UNIT VIII
BIOLOGY IN HUMAN WELFARE

Biology is the youngest of the formalised disciplines of natural science. Progress in physics and chemistry proceeded much faster than in Biology. Applications of physics and chemistry in our daily life also have a higher visibility than those of biology. However, twentieth century and certainly twenty-first century has demonstrated the utility of biological knowledge in furthering human welfare, be it in health sector or agriculture. The discovery of antibiotics, and synthetic plant-derived drugs, anaesthetics have changed medical practice on one hand and human health on the other hand. Life expectancy of human beings have dramatically changed over the years. Agricultural practices, food processing and diagnostics have brought socio-cultural changes in human communities. These are briefly described in the following three chapters of this unit.

M.S. SWAMINATHAN
(1925)

Born in August 1925 in Kumbakonam in Tamil Nadu, Monkambu Sambasivan Swaminathan did his graduation and post-graduation in Botany from Madras University. He worked in different capacities in large number of institutions in India and abroad and developed his expertise in genetics and plant breeding.

The School of Cytogenetics and Radiation Research established at the Indian Agricultural Research Institute (IARI) enabled Swaminathan and his team to develop short-duration high-yielding varieties of rice including scented Basmati. He is also known for the development of the concept of crop cafeteria, crop scheduling and genetically improving the yield and quality.

Swaminathan initiated collaboration with Norman Borlaug, which culminated in the 'Green Revolution' through introduction of Mexican varieties of wheat in India. This was highly recognised and appreciated. He is also the initiator of 'Lab-to-Land', food security and several other environmental programmes. He has been honoured with Padma Bhushan and several other prestigious awards, medals and fellowships by institutions of excellence.

CHAPTER 8

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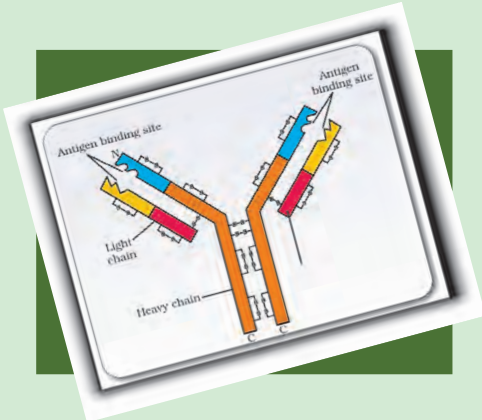


HUMAN HEALTH AND DISEASE

Health, for a long time, was considered as a state of body and mind where there was a balance of certain 'humors'. This is what early Greeks like Hippocrates as well as Indian Ayurveda system of medicine asserted. It was thought that persons with 'blackbile' belonged to hot personality and would have fevers. This idea was arrived at by pure reflective thought. The discovery of blood circulation by William Harvey using experimental method and the demonstration of normal body temperature in persons with blackbile using thermometer disproved the 'good humor' hypothesis of health. In later years, biology stated that mind influences, through neural system and endocrine system, our immune system and that our immune system maintains our health. Hence, mind and mental state can affect our health. Of course, health is affected by –

(i) genetic disorders – deficiencies with which a child is born and deficiencies/defects which the child inherits from parents from birth;
(ii) infections and
(iii) life style including food and water we take, rest and exercise we give to our bodies, habits that we have or lack etc.

The term **health** is very frequently used by everybody. *How do we define it*? Health does not simply mean 'absence of disease' or 'physical fitness'. It could be defined as a state of complete physical, mental and social well-being. When people are healthy, they are more efficient at work. This increases productivity and brings economic prosperity. Health also increases longevity of people and reduces infant and maternal mortality.

Balanced diet, personal hygiene and regular exercise are very important to maintain good health. Yoga has been practised since time immemorial to achieve physical and mental health. Awareness about diseases and their effect on different bodily functions, vaccination (immunisation) against infectious diseases, proper disposal of wastes, control of vectors and maintenance of hygiene in food and water resources are necessary for achieving good health.

When the functioning of one or more organs or systems of the body is adversely affected, characterised by appearance of various signs and symptoms, we say that we are not healthy, i.e., we have a **disease**. Diseases can be broadly grouped into **infectious** and **non-infectious**. Diseases which are easily transmitted from one person to another, are called **infectious diseases**. Infectious diseases are very common and every one of us suffers from these at sometime or other. Some of the infectious diseases like AIDS are fatal. Among non-infectious diseases, cancer is the major cause of death. Drug and alcohol abuse also affect our health adversely.

8.1 Common Diseases in Humans

A wide range of organisms belonging to bacteria, viruses, fungi, protozoans, helminths, etc., could cause diseases in man. Such disease-causing organisms are called **pathogens**. Most parasites are therefore pathogens as they cause harm to the host by living in (or on) them. The pathogens can enter our body by various means, multiply and interfere with normal vital activities, resulting in morphological and functional damage. Pathogens have to adapt to life within the environment of the host. For example, the pathogens that enter the gut must know a way of surviving in the stomach at low pH and resisting the various digestive enzymes. A few representative members from different groups of pathogenic organisms are discussed here alongwith the diseases caused by them. Preventive and control measures against these diseases in general, are also briefly described.

Salmonella typhi is a pathogenic bacterium which causes **typhoid** fever in human beings. These pathogens generally enter the small intestine through food and water contaminated with them and migrate to other organs through blood. Sustained high fever (39° to 40°C), weakness, stomach pain, constipation, headache and loss of appetite are some of the common symptoms of this disease. Intestinal perforation and death may occur in severe cases. Typhoid fever could be confirmed by

Widal test : A classic case in medicine, that of Mary Mallon nicknamed *Typhoid Mary*, is worth mentioning here. She was a cook by profession and was a typhoid carrier who continued to spread typhoid for several years through the food she prepared.

Bacteria like *Streptococcus pneumoniae* and *Haemophilus influenzae* are responsible for the disease **pneumonia** in humans which infects the alveoli (air filled sacs) of the lungs. As a result of the infection, the alveoli get filled with fluid leading to severe problems in respiration. The symptoms of pneumonia include fever, chills, cough and headache. In severe cases, the lips and finger nails may turn gray to bluish in colour. A healthy person acquires the infection by inhaling the droplets/aerosols released by an infected person or even by sharing glasses and utensils with an infected person. Dysentery, plague, diphtheria, etc., are some of the other bacterial diseases in man.

Many viruses also cause diseases in human beings. Rhino viruses represent one such group of viruses which cause one of the most infectious human ailments – the **common cold**. They infect the nose and respiratory passage but not the lungs. The common cold is characterised by nasal congestion and discharge, sore throat, hoarseness, cough, headache, tiredness, etc., which usually last for 3-7 days. Droplets resulting from cough or sneezes of an infected person are either inhaled directly or transmitted through contaminated objects such as pens, books, cups, doorknobs, computer keyboard or mouse, etc., and cause infection in a healthy person.

Some of the human diseases are caused by protozoans too. You might have heard about ***malaria***, a disease man has been fighting since many years. *Plasmodium*, a tiny protozoan is responsible for this disease. Different species of *Plasmodium* (*P. vivax*, *P. malaria* and *P. falciparum*) are responsible for different types of malaria. Of these, malignant malaria caused by *Plasmodium falciparum* is the most serious one and can even be fatal.

Let us take a glance at the life cycle of *Plasmodium* (Figure 8.1). *Plasmodium* enters the human body as sporozoites (infectious form) through the bite of infected female *Anopheles* mosquito. The parasites initially multiply within the liver cells and then attack the red blood cells (RBCs) resulting in their rupture. The rupture of RBCs is associated with release of a toxic substance, haemozoin, which is responsible for the chill and high fever recurring every three to four days. When a female *Anopheles* mosquito bites an infected person, these parasites enter the mosquito's body and undergo further development. The parasites multiply within them to form sporozoites that are stored in their salivary glands. When these mosquitoes bite a human, the sporozoites are introduced into his/her body, thereby initiating the events mentioned above. It is interesting to note that the malarial parasite requires two hosts – human and mosquitoes – to complete its life cycle (Figure 8.1); the female *Anopheles* mosquito is the vector (transmitting agent) too.

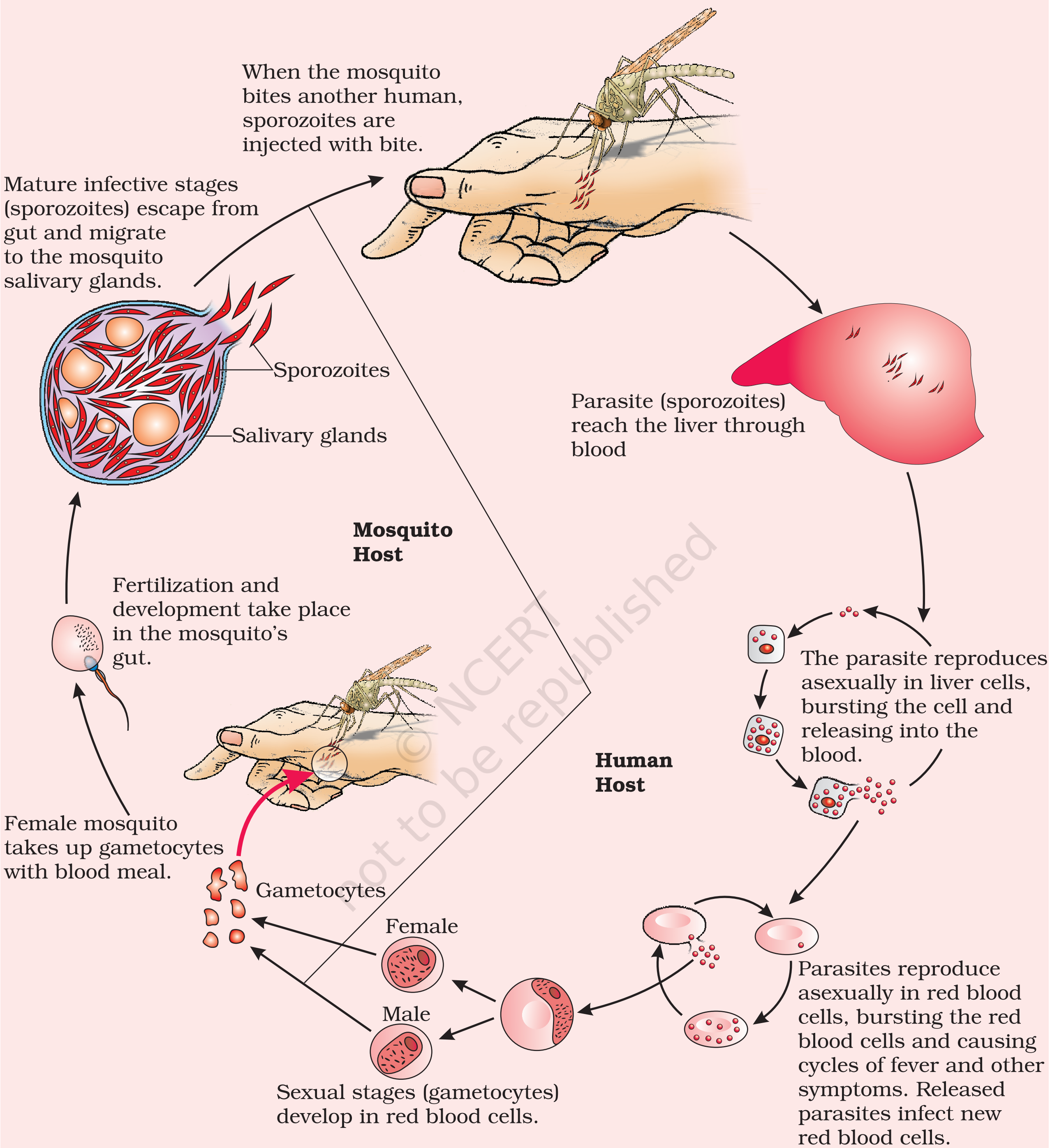


Figure 8.1 Stages in the life cycle of *Plasmodium*

Entamoeba histolytica is a protozoan parasite in the large intestine of human which causes **amoebiasis (amoebic dysentery)**. Symptoms of this disease include constipation, abdominal pain and cramps, stools with excess mucous and blood clots. Houseflies act as mechanical carriers and serve to transmit the parasite from faeces of infected person to food and food products, thereby contaminating them. Drinking water and food contaminated by the faecal matter are the main source of infection.

Ascaris, the common round worm and *Wuchereria*, the filarial worm, are some of the helminths which are known to be pathogenic to man. *Ascaris*, an intestinal parasite causes **ascariasis**. Symptoms of these disease include internal bleeding, muscular pain, fever, anemia and blockage of the intestinal passage. The eggs of the parasite are excreted along with the faeces of infected persons which contaminate soil, water, plants, etc. A healthy person acquires this infection through contaminated water, vegetables, fruits, etc.

Wuchereria (W. bancrofti and *W. malayi),* the filarial worms cause a slowly developing chronic inflammation of the organs in which they live for many years, usually the lymphatic vessels of the lower limbs and the disease is called **elephantiasis** or **filariasis** (Figure 8.2). The genital organs are also often affected, resulting in gross deformities. The pathogens are transmitted to a healthy person through the bite by the female mosquito vectors.

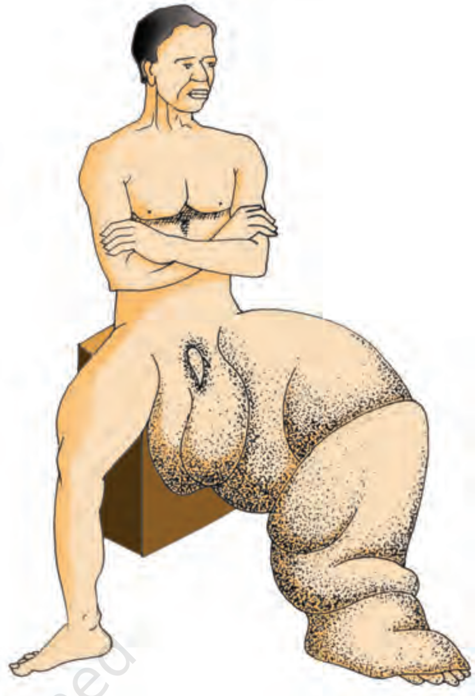


Figure 8.2 Diagram showing inflammation in one of the lower limbs due to elephantiasis

Many fungi belonging to the genera *Microsporum*, *Trichophyton* and *Epidermophyton* are responsible for **ringworms** which is one of the most common infectious diseases in man. Appearance of dry, scaly lesions on various parts of the body such as skin, nails and scalp (Figure 8.3) are the main symptoms of the disease. These lesions are accompanied by intense itching. Heat and moisture help these fungi to grow, which makes them thrive in skin folds such as those in the groin or between the toes. Ringworms are generally acquired from soil or by using towels, clothes or even the comb of infected individuals.

Figure 8.3 Diagram showing ringworm affected area of the skin

Maintenance of personal and public hygiene is very important for prevention and control of many infectious diseases. Measures for personal hygiene include keeping the body clean; consumption of clean drinking water, food, vegetables, fruits, etc. Public hygiene includes proper disposal of waste and excreta; periodic cleaning and disinfection of water reservoirs, pools, cesspools and tanks and observing standard practices of hygiene in public catering. These measures are particularly essential where the infectious agents are transmitted through food and water such as typhoid, amoebiasis and ascariasis. In cases of air-borne diseases such as pneumonia and common cold, in addition to the above measures, close contact with the infected persons or their belongings should be avoided. For diseases such as malaria and filariasis that are transmitted through insect vectors, the most important measure is to control or eliminate the vectors and their breeding places. This can be achieved by avoiding stagnation of water in and around residential areas, regular cleaning of household coolers, use of mosquito nets, introducing fishes like *Gambusia* in ponds that feed on mosquito larvae, spraying of insecticides in ditches, drainage areas and swamps, etc. In addition, doors and windows should be provided with wire mesh to prevent the entry of mosquitoes. Such precautions have become more important especially in the light of recent widespread incidences of the vector-borne (*Aedes* mosquitoes) diseases like dengue and chikungunya in many parts of India.

The advancements made in biological science have armed us to effectively deal with many infectious diseases. The use of vaccines and immunisation programmes have enabled us to completely eradicate a deadly disease like smallpox. A large number of other infectious diseases like polio, diphtheria, pneumonia and tetanus have been controlled to a large extent by the use of vaccines. Biotechnology (about which you will read more in Chapter 12) is at the verge of making available newer and safer vaccines. Discovery of antibiotics and various other drugs has also enabled us to effectively treat infectious diseases.

8.2 Immunity

Everyday we are exposed to large number of infectious agents. However, only a few of these exposures result in disease. Why? This is due to the fact that the body is able to defend itself from most of these foreign agents. This overall ability of the host to fight the disease-causing organisms, conferred by the immune system is called **immunity**.

Immunity is of two types: (i) Innate immunity and (ii) Acquired immunity.

8.2.1 Innate Immunity

Innate immunity is non-specific type of defence, that is present at the time of birth. This is accomplished by providing different types of barriers to the entry of the foreign agents into our body. Innate immunity consist of four types of barriers. These are —

(i) ***Physical barriers*** **:** Skin on our body is the main barrier which prevents entry of the micro-organisms. Mucus coating of the epithelium lining the respiratory, gastrointestinal and urogenital tracts also help in trapping microbes entering our body.

(ii) ***Physiological barriers*** **:** Acid in the stomach, saliva in the mouth, tears from eyes–all prevent microbial growth.

(iii) ***Cellular barriers*** **:** Certain types of leukocytes (WBC) of our body like polymorpho-nuclear leukocytes (PMNL-neutrophils) and monocytes and natural killer (type of lymphocytes) in the blood as well as macrophages in tissues can phagocytose and destroy microbes.

(iv) ***Cytokine barriers*** : Virus-infected cells secrete proteins called **interferons** which protect non-infected cells from further viral infection.

8.2.2 Acquired Immunity

Acquired immunity, on the other hand is pathogen specific. It is characterised by memory. This means when our body encounters a pathogen for the first time it produces a response called **primary response** which is of low intensity. Subsequent encounter with the same pathogen elicits a highly intensified secondary or anamnestic response. This is ascribed to the fact that our body appears to have memory of the first encounter.

The primary and secondary immune responses are carried out with the help of two special types of lymphocytes present in our blood, i.e., **B**-lymphocytes and **T**-lymphocytes.

The B-lymphocytes produce an army of proteins in response to pathogens into our blood to fight with them. These proteins are called antibodies. The T-cells themselves do not secrete antibodies but help B cells to produce them. Each antibody molecule has four peptide chains, two small called **light chains** and two longer called **heavy chains**. Hence, an antibody is represented as H_2L_2. Different types of antibodies are produced in our body. IgA, IgM, IgE, IgG are some of them. A cartoon of an antibody is given in Figure 8.4. Because these antibodies are found in the blood, the response is also called as **humoral immune response**. This is one of the two types of our acquired immune response – antibody mediated. The second type is called cell-mediated immune response or **cell-mediated immunity** (CMI). The T-lymphocytes mediate CMI. Very often, when some human organs like heart, eye, liver, kidney fail to function satisfactorily, transplantation is the only remedy to enable the patient to live a normal life. Then a search begins – to find a suitable donor. *Why is it that the organs cannot be taken from just anybody? What is it that the doctors*

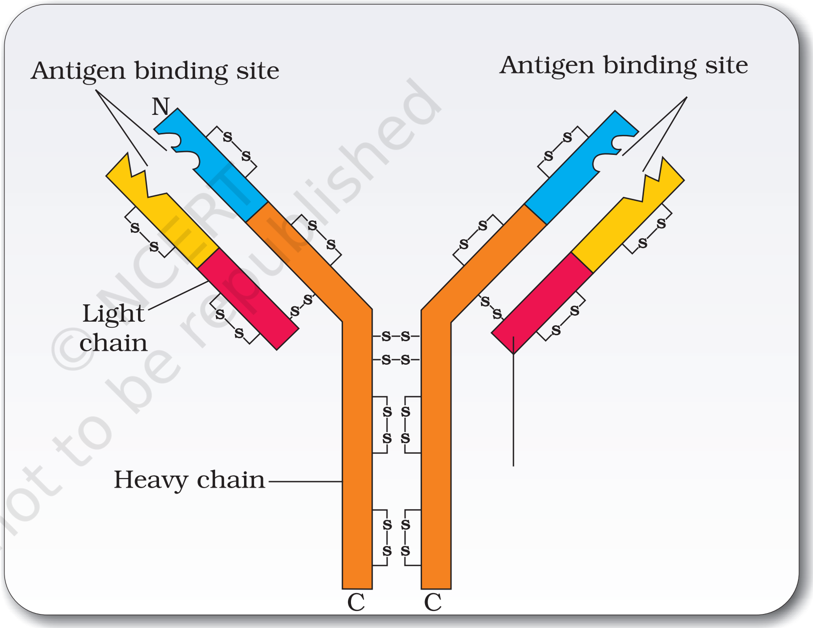


Figure 8.4 Structure of an antibody molecule

check? Grafts from just any source – an animal, another primate, or any human beings cannot be made since the grafts would be rejected sooner or later. Tissue matching, blood group matching are essential before undertaking any graft/transplant and even after this the patient has to take immuno–suppresants all his/her life. The body is able to differentiate 'self' and 'nonself' and the cell-mediated immune response is responsible for the graft rejection.

8.2.3 Active and Passive Immunity

When a host is exposed to antigens, which may be in the form of living or dead microbes or other proteins, antibodies are produced in the host body. This type of immunity is called **active immunity.** Active immunity is slow and takes time to give its full effective response. Injecting the microbes deliberately during immunisation or infectious organisms gaining access into body during natural infection induce active immunity. When ready-made antibodies are directly given to protect the body against foreign agents, it is called **passive immunity**. *Do you know why mother's milk is considered very essential for the new-born infant*? The yellowish fluid **colostrum** secreted by mother during the initial days of lactation has abundant antibodies (IgA) to protect the infant. The foetus also receives some antibodies from their mother, through the placenta during pregnancy. These are some examples of passive immunity.

8.2.4 Vaccination and Immunisation

The principle of immunisation or vaccination is based on the property of 'memory' of the immune system. In vaccination, a preparation of antigenic proteins of pathogen or inactivated/weakened pathogen (vaccine) are introduced into the body. The antibodies produced in the body against these antigens would neutralise the pathogenic agents during actual infection. The vaccines also generate memory – B and T-cells that recognise the pathogen quickly on subsequent exposure and overwhelm the invaders with a massive production of antibodies. If a person is infected with some deadly microbes to which quick immune response is required as in tetanus, we need to directly inject the preformed antibodies, or antitoxin (a preparation containing antibodies to the toxin). Even in cases of snakebites, the injection which is given to the patients, contain preformed antibodies against the snake venom. This type of immunisation is called **passive immunisation**.

Recombinant DNA technology has allowed the production of antigenic polypeptides of pathogen in bacteria or yeast. Vaccines produced using this approach allow large scale production and hence greater availability for immunisation, e.g., hepatitis B vaccine produced from yeast.

8.2.5 Allergies

When you have gone to a new place and suddenly you started sneezing, wheezing for no explained reason, and when you went away, your symptoms dissappeared. Did this happen to you? Some of us are sensitive to some particles in the environment. The above-mentioned reaction could be because of allergy to pollen, mites, etc., which are different in different places.

The exaggerated response of the immune system to certain antigens present in the environment is called **allergy**. The substances to which such an immune response is produced are called allergens. The antibodies produced to these are of IgE type. Common examples of allergens are mites in dust, pollens, animal dander, etc. Symptoms of allergic reactions include sneezing, watery eyes, running nose and difficulty in breathing. Allergy is due to the release of chemicals like histamine and serotonin from the mast cells. For determining the cause of allergy, the patient is exposed to or injected with very small doses of possible allergens, and the reactions studied. The use of drugs like anti-histamine, adrenalin and steroids quickly reduce the symptoms of allergy. Somehow, modern-day life style has resulted in lowering of immunity and more sensitivity to allergens – more and more children in metro cities of India suffer from allergies and asthma due to sensitivity to the environment. This could be because of the protected environment provided early in life.

8.2.6 Auto Immunity

Memory-based acquired immunity evolved in higher vertebrates based on the ability to differentiate foreign organisms (e.g., pathogens) from self-cells. While we still do not understand the basis of this, two corollaries of this ability have to be understood. One, higher vertebrates can distinguish foreign molecules as well as foreign organisms. Most of the experimental immunology deals with this aspect. Two, sometimes, due to genetic and other unknown reasons, the body attacks self-cells. This results in damage to the body and is called **auto-immune** disease. Rheumatoid arthritis which affects many people in our society is an auto-immune disease.

8.2.7 Immune System in the Body

The human immune system consists of lymphoid organs, tissues, cells and soluble molecules like antibodies. As you have read, immune system is unique in the sense that it recognises foreign antigens, responds to these and remembers them. The immune system also plays an important role in allergic reactions, auto-immune diseases and organ transplantation.

Lymphoid organs: These are the organs where origin and/or maturation and proliferation of lymphocytes occur. The primary lymphoid organs are **bone marrow** and **thymus** where immature lymphocytes differentiate

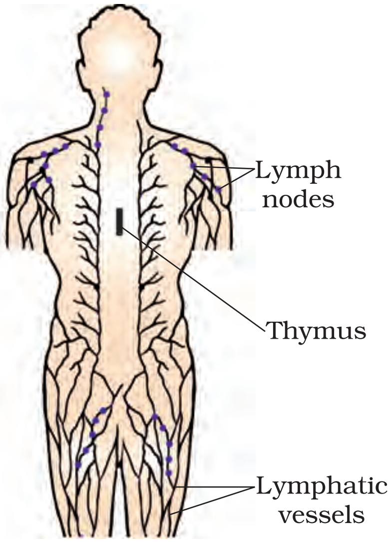


Figure 8.5 Diagrammatic representation of Lymph nodes

into antigen-sensitive lymphocytes. After maturation the lymphocytes migrate to secondary lymphoid organs like spleen, lymph nodes, tonsils, Peyer's patches of small intestine and appendix. The secondary lymphoid organs provide the sites for interaction of lymphocytes with the antigen, which then proliferate to become effector cells. The location of various lymphoid organs in the human body is shown in Figure 8.5.

The bone marrow is the main lymphoid organ where all blood cells including lymphocytes are produced. The thymus is a lobed organ located near the heart and beneath the breastbone. The thymus is quite large at the time of birth but keeps reducing in size with age and by the time puberty is attained it reduces to a very small size. Both bone-marrow and thymus provide micro-environments for the development and maturation of T-lymphocytes. The spleen is a large bean-shaped organ. It mainly contains lymphocytes and phagocytes. It acts as a filter of the blood by trapping blood-borne micro-organisms. Spleen also has a large reservoir of erythrocytes. The lymph nodes are small solid structures located at different points along the lymphatic system. Lymph nodes serve to trap the micro-organisms or other antigens, which happen to get into the lymph and tissue fluid. Antigens trapped in the lymph nodes are responsible for the activation of lymphocytes present there and cause the immune response.

There is lymphoid tissue also located within the lining of the major tracts (respiratory, digestive and urogenital tracts) called **mucosa-associated lymphoid tissue** (MALT). It constitutes about 50 per cent of the lymphoid tissue in human body.

8.3 AIDS

The word AIDS stands for **Acquired Immuno Deficiency Syndrome**. This means deficiency of immune system, acquired during the lifetime of an individual indicating that it is not a congenital disease. 'Syndrome' means a group of symptoms. AIDS was first reported in 1981 and in the last twenty-five years or so, it has spread all over the world killing more than 25 million persons.

AIDS is caused by the Human Immuno deficiency Virus (HIV), a member of a group of viruses called **retrovirus**, which have an envelope enclosing the RNA genome (Figure 8.6). Transmission of HIV-infection generally occurs by (a) sexual contact with infected person, (b) by transfusion of contaminated blood and blood products, (c) by sharing infected needles as in the case of intravenous drug abusers and (d) from infected mother to her child through placenta. So, people who are at high risk of getting this infection includes - individuals who have multiple

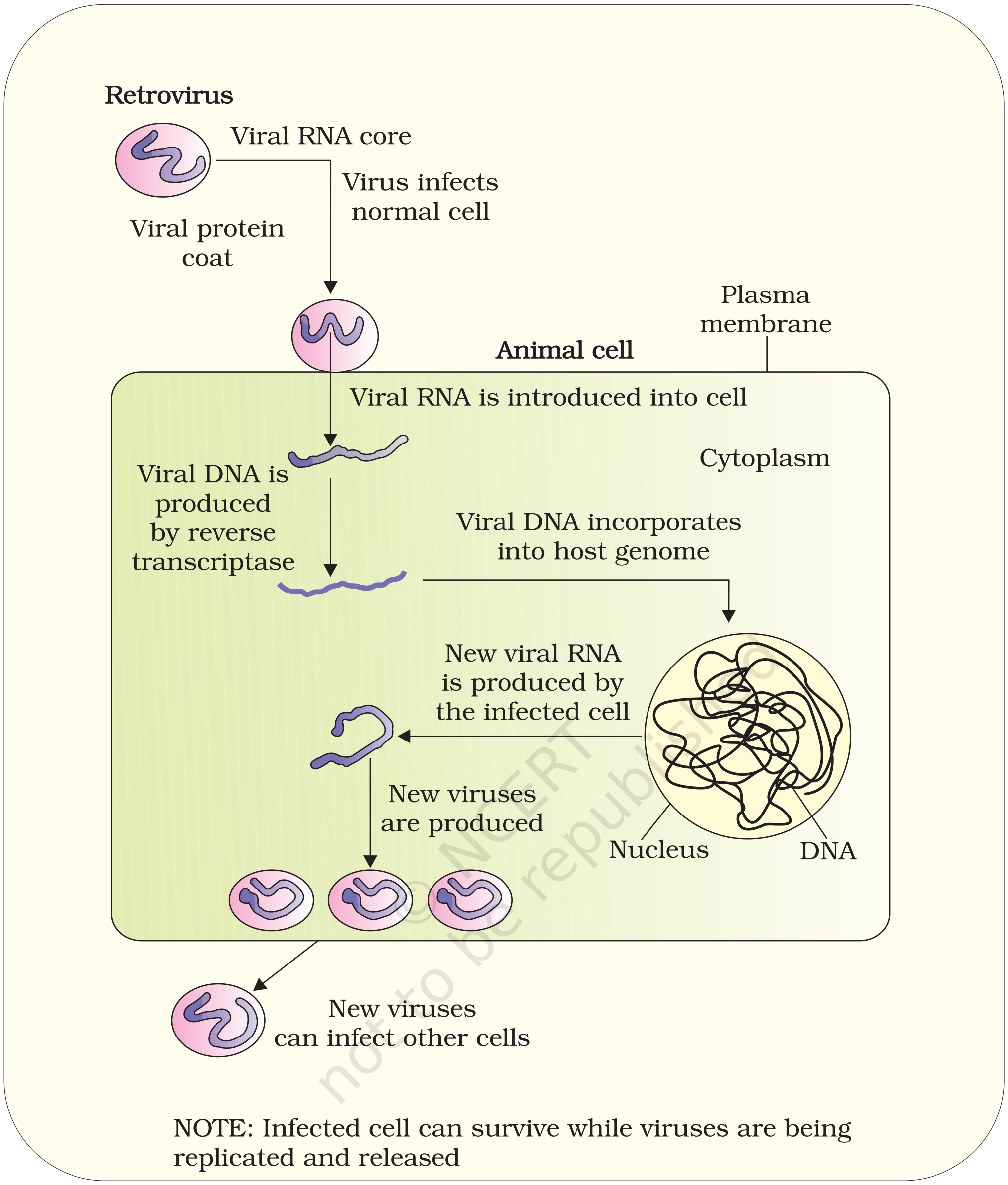


Figure 8.6 Replication of retrovirus

sexual partners, drug addicts who take drugs intravenously, individuals who require repeated blood transfusions and children born to an HIV infected mother. *Do you know–when do people need repeated blood transfusion? Find out and make a list of such conditions.* It is important to note that HIV/AIDS is not spread by mere touch or physical contact; it spreads only through body fluids. It is, hence, imperative, for the physical and psychological well-being, that the HIV/AIDS infected persons are not isolated from family and society. There is always a time-lag between the infection and appearance of AIDS symptoms. This period may vary from a few months to many years (usually 5-10 years).

After getting into the body of the person, the virus enters into macrophages where RNA genome of the virus replicates to form viral DNA with the help of the enzyme reverse transcriptase. This viral DNA gets incorporated into host cell's DNA and directs the infected cells to produce virus particles (Figure 8.6). The macrophages continue to produce virus and in this way acts like a HIV factory. Simultaneously, HIV enters into helper T-lymphocytes (T_H), replicates and produce progeny viruses. The progeny viruses released in the blood attack other helper T-lymphocytes. This is repeated leading to a progressive decrease in the number of helper T-lymphocytes in the body of the infected person. During this period, the person suffers from bouts of fever, diarrhoea and weight loss. Due to decrease in the number of helper T lymphocytes, the person starts suffering from infections that could have been otherwise overcome such as those due to bacteria especially *Mycobacterium*, viruses, fungi and even parasites like *Toxoplasma*. The patient becomes so immuno-deficient that he/she is unable to protect himself/herself against these infections. A widely used diagnostic test for AIDS is **enzyme linked immuno-sorbent assay** (ELISA). Treatment of AIDS with anti-retroviral drugs is only partially effective. They can only prolong the life of the patient but cannot prevent death, which is inevitable.

Prevention of AIDS : As AIDS has no cure, prevention is the best option. Moreover, HIV infection, more often, spreads due to conscious behaviour patterns and is not something that happens inadvertently, like pneumonia or typhoid. Of course, infection in blood transfusion patients, new-borns (from mother) etc., may take place due to poor monitoring. The only excuse may be ignorance and it has been rightly said – "don't die of ignorance". In our country the National AIDS Control Organisation (NACO) and other non-governmental organisation (NGOs) are doing a lot to educate people about AIDS. WHO has started a number of programmes to prevent the spreading of HIV infection. Making blood (from blood banks) safe from HIV, ensuring the use of only disposable needles and syringes in public and private hospitals and clinics, free distribution of condoms, controlling drug abuse, advocating safe sex and promoting regular check-ups for HIV in susceptible populations, are some such steps taken up.

Infection with HIV or having AIDS is something that should not be hidden – since then, the infection may spread to many more people. HIV/AIDS-infected people need help and sympathy instead of being shunned by society. Unless society recognises it as a problem to be dealt with in a collective manner – the chances of wider spread of the disease increase manifold. It is a malady that can only be tackled, by the society and medical fraternity acting together, to prevent the spread of the disease.

8.4 Cancer

Cancer is one of the most dreaded diseases of human beings and is a major cause of death all over the globe. More than a million Indians suffer from cancer and a large number of them die from it annually. The mechanisms that underlie development of cancer or oncogenic transformation of cells, its treatment and control have been some of the most intense areas of research in biology and medicine.

In our body, cell growth and differentiation is highly controlled and regulated. In cancer cells, there is breakdown of these regulatory mechanisms. Normal cells show a property called **contact inhibition** by virtue of which contact with other cells inhibits their uncontrolled growth. Cancer cells appears to have lost this property. As a result of this, cancerous cells just continue to divide giving rise to masses of cells called **tumors**. Tumors are of two types: benign and malignant. **Benign tumors** normally remain confined to their original location and do not spread to other parts of the body and cause little damage. The **malignant tumors**, on the other hand are a mass of proliferating cells called neoplastic or tumor cells. These cells grow very rapidly, invading and damaging the surrounding normal tissues. As these cells actively divide and grow they also starve the normal cells by competing for vital nutrients. Cells sloughed from such tumors reach distant sites through blood, and wherever they get lodged in the body, they start a new tumor there. This property called **metastasis** is the most feared property of malignant tumors.

Causes of cancer : Transformation of normal cells into cancerous neoplastic cells may be induced by physical, chemical or biological agents. These agents are called **carcinogens**. Ionising radiations like X-rays and gamma rays and non-ionizing radiations like UV cause DNA damage leading to neoplastic transformation. The chemical carcinogens present in tobacco smoke have been identified as a major cause of lung cancer. Cancer causing viruses called **oncogenic viruses** have genes called **viral oncogenes**. Furthermore, several genes called **cellular oncogenes** (*c-onc*) or **proto oncogenes** have been identified in normal cells which, when activated under certain conditions, could lead to oncogenic transformation of the cells.

Cancer detection and diagnosis : Early detection of cancers is essential as it allows the disease to be treated successfully in many cases. Cancer detection is based on biopsy and histopathological studies of the tissue and blood and bone marrow tests for increased cell counts in the case of leukemias. In biopsy, a piece of the suspected tissue cut into thin sections is stained and examined under microscope (histopathological studies) by a pathologist. Techniques like radiography (use of X-rays), CT (computed tomography) and MRI (magnetic resonance imaging) are very useful to detect cancers of the internal organs. Computed tomography uses X-rays to generate a three-dimensional image of the internals of an object. MRI uses strong magnetic fields and non-ionising radiations to accurately detect pathological and physiological changes in the living tissue.

Antibodies against cancer-specific antigens are also used for detection of certain cancers. Techniques of molecular biology can be applied to detect genes in individuals with inherited susceptibility to certain cancers. Identification of such genes, which predispose an individual to certain cancers, may be very helpful in prevention of cancers. Such individuals may be advised to avoid exposure to particular carcinogens to which they are susceptible (e.g., tobacco smoke in case of lung cancer).

Treatment of cancer : The common approaches for treatment of cancer are surgery, radiation therapy and immunotherapy. In radiotherapy, tumor cells are irradiated lethally, taking proper care of the normal tissues surrounding the tumor mass. Several chemotherapeutic drugs are used to kill cancerous cells. Some of these are specific for particular tumors. Majority of drugs have side effects like hair loss, anemia, etc. Most cancers are treated by combination of surgery, radiotherapy and chemotherapy. Tumor cells have been shown to avoid detection and destruction by immune system. Therefore, the patients are given substances called biological response modifiers such as **α-interferon** which activates their immune system and helps in destroying the tumor.

8.5 Drugs and Alcohol Abuse

Surveys and statistics show that use of drugs and alcohol has been on the rise especially among the youth. This is really a cause of concern as it could result in many harmful effects. Proper education and guidance would enable youth to safeguard themselves against these dangerous behaviour patterns and follow healthy lifestyles.

The drugs, which are commonly abused are opioids, cannabinoids and coca alkaloids. Majority of these are obtained from flowering plants. Some are obtained from fungi.

Opioids are the drugs, which bind to specific opioid receptors present in our central nervous system and gastrointestinal tract. Heroin (Figure 8.7), commonly called *smack* is chemically diacetylmorphine which is a white, odourless, bitter crystalline compound. This is obtained by acetylation of morphine (Figure 8.7), which is extracted from the latex of

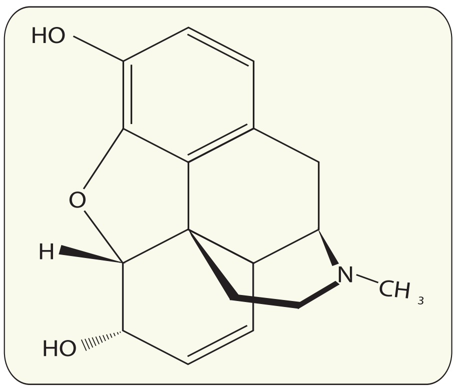


Figure 8.7 Chemical structure of Morphine

Figure 8.8 Opium poppy

poppy plant *Papaver somniferum* (Figure 8.8). Generally taken by snorting and injection, heroin is a depressant and slows down body functions.

Cannabinoids are a group of chemicals (Figure 8.9), which interact with cannabinoid receptors present principally in the brain. Natural cannabinoids are obtained from the inflorescences of the plant *Cannabis sativa* (Figure 8.10). The flower tops, leaves and the resin of cannabis plant are used in various combinations to produce marijuana, hashish, charas and ganja. Generally taken by inhalation and oral ingestion, these are known for their effects on cardiovascular system of the body.

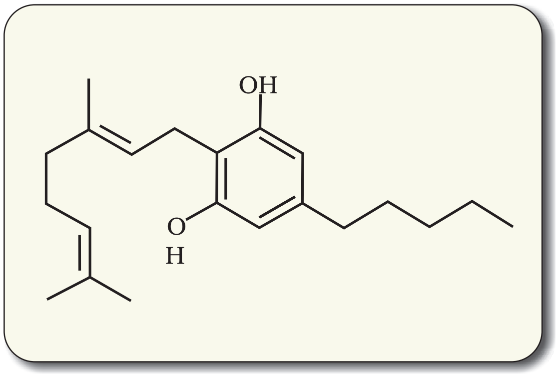


Figure 8.9 Skeletal structure of cannabinoid molecule

Figure 8.10 Leaves of *Cannabis sativa*

Coca alkaloid or **cocaine** is obtained from coca plant *Erythroxylum coca*, native to South America. It interferes with the transport of the neuro-transmitter dopamine. Cocaine, commonly called **coke** or **crack** is usually snorted. It has a potent stimulating action on central nervous system, producing a sense of euphoria and increased energy. Excessive dosage of cocaine causes hallucinations. Other well-known plants with hallucinogenic properties are *Atropa belladona* and *Datura* (Figure 8.11). These days cannabinoids are also being abused by some sportspersons.

Figure 8.11 Flowering branch of *Datura*

Drugs like barbiturates, amphetamines, benzodiazepines, and other similar drugs, that are normally used as medicines to help patients cope with mental illnesses like depression and insomnia, are often abused. Morphine is a very effective sedative and painkiller, and is very useful in patients who have undergone surgery. Several plants, fruits and seeds having hallucinogenic properties have been used for hundreds of years in folk-medicine, religious ceremonies and rituals all over the globe. When these are taken for a purpose other than medicinal use or in amounts/frequency that impairs one's physical, physiological or psychological functions, it constitutes drug abuse.

Smoking also paves the way to hard drugs. Tobacco has been used by human beings for more than 400 years. It is smoked, chewed or used as a snuff. Tobacco contains a large number of chemical substances including nicotine, an alkaloid. Nicotine stimulates adrenal gland to release adrenaline and nor-adrenaline into blood circulation, both of which raise blood pressure and increase heart rate. Smoking is associated with increased incidence of cancers of lung, urinary bladder and throat, bronchitis, emphysema, coronary heart disease, gastric ulcer, etc. Tobacco chewing is associated with increased risk of cancer of the oral cavity. Smoking increases carbon monoxide (CO) content in blood and reduces the concentration of haembound oxygen. This causes oxygen deficiency in the body.

When one buys packets of cigarettes one cannot miss the statutory warning that is present on the packing which warns against smoking and says how it is injurious to health. Yet, smoking is very prevalent in society, both among young and old. Knowing the dangers of smoking and chewing tobacco, and its addictive nature, the youth and old need to avoid these habits. Any addict requires counselling and medical help to get rid of the habit.

8.5.1 Adolescence and Drug/Alcohol Abuse

Adolescence means both 'a period' and 'a process' during which a child becomes mature in terms of his/her attitudes and beliefs for effective participation in society. The period between 12-18 years of age may be thought of as adolescence period. In other words, adolescence is a bridge linking childhood and adulthood. Adolescence is accompanied by several biological and behavioural changes. Adolescence, thus is a very vulnerable phase of mental and psychological development of an individual.

Curiosity, need for adventure and excitement, and experimentation, constitute common causes, which motivate youngsters towards drug and alcohol use. A child's natural curiosity motivates him/her to experiment. This is complicated further by effects that might be perceived as benefits, of alcohol or drug use. Thus, the first use of drugs or alcohol may be out of curiosity or experimentation, but later the child starts using these to escape facing problems. Of late, stress, from pressures to excel in academics or examinations, has played a significant role in persuading the youngsters to try alcohol and drugs. The perception among youth that it is 'cool' or progressive to smoke, use drugs or alcohol, is also in a way a major cause for youth to start these habits. Television, movies, newspapers, internet also help to promote this perception. Other factors that have been seen to be associated with drug and alcohol abuse among adolescents are unstable or unsupportive family structures and peer pressure.

8.5.2 Addiction and Dependence

Because of the perceived benefits, drugs are frequently used repeatedly. The most important thing, which one fails to realise, is the inherent addictive nature of alcohol and drugs. Addiction is a psychological attachment to certain effects – such as euphoria and a temporary feeling of well-being – associated with drugs and alcohol. These drive people to take them even when these are not needed, or even when their use becomes self-destructive. With repeated use of drugs, the tolerance level of the receptors present in our body increases. Consequently the receptors respond only to higher doses of drugs or alcohol leading to greater intake and addiction. However, it should be clearly borne in mind that use of these drugs even once, can be a fore-runner to addiction. Thus, the addictive potential of drugs and alcohol, pull the user into a vicious circle leading to their regular use (abuse) from which he/she may not be able to get out. In the absence of any guidance or counselling, the person gets addicted and becomes dependent on their use.

Dependence is the tendency of the body to manifest a characteristic and unpleasant **withdrawal syndrome** if regular dose of drugs/alcohol is abruptly discontinued. This is characterised by anxiety, shakiness, nausea and sweating, which may be relieved when use is resumed again. In some cases, withdrawal symptoms can be severe and even life threatening and the person may need medical supervision.

Dependence leads the patient to ignore all social norms in order to get sufficient funds to satiate his/her needs. These result in many social adjustment problems.

8.5.3 Effects of Drug/Alcohol Abuse

The immediate adverse effects of drugs and alcohol abuse are manifested in the form of reckless behaviour, vandalism and violence. Excessive doses of drugs may lead to coma and death due to respiratory failure, heart failure or cerebral hemorrhage. A combination of drugs or their intake along with alcohol generally results in overdosing and even deaths. The most common warning signs of drug and alcohol abuse among youth include drop in academic performance, unexplained absence from school/college, lack of interest in personal hygiene, withdrawal, isolation, depression, fatigue, aggressive and rebellious behaviour, deteriorating relationships with family and friends, loss of interest in hobbies, change in sleeping and eating habits, fluctuations in weight, appetite, etc.

There may even be some far-reaching implications of drug/alcohol abuse. If an abuser is unable to get money to buy drugs/alcohol he/she may turn to stealing. The adverse effects are just not restricted to the person who is using drugs or alcohol. At times, a drug/alcohol addict becomes the cause of mental and financial distress to his/her entire family and friends.

Those who take drugs intravenously (direct injection into the vein using a needle and syringe), are much more likely to acquire serious infections like AIDS and Hepatitis B. The viruses, which are responsible for these diseases, are transferred from one person to another by sharing of infected needles and syringes. Both AIDS and Hepatitis B infections are chronic infections and ultimately fatal. Both can be transmitted through sexual contact or infected blood.

The use of alcohol during adolescence may also have long-term effects. It could lead to heavy drinking in adulthood. The chronic use of drugs and alcohol damages nervous system and liver **(cirrhosis)**. The use of drugs and alcohol during pregnancy is also known to adversely affect the foetus.

Another misuse of drugs is what certain sportspersons do to enhance their performance. They (mis)use narcotic analgesics, anabolic steroids, diuretics and certain hormones in sports to increase muscle strength and bulk and to promote aggressiveness and as a result increase athletic performance. The side-effects of the use of anabolic steroids in females include masculinisation (features like males), increased aggressiveness, mood swings, depression, abnormal menstrual cycles, excessive hair growth on the face and body, enlargement of clitoris, deepening of voice. In males it includes acne, increased aggressiveness, mood swings, depression, reduction of size of the testicles, decreased sperm production, potential for kidney and liver dysfunction, breast enlargement, premature baldness, enlargement of the prostate gland. These effects may be permanent with prolonged use. In the adolescent male or female, severe facial and body acne, and premature closure of the growth centres of the long bones may result in stunted growth.

8.5.4 Prevention and Control

The age-old adage of 'prevention is better than cure' holds true here also. It is also true that habits such as smoking, taking drug or alcohol are more likely to be taken up at a young age, more during adolescence. Hence, it is best to identify the situations that may push an adolescent towards use of drugs or alcohol, and to take remedial measures well in time. In this regard, the parents and the teachers have a special responsibility. Parenting that combines with high levels of nurturance and consistent discipline, has been associated with lowered risk of substance (alcohol/drugs/tobacco) abuse. Some of the measures mentioned here would be particularly useful for prevention and control of alcohol and drugs abuse among adolescents

(i) ***Avoid undue peer pressure*** - Every child has his/her own choice and personality, which should be respected and nurtured. A child should not be pushed unduly to perform beyond his/her threshold limits; be it studies, sports or other activities.

(ii) ***Education and counselling*** - Educating and counselling him/her to face problems and stresses, and to accept disappointments and failures as a part of life. It would also be worthwhile to channelise the child's energy into healthy pursuits like sports, reading, music, yoga and other extracurricular activities.

(iii) ***Seeking help from parents and peers*** - Help from parents and peers should be sought immediately so that they can guide appropriately. Help may even be sought from close and trusted friends. Besides getting proper advise to sort out their problems, this would help young to vent their feelings of anxiety and guilt.

(iv) ***Looking for danger signs*** - Alert parents and teachers need to look for and identify the danger signs discussed above. Even friends, if they find someone using drugs or alcohol, should not hesitate to bring this to the notice of parents or teacher in the best interests of the person concerned. Appropriate measures would then be required to diagnose the malady and the underlying causes. This would help in initiating proper remedial steps or treatment.

(v) ***Seeking professional and medical help*** - A lot of help is available in the form of highly qualified psychologists, psychiatrists, and de-addiction and rehabilitation programmes to help individuals who have unfortunately got in the quagmire of drug/alcohol abuse. With such help, the affected individual with sufficient efforts and will power, can get rid of the problem completely and lead a perfectly normal and healthy life.

SUMMARY

Health is not just the absence of disease. It is a state of complete physical, mental, social and psychological well-being. Diseases like typhoid, cholera, pneumonia, fungal infections of skin, malaria and many others are a major cause of distress to human beings. Vector-borne diseases like malaria especially one caused by *Plasmodium falciparum*, if not treated, may prove fatal. Besides personal cleanliness and hygiene, public health measures like proper disposal of waste, decontamination of drinking water, control of vectors like mosquitoes and immunisation are very helpful in preventing these diseases. Our immune system plays the major role in preventing these diseases when we are exposed to disease-causing agents. The innate defences of our body like skin, mucous membranes, antimicrobial substances present in our tears, saliva and the phagocytic cells help to block the entry of pathogens into our body. If the pathogens succeed in gaining entry to our body, specific antibodies (humoral immune response) and cells (cell mediated immune response) serve to kill these pathogens. Immune system has memory. On subsequent exposure to same pathogen, the immune response is rapid and more intense. This forms the basis of protection

afforded by vaccination and immunisation. Among other diseases, AIDS and cancer kill a large number of individuals worldwide. AIDS caused by the human immuno-deficiency virus (HIV) is fatal but can be prevented if certain precautions are taken. Many cancers are curable if detected early and appropriate therapeutic measures are taken. Of late, drug and alcohol abuse among youth and adolescents is becoming another cause of concern. Because of the addictive nature of alcohol and drugs, and their perceived benefits like relief from stress, a person may try taking these in the face of peer pressure, examinations-related and competition-related stresses. In doing so, he/she may get addicted to them. Education about their harmful effects, counselling and seeking immediate professional and medical help would totally relieve the individual from these evils.

EXERCISES

1. What are the various public health measures, which you would suggest as safeguard against infectious diseases?
2. In which way has the study of biology helped us to control infectious diseases?
3. How does the transmission of each of the following diseases take place?
   (a) Amoebiasis (b) Malaria (c) Ascariasis (d) Pneumonia
4. What measure would you take to prevent water-borne diseases?
5. Discuss with your teacher what does 'a suitable gene' means, in the context of DNA vaccines.
6. Name the primary and secondary lymphoid organs.
7. The following are some well-known abbreviations, which have been used in this chapter. Expand each one to its full form:
   (a) MALT (b) CMI (c) AIDS (d) NACO
   (e) HIV
8. Differentiate the following and give examples of each:
   (a) Innate and acquired immunity (b) Active and passive immunity
9. Draw a well-labelled diagram of an antibody molecule.
10. What are the various routes by which transmission of human immuno-deficiency virus takes place?
11. What is the mechanism by which the AIDS virus causes deficiency of immune system of the infected person?
12. How is a cancerous cell different from a normal cell?
13. Explain what is meant by metastasis.
14. List the harmful effects caused by alcohol/drug abuse.
15. Do you think that friends can influence one to take alcohol/drugs? If yes, how may one protect himself/herself from such an influence?
16. Why is that once a person starts taking alcohol or drugs, it is difficult to get rid of this habit? Discuss it with your teacher.
17. In your view what motivates youngsters to take to alcohol or drugs and how can this be avoided?

CHAPTER 9

STRATEGIES FOR ENHANCEMENT IN FOOD PRODUCTION

With ever-increasing population of the world, enhancement of food production is a major necessity. Biological principles as applied to animal husbandry and plant breeding have a major role in our efforts to increase food production. Several new techniques like embryo transfer technology and tissue culture techniques are going to play a pivotal role in further enhancing food production.

9.1 Animal Husbandry

Animal husbandry is the agricultural practice of breeding and raising livestock. As such it is a vital skill for farmers and is as much science as it is art. Animal husbandry deals with the care and breeding of livestock like buffaloes, cows, pigs, horses, cattle, sheep, camels, goats, etc., that are useful to humans. Extended, it includes poultry farming and fisheries. Fisheries include rearing, catching, selling, etc., of fish, molluscs (shell-fish) and crustaceans (prawns, crabs, etc.). Since time immemorial, animals like bees, silk-worm, prawns, crabs, fishes, birds, pigs, cattle, sheep and camels have been used by humans for products like milk, eggs, meat, wool, silk, honey, etc.

It is estimated that more then 70 per cent of the world livestock population is in India and China. However, it is surprising to note that the contribution to the world farm produce is only 25 per cent, i.e., the productivity per unit is very low. Hence, in addition to conventional practices of animal breeding and care, newer technologies also have to be applied to achieve improvement in quality and productivity.

9.1.1 Management of Farms and Farm Animals

A professional approach to what have been traditional practices of farm management gives the much needed boost to our food production. Let us discuss some of the management procedures, employed in various animal farm systems.

9.1.1.1 Dairy Farm Management

Dairying is the management of animals for milk and its products for human consumption. *Can you list the animals that you would expect to find in a dairy? What are different kinds of products that can be made with milk from a dairy farm?* In dairy farm management, we deal with processes and systems that increase yield and improve quality of milk. Milk yield is primarily dependent on the quality of breeds in the farm. Selection of good breeds having high yielding potential (under the climatic conditions of the area), combined with resistance to diseases is very important. For the yield potential to be realised the cattle have to be well looked after – they have to be housed well, should have adequate water and be maintained disease free. The feeding of cattle should be carried out in a scientific manner – with special emphasis on the quality and quantity of fodder. Besides, stringent cleanliness and hygiene (both of the cattle and the handlers) are of paramount importance while milking, storage and transport of the milk and its products. Nowadays, of course, much of these processes have become mechanised, which reduces chance of direct contact of the produce with the handler. Ensuring these stringent measures would of course, require regular inspections, with proper record keeping. It would also help to identify and rectify the problems as early as possible. Regular visits by a veterinary doctor would be mandatory.

You would probably find it interesting if you were to prepare a questionnaire on diverse aspects of dairy keeping and then follow it up with a visit to a dairy farm in your locality and seek answers to the questions.

9.1.1.2 Poultry Farm Management

Poultry is the class of domesticated fowl (birds) used for food or for their eggs. They typically include chicken and ducks, and sometimes turkey and geese. The word poultry is often used to refer to the meat of only these birds, but in a more general sense it may refer to the meat of other birds too.

As in dairy farming, selection of disease free and suitable breeds, proper and safe farm conditions, proper feed and water, and hygiene and health care are important components of poultry farm management.

You may have seen TV news or read newspaper–reports about the 'bird flu virus' which created a scare in the country and drastically affected egg and chicken consumption. Find out more about it and discuss whether the panic reaction was justified. How can we prevent the spread of the flu in case some chicken are infected?

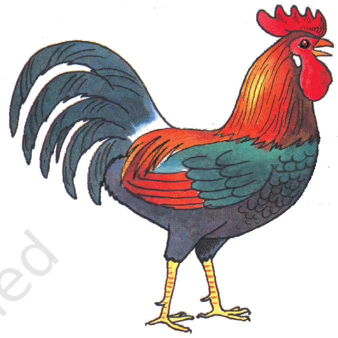
9.1.2 Animal Breeding

Breeding of animals is an important aspect of animal husbandry. Animal breeding aims at increasing the yield of animals and improving the desirable qualities of the produce. *For what kind of characters would we breed animals? Would the selection of characters differ with the choice of animals?*

What do we understand by the term 'breed'? A group of animals related by descent and similar in most characters like general appearance, features, size, configuration, etc., are said to belong to a breed. *Find out the names of some common breeds of cattle and poultry in the farms of your area.*

When breeding is between animals of the same breed it is called **inbreeding**, while crosses between different breeds are called **outbreeding**.

(a)



(b)

Figure 9.1 Improved breed of cattle and chickens (a) Jersey (b) Leghorn

Inbreeding : Inbreeding refers to the mating of more closely related individuals within the same breed for 4-6 generations. The breeding strategy is as follows – superior males and superior females of the same breed are identified and mated in pairs. The progeny obtained from such matings are evaluated and superior males and females among them are identified for further mating. A superior female, in the case of cattle, is the cow or buffalo that produces more milk per lactation. On the other hand, a superior male is the bull, which gives rise to superior progeny as compared to those of other males.

Try to recollect the homozygous purelines developed by Mendel as discussed in Chapter 5. A similar strategy is used for developing purelines in cattle as was used in case of peas. Inbreeding increases **homozygosity**. Thus inbreeding is necessary if we want to evolve a pureline in any animal. Inbreeding exposes harmful recessive genes that are eliminated by selection. It also helps in accumulation of superior genes and elimination of less desirable genes. Therefore, this approach, where there is selection at each step, increases the productivity of inbred population. However, continued inbreeding, especially close inbreeding, usually reduces fertility and even productivity. This is called **inbreeding depression**. Whenever this becomes a problem, selected animals of the breeding population should be mated with unrelated superior animals of the same breed. This usually helps restore fertility and yield.

Out-breeding : Out-breeding is the breeding of the unrelated animals, which may be between individuals of the same breed but having no common ancestors for 4-6 generations (out-crossing) or between different breeds (cross-breeding) or different species (inter-specific hybridisation).

Out-crossing: This is the practice of mating of animals within the same breed, but having no common ancestors on either side of their pedigree up to 4-6 generations. The offspring of such a mating is known as an out-cross. It is the best breeding method for animals that are below average in productivity in milk production, growth rate in beef cattle, etc. A single outcross often helps to overcome inbreeding depression.

Cross-breeding: In this method, superior males of one breed are mated with superior females of another breed. Cross-breeding allows the desirable qualities of two different breeds to be combined. The progeny hybrid animals may themselves be used for commercial production. Alternatively, they may be subjected to some form of inbreeding and selection to develop new stable breeds that may be superior to the existing breeds. Many new animal breeds have been developed by this approach. *Hisardale* is a new breed of sheep developed in Punjab by crossing Bikaneri ewes and Marino rams.

Interspecific hybridisation: In this method, male and female animals of two different related species are mated. In some cases, the progeny may combine desirable features of both the parents, and may be of considerable economic value, e.g., the mule (Figure 9.2). *Do you know what cross leads to the production of the mule?*

Controlled breeding experiments are carried out using **artificial insemination**. The semen is collected from the male that is chosen as a parent and injected into the reproductive tract of the selected female by the breeder. The semen may be used immediately or can be frozen and used at a later date. It can also be transported in a frozen form to where the female is housed. In this way desirable matings are carried. Artificial insemination helps us overcome several problems of normal matings. *Can you discuss and list some of them?*

Figure 9.2 Mule

Often, the success rate of crossing mature male and female animals is fairly low even though artificial insemination is carried out. To improve chances of successful production of hybrids, other means are also used. **Multiple Ovulation Embryo Transfer Technology** (MOET) is one such programme for herd improvement. In this method, a cow is administered hormones, with FSH-like activity, to induce follicular maturation and super ovulation – instead of one egg, which they normally yield per cycle, they produce 6-8 eggs. The animal is either mated with an elite bull or artificially inseminated. The fertilised eggs at 8–32 cells stages, are recovered non-surgically and transferred to surrogate mothers. The genetic mother is available for another round of super ovulation. This technology has been demonstrated for cattle, sheep, rabbits, buffaloes, mares, etc. High milk-yielding breeds of females and high quality (lean meat with less lipid) meat-yielding bulls have been bred successfully to increase herd size in a short time.

9.1.3 Bee-keeping

Bee-keeping or **apiculture** is the maintenance of hives of honeybees for the production of honey. It has been an age-old cottage industry. Honey is a food of high nutritive value and also finds use in the indigenous systems of medicine. Honeybee also produces beeswax, which finds many uses in industry, such as in the preparation of cosmetics and polishes of various kinds. The increased demand of honey has led to large-scale bee-keeping practices; it has become an established income generating industry, whether practiced on a small or on a large scale.

Bee-keeping can be practiced in any area where there are sufficient bee pastures of some wild shrubs, fruit orchards and cultivated crops. There are several species of honeybees which can be reared. Of these, the most common species is *Apis indica*. Beehives can be kept in one's courtyard, on the verandah of the house or even on the roof. Bee-keeping is not labour-intensive.

Bee-keeping though relatively easy does require some specialised knowledge and there are several organisations that teach bee-keeping. The following points are important for successful bee-keeping:

(i) Knowledge of the nature and habits of bees,
(ii) Selection of suitable location for keeping the beehives,
(iii) Catching and hiving of swarms (group of bees),
(iv) Management of beehives during different seasons, and
(v) Handling and collection of honey and of beeswax. Bees are the pollinators of many of our crop species (see chapter 2) such as sunflower, *Brassica*, apple and pear. Keeping beehives in crop fields during flowering period increases pollination efficiency and improves the yield–beneficial both from the point of view of crop yield and honey yield.

9.1.4 Fisheries

Fishery is an industry devoted to the catching, processing or selling of fish, shellfish or other aquatic animals. A large number of our population is dependent on fish, fish products and other aquatic animals such as prawn, crab, lobster, edible oyster, etc., for food. Some of the freshwater fishes which are very common include *Catla*, *Rohu* and common carp. Some of the marine fishes that are eaten include – *Hilsa*, Sardines, Mackerel and Pomfrets. *Find out what fishes are commonly eaten in your area.*

Fisheries has an important place in Indian economy. It provides income and employment to millions of fishermen and farmers, particularly in the coastal states. For many, it is the only source of their livelihood. In order to meet the increasing demands on fisheries, different techniques have been employed to increase production. For example, through aquaculture and pisciculture we have been able to increase the production of aquatic plants and animals, both fresh-water and marine. *Find out the difference between pisciculture and aquaculture.* This has led to the development and flourishing of the fishery industry, and it has brought a lot of income to the farmers in particular and the country in general. We now talk about 'Blue Revolution' as being implemented along the same lines as 'Green Revolution'.

9.2 Plant Breeding

Traditional farming can only yield a limited biomass, as food for humans and animals. Better management practices and increase in acreage can increase yield, but only to a limited extent. Plant breeding as a technology has helped increase yields to a very large extent. Who in India has not heard of **Green Revolution** which was responsible for our country to not merely meet the national requirements in food production but also helped us even to export it? Green revolution was dependent to a large extent on plant breeding techniques for development of high-yielding and disease resistant varieties in wheat, rice, maize, etc.

9.2.1 What is Plant Breeding?

Plant breeding is the purposeful manipulation of plant species in order to create desired plant types that are better suited for cultivation, give better yields and are disease resistant. Conventional plant breeding has been practiced for thousands of years, since the beginning of human civilisation; recorded evidence of plant breeding dates back to 9,000-11,000 years ago. Many present-day crops are the result of domestication in ancient times. Today, all our major food crops are derived from domesticated varieties. Classical plant breeding involves crossing or hybridisation of pure lines, followed by artificial selection to produce plants with desirable traits of higher yield, nutrition and resistance to diseases. With advancements in genetics, molecular biology and tissue culture, plant breeding is now increasingly being carried out by using molecular genetic tools.

If we were to list the traits or characters that the breeders have tried to incorporate into crop plants, the first we would list would be increased crop yield and improved quality. Increased tolerance to environmental stresses (salinity, extreme temperatures, drought), resistance to pathogens (viruses, fungi and bacteria) and increased tolerance to insect pests would be on our list too.

Plant breeding programmes are carried out in a systematic way worldwide–in government institutions and commercial companies. The main steps in breeding a new genetic variety of a crop are –

(i) ***Collection of variability:*** Genetic variability is the root of any breeding programme. In many crops pre-existing genetic variability is available from wild relatives of the crop. Collection and preservation of all the different wild varieties, species and relatives of the cultivated species (followed by their evaluation for their characteristics) is a pre-requisite for effective exploitation of natural genes available in the populations. The entire collection (of plants/seeds) having all the diverse alleles for all genes in a given crop is called **germplasm collection.**

(ii) ***Evaluation and selection of parents:*** The germplasm is evaluated so as to identify plants with desirable combination of characters. The selected plants are multiplied and used in the process of hybridisation. Purelines are created wherever desirable and possible.

(iii) ***Cross hybridisation among the selected parents:*** The desired characters have very often to be combined from two different plants (parents), for example high protein quality of one parent may need to be combined with disease resistance from another parent. This is possible by cross hybridising the two parents to produce hybrids that genetically combine the desired characters in one plant. This is a very time-consuming and tedious process since the pollen grains from the desirable plant chosen as male parent have to be collected and placed on the stigma of the flowers selected as female parent (In chapter 2 details on how to make crosses have been described). Also, it is not necessary that the hybrids do combine the desirable characters; usually only one in few hundred to a thousand crosses shows the desirable combination.

(iv) ***Selection and testing of superior recombinants:*** This step consists of selecting, among the progeny of the hybrids, those plants that have the desired character combination. The selection process is crucial to the success of the breeding objective and requires careful scientific evaluation of the progeny. This step yields plants that are superior to both of the parents (very often more than one superior progeny plant may become available). These are self-pollinated for several generations till they reach a state of uniformity (homozygosity), so that the characters will not segregate in the progeny.

(v) ***Testing, release and commercialisation of new cultivars:*** The newly selected lines are evaluated for their yield and other agronomic traits of quality, disease resistance, etc. This evaluation is done by growing these in the research fields and recording their performance under ideal fertiliser application, irrigation, and other crop management practices. The evaluation in research fields is followed by testing the materials in farmers' fields, for at least three growing seasons at several locations in the country, representing all the agroclimatic zones where the crop is usually grown. The material is evaluated in comparison to the best available local crop cultivar – a check or reference cultivar.

India is mainly an agricultural country. Agriculture accounts for approximately 33 per cent of India's GDP and employs nearly 62 per cent of the population. After India's independence, one of the main challenges facing the country was that of producing enough food for the increasing population. As only limited land is fit for cultivation, India has to strive to increase yields per unit area from existing farm land. The development of several high yielding varieties of wheat and rice in the mid-1960s, as a result of various plant breeding techniques led to dramatic increase in food production in our country. This phase is often referred to as the **Green Revolution**. Figure 9.3 represents some Indian hybrid crops of high yeilding varieties.

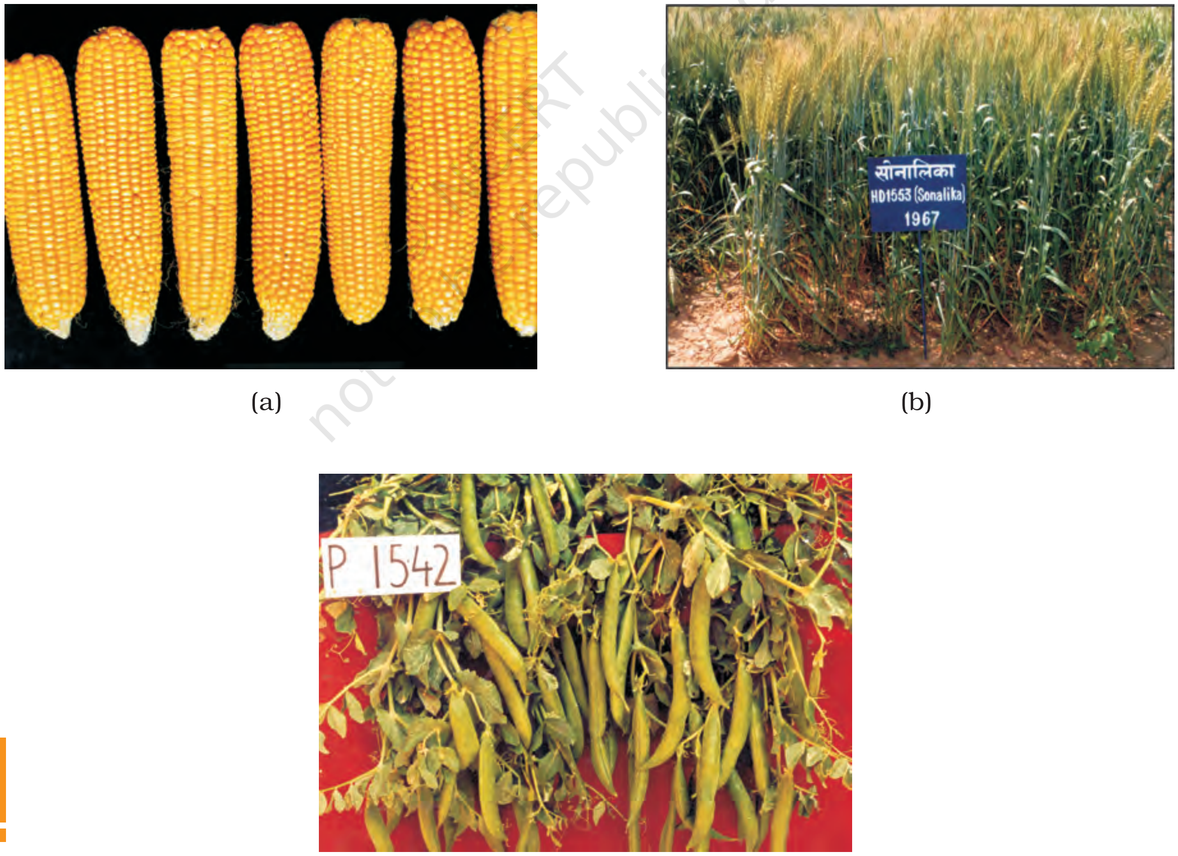


Figure 9.3 Some Indian hybrid crops: (a) Maize; (b) Wheat; (c) Garden peas

Wheat and Rice: During the period 1960 to 2000, wheat production increased from 11 million tonnes to 75 million tonnes while rice production went up from 35 million tonnes to 89.5 million tonnes. This was due to the development of semi-dwarf varieties of wheat and rice. Nobel laureate Norman E. Borlaug, at International Centre for Wheat and Maize Improvement in Mexico, developed semi-dwarf wheat. In 1963, several varieties such as *Sonalika* and *Kalyan Sona*, which were high yielding and disease resistant, were introduced all over the wheat-growing belt of India. Semi-dwarf rice varieties were derived from IR-8, (developed at International Rice Research Institute (IRRI), Philippines) and Taichung Native-1 (from Taiwan). The derivatives were introduced in 1966. Later better-yielding semi-dwarf varieties *Jaya* and *Ratna* were developed in India.

Sugar cane: *Saccharum barberi* was originally grown in north India, but had poor sugar content and yield. Tropical canes grown in south India *Saccharum officinarum* had thicker stems and higher sugar content but did not grow well in north India. These two species were successfully crossed to get sugar cane varieties combining the desirable qualities of high yield, thick stems, high sugar and ability to grow in the sugar cane areas of north India.

Millets: Hybrid maize, jowar and bajra have been successfully developed in India. Hybrid breeding have led to the development of several high yielding varieties resistant to water stress.

9.2.2 Plant Breeding for Disease Resistance

A wide range of fungal, bacterial and viral pathogens, affect the yield of cultivated crop species, especially in tropical climates. Crop losses can often be significant, up to 20-30 per cent, or sometimes even total. In this situation, breeding and development of cultivars resistant to disease enhances food production. This also helps reduce the dependence on use of fungicides and bacteriocides. Resistance of the host plant is the ability to prevent the pathogen from causing disease and is determined by the genetic constitution of the host plant. Before breeding is undertaken, it is important to know about the causative organism and the mode of transmission. Some of the diseases caused by fungi are rusts, e.g., brown rust of wheat, red rot of sugarcane and late blight of potato; by bacteria – black rot of crucifers; and by viruses – tobacco mosaic, turnip mosaic, etc.

Methods of breeding for disease resistance: Breeding is carried out by the conventional breeding techniques (described earlier) or by mutation breeding. The conventional method of breeding for disease resistance is that of hybridisation and selection. It's steps are essentially identical to those for breeding for any other agronomic characters such as high yield. The various sequential steps are : screening germplasm for resistance sources, hybridisation of selected parents, selection and evaluation of the hybrids and testing and release of new varieties.

Some crop varieties bred by hybridisation and selection, for disease resistance to fungi, bacteria and viral diseases are released (Table 9.1).

Table 9.1

Crop	**Variety**	**Resistance to diseases**
Wheat	*Himgiri*	*Leaf and stripe rust, hill bunt*
Brassica	*Pusa swarnim (Karan rai)*	*White rust*
Cauliflower	*Pusa Shubhra, Pusa Snowball K-1*	*Black rot and Curl blight black rot*
Cowpea	*Pusa Komal*	*Bacterial blight*
Chilli	*Pusa Sadabahar*	*Chilly mosaic virus, Tobacco mosaic virus and Leaf curl*

Conventional breeding is often constrained by the availability of limited number of disease resistance genes that are present and identified in various crop varieties or wild relatives. Inducing mutations in plants through diverse means and then screening the plant materials for resistance sometimes leads to desirable genes being identified. Plants having these desirable characters can then be either multiplied directly or can be used in breeding. Other breeding methods that are used are selection amongst somaclonal variants and genetic engineering.

Mutation is the process by which genetic variations are created through changes in the base sequence within genes (see Chapter 5) resulting in the creation of a new character or trait not found in the parental type. It is possible to induce mutations artificially through use of chemicals or radiations (like gamma radiations), and selecting and using the plants that have the desirable character as a source in breeding – this process is called **mutation breeding**. In mung bean, resistance to yellow mosaic virus and powdery mildew were induced by mutations.

Several wild relatives of different cultivated species of plants have been shown to have certain resistant characters but have very low yield. Hence, there is a need to introduce the resistant genes into the high-yielding cultivated varieties. Resistance to yellow mosaic virus in *bhindi* (*Abelmoschus esculentus*) was transferred from a wild species and resulted in a new variety of *A. esculentus* called *Parbhani kranti*.

All the above examples involve sources of resistance genes that are in the same crop species, which has to be bred for disease resistance, or in a related wild species. Transfer of resistance genes is achieved by sexual hybridisation between the target and the source plant followed by selection.

9.2.3 Plant Breeding for Developing Resistance to Insect Pests

Another major cause for large scale destruction of crop plant and crop produce is insect and pest infestation. Insect resistance in host crop plants may be due to morphological, biochemical or physiological characteristics. Hairy leaves in several plants are associated with resistance to insect pests, e.g, resistance to jassids in cotton and cereal leaf beetle in wheat. In wheat, solid stems lead to non-preference by the stem sawfly and smooth leaved and nectar-less cotton varieties do not attract bollworms. High aspartic acid, low nitrogen and sugar content in maize leads to resistance to maize stem borers.

Breeding methods for insect pest resistance involve the same steps as those for any other agronomic trait such as yield or quality and are as discussed earlier. Sources of resistance genes may be cultivated varieties, germplasm collections of the crop or wild relatives.

Some released crop varieties bred by hybridisation and selection, for insect pest resistance are given in Table 9.2.

Table 9.2

Crop	Variety	Insect Pests
Brassica (rapeseed mustard)	*Pusa Gaurav*	*Aphids*
Flat bean	*Pusa Sem 2, Pusa Sem 3*	*Jassids, aphids and fruit borer*
Okra (Bhindi)	*Pusa Sawani Pusa A-4*	*Shoot and Fruit borer*

9.2.4 Plant Breeding for Improved Food Quality

More than 840 million people in the world do not have adequate food to meet their daily food and nutritional requirements. A far greater number – three billion people – suffer from micronutrient, protein and vitamin deficiencies or 'hidden hunger' because they cannot afford to buy enough fruits, vegetables, legumes, fish and meat. Diets lacking essential micronutrients – particularly iron, vitamin A, iodine and zinc – increase the risk for disease, reduce lifespan and reduce mental abilities.

Biofortification – breeding crops with higher levels of vitamins and minerals, or higher protein and healthier fats – is the most practical means to improve public health.

Breeding for improved nutritional quality is undertaken with the objectives of improving –

(i) Protein content and quality;
(ii) Oil content and quality;
(iii) Vitamin content; and
(iv) Micronutrient and mineral content.

In 2000, maize hybrids that had twice the amount of the amino acids, lysine and tryptophan, compared to existing maize hybrids were developed. Wheat variety, Atlas 66, having a high protein content, has been used as a donor for improving cultivated wheat. It has been possible to develop an iron-fortified rice variety containing over five times as much iron as in commonly consumed varieties.

The Indian Agricultural Research Institute, New Delhi has also released several vegetable crops that are rich in vitamins and minerals, e.g., vitamin A enriched carrots, spinach, pumpkin; vitamin C enriched bitter gourd, *bathua*, mustard, tomato; iron and calcium enriched spinach and *bathua*; and protein enriched beans – broad, lablab, French and garden peas.

9.3 Single Cell Protein (SCP)

Conventional agricultural production of cereals, pulses, vegetables, fruits, etc., may not be able to meet the demand of food at the rate at which human and animal population is increasing. The shift from grain to meat diets also creates more demand for cereals as it takes 3-10 Kg of grain to produce 1 Kg of meat by animal farming. *Can you explain this statement in the light of your knowledge of food chains?* More than 25 per cent of human population is suffering from hunger and malnutrition. One of the alternate sources of proteins for animal and human nutrition is **Single Cell Protein (SCP).**

Microbes are being grown on an industrial scale as source of good protein. Blue-green algae like *Spirulina* can be grown easily on materials like waste water from potato processing plants (containing starch), straw, molasses, animal manure and even sewage, to produce large quantities and can serve as food rich in protein, minerals, fats, carbohydrate and vitamins. Incidentally such utilisation also reduces environmental pollution.

Certain bacterial species like *Methylophilus methylotrophus*, because of its high rate of biomass production and growth, can be expected to produce 25 tonnes of protein. The fact that edible mushrooms are eaten by many people and large scale mushroom culture is a growing industry makes it believable that microscopic fungi too would become acceptable as food.

9.4 Tissue Culture

As traditional breeding techniques failed to keep pace with demand and to provide sufficiently fast and efficient systems for crop improvement, another technology called **tissue culture** got developed. What does tissue culture mean? It was learnt by scientists, during 1950s, that whole plants could be regenerated from **explants,** i.e., any part of a plant taken out and grown in a test tube, under sterile conditions in special nutrient media. This capacity to generate a whole plant from any cell/explant is called **totipotency**. You will learn how to accomplish this in higher classes. It is important to stress here that the nutrient medium must provide a carbon source such as sucrose and also inorganic salts, vitamins, amino acids and growth regulators like auxins, cytokinins etc. By application of these methods it is possible to achieve propagation of a large number of plants in very short durations. This method of producing thousands of plants through tissue culture is called **micro-propagation**. Each of these plants will be genetically identical to the original plant from which they were grown, i.e., they are **somaclones**. Many important food plants like tomato, banana, apple, etc., have been produced on commercial scale using this method. Try to visit a tissue culture laboratory with your teacher to better understand and appreciate the process.

Another important application of the method is the recovery of healthy plants from diseased plants. Even if the plant is infected with a virus, the **meristem** (apical and axillary) is free of virus. Hence, one can remove the meristem and grow it *in vitro* to obtain virus-free plants. Scientists have succeeded in culturing meristems of banana, sugarcane, potato, etc.

Scientists have even isolated single cells from plants and after digesting their cell walls have been able to isolate naked protoplasts (surrounded by plasma membranes). Isolated protoplasts from two different varieties of plants – each having a desirable character – can be fused to get hybrid protoplasts, which can be further grown to form a new plant. These hybrids are called **somatic hybrids** while the process is called **somatic hybridisation**. Imagine a situation when a protoplast of tomato is fused with that of potato, and then they are grown – to form new hybrid plants combining tomato and potato characteristics. Well, this has been achieved – resulting in formation of pomato; unfortunately this plant did not have all the desired combination of characteristics for its commercial utilisation.

SUMMARY

Animal husbandry is the practice of taking care and breeding domestic animals by applying scientific principles. The ever-increasing demand of food from animals and animal products both in terms of quality and quantity has been met by good animal husbandry practices. These practices include (i) management of farm and farm animals, and (ii) animal breeding. In view of the high nutritive value of honey and its medicinal importance, there has been a remarkable growth in the practice of bee-keeping or apiculture. Fishery is another flourishing industry meeting the ever-increasing demand for fish, fish products and other aquatic foods.

Plant breeding may be used to create varieties, which are resistant to pathogens and to insect pests. This increases the yield of the food. This method has also been used to increase the protein content of the plant foods and thereby enhance the quality of food. In India, several varieties of different crop plants have been produced. All these measures enhance the production of food. Techniques of tissue culture and somatic hybridisation offer vast potential for manipulation of plants *in vitro* to produce new varieties.

EXERCISES

1. Explain in brief the role of animal husbandry in human welfare.
2. If your family owned a dairy farm, what measures would you undertake to improve the quality and quantity of milk production?
3. What is meant by the term 'breed'? What are the objectives of animal breeding?
4. Name the methods employed in animal breeding. According to you which of the methods is best? Why?
5. What is apiculture? How is it important in our lives?
6. Discuss the role of fishery in enhancement of food production.
7. Briefly describe various steps involved in plant breeding.
8. Explain what is meant by biofortification.
9. Which part of the plant is best suited for making virus-free plants and why?
10. What is the major advantage of producing plants by micropropagation?
11. Find out what the various components of the medium used for propagation of an explant *in vitro* are?
12. Name any five hybrid varieties of crop plants which have been developed in India.

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CHAPTER 10

MICROBES IN HUMAN WELFARE

Besides macroscopic plants and animals, microbes are the major components of biological systems on this earth. You have studied about the diversity of living organisms in Class XI. *Do you remember which Kingdoms among the living organisms contain micro-organisms? Which are the ones that are only microscopic?* Microbes are present everywhere – in soil, water, air, inside our bodies and that of other animals and plants. They are present even at sites where no other life-form could possibly exist–sites such as deep inside the geysers (thermal vents) where the temperature may be as high as 100^0C, deep in the soil, under the layers of snow several metres thick, and in highly acidic environments. Microbes are diverse–protozoa, bacteria, fungi and microscopic animal and plant viruses, viroids and also prions that are proteinacious infectious agents. Some of the microbes are shown in Figures 10.1 and 10.2.

Microbes like bacteria and many fungi can be grown on nutritive media to form colonies (Figure 10.3), that can be seen with the naked eyes. Such cultures are useful in studies on micro-organisms.

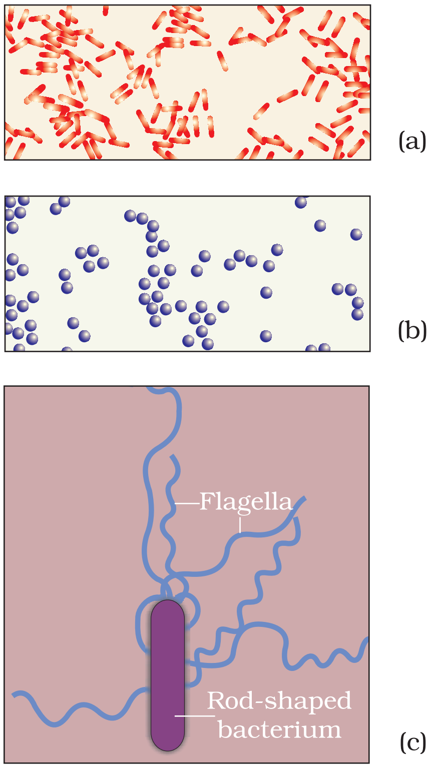

Figure 10.1 Bacteria: (a) Rod-shaped, magnified 1500X; (b) Spherical shaped, magnified1500X; (c) A rod-shaped bacterium showing flagella, magnified 50,000X

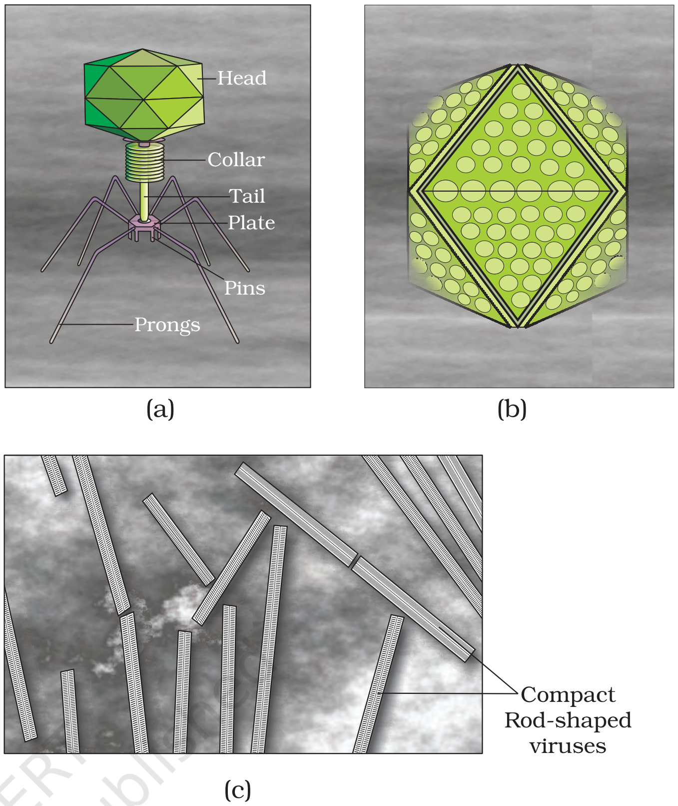

Figure 10.2 Viruses: (a) A bacteriophage; (b) Adenovirus which causes respiratory infections; (c) Rod-shaped Tobacco Mosaic Virus (TMV). Magnified about 1,00,000–1,50,000X

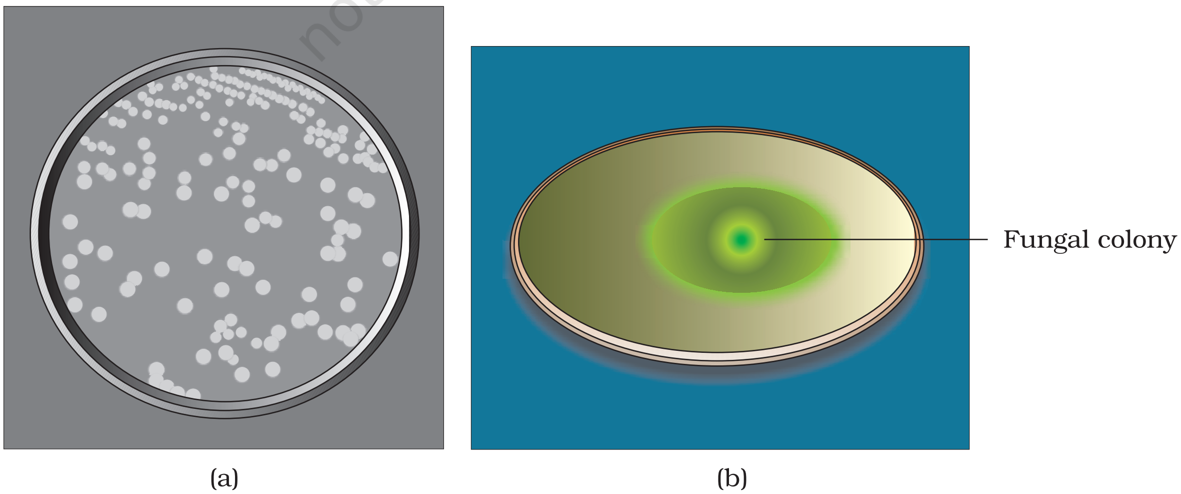

Figure 10.3 (a) Colonies of bacteria growing in a petri dish; (b) Fungal colony growing in a petri dish

In chapter 8, you have read that microbes cause a large number of diseases in human beings. They also cause diseases in animals and plants. But this should not make you think that all microbes are harmful; several microbes are useful to man in diverse ways. Some of the most important contributions of microbes to human welfare are discussed in this chapter.

10.1 Microbes in Household Products

You would be surprised to know that we use microbes or products derived from them everyday. A common example is the production of curd from milk. Micro-organisms such as *Lactobacillus* and others commonly called **lactic acid bacteria (LAB)** grow in milk and convert it to curd. During growth, the LAB produce acids that coagulate and partially digest the milk proteins. A small amount of curd added to the fresh milk as inoculum or starter contain millions of LAB, which at suitable temperatures multiply, thus converting milk to curd, which also improves its nutritional quality by increasing vitamin B_{12}. In our stomach too, the LAB play very beneficial role in checking disease-causing microbes.

The dough, which is used for making foods such as *dosa* and *idli* is also fermented by bacteria. The puffed-up appearance of dough is due to the production of CO_2 gas. *Can you tell which metabolic pathway is taking place resulting in the formation of CO_2? Where do you think the bacteria for these fermentations come from?* Similarly the dough, which is used for making bread, is fermented using baker's yeast (*Saccharomyces cerevisiae*). A number of traditional drinks and foods are also made by fermentation by the microbes. 'Toddy', a traditional drink of some parts of southern India is made by fermenting sap from palms. Microbes are also used to ferment fish, soyabean and bamboo-shoots to make foods. Cheese, is one of the oldest food items in which microbes were used. Different varieties of cheese are known by their characteristic texture, flavour and taste, the specificity coming from the microbes used. For example, the large holes in 'Swiss cheese' are due to production of a large amount of CO_2 by a bacterium named *Propionibacterium sharmanii.* The 'Roquefort cheese' are ripened by growing a specific fungi on them, which gives them a particular flavour.

10.2 Microbes in Industrial Products

Even in industry, microbes are used to synthesise a number of products valuable to human beings. Beverages and antibiotics are some examples. Production on an industrial scale, requires growing microbes in very large vessels called **fermentors** (Figure 10.4).

Figure 10.4 Fermentors

Figure 10.5 Fermentation Plant

10.2.1 Fermented Beverages

Microbes especially yeasts have been used from time immemorial for the production of beverages like wine, beer, whisky, brandy or rum. For this purpose the same yeast *Saccharomyces cerevisiae* used for bread-making and commonly called brewer's yeast, is used for fermenting malted cereals and fruit juices, to produce ethanol. *Do you recollect the metabolic reactions, which result in the production of ethanol by yeast?* Depending on the type of the raw material used for fermentation and the type of processing (with or without distillation) different types of alcoholic drinks are obtained. Wine and beer are produced without distillation whereas whisky, brandy and rum are produced by distillation of the fermented broth. The photograph of a fermentation plant is shown in Figure 10.5.

10.2.2 Antibiotics

Antibiotics produced by microbes are regarded as one of the most significant discoveries of the twentieth century and have greatly contributed towards the welfare of the human society. *Anti* is a Greek word that means 'against', and *bio* means 'life', together they mean 'against life' (in the context of disease causing organisms); whereas with reference to human beings, they are 'pro life' and not against. Antibiotics are chemical substances, which are produced by some microbes and can kill or retard the growth of other (disease-causing) microbes.

You are familiar with the commonly used antibiotic Penicillin. Do you know that Penicillin was the first antibiotic to be discovered, and it was a chance discovery? Alexander Fleming while working on *Staphylococci* bacteria, once observed a mould growing in one of his unwashed culture plates around which *Staphylococci* could not grow. He found out that it was due to a chemical produced by the mould and he named it Penicillin after the mould *Penicillium notatum*. However, its full potential as an effective antibiotic was established much later by Ernest Chain and Howard Florey. This antibiotic was extensively used to treat American soldiers wounded in World War II. Fleming, Chain and Florey were awarded the Nobel Prize in 1945, for this discovery.

After Penicillin, other antibiotics were also purified from other microbes. *Can you name some other antibiotics and find out their sources?* Antibiotics have greatly improved our capacity to treat deadly diseases such as plague, whooping cough (*kali khansi*), diphtheria (*gal ghotu*) and leprosy (*kusht rog*), which used to kill millions all over the globe. Today, we cannot imagine a world without antibiotics.

10.2.3 Chemicals, Enzymes and other Bioactive Molecules

Microbes are also used for commercial and industrial production of certain chemicals like organic acids, alcohols and enzymes. Examples of acid producers are *Aspergillus niger* (a fungus) of citric acid, *Acetobacter aceti* (a bacterium) of acetic acid; *Clostridium butylicum* (a bacterium) of butyric acid and *Lactobacillus* (a bacterium) of lactic acid.

Yeast (*Saccharomyces cerevisiae)* is used for commercial production of ethanol. Microbes are also used for production of enzymes. Lipases are used in detergent formulations and are helpful in removing oily stains from the laundry. You must have noticed that bottled fruit juices bought from the market are clearer as compared to those made at home. This is because the bottled juices are clarified by the use of pectinases and proteases. Streptokinase produced by the bacterium *Streptococcus* and modified by genetic engineering is used as a 'clot buster' for removing clots from the blood vessels of patients who have undergone myocardial infarction leading to heart attack.

Another bioactive molecule, cyclosporin A, that is used as an immunosuppressive agent in organ-transplant patients, is produced by the fungus *Trichoderma polysporum*. Statins produced by the yeast *Monascus purpureus* have been commercialised as blood-cholesterol lowering agents. It acts by competitively inhibiting the enzyme responsible for synthesis of cholesterol.

10.3 Microbes in Sewage Treatment

We know that large quantities of waste water are generated everyday in cities and towns. A major component of this waste water is human excreta. This municipal waste-water is also called sewage. It contains large amounts of organic matter and microbes. Many of which are pathogenic. Have you ever wondered where this huge quantity of sewage or urban waste water is disposed off daily? This cannot be discharged into natural water bodies like rivers and streams directly – you can understand why. Before disposal, hence, sewage is treated in sewage treatment plants (STPs) to make it less polluting. Treatment of waste water is done by the

Figure 10.6 Secondary treatment

heterotrophic microbes naturally present in the sewage. This treatment is carried out in two stages:

Primary treatment : These treatment steps basically involve physical removal of particles – large and small – from the sewage through filtration and sedimentation. These are removed in stages; initially, floating debris is removed by sequential filtration. Then the grit (soil and small pebbles) are removed by sedimentation. All solids that settle form the **primary sludge**, and the supernatant forms the effluent. The effluent from the primary settling tank is taken for secondary treatment.

Secondary treatment or Biological treatment : The primary effluent is passed into large aeration tanks (Figure 10.6) where it is constantly agitated mechanically and air is pumped into it. This allows vigorous growth of useful aerobic microbes into **flocs** (masses of bacteria associated with fungal filaments to form mesh like structures). While growing, these microbes consume the major part of the organic matter in the effluent. This significantly reduces the **BOD (biochemical oxygen demand)** of the effluent. BOD refers to the amount of the oxygen that would be consumed if all the organic matter in one liter of water were oxidised by bacteria. The sewage water is treated till the BOD is reduced. The BOD test measures the rate of uptake of oxygen by micro-organisms in a sample of water and thus, indirectly, BOD is a measure of the organic matter present in the water. The greater the BOD of waste water, more is its polluting potential.

Once the BOD of sewage or waste water is reduced significantly, the effluent is then passed into a settling tank where the bacterial 'flocs' are allowed to sediment. This sediment is called **activated sludge**. A small part of the activated sludge is pumped back into the aeration tank to serve as the inoculum. The remaining major part of the sludge is pumped into large tanks called **anaerobic sludge digesters**. Here, other kinds of bacteria, which grow anaerobically, digest the bacteria and the fungi in the sludge. During this digestion, bacteria produce a mixture of gases such as methane, hydrogen sulphide and carbon dioxide. These gases form **biogas** and can be used as source of energy as it is inflammable.

The effluent from the secondary treatment plant is generally released into natural water bodies like rivers and streams. An aerial view of such a plant is shown in Figure 10.7.

You can appreciate how microbes play a major role in treating millions of gallons of waste water everyday across the globe. This methodology has been practiced for more than a century now, in almost all parts of the world. Till date, no man-made technology has been able to rival the microbial treatment of sewage.

Figure 10.7 An aerial view of a sewage plant

You are aware that due to increasing urbanisation, sewage is being produced in much larger quantities than ever before. However the number of sewage treatment plants has not increased enough to treat such large quantities. So the untreated sewage is often discharged directly into rivers leading to their pollution and increase in water-borne diseases.

The Ministry of Environment and Forests has initiated **Ganga Action Plan** and **Yamuna Action Plan** to save these major rivers of our country from pollution. Under these plans, it is proposed to build a large number of sewage treatment plants so that only treated sewage may be discharged in the rivers. A visit to a sewage treatment plant situated in any place near you would be a very interesting and educating experience.

10.4 Microbes in Production of Biogas

Biogas is a mixture of gases (containing predominantly methane) produced by the microbial activity and which may be used as fuel. You have learnt that microbes produce different types of gaseous end-products during growth and metabolism. The type of the gas produced depends upon the microbes and the organic substrates they utilise. In the examples cited in relation to fermentation of dough, cheese making and production of beverages, the main gas produced was CO_2. However, certain bacteria, which grow anaerobically on cellulosic material, produce large amount of methane along with CO_2 and H_2. These bacteria are collectively called **methanogens**, and one such common bacterium is *Methanobacterium*. These bacteria are commonly found in the anaerobic sludge during sewage treatment. These bacteria are also present in the rumen (a part of stomach) of cattle. A lot of cellulosic material present in the food of cattle is also present in the rumen. In rumen, these bacteria help in the breakdown of cellulose and play an important role in the nutrition of cattle. *Do you think we, human beings, are able to digest the celluose present in our foods?* Thus, the excreta (dung) of cattle, commonly called *gobar*, is rich in these bacteria. Dung can be used for generation of biogas, commonly called *gobar gas*.

The biogas plant consists of a concrete tank (10-15 feet deep) in which bio-wastes are collected and a slurry of dung is fed. A floating cover is

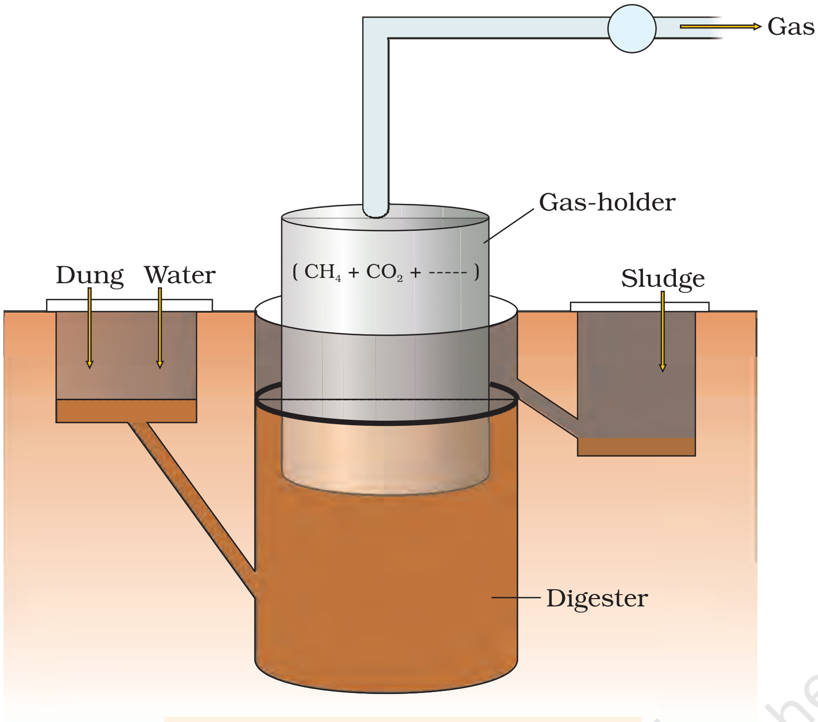

Figure 10.8 A typical biogas plant

placed over the slurry, which keeps on rising as the gas is produced in the tank due to the microbial activity. The biogas plant has an outlet, which is connected to a pipe to supply biogas to nearby houses. The spent slurry is removed through another outlet and may be used as fertiliser. Cattle dung is available in large quantities in rural areas where cattle are used for a variety of purposes. So biogas plants are more often built in rural areas. The biogas thus produced is used for cooking and lighting. The picture of a biogas plant is shown in Figure 10.8. The technology of biogas production was developed in India mainly due to the efforts of Indian Agricultural Research Institute (IARI) and Khadi and Village Industries Commission (KVIC). If your school is situated in a village or near a village, it would be very interesting to enquire if there are any biogas plants nearby. Visit the biogas plant and learn more about it from the people who are actually managing it.

10.5 Microbes as Biocontrol Agents

Biocontrol refers to the use of biological methods for controlling plant diseases and pests. In modern society, these problems have been tackled increasingly by the use of chemicals – by use of insecticides and pesticides. These chemicals are toxic and extremely harmful, to human beings and animals alike, and have been polluting our environment (soil, ground water), fruits, vegetables and crop plants. Our soil is also polluted through our use of weedicides to remove weeds.

Biological control of pests and diseases: In agriculture, there is a method of controlling pests that relies on natural predation rather than introduced chemicals. A key belief of the organic farmer is that biodiversity furthers health. The more variety a landscape has, the more sustainable it is. The organic farmer, therefore, works to create a system where the insects that are sometimes called pests are not eradicated, but instead are kept at manageable levels by a complex system of checks and balances within a living and vibrant ecosystem. Contrary to the 'conventional' farming practices which often use chemical methods to kill both useful and harmful life forms indiscriminately, this is a holistic approach that seeks to develop an understanding of the webs of interaction between the myriad of organisms that constitute the field fauna and flora. The organic farmer holds the view that the eradication of the creatures that are often described as pests is not only possible, but also undesirable, for without them the beneficial predatory and parasitic insects which depend upon them as food or hosts would not be able to survive. Thus, the use of biocontrol measures will greatly reduce our dependence on toxic chemicals and pesticides. An important part of the biological farming approach is to become familiar with the various life forms that inhabit the field, predators as well as pests, and also their life cycles, patterns of feeding and the habitats that they prefer. This will help develop appropriate means of biocontrol.

The very familiar beetle with red and black markings – the Ladybird, and Dragonflies are useful to get rid of aphids and mosquitoes, respectively. An example of microbial biocontrol agents that can be introduced in order to control butterfly caterpillars is the bacteria *Bacillus thuringiensis* (often written as *Bt*). These are available in sachets as dried spores which are mixed with water and sprayed onto vulnerable plants such as brassicas and fruit trees, where these are eaten by the insect larvae. In the gut of the larvae, the toxin is released and the larvae get killed. The bacterial disease will kill the caterpillars, but leave other insects unharmed. Because of the development of methods of genetic engineering in the last decade or so, the scientists have introduced *B. thuringiensis* toxin genes into plants. Such plants are resistant to attack by insect pests. **Bt-cotton** is one such example, which is being cultivated in some states of our country. You will learn more about this in chapter 12.

A biological control being developed for use in the treatment of plant disease is the fungus *Trichoderma*. *Trichoderma* species are free-living fungi that are very common in the root ecosystems. They are effective biocontrol agents of several plant pathogens.

Baculoviruses are pathogens that attack insects and other arthropods. The majority of baculoviruses used as biological control agents are in the genus *Nucleopolyhedrovirus.* These viruses are excellent candidates for species-specific, narrow spectrum insecticidal applications. They have been shown to have no negative impacts on plants, mammals, birds, fish or even on non-target insects. This is especially desirable when beneficial insects are being conserved to aid in an overall integrated pest management (IPM) programme, or when an ecologically sensitive area is being treated.

10.6 Microbes as Biofertilisers

With our present day life styles environmental pollution is a major cause of concern. The use of the chemical fertilisers to meet the ever-increasing demand of agricultural produce has contributed significantly to this pollution. Of course, we have now realised that there are problems associated with the overuse of chemical fertilisers and there is a large pressure to switch to **organic farming** – the use of **biofertilisers**. Biofertilisers are organisms that enrich the nutrient quality of the soil. The main sources of biofertilisers are bacteria, fungi and cyanobacteria. You have studied about the nodules on the roots of leguminous plants formed by the symbiotic association of *Rhizobium*. These bacteria fix atmospheric nitrogen into organic forms, which is used by the plant as nutrient. Other bacteria can fix atmospheric nitrogen while free-living in the soil (examples *Azospirillum* and *Azotobacter*), thus enriching the nitrogen content of the soil.

Fungi are also known to form symbiotic associations with plants (**mycorrhiza**). Many members of the genus *Glomus* form mycorrhiza. The fungal symbiont in these associations absorbs phosphorus from soil and passes it to the plant. Plants having such associations show other benefits also, such as resistance to root-borne pathogens, tolerance to salinity and drought, and an overall increase in plant growth and development. *Can you tell what advantage the fungus derives from this association?*

Cyanobacteria are autotrophic microbes widely distributed in aquatic and terrestrial environments many of which can fix atmospheric nitrogen, e.g. *Anabaena*, *Nostoc*, *Oscillatoria*, etc. In paddy fields, cyanobacteria serve as an important biofertiliser. Blue green algae also add organic matter to the soil and increase its fertility. Currently, in our country, a number of biofertilisers are available commercially in the market and farmers use these regularly in their fields to replenish soil nutrients and to reduce dependence on chemical fertilisers.

SUMMARY

Microbes are a very important component of life on earth. Not all microbes are pathogenic. Many microbes are very useful to human beings. We use microbes and microbially derived products almost every day. Bacteria called lactic acid bacteria (LAB) grow in milk to convert it into curd. The dough, which is used to make bread, is fermented by yeast called *Saccharomyces cerevisiae*. Certain dishes such as *idli* and *dosa*, are made from dough fermented by microbes. Bacteria and fungi are used to impart particular texture, taste and flavor to cheese. Microbes are used to produce industrial products like lactic acid, acetic acid and alcohol, which are used in a variety of processes in the industry. Antibiotics like penicillins produced by useful microbes are used to kill disease-causing harmful microbes. Antibiotics have played a major role in controlling infectious diseases like diphtheria, whooping cough and pneumonia. For more than a hundred years, microbes are being used to treat sewage (waste water) by the process of activated sludge formation and this helps in recycling of water in nature. Methanogens produce methane (biogas) while degrading plant waste. Biogas produced by microbes is used as a source of energy in rural areas. Microbes can also be used to kill harmful pests, a process called as biocontrol. The biocontrol measures help us to avoid heavy use of toxic pesticides for controlling pests. There is a need these days to push for use of biofertilisers in place of chemical fertilisers. It is clear from the diverse uses human beings have put microbes to that they play an important role in the welfare of human society.

EXERCISES

1. Bacteria cannot be seen with the naked eyes, but these can be seen with the help of a microscope. If you have to carry a sample from your home to your biology laboratory to demonstrate the presence of microbes with the help of a microscope, which sample would you carry and why?
2. Give examples to prove that microbes release gases during metabolism.
3. In which food would you find lactic acid bacteria? Mention some of their useful applications.
4. Name some traditional Indian foods made of wheat, rice and Bengal gram (or their products) which involve use of microbes.
5. In which way have microbes played a major role in controlling diseases caused by harmful bacteria?
6. Name any two species of fungus, which are used in the production of the antibiotics.
7. What is sewage? In which way can sewage be harmful to us?
8. What is the key difference between primary and secondary sewage treatment?
9. Do you think microbes can also be used as source of energy? If yes, how?
10. Microbes can be used to decrease the use of chemical fertilisers and pesticides. Explain how this can be accomplished.
11. Three water samples namely river water, untreated sewage water and secondary effluent discharged from a sewage treatment plant were subjected to BOD test. The samples were labelled A, B and C; but the laboratory attendant did not note which was which. The BOD values of the three samples A, B and C were recorded as 20mg/L, 8mg/L and 400mg/L, respectively. Which sample of the water is most polluted? Can you assign the correct label to each assuming the river water is relatively clean?

12. Find out the name of the microbes from which Cyclosporin A (an immunosuppressive drug) and Statins (blood cholesterol lowering agents) are obtained.
13. Find out the role of microbes in the following and discuss it with your teacher.
    (a) Single cell protein (SCP)
    (b) Soil
14. Arrange the following in the decreasing order (most important first) of their importance, for the welfare of human society. Give reasons for your answer.

    Biogas, Citric acid, Penicillin and Curd
15. How do biofertilisers enrich the fertility of the soil?

UNIT IX
BIOTECHNOLOGY

Ever since the days of Rene Descartes, the French philosopher, mathematician and biologist of seventeenth century, all human knowledge especially natural sciences were directed to develop technologies which add to the creature comforts of human lives, as also value to human life. The whole approach to understanding natural phenomena became anthropocentric. Physics and chemistry gave rise to engineering, technologies and industries which all worked for human comfort and welfare. The major utility of the biological world is as a source of food. Biotechnology, the twentieth century off-shoot of modern biology, changed our daily life as its products brought qualitative improvement in health and food production. The basic principles underlying biotechnological processes and some applications are highlighted and discussed in this unit.

HERBERT BOYER
(1936)

Herbert Boyer was born in 1936 and brought up in a corner of western Pennsylvania where railroads and mines were the destiny of most young men. He completed graduate work at the University of Pittsburgh, in 1963, followed by three years of post-graduate studies at Yale.

In 1966, Boyer took over assistant professorship at the University of California at San Francisco. By 1969, he performed studies on a couple of restriction enzymes of the *E. coli* bacterium with especially useful properties. Boyer observed that these enzymes have the capability of cutting DNA strands in a particular fashion, which left what has became known as `sticky ends' on the strands. These clipped ends made pasting together pieces of DNA a precise exercise.

This discovery, in turn, led to a rich and rewarding conversation in Hawaii with a Stanford scientist named Stanley Cohen. Cohen had been studying small ringlets of DNA called plasmids and which float about freely in the cytoplasm of certain bacterial cells and replicate independently from the coding strand of DNA. Cohen had developed a method of removing these plasmids from the cell and then reinserting them in other cells. Combining this process with that of DNA splicing enabled Boyer and Cohen to recombine segments of DNA in desired configurations and insert the DNA in bacterial cells, which could then act as manufacturing plants for specific proteins. This breakthrough was the basis upon which the discipline of biotechnology was founded.

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CHAPTER 11

BIOTECHNOLOGY : PRINCIPLES AND PROCESSES

Biotechnology deals with techniques of using live organisms or enzymes from organisms to produce products and processes useful to humans. In this sense, making curd, bread or wine, which are all microbe-mediated processes, could also be thought as a form of biotechnology. However, it is used in a restricted sense today, to refer to such of those processes which use genetically modified organisms to achieve the same on a larger scale. Further, many other processes/techniques are also included under biotechnology. For example, *in vitro* fertilisation leading to a 'test-tube' baby, synthesising a gene and using it, developing a DNA vaccine or correcting a defective gene, are all part of biotechnology.

The European Federation of Biotechnology (EFB) has given a definition of biotechnology that encompasses both traditional view and modern molecular biotechnology. The definition given by EFB is as follows:

'The integration of natural science and organisms, cells, parts thereof, and molecular analogues for products and services'.

11.1 Principles of Biotechnology

Among many, the two core techniques that enabled birth of modern biotechnology are :

(i) ***Genetic engineering*** : Techniques to alter the chemistry of genetic material (DNA and RNA), to introduce these into host organisms and thus change the phenotype of the host organism.

(ii) ***Bioprocess engineering***: Maintenance of sterile (microbial contamination-free) ambience in chemical engineering processes to enable growth of only the desired microbe/eukaryotic cell in large quantities for the manufacture of biotechnological products like antibiotics, vaccines, enzymes, etc.

Let us now understand the conceptual development of the principles of genetic engineering.

You probably appreciate the advantages of sexual reproduction over asexual reproduction. The former provides opportunities for variations and formulation of unique combinations of genetic setup, some of which may be beneficial to the organism as well as the population. Asexual reproduction preserves the genetic information, while sexual reproduction permits variation. Traditional hybridisation procedures used in plant and animal breeding, very often lead to inclusion and multiplication of undesirable genes along with the desired genes. The techniques of genetic engineering which include creation of **recombinant DNA**, use of **gene cloning** and **gene transfer**, overcome this limitation and allows us to isolate and introduce only one or a set of desirable genes without introducing undesirable genes into the target organism.

Do you know the likely fate of a piece of DNA, which is somehow transferred into an alien organism? Most likely, this piece of DNA would not be able to multiply itself in the progeny cells of the organism. But, when it gets integrated into the genome of the recipient, it may multiply and be inherited along with the host DNA. This is because the alien piece of DNA has become part of a chromosome, which has the ability to replicate. In a chromosome there is a specific DNA sequence called the **origin of replication,** which is responsible for initiating replication. Therefore, for the multiplication of any alien piece of DNA in an organism it needs to be a part of a chromosome(s) which has a specific sequence known as 'origin of replication'. Thus, an alien DNA is linked with the origin of replication, so that, this alien piece of DNA can replicate and multiply itself in the host organism. This can also be called as **cloning** or making multiple identical copies of any template DNA.

Let us now focus on the first instance of the construction of an artificial recombinant DNA molecule. The construction of the first recombinant DNA emerged from the possibility of linking a gene encoding antibiotic resistance with a native **plasmid** (autonomously replicating circular extra-chromosomal DNA) of *Salmonella typhimurium*. Stanley Cohen and Herbert Boyer accomplished this in 1972 by isolating the antibiotic resistance gene by cutting out a piece of DNA from a plasmid which was responsible for conferring antibiotic resistance. The cutting of DNA at specific locations became possible with the discovery of the so-called 'molecular scissors'– **restriction enzymes**. The cut piece of DNA was then linked with the plasmid DNA. These plasmid DNA act as **vectors** to transfer the piece of DNA attached to it. You probably know that mosquito acts as an insect vector to transfer the malarial parasite into human body. In the same way, a plasmid can be used as vector to deliver an alien piece of DNA into the host organism. The linking of antibiotic resistance gene with the plasmid vector became possible with the enzyme DNA ligase, which acts on cut DNA molecules and joins their ends. This makes a new combination of circular autonomously replicating DNA created *in vitro* and is known as recombinant DNA. When this DNA is transferred into *Escherichia coli*, a bacterium closely related to *Salmonella*, it could replicate using the new host's DNA polymerase enzyme and make multiple copies. The ability to multiply copies of antibiotic resistance gene in *E. coli* was called **cloning** of antibiotic resistance gene in *E. coli*.

You can hence infer that there are three basic steps in genetically modifying an organism —

(i) identification of DNA with desirable genes;
(ii) introduction of the identified DNA into the host;
(iii) maintenance of introduced DNA in the host and transfer of the DNA to its progeny.

11.2 Tools of Recombinant DNA Technology

Now we know from the foregoing discussion that genetic engineering or recombinant DNA technology can be accomplished only if we have the key tools, i.e., restriction enzymes, polymerase enzymes, ligases, vectors and the host organism. Let us try to understand some of these in detail.

11.2.1 Restriction Enzymes

In the year 1963, the two enzymes responsible for restricting the growth of bacteriophage in *Escherichia coli* were isolated. One of these added methyl groups to DNA, while the other cut DNA. The later was called **restriction endonuclease**.

The first restriction endonuclease–*Hind II*, whose functioning depended on a specific DNA nucleotide sequence was isolated and characterised five years later. It was found that *Hind II* always cut DNA molecules at a particular point by recognising a specific sequence of six base pairs. This specific base sequence is known as the **recognition sequence** for *Hind II*. Besides *Hind II*, today we know more than 900 restriction enzymes that have been isolated from over 230 strains of bacteria each of which recognise different recognition sequences.

The convention for naming these enzymes is the first letter of the name comes from the genus and the second two letters come from the species of the prokaryotic cell from which they were isolated, e.g., EcoRI comes from *Escherichia coli* RY 13. In EcoRI, the letter 'R' is derived from the name of strain. Roman numbers following the names indicate the order in which the enzymes were isolated from that strain of bacteria.

Restriction enzymes belong to a larger class of enzymes called **nucleases**. These are of two kinds; **exonucleases** and **endonucleases**. Exonucleases remove nucleotides from the ends of the DNA whereas, endonucleases make cuts at specific positions within the DNA.

Each restriction endonuclease functions by 'inspecting' the length of a DNA sequence. Once it finds its specific recognition sequence, it will bind to the DNA and cut each of the two strands of the double helix at specific points in their sugar-phosphate backbones (Figure 11.1). Each restriction endonuclease recognises a specific **palindromic nucleotide sequences** in the DNA.

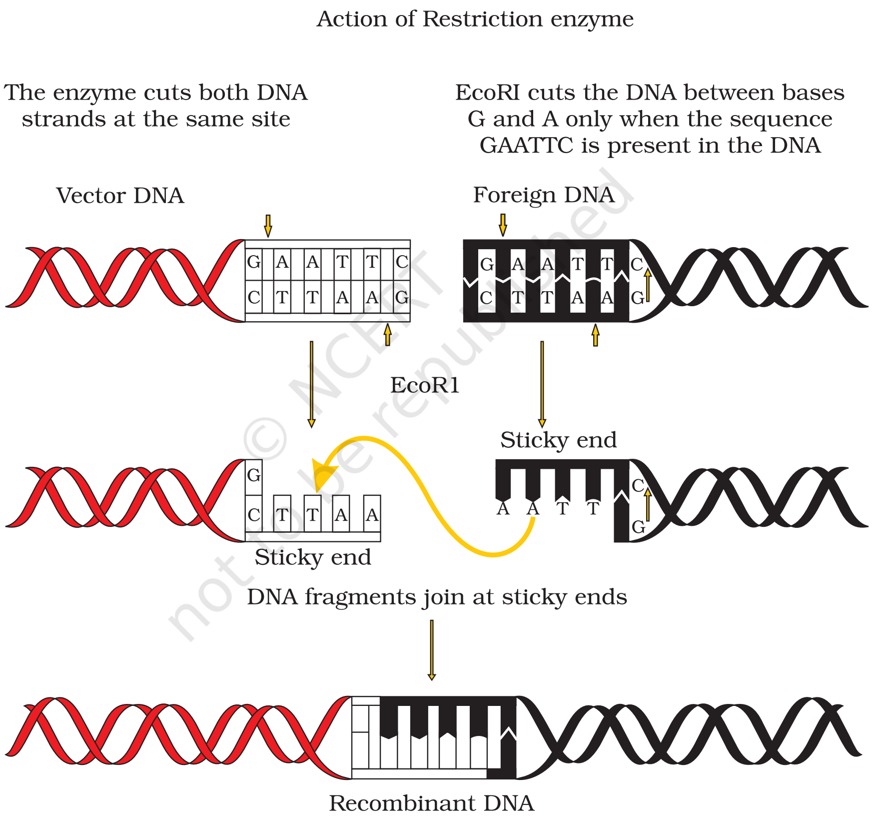

Figure 11.1 Steps in formation of recombinant DNA by action of restriction endonuclease enzyme - EcoRI

Do you know what palindromes are? These are groups of letters that form the same words when read both forward and backward, e.g., "MALAYALAM". As against a word-palindrome where the same word is read in both directions, the palindrome in DNA is a sequence of base pairs that reads same on the two strands when orientation of reading is kept the same. For example, the following sequences reads the same on the two strands in 5′ → 3′ direction. This is also true if read in the 3′ → 5′ direction.

5′ —— GAATTC —— 3′
3′ —— CTTAAG —— 5′

Restriction enzymes cut the strand of DNA a little away from the centre of the palindrome sites, but between the same two bases on the opposite strands. This leaves single stranded portions at the ends. There are overhanging stretches called sticky ends on each strand (Figure 11.1). These are named so because they form hydrogen bonds with their complementary cut counterparts. This stickiness of the ends facilitates the action of the enzyme DNA ligase.

Restriction endonucleases are used in genetic engineering to form ‘recombinant’ molecules of DNA, which are composed of DNA from different sources/genomes.

When cut by the same restriction enzyme, the resultant DNA fragments have the same kind of ‘sticky-ends’ and, these can be joined together (end-to-end) using DNA ligases (Figure 11.2).

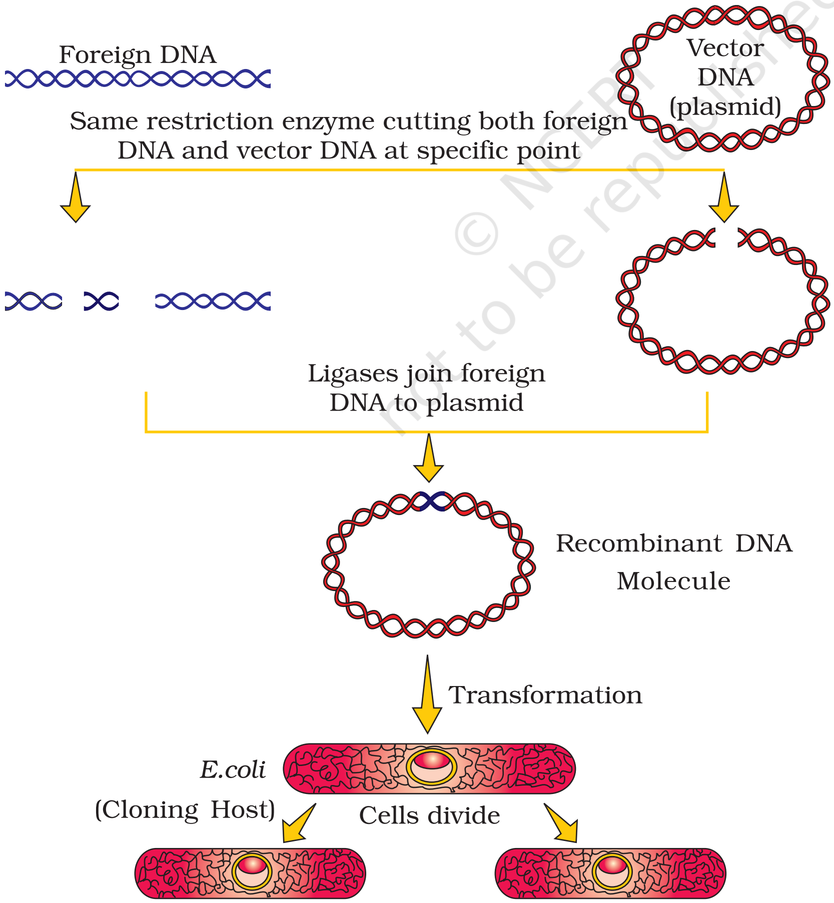

Figure 11.2 Diagrammatic representation of recombinant DNA technology

You may have realised that normally, unless one cuts the vector and the source DNA with the same restriction enzyme, the recombinant vector molecule cannot be created.

Separation and isolation of DNA fragments : The cutting of DNA by restriction endonucleases results in the fragments of DNA. These fragments can be separated by a technique known as **gel electrophoresis**. Since DNA fragments are negatively charged molecules they can be separated by forcing them to move towards the anode under an electric field through a medium/matrix. Nowadays the most commonly used matrix is agarose which is a natural polymer extracted from sea weeds. The DNA fragments separate (resolve) according to their size through sieving effect provided by the agarose gel. Hence, the smaller the fragment size, the farther it moves. *Look at the Figure 11.3 and guess at which end of the gel the sample was loaded.*

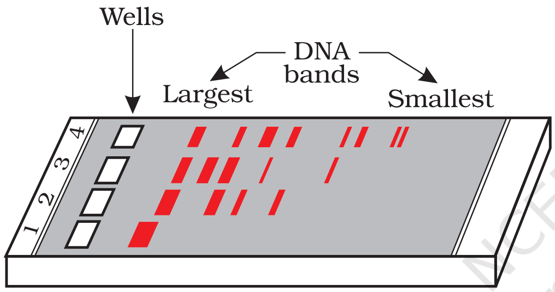

Figure 11.3 A typical agarose gel electrophoresis showing migration of undigested (lane 1) and digested set of DNA fragments (lane 2 to 4)

The separated DNA fragments can be visualised only after staining the DNA with a compound known as ethidium bromide followed by exposure to UV radiation (you cannot see pure DNA fragments in the visible light and without staining). You can see bright orange coloured bands of DNA in a ethidium bromide stained gel exposed to UV light (Figure 11.3). The separated bands of DNA are cut out from the agarose gel and extracted from the gel piece. This step is known as elution. The DNA fragments purified in this way are used in constructing recombinant DNA by joining them with cloning vectors.

11.2.2 Cloning Vectors

You know that plasmids and bacteriophages have the ability to replicate within bacterial cells independent of the control of chromosomal DNA. Bacteriophages because of their high number per cell, have very high copy numbers of their genome within the bacterial cells. Some plasmids may have only one or two copies per cell whereas others may have 15-100 copies per cell. Their numbers can go even higher. If we are able to link an alien piece of DNA with bacteriophage or plasmid DNA, we can multiply its numbers equal to the copy number of the plasmid or bacteriophage. Vectors used at present, are engineered in such a way that they help easy linking of foreign DNA and selection of recombinants from non-recombinants.

The following are the features that are required to facilitate cloning into a vector.

(i) ***Origin of replication (ori)*** *:* This is a sequence from where replication starts and any piece of DNA when linked to this sequence can be made to replicate within the host cells. This sequence is also responsible for controlling the copy number of the linked DNA. So, if one wants to recover many copies of the target DNA it should be cloned in a vector whose origin support high copy number.

(ii) ***Selectable marker*** *:* In addition to 'ori', the vector requires a selectable marker, which helps in identifying and eliminating non-transformants and selectively permitting the growth of the transformants. **Transformation** is a procedure through which a piece of DNA is introduced in a host bacterium (you will study the process in subsequent section). Normally, the genes encoding resistance to antibiotics such as ampicillin, chloramphenicol, tetracycline or kanamycin, etc., are considered useful selectable markers for *E. coli.* The normal *E. coli* cells do not carry resistance against any of these antibiotics.

(iii) ***Cloning sites:*** In order to link the alien DNA, the vector needs to have very few, preferably single, **recognition sites** for the commonly used restriction enzymes. Presence of more than one recognition sites within the vector will generate several fragments, which will complicate the gene cloning (Figure 11.4). The ligation of alien DNA is carried out at a restriction site present in one of the two **antibiotic resistance** genes. For example, you can ligate a foreign DNA at the BamH I site of tetracycline resistance gene in the vector pBR322. The recombinant plasmids will lose tetracycline resistance due to insertion of foreign DNA but can still be selected out from non-recombinant ones by plating the transformants on tetracycline containing medium. The transformants growing on ampicillin containing medium are then transferred on a medium containing tetracycline. The recombinants will grow in ampicillin containing medium but not on that containing tetracycline. But, non- recombinants will grow on the medium containing both the antibiotics. In this case, one antibiotic resistance gene helps in selecting the transformants, whereas the other antibiotic resistance

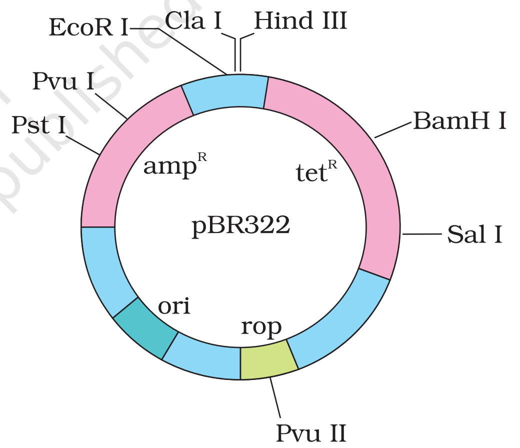

Figure 11.4 *E. coli* cloning vector pBR322 showing restriction sites (*Hind* III, *Eco*R I, *Bam*H I, *Sal* I, *Pvu* II, *Pst* I, *Cla* I), ori and antibiotic resistance genes (amp^R and tet^R). rop codes for the proteins involved in replication of the plasmid.

gene gets 'inactivated due to insertion' of alien DNA, and helps in selection of recombinants.

Selection of recombinants due to inactivation of antibiotics is a cumbersome procedure because it requires simultaneous plating on two plates having different antibiotics. Therefore, alternative selectable markers have been developed which differentiate recombinants from non-recombinants on the basis of their ability to produce colour in the presence of a chromogenic substrate. In this, a recombinant DNA is inserted within the coding sequence of an enzyme, β-galactosidase. This results into inactivation of the gene for synthesis of this enzyme, which is referred to as **insertional inactivation**. The presence of a chromogenic substrate gives blue coloured colonies if the plasmid in the bacteria does not have an insert. Presence of insert results into insertional inactivation of the β-galactosidase gene and the colonies do not produce any colour, these are identified as recombinant colonies.

(iv) ***Vectors for cloning genes in plants and animals :*** You may be surprised to know that we have learnt the lesson of transferring genes into plants and animals from bacteria and viruses which have known this for ages – how to deliver genes to transform eukaryotic cells and force them to do what the bacteria or viruses want. For example, *Agrobacterium tumifaciens*, a pathogen of several dicot plants is able to deliver a piece of DNA known as 'T-DNA' to transform normal plant cells into a **tumor** and direct these tumor cells to produce the chemicals required by the pathogen. Similarly, retroviruses in animals have the ability to transform normal cells into **cancerous** cells. A better understanding of the art of delivering genes by pathogens in their eukaryotic hosts has generated knowledge to transform these tools of pathogens into useful vectors for delivering genes of interest to humans. The tumor inducing (Ti) plasmid of *Agrobacterium tumifaciens* has now been modified into a cloning vector which is no more pathogenic to the plants but is still able to use the mechanisms to deliver genes of our interest into a variety of plants. Similarly, retroviruses have also been disarmed and are now used to deliver desirable genes into animal cells. So, once a gene or a DNA fragment has been ligated into a suitable vector it is transferred into a bacterial, plant or animal host (where it multiplies).

11.2.3 Competent Host (For Transformation with Recombinant DNA)

Since DNA is a hydrophilic molecule, it cannot pass through cell membranes. *Why*? In order to force bacteria to take up the plasmid, the bacterial cells must first be made 'competent' to take up DNA. This is done by treating them with a specific concentration of a divalent cation, such as calcium, which increases the efficiency with which DNA enters the bacterium through pores in its cell wall. Recombinant DNA can then be forced into such cells by incubating the cells with recombinant DNA on ice, followed by placing them briefly at 42^{0}C (heat shock), and then putting them back on ice. This enables the bacteria to take up the recombinant DNA.

This is not the only way to introduce alien DNA into host cells. In a method known as **micro-injection**, recombinant DNA is directly injected into the nucleus of an animal cell. In another method, suitable for plants, cells are bombarded with high velocity micro-particles of gold or tungsten coated with DNA in a method known as **biolistics** or **gene gun**. And the last method uses 'disarmed pathogen' vectors, which when allowed to infect the cell, transfer the recombinant DNA into the host.

Now that we have learnt about the tools for constructing recombinant DNA, let us discuss the processes facilitating recombinant DNA technology.

11.3 Processes of Recombinant DNA Technology

Recombinant DNA technology involves several steps in specific sequence such as isolation of DNA, fragmentation of DNA by restriction endonucleases, isolation of a desired DNA fragment, ligation of the DNA fragment into a vector, transferring the recombinant DNA into the host, culturing the host cells in a medium at large scale and extraction of the desired product. Let us examine each of these steps in some details.

11.3.1 Isolation of the Genetic Material (DNA)

Recall that nucleic acid is the genetic material of all organisms without exception. In majority of organisms this is deoxyribonucleic acid or DNA. In order to cut the DNA with restriction enzymes, it needs to be in pure form, free from other macro-molecules. Since the DNA is enclosed within the membranes, we have to break the cell open to release DNA along with other macromolecules such as RNA, proteins, polysaccharides and also lipids. This can be achieved by treating the bacterial cells/plant or animal tissue with enzymes such as **lysozyme** (bacteria), **cellulase** (plant cells), **chitinase** (fungus). You know that genes are located on long molecules of DNA interwined with proteins such as histones. The RNA can be removed by treatment with ribonuclease whereas proteins can be removed by treatment with protease. Other molecules can be removed by appropriate treatments and purified DNA ultimately precipitates out after the addition of chilled ethanol. This can be seen as collection of fine threads in the suspension (Figure 11.5).

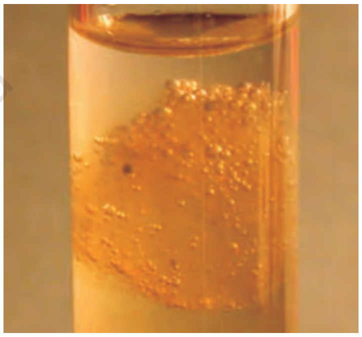

Figure 11.5 DNA that separates out can be removed by spooling

11.3.2 Cutting of DNA at Specific Locations

Restriction enzyme digestions are performed by incubating purified DNA molecules with the restriction enzyme, at the optimal conditions for that specific enzyme. Agarose gel electrophoresis is employed to check the progression of a restriction enzyme digestion. DNA is a negatively charged molecule, hence it moves towards the positive electrode (anode) (Figure 11.3). The process is repeated with the vector DNA also.

The joining of DNA involves several processes. After having cut the source DNA as well as the vector DNA with a specific restriction enzyme, the cut out 'gene of interest' from the source DNA and the cut vector with space are mixed and ligase is added. This results in the preparation of recombinant DNA.

11.3.3 Amplification of Gene of Interest using PCR

PCR stands for **Polymerase Chain Reaction**. In this reaction, multiple copies of the gene (or DNA) of interest is synthesised *in vitro* using two

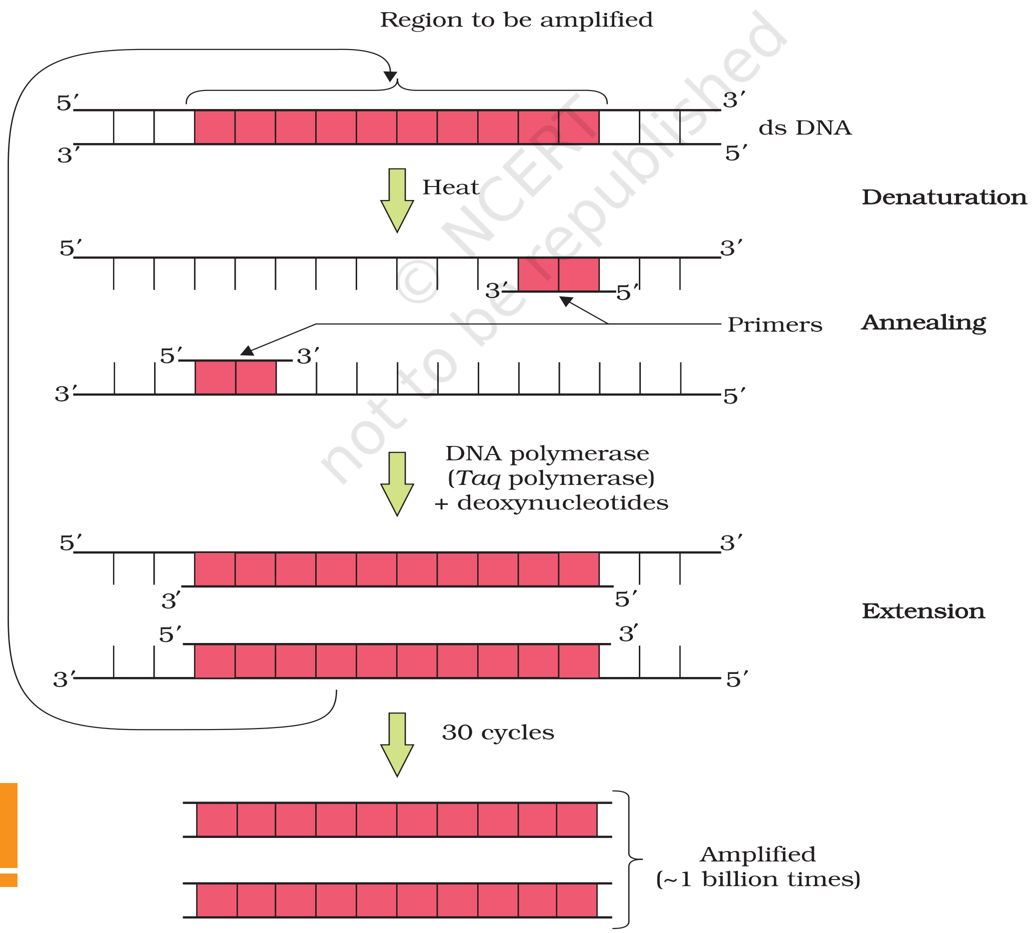

Figure 11.6 Polymerase chain reaction (PCR) : Each cycle has three steps: (i) Denaturation; (ii) Primer annealing; and (iii) Extension of primers

sets of primers (small chemically synthesised oligonucleotides that are complementary to the regions of DNA) and the enzyme DNA polymerase. The enzyme extends the primers using the nucleotides provided in the reaction and the genomic DNA as template. If the process of replication of DNA is repeated many times, the segment of DNA can be amplified to approximately billion times, i.e., 1 billion copies are made. Such repeated amplification is achieved by the use of a thermostable DNA polymerase (isolated from a bacterium, *Thermus aquaticus*), which remain active during the high temperature induced denaturation of double stranded DNA. The amplified fragment if desired can now be used to ligate with a vector for further cloning (Figure11.6).

11.3.4 Insertion of Recombinant DNA into the Host Cell/Organism

There are several methods of introducing the ligated DNA into recipient cells. Recipient cells after making them 'competent' to receive, take up DNA present in its surrounding. So, if a recombinant DNA bearing gene for resistance to an antibiotic (e.g., ampicillin) is transferred into *E. coli* cells, the host cells become transformed into ampicillin-resistant cells. If we spread the transformed cells on agar plates containing ampicillin, only transformants will grow, untransformed recipient cells will die. Since, due to ampicillin resistance gene, one is able to select a transformed cell in the presence of ampicillin. The ampicillin resistance gene in this case is called a **selectable marker**.

11.3.5 Obtaining the Foreign Gene Product

When you insert a piece of alien DNA into a cloning vector and transfer it into a bacterial, plant or animal cell, the alien DNA gets multiplied. In almost all recombinant technologies, the ultimate aim is to produce a desirable protein. Hence, there is a need for the recombinant DNA to be expressed. The foreign gene gets expressed under appropriate conditions. The expression of foreign genes in host cells involve understanding many technical details.

After having cloned the gene of interest and having optimised the conditions to induce the expression of the target protein, one has to consider producing it on a large scale. *Can you think of any reason why there is a need for large-scale production*? If any protein encoding gene is expressed in a heterologous host, it is called a **recombinant protein**. The cells harbouring cloned genes of interest may be grown on a small scale in the laboratory. The cultures may be used for extracting the desired protein and then purifying it by using different separation techniques.

The cells can also be multiplied in a continuous culture system wherein the used medium is drained out from one side while fresh medium is added from the other to maintain the cells in their physiologically most active log/exponential phase. This type of culturing method produces a larger biomass leading to higher yields of desired protein.

Small volume cultures cannot yield appreciable quantities of products. To produce in large quantities, the development of **bioreactors**, where large volumes (100-1000 litres) of culture can be processed, was required. Thus, bioreactors can be thought of as vessels in which raw materials are biologically converted into specific products, individual enzymes, etc., using microbial plant, animal or human cells. A bioreactor provides the optimal conditions for achieving the desired product by providing optimum growth conditions (temperature, pH, substrate, salts, vitamins, oxygen).

The most commonly used bioreactors are of stirring type, which are shown in Figure 11.7.

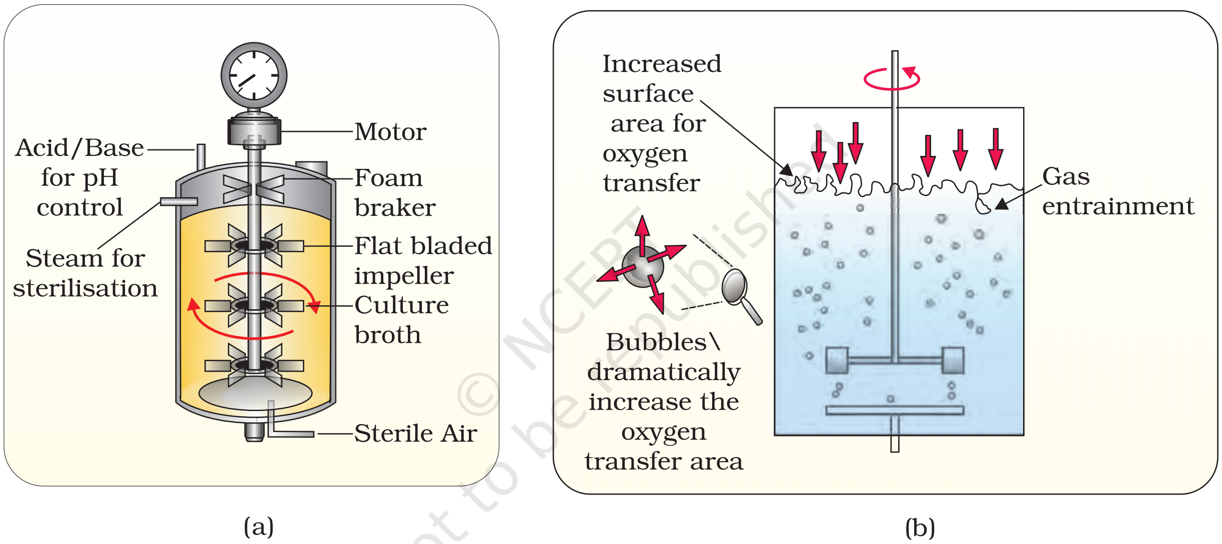

Figure 11.7 (a) Simple stirred-tank bioreactor; (b) Sparged stirred-tank bioreactor through which sterile air bubbles are sparged

A stirred-tank reactor is usually cylindrical or with a curved base to facilitate the mixing of the reactor contents. The stirrer facilitates even mixing and oxygen availability throughout the bioreactor. Alternatively air can be bubbled through the reactor. If you look at the figure closely you will see that the bioreactor has an agitator system, an oxygen delivery system and a foam control system, a temperature control system, pH control system and sampling ports so that small volumes of the culture can be withdrawn periodically.

11.3.6 Downstream Processing

After completion of the biosynthetic stage, the product has to be subjected through a series of processes before it is ready for marketing as a finished product. The processes include separation and purification, which are collectively referred to as downstream processing. The product has to be formulated with suitable preservatives. Such formulation has to undergo thorough clinical trials as in case of drugs. Strict quality control testing for each product is also required. The downstream processing and quality control testing vary from product to product.

SUMMARY

Biotechnology deals with large scale production and marketing of products and processes using live organisms, cells or enzymes. Modern biotechnology using genetically modified organisms was made possible only when man learnt to alter the chemistry of DNA and construct recombinant DNA. This key process is called recombinant DNA technology or genetic engineering. This process involves the use of restriction endonucleases, DNA ligase, appropriate plasmid or viral vectors to isolate and ferry the foreign DNA into host organisms, expression of the foreign gene, purification of the gene product, i.e., the functional protein and finally making a suitable formulation for marketing. Large scale production involves use of bioreactors.

EXERCISES

1. Can you list 10 recombinant proteins which are used in medical practice? Find out where they are used as therapeutics (use the internet).
2. Make a chart (with diagrammatic representation) showing a restriction enzyme, the substrate DNA on which it acts, the site at which it cuts DNA and the product it produces.
3. From what you have learnt, can you tell whether enzymes are bigger or DNA is bigger in molecular size? How did you know?
4. What would be the molar concentration of human DNA in a human cell? Consult your teacher.
5. Do eukaryotic cells have restriction endonucleases? Justify your answer.
6. Besides better aeration and mixing properties, what other advantages do stirred tank bioreactors have over shake flasks?
7. Collect 5 examples of palindromic DNA sequences by consulting your teacher. Better try to create a palindromic sequence by following base-pair rules.
8. Can you recall meiosis and indicate at what stage a recombinant DNA is made?
9. Can you think and answer how a reporter enzyme can be used to monitor transformation of host cells by foreign DNA in addition to a selectable marker?

10. Describe briefly the following:
    (a) Origin of replication
    (b) Bioreactors
    (c) Downstream processing
11. Explain briefly
    (a) PCR
    (b) Restriction enzymes and DNA
    (c) Chitinase
12. Discuss with your teacher and find out how to distinguish between
    (a) Plasmid DNA and Chromosomal DNA
    (b) RNA and DNA
    (c) Exonuclease and Endonuclease

CHAPTER 12

BIOTECHNOLOGY AND ITS APPLICATIONS

Biotechnology, as you would have learnt from the previous chapter, essentially deals with industrial scale production of biopharmaceuticals and biologicals using genetically modified microbes, fungi, plants and animals. The applications of biotechnology include therapeutics, diagnostics, genetically modified crops for agriculture, processed food, bioremediation, waste treatment, and energy production. Three critical research areas of biotechnology are:

(i) Providing the best catalyst in the form of improved organism usually a microbe or pure enzyme.
(ii) Creating optimal conditions through engineering for a catalyst to act, and
(iii) Downstream processing technologies to purify the protein/organic compound.

Let us now learn how human beings have used biotechnology to improve the quality of human life, especially in the field of food production and health.

12.1 Biotechnological Applications in Agriculture

Let us take a look at the three options that can be thought for increasing food production

(i) agro-chemical based agriculture;

(ii) organic agriculture; and
(iii) genetically engineered crop-based agriculture.

The **Green Revolution** succeeded in tripling the food supply but yet it was not enough to feed the growing human population. Increased yields have partly been due to the use of improved crop varieties, but mainly due to the use of better management practices and use of agrochemicals (fertilisers and pesticides). However, for farmers in the developing world, agrochemicals are often too expensive, and further increases in yield with existing varieties are not possible using conventional breeding. Is there any alternative path that our understanding of genetics can show so that farmers may obtain maximum yield from their fields? Is there a way to minimise the use of fertilisers and chemicals so that their harmful effects on the environment are reduced? Use of genetically modified crops is a possible solution.

Plants, bacteria, fungi and animals whose genes have been altered by manipulation are called **Genetically Modified Organisms** (**GMO**). GM plants have been useful in many ways. Genetic modification has:

(i) made crops more tolerant to abiotic stresses (cold, drought, salt, heat).
(ii) reduced reliance on chemical pesticides (pest-resistant crops).
(iii) helped to reduce post harvest losses.
(iv) increased efficiency of mineral usage by plants (this prevents early exhaustion of fertility of soil).
(v) enhanced nutritional value of food, e.g., golden rice, i.e., Vitamin 'A' enriched rice.

In addition to these uses, GM has been used to create tailor-made plants to supply alternative resources to industries, in the form of starches, fuels and pharmaceuticals.

Some of the applications of biotechnology in agriculture that you will study in detail are the production of pest resistant plants, which could decrease the amount of pesticide used. Bt toxin is produced by a bacterium called ***Bacillus thuringiensis*** (**Bt** for short). Bt toxin gene has been cloned from the bacteria and been expressed in plants to provide resistance to insects without the need for insecticides; in effect created a bio-pesticide. Examples are Bt cotton, Bt corn, rice, tomato, potato and soyabean etc.

Bt Cotton: Some strains of *Bacillus thuringiensis* produce proteins that kill certain insects such as lepidopterans (tobacco budworm, armyworm), coleopterans (beetles) and dipterans (flies, mosquitoes). *B. thuringiensis* forms protein crystals during a particular phase of their growth. These crystals contain a toxic **insecticidal protein**. Why does this toxin not kill the *Bacillus*? Actually, the Bt toxin protein exist as inactive *protoxins* but once an insect ingest the inactive toxin, it is converted into an active form of toxin due to the alkaline pH of the gut which solubilise the crystals. The activated toxin binds to the surface of midgut epithelial cells and create pores that cause cell swelling and lysis and eventually cause death of the insect.

Specific Bt toxin genes were isolated from *Bacillus thuringiensis* and incorporated into the several crop plants such as cotton (Figure 12.1). The choice of genes depends upon the crop and the targeted pest, as most Bt toxins are insect-group specific. The toxin is coded by a gene *cryIAc* named **cry**. There are a number of them, for example, the proteins encoded by the genes *cryIAc* and *cryIIAb* control the cotton bollworms, that of *cryIAb* controls corn borer.

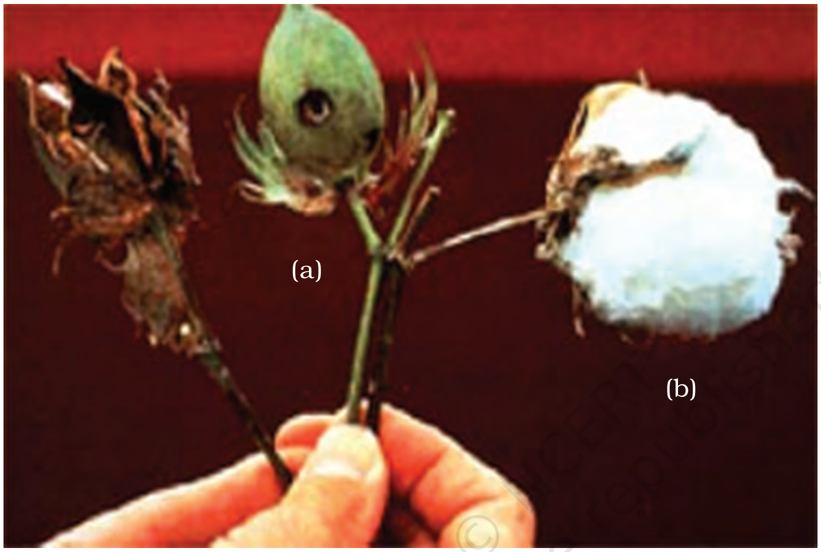

Figure 12.1 Cotton boll: (a) destroyed by bollworms; (b) a fully mature cotton boll

Pest Resistant Plants: Several nematodes parasitise a wide variety of plants and animals including human beings. A nematode *Meloidegyne incognitia* infects the roots of tobacco plants and causes a great reduction in yield. A novel strategy was adopted to prevent this infestation which was based on the process of **RNA interference** (RNAi). RNAi takes place in all eukaryotic organisms as a method of cellular defense. This method involves silencing of a specific mRNA due to a complementary dsRNA molecule that binds to and prevents translation of the mRNA (silencing). The source of this complementary RNA could be from an infection by viruses having RNA genomes or mobile genetic elements (transposons) that replicate via an RNA intermediate.

Using *Agrobacterium* vectors, nematode-specific genes were introduced into the host plant (Figure 12.2). The introduction of DNA was such that it produced both sense and anti-sense RNA in the host cells. These two RNA's being complementary to each other formed a double stranded (dsRNA) that initiated RNAi and thus, silenced the specific mRNA of the nematode. The consequence was that the parasite could not survive in a transgenic host expressing specific interfering RNA. The transgenic plant therefore got itself protected from the parasite (Figure 12.2).

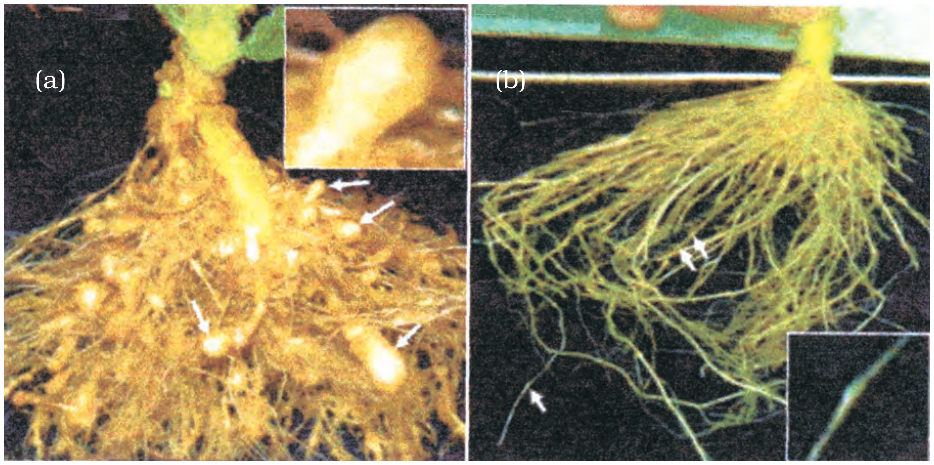

Figure 12.2 Host plant-generated dsRNA triggers protection against nematode infestation: (a) Roots of a typical control plants; (b) transgenic plant roots 5 days after deliberate infection of nematode but protected through novel mechanism.

12.2 Biotechnological Applications in Medicine

The recombinant DNA technological processes have made immense impact in the area of healthcare by enabling mass production of safe and more effective therapeutic drugs. Further, the recombinant therapeutics do not induce unwanted immunological responses as is common in case of similar products isolated from non-human sources. At present, about 30 recombinant therapeutics have been approved for human-use the world over. In India, 12 of these are presently being marketed.

12.2.1 Genetically Engineered Insulin

Management of adult-onset diabetes is possible by taking insulin at regular time intervals. *What would a diabetic patient do if enough human-insulin was not available*? If you discuss this, you would soon realise that one would have to isolate and use insulin from other animals. *Would the insulin isolated from other animals be just as effective as that secreted by the human body itself and would it not elicit an immune response in the human body*? Now, imagine if bacterium were available that could make human insulin. Suddenly the whole process becomes so simple. You can easily grow a large quantity of the bacteria and make as much insulin as you need.

Think about whether insulin can be orally administered to diabetic people or not. Why?

Insulin used for diabetes was earlier extracted from pancreas of slaughtered cattle and pigs. Insulin from an animal source, though caused some patients to develop allergy or other types of reactions to the foreign protein. Insulin consists of two short polypeptide chains: chain A and chain B, that are linked together by disulphide bridges (Figure 12.3). In mammals, including humans, insulin is synthesised as a pro-hormone (like a pro-enzyme, the pro-hormone also needs to be processed before it becomes a fully mature and functional hormone) which contains an extra stretch called the **C peptide**. This C peptide is not present in the mature insulin and is removed during maturation into insulin.The main challenge for production of insulin using rDNA techniques was getting insulin assembled into a mature form. In 1983, Eli Lilly an American company prepared two DNA sequences corresponding to A and B, chains of human insulin and introduced them in plasmids of *E. coli* to produce insulin chains. Chains A and B were produced separately, extracted and combined by creating disulfide bonds to form human insulin.

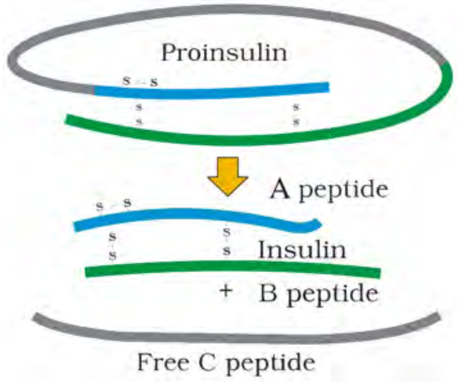

Figure 12.3 Maturation of pro-insulin into insulin (simplified)

12.2.2 Gene Therapy

If a person is born with a hereditary disease, can a corrective therapy be taken for such a disease? Gene therapy is an attempt to do this. Gene therapy is a collection of methods that allows correction of a gene defect that has been diagnosed in a child/embryo. Here genes are inserted into a person's cells and tissues to treat a disease. Correction of a genetic defect involves delivery of a normal gene into the individual or embryo to take over the function of and compensate for the non-functional gene.

The first clinical gene therapy was given in 1990 to a 4-year old girl with adenosine deaminase (ADA) deficiency. This enzyme is crucial for the immune system to function. The disorder is caused due to the deletion of the gene for adenosine deaminase. In some children ADA deficiency can be cured by bone marrow transplantation; in others it can be treated by enzyme replacement therapy, in which functional ADA is given to the patient by injection. But the problem with both of these approaches that they are not completely curative. As a first step towards gene therapy, lymphocytes from the blood of the patient are grown in a culture outside the body. A functional ADA cDNA (using a retroviral vector) is then introduced into these lymphocytes, which are subsequently returned to the patient. However, as these cells are not immortal, the patient requires periodic infusion of such genetically engineered lymphocytes. However, if the gene isolate from marrow cells producing ADA is introduced into cells at early embryonic stages, it could be a permanent cure.

12.2.3 Molecular Diagnosis

You know that for effective treatment of a disease, early diagnosis and understanding its pathophysiology is very important. Using conventional methods of diagnosis (serum and urine analysis, etc.) early detection is not possible. Recombinant DNA technology, Polymerase Chain Reaction (PCR) and Enzyme Linked Immuno-sorbent Assay (ELISA) are some of the techniques that serve the purpose of early diagnosis.

Presence of a pathogen (bacteria, viruses, etc.) is normally suspected only when the pathogen has produced a disease symptom. By this time the concentration of pathogen is already very high in the body. However, very low concentration of a bacteria or virus (at a time when the symptoms of the disease are not yet visible) can be detected by amplification of their nucleic acid by PCR. *Can you explain how PCR can detect very low amounts of DNA?* PCR is now routinely used to detect HIV in suspected AIDS patients. It is being used to detect mutations in genes in suspected cancer patients too. It is a powerful techqnique to identify many other genetic disorders.

A single stranded DNA or RNA, tagged with a radioactive molecule (probe) is allowed to hybridise to its complementary DNA in a clone of cells followed by detection using autoradiography. The clone having the mutated gene will hence not appear on the photographic film, because the probe will not have complementarity with the mutated gene.

ELISA is based on the principle of antigen-antibody interaction. Infection by pathogen can be detected by the presence of antigens (proteins, glycoproteins, etc.) or by detecting the antibodies synthesised against the pathogen.

12.3 Transgenic Animals

Animals that have had their DNA manipulated to possess and express an extra (foreign) gene are known as **transgenic animals**. Transgenic rats, rabbits, pigs, sheep, cows and fish have been produced, although over 95 per cent of all existing transgenic animals are mice. *Why are these animals being produced? How can man benefit from such modifications*? Let us try and explore some of the common reasons:

(i) ***Normal physiology and development:*** Transgenic animals can be specifically designed to allow the study of how genes are regulated, and how they affect the normal functions of the body and its development, e.g., study of complex factors involved in growth such as insulin-like growth factor. By introducing genes from other species that alter the formation of this factor and studying the biological effects that result, information is obtained about the biological role of the factor in the body.

(ii) ***Study of disease:*** Many transgenic animals are designed to increase our understanding of how genes contribute to the development of disease. These are specially made to serve as models for human diseases so that investigation of new treatments for diseases is made possible. Today transgenic models exist for many human diseases such as cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's.

(iii) ***Biological products:*** Medicines required to treat certain human diseases can contain biological products, but such products are often expensive to make. Transgenic animals that produce useful biological products can be created by the introduction of the portion of DNA (or genes) which codes for a particular product such as human protein (α-1-antitrypsin) used to treat emphysema. Similar attempts are being made for treatment of phenylketonuria (PKU) and cystic fibrosis. In 1997, the first transgenic cow, Rosie, produced human protein-enriched milk (2.4 grams per litre). The milk contained the human alpha-lactalbumin and was nutritionally a more balanced product for human babies than natural cow-milk.

(iv) ***Vaccine safety:*** Transgenic mice are being developed for use in testing the safety of vaccines before they are used on humans. Transgenic mice are being used to test the safety of the polio vaccine. If successful and found to be reliable, they could replace the use of monkeys to test the safety of batches of the vaccine.

(v) ***Chemical safety testing:*** This is known as toxicity/safety testing. The procedure is the same as that used for testing toxicity of drugs. Transgenic animals are made that carry genes which make them more sensitive to toxic substances than non-transgenic animals. They are then exposed to the toxic substances and the effects studied. Toxicity testing in such animals will allow us to obtain results in less time.

12.4 Ethical Issues

The manipulation of living organisms by the human race cannot go on any further, without regulation. Some ethical standards are required to evaluate the morality of all human activities that might help or harm living organisms.

Going beyond the morality of such issues, the biological significance of such things is also important. Genetic modification of organisms can have unpredicatable results when such organisms are introduced into the ecosystem.

Therefore, the Indian Government has set up organisations such as **GEAC** (Genetic Engineering Approval Committee), which will make decisions regarding the validity of GM research and the safety of introducing GM-organisms for public services.

The modification/usage of living organisms for public services (as food and medicine sources, for example) has also created problems with patents granted for the same.

There is growing public anger that certain companies are being granted patents for products and technologies that make use of the genetic materials, plants and other biological resources that have long been identified, developed and used by farmers and indigenous people of a specific region/country.

Rice is an important food grain, the presence of which goes back thousands of years in Asia's agricultural history. There are an estimated 200,000 varieties of rice in India alone. The diversity of rice in India is one of the richest in the world. Basmati rice is distinct for its unique aroma and flavour and 27 documented varieties of Basmati are grown in India. There is reference to Basmati in ancient texts, folklore and poetry, as it has been grown for centuries. In 1997, an American company got patent rights on Basmati rice through the US Patent and Trademark Office. This allowed the company to sell a 'new' variety of Basmati, in the US and abroad. This 'new' variety of Basmati had actually been derived from Indian farmer's varieties. Indian Basmati was crossed with semi-dwarf varieties and claimed as an invention or a novelty. The patent extends to functional equivalents, implying that other people selling Basmati rice could be restricted by the patent. Several attempts have also been made to patent uses, products and processes based on Indian traditional herbal medicines, e.g., turmeric neem. If we are not vigilant and we do not immediately counter these patent applications, other countries/individuals may encash on our rich legacy and we may not be able to do anything about it.

Biopiracy is the term used to refer to the use of bio-resources by multinational companies and other organisations without proper authorisation from the countries and people concerned without compensatory payment.

Most of the industrialised nations are rich financially but poor in biodiversity and traditional knowledge. In contrast the developing and the underdeveloped world is rich in biodiversity and traditional knowledge related to bio-resources. Traditional knowledge related to bio-resources can be exploited to develop modern applications and can also be used to save time, effort and expenditure during their commercialisation.

There has been growing realisation of the injustice, inadequate compensation and benefit sharing between developed and developing countries. Therefore, some nations are developing laws to prevent such unauthorised exploitation of their bio-resources and traditional knowledge.

The Indian Parliament has recently cleared the second amendment of the Indian Patents Bill, that takes such issues into consideration, including patent terms emergency provisions and research and development initiative.

SUMMARY

Biotechnology has given to humans several useful products by using microbes, plant, animals and their metabolic machinery. Recombinant DNA technology has made it possible to engineer microbes, plants and animals such that they have novel capabilities. Genetically Modified Organisms have been created by using methods other than natural methods to transfer one or more genes from one organism to another, generally using techniques such as recombinant DNA technology.

GM plants have been useful in increasing crop yields, reduce post-harvest losses and make crops more tolerant of stresses. There are several GM crop plants with improved nutritional value of foods and reduced the reliance on chemical pesticides (pest-resistant crops).

Recombinant DNA technological processes have made immense impact in the area of healthcare by enabling mass production of safe and more effective therapeutics. Since the recombinant therapeutics are identical to human proteins, they do not induce unwanted immunological responses and are free from risk of infection as was observed in case of similar products isolated from non-human sources. Human insulin is made in bacteria yet its structure is absolutely identical to that of the natural molecule.

Transgenic animals are also used to understand how genes contribute to the development of a disease by serving as models for human diseases, such as cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's.

Gene therapy is the insertion of genes into an individual's cells and tissues to treat diseases especially hereditary diseases. It does so by replacing a defective mutant allele with a functional one or gene targeting which involves gene amplification. Viruses that attack their hosts and introduce their genetic material into the host cell as part of their replication cycle are used as vectors to transfer healthy genes or more recently portions of genes.

The current interest in the manipulation of microbes, plants, and animals has raised serious ethical questions.

EXERCISES

1. Crystals of Bt toxin produced by some bacteria do not kill the bacteria themselves because –
   (a) bacteria are resistant to the toxin
   (b) toxin is immature;
   (c) toxin is inactive;
   (d) bacteria encloses toxin in a special sac.
2. What are transgenic bacteria? Illustrate using any one example.
3. Compare and contrast the advantages and disadvantages of production of genetically modified crops.

4. What are Cry proteins? Name an organism that produce it. How has man exploited this protein to his benefit?
5. What is gene therapy? Illustrate using the example of adenosine deaminase (ADA) deficiency.
6. Digrammatically represent the experimental steps in cloning and expressing an human gene (say the gene for growth hormone) into a bacterium like *E. coli*?
7. Can you suggest a method to remove oil (hydrocarbon) from seeds based on your understanding of rDNA technology and chemistry of oil?
8. Find out from internet what is golden rice.
9. Does our blood have proteases and nucleases?
10. Consult internet and find out how to make orally active protein pharmaceutical. What is the major problem to be encountered?

UNIT X
ECOLOGY

Diversity is not only a characteristic of living organisms but also of content in biology textbooks. Biology is presented either as botany, zoology and microbiology or as classical and modern. The latter is a euphemism for molecular aspects of biology. Luckily we have many threads which weave the different areas of biological information into a unifying principle. Ecology is one such thread which gives us a holistic perspective to biology. The essence of biological understanding is to know how organisms, while remaining an individual, interact with other organisms and physical habitats as a group and hence behave like organised wholes, i.e., population, community, ecosystem or even as the whole biosphere. Ecology explains to us all this. A particular aspect of this is the study of anthropogenic environmental degradation and the socio-political issues it has raised. This unit describes as well as takes a critical view of the above aspects.

RAMDEO MISRA
(1908-1998)

Ramdeo Misra is revered as the Father of Ecology in India. Born on 26 August 1908, Ramdeo Misra obtained Ph.D in Ecology (1937) under Prof. W. H. Pearsall, FRS, from Leeds University in UK. He established teaching and research in ecology at the Department of Botany of the Banaras Hindu University, Varanasi. His research laid the foundations for understanding of tropical communities and their succession, environmental responses of plant populations and productivity and nutrient cycling in tropical forest and grassland ecosystems. Misra formulated the first postgraduate course in ecology in India. Over 50 scholars obtained Ph. D degree under his supervision and moved on to other universities and research institutes to initiate ecology teaching and research across the country.

He was honoured with the Fellowships of the Indian National Science Academy and World Academy of Arts and Science, and the prestigious Sanjay Gandhi Award in Environment and Ecology. Due to his efforts, the Government of India established the National Committee for Environmental Planning and Coordination (1972) which, in later years, paved the way for the establishment of the Ministry of Environment and Forests (1984).

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CHAPTER 13

ORGANISMS AND POPULATIONS

Our living world is fascinatingly diverse and amazingly complex. We can try to understand its complexity by investigating processes at various levels of biological organisation–macromolecules, cells, tissues, organs, individual organisms, population, communities, ecosystems and biomes. At any level of biological organisation we can ask two types of questions – for example, when we hear the bulbul singing early morning in the garden, we may ask – 'How does the bird sing?' Or, 'Why does the bird sing ?' The 'how-type' questions seek the *mechanism* behind the process while the 'why-type' questions seek the *significance* of the process. For the first question in our example, the answer might be in terms of the operation of the voice box and the vibrating bone in the bird, whereas for the second question the answer may lie in the bird's need to communicate with its mate during breeding season. When you observe nature around you with a scientific frame of mind you will certainly come up with many interesting questions of both types - *Why are night-blooming flowers generally white? How does the bee know which flower has nectar? Why does cactus have so many thorns? How does the chick spures recognise her own mother*?, and so on.

You have already learnt in previous classes that Ecology is a subject which studies the interactions among organisms and between the organism and its physical (abiotic) environment.

Ecology is basically concerned with four levels of biological organisation – organisms, populations, communities and biomes. In this chapter we explore ecology at organismic and population levels.

13.1 Organism and Its Environment

Ecology at the organismic level is essentially physiological ecology which tries to understand how different organisms are adapted to their environments in terms of not only survival but also reproduction. You may have learnt in earlier classes how the rotation of our planet around the Sun and the tilt of its axis cause annual variations in the intensity and duration of temperature, resulting in distinct seasons. These variations together with annual variation in precipitation (remember precipitation includes both rain and snow) account for the formation of major biomes such as desert, rain forest and tundra (Figure 13.1).

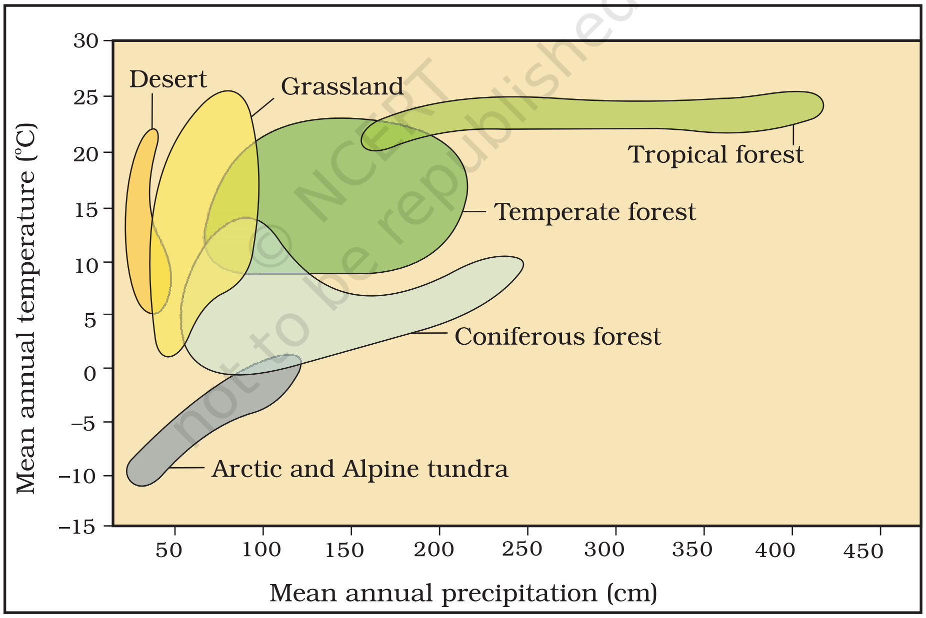

Figure 13.1 Biome distribution with respect to annual temperature and precipitation

Regional and local variations within each biome lead to the formation of a wide variety of habitats. Major biomes of India are shown in Figure 13.2. On planet Earth, life exists not just in a few favourable habitats but even in extreme and harsh habitats – scorching Rajasthan desert, rain-soaked Meghalaya forests, deep ocean trenches, torrential streams, permafrost (snow laden) polar regions, high mountain tops, thermal springs, and stinking compost pits, to name a few. Even our intestine is a unique habitat for hundreds of species of microbes.

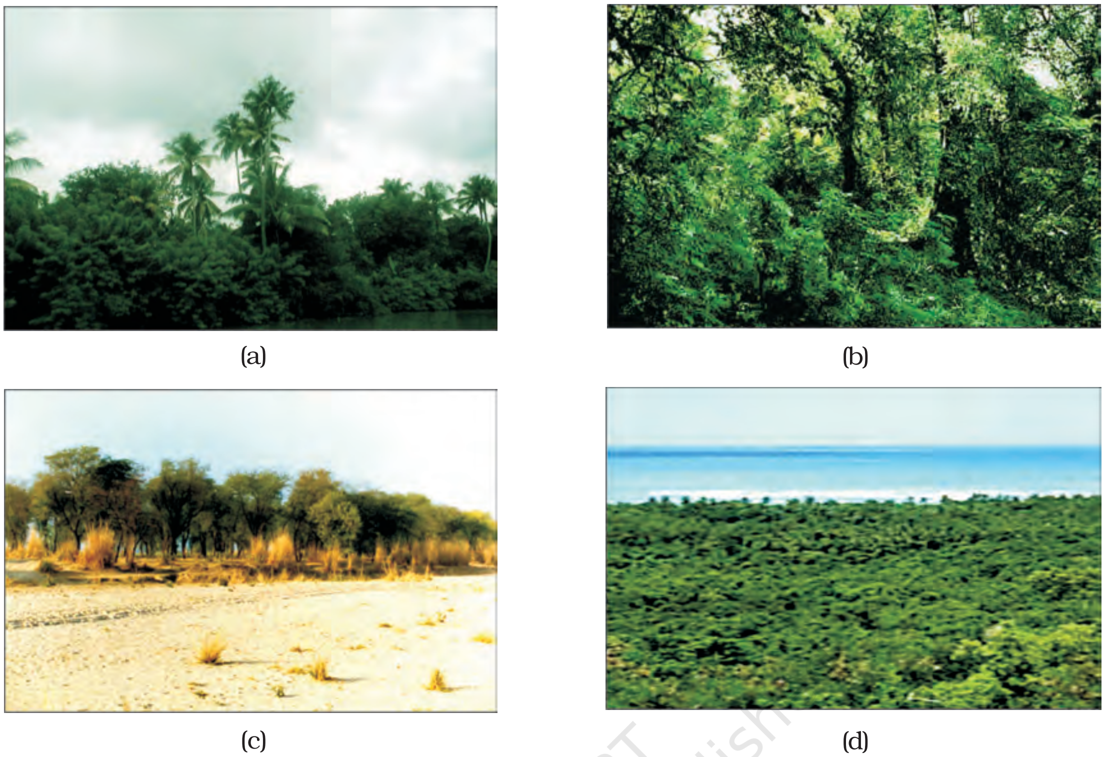

Figure 13.2 Major biomes of India : (a) Tropical rain forest; (b) Deciduous forest; (c) Desert; (d) Sea coast

What are the key elements that lead to so much variation in the physical and chemical conditions of different habitats? The most important ones are temperature, water, light and soil. We must remember that the physico-chemical (abiotic) components alone do not characterise the habitat of an organism completely; the habitat includes biotic components also – pathogens, parasites, predators and competitors – of the organism with which they interact constantly. We assume that over a period of time, the organism had through natural selection, evolved adaptations to optimise its survival and reproduction in its habitat.

Each organism has an invariably defined range of conditions that it can tolerate, diversity in the resources it utilises and a distinct functional role in the ecological system, all these together comprise its **niche**.

13.1.1 Major Abiotic Factors

Temperature: Temperature is the most important ecologically relevant environmental factor. You are aware that the average temperature on land varies seasonally, decreases progressively from the equator towards the poles and from plains to the mountain tops. It ranges from subzero levels in polar areas and high altitudes to >50^0C in tropical deserts in summer. There are, however, unique habitats such as thermal springs and deep-sea hydrothermal vents where average temperatures exceed 100^0 C. It is general knowledge that mango trees do not and cannot grow in temperate countries like Canada and Germany, snow leopards are not found in Kerala forests and tuna fish are rarely caught beyond tropical latitudes in the ocean. You can appreciate the significance of temperature to living organisms when you realise that it affects the kinetics of enzymes and through it the metabolic activity and other physiological functions of the organism. A few organisms can tolerate and thrive in a wide range of temperatures (they are called *eurythermal*), but, a vast majority of them are restricted to a narrow range of temperatures (such organisms are called *stenothermal*). The levels of thermal tolerance of different species determine to a large extent their geographical distribution. *Can you think of a few eurythermal and stenothermal animals and plants?*

In recent years, there has been a growing concern about the gradually increasing average global temperatures (Chapter 16). *If this trend continues, would you expect the distributional range of some species to be affected?*

Water: Water is another the most important factor influencing the life of organisms. In fact, life on earth originated in water and is unsustainable without water. Its availability is so limited in deserts that only special adaptations make it possible for organisms to live there. The productivity and distribution of plants is also heavily dependent on water. You might think that organisms living in oceans, lakes and rivers should not face any water-related problems, but it is not true. For aquatic organisms the quality (chemical composition, pH) of water becomes important. The salt concentration (measured as salinity in parts per thousand), is less than 5 in inland waters, 30-35 in the sea and > 100 in some hypersaline lagoons. Some organisms are tolerant of a wide range of salinities (euryhaline) but others are restricted to a narrow range (stenohaline). Many freshwater animals cannot live for long in sea water and vice versa because of the osmotic problems, they would face.

Light: Since plants produce food through photosynthesis, a process which is only possible when sunlight is available as a source of energy, we can quickly understand the importance of light for living organisms, particularly autotrophs. Many species of small plants (herbs and shrubs) growing in forests are adapted to photosynthesise optimally under very low light conditions because they are constantly overshadowed by tall, canopied trees. Many plants are also dependent on sunlight to meet their photoperiodic requirement for flowering. For many animals too, light is important in that they use the diurnal and seasonal variations in light intensity and duration (photoperiod) as cues for timing their foraging, reproductive and migratory activities. The availability of light on land is closely linked with that of temperature since the sun is the source for both. But, deep (>500m) in the oceans, the environment is dark and its inhabitants are not aware of the existence of a celestial source of energy called Sun. *What, then is their source of energy?*. The spectral quality of solar radiation is also important for life. The UV component of the spectrum is harmful to many organisms while not all the colour components of the visible spectrum are available for marine plants living at different depths of the ocean. *Among the red, green and brown algae that inhabit the sea, which is likely to be found in the deepest waters? Why?*

Soil: The nature and properties of soil in different places vary; it is dependent on the climate, the weathering process, whether soil is transported or sedimentary and how soil development occurred. Various characteristics of the soil such as soil composition, grain size and aggregation determine the percolation and water holding capacity of the soils. These characteristics along with parameters such as pH, mineral composition and topography determine to a large extent the vegetation in any area. This in turn dictates the type of animals that can be supported. Similarly, in the aquatic environment, the sediment-characteristics often determine the type of benthic animals that can thrive there.

13.1.2 Responses to Abiotic Factors

Having realised that the abiotic conditions of many habitats may vary drastically in time, we now ask–*how do the organisms living in such habitats cope or manage with stressful conditions*? But before attempting to answer this question, we should perhaps ask first why a highly variable external environment should bother organisms after all. One would expect that during the course of millions of years of their existence, many species would have evolved a relatively constant internal (within the body) environment that permits all biochemical reactions and physiological functions to proceed with maximal efficiency and thus, enhance the overall 'fitness' of the species. This constancy, for example, could be in terms of optimal temperature and osmotic concentration of body fluids. Ideally then, the organism should try to maintain the constancy of its internal environment (a process called *homeostasis*) despite varying external environmental conditions that tend to upset its homeostasis. Let us take an analogy to clarify this important concept. Suppose a person is able to perform his/her best when the temperature is 25^{0}C and wishes to maintain it so, even when it is scorchingly hot or freezingly cold outside. It could be achieved at home, in the car while travelling, and at workplace by using an air conditioner in summer and heater in winter. Then his/her performance would be always maximal regardless of the weather around him/her. Here the person's homeostasis is accomplished, not through physiological, but artificial means. *How do other living organisms cope with the situation*? Let us look at various possibilities (Figure 13.3).

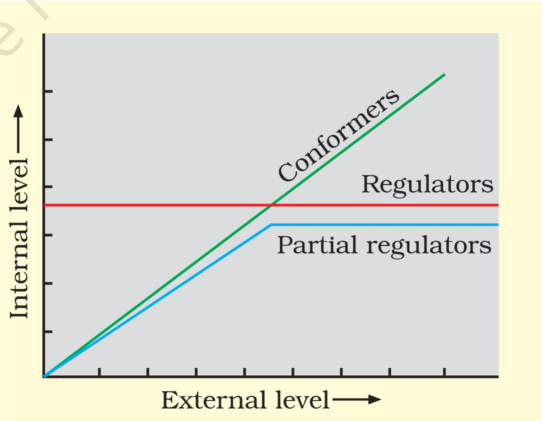

Figure 13.3 Diagrammatic representation of organismic response

(i) ***Regulate:*** Some organisms are able to maintain homeostasis by physiological (sometimes behavioural also) means which ensures constant body temperature, constant osmotic concentration, etc. All birds and mammals, and a very few lower vertebrate and invertebrate species are indeed capable of such regulation (thermoregulation and osmoregulation). Evolutionary biologists believe that the 'success' of mammals is largely due to their ability to maintain a constant body temperature and thrive whether they live in Antarctica or in the Sahara desert.

The mechanisms used by most mammals to regulate their body temperature are similar to the ones that we humans use. We maintain a constant body temperature of 37^0C. In summer, when outside temperature is more than our body temperature, we sweat profusely. The resulting evaporative cooling, similar to what happens with a desert cooler in operation, brings down the body temperature. In winter when the temperature is much lower than 37^0C, we start to shiver, a kind of exercise which produces heat and raises the body temperature. Plants, on the other hand, do not have such mechanisms to maintain internal temperatures.

(ii) ***Conform:*** An overwhelming majority (99 per cent) of animals and nearly all plants cannot maintain a constant internal environment. Their body temperature changes with the ambient temperature. In aquatic animals, the osmotic concentration of the body fluids change with that of the ambient air, water osmotic concentration. These animals and plants are simply conformers. Considering the benefits of a constant internal environment to the organism, we must ask why these conformers had not evolved to become regulators. Recall the human analogy we used above; much as they like, how many people can really afford an air conditioner? Many simply 'sweat it out' and resign themselves to suboptimal performance in hot summer months. Thermoregulation is energetically expensive for many organisms. This is particularly true for small animals like shrews and humming birds. Heat loss or heat gain is a function of surface area. Since small animals have a larger surface area relative to their volume, they tend to lose body heat very fast when it is cold outside; then they have to expend much energy to generate body heat through metabolism. This is the main reason why very small animals are rarely found in polar regions. During the course of evolution, the costs and benefits of maintaining a constant internal environment are taken into consideration. Some species have evolved the ability to regulate, but only over a limited range of environmental conditions, beyond which they simply conform.

If the stressful external conditions are localised or remain only for a short duration, the organism has two other alternatives for survival.

(iii) ***Migrate*:** The organism can move away temporarily from the stressful habitat to a more hospitable area and return when stressful period is over. In human analogy, this strategy is like a person moving from Delhi to Shimla for the duration of summer. Many animals, particularly birds, during winter undertake long-distance migrations to more hospitable areas. Every winter the famous Keolado National Park (Bharatpur) in Rajasthan host thousands of migratory birds coming from Siberia and other extremely cold northern regions.

(iv) ***Suspend:*** In bacteria, fungi and lower plants, various kinds of thick-walled spores are formed which help them to survive unfavourable conditions – these germinate on availability of suitable environment. In higher plants, seeds and some other vegetative reproductive structures serve as means to tide over periods of stress besides helping in dispersal – they germinate to form new plants under favourable moisture and temperature conditions. They do so by reducing their metabolic activity and going into a state of 'dormancy'.

In animals, the organism, if unable to migrate, might avoid the stress by escaping in time. The familiar case of bears going into *hibernation* during winter is an example of escape in time. Some snails and fish go into *aestivation* to avoid summer–related problems-heat and dessication. Under unfavourable conditions many zooplankton species in lakes and ponds are known to enter *diapause*, a stage of suspended development.

13.1.3 Adaptations

While considering the various alternatives available to organisms for coping with extremes in their environment, we have seen that some are able to respond through certain physiological adjustments while others do so behaviourally (migrating temporarily to a less stressful habitat). These responses are also actually, their adaptations. So, we can say that **adaptation** is any attribute of the organism (morphological, physiological, behavioural) that enables the organism to survive and reproduce in its habitat. Many adaptations have evolved over a long evolutionary time and are genetically fixed. In the absence of an external source of water, the kangaroo rat in North American deserts is capable of meeting all its water requirements through its internal fat oxidation (in which water is a by product). It also has the ability to concentrate its urine so that minimal volume of water is used to remove excretory products.

Many desert plants have a thick cuticle on their leaf surfaces and have their stomata arranged in deep pits (sunken) to minimise water loss through transpiration. They also have a special photosynthetic pathway (CAM) that enables their stomata to remain closed during day time. Some desert plants like *Opuntia*, have no leaves – they are reduced to spines– and the photosynthetic function is taken over by the flattened stems.

Mammals from colder climates generally have shorter ears and limbs to minimise heat loss. (This is called the *Allen's Rule*.) In the polar seas aquatic mammals like seals have a thick layer of fat (blubber) below their skin that acts as an insulator and reduces loss of body heat.

Some organisms possess adaptations that are *physiological* which allow them to respond quickly to a stressful situation. If you had ever been to any high altitude place (>3,500m Rohtang Pass near Manali and Leh you must have experienced what is called *altitude sickness*. Its symptoms include nausea, fatigue and heart palpitations. This is because in the low atmospheric pressure of high altitudes, the body does not get enough oxygen. But, gradually you get acclimatised and stop experiencing altitude sickness. *How did your body solve this problem*? The body compensates low oxygen availability by increasing red blood cell production, decreasing the binding affinity of hemoglobin and by increasing breathing rate. *Many tribes live in the high altitude of Himalayas. Find out if they normally have a higher red blood cell count (or total hemoglobin) than people living in the plains.*

In most animals, the metabolic reactions and hence all the physiological functions proceed optimally in a narrow temperature range (in humans, it is 37^{0}C). But there are microbes (archaebacteria) that flourish in hot springs and deep sea hydrothermal vents where temperatures far exceed 100^{0}C. How is this possible?

Many fish thrive in Antarctic waters where the temperature is always below zero. *How do they manage to prevent their body fluids from freezing*?

A large variety of marine invertebrates and fish live at great depths in the ocean where the pressure could be >100 times the normal atmospheric pressure that we experience. *How do they live under such high pressures and do they have any special enzymes*? Organisms living in such extreme environments show a fascinating array of biochemical adaptations.

Some organisms show behavioural responses to cope up with variations in their environment. Desert lizards lack the physiological ability that mammals have to deal with the high temperatures of their habitat, but manage to keep their body temperature fairly constant by behavioural means. They bask in the sun and absorb heat when their body temperature drops below the comfort zone, but move into shade when the ambient temperature starts increasing. Some species are capable of burrowing into the soil to hide and escape from the above-ground heat.

13.2 Populations

13.2.1 Population Attributes

In nature, we rarely find isolated, single individuals of any species; majority of them live in groups in a well defined geographical area, share or compete for similar resources, potentially interbreed and thus constitute a population. Although the term interbreeding implies sexual reproduction, a group of individuals resulting from even asexual reproduction is also generally considered a population for the purpose of ecological studies. All the cormorants in a wetland, rats in an abandoned dwelling, teakwood trees in a forest tract, bacteria in a culture plate and lotus plants in a pond, are some examples of a population. In earlier chapters you have learnt that although an individual organism is the one that has to cope with a changed environment, it is at the population level that natural selection operates to evolve the desired traits. Population ecology is, therefore, an important area because it links ecology to population genetics and evolution.

A population has certain attributes whereas, an individual organism does not. An individual may have births and deaths, but a population has *birth rates* and *death rates*. In a population these rates refer to *per capita* births and deaths. The rates, hence, expressed are change in numbers (increase or decrease) with respect to members of the population. Here is an example. If in a pond there were 20 lotus plants last year and through reproduction 8 new plants are added, taking the current population to 28, we calculate the birth rate as 8/20 = 0.4 offspring per lotus per year. If 4 individuals in a laboratory population of 40 fruitflies died during a specified time interval, say a week, the death rate in the population during that period is 4/40 = 0.1 individuals per fruitfly per week.

Another attribute characteristic of a population is *sex ratio*. An individual is either a male or a female but a population has a sex ratio (e.g., 60 per cent of the population are females and 40 per cent males).

A population at any given time is composed of individuals of different ages. If the age distribution (per cent individuals of a given age or age group) is plotted for the population, the resulting structure is called an age pyramid (Figure 13.4). For human population, the age pyramids generally show age distribution of males and females in a diagram. The shape of the pyramids reflects the growth status of the population - (a) whether it is growing, (b) stable or (c) declining.

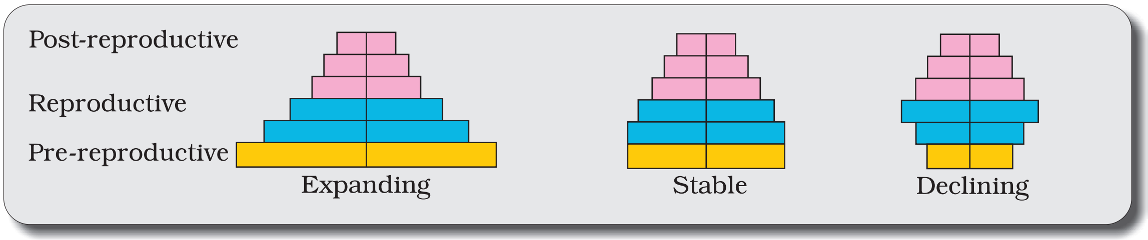

Figure 13.4 Representation of age pyramids for human population

The size of the population tells us a lot about its status in the habitat. Whatever ecological processes we wish to investigate in a population, be it the outcome of competition with another species, the impact of a predator or the effect of a pesticide application, we always evaluate them in terms of any change in the population size. The size, in nature, could be as low as <10 (Siberian cranes at Bharatpur wetlands in any year) or go into millions (*Chlamydomonas* in a pond). Population size, technically called **population density** (designated as N), need not necessarily be measured in numbers only. Although total number is generally the most appropriate measure of population density, it is in some cases either meaningless or difficult to determine. In an area, if there are 200 carrot grass (*Parthenium hysterophorus*) plants but only a single huge banyan tree with a large canopy, stating that the population density of banyan is low relative to that of carrot grass amounts to underestimating the enormous role of the Banyan in that community. In such cases, the per cent cover or biomass is a more meaningful measure of the population size. Total number is again not an easily adoptable measure if the population is huge and counting is impossible or very time-consuming. *If you have a dense laboratory culture of bacteria in a petri dish what is the best measure to report its density?* Sometimes, for certain ecological investigations, there is no need to know the absolute population densities; relative densities serve the purpose equally well. For instance, the number of fish caught per trap is good enough measure of its total population density in the lake. We are mostly obliged to estimate population sizes indirectly, without actually counting them or seeing them. The tiger census in our national parks and tiger reserves is often based on pug marks and fecal pellets.

13.2.2 Population Growth

The size of a population for any species is not a static parameter. It keeps changing with time, depending on various factors including food availability, predation pressure and adverse weather. In fact, it is these changes in population density that give us some idea of what is happening to the population – whether it is flourishing or declining. Whatever might be the ultimate reasons, the density of a population in a given habitat during a given period, fluctuates due to changes in four basic processes, two of which (natality and immigration) contribute to an increase in population density and two (mortality and emigration) to a decrease.

(i) ***Natality*** refers to the number of births during a given period in the population that are added to the initial density.

(ii) ***Mortality*** is the number of deaths in the population during a given period.

(iii) ***Immigration*** is the number of individuals of the same species that have come into the habitat from elsewhere during the time period under consideration.

(iv) ***Emigration*** is the number of individuals of the population who left the habitat and gone elsewhere during the time period under consideration.

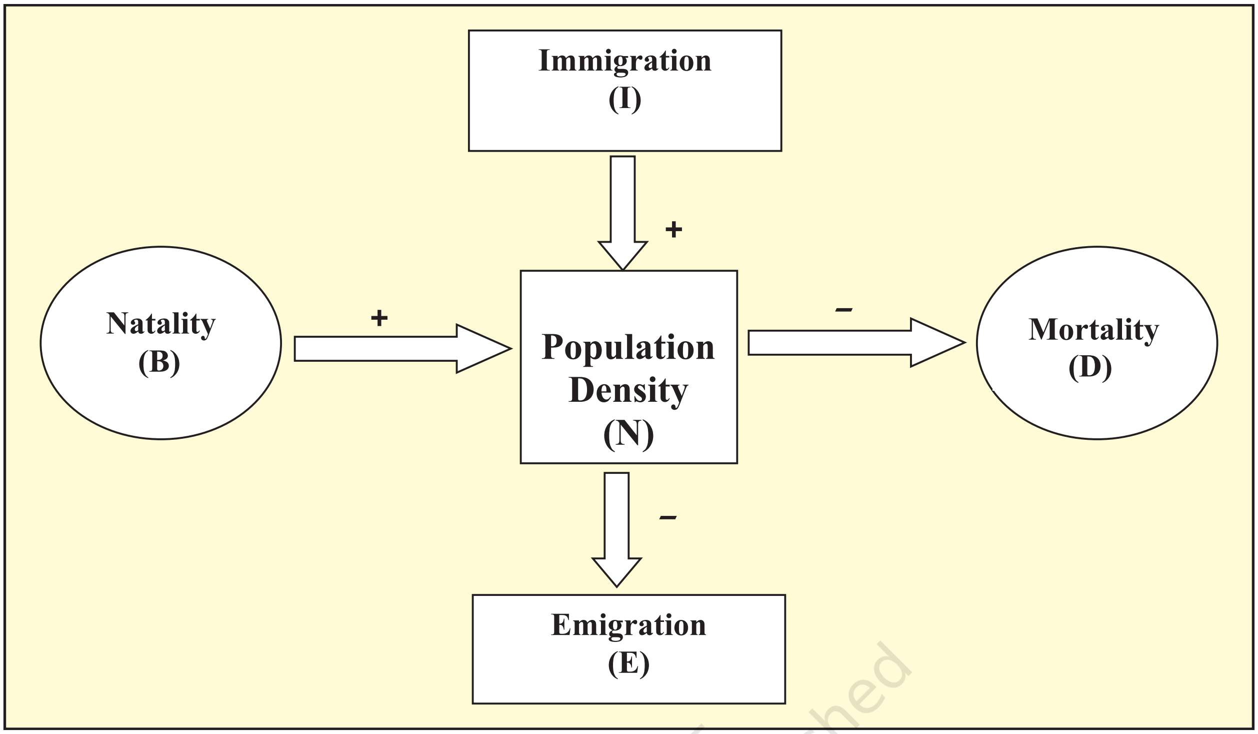

Figure 13.5

So, if N is the population density at time t, then its density at time t +1 is

$$N_{t+1} = N_t + [(B + I) - (D + E)]$$

You can see from the above equation (Fig. 13.5) that population density will increase if the number of births plus the number of immigrants (B + I) is more than the number of deaths plus the number of emigrants (D + E). Under normal conditions, births and deaths are the most important factors influencing population density, the other two factors assuming importance only under special conditions. For instance, if a new habitat is just being colonised, immigration may contribute more significantly to population growth than birth rates.

Growth Models : Does the growth of a population with time show any specific and predictable pattern? We have been concerned about unbridled human population growth and problems created by it in our country and it is therefore natural for us to be curious if different animal populations in nature behave the same way or show some restraints on growth. Perhaps we can learn a lesson or two from nature on how to control population growth.

(i) ***Exponential growth :*** Resource (food and space) availability is obviously essential for the unimpeded growth of a population. Ideally, when resources in the habitat are unlimited, each species has the ability to realise fully its innate potential to grow in number, as Darwin observed while developing his theory of natural selection. Then the population grows in an exponential or geometric fashion. If in a population of size N, the birth rates (not total number but *per capita* births) are represented as *b* and death rates (again, *per capita* death rates) as *d*, then the increase or decrease in N during a unit time period t (dN/dt) will be

$$dN/dt = (b - d) \times N$$
$$\text{Let } (b-d) = r, \text{ then}$$
$$dN/dt = rN$$

The r in this equation is called the 'intrinsic rate of natural increase' and is a very important parameter chosen for assessing impacts of any biotic or abiotic factor on population growth.

To give you some idea about the magnitude of r values, for the Norway rat the r is 0.015, and for the flour beetle it is 0.12. In 1981, the r value for human population in India was 0.0205. *Find out what the current r value is. For calculating it, you need to know the birth rates and death rates.*

The above equation describes the exponential or geometric growth pattern of a population (Figure 13.6) and results in a J-shaped curve when we plot N in relation to time. If you are familiar with basic calculus, you can derive the integral form of the exponential growth equation as

$$N_t = N_0 e^{rt}$$

where

N_t = Population density after time t

N_0 = Population density at time zero

r = intrinsic rate of natural increase

e = the base of natural logarithms (2.71828)

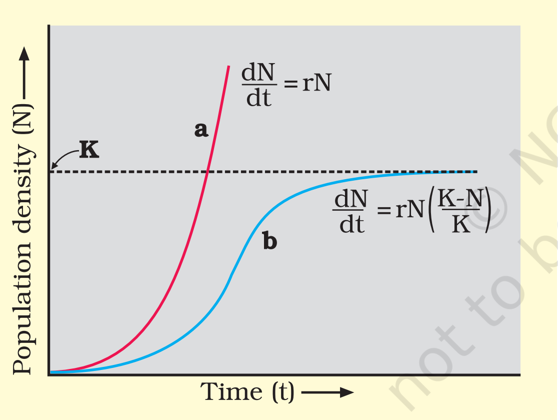

Figure 13.6 Population growth curve **a** when responses are not limiting the growth, plot is exponential, **b** when responses are limiting the growth, plot is logistic, **K** is carrying capacity

Any species growing exponentially under unlimited resource conditions can reach enormous population densities in a short time. Darwin showed how even a slow growing animal like elephant could reach enormous numbers in the absence of checks. The following is an anecdote popularly narrated to demonstrate dramatically how fast a huge population could build up when growing exponentially.

The king and the minister sat for a chess game. The king, confident of winning the game, was ready to accept any bet proposed by the minister. The minister humbly said that if he won, he wanted only some wheat grains, the quantity of which is to be calculated by placing on the chess board one grain in Square 1, then two in Square 2, then four in Square 3, and eight in Square 4, and so on, doubling each time the previous quantity of wheat on the next square until all the 64 squares were filled. The king accepted the seemingly silly bet and started *the game, but unluckily for him, the minister won. The king felt that fulfilling the minister's bet was so easy. He started with a single grain on the first square and proceeded to fill the other squares following minister's suggested procedure, but by the time he covered half the chess board, the king realised to his dismay that all the wheat produced in his entire kingdom pooled together would still be inadequate to cover all the 64 squares. Now think of a tiny Paramecium starting with just one individual and through binary fission, doubling in numbers every day, and imagine what a mind-boggling population size it would reach in 64 days. (provided food and space remain unlimited)*

(ii) ***Logistic growth:*** No population of any species in nature has at its disposal unlimited resources to permit exponential growth. This leads to competition between individuals for limited resources. Eventually, the 'fittest' individual will survive and reproduce. The governments of many countries have also realised this fact and introduced various restraints with a view to limit human population growth. In nature, a given habitat has enough resources to support a maximum possible number, beyond which no further growth is possible. Let us call this limit as nature's *carrying capacity* (K) for that species in that habitat.

A population growing in a habitat with limited resources show initially a lag phase, followed by phases of acceleration and deceleration and finally an asymptote, when the population density reaches the carrying capacity. A plot of N in relation to time (t) results in a sigmoid curve. This type of population growth is called *Verhulst-Pearl Logistic Growth* (Figure 13.6) and is described by the following equation:

$$dN/dt = rN\left(\frac{K-N}{K}\right)$$

Where N = Population density at time t
r = Intrinsic rate of natural increase
K = Carrying capacity

Since resources for growth for most animal populations are finite and become limiting sooner or later, the logistic growth model is considered a more realistic one.

Gather from Government Census data the population figures for India for the last 100 years, plot them and check which growth pattern is evident.

13.2.3 Life History Variation

Populations evolve to maximise their reproductive fitness, also called Darwinian fitness (high r value), in the habitat in which they live. Under a particular set of selection pressures, organisms evolve towards the most efficient reproductive strategy. Some organisms breed only once in their lifetime (Pacific salmon fish, bamboo) while others breed many times during their lifetime (most birds and mammals). Some produce a large number of small-sized offspring (Oysters, pelagic fishes) while others produce a small number of large-sized offspring (birds, mammals). So, which is desirable for maximising fitness? Ecologists suggest that life history traits of organisms have evolved in relation to the constraints imposed by the abiotic and biotic components of the habitat in which they live. Evolution of life history traits in different species is currently an important area of research being conducted by ecologists.

13.2.4 Population Interactions

Can you think of any natural habitat on earth that is inhabited just by a single species? There is no such habitat and such a situation is even inconceivable. For any species, the minimal requirement is one more species on which it can feed. Even a plant species, which makes its own food, cannot survive alone; it needs soil microbes to break down the organic matter in soil and return the inorganic nutrients for absorption. And then, how will the plant manage pollination without an animal agent? It is obvious that in nature, animals, plants and microbes do not and cannot live in isolation but interact in various ways to form a biological community. Even in minimal communities, many interactive linkages exist, although all may not be readily apparent.

Interspecific interactions arise from the interaction of populations of two different species. They could be beneficial, detrimental or neutral (neither harm nor benefit) to one of the species or both. Assigning a **'+'** sign for beneficial interaction, **'-'** sign for detrimental and 0 for neutral interaction, let us look at all the possible outcomes of interspecific interactions (Table13.1).

Table 13.1 : Population Interactions

Species A	Species B	Name of Interaction
+	+	*Mutualism*
–	–	*Competition*
+	–	*Predation*
+	–	*Parasitism*
+	0	*Commensalism*
–	0	*Amensalism*

Both the species benefit in ***mutualism*** and both lose in ***competition*** in their interactions with each other. In both ***parasitism*** and ***predation*** only one species benefits (parasite and predator, respectively) and the interaction is detrimental to the other species (host and prey, respectively). The interaction where one species is benefitted and the other is neither benefitted nor harmed is called **commensalism**. In **amensalism** on the other hand one species is harmed whereas the other is unaffected. Predation, parasitism and commensalism share a common characteristic– the interacting species live closely together.

(i) ***Predation****: What would happen to all the energy fixed by autotrophic organisms if the community has no animals to eat the plants*? You can think of predation as nature's way of transferring to higher trophic levels the energy fixed by plants. When we think of predator and prey, most probably it is the tiger and the deer that readily come to our mind, but a sparrow eating any seed is no less a predator. Although animals eating plants are categorised separately as *herbivores*, they are, in a broad ecological context, not very different from predators.

Besides acting as 'conduits' for energy transfer across trophic levels, predators play other important roles. They keep prey populations under control. But for predators, prey species could achieve very high population densities and cause ecosystem instability. When certain exotic species are introduced into a geographical area, they become invasive and start spreading fast because the invaded land does not have its natural predators. The prickly pear cactus introduced into Australia in the early 1920's caused havoc by spreading rapidly into millions of hectares of rangeland. Finally, the invasive cactus was brought under control only after a cactus-feeding predator (a moth) from its natural habitat was introduced into the country. *Biological control* methods adopted in agricultural pest control are based on the ability of the predator to regulate prey population. Predators also help in maintaining species diversity in a community, by reducing the intensity of competition among competing prey species. In the rocky intertidal communities of the American Pacific Coast the starfish *Pisaster* is an important predator. In a field experiment, when all the starfish were removed from an enclosed intertidal area, more than 10 species of invertebrates became extinct within a year, because of inter-specific competition.

If a predator is too efficient and overexploits its prey, then the prey might become extinct and following it, the predator will also become extinct for lack of food. This is the reason why predators in nature are 'prudent'. Prey species have evolved various defenses to lessen the impact of predation. Some species of insects and frogs are cryptically-coloured (*camouflaged*) to avoid being detected easily by the predator. Some are poisonous and therefore avoided by the predators. The Monarch butterfly is highly distasteful to its predator (bird) because of a special chemical present in its body. Interestingly, the butterfly acquires this chemical during its caterpillar stage by feeding on a poisonous weed.

For plants, herbivores are the predators. Nearly 25 per cent of all insects are known to be *phytophagous* (feeding on plant sap and other parts of plants). The problem is particularly severe for plants because, unlike animals, they cannot run away from their predators. Plants therefore have evolved an astonishing variety of morphological and chemical defences against herbivores. Thorns (*Acacia*, *Cactus*) are the most common morphological means of defence. Many plants produce and store chemicals that make the herbivore sick when they are eaten, inhibit feeding or digestion, disrupt its reproduction or even kill it. You must have seen the weed *Calotropis* growing in abandoned fields. The plant produces highly poisonous cardiac glycosides and that is why you never see any cattle or goats browsing on this plant. A wide variety of chemical substances that we extract from plants on a commercial scale (nicotine, caffeine, quinine, strychnine, opium, etc.,) are produced by them actually as defences against grazers and browsers.

(ii) ***Competition***: When Darwin spoke of the struggle for existence and survival of the fittest in nature, he was convinced that interspecific competition is a potent force in organic evolution. It is generally believed that competition occurs when closely related species compete for the same resources that are limiting, but this is not entirely true. Firstly, totally unrelated species could also compete for the same resource. For instance, in some shallow South American lakes, visiting flamingoes and resident fishes compete for their common food, the zooplankton in the lake. Secondly, resources need not be limiting for competition to occur; in interference competition, the feeding efficiency of one species might be reduced due to the interfering and inhibitory presence of the other species, even if resources (food and space) are abundant. Therefore, competition is best defined as a process in which the fitness of one species (measured in terms of its 'r' the intrinsic rate of increase) is significantly lower in the presence of another species. It is relatively easy to demonstrate in laboratory experiments, as Gause and other experimental ecologists did, when resources are limited the competitively superior species will eventually eliminate the other species, but evidence for such competitive exclusion occurring in nature is not always conclusive. Strong and persuasive circumstantial evidence does exist however in some cases. The Abingdon tortoise in Galapagos Islands became extinct within a decade after goats were introduced on the island, apparently due to the greater browsing efficiency of the goats. Another evidence for the occurrence of competition in nature comes from what is called 'competitive release'. A species whose distribution is restricted to a small geographical area because of the presence of a competitively superior species, is found to expand its distributional range dramatically when the competing species is experimentally removed. Connell's elegant field experiments showed that on the rocky sea coasts of Scotland, the larger and competitively superior barnacle *Balanus* dominates the intertidal area, and excludes the smaller barnacle *Chathamalus* from that zone. In general, herbivores and plants appear to be more adversely affected by competition than carnivores.

Gause's '*Competitive Exclusion Principle*' states that two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually. This may be true if resources are limiting, but not otherwise. More recent studies do not support such gross generalisations about competition. While they do not rule out the occurrence of interspecific competition in nature, they point out that species facing competition might evolve mechanisms that promote co-existence rather than exclusion. One such mechanism is 'resource partitioning'. If two species compete for the same resource, they could avoid competition by choosing, for instance, different times for feeding or different foraging patterns. MacArthur showed that five closely related species of warblers living on the same tree were able to avoid competition and co-exist due to behavioural differences in their foraging activities.

(iii) ***Parasitism**:* Considering that the parasitic mode of life ensures free lodging and meals, it is not surprising that parasitism has evolved in so many taxonomic groups from plants to higher vertebrates. Many parasites have evolved to be host-specific (they can parasitise only a single species of host) in such a way that both host and the parasite tend to co-evolve; that is, if the host evolves special mechanisms for rejecting or resisting the parasite, the parasite has to evolve mechanisms to counteract and neutralise them, in order to be successful with the same host species. In accordance with their life styles, parasites evolved special adaptations such as the loss of unnecessary sense organs, presence of adhesive organs or suckers to cling on to the host, loss of digestive system and high reproductive capacity. The life cycles of parasites are often complex, involving one or two intermediate hosts or vectors to facilitate parasitisation of its primary host. The human liver fluke (a trematode parasite) depends on two intermediate hosts (a snail and a fish) to complete its life cycle. The malarial parasite needs a vector (mosquito) to spread to other hosts. Majority of the parasites harm the host; they may reduce the survival, growth and reproduction of the host and reduce its population density. They might render the host more vulnerable to predation by making it physically weak. *Do you believe that an ideal parasite should be able to thrive within the host without harming it? Then why didn't natural selection lead to the evolution of such totally harmless parasites*?

Parasites that feed on the external surface of the host organism are called *ectoparasites*. The most familiar examples of this group are the lice on humans and ticks on dogs. Many marine fish are infested with ectoparasitic copepods. *Cuscuta*, a parasitic plant that is commonly found growing on hedge plants, has lost its chlorophyll and leaves in the course of evolution. It derives its nutrition from the host plant which it parasitises. The female mosquito is not considered a parasite, although it needs our blood for reproduction. *Can you explain why?*

In contrast, *endoparasites* are those that live inside the host body at different sites (liver, kidney, lungs, red blood cells, etc.). The life cycles of endoparasites are more complex because of their extreme specialisation. Their morphological and anatomical features are greatly simplified while emphasising their reproductive potential.

Brood parasitism in birds is a fascinating example of parasitism in which the parasitic bird lays its eggs in the nest of its host and lets the host incubate them. During the course of evolution, the eggs of the parasitic bird have evolved to resemble the host's egg in size and colour to reduce the chances of the host bird detecting the foreign eggs and ejecting them from the nest. Try to follow the movements of the cuckoo (koel) and the crow in your neighborhood park during the breeding season (spring to summer) and watch brood parasitism in action.

(iv) ***Commensalism**:* This is the interaction in which one species benefits and the other is neither harmed nor benefited. An orchid growing as an *epiphyte* on a mango branch, and barnacles growing on the back of a whale benefit while neither the mango tree nor the whale derives any apparent benefit. The cattle egret and grazing cattle in close association, a sight you are most likely to catch if you live in farmed rural areas, is a classic example of commensalism. The egrets always forage close to where the cattle are grazing because the cattle, as they move, stir up and flush out insects from the vegetation that otherwise might be difficult for the egrets to find and catch. Another example of commensalism is the interaction

(a) (b)

Figure 13.7 Mutual relationship between fig tree and wasp: (a) Fig flower is pollinated by wasp; (b) Wasp laying eggs in a fig fruit

between sea anemone that has stinging tentacles and the clown fish that lives among them. The fish gets protection from predators which stay away from the stinging tentacles. The anemone does not appear to derive any benefit by hosting the clown fish.

(v) ***Mutualism***: This interaction confers benefits on both the interacting species. Lichens represent an intimate mutualistic relationship between a fungus and photosynthesising algae or cyanobacteria. Similarly, the *mycorrhizae* are associations between fungi and the roots of higher plants. The fungi help the plant in the absorption of essential nutrients from the soil while the plant in turn provides the fungi with energy-yielding carbohydrates.

The most spectacular and evolutionarily fascinating examples of mutualism are found in plant-animal relationships. Plants need the help of animals for pollinating their flowers and dispersing their seeds. Animals obviously have to be paid 'fees' for the services that plants expect from them. Plants offer rewards or fees in the form of pollen and nectar for pollinators and juicy and nutritious fruits for seed dispersers. But the mutually beneficial system should also be safeguarded against 'cheaters', for example, animals that try to steal nectar without aiding in pollination. Now you can see why plant-animal interactions often involve *co-evolution* of the mutualists, that is, the evolutions of the flower and its pollinator species are tightly linked with one another. In many species of fig trees, there is a tight one-to-one relationship with the pollinator species of wasp (Figure 13.7). It means that a given fig species can be pollinated only by its 'partner' wasp species and no other species. The female wasp uses the fruit not only as an oviposition (egg-laying) site but uses the developing seeds within the fruit for nourishing

Figure 13.8 Showing bee-a pollinator on orchid flower

its larvae. The wasp pollinates the fig inflorescence while searching for suitable egg-laying sites. In return for the favour of pollination the fig offers the wasp some of its developing seeds, as food for the developing wasp larvae.

Orchids show a bewildering diversity of floral patterns many of which have evolved to attract the right pollinator insect (bees and bumblebees) and ensure guaranteed pollination by it (Figure 13.8). Not all orchids offer rewards. The Mediterranean orchid *Ophrys* employs 'sexual deceit' to get pollination done by a species of bee. One petal of its flower bears an uncanny resemblance to the female of the bee in size, colour and markings. The male bee is attracted to what it perceives as a female, 'pseudocopulates' with the flower, and during that process is dusted with pollen from the flower. When this same bee 'pseudocopulates' with another flower, it transfers pollen to it and thus, pollinates the flower. Here you can see how co-evolution operates. If the female bee's colour patterns change even slightly for any reason during evolution, pollination success will be reduced unless the orchid flower co-evolves to maintain the resemblance of its petal to the female bee.

SUMMARY

As a branch of biology, Ecology is the study of the relationships of living organisms with the abiotic (physico-chemical factors) and biotic components (other species) of their environment. It is concerned with four levels of biological organisation-organisms, populations, communities and biomes.

Temperature, light, water and soil are the most important physical factors of the environment to which the organisms are adapted in various ways. Maintenance of a constant internal environment (*homeostasis*) by the organisms contributes to optimal performance, but only some organisms (regulators) are capable of homeostasis in the face of changing external environment. Others either partially regulate their internal environment or simply conform. A few other species have evolved adaptations to avoid unfavourable conditions in space (migration) or in time (aestivation, hibernation, and diapause).

Evolutionary changes through natural selection take place at the population level and hence, population ecology is an important area of ecology. A population is a group of individuals of a given species sharing or competing for similar resources in a defined geographical area. Populations have attributes that individual organisms do not- birth rates and death rates, sex ratio and age distribution. The proportion of different age groups of males and females in a population is often presented graphically as age pyramid; its shape indicates whether a population is stationary, growing or declining.

Ecological effects of any factors on a population are generally reflected in its size (population density), which may be expressed in different ways (numbers, biomass, per cent cover, etc.,) depending on the species.

Populations grow through births and immigration and decline through deaths and emigration. When resources are unlimited, the growth is usually exponential but when resources become progressively limiting, the growth pattern turns logistic. In either case, growth is ultimately limited by the carrying capacity of the environment. The intrinsic rate of natural increase (*r*) is a measure of the inherent potential of a population to grow.

In nature populations of different species in a habitat do not live in isolation but interact in many ways. Depending on the outcome, these interactions between two species are classified as competition (both species suffer), predation and parasitism (one benefits and the other suffers), commensalism (one benefits and the other is unaffected), amensalism (one is harmed, other unaffected) and mutualism (both species benefit). Predation is a very important process through which trophic energy transfer is facilitated and some predators help in controlling their prey populations. Plants have evolved diverse morphological and chemical defenses against herbivory. In competition, it is presumed that the superior competitor eliminates the inferior one (the Competitive Exclusion Principle), but many closely related species have evolved various mechanisms which facilitate their co-existence. Some of the most fascinating cases of mutualism in nature are seen in plant-pollinator interactions.

EXERCISES

1. How is diapause different from hibernation?
2. If a marine fish is placed in a fresh water aquarium, will the fish be able to survive? Why or why not?
3. Most living organisms cannot survive at temperature above 45^0C. How are some microbes able to live in habitats with temperatures exceeding 100^0C?
4. List the attributes that populations possess but not individuals.
5. If a population growing exponentially double in size in 3 years, what is the intrinsic rate of increase (r) of the population?
6. Name important defence mechanisms in plants against herbivory.

7. An orchid plant is growing on the branch of mango tree. How do you describe this interaction between the orchid and the mango tree?
8. What is the ecological principle behind the biological control method of managing with pest insects?
9. Distinguish between the following:
   (a) Hibernation and Aestivation
   (b) Ectotherms and Endotherms
10. Write a short note on
    (a) Adaptations of desert plants and animals
    (b) Adaptations of plants to water scarcity
    (c) Behavioural adaptations in animals
    (d) Importance of light to plants
    (e) Effect of temperature or water scarcity and the adaptations of animals.
11. List the various abiotic environmental factors.
12. Give an example for:
    (a) An endothermic animal
    (b) An ectothermic animal
    (c) An organism of benthic zone
13. Define population and community.
14. Define the following terms and give one example for each:
    (a) Commensalism
    (b) Parasitism
    (c) Camouflage
    (d) Mutualism
    (e) Interspecific competition
15. With the help of suitable diagram describe the logistic population growth curve.
16. Select the statement which explains best parasitism.
    (a) One organism is benefited.
    (b) Both the organisms are benefited.
    (c) One organism is benefited, other is not affected.
    (d) One organism is benefited, other is affected.
17. List any three important characteristics of a population and explain.

CHAPTER 14

ECOSYSTEM

An ecosystem can be visualised as a functional unit of nature, where living organisms interact among themselves and also with the surrounding physical environment. Ecosystem varies greatly in size from a small pond to a large forest or a sea. Many ecologists regard the entire biosphere as a global ecosystem, as a composite of all local ecosystems on Earth. Since this system is too much big and complex to be studied at one time, it is convenient to divide it into two basic categories, namely the **terrestrial** and the **aquatic**. Forest, grassland and desert are some examples of terrestrial ecosystems; pond, lake, wetland, river and estuary are some examples of aquatic ecosystems. Crop fields and an aquarium may also be considered as man-made ecosystems.

We will first look at the structure of the ecosystem, in order to appreciate the input (productivity), transfer of energy (food chain/web, nutrient cycling) and the output (degradation and energy loss). We will also look at the relationships – cycles, chains, webs – that are created as a result of these energy flows within the system and their inter- relationship.

14.1 Ecosystem – Structure and Function

In chapter 13, you have looked at the various components of the environment- abiotic and biotic. You studied how the individual biotic and abiotic factors affected each other and their surrounding. Let us look at these components in a more integrated manner and see how the flow of energy takes place within these components of the ecosystem.

Interaction of biotic and abiotic components result in a physical structure that is characteristic for each type of ecosystem. Identification and enumeration of plant and animal species of an ecosystem gives its species composition. Vertical distribution of different species occupying different levels is called **stratification**. For example, trees occupy top vertical strata or layer of a forest, shrubs the second and herbs and grasses occupy the bottom layers.

The components of the ecosystem are seen to function as a unit when you consider the following aspects:

(i) Productivity;
(ii) Decomposition;
(iii) Energy flow; and
(iv) Nutrient cycling.

To understand the ethos of an aquatic ecosystem let us take a small pond as an example. This is fairly a self-sustainable unit and rather simple example that explain even the complex interactions that exist in an aquatic ecosystem. A pond is a shallow water body in which all the above mentioned four basic components of an ecosystem are well exhibited. The abiotic component is the water with all the dissolved inorganic and organic substances and the rich soil deposit at the bottom of the pond. The solar input, the cycle of temperature, day-length and other climatic conditions regulate the rate of function of the entire pond. The autotrophic components include the phytoplankton, some algae and the floating, submerged and marginal plants found at the edges. The consumers are represented by the zooplankton, the free swimming and bottom dwelling forms. The decomposers are the fungi, bacteria and flagellates especially abundant in the bottom of the pond. This system performs all the functions of any ecosystem and of the biosphere as a whole, i.e., conversion of inorganic into organic material with the help of the radiant energy of the sun by the autotrophs; consumption of the autotrophs by heterotrophs; decomposition and mineralisation of the dead matter to release them back for reuse by the autotrophs, these event are repeated over and over again. There is unidirectional movement of energy towards the higher trophic levels and its dissipation and loss as heat to the environment.

14.2. Productivity

A constant input of solar energy is the basic requirement for any ecosystem to function and sustain. **Primary production** is defined as the amount of biomass or organic matter produced per unit area over a time period by plants during photosynthesis. It is expressed in terms of weight ($g\,m^{-2}$) or energy ($kcal\ m^{-2}$). The rate of biomass production is called **productivity**. It is expressed in terms of $gm^{-2}\ yr^{-1}$ or $(kcal\ m^{-2})\ yr^{-1}$ to compare the productivity of different ecosystems. It can be divided into gross primary productivity (GPP) and net primary productivity (NPP). **Gross primary productivity** of an ecosystem is the rate of production of organic matter during photosynthesis. A considerable amount of GPP is utilised by plants in respiration. Gross primary productivity minus respiration losses (R), is the **net primary productivity** (NPP).

$$GPP - R = NPP$$

Net primary productivity is the available biomass for the consumption to heterotrophs (herbiviores and decomposers). **Secondary productivity** is defined as the rate of formation of new organic matter by consumers.

Primary productivity depends on the plant species inhabiting a particular area. It also depends on a variety of environmental factors, availability of nutrients and photosynthetic capacity of plants. Therefore, it varies in different types of ecosystems. The annual net primary productivity of the whole biosphere is approximately 170 billion tons (dry weight) of organic matter. Of this, despite occupying about 70 per cent of the surface, the productivity of the oceans are only 55 billion tons. Rest of course, is on land. *Discuss the main reason for the low productivity of ocean with your teacher.*

14.3 Decomposition

You may have heard of the earthworm being referred to as the farmer's 'friend'. This is so because they help in the breakdown of complex organic matter as well as in loosening of the soil. Similarly, decomposers break down complex organic matter into inorganic substances like carbon dioxide, water and nutrients and the process is called **decomposition**. Dead plant remains such as leaves, bark, flowers and dead remains of animals, including fecal matter, constitute **detritus**, which is the raw material for decomposition. The important steps in the process of decomposition are fragmentation, leaching, catabolism, humification and mineralisation.

Detritivores (e.g., earthworm) break down detritus into smaller particles. This process is called **fragmentation.** By the process of **leaching,** water-soluble inorganic nutrients go down into the soil horizon and get precipitated as unavailable salts. Bacterial and fungal enzymes degrade detritus into simpler inorganic substances. This process is called as **catabolism**.

It is important to note that all the above steps in decomposition operate simultaneously on the detritus (Figure 14.1). Humification and mineralisation occur during decomposition in the soil. **Humification** leads

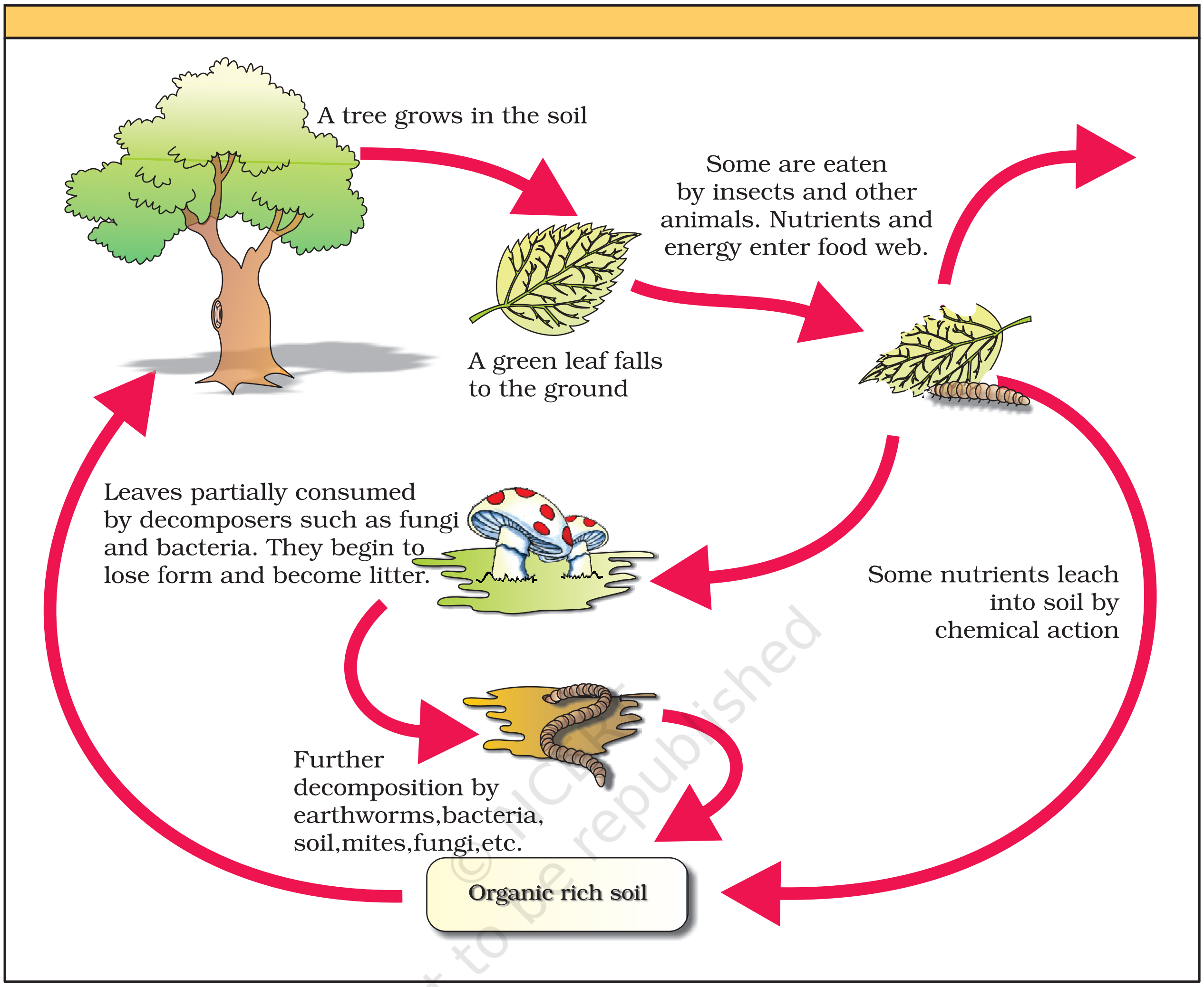

Figure 14.1 Diagrammatic representation of decomposition cycle in a terrestrial ecosystem

to accumulation of a dark coloured amorphous substance called **humus** that is highly resistant to microbial action and undergoes decomposition at an extremely slow rate. Being colloidal in nature it serves as a reservoir of nutrients. The humus is further degraded by some microbes and release of inorganic nutrients occur by the process known as **mineralisation**.

Decomposition is largely an oxygen-requiring process. The rate of decomposition is controlled by chemical composition of detritus and climatic factors. In a particular climatic condition, decomposition rate is slower if detritus is rich in lignin and chitin, and quicker, if detritus is rich in nitrogen and water-soluble substances like sugars. Temperature and soil moisture are the most important climatic factors that regulate decomposition through their effects on the activities of soil microbes. Warm and moist environment favour decomposition whereas low temperature and anaerobiosis inhibit decomposition resulting in build up of organic materials.

14.4 Energy Flow

Except for the deep sea hydro-thermal ecosystem, sun is the only source of energy for all ecosystems on Earth. Of the incident solar radiation less than 50 per cent of it is **photosynthetically active radiation** (PAR). We know that plants and photosynthetic bacteria (autotrophs), fix Sun's radiant energy to make food from simple inorganic materials. Plants capture only 2-10 per cent of the PAR and this small amount of energy sustains the entire living world. So, it is very important to know how the solar energy captured by plants flows through different organisms of an ecosystem. All organisms are dependent for their food on producers, either directly or indirectly. So you find unidirectional flow of energy from the sun to producers and then to consumers. *Is this in keeping with the first law of thermodynamics?*

Further, ecosystems are not exempt from the Second Law of thermodynamics. They need a constant supply of energy to synthesise the molecules they require, to counteract the universal tendency toward increasing disorderliness.

The green plant in the ecosystem are called **producers**. In a terrestrial ecosystem, major producers are herbaceous and woody plants. Likewise, producers in an aquatic ecosystem are various species like phytoplankton, algae and higher plants.

You have read about the food chains and webs that exist in nature. Starting from the plants (or producers) food chains or rather webs are formed such that an animal feeds on a plant or on another animal and in turn is food for another. The chain or web is formed because of this interdependency. No energy that is trapped into an organism remains in it for ever. The energy trapped by the producer, hence, is either passed on to a consumer or the organism dies. Death of organism is the beginning of the detritus food chain/web.

All animals depend on plants (directly or indirectly) for their food needs. They are hence called **consumers** and also heterotrophs. If they feed on the producers, the plants, they are called primary consumers, and if the animals eat other animals which in turn eat the plants (or their produce) they are called secondary consumers. Likewise, you could have tertiary consumers too. Obviously the primary consumers will be **herbivores**. Some common herbivores are insects, birds and mammals in terrestrial ecosystem and molluscs in aquatic ecosystem.

The consumers that feed on these herbivores are carnivores, or more correctly **primary carnivores** (though secondary consumers). Those animals that depend on the primary carnivores for food are labelled **secondary carnivores.** A simple grazing food chain (GFC) is depicted below:

Grass - - - - - →	Goat - - - - - →	Man - - - - - →
(Producer)	(Primary Consumer)	(Secondary consumer)

The **detritus food chain** (DFC) begins with dead organic matter. It is made up of **decomposers** which are heterotrophic organisms, mainly fungi and bacteria. They meet their energy and nutrient requirements by degrading dead organic matter or detritus. These are also known as **saprotrophs** (*sapro:* to decompose). Decomposers secrete digestive enzymes that breakdown dead and waste materials into simple, inorganic materials, which are subsequently absorbed by them.

In an aquatic ecosystem, GFC is the major conduit for energy flow. As against this, in a terrestrial ecosystem, a much larger fraction of energy flows through the detritus food chain than through the GFC. Detritus food chain may be connected with the grazing food chain at some levels: some of the organisms of DFC are prey to the GFC animals, and in a natural ecosystem, some animals like cockroaches, crows, etc., are omnivores. These natural interconnection of food chains make it a **food web**. *How would you classify human beings!*

Organisms occupy a place in the natural surroundings or in a community according to their feeding relationship with other organisms. Based on the source of their nutrition or food, organisms occupy a specific place in the food chain that is known as their **trophic level**. Producers belong to the first trophic level, herbivores (primary consumer) to the second and carnivores (secondary consumer) to the third (Figure 14.2).

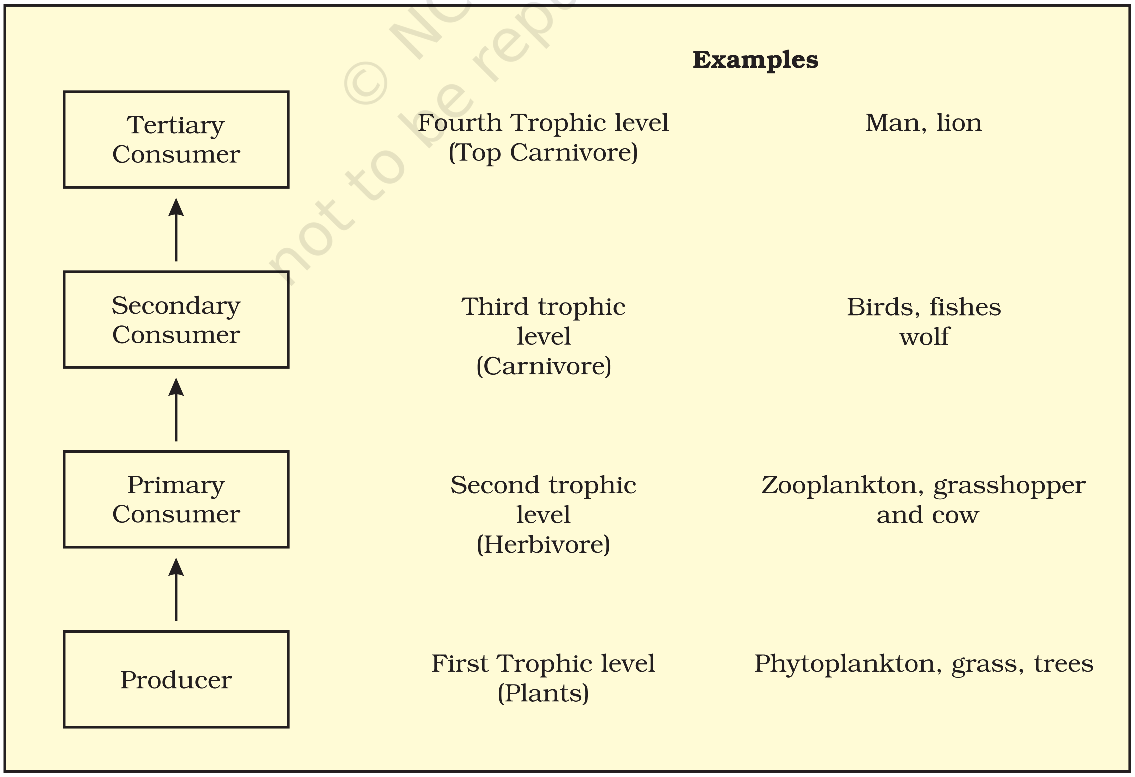

Figure 14.2 Diagrammatic representation of trophic levels in an ecosystem

The important point to note is that the amount of energy decreases at successive trophic levels. When any organism dies it is converted to detritus or dead biomass that serves as an energy source for decomposers. Organisms at each trophic level depend on those at the lower trophic level for their energy demands.

Each trophic level has a certain mass of living material at a particular time called as the **standing crop**. The standing crop is measured as the mass of living organisms **(biomass)** or the number in a unit area. The biomass of a species is expressed in terms of fresh or dry weight. Measurement of biomass in terms of dry weight is more accurate. *Why?*

The number of trophic levels in the grazing food chain is restricted as the transfer of energy follows 10 per cent law – only 10 per cent of the energy is transferred to each trophic level from the lower trophic level. In nature, it is possible to have so many levels – producer, herbivore, primary carnivore, secondary carnivore in the grazing food chain (Figure 14.3) . *Do you think there is any such limitation in a detritus food chain?*

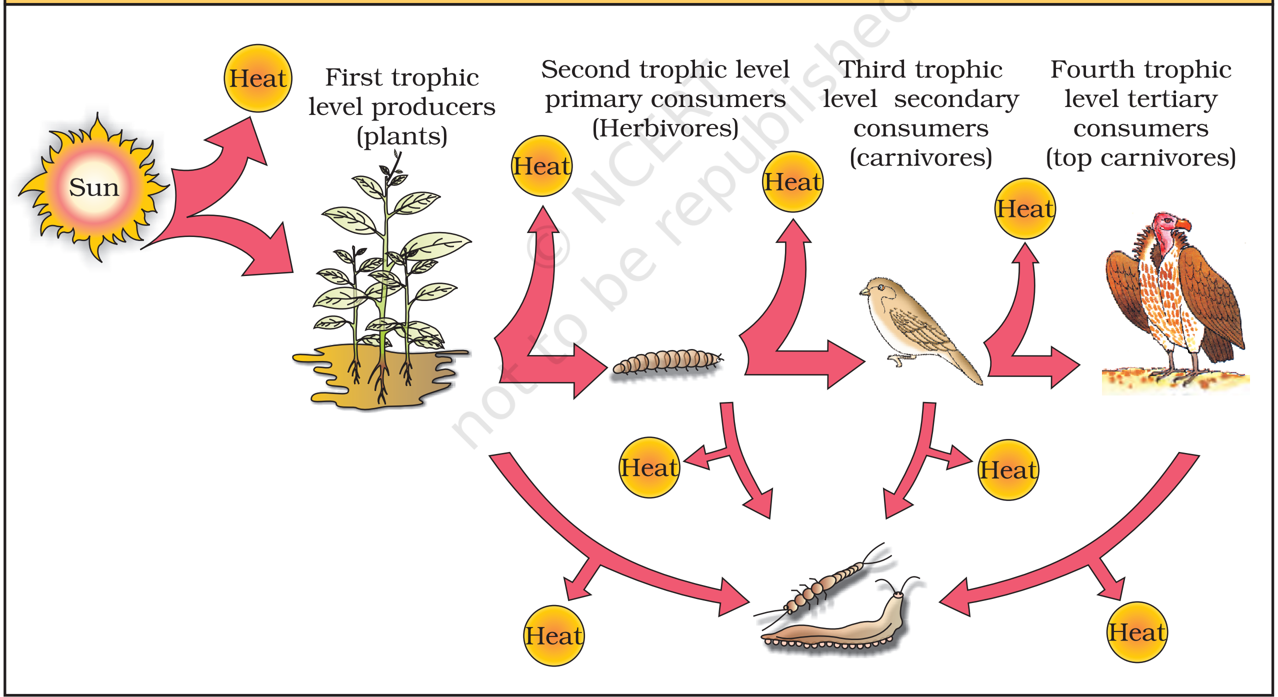

Figure 14.3 Energy flow through different trophic levels

14.5 Ecological Pyramids

You must be familiar with the shape of a pyramid. The base of a pyramid is broad and it narrows towards the apex. One gets a similar shape, whether you express the food or energy relationship between organisms at different trophic levels. This, relationship is expressed in terms of number, biomass or energy. The base of each pyramid represents the producers or the first trophic level while the apex represents tertiary or top level consumer. The three types of ecological pyramids that are usually studied are (a) pyramid of number; (b) pyramid of biomass and (c) pyramid of energy. For detail (see Figure 14.4 a, b, c and d).

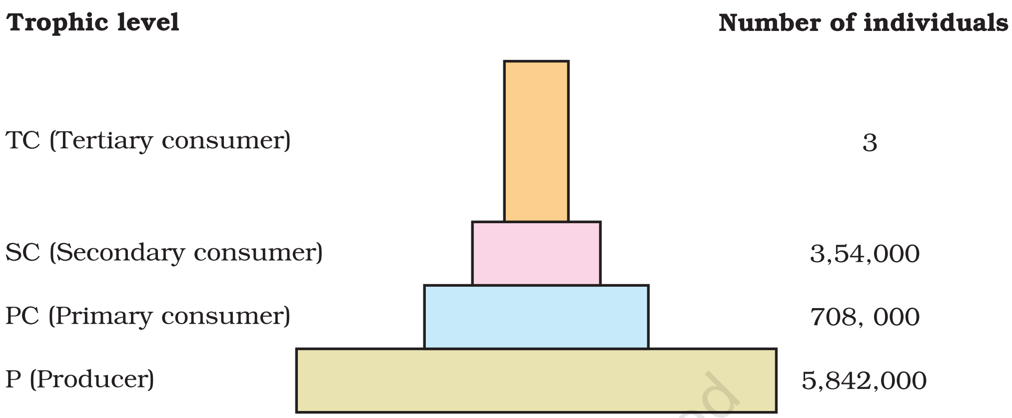

Figure 14.4 (a) Pyramid of numbers in a grassland ecosystem. Only three top-carnivores are supported in an ecosystem based on production of nearly 6 millions plants

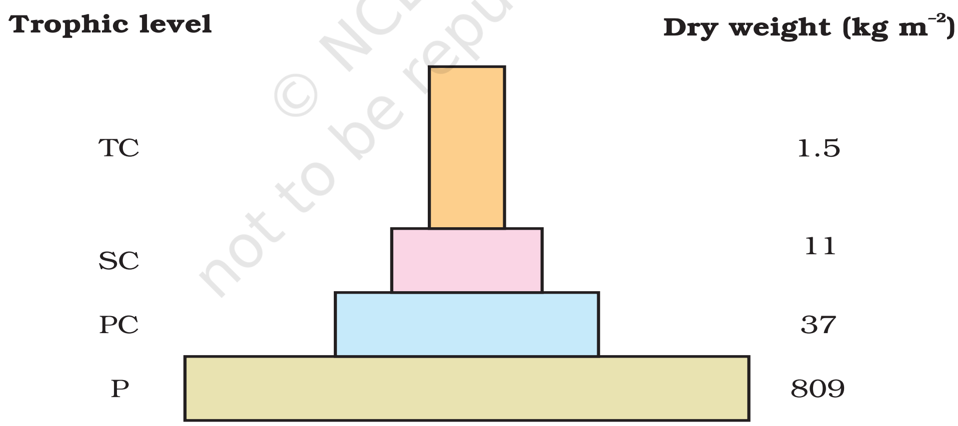

Figure 14.4 (b) Pyramid of biomass shows a sharp decrease in biomass at higher trophic levels

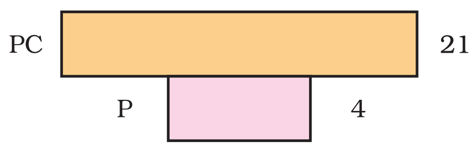

Figure 14.4 (c) Inverted pyramid of biomass-small standing crop of phytoplankton supports large standing crop of zooplankton

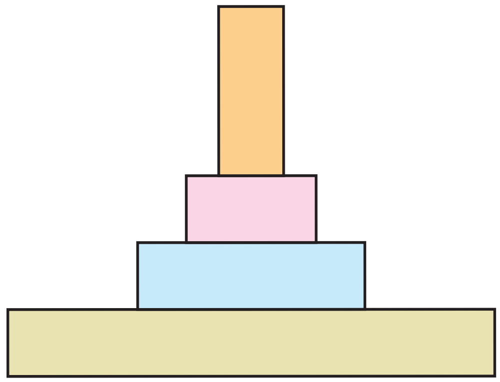

Figure 14.4 (d) An ideal pyramid of energy. Observe that primary producers convert only 1% of the energy in the sunlight available to them into NPP

Any calculations of energy content, biomass or numbers, has to include all organisms at that trophic level. No generalisations we make will be true if we take only a few individuals at any trophic level into account. Also a given organism may occupy more than one trophic level simultaneously. One must remember that the trophic level represents a functional level, not a species as such. A given species may occupy more than one trophic level in the same ecosystem at the same time; for example, a sparrow is a primary consumer when it eats seeds, fruits, peas, and a secondary consumer when it eats insects and worms. *Can you work out how many trophic levels human beings function at in a food chain?*

In most ecosystems, all the pyramids, of number, of energy and biomass are upright, i.e., producers are more in number and biomass than the herbivores, and herbivores are more in number and biomass than the carnivores. Also energy at a lower trophic level is always more than at a higher level.

There are exceptions to this generalisation: If you were to count the number of insects feeding on a big tree what kind of pyramid would you get? Now add an estimate of the number of small birds depending on the insects, as also the number of larger birds eating the smaller. Draw the shape you would get.

The pyramid of biomass in sea is generally inverted because the biomass of fishes far exceeds that of phytoplankton. *Isn't that a paradox? How would you explain this?*

Pyramid of energy is always upright, can never be inverted, because when energy flows from a particular trophic level to the next trophic level, some energy is always lost as heat at each step. Each bar in the energy pyramid indicates the amount of energy present at each trophic level in a given time or annually per unit area.

However, there are certain limitations of ecological pyramids such as it does not take into account the same species belonging to two or more trophic levels. It assumes a simple food chain, something that almost never exists in nature; it does not accommodate a food web. Moreover, saprophytes are not given any place in ecological pyramids even though they play a vital role in the ecosystem.

14.6 Ecological Succession

You have learnt in Chapter 13, the characteristics of population and community and also their response to environment and how such responses vary from an individual response. Let us examine another aspect of community response to environment over time.

An important characteristic of all communities is that their composition and structure constantly change in response to the changing environmental conditions. This change is orderly and sequential, parallel with the changes in the physical environment. These changes lead finally to a community that is in near equilibrium with the environment and that is called a **climax community**. The gradual and fairly predictable change in the species composition of a given area is called **ecological succession**. During succession some species colonise an area and their population become more numerous whereas populations of other species decline and even disappear.

The entire sequence of communities that successively change in a given area are called **sere(s)**. The individual transitional communities are termed seral stages or seral communities. In the successive seral stages there is a change in the diversity of species of organisms, increase in the number of species and organisms as well as an increase in the total biomass.

The present day communities in the world have come to be because of succession that has occurred over millions of years since life started on earth. Actually succession and evolution would have been parallel processes at that time.

Succession is hence a process that starts in an area where no living organisms are there – these could be areas where no living organisms ever existed, say bare rock; or in areas that somehow, lost all the living organisms that existed there. The former is called primary succession, while the latter is termed secondary succession.

Examples of areas where primary succession occurs are newly cooled lava, bare rock, newly created pond or reservoir. The establishment of a new biotic community is generally slow. Before a biotic community of diverse organisms can become established, there must be soil. Depending mostly on the climate, it takes natural processes several hundred to several thousand years to produce fertile soil on bare rock.

Secondary succession begins in areas where natural biotic communities have been destroyed such as in abandoned farm lands, burned or cut forests, lands that have been flooded. Since some soil or sediment is present, succession is faster than primary succession.

Description of ecological succession usually focuses on changes in vegetation. However, these vegetational changes in turn affect food and shelter for various types of animals. Thus, as succession proceeds, the numbers and types of animals and decomposers also change.

At any time during primary or secondary succession, natural or human induced disturbances (fire, deforestation, etc.), can convert a particular seral stage of succession to an earlier stage. Also such disturbances create new conditions that encourage some species and discourage or eliminate other species.

14.6.1 Succession of Plants

Based on the nature of the habitat – whether it is water (or very wet areas) or it is on very dry areas – succession of plants is called hydrarch or xerarch, respectively. **Hydrarch succession** takes place in wet areas and the successional series progress from hydric to the mesic conditions. As against this, **xerarch succession** takes place in dry areas and the series progress from xeric to mesic conditions. Hence, both hydrarch and xerarch successions lead to medium water conditions (mesic) – neither too dry (xeric) nor too wet (hydric).

The species that invade a bare area are called **pioneer species**. In primary succession on rocks these are usually lichens which are able to secrete acids to dissolve rock, helping in weathering and soil formation. These later pave way to some very small plants like bryophytes, which are able to take hold in the small amount of soil. They are, with time, succeeded by higher plants, and after several more stages, ultimately a stable climax forest community is formed. The climax community remains stable as long as the environment remains unchanged. With time the xerophytic habitat gets converted into a mesophytic one.

In primary succession in water, the pioneers are the small phytoplanktons, which are replaced with time by rooted-submerged plants, rooted-floating angiosperms followed by free-floating plants, then reed-swamp, marsh-meadow, scrub and finally the trees. The climax again would be a forest. With time the water body is converted into land (Figure 14.5).

In secondary succession the species that invade depend on the condition of the soil, availability of water, the environment as also the seeds or other propagules present. Since soil is already there, the rate of succession is much faster and hence, climax is also reached more quickly.

What is important to understand is that succession, particularly primary succession, is a very slow process, taking maybe thousands of

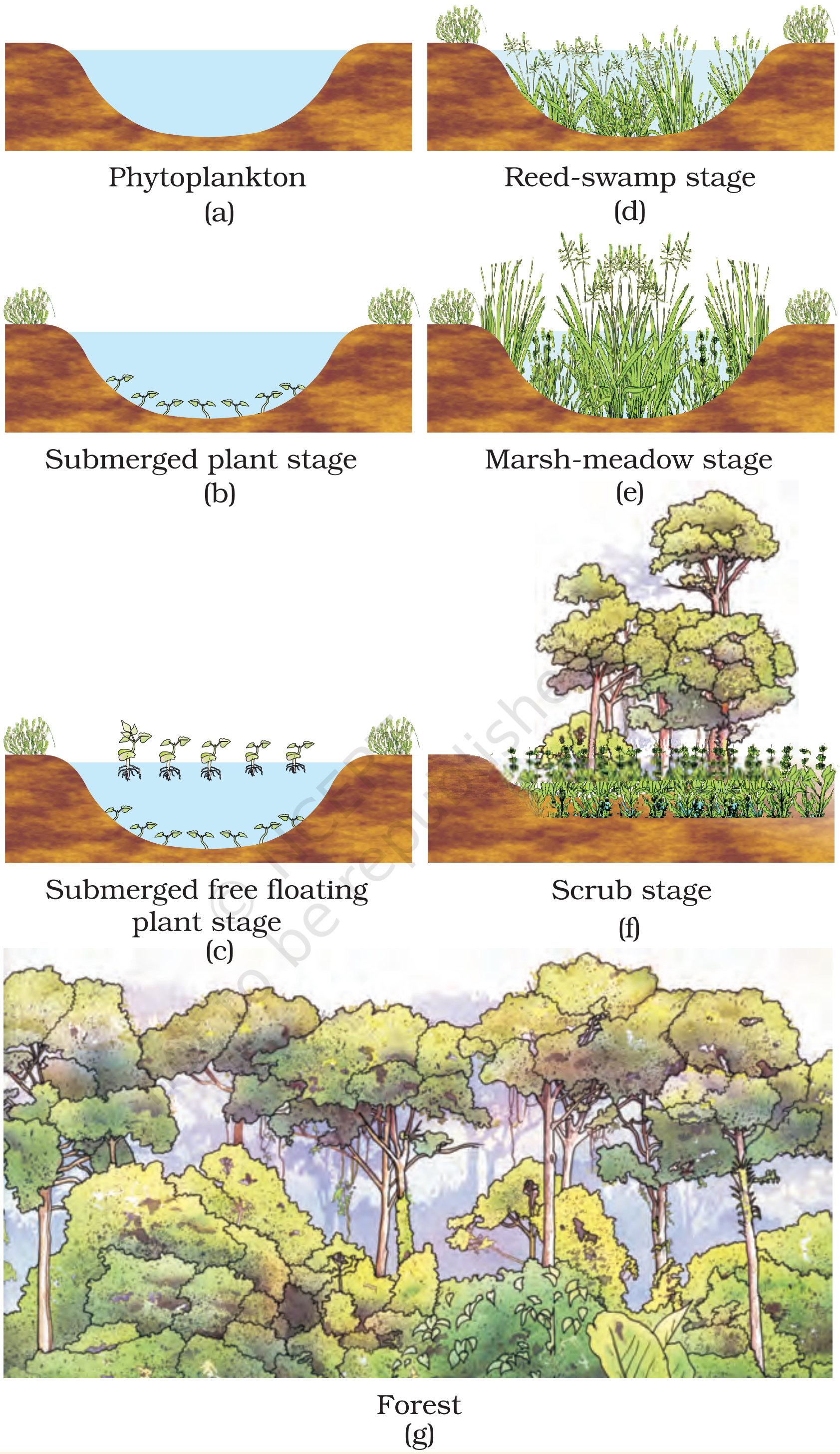

Figure 14.5 Diagrammatic representation of primary succession

years for the climax to be reached. Another important fact is to understand that all succession whether taking place in water or on land, proceeds to a similar climax community – the mesic.

14.7 Nutrient Cycling

You have studied in Class XI that organisms need a constant supply of nutrients to grow, reproduce and regulate various body functions. The amount of nutrients, such as carbon, nitrogen, phosphorus, calcium, etc., present in the soil at any given time, is referred to as the **standing state**. It varies in different kinds of ecosystems and also on a seasonal basis.

What is important is to appreciate that nutrients which are never lost from the ecosystems, rather they are recycled time and again indefinitely. The movement of nutrient elements through the various components of an ecosystem is called **nutrient cycling**. Another name of nutrient cycling is **biogeochemical** cycles (bio: living organism, geo: rocks, air, water). Nutrient cycles are of two types: (a) **gaseous** and (b) **sedimentary.** The

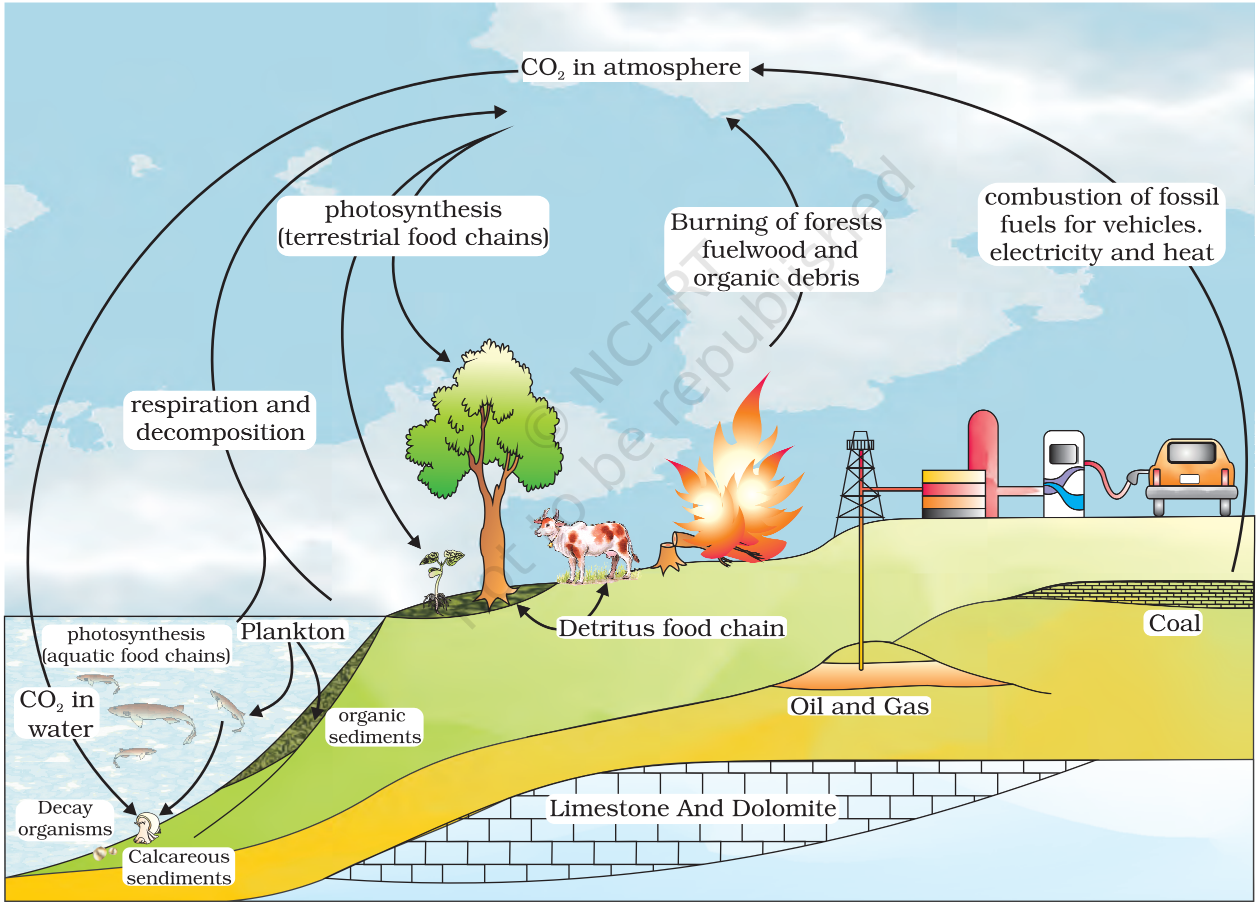

Figure 14.6 Simplified model of carbon cycle in the biosphere

reservoir for gaseous type of nutrient cycle (e.g., nitrogen, carbon cycle) exists in the atmosphere and for the sedimentary cycle (e.g., sulphur and phosphorus cycle), the reservoir is located in Earth's crust. Environmental factors, e.g., soil, moisture, pH, temperature, etc., regulate the rate of release of nutrients into the atmosphere. The function of the reservoir is to meet with the deficit which occurs due to imbalance in the rate of influx and efflux.

You have made a detailed study of nitrogen cycle in class XI. Here we discuss carbon and phosphorus cycles.

14.7.1 Ecosystem – Carbon Cycle

When you study the composition of living organisms, carbon constitutes 49 per cent of dry weight of organisms and is next only to water. If we look at the total quantity of global carbon, we find that 71 per cent carbon is found dissolved in oceans. This oceanic reservoir regulates the amount of carbon dioxide in the atmosphere (Figure 14.6). *Do you know that the atmosphere only contains about 1per cent of total global carbon?*

Fossil fuel also represent a reservoir of carbon. Carbon cycling occurs through atmosphere, ocean and through living and dead organisms. According to one estimate 4×10^{13} kg of carbon is fixed annually in the biosphere through photosynthesis. A considerable amount of carbon returns to the atmosphere as CO_2 through respiratory activities of the producers and consumers. Decomposers also contribute substantially to CO_2 pool by their processing of waste materials and dead organic matter of land or oceans. Some amount of the fixed carbon is lost to sediments and removed from circulation. Burning of wood, forest fire and combustion of organic matter, fossil fuel, volcanic activity are additional sources for releasing CO_2 in the atmosphere.

Human activities have significantly influenced the carbon cycle. Rapid deforestation and massive burning of fossil fuel for energy and transport have significantly increased the rate of release of carbon dioxide into the atmosphere (see greenhouse effect in Chapter 16).

14.7.2 Ecosystem – Phosphorus Cycle

Phosphorus is a major constituent of biological membranes, nucleic acids and cellular energy transfer systems. Many animals also need large quantities of this element to make shells, bones and teeth. The natural reservoir of phosphorus is rock, which contains phosphorus in the form of phosphates. When rocks are weathered, minute amounts of these phosphates dissolve in soil solution and are absorbed by the roots of the plants (Figure 14.7). Herbivores and other animals obtain this element from plants. The waste products and the dead organisms are decomposed by phosphate-solubilising bacteria releasing phosphorus. Unlike carbon cycle, there is no respiratory release of phosphorus into atmosphere. *Can you differentiate between the carbon and the phosphorus cycle?*

The other two major and important differences between carbon and phosphorus cycle are firstly, atmospheric inputs of phosphorus through rainfall are much smaller than carbon inputs, and, secondly, gaseous

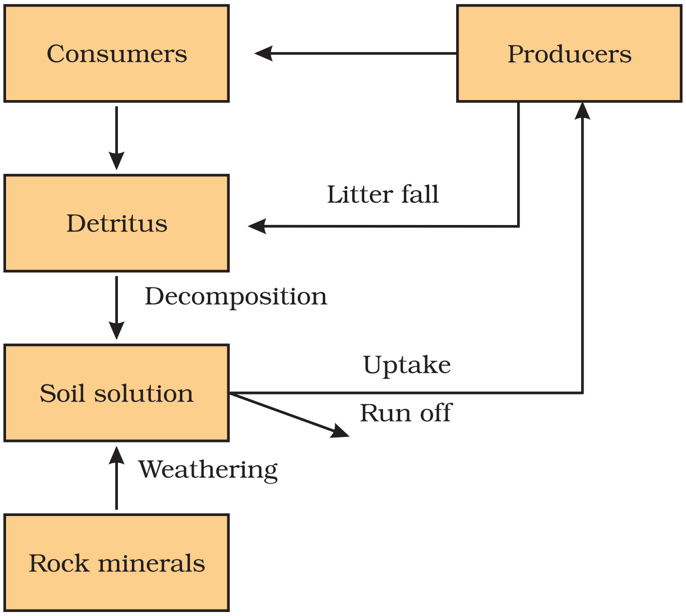

Figure 14.7 A simplified model of phosphorus cycling in a terrestrial ecosystem

exchanges of phosphorus between organism and environment are negligible.

14.8 Ecosystem Services

Healthy ecosystems are the base for a wide range of economic, environmental and aesthetic goods and services. The products of ecosystem processes are named as **ecosystem services**, for example, healthy forest ecosystems purify air and water, mitigate droughts and floods, cycle nutrients, generate fertile soils, provide wildlife habitat, maintain biodiversity, pollinate crops, provide storage site for carbon and also provide aesthetic, cultural and spiritual values. Though value of such services of biodiversity is difficult to determine, it seems reasonable to think that biodiversity should carry a hefty price tag.

Robert Constanza and his colleagues have very recently tried to put price tags on nature's life-support services. Researchers have put an average price tag of US $ 33 trillion a year on these fundamental ecosystems services, which are largely taken for granted because they are free. This is nearly twice the value of the global gross national product GNP which is (US $ 18 trillion).

Out of the total cost of various ecosystem services, the soil formation accounts for about 50 per cent, and contributions of other services like recreation and nutrient cycling, are less than 10 per cent each. The cost of climate regulation and habitat for wildlife are about 6 per cent each.

SUMMARY

An ecosystem is a structural and functional unit of nature and it comprises abiotic and biotic components. Abiotic components are inorganic materials- air, water and soil, whereas biotic components are producers, consumers and decomposers. Each ecosystem has characteristic physical structure resulting from interaction amongst abiotic and biotic components. Species composition and stratification are the two main structural features of an ecosystem. Based on source of nutrition every organism occupies a place in an ecosystem.

Productivity, decomposition, energy flow, and nutrient cycling are the four important components of an ecosystem. Primary productivity is the rate of capture of solar energy or biomass production of the producers. It is divided into two types: gross primary productivity (GPP) and net primary productivity (NPP). Rate of capture of solar energy or total production of organic matter is called as GPP. NPP is the remaining biomass or the energy left after utilisation of producers. Secondary productivity is the rate of assimilation of food energy by the consumers. In decomposition, complex organic compounds of detritus are converted to carbon dioxide, water and inorganic nutrients by the decomposers. Decomposition involves three processes, namely fragmentation of detritus, leaching and catabolism.

Energy flow is unidirectional. First, plants capture solar energy and then, food is transferred from the producers to decomposers. Organisms of different trophic levels in nature are connected to each other for food or energy relationship forming a food chain. The storage and movement of nutrient elements through the various components of the ecosystem is called nutrient cycling; nutrients are repeatedly used through this process. Nutrient cycling is of two types—gaseous and sedimentary. Atmosphere or hydrosphere is the reservoir for the gaseous type of cycle (carbon), whereas Earth's crust is the reservoir for sedimentary type (phosphorus). Products of ecosystem processes are named as ecosystem services, e.g., purification of air and water by forests.

The biotic community is dynamic and undergoes changes with the passage of time. These changes are sequentially ordered and constitute ecological succession. Succession begins with invasion of a bare lifeless area by pioneers which later pave way for successors and ultimately a stable climax community is formed. The climax community remains stable as long as the environment remains unchanged.

EXERCISES

1. Fill in the blanks.
   (a) Plants are called as________because they fix carbon dioxide.
   (b) In an ecosystem dominated by trees, the pyramid (of numbers) is________type.
   (c) In aquatic ecosystems, the limiting factor for the productivity is________.

(d) Common detritivores in our ecosystem are________.

(e) The major reservoir of carbon on earth is________.

2. Which one of the following has the largest population in a food chain?
   (a) Producers
   (b) Primary consumers
   (c) Secondary consumers
   (d) Decomposers
3. The second trophic level in a lake is
   (a) Phytoplankton
   (b) Zooplankton
   (c) Benthos
   (d) Fishes
4. Secondary producers are
   (a) Herbivores
   (b) Producers
   (c) Carnivores
   (d) None of the above
5. What is the percentage of photosynthetically active radiation (PAR) in the incident solar radiation?
   (a) 100%
   (b) 50 %
   (c) 1-5%
   (d) 2-10%
6. Distinguish between
   (a) Grazing food chain and detritus food chain
   (b) Production and decomposition
   (c) Upright and inverted pyramid
   (d) Food chain and Food web
   (e) Litter and detritus
   (f) Primary and secondary productivity
7. Describe the components of an ecosystem.
8. Define ecological pyramids and describe with examples, pyramids of number and biomass.
9. What is primary productivity? Give brief description of factors that affect primary productivity.
10. Define decomposition and describe the processes and products of decomposition.
11. Give an account of energy flow in an ecosystem.
12. Write important features of a sedimentary cycle in an ecosystem.
13. Outline salient features of carbon cycling in an ecosystem.

CHAPTER 15

BIODIVERSITY AND CONSERVATION

If an alien from a distant galaxy were to visit our planet Earth, the first thing that would amaze and baffle him would most probably be the enormous diversity of life that he would encounter. Even for humans, the rich variety of living organisms with which they share this planet never ceases to astonish and fascinate us. The common man would find it hard to believe that there are more than 20,000 species of ants, 3,00,000 species of beetles, 28,000 species of fishes and nearly 20,000 species of orchids. Ecologists and evolutionary biologists have been trying to understand the significance of such diversity by asking important questions– *Why are there so many species? Did such great diversity exist throughout earth's history? How did this diversification come about? How and why is this diversity important to the biosphere? Would it function any differently if the diversity was much less? How do humans benefit from the diversity of life?*

15.1 Biodiversity

In our biosphere immense diversity (or heterogeneity) exists not only at the species level but at all levels of biological organisation ranging from macromolecules within cells to biomes. Biodiversity is the term popularised by the sociobiologist Edward Wilson to describe the

combined diversity at all the levels of biological organisation.
The most important of them are–

(i) ***Genetic diversity**:* A single species might show high diversity at the genetic level over its distributional range. The genetic variation shown by the medicinal plant *Rauwolfia vomitoria* growing in different Himalayan ranges might be in terms of the potency and concentration of the active chemical (reserpine) that the plant produces. India has more than 50,000 genetically different strains of rice, and 1,000 varieties of mango.

(ii) ***Species diversity**:* The diversity at the species level, for example, the Western Ghats have a greater amphibian species diversity than the Eastern Ghats.

(iii) ***Ecological diversity**:* At the ecosystem level, India, for instance, with its deserts, rain forests, mangroves, coral reefs, wetlands, estuaries, and alpine meadows has a greater ecosystem diversity than a Scandinavian country like Norway.

It has taken millions of years of evolution, to accumulate this rich diversity in nature, but we could lose all that wealth in less than two centuries if the present rates of species losses continue. Biodiversity and its conservation are now vital environmental issues of international concern as more and more people around the world begin to realise the critical importance of biodiversity for our survival and well- being on this planet.

15.1.1 How Many Species are there on Earth and How Many in India?

Since there are published records of all the species discovered and named, we know how many species in all have been recorded so far, but it is not easy to answer the question of how many species there are on earth. According to the International Union for Conservation of Nature and Natural Resources (IUCN) (2004), the total number of plant and animal species described so far is slightly more than 1.5 million, but we have no clear idea of how many species are yet to be discovered and described. Estimates vary widely and many of them are only educated guesses. For many taxonomic groups, species inventories are more complete in temperate than in tropical countries. Considering that an overwhelmingly large proportion of the species waiting to be discovered are in the tropics, biologists make a statistical comparison of the temperate-tropical species richness of an exhaustively studied group of insects and extrapolate this ratio to other groups of animals and plants to come up with a gross estimate of the total number of species on earth. Some extreme estimates range from 20 to 50 million, but a more conservative and scientifically sound estimate made by Robert May places the global species diversity at about 7 million.

Let us look at some interesting aspects about earth's biodiversity based on the currently available species inventories. More than 70 per cent of all the species recorded are animals, while plants (including algae, fungi, bryophytes, gymnosperms and angiosperms) comprise no more than 22 per cent of the total. Among animals, insects are the most species-rich taxonomic group, making up more than 70 per cent of the total. That means, out of every 10 animals on this planet, 7 are insects. Again, how do we explain this enormous diversification of insects? The number of fungi species in the world is more than the combined total of the species of fishes, amphibians, reptiles and mammals. In Figure 15.1, biodiversity is depicted showing species number of major taxa.

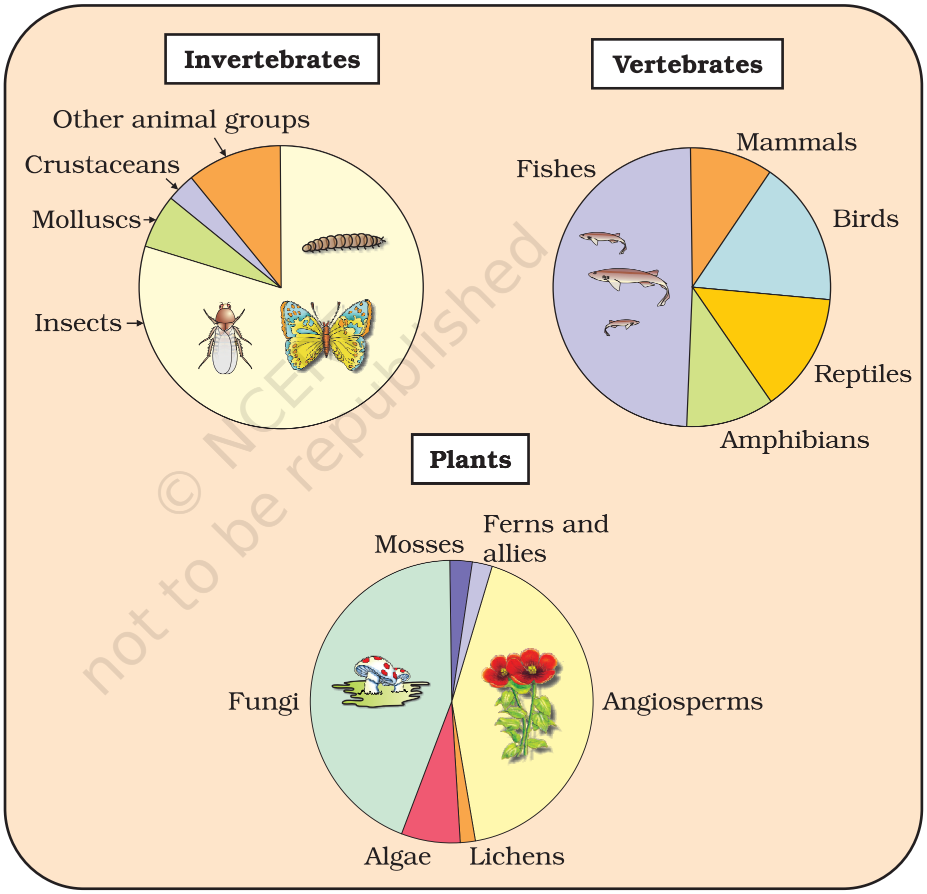

Figure 15.1 Representing global biodiversity: proportionate number of species of major taxa of plants, invertebrates and vertebrates

It should be noted that these estimates do not give any figures for prokaryotes. Biologists are not sure about how many prokaryotic species there might be. The problem is that conventional taxonomic methods are not suitable for identifying microbial species and many species are simply not culturable under laboratory conditions. If we accept biochemical or molecular criteria for delineating species for this group, then their diversity alone might run into millions.

Although India has only 2.4 per cent of the world's land area, its share of the global species diversity is an impressive 8.1 per cent. That is what makes our country one of the 12 mega diversity countries of the world. Nearly 45,000 species of plants and twice as many of animals have been recorded from India. How many living species are actually there waiting to be discovered and named? If we accept May's global estimates, only 22 per cent of the total species have been recorded so far. Applying this proportion to India's diversity figures, we estimate that there are probably more than 1,00,000 plant species and more than 3,00,000 animal species yet to be discovered and described. Would we ever be able to complete the inventory of the biological wealth of our country? Consider the immense trained manpower (taxonomists) and the time required to complete the job. The situation appears more hopeless when we realise that a large fraction of these species faces the threat of becoming extinct even before we discover them. Nature's biological library is burning even before we catalogued the titles of all the books stocked there.

15.1.2 Patterns of Biodiversity

(i) ***Latitudinal gradients****:* The diversity of plants and animals is not uniform throughout the world but shows a rather uneven distribution. For many group of animals or plants, there are interesting patterns in diversity, the most well- known being the latitudinal gradient in diversity. In general, species diversity decreases as we move away from the equator towards the poles. With very few exceptions, tropics (latitudinal range of 23.5° N to 23.5° S) harbour more species than temperate or polar areas. Colombia located near the equator has nearly 1,400 species of birds while New York at 41° N has 105 species and Greenland at 71° N only 56 species. India, with much of its land area in the tropical latitudes, has more than 1,200 species of birds. A forest in a tropical region like Equador has up to 10 times as many species of vascular plants as a forest of equal area in a temperate region like the Midwest of the USA. The largely tropical Amazonian rain forest in South America has the greatest biodiversity on earth- it is home to more than 40,000 species of plants, 3,000 of fishes, 1,300 of birds, 427 of mammals, 427 of amphibians, 378 of reptiles and of more than 1,25,000 invertebrates. Scientists estimate that in these rain forests there might be at least two million insect species waiting to be discovered and named.

What is so special about tropics that might account for their greater biological diversity? Ecologists and evolutionary biologists have proposed various hypotheses; some important ones are (a) Speciation is generally a function of time, unlike temperate regions subjected to frequent glaciations in the past, tropical latitudes have remained relatively undisturbed for millions of years and thus, had a long evolutionary time for species diversification, (b) Tropical environments, unlike temperate ones, are less seasonal, relatively more constant and predictable. Such constant environments promote niche specialisation and lead to a greater species diversity and (c) There is more solar energy available in the tropics, which contributes to higher productivity; this in turn might contribute indirectly to greater diversity.

(ii) ***Species-Area relationships*** *:* During his pioneering and extensive explorations in the wilderness of South American jungles, the great German naturalist and geographer Alexander von Humboldt observed that within a region species richness increased with increasing explored area, but only up to a limit. In fact, the relation between species richness and area for a wide variety of taxa (angiosperm plants, birds, bats, freshwater fishes) turns out to be a rectangular hyperbola (Figure15.2). On a logarithmic scale, the relationship is a straight line described by the equation

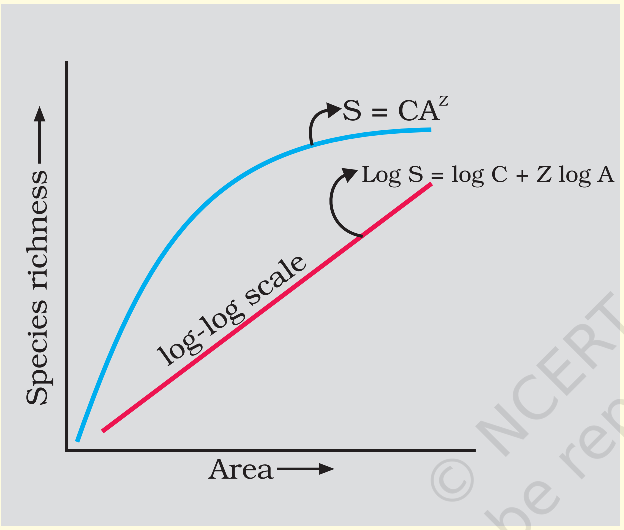

Figure 15.2 Showing species area relationship. Note that on log scale the relationship becomes linear

log S = log C + Z log A

where

S= Species richness A= Area

Z = slope of the line (regression coefficient)

C = Y-intercept

Ecologists have discovered that the value of Z lies in the range of 0.1 to 0.2, regardless of the taxonomic group or the region (whether it is the plants in Britain, birds in California or molluscs in New York state, the slopes of the regression line are amazingly similar). But, if you analyse the species-area relationships among very large areas like the entire continents, you will find that the slope of the line to be much steeper (Z values in the range of 0.6 to 1.2). For example, for frugivorous (fruit-eating) birds and mammals in the tropical forests of different continents, the slope is found to be 1.15. *What do steeper slopes mean in this context?*

15.1.3 The importance of Species Diversity to the Ecosystem

Does the number of species in a community really matter to the functioning of the ecosystem?This is a question for which ecologists have not been able to give a definitive answer. For many decades, ecologists believed that communities with more species, generally, tend to be more stable than those with less species. What exactly is stability for a biological community? A stable community should not show too much variation in productivity from year to year; it must be either resistant or resilient to occasional disturbances (natural or man-made), and it must also be resistant to invasions by alien species. We don't know how these attributes are linked to species richness in a community, but David Tilman's long-term ecosystem experiments using outdoor plots provide some tentative answers. Tilman found that plots with more species showed less year-to-year variation in total biomass. He also showed that in his experiments, increased diversity contributed to higher productivity.

Although, we may not understand completely how species richness contributes to the well-being of an ecosystem, we know enough to realise that rich biodiversity is not only essential for ecosystem health but imperative for the very survival of the human race on this planet. At a time when we are losing species at an alarming pace, one might ask– Does it really matter to us if a few species become extinct? Would Western Ghats ecosystems be less functional if one of its tree frog species is lost forever? How is our quality of life affected if, say, instead of 20,000 we have only 15,000 species of ants on earth?

There are no direct answers to such näive questions but we can develop a proper perspective through an analogy (the 'rivet popper hypothesis') used by Stanford ecologist Paul Ehrlich. In an airplane (ecosystem) all parts are joined together using thousands of rivets (species). If every passenger travelling in it starts popping a rivet to take home (causing a species to become extinct), it may not affect flight safety (proper functioning of the ecosystem) initially, but as more and more rivets are removed, the plane becomes dangerously weak over a period of time. Furthermore, which rivet is removed may also be critical. Loss of rivets on the wings (key species that drive major ecosystem functions) is obviously a more serious threat to flight safety than loss of a few rivets on the seats or windows inside the plane.

15.1.4 Loss of Biodiversity

While it is doubtful if any new species are being added (through speciation) into the earth's treasury of species, there is no doubt about their continuing losses. The biological wealth of our planet has been declining rapidly and the accusing finger is clearly pointing to human activities. The colonisation of tropical Pacific Islands by humans is said to have led to the extinction of more than 2,000 species of native birds. The IUCN Red List (2004) documents the extinction of 784 species (including 338 vertebrates, 359 invertebrates and 87 plants) in the last 500 years. Some examples of recent extinctions include the dodo (Mauritius), quagga (Africa), thylacine (Australia), Steller's Sea Cow (Russia) and three subspecies (Bali, Javan, Caspian) of tiger. The last twenty years alone have witnessed the disappearance of 27 species. Careful analysis of records shows that extinctions across taxa are not random; some groups like amphibians appear to be more vulnerable to extinction. Adding to the grim scenario of extinctions is the fact that more than 15,500 species world-wide are facing the threat of extinction. Presently, 12 per cent of all bird species, 23 per cent of all mammal species, 32 per cent of all amphibian species and 31per cent of all gymnosperm species in the world face the threat of extinction.

From a study of the history of life on earth through fossil records, we learn that large-scale loss of species like the one we are currently witnessing have also happened earlier, even before humans appeared on the scene. During the long period (> 3 billion years) since the origin and diversification of life on earth there were five episodes of mass extinction of species. How is the 'Sixth Extinction' presently in progress different from the previous episodes? The difference is in the rates; the current species extinction rates are estimated to be 100 to 1,000 times faster than in the pre-human times and our activities are responsible for the faster rates. Ecologists warn that if the present trends continue, nearly half of all the species on earth might be wiped out within the next 100 years.

In general, loss of biodiversity in a region may lead to (a) decline in plant production, (b) lowered resistance to environmental perturbations such as drought and (c) increased variability in certain ecosystem processes such as plant productivity, water use, and pest and disease cycles.

Causes of biodiversity losses: The accelerated rates of species extinctions that the world is facing now are largely due to human activities. There are four major causes (' The Evil Quartet ' is the sobriquet used to describe them).

(i) ***Habitat loss and fragmentation:*** This is the most important cause driving animals and plants to extinction. The most dramatic examples of habitat loss come from tropical rain forests. Once covering more than 14 per cent of the earth's land surface, these rain forests now cover no more than 6 per cent. They are being destroyed fast. By the time you finish reading this chapter, 1000 more hectares of rain forest would have been lost. The Amazon rain forest (it is so huge that it is called the 'lungs of the planet') harbouring probably millions of species is being cut and cleared for cultivating *soya beans* or for conversion to grasslands for raising beef cattle. Besides total loss, the degradation of many habitats by pollution also threatens the survival of many species. When large habitats are broken up into small fragments due to various human activities, mammals and birds requiring large territories and certain animals with migratory habits are badly affected, leading to population declines.

(ii) ***Over-exploitation:*** Humans have always depended on nature for food and shelter, but when 'need' turns to 'greed', it leads to over-exploitation of natural resources. Many species extinctions in the last 500 years (Steller's sea cow, passenger pigeon) were due to overexploitation by humans. Presently many marine fish populations around the world are over harvested, endangering the continued existence of some commercially important species.

(iii) ***Alien species invasions:*** When alien species are introduced unintentionally or deliberately for whatever purpose, some of them turn invasive, and cause decline or extinction of indigenous species. The Nile perch introduced into Lake Victoria in east Africa led eventually to the extinction of an ecologically unique assemblage of more than 200 species of cichlid fish in the lake. You must be familiar with the environmental damage caused and threat posed to our native species by invasive weed species like carrot grass (*Parthenium*), *Lantana* and water hyacinth (*Eicchornia*). The recent illegal introduction of the African catfish *Clarias gariepinus* for aquaculture purposes is posing a threat to the indigenous catfishes in our rivers.

(iv) ***Co-extinctions:*** When a species becomes extinct, the plant and animal species associated with it in an obligatory way also become extinct. When a host fish species becomes extinct, its unique assemblage of parasites also meets the same fate. Another example is the case of a coevolved plant-pollinator mutualism where extinction of one invariably leads to the extinction of the other.

15.2 Biodiversity Conservation

15.2.1 Why Should We Conserve Biodiversity?

There are many reasons, some obvious and others not so obvious, but all equally important. They can be grouped into three categories: narrowly utilitarian, broadly utilitarian, and ethical.

The **narrowly utilitarian** arguments for conserving biodiversity are obvious; humans derive countless direct economic benefits from nature-food (cereals, pulses, fruits), firewood, fibre, construction material, industrial products (tannins, lubricants, dyes, resins, perfumes) and products of medicinal importance. More than 25 per cent of the drugs currently sold in the market worldwide are derived from plants and 25,000 species of plants contribute to the traditional medicines used by native peoples around the world. Nobody knows how many more medicinally useful plants there are in tropical rain forests waiting to be explored. With increasing resources put into 'bioprospecting' (exploring molecular, genetic and species-level diversity for products of economic importance), nations endowed with rich biodiversity can expect to reap enormous benefits.

The **broadly utilitarian** argument says that biodiversity plays a major role in many ecosystem services that nature provides. The fastdwindling Amazon forest is estimated to produce, through photosynthesis, 20 per cent of the total oxygen in the earth's atmosphere. Can we put an economic value on this service by nature? You can get some idea by finding out how much your neighborhood hospital spends on a cylinder of oxygen. Pollination (without which plants cannot give us fruits or seeds) is another service, ecosystems provide through pollinators layer – bees, bumblebees, birds and bats. *What will be the costs of accomplishing pollination without help from natural pollinators?* There are other intangible benefits – that we derive from nature–the aesthetic pleasures of walking through thick woods, watching spring flowers in full bloom or waking up to a bulbul's song in the morning. Can we put a price tag on such things?

The **ethical** argument for conserving biodiversity relates to what we owe to millions of plant, animal and microbe species with whom we share this planet. Philosophically or spiritually, we need to realise that every species has an intrinsic value, even if it may not be of current or any economic value to us. We have a moral duty to care for their well-being and pass on our biological legacy in good order to future generations.

15.2.2 How do we conserve Biodiversity?

When we conserve and protect the whole ecosystem, its biodiversity at all levels is protected - we save the entire forest to save the tiger. This approach is called *in situ* (on site) conservation. However, when there are situations where an animal or plant is endangered or threatened (organisms facing a very high risk of extinction in the wild in the near future) and needs urgent measures to save it from extinction, *ex situ* (off site) conservation is the desirable approach.

***In situ* conservation–** Faced with the conflict between development and conservation, many nations find it unrealistic and economically not feasible to conserve all their biological wealth. Invariably, the number of species waiting to be saved from extinction far exceeds the conservation resources available. On a global basis, this problem has been addressed by eminent conservationists. They identified for maximum protection certain 'biodiversity hotspots' regions with very high levels of species richness and high degree of **endemism** (that is, species confined to that region and not found anywhere else). Initially 25 biodiversity hotspots were identified but subsequently nine more have been added to the list, bringing the total number of biodiversity hotspots in the world to 34. These hotspots are also regions of accelerated habitat loss. Three of these hotspots – Western Ghats and Sri Lanka, Indo-Burma and Himalaya – cover our country's exceptionally high biodiversity regions. Although all the biodiversity hotspots put together cover less than 2 per cent of the earth's land area, the number of species they collectively harbour is extremely high and strict protection of these hotspots could reduce the ongoing mass extinctions by almost 30 per cent.

In India, ecologically unique and biodiversity-rich regions are legally protected as biosphere reserves, national parks and sanctuaries. India now has 14 biosphere reserves, 90 national parks and 448 wildlife sanctuaries. India has also a history of religious and cultural traditions that emphasised protection of nature. In many cultures, tracts of forest were set aside, and all the trees and wildlife within were venerated and given total protection. Such **sacred groves** are found in Khasi and Jaintia Hills in Meghalaya, Aravalli Hills of Rajasthan, Western Ghat regions of Karnataka and Maharashtra and the Sarguja, Chanda and Bastar areas of Madhya Pradesh. In Meghalaya, the sacred groves are the last refuges for a large number of rare and threatened plants.

***Ex situ* Conservation–** In this approach, threatened animals and plants are taken out from their natural habitat and placed in special setting where they can be protected and given special care. Zoological parks, botanical gardens and wildlife safari parks serve this purpose. There are many animals that have become extinct in the wild but continue to be maintained in zoological parks. In recent years *ex situ* conservation has advanced beyond keeping threatened species in enclosures. Now gametes of threatened species can be preserved in viable and fertile condition for long periods using cryopreservation techniques, eggs can be fertilised *in vitro*, and plants can be propagated using tissue culture methods. Seeds of different genetic strains of commercially important plants can be kept for long periods in seed banks.

Biodiversity knows no political boundaries and its conservation is therefore a collective responsibility of all nations. The historic Convention on Biological Diversity ('The Earth Summit') held in Rio de Janeiro in 1992, called upon all nations to take appropriate measures for conservation of biodiversity and sustainable utilisation of its benefits. In a follow-up, the World Summit on Sustainable Development held in 2002 in Johannesburg, South Africa, 190 countries pledged their commitment to achieve by 2010, a significant reduction in the current rate of biodiversity loss at global, regional and local levels.

SUMMARY

Since life originated on earth nearly 3.8 billion years ago, there had been enormous diversification of life forms on earth. Biodiversity refers to the sum total of diversity that exists at all levels of biological organisation. Of particular importance is the diversity at genetic, species and ecosystem levels and conservation efforts are aimed at protecting diversity at all these levels.

More than 1.5 million species have been recorded in the world, but there might still be nearly 6 million species on earth waiting to be discovered and named. Of the named species, > 70 per cent are animals, of which 70 per cent are insects. The group Fungi has more species than all the vertebrate species combined. India, with about 45,000 species of plants and twice as many species of animals, is one of the 12 mega diversity countries of the world.

Species diversity on earth is not uniformly distributed but shows interesting patterns. It is generally highest in the tropics and decreases towards the poles. Important explanations for the species richness of the tropics are: Tropics had more evolutionary time; they provide a relatively constant environment and, they receive more solar energy which contributes to greater productivity. Species richness is also function of the area of a region; the species-area relationship is generally a rectangular hyperbolic function.

It is believed that communities with high diversity tend to be less variable, more productive and more resistant to biological invasions. Earth's fossil history reveals incidence of mass extinctions in the past, but the present rates of extinction, largely attributed to human activities, are 100 to 1000 times higher. Nearly 700 species have become extinct in recent times and more than 15,500 species (of which > 650 are from India) currently face the threat of extinction. The causes of high extinction rates at present include habitat (particularly forests) loss and fragmentation, over-exploitation, biological invasions and co-extinctions.

Earth's rich biodiversity is vital for the very survival of mankind. The reasons for conserving biodiversity are narrowly utilitarian, broadly utilitarian and ethical. Besides the direct benefits (food, fibre, firewood, pharmaceuticals, etc.), there are many indirect benefits we receive through ecosystem services such as pollination, pest control, climate moderation and flood control. We also have a moral responsibility to take good care of earth's biodiversity and pass it on in good order to our next generation.

Biodiversity conservation may be *in situ* as well as *ex situ.* In *in situ* conservation, the endangered species are protected in their natural habitat so that the entire ecosystem is protected. Recently, 34 'biodiversity hotspots' in the world have been proposed for intensive conservation efforts. Of these, three (Western Ghats-Sri Lanka, Himalaya and Indo-Burma) cover India's rich biodiversity regions. Our country's *in situ* conservation efforts are reflected in its 14 biosphere reserves, 90 national parks, > 450 wildlife sanctuaries and many sacred groves. *Ex situ* conservation methods include protective maintenance of threatened species in zoological parks and botanical gardens, *in vitro* fertilisation, tissue culture propagation and cryopreservation of gametes.

EXERCISES

1. Name the three important components of biodiversity.
2. How do ecologists estimate the total number of species present in the world?

3. Give three hypotheses for explaining why tropics show greatest levels of species richness.
4. What is the significance of the slope of regression in a species – area relationship?
5. What are the major causes of species losses in a geographical region?
6. How is biodiversity important for ecosystem functioning?
7. What are sacred groves? What is their role in conservation?
8. Among the ecosystem services are control of floods and soil erosion. How is this achieved by the biotic components of the ecosystem?
9. The species diversity of plants (22 per cent) is much less than that of animals (72 per cent). What could be the explanations to how animals achieved greater diversification?
10. Can you think of a situation where we deliberately want to make a species extinct? How would you justify it?

CHAPTER 16

12083CH16

ENVIRONMENTAL ISSUES

Human population size has grown enormously over the last hundred years. This means increase in demand for food, water, home, electricity, roads, automobiles and numerous other commodities. These demands are exerting tremendous pressure on our natural resources, and are also contributing to pollution of air, water and soil. The need of the hour is to check the degradation and depletion of our precious natural resources and pollution without halting the process of development.

Pollution is any undesirable change in physical, chemical or biological characteristics of air, land, water or soil. Agents that bring about such an undesirable change are called as **pollutants.** In order to control environmental pollution, the Government of India has passed the **Environment (Protection) Act, 1986** to protect and improve the quality of our environment (air, water and soil).

16.1 Air Pollution and its Control

We are dependent on air for our respiratory needs. Air pollutants cause injury to all living organisms. They reduce growth and yield of crops and cause premature death of plants. Air pollutants also deleteriously affect the respiratory system of humans and of animals. Harmful effects depend on the concentration of pollutants, duration of exposure and the organism.

Smokestacks of thermal power plants, smelters and other industries release particulate and gaseous air pollutants together with harmless gases, such as nitrogen, oxygen, etc. These pollutants must be separated/ filtered out before releasing the harmless gases into the atmosphere.

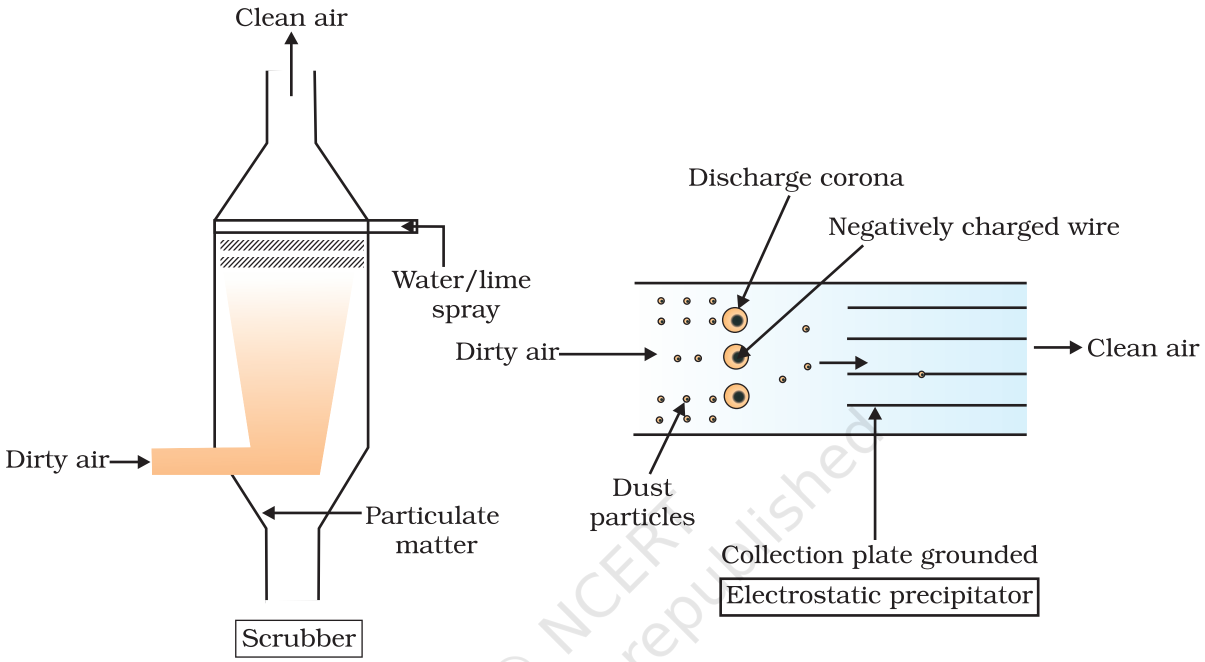

Figure 16.1 Electrostatic precipitator

There are several ways of removing particulate matter; the most widely used of which is the **electrostatic precipitator** (Figure 16.1), which can remove over 99 per cent particulate matter present in the exhaust from a thermal power plant. It has electrode wires that are maintained at several thousand volts, which produce a corona that releases electrons. These electrons attach to dust particles giving them a net negative charge. The collecting plates are grounded and attract the charged dust particles. The velocity of air between the plates must be low enough to allow the dust to fall. A scrubber (Figure 16.1) can remove gases like sulphur dioxide. In a scrubber, the exhaust is passed through a spray of water or lime. Recently we have realised the dangers of particulate matter that are very very small and are not removed by these precipitators. According to Central Pollution Control Board (CPCB), particulate size 2.5 micrometers or less in diameter (PM 2.5) are responsible for causing the greatest harm to human health. These fine particulates can be inhaled deep into the lungs and can cause breathing and respiratory symptoms, irritation, inflammations and damage to the lungs and premature deaths.

Automobiles are a major cause for atmospheric pollution atleast in the metro cities. As the number of vehicles increase on the streets, this problem is now shifting to the other cities too. Proper maintenance of automobiles along with use of lead-free petrol or diesel can reduce the pollutants they emit. Catalytic converters, having expensive metals namely platinum-palladium and rhodium as the catalysts, are fitted into automobiles for reducing emission of poisonous gases. As the exhaust passes through the catalytic converter, unburnt hydrocarbons are converted into carbon dioxide and water, and carbon monoxide and nitric oxide are changed to carbon dioxide and nitrogen gas, respectively. Motor vehicles equipped with catalytic converter should use unleaded petrol because lead in the petrol inactivates the catalyst.

In India, the **Air (Prevention and Control of Pollution) Act** came into force in 1981, but was amended in 1987 to include noise as an air pollutant. **Noise** is undesired high level of sound. We have got used to associating loud sounds with pleasure and entertainment not realising that noise causes psychological and physiological disorders in humans. The bigger the city, the bigger the function, the greater the noise!! A brief exposure to extremely high sound level, 150 dB or more generated by take off of a jet plane or rocket, may damage ear drums thus permanently impairing hearing ability. Even chronic exposure to a relatively lower noise level of cities may permanently damage hearing abilities of humans. Noise also causes sleeplessness, increased heart beat, altered breathing pattern, thus considerably stressing humans.

Considering the many dangerous effects of noise pollution can you identify the unnecessary sources of noise pollution around you which can be reduced immediately without any financial loss to anybody? Reduction of noise in our industries can be affected by use of sound-absorbent materials or by muffling noise. Stringent following of laws laid down in relation to noise like delimitation of horn-free zones around hospitals and schools, permissible sound-levels of crackers and of loud-speakers, timings after which loudspeakers cannot be played, etc., need to be enforced to protect ourselves from noise pollution.

16.1.1 Controlling Vehicular Air Pollution: A Case Study of Delhi

With its very large population of vehicular traffic, Delhi leads the country in its levels of air-pollution – it has more cars than the states of Gujarat and West Bengal put together. In the 1990s, Delhi ranked fourth among the 41 most polluted cities of the world. Air pollution problems in Delhi became so serious that a public interest litigation (PIL) was filed in the Supreme Court of India. After being censured very strongly by the Supreme Court, under its directives, the government was asked to take, within a specified time period, appropriate measures, including switching over the entire fleet of public transport, i.e., buses, from diesel to **compressed natural gas** (**CNG**). All the buses of Delhi were converted to run on CNG by the end of 2002. You may ask the question as to why CNG is better than diesel. The answer is that

CNG burns most efficiently, unlike petrol or diesel, in the automobiles and very little of it is left unburnt. Moreover, CNG is cheaper than petrol or diesel, cannot be siphoned off by thieves and adulterated like petrol or diesel. The main problem with switching over to CNG is the difficulty of laying down pipelines to deliver CNG through distribution points/ pumps and ensuring uninterrupted supply. Simultaneously parallel steps taken in Delhi for reducing vehicular pollution include phasing out of old vehicles, use of unleaded petrol, use of low-sulphur petrol and diesel, use of catalytic converters in vehicles, application of stringent pollution-level norms for vehicles, etc.

The Government of India through a new auto fuel policy has laid out a roadmap to cut down vehicular pollution in Indian cities. More stringent norms for fuels means steadily reducing the sulphur and aromatic content in petrol and diesel fuels. Euro III norms, for example, stipulate that sulphur be controlled at 350 parts-per-million (ppm) in diesel and 150 ppm in petrol. Aromatic hydrocarbons are to be contained at 42 per cent of the concerned fuel. The goal, according to the roadmap, is to reduce sulphur to 50 ppm in petrol and diesel and bring down the level to 35 per cent. Corresponding to the fuel, vehicle engines will also need to be upgraded.

Mass Emission Standards (Bharat Stage II which is equivalent to Euro-II norms) are no more applicable in any of the cities of India. Details of the latest Mass Emission Standards in India are provided below (Table 16.1)

Table 16.1: Table Showing the Mass Emission Standards in India

Type of Vehicles	Norms	Cities of Implementation
4 Wheelers	*Bharat Stage IV*	*Throughout the country since April 2017*
3 Wheelers	*Bharat Stage IV*	*Throughout the country since 1st April 2017*
2 Wheelers	*Bharat Stage IV*	*Throughout the country since April 2017*

Thanks to the efforts made, the air quality of Delhi has significantly improved. According to an estimate, a substantial fall in CO_2 and SO_2 level has been found in Delhi between 1997 and 2005.

16.2 Water Pollution and its Control

Human beings have been abusing the water-bodies around the world by disposing into them all kinds of waste. We tend to believe that water can wash away everything not taking cognizance of the fact that the water bodies are our lifeline as well as that of all other living organisms. *Can you list what all we tend to try and wash away through our rivers and drains?* Due to such activities of human kind, the ponds, lakes, stream, rivers, estuaries and oceans are becoming polluted in several parts of the world. Realising the importance of maintaining the cleanliness of the water bodies, the Government of India has passed the **Water (Prevention and Control of Pollution) Act, 1974** to safeguard our water resources.

16.2.1 Domestic Sewage and Industrial Effluents

As we work with water in our homes in the cities and towns, we wash everything into drains. Have you ever wondered where the sewage that comes out of our houses go? What happens in villages? Is the sewage treated before being transported to the nearest river and mixed with it? A mere 0.1 per cent impurities make domestic sewage unfit for human use (Figure 16.2). You have read about sewage treatment plants in Chapter 10. Solids are relatively easy to remove, what is most difficult to remove are

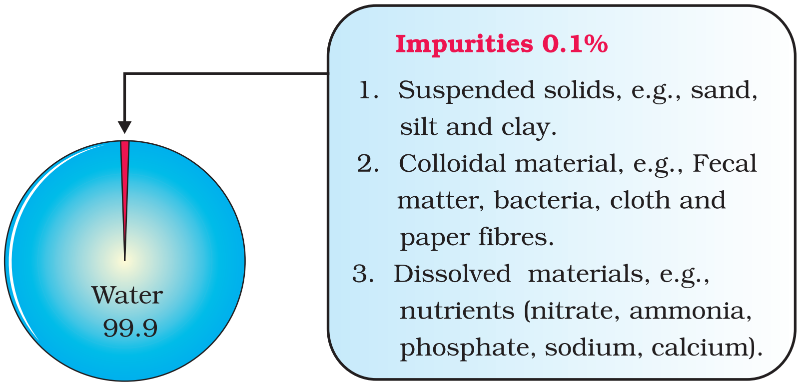

Figure 16.2 Composition of waste water

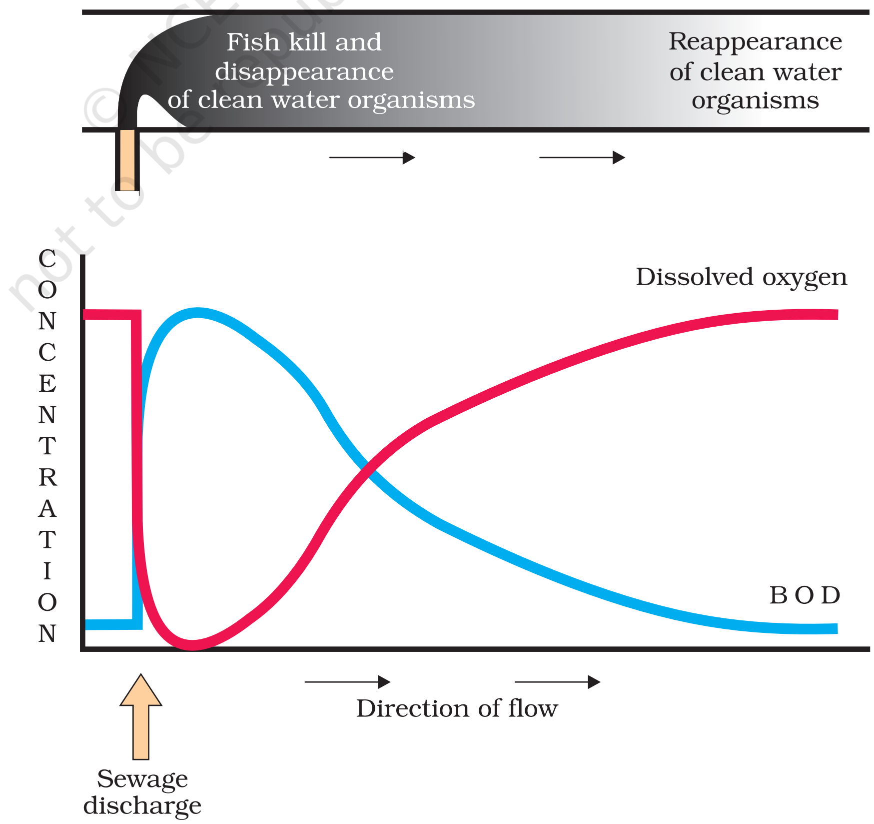

Figure 16.3 Effect of sewage discharge on some important characteristics of a river

dissolved salts such as nitrates, phosphates, and other nutrients, and toxic metal ions and organic compounds. Domestic sewage primarily contains biodegradable organic matter, which readily decomposes – thanks to bacteria and other micro-organisms, which can multiply using these organic substances as substrates and hence utilise some of the components of sewage. It is possible to estimate the amount of biodegradable organic matter in sewage water by measuring **Biochemical Oxygen Demand (BOD).** *Can you explain how?* In the chapter on micro-organisms you have read about the relation between BOD, micro-organisms and the amount of biodegradable matter.

Figure 16.3 shows some of the changes that one may notice following discharge of sewage into a river. Micro-organisms involved in biodegradation of organic matter in the receiving water body consume a lot of oxygen, and as a result there is a sharp decline in dissolved oxygen downstream from the point of sewage discharge. This causes mortality of fish and other aquatic creatures.

Presence of large amounts of nutrients in waters also causes excessive growth of **planktonic** (free-floating) algae, called an **algal bloom** (Figure 16.4) which imparts a distinct colour to the water bodies. Algal blooms cause deterioration of the water quality and fish mortality. Some bloom-forming algae are extremely toxic to human beings and animals.

You may have seen the beautiful mauve-colored flowers found on very appealingly-shaped floating plants in water bodies. These plants which were introduced into India for their lovely flowers have caused havoc by their excessive growth by causing blocks in our waterways. They grow faster than our ability to remove them. These are plants of water hyacinth (*Eichhornia crassipes*), the world's most problematic aquatic weed, also

Figure 16.4 Pictorial view of an algal bloom

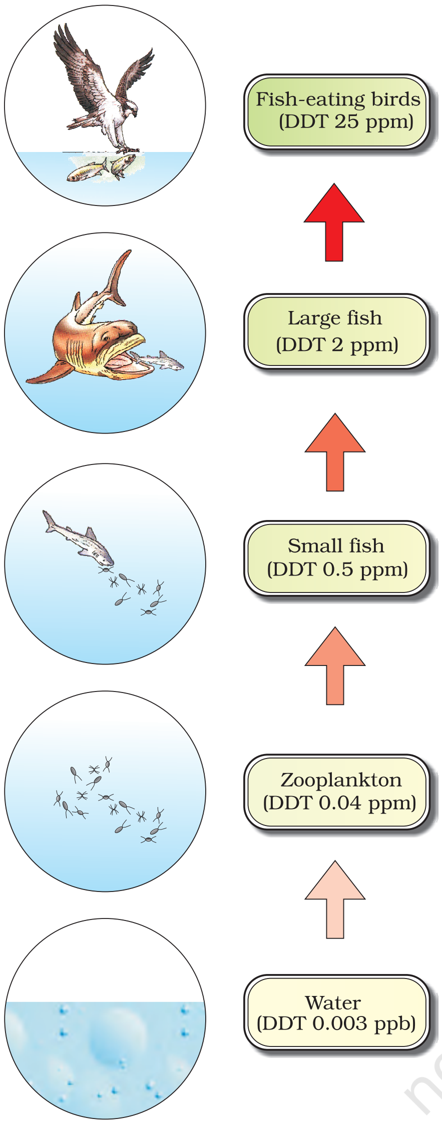

Figure 16.5 Biomagnification of DDT in an aquatic food chain

called 'Terror of Bengal'. They grow abundantly in eutrophic water bodies, and lead to an imbalance in the ecosystem dynamics of the water body.

Sewage from our homes as well as from hospitals are likely to contain many undesirable pathogenic micro-organisms, and its disposal into a water without proper treatment may cause outbreak of serious diseases, such as, dysentery, typhoid, jaundice, cholera, etc.

Unlike domestic sewage, waste water from industries like petroleum, paper manufacturing, metal extraction and processing, chemical manufacturing, etc., often contain toxic substances, notably, heavy metals (defined as elements with density > 5 g/cm^3 such as mercury, cadmium, copper, lead, etc.) and a variety of organic compounds.

A few toxic substances, often present in industrial waste waters, can undergo biological magnification **(Biomagnification)** in the aquatic food chain. Biomagnification refers to increase in concentration of the toxicant at successive trophic levels. This happens because a toxic substance accumulated by an organism cannot be metabolised or excreted, and is thus passed on to the next higher trophic level. This phenomenon is well-known for mercury and DDT. Figure 16.5 shows biomagnification of DDT in an aquatic food chain. In this manner, the concentration of DDT is increased at successive trophic levels; say if it starts at 0.003 ppb (ppb = parts per billion) in water, it can ultimately reach 25 ppm (ppm = parts per million) in fish-eating birds, through biomagnification. High concentrations of DDT disturb calcium metabolism in birds, which causes thinning of eggshell and their premature breaking, eventually causing decline in bird populations.

Eutrophication is the natural aging of a lake by nutrient enrichment of its water. In a young lake the water is cold and clear, supporting little life. With time, streams draining into the lake introduce nutrients such as nitrogen and phosphorus, which encourage the growth of aquatic organisms. As the lake's fertility increases, plant and animal life burgeons, and organic remains begin to be deposited on the lake bottom. Over the centuries, as silt and organic debris pile up, the lake grows shallower and warmer, with warm-water organisms supplanting those that thrive in a cold environment. Marsh plants take root in the shallows and begin to fill in the original lake basin. Eventually, the lake gives way to large masses of floating plants (bog), finally converting into land. Depending on climate, size of the lake and other factors, the natural aging of a lake may span thousands of years. However, pollutants from man's activities like effluents from the industries and homes can radically accelerate the aging process. This phenomenon has been called **Cultural** or **Accelerated Eutrophication**. During the past century, lakes in many parts of the earth have been severely eutrophied by sewage and agricultural and industrial wastes. The prime contaminants are nitrates and phosphates, which act as plant nutrients. They overstimulate the growth of algae, causing unsightly scum and unpleasant odours, and robbing the water of dissolved oxygen vital to other aquatic life. At the same time, other pollutants flowing into a lake may poison whole populations of fish, whose decomposing remains further deplete the water's dissolved oxygen content. In such fashion, a lake can literally choke to death.

Heated (thermal) wastewaters flowing out of electricity-generating units, e.g., thermal power plants, constitute another important category of pollutants. Thermal wastewater eliminates or reduces the number of organisms sensitive to high temperature, and may enhance the growth of plants and fish in extremely cold areas but, only after causing damage to the indigenous flora and fauna.

16.2.2 A Case Study of Integrated Waste Water Treatment

Wastewater including sewage can be treated in an integrated manner, by utilising a mix of artificial and natural processes. An example of such an initiative is the town of Arcata, situated along the northern coast of California. Collaborating with biologists from the Humboldt State University, the townspeople created an integrated waste water treatment process within a natural system. The cleaning occurs in two stages – (a) the conventional sedimentation, filtering and chlorine treatments are given. After this stage, lots of dangerous pollutants like dissolved heavy metals still remain. To combat this, an innovative approach was taken and (b) the biologists developed a series of six connected marshes over 60 hectares of marshland. Appropriate plants, algae, fungi and bacteria were seeded into this area, which neutralise, absorb and assimilate the pollutants. Hence, as the water flows through the marshes, it gets purified naturally.

The marshes also constitute a sanctuary, with a high level of biodiversity in the form of fishes, animals and birds that now reside there. A citizens group called Friends of the Arcata Marsh (FOAM) are responsible for the upkeep and safeguarding of this wonderful project. .

All this time, we have assumed that removal of wastes requires water, i.e., the creation of sewage. But what if water is not necessary to dispose off human waste, like excreta? Can you imagine the amount of water that one can save if one didn't have to flush the toilet? Well, this is already a reality. Ecological sanitation is a sustainable system for handling human excreta, using dry composting toilets. This is a practical, hygienic, efficient and cost-effective solution to human waste disposal. The key point to note here is that with this composting method, human excreta can be recycled into a resource (as natural fertiliser), which reduces the need for chemical fertilisers. There are working 'EcoSan' toilets in many areas of Kerala and Sri Lanka.

16.3 Solid Wastes

Solid wastes refer to everything that goes out in trash. **Municipal solid wastes** are wastes from homes, offices, stores, schools, hospitals, etc., that are collected and disposed by the municipality. The municipal solid wastes generally comprise paper, food wastes, plastics, glass, metals, rubber, leather, textile, etc. Burning reduces the volume of the wastes, although it is generally not burnt to completion and open dumps often serve as the breeding ground for rats and flies. **Sanitary landfills** were adopted as the substitute for open-burning dumps. In a sanitary landfill, wastes are dumped in a depression or trench after compaction, and covered with dirt everyday. *If you live in a town or city, do you know where the nearest landfill site is?* Landfills are also not really much of a solution since the amount of garbage generation specially in the metros has increased so much that these sites are getting filled too. Also there is danger of seepage of chemicals, etc., from these landfills polluting the underground water resources.

A solution to all this can only be in human beings becoming more sensitive to these environment issues. All waste that we generate can be categorised into three types – (a) bio-degradable, (b) recyclable and (c) the non-biodegradable. It is important that all garbage generated is sorted. What can be reused or recycled should be separated out; our *kabadiwallahs* and rag-pickers do a great job of separation of materials for recycling. The biodegradable materials can be put into deep pits in the ground and be left for natural breakdown. That leaves only the non-biodegradable to be disposed off. The need to reduce our garbage generation should be a prime goal, instead, we are increasing the use of non-biodegradable products. Just pick any readymade packet of any 'good quality' eatable, say a biscuit packet, and study the packaging – do you see the number of protective layers used? Note that atleast one layer is of plastic. We have started packaging even our daily use products like milk and water in polybags!! In cities, fruits and vegetables can be bought packed in beautiful polysterene and plastic packaging – we pay so much and what do we do? Contribute heavily to environmental pollution. State Governments across the country are trying to push for reduction in use of plastics and use of eco-friendly packaging. We can do our bit by carrying cloth or other natural fibre carry-bags when we go shopping and by refusing polythene bags.

Hospitals generate hazardous wastes that contain disinfectants and other harmful chemicals, and also pathogenic micro-organisms. Such wastes also require careful treatment and disposal. The use of incinerators is crucial to disposal of hospital waste.

Irreparable computers and other electronic goods are known as **electronic wastes (e-wastes)**. E-wastes are burried in landfills or incinerated. Over half of the e-wastes generated in the developed world are exported to developing countries, mainly to China, India and Pakistan, where metals like copper, iron, silicon, nickel and gold are recovered during recycling process. Unlike developed countries, which have specifically built facilities for recycling of e-wastes, recycling in developing countries often involves manual participation thus exposing workers to toxic substances present in e-wastes. Recycling is the only solution for the treatment of e-waste, provided it is carried out in an environment-friendly manner.

16.3.1 Case Study of Remedy for Plastic Waste

A plastic sack manufacturer in Bangalore has managed to find the ideal solution to the ever-increasing problem of accumulating plastic waste. Ahmed Khan, aged 57 years old, has been producing plastic sacks for 20 years. About 8 years ago, he realised that plastic waste was a real problem. Polyblend, a fine powder of recycled modified plastic, was developed then by his company. This mixture is mixed with the bitumen that is used to lay roads. In collaboration with R.V.College of Engineering and the Bangalore City Corporation, Ahmed Khan proved that blends of Polyblend and bitumen, when used to lay roads, enhanced the bitumen's water repellant properties, and helped to increase road life by a factor of three. The raw material for creating Polyblend is any plastic film waste. So, against the price of Rs. 0.40 per kg that rag pickers had been getting for plastic waste, Khan now offers Rs.6. Using Khan's technique, by the year 2002, more than 40 kms of road in Bangalore has already been laid. At this rate, Khan will soon be running short of plastic waste in Bangalore, to produce Polyblend. Thanks to innovations like Polyblend, we might still avoid being smothered by plastic waste.

16.4 Agro-chemicals and their Effects

In the wake of green revolution, use of inorganic fertilisers and pesticides has increased manifold for enhancing crop production. Pesticides, herbicides, fungicides, etc., are being increasingly used. These incidentally, are also toxic to non-target organisms,that are important components of the soil ecosystem. Do you think these can be biomagnified in the terrestrial ecosystems? We know what the addition of increasing amounts of chemical fertilisers can do to aquatic ecosystems vis-à-vis eutrophication. The current problems in agriculture are, therefore, extremely grave.

16.4.1 Case Study of Organic Farming

Integrated organic farming is a cyclical, zero-waste procedure, where waste products from one process are cycled in as nutrients for other processes. This allows the maximum utilisation of resource and increases the efficiency of production. Ramesh Chandra Dagar, a farmer in Sonipat, Haryana, is doing just this. He includes bee-keeping, dairy management, water harvesting, composting and agriculture in a chain of processes, which support each other and allow an extremely economical and sustainable venture. There is no need to use chemical fertilisers for crops, as cattle excreta (dung) are used as manure. Crop waste is used to create compost, which can be used as a natural fertiliser or can be used to generate natural gas for satisfying the energy needs of the farm. Enthusiastic about spreading information and help on the practice of integrated organic farming, Dagar has created the Haryana Kisan Welfare Club, with a current membership of 5000 farmers.

16.5 Radioactive Wastes

Initially, nuclear energy was hailed as a non-polluting way for generating electricity. Later on, it was realised that the use of nuclear energy has two very serious inherent problems. The first is accidental leakage, as occurred in the Three Mile Island and Chernobyl incidents and the second is safe disposal of radioactive wastes.

Radiation, that is given off by nuclear waste is extremely damaging to organisms, because it causes mutations at a very high rate. At high doses, nuclear radiation is lethal but at lower doses, it creates various disorders, the most frequent of all being cancer. Therefore, nuclear waste is an extremely potent pollutant and has to be dealt with utmost caution.

It has been recommended that storage of nuclear waste, after sufficient pre-treatment, should be done in suitably shielded containers buried within the rocks, about 500 m deep below the earth's surface. However, this method of disposal is meeting stiff opposition from the public. *Why do you think this method of disposal is not agreeable to many people?*

16.6 Greenhouse Effect and Global Warming

The term 'Greenhouse effect' has been derived from a phenomenon that occurs in a greenhouse. Have you ever seen a greenhouse? It looks like a small glass house and is used for growing plants especially during winter. In a greenhouse the glass panel lets the light in, but does not allow heat to escape. Therefore, the greenhouse warms up, very much like inside a car that has been parked in the sun for a few hours.

The greenhouse effect is a naturally occurring phenomenon that is responsible for heating of Earth's surface and atmosphere. You would be

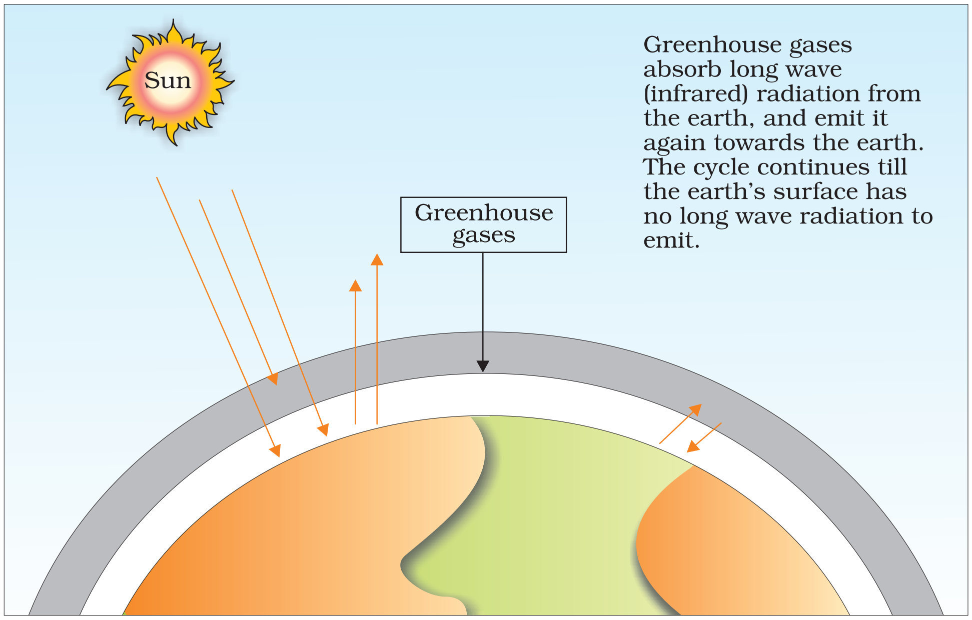

Figure 16.6 Sunlight energy at the outermost atmosphere

surprised to know that without greenhouse effect the average temperature at surface of Earth would have been a chilly –18°C rather than the present average of 15°C. In order to understand the greenhouse effect, it is necessary to know the fate of the energy of sunlight that reaches the outermost atmosphere (Figure16.6). Clouds and gases reflect about one-fourth of the incoming solar radiation, and absorb some of it but almost half of incoming solar radiation falls on Earth's surface heating it, while a small proportion is reflected back. Earth's surface re-emits heat in the form of infrared radiation but part of this does not escape into space as atmospheric gases (e.g., carbon dioxide, methane, etc.) absorb a major fraction of it. The molecules of these gases radiate heat energy, and a major part of which again comes to Earth's surface, thus heating it up once again. This cycle is repeated many a times. The above-mentioned gases – carbon dioxide and methane – are commonly known as greenhouse gases (Figure 16.7) because they are responsible for the greenhouse effect.

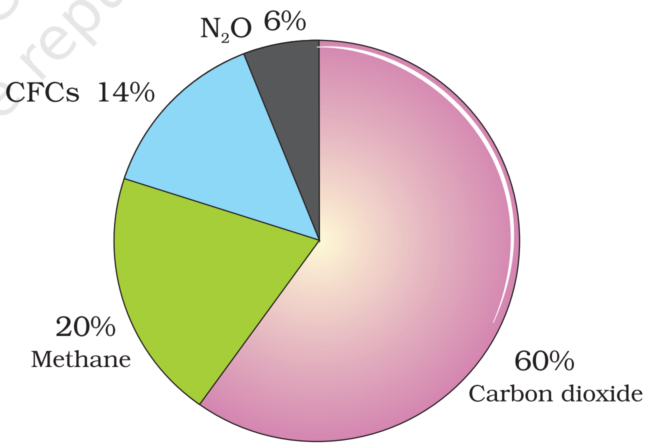

Figure 16.7 Relative contribution of various greenhouse gases to total global warming

Increase in the level of greenhouse gases has led to considerable heating of Earth leading to global warming. During the past century, the temperature of Earth has increased by 0.6 °C, most of it during the last three decades. Scientists believe that this rise in temperature is leading to deleterious changes in the environment and resulting in odd climatic changes (e.g. El Nino effect) , thus leading to increased melting of polar ice caps as well as of other places like the Himalayan snow caps. Over many years, this will result in a rise in sea level that can submerge many coastal areas. The total spectrum of changes that global warming can bring about is a subject that is still under active research.

How can we control global warming? The measures include cutting down use of fossil fuel, improving efficiency of energy usage, reducing deforestation, planting trees and slowing down the growth of human population. International initiatives are also being taken to reduce the emission of greenhouse gases into the atmosphere.

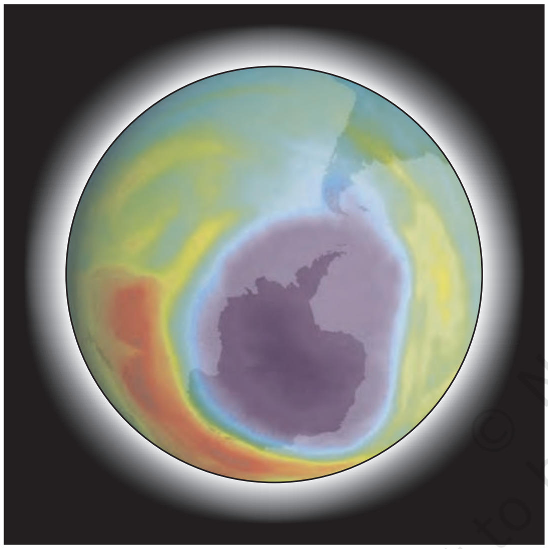

Figure 16.8 Ozone hole is the area above Antarctica, shown in purple colour, where the ozone layer is the thinnest. Ozone thickness is given in Dobson unit (see carefully the scale shown in colour violet to red). The ozone hole over Antarctica develops each year between late August and early October. *Courtesy: NASA*

16.7 Ozone Depletion in the Stratosphere

You have earlier studied in the Chemistry textbook of Class XI about 'bad' ozone, formed in the lower atmosphere (troposphere) that harms plants and animals. There is 'good' ozone also; this ozone is found in the upper part of the atmosphere called the **stratosphere**, and it acts as a shield absorbing ultraviolet radiation from the sun. UV rays are highly injurious to living organisms since DNA and proteins of living organisms preferentially absorb UV rays, and its high energy breaks the chemical bonds within these molecules. The thickness of the ozone in a column of air from the ground to the top of the atmosphere is measured in terms of **Dobson units** (DU).

Ozone gas is continuously formed by the action of UV rays on molecular oxygen, and also degraded into molecular oxygen in the stratosphere. There should be a balance between production and degradation of ozone in the stratosphere. Of late, the balance has been disrupted due to enhancement of ozone degradation by **chlorofluorocarbons** (**CFC**s). CFCs find wide use as refrigerants. CFCs discharged in the lower part of atmosphere move upward and reach stratosphere. In stratosphere, UV rays act on them releasing Cl atoms. Cl degrades ozone releasing molecular oxygen, with these atoms acting merely as catalysts; Cl atoms are not consumed in the reaction. Hence, whatever CFCs are added to the stratosphere, they have permanent and continuing effects on Ozone levels. Although ozone depletion is occurring widely in the stratosphere, the depletion is particularly marked over the Antarctic region. This has resulted in formation of a large area of thinned ozone layer, commonly called as the **ozone hole** (Figure 16.8).

UV radiation of wavelengths shorter than UV-B, are almost completely absorbed by Earth's atmosphere, given that the ozone layer is intact. But, UV-B damages DNA and mutation may occur. It causes aging of skin, damage to skin cells and various types of skin cancers. In human eye, cornea absorbs UV-B radiation, and a high dose of UV-B causes inflammation of cornea, called **snow-blindness,** cataract, etc. Such exposure may permanently damage the cornea.

Recognising the deleterious affects of ozone depletion, an international treaty, known as the **Montreal Protocol**, was signed at Montreal (Canada) in 1987 (effective in 1989) to control the emission of ozone depleting substances. Subsequently many more efforts have been made and protocols have laid down definite roadmaps, separately for developed and developing countries, for reducing the emission of CFCs and other ozone depleting chemicals.

16.8 Degradation by Improper Resource Utilisation and Maintenance

The degradation of natural resources can occur, not just by the action of pollutants but also by improper resource utilisation practices.

Soil erosion and desertification: The development of the fertile top-soil takes centuries. But, it can be removed very easily due to human activities like over-cultivation, unrestricted grazing, deforestation and poor irrigation practices, resulting in arid patches of land. When large barren patches extend and meet over time, a desert is created. Internationally, it has been recognised that desertification is a major problem nowadays, particularly due to increased urbanisation.

Waterlogging and soil salinity: Irrigation without proper drainage of water leads to waterlogging in the soil. Besides affecting the crops, waterlogging draws salt to the surface of the soil. The salt then is deposited as a thin crust on the land surface or starts collecting at the roots of the plants. This increased salt content is inimical to the growth of crops and is extremely damaging to agriculture. Waterlogging and soil salinity are some of the problems that have come in the wake of the Green Revolution.

16.9 Deforestation

Deforestation is the conversion of forested areas to non-forested ones. According to an estimate, almost 40 per cent forests have been lost in the tropics, compared to only 1 per cent in the temperate region. The present scenario of deforestation is particularly grim in India. At the beginning of the twentieth century, forests covered about 30 per cent of the land of India. By the end of the century, it shrunk to 21.54 per cent, whereas the National Forest Policy (1988) of India has recommended 33 per cent forest cover for the plains and 67 per cent for the hills.

How does deforestation occur? A number of human activities contribute to it. One of the major reasons is the conversion of forest to agricultural land so as to feed the growing human population. Trees are axed for timber, firewood, cattle ranching and for several other purposes. **Slash and burn agriculture**, commonly called as **Jhum cultivation** in the north-eastern states of India, has also contributed to deforestation. In slash and burn agriculture, the farmers cut down the trees of the forest and burn the plant remains. The ash is used as a fertiliser and the land is then used for farming or cattle grazing. After cultivation, the area is left for several years so as to allow its recovery. The farmers then move on to other areas and repeat this process. In earlier days, when Jhum cultivation was in prevalence, enough time-gap was given so that the land recovered from the effect of cultivation. With increasing population, and repeated cultivation, this recovery phase is done away with, resulting in deforestation.

What are the consequences of deforestation? One of the major effects is enhanced carbon dioxide concentration in the atmosphere because trees that could hold a lot of carbon in their biomass are lost with deforestation. Deforestation also causes loss of biodiversity due to habitat destruction, disturbs hydrologic cycle, causes soil erosion, and may lead to desertification in extreme cases.

Reforestation is the process of restoring a forest that once existed but was removed at some point of time in the past. Reforestation may occur naturally in a deforested area. However, we can speed it up by planting trees with due consideration to biodiversity that earlier existed in that area.

16.9.1 Case Study of People's Participation in Conservation of Forests

People's participation has a long history in India. In 1731, the king of Jodhpur in Rajasthan asked one of his ministers to arrange wood for constructing a new palace. The minister and workers went to a forest near a village, inhabited by Bishnois, to cut down trees. The Bishnoi community is known for its peaceful co-existence with nature. The effort to cut down trees by the kings was thwarted by the Bishnois. A Bishnoi woman Amrita Devi showed exemplary courage by hugging a tree and daring king's men to cut her first before cutting the tree. The tree mattered much more to her than her own life. Sadly, the king's men did not heed to her pleas, and cut down the tree along with Amrita Devi. Her three daughters and hundreds of other Bishnois followed her, and thus lost their lives saving trees. Nowhere in history do we find a commitment of this magnitude when human beings sacrificed their lives for the cause of the environment. The Government of India has recently instituted the **Amrita Devi Bishnoi Wildlife Protection Award** for individuals or communities from rural areas that have shown extraordinary courage and dedication in protecting wildlife.

You may have heard of the **Chipko Movement** of Garhwal Himalayas. In 1974, local women showed enormous bravery in protecting trees from the axe of contractors by hugging them. People all over the world have acclaimed the Chipko movement.

Realising the significance of participation by local communities, the Government of India in 1980s has introduced the concept of **Joint Forest Management (JFM)** so as to work closely with the local communities for protecting and managing forests. In return for their services to the forest, the communities get benefit of various forest products (e.g., fruits, gum, rubber, medicine, etc.), and thus the forest can be conserved in a sustainable manner.

SUMMARY

Major issues relating to environmental pollution and depletion of valuable natural resources vary in dimension from local, regional to global levels. Air pollution primarily results from burning of fossil fuel, e.g., coal and petroleum, in industries and in automobiles. They are harmful to humans, animals and plants, and therefore must be removed to keep our air clean. Domestic sewage, the most common source of pollution of water bodies, reduces dissolved oxygen but increases biochemical oxygen demand of receiving water. Domestic sewage is rich in nutrients, especially, nitrogen and phosphorus, which cause eutrophication and nuisance creating algal blooms. Industrial waste waters are often rich in toxic chemicals, especially heavy metals and organic compounds. Industrial waste waters harm living organisms. Municipal solid wastes also create problems and must be disposed off in landfills. Disposal of hazardous wastes like defunct ships, radioactive wastes and e-wastes requires additional efforts. Soil pollution primarily results from agricultural chemicals (e.g., pesticides) and leachates from solid wastes deposited over it.

Two major environmental issues of global nature are increasing greenhouse effect, which is warming Earth, and depletion of ozone in the stratosphere. Enhanced greenhouse effect is mainly due to increased emission of carbon dioxide, methane, nitrous oxide and CFCs., and also due to deforestation. It may drastically change rainfall pattern, global temperature, besides deleteriously affecting living organisms. Ozone in the stratosphere, which protects us from harmful effects of ultraviolet radiation, is depleting fast due to emission of CFCs thus increasing the risks of skin cancer, mutation and other disorders.

EXERCISES

1. What are the various constituents of domestic sewage? Discuss the effects of sewage discharge on a river.
2. List all the wastes that you generate, at home, school or during your trips to other places. Could you very easily reduce the generation of these wastes? Which would be difficult or rather impossible to reduce?
3. Discuss the causes and effects of global warming. What measures need to be taken to control global warming?
4. Match the items given in column A and B:

Column A	Column B
(a) Catalytic converter	(i) Particulate matter
(b) Electrostatic precipitator	(ii) Carbon monoxide and nitrogen oxides
(c) Earmuffs	(iii) High noise level
(d) Landfills	(iv) Solid wastes

5. Write critical notes on the following:
   (a) Eutrophication
   (b) Biological magnification
   (c) Groundwater depletion and ways for its replenishment
6. Why does ozone hole form over Antarctica? How will enhanced ultraviolet radiation affect us?
7. Discuss the role of women and communities in protection and conservation of forests.
8. What measures, as an individual, would you take to reduce environmental pollution?
9. Discuss briefly the following:
   (a) Radioactive wastes
   (b) Defunct ships and e-wastes
   (c) Municipal solid wastes
10. What initiatives were taken for reducing vehicular air pollution in Delhi? Has air quality improved in Delhi?
11. Discuss briefly the following:
    (a) Greenhouse gases
    (b) Catalytic converter
    (c) Ultraviolet B