.g., glucose breakdown in glycolysis). Anabolism: Synthesis of complex molecules using energy (e.g., protein synthesis).
- Energy Coupling: Biological systems couple exergonic and endergonic reactions to ensure that energy released from one process (e.g., ATP hydrolysis) drives another (e.g., muscle contraction).
- Role of Enzymes: Enzymes lower the activation energy of biochemical reactions, making energy transformations efficient and specific.

Energy production in living cells, aerobic/anaerobic respiration

Living cells produce energy through the breakdown of glucose and other molecules, a process vital for sustaining life. This energy is stored in the form of ATP (adenosine triphosphate), which powers various cellular processes. Energy production occurs via two main pathways: **aerobic respiration** and **anaerobic respiration**.

Aerobic Respiration: A process that requires oxygen to completely oxidize glucose, producing a large amount of energy.

1. **Glycolysis**:
   - Occurs in the cytoplasm.
   - One Glucose (6C) is broken into 2 pyruvate (3C) molecules.
   - Produces 2 ATP (net) and 2 NADH.
2. **Pyruvate Oxidation**:
   - Pyruvate enters mitochondria and is converted to acetyl-CoA.
3. **Krebs Cycle**:
   - Occurs in the mitochondrial matrix.
   - Acetyl-CoA is fully oxidized to CO_2.

- Generates 2 ATP, 6 NADH, and 2 $FADH_2$ per glucose molecule.

4. **Electron Transport Chain (ETC)**:

   - Occurs in the mitochondrial inner membrane.
   - NADH and $FADH_2$ donate electrons to the ETC.
   - Oxygen acts as the final electron acceptor, forming water.
   - Proton gradient drives ATP synthesis via oxidative phosphorylation, yielding ~32-34 ATP.

Total ATP Yield: ~36-38 ATP per glucose.

Anaerobic Respiration: Energy production in the absence of oxygen, yielding less ATP compared to aerobic respiration.

1. **Glycolysis** (same as in aerobic respiration):

   - Produces 2 ATP and 2 NADH.

2. **Fermentation**:

   - **Lactic Acid Fermentation** (e.g., in muscle cells):

     - Pyruvate is converted to lactic acid.
     - Regenerates NAD^+ for glycolysis.

   - **Alcohol Fermentation** (e.g., in yeast):

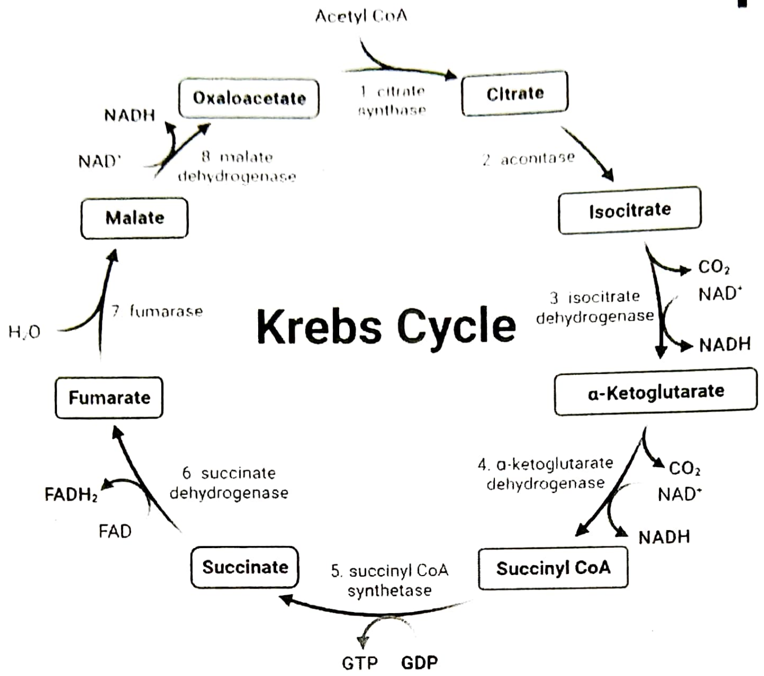
     - Pyruvate is converted to ethanol and CO_2.
     - Regenerates NAD^+ for glycolysis.

ATP Yield: Only 2 ATP per glucose (from glycolysis).

Significance:

- **Aerobic respiration** is more efficient and supports sustained energy needs in multicellular organisms.
- **Anaerobic respiration** provides a quick energy supply under low oxygen conditions, crucial in emergencies (e.g., exercise or hypoxia).

TCA Cycle

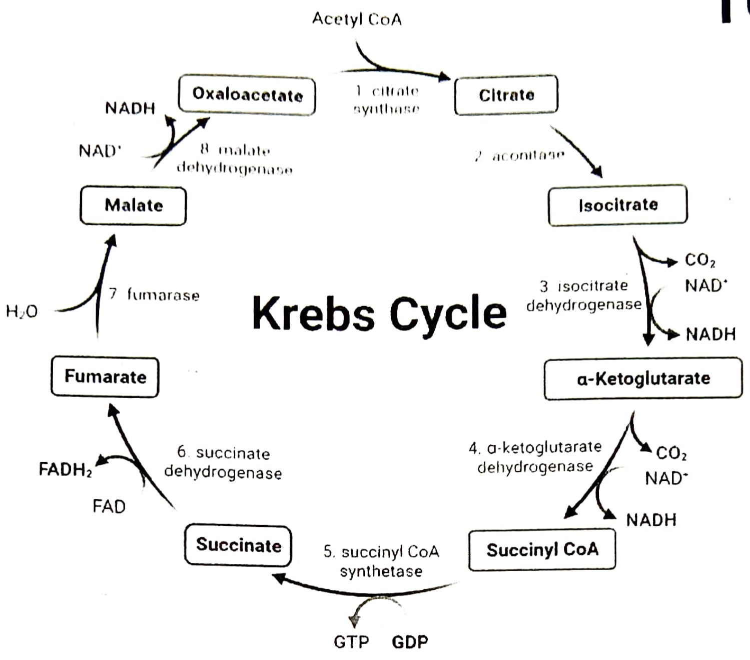


Products
(Each Cycle)

1 ATP (GTP)
3 NADH
1 $FADH_2$
2 CO_2

Process	*Direct product*	*Final ATP*
Glycolysis	2 NADH (cytosolic)	3 or 5*
	2 ATP	2
Pyruvate oxidation (two per glucose)	2 NADH (mitochondrial matrix)	5
Acetyl-CoA oxidation in citric acid cycle	6 NADH (mitochondrial matrix)	15
(two per glucose)	2 $FADH_2$	3
	2 ATP or 2 GTP	2
Total yield per glucose		30 or 32

TCA Cycle



Products

(Each Cycle)

1 ATP (GTP)

3 NADH

1 $FADH_2$

2 CO_2

Process	*Direct product*	*Final ATP*
Glycolysis	2 NADH (cytosolic)	3 or 5*
	2 ATP	2
Pyruvate oxidation (two per glucose)	2 NADH (mitochondrial matrix)	5
Acetyl-CoA oxidation in citric acid cycle	6 NADH (mitochondrial matrix)	15
(two per glucose)	2 $FADH_2$	3
	2 ATP or 2 GTP	2
Total yield per glucose		30 or 32