THE GOVERNMENT OF
THE REPUBLIC OF THE UNION OF MYANMAR

MINISTRY OF EDUCATION

TEXTBOOK

BIOLOGY

GRADE 12

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PREFACE

The Grade 12 textbook is written for the students who intend to pursue the biological related professional areas such as Medical and Paramedical Sciences, Forestry, Veterinary, Agriculture, Fisheries, Microbiology and Biotechnology as well as basic life sciences like Botany, Zoology, Geology, Chemistry, Biochemistry and Environmental Science in Universities. Grade 12 is the final grade of basic high school and after completion, the students are eligible to join the Universities and Institutes based on their educational performance. Therefore, this grade is very important for the students and they should be known thoroughly with the subjects. The textbook is prepared to provide with required knowledge and information on life sciences that has not been covered in previous grades.

This textbook consists of six chapters. Chapter one is presented with five main themes of biology and it also highlights the importance of biology in our daily life focusing on agriculture, horticulture and hydroponic culture, aquaculture and livestock, food, health, medicine, clothing and shelter. Chapter two deals with the molecular biology emphasizing on deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) which are essential constituents of all living cells of life. Moreover, this chapter explains how proteins are synthesized in the cells via the information coded in DNA molecule and how various RNA molecules are involved in the synthesis process. The basic knowledge of genetically modified organisms is also presented. In chapter three, transport system in both plants and animals are described with relevant colourful diagrams. It includes transpiration and translocation in plants and the human circulatory system. In chapter four, diseases in plants and in human together with examples of diseases and disease-causing organisms are explained. In human, non-infectious and infectious diseases are explained and exemplify with cardiovascular disease and malaria respectively. Chapter five is concerned with the coordination and responses in both plants and animals, in which the plants hormones and human hormones and their effects are presented. The detailed descriptions on structure and functions of different parts of brain and nerve cells as well as the sense organ, the eye, are given. The last chapter of this book is about biodiversity and conservation and it describes the three levels of biodiversity, endangered species of biodiversity in Myanmar and factors threatening to biodiversity. It also includes the conservation methods and protected areas of Myanmar.

In this book precise colourful diagrams, photomicrographs, figures and charts are provided for clear and better understanding of the subject. Sample questions are also given at the end of each chapter to test the ability of the students in applying their biological knowledge. Moreover, after the last chapter the glossary is added to overcome the difficulties with terminology. It is also hoped that students with increase knowledge and information on life sciences will be able to achieve **the 21st century skills for learning as:**

- **Collaboration** – in lessons, students will be working in groups, share ideas with their classmates and find out the solutions together
- **Communication** – students will develop verbal and non-verbal communication skills in-group works
- **Critical thinking and Problem solving** – students will be given interesting problems to solve-finding and explaining solutions, looking for correcting errors
- **Creativity and Innovation** – thinking 'outside the box' is an important 21st century skill. Students will be encouraged to explore new ideas and solve problems in new ways
- **Citizenship** – students will join the school community and develop fairness and conflict resolution skills to become a good citizenship.

It is expected that after completion of the study on the contents of this book, the students will be well qualified to extend further study in biology and in other related fields as career.

CONTENTS

CHAPTER 3 TRANSPORT SYSTEM IN ORGANISMS

CHAPTER 4 DISEASES IN PLANTS AND ANIMALS

CHAPTER 5 COORDINATION AND RESPONSE

CHAPTER 6 BIODIVERSITY AND CONSERVATION

CHAPTER 1
INTRODUCTION TO BIOLOGY

Learning Outcomes

It is expected that students will be able to

- identify, explain and give examples of the five themes that central to living organisms
- understand the core theme of evolution, together with organization, information, energy and matter, and their interactions
- review the importance of biology in the daily lives of people
- increase the awareness of production and productivity of cereals and vegetable crops
- understand the basic knowledge of aquaculture and livestock
- gain knowledge about the food resources
- promote the knowledge of health and how to prevent diseases by using medicines
- learn the uses of fibres and materials used in making clothing and shelter

1.1 THEMES OF BIOLOGY

Biology is broadly divided into five major themes: organization, information, energy and matter, interactions and evolution. Each of these themes will be described and explained their importance to understand life as a whole. Life on Earth is simply amazing - diverse, resilient, powerful, intelligent, and mystify. In the time, that humans have studied biology understanding of its five major themes has been able to be categorized.

1.1.1 Theme 1: New Properties Emerge at Successive Levels of Biological Organization

The hierarchy of life on earth is unfolded as follows: biosphere, ecosystem, community, population, organism, organ system, organ, tissue, cell, organelle, molecule and atom. With each set up, new properties emerge (emergent properties) because of interactions among components at the lower levels.

The structure and function of biological components are interrelated. At each level of the biological hierarchy, a correlation of structure and function can be observed. For example, the hummingbird's anatomy allows the wings to rotate at the shoulder, so hummingbirds have the ability, unique among birds, to fly backward or hover in place. While hovering, the birds can extend their long, slender beaks into flowers and feed on nectar (Figure 1.1).

Figure 1.1 Structure of hummingbird related to its function

The cell, one of the steps composed in the hierarchy of life is a basic unit structure and function of an organism. It is the lowest level of organization that can perform all activities required for life. Cells are either prokaryote or eukaryote. Eukaryotic cells contain membrane-enclosed organelles, including DNA in nucleus whereas prokaryotic cells lack membrane-enclosed organelles (Figure 1.2).

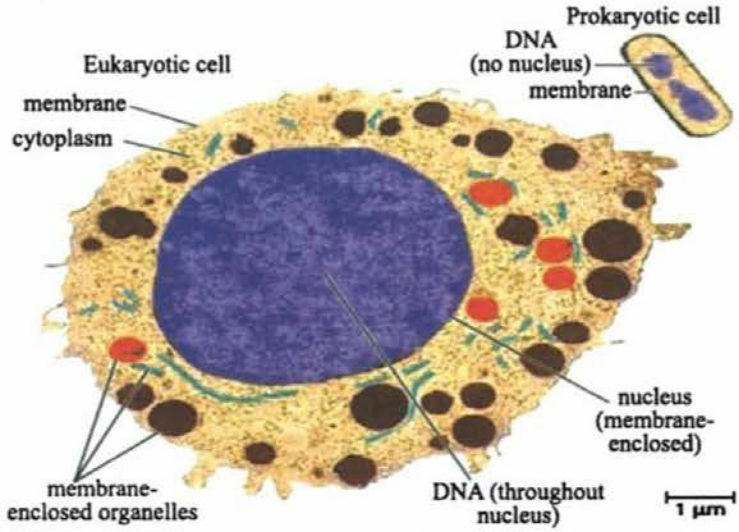


Figure 1.2 Contrasting eukaryotic and prokaryotic cells in size and complexity

1.1.2 Theme 2: Life's Processes Involve the Expression and Transmission of Genetic Information

The genetic information is encoded in the nucleotide sequences of DNA. The DNA transmits heritable information from parents to offspring. DNA sequences (called genes) act as instructions to make a cell's protein production by being transcribed into mRNA and then translated into specific proteins. These processes are called **gene expression**. Gene expression can also produce some RNAs that are not translated into proteins but serve other important functions (Figure 1.3 A and B).

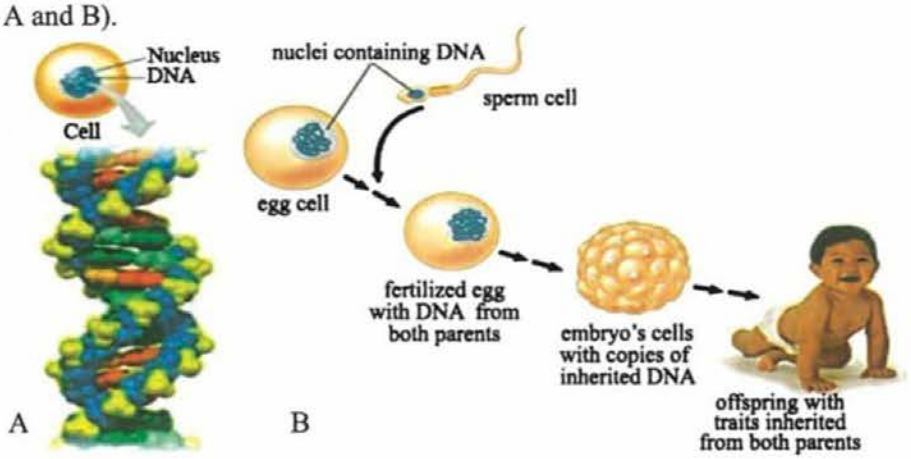


Figure 1.3 A. DNA double helix and B. Inherited DNA directs development of an organism

1.1.3 Theme 3: Life Requires the Transfer and Transformation of Energy and Matter

Energy flows through the ecosystem. All organisms require energy for their life. Producers convert energy from sunlight to chemical energy and some of which is then passed to consumers (the rest is lost from the ecosystem as heat). Chemical cycle occurs between organisms and the environment (Figure 1.4).

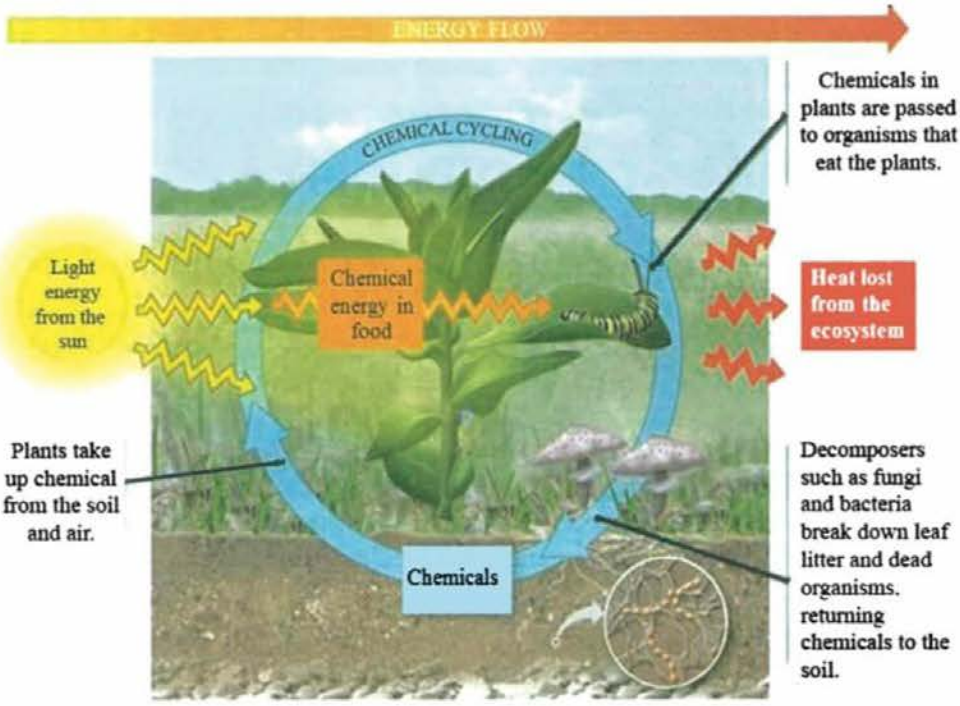


Figure 1.4 Energy flow and chemical cycling

1.1.4 Theme 4: Molecules to Ecosystems, Interactions in Biological Systems

Organisms interact continuously with physical factors. Plants take up nutrients from the soil and chemicals from the air and use energy from the sun. Interactions among plants, animals, and other organisms affect the participants in varying ways.

In feedback regulation, a process is regulated by its output or product. In negative feedback, accumulation of the product slows its production. In positive feedback, a product speeds up its own production. Feedback is a type of regulation common to life at all levels, from molecules to ecosystems (Figure 1.5 A and B).

1.1.5 Theme 5: Evolution for the Unity and Diversity of Life

Evolution is the process of change that has transformed life on Earth, accounts for the unity and diversity of life. It also explains evolutionary adaptation and the match of organisms to their environment.

Biologists classify species according to a system of broader and broader groups. Domain **Bacteria** and **Archaea** consist of prokaryotes. Domain **Eukarya** includes various groups of protists as well as fungi, plants, and animals (Figure 1.6).

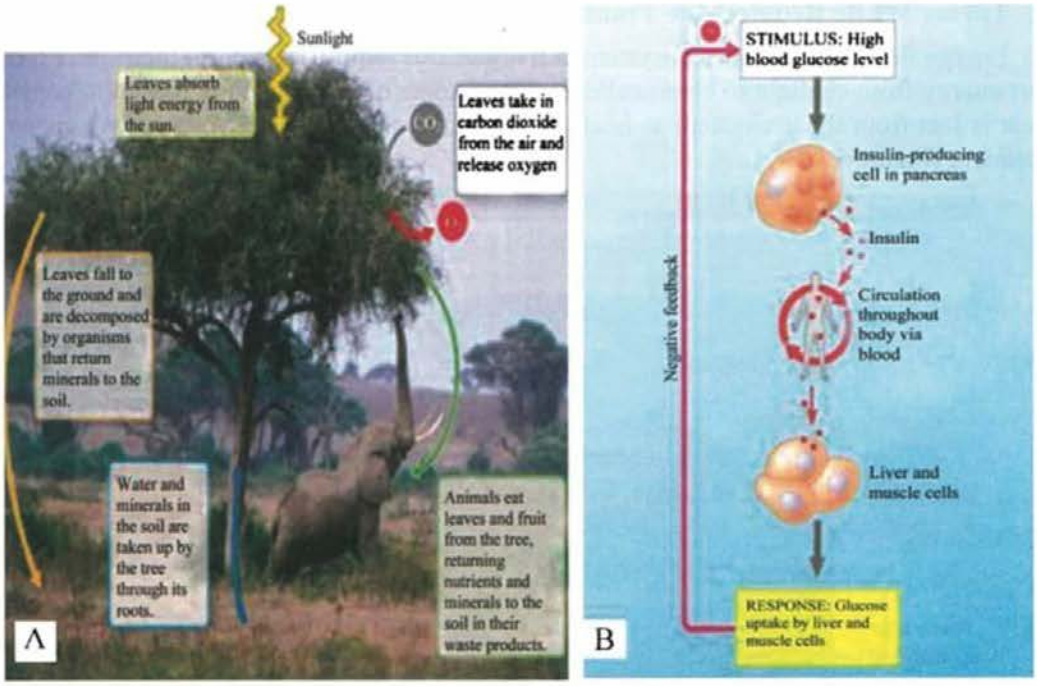


Figure 1.5 A. Interactions of an acacia tree with other organisms and the physical environment, B. Feedback regulation

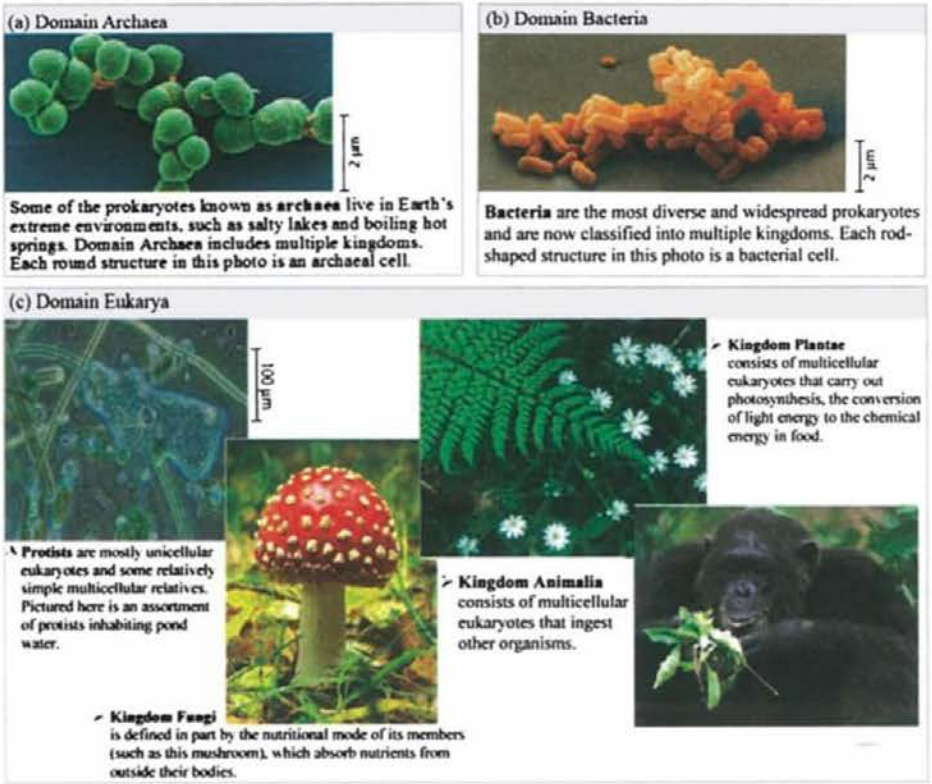


Figure 1.6 The three domains and six kingdoms of life

Darwin (1809-1882) proposed natural selection as the mechanism for evolutionary adaptation of populations to their environments. Natural selection is thus defined as the evolutionary process that occurs when a population is exposed to environmental factors that consistently cause individuals with certain heritable traits to have greater reproductive success than do individuals with other heritable traits.

1.2 IMPORTANCE OF BIOLOGY IN DAILY LIFE

Scientific research and the development of new tools and techniques have undoubtedly improved the quality of our lives. Generally, the relevance of biology is the important of the human society and humankind. Biology is also important to our everyday life because it allows human beings to know better their bodies, their resources and potential threats in the environment.

Biology being the study of living things help us to understand every organism. As a field of science, biology helps us to understand the living world and the ways its many species (including humans) function, evolve, and interact. Advances in medicine, agriculture, biotechnology, and many other areas of biology have brought improvements in the quality of life.

Fields such as genetics and evolution give insight into the past and can help shape the future, and research in ecology and conservation inform how we can protect this planet's precious biodiversity. Biology has also helped us to understand the characteristics of living things, the similarities between plants and animals, as well as how germs work and help us staying healthier.

1.2.1 Agriculture, Horticulture and Hydroponic Culture

The food that we consume is the results of agriculture. Humans and animals depend on the agricultural products for sustaining themselves. Fruits, vegetables, grains, pulses, oils, sugar, tea, coffee, and other foods are obtained from the plants.

Agriculture

Agriculture is defined to produce commodities which maintain life, including foods, fibers, forest products, agricultural crops, horticultural crops, and their related services. Agricultural crops mean food or fiber commodities grown for resale or commercial or economic purposes that provide foods, clothing, or animal feeds, and include nursery products and florist items while in the hands of a nursery grower. The global major agricultural products can be broadly grouped into foods, fibers, fuels, and raw materials (such as rubber). Myanmar's agricultural exports include rice, maize, blackgram, greengram, pigeonpea, chickpea, sesame, onion, tamarind, raw rubber, vegetables, and fruits. Commercially cultivating agricultural crops in Myanmar are mainly cereals, pulses and oilseed crops. Myanmar's farms are well diversified, with most farms producing rice paddy during the monsoon season and other crops such as beans, pulses, oilseeds and maize, during the cool and dry seasons.

Rice (*Oryza sativa*) production is based on its environment, resulting in rain fed lowland rice, winter rice, deep-water rice, upland rice and irrigated rice. Out of the three distinct seasons, the monsoon season is the main rice production season as rice paddies rely on copious amounts of water. There are two dominant rice production systems: rain fed lowland and irrigated lowland. The traditional method for cultivating rice is flooding the fields while, or after, setting the young seedlings. This simple method requires sound irrigation planning but reduces the growth of less

robust weed and pest plants that have no submerged growth state and deters vermin. While flooding is not mandatory for the cultivation of rice, all other methods of irrigation require higher effort in weed and pest control during growth periods and a different approach for fertilizing the soil (Figure 1.7 A).

Wheat (*Triticum aestivum*) is a grass widely cultivated for its seeds, a cereal grain that is a worldwide staple food. The wheat can be cultivated once a year. It is sown by four methods: broadcasting, behind the local plough, drilling and dibbling. The zero-tillage technique is a new method of wheat cultivation that is used in the Rice-Wheat cropping system. The wheat crop requires a well-pulverized but compact seedbed for good and uniform germination (Figure 1.7 B).

Maize (*Zea mays*) is a tropical plant that prefers warm humid weather. It is a short-day plant. It is very sensitive to excess or deficit soil moisture. It cannot withstand frost at any stage of growth. Maize seeds are sown with dibbling or drilling method depending on purposes of sowing, types of maize, varieties and farm conditions. Seeds should not be sown more than 5-6 cm depth of soil (Figure 1.7 C).

Figure 1.7 Habits of A. Rice, B. Wheat and C. Maize

Among the ASEAN countries, Myanmar is the leading pulse and bean producer. Globally, Myanmar is the third-largest producer of pulses after India and Canada. About 18 types of pulses are produced in Myanmar, led by blackgram (*Vigna mungo*) and followed by greengram (*Vigna radiata*), pigeonpea (*Cajanus cajan*), chickpea (*Cicer arietinum*), groundnut (*Arachis hypogaea*) and including a number of "other pulses" and sesame (*Sesamum indicum*) (Figure 1.8 A to F).

Horticulture

Horticulture is a branch of agriculture. It is defined as the applied science of cultivating and growing plants used for both consumption and aesthetic or ornamental purposes. Horticulture involves plant propagation and cultivation to improve the plant growths, yields, quality, nutritional values, and resistance to insects, diseases, and environmental stresses. It also includes plant conservations, landscape restoration, soil management, landscape and garden designs, construction and maintenance, and arboriculture. The word **"horticulture"** is derived from the Latin words 'hortus' and 'cultura', which mean 'garden' and 'cultivation'.

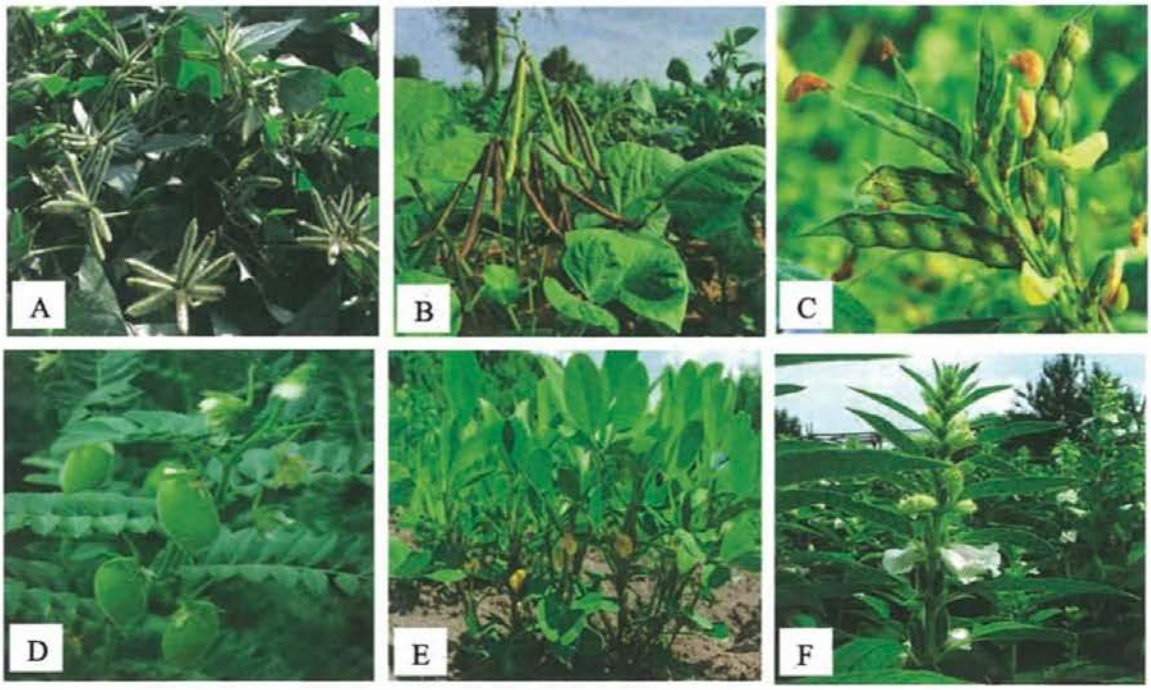


Figure 1.8 Habits of A. Blackgram, B. Greengram, C. Pigeonpea, D. Chickpea, E. Groundnut and F. Sesame

In contrast to agriculture, horticulture does not include the intensive crop farming and large-scale crop production or animal husbandry. Additionally, horticulture focuses on the use of small plots with a wide variety of mixed crops while agriculture focuses on one large primary crop at a time. The major types of horticulture include olericulture, pomology, viticulture, floriculture, turf management, arboriculture, landscape horticulture, and postharvest physiology. ***Olericulture*** is the vegetable growing, dealing with the culture of non-woody (herbaceous) plants for foods. **Pomology or Fruticulture** is the production of fruits and nuts. **Viticulture** is the production of grapes (largely intended for winemaking). **Floriculture** is the growing and marketing of flowers and ornamental plants for floristry. **Turf Management** is the production and upkeep of turf, artificial and live, for use in recreation. Sports stadiums, civilian landscaping, and leisure are among the largest users of turf management services. **Arboriculture** is the cultivation and care of individual trees, shrubs, vines, and other perennial woody plants, primarily to maintain individual woody plants and trees for long-term landscape and amenity purposes. **Landscape Horticulture** is the selection, production and care of plants used in landscape architecture. **Postharvest Physiology is** the management of harvested horticultural crops to determine the best storage and transportation conditions to optimize shelf life after harvest (Figure 1.9 A to H).

Figure 1.9 A. Olericulture, B. Pomology, C. Viticulture, D. Floriculture, E. Turf Management, F. Arboriculture, G. Landscape Horticulture and H. Postharvest Commodities

Hydroponic culture

Hydroponics is a method of growing plants without soil. Hydroponics uses less water than traditional soil-based systems. Hydroponic growing allows for faster growth and higher yields than traditional soil-based growing systems. Hydroponics is a type of horticulture and a subset of hydroculture which involves growing plants, usually crops, without soil, by using water-based mineral nutrient solutions in aqueous solvents. Terrestrial or aquatic plants may grow with their roots exposed to the nutritious liquid. In addition, the roots may be physically supported by an inert medium such as perlite, gravel, or other substrates. Despite inert media, roots can cause changes of the rhizosphere pH and root exudates can affect rhizosphere biology and physiological balance of the nutrient solution by secondary metabolites.

The nutrients used in hydroponic systems can come from many different sources, including fish excrement, duck manure, purchased chemical fertilizers, or artificial nutrient solutions. Plants are commonly grown hydroponically in a greenhouse, on inert media, include tomatoes, peppers, cucumbers, strawberries, lettuces, and cannabis, usually for commercial use, and *Arabidopsis*, which serves as a model organism in plant science and genetics. Hydroponics offers many advantages, notably a decrease in water usage in agriculture. Since hydroponics takes much less water to grow and produce, it could be possible in the future for people in harsh environments with little accessible water to grow their own food (Figure 1.10).

Figure 1.10 Hydroponic cultures

1.2.2 Aquaculture and Livestock

Aquaculture

Aquaculture, also known as **aquafarming**, is the farming of aquatic organisms such as fish, crustaceans, molluscs, algae and other aquatic plants. Aquaculture involves cultivating freshwater, brackish water and saltwater populations under controlled or semi-natural conditions, and can be contrasted with commercial fishing, which is the harvesting of wild fish. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. (Figure 1.11 A and B).

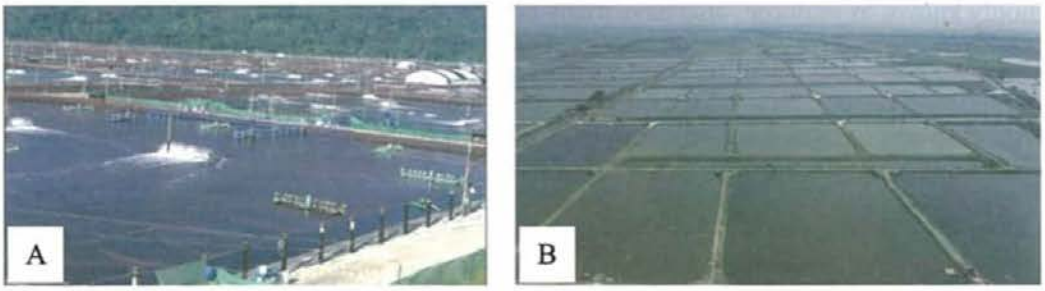


Figure 1.11 Aquaculture A. Shrimp Farm
B. Global Earth Agro and Aqua Industry Catfish Farm

Particular kinds of aquaculture

Fish farming or **pisciculture** involves commercial breeding of fish, usually for food, in fish tanks or artificial enclosures such as fish ponds. It is a particular type of aquaculture, which is the controlled cultivation and harvesting of aquatic animals such as fish, crustaceans, molluscs and so on. Worldwide, the most important fish species used in fish farming are, in order, carp, salmon, tilapia and catfish (Figure 1.12 A to D).

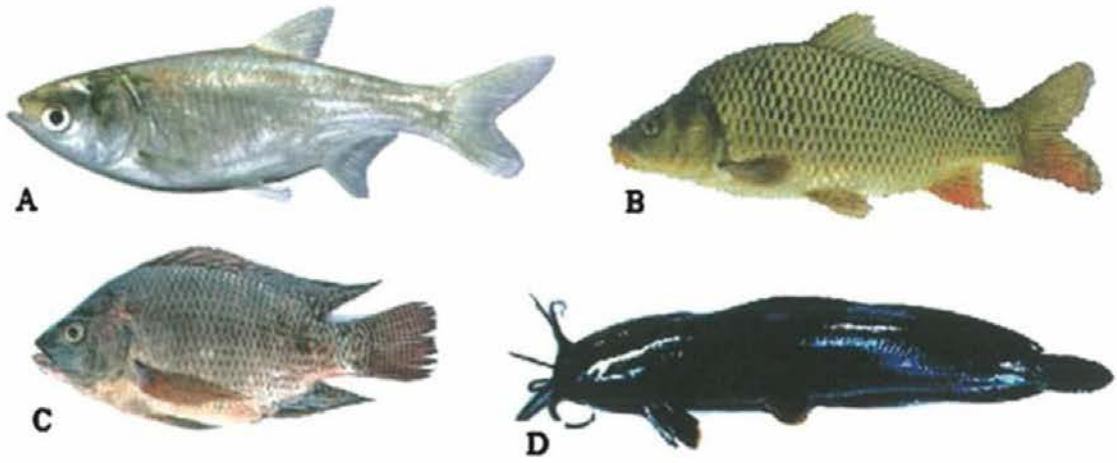


Figure 1.12 Freshwater culture fish species A. Silver carp, B. Common carp, C. Nile tilapia and D. Walking catfish

Mariculture or **marine farming** is a specialized branch of aquaculture involving the cultivation of marine organisms for food and other animal products in enclosed sections of the open ocean (**offshore mariculture**), or in fish farms built on littoral waters (**inshore mariculture**), or in artificial tanks, ponds, raceways which are filled with seawater (**onshore mariculture**).

Shrimp farming is an aquaculture business that exists in either a marine or freshwater environment, producing shrimp or prawns for human consumption.

Oyster farming is an aquaculture (or mariculture) practice in which oysters are bred and raised mainly for their pearls, shells and inner organ tissue, which is eaten.

Algaculture is the farming of algae species including microalgae and macroalgae. The majority of algae that are intentionally cultivated fall into the category of microalgae. Macroalgae, commonly known as seaweed, also have many commercial and industrial uses.

Integrated fish farming is a system of producing fish in combination with other agricultural or livestock farming operations centered on the fish pond. The farming sub-systems eg., fish, crop and livestock are linked to each other in such a way that the byproducts or wastes from one sub-system become the valuable inputs to another sub-system.

Uses of aquaculture

Aquaculture serves different purposes such as food production, restoration of threatened and endangered species populations, wild stock population enhancement, the building of aquariums, and fish cultures, and habitat restoration.

Livestock

The term "**Livestock**" refers to any domesticated, land-living animal that is raised to provide resources like meat, milk, eggs, and feathers, or to provide services like transportation or cultivation assistance. The most common livestock animals are cattle, sheep, goat, pig, horse, chicken, and duck (Figure 1.13 A to F).

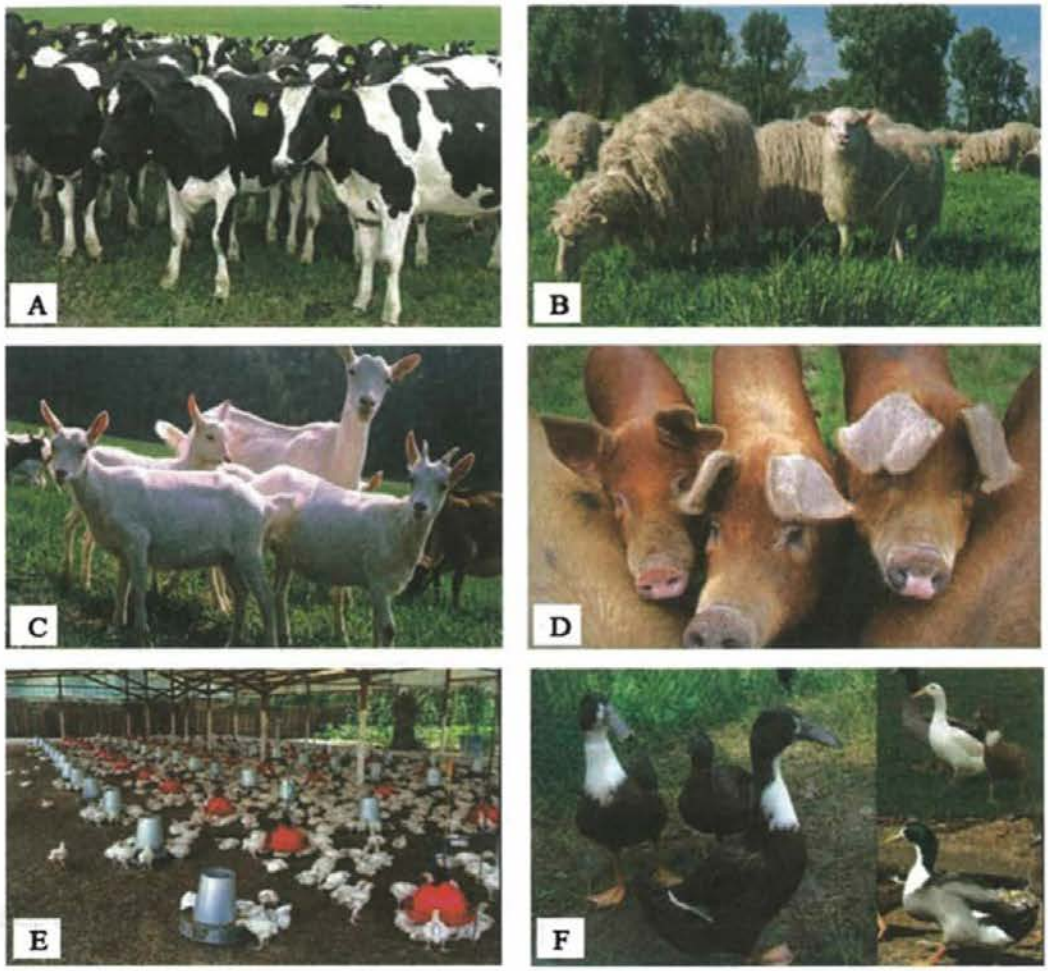


Figure 1.13 Livestock animals A. A herd of cows, B. Sheep, C. Goats, D. Duroc pig, E. Poultry farm and F. Ducks

The economic value of livestock

- **Meat:** Livestock can be raised for the production of a useful form of dietary protein and energy.
- **Dairy products:** Livestock can be used as a source of milk, other dairy products, such as yogurt, cheese, butter.
- **Fibre:** Livestock produce a range of fibre or textiles. For example, sheep and goats produce wool and mohair.
- **Fertilizer:** Manure can be spread on fields to increase crop yields. Manure is also used to make plaster for walls and floors and can be used as a fuel for fires. The blood and bone of animals are also used as fertilizer.
- **Labour:** Animals such as horses, donkey, and yaks can be used for mechanical energy. They are non-human labor and still using in plowing fields, transporting goods, and military functions.

- **Land management:** The grazing of livestock is sometimes used as a way to control weeds and undergrowth.
- **Breeding:** Livestock may be kept for the commercial value of breeding the animals, such as in horse breeding.
- **Sports:** Livestock may be raised for sports purposes, such as raising horses for horse racing or polo.
- **Pets industry:** Livestock may be raised to be sold commercially as pets.

Importance of livestock

The global demand and production of livestock products are increasing rapidly, due to the population growth, rising income, and changes in lifestyle and diets. Livestock are key drivers for sustainable development in agriculture. They contribute to food security, nutrition, poverty alleviation, and economic growth.

Livestock contribute to the conservation of biodiversity and genetic resources for food and agriculture. If managed sustainably, livestock can contribute to important ecosystem functions, nutrient cycling, soil organic carbon sequestration and maintaining agricultural landscapes.

1.2.3 Food

Food is one of the major requirements of life. All forms of living matter required food in one form or the other as the source of life-sustaining energy. However, plant only is able to manufacture food through the process of photosynthesis.

Food may be classified into the following groups:

- heat or energy producing food such as carbohydrates and fats;
- body-building food such as protein;
- protective food such as vitamins and some minerals; and
- luxury food such as confectioneries, etc.

It is evident that food must contain sufficiently carbohydrate, protein and fats or oil together with vitamins and essential minerals (Figure 1.14).

Figure 1.14 Variety of food

Without food, the viability of life is not feasible. Our food items come from plants and animals. Microbes aid in the formation of dairy products like curd, cheese, and yoghurt. The bacterium *Lactobacillus* helps in the formation of curd from milk. Similarly, yeast, one of the simplest eukaryotes, is used in the process of fermentation. Wine is obtained from grapes through a similar process. Furthermore, there are certain microbes and other biological processes that indirectly help in the production of food. The microorganisms present in the soil act as a decomposing agent, which assist in the production of the compost from dead and decaying organic matter. This compost acts as an effective fertilizer for the growing plants.

1.2.4 Health and Medicine

Whenever we get sick, we consult a doctor. The doctor gives us medicines and we get well. How has this been made possible? The answer to this question lies in biology. It is only because of biology that the study of various disease-causing microorganisms has been made possible. Researchers have investigated the biology of microorganisms and have discovered the methods of controlling the diseases. Even the formulation of drugs for fighting the disease-causing microorganisms has been made possible because of the study of the biology of those microorganisms.

Pharmacognosy is a name derived from Greek words, which mean drug and knowledge. In this field of science, researcher deals with the secondary metabolites found in many plants, animals, and microbial natural sources. The American Society of Pharmacognosy (ASP) defines it as "the study of the physical, chemical, biochemical and biological properties of drugs, drug substances, or potential drugs or drug substances of natural origin as well as the search for new drugs from different natural sources". Most of the countries in South-East Asia Region have a heritage of traditional medicine system. According to the recent WHO report, about 80% of world population is still using natural product for their primary healthcare needs. Pharmacognosy can provide safe and effective drugs in combination with modern medical system.

Like the first medicines, many of today's medicines are made from plants. The chief ingredient of aspirin, salicylic acid, was originally obtained from the bark of willow tree. The willow is in the genus *Salix*, hence the same name salicylic acid. The bark of cinchona tree, *Cinchona* sp., contains quinine a drug used to treat malaria. *Digitalis*, which is used in treatment of heart disease, is obtained from the leaves of foxglove plant, *Digitalis purpurea*. Periwinkle, *Catharanthus* sp. is the source of two drugs that are effective against Hodgkin disease and some leukemia. Two powerful pain relieved compounds, morphine and codeine are extracted from opium poppy, *Papaver somniferum* (Figure 1.15 A to D).

Figure 1.15 Habits of A. Cinchona, B. Foxglove, C. Periwinkle and D. Poppy

Medicinal animals are important resources linking people to the environment and their use promotes the traditional knowledge related to them. Over 50% of commercially available drugs are based on bioactive compounds extracted from non-human species. Almost every class of drug includes a model structure derived from nature, exhibiting the classical effects of the specific pharmacological category. A great number of these natural products have come to human society from the scientific study of remedies traditionally employed by various cultures.

In addition to plants and microbes, there has been increasing attention paid to animals, both vertebrates and invertebrates, as sources for new medicines. The healing of human minor illness by using therapies based on medicines obtained from animals or ultimately derived from them is known as **zootherapy**. Animals have been methodically tested by pharmaceutical companies as sources of drugs for modern medical science, and the current percentage of animal sources for producing essential medicines is quite significant. Some examples of the animal-based medicines are:

(i) **Leeches** are slimy bloodsuckers that can eat ten times, its own body weight of blood. Today, medicinal leeches are used after severe trauma to help reattach digits, close wounds and help mend skin after plastic surgery. The leech, *Hirudo medicinalis*, is approved by the Food and Drug Administration for medical use. While the leech feeding on the surface of the skin, they also secrete anti-coagulants which helps to keep the blood flowing. The blood pools in the reattached thumb can be sucked out by the leech until the veins redevelop (Figure 1.16 A).

(ii) A molecule called bradykinin from the **viper venom** is found to be related to a class of molecules that stop **Angiotensis-Converting Enzymes** (ACE) from blocking bradykinins, a protein that causes blood vessels to dilate and lower blood pressure. Bradykinins were eventually developed into the drug captopril, used to treat hypertension, cardiac conditions and to preserve kidney functions in diabetics (Figure 1.16 B).

(iii) **Maggots** are small, voracious eaters that feed on diseased and dying flesh. Their feeding habit is a life-saving asset for those suffering from chronic wounds and infections. Maggots can turn a chronic wound into an acute wound in a matter of days by eating the chronic tissue and bacteria. From there the wound becomes treatable and can finally heal. These hungry insect larvae are sterile, work quickly and also cost less than traditional treatments (Figure 1.16 C).

(iv) **Spider silk** is referred to by many scientists as bio-steel. Much like in the Spider-Man movies, spider silk has super tensile strength. Spider silk can also be used to make artificial ligaments and tendons that support tissue, bone and nerve cells, holding them steady while they grow. These artificial silk parts then fall apart gradually, after the cells have been given enough time to grow. The spider silk gene for the silk protein is connected to DNA in the mammary gland of goat. The cell of the mammary gland is then combined with an egg to ultimately produce an embryo that has the gene incorporated into its DNA. The silk protein is then made when the female starts lactating (Figure 1.16 D, E and F).

(v) **Salmon** belongs on a dinner plate, but it can also be found at the pharmacy, too. They do produce calcitonin hormones to regulate their own calcium levels from an endocrine gland in their neck. Humans make calcitonin, a hormone that inhibits bone loss, in the thyroid gland. But in postmenopausal women and people with Paget's disease, the rate of bone loss increases. The synthetic version of this calcitonin from the coho salmon, the calcitonin-salmon, can be used to treat people with calcium regulation disorders (Figure 1.16 G).

(vi) Over millions of years the **horseshoe crab** has been exposed to an awful lot of microbes making them immune to a wider range of threats than any other animal. Every person in the world today, who receives vaccines, antibiotics, or implanted medical devices such as

pacemakers, has had their safety ensured by the blue blood of the horseshoe crab. A protein in the blood called **Limulus Amebocyte Lysate** (LAL) reacts to all kinds of microorganisms and can easily detect dangerous endotoxins that cause fever and can be fatal. Scientists observed that the blood react to any contamination (Figure 1.16 H).

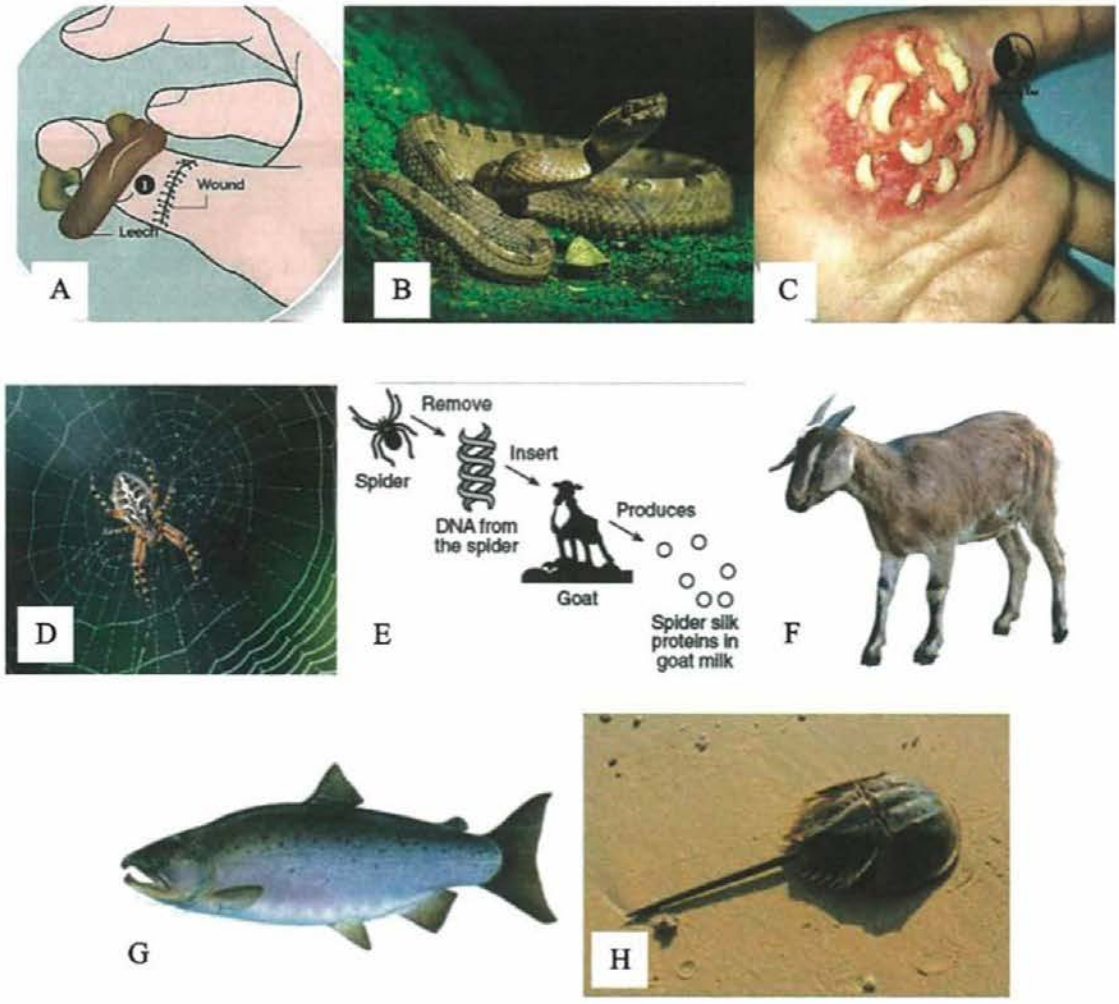


Figure 1.16 Different animals used in medicinal purposes A. Treatment with leeches, B. Pit viper, C. Treatment with maggots, D. Spider with web, E. A process of spider silk gene inserted into goat to produce silk protein in goat milk, F. Transgenic goat, G. Coho salmon and H. Horseshoe crab

1.2.5 Clothing and Shelter

Be it heat scorching summers or spine-chilling winters; it is the biology, which keeps you protective and safe. You wear breathable cotton clothes in summers that are obtained from plants. The thick sweaters, which cover you up in cold winters, are made of wool that from sheep. Linen, nylon, and fabric dyes are derived from the plants and polyester produced from fossils; nonetheless, whatever be the fabric, it ought to be plant-based.

Structurally, plant fibres are sclerenchymatous cells and are parts of the plant skeleton. Although fibres differ in texture, strength and chemical composition, they are mostly elongated cells with thick walls, small cavities and tapering ends. The thickening walls are due to deposition of cellulose and lignin. Fibres occur as sheet of tissue with overlapping and interlocking cell walls though they may sometimes occur singly or in small groups. Some of the fibres yielded plants for clothing are as follow.

Figure 1.17 Habit of cotton

Cotton, *Gossypium* spp., is the world's chief fibre plant. It is the industrial crop of Myanmar for raw materials supplied to domestic industries as well as export. The main areas of cotton cultivation are central Myanmar around Mandalay, Magway and Sagaing Regions (Figure 1.17).

Jute, *Corchorus* spp., is a very valuable best fibre. Jute is a tropical plant that grows best in hot and humid climate, under condition of plenty of rain and flooding at a later stage. Jute fibre is the world's chief material for manufacturing textiles in making roofing materials, curtains and gunny bags (Figure 1.18).

Figure 1.18 Habits of jute

Sericulture is an agro-based industry. It involves rearing of **silkworm** moths, *Bombyx mori* for the production of raw silk, which is the yarn obtained out of **cocoons**. Sericulture plays a major role in rural employment, poverty alleviation and earning foreign exchange.

Silkworm has four stages in its life cycle: egg, caterpillar (larva), pupa and adult moth. When the worms hatched, they are called caterpillars which are food specific and eat voraciously on mulberry leaves. One important factor to silk production is the cultivation of mulberry trees as

food for the silkworm. After reaching the complete stage, caterpillars secrete fluid protein called silk and spin cocoon as a protective shell around the pupa. Changing into the adult form from the pupa inside the cocoon is called metamorphosis. Humans obtain silk which is a continuous protein filament from the cocoon (Figure 1.19 A and B).

Silk is called the "Queen of Textiles" and is known for its qualities like luxury, elegance, class and comfort. It is one of the most expensive fibres, due to its cost and the tedious production process. Silk acts as the major source of textile industry around the world after cotton (Figure 1.19 C).

Sericulture has become one of the most important cottage industries in a number of countries like China, Japan, India, Korea, Brazil, Russia, Italy and France. Today, China and India are the two main producers, together manufacturing more than 90 % of the world production each year. In Myanmar, it is cultured in Pyin Oo Lwin, Mandalay Region and certain areas of Chin State.

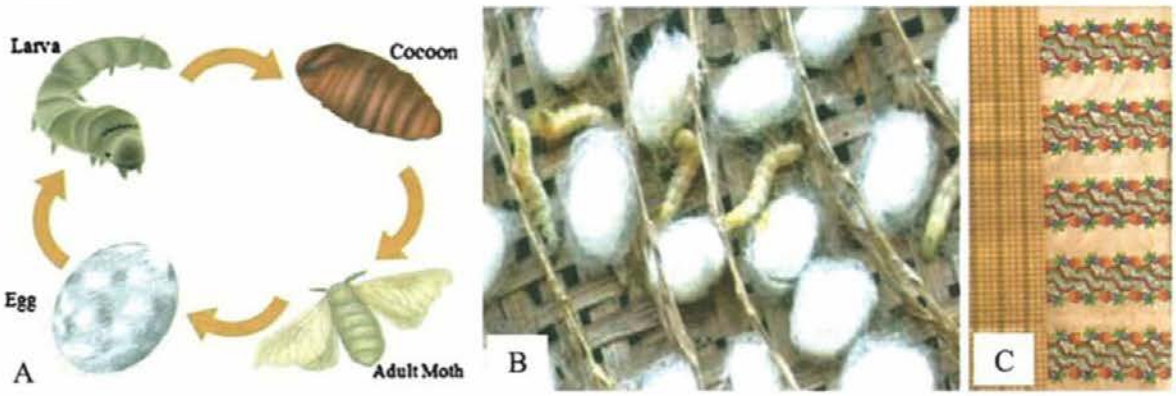


Figure 1.19 Sericulture A. Life cycle of silkworm, B. Cocoons of silkworm and C. Silk fabric

Wool is one of the most widely used animal fibres and mainly harvested by shearing. Wool is the textile fibre obtained from sheep and other mammals, especially goats, rabbits, and camelids. As an animal fibre, wool consists of protein together with a small percentage of lipids. This makes it chemically quite distinct from cotton and other plant fibres, which are mainly cellulose. The quality of wool is determined by its fibre diameter, crimp, yield, color, and staple strength. Fibre diameter is the most important wool characteristic determining quality and price.

In addition to clothing, wool has been used for blankets, horse rugs, saddle cloths, carpeting, insulation and upholstery. Wool as well as cotton has also been traditionally used for cloth diapers. Wool is an essential fibre for winter clothing, suiting, floor coverings and certain industrial applications.

Today, wool is a global industry found in Australia, Argentina, the United States, and New Zealand serving as the major suppliers of raw wool (Figure 1.20 A to C).

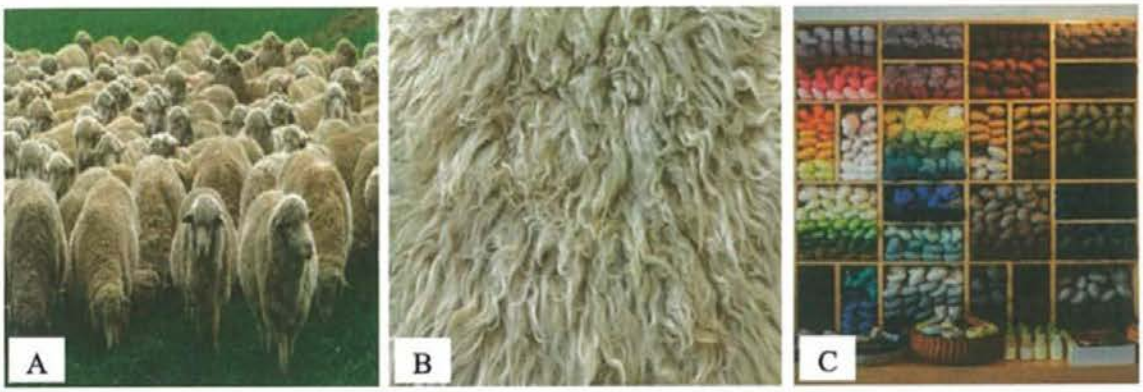


Figure 1.20 Sheep and wool products A. A flock of sheep, B. Raw wool and C. Yarns of different wool

Wood is an important plant product, which has been in the service of humankind since the dawn of civilization and has contributed much to its advancement. The primitive man used wood to construct his crude shelter as well as to design various implements, utensil and rough boats for his use. Today wood ranks next to food and fibres, as the most widely used plant product. In spite of the use of various metals, wood seems to be indispensable and has no satisfactory substitute, for the single fact that its supply can be renewed.

The unprocessed wood may be used in the form of lumber i.e. wood intended for heavy construction. Since the very beginning of civilization, wood has been the cheapest and most widely used construction material. Its significant qualities of high strength, lightweight, easy availability, continuous supply, high resistance to electrical and chemical stimuli, favour it for constructional work.

The major portion of the **timber** is used for structural purpose. The essential requirements of good structural timbers are strength durability toughness, resistance to stress and easy workability. Structural timbers are obtained mainly from the softwoods and from the heart of the tree. Teak, *Tectona grandis*; Pyinkado, *Xylia dolabriformis* are the most valuable of timber yielding plants of Myanmar and the most important commercial timbers (Figure 1.21 and 1.22).

Figure 1.21 Habits and inflorescences of Teak

Figure 1.22 Habits and inflorescences of Pyinkado

Sample Questions

1. State **TRUE** or **FALSE** to the following statements. Do not copy the statements. (6 marks)

i. The wings of hummingbird can rotate at the shoulder.
ii. All organisms require energy for their life.
iii. Domain Bacteria and Eukarya are prokaryotes.
iv. Hydroponic culture is a type of hydroculture that involves growing plants, with soil.
v. Livestock is domesticated land-living animals.
vi. The bacterium *Lactobacillus* helps in the formation of curd from milk.

2. Complete the following statements with appropriate words. Do not copy the statements. (6 marks)

i. The structure and function of biological components are ----------.
ii. Chemical cycle occurs between ---------- and the environment.
iii. Humans and animals depend on the ---------- products.
iv. The life stages of silkworm include egg, caterpillar, ---------- and adult.
v. Changing into adult form from pupa inside the cocoon is called ----------.
vi. The scientific name of teak is ----------.

3. Choose the correct answer for the following statements. Do not copy the statements. (6 marks)

i. Life on Earth is simply (A. wonderful B. afraid C. amazing D. dividing) diverse, resilient, powerful, intelligent and mystify.
ii. The cell is a basic unit structure and (A. making B. tasking C. function D. loading) of an organism.
iii. (A. Ecosystem B. Evolution C. Genetics D. Taxonomy) is the process of change that has transformed life on Earth.
iv. The cultivation of marine organisms in fish farms built on littoral water is called (A. offshore B. inshore C. onshore D. integrated) mariculture.
v. Digitalis, which is used in treatment of heart disease, is obtained from the leaves of (A. *Digitalis purpurea* B. *Vinca* sp. C. *Papaver somniferum* D. *Cinchona* sp.).
vi. Plant fibres are (A. parenchymatous B. collenchymatous C. sclerenchymatous D. all of these) cells and are parts of the plant skeleton.

Sample Questions (Continued)

4. Match items in column A and B. Do not copy the statements. (6 marks)

Column A	Column B
i. Membrane-enclosed organelles	A. Jute
ii. Production of fruits and nuts	B. Protein
iii. Commercial breeding of fish	C. Microorganisms
iv. Body-building food	D. Pisciculture
v. Present in the soil act as a decomposing agent	E. Eukaryotes
vi. Very valuable best fibre	F. Pomology

5. Complete this paragraph about the themes of biology. Use words from this list. Each word may be used once, more than once, or not at all. (6 marks)

plants	animals	organisms	Eukarya
Bacteria	Archaea	evolutionary	species

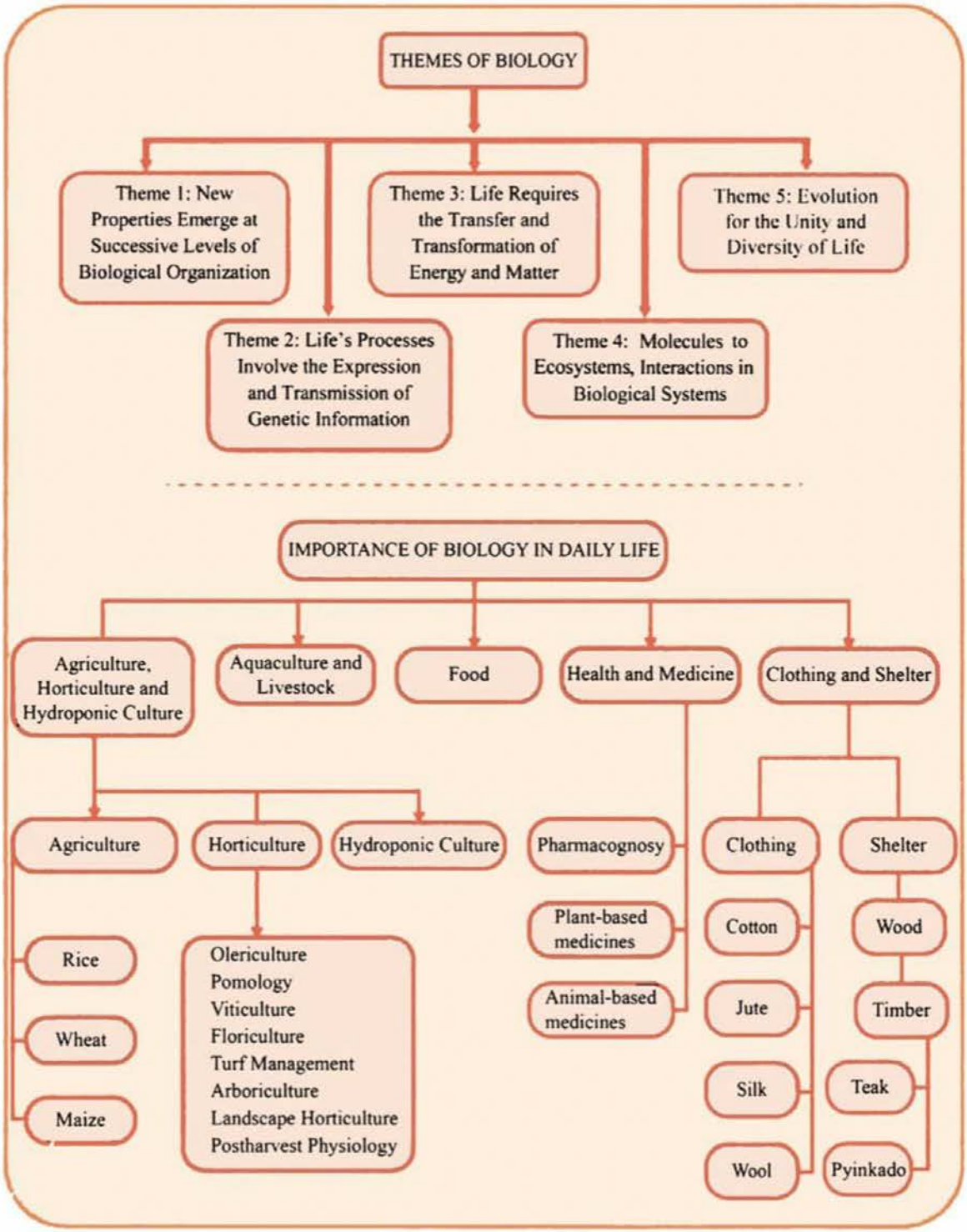
Biologists classify -----(a)----- according to a system of broader and broader groups. Domain -----(b)----- and -----(c)----- consist of prokaryotes. Domain -----(d)----- includes various groups of protists as well as plants, fungi, and -----(e)-----. Darwin proposed natural selection as the mechanism for -----(f)----- adaptation of populations to their environments.

6. Answer **ANY TWO** questions. (4 marks)
   a. State how to grow *Zea mays*.
   b. What is the integrated fish farming?
   c. Give a short account on the uses of wool.

7. Answer **ANY TWO** questions. (8 marks)
   a. How do you understand the gene expression?
   b. Briefly explain the pharmacognosy.
   c. Clarify the pharmacological role of salmon in the treatment of calcium regulating disorder.

8. Answer **ANY ONE** question. (8 marks)
   a. Write an interesting account on the hydroponic culture.
   b. Explain the role of leeches and maggots as animals-based medicines.
   c. Describe the economic value of livestock.

Concept Map


THEMES OF BIOLOGY
Theme 1: New Properties Emerge at Successive Levels of Biological Organization
Theme 2: Life's Processes Involve the Expression and Transmission of Genetic Information
Theme 3: Life Requires the Transfer and Transformation of Energy and Matter
Theme 4: Molecules to Ecosystems, Interactions in Biological Systems
Theme 5: Evolution for the Unity and Diversity of Life
IMPORTANCE OF BIOLOGY IN DAILY LIFE
Agriculture, Horticulture and Hydroponic Culture
Aquaculture and Livestock
Food
Health and Medicine
Clothing and Shelter
Agriculture
Horticulture
Hydroponic Culture
Rice
Wheat
Maize
Olericulture
Pomology
Viticulture
Floriculture
Turf Management
Arboriculture
Landscape Horticulture
Postharvest Physiology
Pharmacognosy
Plant-based medicines
Animal-based medicines
Clothing
Cotton
Jute
Silk
Wool
Shelter
Wood
Timber
Teak
Pyinkado

CHAPTER 2
MOLECULAR BIOLOGY

Learning Outcomes

It is expected that students will be able to

- learn the structure of DNA and RNA
- understand the role of DNA and the nature of its replication
- demonstrate how the sequence of three nucleotides combination is specified for a particular function
- describe two processes of transcription and translation in protein synthesis
- understand the basic knowledge of genetic engineering
- learn how transgenic golden rice is produced by genetic engineering method
- explain the processes how genetically modified animals are propagated

2.1 INTRODUCTION TO MOLECULAR BIOLOGY

Molecular biology is the branch of biology that seeks to understand the molecular basis of biological activity in and between cells, including biomolecular synthesis, modification, mechanisms, and interactions. The study of chemical, physical structures, and functions of biological macromolecules is known as molecular biology.

Nucleic acids are the main information-carrying molecules of the cell which direct the process of protein synthesis by determining the inherited characteristics of every living thing. The two main classes of nucleic acids are **deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)**. DNA is the master blueprint for life and constitutes the genetic material in all free-living organisms and most viruses. RNA is the genetic material of certain viruses, but it is also found in all living cells, where it plays an important role in certain processes such as the **making of proteins**.

2.1.1 The Structure of DNA

DNA is a **double helix** structure consisting of two polynucleotide strands twine around each other. Each polynucleotide strand is made up of many **nucleotide** molecules. Each nucleotide in DNA is composed of a five-carbon **deoxyribose sugar**, **a phosphate group**, and **a nitrogen-containing base**, all linked together by covalent bonds (Figure 2.1 A and B). Four different nitrogenous bases in DNA that can be categorized into two different forms: **purines** and **pyrimidines**. The purine bases are **adenine (A)** and **guanine (G)**. They have two fused rings in their chemical structures. The pyrimidine bases are **cytosine (C)** and **thymine (T)**. They have a single ring in their chemical structure.

Each strand forms a backbone of alternating phosphate groups and sugars. The bases of each nucleotide are attached to each sugar and protrude inward at regular intervals along each strand. There is a constant total distance between the sugar-phosphate backbones. The two strands of a DNA molecule are not identical but are, instead, complementary to each other. This means that a purine molecule is always paired with a pyrimidine molecule.

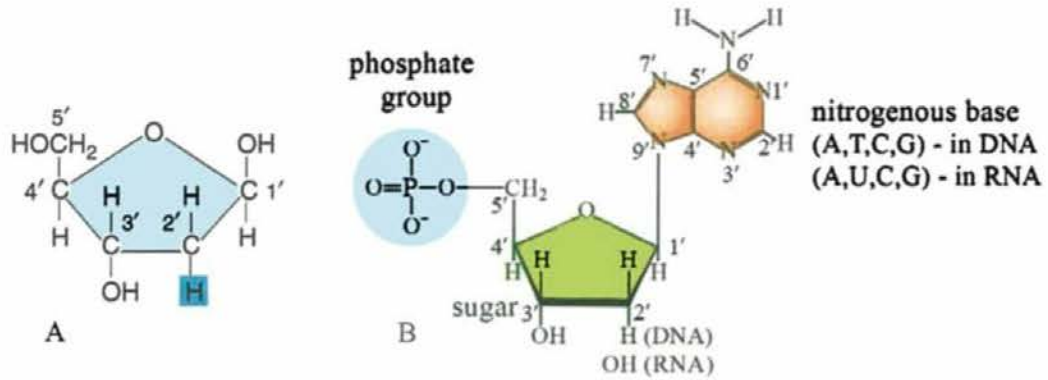


Figure 2.1 A. Position of carbon atom in deoxyribose sugar and B. A nucleotide molecule

Specifically, adenine (A) always pairs with thymine (T) and guanine (G) always pairs with cytosine (C). This pairing is called **complementary base pairing**. As the same bases always complement each other, the base sequence of one strand can be determined from the base sequence of the other strand (Figure 2.2 A). Hydrogen bonds link each complementary base pair. A and T are joined by two hydrogen bonds, while C and G with three hydrogen bonds (Figure 2.2 B).

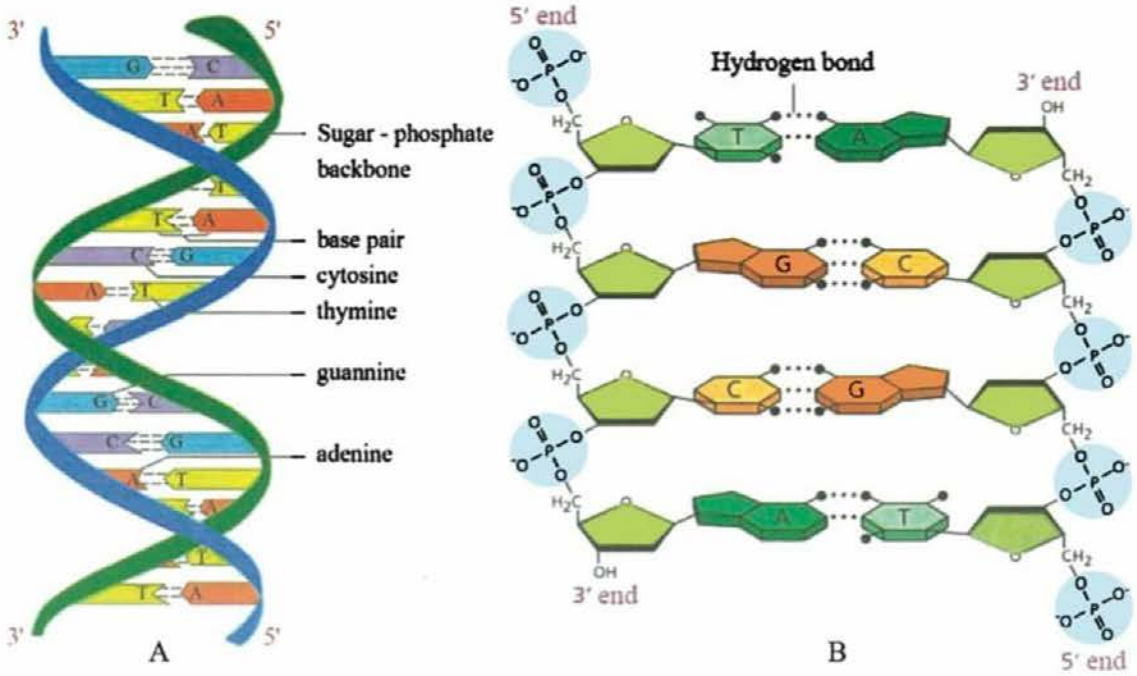


Figure 2.2 A. Double helix structure of DNA and B. Part of unwind DNA

The two strands of a DNA molecule are antiparallel (Figure 2.2 A). So, the sugar molecules are oriented differently. Therefore, each strand has directionality, or a specific orientation. (This is similar to how two sports teams are facing in a different direction when they shake hands before and after a game.). **One strand lies in 5′ to 3′ direction** and **another strand in 3′ to 5′ direction**.

The 5′ and 3′ come from the numbering of the carbons on the **deoxyribose sugar**. The **phosphate group** is on the **5′ carbon**, and the **OH group** is on the **3′ carbon**. Therefore, the **end with phosphate group** is always referred as **5′ end** and the **opposite end** of it will be **3′ end** (Figure 2.2 B). By convention, the sequence of a DNA strand is always written in the 5′ to 3′ direction.

2.1.2 The Structure of RNA

Like DNA, RNA is a polymer of nucleotides. RNA contains four nucleotides with the bases adenine (A), uracil (U), cytosine (C), and guanine (G). Unlike DNA, RNA is single-stranded. However, tRNA can fold back on itself, and complementary base pairing within the same molecule stabilizes the looped structure (Figure 2.3).

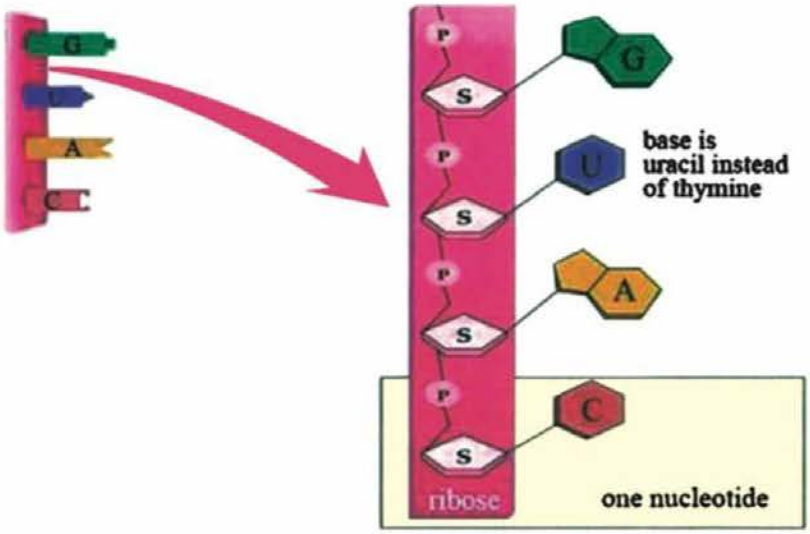


Figure 2.3 Structure of RNA

There are several types of RNA molecules. Since all are produced from a DNA template, all are synthesized in the nucleus. Only three different RNA molecules that involved in protein synthesis and their functions are listed in Table 2.1.

Table 2.1 Some different types of RNA molecules involved in protein synthesis

Types of RNA	Function
Messenger RNA (mRNA)	Acts as the template for translation
Transfer RNA (tRNA)	Carries specific amino acid to mRNA at ribosome
Ribosomal RNA (rRNA)	Reads the codon on mRNA

2.1.3 The Role of DNA

DNA is the hereditary material responsible for passing genetic information from cell to cell and generation to generation. In total, there are around 3.2 billion base pairs in the DNA of a typical mammalian cell. This vast number means that there are an almost infinite variety of sequences or bases along the length of a DNA molecule. It is this variety that provides the genetic diversity within living organisms.

The DNA molecule is adapted to carry out its functions in a number of ways:

- It is a very stable structure which normally passes from generation to generation without change. Only rarely does it mutate.
- Its two separate strands are joined only with hydrogen bonds, which allow them to separate during DNA replication and protein synthesis.
- It is an extremely large molecule and therefore carries a large amount of genetic information.
- By having the base pairs within the helical structure of the deoxyribose-phosphate backbone, the genetic information is to some extent protected from being corrupted by outside chemical and physical forces.
- Base pairing leads to DNA being able to replicate and to transfer information to mRNA.

The function of the remarkable molecule, DNA depends on the sequence of base pairs that it possesses. This sequence is important to everything it does and, indeed, to life itself.

2.1.4 DNA Replication

DNA replication is the making of an exact copy of the DNA molecule. The replication is made by a semiconservative method, which was predicted by Watson and Crick and proven by Meselson and Stahl. It is regarded as **semiconservative** because each of the resulting two molecules **consists of one old strand and one new strand**.

The description of DNA replication is as follow:

1. Proteins and enzymes assist in replication of DNA. Replication begins at special sites called origins of replication, the replication bubbles form (Figure 2.4). **Helicase** enzymes unwind the double helix and unzip the two parental strands by breaking hydrogen bonds. The separated two parental strands act as templates. Single-stranded binding proteins act as scaffolding, holding the two strands apart. **Topoisomerase** lessens the tension on the tight helix.

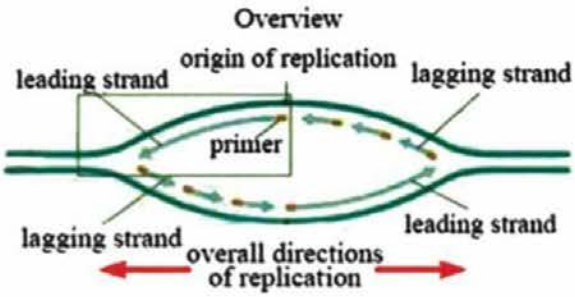


Figure 2.4 A replication bubble

2. At each end of the replication bubble is a replication fork, a Y-shaped region where the new strands of DNA are elongating (Figure 2.5).
3. DNA polymerase III cannot initiate the synthesis. The preexisting chain actually consists of RNA primer produced by an enzyme called primase. As the two strands of DNA are antiparallel, they are oriented in opposite directions to each other. Therefore, the formation of two new strands must also be antiparallel to their template strands. DNA polymerase can only add complementary nucleotides, C with G and A with T, to the free 3′ end of the primer, never to the 5′ end. Thus, a new DNA strand can elongate only in the 5′ to 3′ direction.

4. DNA polymerase replicates the two original strands differently. Although it builds both new strands in the 5′ to 3′ direction, one strand is formed towards the replication fork in **continuous** and **linear fashion**. This is called the **leading strand**. The other strand, the **lagging strand**, forms in direction away from the replication fork, in a series of segments called **Okazaki fragments**. Each Okazaki fragment is about 100-200 nucleotides long and then they are joined into one continuous strand by the enzyme DNA ligase.

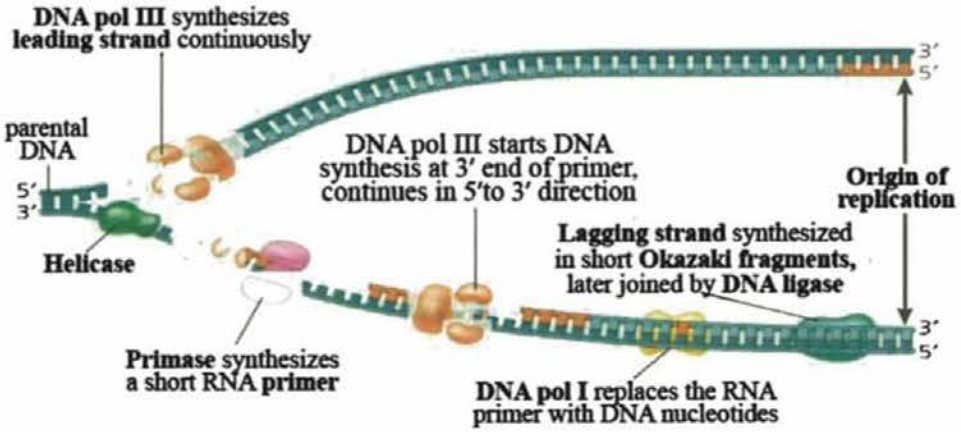


Figure 2.5 DNA replication at one replication fork

5. DNA polymerase I carry out mismatch repair, a kind of proofreading that corrects errors. Damaged regions of DNA are excised out by DNA nuclease (Figure 2.6).

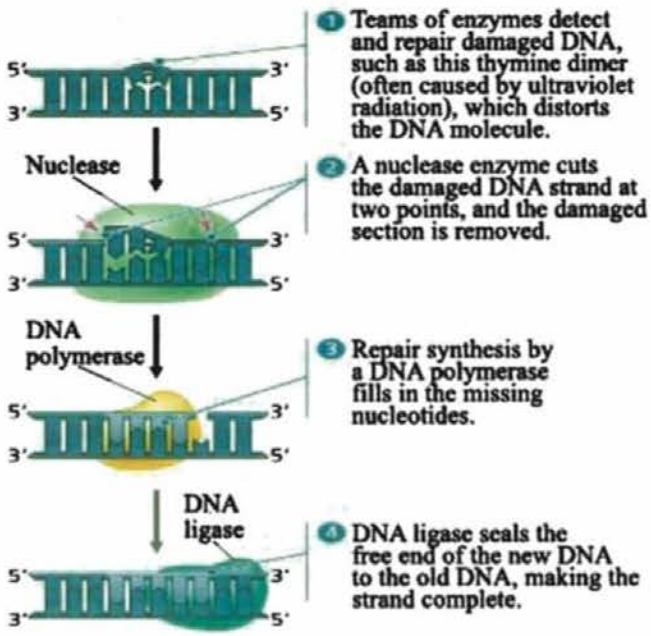


Figure 2.6 Nucleotide excision repair of DNA damage

6. Each time the DNA replicates, some nucleotides from the chromosome are lost. To protect against the possible loss of genes at the end of the chromosomes, eukaryotes have special nonsense nucleotide sequences (TAAGGG) at the ends of chromosomes that repeat thousands of times. These protective ends are called telomeres, which are created and controlled by the enzyme telomerase. So, every time DNA replicate, the telomeres get shorter (Figure 2.7).

Protein	Function
Helicase 	Unwinds parental double helix at replication forks
Single-strand binding protein 	Binds to and stabilize single-stranded DNA until it is used as a template
Topoisomerase 	Relieves overwinding strain ahead of replication forks by breaking, swiveling, and rejoining DNA strands
Primase 	Synthesizes an RNA primer at 5' end of leading strand and at 5' end of each Okazaki fragment of lagging stand
DNA pol III 	Using parental DNA as a template, synthesizes new DNA strand by adding nucleotides to an RNA primer or a pre-existing DNA strand
DNA pol I 	Removes RNA nucleotides of primer from 5' end and replaces them with DNA nucleotides
DNA ligase 	Joins Okazaki fragments of lagging strand; on leading strand, joins 3' end of DNA that replaces primer to rest of leading strand DNA

Figure 2.7 Enzymes that take part in DNA replication and their function

2.2 GENETIC CODE

Genetic code is a set of rules for determining how genetic information in the form of a nucleotide sequence is converted to an amino acid sequence of a protein. It defines a code specifying the relationship between a nucleotide codon and an amino acid.

Researchers knew that there are only four nucleotides in RNA (A, U, G, and C), but 20 different kinds of amino acids. Therefore, there could not be a one-to-one relationship between nucleotides and amino acids. Even using two nucleotides per amino acid would only provide 4 ×

4, or 16 possible combinations, which is not enough to code for 20 amino acids. Thus, the minimum combination of the four nucleotides was **a triplet code**, which could produce 4 × 4 × 4, or **64 possible combinations**. From this reasoning came the triplet hypothesis, which proposed that the genetic code consists of **a combination** of **three nucleotides**, called **a codon**.

Between 1961 and 1965, various research groups compared artificially synthesized RNA molecules of known nucleotide sequences with the amino acid sequences of polypeptides. From these studies, the mRNA codons and their corresponding amino acids were determined. These are listed in Table 2.2.

Table 2.2 The Genetic Code of mRNA

First mRNA base (5′ end of codon)	Second mRNA base: U	C	A	G	Third mRNA base (3′ end of codon)
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	UGU Arg	U
	CUC Leu	CCC Pro	CAC His	UGC Arg	C
	CUA Leu	CCA Pro	CAA Gln	UGA Arg	A
	CUG Leu	CCG Pro	CAG Gln	UGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	UGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	UGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	UGA Arg	A
	AUG Met or Start	ACG Thr	AAG Lys	UGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	UGU Gly	U
	GUC Val	GCC Ala	GAC Asp	UGC Gly	C
	GUA Val	GCA Ala	GAA Glu	UGA Gly	A
	GUG Val	GCG Ala	GAG Glu	UGG Gly	G

AUG is a **start codon**. It also codes for **the amino acid methionine**.
UAA, UAG, and **UGA** are **terminator codons**.

By convention, the genetic code is always interpreted in terms of the mRNA codon rather than the nucleotide sequence of the DNA.

The genetic code has three important characteristics.

1. The genetic code is **redundant**. This means that **more than one codon can code for the same amino acid**. There are **only three codons that do not code for any amino acid**. These codons serve as **"stop" signals** to end protein synthesis.
2. The genetic code is **continuous**. This means that it reads as **a series of three-letter codons without spaces, punctuation, or overlap**. Therefore, knowing exactly where to start and stop protein synthesis is essential. A shift of one or two nucleotides in either direction can alter the codon groupings and result in an incorrect amino acid sequence.

3. The genetic code is **nearly universal**. Almost all organisms build **proteins with the genetic code** shown in Table 2.2. (Some rare exceptions are known in some species of protists, for example.) The universality of the genetic code means that a codon in the fruit fly codes for the same amino acid as in a human. This has important implications for gene technology, such as cloning. A gene that is taken from one kind of organism and inserted into another kind of organism will produce the same protein.

2.3 PROTEIN SYNTHESIS

The two steps in protein synthesis are transcription and translation. In transcription, mRNA is synthesized based on the DNA template of a gene. This is followed by translation, which involves the production of a protein with an amino acid sequence that is based on the nucleic acid sequence of the mRNA. The central dogma of molecular biology stated that genetic information flows from DNA to RNA to Protein. The translation of nucleotide sequence to amino acid sequence uses the genetic code (Figure 2.8).

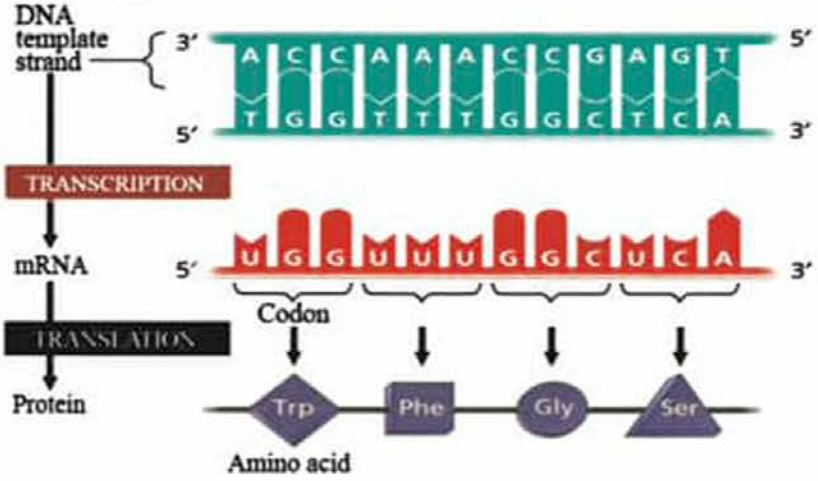


Figure 2.8 Two steps in protein synthesis; transcription and translation

2.3.1 Transcription

Transcription occurs in the nucleus of the cell (Figure 2.15). It is the process of copying sequence of DNA to mRNA. There are three defined stages in the transcription process; initiation, elongation, and termination.

Initiation: For each gene, **only one strand of the double-stranded DNA molecule is transcribed**. This strand is called the **antisense strand** or **template strand**. The other strand, which is not transcribed, is called the **sense strand** or **coding strand**. It has the same sequence as the product mRNA, with thymine instead of uracil.

Elongation: During the elongation phase shown, the RNA polymerase complex works its way along the DNA molecule, synthesizing a strand of mRNA that is complementary to the template strand of DNA in 5′ to 3′ direction.

Termination: When the RNA polymerase complexes reach the termination signal, they detach from the DNA strand. The new mRNA strand is released from the transcription assembly.

2.3.2 Modification of mRNA

The newly synthesized mRNA is called **precursor mRNA** or **pre-mRNA**. Before moving out from the nucleus to the cytoplasm, the following modifications convert pre-mRNA to mature mRNA.

1. Addition of a 5′ cap at 5′ end (Figure 2.9 A)
2. Addition of a 3′ poly-A tail at 3′ end (Figure 2.9 B)
3. Removal of introns (non-coding regions) with specific enzyme and the remaining exons (coding regions) are joined (Figure 2.10).

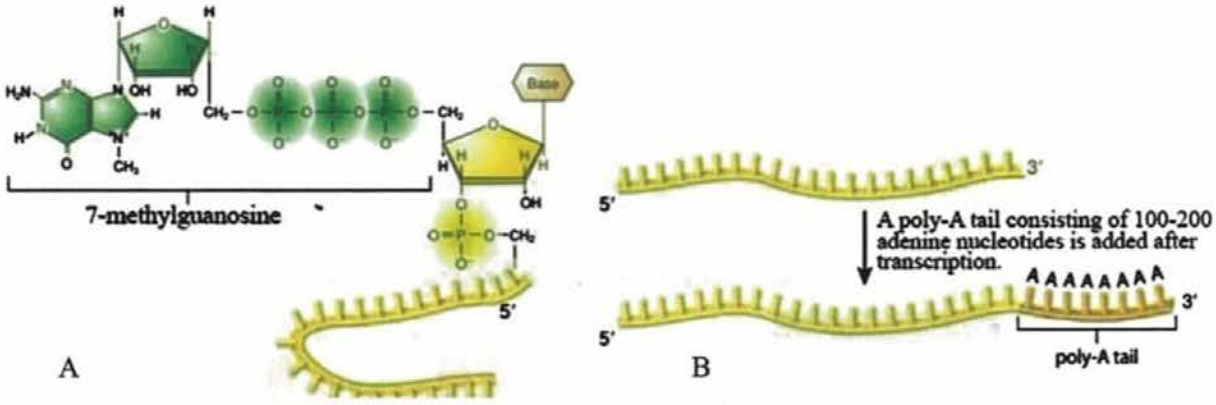


Figure 2.9 A. Addition of G cap at the 5′end
B. Addition of a poly-A tail at the 3′end of eukaryotic mRNA molecule

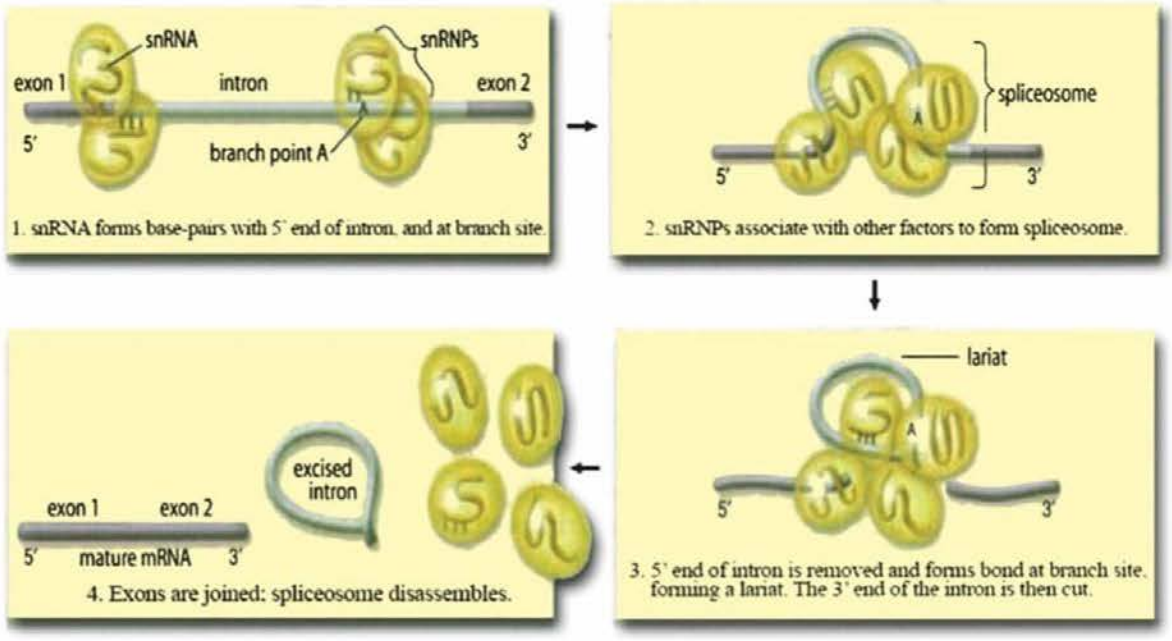


Figure 2.10 The process of splicing (removal of introns and joining of exons)

2.3.3 Translation

The second stage of protein synthesis involves translation which occurs in the cytoplasm (Figure 2.15). It is the conversion of a sequence of nucleotides into a sequence of amino acid in the polypeptide chain. There are two subunits in the ribosome. At the small subunit, mature mRNA is attached. There are three binding sites for tRNA on the large subunit of ribosome: A site, P site and E site. Each tRNA carries the specific amino acid at a time at its **acceptor stem** (Figure 2.11). Opposite to the acceptor stem is **the anticodon** which connects to the specific codon on the mRNA.

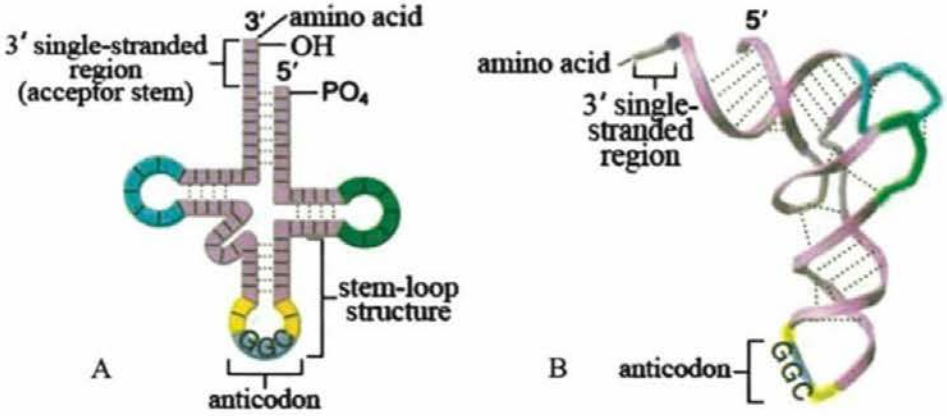


Figure 2.11 A. Two-dimensional structure of tRNA and B. Three-dimensional structure of tRNA

Initiation

In the initiation phase, all the translation components come together. The small ribosomal sub-unit attaches to the mRNA near the **start codon (AUG)**. The first tRNA that binds to the codon is the initiator tRNA with its **UAC anticodon,** which joins with the **AUG codon** of mRNA. Then, a large ribosomal sub-unit joins to form the active ribosome (Figure 2.12).

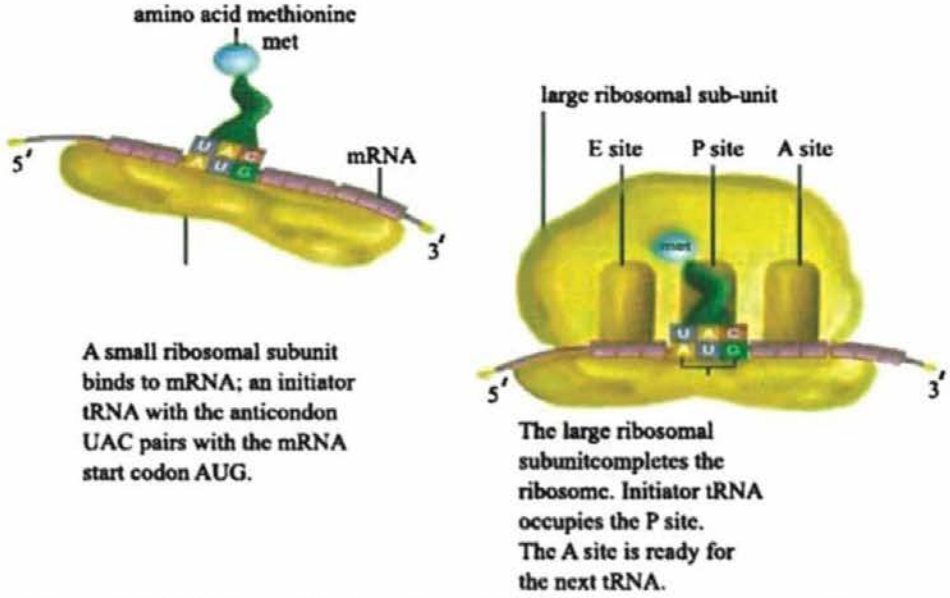


Figure 2.12 During initiation of translation, the components assemble. The first tRNA base-pairs with the start codon AUG.

Elongation

The polypeptide becomes longer, adding one amino acid at a time. During elongation, a cycle of four steps is rapidly repeated. First, a tRNA with an attached polypeptide is in the P site, then, peptide bond is formed and tRNA carrying the next amino acid enters the A site. Next, the polypeptide chain is transferred to the amino acid of the tRNA in the A site. This makes the polypeptide chain one amino acid longer than before. Last, the mRNA moves forward by one codon, and the polypeptide-bearing tRNA is now at the ribosome P site. The uncharged tRNA exits. The new codon is at the A site and can receive the next complementary tRNA carrying the next amino acid of the polypeptide (Figure 2.13).

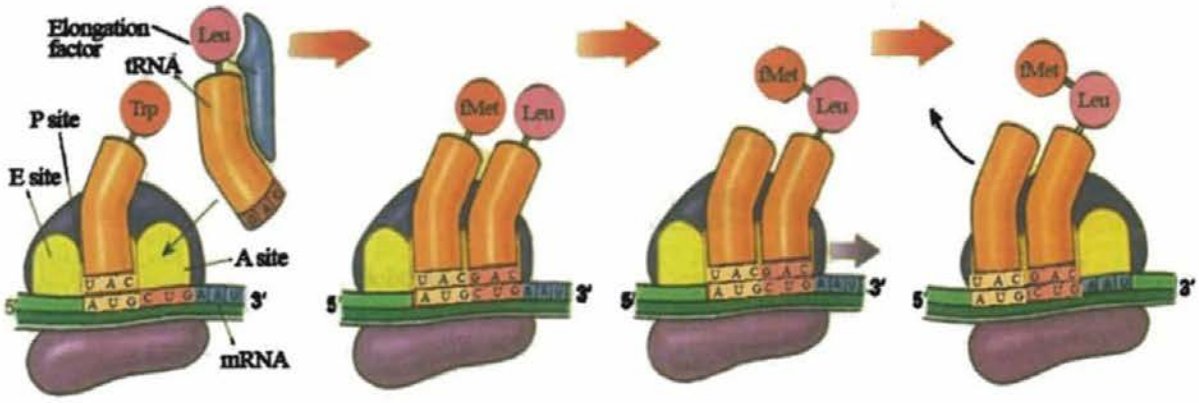


Figure 2.13 Elongation

Termination

The termination phase begins when a stop codon on the mRNA is reached. The polypeptide and the components of the translation machinery are separated. A protein, called a release factor, cleaves (cuts) the polypeptide from the last tRNA. The polypeptide is released and will eventually fold into its three-dimensional shape as protein, ready to carry out its cellular activities (Figure 2.14 and 2.15).

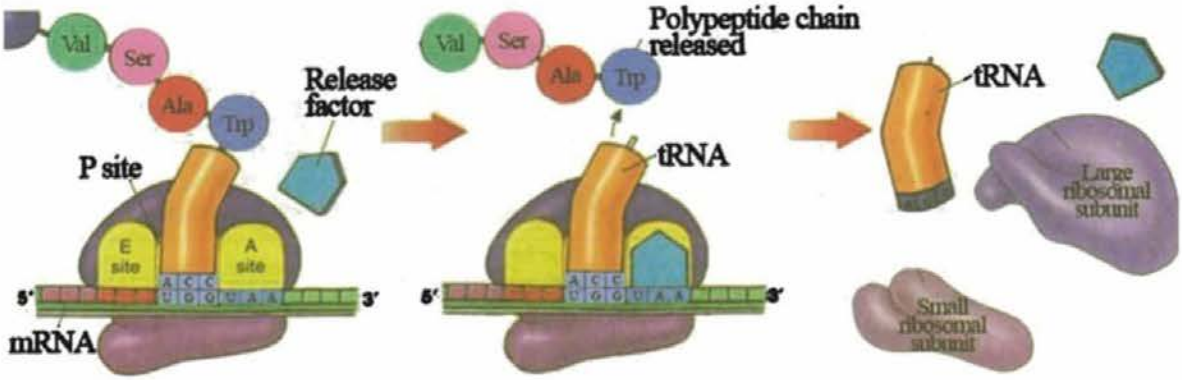


Figure 2.14 Termination

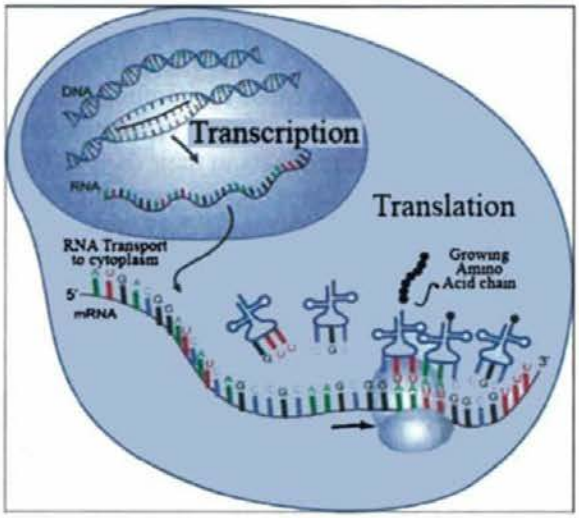


Figure 2.15 Protein synthesis: Transcription and translation

2.4 SOME TECHNIQUES IN MOLECULAR BIOLOGY

There are some exciting technologies emerging from research in molecular genetics, which has provided the ability to manipulate the genes of organisms (microorganisms, plants, and animals). Scientists can now use genetically modified organisms (GMOs) to produce medications, to profile the DNA sequence of a cancerous tumour, and to treat genetic disorders by introducing the correct form of a disease-related gene into an individual's genome. Another intriguing research focus is the relationship between aging and chromosomes.

2.4.1 Production of Genetically Engineered Organisms

Genetic engineering is the alteration of the genetic material of an organism in a specific manner. Transgenic bacteria, plants, and animals are commonly referred to as genetically modified organisms (GMOs). Transgenic describes an organism that is produced from the introduction of foreign DNA into its genome, providing it with a new phenotype. The recombinant DNA techniques and methods of DNA analysis are integral to the production of GMOs.

2.4.2 Recombinant DNA

It is a method of transferring a gene from one organism into the genome of another organism of different species. In order to insert the recombinant gene into a target cell, a vector is needed, which may be plasmid of bacteria, harmless virus, liposome or gene gun (Figure 2.16).

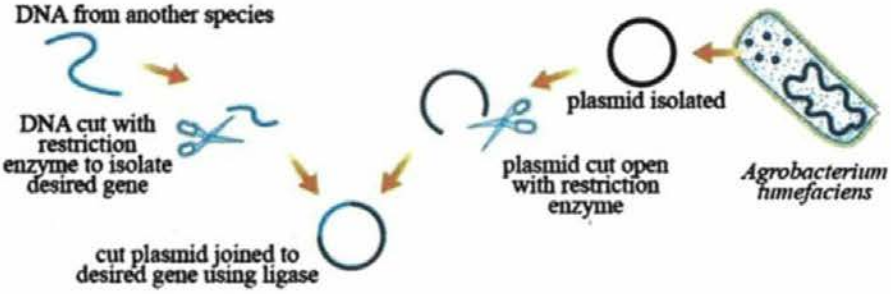
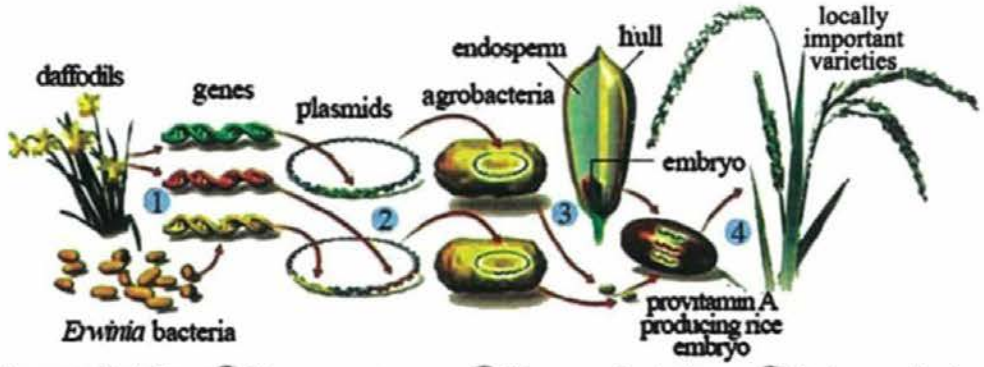


Figure 2.16 Production of recombinant DNA

2.4.3 Production of Golden Rice

Rice is a staple food in many parts of the world. Vitamin A deficiency can cause blindness. Even more importantly, lack of vitamin A can cause an immune deficiency syndrome, and this is a significant cause of mortality in some parts of the world, particularly in children. Children of families living in poverty often lack animal products in their diets as they are too expensive. Even if such children have a diet containing a wide range of vegetables rich in carotenoids, it is still difficult for them to avoid vitamin A deficiency. Figure 2.17 shows how the transgenic rice plant was carried out.



1. The genes that give golden rice its ability to make betacarotene in its endosperm come from daffodils and *Erwinia* bacteria
2. These genes are inserted into the plasmids that occur inside *Agrobacterium*.
3. These agrobacteria are then added to a petridish containing rice embryo. As they infect the embryo, they transfer the genes that encode the instructions for making beta-carotene.
4. The transgenic rice plants must now be crossed with strains of rice that are grown locally and are suited to a particular region's climate and growing conditions.

Figure 2.17 Production of golden rice

Further research showed that substituting the gene from daffodils plant with one from maize gave even higher quantities of carotene, and the single transformation with these genes is the basis of all current Golden Rice. The genetically modified rice is called **Golden Rice**, because it contains a lot of the orange pigment **beta-carotene** which can be converted into **vitamin A** when it is eaten.

Benefits of genetic engineering of crops include:

i. increased crop yield,
ii. increased heat and drought tolerance,
iii. increased resistance to a range of pests and pathogens,
iv. increased salt tolerance, reduction in harvesting cost and pesticide use, and
v. enhanced nutritional value and food quality due to slower spoilage.

Moreover, plants are also being engineered to produce medicinal products. Since the mid-1980s, products such as **human growth hormone**, **clotting factors**, and **antibodies** have been produced in **transgenic plants**. For instance, one type of antibody made by **corn** can deliver **radioisotopes** to **tumour cells**. Another made by **soybeans** can be **used to treat genital herpes**.

2.4.4 Production of Genetically Modified Animals

The production of transgenic animals is a much more complex process than the production of transgenic plants, and not surprisingly, it is also highly controversial. To produce transgenic animals, a foreign gene is inserted into the genome of an animal oocyte (egg) that is then fertilized. The fertilized egg is implanted in a host female and allowed to develop. The resulting offspring are the transgenic form of the animal. The procedure has been used to **produce transgenic fish**, **pigs**, **cows**, **rabbits**, and **sheep**.

Transgenic animals can be used to produce **pharmaceutical products** such as **human proteins** by using a **recombinant plasmid vector**. The vector contains the gene for the growth protein as well as the promoter that directs the expression of the genes in mammary cells. The recombinant DNA is then injected into an oocyte. The oocyte is fertilized and implanted into a host female. The transgenic animals are the offspring produced from that implantation. The milk of female transgenic offspring contains human growth protein (Figure 2.18).

Benefits of GM animals are (i) increased production of a particular product, higher milk yield in cows, greater muscle mass in animals used for meat, (ii) increased resistance to disease, (iii) manufacture of human proteins, such as antibodies, blood clotting factors or important proteins for medicinal purposes and (iv) production of organs for transplantation (**xero-transplantation**).

Figure 2.18 Production of genetically modified animal

Sample Questions

1. State **TRUE** or **FALSE** to the following statements. Do not copy the statements. (6 marks)
   i. By convention, the sequence of a DNA strand is always written in the 3′ to 5′ direction.
   ii. DNA polymerase III cannot initiate the synthesis of new DNA strand.
   iii. Okazaki fragments are joined into one continuous strand by the enzyme DNA ligase.
   iv. The second stage of protein synthesis involves translation which occurs in the nucleus.
   v. The disease-free gene was introduced into an individual's genome to treat the genetic disorders.
   vi. Children of families living in poverty often lack animal products in their diets.

2. Complete the following statements with appropriate words. Do not copy the statements. (6 marks)
   i. DNA is a double ---------- consisting of two polynucleotide strands twine around each other.
   ii. DNA consists of two ---------- sugar-phosphate chains.
   iii. During DNA replication, the damaged regions of DNA are excised out by DNA ----------.
   iv. The two steps in protein synthesis are transcription and ----------.
   v. Vitamin A deficiency can cause ----------and immune deficiency syndrome.
   vi. One type of antibody made by corn can deliver radioisotopes to ---------- cells.

3. Choose the correct answer for the following statements. Do not copy the statements. (6 marks)
   i. Unlike DNA molecule, RNA molecule does not consist of (A. adenine B. guanine C. uracil D. thymine).
   ii. (A. Messenger B. Transfer C. Ribosomal D. Template) RNA reads the codon on mRNA.
   iii. (A. DNA polymerase III B. Helicase C. Topoisomerase D. DNA ligase) enzyme unwind the double helix and unzip the two parental strands.
   iv. A triple code of nucleotides could produce (A. 8 B. 16 C. 64 D. 32) possible combinations.
   v. The small ribosomal sub-unit attaches to the mRNA near the start codon (A. UAA B. AUG C. UAG D. UGA).
   vi. In order to insert the recombinant gene into a target cell, a vector such as (A. parasite B. fungus C. plasmid of bacteria D. harmful virus) is needed.

Sample Questions (Continued)

4. Match items in column A and B. Do not copy the statements. (6 marks)

Column A	Column B
i. Cytosine and guanine	A. Always pairs with thymine
ii. A codon	B. Copying the sequence of DNA to mRNA
iii. Adenine	C. Semiconservative method
iv. Transgenic	D. Joined by three hydrogen bonds
v. DNA replication	E. Genetically modified organism
vi. Transcription	F. A combination of three nucleotides

5. Complete this paragraph about the structure of DNA. Use words from this list. Each word may be used once, more than once, or not at all. (6 marks)

thymine	uracil	oxyribose	deoxyribose
purines	nucleotide	covalent	guanine

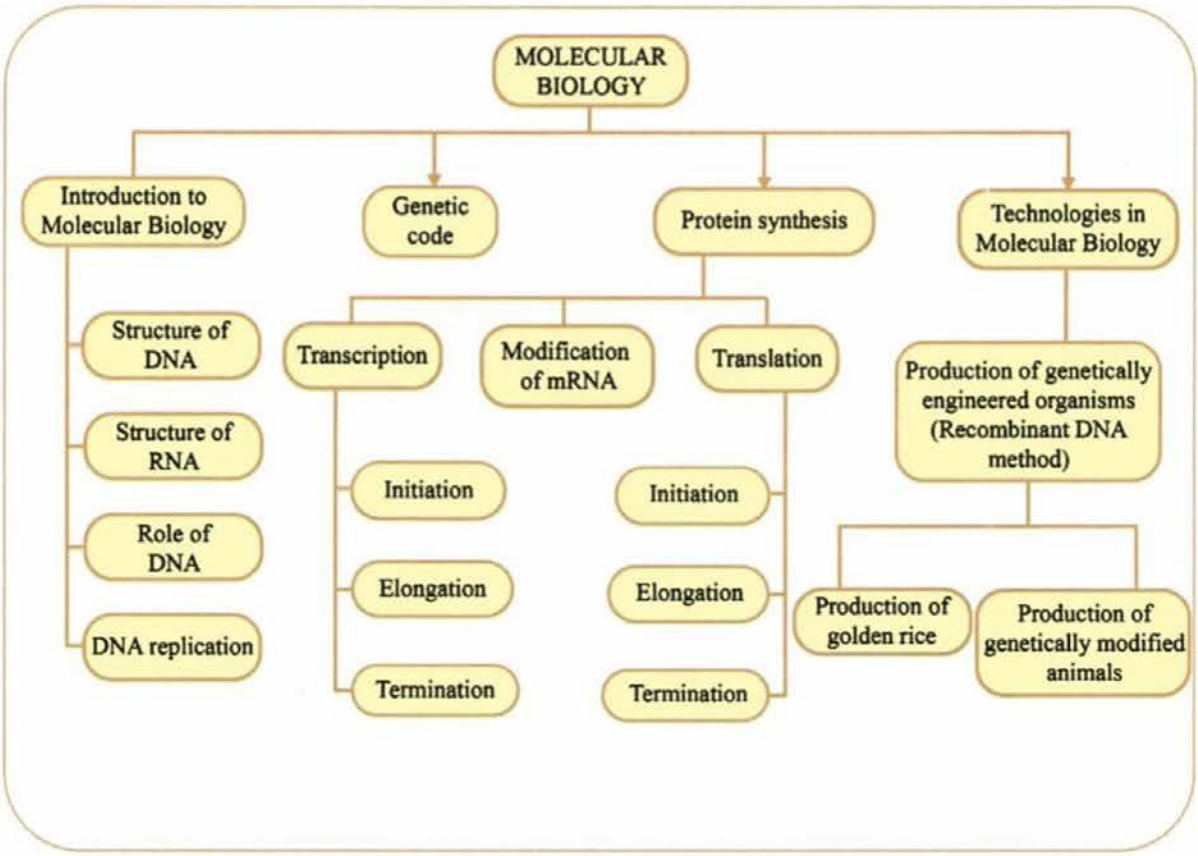
Each -----(a)----- in DNA is composed of a five-carbon -----(b)----- sugar, a phosphate group, and a nitrogen-containing base, all linked together by -----(c)----- bonds. Four different nitrogenous bases in DNA that can be categorized into two different forms: -----(d)----- and pyrimidines. The purine bases are adenine and -----(e)-----. They have two fused rings in their chemical structures. The pyrimidine bases are cytosine and -----(f)-----. They have a single ring in their chemical structure.

6. Answer **ANY TWO** questions. (4 marks)
   a. Give a short account on the formation of leading strand and lagging strand during DNA replication.
   b. State briefly on the recombinant DNA method.
   c. Mention four benefits of crops engineered by genetically modified method.

7. Answer **ANY TWO** questions. (8 marks)
   a. Give the structure of RNA molecule together with different types and their function.
   b. Clarify the different stages of the transcription in protein synthesis.
   c. How does a strand of mRNA elongate during protein synthesis?

8. Answer **ANY ONE** question. (8 marks)
   a. Discuss the role of DNA in molecular biology as far as you can.
   b. State the three important characteristics of the genetic code.
   c. Give an account of the production of genetically modified animals.

Concept Map


MOLECULAR BIOLOGY
Introduction to Molecular Biology
Genetic code
Protein synthesis
Technologies in Molecular Biology
Structure of DNA
Structure of RNA
Role of DNA
DNA replication
Transcription
Modification of mRNA
Translation
Initiation
Elongation
Termination
Initiation
Elongation
Termination
Production of genetically engineered organisms (Recombinant DNA method)
Production of golden rice
Production of genetically modified animals

CHAPTER 3
TRANSPORT SYSTEM IN ORGANISMS

Learning Outcomes

It is expected that students will be able to

- investigate the important functions and operation of a transport system as well as their mechanisms in plants
- describe the structure of transport tissues (xylem and phloem) in plants
- explain how water is conducted in a plant
- define transpiration and explain the factors that are affecting on the transpiration and its benefits
- demonstrate how transpiration pull takes place
- define translocation and explain its functions in plants
- understand why a circulatory system is needed in larger animals
- understand the features of mass transport system
- differentiate the types of circulatory system in animals
- demonstrate the components of cardiovascular system in mammals
- understand vividly on how the structures of the heart, arteries, veins and capillaries are related to their functions
- achieve the knowledge on the sequential events of the cardiac cycle
- know the role of lymphatic system in human

3.1 TRANSPORT SYSTEM IN PLANTS

Plants make their own organic molecules, using the process of photosynthesis. Carbon dioxide is the source of carbon and light is the source of energy. The main photosynthetic organs are the leaves, which have evolved a large surface area to volume ratio for efficient capturing of carbon dioxide and light. A large surface area to volume ratio means more area for collection of light and carbon dioxide and less distance for carbon dioxide to diffuse into the leaf and for oxygen to diffuse out.

As a result, most plants do not have compact bodies like animals, but have extensive branching bodies with leaves above the ground. In order to obtain the water and mineral salts they needed for nutrition, plants have extensive root systems below the ground. The plant body therefore spreads out to obtain the carbon dioxide, light energy, water and inorganic mineral ions from its environment to make organic molecules like sugars and amino acids (Figure 3.1).

Transport systems are needed for the following reasons:

- To move substances from where they are absorbed to where they are needed, for example, water and mineral ions are absorbed by roots and transported through the xylem to other parts of the plant.

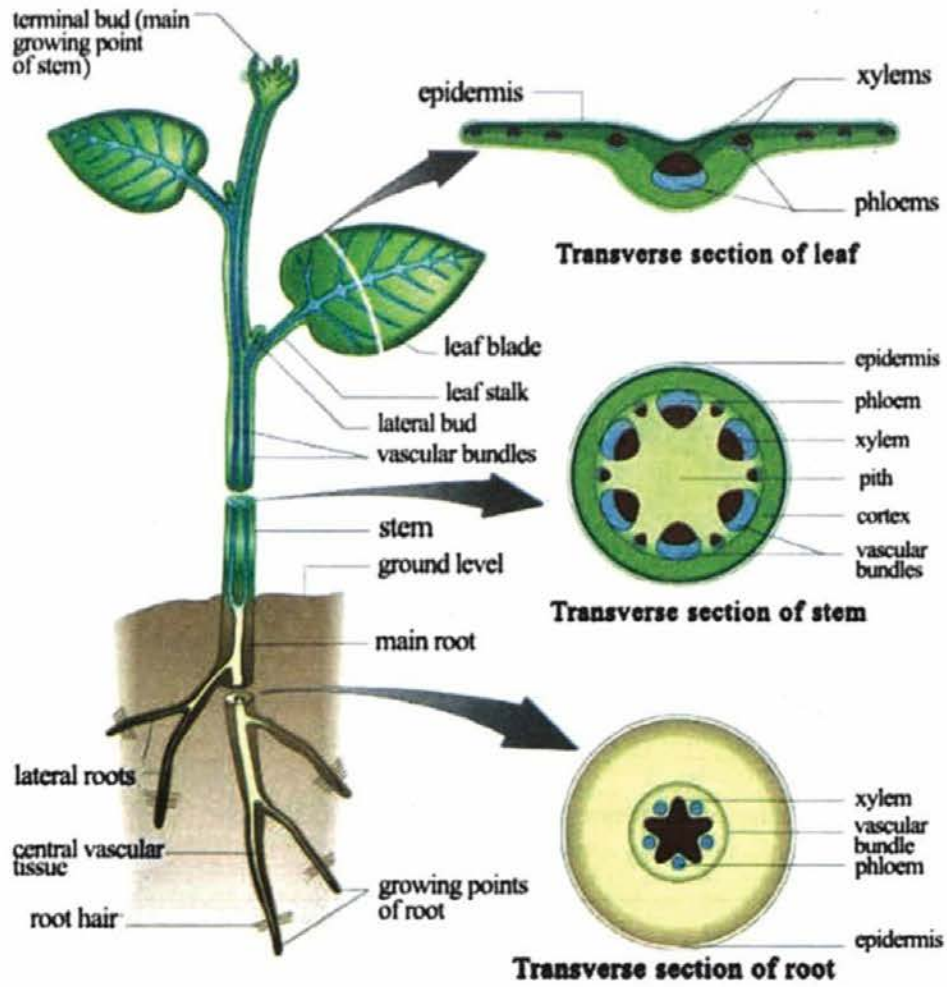


Figure 3.1 Transport in a plant

- To move substances from where they are produced to where they are needed for metabolism. For example, sugars are produced in leaves, but glucose is needed by all parts of the plant for respiration and for converting to cellulose for making cell walls in areas of growth. Glucose can be moved through the phloem as part of the sucrose molecule.
- To move substances to a certain part of the plant for storage, for example, sugars usually change into the form of starch, for storage in a potato tuber.

3.1.1 Structure of Transport Tissues

Plants can be very large, but they have a branching shape that helps to keep the surface area to volume ratio large. Their energy needs are generally small compared with those of animals, so respiration does not take place quickly. They can rely on diffusion to supply their cells with oxygen and to remove carbon dioxide. Their leaves are very thin and have a large surface area inside them in contact with the air spaces. This means that diffusion is sufficient to supply the mesophyll cells with carbon dioxide for photosynthesis, and to remove oxygen.

Plants have two transport systems:

- **Xylem**, which transports water and inorganic ions from the roots to all parts of the plant.
- **Phloem**, which transports substances made in the plant, such as sucrose and amino acids, from the leaves to all other parts of the plant.

Xylem tissue contains dead, empty hollow cells with no end walls. These are composed of **xylem vessels** which are arranged in long lines to form a hollow tube. Water moves through these long, hollow tubes by mass flow from the roots to all other parts of the plant.

Phloem tissue contains cells called **sieve tube**. Unlike xylem vessel, these are living cells and contain cytoplasm and a few organelles but no nucleus. Their walls are made of cellulose. A **companion cell** is associated with each sieve tube (Figure 3.2).

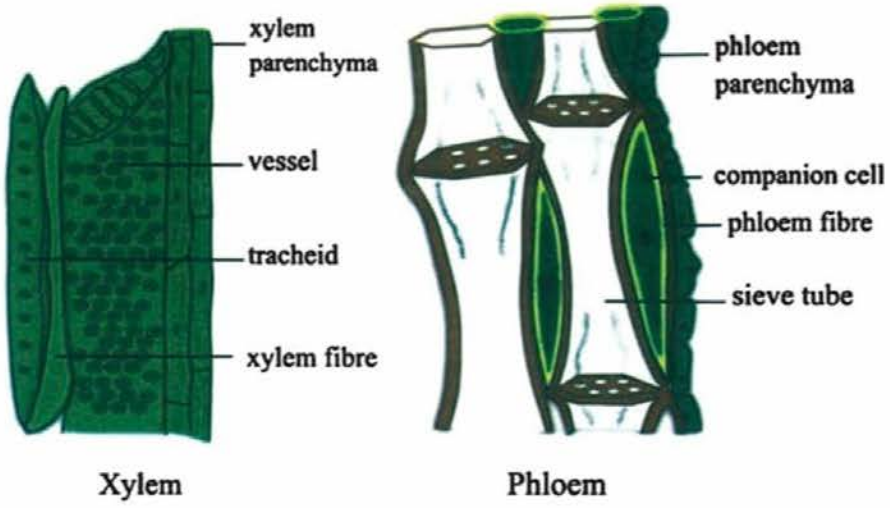


Figure 3.2 Transport tissues in plants

3.2 TRANSPORT MECHANISMS IN PLANTS

Within a plant, **mineral ions** and **organic compounds** (e.g., sucrose) are transported by being **dissolved in water**. The **dissolved mineral ions** are transported in the **xylem** tissue and the **dissolved organic compounds** are transported in the **phloem** tissue. The plant roots are responsible for the uptake of water and mineral ions and can have root hairs to increase the surface area for absorption of the substances. The **uptake of water** is a **passive** process and occurs by **osmosis** (the diffusion of water from a higher water potential to a lower water potential). The uptake of minerals can be passive transport such as diffusion and osmosis, and/or active transport.

3.2.1 Movement of Water in a Plant

In the active absorption, the water first enters the cell sap and passes from one cell to another. This type of movement where protoplasm is involved is called **symplast**. In passive absorption, water moves through the **apoplast** of the root. The apoplast path includes the cell wall and intercellular spaces.

Two pathways are apoplastic and symplastic that initiate the passage of water along with ions from root hair via root cortex to xylem. These routes may exist either simultaneously or separately having different rates (Figure 3.3).

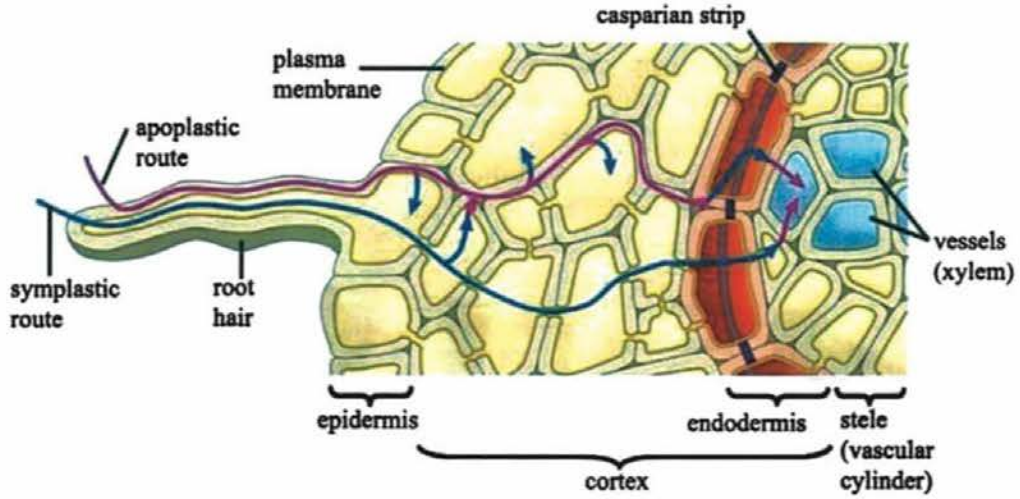


Figure 3.3 Apoplastic and symplastic pathway

Apoplastic pathway

- Most water travels via the apoplastic pathway (when transpiration rates are high), which is the series of **spaces** running through the **cellulose cell walls**, dead cells, and the hollow tubes of the xylem.
- The water moves by **diffusion** (as it does not pass through a partially permeable membrane).
- The water can move from cell wall to cell wall directly or through the intercellular spaces.
- The movement of water through the apoplastic pathway occurs more rapidly than the symplastic pathway.
- When the water reaches the endodermis the presence of a thick, waterproof, waxy band of **suberin** within the cell wall blocks the apoplastic pathway.
- This band is called the **Casparian strip** and forms an impassable barrier for the water.

Symplastic pathway

- A smaller amount of water travels via the symplastic pathway, which is the **cytoplasm** and **plasmodesmata** or vacuole of the cells.
- The water moves by **osmosis** into the cell (across the partially permeable cell surface membrane), possibly into the vacuole (through the tonoplast by osmosis) and between cells through the plasmodesmata.
- The movement of water in the symplastic pathway is slower than the apoplastic pathway.

3.3 TRANSPIRATION

The cells in the mesophyll layers are not tightly packed and have many spaces around them filled with air. The walls of the mesophyll cells are wet and some of this water evaporates into the air space, so that the air inside the leaf is usually saturated with water vapour.

The air in the internal spaces of the leaf has directly contacted with the air outside the leaf, through small pores called stomata. If there is a water potential gradient between the air inside the leaf (higher water potential) and the air outside of the leaf (lower water potential), then water vapour will diffuse out of the leaf down this gradient. Although some of the water in the leaf will be used, for example, in photosynthesis, most eventually evaporates and diffuses out of the leaf by the process of transpiration (Figure 3.4).

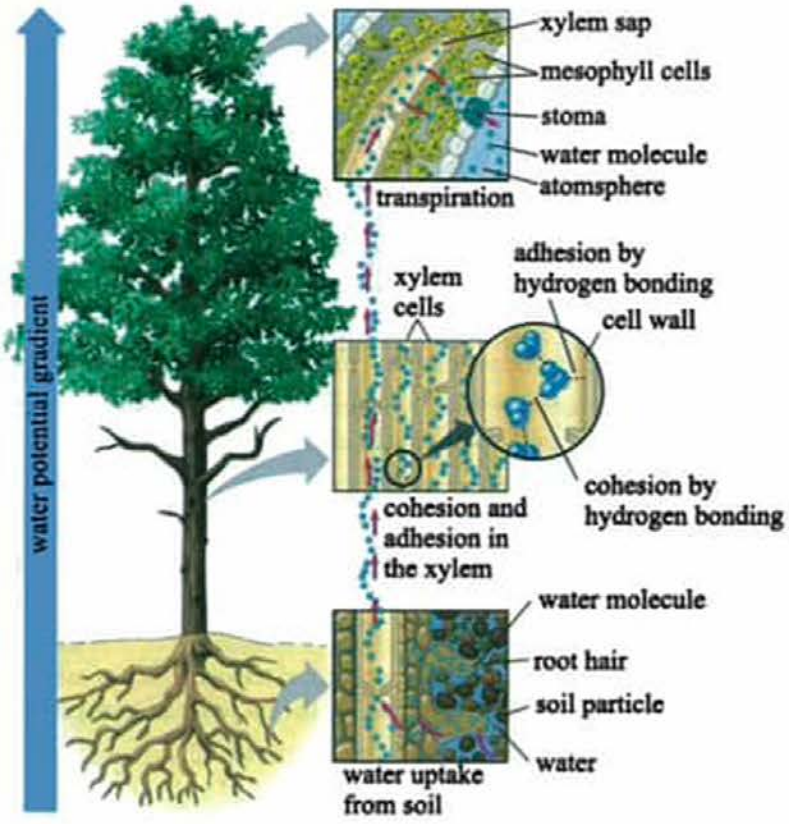


Figure 3.4 Transpiration in a plant

3.3.1 Factors Affecting Transpiration

The environmental factors affecting the rate of transpiration are:

- **Humidity**: If the water potential gradient between the air spaces in the leaf and the air outside becomes steeper, the rate of transpiration will increase. In condition of low humidity, the gradient is steep, so transpiration takes place more quickly than in high humidity.

- **Wind speed and temperature**: Transpiration rate may also be increased by an increasing in wind speed or rising in temperature.
- **Light intensity**: In most plants, stomata open during the day and close at night. Most transpiration takes place through the stomata, so the rate of transpiration is almost zero at night. Stomata must be opened during the day to allow carbon dioxide to diffuse into the leaf for photosynthesis. This inevitably increases the rate of transpiration. Closing at night, when photosynthesis is impossible, reduces unnecessary water loss.
- **Very dry conditions**: In especially dry conditions, when the water potential gradient between the internal air spaces and the external air is steep, a plant may have to compromise by partially or completely closing its stomata to prevent its leaves drying out, even if this mean reducing the rate of photosynthesis.

In hot conditions, transpiration plays an important role in cooling the leaves. As water evaporates from the cell walls inside the leaf, it absorbs heat energy from these cells, thus reducing their temperature.

If the rate at which water vapour is lost by transpiration exceeds the rate at which a plant can take up water from the soil, then the amount of water in its cells decreases. The cells become less turgid and the plant wilts as the soft parts such as leaves loose the support provided turgid cells. In this situation, the plant will also close its stomata.

3.3.2 Benefits of Transpiration

Transpiration is regarded as a beneficial fact to the plants for many reasons:

- **Ascent of sap:** Ascent of sap mostly occurs due to transpiration pull exerted by transpiration of water. This pull also helps in absorption of water.
- **Removal of excess water:** It has been held that plants absorb far more amount of water than is actually required by them. Transpiration, therefore, removes the excess of water.
- **Cooling effect:** Radiant heat falling on the plants increases their temperature that may be dangerous to the plants. Transpiration, by evaporating water, bring down (or lowers) their temperature by 10°-15°C.
- **Mechanical tissue:** The development of mechanical tissue, which is essential for providing rigidity and strength to the plant, is favoured by the increase in transpiration.
- **Distribution of mineral salts:** Mineral salts are mostly distributed by rising column of sap.
- **Increasing concentration of mineral salts:** The sap absorbed from the soil contains low concentration of mineral salts. The loss of water through transpiration increases the concentration of mineral salts in the plant.
- **Root system:** Transpiration helps in better development of root system, which is required for support, and absorption of mineral salts.
- **Quality of fruits:** The ash and sugar content of the fruit increases with the increase in transpiration.
- **Resistance:** Excessive transpiration induces hardening and resistant to moderate drought.

- **Turgidity:** Transpiration helps the shape and structure of plant parts by keeping cells turgid.
- **Photosynthesis:** Transpiration supplies water for photosynthesis. As water evaporates through the stomata, it results in pulling of water, molecule by molecule into the leaf from the xylem.

3.3.3 Demonstration of Transpiration Pull

A thistle funnel is filled with water and rubber stopper attaches a leafy twig to it. The bottom of the funnel is immersed in a bowl of mercury.

After some time, the level of mercury in the thistle funnel rises. Loss of water from the twig (i.e., transpiration) produces a vacuum in the thistle funnel and water will be drawn up. This in turn produces a vacuum at the bottom of the funnel, which is then filled by the rising mercury. This rise of water and mercury is due to transpiration pull (Figure 3.5).

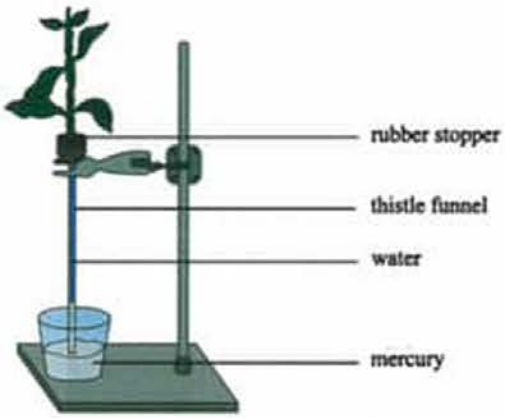


Figure 3.5 Demonstration of transpiration pull

3.4 TRANSLOCATION

Translocation is the movement of dissolved substances through a plant. In general, water and dissolved salts from the soil travel upwards through the vessels of the xylem and food synthesized in the leaves passes downwards or upwards in the sieve tubes of the phloem.

When leaves photosynthesize, they produce carbohydrates. These carbohydrates are transported out of the leaf in the form of sucrose to the stem. Once in the stem it may travel upwards to actively growing regions or maturing fruits and seeds or downwards to the roots and underground storage organs. Both upward and downward movement may take place at the same time in the phloem.

The phloem tissue is a complex tissue. The consisting components are sieve tube, companion cell, phloem parenchyma and phloem fibre. They are living cells except phloem fibre. In the translocation process, sieve tubes or sieve cells which have no nucleus and companion cells possess do work together. They are cylindrical cells with layers of cytoplasm like materials just inside their cell walls. They are so called because of the presence of perforations in the cell septate walls known as sieve plates. These are main components through which translocation take place and permit the plant materials to pass from one cell to another.

Sieve cells can manage translocation without nuclei because they are kept alive by the nucleated companion cells that always situated adjacent to sieve cells. There are profuse cytoplasmic connections between sieve and companion cells. Moreover, phloem tissue is strengthened by fibre cells besides the sieve and companion cells (Figure 3.6).

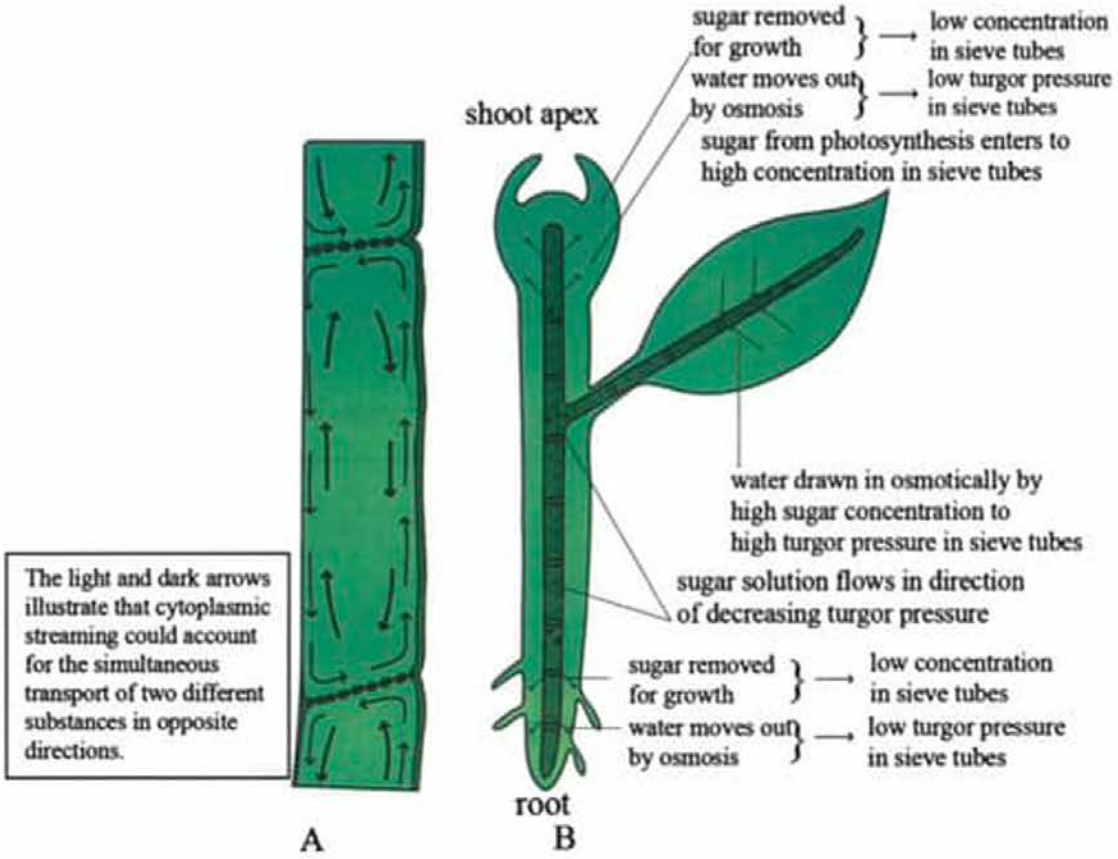


Figure 3.6 Transport of phloem A. Cytoplasmic streaming in a phloem tube
B. The pressure flow theory of phloem transport in a plant

3.5 TRANSPORT SYSTEM IN ANIMALS

Large multicellular animals have evolved transport system as organisms get larger and have higher metabolic rates.

3.5.1 Principles of Circulation

In many large animals, including all the vertebrates, circulatory system is in the form of mass transport system. Mass transport system is an arrangement of structures by which substances are transported in the flow of a fluid with a mechanism for moving it around the body.

3.5.2 The Need for Transport

Within any organism, substances need to be moved from one place to another. Single-celled organisms have a high surface area to volume ratio. Their surface membrane has a large enough area to supply all the oxygen and other materials that their volume demands. In large multicellular organisms, the surface area to volume ratio is low. So, there is not enough surface area to supply all their metabolic demands. To overcome this problem, they need transport system.

In multicellular animals, many chemical reactions take place inside every microscopic cell. These cells require a supply of chemical substances such as glucose and oxygen for cellular respiration. These must be transported from outside of a large organism into the cells. Respiration supplies energy for the other reactions of life, but it also produces the toxic waste product carbon dioxide. This and other waste products need to be removed from the cells before they cause damage to them.

3.5.3 Features of Mass Transport Systems

Mass transport systems are very effective for moving substances around the body. Most mass transport systems have certain similar features as follow:

(i) exchange surfaces to get materials into and out of the transport system.

(ii) a system of vessels that carry substances - these are usually tubes, sometimes following a very specific route, sometimes widespread and branching.

(iii) a way of making sure that substances are moved in the right direction (e.g., nutrients in and waste out).

(iv) a way of moving materials fast enough to supply the needs of the organism - this may involve mechanical methods such as the pumping of the heart or ways of maintaining a concentration gradient so that substances move quickly from one place to another (e.g., using facilitated diffusion and active transport).

(v) a suitable transport medium (e.g., fluid).

(vi) in many cases, a way of adapting the rate of transport to the needs of the organism.

3.6 CIRCULATORY SYSTEM

There are two main types of circulatory system; open circulatory system and closed circulatory system.

Open circulatory system - Blood pumped by the tubular heart leaves the open-ended vessels to a series of blood spaces surrounding the tissues. When the heart relaxes, the blood flows back into the vessels through pores called ostia. This type is found in most arthropods (jointed leg animals such as insects, spiders and crabs) (Figure 3.7).

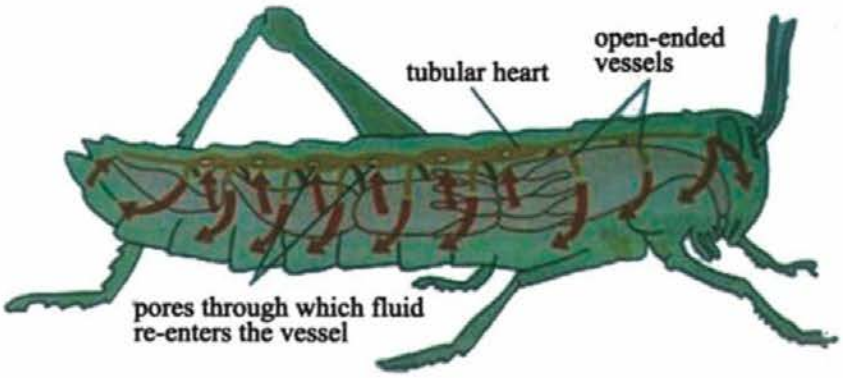


Figure 3.7 Open circulatory system in insect (grasshopper)

Closed circulatory system- Blood is pumped by the heart into the blood vessels which carry the blood to the tissues of the entire body. Then, the blood from the tissues is carried back to the heart by the blood vessels. The main advantages of a closed system are- (i) the pressure can be increased to make the blood flow more quickly and (ii) the flow can be directed more precisely to the organs that need most oxygen and nutrients. There are two types of closed circulatory system; single circulatory system and double circulatory system.

Single circulatory system - It is found in fish. The heart pumps deoxygenated blood to the gills, the organs of gas exchange where the blood takes in oxygen (becomes oxygenated) and gives up carbon dioxide at the same time. The blood then travels on around the rest of the body of the fish, giving up oxygen to the body cells before returning to the heart. In this type, blood passes once through the heart (Figure 3.8 A).

Double circulatory system – Birds and mammals have evolved the most complex type of transport system, known as a double circulatory system because it involves two separate circulations. **The systemic circulation** carries oxygenated blood (oxygen-rich blood) from the heart to the cells of the body where the oxygen is used. It also carries the deoxygenated blood (blood that has given up its oxygen to the body cells) back to the heart. **The pulmonary circulation** carries deoxygenated blood from the heart to the lungs to be oxygenated and then carries the oxygenated blood back to the heart. Thus, blood passes twice through the heart.

Birds and mammals need much more oxygen than fish. Not only do they have to move around without the support of water, but they also maintain a constant body temperature that may be higher or lower than their surroundings. This takes a lot of resources, so their cells need plenty of oxygen and glucose and make waste products that need to be removed quickly (Figure 3.8 B).

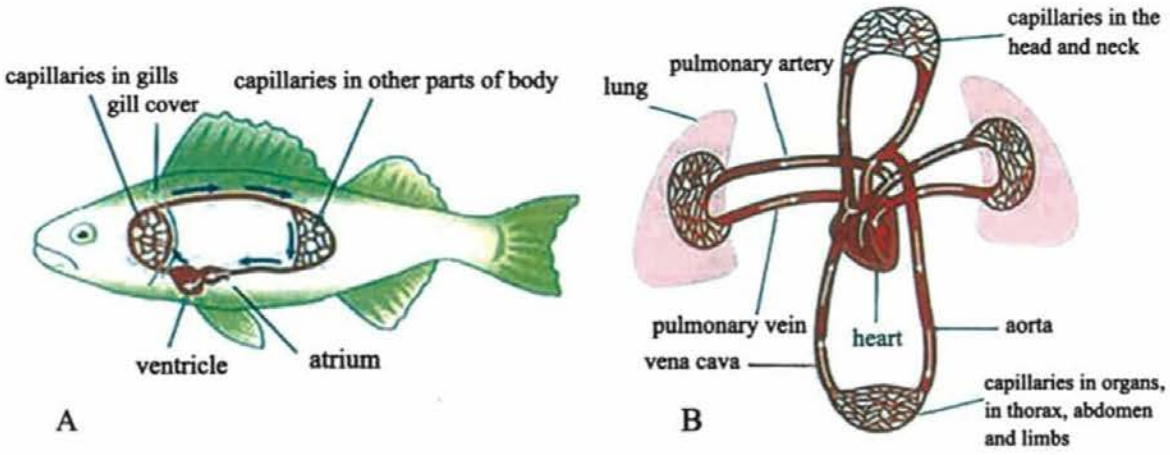


Figure 3.8 Closed circulatory system A. Single circulatory system in fish
B. Double circulatory system in human

The advantages of double circulation are:

(i) The separate circuits of a double circulatory system ensure that the oxygenated and deoxygenated blood cannot mix, so the tissues receive as much oxygen as possible.

(ii) The fully oxygenated blood can be delivered quickly to the body tissues at high pressure.

(iii) The blood going through the tiny blood vessels in the lungs is at relatively low pressure, so it does not damage the vessels and allows gas exchange to take place.

(iv) When the oxygenated blood returns to the heart, it can be pumped hard and sent around the body at high pressure. This means it reaches all the tiny capillaries between the body cells quickly, supplying oxygen for an active way of life.

3.7 CARDIOVASCULAR SYSTEM IN MAMMALS

In mammals, the cardiovascular system delivers the materials needed by the cells of the body, and carries away the waste products of their metabolism.

The cardiovascular system is made up of **the heart** - which acts as a pump to move blood through the vessels, **a series of blood vessels** - which carry blood and **the blood** - as transport medium. The passage of blood through the vessels is called **the circulation**.

3.7.1 The Structure of the Heart

The human heart, like other mammalian hearts, is a muscular pump with four chambers. The upper two chambers are called the right atrium and the left atrium. The lower chambers are the right ventricle and the left ventricle. Both sides of the heart work simultaneously. The walls of the atria are thinner than those of the ventricles.

The right atrium receives the blood from the superior vena cava which collects deoxygenated blood from the head, neck, arms and chest, and from the inferior vena cava which receives deoxygenated blood from the lower parts of the body. The left atrium receives oxygenated blood from the lungs via pulmonary veins.

After the blood enters into both ventricles from the corresponding atrium, the deoxygenated blood in right ventricle enters the lungs through pulmonary artery. The oxygenated blood in the left ventricle enters into aorta and then passes throughout the body. As the two sides are separated by a complete thick, muscular septum, the blood in one side of the heart does not mix with the blood from the other side.

The heart is made of a unique type of muscle, known as cardiac muscle, which has special properties, it can carry on contracting regularly without resting or getting fatigued. Cardiac muscle has a good blood supply by the coronary arteries bringing oxygenated blood while coronary veins carry away the deoxygenated blood. It also contains lots of myoglobin, a respiratory pigment which has a stronger affinity for oxygen than haemoglobin.

The muscular wall of the left ventricle is much thicker than that of the right. The right ventricle pumps blood to the lungs, which are relatively close to the heart. The delicate capillaries of the lungs need blood delivered at relatively low pressure. The left ventricle must produce sufficient force to move the blood under pressure to all the extremities of the body and overcome the elastic recoil of the arteries (Figure 3.9 A and B).

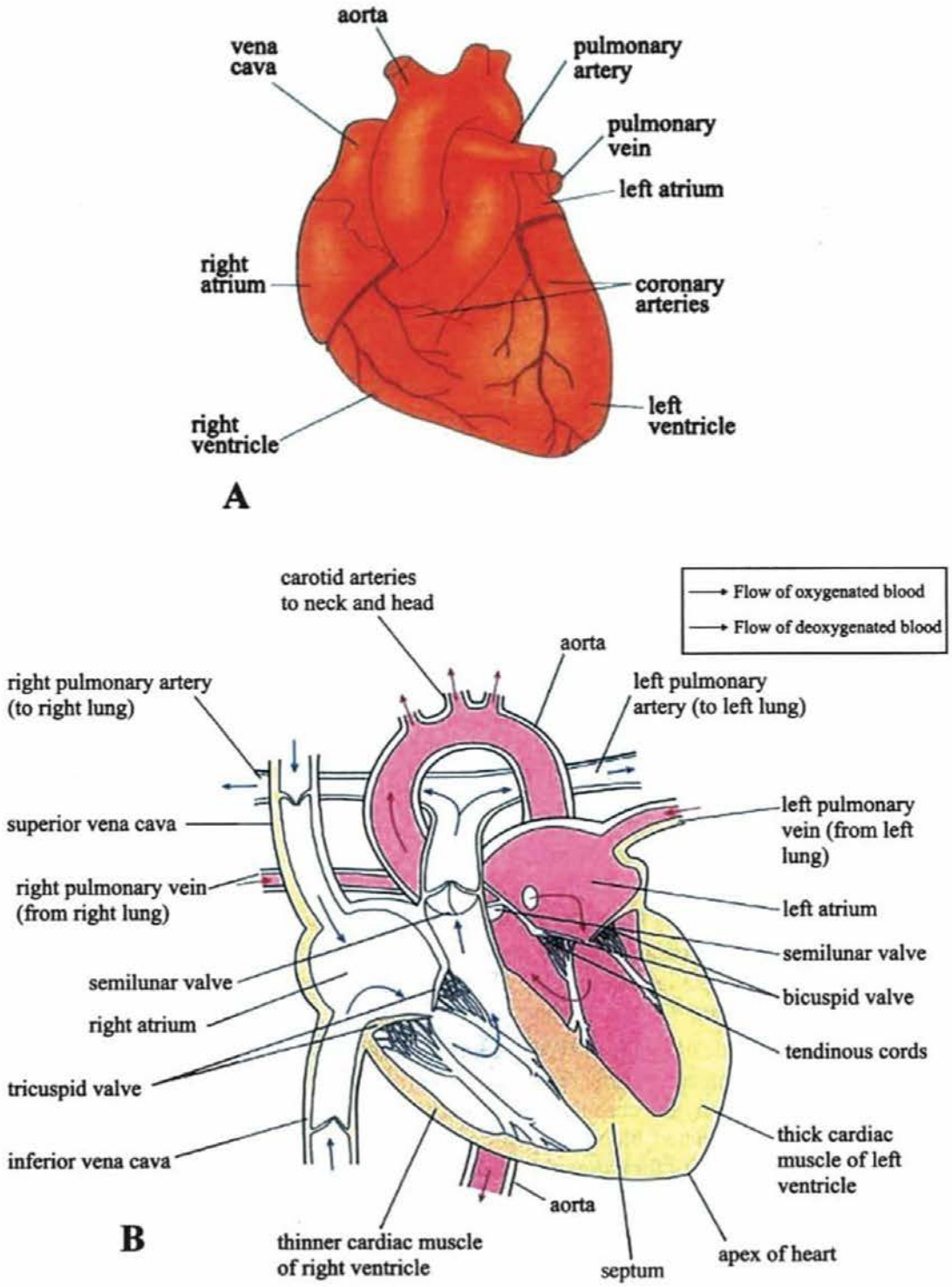


Figure 3.9 Structure of the human heart A. External view, B. Interior view

There are four sets of valves in the heart; two sets of atrioventricular valves and two sets of semilunar valves.

The right atrioventricular valve is called **tricuspid valves** which is made up of three flaps and is located between the right atrium and right ventricle. The function of the tricuspid valve is prevention of backflow of blood from the right ventricle into the right atrium.

The left atrioventricular valve is called **bicuspid valve** (Mitral valve) which is made up of two flaps and is located between the left atrium and left ventricle. Its function is prevention of backflow of blood from the left ventricle into the left atrium.

The flaps of both atrioventricular valves are supported by the cordae tendineae (tendinous cords) which prevent the flaps from turning inside out by the pressure exerted when the ventricles contract.

Semilunar valves (semi means half and lunar means moon) - Both are pocket-like valves with half-moon shaped like those in veins. One set is located at the base of the pulmonary artery while the other set is at the base of the aorta and their function is prevention of backflow of blood from the pulmonary artery into the right ventricle and from the aorta into the left ventricle, respectively.

3.7.2 The Blood Vessels

The main types of blood vessel; the arteries, veins and capillaries have very different characteristics. These affect the way the blood flows through the body, and what the vessels do in the body.

Arteries

Arteries carry blood away from the heart towards the cells of the body. The structure of an artery is shown in Figure 3.10 A and 3.11.

Almost all arteries carry oxygenated blood. The exceptions are: the **pulmonary artery** - carrying deoxygenated blood from the heart to the lungs and **the umbilical artery** - during pregnancy, this carries deoxygenated blood from the foetus to the placenta.

The aorta (large artery) leaving the heart branches off into arteries in every direction, and the diameter of the lumen, the central space inside the blood vessel, gets smaller the further away it is from the heart. The very smallest branches of the arterial system, furthest from the heart, are the arterioles.

The major arteries close to the heart must withstand pressure surges. Their walls contain a lot of elastic fibers so they can stretch to accommodate the greater volume of blood without being damaged. Between surges, the elastic fibers return to their original length, squeezing the blood to move it along in a continuous flow. The role of the elastic fibers in artery walls is to return to their original length to help maintain the pressure. This is called recoil. The elastic recoil does not help to increase pressure, it simply helps to maintain the pressure. A thick muscular wall helps control the flow of blood by dilating (widening) or constricting (narrowing) the vessels.

Veins

Veins carry blood back towards the heart. Most veins carry deoxygenated blood. The exceptions are: **the pulmonary vein,** carries oxygen-rich blood from the lungs back to the heart for circulation around the body and **the umbilical vein**, carries oxygenated blood from the placenta into the foetus, during pregnancy.

Tiny venules lead from the capillary network, combining into larger and larger vessels going back to the heart as vena cava (large vein). Veins can hold a large volume of blood, in fact more than half of the body's blood volume is in the veins at any one time. They act as a blood reservoir. The blood pressure in the veins is relatively low and the pressure surges from the heart are eliminated before the blood reaches the capillary system. This blood at low pressure must be returned to the heart and lungs to be oxygenated again and recirculated. The walls of the veins are thinner than those of the arteries and contain less elastic tissue and muscle (Figure 3.10 B and 3.11).

There are one-way valves at frequent intervals throughout the venous system. These are called semilunar valves because of their half-moon shape. They develop from enfolding's of the inner wall of the vein. Blood can pass through towards the heart, but if it starts to flow backwards the valves close, preventing any backflow. The contraction of large muscles encourages blood flow through the veins (Figure 3.13).

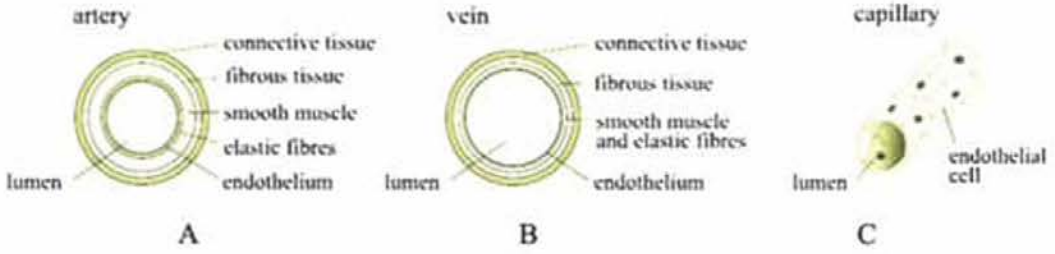


Figure 3.10 Diagrammatic structure of A. Artery, B. Vein and C. Capillary

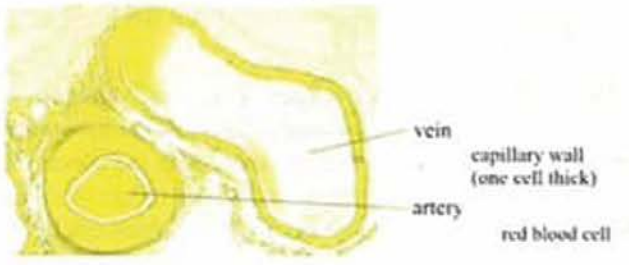


Figure 3.11 Transverse section of artery and vein

Figure 3.12 Exchange of materials between capillaries and cells

Capillaries

Capillaries have a very simple structure which is well adapted to their function. Their walls are very thin and contain no elastic fibers, smooth muscle or cóllagen. This helps them fit between individual cells and allows rapid diffusion of substances between the blood and the cells. The walls consist of just one very thin cell. Oxygen and other molecules, such as digested food molecules and hormones, quickly diffuse out of the blood in the capillaries into the nearby body cells, and carbon dioxide and other waste molecules diffuse into the capillaries. Blood entering the capillary network from the arteries is oxygenated. When it leaves, it carries less oxygen and more carbon dioxide (Figure 3.10 C and 3.12).

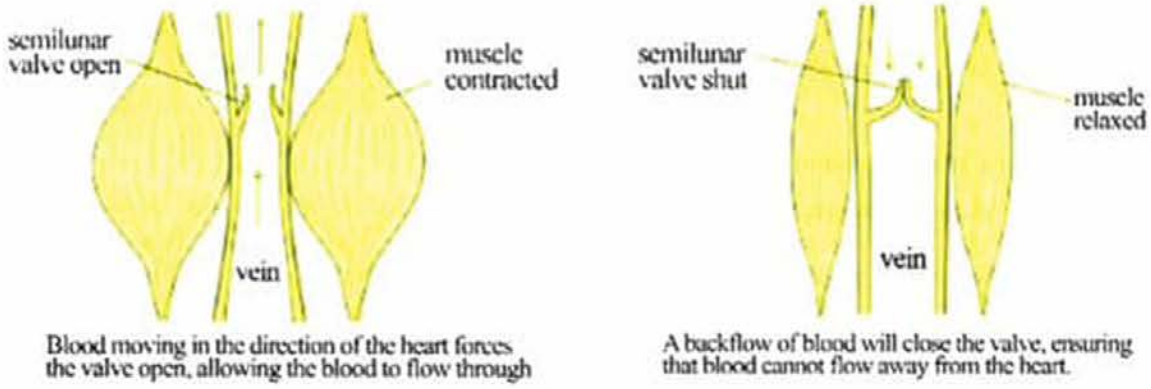


Figure 3.13 Valves in the veins make sure blood only flow one direction towards the heart

3.7.3 The Components of the Blood

The blood is composed of the plasma, blood cells, which are erythrocytes (red blood cells) and several types of leucocytes (white blood cells), and platelets.

Plasma

Plasma is the liquid part of the blood. Over 50% of the blood volume in the body is plasma, and it carries all of blood cells and everything else that needs transporting around the body.

This includes:

(i) digested food products (e.g., glucose and amino acids) from the small intestine to the liver and then to all the parts of the body where they are needed either for immediate use or for storage,

(ii) nutrient molecules from storage areas to the cells that need them,

(iii) excretory products (e.g., carbon dioxide and urea) from cells to the excretory organs such as the lungs or kidneys, to be excreted from the body,

(iv) chemical messages (hormones) from where they are made to the target organs in the body,

(v) carries heat around the system from internal organs (e.g., the gut) or very active tissues (e.g., leg muscles in someone running) to the skin, where it can be lost to the surroundings,

(vi) also acts as a buffer to regulate pH changes.

Erythrocytes or red blood cells

There are approximately 5 million erythrocytes per mm^3 of blood (4-5 million per mm^3 in women, 5-6 million per mm^3 in men). They contain haemoglobin, a red pigment that carries oxygen and gives them their colour. They are made in the bone marrow. Mature erythrocytes do not contain a nucleus and have a limited life of about 120 days.

The erythrocytes transport oxygen from the lungs to all the cells. They are well adapted for their function. The biconcave disc shape of the cells means that they have a large surface area to volume ratio, so oxygen can diffuse into and out of them rapidly. Having no nucleus leaves much more space inside the cells for the haemoglobin molecules that carry the oxygen. In fact, each red blood cell contains around 250-300 million molecules of haemoglobin and can carry approximately 1000 million molecules of oxygen. Haemoglobin also carries some of the carbon dioxide produced in respiration back to the lungs. The rest is transported in the plasma (Figure 3.14).

Leucocytes or white blood cells

They are much larger than erythrocytes but can also squeeze through tiny blood vessels because they can change their shape. There are around 4,000 - 11,000 per mm^3 of blood and there are several different types. They are made in the bone marrow, although some mature in the thymus gland. Their main function is to defend the body against infection.

Leucocytes are also very important in the inflammatory response of the body when an area of tissue is damaged. They all contain a nucleus and have colourless cytoplasm, although some types contain granules which can be stained (Figure 3.14).

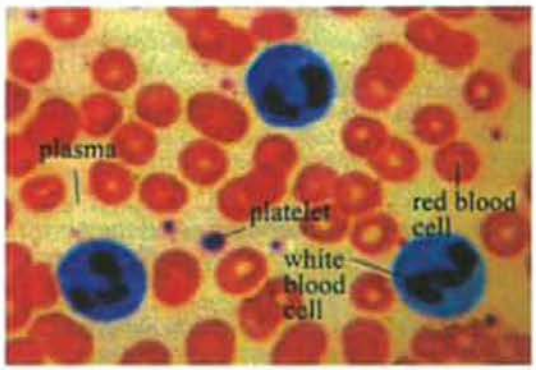


Figure 3.14 The light micrograph showing composition of blood

Platelets

Platelets are tiny fragments of large cells called **megakaryocytes**, which are found in the bone marrow. There are about 150,000 - 400,000 platelets per mm^3 of blood. They are involved in blood clotting (Figure 3.14).

3.7.4 The Clotting of the Blood

The body has a limited volume of blood. In theory, a minor cut could endanger life as the torn blood vessels allow blood to escape. First, the blood volume will reduce and if too much blood losses, you will die. Second, pathogens can get into the body through an open wound. In normal circumstances, the body protects through the clotting mechanism of the blood. This mechanism seals damaged blood vessels to minimize blood loss and prevent pathogens getting in.

Formation of clot

Plasma, blood cells and platelets flow from a cut vessel. Contact between the platelets and components of the tissue (e.g., collagen fibres in the skin) causes the platelets to break open in large numbers. They release several substances, two of which are particularly important.

- Serotonin causes the smooth muscle of the blood vessel to contract. This narrows the blood vessels, cutting off the blood flow to the damaged area.
- Thromboplastin is an enzyme that starts a sequence of chemical changes that clot the blood.

The blood clotting process

The blood clotting process is a very complex sequence of events in which there are many different clotting factors. Vitamin K is important in the production of many of the compounds needed for the blood to clot, including prothrombin. The events in the blood clotting process is as follow;

First, thromboplastin catalyses the conversion of a large soluble protein called **prothrombin** found in the plasma into another soluble protein, the enzyme called **thrombin**. Prothrombin, a precursor of a thrombin, is biologically inactive while thrombin is biologically active. This conversion happens on a large scale at the site of a wound. Calcium ions need to be present in the blood at the right concentration for this reaction to happen.

Second, thrombin acts on another soluble plasma protein called **fibrinogen**, converting it to an insoluble substance called **fibrin**. Again, fibrinogen is the biologically inactive precursor of biologically active fibrin.

Finally, the fibrin forms a mesh of fibres to cover the wound and trap the red blood cells, forming blood clot (Figure 3.15 and 3.16).

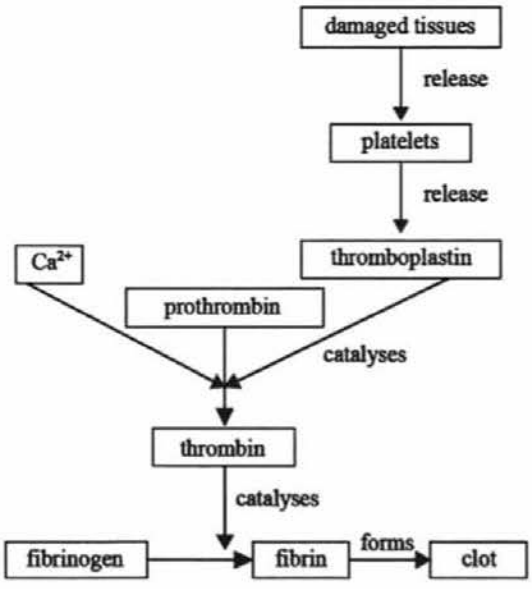


Figure 3.15 Flow diagram of clotting process

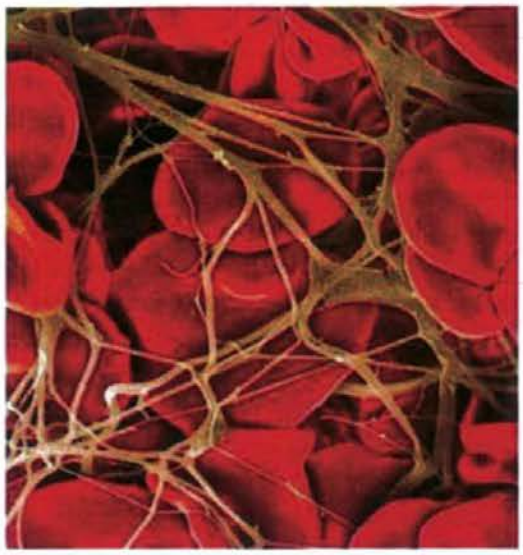


Figure 3.16 Red blood cells trapped in fibrin network

3.7.5 The Cardiac Cycle

The blood is moved through the heart by a series of continuous contraction and relaxation of the muscles in the walls of the four chambers. These events form the cardiac cycle. The contractions of the heart are called **systole**. Systole can be divided into **atrial systole,** the contraction of atria and the **ventricular systole**, the contraction of ventricles. Ventricular systole happens about 0.13 seconds after atrial systole. Between contractions the heart relaxes and fills with blood. This relaxation stage is called **diastole**. One cycle of systole and diastole makes up a single heartbeat, which lasts about 0.8 seconds in humans. The main stages are illustrated in Figure 3.17.

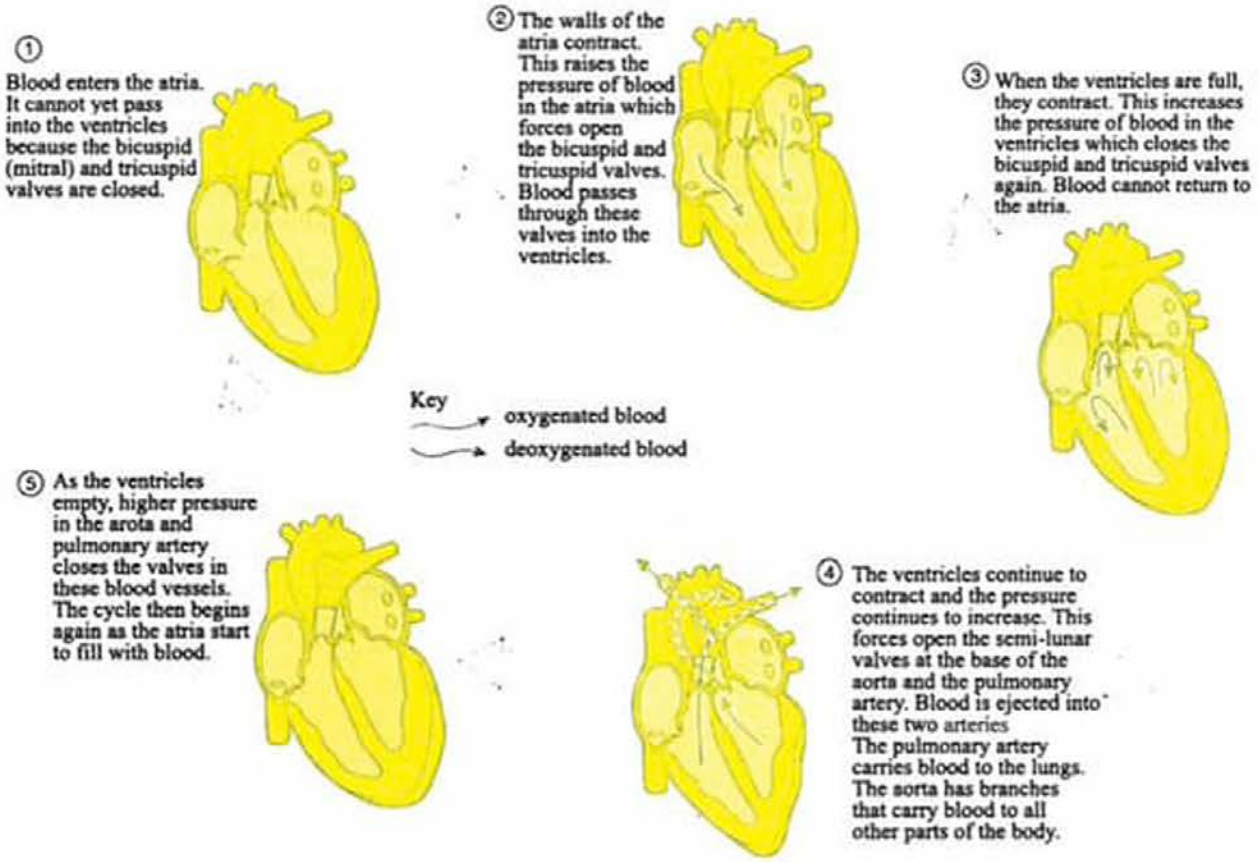


Figure 3.17 The cardiac cycle

3.7.6 Control of Heartbeat

Cardiac muscle cells are **myogenic**, which means they contract without any external stimulus. They also have intrinsic rhythmicity. An adult heart removed from the body will continue to contract as long as it is bathed in a suitable oxygen-rich fluid. The intrinsic rhythm of the heart is around 60 beats per minute which is slower than the heartbeat most of the time when awake. There may have many different ways of controlling the heart to make sure it delivers the exact amount of blood when it is needed.

The intrinsic rhythm of the heart is maintained by a wave of electrical excitation similar to a nerve impulse which spreads through special tissue in the heart muscle.

The area of the heart with the fastest intrinsic rhythm is a group of cells in the right atrium known as the **sinoatrial node**, and this acts as the heart's own natural pacemaker which keeps the heart beating regularly.

The sinoatrial node (SAN) establishes a wave of electrical excitation (depolarization) which causes the atria to start contracting. This initiates the heartbeat.

- Excitation also spreads to another area of similar tissue called the **atrioventricular node** (AVN).
- The AVN is excited as a result of the SAN but it produces a slight delay before the wave of depolarization passes into the bundle of His, a group of conducting fibres in the septum of the heart. This makes sure the atria have stopped contracting before the ventricles start.
- The bundle of His splits into two branches and carries the wave of excitation to the Purkyne tissue.
- The Purkyne tissue consists of conducting fibres that penetrate down through the septum, spreading around the ventricles.

As the depolarization travels through the tissue, it starts the contraction of the ventricles, starting at the bottom and so squeezing blood out of the heart. The speed at which the excitation spreads through the heart, with the hesitation before the AVN stimulates the bundle of His, to ensure that the atria have stopped contracting before the ventricles start. It is these changes in the electrical excitation of the heart that cause the repeating cardiac cycle. These electrical changes can be measured in an electrocardiogram (ECG).

Because the heart has its own basic rhythm, no one has to think about it. However, many people have a faster resting heart rate than this basic rhythm; the average is around 70 beats per minute. This is because lots of other factors, including nerve impulses and hormones, constantly affect the heart rate (Figure 3.18).

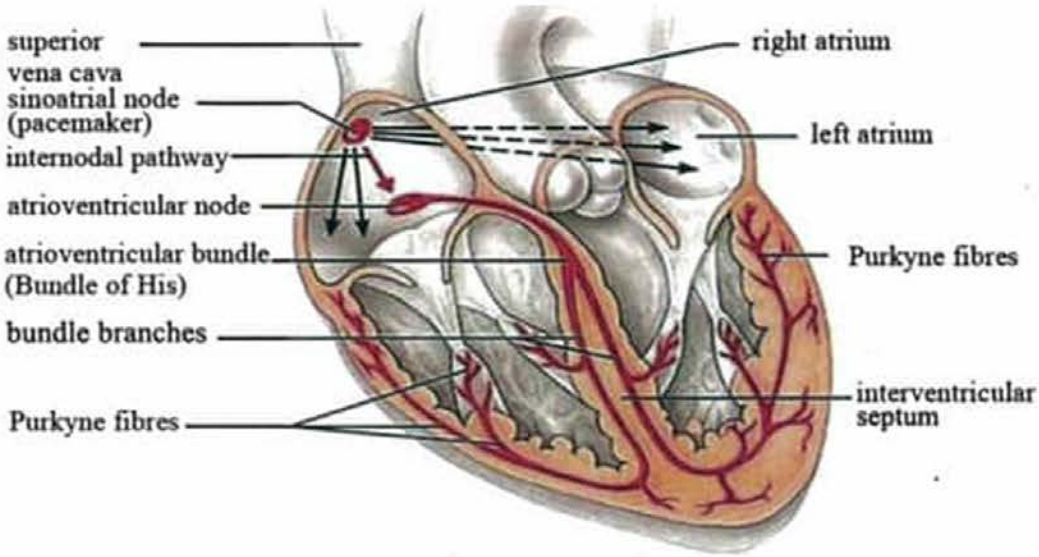


Figure 3.18 Impulse generation in sinoatrial node and transmission

3.8 LYMPHATIC SYSTEM

Between the capillaries and the cells is a watery liquid called **tissue fluid**. Most of the water from tissue fluid reenters capillaries by **osmosis**. Some fluid passes into another system called the **lymphatic system**. The lymphatic system consists of vessels similar to blood capillaries, which are sometimes called **lymphatic capillaries**. They transport the fluid, called **lymph**, back to the blood by opening into the subclavian veins. The **lacteals** that carry fats from villi of the small intestine are part of the lymphatic system. Before lymph passes back into the blood, it is filtered to remove dead cells and bacteria. This takes place in swellings called **lymph nodes**, which contains white blood cells that are important in destroying harmful bacteria. When a person gets infection, one of the first sign may be swelling of the lymph nodes, often referred to as swollen glands (Figure 3.19 and 3.20).

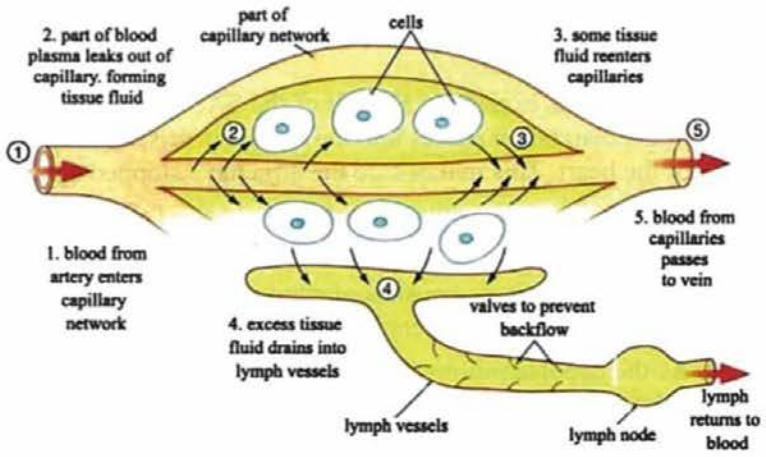


Figure 3.19 Relationship between capillaries and the cells

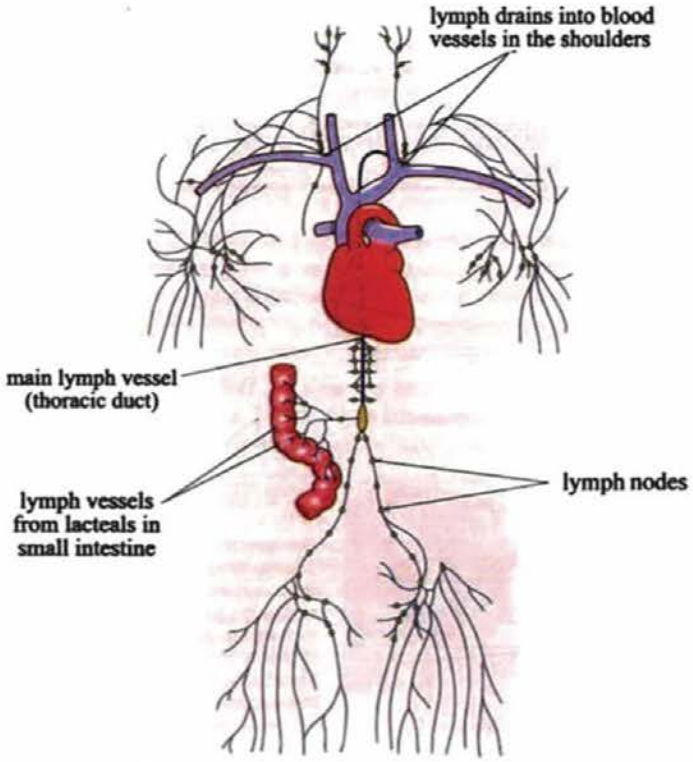


Figure 3.20 Human lymphatic system

Sample Questions

1. State **TRUE** or **FALSE** to the following statements. Do not copy the statements. (6 marks)
   i. Plants have extensive root systems below the ground.
   ii. Xylem tissue contains living, empty cells with no end walls.
   iii. The movement of water in the apoplastic pathway is slower than the symplastic pathway.
   iv. Fish need much more oxygen than birds and mammals.
   v. Veins carry blood back towards the heart.
   vi. Cardiac muscle cells are myogenic.

2. Complete the following statements with appropriate words. Do not copy the statements. (6 marks)
   i. Root hairs increase the surface area for ---------- of the substances.
   ii. Most transpiration take place through the ----------.
   iii. Radiant heat falling on the plants increases their ---------- that may be dangerous to the plants.
   iv. The human heart is a ---------- pump with four chambers.
   v. Leucocytes are much larger than ----------.
   vi. Most of the water from tissue fluid reenters ---------- by osmosis.

3. Choose the correct answer for the following statements. Do not copy the statements. (6 marks)
   i. (A. Xylem B. Phloem C. Parenchyma D. Fibre) transports water and minerals from the roots to the leaves.
   ii. In plants, stomata closing at night when (A. absorption B. photosynthesis C. turgidity D. respiration) is impossible.
   iii. The cells become less (A. cooling B. turgid C. temperature D. humidity) and the plant wilts.
   iv. Within any organism, (A. substances, B. oxygen, C. blood, D. carbon dioxide) need to be removed from one place to another.
   v. Over (A. 50% B. 70% C. 60% D. 90%) of the blood volume in the body is plasma.
   vi. Excitation also spreads to another area of similar tissue called the (A. sinoatrial node, B. atrioventricular node, C. atrioventricular bundle, D. Purkyne fibres).

Sample Questions (Continued)

4. Match items in column A and B. Do not copy the statements. (6 marks)

Column A	Column B
i. Loss of water from the surface of the plant	A. Erythrocytes
ii. Transport substances made in plant	B. Tricuspid valves
iii. Movement of dissolved substances through a plant	C. Phloem
iv. The mature blood cells do not contain a nucleus	D. Veins
v. The valves which is made up of three flaps	E. Translocation
vi. The vessels carry blood back towards the heart	F. Transpiration

5. Complete this paragraph about the need for transport. Use words from this list. Each word may be used once, more than once, or not at all. (6 marks)

life	organism	toxic	oxygen
cells	multicellular	materials	metabolic

In ----(a)---- animals, many chemical reactions take place inside every microscopic cell. These cells require a supply of chemical substances such as glucose and ----(b)---- for cellular respiration. These must be transported from outside of a large ----(c)---- into the cells. Respiration supplies energy for the other reactions of ----(d)----, but it also produces the ----(e)---- waste product carbon dioxide. This and other waste products need to be removed from the ----(f)---- before they cause damage to them.

6. Answer **ANY TWO** questions. (4 marks)

a. How do you understand the symplastic pathway?
b. Name the components of cardiovascular system found in mammals.
c. Mention the main types of blood vessel.

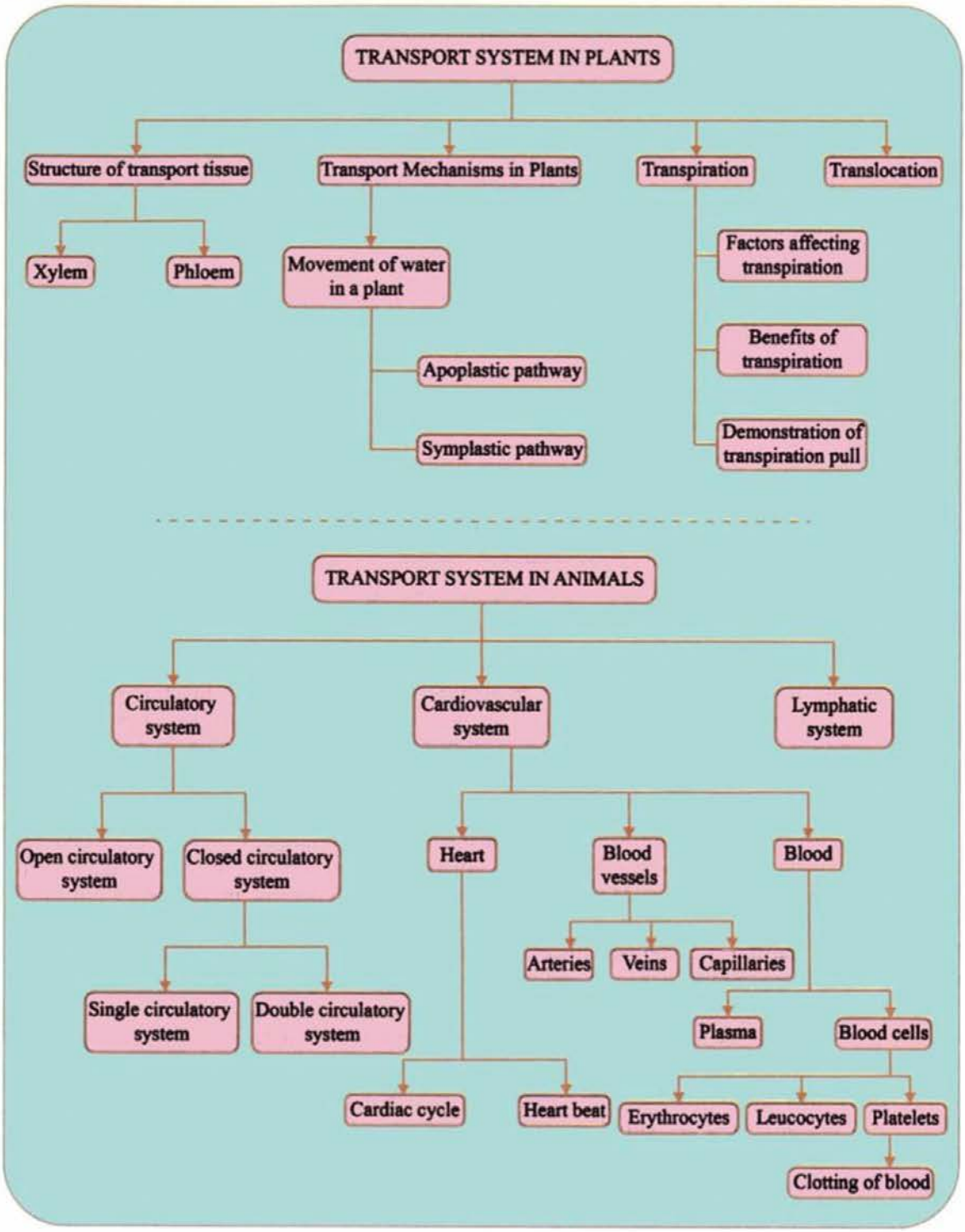
7. Answer **ANY TWO** questions. (8 marks)

a. Discuss the movement of dissolved substances through a plant.
b. Briefly explain the advantages of double circulation.
c. Give a flow diagram of blood clotting process.

8. Answer **ANY ONE** question. (8 marks)

a. Demonstrate the transpiration pull with illustration.
b. Give precise explanation on the plasma.
c. Explain all you know about the human lymphatic system.

Concept Map


TRANSPORT SYSTEM IN PLANTS
Structure of transport tissue
Transport Mechanisms in Plants
Transpiration
Translocation
Xylem
Phloem
Movement of water in a plant
Factors affecting transpiration
Benefits of transpiration
Apoplastic pathway
Symplastic pathway
Demonstration of transpiration pull
TRANSPORT SYSTEM IN ANIMALS
Circulatory system
Cardiovascular system
Lymphatic system
Open circulatory system
Closed circulatory system
Heart
Blood vessels
Blood
Arteries
Veins
Capillaries
Single circulatory system
Double circulatory system
Plasma
Blood cells
Cardiac cycle
Heart beat
Erythrocytes
Leucocytes
Platelets
Clotting of blood

CHAPTER 4
DISEASES IN PLANTS AND ANIMALS

Learning Outcomes

It is expected that students will be able to

- know the types of plant diseases and the factors for causing diseases
- study the signs and symptoms of plant diseases and types of pathogens
- increase knowledge about how to control diseases in plants
- understand the different types of non-infectious and infectious diseases in animals
- learn the cardiovascular disease as an example of non-infectious diseases
- know the non-modificable risk factors and modificable risk factors for cardiovascular disease
- learn the knowledge about prevention and treatment of cardiovascular disease
- study the malaria disease as an example of infectious diseases
- gain the knowledge about transmission of malaria through observing life stages of *Plasmodium*
- understand how to treat and prevent malaria
- learn the history of worldwide control of malaria

4.1 PLANT DISEASES

A plant disease is usually defined as abnormal growth and/or dysfunction of a plant. Diseases are the result of some disturbance in the normal life process of the plant. Diseases may be the result of living and/or non-living causes. **Biotic diseases** are caused by living organisms (e.g., fungi, bacteria, and viruses). **Abiotic diseases** are caused by non-living environmental conditions (e.g., soil compaction, wind, frost, soil salt damage, and girdling roots).

Plant disease is any abnormal condition that alters the appearance or function of a plant. It is a physiological process that affects some or all plant functions. Disease may also reduce yield and quality of harvested product. Most plant diseases, around 85 percent are caused by fungal or fungal-like organisms. However, other serious diseases of food and feed crops are caused by viral and bacterial organisms. Certain nematodes also cause plant diseases. **Nematodes** are very tiny roundworms. They are plant parasites and help distribute bacteria and fungi through the soil as well as along roots. Some plant diseases are classified as "abiotic," or diseases that are non-infectious and include damage from air pollution, nutritional deficiencies or toxicities, and grow under less than optimal conditions.

Infectious plant diseases are caused by a pathogenic organism such as a fungus, bacterium, mycoplasma, virus, viroid, nematode, or parasitic flowering plant. An infectious agent is capable of reproducing within or on its host and spreading from one susceptible host to another. **Non-infectious plant diseases** are caused by unfavourable growing conditions, including

extremes of temperature, disadvantageous relationships between moisture and oxygen, toxic substances in the soil or atmosphere, and an excess or deficiency of an essential mineral. Because non-infectious causal agents are not organisms capable of reproducing within a host, they are not transmissible. The study of plant diseases is called **plant pathology**. **Pathology** is derived from the two Greek words *pathos* (suffering, disease) and *logos* (discourse, study). Plant pathology thus means a study of plant diseases (Figure 4.1).

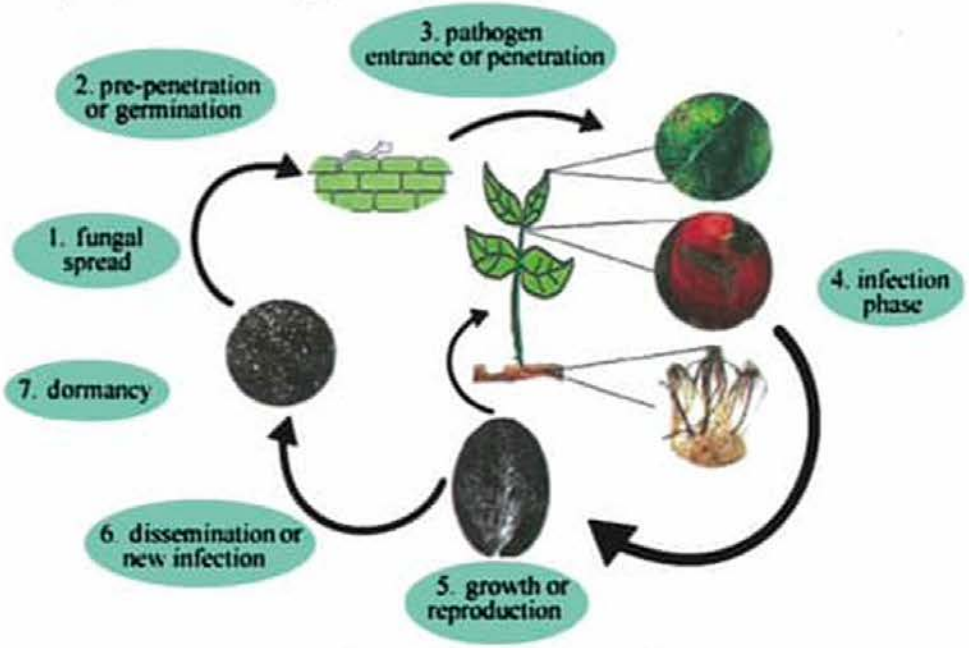


Figure 4.1 Plant disease cycle

4.1.1 Disease Causing Factors

Plant disease is caused by a pathogen (biotic or infectious disease) or an environmental factor (abiotic or non-infectious disease).

Biotic or infectious diseases

Biotic diseases can spread throughout one plant and also may spread to neighbouring plants of the same species. These include biotic problems caused by living organisms such as pathogens, nematodes, insects and other arthropods. Biotic diseases sometimes show physical evidence (signs) of the pathogen, such as fungal growth, bacterial ooze, or nematode cysts, or the presence of mites or insects. Many plant problems, especially biotic problems, if not recognized and controlled early in their development, they can result in significant economic damage for the producer. Therefore, timely and accurate diagnoses are required so that appropriate pest and disease management options and other corrective measures can be implemented.

Abiotic or non-infectious diseases

Abiotic diseases are caused by nonliving factors, such as drought stress, sunscald, freeze injury, wind injury, chemical injury, nutrient deficiency, or improper cultural practices, such as overwatering or planting conditions. These diseases are caused by conditions external to the plant,

not due to living agents. They cannot spread from plant to plant but are very common and should be considered when assessing the health of any plant. Examples of abiotic disease include nutritional deficiencies, soil compaction, salt injury, ice, and sun scorch.

Abiotic damage often occurs on many plant species. Drought stress or chemical injury will likely cause damage on several types of plants. In contrast, biotic disease problems are more limited to a certain species. For example, the fungi that cause tomato leaf blight do not cause damage on sweet corn. Abiotic damage does not spread from plant to plant over time. Abiotic diseases do not show the presence of disease signs.

Plant diseases are their occurrence and severity result from the impact of three factors. They are the host plant, the pathogen and the environmental conditions. This is represented with the disease triangle as shown in Figure 4.2.

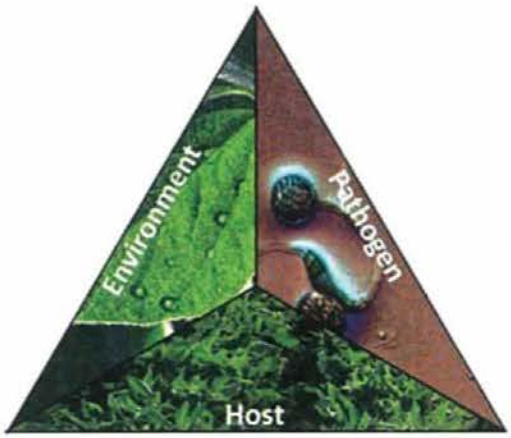


Figure 4.2 The disease triangle

4.1.2 Signs and Symptoms of Diseases

Signs of plant disease are physical evidence of the pathogen. For example, fungal fruiting bodies, bacterial ooze, or nematode cysts. Signs can also help with plant disease identification. Signs are the actual organisms causing the disease. Signs include conks, fruiting bodies, mildew, mushrooms, mycelium, rhizomorphs, slime flux or ooze, spore masses, insects and/or their frass.

Symptoms are visible effects of disease on plants. Any detectable changes in colour, shape, and/or functions of the plant in response to a pathogen or disease-causing agent is a symptom. **Symptoms** of disease are the plant's reaction to the causal agent.

Plant symptoms include blight, canker, chlorosis, decline, dieback, distortion, gall or gall-like, gummosis, leaf distortion, leaf scorch, leaf spot, mosaic, necrosis, stunting, wilt, witches' broom, insect feeding injury.

Viruses cause mottling, spots, mosaic-like patterns, crinkling, and other malformations on leaves and fruits, and may stunt plants. Because viruses are systemic, infected plants must be rogued or discarded (Figure 4.3). For example, common virus diseases in Colorado include curly top virus of tomatoes, cucumber mosaic virus in tomatoes and vine crops, tomato spotted wilt virus, and a variety of greenhouse plant viruses.

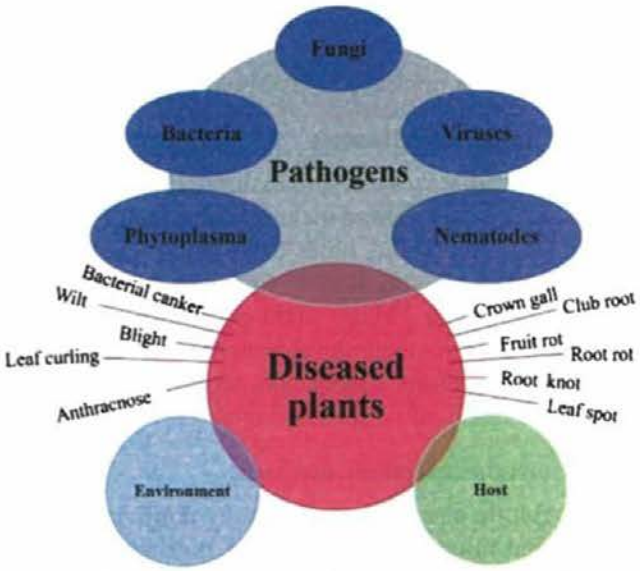


Figure 4.3 Signs and symptoms of plant diseases

4.1.3 Types of Pathogens

Plant pathogens are very similar to those that cause disease in humans and animals. Infectious plant diseases are caused by living organisms that attack and obtain their nutrition from the plant they infect. The parasitic organism that causes a disease is a pathogen. **Pathogens** can spread from plant to plant and may infect all types of plant tissues including leaves, shoots, stems, crown, roots, tubers, fruits, seeds and vascular tissues.

Groups of plant pathogens – fungi

Fungi and fungal-like organisms (FLOs) cause more plant diseases than any other group of plant pest with over 8,000 species shown to cause disease. FLOs are organisms like *Pythium* and *Phytophthora* and cause downy mildew. All plants are attacked by one species or another of phytopathogenic fungi. Individual species of fungi can parasitize one or many different kinds of plants (Figure 4.4). Most pathogenic fungi belong to the following genera: *Alternaria, Aspergillus, Botrytis, Fusarium, Puccinia, Rhizopus,* and *Sclerotinia* (Table 4.1).

Figure 4.4 Rust symptoms on the apple leaves

Table 4.1 Some diseases of plants caused by fungi

No.	Genus	Diseases
1.	*Alternaria*	Leaf spots and blight of various plants
2.	*Aspergillus*	Rots of seeds
3.	*Botrytis*	Blights of various plants
4.	*Fusarium*	Root rot of many plants
5.	*Puccinia*	Rust of cereals
6.	*Rhizopus*	Soft rot of fruits
7.	*Sclerotinia*	Soft rot of vegetables

Groups of plant pathogens – bacteria

Not all bacteria are bad for plants and soil. In fact, most are beneficial. However, there are approximately 200 types of bacteria that cause diseases in plants. They are most active in warm and humid environments. Bacteria that cause plant diseases are spread in many ways. They can be splashed about by rain or carried by the wind, birds or insects (Figure 4.5). Most plant pathogenic bacteria belong to the following genera: *Agrobacterium, Erwinia, Pseudomonas, Streptomyces* and *Xanthomonas* (Table 4.2).

Figure 4.5 Citrus canker symptoms on fruit

Table 4.2 Some diseases of plants caused by bacteria

No.	Genus	Diseases
1.	*Agrobacterium*	Crown gall of various plants
2.	*Erwinia*	Fire blight of pears and apple, wilt of cucurbits and corn, soft rot of fruit
3.	*Pseudomonas*	Leaf spot of tobacco, blight of peas and soybeans
4.	*Streptomyces*	Scab of potato, pox of sweet potato
5.	*Xanthomonas*	Blight of beans, rice and walnut, leaf spot of fruits, black rot of crucifers, citrus canker

Groups of plant pathogens – viruses

Viruses are intracellular (inside cells) pathogenic particles that infect other living organisms. They cause human and animal diseases such as influenza, polio, rabies, smallpox, and warts. Unlike bacteria and fungi, viruses are not spread by water or wind. Instead, they must physically enter the plant. One of the most common vectors of viruses are insects. Examples of some viruses are tobacco mosaic, tomato mosaic, barley yellow dwarf, potato leaf roll, tomato spotted wilt, and tobacco ringspot (Figure 4.6).

Figure 4.6 Tomato mosaic virus disease

Mosaics are characterized by the formation of light green, yellow, or white spots intermingled with the normal green aerial plant structures (Figure 4.7). **Ringspots** are characterized by the appearance of chlorotic or necrotic rings on the leaves (Figure 4.8). These primary symptoms may be accompanied by a variety of other symptoms in specific viral plant diseases.

Figure 4.7 Mosaic disease

Figure 4.8 Ringspot disease

Groups of plant pathogens – nematodes

Nematodes are simple, multicellular animals and are bilaterally symmetrical, soft-bodied (no skeleton), non-segmented roundworms. Most nematode species that attack plants are microscopic. A number of genera and species of nematodes are highly damaging to a great range of hosts, including foliage plants, agronomic and vegetable crops, fruit and nut trees. **Plant parasitic nematodes** have a stylet, a piercing mouthpart. The presence of a **stylet** is the key diagnostic sign differentiating plant parasitic nematodes from all other types of nematodes. Based on the plant part, the nematode invaded can be classified into wheat nematode: *Anguina tritici*, spring dwarf nematode: *Aphelenchoides fragariae*, Stubby-root nematodes: *Trichodorus* sp., and root-knot nematodes, *Meloidogyne* spp. (Figure 4.9).

Figure 4.9 Diseases caused by nematode

4.1.4 Control of Plant Diseases

Plant diseases caused by infectious pathogens have seriously affected human society and nature through their damages to food production, economic development. It is need to be controlled to maintain the quality and abundance of food, feed, and fibre produced by growers around the world. To prevent, mitigate or control plant diseases, different approaches can be used. There are three plant diseases control approaches: biological, physical and chemical.

Biological control

Biological control is control of plant diseases using living microorganisms. Four main mechanisms involved in the biocontrol are (i) the biological agent (antagonist) may parasite the other organism, (ii) antagonist may secrete metabolites (antibiotics) harmful to the pathogens (antibiosis) (iii) antagonist may compete with the pathogens for nutrients or space (competition) and (iv) may cause death of the parasite by producing enzymes (lysis).

Physical control

Physical methods of disease prevention and control are based on the physiological tolerance of disease agents to adverse conditions such as high or low temperature, absence of moisture, presence of deleterious irradiation and the removal of pathogen sources or presence of physical barriers to prevent contact between the disease agent and the host.

Chemical control

A variety of chemicals are available that have been designed to control plant diseases by inhibiting the growth or by killing the disease-causing pathogens. Chemicals used to control bacteria (bactericides), fungi (fungicides), and nematodes (nematicides) may be applied to seeds, foliage, flowers, fruit, or soil.

4.2 ANIMAL DISEASES

A disease is an illness or disorder of the body or mind that leads to poor health; each disease is associated with a set of signs and symptoms. All animals, including human, suffer from one kind of disease or another during their lifespan. Animal diseases can be divided into non-infectious diseases and infectious diseases.

4.2.1 Non-infectious Diseases

Non-infectious diseases are those that are not caused by pathogens, so that they cannot spread from one person to another. In fact, they are caused by factors such as aging, genetics, malnutrition, lifestyle and environment. Examples of non-infectious diseases include cardiovascular disease, cancer, chronic respiratory disease, diabetes, and Alzheimer's.

Cardiovascular disease (CVD)

Most cardiovascular disease starts with atheroma formation. If the endothelium, the inner lining of the wall of the artery, is damaged by high blood pressure, an inflammatory response where by white blood cells (mostly macrophages) move into the area. These white blood cells and lipids from the blood clump together under the endothelium to form fatty streaks. Overtime, more white blood cells, lipids and connective tissue build up and harden to form a fibrous plaque called **atheroma**. This plaque partially blocks the lumen of the artery and restricts blood flow, which causes blood pressure to increase. The hardening of arteries, caused by atheroma, is called **atherosclerosis** (Figure 4.10).

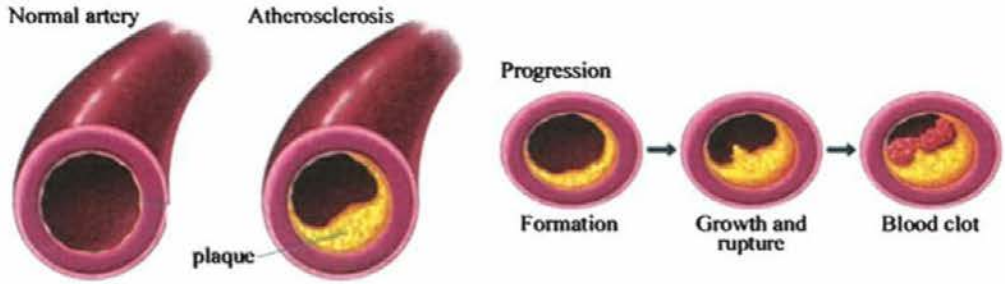


Figure 4.10 Formation of atheroma and blood clot

In **angina**, plaques build up slowly in the coronary arteries, reducing blood flow to the parts of the heart muscle beyond the plaques. Often symptoms are first noticed during exercise, when the cardiac muscle is working harder and needs more oxygen. The narrowed coronary arteries cannot supply enough oxygenated blood and the heart muscle resorts to anaerobic respiration. This causes a gripping pain in the chest that can extend into the arms, particularly the left one, and the jaw, and often also causes breathlessness. The symptoms of angina subside once exercise stops, but the experience is painful and frightening (Figure 4.11).

Figure 4.11 Angina

Oxygen is supplied to the heart muscle by the coronary arteries. If the coronary artery becomes completely blocked by a blood clot, an area of the heart muscle will be totally cut off from its blood supply and will not receive any oxygen. This causes **myocardial infarction**, more commonly known as a **heart attack**, due to damage and death of the heart muscle. Symptoms include pain in the chest as in angina and upper body, shortness of breath and sweating. If large areas of the heart are affected, complete heart failure can occur. Death may be instantaneous without any previous symptoms or may happen after several days of feeling tired and suffering symptoms mistaken for indigestion (Figure 4.12 A and B).

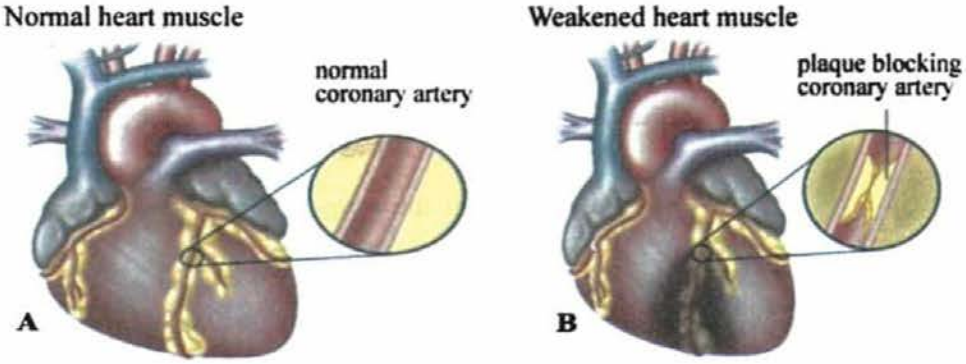


Figure 4.12 A. Normal healthy heart and B. Heart with blocking coronary

A **stroke** is caused by an interruption to the normal blood supply to an area of the brain. This may be due to bleeding from damaged capillaries or a blockage cutting off the blood supply to the brain. A blockage is usually caused by a blood clot, an atheroma or a combination of the two. Sometimes, the blood clot forms somewhere else in the body and is carried in the bloodstream until it gets stuck, blocking an artery in the brain. The damage happens very quickly. A blockage in one of the main arteries leading to the brain causes a very serious stroke that may lead to death. If it happens in one of the smaller arterioles the effects may be less disastrous.

The symptoms of strokes vary, depending on how much of the brain is affected. Very often, the blood is cut off from one part or one side of the brain only. Symptoms include dizziness, confusion, slurred speech, blurred vision or partial loss of vision (usually one eye) and numbness. In more severe strokes, there can be paralysis, usually on one side of the body (Figure 4.13).

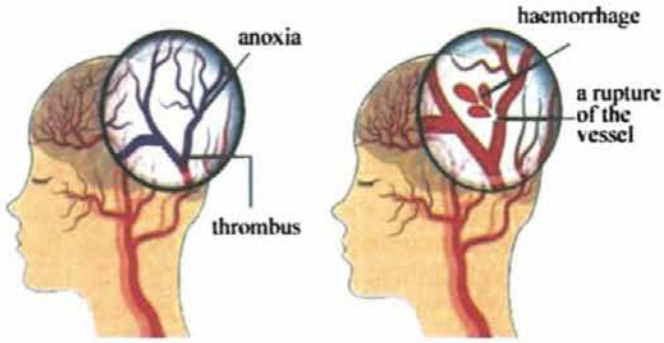


Figure 4.13 Stroke due to blockage of blood clot (thrombus) and rupture of blood vessel

Deep vein thrombosis (DVT) is the formation of a blood clot in a vein deep inside the body and it usually happens in leg veins. It can be caused by prolong inactivity such as during long-haul flights, and the risk increased with age (Figure 4.14).

Figure 4.14 Deep vein thrombosis

Risk factor for cardiovascular disease

The risk factors may be non-modifiable or modifiable.

Non-modifiable risk factors for cardiovascular disease

The three main risk factors for CVDs which cannot be changed are:

- **Genes**: there is a genetic tendency (trend) in some families, and also in some ethnic groups, to develop CVDs. These trends can include (i) arteries which are easily damaged, (ii) a tendency to develop hypertension which can cause arterial damage and make CVDs more likely, and (iii) problems with the cholesterol balance of the body.
- **Age**: as a person gets older, the blood vessels begin to lose their elasticity and to narrow slightly. This can make more likely to suffer from CVDs, particularly heart disease.
- **Gender**: men are more likely to suffer from heart disease (and other CVDs) than women.

Modifiable risks factors for cardiovascular disease

The development of atherosclerosis is linked to many types of CVD.

Lifestyle can affect the risk of developing atherosclerosis in the future. Epidemiological studies have shown links with smoking, diet and weight, lack of activity and high blood pressure.

Smoking - Studies have shown that smokers are far more likely to develop atherosclerosis than non-smokers with a similar lifestyle. Studies found that the substances in tobacco smoke: (i)can damage the artery linings, which makes the build-up of plaques more likely, (ii) can cause the arteries to narrow, raise the blood pressure and increase the risk of atherosclerosis, and (iii) smoking also changes the balance of lipoproteins in the blood.

Inactivity - Sedentary lifestyle can lead to heart diseases. It also causes obesity, high blood pressure and diabetes. Regular exercise helps to prevent these adverse health effects. It also lowers blood cholesterol levels, balance lipoproteins and reduce stress. And thus, lower the risk of developing atherosclerosis and CVDs.

High blood pressure - A healthy blood pressure is around 120 mmHg during systole and around 80 mmHg during diastole. If the blood pressure is regularly above 140/90 mmHg, it is a sign of high blood pressure or hypertension and can also be a sign of atherosclerosis. The blood pressure goes up when the walls of the arteries become less flexible due to the build-up of the plaques. This means that raised blood pressure can be the result of atherosclerosis. Measuring blood pressure is used as an indicator of both the heart and blood vessels.

Diet and obesity - An increasing number of studies suggest that being overweight does not directly affect the risk of developing CVDs, but it is a very important indicator of risk. Most scientists think that the best predictors of future CVDs are: (i) where fat is stored on the body, (ii) how much exercise a person does and (iii) the levels of different fats in the blood.

Two other factors which are often a direct result of being overweight do increase the risk of atherosclerosis and CVDs. These are:

- high blood pressure which increases the risk of damage to blood vessel linings, and so of plaque formation
- type 2 diabetes- this can result in damage to the lining of the blood vessels which increases the risk of plaque formation.

Many studies are starting to find that an increased risk of developing a disease is often due to a combination of factors.

Prevention of cardiovascular disease

Eating a balanced diet with a variety of fats and plenty of fruit and vegetables helps prevent atherosclerosis. Not smoking and maintaining a healthy weight- a body mass index (BMI) of 18.5-25 kgm^{-2} is the ideal range. It is needed to control high blood pressure and type 2 diabetes. Taking regular exercise strengthens the heart muscle and helps to control blood pressure and cholesterol level. It also reduces constant stress. Thus, all these factors contribute towards the prevention of cardiovascular disease.

Treatment

Antihypertensives drugs that such as **beta blockers, sympathetic nerve inhibitors, ACE inhibitors** are some of the commonly prescribed drugs to reduce blood pressure. They reduce the risks of CVDs and also reduce the risk of damage to the kidneys and eyes from high blood pressure. But there are risks. If the treatment is not monitored carefully, the blood pressure may become too low. That can lead to falls and injuries which, particularly in elderly patients, can be serious and even life-threatening.

To lower the level of cholesterol in the blood, a group of drugs known as **statin** is used. They also improve the balance of LDLs (low-density lipoprotein) to HDLs (high-density lipoprotein) and reduce inflammation in the lining of the arteries. Both functions reduce the risk of atherosclerosis developing. **Plant stanols and sterols** compounds are now widely sold in spreads and yoghurts, which also reduce the levels of LDLs in the blood.

Anticoagulants (e.g., warfarin and heparin) are a class of medicines used to reduce blood clotting. **Platelet inhibitory drugs** such as aspirin are also a type of anticoagulant. These drugs prevent platelets clumping together. As they reduce the formation of blood clots, the chance of a blood vessel becoming blockage can be reduced.

4.2.2 Infectious Diseases

Infectious diseases are diseases that are caused by organisms known as **pathogens**. They are sometimes called communicable diseases as they are passed from infected to uninfected people. Some also affect animals and are passed from animals to humans. The way in which a pathogen passes from one host to another is called the **transmission cycle**.

The prevalence of a disease is the number of people who have that disease at any one time. Diseases that are always in populations are described as **endemic**. **An epidemic** occurs when there is a sudden increase in the number of people with a disease. **A pandemic** occurs when there is an increase in the number of cases throughout a continent or across the world. The death rate from different diseases is referred to as mortality. Some diseases of worldwide importance are shown in Table 4.3.

Table 4.3 Some diseases of worldwide importance

Disease	Pathogen	Type of organism
Cholera	*Vibrio cholerae*	Bacterium
Malaria	Four species of *Plasmodium*	Protist
HIV/AIDS	Human Immunodeficiency Virus (HIV)	Virus
Tuberculosis (TB)	*Mycobacterium tuberculosis* and *M. bovis*	Bacterium
Measles	A species of *Morbillivirus*	Virus
Covid	Coronavirus	Virus

Malaria

Transmission of malaria

The features of this disease are summarized in Table 4.4. Most cases of malaria are caused by one of four species of the protist *Plasmodium*, whose life cycle is shown in Figure 4.15. Genetic analysis of infections shows that some species of *Plasmodium* that cause malaria in monkeys also affect humans.

Table 4.4 Features of malaria

Pathogen	*Plasmodium falciparum*, *P. vivax*, *P. ovale*, *P. malariae*
Method of transmission	Insect vector: female *Anopheles* mosquito
Global distribution	Throughout the tropics and subtropics (endemic in 106 countries)
Incubation period	From a week to a year
Site of action of pathogen	Liver, red blood cells, brain
Clinical features	Fever, anaemia, nausea, headaches, muscle pain, shivering, sweating, enlarged spleen
Method of diagnosis	Microscopical examination of blood, dip stick test for malaria antigens in blood
Annual incidence worldwide	About 207 million cases of malaria in 2012 (about 80% are in Africa)
Annual mortality worldwide	About 630,000 deaths in 2012 (about 90% are in Africa)

Female *Anopheles* mosquitoes feed on human blood to obtain the protein they need to develop their eggs. If the person they bite is infected with *Plasmodium*, they will take up some of the pathogen's gametes with the blood meal. Male and female gametes fuse in the mosquito's gut and develop to form infective stages, which move to the mosquito's salivary glands. When the mosquito feeds again, it injects an anticoagulant from its salivary glands that prevents the blood meal from clotting, so that it flows out of the host into the mosquito. The infective stages pass from the mosquito's salivary glands into the human's blood together with the anticoagulant in the saliva. The parasites enter the red blood cells, where they multiply.

The female *Anopheles* mosquito is therefore a vector of malaria and it transmits the disease when it passes the infective stages into an uninfected person. Malaria may also be transmitted during blood transfusion and when unsterile needles are re-used. *Plasmodium* can also pass across the placenta from mother to fetus.

Plasmodium multiplies in both hosts, the human and the mosquito; at each stage there is a huge increase in the number of parasites, and this improves the chances of infecting another mosquito or human host. If people are continually re-infected by different strains of malaria they become immune. However, this only happens if they survive the first five years of life, when mortality from malaria is very high. The immunity only lasts as long as people are in contact with the disease. This explains why epidemics in places where malaria is not endemic can be very serious, and why malaria is more dangerous in those areas where it only occurs during and after the rainy season. This often coincides with the time of maximum agricultural activity, so the disease has a disastrous effect on the economy: people cannot cultivate the land when they are sick (Figure 4.15, 4.16 A and B).

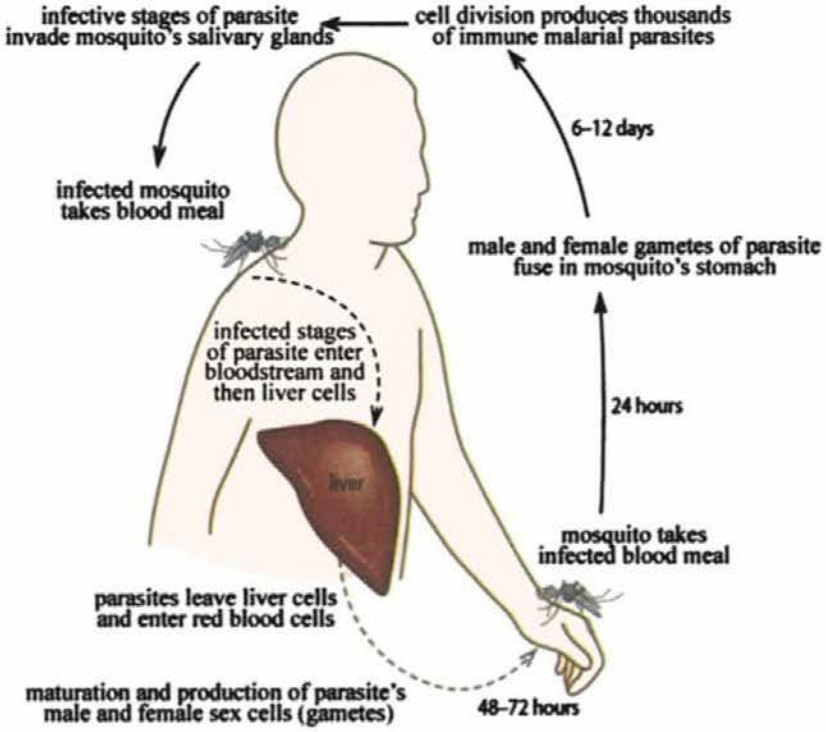


Figure 4.15 Life cycle of *Plasmodium*

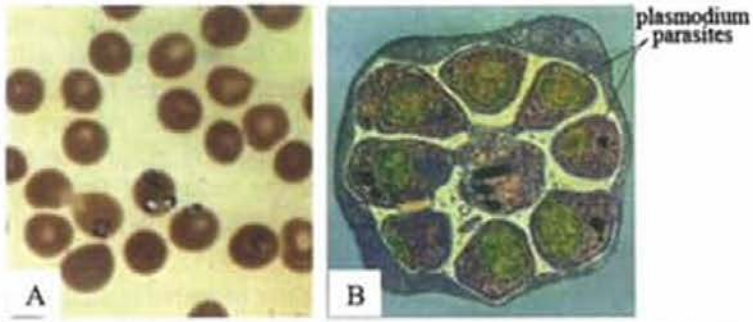


Figure 4.16 A. Red blood cells infected with *Plasmodium falciparum*. Notice the characteristic 'signet ring' appearance of the parasites inside the red blood cells
B. A transmission electron micrograph of a section through a red blood cell packed tightly with malarial parasites

Treating malaria

Quinine and **chloroquine** – are anti-malarial drugs used to treat infected people. They are also used as **prophylactic (preventative) drugs**, stopping an infection occurring if a person is bitten by an infected mosquito. Prophylactic drugs are taken before, during and after visiting an area where malaria is endemic. Chloroquine inhibits protein synthesis and prevents the parasite spreading within the body.

Proguanil is another prophylactic, has the added advantage of inhibiting the sexual reproduction of *Plasmodium* inside the biting mosquito. Where anti-malarial drugs have been used widely, there are strains of drug-resistant *Plasmodium* – the drug is no longer effective against the pathogen.

Mefloquine is a new drug used in South America, Africa and New Guinea. However, mefloquine is expensive and sometimes causes unpleasant side-effects such as restlessness, dizziness, vomiting and disturbed sleep. Resistance to mefloquine has developed in some areas, notably the border regions of Thailand. The antibiotic **doxycycline** is also used as a prophylactic drug. **Artesunate**, a drug derived from the plant compound artemisinin, is used in combination with mefloquine to treat infections of *P. falciparum*.

Preventing malaria

There are three main ways to control malaria:

- reduce the number of mosquitoes,
- avoid being bitten by mosquitoes and
- use drugs to prevent the parasite infecting people.

It is possible to kill the insect vector and break the transmission cycle. Mosquitoes lay their eggs in water. Larvae hatch and develop in water but breathe air by coming to the surface. Oil can be spread over the surfaces of water to make it impossible for mosquito larvae and pupae to breathe. Marshes can be drained and vegetation cleared.

Two biological control measures that can be used are:

- stocking ponds, irrigation and drainage ditches and other permanent bodies of water with fish which feed on mosquito larvae e.g., mosquito fish *Gambusia affinis*

- spraying a preparation containing the bacterium *Bacillus thuringiensis*, which kills mosquito larvae but is not toxic to other forms of life

However, mosquitoes will lay their eggs in any small puddle or pool, which makes it impossible to completely eradicate breeding sites, especially in the rainy season.

The best protection against malaria is to avoid being bitten. People are advised to sleep beneath mosquito nets and use insect repellents. Soaking mosquito nets in insecticide every six months has been shown to reduce mortality from malaria. People should not expose their skin when mosquitoes are active at dusk.

Worldwide control of malaria

In the 1950s, the World Health Organization (WHO) coordinated a worldwide eradication programme. Although malaria was cleared from some countries, the programme was not generally successful. There were two main reasons for this:

- *Plasmodium* became resistant to the drugs used to control it
- mosquitoes became resistant to dichloro-diphenyl-trichloroethane (DDT) and the other insecticides that were used at the time, such as dieldrin

The reasons for the worldwide concern over the spread of malaria are:

- an increase in drug-resistant forms of *Plasmodium*
- an increase in the proportion of cases caused by *P. falciparum*, the form that causes severe, often fatal malaria
- difficulties in developing vaccines against malaria
- an increase in the number of epidemics, because of climatic and environmental changes that favour the spread of mosquitoes
- the migration of people from areas where malaria is endemic, for economic and political reasons

Malaria is still one of the world's biggest threats to health: 40% of the world's population lives in areas where there is a risk of malaria. Between 2000 and 2011, control measures have achieved a decrease in mortality rates of about 25% across the world, and 33% in the WHO's African region.

Control methods now concentrate on working within the health systems to improve diagnosis, improve the supply of effective drugs and promote appropriate methods to prevent transmission. Several recent advances give hope that malaria may one day be controlled. The introduction of simple dip stick tests for diagnosing malaria means that diagnosis can be done quickly without the need for laboratories. The whole genome of *Plasmodium* has been sequenced, and this may lead to the development of effective vaccines. Several vaccines are being trialed, but it is not likely that a successful vaccine will be available for some time. Drugs are used in combination to reduce the chances of drug resistance arising.

Three factors may lead to improvements in the control of malaria:

- use of modern techniques in gene sequencing and drug design
- development of vaccines targeted against different stages of the parasite's life cycle and
- a renewed international will to remove the burden of disease from the poorest parts of the world, allied to generous donations from wealthy individuals and foundations.

Sample Questions

1. State **TRUE** or **FALSE** to the following statements. Do not copy the statements. (6 marks)
   i. Diseases may be the result of living causes.
   ii. Ringspots are characterized by the appearance of necrotic rings on the leaves.
   iii. Oxygen is supplied to the heart muscle by the pulmonary arteries.
   iv. Smoking is one of the non-modifiable factors for cardiovascular disease.
   v. *Plasmodium* multiplies only in single host.
   vi. Chloroquine inhibits protein synthesis and prevents the parasite spreading within the body.

2. Complete the following statements with appropriate words. Do not copy the statements. (6 marks)
   i. Abiotic diseases are caused by non-living ---------- conditions.
   ii. The parasitic organism that causes a disease is a ----------.
   iii. The hardening of arteries, caused by atheroma, is called ----------.
   iv. Deep vein thrombosis (DVT) is the formation of a blood ---------- in a vein deep inside the body.
   v. *Plasmodium* can pass across the ---------- from mother to fetus.
   vi. One of the reasons for the worldwide concern over the spread of malaria is an increase in drug-resistant forms of ----------.

3. Choose the correct answer for the following statements. Do not copy the statements. (6 marks)
   i. (A. Signs B. Symptoms C. Mosaics D. Ringspots) are visible effects of disease on plants.
   ii. (A. Physical B. Chemical C. Biological D. Geological) control is control of plant diseases using living microorganisms.
   iii. A stroke is caused by an interruption of the normal blood supply to an area of the (A. leg B. thorax C. brain D. abdomen).
   iv. Measuring blood pressure is used as an indicator of (A. heart B. blood vessels C. both heart and blood vessels D. overweight).
   v. Female *Anopheles* mosquitoes feed on human blood to obtain the (A. carbohydrate B. protein C. lipid D. glucose) they need to develop their eggs.
   vi. Artesunate is a drug derived from the plant compound (A. proguanil B. mefloquine C. artemisinin D. deoxycycline).

Sample Questions (Continued)

4. Match items in column A and B. Do not copy the statements. (6 marks)

Column A	Column B
i. Diet and obesity	A. Heart attack
ii. Diseases	B. Prophylactic drug for malaria
iii. Signs	C. Result of disturbance in the normal life process
iv. Myocardial infarction	D. Modifiable risks factors for cardiovascular disease
v. Malaria	E. Physical evidence of the pathogen
vi. Proguanil	F. Disease caused by *Plasmodium*

5. Complete this paragraph about the angina in cardiovascular disease. Use words from this list. Each word may be used once, more than once, or not at all. (6 marks)

anaerobic	coronary	breathlessness	oxygen
chest	painful	heart	frightening

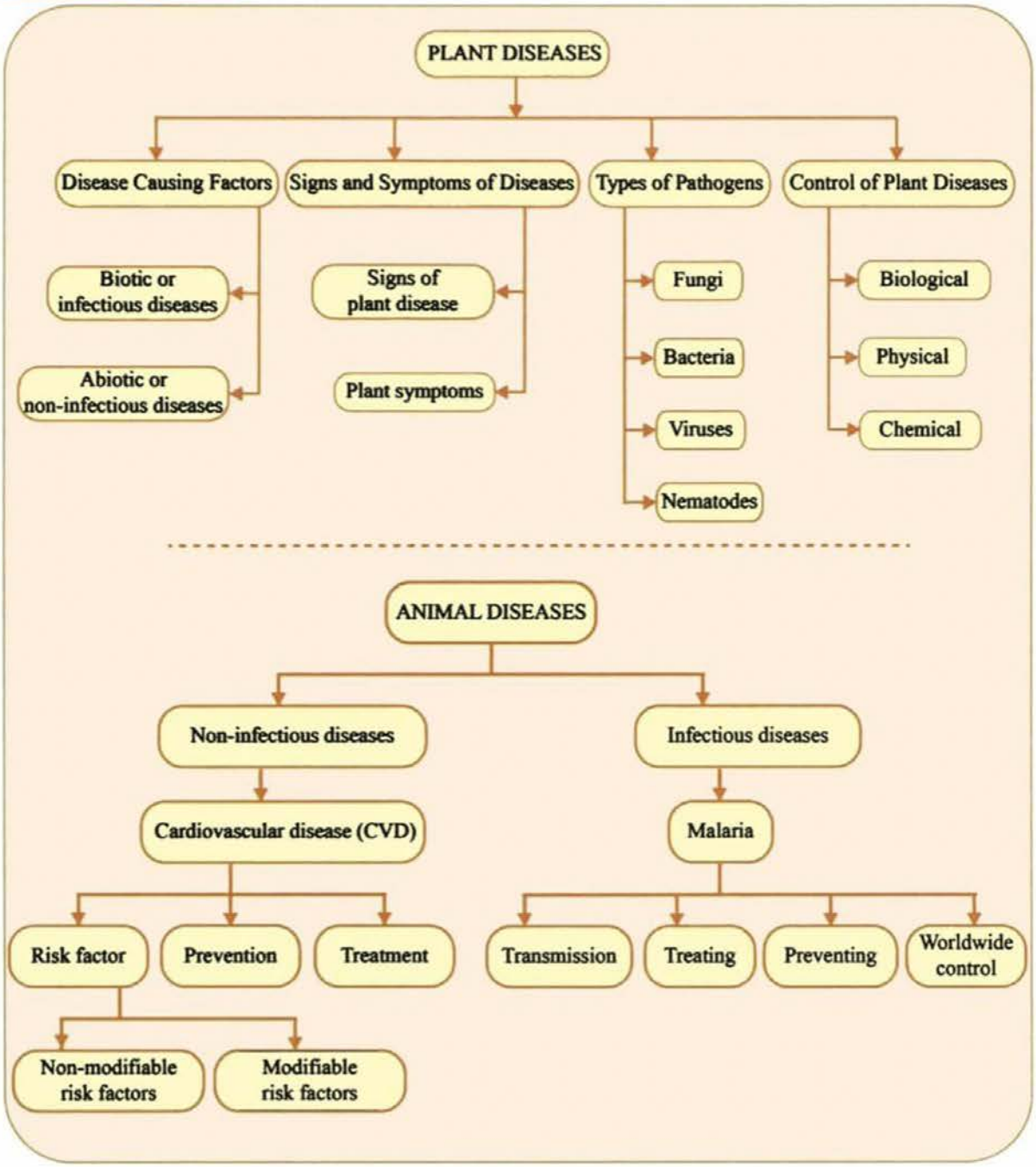
In angina, plaques build up slowly in the ----(a)---- arteries, reducing blood flow to the parts of the ----(b)---- muscle beyond the plaques. Often symptoms are first noticed during exercise, when the cardiac muscle is working harder and needs more ----(c)----. The narrowed coronary arteries cannot supply enough oxygenated blood and the heart muscle resorts to ----(d)---- respiration. This causes a gripping pain in the ----(e)---- that can extend into the arms, particularly the left one, and the jaw, and often also causes ----(f)----.

6. Answer **ANY TWO** questions. (4 marks)
   a. How do you understand the symptoms?
   b. State the role of genes as non-modifiable risk factors for cardiovascular disease.
   c. Mention the symptoms of stroke.

7. Answer **ANY TWO** questions. (8 marks)
   a. Briefly explain the types of plant pathogens.
   b. Tabulate some features of infectious diseases of worldwide importance.
   c. Give short account on the smoking and inactivity as modifiable risk factors for cardiovascular disease.

8. Answer **ANY ONE** question. (8 marks)
   a. Clarify the plant diseases control methods.
   b. Explain the prevention and treatment of cardiovascular disease.
   c. Discuss about the preventing malaria.

Concept Map


PLANT DISEASES
Disease Causing Factors
Signs and Symptoms of Diseases
Types of Pathogens
Control of Plant Diseases
Biotic or infectious diseases
Abiotic or non-infectious diseases
Signs of plant disease
Plant symptoms
Fungi
Bacteria
Viruses
Nematodes
Biological
Physical
Chemical
ANIMAL DISEASES
Non-infectious diseases
Infectious diseases
Cardiovascular disease (CVD)
Malaria
Risk factor
Prevention
Treatment
Transmission
Treating
Preventing
Worldwide control
Non-modifiable risk factors
Modifiable risk factors

CHAPTER 5
COORDINATION AND RESPONSE

Learning Outcomes

It is expected that students will be able to

- explain the production of hormones and their role in both plants and animals
- understand how coordination and response interact between parts of plant bodies
- understand the plant growth and development
- promote the knowledge about seed germination in plants
- know the process of photoperiodism
- understand the process of photomorphogenesis after seed germination
- study the structure of human nervous system
- know the structure of different types of neurones and their functions
- understand the structure and function of synapses
- describe the reflexes and reflex arc
- demonstrate the structure of human eye and mechanism of vision
- know the two different types of hormones
- explain the location of endocrine glands in human body and the role of hormones produced by endocrine glands
- make comparison between nervous system and endocrine system

5.1 COORDINATION AND RESPONSE IN PLANTS

Stimulus is a detectable change in the internal or external environment which influence a temporary increase of physiological activity or response in the whole plant or any part of plant. In the plant, there are two types such as internal stimuli and external stimuli.

The responses to external stimuli or environmental changes that are produced by the working of various organs in a systematic and controlled manner are known as **coordination**. The movement of plant parts is due to various external and internal stimuli. External stimuli are water, gravity, light intensity and duration, chemicals, temperature and touch. Internal stimuli or internal control are chemicals called plant hormones. Plants lack a nervous system like animals. But they can sense things around them and respond to them. Thus, coordination and response in plants are undertaken by plant hormones or plant growth regulators or phytohormones.

Plants can **respond** to their **environment** in various ways. These plant responses have evolved because they provide the plant with some type of **selective advantage** (e.g., making them **better adapted to survive and reproduce** in their environment).

The **environmental stimuli** to which plants respond to **abiotic** or **biotic stress.** Examples of plant responses include the **tropisms**, **responses to touch**, **responses to herbivory** and **responses to abiotic stress.**

5.2 PLANT GROWTH AND DEVELOPMENT

There are various types of tissues present in plants, which occupy specific locations throughout their body. These tissues have different structural and functional aspects like growth and development. Growth in general is considered as an increase in size of the object.

The process of development occurs in an ordered fashion within a single diploid cell called zygote. It grows through various types of mitotic divisions. The cells produced after such divisions differentiate to give required tissue.

Growth

Growth can be defined as an irreversible increase in size of an individual cell or organ or its parts. This increase occurs as a result of all the metabolic activities. These activities make use of energy obtained by nutrition.

Phases of growth

In plants, growth occurs in three phases depending upon the region of its occurrence.

1. **Meristematic phase** (Formative phase): It occurs in the meristematic regions, e.g., shoot apex and root apex. The cells in this phase can be easily differentiated from other cells. The cells of meristems are isodiametric, thin walled, and consist of large nucleus and dense cytoplasm.
2. **Elongation phase** (Phase of cells enlargement): cells of this phase are found around the meristematic cells. These cells are highly vacuolated.
3. **Maturation phase** (Phase of cell maturation and differentiation): Cells of this phase undergo structural and functional differentiation and thus, these cells develop into a specialized tissue.

Conditions for growth

The conditions required by a plant for growth are as follow:

1. **Light** is required for tissue differentiation, synthesis of photosynthetic pigments and photosynthesis.
2. **Optimum temperature** for growth is 20-35°C.
3. **Water** maintains the turgidity of plants. It is essential for enzymatic activities in protoplasm and cell elongation.
4. **Oxygen** is necessary for cellular respiration to produce metabolic energy.
5. **Mineral nutrition** is raw material for synthesis of protoplasm as well as source of energy.
6. **Growth regulators** are manufactured by living protoplasm.
7. **Genetic factors** are involved in overall maintenance of a plant.

Development

Life cycle of an organism consists of a sequence of changes, which are collectively called **development**. During development, structures and functions of organs or cells are changed. It involves a switch from one developmental phase of an organism to another.

5.2.1 Plant Growth Regulators

Some special chemical substances regulate growth and development in plants. These substances are also called plant hormones or **phytohormones**. A plant hormone is an organic compound. It is synthesized in one part of a plant in minute quantities and from there it is translocated to another part where it causes a physiological response.

Characteristics of plant growth regulators

- Phytohormones are essential organic compounds required in very small quantities.
- These are generally synthesized at the apices of root, stem and in leaves.
- A single hormone may regulate different aspects of growth.
- Their synthesis is under genetic control and influenced by environmental factors.

Type of plant growth regulators

They can be placed under two groups based on their function.

i. **Growth promoters**, e.g., auxin, gibberellin and cytokinin
ii. **Growth inhibitors**, e.g., ethylene and abscisic acid can induce dormancy and abscission.

(1) Auxin

Auxins are weak organic acids produced naturally by plants. It is the first plant growth regulator. Chemically this hormone is **indole acetic acid** (IAA). Actively growing regions of a plant usually produce the largest amounts of auxins. The regions rich in auxins are the meristems, including shoot tips, root tips, cambia and also young leaves, developing flowers and fruits.

Physiological effects of auxin

Some physiological effects of auxin in plants are as follows:

i. **Root inhibition**: Auxin inhibits the elongation of primary roots. However, it can stimulate the initiation of lateral and adventitious roots.
ii. **Parthenocarpy**: Application of auxin to unpollinated pistil makes them develop seedless fruits or parthenocarpy.
iii. **Cell elongation**: It stimulates the elongation of cells in the shoot and promotes cell enlargement.
iv. **Abscission**: In younger parts, auxin delays abscission. On the other hand, in mature parts, it stimulates abscission.
v. **Cell division**: Auxin initiates and promotes cell division in vascular cambium.

(2) Gibberellin

Gibberellins are plant hormones that include gibberellic acid. They are produced in young organs such as apical leaves, developing buds, root tips and germinating seeds. Gibberellins transport usually by diffusion and may be transported in the xylem and phloem.

Physiological effects of gibberellin

Some physiological effects of gibberellin in plants are as follows:

i. **Fruit growth**: Gibberellins promote growth of fruits.
ii. **Stem and leaf growth**: Gibberellins can stimulate stem elongation.
iii. **Seed germination**: Gibberellins promote seed germination. They stimulate the synthesis of hydrolytic enzymes like amylases, proteases, etc.

(3) Cytokinin

Cytokinin is a basic hormone and purine (adenine) derivative. It primarily acts on cell division, but it also has important interactions with auxin in the growth and development of plants. Cytokinin occurs naturally in the regions with high cell division, e.g., root apices. Coconut milk is a rich source of cytokinins.

Physiological effects of cytokinin

Some physiological effects of cytokinin in plants are as follows:

i. Flowering: Cytokinins induce flowering in plants.
ii. Promote lateral bud developments in dicots.
iii. Development of the chloroplast.

(4) Ethylene

Ethylene is the only gaseous phytohormone. It is produced naturally in plants from amino acid methionine. All parts of seed plants produce ethylene. Maximum synthesis of ethylene occurs during the ripening of fruits.

Physiological effects of ethylene

Some physiological effects of ethylene in plants are as follows:

i. Ethylene stimulates ripening of fruits. It also increases the rate of respiration. Due to this, ethylene is used in post-harvest technology i.e., for commercial ripening of fruits.
ii. Ethylene causes drooping of leaves and flowers.
iii. Ethylene induces rapid growth of internodes and leaf bases.

(5) Abscisic acid

Abscisic acid, also known as abscisin or dormin, is an example in the group of hormones that promote **dormancy** in plants. It is also known as stress hormone. It is produced naturally, when a plant is exposed to stress. The common stresses include lack of water, saline soils, cold temperature and frost.

Physiological effects of abscisic acid

Some physiological effects of abscisic acid in plants are as follows:

i. It causes abscission in leaves, flowers and fruits.
ii. Abscisic acid includes synthesis of carotenoids. It is applied to green-orange colour to turn yellow.
iii. Abscisic acid acts as antagonist of all growth promoters.

5.2.2 Seed Dormancy

The internal inhibition of germination of a normal or viable seed even, when it is placed under most favourable conditions required for its germination is called **seed dormancy**. Causes of seed dormancy are hard seed coats impermeable to water and gases, presence of immature embryo, light sensitive seeds and presence of germination inhibitors.

Dormant seeds remain under non-germinating condition only for a specific period of time that may vary from days to years. This specific period is called their **dormancy period**. The dormancy of seeds can be broken by scarification, stratification, hormonal treatment, etc.

5.2.3 Seed Germination

Seed germinates in favourable conditions. It absorbs water through micropyle and softens the seed coat. The food present in seed is mobilized by the activation of enzymes like amylase, lipase, protease which are transported to the embryo. The radicle grows first, followed by the growth of either epicotyl or hypocotyl. After that, the plumule grows.

Seed germination can be of following types.

i. **Epigeal germination** takes place above the ground. The cotyledons are first pushed above the ground by the rapid elongation of hypocotyl. e.g., bean seed, castor seed etc. (Figure 5.1 A).

ii. **Hypogeal germination** in which the epicotyl elongates faster than hypocotyl at the time of seed germination. It keeps cotyledons inside the soil or may bring them just above the soil surface. e.g., mango, coconut etc. (Figure 5.1 B).

iii. **Vivipary germination** of seeds inside the fruit, which is still attached to the parent tree is called **vivipary**. e.g., *Agave* and mangroves (Figure 5.1 C).

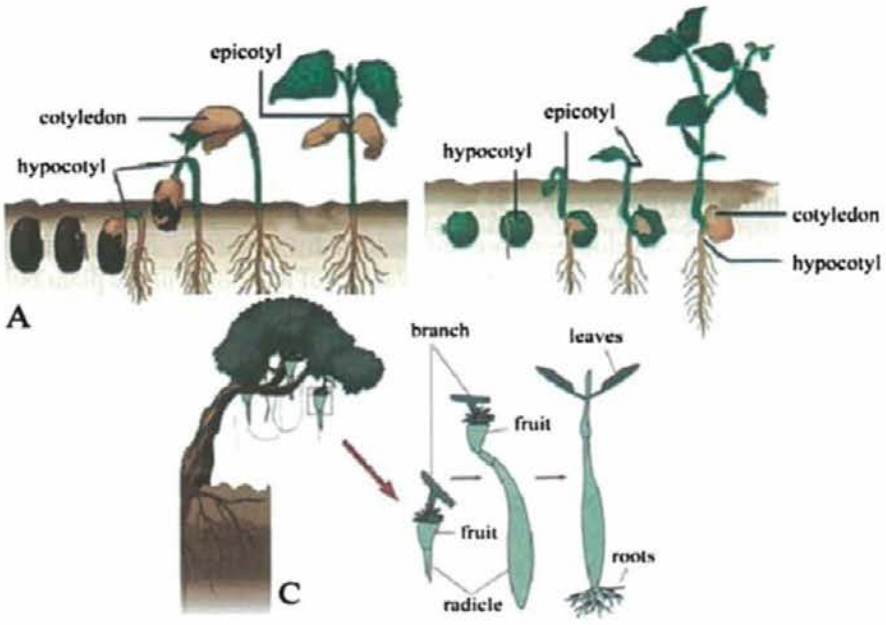


Figure 5.1 Germination of A. epigeal, B. hypogeal and C. vivipary

5.2.4 Photoperiodism

Effect or requirements of relative length of day and night on flowering is called **photoperiodism**. Most plants flower only when they are subjected to a light phase for less or more than a critical period. A critical period is the period of light or darkness required by the plant to induce flowering.

Depending upon the duration of photoperiod, plants have been divided into following categories.

i. **Short day plants**: They require shorter photoperiod than their critical photoperiod in order to initiate flowering. They are long night plants. e.g., soybean, onion etc.

ii. **Long day plants**: They require longer day light period than their critical photoperiod for flowering. They are short night plants. e.g., radish, potato etc.

iii. **Day neutral plants**: They are indeterminate plants. The floral initiation in them is independent of photoperiodism. e.g., tomato, cotton, etc.

Physiology of flowering

It is proposed that a hormone called **florigen** is synthesized in leaves which is responsible for initiation of flowering.

5.2.5 Photomorphogenesis

Plants can sense light direction, quality, intensity and periodicity. Light induces phototropism, photomorphogenesis, flowering, germination, etc. Plants exhibit different growth habits in dark and light. In the dark, they have elongated stems, undifferentiated chloroplasts and unexpanded leaves. This is called **photomorphogenesis**.

Photomorphogenesis involves inhibition of stem elongation, differentiation of chloroplast, accumulation of chlorophyll, and expansion of leaves. Photomorphogenesis can be induced by red, far-red and blue light. Light is perceived in plants by photoreceptor i.e., phytochrome, cryptochrome and phototropin. The photomorphogenesis stimulus is perceived in leaves by phytochrome. **Phytochrome** is a protein containing covalently attached chromophore. It is a blue-green pigment.

Importance of photomorphogenesis

Plant growth and development are influenced by a variety of environmental factors, including light. Light, on the other hand, causes a variety of responses in the plant body in addition to photosynthesis. These responses have a significant impact on the course of plant growth and the final plant appearance. They are morphogenic responses to light.

Many plant seeds, for example, do not germinate unless they are exposed to light. Seed germination in light demonstrates that seedlings require light to grow. Phototropic responses of seedlings and mature plant leaves are also photomorphogenic processes.

Older plants rely on photomorphogenesis responses as well. Many of these responses are in response to the relative lengths of day and night by forming reproductive structures or dormant buds that can withstand a cold winter (i.e., the phenomenon of photoperiodism and vernalization).

5.3 COORDINATION AND RESPONSE IN ANIMALS

Coordination is the process involved in the detection of stimuli by receptors, and also the integration of the information received and the subsequent actions of the effectors to produce responses to the stimuli. The coordination process starts with the stimulus and ends with the response. Coordination involves two main body systems: the **nervous system**, which is involved in the transmission of nerve impulses and the **endocrine system**, which is involved in the secretion of hormones.

Living organisms respond to changes in the internal environment and the external environment. A change in the environment which can be detected by the body is called **stimulus** (plural: stimuli). The main purpose for living organisms respond to certain stimuli is to ensure the continuity of life or survival of the organisms. It is necessary for animals respond to stimuli are (a) to adapt to the environment, (b) for protection from danger, (c) for safety (to move to a safer place) and (d) to regulate the internal environment by **homeostasis**.

5.3.1 Human Nervous System

The human nervous system is made up of the central nervous system and the peripheral nervous system. The components of the nervous system shown in Figures 5.2 A and B.

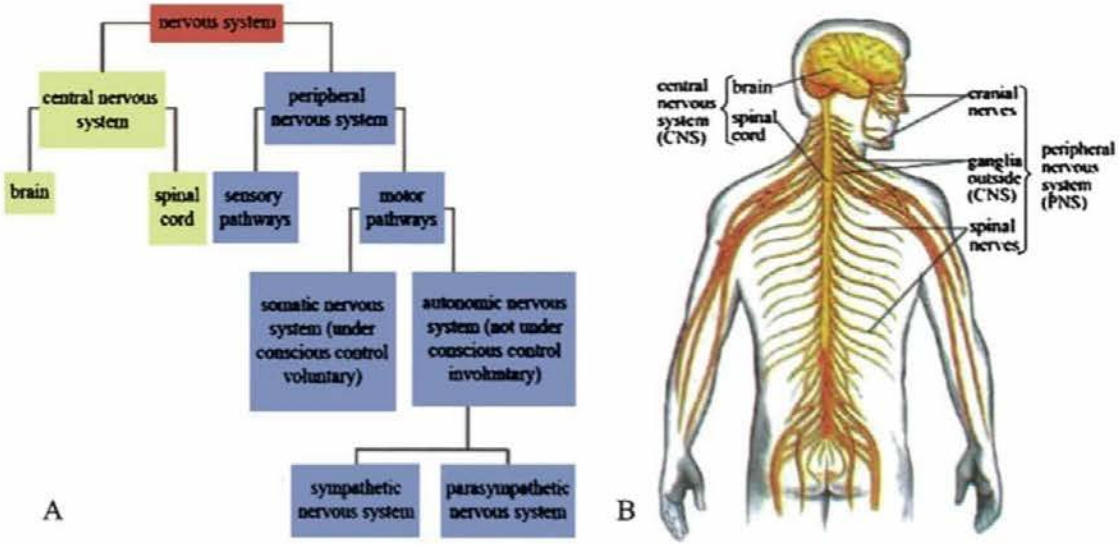


Figure 5. 2 Human nervous system A. Flow chart
B. Central and peripheral nervous system and its nerves

The central nervous system

The central nervous system is composed of the brain and the spinal cord which are located at the central axis of the body.

The brain

The brain can be subdivided into three general regions: the **forebrain**, the **midbrain**, and the **hindbrain**. The forebrain comprises the **cerebrum**, **thalamus** and **hypothalamus**, and the

hindbrain consists of the **cerebellum**, **pons** and **medulla oblongata**. Despite its central importance, the brain is fragile and has a gelatin-like consistency. The **skull** forms a protective bony armour around the brain. In addition, the **meninges**, three layers of tough, elastic tissue within the skull and spinal column, directly enclose the brain and spinal cord (Figure 5.3, 5.4 and Table 5.1).

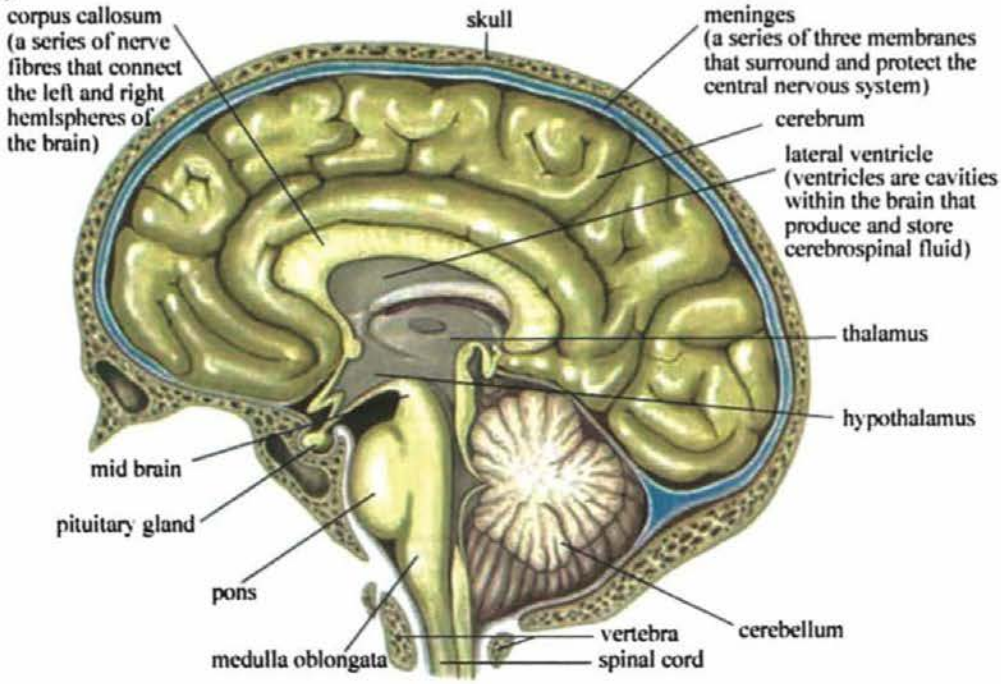


Figure 5.3 Human brain (Lateral view of vertical section)

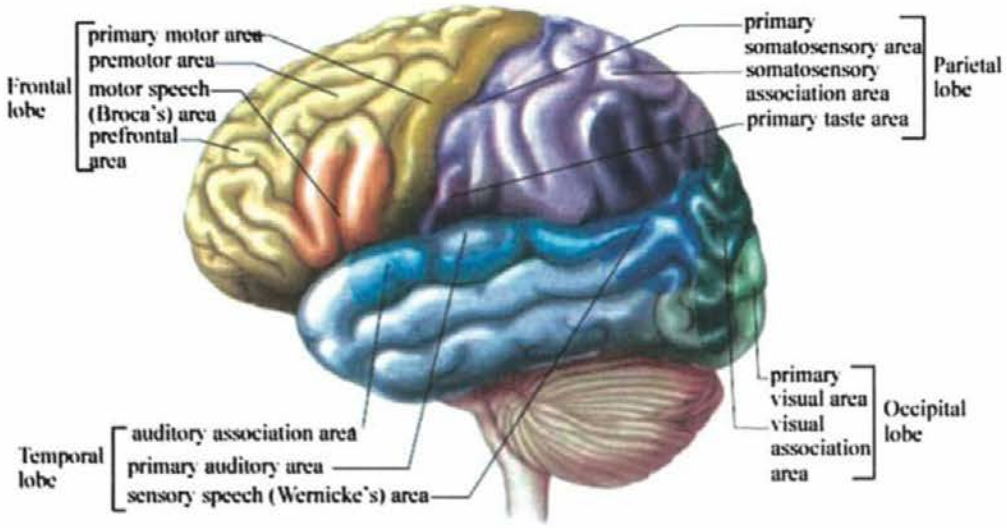


Figure 5.4 Cerebral cortex of human brain (Lateral view)

Table 5.1 The parts of brain and their structures, locations and functions

Parts of brain	Structure and location	Function
cerebrum	- the largest part of the brain and accounts for more than four fifths of the total weight of the brain - it is divided into right and left cerebral hemispheres	- acts as the centres for intellect, learning and memory, consciousness, and language; it interprets and controls the response to sensory information
thalamus	- at the base of the forebrain. It consists of neurones that provide connections between various parts of the brain. These connections are mainly between the forebrain and hindbrain, and between areas of the sensory system (except for the sense of smell) and cerebellum.	- acts as "the great relay station" of the brain
hypothalamus	- lies just below the thalamus	- helps to regulate the body's internal environment, as well as certain aspects of behaviour - contains neurones that control blood pressure, heart rate, body temperature, and basic drives (such as thirst and hunger) and emotions (such as fear, rage, and pleasure) - brain damage or a tumour that affects the hypothalamus can cause a person to display unusual, even violent behaviour - also acts as a major link between the nervous and endocrine (hormone) systems
midbrain	- above the pons in the brainstem	- involved in processing information from sensory neurones in the eyes, ears, and nose - relays visual and auditory information between areas of the hindbrain and forebrain - it plays an important role in eye movement and control of skeletal muscles
cerebellum	- walnut-shaped structure located below and largely behind the cerebrum	- involved in the unconscious coordination of posture, reflexes, and body movements, as well as fine, voluntary motor skills - receives information from specialized sensors, called proprioceptors, located within skeletal muscles and joints
pons	- above and in front of the medulla oblongata in the brainstem	- serves as a relay centre between the neurones of the right and left halves of the cerebrum, the cerebellum, and the rest of the brain
medulla oblongata	- at the base of the brainstem, where it connects the brain with the spinal cord	- coordinates many reflexes and automatic bodily functions that maintain homeostasis, including heart rate, constriction or dilation of blood vessels, and the rate and depth of breathing, swallowing, and coughing.

Spinal cord

A cross section of the spinal cord, reveals both white matter and grey matter. The outer white matter consists of myelinated nerve fibres. The butterfly-shaped core is made up of grey matter, which contains unmyelinated neurones as well as the cell bodies and dendrites of many spinal neurones (Figure 5.5 A and B).

The delicate tissues of the spinal cord are protected by cerebrospinal fluid, soft tissue layers, and the spinal column. The spinal column consists of a series of backbones (vertebrae) (Figure 5.6). Injury to the spinal column can also damage the spinal cord, resulting in paralysis.

Peripheral nervous system

The peripheral nervous system consists of nerves that link the brain and spinal cord to the rest of the body, including the senses, muscles, glands, and internal organs.

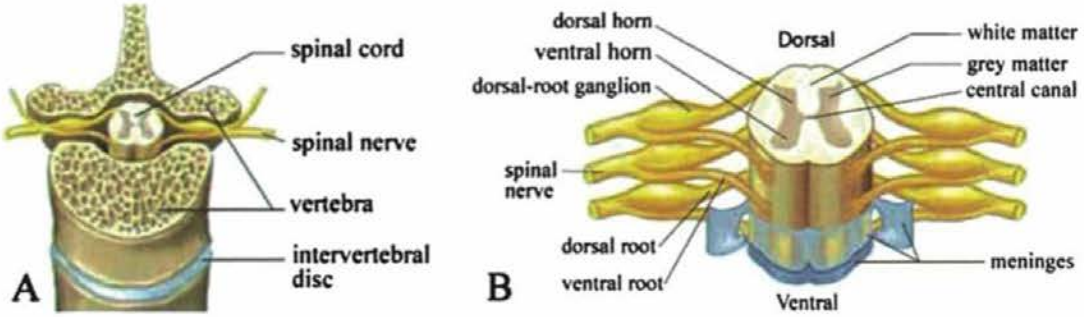


Figure 5.5 The spinal cord A. inside of the vertebra and B. exposed

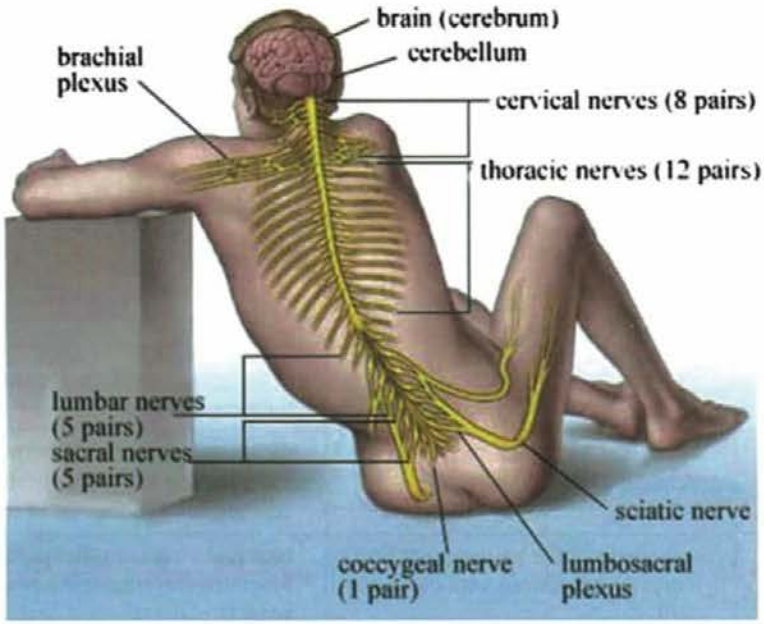


Figure 5.6 The spinal nerves are named for the region of the body where they are located: cervical, thoracic, lumbar and sacral

The somatic nervous system

The somatic nervous system is under the voluntary control, and its neurones service to the head, trunk, and limbs. Its sensory neurones carry information from the receptors in the skin, tendons, and skeletal muscles. Its motor neurones carry information to the skeletal muscles.

The somatic system includes 12 pairs of cranial nerves and 31 pairs of spinal nerves, all of which are myelinated. The **cranial nerves** are largely associated with functions in the head, neck, and face. An exception is the vagus nerve, which has branches to the throat and larynx, but also connects to many internal organs, including the heart, lungs, bronchi, digestive tract, liver, and pancreas.

The basic divisions of the spinal nerves that emerge from each side of the spinal cord are shown in Figure 5.6. Each **spinal nerve** contains both sensory and motor neurones, which service the area of the body where they are found. For example, thoracic nerves control the muscles of the rib cage.

The autonomic nervous system

Internal reactions to the situation would be controlled by the autonomic nervous system. In contrast to the somatic system, the autonomic system is under automatic, or involuntary control. Its nerves either stimulate or inhibit the glands or the cardiac or smooth muscle. The autonomic system maintains homeostasis by adjusting the body to variations in the external and internal environments without an individual having to think about it and control it consciously.

The reflex arc

Some neurones are organized to enable the body to react rapidly in times of danger, even before consciously aware of the threat. These sudden, involuntary responses to certain stimuli are called reflexes (Figure 5.7). Examples of reflexes are (i) jerking the hand away from a hot or sharp object, (ii) blinking when an object moves toward the eye, or (iii) vomiting in response to food that irritates the stomach.

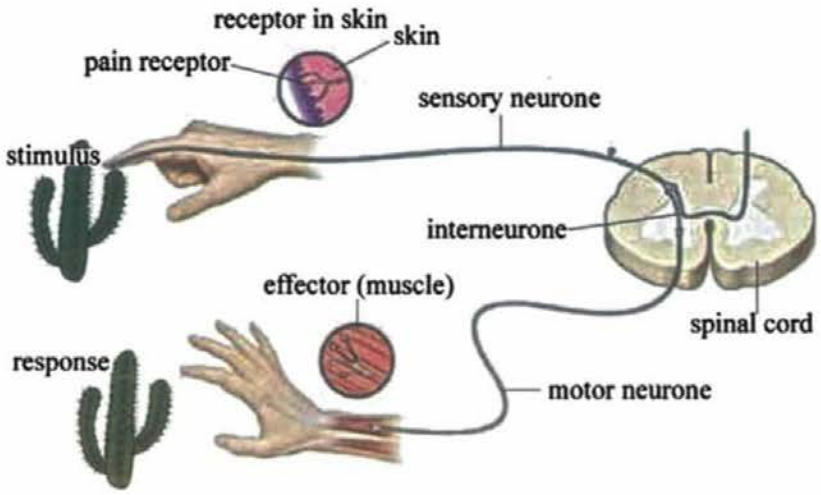


Figure 5.7 The reflex arc

Reflex arcs are simple connections of only three neurones to transmit messages. As a result, reflexes can be very rapid, occurring in about 50 ms (milliseconds). For example, Figure 5.7 illustrated a typical neural circuit of withdrawal reflex from a potentially painful situation. Receptors in the skin sense the pressure of the cactus needle and initiate an impulse in a sensory neurone. The impulse carried by the sensory neurone then activates the interneurone in the spinal cord which then signals the motor neurone to instruct the muscle to contract and withdraw the hand. A reflex arc moves directly to and from the brain or spinal cord, before the brain centres involved with voluntary control have time to process the sensory information.

Sympathetic and parasympathetic nervous systems

The sympathetic nervous system is typically activated in stressful situations, a response often referred to as the **fight-or-flight response**. The sympathetic neurones release a neurotransmitter called **norepinephrine**, which has an excitatory effect on its target muscles.

The parasympathetic nervous system is activated when the body is calm and at rest. It acts to restore and conserve energy. Sometimes referred to as the **rest-and-digest response**. The parasympathetic system uses the neurotransmitter acetylcholine to control organ responses (Table 5.2).

Table 5.2 Effects of the sympathetic and parasympathetic nervous systems

Effector	Effect of sympathetic nervous system	Effect of parasympathetic nervous system
Tear ducts	Inhibits tears	Stimulates tears
Pupils	Dilates pupils	Constricts pupils
Salivary glands	Inhibits salivation	Stimulates salivation
Lungs	Dilates air passages	Constricts air passages
Heart	Speeds heart rate	Slows heart rate
Liver	Stimulate liver to release glucose	Stimulate gall bladder to release bile
Kidneys, stomach, pancreas	Inhibits activity of kidneys, stomach, and pancreas	Increases activity of stomach and pancreas
Adrenal glands	Stimulates adrenal secretion	No known effect
Small and large intestine	Decreases intestinal activity	Increases intestinal activity
Urinary bladder	Inhibits urination	Stimulates urination

5.3.2 Structure of Neurones

The nervous system is composed of only two main types of cells: **neurones** or nerve cells and cells that support the neurones, which are called **glial cells**. Neurones are the basic structural and functional units of the nervous system. They are specialized to respond to physical and chemical stimuli, to conduct electrochemical signals, and to release chemicals that regulate various body processes. Individual neurones are organized into tissues called **nerves**. The activity of neurones is supported by another type of cells called glial cells. The word glial comes from a Greek

word that means "glue." Collectively, glial cells nourish the neurones, remove their wastes, and defend against infection. Glial cells also provide a supporting framework for all the nervous-system tissue (Figure 5.8).

Figure 5.8 A micrograph showing glial cells and neurones

Neurones have many of the same features as other body cells, such as a cell membrane, cytoplasm, mitochondria, and a nucleus. In addition, neurones have specialized cell structures: dendrites and axons, that enable them to transmit nerve impulses. **Dendrites** are short, branching terminals of **dendron** that receive nerve impulses from other neurones or sensory receptors, and relay the impulse to the cell body. The dendrites are numerous and highly branched, which increases the surface area available to receive information. The **axon** conducts impulses away from the cell body. Axons range in length from 1 mm to 1 m, depending on the neurone's location in the body. The terminal end of an axon branches into many fibres to communicate with adjacent neurones, glands, or muscles. The axon terminal releases chemical signals into the space between it and the receptors or dendrites of neighbouring cells (Figure 5.9).

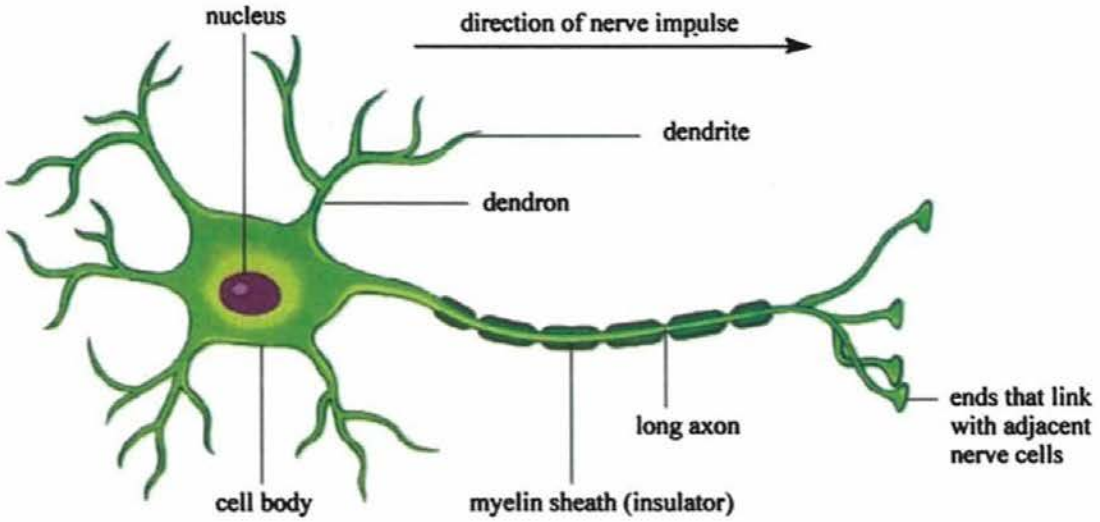


Figure 5.9 Structure of a typical neurone

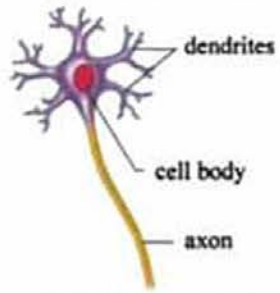
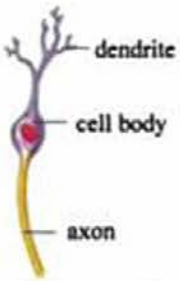
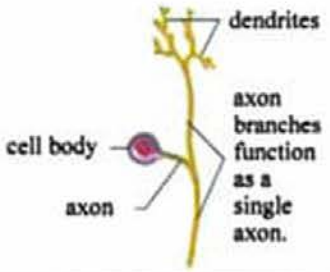
The axons of some neurones are enclosed in a fatty, insulating layer called the **myelin sheath**, which is made up of Schwann cells, a type of glial cell, by wrapping themselves around the axon. Functions of the myelin sheath are;

(i) to protect the nerve fibre or axon from injury,
(ii) to supply nutrients to axon,
(iii) to act as an insulator to the nerve impulses,
(iv) to increase the speed of transmission of the nerve impulses.

Neurones can be classified based on their structure as well as their function. Structurally, neurones are classified based on the number of processes that extend from the cell body.

Functionally, neurones are classified as one of **three main types**: sensory neurones, interneurones and motor neurones. **Sensory** neurones transmit impulses from the sensory receptors to the central nervous system (brain and spinal cord). **Interneurones** are found entirely within the **central nervous** system. They act as a link between the sensory and motor neurones. **Motor neurones** transmit information from the central nervous system to effectors (muscles and glands) (Table 5.3 and Figure 5.10).

Table 5.3 The structures and functions of each neurone

Multipolar Neurone	Bipolar Neurone	Unipolar Neurone
		
• Has several dendrites • Has a single axon • Found in the brain and spinal cord	• Has a single main dendrites • Has a single axon • Found in the inner ear, the retina of the eye, and the olfactory area of the brain	• Has a single process that extends from the cell body • Dendrite and axon are fused • Found in the peripheral nervous system

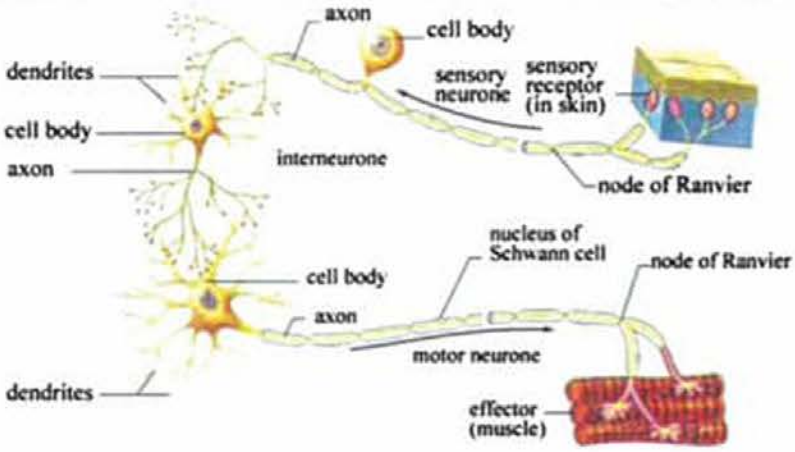


Figure 5.10 Sensory neurone, interneurone and motor neurone

5.3.3 Synapses

The connection between two neurones, or a neurone and an effector, is called a **synapse**. A neuromuscular junction is a synapse between a motor neurone and a muscle cell. An impulse travels the length of the axon until it reaches the far end, called the synaptic terminal. Neurones are not directly connected but have a small gap between them called **the synaptic cleft**. Although the synaptic cleft is only about **0.02 µ** wide, neurones are not close enough for the impulse to jump from one to the other.

Chemical messengers called **neurotransmitters** carry the neural signal from one neurone to another. Neurotransmitters can also carry the neural signal from a neurone to an effector, such as a gland or muscle fibre. Figure 5.11 shows the sequence of events in the movement of an impulse across a synapse. When an action potential arrives at the end of a **presynaptic neurone**, the impulse causes intracellular sacs that contain neurotransmitters to fuse with the membrane of the axon. These sacs, called **synaptic vesicles**, release their contents into the synaptic cleft by **exocytosis**. The neurotransmitters then diffuse across the synapse, taking **about 0.5 to 1 ms** to reach the dendrites of the **postsynaptic neurone**, or cell membrane of the effector.

Upon reaching the postsynaptic membrane, the neurotransmitters bind to **specific receptor proteins** in this membrane. The receptor proteins trigger ion-specific channels to open. This depolarizes the postsynaptic membrane and, if the threshold potential is reached, initiates an action potential. The impulse will travel along the postsynaptic neurone to its terminal and to the next neurone or an effector.

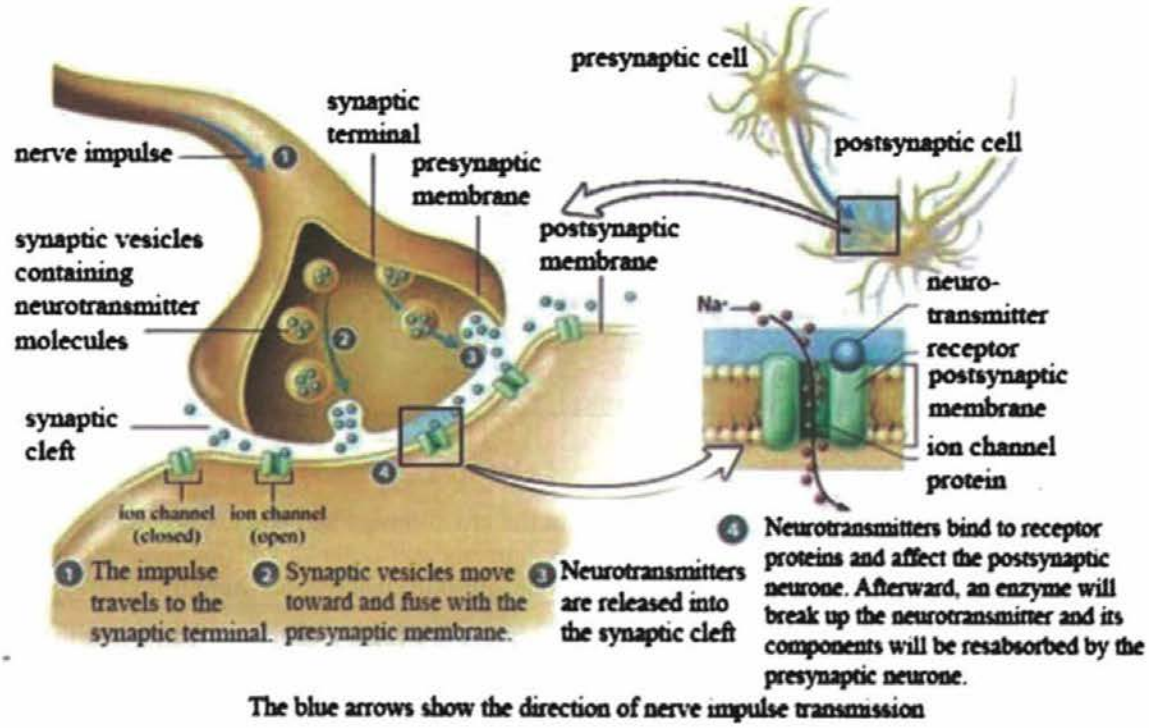


Figure 5.11 Neurotransmitters carry a nerve impulse across the synapse

Neurotransmitters

Neurotransmitters have either excitatory or inhibitory effects on the postsynaptic membrane. If the effect is **excitatory**, the receptor proteins will trigger ion channels that open to allow positive ions, such as sodium, to flow into the postsynaptic neurone. As a result, the membrane becomes slightly depolarized. If the neurotransmitter is **inhibitory**, the receptor will trigger potassium channels to open, allowing potassium ions to flow out. This results in a more negative membrane potential, resulting in **hyperpolarization**.

One example of an excitatory neurotransmitter is acetylcholine. Acetylcholine is a neurotransmitter that crosses a neuromuscular junction. Acetylcholine excites the muscle cell membrane, causing depolarization and contraction of the muscle fibre. There are more than 50 substances in the human body that can act as neurotransmitters. Some are shown in Table 5.4.

Table 5.4 List of some common neurotransmitters and their functions

Neurotransmitters	Function	Effects of abnormal production
Dopamine	- affects the brain synapses in the control of body movements - is linked to sensations of pleasure, such as eating	- excessive production linked to schizophrenia, a disorder in which the individual's perception of reality is greatly distorted - inadequate production linked to Alzheimer's disease, Parkinson's disease, a progressive disorder that destroys neurones, causing tremors, slurred speech, and coordination problems
Serotonin	- regulates temperature and sensory perception - is involved in mood control	- inadequate amounts in the brain synapses linked to depression
Endorphins	- act as natural painkillers in synapses in the brain - also affect emotional areas of the brain	- deficiency linked to an increased risk of alcoholism
Norepinephrine	- used by the brain and some autonomic neurones - complements the actions of the hormone epinephrine, which readies the body to respond to danger or other stressful situations	- overproduction linked to high blood pressure, anxiety, and insomnia - deficiency linked to hunger cravings and exhaustion

5.4 SENSE ORGANS

To survive, organisms must detect changes in the environment and react appropriately to the changes. To detect changes in the environment, humans and other organisms have highly developed sense organs, such as eyes, ears, nose, tongue and skin- that receive stimuli.

Sense organs are organs in which sensory receptors are highly concentrated. When the sensory receptors of a particular sense organ receive appropriate stimulation, they convert the stimulus into electrical signals or action potential. These electrical signals are sent to the specific region of the brain. The brain has a specific region for each sense. Thus, signal received by the vision region of the occipital lobe of brain interpreted as images. Different parts of human eyes are described in the Table 5.5, Figures 5.12 and 5.13.

Table 5.5 The different parts of the eye

Parts	Description	Function
Sclera	- outermost coat of the eyeball - tough, fibrous and opaque	- protects the eye from physical injuries - maintains the shape of the eyeball
Cornea	- a transparent layer continuous with the sclera - light enters the eye through the cornea	- refracts the light rays that enter the eye
Conjunctiva	- a transparent membrane that covers the exposed part of the eyeball	- protects the cornea
Choroid	- the middle coat of the eyeball - contains a black pigment and has a network of blood capillaries	- black pigment absorbs light and prevents internal reflection of light - blood vessels supply oxygen and nutrients to the cells of the retina
Ciliary body	- a thickened region at the front end of the choroid	- changes the thickness of the lens during accommodation
Iris	- a circular sheet of muscles -circular muscles and radial muscles - contains pigments that give the eye its colour	- changes the size of the pupil through the antagonistic action of the circular and radial muscles, thereby adjusting the amount of light that enters the eye
Pupil	- a round opening in the iris	- allows light to enter
Retina	- innermost layer of the eye - consists of two types of photoreceptor cells: cone cells and rod cells	- acts as a screen for the formation of images - rod cells are sensitive under low light and responsible for vision at night - cone cells are responsible for colour vision under conditions of high light intensity
Fovea (Yellow spot)	- situated in line with the optical axis of the lens - contains only cone cells and is the most photosensitive area of the retina	- where images are normally focused - provides the clearest vision
Blind spot	- the area where neurones leave the retina and form the optic nerve - does not contain any photoreceptors	- has no photoreceptors, so it is not sensitive to light (no vision when image falls on it)
Lens	- flexible biconvex crystalline structure behind the iris - divides the eye into two chambers- aqueous chamber and vitreous chamber	- curvature, and thus the focal length, can be changed to focus on near or far objects - refracts light rays onto retina
Aqueous humour	- clear watery fluid in the aqueous chamber	- maintains the internal pressure of the eye - provides nutrients for the lens and cornea - refracts light rays onto the lens
Vitreous humour	- jelly-like substance in the vitreous chamber	- maintains the shape of the eye - prevent collapse of the eye - refracts light rays
Suspensory ligament	- attaches the lens to the ciliary body	- holds the lens vertically in the eye - assists the lens to change its thickness during accommodation
Optic nerve	- a nerve in the eyeball	- transmits nerve impulses from the retina to the brain

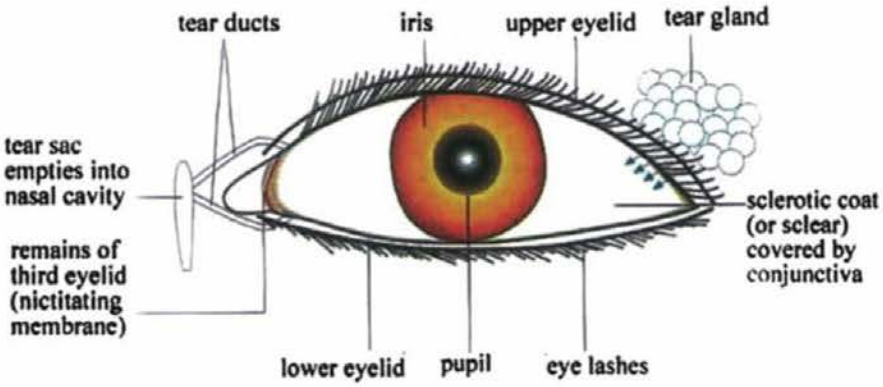


Figure 5.12 The front view of the left eye

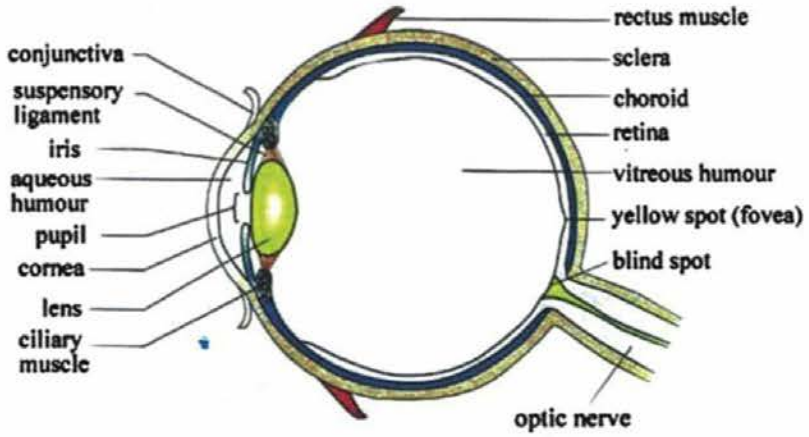


Figure 5.13 The vertical section of the eye

There are several advantages by having two eyes, such as cancelling the blind spot and providing a wider field of view. In addition, each eye forms a slightly different image of an object. The brain combines the information from each eye, giving a person stereoscopic or three-dimensional vision. This allows a person to judge the distance and depth of objects and to estimate the speed of moving objects more accurately (Figure 5.14).

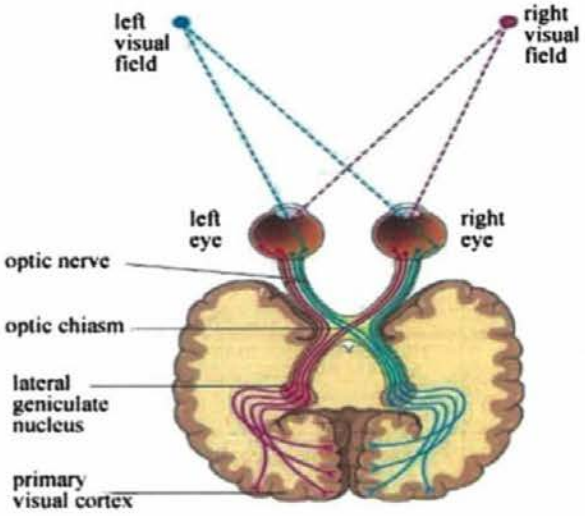


Figure 5.14 Neural pathways for vision

The role of the iris is to control the amount of light entering the eye, by changing the size of the pupil. The iris contains two types of muscle. Circular muscles form a ring shape in the iris and radial muscles lie like the spokes of the wheel.

In bright light, the pupil is constricted. This happens because the circular muscles contract and the radial muscles relax.

In dim light, the opposite happens. The radial muscles contract and the circular muscles relax, dilating (widening) the pupil (Figure 5.15).

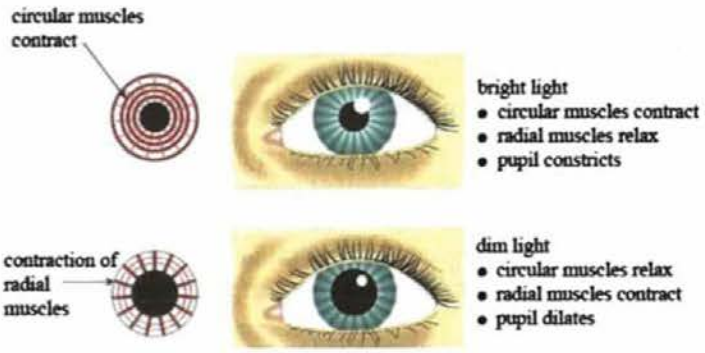


Figure 5.15 Adjusting bright light and dim light

Accommodation: Focusing on objects at different distances

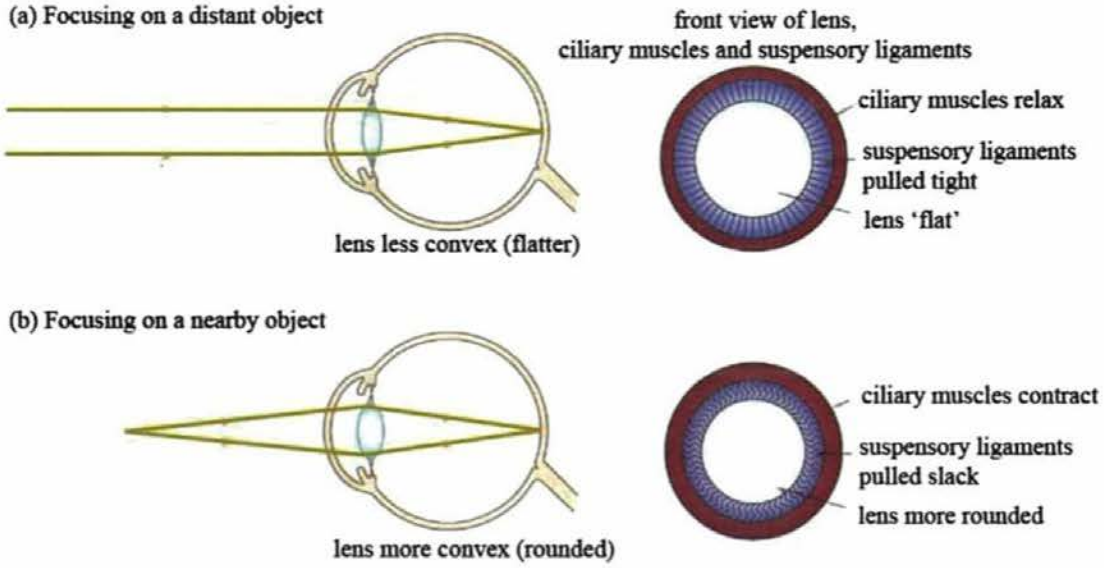


Figure 5.16 Accommodation: how the eye focuses on objects at different distances
A. Focusing on a distant object and B. Focusing on a nearby object

When the eye is focused on a distant object, the rays of light from the object are almost parallel when they reach the cornea (Figure 5.16 A). The cornea refracts the rays, but the lens does not need to refract them much more to focus the light on the retina. This means the lens does not need to be more convex. The ciliary muscles relax and the pressure in the eye pushes outwards on the lens, flattening it and stretching the suspensory ligaments. This is the condition when an eye is at rest, the eyes are focusing on the long distance.

When the eyes focus on a nearby object, for example reading a book, the light rays from the object are spreading out (diverging) as they enter the eye (Figure 5.16 B). In this situation, the lens has to be more convex in order to refract the rays enough to focus them on the retina. The ciliary muscles now contract; the suspensory ligaments become slack and the elastic lens bulges outwards into a more convex shape.

5.5 THE ENDOCRINE SYSTEM

The endocrine glands and their hormones make up the endocrine system. Endocrine glands secrete chemical messengers called **hormones** directly into the bloodstream, which transports the hormones throughout the body. The original Greek meaning of the word hormone is to "excite" or "set in motion." Compared to the rapid actions of the nervous system, the endocrine system typically has slower and longer acting effects and affects a broader range of cell types.

5.5.1 Endocrine Glands and Hormones

The endocrine glands found in human body are shown in Figure 5.17 and Table 5.6.

There are two main types of hormones; steroid hormones and water-soluble hormones.

Steroid hormones, such as testosterone, estrogen, and cortisol, are lipid-based.

Water-soluble hormones are epinephrine, human growth hormone (hGH), thyroxine (T_4), and insulin.

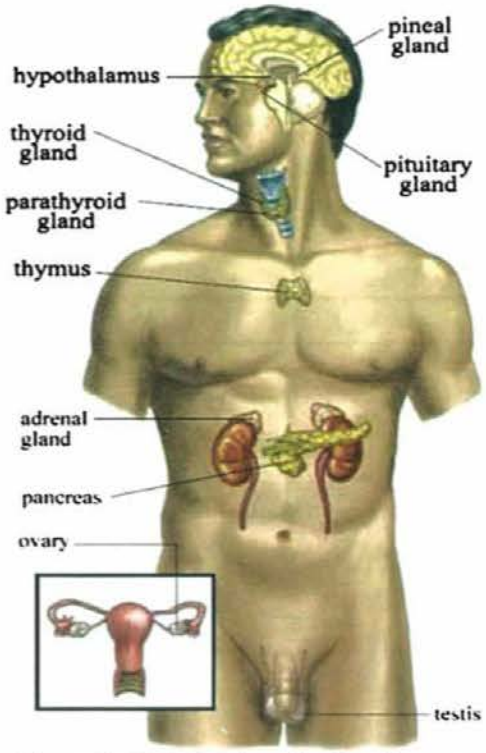


Figure 5.17 Endocrine glands of human

Table 5.6 Human endocrine glands and some of their hormones

Endocrine gland	Hormone secreted	Effects of hormone on target tissue/organs
Hypothalamus	Hypothalamic releasing and inhibiting hormones	Regulates anterior pituitary hormones
Anterior pituitary	Human growth hormone (hGH)	Stimulates cell division, bone and muscle growth, and metabolic function
	Thyroid-stimulating hormone (TSH)	Stimulates the thyroid gland to produce thyroxine

Table 5.6 Human endocrine glands and some of their hormones (Continued)

Endocrine gland	Hormone secreted	Effects of hormone on target tissue/organs
Anterior pituitary	Adrenocorticotropic hormone (ACTH)	Stimulates the adrenal cortex to secrete glucocorticoids
	Follicle-stimulating hormone (FSH)	Stimulates production of ova and sperm from the ovaries and testes
	Luteinizing hormone (LH)	Stimulates sex hormone production from the ovaries and testes
	Prolactin (PRL)	Stimulates milk production from the mammary glands
Posterior pituitary	Antidiuretic hormone (ADH)	Promotes the retention of water by the kidneys
	Oxytocin (OCT)	Stimulates uterine muscle contractions and release of milk by the mammary glands
Thyroid	Thyroxine (T_4)	Affects all tissues; increases metabolic rate and regulates growth and development
	Calcitonin	Targets bones and kidneys to lower blood calcium by inhibiting release of calcium from bone and reabsorption of calcium by kidneys
Parathyroid	Parathyroid hormone (PTH)	Raises blood calcium levels by stimulating the bone cells to release calcium, the intestine to absorb calcium from food, and the kidneys to reabsorb calcium
Adrenal cortex	Glucocorticoides (for example, cortisol)	Stimulates tissues to raise blood glucose and break down protein
	Mineralocorticoides (for example, aldosterone)	Promotes reabsorption of sodium and water by the kidneys
	Gonadocorticoides	Promotes secondary sexual characteristics
Adrenal medulla	Epinephrine and nor-epinephrine	Fight-or- flight hormones
Pancreas	Insulin	Lowers blood glucose levels and promotes the formation of glycogen in the liver
	Glucagon	Raises blood glucose levels by converting glycogen in the liver to glucose
Ovaries	Estrogen	Stimulates uterine lining growth and promotes development of the female secondary sexual characteristics
	Progesterone	Promotes growth of the uterine lining and prevents uterine muscle contractions
Testes	Testosterone	Promotes sperm formation and development of the male secondary sexual characteristics

5.5.2 Comparison between Nervous System and Endocrine System

Similarities between nervous system and endocrine system

1. Both the nervous system and endocrine system coordinate the body's activities.
2. Both systems need a stimulus to produce a response.
3. Both types of coordination have specific effectors as target organs.

Differences between nervous system and endocrine system

The differences between nervous system and endocrine system are shown in Table 5.7.

Table 5.7 Differences between nervous and endocrine systems

Feature	Nervous system	Endocrine system
Transmission of information	- information is transmitted as a nerve impulse (electrical in nature along a neurone) - it is transmitted as chemical substance (neurotransmitters) between neurones or a neurone and muscle cells (synaptic cleft)	- information is transmitted as a chemical substance (hormone)
Mode of transmission	- by nerve cells (neurones)	- by bloodstream
Speed of transmission	- fast	- slow - it is determined by the speed of blood flows through the blood vessels
Duration of effect	- short-lived, within milliseconds	- usually longer lasting, from minutes to days
Localization of effect	- may affect only a localized region of the body	- may affect one or more organs in different parts of the body (e.g., removal of hand from a painful situation, it effect is only the muscle in hand that responsible for it)

Sample Questions

1. State **TRUE** or **FALSE** to the following statements. Do not copy the statements.

(6 marks)

i. The chief growth hormone of plants is auxin.
ii. The main effect of cytokinin is to decrease the rate of cell division.
iii. Ethylene is important in the ripening of fruits.
iv. A stimulus is detected by a sensory receptor.
v. The lens focuses the image on the cornea of the eye.
vi. Insulin is produced by the islets of Langerhans in the liver.

2. Complete the following statements with appropriate words. Do not copy the statements.

(6 marks)

i. Plants can respond to their ---------- in various ways.
ii. The cells of ---------- are isodiametric.
iii. A plant hormone is an ---------- compound.
iv. The nervous system consists of nerve cells called ----------.
v. Aqueous and vitreous chambers are involved in the ---------- of light rays onto the retina.
vi. Thyroid-stimulating hormone stimulates the thyroid gland to produce ----------.

3. Choose the correct answer for the following statements. Do not copy the statements.

(6 marks)

i. Flowering hormone is suggested to be (A. auxin B. gibberellin C. ethylene D. florigen).
ii. (A. Cytokinin B. Abscisin C. Ethylene D. Abscission) is in the group of hormones that promote dormancy in plants.
iii. Effect of relative length of day and night on flowering is called (A. photoperiodism B. photomorphogenesis C. florigen D. morphogenesis).
iv. The central nervous system is made up of (A. brain and cranial nerves B. Spinal cord and spinal nerves C. brain and spinal cord D. cranial nerves and spinal nerves).
v. Which one of the following normally enters the blood as it passes through the pancreas? (A. glycogen B. insulin C. lipase D. urea).
vi. How do hormones travel around the body? (A. in glands B. in nerves C. in the blood stream D. in white blood cells).

Sample Questions (Continued)

4. Match items in column A and B. Do not copy the statements. (6 marks)

Column A	Column B
i. Phytohormone	A. Insulating layer surrounded the axon
ii. Axon	B. Branches of dendron as threadlike structure
iii. Cerebrum	C. Carries nerve impulses away from the cell body
iv. Dendrites	D. Plant hormone
v. Myelin sheath	E. A nerve cell
vi. Neurone	F. The largest part of the brain

5. Complete this paragraph about the nerve pathway. Use words from this list. Each word may be used once, more than once, or not at all. (6 marks)

synapse	white	arc	inter
motor	sensory	effectors	transporter

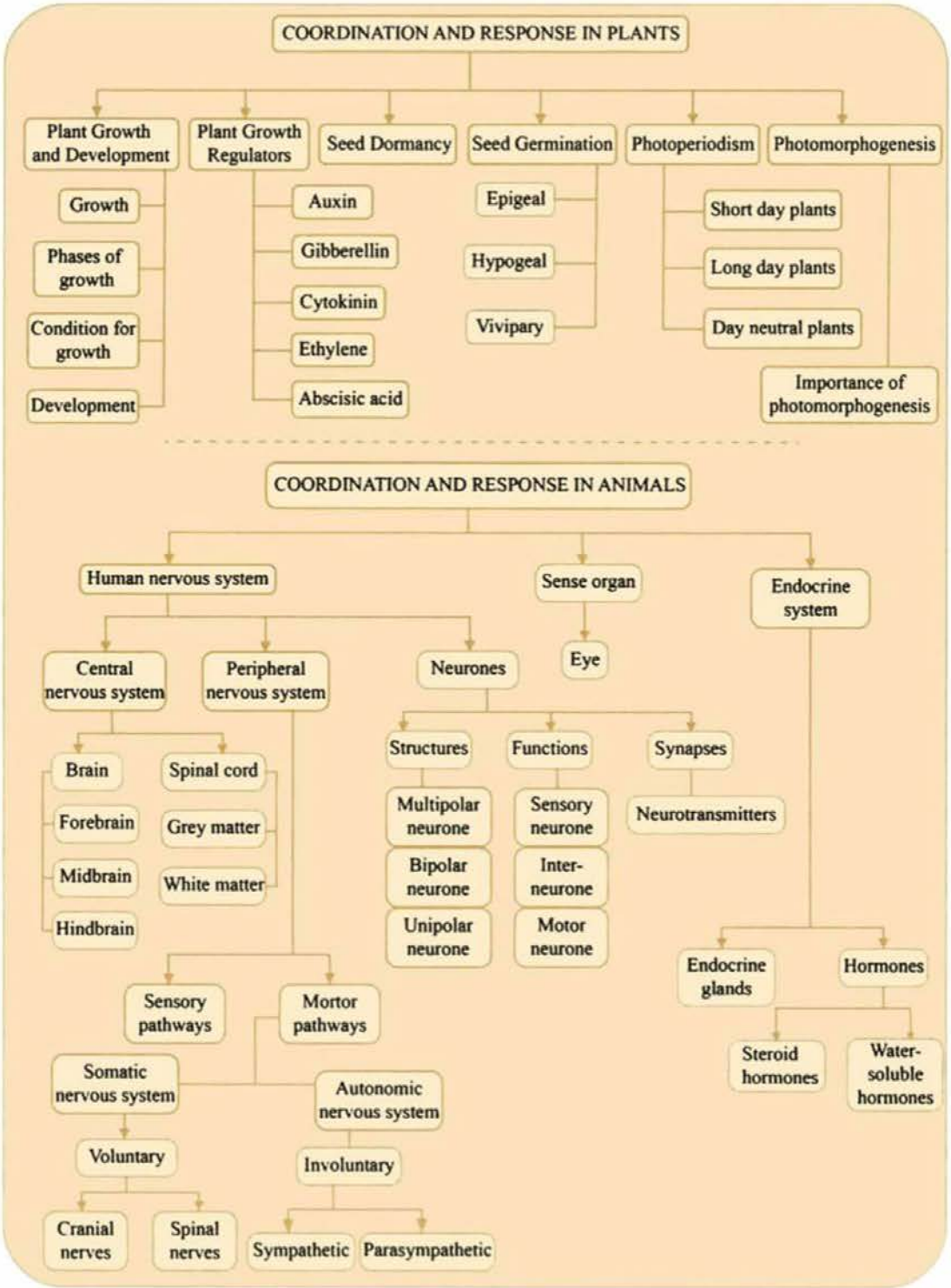
In a reflex ----(a)---- nerve impulse is transmitted to the spinal cord by ----(b)---- neurones. Inside the grey matter of the spinal cord the impulses are passed on to ----(c)---- neurones. The impulses leave the spinal cord along ----(d)---- neurones to go to ----(e)----. There is a gap between two neurones called a ----(f)---- where chemical transmitter substances are released to pass the impulse to the next neurone.

6. Answer **ANY TWO** questions. (4 marks)
   a. Give the characteristics of plant growth regulators.
   b. Name the component parts of nervous system in human.
   c. State the two types of photoreceptor cells in retina and their functions.

7. Answer **ANY TWO** questions. (8 marks)
   a. Give an account of the seed germination.
   b. Tabulate the parts of the hindbrain with their structures, locations and functions.
   c. Describe the nature of myelin sheath and its functions.

8. Answer **ANY ONE** question. (8 marks)
   a. Differentiate the photoperiodism and photomorphogenesis.
   b. Give an account of the structure and function of synapse (Diagram not necessary).
   c. Compare and contrast the nervous system and the endocrine system.

Concept Map


COORDINATION AND RESPONSE IN PLANTS
Plant Growth and Development
Plant Growth Regulators
Seed Dormancy
Seed Germination
Photoperiodism
Photomorphogenesis
Growth
Phases of growth
Condition for growth
Development
Auxin
Gibberellin
Cytokinin
Ethylene
Abscisic acid
Epigeal
Hypogeal
Vivipary
Short day plants
Long day plants
Day neutral plants
Importance of photomorphogenesis
COORDINATION AND RESPONSE IN ANIMALS
Human nervous system
Sense organ
Endocrine system
Central nervous system
Peripheral nervous system
Neurones
Eye
Brain
Spinal cord
Forebrain
Grey matter
Midbrain
White matter
Hindbrain
Structures
Functions
Synapses
Multipolar neurone
Bipolar neurone
Unipolar neurone
Sensory neurone
Inter-neurone
Motor neurone
Neurotransmitters
Endocrine glands
Hormones
Steroid hormones
Water-soluble hormones
Sensory pathways
Mortor pathways
Somatic nervous system
Autonomic nervous system
Voluntary
Involuntary
Cranial nerves
Spinal nerves
Sympathetic
Parasympathetic

CHAPTER 6
BIODIVERSITY AND CONSERVATION

Learning Outcomes

It is expected that students will be able to

- suggest reasons why biodiversity is important in nature
- describe the different levels and examples of biodiversity such as ecosystem or community diversity, species or taxonomic diversity and genetic diversity
- promote knowledge about biodiversity in Myanmar including forest types and endangered species
- identify and explain the natural and man-made factors that threatened on biodiversity
- evaluate the various measures taken to conserve the different levels of biodiversity including *in situ* and *ex situ* conservation methods
- know about the types and locations of protected areas that established in Myanmar

6.1 BIODIVERSITY

Biodiversity comes from two words; **Bio** means life and **diversity** means variability. The term 'Biodiversity' was coined by Walter G. Rosen in 1985 but was popularized by Edward O. Wilson who is now known as 'Father of Biodiversity'. The term 'biodiversity' refers to the variety and variability among living organisms and the ecological complexes in which they occur. Thus, biodiversity can be defined as the totality of genes, species and ecosystem of a region. Biodiversity play a significant role in both human life and the natural ecosystem by maintaining the balance of the ecosystem.

6.1.1 Levels of Biodiversity

Biodiversity can be defined as the degree of variation of life forms in an ecosystem. This is usually taken to include diversity at three levels:

- the variation in ecosystems or habitats
- the number of different species in the ecosystem and their relative abundance
- the genetic variation within each species

Ecosystem diversity: An ecosystem is a community of organisms and their physical environment interacting each other's together. The diversity of ecological complexity includes variations in ecological niches, trophic structure, food-webs and nutrient cycling etc. The ecosystems also show variations with respect to physical parameters like moisture, temperature, altitude, precipitation etc. Many ecosystems like deserts, rainforests and mangroves etc., exhibit a vast diversity of life forms residing in their respective ecosystems. Thus, there occurs tremendous diversity within the ecosystem, along these gradients.

Species diversity: Species diversity is defined as the number of species and abundance of each species that lives in a particular location. The number of species in a community is known as **species richness**. Species diversity not only considers richness, but also includes a measure of the evenness of the abundance of the different species. The more species there are, and the more evenly the numbers of organisms are distributed among the different species and the greater the species diversity. Coral reefs have a very high biodiversity; such an ecosystem offers many different ecological niches, which are exploited by different species. Species diversity is considered important because ecosystems with high species diversity tend to be more stable than ones with limited diversity; they are more able to resist changes.

Genetic diversity: Genetic diversity refers to the variety of genetic information contained in all of the individual plants, animals, fungi and microorganisms. Genetic diversity is the variety of genes within a species. The genetic diversity that exists between varieties of cultivated plants and domesticated animals is obvious. Similar genetic diversity, although not always so obvious, exists in natural populations (Figure 6.1).

Figure 6.1 Different types of same species of snail *Cepaea nemoralis*

The genetic differences between populations of the same species exist because populations may be adapted slightly differences in different parts of their ranges. There is also genetic diversity within each population. This diversity is important in providing populations with the ability to adapt to changes in biotic and abiotic factors, such as competition with other species, evading new predators, resisting new strains of disease and changes in temperature, salinity, humidity and rainfall.

6.1.2 Importance of Biodiversity

Biodiversity is very important for the well-being of our planet, human health, food security, economy and livelihoods. All organisms in an ecosystem live in interdependence sharing living space, shelter and available food. They can affect the physical conditions around them. Rich biodiversity allows large-scale ecosystems to function and self-regulate. These ecosystems are also interlinked on a large scale across the earth. If biodiversity is reduced in one area, the natural balance may be destroyed elsewhere.

Healthy ecosystem and rich biodiversity will:

(a) increase ecosystem productivity; each species in an ecosystem has a specific niche which is a role to play
(b) support a larger number of plant species and, therefore, a greater variety of crops
(c) protect fresh water resources
(d) promote soil formation and protection
(e) provide nutrient storage and recycling
(f) aid in breaking down pollutants
(g) contribute to climate stability

(h) speed recovery from natural disasters
(i) provide more food resources
(j) provide more medicinal resources and pharmaceutical drugs

6.2 BIODIVERSITY IN MYANMAR

Myanmar is the largest country in mainland Southeast Asia with a land area of 676,577 km^2. Because of its size, its large latitudinal range of 2,100 km, and the diversity of its topography and habitats, the country is rich in biological diversity (biodiversity).

Myanmar spans a vast area and has diverse geographical features and climates from tropical coral reefs to alpine habitats. Forests cover ranges from moist tropical rain forests in the south, through dry deciduous forests in central areas to temperate broad leaf and alpine forests toward the north. The diverse habitats are home for a wide range of species.

6.2.1 Forest Diversity

Forest ecosystems are a carbon sink and stabilize soils. By slowing water flow due to increased infiltration, forests help regulates the seasonal flow of water downstream and recharge sources of groundwater, which supports base flow in streams. People living downstream benefit from increased stream flows during the dry season, thereby improving access to water for drinking, irrigation and freshwater fisheries etc. By impeding the loss of soils, forests help to maintain the functioning of dam and reservoir infrastructure.

Forest constitutes the dominant vegetation type in Myanmar as shown in Table 6.1. The total area of forest is 290,410 km^2 which is 43% of the total land area. However, only half of this is described as closed forest, whereas the other half is 'open' or 'degraded'. Rainfall and elevation strongly influence the distribution of different vegetation types. Dry forest occurs where rainfall is usually less than 400 mm a year and support xerophytic types of vegetation (Table 6.1).

Table 6.1 Forest cover in Myanmar vegetation type

Forest Types	% of Forest Areas
Mixed Deciduous Forest	38
Hill and Temperate Evergreen Forest	25
Tropical Evergreen Forest	16
Dry Forest	10
Deciduous Dipterocarp (Indaing) Forest	5
Tidal Forest, Beach and Dune Forest, Swamp Forest	4
Fallow Land	2

6.2.2 Endangered Species

The **International Union for Conservation of Nature and Natural Resources (IUCN)** publishes the **Red Data Book**, which includes the list of endangered species of plants and animals. The red data symbolizes the warning signal for those species, which are endangered and if not protected are likely to become extinct in near future.

Myanmar is moderately biodiverse country with many species of trees, shrubs, flowering plants, grasses, insects, fish, amphibians, reptiles, birds, mammals, fungi and micro-organisms. About 250 mammal species, more than 1,000 birds, 370 reptiles and 7,000 plants are recorded in Myanmar, among them 39 species of mammals, 45 of birds, 21 of reptiles and 38 of plants are globally threatened. Some examples of endangered species in Myanmar are as follow:

Examples of some endangered plant species in Myanmar

(1) Scientific Name: *Dipterocarpus alatus*
Common Name: Gurjum tree
Myanmar Name: Kanyin
IUCN Status: Endangered

(2) Scientific Name: *Swietenia macrophylla*
Common Name: Mahogany
Myanmar Name: Mahogany
IUCN Status: Endangered

(3) Scientific Name: *Cephalotaxus mannii*
Common Name: Mann's plum yew
Myanmar Name: Kyauk Htinn shuu
IUCN Status: Endangered

(4) Scientific Name: *Paphiopedilum wardii*
Common Name: Black Orchid
Myanmar Name: Thit- khwa net
IUCN Status: Critically Endangered

(5) Scientific Name: *Rhododendron arboreum*
Common Name: Rhododendron
Myanmar Name: Taung Zalat Ni
IUCN Status: Endangered

Examples of some endangered vertebrate species in Myanmar

(1) Scientific Name: *Elephas maximus*
Common Name: Asian Elephant
Myanmar Name: Sin
IUCN Status: Endangered

(2) Scientific Name: *Rucervus eldii thamin*
Common Name: Eld's Deer
Myanmar Name: Shwe Thamin
IUCN Status: Endangered

(3) Scientific Name: *Orcaella brevirostris*
Common Name: Irrawaddy Dolphin
Myanmar Name: Linpai
IUCN Status: Endangered

(4) Scientific Name: *Pavo muticus*
Common Name: Green Peafowl
Myanmar Name: Daun
IUCN Status: Endangered

(5) Scientific Name: *Geochelone platynota*
Common Name: Burmese Star Tortoise
Myanmar Name: Kyelait
IUCN Status: Critically Endangered

6.3 THREATS TO BIODIVERSITY

Biodiversity ensures natural sustainability for all life on the earth, for example, abundant crops and fresh air. More than 3 billion people depend on marine and coastal biodiversity, while more than 1.6 billion people rely on forests for their livelihoods. The loss of biodiversity affects the lives of more than 1 billion people living in dry lands.

Biodiversity is under threat in many aquatic and terrestrial ecosystems as the human population continues to increase and taking more resources from the environment which produce increasing quantities of waste. Ecosystems and species are being lost at an alarming rate, not just by the direct action of humans, but also indirectly as a result of climate change.

There are five major threats to biodiversity:

- habitat loss and the degradation of the environment
- climate change
- excessive use of fertilizers and industrial and domestic forms of pollution
- the overexploitation and unsustainable use of resources
- the effects of invasive alien species on native species and especially endemics

6.3.1 Habitat Destruction

Habitat destruction has played a key role in extinction. The destruction of the natural environment leads to **habitat loss**. The clearing of land for agriculture, housing, transport, leisure facilities and industry are removes vegetation. Consequently, many species of plants and animals are either lose their habitats completely or their habitats become divided into small areas. This is known as **habitat fragmentation**.

Factors causing habitat destruction are overpopulation, deforestation, pollution and global warming. Habitat size and number of species are systematically related. Physically larger species and those living at lower latitudes or in forests or oceans are more sensitive to reduction in habitat area. Major reasons for habitat destruction are:

- large scale industrial and commercial activities
- mining
- cattle rearing
- commercial fishing
- dam construction
- encroaching
- plantation cropping and agriculture

Land-use change

Myanmar is a large agricultural country. However, most cultivation employs techniques that can significantly degrade the natural environment. For example, shifting cultivation in upland areas, gold mining, urbanization and the clearance of natural forests for agricultural expansion and so on (Figure 6.2 A to C).

Figure 6.2 A. Soil erosion resulting from shifting cultivation, B. Clearing natural forest for agricultural expansion and C. Mining causes deterioration of aquatic ecosystems

Habitat loss

Habitat loss occurs when natural environments are transformed or modified to serve human needs. It is the most significant cause of biodiversity loss globally. For example, deforestation, damming rivers and so on (Figure 6.3 A and B).

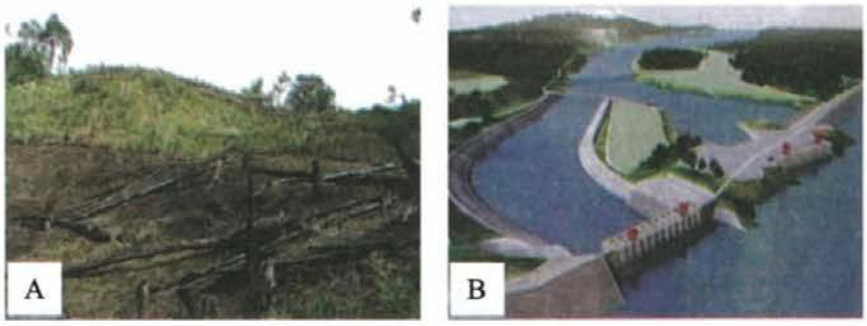


Figure 6.3 A. Deforestation and B. Damming river

Threats to Agrobiodiversity

A variety of human activities threatens the agrobiodiversity of Myanmar. Factors such as the replacement of local landraces with modern varieties, agricultural area expansion, overgrazing, dams and canal construction and urbanization are major threats to the agrobiodiversity of Myanmar (Figure 6.4 A to C).

Figure 6.4 A. Overgrazing, B. Canal construction and C. Urbanization in Myanmar

Pollution

Pollution (soil, water or air) is a growing threat on both land and in aquatic ecosystems. Pollution is caused by uncontrolled pesticide and herbicide uses, various factory wastes, different kinds of rubbish, human sewage, radioactive materials and industrial wastes (Figure 6.5 A to C).

Figure 6.5 A. Soil pollution by mining, B. Air pollution from alcohol industry and C. Water pollution by industries

6.3.2 Invasive Alien Species (IAS)

Little is known about the status of invasive alien species in Myanmar, but a few IAS have been observed in the country. IAS can also be introduced unintentionally by tourists or through the transport of cargo or movement of pets, plant parts and seeds. Some may be intentionally imported for use in research, manufacture of medicine or ornamental and industrial uses (Figure 6.6 A and B).

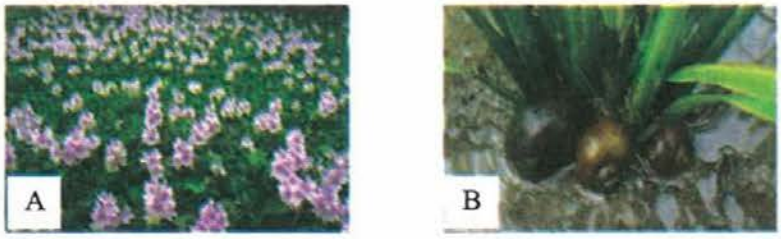


Figure 6.6 A. Invasive alien plant species (Water-hyacinth)
B. Invasive alien animal species (Golden apple snails)

6.3.3 Genetic Pollution

Genetic pollution indicates the loss of identity of wild plant species as a result of transfer of genes from crop plants, with engineered fitness genes causing special concern. However, significant reproductive barriers exist between most wild species and crop plants. Gene flow is expected to have its greatest effect on weed species that are closely related to crop plants taxonomically, ecologically and in their reproductive biology.

The introduction of genetically engineered (GE) organisms into the complex ecosystems of our environment is a dangerous global experiment with nature and evolution. Genetic pollution is undesirable gene flow into wild populations. The term is usually associated with the gene flow from a genetically engineered (GE) organism (or genetically modified organism - GMO) to a non-GE organism. "Genetic pollution" and collateral damage from GE field crops already have begun to wreak environmental havoc. Wind, rain, birds, bees, and insect pollinators have begun carrying genetically altered pollen into adjoining fields, polluting the DNA of crops of organic and non-GE farmers. Once released, it is virtually impossible to recall genetically engineered organisms back to the laboratory or the field.

6.3.4 Overexploitation

Overexploitation, also called **overharvesting**, can lead to the destruction of the resource, as it will be unable to replenish. The term applies to natural resources such as water aquifers, grazing pastures and forests, wild medicinal plants, fish stocks and other wildlife.

Overfishing is the removal of a species of fish (i.e. fishing) from a body of water at a rate greater than that the species can replenish its population naturally. Overfishing can occur in water bodies of any sizes, such as ponds, wetlands, rivers, lakes or oceans, and can result in resource depletion, reduced biological growth rates and low biomass levels.

Overlogging is a form of overexploitation caused by legal or illegal logging activities that lead to unsustainable or irrecoverable deforestation and permanent habitat destruction for forest wildlife.

Overhunting threatens one-third of endangered vertebrates, as well as other groups. Excluding edible fish, the illegal trade in wildlife is valued at $10 billion per year. As of 2016, 301 terrestrial mammals were threatened with extinction due to hunting for bushmeat including primates, even-toed ungulates, bats, diprotodontid marsupials, rodents and carnivores occurring in developing countries. Bushmeat provides increased opportunity for transmission of several zoonotic viruses from animal hosts to humans, such as Ebola virus and HIV.

6.3.5 Climate Change

Climate change is a growing threat to biodiversity. It alters the climate patterns and ecosystems in which species have evolved and on which they depend. For example, rising ocean temperatures and diminishing Arctic sea ice affects marine biodiversity and can shift vegetation zones, having global implications. Overall, climate is a major factor in the distribution of species across the globe; climate change forces them to adjust. But many are not able to cope, causing them to become extinct (Figure 6.7 A to D).

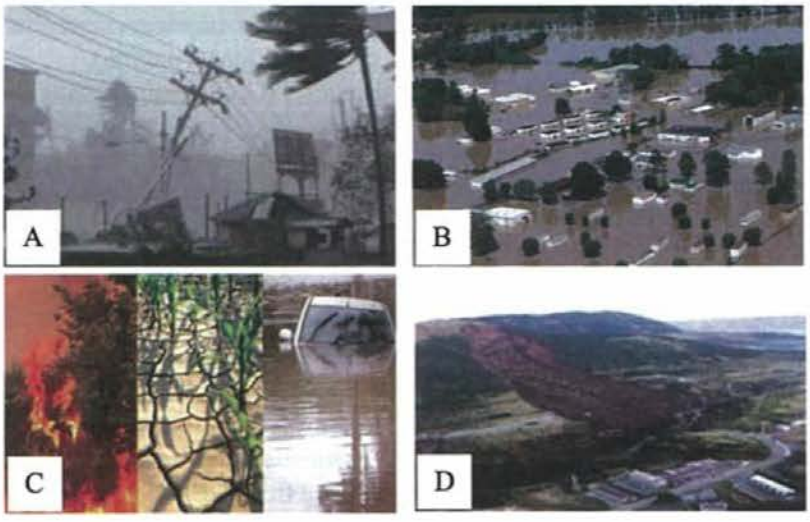


Figure 6.7 A. Cyclone Nargis in Myanmar, B. Flooding after Nargis, C. Effects of climate change and D. Landslide in Paung Township of Mon State

6.3.6 Human Overpopulation

It is only logical that an increase in the world's population will cause additional strains on resources. More people increased demand for food, water, housing, energy, healthcare, transportation, and more. And all that consumption contributes to ecological degradation, increased conflicts, and a higher risk of large-scale disasters like pandemics.

An increase in population will inevitably create pressures leading to more deforestation, decreased biodiversity, and spikes in pollution and emissions, which will exacerbate climate change. Ultimately, unless we take action to help minimize further population growth heading into the remainder of this century, many scientists believe the additional stress on the planet will lead to ecological disruption and collapse so severe it threatens the viability of life on Earth, as we know it.

6.3.7 Wildlife Trade

Wildlife trade refers to the commerce of products that are derived from non-domesticated animals or plants usually extracted from their natural environment or raised under controlled conditions. It can involve the trade of living or dead individuals, tissues such as skins, bones, feathers, meat, or other products of wild plants and wild animals.

Wildlife trade can be differentiated in legal and illegal trade, and both can have domestic (local or national) or international markets that involve products travelling across the world to different countries. Illegal wildlife trade contributes directly to the loss of species and habitat destruction, but it also directly and indirectly impacts local communities. Recent overexploitation of wildlife for trade has affected countless species for example pangolins, tigers, rhinoceroses, elephants, monkeys and others. High demand from expanding illegal wildlife markets in neighboring countries is rapidly threatening the endangered wildlife of Myanmar. Poverty and a lack of alternative livelihoods aggravate the situation (Figure 6.8 A and B).

Figure 6.8 A. Exporting timber illegally from Myanmar
B. Cutting mangrove trees for illegal charcoal trade

In **wildlife smuggling or trafficking**, the products demanded by the trade include exotic pets, food, traditional medicine, clothing, and jewelry made from animals' tusks, fins, skins, shells, horns, and internal organs. Smuggled wildlife is an increasing global demand. Much of demand for rhinoceros' horns, tiger bones, and other animal products arises out of the practice of traditional Chinese medicine, which uses these ingredients to treat fevers, gout, and other illnesses; maintain good health and longevity; and enhance sexual potency (Figure 6.9 and 6.10).

Figure 6.9 Firing the elephant ivory recovered from poachers

Figure 6.10 Confiscated animal pelts from the illegal wildlife trade

However, the most trafficked animal in the world is the pangolin, accounting for as much as 20% of all illegal wildlife trade. Pangolins are the only scaly mammal on earth. In the last decade, more than one million pangolins were poached and killed for their scales. The **pangolin trade** is the illegal poaching, trafficking, and sale of pangolins, parts of pangolins, or pangolin-derived products on the black market. The animals are trafficked mainly for their scales, which are believed to be effective in treating a variety of health conditions. Though meat and scales are the primary drivers of the intercontinental pangolin trade, there are also other less common parts and uses (Figure 6.11).

Figure 6.11 Chinese pangolin

Wildlife smuggling directly affects the biodiversity of different ecosystems. Certain animals are in higher demand by smugglers and leading to a visible decline of these species in their native habitats. Wildlife smuggling may also cause the introduction of invasive and harmful species into an ecosystem, which can endanger indigenous wildlife by putting a strain on the environment's resources through interspecific competition between species. Therefore, wildlife trade is a serious conservation problem, has a negative effect on the viability of many wildlife populations and one of the major threats to the survival of vertebrate species.

The illegal wildlife trade has been linked to the emergence and spread of new infectious diseases in humans, including emergent viruses. Outbreaks of **zoonotic diseases** including COVID -19, H_5N_1 avian flu, severe acute respiratory syndrome (SARS), and monkeypox have been traced to live wildlife markets where the potential for zoonotic transmission is greatly increased.

There are certain places in the world where wildlife trade is particularly threatening or where targeted action would be particularly worthwhile. These places are called **'wildlife trade hotspots'**. Therefore, national and international laws are in place for wildlife protection, such as **CITES** (the Convention on International Trade in Endangered Species of Wild Flora and Fauna), and Conservation of Biodiversity and Protected Areas Law (2018) in Myanmar.

6.4 CONSERVATION

Biodiversity is being reduced through human activities such as overexploitation, deforestation, habitat destruction, pollution and as a result of climate change. However, many people around the world are working hard to reduce these trends and to conserve the biodiversity we still have. This can be tackled in many different ways.

Conservation means keeping and protecting a living and changing environment. It is an active process involving an enormous range of projects. In order to keep the beauty and diversity of nature reserves. It is important to manage it effectively. Active intervention is required to restore areas and to protect native species, and sustainable benefits for the present as well as future strategies.

6.4.1 Reasons for Conservation

Biodiversity is important and should be conserved for its values and benefits to human health and well-beings. The followings are the three major reasons to conserve biodiversity:

i. **Narrowly Utilitarian**: The useful human products like food, fibres, drugs and medicines are obtained from biodiversity.
ii. **Broadly Utilitarian**: Biodiversity provides ecosystem services like providing oxygen, pollinating crops and controlling floods, erosions, etc.
iii. **Ethical Utilitarian**: Every living species has an intrinsic value, though it may not have direct economic value and every species has the right to live.

6.4.2 Conservation Methods

There are mainly two conservation methods; ***in situ*** and ***ex situ*** conservation methods.

In situ conservation methods

In situ methods are the ways of conservation of species which take place in the natural habitat of the organism. The best way to conserve any species is to keep it in its natural habitat. Maintaining the natural habitat means that all the "life support systems" are provided.

Nature reserves such as wildlife sanctuary, national park and biosphere reserve help endangered species by maintaining their habitat and genetic diversity, defending the target species from predators and preventing competition from invasive species. Keeping these organisms' *in situ* means putting them in the ecosystem where they belong. As a result of this, the target species can continue to adapt to conditions in the reserve without interference from outside influences.

Active management of nature reserves involves; (1) continuous monitoring, (2) maintenance of effective boundaries (3) measures to facilitate the successful completion of life cycles and (4) restocking and reintroducing of once-common species from stocks produced by captive breeding programmes of zoological and botanical gardens.

Ex situ conservation methods

Ex situ, methods are the ways to conserve animals and plants outside their natural habitats. It is not always possible to conserve animal species in the wild because the conditions that have put them under threat of extinction. Zoos and wildlife parks used to exist just for people to look at the animals, but today they are very important in animal conservation by *ex situ* conservation methods. These methods are usually used as a last resort.

The three methods of *ex situ* conservation are captive breeding of animals, storage of seeds in the seed bank and cultivation of plants in botanical garden.

(1) Captive breeding

Endangered species typically have very low population numbers and are in serious danger of becoming extinct. For some species whose numbers have dwindled drastically, captive breeding may be their last hope of survival. In captive breeding programmes, individuals of an endangered species are bred in zoos and parks in an attempt to save the species from extinction. Usually, the ultimate aim is to reintroduce the captive-bred animals into the wild to restore the original populations. Reintroduction does not always work, but it can programme to be successful in national parks or other protected areas.

Some techniques used in captive breeding programmes are:

i. Artificial insemination
ii. Embryo transfer to a surrogate mother
iii. Cryogenics (eggs, sperm cells and embryos can be frozen for future use)
iv. Human-raised young
v. Keeping a pedigree (prevent from inbreeding)

Problems with captive breeding and reintroduction programmes are:

i. not enough space or resources in zoos and parks for all the endangered species
ii. difficulty in providing the right conditions for breeding, even if scientists know what those conditions are
iii. continuation of the conditions that pushed the species close to extinction
iv. animals that have been bred in captivity may have problems adjusting to unsupported life in the wild
v. reintroduction programmes can be very expensive and time consuming and they may be fail

(2) Seed bank

It has been estimated that 25% of the world's flowering plant species could disappear within the next 50 years. There are thought to be about 242,000 species of flowering plants now, so this would mean 60,500 species disappearing in less than one human lifetime. Seed banks have been set up to help conserve rare plant species. Seeds in a seed bank are kept in cold, dark conditions in which the metabolism of the seed slows down so the seed is prevented from germinating (Figure 6.12 and 6.13).

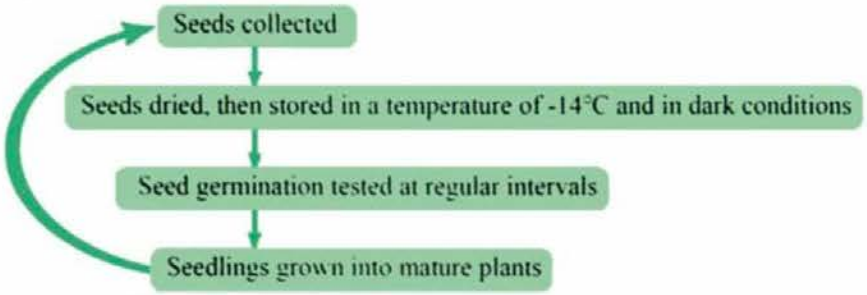


Figure 6.12 Some of the steps involved in storing seeds

Figure 6.13 Storage of seeds in a seed bank, Department of Agricultural Research, Yezin

The storage of seeds is one of the most widespread and valuable *ex situ* approaches to conservation. Seed banks protect and save plant genetic diversity, which is important for a number of reasons. These saved and viable seeds contain a treasure trove of useful genes that breeders can use for developing improved varieties of our major food crops. For example:

i. Improve resistance to current and emerging plant diseases and insects
ii. Provide drought or flood tolerance
iii. Improve yields and nutrition to feed a growing global population

(3) Botanical garden

Plants are easily kept in captivity. About 80,000 plant species are grown in private gardens, arboretums and botanical gardens all over the world. Botanical gardens also have an important role in the preservation of species necessary for human use and well-being. These gardens are good locations for many branches of scientific research. Botanical gardens not only serve as taxonomic and systematic research centers but they play an important role as valuable sources of plant ecology. One of the major objectives of botanical gardens is to create and support collections of native taxa, and to build and maintain stocks of plants for *ex situ* conservation and sustainable utilization of plant resources in the world. Botanical gardens are also ideal places to integrate the study and conservation of trees species that are endangered in the wild.

6.4.3 Protected Areas in Myanmar

Protected areas (PAs) are important tools for biodiversity conservation and sustainable development. PAs are safeguard ecosystems and their services, such as water provision, food production, carbon sequestration and climate regulation, thus improving people's livelihoods. They preserve the integrity of spiritual and cultural values placed by indigenous people on wild areas and offer opportunities of inspiration, study and recreation.

In Myanmar, 42 protected areas have been established as following categories:

- Scientific reserve
- National park
- Marine national park
- Nature reserve
- Wildlife sanctuary
- Community forest

Scientific reserve

Scientific reserve has some similarities to nature reserves. They are held for the protection of their features (including flora and fauna) for "scientific study, research, education, and the benefit of the country" e.g., Tanintharyi Nature Reserve (Figure 6.14).

Fig. 6.14 Tanintharyi Nature Reserve

National park

A national park is an area set aside by a national government for the preservation of the natural environment. It is maintained for biodiversity conservation and representativeness and firm management control. No settlement or resource harvesting is allowed. Visitors are permitted e.g., Alaungdawkathapa National Park, Namataung National Park (Figure 6.15).

Fig. 6.15 Namataung National Park

Marine national park

A marine park is a permanent marine reservation for the conservation of species. It constitutes an extension, to the undersea world, of the concept of the terrestrial national park.

It is the same as national park but in marine, island and coastal environments e.g., Lampi Island Marine National Park (Figure 6.16).

Fig. 6.16 Lampi Island Marine National Park

Nature reserve

Nature reserve is a protected area of importance for flora, fauna, or features of geological or other special interest, which is reserved and managed for purposes of conservation and to provide special opportunities for study or research e.g., Popa Mountain Park, Hkakaborazi National Park (Figure 6.17).

Fig. 6.17 Popa Mountain Park

Wildlife sanctuary

A wildlife sanctuary is an area where animal habitats and their surroundings are protected from any sort of disturbance. The capturing, killing and poaching of animals is strictly prohibited in these regions. They aim at providing a comfortable living to the animals e.g., Hlawga Park, Chatthin Wildlife Sanctuary (Figure 6.18 A and B).

Figure 6.18 A. Hlawga Park and B. Chatthin Wildlife Sanctuary

Community forest

In the early 1990s, the Government of Myanmar introduced **Community forest (CF)** as a way to protect endangered forest resources and support the subsistence needs of rural communities. Community forest means all sustainable forest management and utilization activities, in which the local community itself is involved. This expression includes establishing new plantations and managing existing forests, creating employment and income opportunities for subsistence to commercial purposes, generating food, stabilizing ecosystems, and improving the environmental conditions. Community forests are an important tool for biodiversity conservation and sustainable community-driven development (Figure 6.19).

Figure 6.19 Community forest

Sample Questions

1. State **TRUE** or **FALSE** to the following statements. Do not copy the statements. (6 marks)

   i. Biodiversity is the variety of all living things.
   ii. Genetic diversity is the variety of genes within a genus.
   iii. Some organisms in an ecosystem live in interdependence.
   iv. The destruction of the natural environment leads to habitat loss.
   v. The illegal wildlife trade has been linked to the emergence and spread of new non-infectious diseases in humans.
   vi. *In situ* methods are the way to conserve animals and plants outside their natural habitats.

2. Complete the following statements with appropriate words. Do not copy the statements. (6 marks)

   i. Healthy ecosystem and rich ---------- will provide for nutrient storage and recycling.
   ii. Forest ---------- are a carbon sink and stabilize soils.
   iii. The abbreviation of the International Union for Conservation of Nature and Natural Resources is ----------.
   iv. *Rhododendron* is the ---------- plant species.
   v. The keeping and protecting a living and changing environment is called ----------.
   vi. National park is the ---------- areas in Myanmar.

3. Choose the correct answer for the following statements. Do not copy the statements. (6 marks)

   i. The (A. ecology B. ecosystem C. biodiversity D. conservation) is a community of organisms and their physical environment interacting together.
   ii. Zoonotic diseases cause acute respiratory syndrome (A. COVID-19 B. H_5N_1 C. SARS D. IAS).
   iii. (A. Narrowly B. Broadly C. Ethical D. Ecological) utilitarian is the biodiversity that provides ecosystem services.
   iv. The storage of seeds is the (A. *in situ* B. *ex situ* C. deforestation D. destruction) approaches to conservation.
   v. Dried seeds are stored in a temperature of -14°C and in (A. light B. dark C. dim-light D. shade) condition.
   vi. (A. Botanical B. Zoological C. Microbiological D. Ecological) gardens are places to integrate the study of conservation on plant species.

Sample Questions (Continued)

4. Match items in column A and B. Do not copy the statements. (6 marks)

Column A	Column B
i. Variation of life forms in an ecosystem	A. *In situ* conservation
ii. Number of species in a particular location	B. *Ex situ* conservation
iii. Natural environments are transformed	C. Biodiversity
iv. Overexploitation	D. Species diversity
v. Conserve any species is to keep it in natural habitat	E. Overharvesting
vi. Conserve animals and plants outside their natural habitat	F. Habitat loss

5. Complete this paragraph about the conservation. Use words from this list. Each word may be used once, more than once, or not at all. (6 marks)

biodiversity	diversity	conservation	habitat
enormous	reduce	deforestation	climate

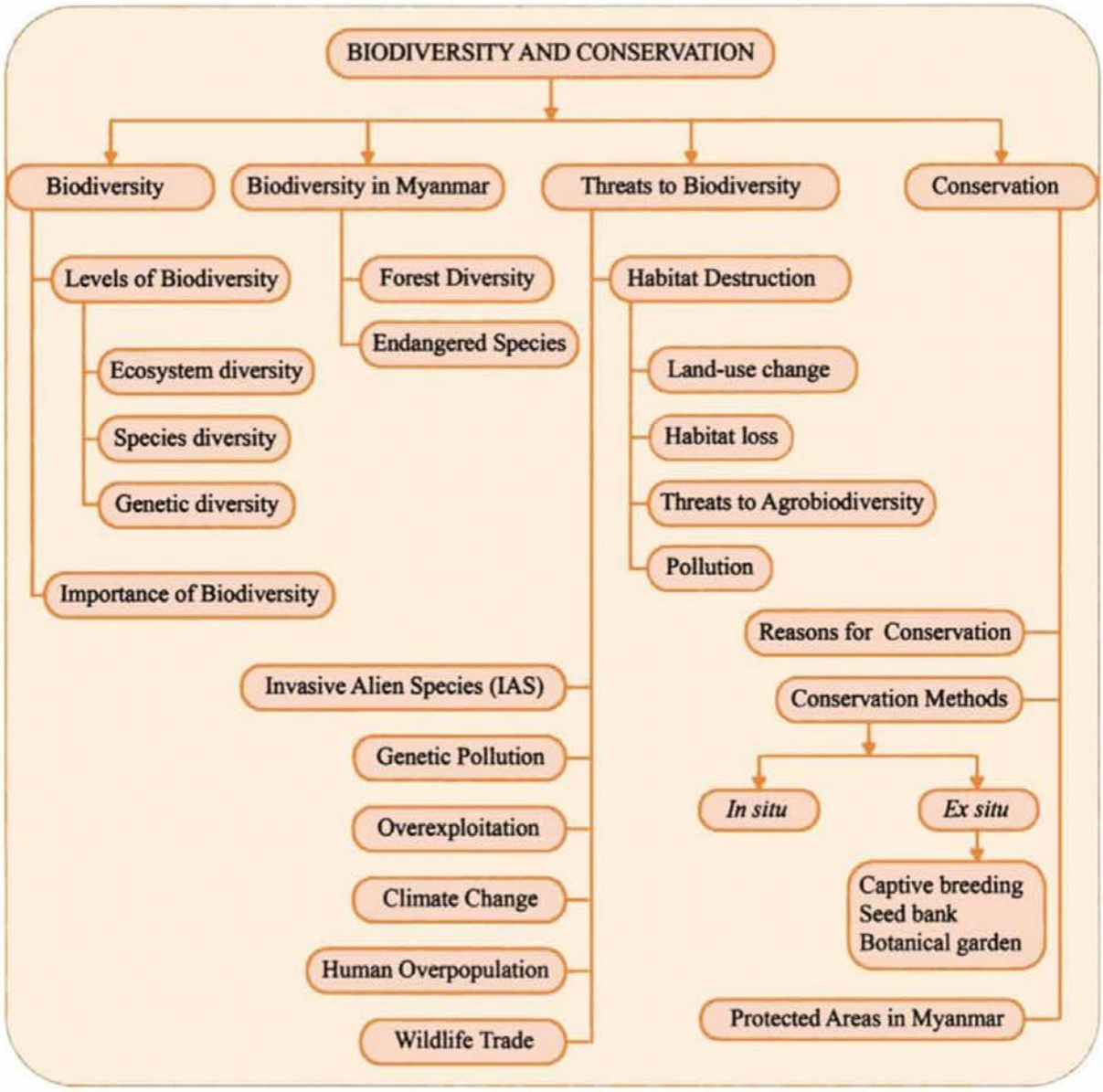
Biodiversity is being reduced through human activities such as overfishing, ----(a)----, habitat reduction, and as a result of ----(b)---- change. However, many people around the world are working hard to ----(c)---- these trends and to conserve the ----(d)---- we still have. This can be tackled in many different ways. Conservation is an active process involving an ----(e)---- range of projects. In order to keep the beauty and ----(f)---- of nature reserves, it is important to manage it effectively.

6. Answer **ANY TWO** questions. (4 marks)
   a. Define the term 'biodiversity'.
   b. Differentiate the terms species diversity and species richness.
   c. How do you understand wildlife trade?

7. Answer **ANY TWO** questions. (8 marks)
   a. State the major threats to biodiversity.
   b. Give the reasons for habitat destruction.
   c. Why conservation is important?

8. Answer **ANY ONE** question. (8 marks)
   a. Explain how biodiversity is important.
   b. State the differences between *in situ* and *ex situ* conservation methods.
   c. List the categories of protected areas in Myanmar and explain any three of them.

Concept Map


BIODIVERSITY AND CONSERVATION
Biodiversity
Biodiversity in Myanmar
Threats to Biodiversity
Conservation
Levels of Biodiversity
Ecosystem diversity
Species diversity
Genetic diversity
Importance of Biodiversity
Forest Diversity
Endangered Species
Habitat Destruction
Land-use change
Habitat loss
Threats to Agrobiodiversity
Pollution
Invasive Alien Species (IAS)
Genetic Pollution
Overexploitation
Climate Change
Human Overpopulation
Wildlife Trade
Reasons for Conservation
Conservation Methods
In situ
Ex situ
Captive breeding
Seed bank
Botanical garden
Protected Areas in Myanmar

GLOSSARY

A

absorption The process of taking up water through the roots

acetylcholine An organic chemical, neurotransmitter released by neurones in the nervous system

action potential Change in voltage of a cell membrane in response to a stimulus that results in transmission of an electrical signal; (Unique to neurone and muscle fibres)

active transport The process of moving molecules across a cellular membrane through the use of cellular energy

Alzheimer's A type of dementia that affects memory, thinking and behavior

anaerobic respiration The type of respiration through which cells can break down sugars to generate energy in the absence of oxygen

anatomy The scientific study of the body and how its parts are arranged

angina Chest pain caused by reduced blood flow to the heart muscles

anticoagulants Chemical substances that prevent or reduce coagulation of blood, prolonging the clotting time

anticodon A sequence of three nucleotides forming a unit of genetic code in a transfer RNA molecule, corresponding to a complementary codon in messenger RNA

antiparallel The opposite orientations of the two strands of a DNA double helix; the 5′ end of one strand aligns with the 3′ end of the other

antisense strand The non-coding DNA strand of a gene

aorta Main artery which carries oxygenated blood from the heart in mammals

aquifers A layer of rock, sand, or earth that contains water or allows water to pass through it

arteries Blood vessels that carry blood away from the heart

arteriole Small vessel that connects an artery to a capillary bed

aspirin A white crystalline derivative $C_9H_8O_4$ of salicylic acid used for relief of pain and fever

atheroma A fatty material that builds up inside your arteries

atherosclerosis A build-up of fatty material in the wall of the coronary artery that causes narrowing of the artery

atom The smallest unit of any chemical element

atria Upper chambers of the heart which receive blood from veins

B

backbone The longest chain of atoms or groups of atoms in a usually long molecule (such as a polymer or protein)

beta blockers A type of drug that blocks the action of substances, such as adrenaline, on nerve cells and causes blood vessels to relax and dilate (widen)

beta-carotene A substance found in yellow and orange fruits and vegetables and in dark green, leafy vegetables

bicuspid valve One-way membranous flap between the atrium and the ventricle in the left side of the heart

biomolecular A chemical compound found in living organisms, composed of mainly carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus

biosphere The regions of the surface, atmosphere, and hydrosphere of the earth occupied by living organisms

biotechnology The use of living things, especially cells and bacteria, in industrial processes

bipolar Shape of a neurone with two processes extending from the neurone cell body - the axon and one dendrite; nerve cells having a process at each end

blight A disease that damages and kills plants

blood plasma The liquid part of the blood containing useful things like glucose, amino acids, minerals, vitamins (nutrients) and hormones, as well as waste materials such as urea

blood transfusion A medical treatment in which someone's blood is put into the body of another person

blurred vision Lack of sharpness of vision with, as a result, the inability to see fine detail

brainstem Region of the adult brain that includes the midbrain, pons, and medulla oblongata and connects with the spinal cord

breathlessness Shortness of breath, or breathlessness, is described as the frightening sensation of being unable to breathe normally or feeling suffocated

bundle of His A bundle of modified heart muscle that transmits the cardiac impulse from the atrioventricular node to the ventricles causing them to contract

C

cAMP Cyclic Adenosine Monophosphate, second messenger that, in response to adenyl cyclase activation, triggers a phosphorylation cascade

cancerous tumour Malignant, meaning it can grow and spread to other parts of the body, act as a type of antioxidant for humans

canker A disease that attacks the wood of trees

capillary Smallest blood vessel that allows the passage of individual blood cells and the site of diffusion of oxygen and nutrient exchange

carbon sink A forest, ocean, or other natural environment viewed in terms of its ability to absorb carbon dioxide from the atmosphere

cardiac cycle Filling and emptying the heart of blood by electrical signals that cause the heart muscles to contract and relax

cardiac muscle An involuntary striated muscle tissue found only in the heart

cardiac output The volume of blood pumped by the heart in one minute as a product of heart rate multiplied by stroke volume

cardiovascular Of relating to, or involving the heart and blood vessels

carotenoids Pigments in plants, algae, and photosynthetic bacteria and produce the bright yellow, red, and orange colors in plants, vegetables, and fruits

casparian strip The waterproof layer covering the side and end walls of endodermal root cells

cellular respiration A series of chemical reactions that break down glucose to produce ATP, which may be used as energy to power many reactions throughout the body

cellulose The main substance in the cell walls of plants, also used in making paper, artificial threads and cloth, and plastics

cereals A grain used for food, such as wheat, oats, or corn

cerebrospinal fluid (CSF) Clear liquid that surrounds or fills the brain (ventricles) and the spinal cord (central canal); acts as a shock absorber and circulates material throughout the brain and spinal cord

cholera Any of several diseases of humans and domestic animals usually marked by severe gastrointestinal symptoms

chordae tendineae Strong, fibrous connections between the valve leaflets and the papillary muscles

chromosomes A structure found inside the nucleus of a cell and made up of proteins and DNA organized into genes

circulation The continuous movement of blood through all parts of the body under the action of the heart

circulatory system Bodily system made up of the heart, blood vessels and blood that delivers nutrients and other essential materials to cells whilst removing waste products

clone An organism or cell, or group of organisms or cells, produced asexually from one ancestor or stock, to which they are genetically identical

coding strand When referring to DNA transcription, the coding strand (or informational strand) is the DNA strand whose base sequence is identical to the base sequence of the RNA transcript produced (although with thymine replaced by uracil)

codon A sequence of three consecutive nucleotides in a DNA or RNA molecule that codes for a specific amino acid

community A group of living in the same place or having a particular characteristic in common

cone Weakly photosensitive, chromatic, cone-shaped neurone in the fovea of the retina that detects bright light and is used in daytime colour vision

confusion A situation in which people do not understand what is happening, what they should do or who someone or something is

coronary artery Vessel that supplies the heart tissue with blood

coronary vein Vessel that takes blood away from the heart tissue back to the chambers in the heart

cortex The region of a stem or root surrounding the vascular bundle but inside the epidermis

cranial nerve Sensory and/or motor nerve that emanates from the brain

crinkling To become covered in many small lines and folds

cryptochrome A type of protein, found in plants and animals, that reacts quickly to changes in blue light

D

decline To gradually become less, worse, or lower

depolarization Change in the membrane potential to a less negative value; a reduction af polarization (i.e. of potential difference) across a membrane

diabetes A disease in which the body cannot the control the level of sugar in the blood

diastole Relaxation phase of the cardiac cycle when the heart is relaxed and the ventricles are filling with blood

diastolic blood pressure The lower of two blood pressure measurements (for example, 120/80, where 80 is the diastolic pressure)

dieback A disease of plants characterized by the gradual dying of the young shoots starting at the tips and progressing to the larger branches

diffusion The movement of molecules from an area of higher concentration to an area of lower concentration

distortion A change for the worse

dizziness The feeling of being lightheaded, woozy, or off-balance

E

ecosystem A biological community of interacting organisms and their physical environment

electrocardiogram (ECG) Recording of the electrical impulses of the cardiac muscle

endangered species A type of animal or plant that might stop existing because there are only a few of that type alive broom

endemic Restricted or peculiar to a locality or region

endocrine gland Gland that secretes hormones into the surrounding interstitial fluid, which selected hydrophilic ions or molecules can pass see faciliate diffusion

endodermis This is a layer of cells which surrounds the central core of vascular tissue

endorphins Any of a group of hormones secreted within the brain and nervous system and having a number of physiological functions; a group of morphine like chemicals in the brain

epinephrine Hormone released by the adrenal at medulla in response to a short-term stress, also known as adrenaline, first messenger

eukaryote A type of organism that has one or more cells each with a separate nucleus containing chromosomes

evenness A quality of uniformity and lack of variation witches

excitatory Characterized by, causing, or constituting excitation

exocytosis The bulk movement of liquids or solids out of a cell, by the fusion of vesicles containing the substance with the cell surface membrane; (exocytosis)is an active process requiring ATP

F

food webs The relationship between all the living things in a particular area, when thinking about how they eat each other

fossils The shape of a plant or animal that has been preserved in rock for a very long period

frontal lobe Region of the cerebral cortex directly beneath the frontal bone of the cranium; frontal means in region of forehead

G

gall Abnormal outgrowth of tissues in plants, caused by a variety of parasites

gene Length of DNA that codes for a protein

genetic The study of how, in all living things, the characteristics and qualities of parents are given to their children by their genes

genome The entire set of DNA instructions found in a cell, contains all the information needed for an individual to develop and function

greenhouse A glass building in which plants are grown that need protection from cold weather

gripping pain A contracting or constricting pain

gummosis Disease of citrus trees caused by the fungus *Phytophthora citrophthora*

H

haemoglobin The red protein found in red blood cells that transports oxygen round the body

hereditary Genetically transmitted or transmittable from parent to offspring

hierarchy Things are arranged according to their importance

hydroponics The process of growing plants in sand, gravel, or liquid, with added nutrients but without soil

hyperpolarization Change in the membrane potential to a more negative value; an increased potential difference across a membrane

I

implanted Insert or fix (tissue or an artificial object) in a person's body, especially by surgery

inferior vena cava Drains blood from the veins that come from the lower organs and the legs

inhibitory Hindering or preventing an action; slowing down or preventing a process, reaction, or function; nerves which control movement or secretion by decreasing these activities

interaction An occasion when two or more people or things communicate with or react to each other

L

lacteals A lacteal is a lymphatic capillary that absorbs dietary fats in the villi of the small intestine

leaf scorch Plant disease causing a burned or scorched appearance of the foliage

leukemia A type of cancer which affects the production and function of blood cells

lifespan The duration of existence of an individual

lignin A substance found in the edges of some plant cells that makes the plant hard like wood

liposome A spherical-shaped vesicle that is composed of one or more phospholipid bilayers, which closely resembles the structure of cell membranes

lymph node or lymph gland This is a kidney-shaped organ of the lymphatic system and the adaptive immune system

lymphatic system A network of vessels, nodes, and ducts that collect and circulate excess fluid in the body

M

macromolecule Large, complex molecules

macrophages Specialized cells involved in the detection, phagocytosis and destruction of bacteria and other harmful organisms

malnutrition Physical weakness and bad health caused by having too little food, or too little of the types of food necessary for good health

measles An acute infectious disease occurring mostly in children, characterized by catarrhal and febrile symptoms and an eruption of small red spots; rubeola

messenger RNA (mRNA) A single-stranded RNA molecule that carries the genetic code from DNA to ribosome

metabolites A substance formed in or necessary for metabolism

microorganisms Small to be viewed by the unaided eye, as bacteria, protozoa, and some fungi and algae

mildew A black, green, or whitish area caused by a fungus that grows on things

mosaic A pattern or picture made using many small pieces of coloured stone

multicellular Having more than one cell

multipolar Shape of a neurone that has multiple processes the axon and two or more dendrites

mutate To become physically different from other plants or animals of the same type as a result of a genetic change

mycoplasma Any of a group of small parasitic bacteria that lack cell walls and can survive without oxygen

myocardial infarction A lack of blood supply to the heart that is usually caused by a blood clot in the coronary artery

mystify Impossible to explain

N

natural pacemaker A group of specialized cells that generates electrical impulses that pass through the heart muscle and make the heart contract

necrosis Death of cell tissues

nectar A sugary fluid secreted by plants, especially within flowers to encourage pollination by insects and other animals

nervous system Body system that includes the brain, spinal cord and nerves.

neurotransmitter Chemical signal that is released from the synaptic end bulb of a neurone to cause a change in the target cell

niches An area or position that is exactly suitable for a small group of the same type

node of Ranvier Gaps in the myelin sheath where the signal is recharged

non-infectious diseases Not caused by pathogens and therefore cannot be spread from one person to another

norepinephrine Neurotransmitter and hormone released by activation of the sympathetic nervous system, anger hormone

nucleotide An organic molecule that is the building block of DNA and RNA

O

optic nerve Second cranial nerve; responsible for visual sensation

organelle Any structure that has a particular purpose inside a living cell

osmosis The diffusion of fluids through a semipermeable membrane, as in a living cell

P

pacemaker A medical device that uses electrical impulses to regulate heart beats

pandemic An outbreak of a disease that occurs over a wide geographic area and typically affects a significant proportion of the population

paralysis The loss of the ability to more in part or most of the body

parietal lobe Region of the cerebral cortex directly beneath the parietal bone of the cranium

Parkinson's disease Neurodegenerative disorder that affects the control movement

pathogen A specific causative agent (such as a bacterium or virus) of disease

pedigree A list of the parents and other relations of an animal

pharmacological Relating to the branch of medicine concerned with the uses, effects, and modes of action of drugs

photoreceptor Receptor cell specialized to respond to light stimuli

plasmid An extrachromosomal ring of DNA especially of bacteria that replicates autonomously

plasmodesmata Channels, piercing the cell walls of plants, through which cytoplasmic threads connect with adjacent cells

platelets or thrombocytes Small, colorless cell fragments in our blood that form clots and stop or prevent bleeding

polypeptide A peptide is two or more amino acids joined together by peptide bonds; a polypeptide is a chain of many amino acids; and a protein contains one or more polypeptides

population All the people living in a particular country, area, or place

postsynaptic neurone The neurone on the opposite side of a synapse to the neurone in which the action potential arrives

precursor mRNA An immature or incompletely processed mRNA molecule in eukaryotes that needs to be processed before it becomes a fully functional mature mRNA for transport into the cytoplasm

presynaptic neurone A neurone ending at a synapse from which neurotransmitter is secreted when an action potential arrives

prokaryote A type of organism that has only one cell and does not have a nucleus

propagation The breeding of specimens of a plant

prothrombin A plasma protein produced in the liver in the presence of vitamin K and converted into thrombin in the clotting of blood

protist Any of various one-celled organisms (protozoans, eukaryotic algae, and slime molds)

pulmonary artery The artery which carries deoxygenated blood from the heart to the lungs

pulmonary vein One of the four veins that carries oxygenated blood to the heart from the lungs

purkyne tissue A network of Purkinje fibres that carry the cardiac impulse from the atrioventricular node to the ventricles of the heart and causes them to contract

R

radioisotope An unstable form of a chemical element that releases radiation as it breaks down and becomes more stable

red blood cell Also called erythrocyte or red corpuscle, the blood cell which contains the pigment haemoglobin responsible for the transport of oxygen

remedies A medicine or treatment for a disease or injury

replication bubbles An unwound and open region of DNA where DNA replication occurs. Bubbles are created when the enzyme helicase separates the two strands of DNA so that they can be replicated

resilient Able to recoil or spring back into shape after bending

rhizomorph A dense mass of hyphae forming a root-like structure characteristic of many fungi

rhizosphere The region of soil in the vicinity of plant roots

rod Strongly photosensitive, achromatic, cylindrical neurone in the outer edges of the retina that detects dim light and is used in peripheral and nighttime vision

S

schizophrenia Mental disorder characterized by the inability to accurately perceive reality; patients often have difficulty thinking clearly and can suffer from delusions

Schwann cell Glial cell that creates myelin sheath around a peripheral nervous system, neurone axon

semiconservative replication The process by which DNA makes copies of itself, each strand, as it separates, synthesizing a complementary strand

semilunar valve Membranous flap of connective tissue between the aorta and a ventricle of the heart (the aortic or pulmonary semilunar valves)

sense strand Strand of DNA running from 5′ to 3′ complementing the antisense strand, and transcribed into mRNA

serotonin A substance that is found mostly in the digestive tract, central nervous system (brain and spinal cord), and platelets

signs and symptoms Symptoms are feelings or sensations a person has, whereas signs are observable characteristics

sinoatrial (SA) node The heart's internal pacemaker; located near the wall of the right atrium

spinal nerve Nerve projecting between skin or muscles and spinal cord

statin A drug that reduces the level of cholesterol

steroid hormone Any of a group of hormones that belong to the class of chemical compounds; they are secreted by three "steroid glands" the adrenal cortex, testes and ovaries

stomata Openings in the epidermis of a stem or leaf of a plant which permit gas exchange with the air

subclavian veins A large, deep, paired vein that drains blood from the arms and shoulders, transporting blood back to the heart

suberin A waxy, waterproof, air-proof substance found in the layers of cork cells that sheath the woody stems and mature roots

superior vena cava Drains blood from the jugular vein that comes from the brain and from the veins that come from the arms

synthesis The production of a substance by the union of chemical elements, groups, or simpler compounds or by the degradation of a complex compound

systole Contraction phase of cardiac cycle when the ventricles are pumping blood into the arteries

T

T_4 Tetraiodothyronine, is one of the two main thyroid hormones, and alternative names for thyroxine hormone

target cells or organs Cells or organs that responds to the hormones

telomerase An enzyme found inside our cells, which may be related to the aging process

telomeres Structures made from DNA sequences and proteins found at the ends of chromosomes

template strand The DNA sequence that can duplicate itself during mRNA synthesis

temporal lobe Region of the cerebral cortex directly beneath the temporal bone of the cranium

threshold Membrane voltage at which an action potential is initiated

thromboplastin An enzyme liberated from blood platelets that converts prothrombin into thrombin as blood starts to clot

thrombosis A medical condition in which the flow of blood in the body is blocked by a clot (= partly solid mass) of blood

tissue fluid Fluid which is derived from blood plasma that passes through the walls of capillaries

traits A distinguishing character

transgenic Relating to or denoting an organism that contains genetic material into which DNA from an unrelated organism has been artificially introduced

tricuspid valve One-way membranous flap of connective tissue between the atrium and the ventricle in the right side of the heart; also known as atrioventricular valve

transfer RNA (tRNA) Any of a class of RNA molecules that transport amino acids to ribosomes for incorporation into a polypeptide undergoing synthesis

tropisms An involuntary orienting response; positive or negative reaction to a stimulus source

tuberculosis A bacterial infection spread through inhaling tiny droplets from the coughs or sneezes of an infected person

U

umbilical artery Carry deoxygenated blood from fetal circulation to the placenta

umbilical vein A vein present during foetal development that carries oxygenated blood from the placenta into the growing foetus

unipolar Shape of a neurone which has only one process that includes both the axon and dendrite

urbanization The process by which more and more people leave the countryside to live in cities mottling

V

valve The structure in veins that prevents the backflow of blood

vein A blood vessel with valves that transports blood to the heart

vena cava A blood vessel with valves that transports blood to the heart

ventricle The lower chamber of the heart that receives blood from the atrium and pumps it into arteries

viroid Short pieces of RNA, with no protein coat, that cause several plant diseases

W

white blood cell Also called leukocyte or white corpuscle, a cellular component of the blood that lacks hemoglobin, has a nucleus, is capable of motility, and defends the body against infection and disease by ingesting foreign materials

X

xerophytic Adapted to a dry environment

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