3 BIOCHEMISTRY AND BIOTECHNOLOGY

In this chapter you will learn:

- Definition of metabolism and explanation.
- Introduction to enzymes, their role in metabolism and our daily life.
- Composition of blood, its types and functions.
- DNA as a hereditary material
- Introduction to genetic engineering and its role in agriculture and live stock.
- Improvement of crops and disease control.
- Introduction to antibiotics and vaccines.
- Recycling of waste materials.

Biochemistry is a branch of chemistry which deals with all the chemical reactions taking place in living organisms like plants, animals, bacteria, etc. These chemical reactions can help in the synthesis (anabolism) or breakdown (catabolism) of biological molecules. The digested food become part of the body due to anabolic reactions while respiration is a simple catabolic reaction. Its knowledge has been used to produce a large number of material for the benefits of human beings. The term biotechnology was introduced in 1970. The techniques of biotechnology can be used to alter the genetic make up of microscopic organisms to produce useful materials like enzymes and hormones etc.

3.1 Metabolism

A large number of chemical reactions take place in animal and plant cells and cells of biological organisms which are collectively called **metabolism**. Metabolism consists of two types of reactions which can either synthesize molecules (anabolic reactions) or break the complex molecules. Catabolism is a catabolic reaction in the result of which the complex organic molecules are broken down into simple molecules. Catabolic reactions release energy. This energy can be used in several biological processes.

In the result of catabolic reactions carbohydrates, proteins and lipids are broken down and oxidized with the help of various enzymes. These reactions release energy which is used to perform many activities in the animals. Anabolism is a synthesining process and the production of carbohydrates is one of its example in which plants use sunlight, carbon dioxide and water. This process is called photosynthesis.

The sum of all energy using and energy releasing reactions is called **metabolism**.

Digestion and Assimilation

Digestion is a process which breaks down large food particles into smaller molecules. These smaller molecules can then be absorbed by cells for synthetic purposes which is called **assimilation**.

Digestion of food is necessary to split the macromolecules like carbohydrates , proteins and fats into simple molecules. These are necessary to be used by organisms to build new compounds. After this the products of digested material is absorbed by the cells of animals and are used either to produce new protoplasm or to provide energy.

Carbohydrate Metabolism

Wheat, rice, corn, maize are the best sources of carbohydrates. The end products of carbohydrate are simple sugars like glucose, fructose and galactose. One gram of carbohydrate can supply 3.8k calories of energy. The carbohydrates are the cheapest source of diet which provide us the required energy. Excess carbohydrates are converted to glycogen and are stored in muscles and liver.

Fat Metabolism

There are two sources of fats. We can obtain animal fat from butter oil (ghee) butter or cream, fatty meat and fish oil. The other source of fats is plants like sarson (brassica) , olive, coconut, maize, soya bean, cotton seed, sunflower and peanut. Fats are made up of glycerol and fatty acids. They are digested and absorbed by small intestine. Excess fats may be stored in the adipose (fat storing) tissues of the body. During glucose deficiency or starvation, fats are used in respiration in place of glucose.

Protein Metabolism:

Digestion of protein starts in the stomach. Undigested protein is digested by an enzyme and is converted into amino acids. These amino acids can be used for the synthesis of new proteins or oxidized to provide energy to the body. Other than this during the deficiency of carbohydrates, proteins are the effective source of energy.

3.2 Enzymes:

Enzymes are biological catalysts. A catalyst is a substance which can change or speed up a chemical reaction. Enzymes catalyze biochemical reaction and are protein in chemical structure. Enzymes speed up different catabolic and anabolic reactions.

Enzymes are required in very small amounts. They are very specific in their reaction. For example, amylase acts on starch but not on proteins or fats. The substances on which the enzymes act are called **substrates**. The specificity of an enzyme is due to its shape.

Some enzymes need other compounds to complete catabolic reactions. These are called **coenzymes**. Coenzymes are non protein substances.

Role of Enzymes in our Daily Life

Enzymes play an important role in our daily life. They are useful in industry. Enzymes are used in chemical and pharmaceutical industry. They are used in cheese production. Enzymes are commonly used in food processing industry. The enzyme papain is obtained from papya and is used as a meat tenderizer.

3.3 Blood and its Functions

Blood is the most important fluid of human body. It transports digested food and oxygen to the cells of all parts of the body. It brings back the useless products of metabolism into kidneys and liver. Blood is a very complex fluid. It consists of a liquid blood plasma in which blood cells are suspended.

Red blood cells, (erythrocytes) white blood cells (leucocytes) and platelets float in the plasma. The fluid part of blood with out blood cells is called **plasma**. If we remove blood clotting protein (fibrinogen) from plasma then the remaining fluid is called **serum**. The blood cells are helpful in transport of gases, white blood cells control body immunity system and blood platelets are helpful in blood clotting.

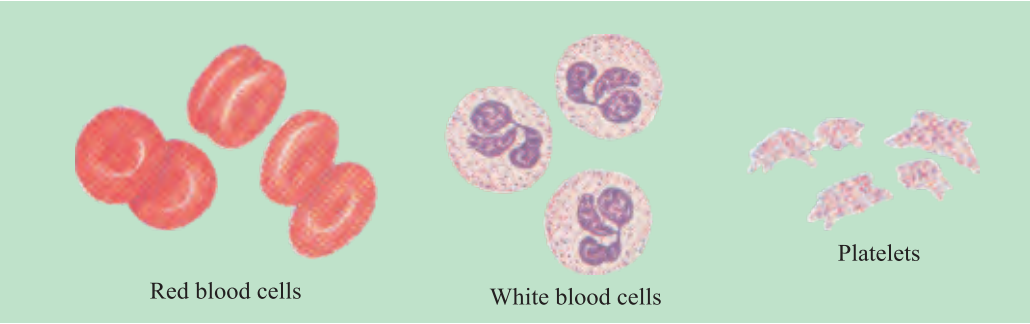


Fig. 3.1 Blood Cells

Blood Groups

Human blood appears simply same but chemically people have different types of blood . This difference is based on antigen present on the surface of red blood cells. The human blood is divided into A, B, AB, and O groups on the basis of antigens and antibodies and is called **ABO system** of blood.

If a certain person belongs to A group of blood then this is due to the A antigens present on the surface of red blood cells. If another person's red blood cells have B

Landsteiner in 1902 divided human population in four groups on the basis of blood groups

antigens then he belongs to B group. Type AB individuals have both A and B antigens. Type O individuals are known as universal donor because their blood cells carry neither A nor B antigens. They can donate their blood to any person. Type AB individuals are universal recipients because their red cells have both antigens and they can receive blood from any individual.

Table 3.1 Characteristics of ABO Blood groups

Blood Group	Antigens on RBCs	Type of antibodies in plasma	Donor	Recipients
A	A	B	A, O	A, AB
B	B	A	B,O	B, AB
AB	AB	None	A,B,AB,O	AB
O	None	AB	O	A, B, AB, O

There is a second blood group system called **Rh system**. It is based on another red blood cell antigen called the **Rh factor**. A can be Rh-positive or Rh-negative depending on the presence or absence of Rh factor. A pregnant Rh-negative mother cannot receive Rh-Positive blood because it can harm unborn Rh-Positive blood (inherited from father). It is dangerous and the mother is injected with anti Rh antibodies after delivering her first Rh-Positive body.

Table 3.2 Rh-Factor System

Blood of the type of Rh-factor	Type of antigens or RBCs	Type of antibodies in Plasma	Matching Recipients	Matching Donors
Rh^+	Rh^+	Rh^+	Rh^+, Rh^-	Rh^+
Rh^-	None	None	Rh^-	Rh^-, Rh^+

3.4 DNA as Hereditary

The information for hereditary characters of a person are present in his genes. These genes are made up of a chemical compound called **DNA** or deoxy ribose nucleic acid and are part of the chromosomes located in the cell nucleus. DNA is made up of building blocks or units called **nucleotides**. Nucleotides are composed of a base, sugar and a phosphate group. These nucleotides are present in pairs and form double helical molecule called DNA.

The special parts of DNA has coded information and these parts are called **genes**. The bases are specifically arranged on DNA.

When a DNA molecule produces another molecule like itself then this process is called **DNA replication**.

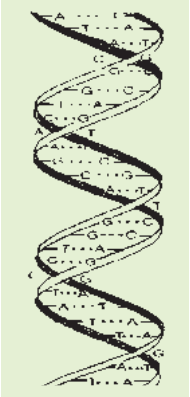
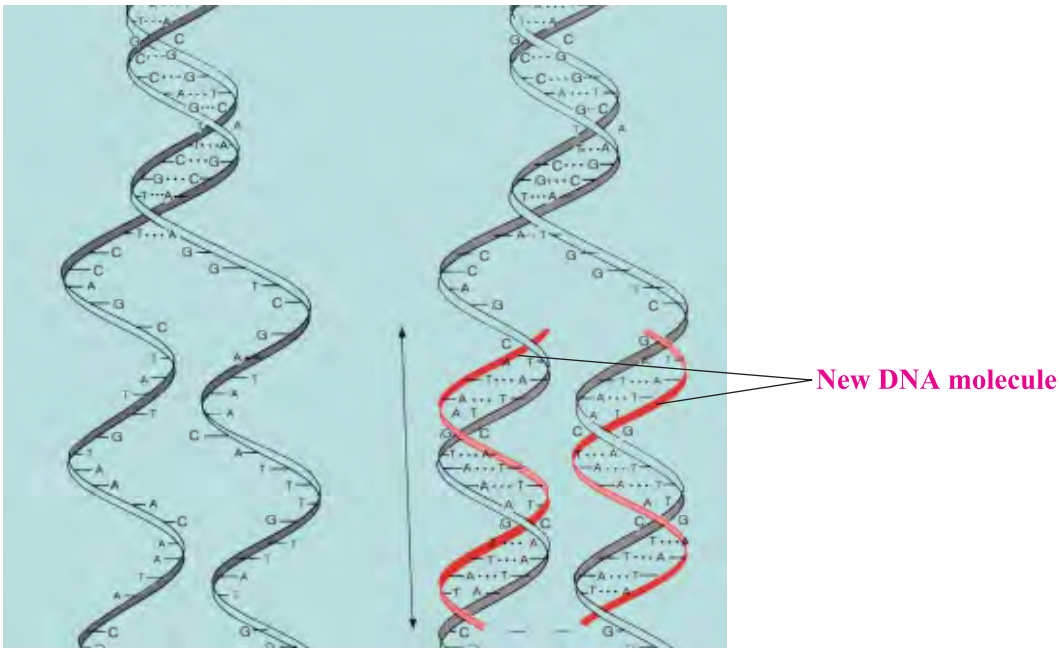


Fig. 3.2 DNA molecule

DNA is present in all the biological organisms. A child receives its DNA from both the parents. The characters of an individual, for example, skin colour, height, fitness, etc. are transferred to its offspring inheritedly. The defects in DNA are responsible for certain diseases like diabetes and haemophilia which are transmitted from parents to their offspring.

A set of all the genes in a cell is called **genome**. Human genome consists of 3.2 billion DNA letters or base pairs. The map or nucleotide sequence of 99.9 percent of human genome has been completed. This information is very important for medical science.



(a) Opening of DNA molecule (b) Formation of new DNA molecule

Fig. 3.3: Replication of DNA

3.5 Genetic Engineering

Genetic engineering is a set of techniques used to transfer genes from one organism to another. Individual genes can be cut off from the cells of one organism and inserted into the cells of another. The genes from different sources can be combined in a test tube and then transferred into living cells. This technique is called **genetic engineering.**

Role of Genetic Engineering in Human Welfare

Any organism which receive a foreign gene is called a **transgenic organism**. Following are the steps for the production of genetically engineered organism.

i) Identification of the gene of interest.
ii) Removal of the gene from the donor.
iii) Conversion of the gene into chromosome or DNA.
iv) Introduction of the desired gene-carrying into the recepient.

Significance of Genetic Engineering in Agriculture and Livestock.

Genetic engineering has revolutionized the agriculture which is apparent from the following examples.

i) Production of high yield crop varieties and animals (milk and meat production)
ii) Improvement in the nutritional quality of edible parts of plants.
iii) Introduction of herbicide (weed killing chemicals), pesticide (insect killing chemical)
iv) Increase in the shelf-life of fruits and vegetables
v) Transfer of nitrogen-fixing genes into non-legumes (wheat, rice, etc)
vi) Improvement in fruit quality.

1) Production of high yield crops

We can use the techniques of biotechnology to obtain genetically modified (GM) varieties of plants. It has been observed that most of the high yield crops or fruit trees are quite susceptible to diseases. It is quite desirable to introduce the disease resistant genes into high yield disease check plants.

2) Production of high yield animals

It is desirable to produce high milk and meat producing animals to feed the constantly increasing human population. A normal breeding programme in animal is quite lengthy. Biotechnology techniques can not only shorten the time for the production of desirable breed but also controls the diseases caused by crossing the closely related animals.

The cloning or the production of genetically similar individuals has already been carried out for sheep. This technique can be used for the production of animal organs in future.

Fig. 3.4: Genetically engineered sheep (Dolly)

3.6 The Role of Biotechnology in Betterment of Crops

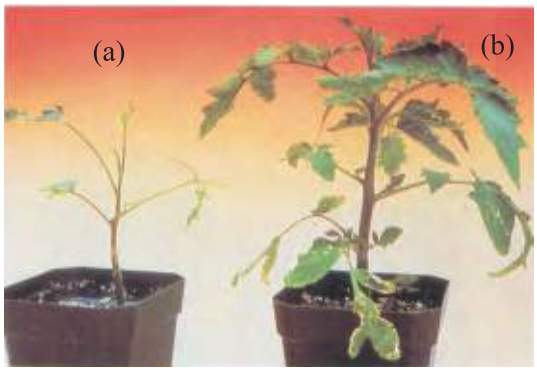
1. Weed killing ability

Herbicides are the chemicals which are used to control the weeds or unwanted plants growing in crops. Sometimes these herbicides also affect the crop besides killing the weeds. A weak solution of cynamide kills weeds, but is also causes some damage to tobacco plants.

Such genes are transferred in the tobacco plant due to which the plant not only shows resistance against herbicide but also gets advantage in their growth.

2. Pest resistance

BT gene, can induce pest resistance in plants. This gene has been introduced in cotton and the crop has become resistant to the attack of the insects. In 2002-2003 wheat season, the insects called aphids damaged the wheat crop on some parts of Sindh province. A huge amount of expensive pesticides were used to control aphid. This problem can be solved by producing aphid resistant varieties with the help of genetic engineering techniques.



(a) The non-engineered tomato plant that has been completely eaten by caterpillar.
(b) The engineered tomato plant that is not affected by caterpillar.

Fig. 3.6: A successful experiment in pest resistance

3. Improvement of crop yield

Classical techniques of plants breeding require several years and large amount of money for the production of new high yield crops. Through genetic engineering in a short time, high yield crops are produced.

3.7 Antibiotics and Vaccines

Compounds that inhibit the growth or kill bacteria are called antibiotics. There are millions of antibiotics, produced mainly from soil bacteria and fungi but only a few are used to control human bacterial diseases. They do not have any bad effect on humans and can not harm viruses.

Penicillins, tetracyclines, erythromycin etc. are some example of antibiotics.

1. Penicillins

Penicillins are made by a fungus called *Penicillium*. These attack a fairly narrow range of bacteria and are therefore called narrow spectrum antibiotics. Penicillin was discovered by Sir Alexander Fleming and Howard Florey in 1928.

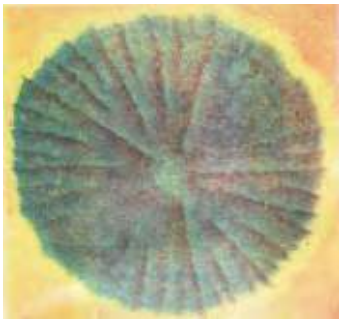


Fig. 3.7: Penicillin

2. Cephalosporins

These antibiotics are obtained from fungus *Manlosporium* and were discovered in 1948. These antibiotics are effective against bacteria which have developed resistance against penicillin.

3. Tetracyclines

Tetracyclines are made by the *Streptomyces* bacteria. They are effective against a variety of bacteria. Hence they are called broad spectrum antibiotics.

4. Erythromycines

They work against the same type of bacteria which have developed resistance against penicillin.

Antibiotics work in two ways. Penicillin prevents the bacteria from forming cell wall which makes body's immunity system to destroy. Tetracycline on the other hand damage the protein producing machinery of bacterium. They prevent bacteria from dividing and inhibits their growth.

Vaccines

Vaccines are harmless form of disease causing microbes that stimulate the immune system. The term vaccine is derived from vacca the Latin for cow. The first vaccine against small pox consisted of cow pox virus in the late 1700s. Edward Jenner an English physician learned from his patients that people who had contacted cow pox were resistant to subsequent small pox infections, in 1796. Jenner scratched a farm boy with needle bearing fluid from a sore of a milk maid who has cow pox. When the boy was later exposed to small pox, he resisted the disease. Vaccination stimulates the body's immune system.

3.8 Recycling of Waste and Scarce Materials

Recycling is the retrieval and reuse of waste materials for manufacturing purposes. A large number of solid wastes like iron, glass, plastic and rubber can be recovered and made reusable. Recycling is important for:

(1) Reduction in rubbish to control environmental pollution. (2) Conservation of raw materials and natural resources. (3) Treatment of sewage saves water which is scarce in many parts of world. (4) Recycling saves energy and money.

Many of the materials discarded as rubbish, such as paper, card board, plastic, rubber, metal glass etc. can be retrieved and recycled through respective industries.

We have to conserve the natural resources so that the environmental pollution could be controlled. A large amount of domestic and industrial rubbish is dumped as waste. Many of the discarded materials are valuable, which could be recycled and used. For example news papers, paper bags, card board boxes, if thrown away, represent a loss of materials. More trees would have to be cut down to make papers. This would result in deforestation. By reusing waste materials, recycling helps to reduce the problem of solid waste disposal. The recycling of solid

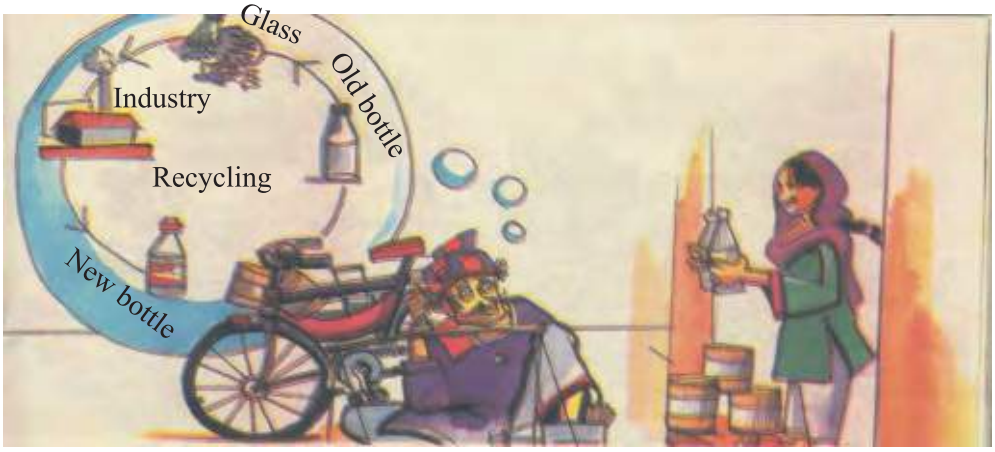


Fig. 3.7: Recycling (Production of new bottles from old one)

wastes means that there is less rubbish to be burnt. Many industries produce wastes that contain metals. Recovery of these metals from the wastes not only helps to conserve the metal but also reduce environmental pollution.

Recycling of sewage wastes through treatment can make it reusable. This is important in those parts of the world where water is very scarce. Sewage, if untreated, represents a loss of water. Untreated sewage also pollutes streams, rivers and lakes. This makes the water unfit for human consumption. In urban areas sewage can be treated in sewage tank. The purified effluent water is then discharged into rivers, streams or lakes, such water may flow into reservoirs, and later be treated and used for human consumption.

Recycling of waste materials can save energy and money. Some household rubbish, e.g. paper can be burnt to provide energy for domestic purposes. This can be done to provide heat for hot water and central heating system.

Broken glass bottles, cup, jars can be crushed and recycled. The use of crushed glass to make new containers saves materials. The energy and cost is reduced as this process uses less fuel.

Similarly, the recycling of aluminium cans and bottle caps can save materials, energy and money.

Organic manure and heat energy are the more practical things which we can obtain from recycling of waste materials. Some developed countries are trying to generate electricity by burning rubbish.

Disposal of rubbish.

There are three methods for waste disposal in developed countries.

(i) Compost of natural fertilizer (ii) Burning in incinerators

(iii) To bury underground according to methods of hygiene.

IMPORTANT POINTS

- Human diet mainly consists of important organic compounds like protein, carbohydrates and fats.
- In living organism different chemical reactions take place which are collectively called metabolism.
- Macromolecules are broken down to monomers during digestion.
- The end products of carbohydrate digestion are glucose, fructose and galactose.
- Fats are digested and absorbed in small intestine.
- Protein are digested in intestine and finally converts into amino acids.
- Enzymes work as catalysts in biological reactions.
- Blood consists of two parts called plasma and blood cells.
- DNA is the abbreviation for deoxyribose nucleic acid and it consists of sub units called nucleotides.
- Diabetes and haemophilia occur due to changes in DNA molecule.
- Penicillin is obtained from the fungus called penicillium.
- Gene is the basic unit of genetic information. These are small parts of DNA present in the chromosome

GLOSSARY

Biochemistry:	The study of biochemical reactions in living organisms.
Maltose :	It is a disaccharide sugar produced by the digestion of starch.
Catalyst.	Change the speed of chemical reaction without undergoing any chemical change in structure.
Genome :	All the genes present in a cell.
Genetic engineering:	A technique to transfer genes from one organism to another.
Antibiotics :	Chemical compounds obtained from microorganisms and used to control infectious diseases caused by bacteria.
Fatty Acids :	Organic acids having hydrocarbon chain and released on hydrolysis of fats.
Recycling :	To produce new products from useless wastes or rubbish.

QUESTIONS

1. Fill in the blanks.
   - (i) Penicillins are made by a fungus called _____.
   - (ii) Human blood can be classified into A,B, AB and O groups on the bases of antigen and _____.
   - (iii) Diabetes and haemophilia are due to change in _____ molecule.
   - (iv) The products of fat digestion are called_____
   - (v) Cephalosporins are obtained from fungus _____.

2. Put a (✓) against right question and (✗) against wrong question.
   - (i) Metabolism is a combination of anabolic and catabolic reaction.
   - (ii) Fats are stored in the epithelial cells of human body.
   - (iii) Penicillin is a broad spectrum antibiotic .

3. Each of the following question has four answers. Encircle the right answer.
   - (i) The function of platelets is
     - (a) Blood Clotting (b) Engulfing the bacteria
     - (c) To produce antibiotics (d) Transfer of oxygen
   - (ii) Genetic information is transferred by
     - (a) Nucleus (b) Chromosomes
     - (c) Genes (d) Gametes
   - (iii) Fats are formed by the combination of
     - (a) Glucose + glucose (b) Water + carbondioxide
     - (c) Glycerol + fatty acids. (d) Amino Acids water
   - (iv) Penicillins was discovered by
     - (a) Robert Brown (b) Sir Alexander Fleming and Howard Florey
     - (c) Edward Jenner (d) Robert Hooke.
   - (v) The antibiotic cephalosporin was discovered in
     - (a) 1848 (b) 1948 (c) 1928 (d) 1998

4. Write brief answers.
   (i) Write the names of three main types of cells in blood ?
   (ii) Which tissues store fats in human body?
   (iii) What is transgenic organism?
   (iv) What is a catalyst?

5. What is metabolism? Explain its different types.
6. What is meant by digestion and assimilation of food.
7. What is an enzyme? What role is played by enzymes in our daily life?
8. What are the components of blood?
9. How is DNA the hereditary material ? Explain in detail.
10. What is genetic engineering? How can it help in improving agriculture and livestock?
11. What is an antibiotic? Write down its types.
12. What is recycling? Give a detailed account how the waste and scarce materials can be made useable.