NUTRITIONAL BIOCHEMISTRY

UNIT – 1

Food

- Food is defined as the substance that can be metabolized by an organism to give energy and build tissue any solid substance (as opposed to liquid) that is used as a source of nourishment
- A healthy body is able to perform two basic physiological functions.
- It has both the capacity to grow and to convert certain substances into energy.
- Growth means an increase in size, not only of the entire body but also of every body part. It also involves replacement of worn-out tissues and the healing of wounds caused by injury or disease.
- The body requires a steady supply of building materials and fuel to produce the energy that powers all the body's vital processes.
- Since the body does not maintain an unlimited supply of building materials or fuels, these must be obtained from an outside source--food.

Nutrition

- Nutrition is the taking in and use of food and other nourishing material by the body.
- It is the process by which, living creatures obtain energy from food and drink for the purpose of body growth and maintenance.
- Nutrition is interpreted as the study of the organic process by which an organism assimilates and uses food and liquids for normal functioning, growth and maintenance and to maintain the balance between health and disease.
- Also included is the idea of an optimal balance of nutrients and whole foods, to enable the optimal performance of the body.
- Nutrition is a 3-part process. First, food or drink is consumed. Second, the body breaks down the food or drink into nutrients. Third, the nutrients travel through the bloodstream to different parts of the body where they are used as "fuel" and for many other purposes.
- To give the body proper nutrition, a person has to eat and drink enough of the foods that contain key nutrients.
- It provides information about the type of food a person must eat to promote and maintain good health.
- Such knowledge helps thus the person develop and apply proper nutritional habits in order to maintain healthful living.

- A diet, or the food regularly eaten, must contain all the essential nutritional elements: proteins, carbohydrates, fats, vitamins, minerals, and water.
- If a person's diet is consistently deficient in any of these nutrients, health is impaired and disease may result. Lack of the mineral iron, for example, is typical of the disease anemia; scurvy is a disease caused by a deficiency of vitamin C.

Food Groups

- Foods may be broadly classified into 11 groups, based on their nutritive value as,
    - Cereals and millets
    - Pulses (legumes)
    - Nuts and oilseeds
    - Vegetables
    - Fruits
    - Milk and milk products
    - Eggs
    - Meat, fish, and other animal foods
    - Fats & oils
    - Sugar and other carbohydrate foods
    - Spices and condiments

The characteristic features of these food groups are explained as follows:

1.Cereals and Millets

- Most important group of foodstuffs. Staple food for large majority.
- General composition of cereals:
    - Proteins – 11% (Glutelins & Gliadins)
    - Carbohydrates – 70% (Mainly starch)
    - Mineral matter – 2% (Ca & PO_4 – Most predominant)
    - Fats – 0.5 to 8% (Predominant component – Olein)
    - Water – 11%
- Good source of vitamin B1, niacin, pantothenic acid, B6, minerals.
- Ragi – Good source of Ca. Oats – Richest in proteins and fats.
- Cereals deficient in vitamins A, D, B12, & C.

2.Pulses

- Dried pulses – rich in proteins (19 – 24%). Chief protein - Legumin
- Good sources of B vitamins and minerals.
- Deficient in vitamins A, D, B12, C.
- Tender pulses like green peas, green Bengal gram, green field beans – Fair amounts of Vitamin C.

3.Nuts and Oilseeds

- Nuts – High fat, low carbohydrate content.
- Rich sources of protein (18 – 40%). Soyabean- richest source.

- Rich sources of B-vitamins, vitamin E, some minerals (P, Fe).
- Deficient in vitamins A, D, B12, C.
- Sesame seeds rich in Ca.

4.Vegetables

- Broadly divided into 3 groups.
    - Green leafy vegetables
        - Rich sources of carotene (provitamin A), vitamin B2, vitamin C & folate. Also rich Fe and Ca salts.
        - The cellulose present in them provides a key source of roughage in the diet.
    - Roots and tubers
        - Important source of carbohydrate nutrition.
        - Potatoes, sweet potatoes, tapioca, colocasia, carrots, etc… belong to this group.
        - The main form of carbohydrate present is starch.
        - The chief protein is *Tuberin*. The remaining nitrogen component is in the form of Asparagine.
        - Potatoes - rich in vitamin C. Carrots – Rich in sugars & vitamin A.
    - Other vegetables
        - Includes a large number of vegetables.
        - Good sources of vitamin C.
        - Yellow pumpkin – Rich in carotenes.

5.Fruits

- They are essential protective foods.
- Contain large amounts of carbohydrates as sugars (pentoses and pectins) and starch.
- They are in general, good sources of vitamin C.
- Mango, papaya – Additional fair sources of carotene.
- Indian gooseberry, guava, tomatoes, citrus fruits, papaya, cashew fruit and pineapple – Vitamin C
- Apple, banana – Poor sources of vitamin C.

6.Milk and milk products

- Milk is almost a complete food except for its deficiency in Fe, Cu and vitamins C and D.
- The important proteins in milk include caseinogen, lactalbumin and lacto globulin.
- Lactose – Principal carbohydrate present in milk.
- Milk proteins are of high biological value.
- On an average, cow's milk provides about 35g protein, 35g fat, 1g Ca, 1.5mg riboflavin, 1500I.U. of vitamin A per litre. Buffalo milk contains nearly twice the amount of fat as that of cow's milk.
- Human milk in comparison with cow's milk has lower protein content and much higher lactose content.

7.Eggs

- Hen's egg consists of the following components:
  - Water = 73%
  - Proteins = 12.5%
  - Lipids = 12%
  - Carbohydrates = 1.6%
- The important proteins in eggs include ovalbumin, conalbumin, ovoglobulin and ovo-mucoid. The yolk consists of vitellin and livetin.
- Yolk – rich in cholesterol, appreciable amounts of PUFAs like linoleic acid.
- Rich source of vitamin A and some B vitamins.
- Moderate source of vitamin D, E, B1, B2, and Fe. Absence of vitamin C.

8.Meat, fish and other animals

- ***Meat*** is rich in proteins (18 – 22%) of high biological value, fair source of B vitamins. Doesn't contain vitamins A, C, and D.
- ***Fish*** is rich in proteins (18 – 22%) of high biological value, fair source of B vitamins. Fatty fish contain some vitamins A & D. Large fish are rich in P, but deficient in Ca.
- ***Liver*** is rich in proteins (18 – 20%), vitamin A, and B complex. It is the richest natural source for vitamin B12.

9.Fats and oils

- Main source of energy, provide EFAs.
- Butter, ghee, and vanaspathi – Vitamin A (2500I.U. per 100g), also contain vitamin E.
- Poor source of vitamin A.

10.Sugar and other carbohydrate foods

- Commonly used carbohydrate foods are cane sugar, jaggery, glucose, honey, sago, arrowroot flour, custard powder, etc…
- Mainly serve as source of energy.
- Honey and jaggery – small amounts of vitamins and minerals.

11.Condiments and spices

- Important source of nutrients in diet.
- Enhance palatability of the diet.
- Essential oils present in them helps in improving the flavor and acceptability of food preparations.

Foods can be classified based on their functions as follows:

1. Energy yielding foods
2. Body building foods
3. Protective foods

1.Energy yielding foods

- Foods rich in carbohydrates, and fats are called energy yielding foods.

- Cereals, roots and tubers, dried fruits, sugars and fats are included in this group.

2.Body building foods

- Foods rich in proteins are called bodybuilding foods.
- They are divided into 2 groups.
  - Milk, egg, meat and fish rich in proteins of high biological value.
  - Pulses, oilseeds, and nuts and low fat oilseed flours rich in proteins of medium nutritive value.

3.Protective foods

- Foods rich in proteins, vitamins and minerals are called protective foods.
- Milk, eggs, liver, green leafy vegetables, and fruits are included in this group.
- They are broadly classified into 2 groups:
  - Foods rich in vitamins, minerals and proteins of high biological value such as milk, eggs, liver.
  - Foods rich in certain vitamins and minerals only, such as green leafy vegetables and some fruits.

Other food groups

- There are 3 other types of food groups, which are useful in planning a balanced diet. They are:
  - 7-Food group plan
  - 4-Food group plan
  - 11-Food group plan

- ***The 7-Food group plan***

  Developed in 1943.

S.No.	The 7 food groups	Main nutrients contributed
1.	Green and yellow vegetables	Carotene (provitamin A), ascorbic acid and iron.
2.	Oranges, grape fruit, tomatoes, raw cabbage, salad greens.	Ascorbic acid.
3.	Potatoes, other vegetables and fruits	Vitamins and minerals in general and cellulose
4.	Milk and milk products	Ca, P, proteins and vitamins
5.	Meat, poultry, fish and eggs	Proteins, P, Fe, & B vitamins

6.	Bread, flour, and cereals (whole grain, enriched or restored)	Thiamine, Niacin, Riboflavin, Fe, Carbohydrates and cellulose
7.	Butter or fortified margarine	Vitamin A and fat

- ***<u>The 4-Food group plan</u>***
    - Developed in 1956

S.No.	The 4 food groups	Main nutrients contributed
1.	*<u>Milk group:</u>* Milk, cheese, ice cream, etc…	Ca, P, proteins, and vitamins
2.	*<u>Meat group:</u>* Beef, veal, pork, lamb, poultry, fish, eggs.	Proteins, P, Fe, B-Vitamins
3.	*<u>Vegetable – fruit group</u>*	Vitamins and minerals in general and cellulose
4.	*<u>Bread – Cereals group</u>*	Thiamine, Niacin, Riboflavin, Fe, Carbohydrates and cellulose

- ***<u>The 11-food group plan</u>***
    - Developed in 1964

S.No.	The 11 food groups	Main nutrients contributed
1.	(a)Milk and cheese (b)Ice cream	Ca, P, vitamins and proteins. Fat & carbohydrates
2.	Meat, poultry and fish	Proteins, P, Fe, B-vitamins
3.	Eggs	Proteins, fat, vitamins, Fe & P
4.	Dry beans, peas and nuts	Proteins and B-vitamins
5.	Flour, cereals, & baked products (whole grain, enriched, restored)	Thiamine, Niacin, Riboflavin, Fe, Carbohydrates and cellulose
6.	Citrus fruits and tomatoes	Ascorbic acid and potassium
7.	Dark green & deep yellow vegetables	Provitamin A (Carotene), ascorbic acid and Fe.
8.	Potatoes	Carbohydrates and ascorbic acid
9.	Other vegetables and fruits	Ascorbic acid and cellulose.
10.	Fats and oils	EFAs & vitamin E
11.	Sugar syrup and preservatives.	Carbohydrates

Balanced Diet

- It is defined as one, which contains various food groups or foodstuffs such as energy yielding, body building and protective foods at the right proportions, so that the individual is assured of obtaining the minimum requirements of all the nutrients.
- The components of a balanced diet will differ with age, sex, physical activity and economic status and the physiological state.
- A balanced diet should be based on:
  - Locally available foods.
  - Economic means of the people.
  - Should fit with the local food habits.
  - Diet should be easily digestible and palatable.
  - Should contain enough roughage material.

Basic concepts of Energy

Units of Energy expenditure

Energy metabolism is measured in units of heat.

- With varying degrees of efficiency the different forms of energy can be converted one to another; all, however, can be converted completely to heat, so that units used for measuring heat can serve as a "common currency" for all measuring all forms of energy.
- The SI unit of work, energy, and heat, is the joule, which is defined as the work done when a force of 1 N advances its point of application by one metre.
- A unit still commonly used in biological studies of energy metabolism is the kilocalorie (not a SI unit), which is defined as the amount of heat required to heat one kg of water by 1OC.
- A kilocalorie has been called a 'large calorie' and has been written as 'Cal.'.
- Since the calorie is a precisely defined unit (one-thousandth of a kilocalorie), it is confusing to refer to 'large' and 'small' calories. The metric system of units recognizes only one calorie (cal.) which can be used with the usual prefixes of the metric system, kilo-, milli- etc. 1 kilocalorie = 4185.5 joules or 4.1855 kJ (kilojoules); 1 joule = 0.2390 calories.

Calorific Value (or Heating value)

- ***Calorific value*** *is defined as the amount of heat energy obtained by burning 1g of the foodstuff completely in the presence of* O_2.
- It is used to define the amount of heat released during the combustion of a fuel or food. It is measured in units of energy per amount of material.

- Depending on the context, heating values may be reported as Btu/m^3, kcal/kg, J/mol, or a variety of other combinations of units.
- Heating value in commonly determined by use of a bomb calorimeter.
- The quantity known as higher heating value (or *gross calorific value* or *gross energy*) is determined by bringing all the products of combustion back to the original pre-combustion temperature. The quantity known as lower heating value (or *net calorific value*) is determined by subtracting the heat of vaporization of the water in the by-product from the higher heating value results.
- The lower heating value is what is typically used for vehicle engine analysis.
- Since most gas burning appliances cannot utilize the heat content of the water vapor, gross calorific value is of little interest. Fuel should be compared based on the net calorific value. This is especially true for natural gas, since increased hydrogen content results in high water formation during combustion.

Measures of Heat

Temperature is a measure of the average translational kinetic energy of the molecules of a system. Heat is commonly expressed in either of two units: the calorie, an older metric unit, and the British thermal unit (Btu), an English unit commonly used in the United States. Scientists express heat in terms of the joule, a unit used for all forms of energy.

Specific Heat

- It represents the energy in the metric system. The measurement of heat is called **calorimetry**. It is the measurement of heat and the determination of heat capacity.
- Heat is evolved in exothermic processes and absorbed in endothermic processes; such processes include chemical reactions, transitions between the states of matter, and the mixing of two substances to form a solution.
- The calorie, or gram calorie, is the quantity of heat required to raise the temperature of 1 gram of pure water 1°C.
- The kilocalorie, or kilogram calorie, is the quantity of heat required to raise the temperature of 1 kg of pure water 1°C; it is equal to 1,000 cal.
- The kilocalorie is used in dietetics for stating the heat content of a food, i.e., the amount of heat energy that the food can yield as it passes through the body; in this context, the kilocalorie is usually called simply the calorie.
- The amount of heat energy needed to effect a 1°C; temperature increase in 1 gram of water varies with temperature; thus the

temperature range over which the heating takes place must be stated to define the calorie precisely. The 15° calorie, or normal calorie, is widely used in chemistry and physics; it is measured by heating a 1-gram water sample from 14.5°C; to 15.5°C; at 1 atmosphere pressure.

- The 4° calorie, also called the small calorie or therm, is measured from 3.5°C; to 4.5°C; (water is most dense at 3.98°C;); the large calorie, or Calorie, is equivalent to 1,000 small calories.
- The average value of the calorie in the range 0°C; to 100°C; is called the mean calorie; it is 1-100 of the energy needed to heat 1 gram of water from its melting point to its boiling point.
- The calorie may also be defined by expressing its value in some other energy units.
- The 15° calorie is equivalent to 4.186 **joule** (j l, joul), abbr. J, unit of work or energy in the mks system of units, which is based on the metric system; it is the work done or energy expended by a force of 1 newton acting through a distance of 1 meter. (J), 1.162×10^{-6} kilowatt-hours, 3.968×10^{-3} British thermal units, and 3.087 foot-pounds; the 4° calorie equals 4.204 J; and the mean calorie equals 4.190 J.
- Two other calories sometimes used are the International Steam Table calorie, equal to 4.187 J, and the thermochemical calorie, equal to 4.184 J. When the calorie is used for precision measurement of heat energy, the particular calorie being used must be specified.

Specific dynamic action

- Ingestion of food is accompanied by an increased rate of heat production.
- Various names for this effect have been suggested, including specific dynamic action (SDA), specific dynamic effect, heat increment of a feeding, calorigenic effect of foods, and thermogenic effect.
- Specific dynamic action is defined as the extra heat production; over and above the actual heat ought to be produced outside from a given amount of food, when the given food is metabolized in the body.
- Some important observations of physiological SDA are:

1. ***Proteins have the greatest SDA, amounting up to 30% of its calorific value.***
2. ***Carbohydrates cause an increase of about 5% or 6%.***
3. ***Fats cause about 4%.***
4. ***Ordinarily, SDA all together amounts to about 6% of BMR.***

Basal Metabolism and BMR

- The amount of energy required for any individual varies directly with the degree of activity & the environmental conditions.
- However, the rate of energy production in an individual by its overall cellular metabolism is more or less constant, under some standard conditions.
- This is known as *basal metabolism*.
- The basal conditions are as follows:
  - Person should be awake but at complete physical and mental rest.
  - Person should be without food at least 12-18 hours, i.e., in postabsorptive state.
  - This period is allowed to pass for avoiding:
    1. Effects of digestion and absorption.
    2. Effects of SDA of foodstuffs.
    3. Prevent any chance of starvation.
  - Should be in recumbent/reclining position in bed.
  - Person should remain in normal environmental conditions (Normal temperature, pressure, humidity).

The rate of energy production under such basal conditions is known as BMR (or) Basal metabolic rate.

BASAL METABOLIC RATE

It is defined as the amount of heat given out by a subject lying awake in a state of complete physical and mental rest, in postabsorptive state, under normal and neutral environmental conditions.

Factors affecting BMR

- ***AGE***
  - BMR of children > BMR of adults.
  - This is because children possess a greater surface area in proportion to their body weight.
- ***Sex***
  - Women BMR < Men BMR.
  - BMR of women declines between the age 5 – 17 more rapidly than men.
- ***Surface area***
  - Basal metabolism is for the maintenance of body temperature.
  - Since heat loss is proportional to surface area of the body, *BMR is directly proportional to the surface area.*
- ***Climate***
  - In colder climates, BMR is high, and in tropical climates the BMR is proportionally low.

- ***State of nutrition***
  - BMR is lowered in conditions of malnutrition, starvation and wasting diseases.
- ***Body temperature***
  - BMR increases by 12% with the rise of 1^0C.
  - This is due to the fact that, increased temperature stimulates the chemical processes in the body, which stimulates the BMR.
- ***Barometric pressure***
  - Moderate lowering of atmospheric pressure – No effect.
  - Lowering to ½ atm pressure (viz., O_2 tension 75 mm Hg) = increases BMR.
  - However, increased pressure of oxygen doesn't raise BMR.
- ***Habits***
  - Trained athletes and manual workers have slightly higher BMR than persons leading a sedentary life.
- ***Drugs***
  - Drugs such as caffeine, Benzedrine, epinephrine, nicotine, alcohol, etc… increase the BMR.
  - BMR is reduced by the action of anesthetics.
- ***Hormones***
  - Circulating levels of hormones secreted by thyroids, adrenal medulla, and anterior pituitary increase the BMR.
  - Increase in the secretion of adrenalin in case of fear or nervousness also results in an increase in BMR.
  - In *thyrotoxicosis*, BMR may increase by 50-100% above normal.
  - In *myxoedema*, BMR is diminished to 30% or even 45% below normal.
  - TSH, GH, catecholamines = Increase BMR by 20%.
  - Male sex hormones = Increase BMR by 10%.
- ***Pregnancy***
  - BMR of mother after 6 months of gestation rises.
  - This is because; the BMR of a pregnant mother is the sum of her own BMR and that of the foetus.
- ***SDA of food***
  - Food has a stimulating effect on BMR.
  - Food given in postabsorptive state increases BMR by about 8%.
- ***Sleep***
  - BMR in sleep is 5% lesser than the basal metabolic state.

Clinical variations of BMR and its importance

Pathological variations

- Fever: Infections and febrile diseases elevate BMR, usually in proportion to the increase in temperature.
- *Diseases*: They are characterized by increase in activity of cells, which increases the temperature, thereby raising the BMR. BMR increases in conditions such as:
  - Leukemia (21 – 80%).
  - Polycythemia (10 – 40%).
  - Some types of anaemia, cardiac failure, hypertension, & dyspnoea (25 – 80%).
- *Perforation of an eardrum*: This causes falsely high BMR readings.
- *Endocrine diseases*: Thyroid function has a direct effect on BMR. Hence BMR values are used to assess thyroid function.
  - *Hyperthyroidism*: BMR increased to +75% or more.
  - *Hypothyroidism*: BMR reduced to 40% or more.
  - *BMR increased* in Cushing's disease, Cushing's syndrome and acromegaly.
  - *BMR reduced* in Addison's disease.

Determination of BMR

BMR can be determined by the following methods:

- Open circuit system
- Closed circuit system

1. ***Open circuit system***

- In this method, both the consumption of O_2, and CO_2 output are measured.
- Requires high level of technical skill, more cumbersome apparatus and is less rapid.
- However, the results are more required.
- Tissot method and Douglas method are both open circuit methods.

2. ***Closed circuit method***

- In clinical practice, BMR is estimated with sufficient accuracy merely by measuring O_2 consumption of the patient for 2-6 minute periods under basal conditions.
- The O_2 consumption is measured in a closed circuit system.
- The Benedict-Roth apparatus is commonly used.

Calculation of BMR

Can be calculated by 2 ways:

- Using the surface area of the body
- Using Read's formula

1. Using the surface area of the body

$$BMR = \frac{\text{Oxygen consumed per hour} \times 4.825}{\text{Surface area of the body}}$$

Here 4.825 represent the energy output produced by the consumption of 1 litre of O_2.

CALCULATION OF SURFACE AREA

The surface area of an average adult is 1.8 sq.m.

Surface area can be calculated as follows:

1. Simple method

   O^{ee} of mid thigh (cm) x 2 x Height (cm) = Surface area (sq.cm)

2. Du Bois' classical formula

   $A = (H^{0.725} \times W^{0.425} \times 71.84)/10,000$

Where,

A = Surface area (sq.m.) H = Height (cm) W = weight (Kg)

The BMR of the person is compared with the standard values and it is expressed in %.

$$BMR = \frac{\text{Normal BMR} - \text{Actual BMR}}{\text{Normal BMR}} \times 100$$

2. Using Read's formula

BMR = 0.75 (PR+0.74 x PP)-72

Where,

PR = Pulse rate
PP = Pulse pressure

Measurement of Foodstuffs – BOMB CALORIMETER

- A bomb calorimeter is used for the determination of the calorific value of foodstuffs *in-vitro.*

The Bomb

- Outer chamber – Filled with water for thermal insulation
- Inner chamber – Thermally insulated with air space. Encloses another chamber filled with a weighed amount of water.

- This inner water chamber is utilized for the determination of the amount of heat generated by the system.
- A highly sensitive thermometer is immersed into this water chamber to determine small changes in temperature accurately.
- The inner water chamber encloses the combustion chamber or the bomb.
- The combustion chamber consists of the petri dish for placing the foodstuff to be estimated.
- The combustion chamber is adequately supplied with oxygen through the oxygen inlet.
- Platinum wires are inserted into the combustion chamber in order to initiate the combustion process.

Procedure

- The foodstuff to be estimated is placed on the petri dish.
- Now, the oxygen supply is turned on and the current is supplied to the platinum wires to initiate ignition.
- The foodstuff is allowed to undergo complete combustion.
- The heat evolved is absorbed by the weighed amount of water surrounding the combustion chamber.
- The rise in temperature is recorded with the thermometer, and the calorific value of the foodstuff is thus calculated.
- Calculation of the calorific value of the foodstuff is done with the experimental data by using the formula;

$$H = \frac{W(T'' - T')}{M(1000)} \text{ K cal/g}$$

Where,
W = Water equivalent of calorimeter and its water.
T''-T' = Rise in temperature (^{0}C)
M = Amount of food burnt (g)

Calorific Value of Proteins

- The calorific value of proteins is the least of all other nutrients.
- Calorific value = 4.1 C.
- This is because, the primary function of proteins is body building and not energy releasing.
- Moreover proteins are not completely oxidized, as the amino group is excreted in the form of urea.
- However, proteins may release energy under conditions of gluconeogenesis, by the formation of glucose.

Calorific Value of Carbohydrates

- It is the primary source of energy for the body.
- The calorific value of carbohydrates is 4.1. It ranges between 3.7 & 4.3.
- All cells absorb carbohydrates in the form of glucose to generate ATP molecules for energy.

Calorific Value of Fats

- It has the maximum calorific value of all the foodstuffs.
- The calorific value of fats is about 9.3C.
- It acts as the secondary source of energy in the body.

RQ of Foods

- Respiratory quotient (RQ) is defined as the ratio of volume of carbon dioxide produced by the volume of oxygen consumed during a given time.
- RQ is simply a ratio and has no unit.
- Proportion increases with the diminution of carbon dioxide produced and the oxygen utilized.
- ***NORMAL RQ = 0.85.*** (In an adult, on a mixed diet).
- RQ of foods can be determined by measuring the volume of oxygen consumed and the amount of carbon dioxide produced in a given time with the help of Douglas bag and other similar instruments.

Factors affecting RQ

1. Role of diet

(a)CARBOHYDRATES: In carbohydrate diet, RQ = 1, as the amount of oxygen consumed and the amount of carbon dioxide produced is same.
(b)FATS: RQ is the lowest at 0.7, as fat is an oxygen poor compound. The oxygen present in it cannot fully oxidize the H of the molecule and so that oxygen consumed from outside is used for 2 purposes:

- For oxidizing C and producing CO_2.
- For oxidizing H to give H_2O.

Since volume of CO_2 is lesser than O_2, RQ is low
(c)PROTEINS: The oxidation of proteins cannot be so readily expressed. By indirect methods, the RQ for proteins has been calculated to be about 0.8.
(d)MIXED DIET UNDER VARYING CONDITIONS: RQ on an average is 0.85, for diets containing varying proportions of proteins, fats and carbohydrates. Increase in metabolism of carbohydrates shows the increase in RQ, approaching 1.0.

2. ***Effect of interconversion in the body***

- RQ rises when carbohydrates are converted to fats.
- Since an O_2 rich molecule is converted into an $O_{2\ poor}$ molecule, some amount of O_2 released will be used for the purpose of oxidation.
- Therefore, lesser O_2 is required from outside and hence RQ is much higher.
- However, the reversal of this process results in lowering or RQ to 0.7.
- Hence, RQ indicates:
  - The type of foodstuffs burning in the body.
  - The nature of conversion of one foodstuff into another in the body.

3. ***Muscular exercise***

- Moderate exercise = Almost unaltered RQ. This is because the body uses different foodstuffs in the same proportion as at rest.
- Violent exercise = RQ rises. This is because, lactic acid enters blood and produce acidosis, as a result, pulmonary ventilation will be increased and more amounts of CO_2 are washed out. Hence RQ increases. The increase may even go up to 2.0.
- RQ rise in conditions of violent exercise can be brought back to normal levels by taking rest.

Value and significance of determination of RQ

- Acts as a guide as to type of food burning or to the nature of synthesis, taking place in the whole body as well as in the particular organ.
- Helps in determining metabolic rate.
- Non-protein RQ can be used for calculating the total energy output and the proportions of various foodstuffs being burnt.
- Helps in diagnosis of various pathological conditions such as acidosis, alkalosis, and diabetes mellitus.