BIOCHEMISTRY

FIRST STAGE

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Lecture 1

Biochemistry is the branch of science that studies the **chemical substances and life processes** that occur in living organisms such as humans, animals, and plants.

It explains how the body's **molecules** — like proteins, carbohydrates, fats, and enzymes — work together to keep us alive.

In simple words, **biochemistry connects biology and chemistry** to help us understand how cells, tissues, and organs function at the molecular level.

Importance of Biochemistry in Nursing

Biochemistry is very important for nurses because it helps them understand what happens inside the human body and how diseases or treatments affect it.

Here are the main reasons why biochemistry is useful in nursing:

1. **Understanding laboratory tests:**
   Helps nurses understand the meaning of lab results such as blood sugar, urea, creatinine, cholesterol, and liver enzymes.
2. **Monitoring patients' conditions:**
   Helps nurses recognize chemical changes in the body, like electrolyte or acid-base imbalance.
3. **Preparing and giving IV solutions:**
   Nurses must know the chemical composition of IV fluids (like glucose or saline) and their effects on body fluids and electrolytes.
4. **Understanding drugs:**
   Explains how medicines work inside the body — how they are metabolized, used, and removed.
5. **Health education:**
   Helps nurses teach patients about healthy nutrition and how food affects energy, blood sugar, and body chemistry.

General Chemistry

Main areas of Chemistry:

- **Organic** – compounds of carbon (some exceptions CO2 CO considered inorganic)
- **Inorganic** – compounds that do not include carbon

- **Analytical** – composition of matter and mixtures (what is there and how much)
- **Physical** – applies ideas of math and physics to chemistry
- **Biochemistry** – chemistry of living things (from bacteria to humans)

Atom

- Is the basic unit of matter and the defining structure of elements.
- is the smallest component of an element,
- Atoms are building blocks of nature
- Characterized by a sharing of the chemical properties of the element and a nucleus with neutrons, protons and electrons.
- consist of a **nucleus** (is positively charged center of an atom made of protons and neutrons) and **electrons** (are negatively charged particles with much less mass) located in the region between the nucleus and the edge of the atom
- Atoms come together to form compounds

Elements

- Is a substance whose atoms all have the same number of protons
- Elements are chemically the simplest substances and hence cannot be broken down using chemical reactions.
- Elements can only be changed into other elements using nuclear methods
- composed of one type of atom , cannot be decomposed into simple substances
- An element can combine with one or more other elements to form compound.

Compounds

- is a substance formed when two or more chemical elements are chemically bonded together.
- The type of bonds holding elements together in a compound can vary: two common types are covalent bonds and ionic bonds.
- Compounds can be decomposed chemically into their constituent elements. can be decomposed into elements Compounds are composed of two or more types of atoms Some compounds are made of molecules (linked collection of atoms like H2O) and some are made of ions (positive

and negative charged atoms) NaCl is made of a number Na + and Cl– ions in a three-dimensional array but NOT NaCl molecules

Molecule

- Is the smallest particle in a chemical element or compound that has the chemical properties of that element or compound.
- Molecules are made up of atoms that are held together by chemical bonds. These bonds form as a result of the sharing or exchange of electrons among atoms. The atoms of certain elements readily bond with other atoms to form molecules.
- Examples of such elements are oxygen and chlorine. The atoms of some elements do not easily bond with other atoms. Examples are neon and argon.
- is a particle made up of two or more atoms that are chemically bonded together; the number of atomic nuclei making up a molecule is a determinate number

Types of Chemical Bonds

There are two **main** types and some **secondary** types of chemical bonds

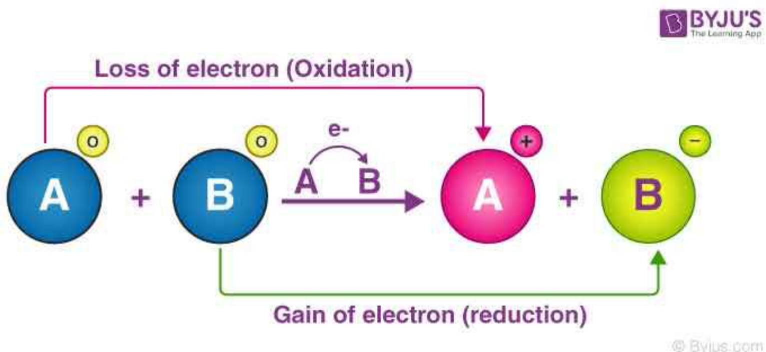
1. **Ionic bonding** involves a transfer of an electron, so one atom gains an electron while one atom loses an electron. Such as NaCl, KCl, KI.
2. **Covalent bond** the most common bond in organic molecules, involves the sharing of electrons between two atoms. Such as H_2O, CH_4.
3. **Hydrogen bond** because they're polarized, two adjacent H2O (water) molecules can form a linkage known as a hydrogen bond, where the (electronegative) hydrogen atom of one H2O molecule is electrostatically attracted to the (electropositive) oxygen atom of an adjacent water molecule.

Chemical reactions

- Occur when chemical bonds between atoms are formed or broken.
- The substances that go into a chemical reaction are called the **reactants**, and the substances produced at the end of the reaction are known as the **products**.

An oxidation-reduction (redox) reaction

- ✓ Is a type of chemical reaction that involves a transfer of electrons between two species.
- ✓ An oxidation-reduction reaction is any chemical reaction in which the oxidation number of a molecule, atom, or ion changes by gaining or losing an electron.
- ✓ Redox reactions are common and vital to some of the basic functions of life, including photosynthesis, respiration…etc.
- ✓ Redox reactions are comprised of two parts, a reduced part and an oxidized part, that *always* occur together.
- ✓ The reduced part gains electrons and the oxidation number decreases, while the oxidized part loses electrons and the oxidation number increases.
- ✓ The ion or molecule that accepts electrons is called the **oxidizing agent**; by accepting electrons it causes the oxidation of another species.
- ✓ The species that donates electrons is called the **reducing agent**; when the reaction occurs, it reduces the other species.



Applications of REDOX reactions in Biochemistry

Oxidation:

- **Meaning:** Loss of electrons or addition of oxygen.
- **Example in the body:**
  Glucose is oxidized during **cellular respiration** to produce energy (ATP).
  👉 Example reaction:
  $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$ + Energy (ATP)

Reduction:

- **Meaning:** Gain of electrons or removal of oxygen.
- **Example in the body:**
  During energy production, **NAD^+** is reduced to **NADH**, which stores energy for later use.
  👉 Example reaction:
  $NAD^+ + H^+ + 2e^- \rightarrow NADH$

Example 1: identifying oxidized elements

Using the equations from the previous examples, determine what is oxidized in the following reaction.

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

SOLUTION

The oxidation state of H changes from +1 to 0, and the oxidation state of Zn changes from 0 to +2. Hence, Zn is oxidized and acts as the reducing agent.

Example 2: identifying reduced elements

What is reduced species in this reaction?

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

SOLUTION

The oxidation state of H changes from +1 to 0, and the oxidation state of Zn changes from 0 to +2. Hence, H+ ion is reduced and acts as the oxidizing agent.

Hydrolysis reaction

- ❖ **Hydrolysis** is the chemical breakdown of substances by water
- ❖ **Hydrolysis** depends on the chemistry, solubility, pH, and the oxidation–reduction potential of compound.
- ❖ Hydrolysis reaction involving an ester link, such as that found between two amino acids in a protein, the products that result include one that receives

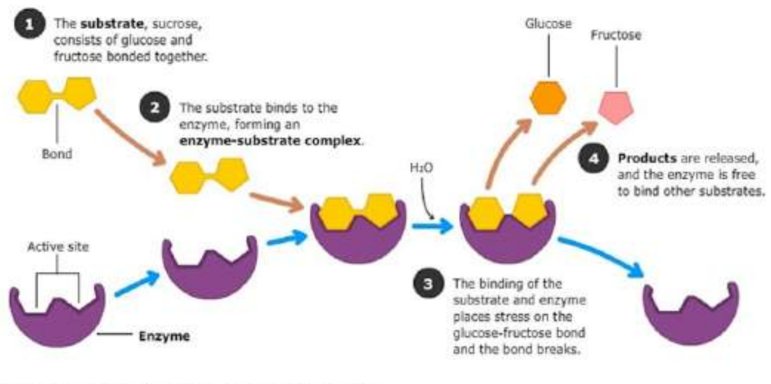
the hydroxyl (OH) group from the water molecule and another that becomes a carboxylic acid with the addition of the remaining proton (H+).

$$RCO\text{-}OR' + H_2O \rightarrow RCO\text{-}OH + R'\text{-}OH$$

- ❖ Hydrolysis reactions in living organisms are performed with the help of catalysis by a class of enzymes known as hydrolases.
- ❖ A good example to hydrolysis in biological cells is the hydrolysis of the energy molecule adenosine triphosphate, or ATP.

Hydrolysis:

- **Meaning:** Breaking down a large molecule by adding water.
- **Example in the body:**
  In digestion, **starch** is broken into **simple sugars (glucose)** with the help of enzymes and water.
  👉 Example reaction:
  Starch + H_2O → Glucose units



Measurements in chemistry

Qualitative analysis

- ➦ A qualitative analysis determines the presence or absence of a particular compound (on the basis of their chemical or physical properties, such as solubility, molecular weight) but not the mass or concentration.
- ➦ By definition, qualitative analyses do not measure quantity.

- It tells **what** a substance is, or **if it is present or not**.

- It does **not** give a number or amount.
- Used to detect the **presence or absence** of a chemical compound.
  🧪 **Example:** A urine test that shows if sugar is present (positive or negative result).

Quantitative analysis

➔ Quantitative analysis is the measurement of the quantities of particular chemical constituents present in a substance

➔ Is expressed as a numerical value in appropriate units

- It tells **how much** of a substance is present.
- The result is given in **numbers or concentration**.
- Used to **measure the exact amount** of a chemical.
  📊 **Example:** Measuring blood glucose level (e.g., 90 mg/dL).

Lecture 2

History and scope of biochemistry

- **Biochemistry** is the science that studies the **chemical substances and processes in living organisms**.
- It began in the **19th century** when scientists started linking chemistry and biology.

🧬 Main Historical Points:

1. **1828 – Friedrich Wöhler** made urea in the lab from an inorganic compound.
   → This showed that biological substances can be made artificially, not only by living things.
2. **Late 1800s – Enzyme discovery:** Scientists found that enzymes (biological catalysts) help chemical reactions in the body.
3. **1900s – Vitamins, hormones, and metabolism** were studied.
4. **1953 – DNA structure** was discovered by Watson and Crick.
   → This discovery explained how genetic information is stored and passed on.

Scope of Biochemistry

Biochemistry connects **biology**, **chemistry**, and **medicine**.
It explains **how life works at the molecular level**.

🩸 Main areas of study:

1. **Structure and function of biomolecules** – like proteins, carbohydrates, lipids, and nucleic acids.
2. **Metabolism** – how the body produces and uses energy.
3. **Enzymes** – how they speed up chemical reactions.
4. **Genetic biochemistry** – DNA, RNA, and protein synthesis.
5. **Clinical biochemistry** – how chemical tests help diagnose diseases.

In Nursing Field

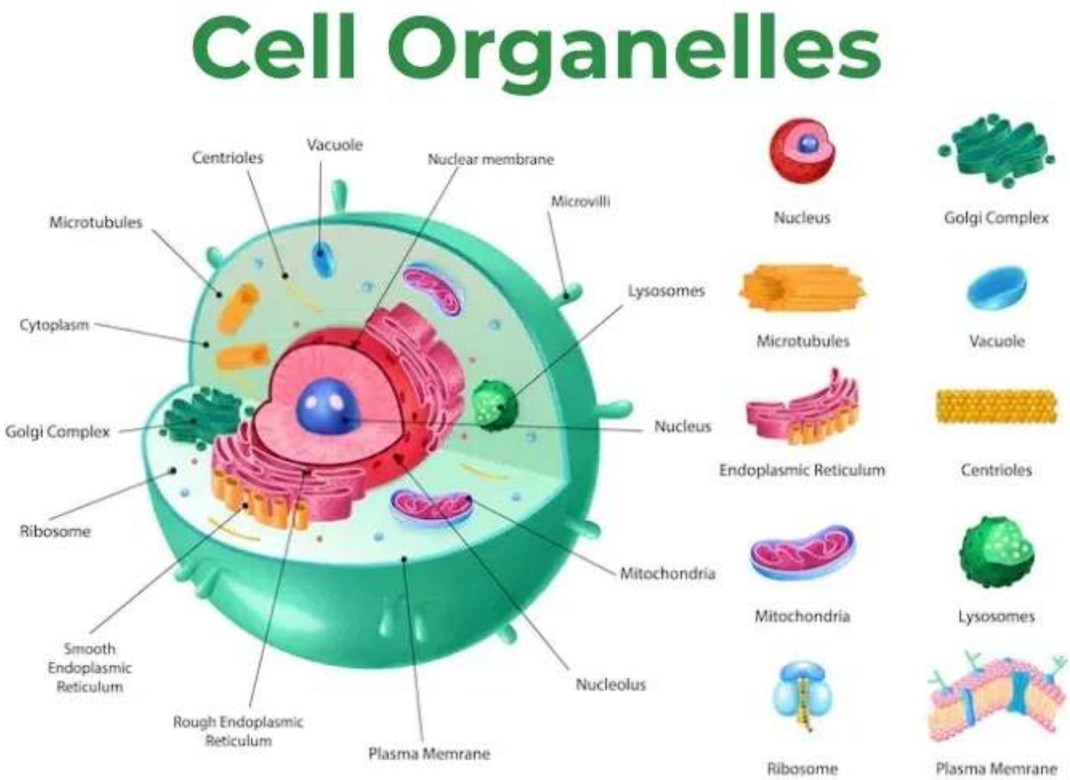
- Helps understand **how the body works normally**.
- Explains **why diseases occur** (when chemical balance changes).

- Guides **laboratory tests and treatment monitoring** (like blood glucose, liver enzymes, etc.).

Subcellular organelles

Cells contain various organized structures, collectively called as cell organelles

- **Nucleus** (All cells in the body contain nucleus except mature erythrocytes)
- **Endoplasmic reticulum**(is involved in protein synthesis and also detoxification of various drugs)
- **Golgi apparatus** (is primarily involved in glycosylation, protein sorting, packaging and secretion)
- **Lysosomes** (contain many hydrolyzing enzymes)
- **Mitochondria** (the 'power house' of the cell has its own DNA, can synthesize its own proteins)
- **Plasma membrane** (separates the cell from the external environment. Membranes are mainly composed of lipids (phospholipids), proteins and a small percentage of carbohydrates)

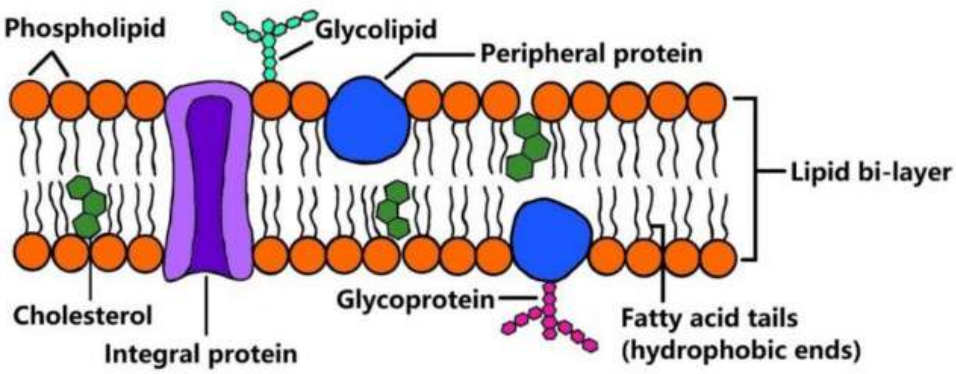


Structure of the Cell Membrane

The **cell membrane** (also called the **plasma membrane**) surrounds the cell and controls what enters and leaves it.
It is mainly made of **lipids and proteins**.

-Main Components:

1. **Phospholipid Bilayer:**
   - Two layers of phospholipids.
   - Each phospholipid has a **hydrophilic (water-loving) head** and **hydrophobic (water-fearing) tails**.
   - This structure makes the membrane **selectively permeable** (allows some substances to pass and blocks others).
2. **Proteins:**
   - **Integral proteins** go through the membrane and help in **transport** (channels, carriers).
   - **Peripheral proteins** are on the surface and help in **cell recognition or enzyme activity**.
3. **Carbohydrates:**
   - Attached to proteins or lipids (glycoproteins, glycolipids).
   - Help in **cell recognition** and **communication**.
4. **Cholesterol:**
   - Found between phospholipids.
   - Keeps the membrane **stable and flexible**.



2. Functions of the Cell Membrane

1. **Protection:**
    - Acts as a barrier separating the inside of the cell from the outside environment.
2. **Selective Permeability:**
    - Controls what substances enter or leave the cell (like nutrients, gases, and wastes).
3. **Transport:**
    - Allows movement of materials by **diffusion, osmosis, and active transport**.
4. **Communication:**
    - Contains **receptor proteins** that receive signals (like hormones).
5. **Cell Recognition:**
    - Carbohydrate chains identify the cell (important in immunity).
6. **Support and Shape:**
    - Gives structural support and maintains cell shape.

Acid–Base balance

- The body is very sensitive to its pH level, so strong mechanisms exist to maintain it.
- A buffer solution is an aqueous solution of a weak acid and its anion, or a weak base and its anion.
- Buffer solutions are used to keeping pH at a nearly constant value in a wide variety of chemical applications.

The buffer systems of the body

1. **Proteins**
    - The most important buffers in the body.
    - They are mainly intracellular and include hemoglobin.
    - The plasma proteins are buffers but the absolute amount is small compared to intracellular protein.
    - Protein molecules possess basic and acidic groups which act as H^+ acceptors or donors if H^+ is added or removed.

2. **Phosphate**
    - Buffer (H_2PO^{4-} : $HP0_4^{2-}$) is mainly intracellular.
    - The concentration of phosphate is low in the extracellular fluid but the phosphate buffer system is an important urinary buffer.

3. **Carbonic acid-bicarbonate buffer system H_2CO**2 **and HCO** $^{-3}$ are involved in pH control.

$$CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^{-1} \longleftrightarrow H^+ + CO_3^{-2}$$

Mechanisms of pH control

- One example of a buffer solution found in nature is blood. **The body's acid–base balance** is normally tightly regulated, keeping the arterial blood pH between 7.38 and 7.42.

- **The kidneys** have two very important roles in maintaining the acid–base balance:

    1. They reabsorb bicarbonate from urine. 2.
    They excrete hydrogen ions into urine.

- **Regulation of H^+ by the Lungs**: Acid–base imbalances in the blood's pH can be altered by changes in breathing to expel more CO_2 and raise pH back to normal.

- **Respiratory Regulation (Acts in Minutes)**

Lungs help control pH by removing CO_2.

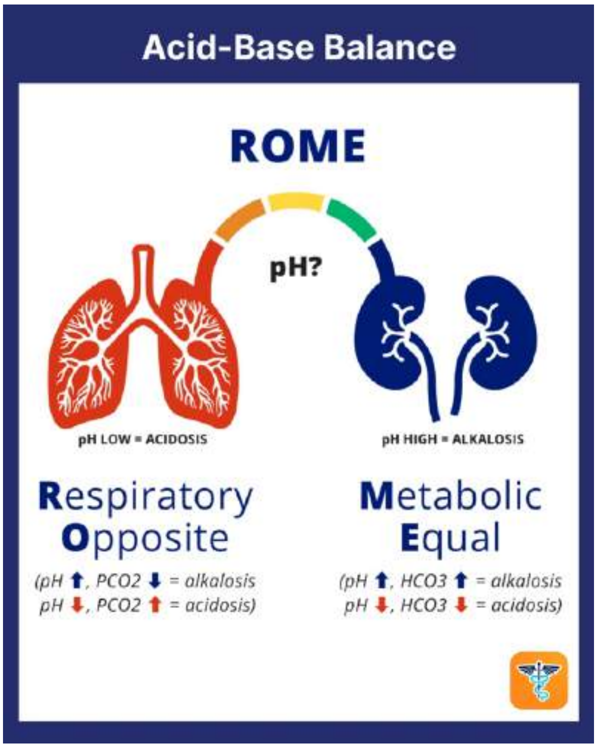
- **$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$**
- If blood becomes **acidic (↓pH)** → respiratory center increases breathing → more CO_2 is exhaled → pH rises.
- If blood becomes **alkaline (↑pH)** → breathing slows → CO_2 retained → pH decreases.

- **Renal Regulation (Acts in Hours to Days)**

Kidneys control pH by excreting H^+ and reabsorbing HCO_3^-.

- When blood is **acidic** → kidneys excrete more H^+ and keep more HCO_3^-.
- When blood is **alkaline** → kidneys keep H^+ and excrete more HCO_3^-.

This system is **slow but very powerful** in long-term control of pH.



Homeostasis

The main mechanisms of homeostasis

- Homeostasis is the ability to maintain internal stability in an organism to compensate for environmental changes.
- Human body include mechanisms that help regulate the body, this includes organs, glands, tissues and cells.
- The adjusting of these enables the body to constantly be in a steady state.
- The main mechanisms of homeostasis are body temperature, body fluid composition, blood sugar, gas concentrations, and blood pressure.

Transport Through Biological Cell Membrane

The **cell membrane** controls the movement of substances **into and out of the cell** — this is called **membrane transport**.
It helps maintain the **internal balance (homeostasis)** of the cell.

Types of Transport

There are **two main types:**

1. **Passive Transport** (no energy required)
2. **Active Transport** (requires energy – ATP)

1. Passive Transport

- Movement **without using energy (ATP)**.
- Molecules move **from high concentration → to low concentration**.
- Like rolling downhill — it happens naturally.

Types of Passive Transport:

a) Simple Diffusion

- Movement of small molecules (O_2, CO_2) directly through the lipid bilayer.
- Example: Oxygen moving from lungs into blood.

b) Facilitated Diffusion

- Uses **protein channels or carrier proteins** to move larger or charged molecules (like glucose or ions).
- Example: Glucose entering cells through GLUT transporters.

c) Osmosis

- **Diffusion of water** through a semipermeable membrane.
- Water moves **from low solute → to high solute concentration**.
- Example: Water movement in red blood cells.

2. Active Transport

- Requires **energy (ATP)**.

- Molecules move **from low concentration → to high concentration** (against the gradient).
- Like pushing uphill — needs effort.

Types of Active Transport:
a) Primary Active Transport

- Direct use of ATP to move substances.
- **Example:** Sodium–Potassium pump (Na^+/K^+ pump) — moves Na^+ out and K^+ into the cell to maintain electrical balance.

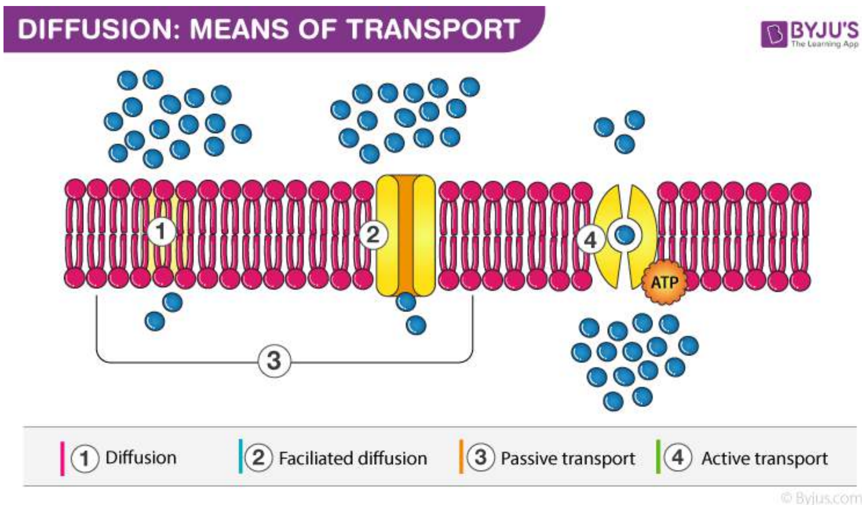
b) Secondary Active Transport

- Uses energy stored in another molecule's gradient (not directly from ATP).
- Example: Sodium-glucose co-transport in intestines.

🧫 3. Bulk Transport (Vesicular Transport)

Used for **large molecules** or **particles** that cannot pass through the membrane.

- **Endocytosis:** Cell takes in materials (e.g., nutrients, bacteria).
  - *Phagocytosis* – "cell eating" solids.
  - *Pinocytosis* – "cell drinking" liquids.
- **Exocytosis:** Cell releases materials (e.g., hormones, waste).



Lecture 3

Water and electrolytes balance and imbalance

1. What is Water Balance?

- **Water balance** means keeping the **amount of water intake** equal to the **amount of water lost**.
- The human body is about **60–70% water**.
- Water is essential for:
  - Transport of nutrients and waste
  - Temperature regulation
  - Lubrication of joints and tissues
  - Chemical reactions inside cells

2. Water Intake and Output

Source of Water Intake	Average Amount per Day
Drinking water & beverages	1.5 – 2.0 L
Food (fruits, vegetables, etc.)	0.5 – 1.0 L
Metabolic water (from oxidation)	~0.3 L
Total Intake	**≈ 2.5 – 3.0 L/day**

Routes of Water Loss	Average Amount per Day
Urine	1.5 L
Skin (sweat)	0.5 L
Lungs (breathing)	0.3 L
Feces	0.2 L
Total Loss	**≈ 2.5 L/day**

✅ When **intake = loss → water balance**
⚠️ When **intake ≠ loss → water disturbance**

3. Regulation of Water Balance

Controlled by:

1. **Thirst center (in hypothalamus):**
   - Stimulates drinking when body water is low.
2. **Antidiuretic Hormone (ADH):**

    - Released from the **posterior pituitary gland**.
    - Makes kidneys reabsorb more water → less urine → conserves water.
3. **Aldosterone (from adrenal gland):**
    - Helps retain sodium (and water follows sodium).

4. Water Disturbances

A. Dehydration (Water Deficit)

- **Cause:** Excess loss or low intake (vomiting, diarrhea, sweating, burns, fever).
- **Effects:**
    - Dry mouth and skin
    - Thirst
    - Low urine output
    - Low blood pressure, weakness
- **In severe cases:** Confusion, shock.

B. Overhydration (Water Excess)

- **Cause:** Excess intake or decreased excretion (kidney failure, excess ADH).
- **Effects:**
    - Swelling (edema)
    - Low sodium levels (hyponatremia)
    - Headache, nausea, confusion
    - In severe cases: Brain swelling.

5. Clinical Importance for Nursing

- Monitor **fluid intake and output (I&O chart)**.
- Check for **signs of dehydration or edema**.
- Regulate **IV fluid therapy** carefully.
- Observe **urine color and volume** as indicators of hydration status.

Electrolytes: Electrolytes are present in the human body, and the balance of the electrolytes in our bodies is essential for normal function of our cells and our organs. Electrolytes such as Sodium, Potassium, Calcium, Phosphor, Chloride and Iron. Keeping electrolyte concentrations in balance also includes stimulating the thirst mechanism when the body gets dehydrated.

Electrolytes (Minerals)

1- **Macro minerals**: - Which are required in amounts greater than 100 mg per day , ex. (Na , K , Ca , Mg , Cl and P)

2- **Micro minerals**: - Which are required in amounts less than 100 mg per day, ex. (Fe , Cu , Co , Mn , Zn, I and Li)

3- **Trace elements**: - a trace element is one whose average concentration is less than 100 parts per million (ppm) measured in the atomic count Although they are essential, they become toxic at high concentrations, ex. (Se, Ag, As, Cd, Cr, Hg, and Pb)

Electrolytes are present in the human body, and the balance of the electrolytes in our bodies is essential for normal function of our cells and our organs. Electrolytes such as **Sodium, Potassium, Calcium, Phosphor, Chloride and Iron**. Keeping electrolyte concentrations in balance also includes stimulating the thirst mechanism when the body gets dehydrated.

Sodium

Sodium is most often found outside the cell, in the plasma of the blood stream, Too much or too little sodium therefore can cause cells to malfunction, and extremes in the blood sodium levels can be fatal.

Distribution in the Body

- **Sodium is the major extracellular cation** (positive ion).
- It is mainly found **outside the cells (in extracellular fluid – ECF)**.
- **Normal blood sodium level: 135–145 mEq/L**

Location	Percentage / Concentration
Extracellular fluid (plasma, interstitial fluid)	~90–95% of body sodium
Inside cells (intracellular fluid)	Very little sodium
Bones	Small amount stored

2. Principle (Regulation of Sodium Balance)

The body maintains sodium balance mainly through the **kidneys** and certain **hormones**:

1. **Aldosterone (from adrenal gland):**
   - Increases sodium reabsorption by kidneys → retains Na^+ and water.
2. **Antidiuretic hormone (ADH):**
   - Controls water balance → indirectly affects sodium concentration.
3. **Atrial natriuretic peptide (ANP):**
   - Released by the heart → promotes sodium and water excretion (lowers blood volume).

Sodium balance helps maintain **normal fluid volume, blood pressure, and nerve function**.

3. Functions of Sodium

Function	Explanation
1. Fluid Balance	Controls movement of water between body compartments (by osmosis).
2. Nerve Transmission	Needed for generating nerve impulses (action potentials).
3. Muscle Contraction	Works with potassium and calcium for muscle activity.
4. Acid–Base Balance	Helps maintain normal blood pH.
5. Blood Pressure Regulation	Retention or loss of sodium affects blood volume and pressure.

4. Sodium Imbalance

Condition	Cause	Main Effects / Symptoms
Hyponatremia (Low Na^+)	Excess water intake, vomiting, diarrhea, kidney disease, loss through sweat	Confusion, headache, muscle weakness, seizures
Hypernatremia (High Na^+)	Dehydration, high salt intake, low water intake	Thirst, dry mouth, restlessness, high BP

Potassium (K^+)

Distribution in the Body

- **Potassium is the major intracellular cation** (inside the cells).
- **Normal blood potassium level:** 3.5–5.0 mEq/L

Location	Percentage / Description
Inside cells (intracellular fluid, ICF)	~98% of total body potassium
Extracellular fluid (plasma, interstitial fluid)	~2%
Bones	Small reserve

Potassium balance is essential for **cell function, heart, and muscle activity**.

2. Principle (Regulation of Potassium)

- **Potassium balance** is mainly controlled by the **kidneys** and influenced by **hormones**:

1. **Aldosterone (adrenal gland)** → increases K^+ excretion in urine.
2. **Insulin** → moves K^+ into cells after meals.
3. **Acid–base balance** → pH changes affect K^+ distribution between ICF and ECF.

✅ Maintaining proper K^+ levels is critical for **heart rhythm and muscle function**.

3. Functions of Potassium

Function	Explanation
1. Nerve Transmission	Helps generate action potentials in nerves.
2. Muscle Contraction	Essential for skeletal and cardiac muscle activity.
3. Heart Function	Maintains normal heart rhythm; prevents arrhythmias.
4. Acid–Base Balance	Helps regulate intracellular pH.
5. Osmotic Balance	Maintains proper fluid distribution inside cells.

4. Potassium Imbalance

Condition	Cause	Main Effects / Symptoms
Hypokalemia (Low K^+)	Vomiting, diarrhea, diuretics, low intake	Weakness, fatigue, muscle cramps, cardiac arrhythmias
Hyperkalemia (High K^+)	Kidney failure, excessive intake, cell breakdown	Muscle weakness, cardiac arrhythmias, possible cardiac arrest

Chloride (Cl^-)

- Major **extracellular anion** (mainly in blood and interstitial fluid).
- Normal serum level: **96–106 mEq/L**

Regulation:

- Mostly controlled by **kidneys**.
- Follows **sodium (Na^+)** to maintain **electrolyte and fluid balance**.
- **Acid–base balance** also affects Cl^- level

Principle Functions

1- As compound of gastric hydrochloride acid .

2- Maintain the normal distribution of water in space .

3- Maintain of osmotic pressure and cat ion-anion balance .

Calcium (Ca)

Most of body's calcium is found in the bones and teeth (99 %) in form calcium carbonate and calcium phosphate , the remain ratio which is (1%), is present in the blood in two forms :

Form	Percentage	Description
Ionized (free) calcium (Ca^{2+})	~50%	Active form — used by body cells
Bound calcium (mainly bound to plasma proteins like albumin)	~50%	Inactive form — serves as a reservoir

3. Principle (Importance of Calcium Balance)

- Blood calcium is **tightly regulated** by three hormones:
  1. **Parathyroid hormone (PTH)** → Increases blood Ca^{2+} by releasing it from bones and increasing absorption.
  2. **Calcitonin** (from thyroid gland) → Lowers blood Ca^{2+} by storing calcium in bones.
  3. **Vitamin D (Calcitriol)** → Helps intestines absorb calcium from food.

Normal blood calcium level: 8.5 – 10.5 mg/dL

Maintaining this balance is **essential for life**, because both **low (hypocalcemia)** and **high (hypercalcemia)** levels can cause serious problems (muscle spasms, heart rhythm disturbances).

4. Functions of Calcium

Function	Explanation
1. Bone and Teeth Formation	Main component of bones and teeth (gives hardness and strength).
2. Muscle Contraction	Needed for contraction of skeletal, smooth, and cardiac muscles.
3. Nerve Transmission	Helps transmit nerve impulses across synapses.
4. Blood Clotting	Required for activation of clotting factors.
5. Enzyme Activation	Acts as a cofactor for many enzymes.
6. Hormone Secretion	Needed for secretion of hormones like insulin.
7. Cell Membrane Stability	Helps maintain the integrity and permeability of cell membranes.

Phosphorus (P)

Most of body's phosphorus is found in the bones (80%) as calcium phosphate and other (20%) is transfer in blood .

Principle Functions

1-Asist in carbohydrates metabolism .

2-Chief role in R.B.C composition .

4- Acid basebalance .

4-Production of ATP.

5-Calcification of bones .

Iron (Fe)

Distribution in the Body

- **Total body iron:** about **3–5 grams** in adults.
- **Main locations:**

Site	Percentage / Form
Hemoglobin (in red blood cells)	~70%
Myoglobin (in muscles)	~5–10%
Stored iron (ferritin, hemosiderin)	~20–25%
Other forms (enzymes, plasma)	<1%

🩸 Most iron in the body is found in **hemoglobin**, the molecule that carries **oxygen** in red blood cells.

2. Forms of Iron in Blood

Iron in the blood exists mainly in two forms:

1. **Hemoglobin iron** – inside RBCs, part of the heme group.
2. **Plasma iron** – small amount carried by **transferrin** (a transport protein).

3. Principle (Regulation of Iron Balance)

- The body **cannot excrete iron easily**, so **iron balance** is controlled mainly by **absorption** in the small intestine (duodenum).
- **Main controlling factors:**
    1. **Dietary intake** (iron from food)
    2. **Body demand** (e.g., in anemia or pregnancy)
    3. **Hormone hepcidin** – made by the liver; it decreases iron absorption when levels are high.

🧩 **Normal blood iron levels:**

- **Serum iron:** 50–150 µg/dL
- **Hemoglobin:** ~13–17 g/dL (men), 12–15 g/dL (women)

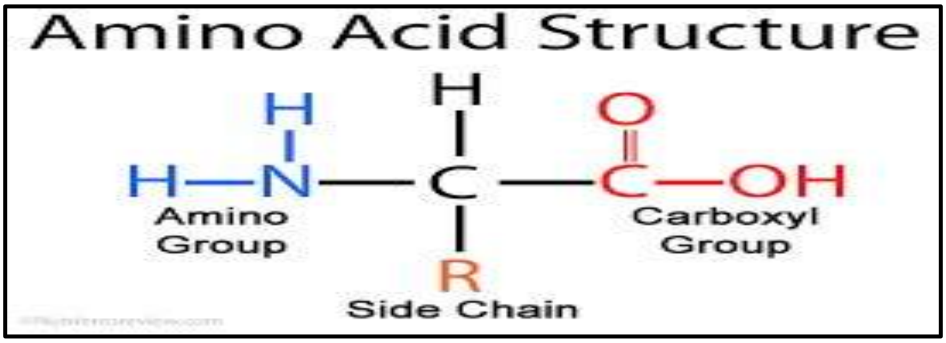
4. Functions of Iron

Function	Explanation
1. Oxygen Transport	Iron is part of **hemoglobin**, which carries oxygen from lungs to tissues.
2. Oxygen Storage	In **myoglobin** (muscles), stores oxygen for muscle activity.
3. Enzyme Function	Component of many enzymes (cytochromes) for **energy production** (cell respiration).
4. Immune Function	Helps immune cells fight infection.
5. Brain Function	Important for normal brain development and neurotransmitter production.

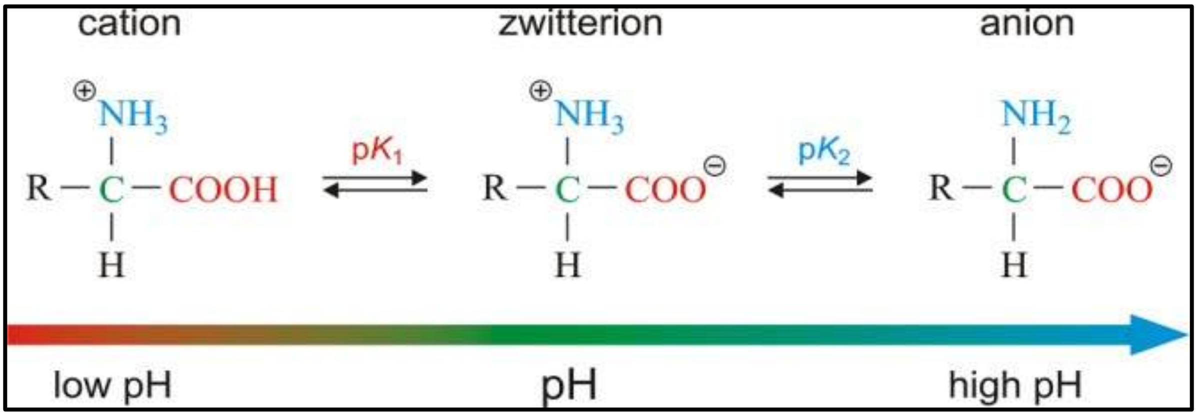
Amino Acids and Proteins

Amino Acids

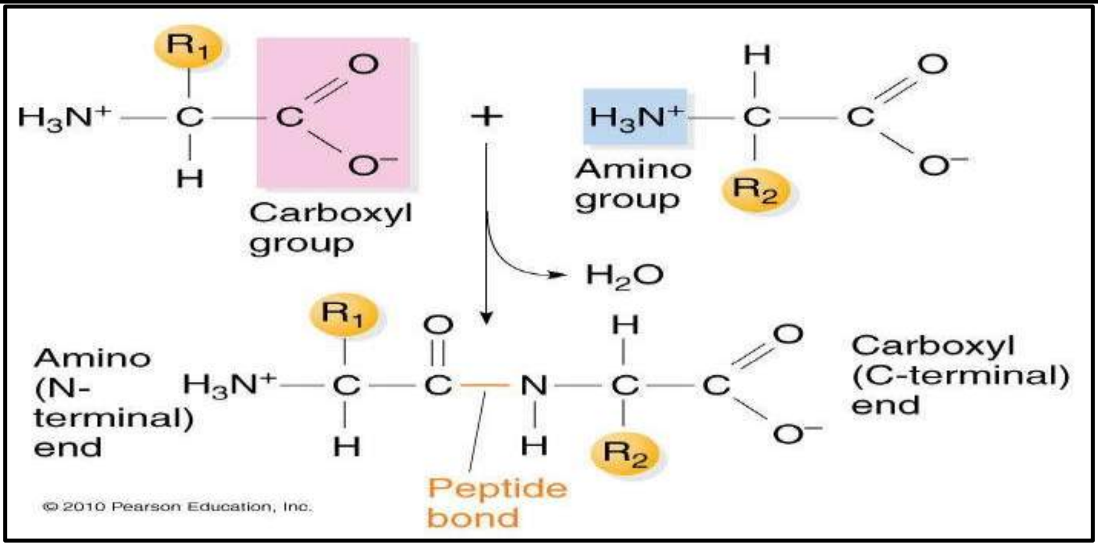
- All proteins are polymers of amino acids.
- Proteins are composed of a number of amino acids linked by peptide bonds.
- Although about 300 amino acids occur in nature, only 20 of them are seen in human body.
- Amino acids have tow active groups (amino group) & (carboxyl group)



- Amino acids can be classified based on their (i) Structure (ii) Side chain characters (iii) Metabolic fate (iv) Nutritional requirements.
- In solution, amino acids exist as 'Zwitterions'

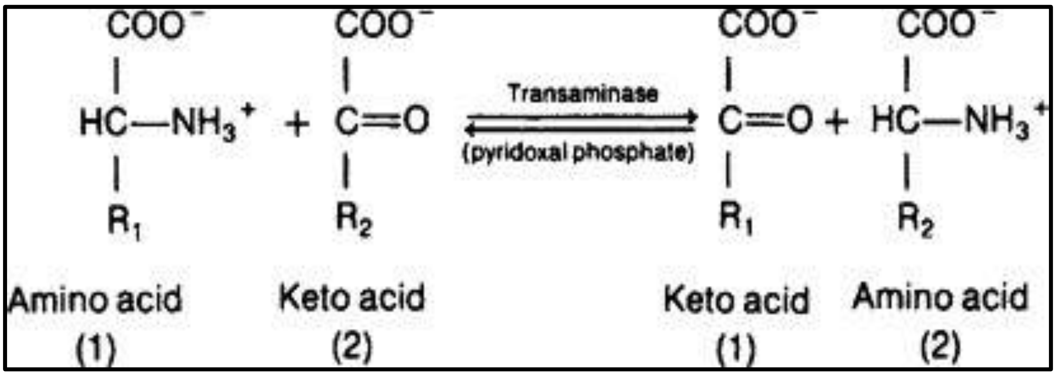


- Alpha carboxyl group of one amino acid reacts with the alpha amino group of another amino acid to form a **peptide bond** or CO-NH bridge.



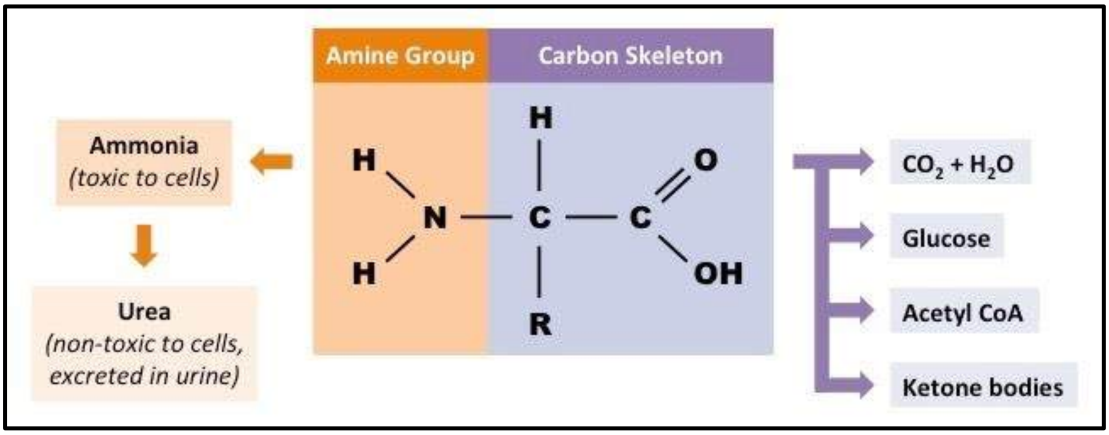
General Metabolism of Amino Acids

1. <u>**Anabolic reactions**</u> where proteins are synthesized. Amino acids are also used to make **specialized compounds** such as **heme, creatine, purines, and pyrimidines**.
2. <u>**Catabolic reactions**</u> where dietary proteins and body proteins are broken down to amino acids. These amino acids can be further degraded to produce **energy** or used for other metabolic needs.
3. **Transamination**: Amino group is removed to produce the carbon skeleton (keto acid). The carbon skeleton is used for synthesis of **nonessential** amino acids.



Formation of ammonia

- ❖ The first step in the catabolism of amino acids is to remove the amino group as **ammonia**. This is the major source ammonia.
- ❖ However, small quantities of ammonia may also be formed from catabolism of purine and pyrimidine bases.
- ❖ Ammonia is **highly toxic** especially to the nervous system. Detoxification of ammonia is by conversion to urea and excretion through urine.



Proteins

- ✸ Proteins contain Carbon, Hydrogen, Oxygen and Nitrogen as the major components while Sulfur and Phosphorus are minor constituents.
- ✸ Proteins are polymers of amino acids linked by peptide bonds.
- ✸ Two amino acids are combined to form a **dipeptide**;
  - three amino acids form a **tripeptide**;
  - four will make a **tetrapeptide**;
  - a few amino acids together will make an **oligopeptide**;
  - and combination of 10 to 50 amino acids is called as a **polypeptide**.
  - polypeptide chains containing $<$ 50 amino acids are called **proteins**.

Physical properties of proteins

a) **Molecular weights** of some of the proteins are: Insulin(5,700); Hemoglobin (68,000); Albumin (69,000); Immunoglobulins (150,000); Virus Protein (47,000,000).

b) **Shapes** of the proteins also vary. Thus, Insulin is globular; Albumin is oval in shape, while Fibrinogen molecule is elongated. Bigger and elongated molecules will increase the viscosity of the solution.

c) **Isoelectric pH** of amino acids has been described since proteins are made of amino acids, the isoelectric PH of all the constituent amino acids will influence the isoelectric PH of the protein.

d) **Solubility** of a protein is dependent on 1- Ionic concentration. 2- PH. 3- Temperature. 4- Charge of the solvent.

e) **Denaturation**:-a change in composition of protein so that physical, chemical &biological properties to be changed. **Proteins classified into:-**

1. **Simple protein**; composed only of amino acids such as Albumin, Globulin.
2. **Conjugated protein**; made up of amino acids and a nonprotein part which is known as the prosthetic group such as phosphoprotein, glycoprotein.
3. **Derived protein**; These are proteins derived from native (natural) proteins by physical or chemical changes.

Examples:

- **Metaproteins** – formed when proteins are treated with acids, alkalis, or heat, causing partial denaturation.
- **Coagulated proteins** – formed when soluble proteins become **insoluble** due to heat or other factors (e.g., **boiled egg white**).

Functions of proteins

1. Maintain the structural integrity of bones, tendons, hair and teeth- collagen, elastin, keratin.
2. Acts as enzymes (catalytic function).
3. Hormones (regulatory function).
4. Antibodies- immunoglobulins (defense protein).
5. Coagulation factors.

6. Carrier proteins (e.g. albumin, thyroglobulin)
7. Contractile element in the muscle (actin, myosin)
8. Proteins act as intracellular buffer in maintaining the acid-base balance.

Urea cycle

The **urea cycle** is a metabolic pathway that converts **toxic ammonia (NH_3)** into **urea**, a **non-toxic compound** excreted in urine. It occurs mainly in the **liver**.

Location:

- The cycle consists of **five main reactions**:
  - **Two reactions** occur in the **mitochondria**.
  - **Three reactions** occur in the **cytosol**.

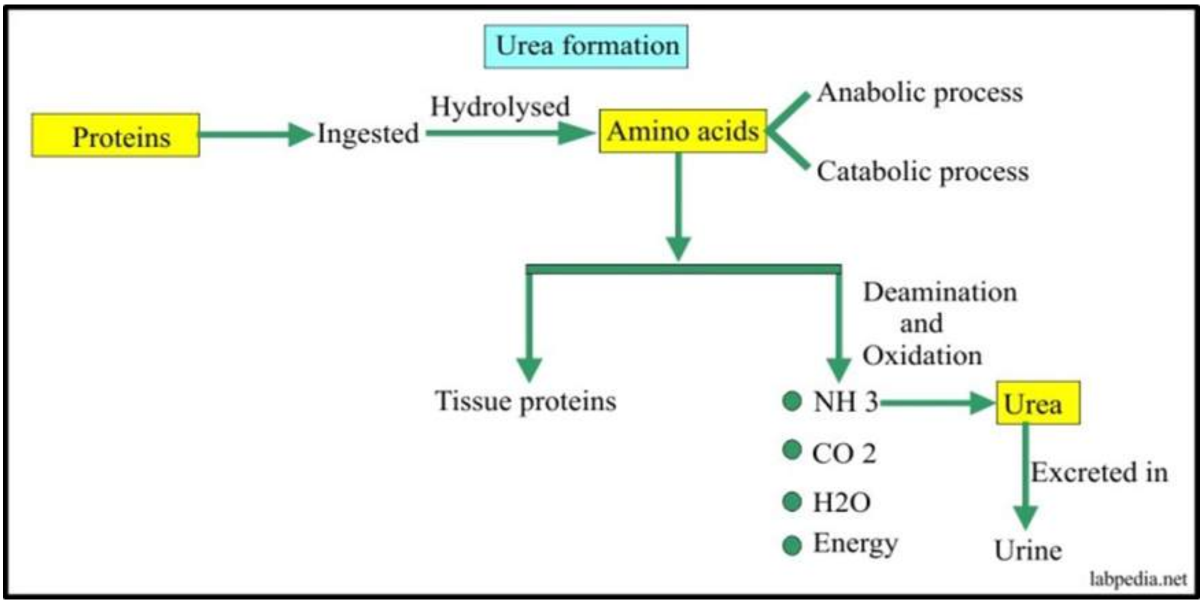
Overall Reaction:

$$2NH_3 + CO_2 + 3ATP \rightarrow \text{urea} + 2ADP + AMP + 4Pi$$

- **Two amino groups** (from ammonia and aspartate) and **one carbon atom** (from CO_2) form **urea**.
- The process **requires four high-energy phosphate bonds** (from 3 ATP molecules).

Regulation of the Urea Cycle:

1. **High Protein Diet:**
   - Increased protein intake → more amino acids broken down → **more ammonia → higher urea production**.
2. **Prolonged Starvation:**
   - **Muscle protein breakdown** provides amino acids for energy → increased **urea formation**.
3. **Enzyme Regulation:**
   - The **rate of synthesis of the four urea cycle enzymes** increases when amino acid breakdown is high.
   - The key enzyme, **carbamoyl phosphate synthetase I**, is **activated by N-acetylglutamate**.



Lecture 6

Enzymes

- Enzymes are proteins that act as catalysts for biological reactions.
- Enzymes, like all catalysts, speed up reactions without being used up themselves. They do this by lowering the activation energy of a reaction.
- All biochemical reactions are catalyzed by enzymes.
- Enzymes are names derived by adding (ase)to the name of the substrate or to a combination of substrate name and type of reaction (Enzyme Commission EC system)

Characteristics of Enzymes

i. Almost all enzymes are proteins. Enzymes follow the physical and chemical reactions of proteins.

ii. Enzymes are considered as a catalyst

Without enzymes most cellular reactions too slowly and some enzyme can increase reaction rates by 10^{20} times

iii. All enzymes are globular proteins. **iv.** They have optimum pH and temperature.

v. Activated by some substances such as Cl^{-1}, Mg^{+2}, Ca^{+2} (coenzyme)

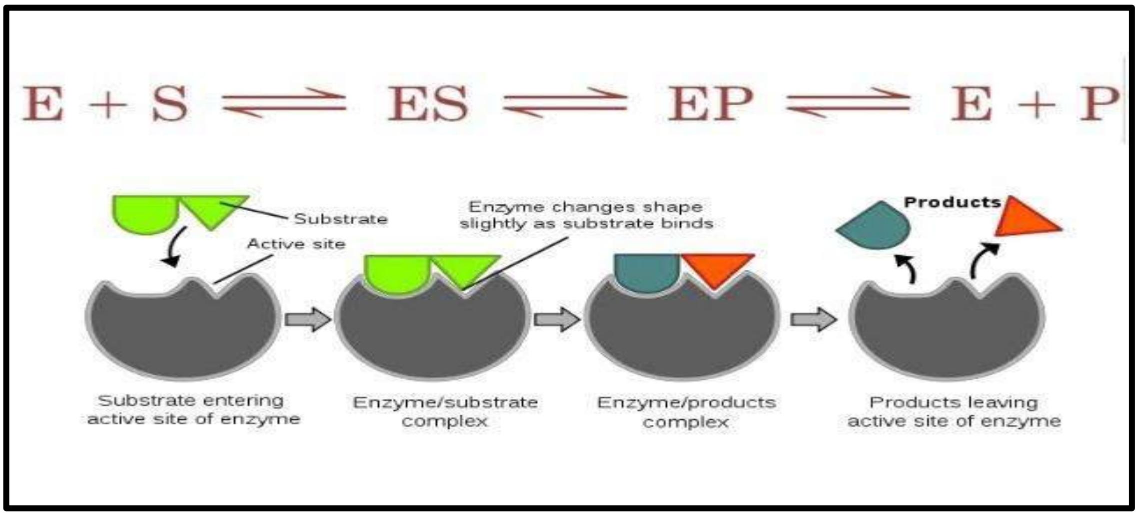
vi. Inhibited by some substances (inhibiting agents).such as salt of mercury, silver and gold.

Classification of enzymes

1. Class 1: Oxidoreductases: Transfer of hydrogen or addition of oxygen; Ex. lactate dehydrogenase and dioxygenases.
2. Class 2: Transferases: Transfer of groups other than hydrogen. Ex. aminotransferase and hexokinase.
3. Class 3: Hydrolases: Cleave bond and add water; Ex. acetylcholine esterase; Trypsin.
4. Class 4: Lyases: Cleave without adding water, Ex. Aldolase; CoA lyase; Citrate lyase.
5. Class 5: Isomerases: Intramolecular transfers. Ex. Triose phosphate isomerase.
6. Class 6: Ligases: ATP dependent condensation of two molecules, Ex. acetyl CoA carboxylase; Glutamine synthetase.

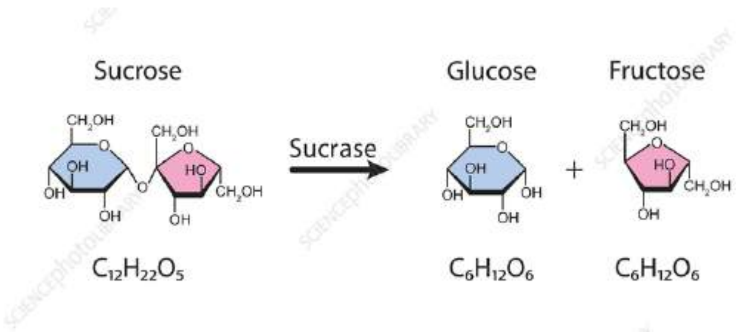
The Mechanism of Enzyme Action

- Enzymes differ widely in structure and specificity, but a general theory that accounts for their catalytic behavior is widely accepted.
- The enzyme and its substrates interact only over a small region of the surface of the enzyme, called the **active site**.
- When the substrate binds to the active site via some combination of intermolecular forces, an enzyme-substrate (ES) complex is formed.
- Once the complex forms, the conversion of the substrate (S) to product (P) takes place
- The chemical transformation of the substrate occurs at the active site, aided by functional groups on the enzyme that participate in the making and breaking of chemical bonds.
- After the conversion is complete, the product is released from the active site, leaving the enzyme free to react with another substrate molecule.



Example

sucrase + sucrose	⟷	**sucrase- sucrose complex**	⟷	**sucrase + glucose + fructose**
enzyme substrate				**enzyme products**



<u>Specificity of enzymes</u>

Enzymes are very specific they only act on one substrate or one class of related substrate molecules. The reason for this is that the active site of the enzyme is complementary to the shape and polarity of the substrate. The specificity is an important of enzyme action. The specificity may be of various types:-

1. Absolute Specificity

Some enzymes are absolutely specific (the enzyme will catalyze only one reaction.).

- Urea is the only substrate for **urease**.
- Maltose the substrate of **maltase**.

2. Relative Specificity

An enzyme with relative specificity (catalyzes the reaction of structurally related substances).

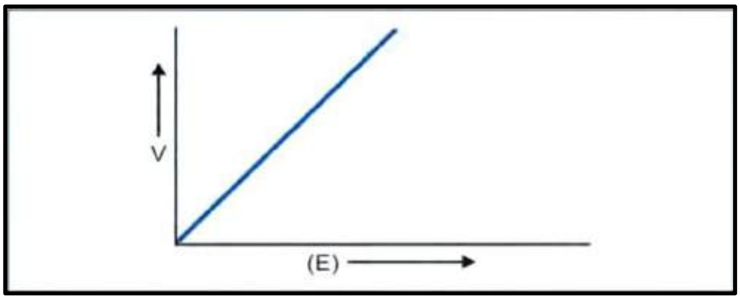
- **Esterase** hydrolyze lipid
- **Protease** split up protein.
- **Phosphatase** hydrolyzes phosphate ester.

Enzyme activity and factors affecting enzyme activity

- **Enzyme activity** refers to the catalytic ability of an enzyme to increase the rate of a reaction.
- The various factors which affect enzyme activity are :-

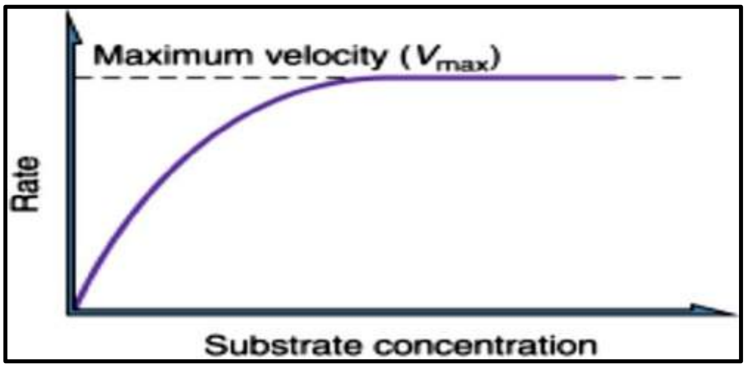
1. Enzyme concentration

Rate of a reaction or velocity (V) is directly proportional to the enzyme concentration [E]



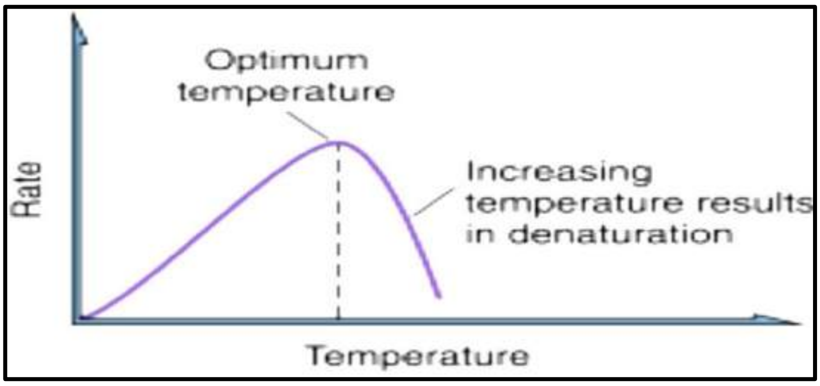
2. Substrate concentration

- Increasing **[S]** increases the rate of the reaction, but eventually, the rate reaches a maximum (V_{max}) and remains constant after that.
- The maximum rate is reach when the enzyme is saturated with substrate, and cannot react any faster under those conditions.



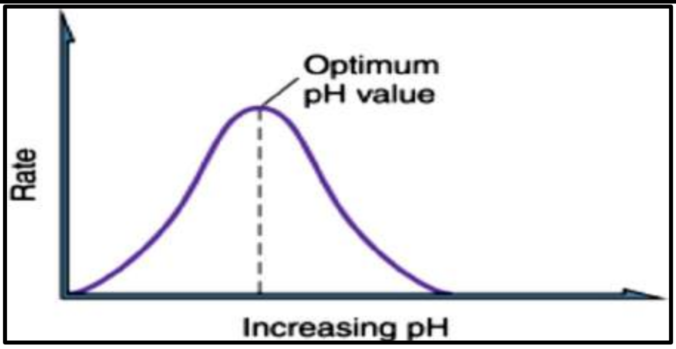
3. Effect of temperature

- The rate of enzyme reactions increases with temperature.
- Because enzymes are proteins, in highly temperature, the enzyme denatures.
- Every enzyme has an **optimum temperature** at which the enzyme activity is highest, usually from (25- 40C^0) above or below that value, the rate is lower.



4. Effect of pH

- Raising or lowering the pH influences the acidic and basic side chains in enzymes. Many enzymes are also denatured by pH increases.
- Many enzymes have an **optimum pH**, where activity is highest, near a pH of 7, but some operate better at low pH (e.g., pepsin in the stomach).



Lecture 7: Carbohydrate

- Carbohydrates (also called sugars) are polyhydroxy aldehydes or ketones or compounds which yield these on hydrolysis

- The general molecular formula of carbohydrate is $\mathbf{C_n (H_2O)_n}$. For example, glucose has the molecular formula $\mathbf{C_6H_{12}O_6}$.

- A **reducing sugar** is any sugar that is capable of acting as a reducing agent because it has a free aldehyde group or a free ketone group.
- All monosaccharides are reducing sugars.

Classification of carbohydrates

Carbohydrates are classified based on the number of sugar into:-

1. **Monosaccharides**:- include Glucose, Fructose, Galactose, and Mannose.
2. **Disaccharides**:- products of the condensation of two monosaccharide with elimination of H_2O ,general formula $Cn(H_2O)n$-1.
   Such as; Sucrose (glucose +fructose) can sugar
   Lactose (glucose +galactose) milk sugar,
   Maltose (glucose +glucose) malt sugar
3. **Oligosaccharides** consist of monosaccharide units (2-12 unit), joined together by a glycosidic bond. Such as raffinose, stachyose.

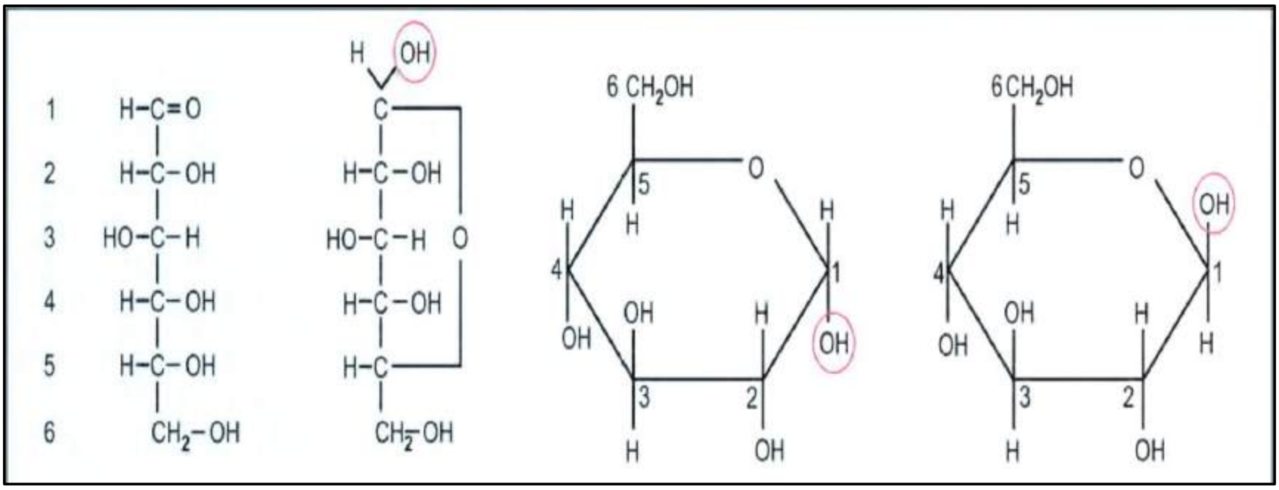
4. **Polysaccharides** having more than ten monosaccharide units such as starch, glycogen, cellulose.

Functions of Carbohydrates

1. Carbohydrates are the main sources of **energy** in the body. Brain cells and RBCs are almost wholly dependent on carbohydrates as the energy source. Energy production from carbohydrates will be (4) kcal/g.
2. Storage form of energy (starch and glycogen).
3. Excess carbohydrate is converted to fat.
4. Glycoproteins and glycolipids are components of cell membranes and receptors.
5. Structural basis of many organisms: Cellulose of plants; exoskeleton of insects, cell wall of microorganisms, mucopolysaccharides as ground substance in higher organisms.

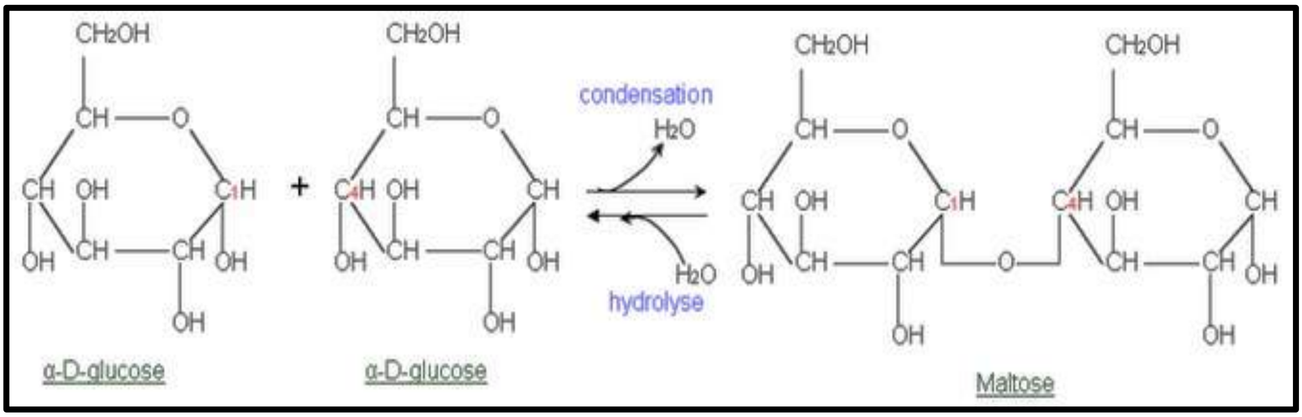
Glucose Structure

- Glucose the most predominant sugar in human body.
- It is the major source of energy. It is present in blood.
- Glucose has the open chain formula and ring structure.
- Glucose exists in biological systems as a ring structure.
- Ring structure produce when the 1st carbon of aldehyde group is condensed with the hydroxyl group of the 5th carbon to form a ring by the condensation reaction.



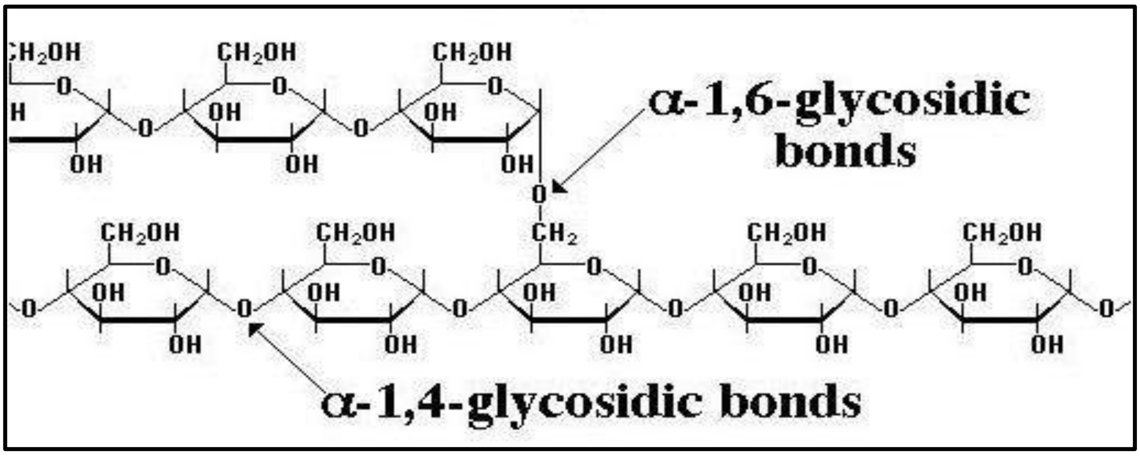
Glycosidic bond

Is formed from the reaction of the carbon of one cyclic monosaccharide with the OH group of a second monosaccharide, so the two monosaccharide units are joined by a carbon–oxygen-carbon linkage



❖ **There are two types of Glycosidic bond**

1. α 1-4 glycosidic bond
2. α 1-6 glycosidic bond



02

Digestion of carbohydrate

- The principle sites of carbohydrate digestion are the mouth and small intestine.
- The dietary carbohydrate consist of :

Polysaccharides: Starch, glycogen and cellulose
Disaccharides: Sucrose and Lactose
Monosaccharides: Mainly glucose and fructose

- Monosaccharides need no digestion prior to absorption, whereas disaccharides and polysaccharides must be hydrolyzed to simple sugars before their absorption.
- Carbohydrates are digested through:-

1. **Salivary amylase** partially digests starch and glycogen. It acts on cooked starch.
2. **Pancreatic amylase** completely digests starch, glycogen, and dextrin. It acts on cooked and uncooked starch.
3. **Maltase, lactase and sucrase** are enzymes secreted from intestinal mucosa, which hydrolyses the corresponding disaccharides to produce glucose, fructose, and galactose.
4. **HCl** secreted from the stomach can hydrolyze the disaccharides and polysaccharides.

Fate of absorbed sugars

The absorbed monosaccharides are either hexoses or pentose.

- ➔ The absorbed **pentoses** are excreted in urine because the body does not deal with them.
- ➔ The absorbed **hexoses** are glucose, fructose, or galactose. Fructose and galactose are converted into glucose in the liver.

Glucose source in the body

Glucose in the body comes from 3 main sources:

- Absorbed glucose from diet.
- Glcogenolysis of liver glycogen.
- Synthesis of glucose from other substances by gluconeogenesis

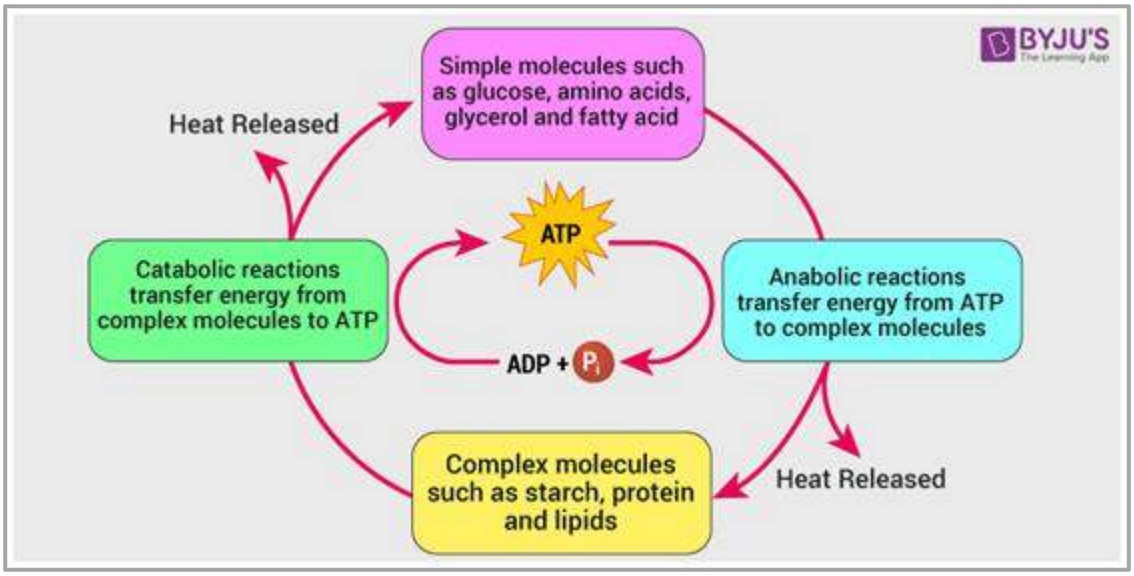
The pathways of the absorbed glucose:

1- **Oxidation: (**For energy: glycolysis, and Kreb's cycle).
2- **Synthesis of other CHO substances** (amino-sugar (glucosamine) for mucopolysaccharides formation.
3- **Synthesis of non-essential amino acids.**
4- **Excess glucose is stored as glycogen in liver and muscles (glycogenesis).**
5- **More excess glucose is stored as lipid in adipose tissue (lipogenesis).**

Lecture 8

Metabolism of carbohydrate

- ✓ Is the sum of all the reactions that take place in a living cell.
- ✓ **Metabolic pathway** Divided into two categories **Catabolism** and **Anabolism**
- ✓ **Catabolism** - break down of large molecules to obtain energy
- ✓ **Anabolism** - the synthesis of all larger molecules needed by cells this process usually requires energy.
- ✓ These reactions take place in a specialized organelle called the **mitochondria**
- ✓ One of the common links between catabolism and anabolism is ATP.
- ✓ ATP is used to shuttle chemical energy from catabolism to anabolism.

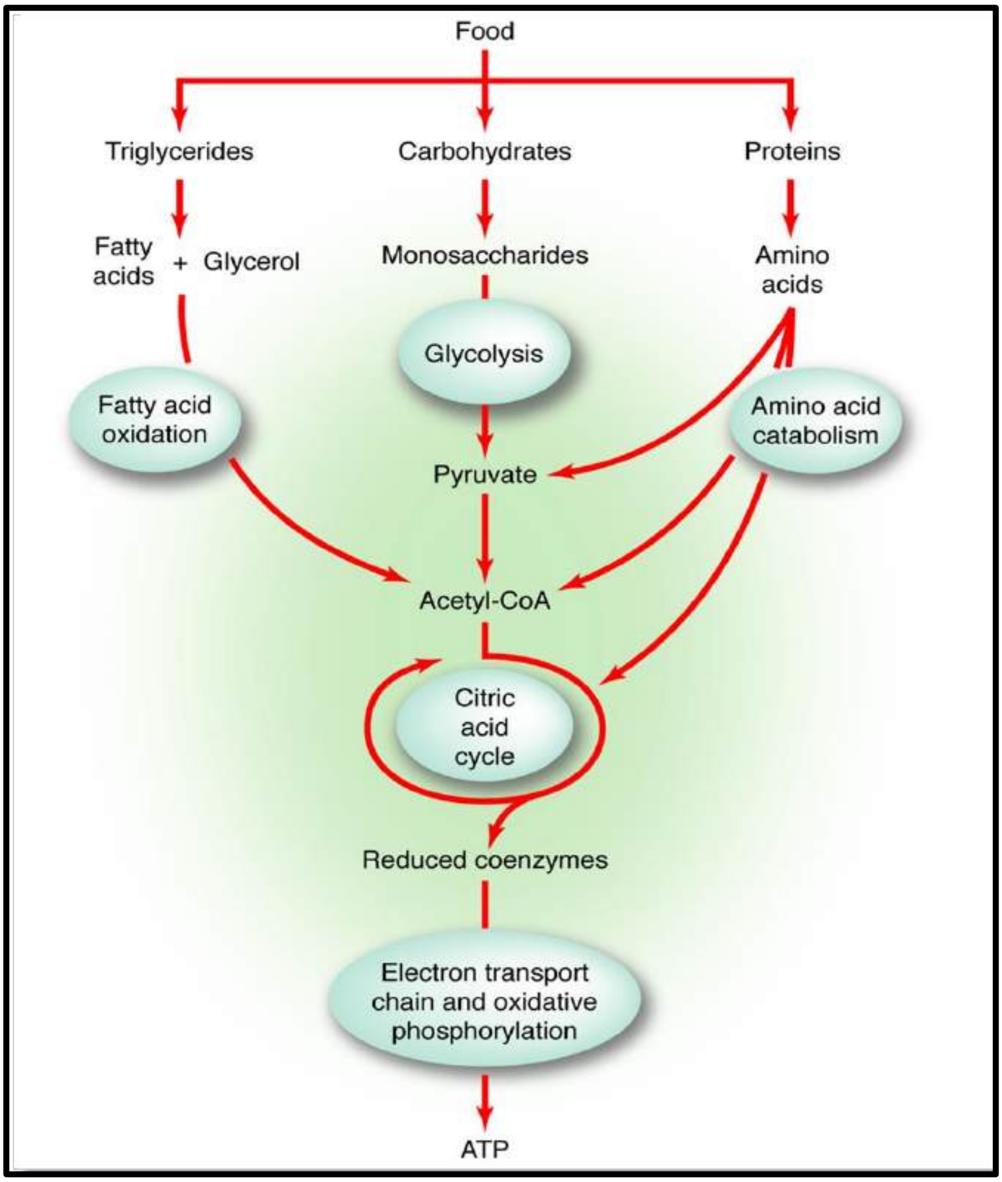


- ✓ Metabolic pathways are regulated at three levels:
  1. Regulation through the action of enzymes.
  2. Hormonal regulation.
  3. Regulation at the DNA level; the concentration of the enzyme is changed by regulation at the level of synthesis of the enzyme.
- ✓ Digestion is the first stage of metabolism when large molecule is broken done in small molecules that can be absorbed in the small intestine.
- ✓ Most of metabolic pathways reactions are hydrolysis reactions (Proteins are hydrolyzed in to amino acids, Polysaccharides into monosaccharides and Triglycerides are hydrolyzed into fatty acids and glycerol).

Energetic of metabolic pathways

- **Energy Metabolism** is energy composition of metabolism and deals with the overall energy production as requirement of the organisms.
- The basic unit for supply of energy for processes within the body is **adenosine triphosphate (ATP)**, a molecule that has high energy bonds with its attached phosphate groups.
- The breakdown of adenosine *triphosphate* to **adenosine *diphosphate* (ADP)** releases energy.
- ATP and ADP are intracellular molecules that provide energy but cannot be transferred around the body from one organ to another.
- A 70-kg adult human being requires about 1920-2900 kcal from metabolic energy per day, depending on physical activity.

- This energy requirement is met from
  a. Carbohydrates (40%-60%)
  b. Lipids (mainly triacylglycerol, 30%-40%)
  c. Protein (10%-15%), as well as alcohol.
- There is a constant requirement for metabolic energy throughout the day
- Most people consume their daily intake of metabolic energy in two or three meals, so there is a need to form reserves
- Reserves of
  a. Carbohydrate: glycogen in liver and muscle
  b. Lipid: triacylglycerol in adipose tissue
  c. protein
- **IF** the intake of metabolic energy is greater than energy expenditure. Surplus is stored, largely as triacylglycerol in adipose tissue leading to the development of obesity
- **IF** the intake of metabolic energy is lower than energy expenditure. Reserves of fat and carbohydrate, and amino acids are used for energy metabolism.
- All the products of digestion are metabolized to **acetyl CoA** oxidized by the citric acid cycle.



Metabolism of Carbohydrate

1. Glycolysis

- Is converted glucose to pyruvate (aerobic condition) or lactate (anaerobic condition), along with production of a small quantity of energy.
- Site of reactions: All the reaction steps take place in the cytoplasm.
- Glucose a major fuel of most tissues so the pathway starts with glucose.
- The pathway then goes on to split the glucose molecule (6-carbon) into two molecules (3-carbon) Pyruvic acid.

- The energy released in the pathway is used to produce two types of energy rich molecules: 2 ATP & 2 NADH.

Glucose + 2 NAD+ + 2 ADP + 2 Pi ⟶ 2 pyruvate + 2 NADH + 2 ATP

- After glycolysis pyruvate Conversion (by reducing) into acetyl CoA to enter the Citric acid

In TCA cycle (Kreb's cycle)

- The citric acid cycle is a cyclical set of eight reactions that accomplish the final steps of the breakdown of glucose to carbon dioxide and water.
- Its actual starting point is acetyl co A.
- Occurs in mitochondria
- Called Citric Acid cycle or Tricarboxylic Acid cycle (TCA) or Krebs Cycle

Gluconeogenesis (The Synthesis of Glucose)

- **Definition**: formation of glucose from non–carbohydrate precursors like pyruvate and related three and four carbon compounds.
- Important precursors of glucose in animals are three carbon compounds such as lactate, pyruvate and glycerol, as well as certain amino acids.
- Mainly in starvation conditions Process occurs in liver.
- Gluconeogenesis is not a reversal of glycolysis

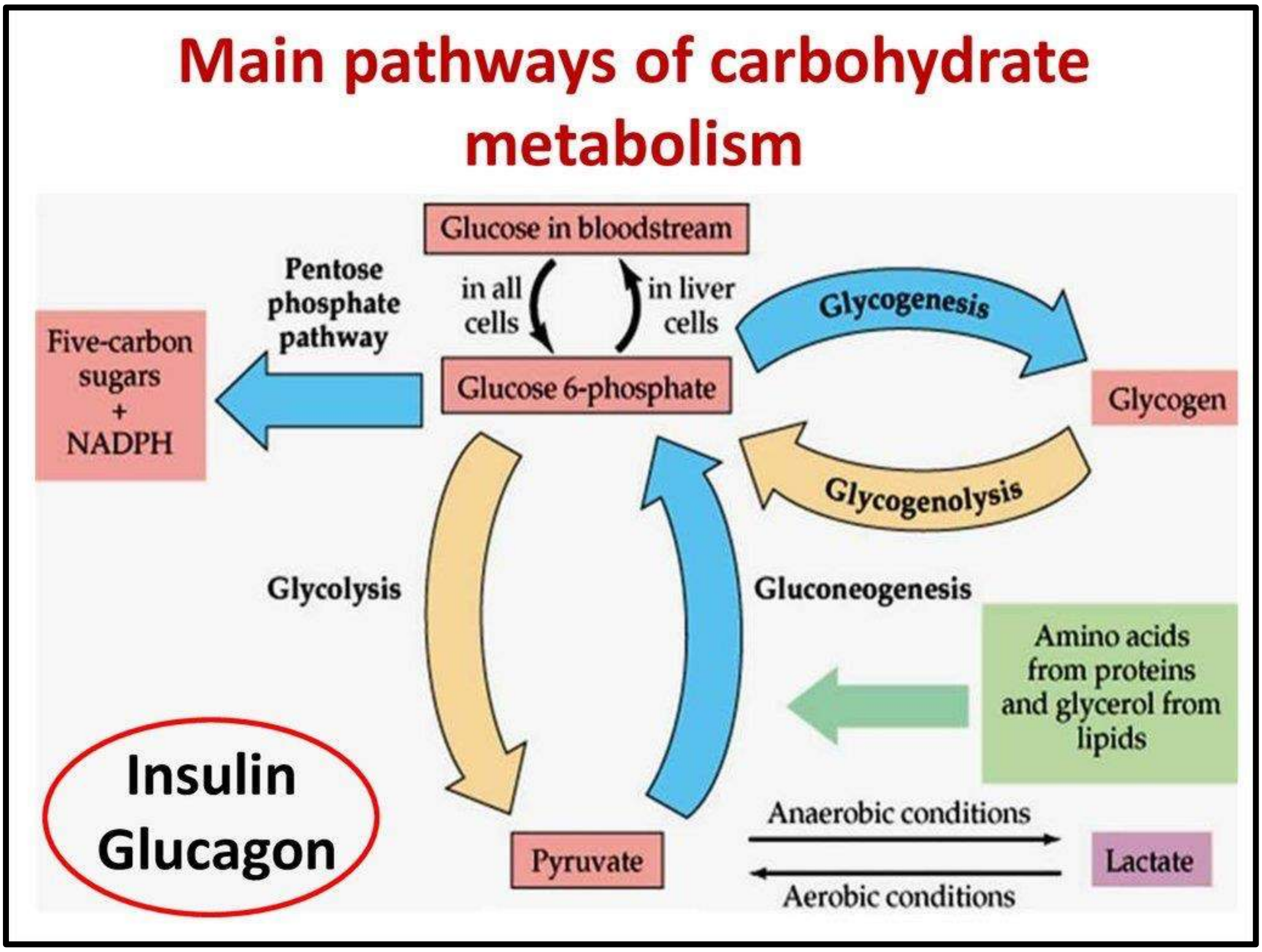
Glycogenolysis

- When glucose is not needed to meet energy needs, it can be stored as the polysaccharide **glycogen** and used for future energy needs.
- The liver and the muscles are where glycogen is synthesized and stored.
    - The muscles store it for future muscular activity.
    - The liver stores it to help regulate blood glucose levels.
- When energy stores (glycogen) are full, this means that Additional glucose is converted to body fat.

➔ Glycogen is broken down to Glucose.
➔ glucose Molecules are Removed one by One from the end Of the glycogen Chain to yield Glucose-1- Phosphate
➔ Is activated by Glucagon hormone (when low Blood glucose).

Glycogenesis

❖ It is biosynthesis of glycogen from glucose, occurs especially in skeletal muscle and liver
❖ muscle glycogen is reserve for muscle Contraction



Lecture 8

Lipids

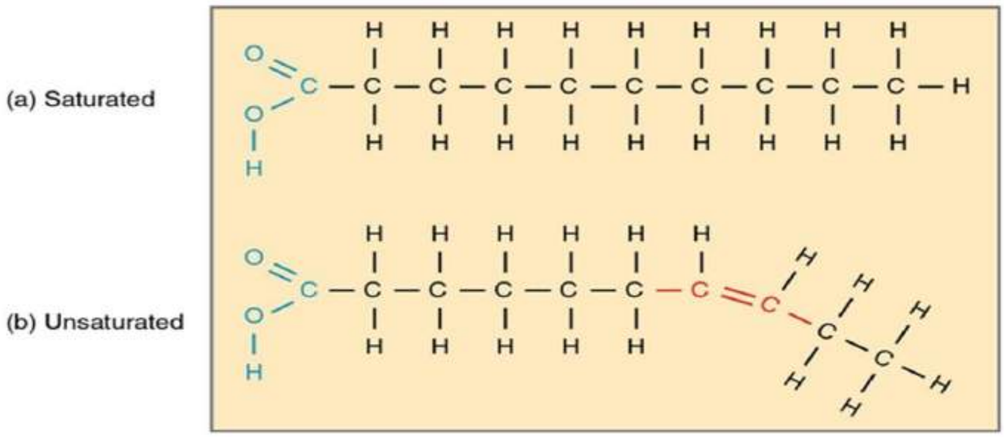
- **Lipids** are organic compounds that are fatty acids or derivatives of fatty acids which are nonpolar molecules so, they insoluble in water but soluble in nonpolar organic solvents.
- Lipids are easily stored in the body. They serve as a source of fuel and are an important constituent of the structure of cells.
- In the human body, these molecules can be synthesized in the liver.
- Lipids are the ester of fatty acids that contain **a long, non-polar hydrocarbon chain** with a small polar region containing oxygen.

Function of lipids

1. Storage form of energy (triacylglycerol)
2. Structural components of bio-membranes (phospholipids and cholesterol)
3. Metabolic regulators (steroid hormones)
4. Act as surfactants, detergents and emulsifying agents
5. Act as electric insulators in neurons
6. Provide insulation against changes in external temperature.
7. Give shape and contour to the body
8. Help in absorption of fat soluble vitamins (A, D, E and K).

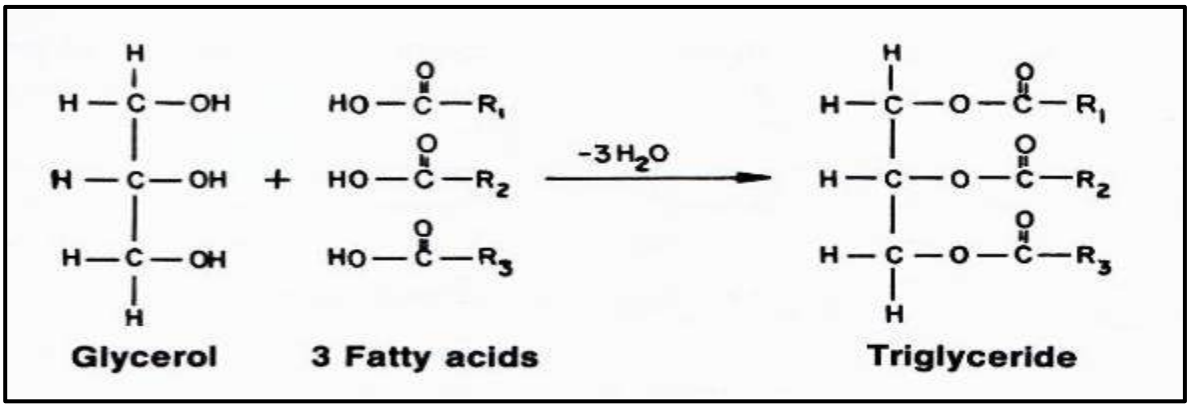
Fatty Acids

- Fatty acids are carboxylic acid often with long chain (The length of the chain is usually between 14 and 22 carbons long).
- There are two types of fatty acid:
    1. **Saturated fatty acids (**there are no carbon-carbon double bonds).
    2. **Unsaturated fatty acids(**has more than one double bond)

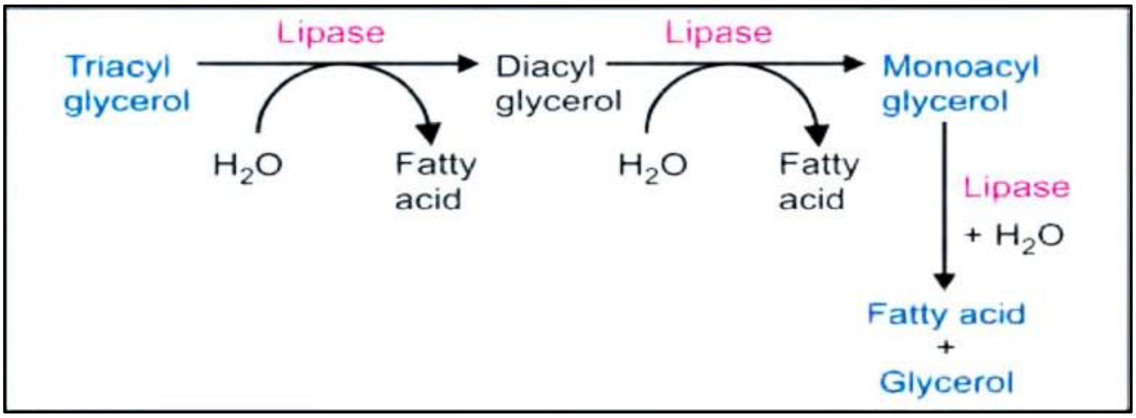


Triglycerides (TG) formation& hydrolysis

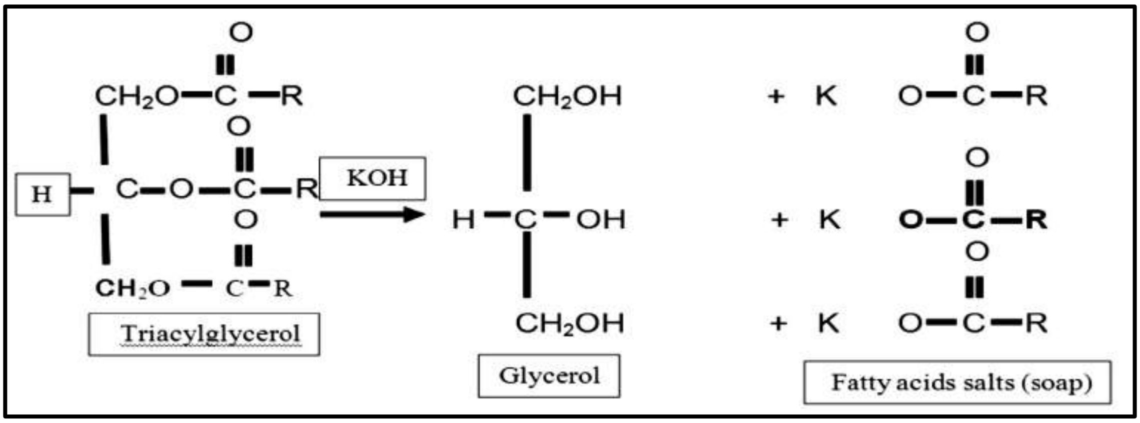
- Triglycerides (TG) also called Neutral fats or triacylglycerol (TAG)
- Function of TG is energy storage
- These are made up of 3 fatty acid chains attached to a glycerol molecule.
- Three of these chains become attached to a glycerol molecule which has 3 OH groups attached to its 3 carbons.
- This is a condensation reaction because 3 water molecules are formed from 3 OH groups from the fatty acids chains and 3 H atoms from the glycerol.
- The bond between the fatty acid chain and the glycerol is called an ester linkage.



- **Hydrolysis of triglycerols**: Triglycerols like any other esters react with water to form their carboxylic acid and alcohol
- This occurs in the body during digestion of dietary fat and mobilization of TAG from adipose tissue.
- Triacylglycerol in the body are hydrolyzed by enzymes, **lipases** which are hydrolases (class 3 enzymes).
- Mechanism of Triacylglycerol is **sequentially hydrolyzed** to diacylglycerol and monoacylglycerol and finally glycerol plus 3 fatty acids



❖ In the laboratory and commercial production of soap, hydrolysis of fats and oils is usually carried out by strong aqueous bases such as NaOH and KOH and this process called **Saponification**. The products are glycerol and soaps



❖ **Rancidity**: Rancidity refers to the appearance of unpleasant odor and taste to all natural fats exposed to air, light & moisture. Rancidity can be of two types, **Hydrolytic** and **Oxidative**

CLASSIFICATION OF LIPIDS

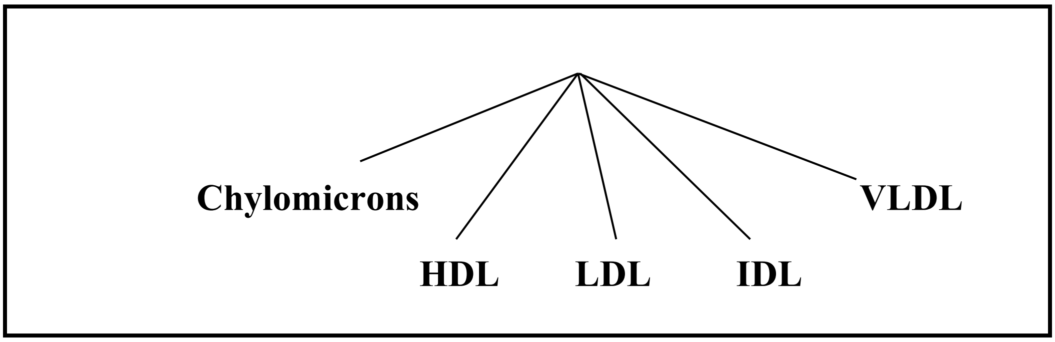
Lipids are classified based on the chemical nature as:

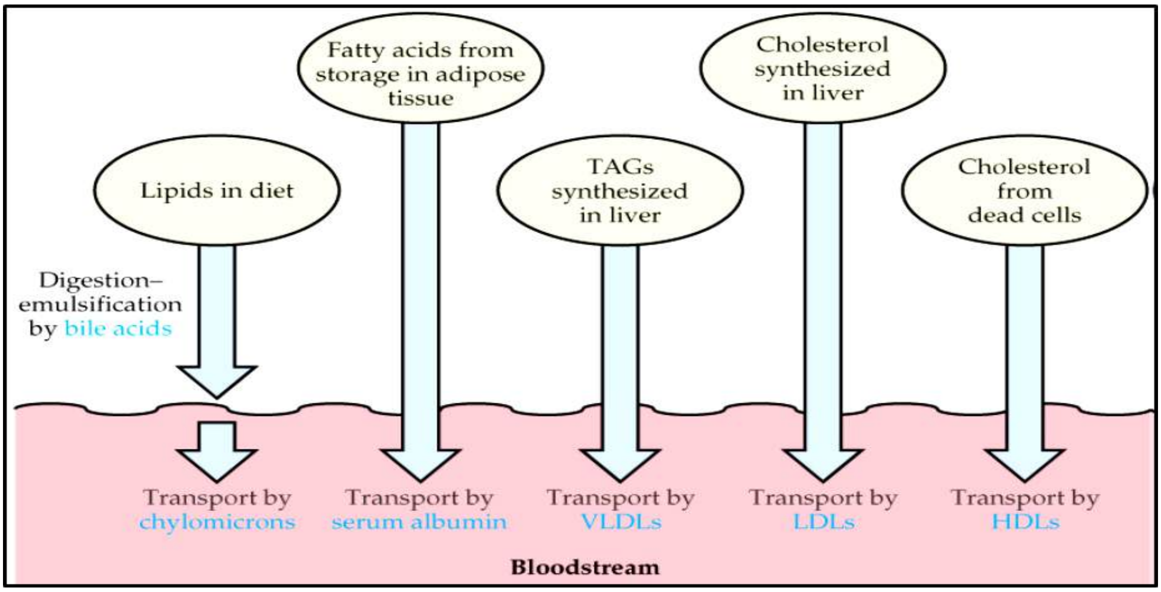
1. **Simple lipids**: They are esters of fatty acids with glycerol or other higher alcohols. Such as:
    a. Oils: A mixture of triglycerols that is liquid because it contains high proportions of unsaturated fatty acids .
    b. Fats: A mixture of triglycerols that is solid because it contains high proportions of saturated fatty acids.
    c. Waxes have a different structure (esters of fatty acids with long chain alcohols) and can be found in both animals and plants.
2. **Compound lipids**: They are fatty acids esterified with alcohol; but in addition they contain other groups. Phospholipids, Glycolipids
3. **Derived lipids**: They are compounds, which are derived from lipids or precursors of lipids such as steroids, some hormone and fat soluble vitamins.

Lipoproteins for Lipid Transport

- Lipids enter metabolism from three different sources:
  1. The diet
  2. Storage in adipose tissue
  3. Synthesis in the liver.
- Whatever their source these lipids must be transported in blood, an aqueous media.
- To become water soluble, fatty acid release from adipose tissue associate with albumin. All other lipids are carried by lipoproteins.
- Lipoprotein classified into five major types
  1. Chylomicrons
  2. Very low density lipoproteins (VLDL) 3. Intermediate density lipoproteins (IDL) .
  4. Low density lipoproteins (LDL)

5. High density lipoproteins (HDL)

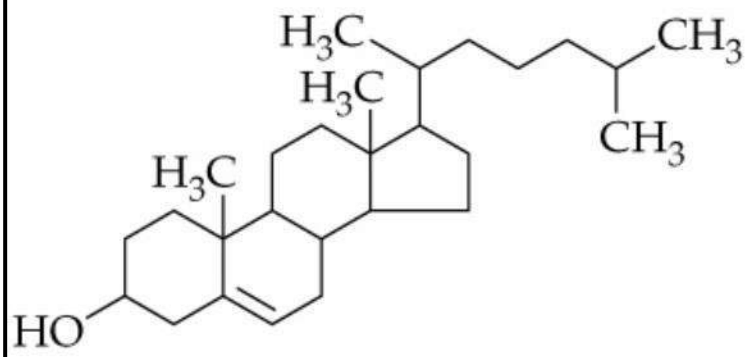




Lipoprotein

Cholesterol

- Cholesterol is a steroid, a member of the class of lipids that all contain the same four ring system.



Cholesterol

- Cholesterol serves two important purposes:
    1. as a component of cell membranes and
    2. as a starting materials for the synthesis of all other steroids.
- In the human body, cholesterol is synthesized in the liver.
- In the cell membrane, the steroid ring structure of cholesterol provides a rigid hydrophobic structure that helps boost the rigidity of the cell membrane. Without cholesterol, the cell membrane would be too fluid.
- Cholesterol must important sterol in human body is needed to make bile, sex hormones, steroids and vitamin D.
- Dietary recommendation - <300 mg/d
- Sources – egg yolks, liver, shellfish, organ foods

Lecture 10

Metabolism of Lipids

- The end product of lipid metabolism just like glucose are

$$\text{Lipid} \longrightarrow CO_2 + H_2O + ATP$$

- Lipids are biomolecules consist of monomers.

Lipid (polymers)

- TG
- Cholesterol ester
- Phospholipid (PL)

↓ Catabolism — enzymatic steps — Hydrolysis (H_2O)

Monomers

- FA + MAG
- Cholesterol
- Glycerol + FA

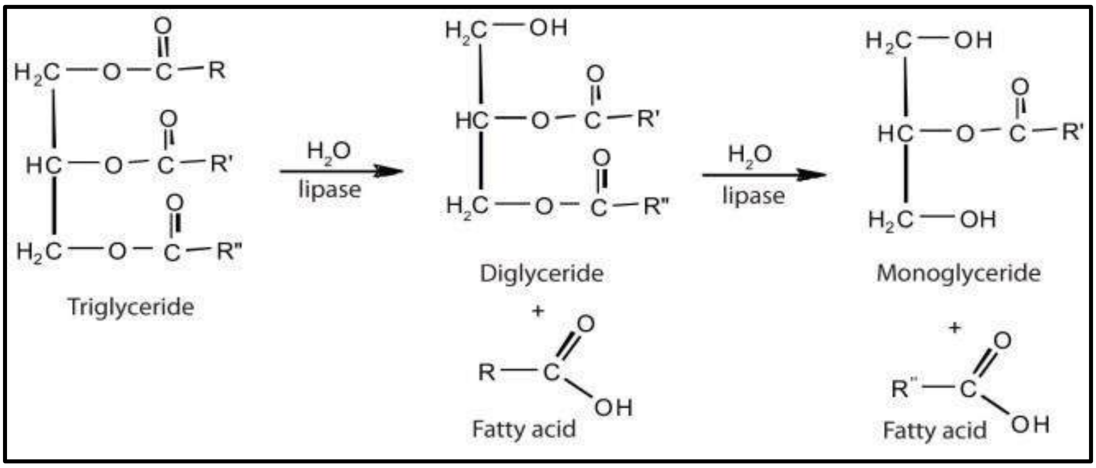
Metabolism of Lipids

- Dietary lipids are triglycerides, phospholipids, steroids, especially cholesterol and cholesterol esters, fat-soluble vitamins.
- **Triglycerides or triacylglycerol** account for about 90% of dietary
- lipid. They have energy (1 gm give 9 kcal) they must release their fatty acid to be used as a source of energy.
- **Cholesterol** and its esters, together with small amounts of steroid hormones, are found **only** in animal products, unlike the **lipids** which are also found in plant products.

- Cholesterol found in blood in tow forms:- **a**- free cholesterol (1/3) **b**-esterified cholesterol. (2/3)
- Non-esterified form the only form of cholesterol that can be absorbed in the small intestine.

Lipid digestion and absorption

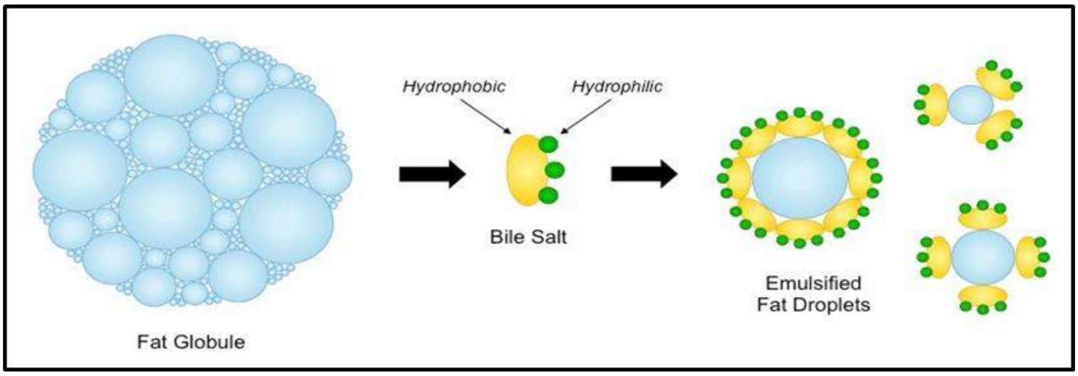
- **Process:**
  Lipid (fat) digestion starts in the mouth, continues in **the** stomach, and is completed in the small intestine by soluble enzymes.
- **Main Enzymes Involved:**
  1. **Lipase:**
     Proteins that catalyze the partial breakdown (hydrolysis) of triglycerides into **free fatty acids (FFAs)** and **monoacylglycerol (MAG)**.
  2. **Cholesterol esterase:**
     Breaks down cholesterol esters into **cholesterol** and **fatty acids**.
  3. **Phospholipases A_1 and A_2:**
     Hydrolyze phospholipids to release **fatty acids** and **lysophospholipids**.
- **End Products (in mouth and stomach):**
  2 free fatty acids + 1 monoacylglycerol (MAG)



- Triglycerides, cholesterol and fat-soluble vitamin esters are extremely hydrophobic, and aggregate into large droplets in the stomach and small intestine. These droplets will then be emulsified in order to allow hydrolases to catalyze lipid digestion.
- Minor digestion of lipids in **stomach** by acid lipase
- acid lipase act on fat containing short chain fatty acid at neutral pH
- ❖ Digestion of lipids in stomach is little.

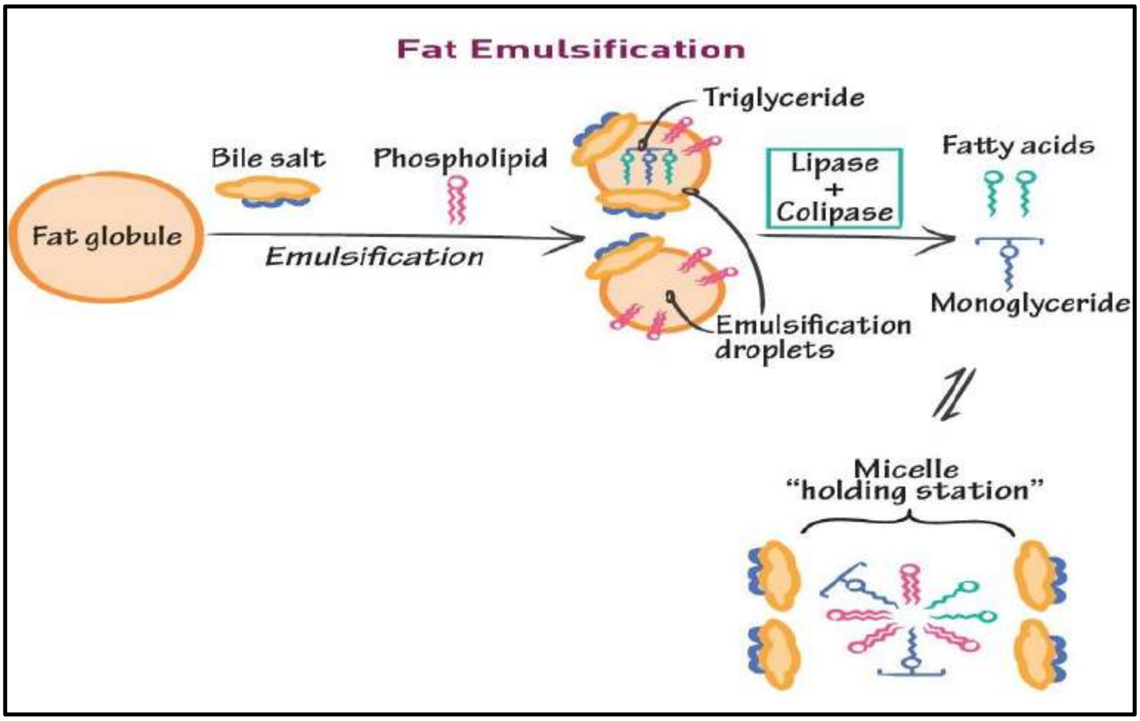
Emulsification of lipids

- is dispersion of lipids into smaller droplets due to reduction in surface tension (increase in surface area of oil droplets)
- Emulsification is essential as lipases act only on surface of lipid droplets.



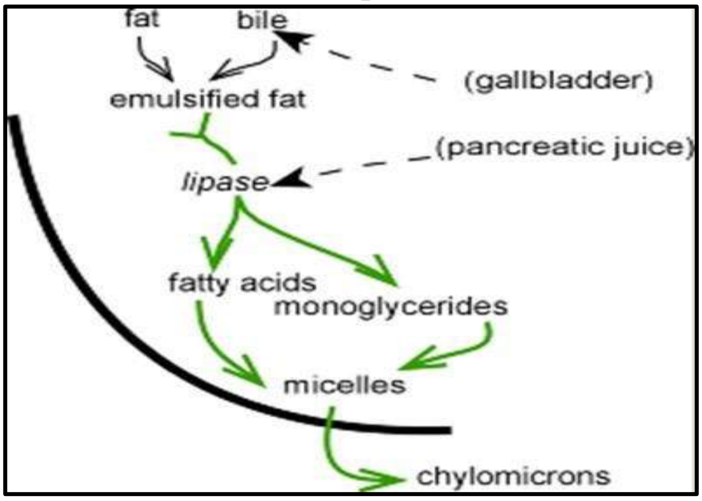
Role of Bile salts in lipid digestion

- **Bile salts** Synthesized from Cholesterol
- Help in emulsification interact with lipid particles & aqueous duodenal content by convert them into smaller particles
- Stabilize smaller particles & prevent them from coalescing



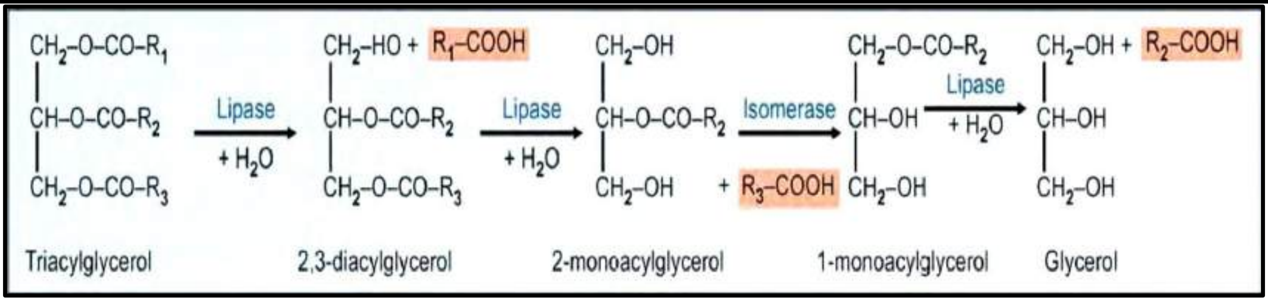
Mechanism of absorption of lipids

- Mixed micelles serve as the major vehicle for transport of lipid from intestinal lumen to membrane of the intestinal mucosal cells,(site of lipid absorption)
- The lipid components pass unstirred fluid layer & are absorbed through plasma membrane by diffusion.
- Absorption is complete for free fatty acids& Monoacyl Glycerol (water soluble)
- Micelle formation essential for absorption of fat soluble vitamins.



Lipid metabolism

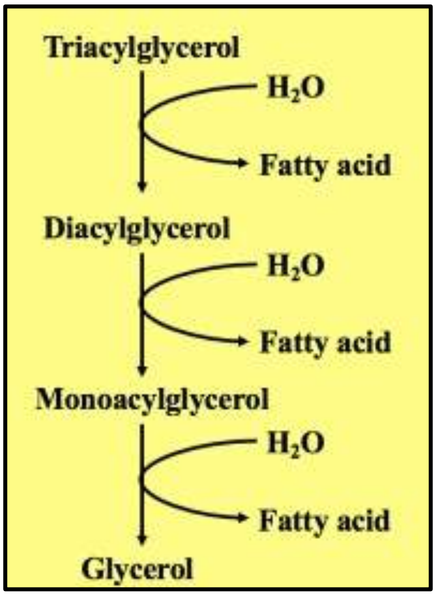
- ➔ Fats (or triglycerides) within the body are ingested as food or synthesized by adipocytes or hepatocytes from carbohydrate precursors.
- ➔ Lipid metabolism requires the oxidation of fatty acids to either generate energy or synthesize new lipids from smaller constituent molecules.
- ➔ Lipid metabolism is associated with carbohydrate metabolism, as products of glucose (such as acetyl CoA) can be converted into lipids.
- ➔ Lipid metabolism begins in the intestine where ingested triglycerides are broken down into free fatty acids and a monoglyceride molecule by pancreatic lipases.



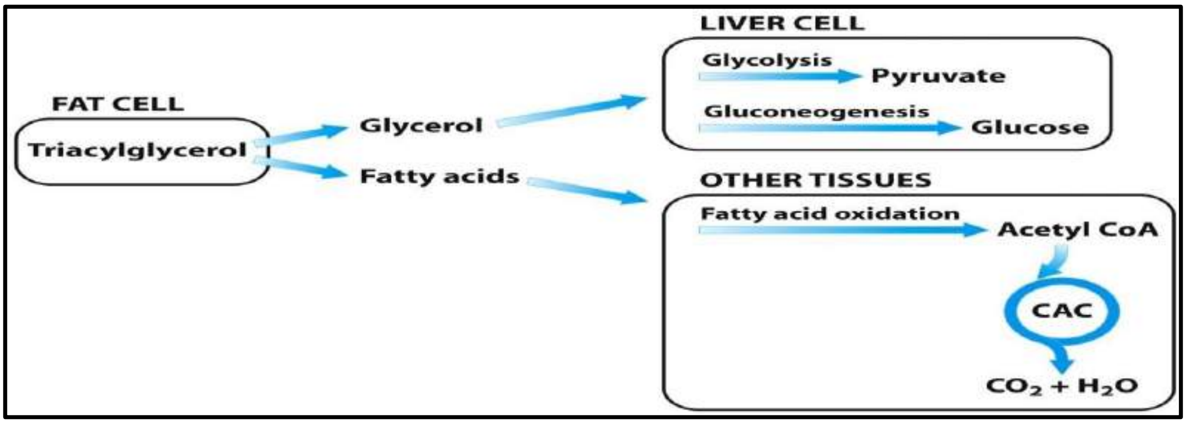
- ➔ When food reaches the small intestine a digestive hormone is released by intestinal cells
- ➔ Digestive hormone stimulates the release of pancreatic lipase from the pancreas and stimulates the contraction of the gallbladder to release stored bile salts into the intestine.
- ➔ Once the bile salts have emulsified the triglycerides, the pancreatic lipases down triglycerides into free fatty acids. These fatty acids can be transported across the intestinal membrane.
- ➔ Within the intestinal cells, these triglycerides are packaged along with cholesterol molecules in phospholipid as a molecule called chylomicrons
- ➔ Once in the circulation, they can either go to the liver or be stored in fat cells (adipocytes).

Lipolysis

- **Lipolysis:-** obtain energy from fat, triglycerides must first be broken down by hydrolysis into their two principal components, fatty acids and glycerol.



- Lipolysis, takes place in the cytoplasm.
- The resulting fatty acids are oxidized by β-oxidation into acetyl CoA, which is used by the Krebs cycle
- The glycerol that is released from triglycerides after lipolysis directly enters the glycolysis pathway.
- Because one triglyceride molecule yields three fatty acid molecules with as much as 16 or more carbons in each one, fat molecules yield more energy than carbohydrates and are an important source of energy for the body.
- The breakdown of fatty acids is called fatty acid oxidation or beta (β)-oxidation. It begins in the cytoplasm, where fatty acids are first activated by combining with Coenzyme A (CoA) to form fatty acyl-CoA molecules. These activated fatty acids (acyl-CoA) are then transported into the mitochondria, where the β-oxidation process takes place to produce energy (ATP).



Hormonal control of lipolysis

The breakdown of triglycerides by lipases is under hormonal control. Hormones involved are:

- **Epinephrine (adrenaline)** and **Glucagon → Stimulate lipolysis**

They activate lipase enzymes, promoting the **breakdown of fat** to release energy during fasting or stress.

- **Insulin → Inhibits lipolysis**

It prevents fat breakdown and **promotes fat storage**, especially after eating when glucose levels are high.

Lipogenesis

- When glucose levels are plentiful, the excess acetyl CoA generated by glycolysis can be converted into fatty acids, triglycerides, cholesterol, steroids, and bile salts.
- This process called lipogenesis creates lipids (fat) from the acetyl CoA and takes place in the cytoplasm of adipocytes (fat cells) and hepatocytes.
- Lipogenesis begins with acetyl CoA and advances by the subsequent addition of two carbon atoms from another acetyl CoA; this process is repeated until fatty acids are the appropriate length.

Lecture 11

Hormones

- **Hormone** a chemical substance messengers produced in the body, directly secreted into the blood or extracellular fluid, which bind specific receptors on/in target cells.
- **Factor effecting on hormones activity**
    1. Age (hormones concentration $\frac{1}{\alpha}$ age)
    2. Gland diseases.
    3. Other hormones or drugs may modulate normal endocrine responses.
- **Endocrine system:** Glands and other hormone-secreting sources.
- **Endocrine glands:** secrete hormones directly into the blood, which transported in the blood to target cells that contain the appropriate receptors.
- Even though the endocrine glands are scattered throughout the body, they are still considered to be one system because they have similar functions, similar mechanisms of influence, and many important interrelationships.
- **The endocrine system composed of**:
    1. Endocrine glands
    2. Hormones
    3. Receptors
    4. Target tissues
- **Hormone receptors** are molecules within or on the surface of target cells that bind hormones with high affinity and specificity.
- According to the location of **the receptors, they could be**:
    1. Cell surface receptors

2. Intracellular receptors (Nuclear receptors &Cytoplasmic receptors)

- **Target cells**: Hormones will only produce the response in cells that express the receptors for this particular hormone these cells are called (target cells) **ONLY** target cells respond to hormone. While the cells that do not have receptors for the hormone "ignore" the hormone.
- **Endocrine-related Problems**
    1. Overproduction of a hormone
    2. Underproduction of a hormone
    3. Nonfunctional receptors that cause target cells to become insensitive to hormones.

Hormones functions

1. Regulate Growth and Morphological change.
2. Maintain internal homeostasis (regulation of internal environment &maintained water relatively narrow limits)
3. Coordinate Development
4. Control of reproductive system processes (ovulation, maintenance of pregnancy)
5. Effects on behavior (initiation of specific patterns and Social interactions).

Chemical Classification of hormones

There are two major classes of hormones:

1. Steroids hormones (are derived from cholesterol)

Example: testosterone, estrogen, progesterone & cortisol.

2. Non-steroid hormones

I. **Amine-derived hormones** are derived from the amino acids
Example:[epinephrine and nor epinephrine, thyroid]

II. **Peptides** are made up of amino acids
Example: [oxytocin]

III. **Proteins** [growth hormone, insulin]

IV. **Glycoprotein** [FSH,TSH]

Mechanisms of regulation hormone

The levels of hormones circulating in the blood are controlled by three homeostatic mechanisms:

1. **When one hormone stimulates the production of a second, the second suppresses the production of the first.**

Example: The follicle stimulating hormone (FSH) stimulates the release of estrogens from the ovarian follicle. A high level of estrogen, in turn, suppresses the further production of FSH.

2. **Antagonistic pairs of hormones.**
   Example: Insulin causes the level of blood sugar (glucose) to drop when it has risen. Glucagon causes it to rise when it has fallen.
3. **Hormone secretion is increased (or decreased) by the same substance whose level is decreased (or increased) by the hormone.**
   Example: a rising level of Ca^{2+} in the blood suppresses the production of the parathyroid hormone (PTH). A low level of Ca^{2+} stimulates it.

The major human endocrine glands and there hormones

A. *Pituitary gland hormones*

-The most important glands in the endocrine system included:-

1. Growth hormone (GH)

- Is a protein
- Helps adults maintain muscle and bone mass
- Affecting on lipolysis, blood glucose, and skeletal growth.

2. Thyroid-stimulation hormone (TSH)

- It is a glycoprotein.
- Is required for synthesis of thyroid hormones in thyroid gland.
- Accelerate the uptake of iodine in the thyroid gland.

3. Adrenocorticotrophic hormone (ACTH)

- It is an oligopeptide.
- Stimulates the production and secretion of steroid hormones by the adrenal cortex.

B. *Thyroid gland hormones*

➔ included thyroxin (T4) &triiodothyronine (T3) and Calcitonin

➔ T4 and T3 hormones responsible

1. for metabolic rate,
2. synthesis of protein,
3. breakdown of fats,
4. use of glucose for ATP production

➔ Calcitonin responsible for

1. building of bone
2. stops reabsorption of bone (lower blood levels of calcium)

C. *Parathyroid gland hormones*

Parathyroid (PTH)

- Is a polypeptide.
- Synthesized by parathyroid gland. Important in calcium metabolism.
- Targets bone cells and kidney cells
- Stimulates conversion of vitamin D to calcitriol.

D. *Pancreatic gland hormones*

❖ The hormones are produced in islets of langerhans. ❖
There are: - [insulin, glucagon, somatostatin]

i. Insulin

- Produced by the β-cell of langerhans isles of the pancreas.
- The role of insulin
  1. Promoting the cellular uptake of glucose (except brain cells)
  2. Slowing glycogen breakdown in the liver
  3. Promoting fat storage
  4. Inhibit the conversion to glucose.

ii. Glucagon

- Secreted by the α-cell.
- Has an opposite action of insulin.
- The role of glucagon

  1. Stimulating the conversion of glycogen to glucose in the liver 2. Stimulating the breakdown of fat and protein into glucose

Lecture 12

Vitamins

- **Vitamins** are organic molecules that function in a wide variety of capacities within the body.
- The most prominent function is as **cofactors** for enzymatic reactions.
- The distinguishing of the vitamins is that they generally cannot be synthesized by cells and must be supplied in the diet.

Types of vitamins

1. Lipid -soluble vitamins

- Include A , D , E , K
- Some kinds can be synthesized inside the body
- Non polar (hydrophobic) compounds that can be absorbed efficiently when there is normal fat absorption.
- They are transported in the blood, like any other non -polar lipid, in lipoproteins or attached to specific binding proteins.
- Stored in liver.
- Stable to normal cooking conditions. ▪ Excreted in feces.

2. Water -soluble vitamins

- Include Vit. B complex, Vit. C(ascorbic acid)and folic acid
- can be synthesized inside the body
- Cannot be stored in human tissues.
- Their excess is excreted with urine.
- Unstable to normal cooking conditions.

Vitamins

Water–soluble Vit.

Vit. B_1 , B_2 , B_6 , folic acid & ascorbic acid

Fat-soluble Vit.

Vit. A , D , E , K

Biological importance

1. Vitamins are essential for growth, maintenance and reproduction
2. Do NOT yield energy when broken down.
3. Fat soluble vitamins are required for normal color vision, blood clotting, bone formation and maintenance of membrane structure.
4. Most of the water soluble vitamins function as coenzymes or prosthetic groups of several enzymes involved in carbohydrate, lipid and amino acid metabolism etc.
5. Vitamins A and D act as steroid hormones.

Water - Soluble Vitamins

1. **Vitamin B_1** (Thiamin)

   - Stable at cooking Lost in boiling process.
   - Found in cereal , egg yolk ,yeast , bread & rice
   - The dietary requirement **from 1.0 - 1.5 mg/day** for normal adults.
   - Clinical sig. Beriberi (loss of appetite)

2. **Vitamin B_2** (Riboflavin)

   - The vitamin presence in eggs, milk, meat and cereals.
   - The normal daily requirement **1.2 - 1.7 mg/day** for normal adults.
   - Riboflavin decomposes when exposed to visible light.
   - Riboflavin deficiencies in newborns treated for hyperbilirubinemia by phototherapy.
   - Clinical sig. cheilosis, weakness of the legs.

3. **Vitamin B_6** (pyridoxine)
   - ✓ Found in liver, yeast, egg yolk, meat,& cereals.
   - ✓ The requirement from **1.4 - 2.0 mg/day** for a normal adult (during pregnancy increases approximately 0.6 mg/day).
   - ✓ Clinical sig. some types of anemia & affecting on the nervous system.

4. **Folic Acid**

   - Sources :- leafy vegetables as well as animal liver.

- Clinical Significance :- Folate deficiencies are rare due to the presence of folate in food but under condition of antibiotic therapy deficiency occur
- Daily requirements = **300 – 500 micrograms**.

5. **Vitamin C** (Ascorbic Acid)

• Sources ;- fresh green vegetables , citrus fruits Effected by temperature.
• Deficiency in vitamin C leads to the disease **scurvy** .(Scurvy is characterized by easily bruised skin, muscle fatigue, soft swollen gums, decreased wound healing and hemorrhaging) Daily need 30 mg -70 mg (more that in pregnancy)

Fat-soluble Vit.

1. **Vitamin A**

- Source vegetable (potato ,spinach ,carrots) & fish liver oil
- Vit. A is stored in the liver and deficiency of the vitamin occurs only after prolonged lack of dietary intake.
- Clinical Significances **;-** **night blindness**.
- Daily needs 300-750 micrograms
- Destroyed by cooking & sun drying.

2. **Vitamin D**

- Vitamin D is a steroid hormone.
- Sources ;- egg yolk , milk & fish oil
- Daily needs 200-400 I.U
- Clinical Significance
  1. Vitamin D deficiency in children causes **rickets**
  2. Vitamin D deficiency in adults causes **osteomalacia.**
- Factors affecting on Vit. D absorption:-
  1. Deficiency of calcium & phosphate.
  2. Lack of sun-light.
  3. Parathyroid gland hormones.

3. **Vitamin E**

- sources vegetable oils ,corn oil & wheat oil
- Daily needs **30 I.U**

- vitamin E natural **antioxidant**
- Clinical sig. 1-An increase in red blood cell fragility.
.   2- Muscular dystrophy.

4. **<u>Vitamin K</u>**

- Found in green vegetables & produced by intestinal bacteria.
- Maintenance levels of blood clotting proteins.
- Clinical sig. Deficiency in adults is rare.
  (Antibiotic treatment can lead to deficiency in adults)