Proteins are constituents of all living cells and are dietary essentials. They are polymers of amino acids joined by peptide bonds. Chemically, they are distinguished from fats and carbohydrates by containing nitrogen. Proteins occupy a central position in the architecture and functioning of living matter. They are intimately connected with all phase of chemical and physical activities that constitute the life of the cell.

Amino acids known as the building blocks of proteins have the general formula as:

\[
\begin{align*}
\text{NH}_2 &- \text{C} \quad \text{O} \\
\text{H} &\quad \text{C} \quad \text{OH}
\end{align*}
\]

Chemically, they are compounds with an amino group (-NH\textsubscript{2}) and a carboxyl group (-COOH) attached to the same carbon atom. R stands for the side chains that are different for each amino acid.

R can be as simple as a hydrogen atom (H) in the case of glycine or a methyl group (-CH\textsubscript{3}) in the case of alanine or a more complex structure as the case of leucine.

\[
\begin{align*}
\text{NH}_2 &- \text{C} \quad \text{O} \\
\text{H} &\quad \text{C} \quad \text{OH} &\text{glycine} \\
&\quad \text{CH}_3 \quad \text{O} \\
\text{H} &\quad \text{C} \quad \text{OH} &\text{alanine}
\end{align*}
\]
There are 20 main amino acids used in the synthesis of different proteins needed in the body and any one of these proteins may contain several hundreds or thousands of amino acids. The sequence of the amino acids in a protein determines its overall structure and functions.

Some of these amino acids can be synthesized in the body and so are called non-essential or dispensable amino acids, since they do not have to be provided in the diet. They are alanine, arginine, aspartic acid, glutamine, glycine, proline, serine and tyrosine.

However, cysteine and hydroxyl proline are also amino acids utilized in the body for body protein synthesis and are also non-essential amino acids, hence the 13 known non-essential amino acids.

9 amino acids cannot be synthesized in the body at all and so must be provided in the diet; they are called the essential or indispensable amino acids and these are histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine.

However, arginine may be essential for infants since their requirement is greater than their ability to synthesize it.

Two of the non-essential amino acids can be synthesized in the body from essential amino acids: cysteine and cysteine can be synthesized from methionine while tyrosine can be synthesized from phenylalanine.

Structural formulae of the major or primary amino acids.

**Small neutral amino acids**

\[
\begin{align*}
\text{Leucine} & \quad \text{Ala} & \quad \text{Gly} \\
\text{C} & \quad \text{C} & \quad \text{C} \\
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{NH}_{2} & \quad \text{H} & \quad \text{H} \\
\text{COOH} & \quad \text{COOH} & \quad \text{COOH}
\end{align*}
\]
Large neutral amino acids

Glycine

\[ \text{H}_3\text{C} - \text{C} - \text{CH}_2 - \text{CH} - \text{NH}_2 \]

Alanine

\[ \text{H}_3\text{C} - \text{C} - \text{CH}_2 - \text{CH} - \text{COOH} \]

Proline

\[ \text{H}_3\text{C} - \text{C} - \text{CH}_2 - \text{CH} - \text{COOH} \]

Leucine

\[ \text{H}_3\text{C} - \text{CH} - \text{COOH} \]

Valine

\[ \text{H}_3\text{C} - \text{CH} - \text{COOH} \]

Isoleucine

\[ \text{H}_3\text{C} - \text{S} - \text{CH}_3 - \text{CH}_2 - \text{CH} - \text{COOH} \]

Methionine

\[ \text{H}_3\text{C} - \text{S} - \text{CH}_3 - \text{CH}_2 - \text{CH} - \text{COOH} \]

Aromatic amino acids

Phenylalanine

\[ \text{H}_3\text{C} - \text{CH}_2 - \text{CH} - \text{COOH} \]

Tyrosine

\[ \text{HO} - \text{CH}_2 - \text{CH} - \text{COOH} \]
Tryptophan

Neutral hydrophilic Amino acids

Serine

Threonine

Cysteine

Acidic amino acids

Aspartate
Amino acid amines

HOOC–CH₂–CH₂–CH

Glutamate

H₂N–C–CH₃–CH

Asparagine

H₂N–C–CH₂–CH₂–CH

Glutamine

Basic amino acids

Histidine

H₃N–CH₃–CH₂CH₂CH₂–CH

Lysine
From the general formula of amino acids, the first carbon is the part of the carboxyl group. The second carbon to which is attached the amino group is called the $\alpha$ carbon. The $\alpha$ carbon of most amino acids is joined by covalent bonds to 4 different groups, thus exhibits asymmetric or chiral property. The $\alpha$-carbon in all amino acids is asymmetric except a glycine where the $\alpha$-carbon is symmetric. Because of this asymmetric nature, amino acids except glycine can exist in two optically active forms: those having the $-\text{NH}_2$ group to the right as D-forms and those having the $-\text{NH}_2$ group to the left as L-forms.

**Examples**

\[
\begin{align*}
\text{COOH} & \quad \text{COOH} \\
\text{H} - \text{C} - \text{NH}_2 & \quad \text{H}_2\text{N} - \text{C} - \text{H} \\
\text{R} & \quad \text{R}
\end{align*}
\]

D- amino acid 
L- amino acid.

It is important to note that all the amino acids found in proteins belong to the L-series. Many of the naturally occurring L-amino acids rotate the plane of polarized light to the left (i.e. levorotatory) while others rotate the plane of polarized light to the right (i.e. dextrorotatory). Thus, it is evident that the symbols D and L do not identify the property of light rotation i.e. D isomers can be either dextrorotatory (d) or levorotatory (l); similarly, L-isomers can be either (d) of (l).
However, to minimize confusion, the symbols d and l are usually not used nowadays. Moreover, the DL nomenclature has limitations because it describes the asymmetry of only one carbon atom in a compound and many biomolecules contain two or more asymmetric carbon atoms.

The R and S Classification is currently in use as this is more useful for defining the asymmetry of biomolecules because it accounts for all the asymmetric carbons in an isomer. In this case, if any atom (except H) or group on the asymmetric carbon is on the right side, that asymmetric carbon is designated R. Conversely, if any atom other than H or group is on the left side, the asymmetric carbon atom is designated S.

Example:

Isoleucine with two asymmetric carbon atoms: C-2 and C-3 will have four stereoisomers as shown below:

\[
\text{COOH} \quad \text{COOH}
\]
\[
\text{H}_2\text{N} - C^* - \text{H} \quad \text{H} - C^*\text{NH}_2
\]
\[
\text{H}_2\text{C} - C^* - \text{H} \quad \text{H} - C^*\text{CH}_3
\]
\[
\text{CH}_2 \quad \text{CH}_2
\]
\[
\text{CH}_3 \quad \text{CH}_3
\]

\((2S)(3S)\) Isoleucine \quad \((2R)(3R)\) Isoleucine
Classification of Amino Acids
Amino acids are classified in 3 ways.

(A) On the basis of the composition of the side chain or R-group.
The 20 different amino acids vary only in their side chains while the other features such as α-carbon, carboxyl group and amino group are common to all of them. On the basis of this variation in their side chains, they are classified into the following:

(1) Simple Amino Acids
These amino acids do not have any functional group in their side chain and examples are glycine, alanine, valine, leucine and isoleucine.

(2) Hydroxyl amino acids
These contain a hydroxyl group in their side chain e.g. serine and threonine.

(3) Sulfur-containing amino acids
These possess a sulfur atom in their side chain e.g. cysteine and methionine.

(4) Acidic amino acids
These contain carboxyl group in their side chain e.g. aspartic acid and glutamic acid.

(5) Amino acid amides
These are derivatives of acidic amino acids in which one of the carboxyl group has been transformed into an amide group (–CO.NH₂) e.g. asparagine and glutamine.

(6) Basic amino acids
These possess an amino group in the side chain e.g. lysine and arginine.

(7) Heterocyclic amino acids
These possess a ring which possesses at least one atom other than the carbon e.g. tryptophan, histidine and proline.

(8) Aromatic amino acids
These contain a benzene ring in their side chain e.g. phenylalanine and tyrosine.

This classification which is based on the nature of the side chain does not delimit the various groups. For example, tryptophan may also be included under aromatic amino acids and similarly histidine under basic amino acids.

(B) On the basis of the number of amino and carboxylic groups

(1) Monoamino-monocarboxylic groups: These class of amino acids contain one amino group and one carboxylic group in their structure. Examples:
   (a) Unsubstituted aliphatic - glycine, alanine, valine, leucine, isoleucine.
   (b) Heterocyclic - proline
   (c) Aromatic - Phenylalanine, tyrosine, tryptophan.
   (d) Thioether - methionine.

(2) Monoamino – dicarboxylic amino acids: These contain one amino group and 2 carboxylic groups in their structure. E.g. aspartic acid and glutamic acid.

(3) Diamino – monocarboxylic amino acids: These contain 2 amino group and one carboxylic group in their structure. E.g. lysine, arginine and histidine.

(C) Classification on the basis of polarity of the side chain or R group.
This is classification based on the polarity of the R group present in the molecules of the amino acids i.e. their tendency to interact with water at biological pH (near pH 7.0). The R groups of amino acids vary widely with
respect to their polarity from totally nonpolar or hydrophobic (water-hating) R
groups to highly polar or hydrophilic (water-loving) R groups. This
classification of amino acids emphasizes the possible functional roles which
they perform in proteins. Under this classification, we have:

(a) Amino acids with nonpolar R groups: The R groups in this category of
amino acids are hydrocarbon in nature and thus hydrophobic. This group
includes five amino acids with aliphatic R groups (alanine, valine, leucine,
isoleucine, proline), two with aromatic rings (phenylalanine, tryptophan)
and one containing sulfur (methionine).

(b) Amino acids with polar but uncharged R groups: The R groups of these
amino acids are more soluble in water i.e. more hydrophilic than those of
the non-polar amino acids because they contain functional groups that form
hydrogen bonds with water. This category includes 7 amino acids: glycine,
serine, threonine, tyrosine, cysteine, asparagine and glutamine. The polarity
of these amino acids may be attributed to the hydroxyl group (serine,
threonine, tyrosine) or the sulphydryl group (cysteine) or the amide group
(asparagine, glutamine).

NOTE: The R group of glycine, a single hydrogen atom is too small to influence
the high degree of polarity of the α-amino and ω-carboxyl groups.

c) Amino acids with negatively charged (− acidic) R groups: These are
monoamino-dicarboxylic acids. Their side chains contain extra carboxyl
group with a dissociable proton. The resulting additional negative charge
accounts for the electrochemical behaviour of the amino acids. The two
amino acids which belong to this category are aspartic and glutamic acids.

(d) Amino acids with positively charged (+ basic) R groups: These are
diamino-monocarboxylic acids. In other words, their side chains contain
extra amino group which imparts basic properties to them. Lysine, arginine
and histidine belong to this category.

In addition to the above mentioned 20 standard amino acids which are building
blocks of proteins and have wide range of distribution in proteins, several other
amino acids exist. These have limited distribution but may be present in high amounts in a few proteins. These class of amino acids are called non standard protein amino acids.

Examples
(a) Hydroxyproline: This has limited distribution in nature but constitutes as much as 12% of the composition of collagen, an important structural protein in animals.
(b) Hydroxylsine: This accounts about 1% of the total amino acids in collagen.
(c) N-methyllysine: This is a type of amino acid found in myosin which is a contractile protein of muscle.
(d) Gamma (\(\gamma\)) - carboxyglutamate: found in blood-clotting protein: the prothrombi.

There are also about 300 additional amino acids which are never found as constituents of proteins but which either play metabolic role or occur as natural products.

**PEPTIDE BOND**
Amino acid units are linked together through the carboxyl and amino groups to produce the primary structure of protein chain. The bond between two adjacent amino acids is a special type of amide bond called peptide bond.

Note: Amide bond consist of carbonyl group and amino group while carbonyl group consist of carbonyl group and hydroxyl. Group.

This is the bond formed when the (C) atom of the carboxyl group (-COOH) of one amino acid is linked with the (N) atom of the amino group (-NH\(_2\)) of the adjacent amino acid.

Example
Peptide bond between glycine and alanine.

\[
\text{H} \quad \text{CH} \quad \text{COOH} \quad + \quad \text{CH}_3 \quad \text{CH} \quad \text{COOH} \\
\text{NH}_2 \quad \text{H}_2\text{O} \quad \text{H}_2\text{N} \\
\text{glycine} \quad \text{alanine}
\]
Peptide bond between glycine, alanine and serine

H - CH - COOH - CH₂ - CH - COOH + HO - CH₂ - CH - COOH
  NH₂           H₂N           H₂N
glycine        alanine       serine

- 2H₂O  \rightleftharpoons  + 2H₂O  Hydrolysis
Dehydration

Glycyl-L-alanyl-L-serine
Each amino acid in a peptide bond is called a residue. The two ends of the peptide chain are named as amino terminal and carboxyl terminal or simply as an N-terminal and C-terminal respectively. These two terminals: one basic and the other acidic are the only ionizable groups of any peptide chain except those present in the side chain. The terminal amino acid with the free amino group is called the N-terminal amino acid and the one with the free carboxyl group at the other end as C-terminal amino acid.

The chain formed by linking together of many amino acid units is called a peptide chain.

Each peptide chain is of considerable length and may possess 50 millions of amino acid units. Depending on the number of amino acid molecules composing a chain, the peptides may be termed:

(a) Dipeptide: contain 2 amino acids in their chain.
(b) Tripeptide: contain 3 amino acids in their chains
(c) Oligopeptides: contain not more than 10 amino acids in its chain.
(d) Polypeptides: contain more than 10 amino acids.
(e) Macropeptides: contain more than 100 amino acids in their chain.

PROTEINS

These are polypeptides with more than 100 amino acids in their chains

(A) Proteins are classified on the bases of their source as:

(1) Animal proteins: These are proteins derived from animal sources such as egg, milk, meat and fish. They are usually called higher-quality proteins because they contain adequate amounts of all the essential amino acids.

(2) Plant proteins: These are proteins from plants and are usually called lower-quality proteins since they have a low content (limiting amount) of one or more of the essential amino acids. The four most common limiting amino acids in plant proteins are methionine, lysine, threonine and tryptophan.
Limiting amino acids in some plant proteins

Cereal grains and millets: lysine, threonine
Rice / soybeans: methionine
Legume (peas and beans): methionine, tryptophan
Groundnuts: methionine, lysine, threonine
Sunflower seeds: lysine
Green leafy vegetables: methionine.

(B) Classification based on the shape of protein molecule

1) **Globular proteins**: These possess a relatively spherical or ovoid shape. They are soluble in water or in aqueous media containing acids, bases, salts or alcohol. They have a far greater variety of biological activities and are dynamic rather than static in their functions. Examples are enzymes, protein hormones, blood transport proteins, antibodies and nutrient storage proteins.

2) **Fibrous Proteins**: These resemble long ribbons or fibres in shape. They are mainly of animal origin and are insoluble in all common solvents such as water, dilute acids, alkalis and salts and also in organic solvents. This group is a heterogeneous group and includes the proteins of the connective tissues, bones, blood vessels, skin, hair, nails, horns, hoofs, wool and silk. The important examples are:
   (a) Collagens (major proteins of white connective tissue e.g. tendons and cartilages).
   (b) Keratins (major constituents of epithelial tissues like skin, hair, feathers, horns, hoofs, nails).
   (c) Elastins (major constituents of yellow elastic tissues like ligaments and blood vessels).
   (d) Fibroin (major constituents of fibres of silk).

(C) Classification based on composition and solubility

This is the most accepted system of classification of proteins which divides proteins into 3 major groups: simple, conjugate and derived proteins.
Simple proteins or Holoproteins: These are mainly globular proteins. They are proteins containing only amino acids as their structural components. On decomposition with acids, yield the constituents amino acids. Examples of these proteins are albumins e.g. leucosine found in cereals, legumeline found in legumes, ovalbumin found in egg white, lactalbumin found in milk whey. Another example is globulins such as pseudoglobulins found in milk whey.

Conjugated or complex proteins: These are proteins which contain a separable nonprotein portion in their structural chain called prosthetic group. The prosthetic group may be metal or a compound. On decomposition with acids, liberate the constituent amino acids as well as the prosthetic group. They can further be classified based on the nature of the prosthetic group present as:

(a) Metalloproteins: These are proteins which contain metals in their structural chain. Example is collagen, albumin and casein which contain Ag (silver) Cu and Zn.

(b) Chromoproteins: These contain coloured pigments in their chains. Example is chloroplastin which contains chlorophyll (green pigment) and the red blood cells which contain the myoglobin, the red pigment.

(c) Glycoproteins and Mucoproteins: These contain carbohydrates as their prosthetic group. Examples are glycoproteins found in egg albumin which contains less than 4% CHO and mucoproteins found in Dioscorea tubers which contain more than 4% CHO.

(d) Phosphoproteins: These are proteins linked with phosphoric acid. Example casein from milk.

(e) Lipoproteins: Proteins that form complexes with lipids. Examples cholesterol and lecithin.

(f) Nucleoproteins: These are compounds containing nucleic acid and protein. These are considered as the sites for the synthesis of proteins and enzymes. E.g. nucleoprotein from yeast.
(g) **Derived Proteins:** These are derivatives of proteins resulting from the action of heat, enzymes or chemical reagents. Examples are proteoses and polypeptides which are derivatives of protein hydrolysis. Another type of derived protein is the coagulated protein produced by the action of heat or alcohol on protein. Example coagulated eggwhite.

<table>
<thead>
<tr>
<th>Class of protein</th>
<th>Function</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enzymic proteins</td>
<td>Biological catalysts</td>
<td>Amylase, peptidases</td>
</tr>
<tr>
<td>Structural proteins</td>
<td>Protecting and strengthening biological structures</td>
<td>Collagens, elastin, keratins, etc</td>
</tr>
<tr>
<td>Transport or carrier proteins</td>
<td>Transport of ions or molecules in the body.</td>
<td>Myoglobin, hemoglobin, lipoproteins, etc</td>
</tr>
<tr>
<td>Nutrient and storage proteins</td>
<td>Provide nutrition to growing embryos and store ions.</td>
<td>Ovalbumin, casein, ferritin.</td>
</tr>
<tr>
<td>Contractile or motile proteins</td>
<td>Function in the contractile system</td>
<td>Actin, myosin, tubulin.</td>
</tr>
<tr>
<td>Defense proteins</td>
<td>Defend against other organisms</td>
<td>Antibodies</td>
</tr>
<tr>
<td>Regulatory proteins</td>
<td>Regulate metabolic activities</td>
<td>Insulin, growth hormones</td>
</tr>
<tr>
<td>Toxic proteins</td>
<td>Hydrolyze enzymes or degrade enzymes</td>
<td>Snake venom and toxic plant proteins like ricin.</td>
</tr>
</tbody>
</table>

Examples of nutrient and storage proteins are egg proteins and milk proteins.

**Egg proteins:** Eggs contain 2 types of proteins: the egg white protein and egg yolk protein. The components of egg white protein are:

1. **Ovalbumin** which accounts for about 55% of the total proteins in egg.
(2) **Conalbumin**: This accounts for about 12% of the total proteins in egg.
(3) **Ovomucoid**: Accounting for about 12% of the total proteins in egg.
(4) **Globulins**: Class 1 proteins in egg white which accounts for about \( \geq 15\% \) of the total proteins.

**Egg Yolk** contains 2 phosphoproteins; lipovitellin and lipovitellinenin which contain lipid and phosphorous in the % shown below:

<table>
<thead>
<tr>
<th></th>
<th>Lipovitellin</th>
<th>Lipovitellinenin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipid concen.</td>
<td>17 – 18%</td>
<td>36 – 41%</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>1%</td>
<td>0.29%</td>
</tr>
<tr>
<td>Protein</td>
<td>vitellin</td>
<td>vitellenin</td>
</tr>
</tbody>
</table>

Whole egg is excellent food because it is very rich source not only of protein and lipid but also of most of the vitamins (except Vit. C) and most of the minerals (except a).

**Milk Proteins**

Milk contains about 3 major types of proteins and these are casein, lactalbumin and lactoglobulin. Casein accounts for about 75% of the milk proteins and are classified as \( \alpha \) (alpha), \( \beta \) (beta), \( \gamma \) (gamma) and \( \kappa \) (kappa) caseins.

Casein is that fraction of protein that precipitates by acidifying milk to a pH of 4.7, e.g. the case of cheese making. Lactalbumin and lactoglobulins are proteins of milk that do not precipitate at pH of 4.7. Thus are contained in the whey after precipitation of casein and can be precipitated by heat to form a whey cheese.

**Physical Properties of Proteins**

1. **Colour and Taste**: Proteins are colourless and tasteless. They are homogeneous and crystalline.
(2) **Shape and Size:** Proteins range in shape from simple crystalloid spherical structures (globular) to long fibrous structures. Two distinct patterns of shape have been noted of proteins: the globular and fibrous. Protein molecules are characterized by their sizes and weights. Example: albumin from egg is 65,000nm in size and hemoglobin is 64,450nm in size with molecular weight of 64,500nw.

(3) **Colloidal Nature:** Because of the giant size of proteins, they exhibit many colloidal properties such as:
   (i) Slow diffusion rate
   (ii) Light scattering effect when in solution, thus resulting in visible turbidity.

(4) **Denaturation:** This results to changes (unfolding) of the secondary, tertiary and quaternary structures of a protein which results to loss of biological activity. This is usually followed by coagulation—a process in which denatured protein molecules form large aggregates and thus precipitate from solutions. Denaturation of protein can be brought about by physical agents like shaking and treatment including cooling and freezing as well as chemical agents like ionizing radiations organic solvents (acetone and alcohols).

(5) **Amphoteric Nature:** Proteins like the amino acids exhibit amphoteric property i.e., they can act as acids and alkalis depending on pH. E.g.

\[
\begin{align*}
\text{R} & \quad \text{C} \quad \text{NH}_2 \\
\text{COOH} & \quad \text{R} \quad \text{C} \quad \text{NH}_2 + \text{H}^+ \\
\text{Acidic behaviour} & \\
\text{R} & \quad \text{C} \quad \text{NH}_2 \\
\text{COOH} & \quad \text{R} \quad \text{C} \quad \text{NH}_2^- + \text{Cl}^- \\
\text{Basic behaviour} &
\end{align*}
\]
Under an electric field, the behaviour of a protein depends on the net charge possessed by the molecule. The net charge is influenced by the pH value. Each protein has a fixed value of isoelectric point at which it will move in an electric field. Isoelectric point is the pH value at which the number of cations in a protein is equal to that of the anions. Thus, at isoelectric point, the net charge of a protein is always zero while the total charge on the protein molecule at this point is always maximum. Thus, proteins are dipolar ions or Zwitterions at isoelectric point with lowest solubility at isoelectric point and increases with increasing acidity or alkalinity.

6. Salting-in Effect: globulins are sparingly soluble in water but their solubility is greatly increased by the addition of neutral salts like NaCl. This phenomenon is known as salting-in effect.

Salting-out effect: Proteins can also be precipitated out from an aqueous solution by high concentrations of neutral salts. This is known as "salting-out" process.

7. Optical Activity: All proteins are optically active and this is due to the asymmetric nature of the amino acids that make up the protein molecule. Thus all protein solutions rotate the plane of polarized light to the left i.e. laevorotatory and their level of rotation is characterized to each protein which is used in their identification.

Water

Water is a colourless, transparent, odourless liquid which forms the seas, lakes, rivers and rain and is the basis of fluid of living organisms.

Water contains two hydrogen atoms and one oxygen atom. The hydrogen atoms are attached to one side of the oxygen atom resulting in a water molecule having a positive charge on the side where the hydrogen atoms are and a negative charge on the other side where the oxygen atom is. These opposite electrical charges form hydrogen bonds between the molecules which make
water molecule to attract each other. The side with hydrogen atoms attracts the oxygen side thus making the water molecules to follow themselves thus forming a flow or drop when separated.

Pure water boils at 100°C and freezes at 0°C. The high boiling and low freezing point of water is due to the presence of the hydrogen bonds between its molecules.

Water can exist in three states: solid (ice), liquid (water), gas (vapour). The density of water in solid state is lower than its density in the liquid state. This is because as water freezes, the hydrogen bonds between the molecules gather water molecules to form the ice crystals which have hexagonal shape. Under this condition the water molecules are loosely packed together thereby creating large spaces between them which also confer large volume to the ice.

The density of water is 1000 kg per m³ while that of ice is 917 kg per m³.

**Importance of water in foods**

1. Water is the major constituent of most foods though it contributes no calories to the diet.
2. It determines the texture of a food as can be seen when comparing grapes and raisins (dried grapes), or fresh and wilted lettuce. It gives crisp texture or turgor to fruits and vegetables, and it also affects perception of the tenderness of meat.
3. Determine the keeping quality of foods. Because bacteria cannot grow without water and many enzyme catalyzed and chemical reactions cannot occur without water, water has a significant effect in determining the keeping quality of a food. This explains why freezing, dehydration, or concentration of foods increases shelf life and inhibits bacterial growth and delays enzyme catalyzed reactions in foods.
4. Important solvent or dispersing medium in food processing. Almost all food processing involve the use of water, example breadmaking, thickening of starch, and making pectin gels.
5. It is also important as a heating and cooling medium. Water has a high specific heat index. This means that water can absorb or lose a lot of heat before it begins to get hot or cold. This is why water is valuable to industries as a coolant or as a heating medium.
(6) Water is a good solvent and dispersing medium thus is used for cleaning and sanitation in food industries.

Note: Specific heat of water is the energy (in calories or joule) required to raise the temperature of 1g of water by 1°C and is the same whether heating water or ice. It is higher in water when compared with other solvents. This is because of the hydrogen bonds holding water molecules together.

Forms of water in foods are
Water exists in three forms in foods and these are

1. Free water: This is water that is lightly entrapped in foods and is therefore easily expressed out from foods. They act as dispersing agent or solvent in foods and are easily remove by drying. This form of water is very much available for microbial, enzymatic and chemical reactions which cause deterioration of foods thus reduces shelf life of foods.

2. Adsorbed water: Water attached to surface of molecules such as proteins and carbohydrates contained in foods. It is referred to as water of hydration and it is not easily squeezed out like the free water but can be removed by drying. This can also encourage microbial, enzymatic and chemical reactions thus can lead to spoilage.

3. Bound water: This is the water trapped within the crystalline structure of food molecules thus cannot act as a solvent. It is not available for microbial action. Does not have effect on the storage stability of foods.

Water Activity ($a_w$)
This is the partial vapour pressure of water in a substance divided by the standard partial vapour pressure of pure water. This means actual equilibrium vapour pressure of air-space over the food divided by equilibrium vapour pressure of pure water at the same temperature.

Mathematically, $a_w = P/P_0 = ERH/100$

$P =$ partial vapour pressure of water over a food at temp $T$
$P_0 =$ saturated vapour pressure of pure water at temp $T$
$ERH =$ equilibrium relative humidity at temp $T$

Water content of foods is used mainly to control the amount of water present in a product for quantitative reasons example where a product is sold by weight.
controlling its water content may be important to meet legal and commercial requirements.

Water activity is more significant for qualitative considerations such as product stability, shelf life (microbiological and enzymatic stability), handling characteristics, physical properties and chemical stability.
controlling its water content may be important to meet legal and commercial requirements.
Water activity is more significant for qualitative considerations such as product stability, shelf life (microbiological and enzymatic stability), handling characteristics, physical properties and chemical stability.