Volgograd State Medical University
Department of Normal Physiology

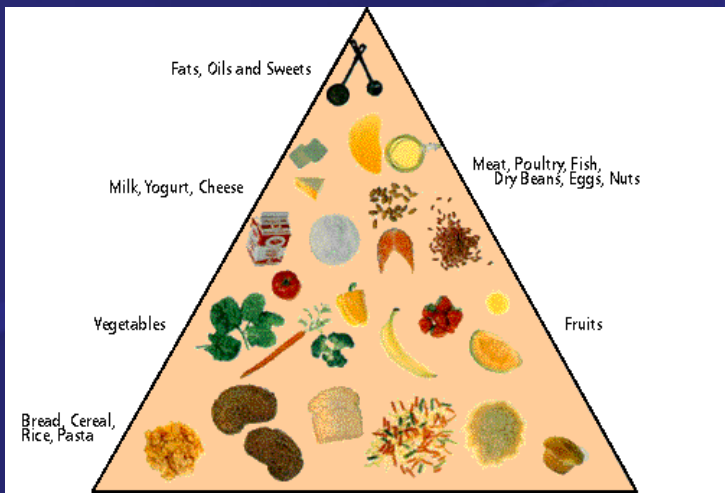
Physiology Of Nutrition

Importance of food

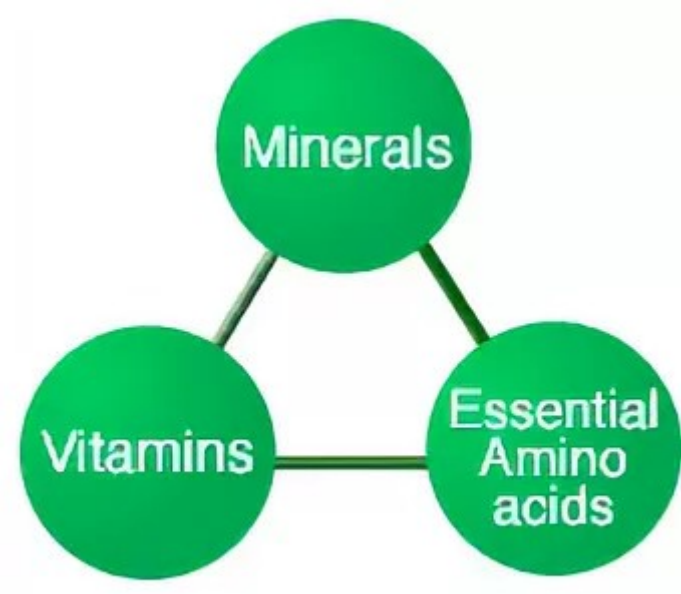
Food is eaten for the purpose of supplying the energy for such vital activities like pumping action of heart, maintenance of respiration, keeping the body warm, for various metabolic activities and so on.

These are instances of energy expenditure which occurs even at rest.

Additional energy expenditure occurs during muscular activities or during exposure to cold.



Importance of food



We also require food for other purposes. These include:

(i) supplying of **vitamins** and **essential amino acids**, i.e., substances which cannot be synthesized in the body. Even regarding substances which can be synthesized in the body the source of the raw materials, ultimately, is the food.

For the children and convalescents, food is the **basis of growth** (in children) or **replenishment of materials lost** from the body during the sickness (in convalescents).

Importance of food

In short, **food serves the following purposes mainly**:
(I) **supply of energy**;
(ii) **formation of tissues of the body** (growth, replenishment of loss due to wear and tear);
(iii) **maintenance of body temperature**, which is actually a corollary of the first point (energy supply).

Principles of Dietetics

Introduction

The scientific basis of **NUTRITION** is called "the principle of dietetics".

The amount, proportions of the different food matters (e. g., protein, carbohydrate, fat), content of vitamins and minerals etc. are optimal.

Principles of Dietetics

The principles of dietetics are as follows:

1. **The calorie need** must be satisfied and extra calories provided for growing children or convalescents. Under supply of calories leads to ***"calorie starvation"*** whereas excess supply of calorie leads to ***"obesity"***; both conditions are harmful.

Principles of Dietetics

[*1 gm of protein or 1 gm of carbohydrate supply 4 Kcal each but 1 gm fat supplies 9 Kcal.*
Protein intake per day in healthy adult should be constant, about 1 gm/kg body wt; caloric needs are adjusted by varying the fat and carbohydrate].

CALORI

Calculating Calories

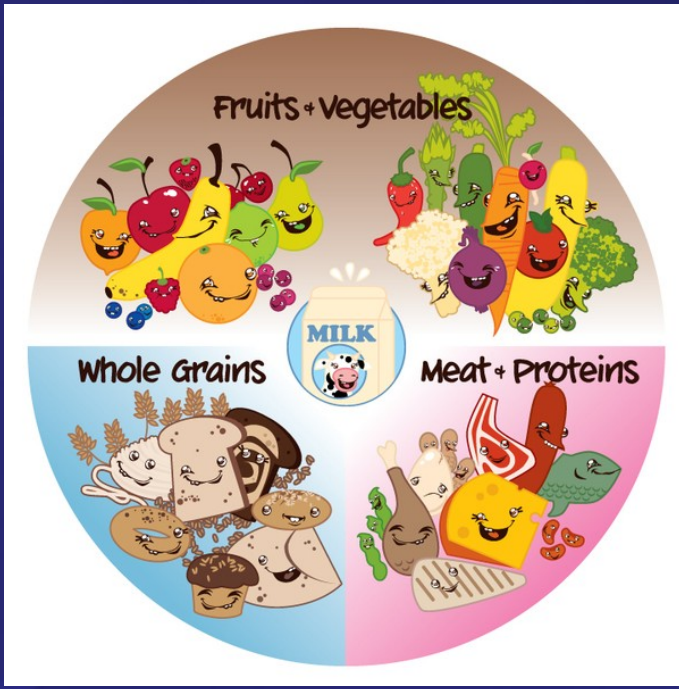
- 25 gm protein — 25 gm X 4 kcal = 100 kcal
- 25 gm carbohydrate — 25 gm X 4 kcal = 100 kcal
- 25 gm fat — 25 gm X 9 kcal = 225 kcal

Principles of Dietetics

2. **The proximate constituents of the food**, that is protein, carbohydrate and fat should be in ideal **proportion in the food**.

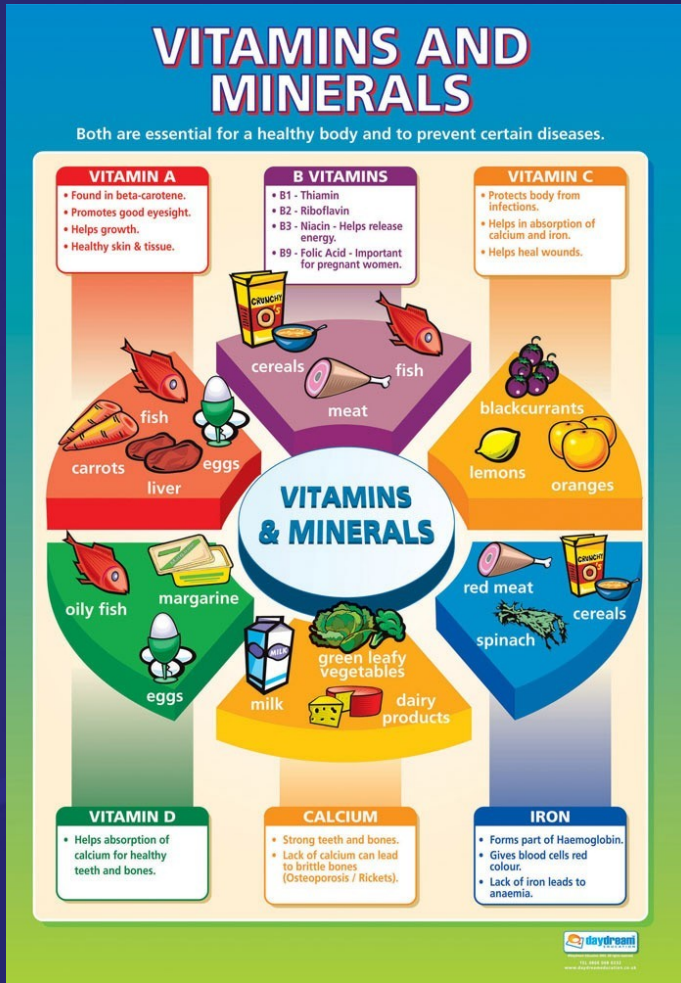
Too much deviation from this optimal proportion leads to disease.

Quality of these proximate constituents, particularly *protein and fat must be satisfactory.*



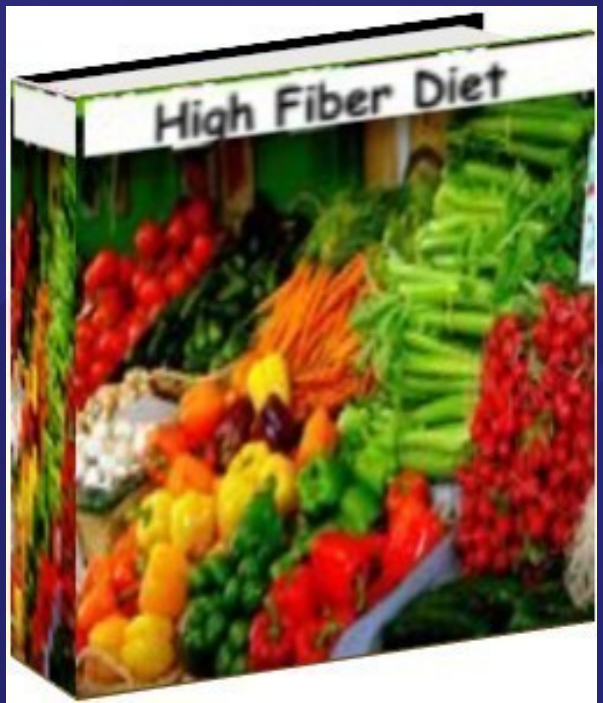
Principles of Dietetics

3. **Vitamins and minerals** must be present satisfactorily in the food.



Principles of Dietetics

4. **Food must contain** sufficient **fibrous element and roughage**. However, a great increase of them is not desirable.



Principles of Dietetics

5. **Food habits, religious or other taboos**, availability of prescribed food, all must get due considerations.

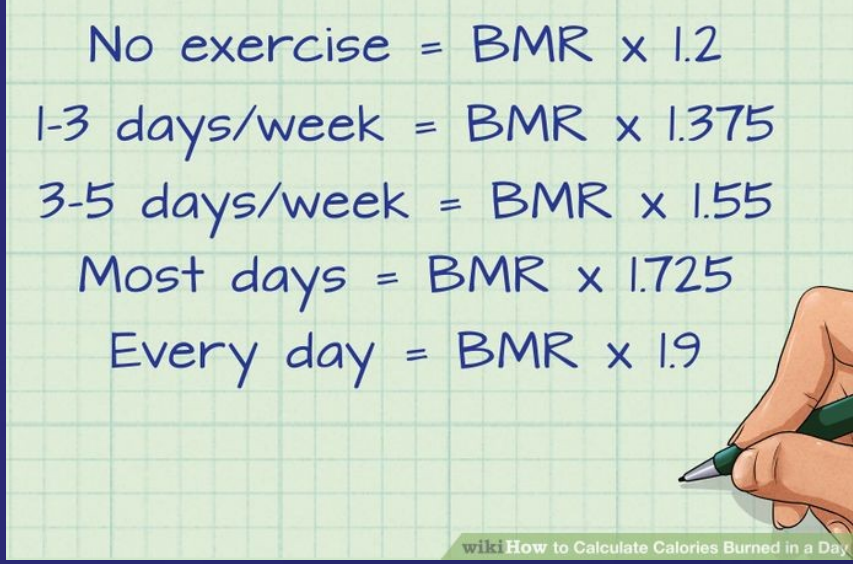
Principles of Dietetics

6. **Loss of food values** due to cooking must get due **consideration**. In addition, digestibility of a food also should be considered.

Principles of Dietetics

7. **The water intake should be sufficient**. However, in general, water is not considered as a food.

Calorie need



This must be satisfied. Question arises what is the calorie need of a given individual (whose diet is to be formulated) and how to calculate it ?

In an adult healthy man (= a man who is not gaining or losing body weight) the calorie intake = the calorie expenditure.

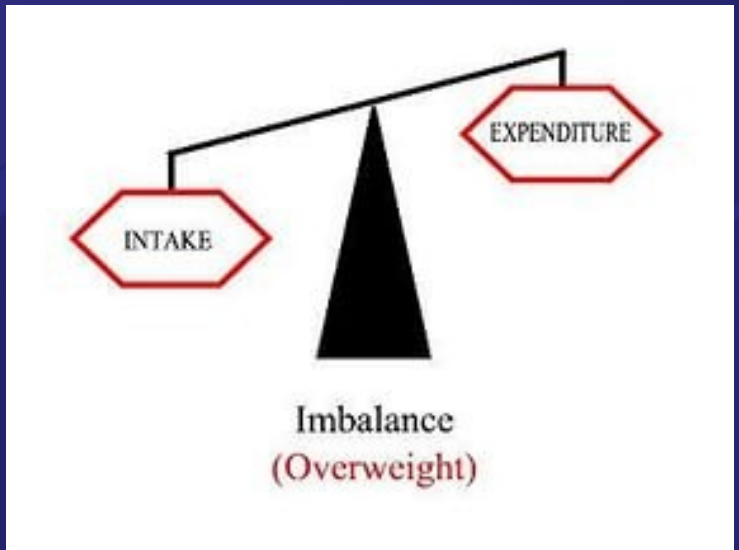
Again, the calorie expenditure = BMR + extra calories expended during various works.

BMR in a healthy adult person can be calculated, BMR is 40 K cal or 37 K cal, per sq m per hour in males and females respectively.

Calorie need

On an 'average', moderately working healthy adult male require about 2200 Kcal/day.

Excess intake of calories will lead to as stated earlier, obesity, whereas the reverse produces starvation.



Calorie need

Daily calorie needs

The principle of ***'appetite governing the amount of food to be taken'*** works excellently with the animals.

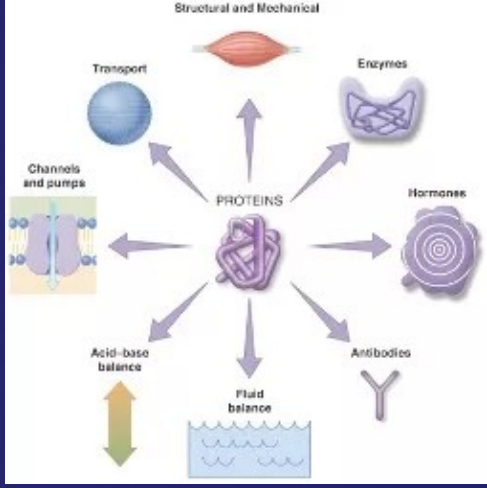
The animals, when given a free access to food, will eat only that much food required by it, not more not less.

However, some human beings are prone to eat excess and develop obesity when they have free access to food.

However, there is no easy and practical method (which can be used by the masses), to determine the exact number of calories needed in a given individual.

The best method for him is to follow appetite governing the amount of food and watch his own weight.

Protein



***Cause of indispensability**: protein of satisfactory quality must be present in the diet, in sufficient quantity.*

Protein is required for:

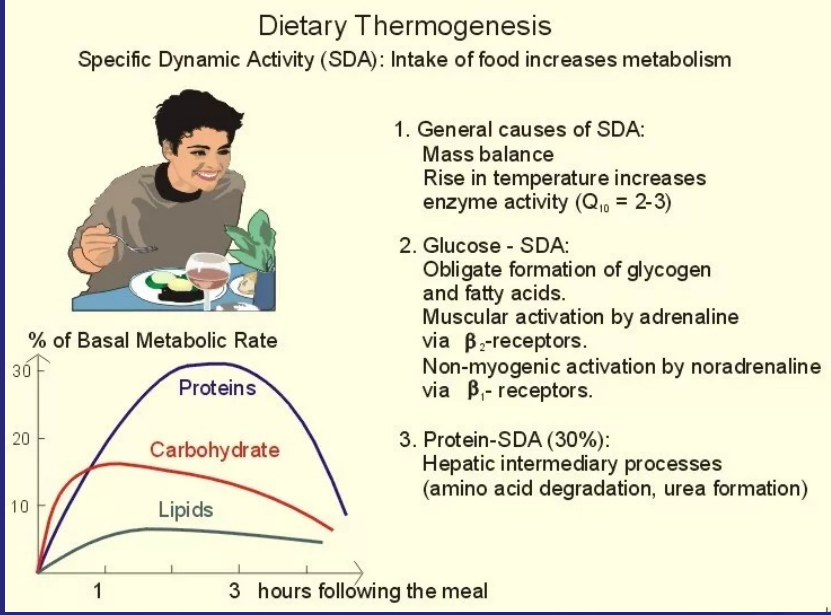
(i) *replenishment* of the lost tissues, lost due to wear and tear,

(ii) for accretion of new tissue during *growth, convalescence* and *pregnancy;*

(iii) for synthesis of *enzymes* (all enzymes are protein in nature), *protein hormones* (e. g. insulin, parathormone, ADH etc.) and *breast milk;*

(iv) for maintenance of concentration of plasma proteins. These are the reasons, which make food protein, an essential (essential = indispensable) article of diet.

Protein



Besides these reasons, there are **other reasons why protein is needed by the body**:

(i) Extra heat: protein helps generation of excess heat due to its SDA *(specific dynamic action).*

For this, people living in cold environment like to take extra protein in their diet.

By the same token, persons living in hot and tropical climates do not like to have *excess* protein.

(ii) many persons have a great fascination for such proteins like meat or fish which whets up their *appetite.*

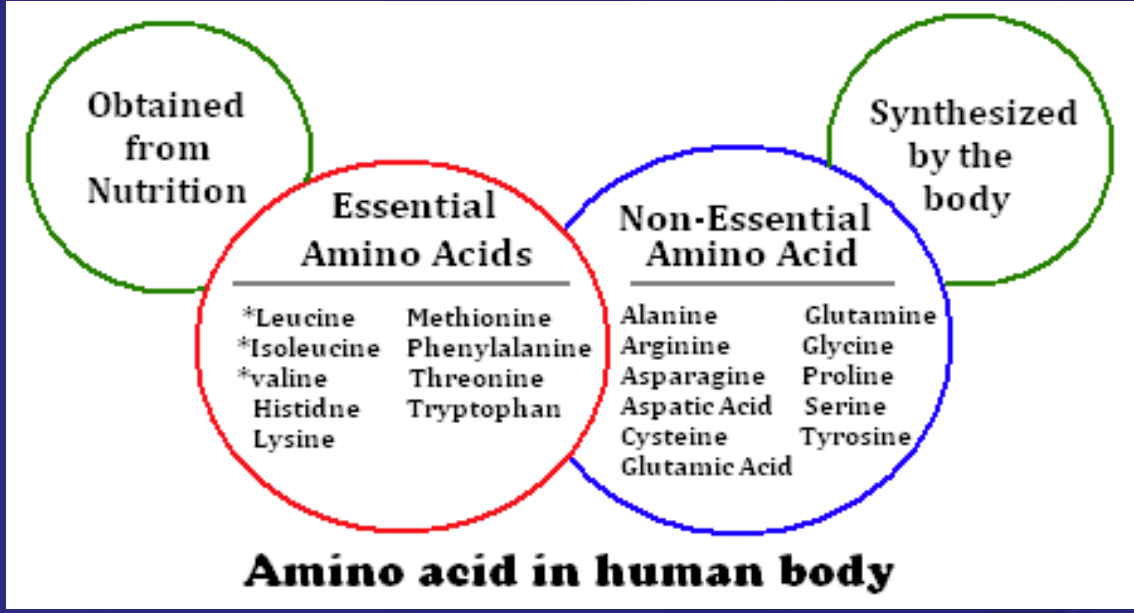
Protein

Of the 20 amino acids found in our body, some can be synthesized by the body whereas others cannot be synthesized.

Those amino acids which ***cannot* be synthesized**, obviously have to be supplied from outside in the form of food.

Such amino acids, which *must* be supplied from outside are called ***essential*** *(i.e., indispensable)* amino acids (*isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine).*

Protein



The great majority of proteins of our body contains all the (essential as well as non-essential) amino acids.

Therefore our food proteins should be such that they supply all the essential amino acids in addition to the non essential amino acids (**non-essential** amino acids, however, **can be synthesized in our body**, provided the raw materials for synthesis are available).

Protein

Proteins *that* ***contain all the essential amino acids*** are called ***first class proteins***.

Proteins in which **one or more essential amino acids are missing** are **called *second class proteins***.

As a rule, the *animal proteins* [that is proteins of animal origin (like the proteins of meat, fish, milk and egg)] are first class proteins.

One exception is, *gelatin,* which although an animal protein (obtained from tendons and ligaments) is a second class protein.

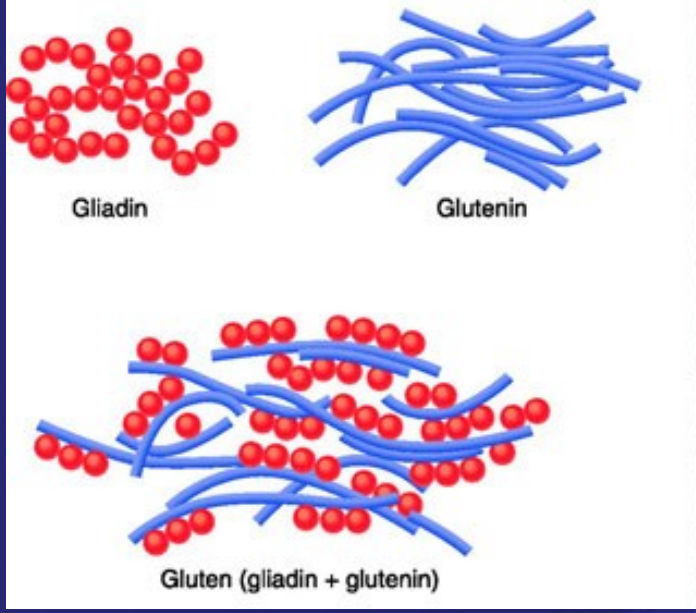
Protein

Some vegetable proteins (that is proteins of plant origin) are second class proteins. However, some vegetable proteins, e. g. *rice protein,* is first class protein.

Previously, *(unfortunately)* first class proteins and second class proteins were equated with animal and vegetable proteins respectively.

As it is now well known that many vegetable proteins are first class proteins, such equations are not made now.

Supplementary proteins



Wheat contains two proteins, ***gliadin*** and ***glutenin***.

Now, gliadin is poor in lysine and so it is an *incomplete* or second class protein.

Glutenin, which is also present in the wheat, is very rich in lysine.

When one eats, he eats not gliadin or glutenin in isolated way but eats wheat as a whole, so that the deficiency of gliadin is made good by glutenin.

This is an example of *supplementary role of proteins.*

Supplementary proteins

In the world of vegetarians *('vegans'),* this knowledge seems to be naturally present, although those vegans may be totally unaware of any idea of proteins, let alone supplementary role of proteins.

Biological value of proteins

Ingredient	Biological Value
Eggs	100
Fish Meal	92
Beef	78
Milk	78
Wheat	60
Corn	54
Wheat Gluten	40

Amino acid composition of our body protein may simulate closely or differ widely from the amino acid composition of the food proteins.

Where the similarity is close, the food proteins (provided they have been digested satisfactorily) can synthesize body proteins *more economically.*

Such food proteins (whose amino acid composition resembles that of our body proteins closely) are called ***"protein of high biological value"***.

In general animal proteins have high biological values.

Biological value of proteins

Conversely, where the amino acid composition of the food protein differs widely from that of our body protein, the food protein cannot be used by our body very economically.

Such proteins are called proteins of *low biological values.* Some vegetable proteins are of low biological value and some other vegetable proteins (e. g., rice protein, wheat protein) have a high biological value.

Biological value of proteins

According to the biological values, ranking of the protein can be (and has been) made. Thus, egg protein is superior to milk though both belong to the class of animal proteins.

For human infants, mother's milk protein has a superior biological value than cow's milk protein. If the biological value is high, *the amount of the food protein needed will be less.*

Therefore, in spite of the lower concentration of protein in mother's milk (compared to cow's), mother's milk is fully satisfactory from nutritional point of view, to the *human* baby.

Biological value of proteins

But it is important to remember that too much stress need not be given on biological values of food protein (excepting for the growing children).

From what has been stated in connection with supplementary protein, it is obvious that combinations of several food proteins, covers up any possible deficiency in the biological values.

Quantity of protein required

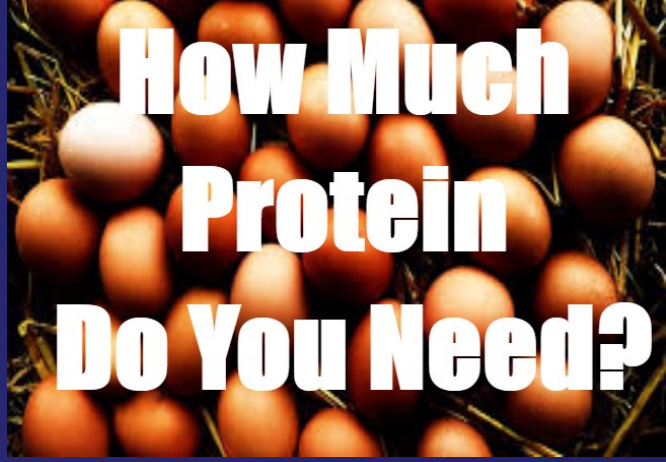
How much **protein is required per day per head**?

In the 1900s Chittenden in USA found that only 42 gms/ day for healthy adults is enough.

On the other hand, Voigt found from his studies on German workers that the daily requirement may be around 150 gms of protein.

These two represent two extreme ends of the view.

Quantity of protein required



According to a recommendation of BMA (British Medical Association) Committee of Nutrition, 11 % of the total calories should come from protein.

As an example, a person requires 2200 Kcal/day. 11 % of 2200 = 242 Kcal.

Now each gm of protein = 4 Kcal.

242 Kcal can come from 242 / 4 = 60 gms of protein approximately.

The most widespread idea is, an adult requires 1 gm/kg/ day of food protein.

Thus, if he (or she) weighs 65 kg, the protein requirement is 65 gm/day.

The protein requirement increases in the following conditions:

(i) ***Growing children.***

Infants require 3 to 5 gms of protein/kg body wt/day and most of the protein should be animal proteins or proteins of very high biological value.

Throughout the period of growth, (which completes around 18th year in the boys) greater proportion of protein is required.

Between 14^{th} to 16^{th} year in the boys, when there is again a fresh spurt of growth, heavier quantity of protein is to be given.

The protein requirement increases in the following conditions:

(ii) ***Lactation, pregnancy***. The protein requirement is about 1.5 gm/kg body wt/day.

(iii) ***Convalescence***.

If the food protein is mainly from proteins of very high biological values (meat, egg, fish) the amount of the daily requirements will be on the lower side whereas if the proteins are mainly from those of the lower biological values, the requirements will be on the higher side.

Protein rich foods

Meat (20 %), fish (20 %), egg (15 %), cow's milk (3.5 %) are some of the excellent sources of protein of high biological value.

Thus, 100 gms of lean meat (free from fat and bones) contain 20 gms of protein.

Protein rich foods

Dal (about 20 %), legumes (about 25 %), rice (10 %), wheat (10 %) are some examples of vegetable proteins.

Protein rich foods

Because of the quantity consumed, rice and wheat have assumed major importance as protein suppliers of Indian diet.

Soya bean is another vegetable rich in protein, but the quality of protein in soya bean is low.

Protein malnutrition

In the underdeveloped countries, protein malnutrition is a serious problem. One dangerous form of protein malnutrition is '**Kwashiorkor**'.

This disease was first reported in Africa, but it is quite common in India and other poorer Asiatic Nations.

It occurs in infants, and young children, who after weaning from breast milk cannot get cow's milk or any other good protein and instead have to thrive mainly on carbohydrate diet.

Protein malnutrition

There is also **a** concomitant lack of energy (calorie) supply and hence the disease should be called a ***'protein-energy starvation'***.

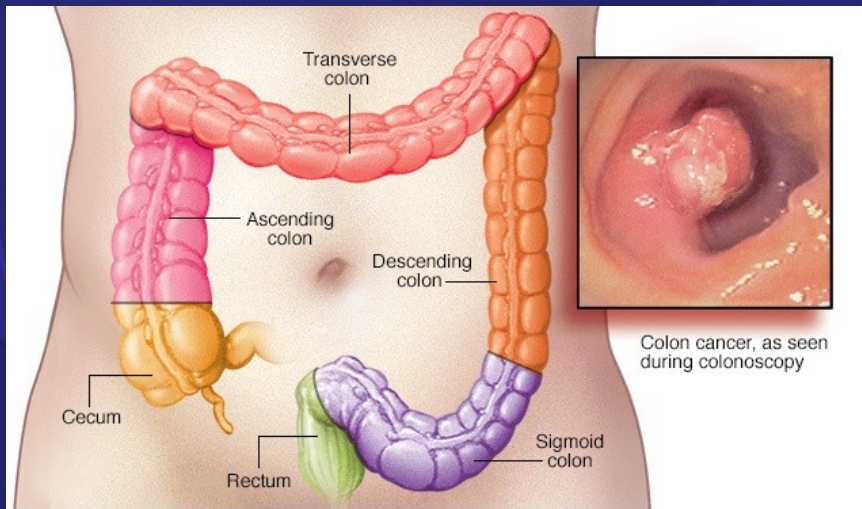
Victims cease to grow, become edematous and show dermatitis (due to associated vitamin deficiency).

A very important laboratory finding is low serum albumin concentration.

Effects of excess protein intake

It is often stated excess protein eaters are prone to suffer from *gout,* **hypertension and constipation**. It is also sometimes stated that an excess protein eater *begins to look* **older than his or her real age**.

The European and North American pattern of food (= a food containing high proportion of meat), perhaps is a heavy predisposing factor for **cancer of the colon**.



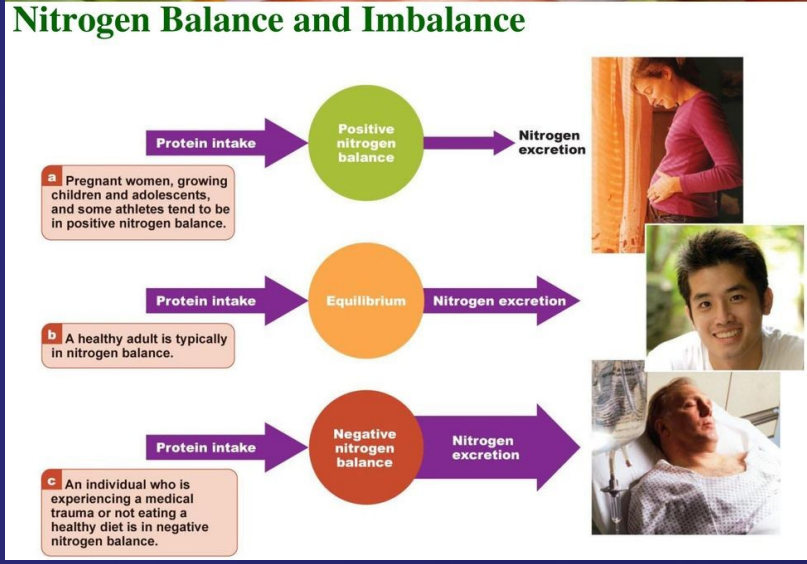
Effects of excess protein intake

Proteins, when taken in excess, produce a rise of body temperature due to its high SDA (specific dynamic action).

In colder climates, this is beneficial to the person but in tropical countries like India, this is deleterious.

Further, heavy physical workers and sportsmen may find, due to the high SDA values of food protein, that excess amounts of proteins cause deterioration of his (or her) efficiency (as higher body temperature reduces the physical working capacity of an individual).

Nitrogen balance



NH_2 group of deaminated amino acids are removed from the body as urinary nitrogen (urea).

Thus from the quantity of nitrogen excreted, the protein equivalent can be calculated.

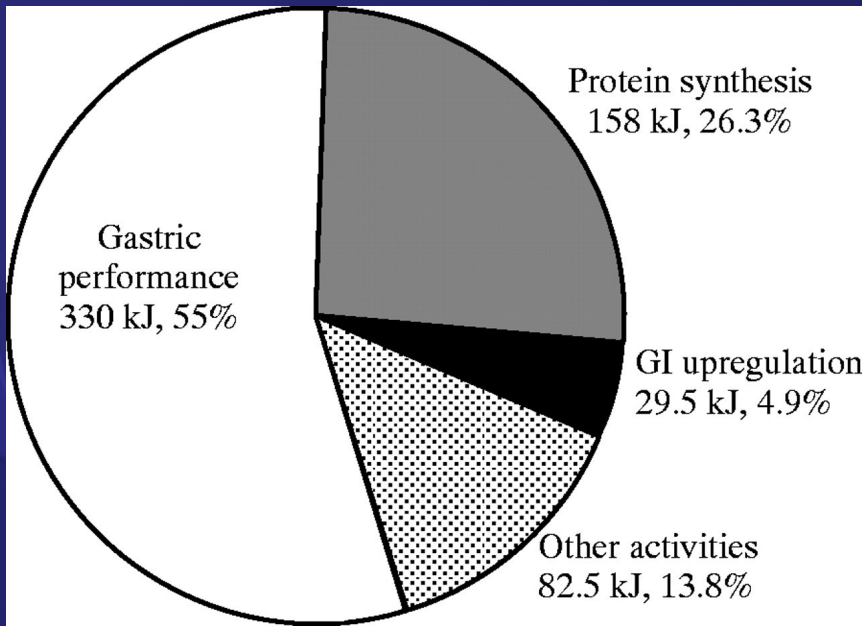
In an adult, due to wear and tear, endogenous protein breakdown occurs but is **exactly** replenished by food N_2 and he is thus in N_2 equilibrium.

Similarly, during growth, there is +ve N_2 balance, ie, more N_2 input occurs than N_2 excretion and so on.

Specific dynamic action of food

All the three proximate constituents of foodstuff, viz protein, carbohydrate and fat, exhibit this phenomenon.

However, it is with the protein, the phenomenon assumes great importance, because the SDA value for protein is highest.



Specific dynamic action of food

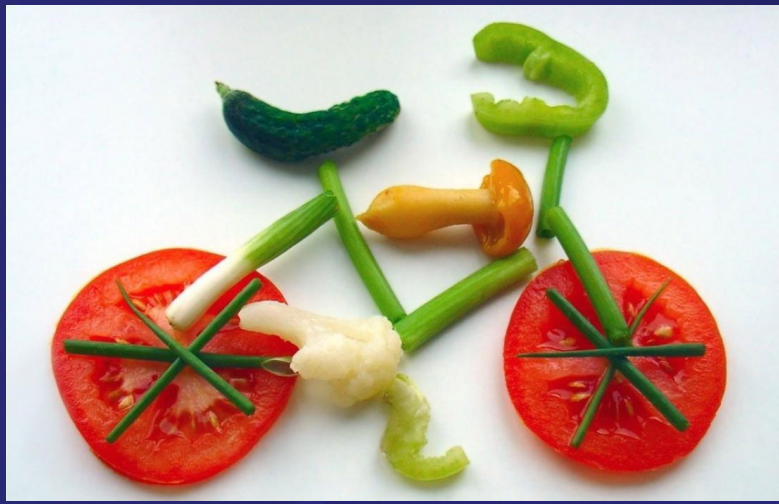
An example will help to understand the phenomenon of SDA:
25 gms of protein is supposed to yield 100 Kcal of heat.
But if 25 gms of protein be ingested, *within the body,* not 100 Kcal but 130 Kcal of heat will be evolved.
This extra 30 Kcal is due to the SDA of protein.
Therefore, SDA of protein is 30 %; similarly, for fat and carbohydrate, the values are approximately 13 % and 5 % respectively.

Specific dynamic action of food

The cause of SDA of protein is believed primarily to be due to two reasons:

(I) deamination of amino acid;

(ii) urea synthesis,



both of which produce heat.

For glucose it may be the conversion glucose into glycogen.

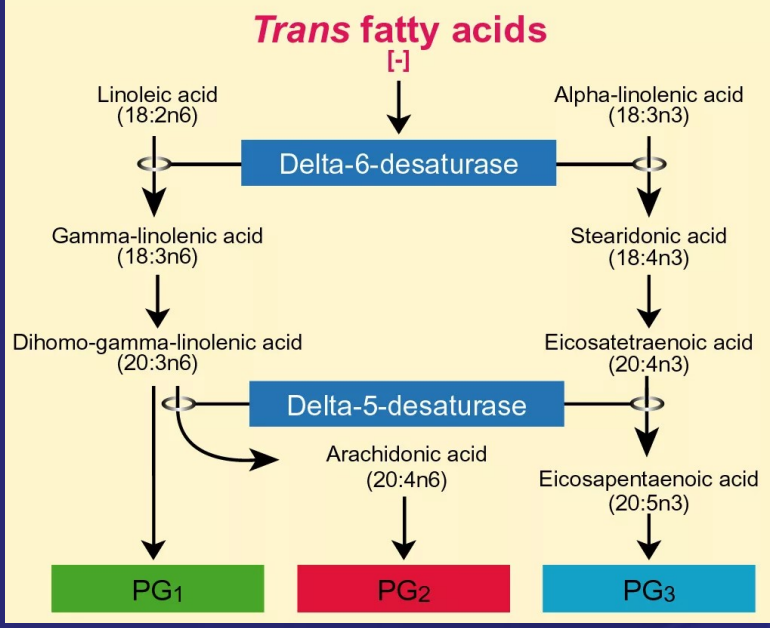
While formulating a diet, provisions for SDA must be kept.

Fat

Is fat indispensable in the food?

By the term 'indispensable', it is meant that if this item is absent in the food, there will be deleterious effects on health.

Fat



There are a few fatty acids, called '**essential fatty acids**' **(EFA)** which **cannot be synthesized** by the animals and therefore have to be supplied through the food. These essential fatty acids are ***linoleic***, ***linolenic*** and ***arachidonic acids***. Incidentally all these acids are also *'polyunsaturated'* fatty acids (that is, fatty acids which have more than one double bond).

People who consume polyunsaturated fatty acids (vegetable oils) do not develop ***hypercholesteremia easily****.*

Fat

In growing human infants, essential fatty acid deficiency has been reported. It has also been reported, under extraordinary circumstances, in adult persons too. However, the incidences of such EFA deficiency in adults are very rare.

Eicosanoids (= *prostaglandins, leucotriens and thromboxane)* are derived from arachidonic acid. *It is advocated that about 2 % of total energy expenditure should come from arachidonic acid.*

Fat

Fat-soluble vitamins

Vitamin A
Vitamin D
Vitamin E
Vitamin K

Besides, the **fat soluble vitamins** (A, D and E) are present in the edible fats, A and D in the animal fats and E in the vegetable oils.

For all these reasons, on the whole, some amount of fat, particularly polyunsaturated fatty acids are desirable in the food.

However, the middle aged or elderlies should take low quantities of fat.

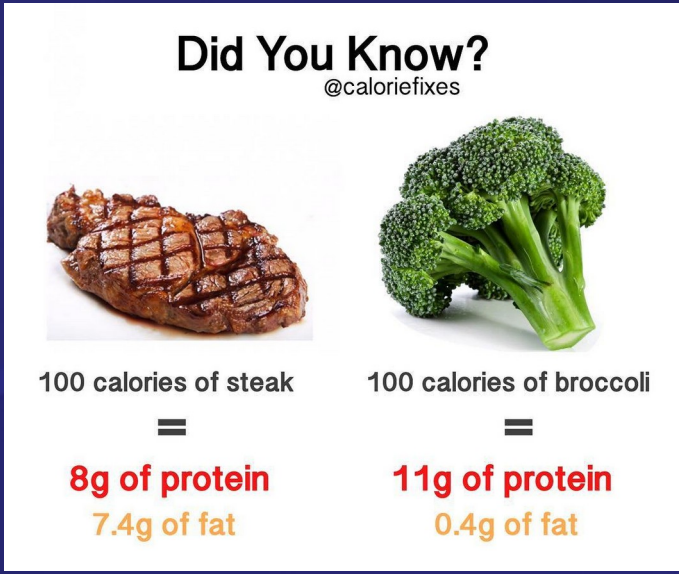
Advantages of fat in the diet

(i) **1 gm of fat yields 9 Kcal of heat**.

Therefore, where the calorie requirement per day is very large (e. g. hard manual laborers), a greater amount of food fat is desirable as it reduces the bulk of the food.

A *great bulk of the food is inconvenient.*

Further, during cooking, carbohydrate imbibes water and increases the bulk of the food to a still greater extent.



Advantages of fat in the diet

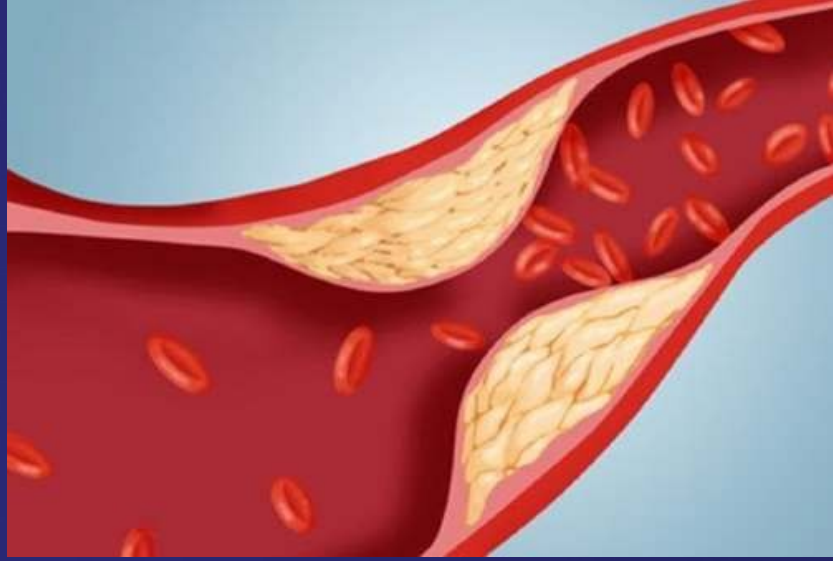
A classical example is the lumbermen (of yesteryears) of Sweden and Canada who used to consume about 6,000 Kcal/day and 60 % of the energy came from food fats. Champion sportsmen during their training period consumes heavier quantity of fat.

(ii) **Fat makes the food more palatable**. As a rule, attractive and palatable items of food are those which contain good deal of fat or oils.

(iii) **Fat prevents too rapid emptying of the stomach and thus prevents the need of too frequent eating**.

(iv) As already stated, **fat supplies EFA as well as vitamins A, D and E** in the food.

Dangers of excess food fat



1. ***Atherosclerosis***.

People who ingests greater quantity of *saturated* fats, are prone to develop hypercholesteremia and atherosclerotic disorders (coronary thrombosis, cerebral thrombosis and so on).

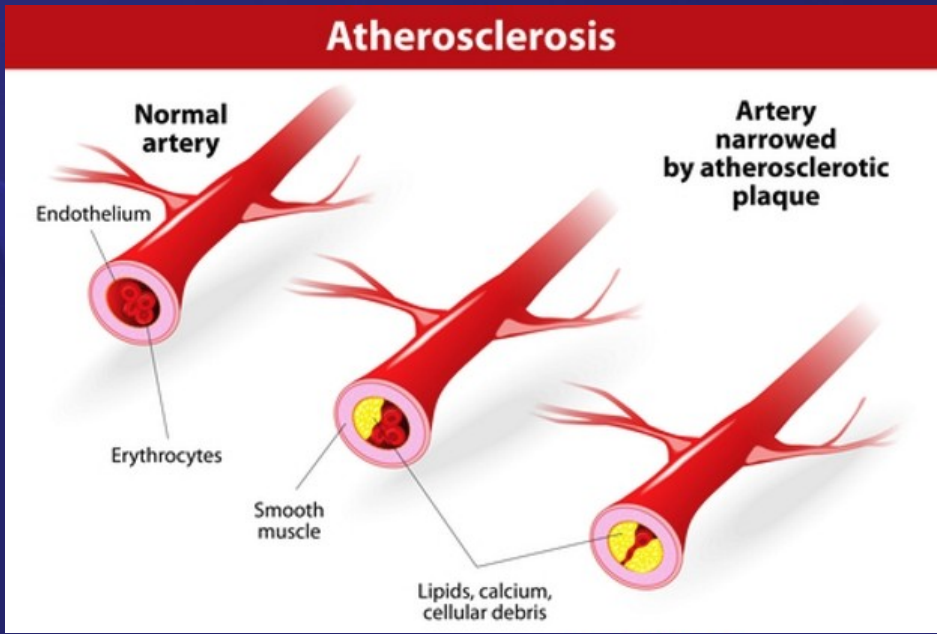
As a rule animal fats like tallow (beef fat), mutton fat, lard (pork fat), ghee etc and *hydrogenated* fats like *'Vanaspati'* are saturated fats.

Edible oils like ground nut oil, safflower oil etc are rich in polyunsaturated fatty acids.

Dangers of excess food fat. Saturated and unsaturated fats

Oils containing rich amounts of polyunsaturated fatty acids *reduce* the serum cholesterol level and hence are antiatherosclerotic.

Coconut oil is an exception; although of vegetable origin it is a saturated fat.

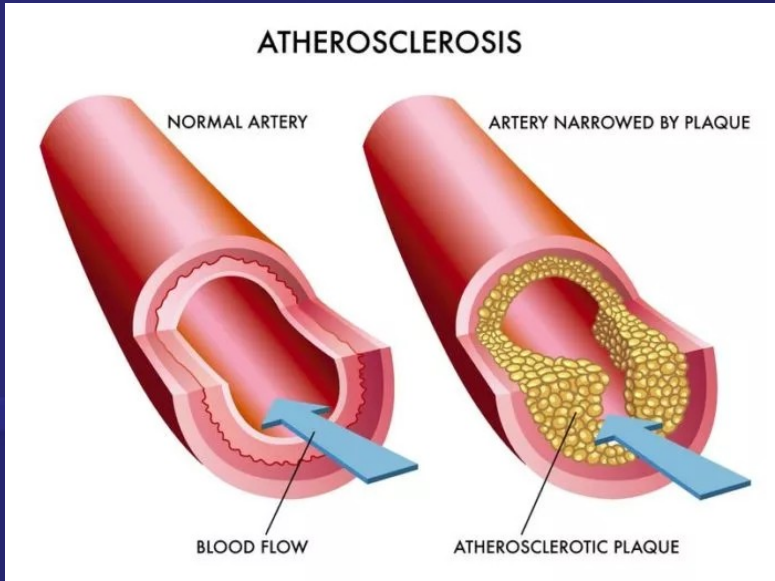


Dangers of excess food fat. Saturated and unsaturated fats

All races which consume heavy amounts of meat, concomitantly ingest heavy quantity of saturated fats and have greater tendencies to suffer from atherosclerotic disorders.

Examples of the Japanese may be cited. A Japanese in Japan eats very low quantity of saturated fat and coronary thrombosis is not a common disease in Japan.

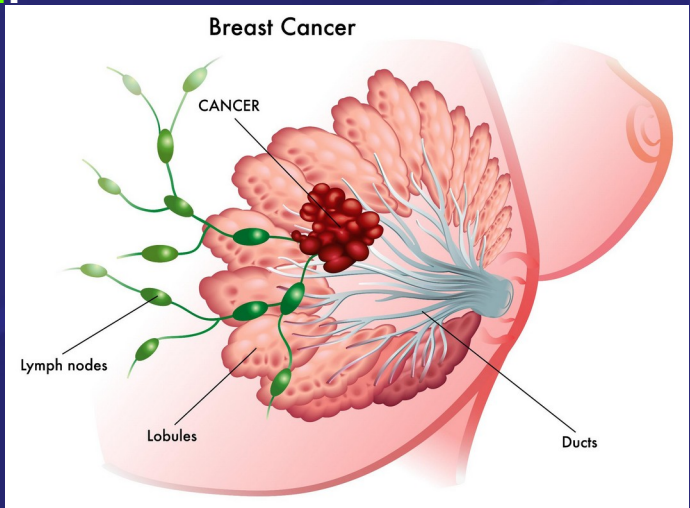
But the Japanese of USA, who consume the American styled food containing high quantities of saturated fat, suffer frequently from coronary heart disease.



Dangers of excess food fat. Saturated and unsaturated fats

2. Another disadvantage of fat is that, it is **comparatively undigestible**. Too much fat in a single meal can produce acute indigestion. Saturated fats are usually more indigestible.
3. There are strong reasons to suspect that women (particularly obese women) consuming excess fat are more susceptible to **cancer of the mammary gland**.

More important, *unlike atherosclerosis, both saturated and unsaturated dietary fats can predispose to mammary cancers.*



Optimal requirement

1. The amount of dietary fat which will satisfy a per son varies from race to race.

Orientals, particularly east and south east Asiatics, consume and remain satisfied with very low amounts of fat (sometimes with only **20 gms/day**) whereas Westerners, particularly the north Europeans and Canadians, consume great quantities of fat (often **150 gms** or more for a moderately working man).

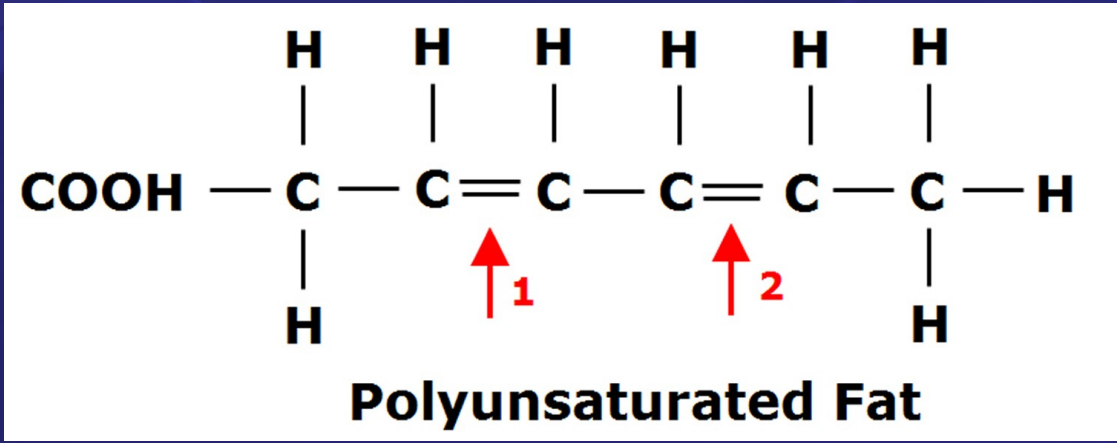
The low fat consuming orientals, however, do not suffer from any disease for their low fat intake.

Optimal requirement

2. Many authors prescribe that **25 %** (but no more) **of the total calories consumed, should come from fat**.

Thus, for a person consuming 2,500 Kcal/day, 625 Kcal (i.e., about 70 gms) but not more, may come from fat.

A good portion of food fat should come from the oils (polyunsaturated fatty acids).



Carbohydrate

Quantity required

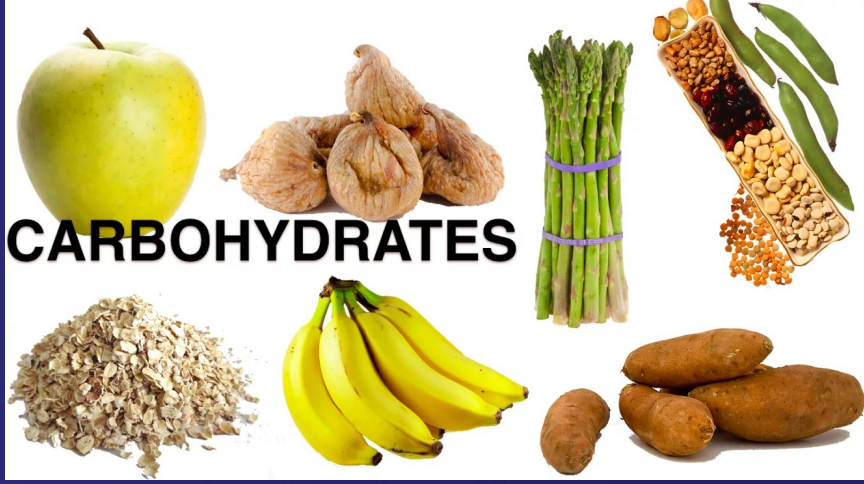
The rest of the energy should come from carbohydrate.

Example

Let a man, weighing 70 kg, require 2500 Kcal/day.

How much of it should come from carbohydrate?

Carbohydrate



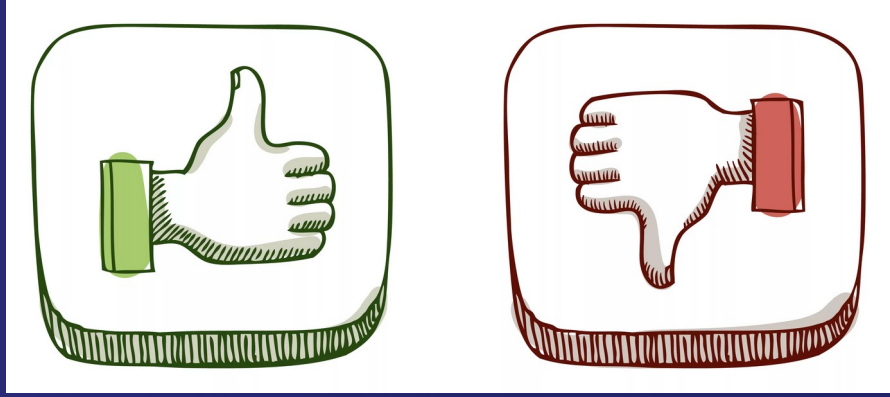
Protein requirement is 1 gm/kg body wt/day = 70 gm protein = (70 x 4) = 280 Kcal.

Fat requirement is 25 % of 2,500 Kcal = 625 KCal (= 70 gms of fat).

The rest, that is [2500 - (280 + 625)] = 1,600 Kcal (approx) must be provided by carbohydrate.

Carbohydrate requirement is 1,600 / 4 = 400 gms/day (= 64 % of calories).

Carbohydrate



Advantages and disadvantages

Carbohydrates are the cheapest of all foodstuff. However, they are apt to produce fermentation in the gastrointestinal tract.

Among the poorer sections of Indians over 80 % of the calorie needs are satisfied by the carbohydrates.

Carbohydrate rich foods are rice (about 70 %), wheat (about 70 %), cane sugar (100 %), potato and so on.

Carbohydrate

Protein sparers

The non essential amino acids can be synthesized provided the raw materials are available in the body.

Intermediaries of glucose and fatty acids are such raw materials and the NH_2 group can be obtained from transamination and deamination processes.

Therefore, excess carbohydrate and fat intake can reduce the need of food proteins.

For this, carbohydrates and fats are called *'protein sparers'.*

Vitamins and Minerals

Diet should be rich in vitamins. Recall further, vitamin A has anticancer effect.

Of the minerals, Na, K, Ca, Fe, iodine and fluorine are important.

In short, between 10 to 15 gms of *NaCl* are consumed/ day.

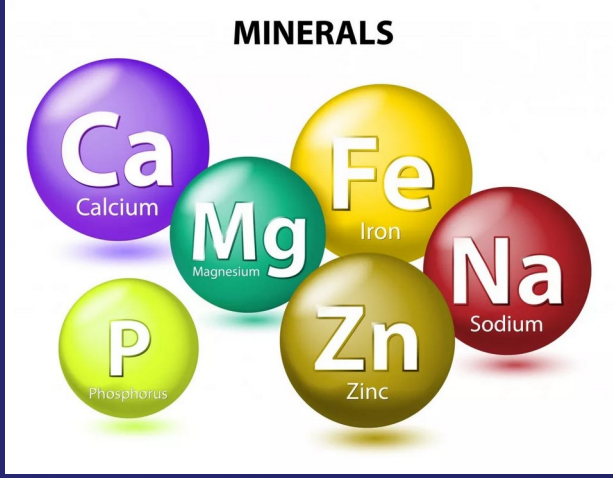
If the supply is short, the body tries to retain Na tenaciously (that is, Na excretion is remarkably reduced).

Vitamins and Minerals

Short supply of Na, however, from *nutritional* point of view, is not important because ordinarily it does not occur (shortage of Na occurs in some special conditions, e. g. some forms of renal disease. They are, however, not important from nutritional standpoint).

Excess Na supply is however important as our ability to excrete sodium is not highly satisfactory; excess sodium in food may help to develop high blood pressure. There are conditions where it is necessary to use a *'salt free'* (Na restricted diet). **Foods comparatively deficient in sodium are rice, wheat, fruits, milk and sugar.**

Vitamins and Minerals

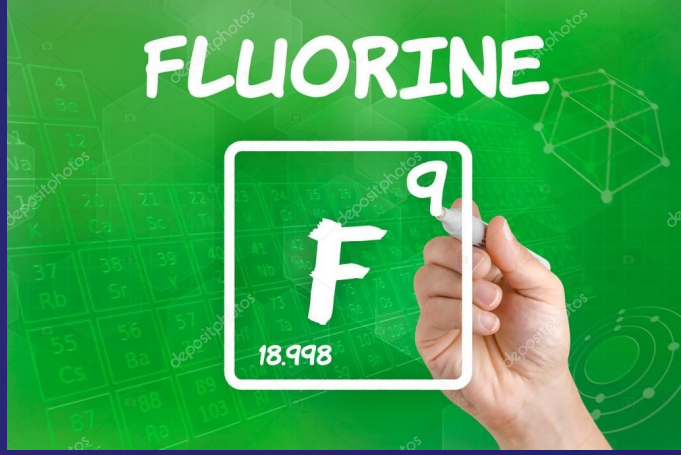


The daily intake of **K** is between 2 to 3 gms in average. Plant foods are rich in K.

Calcium is obtainable from milk, milk products and egg. Growing children and lactating women require more calcium.

Iodine is obtainable from sea fish and sea water. People living far away from the sea should be supplied with *table salts containing iodine,* otherwise they may develop goiter.

Vitamins and Minerals



Iron rich foods are *egg, liver, meat and some vegetable food. Milk is, deficient in iron.*

Fluorine deficiency causes 'mottlings' on the teeth and *dental caries.*

Fluoride ions are widely distributed in nature but our chief source of fluoride are plants, foods and water.

In certain areas of the world, drinking water is deficient in fluorine.

That is why fluoride ion is added to the water supply to the extent of 1 ppm (part per million) in some countries.

Fibers and Roughage

Leafy vegetables containing a cellulose or hemicellulose coating, are indigestible in human intestine.

Hence if such substances are present, they tend to increase the bulk of the feces and *'mass peristalsis'* is favored, and constipation can be avoided.

Great amounts of leafy vegetables however can produce diarrhea.

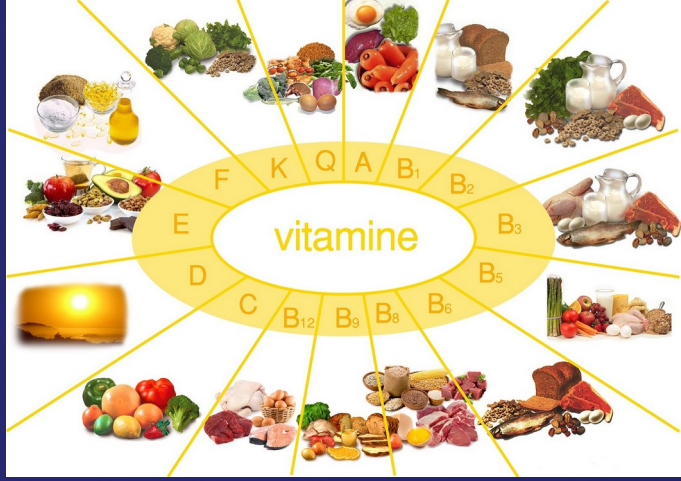
Fibers and Roughage

Plant components (cellulose/ hemicellulose/pectins/ lignins etc.) which cannot be digested by the enzymes of our digestive tract are collectively called fibers.

Strong evidences indicate that, lack of fibers in the diet predispose **colorectal cancer**, **breast cancer**, **diverticulosis** and **coronary heart disease**.

Grams, peas and *dal* contain good deal of indigestible vegetable fibers.

Vitamins

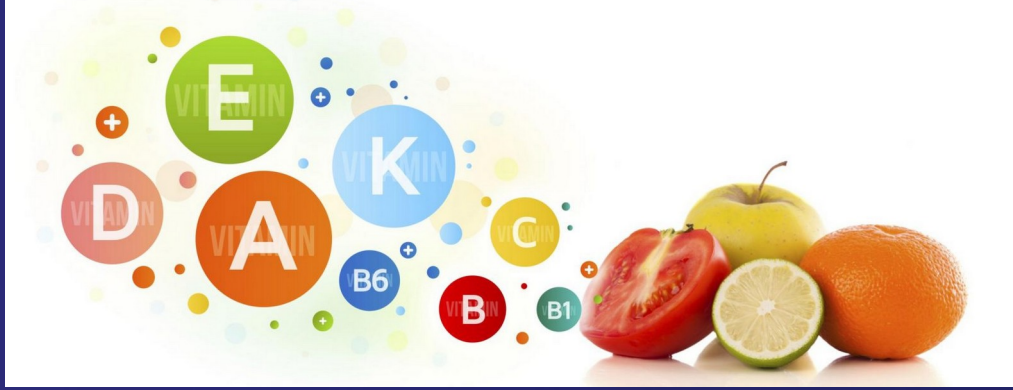


Definition

The vitamins are *"**accessory food factors**"* which are organic in nature and must be supplied from outside to maintain the *health, growth* and the *state of well being* of a person.

As a rule, only trace quantities of vitamins are required by the body.

Vitamins



'**Accessory food factors**' are substances which are to be *taken, not* for obtaining calories (in contrast to carbohydrate, fat and protein of food, which between them take care of the calorie needs of the person) but for some other purpose.

Without these accessory factors the person will suffer from ill health and may even die.

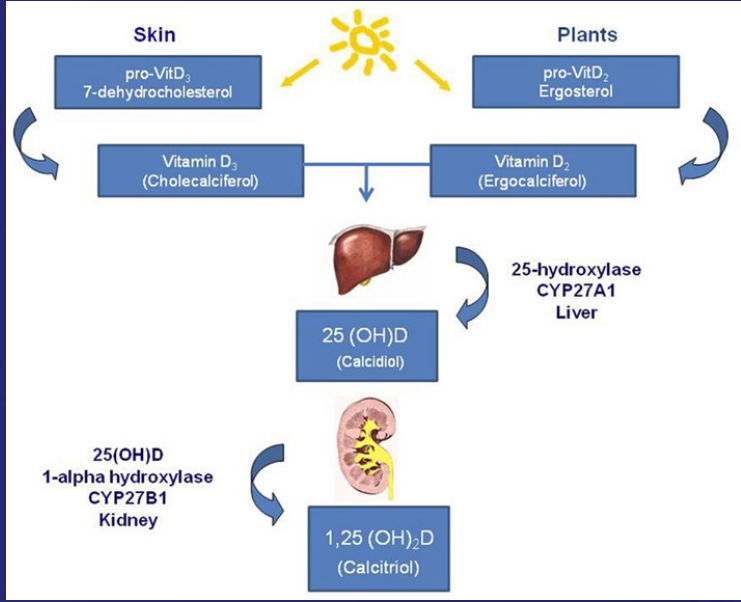
Vitamins are such accessory factors.

Vitamins

Vitamins cannot be synthesized in the body. Thus, they must be supplied from outside, e. g., through foods. Some vitamins (e. g., vitamin K, some members of vitamin B complex) are synthesized by the *bacteria of the intestine.*

However, the intestinal content is, from the physiological, developmental and clinical points of view, outside the body (so that synthesis by intestinal bacteria is to be considered as outside the body).

Vitamins



One apparent exception is vitamin D.

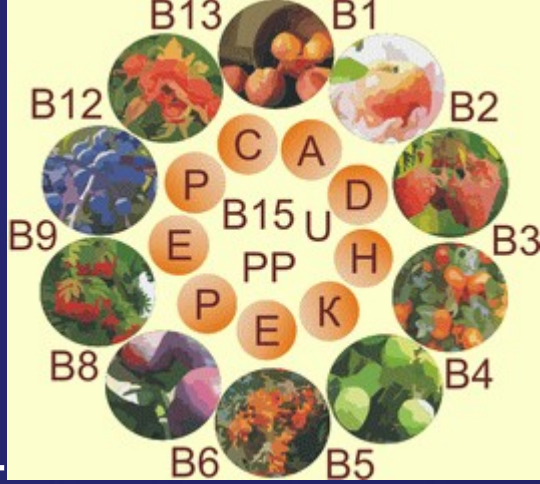
7 dehydrocholesterol, is normally present in our skin and on exposure to sunlight is converted into vitamin D.

Sunlight therefore can replace dietary vitamin D.

Vitamins as a rule, are required in trace quantity and our daily foods, as a rule, contain very small amounts of the vitamins.

However, the amount is usually sufficient. One apparent exception is vitamin C (ascorbic acid) whose daily requirement is not exactly a trace quantity.

Classification of Vitamins



The vitamins are divided into two great classes:

- ***fat Soluble Vitamins –*** A, D, E, K;
- ***water Soluble Vitamins –*** B complex and C.

Later on it was found that within the water soluble vitamin B, many different vitamins (e. g, thiamine, riboflavin, niacin etc.) are present.

So today, the term 'vitamin B' is no longer used and instead, *'vitamin B complex' is used.*

Thanks for your attention!